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Transit Investments for Greenhouse Gas and Energy Reduction Program: Second Assessment Report

AUGUST 2014

FTA Report No. 0064
Federal Transit Administration

PREPARED BY
National Renewable Energy Laboratory
Leslie Eudy
Melanie Caton
Matthew Post

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TIGGER Transit Investments for Greenhouse Gas & Energy Reduction

AUGUST 2014

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PREPARED BY

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Federal Transit Administration
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SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^{o}F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^{o}C

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

This report is the second assessment of the U.S. Department of Transportation, Federal Transit Administration's Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) Program. The TIGGER Program provides capital funds to transit agencies for projects that work to reduce the agency's energy use and/or greenhouse gas (GHG) emissions from their operations. The purpose of this report is to provide an overall status update for the program, provide an outlook on specific projects, and begin presenting an analysis of program results. This report briefly outlines the program and its goals, as well as the technologies being implemented. It also provides status updates for each project and analyzes results for projects that have accumulated a sufficient amount of data to do so.

EXECUTIVE SUMMARY

In 2009, the U.S. Department of Transportation's Federal Transit Administration (FTA) funded a program to promote energy saving and sustainable technologies to the transit industry through a program entitled Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER). The TIGGER Program made funds available for capital investments over a three-year period from 2009 through 2011 that would reduce greenhouse gas (GHG) emissions or lower the energy use of public transportation systems. In the initial round of the program, funded through the American Recovery and Reinvestment Act of 2009 (ARRA), 43 projects were selected representing a wide variety of technologies, including building efficiency improvements, solar installations, wind technology, wayside energy storage for rail, and purchase of technologically-innovative, energy-efficient buses.

In 2010 and 2011, Congress appropriated additional funding for the TIGGER Program. Interested agencies submitted proposals to meet the original goals with an emphasis on innovation and national applicability. A total of 26 projects were selected in the second round (TIGGER II), and 17 projects were awarded in the third round (TIGGER III). Under the program, grants totaling nearly $225 million have been awarded to 86 competitively-selected projects implementing a wide variety of technologies to meet program goals. The awarded projects are geographically-diverse, covering 35 states and 69 transit agencies in both urban and rural settings.

Through the TIGGER Program, transit agencies are implementing a diverse selection of technologies to meet the overall program goals of reducing energy and GHG emissions. Projects fall into three primary categories: Facility Efficiency, Bus Efficiency, and Rail. These categories were assigned sub-categories according to technology type to support comparison of similar projects and provide information for transit agencies.

FTA established special reporting requirements to aid in determining the overall effectiveness of the program. The data collected for these requirements will be used in the program assessment and also will assist FTA in preparing a report to Congress on program results. All recipients of TIGGER funds must report the following after one full year of operation using the new technology:

- Actual annual energy consumed within the project scope attributable to the investment for energy consumption reduction projects, and/or
- Actual GHG emissions within the project scope attributable to the investment for GHG emissions reduction projects, and
- Actual annual reductions or increases in operating costs attributable to the investment for each TIGGER project.

FTA is required to evaluate the results of the program and identify which technologies have the most potential impact on reducing emissions and increasing the energy efficiency of public transit agencies. To assist in developing a program analysis, FTA enlisted the help of the National Renewable Energy Laboratory (NREL) through an interagency agreement to provide a third-party assessment of the TIGGER Program. Under FTA direction, NREL is collecting data and information on each project. An analysis is currently underway to determine the overall impacts and assess how each project has contributed toward meeting overall program goals. This report is the second assessment report on the program and includes results from the data collected through March 2014.

The projects awarded under the program are progressing. As of the end of March 2014, 59% of the TIGGER projects had been completed (51 of 86). The majority (34) of those completed projects have provided a full year of data. To date, these projects represent a combined annual energy savings of 107,753 million British thermal units (MBtu), or 24,801,896 kilowatt-hours (kWh), and a reduction in GHG emissions (carbon dioxide equivalent, CO_2^e) of 30,863 tons. To assess the program as a whole, NREL continues to work with the transit agencies to collect and analyze the data as projects reach one of year operation using the new technology.

NREL developed a comprehensive template to aid in collecting the required data from the project partners. The template, in Microsoft Excel format, contains 28 separate tabs for the various types of data to be collected on TIGGER projects. NREL has shared this template with TIGGER grantees and has received complete or partial data sets from 34 TIGGER projects. All of these are included in the analysis. The data provided represent 37% of the total projects—not a sufficient amount of information to formulate an overall assessment of the program as a whole. However, this report begins to summarize the results to date. Based on actual annual savings attributed to the technologies used, the program has resulted in the following:

- Bus Efficiency projects have reported savings totaling more than 16,921 MBtu and 1,594 fewer tons CO_2^e emissions.
- Rail projects completed to date have resulted in an energy reduction of 16,887 MBtu.
- Facility Efficiency projects have shown the most promise in reducing energy use, resulting in a combined reduction in annual energy use of 73,945 MBtu and 29,270 fewer tons CO_2^e emissions.
- Solar projects reported an annual energy savings of 17,230 MBtu.
- Wind projects reported an annual energy reduction of 505 MBtu.
- Geothermal projects reported a 97-ton decrease in CO_2^e emissions.

The annual cost savings for reduced fuel and electricity use by the reporting projects totals more than $3 million using the average cost of fuel and electricity in 2011 provided by the Energy Information Agency. Table ES-1 shows the average cost savings per TIGGER dollar for the project sub-categories. The calculations use the expected lifetime of the technology, the annual cost savings, and the TIGGER award amount. The overall cost savings for the agencies that have provided data is $1.22 per TIGGER dollar awarded. Some of these projects provided a partial data set; however, the total TIGGER award to the agency was used to calculate this amount. Once complete data sets are submitted, this number should increase.

Table ES-1

Average Cost Savings per TIGGER Dollar by Project Sub-Category

	TIGGER Award	Projected Lifetime Cost Savings per TIGGER $	Return on Investment (ROI)	Number of Projects Reporting
Diesel Hybrid Bus	$26,488,289	$0.96	-4%	11
Retrofit Bus	$1,070,000	$2.88	188%	2
Facility Efficiency	$9,352,936	$3.93	293%	9
Solar PV	$30,604,788	$0.62	-38%	9
Wind	$2,180,750	$0.13	-87%	1
Geothermal	$450,000	$0.89	-11%	1
Rail	$2,484,766	$1.97	97%	1

SECTION

1

Introduction

The Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER)[1] Program was implemented in 2009 by the U.S. Department of Transportation's Federal Transit Administration (FTA) and ran for three consecutive years, providing approximately $225 million in grants to the transit industry. The TIGGER Program made funds available for capital investments that would reduce greenhouse gas (GHG) emissions or lower the energy use of public transportation systems. The projects selected under the TIGGER Program employ a variety of technologies or strategies to meet program goals. Projects incorporated, but were not limited to, such strategies as solar installations, building efficiency improvements, wind technology, wayside energy storage for rail, and purchase of more efficient buses. In 2012, FTA published the first TIGGER assessment report,[2] which provided a framework of the program and a status of the program's implementation, including descriptions of the goals and technologies being pursued and implemented. The report also summarized each of the projects by category and provided a preliminary analysis of estimated energy and GHG emissions[3] savings. This report serves as the second assessment for the TIGGER Program and focuses on the current status and early results of these energy and GHG emissions saving strategies through March 2014.

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[1] FTA's TIGGER Program should not be confused with the U.S. Department of Transportation's similarly named TIGER Program (Transportation Investment Generating Economic Recovery).

[2] *Transit Investments for Greenhouse Gas and Energy Reduction Program: First Assessment Report*, FTA Report No. 0016, Federal Transit Administration, June 2012.

[3] Greenhouse gases trap heat in the atmosphere, contributing to the "greenhouse effect." Primary GHGs are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

SECTION

2

TIGGER Program Overview

The TIGGER Program was initiated under the American Recovery and Reinvestment Act of 2009 (ARRA) and provided $100 million in fiscal year (FY) 2009 for competitively-selected projects to help meet program goals. Potential projects could include only energy or GHG emissions directly attributable to the operation of public transportation agencies. Within the TIGGER Program, energy consumption is defined as energy purchased directly by the agency, such as vehicle fuel or electricity purchased from power plants, expressed in million British thermal units (MBtu). Emissions are defined as those emitted directly by the assets of the public transportation agency, expressed in carbon dioxide equivalents (CO_2^e). Agencies could not count indirect or displaced emissions (such as from third-party power plants or removing personal vehicles from the road). The TIGGER Program focuses on the total energy savings and/or emissions reductions of a project over its expected useful life.

Projects were submitted under the premise that they would reduce either energy or GHG emissions, or both. Project selection was based on specific evaluation criteria described in the program notice of funding availability[4] (NOFA):

1. Total projected energy or greenhouse gas emission savings results for the project
2. Project innovation
3. National applicability
4. Project readiness
5. Project management
6. Return on investment

In the initial round of program funding, 43 projects were selected, representing a wide variety of technologies including solar installations, building efficiency improvements, wind technology, wayside energy storage for rail, and the purchase of technologically innovative, energy efficient buses.

[4] NOFA: 74 FR 12447—Solicitation of Comments and Notice of Availability of Fiscal Year 2009 Funding for Transit Investments for Greenhouse Gas and Energy Reduction Grants, http://www.gpo.gov/fdsys/granule/FR-2009-03-24/E9-6420/content-detail.html/.

In FY 2010 and FY 2011, Congress appropriated additional funding for the TIGGER Program. Interested agencies submitted proposals to meet the original goals with an emphasis on innovation and national applicability. A total of 26 projects were selected in the second round (TIGGER II), and 17 projects were awarded in the third round (TIGGER III). Under the entire TIGGER Program a total of 86 projects were awarded nearly $225 million in funds. Table 2-1 summarizes the program by funding round. The awarded projects are geographically-diverse, covering 35 states and 69 transit agencies in both urban and rural settings. Figure 2-1 shows the location of each TIGGER project awarded in the three rounds of funding. All 10 FTA regions are represented in the project portfolio.

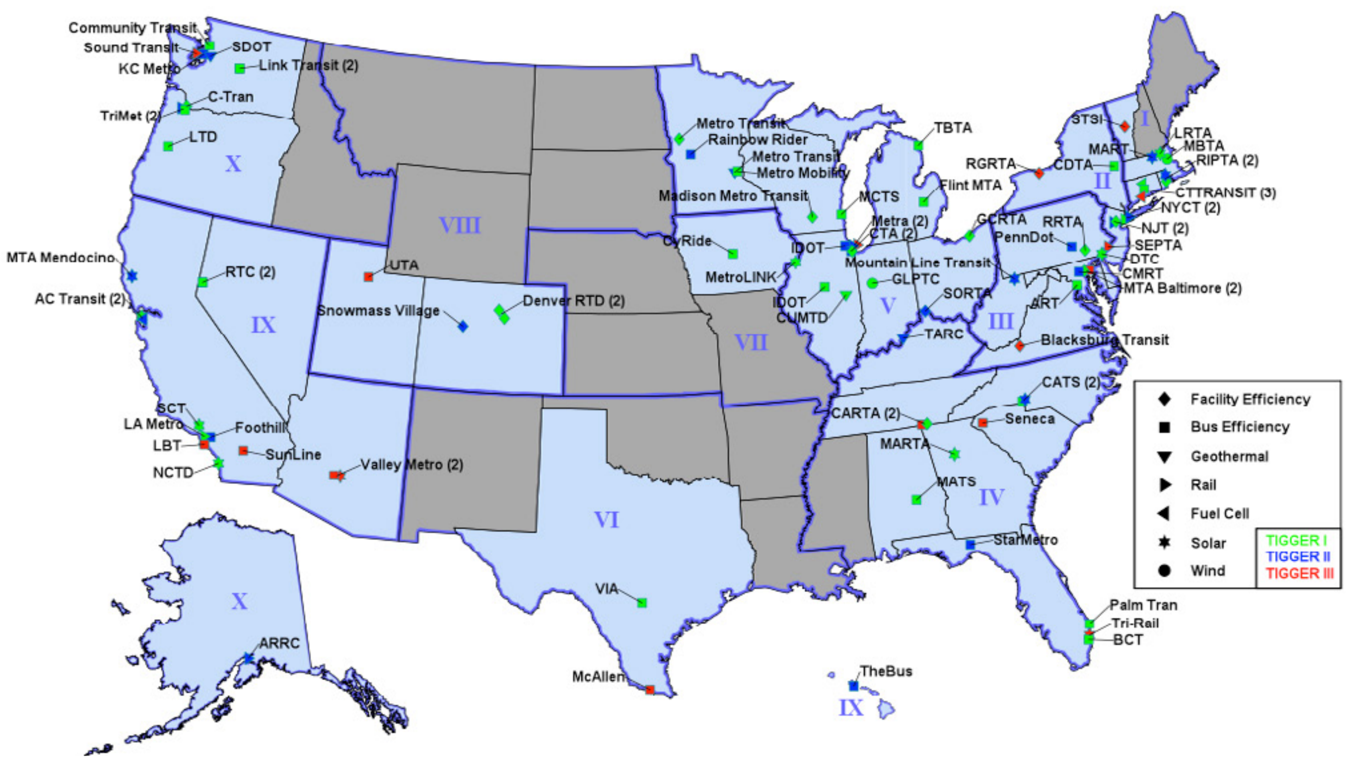


Figure 2-1 *Map of TIGGER Project Locations by Funding Cycle*

Table 2-1

Summary of TIGGER Program by Funding Round

	Funding Year	Funds Available (millions)	Number of Projects Selected
TIGGER I	FY 2009	$100	43
TIGGER II	FY 2010	$75	26
TIGGER III	FY 2011	$49.9	17
Total		*$225*	*86*

Through the TIGGER Program, FTA is investigating a variety of technologies to promote energy efficiency and sustainability within the transit industry. Over the course of the program, FTA will analyze the results to determine which technologies have the most potential to lower energy use and GHG emissions.

Program Assessment

FTA is required to evaluate the results of the program and identify which technologies have the most potential impact on reducing emissions and increasing the energy efficiency of public transit agencies. The final evaluation and assessment will be delivered to Congress as a final report on TIGGER. To enable a baseline analysis of the TIGGER Program, FTA established special reporting requirements for each funded project as described in each TIGGER NOFA.[5,6,7] All recipients of TIGGER funds must report the following after a year has passed:

- Actual annual energy consumed within the project scope attributable to the investment for energy consumption reduction projects; and/or
- Actual GHG emissions within the project scope attributable to the investment for GHG emissions reduction projects; and/or
- Actual annual reductions or increases in operating costs attributable to the investment for each TIGGER project.

To aid in determining the effectiveness of the program, FTA entered into an interagency agreement with the National Renewable Energy Laboratory (NREL) to provide a third-party assessment. NREL is a U.S. Department of Energy national laboratory that is focused on renewable energy and energy efficiency research and development. NREL conducts renewable energy and energy efficiency research and development in 13 main program areas, including buildings, vehicles, solar, wind, geothermal, and hydrogen and fuel cells.

Under FTA direction and with assistance from transit agency TIGGER grantees, NREL is collecting data and information on each project and analyzing the results to determine the overall impact and assess how each project has contributed

[5] NOFA: 74 FR 12447—Solicitation of Comments and Notice of Availability of Fiscal Year 2009 Funding for Transit Investments for Greenhouse Gas and Energy Reduction Grants, http://www.gpo.gov/fdsys/granule/FR-2009-03-24/E9-6420/content-detail.html.

[6] NOFA: 75 FR 18942—FY 2010 Discretionary Sustainability Funding Opportunity; Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) Program and Clean Fuels Grant Program, Augmented With Discretionary Bus and Bus Facilities Program, http://www.gpo.gov/fdsys/granule/FR-2010-04-13/2010-8398/content-detail.html.

[7] NOFA: 76 FR 37175—FY 2011 Discretionary Sustainability Funding Opportunity Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER) Program and Clean Fuels Grant Program, Augmented With Discretionary Bus and Bus Facilities Program, http://www.gpo.gov/fdsys/granule/FR-2011-06-24/2011-15913/content-detail.html.

toward meeting overall program goals. This analysis includes environmental impacts, reduction of fossil fuel use, emission savings, economic impacts, viability of technologies adopted, and a cost vs. benefits analysis. The results from this analysis can be used by the transit agencies to meet their reporting requirements. Each transit agency is collaborating with NREL to provide the data needed for the analysis.

NREL's tasks also include developing and delivering the following:

1. Fact sheets for each project
2. Data collection and analysis for each project
3. Annual assessment reports of the program
4. Detailed case studies on selected projects
5. Overall final report on the TIGGER Program to be presented to Congress

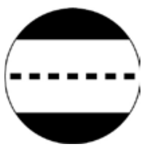
Program Management

The TIGGER Program is managed by FTA's Office of Research, Demonstration, and Innovation in coordination with the Office of Program Management and FTA regional offices. A working group of FTA staff provided input and expertise on the program through its development and deployment; this group included engineers, policy analysts, program managers, and experts in various transit technologies such as rail and vehicle propulsion systems. Technical support is provided by NREL, Volpe, and ActioNet. Volpe, the National Transportation Systems Center, is part of the U.S. Department of Transportation's Research and Innovative Technology Administration. ActioNet is an information technology solutions company on contract to FTA.

SECTION
3

Technologies Being Implemented

Through the TIGGER Program, transit agencies across the country are implementing a diverse selection of technologies to meet the overall goals for reducing energy and GHG emissions within their operations. These projects support FTA's commitment to the environment while promoting cost-efficient alternatives and sustainable operations. Table 3-1 provides a summary of projects categorized by technology. The primary project categories are Bus Efficiency, Rail, and Facility Efficiency. Many of the Facility Efficiency projects focus on secondary categories such as renewable power generation, including solar, wind, geothermal, and fuel cell projects. These categories are designated throughout this report by the icons described below.



Bus Efficiency: Projects include the purchase of fuel-efficient buses as well as retrofits to existing buses to improve fuel economy and reduce fuel use. These projects achieve added benefits across their communities by improving air quality and working toward visibility and acceptance of innovative, new technologies.

Rail: Rail projects selected for TIGGER funding include installation of technologies to store and reuse braking energy, as well as projects to improve locomotive efficiency. Technologies include on-board energy storage, wayside energy storage, locomotive upgrades, and installation of efficient controls for rail heaters.

Facility Efficiency: Projects designed to improve the sustainability of transit facilities include installation of energy efficient lighting, improved boiler technologies, and window or roof replacement. These projects are designed to provide a more efficient operation of transit agency facilities.

Solar: Solar energy projects vary in size from small systems designed to heat water to full-size systems that power entire facilities. Commercially-available photovoltaic (PV) panels are being used to produce power directly from the sun's energy. These solar systems are capable of supplying a portion of the transit agency's power, placing excess power back onto the grid when energy demand is low or being stored for later use by the agency.

Wind: Small-scale wind power projects covered under the TIGGER Program include wind turbines designed to supplement the power usage at transit agency facilities. These projects are designed to reduce transit agency electrical energy consumption.

Geothermal: Geothermal projects selected for funding include new, in-ground installations for providing improvements in the heating and cooling of transit agency facilities. These improvements will reduce heating and cooling loads through an advanced, cost-effective alternative to conventional ventilation systems.

Fuel Cell: Fuel cell (FC) projects include the installation of stationary systems to provide power for transit facilities as well as fuel cell electric buses. Fuel cells—which react hydrogen or other fuels such as biogas and natural gas with air to produce electricity, water, and heat—can be used to supply prime power, backup power, or combined heat and power for a facility or to power hybrid electric propulsion systems in buses.

Table 3-1

Summary of Projects by Technology Category[a]

Technology Category	Sub Category	Number of Projects
Bus Efficiency	Hybrid buses	19
	Efficiency retrofit	5
	Zero-emission buses	15
Total Bus Efficiency Projects		**39**
Rail	Wayside energy storage system	3
	Locomotive upgrades	3
	On-board energy storage	2
	Controls	2
Total Rail Projects		**10**
Facility Efficiency	Facility upgrades	14
	Solar	15
	Wind	2
	Stationary fuel cell	3
	Geothermal	5
Total Facility Efficiency Projects		**39**

[a] Several projects employ multiple energy-efficient technologies.

SECTION
4

Summary of Progress

Projects within the TIGGER Program were awarded in three sequential funding appropriations in FY 2009, FY 2010, and FY 2011. This section outlines the continued progress projects have made as of the end of December 2013, followed by an update on progress with the program assessment. Table 4-1 summarizes the status of the TIGGER projects by funding cycle. A project is considered completed once it has been fully implemented and funds have been exhausted. For example, a facility project is complete once construction is done and the facility is operational. Bus projects are considered complete once all buses have been delivered. Completed projects do not necessarily have a full year of data collected and, therefore, may not have results that are included in the report.

Table 4-1

Summary of TIGGER Projects by Status

	Completed		In Process		In Development		Total
	Number	Percent	Number	Percent	Number	Percent	
TIGGER I	36	84	7	16	0	0	43
TIGGER II	12	46	14	54	0	0	26
TIGGER III	3	18	13	76	1	6	17
Total	*51*	*59*	*34*	*40*	*1*	*1*	*86*

TIGGER I Projects

TIGGER I awards totaled 43 projects at $100 million in funding. As of the end of March 2014, 84% of the TIGGER I projects had been completed (36 of 43). The majority (28) of those completed projects have collected a full year of data.

TIGGER II Projects

TIGGER II awards originally totaled 27 projects at $75 million in funding. Due to difficulties encountered after a system provider went out of business, one awardee determined that it could not accomplish the original project goals and the funds were returned. FTA reviewed proposals for selected TIGGER II projects that had not received their fully-requested funding and awarded these funds to another existing project. This change brings the total TIGGER II projects to 26. As of the end of March 2014, 12 of the projects were completed and the remainder were in progress. Six of the 12 completed projects have provided the one year of required data.

TIGGER III Projects

TIGGER III awards totaled 17 projects at $49.9 million in funding. All of the projects but one are in progress.

Program Assessment

Work on the TIGGER Program assessment began in April 2011. NREL completed the first annual assessment report in June 2012. This report is the second annual assessment of the program. NREL has collected data from more than 30 projects. The results for projects that have collected a full year of data after implementation are included in the analysis that follows. Several projects that have provided a partial data set are also included.

Project Fact Sheets

Since initiating the TIGGER assessment, NREL has been coordinating with each transit agency awarded a grant to collect project information for the development and publication of individual fact sheets. As of December 2013, 43 fact sheets were complete. Fact sheets are posted on the FTA TIGGER website (http://fta.dot.gov/TIGGER). The remaining project fact sheets are in the development process and will be completed as soon as necessary project information is available.

Case Studies

FTA has selected seven projects on which to conduct more detailed case studies. These case studies will provide an opportunity for the transit industry to review and investigate technologies and implementation strategies in depth. NREL is working closely with these grantees to document the experience of the specific transit agency. Each case study will include, but not be limited to, descriptions of the project and technology being implemented, analysis of the data and results, documentation of the experience for the agency, and discussion of the potential impact of the technology to the U.S. transit industry. FTA's intent is to include a variety of technologies within these case studies that represent the broad portfolio of TIGGER projects. Selections were made prior to the announcement of the TIGGER III funding availability; therefore, all of the case study projects are part of the first two rounds of funding. As the assessment progresses and funding allows, FTA may select additional projects for detailed study. The current portfolio of case studies includes the following projects listed by technology type.

Bus Efficiency

The category of Bus Efficiency accounts for 45% of TIGGER projects. To evaluate the impact of this group FTA has selected two technologies being implemented under the program, one bus efficiency retrofit project and one zero-emission bus project.

Bus Efficiency Retrofit

TriMet MiniHybrid Thermal System
Portland, Oregon
Several agencies under the TIGGER Program are retrofitting existing buses with electrically-driven cooling systems to reduce fuel use. The MiniHybrid Thermal System, developed by Engineered Machined Products (EMP) Advanced Development, replaces the mechanically-driven cooling system on an existing bus with a high-output alternator and cooling package consisting of heat exchangers and electronically-controlled fans. The system is expected to improve fuel economy by at least 5%. Because this is a retrofit of an existing bus, the technology offers an easy, low-cost way to lower energy consumption. The technology is applicable to all bus fleets around the country, giving the project a high score for national applicability. An assessment of the technology compared to baseline diesel buses will validate the energy savings for fleets and will provide valuable information to the transit industry for replicating the project at other agencies.

Case Study Status: NREL has collected the data and completed the detailed analysis. The case study is complete and is included in Section 8 of this report. Table 4-2 provides a summary of results for the project. Fuel cost savings from this project average $81,000 annually.

Table 4-2

Summary of Results for TriMet Bus Efficiency Project

TriMet	Before	After	Savings	Unit
Total Fuel Used	438,130	417,466	20,664	gal
Annual GHG Emissions	5,206.0	4,962.0	244.0	tons CO_2^e
Annual Energy Use	60,335	57,502	2,833	MBtu
Lifetime of Technology			16	years
Projected Lifetime GHG Savings			3,904	tons CO_2^e
Projected Lifetime Energy Savings			45,328	MBtu
Lifetime GHG Savings per TIGGER $			10.4	lb CO_2^e
Lifetime Energy Savings per TIGGER $			60,437	Btu

Zero-Emission Buses

Foothill Transit Fast-Charge Electric Bus Project
West Covina, California

To evaluate the impact of adding advanced zero-emission bus technology to a fleet, NREL is working with Foothill Transit to study its electric bus project. The agency is deploying 12 electric buses with fast-charge capability into its fleet in West Covina, California. The agency plans to completely electrify a specific route, replacing all of the buses with the new technology and installing two charging stations at selected points along the route. This will allow the buses to charge quickly during layover time. This project represents a significant investment because it is the largest electric fleet funded under the program. An assessment of this unique bus technology will help validate the performance and provide the industry with valuable information about its potential at other agencies. While other projects within the program plan to deploy similar bus technology, the Foothill Transit project will provide data on the largest set of buses.

Case Study Status: This project is still in the early stage of implementation. The buses currently are being delivered, and NREL will begin data collection and analysis once the buses are in service.

Facility Efficiency

The category of Facility Efficiency accounts for 43% of the TIGGER projects and includes renewable power generation. To evaluate the various technologies in this category, FTA has selected four projects featuring a range of efficiency upgrades and renewable power.

Greater Cleveland Regional Transit Authority Energy Conservation Project
Cleveland, Ohio

The Greater Cleveland Regional Transit Authority (GCRTA) was selected for a building efficiency improvement project totaling $2,257,000. The project includes efficiency upgrades to nine of GCRTA's transit facilities. This case study provides details of the GCRTA project, encompassing results from the planning phase to end results. Based on energy analyses from two independent energy consulting firms, the agency developed an energy conservation plan to improve efficiency. The agency estimates these retrofits will result in substantial energy savings over the lifetime of the project. The technologies selected are commercially-available and could be implemented at any agency, resulting in a high national applicability. This case study is a resource for the industry in implementing these technologies across the country.

Case Study Status: This project is complete, and all data have been analyzed. A detailed report can be found in Section 8 of this document. GCRTA's energy audit identified numerous opportunities to improve its overall energy efficiency. These included replacing lighting fixtures with new improved efficient fixtures, replacing fluorescent magnetic ballasts with electronic ballasts, replacing incandescent bulbs with compact fluorescent bulbs or light-emitting diode (LED) lighting, providing better task lighting in some locations, using natural light, and improving controls such as motion sensors. The agency was able to upgrade approximately 65% of its facility lighting using TIGGER funds. The facilities that received lighting upgrades were the highest-priority projects identified during the audit as providing the highest savings with the best payback. Table 4-3 provides the summary of energy savings at each location and the annual cost savings to the agency.

Table 4-3

GCRTA Lighting Replacement Annual Savings Estimate

GCRTA Facility	Utility Savings (kWh)	Utility Savings
Central Bus Maintenance Garage	1,485,266	$129,918
Harvard Bus Garage	552,770	$45,230
Hayden Bus Garage	1,190,006	$81,420
Central Rail Maintenance Facility and Rail Service Building	4,869,906	$310,776
GCRTA Main Office	89,159	$7,904
Triskett Bus Garage	1,427,423	$132,901
Paratransit Bus Garage	143,154	$14,403
Total	*9,757,684*	*$722,552*

King Street Station Efficiency Improvements
Seattle, Washington

This project involves a major effort to increase the energy efficiency of a landmark historic building in downtown Seattle. The improvements incorporate a number of technologies such as geothermal heating and cooling, building envelope improvements, window refurbishment, and solar power. The building is a hub for transportation in the area, making this a high-visibility project. The upgrades are particularly challenging because the restorations and improvements must be made without sacrificing the historic character of the building. The technologies and techniques could be applicable not only to transit agencies with older buildings but to any historic building in the country.

Case Study Status: Construction was completed in June 2013, and the agency is compiling the data requested for analysis. EnergyPlus will be used to develop models of the Seattle King Street Station before and after all retrofit efforts supported by the TIGGER project in order to estimate the resulting energy savings of the renovation. EnergyPlus is a publically-available building energy simulation engine and was selected for this analysis because of its capability to compute annual energy consumption based on environmental conditions; building envelope; heating, ventilation, and air conditioning (HVAC) systems; and internal gains, including lighting, electrical end use equipment, and occupancy. To develop the models, building information will be gathered from architectural, mechanical, and electrical drawings of the building provided by the construction project managers. Utility data also will be collected from project partner Amtrak and will be used to perform general calibration and model validation. Annual simulations of the pre- and post-retrofit models will be performed in EnergyPlus using Typical Meteorological Year (TMY-3) weather data for Seattle and the resulting total building energy consumption will be compared. The estimated energy savings will then be used to determine the economic impact of the project with various metrics including payback period and energy savings per TIGGER dollar invested.

MARTA Laredo Bus Facility Solar Canopies
Decatur, Georgia

The Laredo bus facility project falls under the renewable solar power project category. The Metropolitan Atlanta Rapid Transit Authority (MARTA) installed canopies over the Laredo facility bus parking area with solar panels for renewable power generation, translucent panels for day lighting, and LED lights for efficient night lighting. The agency estimates the system will produce about 1.2 million kWh of electricity per year, with the following added benefits:

- Protecting the bus fleet from ultraviolet (UV) rays and rain during parking
- Lowering fuel consumption by decreasing use of bus air conditioning
- Providing a better work environment for transit staff

The project has good national applicability for agencies in areas with high solar potential. Studies have been conducted to estimate the technical potential of solar and other renewable resources in the United States. In a recent NREL study, renewable energy technical potential is defined as the achievable energy generation of a particular technology given system performance, topographic limitations, environmental considerations, and land-use constraints.[8] (See http://www.nrel.gov/gis/maps.html) for detailed maps showing the renewable energy potential for various energy technologies.

Case Study Status: The construction on the solar canopy was completed, and the system was operational in early 2012. The case study is complete and included in Section 8. Table 4-4 provides a summary of the results for the project.

[8] *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*, Technical Report, NREL/TP-6A20-51946, July 2012, http://www.nrel.gov/docs/fy12osti/51946.pdf.

Table 4-4

Summary of Results for MARTA Solar Project

MARTA	kWh	MBtu
Estimated Energy Savings	1,199,180	4,094
Actual Energy Use Before	3,042,472	10,387
Actual Energy Use After	1,711,189	5,842
Annual Energy Savings	1,331,283	4,545
Technology Lifetime (yr)	45	45
Projected Lifetime Savings	59,907,733	204,525
Projected Lifetime Savings per TIGGER $	5.55	0.02

MBTA Wind Energy Project
Massachusetts

As one of only two projects to explore wind power for transit, Massachusetts Bay Transportation Authority (MBTA) is installing two turbines to offset power for rail operation. The energy costs for MBTA's rail operations are a significant component of the agency's budget. Because electricity costs are high in the northeast region, replacing grid electricity with renewable power has the potential for high cost savings. The first installation is a 100 kW turbine at the Kingston layover facility. The turbine is expected to offset approximately 65% of the power needs for the facility. A second turbine, planned for construction adjacent to the MBTA right-of-way near the Old Colony Correctional Center, will be 750 kW. A case study of this technology will investigate the potential for wind power at other transit facilities.

Case Study Status: The first turbine was completed and began operation in January 2012. The second turbine is in the construction stage.

Rail Technology

Only 11% of the TIGGER projects are implementing technologies in the rail category. Three projects are planning to install wayside energy storage technology to capture and reuse braking energy from trains. FTA has selected one of those projects for further study.

LACMTA Wayside Energy Storage System
Los Angeles, California

Within the category of rail projects, the Los Angeles County Metropolitan Transportation Authority (LACMTA) wayside energy storage system (WESS) is of high interest. The project involves installation of a WESS at the Westlake station on the Red line (heavy rail) that will capture braking energy from a train as it slows or stops and transfer it later to a train as it starts or accelerates. The traction power substation will be switched off while the WESS is in use. LACMTA estimates an energy savings of 48% based on current use of the rail line. With a 20-year estimated life of the system, this project could result in significant energy savings. The technology could be adopted by any other rail operation in the country, giving it a high score for national applicability.

Case Study Status: This project is in the construction stage. Installation is expected to be complete in 2015, and data collection will begin at that time.

SECTION

5

Analysis of GHG Emissions and Energy Savings

Data Analysis Process

To frame the TIGGER analysis, NREL developed a comprehensive template to aid in collecting the required data from project partners. The template, in Microsoft Excel format, contains 28 separate tabs for the various types of data to be collected on TIGGER projects. To reduce the burden on project partners, NREL added a feature to the spreadsheet that automatically displays only relevant tabs for each specific project. When a TIGGER grantee first opens the file, an instruction page is the only tab that is shown. The grantee agency selects its project from a drop-down list and appropriate tabs are then displayed. The file also pre-populates basic project information on the headers for each tab. This file provides a guideline to show what level of detail is preferred for data requests. NREL expects that a majority of transit agencies should be able to provide the requested level of detail; however, some agencies may not employ a data collection system able to provide such detail. In these cases, NREL is working with the agencies to determine what data can be reported to allow a sufficient analysis. A list of data items is provided in Section 10.

NREL first provided the template to all TIGGER I project contacts. Most of these projects had been completed, and the contacts were able to provide the required data for analysis. Once all TIGGER I grantees received the template, NREL began contacting the remaining grantees from TIGGER II and TIGGER III. Of the 43 TIGGER I projects, NREL has received complete or partial data sets from 28 projects; 6 TIGGER II projects have provided full data sets. The majority of this information is included in this report.

Energy Use and GHG Emissions Calculations

Of the TIGGER grantees currently able to provide data, most have reported approximately one year of data prior to project implementation and one year of data following the project completion. For building efficiency and renewable energy projects, data were collected from monthly energy company invoices. NREL tabulated total energy use before and after project completion and calculated the annual total savings in both kWh and MBtu. For projects that had not completed a full year of operation, NREL used the data provided to estimate the total savings for a full year. These projects will be updated with actual data in follow-on reports. Building efficiency projects that resulted in heating fuel reductions could claim GHG emissions reductions as well as energy savings. For these projects, NREL calculated total fuel (natural gas, heating oil) used before and after project implementation and used conversion factors to calculate estimated GHG emissions savings. The list of conversion factors originally was developed for grantees to use during the application process when submitting proposals for the TIGGER Program. The list of all conversion factors is provided in Section 10.

To calculate projected lifetime energy and GHG emissions savings, NREL used the total savings for the first year and the estimated lifetime of the technology. For solar technology, NREL used the estimated lifetime recommended by the specific solar panel manufacturer. In some cases, this lifetime was different than what was originally proposed. NREL used several modeling tools to verify projected performance results. The System Advisor Model[9] predicts performance and cost estimates for grid-connected power projects based on installation and operating costs and system design parameters that are specified as user inputs to the model. NREL's PVWatts was used for many of the PV projects to estimate the lifetime energy production and obtain the efficiency of each system. PVWatts is a Web application used to estimate the electricity production of a grid-connected roof- or ground-mounted PV system based on a few simple inputs that allow homeowners, installers, manufacturers, and researchers to easily gauge the performance of hypothetical PV systems that use crystalline modules. A normalized degradation factor of 0.5% was applied to all PV systems over the expected lifetime beginning in the second year of operation.

For bus efficiency projects, two sets of individual fueling records for each applicable bus were provided: one year of baseline fueling records for buses that were replaced with buses funded through TIGGER and one year of fueling records for the new buses procured under the program. In a few cases, data for the replaced buses were not available because the buses were not being used. For these projects, the agencies provided data for buses of the same type and size. For the bus retrofit projects, grantees provided fueling records from one year prior to and one year after the installation of the new system on the bus. These records were used to calculate individual fuel economy values for each bus, the monthly average fuel economy for the TIGGER and baseline buses, and an overall average fuel economy for the entire data period for each bus group. Erroneous fueling records were removed from the data set. These erroneous records were most often due to inaccurate odometer readings or missing fuel records. Many of the grantees provided the individual fueling records requested.

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[9] https://sam.nrel.gov/.

Some projects only reported monthly total fuel and miles for each bus. For many projects, the older buses that were being replaced accumulated much fewer miles because of low reliability. A comparison of actual fuel used would skew the results to favor the lower-use buses. To fairly calculate energy use and GHG emissions, NREL used the average fuel economy for each bus group and normalized for the mileage of the new buses.

For example, a baseline bus accumulated 7,000 miles in the year prior to being replaced with a new TIGGER-funded bus that accumulated 20,000 miles during its first year of service. NREL used the average fuel economy of the baseline bus to calculate the fuel that would have been used if the bus had actually traveled 20,000 miles. The conversion factors were then used to calculate the GHG emissions and energy use for the buses.

Cost Calculations

Reported costs for energy and fuel varied from one location to another and tended to increase over time. For the individual project summaries in Section 7, NREL used actual costs per unit when reported by the agencies for the year after a project was completed. NREL used actual maintenance costs to determine cost per mile and then normalized the estimated total cost by the mileage of the new buses.

Aggregated results for the program were normalized by using average utility and fuel costs from the U.S. Energy Information Administration (EIA). For consistency and to facilitate comparison from year to year, NREL has set the monetary values to that of calendar year 2011. For the building efficiency projects, the average cost per unit (kWh, therm, gallon) for the year after implementation was used to estimate the total cost of energy before and after project implementation. For the bus efficiency projects, the average fuel cost per gallon for the year after implementation was used to normalize the data.

NREL quantified GHG emission reductions (CO_2^e) using the Social Cost of Carbon (SCC) estimates published by the Environmental Protection Agency. The SCC uses a combination of three models—DICE, PAGE, FUND—to develop the estimated cost of impacts per ton of CO_2 emissions. The models assess numerous environmental factors such as agricultural productivity, human health, and property damage impacted by CO_2 emissions. Inputs such as sea-level rise, carbon cycle, temperature rise, and ecosystem carbon saturation are used to assess the cost of damages with the increase or decrease of carbon emissions.[10] A wide range of costs are included in the SCC factors, using 2011

[10] http://www.whitehouse.gov/sites/default/files/omb/inforeg/for-agencies/Social-Cost-of-Carbon-for-RIA.pdf, http://www.epa.gov/climatechange/EPAactivities/economics/scc.html/.

dollars and different discount rates as shown in Table 5-1. These costs are used in this report to quantify the social benefits, or avoided costs, of GHG emissions reductions achieved by the TIGGER projects.

Table 5-1

Social Cost of CO_2, 2015–2050[a] (in 2011 $)

Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2015	$12	$39	$61	$116
2020	$13	$46	$68	$137
2025	$15	$50	$74	$153
2030	$17	$55	$80	$170
2035	$20	$60	$85	$187
2040	$22	$65	$92	$204
2045	$26	$70	$98	$220
2050	$28	$76	$104	$235

[a] The SCC values are dollar-year and emissions-year specific.

Explanation of Results Figures

To present the results of energy use and GHG emissions in a consistent and comparable format, NREL created pie charts for each project. Figure 5-1 provides an example pie chart demonstrating energy savings. The energy use or GHG emissions before project implementation is represented by the whole pie. The energy use or GHG emissions after project implementation is represented by the colored section of the pie—green for GHG emissions and blue for energy use. The white section indicates the savings as a percentage. Greater areas of white indicate better energy savings. For several projects, the actual energy or GHG emissions savings was negative, indicating the project used more energy or emitted more GHGs than the baseline. These pie charts have no white section; instead, a lightly-shaded section indicates the percent increase in energy use (light blue) or GHG emissions (light green). Potential explanations for the increases are included in the individual project results in Section 7. Figure 5-2 provides an example for a project that emitted more GHGs than the baseline.

Figure 5-1

Example Chart Showing Energy Savings Attributable to TIGGER Project

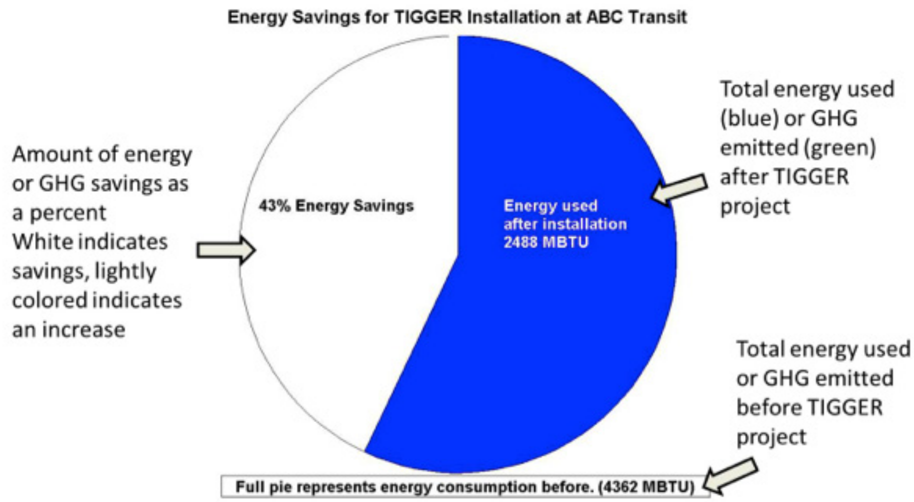
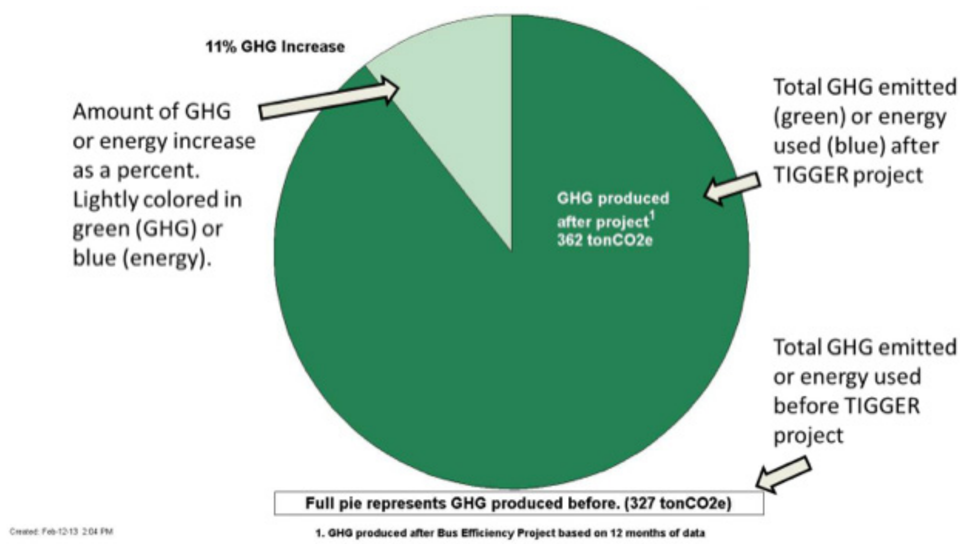


Figure 5-2

Example Chart Showing GHG Emissions Increase Attributable to TIGGER Project



Summary of Results by Project Category

NREL has received complete or partial data sets from 34 TIGGER projects. The data provided represent 37% of the total projects—not a sufficient amount to formulate an overall assessment of the program as a whole. As a result, this section summarizes results gathered to date.

The tables in this section provide annual energy and GHG emissions savings, projected lifetime savings based on estimated life of the technology, and lifetime savings per TIGGER dollar invested, by specific categories. The number of projects included in the analysis is also provided along with the total number of projects in each specific category. Table 5-2 summarizes the results to date for the program by each funding round. As expected, the majority of projects providing data are from the earliest funding round—TIGGER I—because those projects have had sufficient time to be completed and to collect a full year of data. Six of the TIGGER II projects have provided data, and none of the TIGGER III projects have progressed enough to provide sufficient data. All but five of the completed projects have provided a complete data set and three of those have provided partial data for analysis. NREL is working with each project partner to collect and analyze the remaining data.

Table 5-2 *Energy and GHG Emissions Savings by Funding Round*

	Annual Energy Savings (MBtu)	Lifetime Energy Savings (MBtu)	Annual GHG Savings (tons CO_2^e)	Lifetime GHG Savings (tons CO_2^e)	Lifetime Energy Savings per TIGGER $ (Btu/$)	Lifetime GHG Savings per TIGGER $ (lb/$)	Number of Projects Reporting
TIGGER I	83,800	1,788,003	30,515	75,974	1,012,928	172.04	28
TIGGER II	23,929	309,196	280	5,603	1,339,285	151.56	6
TIGGER III	0	0	0	0	0	0.00	0
Total	*107,729*	*2,097,199*	*30,795*	*81,577*	*2,352,213*	*323.60*	*34*

Table 5-3 summarizes the results to date by technology category. A total of 20 facility projects, 13 bus efficiency projects, and 1 rail project have provided full or partial data sets for analysis. Figure 5-3 provides a pie chart with a breakdown of the total energy saved to date by technology category. Figure 5-4 provides a similar chart showing the GHG emissions reductions to date.

Table 5-3 *Energy and GHG Emissions Savings by Technology Category*

	Annual Energy Savings (MBtu)	Lifetime Energy Savings (MBtu)	Annual GHG Savings (tons CO_2^e)	Lifetime GHG Savings (tons CO_2^e)	Lifetime Energy Savings per TIGGER $ (Btu/$)	Lifetime GHG Savings per TIGGER $ (lb/$)	Number of Projects Reporting
Bus	16,921	245,151	1,525	21,731	121,062	29.30	13
Facility	73,923	1,683,177	29,270	59,846	2,163,188	294.30	20
Rail	16,887	168,871	0	0	67,963	0.00	1
Total	*107,731*	*2,097,199*	*30,795*	*81,577*	*2,352,213*	*323.60*	*34*

Figure 5-3

Energy Savings by Project Type—107,731 MBtu Total

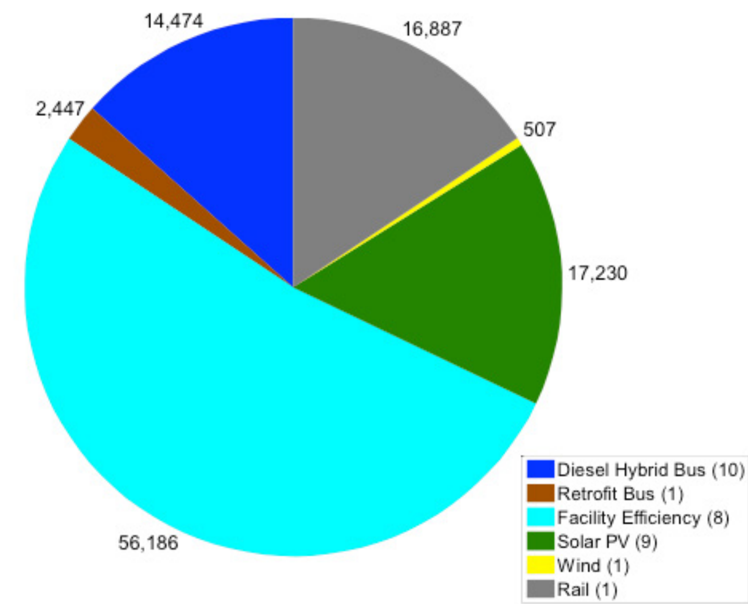


Figure 5-4

GHG Emissions Savings by Project Type—30,795 Tons CO_2e Total

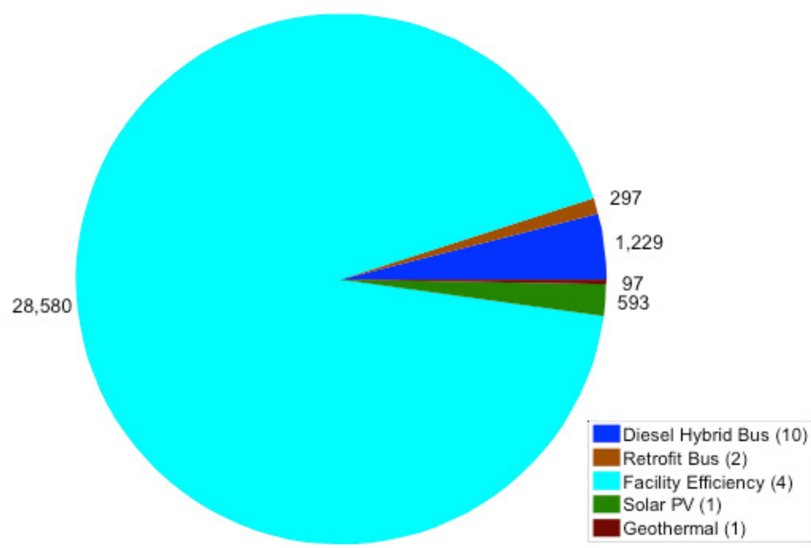


Table 5-4 summarizes the results to date for facility projects by sub-category. The majority of projects reporting have been sustainable facility upgrades and repairs or new solar installations. These have resulted in significant savings for the transit agencies involved.

Table 5-4 *Facility Efficiency Savings by Sub-Category*

	Annual Energy Savings (MBtu)	Lifetime Energy Savings (MBtu)	Annual GHG Savings (tons CO_2^e)	Lifetime GHG Savings (tons CO_2^e)	Lifetime Energy Savings per TIGGER $ (Btu/$)	Lifetime GHG Savings per TIGGER $ (lb/$)	Number of Projects Reporting
Renewable – PV	17,230	412,204	593	7,115	145,400	2.22	9
Renewable – Wind	507	10,145	0	0	4,652	0.00	1
Renewable – FC	0	0	0	0	0	0.00	0
Upgrades	56,186	1,260,828	28,580	49,815	2,013,136	279.12	9
Geothermal	0	0	97	2,916	0	12.96	1
Total	*73,923*	*1,683,177*	*29,270*	*59,846*	*2,163,188*	*294.30*	*20*

Table 5-5 summarizes the results to date for bus efficiency projects by sub-category. The majority of projects that have been implemented have been hybrid bus deployments and bus retrofits. This is not unexpected because these technologies are commercially available products. Because zero-emission buses are still in the early development stages, they can take additional time to fully develop and deliver prior to being put into service. Several TIGGER electric bus projects have recently gone into service, and operational results for those buses will be included in the next report.

Table 5-5 *Bus Efficiency Savings by Sub-Category*

	Annual Energy Savings (MBtu)	Lifetime Energy Savings (MBtu)	Annual GHG Savings (tons CO_2^e)	Lifetime GHG Savings (tons CO_2^e)	Lifetime Energy Savings per TIGGER $ (Btu/$)	Lifetime GHG Savings per TIGGER $ (lb/$)	Number of Projects Reporting
Hybrid	14,474	205,999	1,228	17,317	68,859	13.81	11
Retrofit	2,447	39,152	298	4,414	52,203	15.49	2
Zero-Emission	0	0	0	0	0	0.00	0
Total	*16,921*	*245,151*	*1,525*	*21,731*	*121,062*	*29.30*	*13*

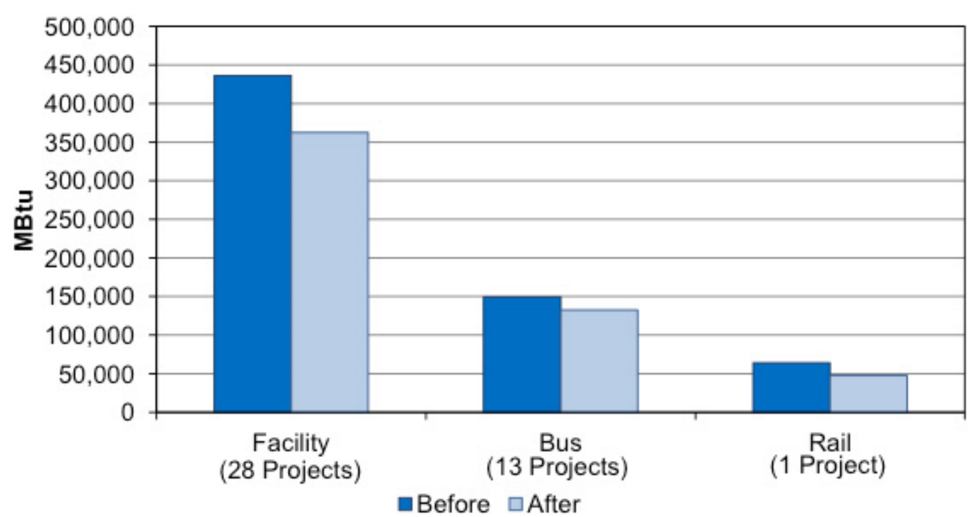
Several bus efficiency projects were not as successful as originally proposed. In some cases, the baseline and new buses were not similar enough with respect to size and weight to allow a direct comparison. For example, replacing a smaller vehicle with a larger one is not likely to show an advantage in fuel efficiency even if the new vehicle has a hybrid drivetrain. In these cases, fuel use actually increased with the new buses and therefore resulted in higher GHG emissions and energy use. If the larger vehicles increased the passenger capacity, calculations by passenger could show a reduction in energy use and

GHG emissions. A majority of projects reporting increased energy use and GHG emissions were implementing a new-technology vehicle that was still in an early development and testing phase. Over the last two years, several of the original equipment manufacturers (OEMs) or technology providers within original project proposals or grant agreements have experienced economic problems (such as bankruptcy) or operational problems with the new-technology vehicles that have caused them to abandon their participation in TIGGER. As a result, transit agencies have had issues with implementing or adopting the new-technology vehicles originally proposed for implementation. When manufacturers stop actively participating, transit agencies are forced to troubleshoot and repair advanced technology vehicles with existing maintenance staff. Low reliability for the newer-technology buses and difficulties acquiring parts and technical support also resulted in higher costs for these specific agencies.

Annual energy savings for the reporting projects are shown in Figure 5-5 by technology category. One rail project has been completed, and the data collected showed a 26% decrease in energy consumption. Facility projects resulted in a 17% energy reduction, and the bus projects showed an 11% decrease in energy use. Some of the analyzed bus projects showed increased energy use after the new technology was implemented. This lower savings for the bus projects is due primarily to two factors. First, the increased energy use for the projects mentioned above was subtracted from the total savings. Second, the fuel economy for hybrid buses is highly dependent on duty cycle. The early estimates for many of the projects assumed a fuel economy at the high end of the manufacturer-reported fuel economy range. In-use fuel economy is affected by several factors such as speed, idle time, number of stops, use of auxiliary loads (air conditioning, heating), and differences in terrain.

Figure 5-5

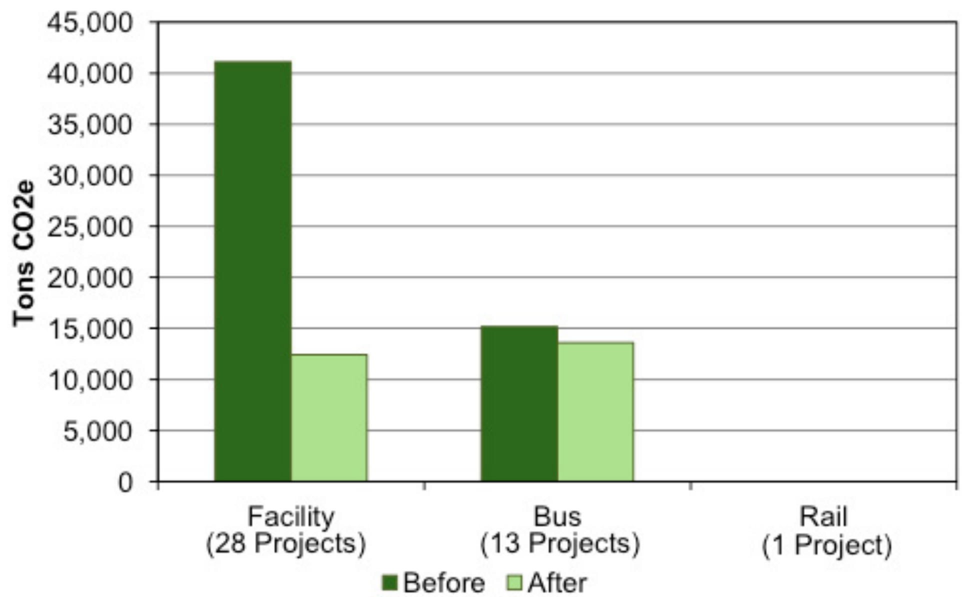
Annual Energy Savings for Reported Projects by Technology Category



Annual GHG emissions savings for the reporting projects are shown in Figure 5-6. The chart shows the total annual emissions reported before and after the new technology implementation. Facility projects were only allowed to count GHG emissions reductions if the improvements lowered the use of fuel such as natural gas or heating oil. That was the case for four of the projects reported to date. Savings for these projects was 70% compared to prior emission levels. The bus efficiency projects resulted in GHG emissions savings of 10% for the same reasons mentioned earlier. The one rail project included in the analysis was for energy reduction and was only allowed to count energy savings.

Figure 5-6

Annual GHG Emissions Savings for Reported Projects by Technology Category



SECTION
6

Economic Analysis

Energy and GHG Emissions Reduction Calculations

The first TIGGER assessment report included an analysis of projected cost savings for individual projects based on the *estimated* reductions in fuel or electricity use presented in original project proposals. This report provides cost savings based on the first year of results for the projects that have been completed and provided a full data set. For projects that reduced fuel use, the MBtu savings was converted to gallons of fuel saved (bus efficiency projects) or therms of natural gas saved (facility efficiency projects). Energy savings projects were converted to kWh of electricity saved. The costs were calculated based on the average 2011 U.S. energy prices from EIA data as follows:

- Electricity cost per kWh: $0.099
- Diesel cost per gallon: $3.791
- Gasoline cost per gallon: $3.552
- Natural gas cost per 1,000 standard cubic foot (commercial rate): $8.16.

The calculations account for energy or fuel savings and maintenance or operating cost savings associated with the technologies provided by the agencies.

Operational Cost Calculations

TIGGER grantees also were required to provide data on the difference in operational costs and related expenses for each project. This information was most often provided as maintenance costs for parts and/or labor. For building efficiency projects, maintenance for most of the new technologies—such as solar systems or wind turbines—is covered under a warranty and does not result in out-of-pocket costs to the agency. NREL reports any cost for warranty or maintenance on these projects as provided by the agencies.

For bus projects, NREL requested detailed maintenance records for the baseline and new buses. The level of detail provided by each agency varied from monthly totals by bus to actual detailed work orders on each maintenance action. For the more detailed data, NREL was able to separate the maintenance by system as well as to report scheduled and unscheduled maintenance separately. NREL used the actual data to calculate cost per mile for each bus type. The actual costs are provided for each project. As with the energy use and GHG emissions calculations, NREL used the mileage of the new buses to normalize the comparison of costs between the agency's old buses and the new TIGGER buses. The results are summarized for each project in tabular form (see individual results for each project in Section 7). Projections can be made on total lifetime savings based on the estimated useful life provided by the agency. However, these projections should be used cautiously, as they assume the same savings per year without taking into account any degradation of performance over time.

Economic Analysis Summary

TIGGER projects have resulted in significant cost savings for the participating transit agencies. The transit agencies report very little cost to operate and maintain the new systems primarily because this cost is currently covered under manufacturer warranties. The facility and bus projects report lower-than-expected energy cost savings; however, most of the agencies report much lower costs to operate and maintain the newer technology. The maintenance cost analysis has been completed for six of the seven bus efficiency projects. Of these, five report significant maintenance cost savings totaling more than $698,000 for the first year of operation.

Table 6-1 represents the annual energy savings for the projects included in the analysis by technology category. The table shows the actual annual energy savings, the estimated lifetime energy savings, and the cost savings associated with the reduction. The completed projects have reduced energy consumption by enough to power 2,794 homes annually. The per-TIGGER-dollar cost savings for each category is included in the table. The cost savings is based on the projected lifetime savings calculated using the data provided by the reporting agencies. Some of these are partial data sets, but the total award amount is used in the calculation as it is difficult to determine the dollar amount spent to date. The per-TIGGER-dollar total is expected to rise when complete data sets are provided.

Table 6-1

Total Energy Savings by Category

	Annual Energy Savings (MBtu)	Lifetime Energy Savings (MBtu)	Total Annual Cost Savings $ (2011)	Lifetime Cost Savings per TIGGER $	Homes Powered for One Year	Number of Projects Reporting
Bus	16,921	245,151	$2,029,081.01	$1.03	439	13
Facility	73,923	1,683,177	$2,273,107.04	$1.29	1,920	20
Rail	16,887	168,871	$489,697.07	$1.97	439	1
Total	*107,731*	*2,097,199*	*$4,791,885.11*	*$1.22*	*2,797*	*34*

Table 6-2 presents the annual GHG emissions savings for the projects included in the analysis by technology category. The table shows the actual GHG emissions savings and estimated lifetime GHG emissions savings for the projects that had a goal of GHG emissions reduction (18 of the 53 projects). Facility projects were only allowed to count GHG emissions reductions if the improvements lowered the use of fuel such as natural gas or heating oil. That was the case for six of the projects reported to date. The facility and bus projects both estimated higher GHG emissions savings than they have achieved.

Table 6-2

GHG Emissions Savings by Technology Category

	Annual GHG Savings (tons CO_2^e)	Lifetime GHG Savings (tons CO_2^e)	Cars Removed from Road for One Year	Number of Projects Reporting
Bus	1,525	21,731	268	13
Facility	29,270	59,846	5,135	20
Rail	0	0	0	1
Total	*30,795*	*81,577*	*5,403*	*34*

The avoided costs from the annual CO_2^e emissions reductions are shown in Table 6-3. These values are published by the Environmental Protection Agency and applied to each metric ton of CO_2 reduced. These are indirect costs to society calculated using a range of cash discount rates to account for future inflation. Because predicting the future value of the dollar is a controversial subject, a range of discount rates are used for the calculations.

Table 6-3

Total Avoided Costs from Annual GHG Emissions Reduction

Annual Social Cost of CO2, 2015 2050[a] (in 2011 $)				
	Discount Rate and Statistic			
Year	5% Average	3% Average	2.5% Average	3% 95th percentile
2015	$369,537.60	$1,200,997.20	$1,878,482.80	$ 3,572,196.80
2020	$400,332.40	$1,416,560.80	$2,094,046.40	$ 4,218,887.60
2025	$461,922.00	$1,539,740.00	$2,278,815.20	$ 4,711,604.40
2030	$523,511.60	$1,693,714.00	$2,463,584.00	$ 5,235,116.00
2035	$615,896.00	$1,847,688.00	$2,617,558.00	$ 5,758,627.60

[a] The SCC values are dollar-year and emissions-year specific.

SECTION

7

Project Status

This section provides information on each TIGGER project including an overview, current status of implementation, and an early analysis of results. Projects are organized by FTA region. Table 7-1 lists the FTA regions along with the number of projects and specific technologies being implemented. A sub-section on each region provides a map and a list of projects within that region. An index of all projects is provided in Section 9.

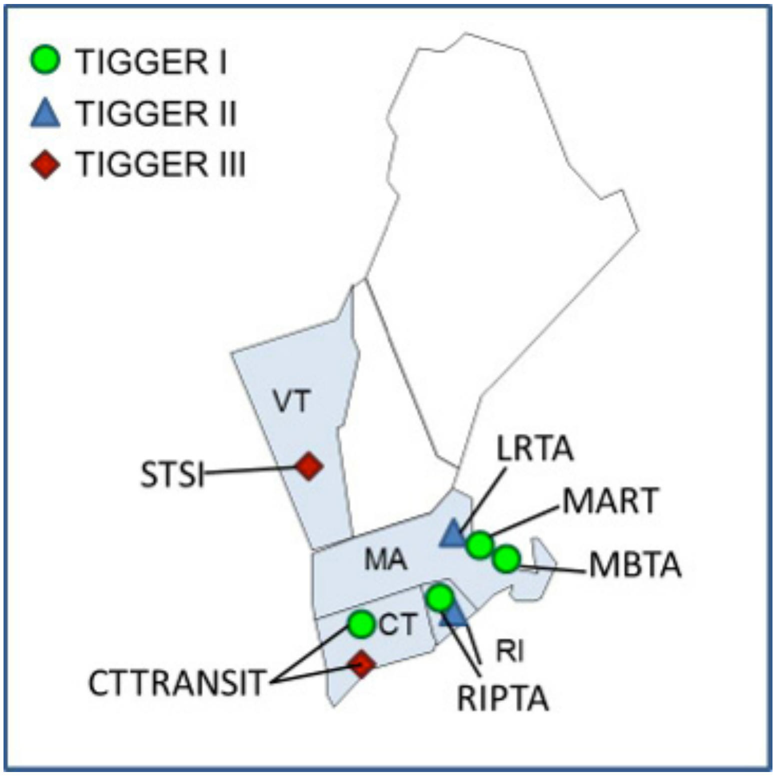
Table 7-1 *Number of Projects by Region*

Region	Number of Projects	Technologies
I	8	Bus Efficiency, Facility Efficiency, Fuel Cell, Solar, Wind
II	6	Bus Efficiency, Facility Efficiency, Rail
III	10	Bus Efficiency, Facility Efficiency, Rail, Solar
IV	12	Bus Efficiency, Facility Efficiency, Solar, Geothermal
V	19	Bus Efficiency, Facility Efficiency, Rail, Solar, Wind, Geothermal
VI	2	Bus Efficiency
VII	1	Bus Efficiency
VIII	4	Bus Efficiency, Facility Efficiency
IX	14	Bus Efficiency, Solar, Rail, Fuel Cell
X	11	Bus Efficiency, Facility Efficiency, Rail, Solar, Geothermal

Region I

Figure 7-1

Map of FTA Region I Project Locations



Region I projects:

1. Connecticut Transit (CTTRANSIT), hybrid bus and stationary fuel cell installation
2. Connecticut Transit (CTTRANSIT), stationary fuel cell installation
3. Lowell Regional Transit Authority (LRTA), Hale Street solar installation
4. Massachusetts Bay Transit Authority (MBTA), wind energy project—see case study in Section 8
5. Montachusett Regional Transit Authority (MART), solar installation
6. Rhode Island Public Transit Authority (RIPTA), facility lighting conversion
7. Rhode Island Public Transit Authority (RIPTA), solar installation
8. Stagecoach Transportation Services, Inc. (STSI), energy efficiency improvements

Project Name: CTTRANSIT Hybrid Bus and Stationary Fuel Cell Installation

Transit Agency: Connecticut Department of Transportation
Location: Statewide, Connecticut
Award Amount: $7,000,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary (Project 1 – 40-foot hybrid buses):

First Year Energy/GHG Savings: 2,802 MBtu / 242 tons CO_2^e
First Year Fuel Cost Savings: $92,360
Projected Lifetime Energy/GHG Savings: 33,627 MBtu / 2,899 tons CO_2^e

Transit Agency Profile: Connecticut Transit (CTTRANSIT), owned by the Connecticut Department of Transportation, provides fixed-route transportation services to metro Hartford, New Haven, and Stamford. The Hartford division is the largest of the three areas, operating 237 buses over 30 local routes and 12 express routes.

Project Description: The CTTRANSIT project consists of two parts:

1. Replacement of older diesel buses with more efficient hybrid-electric buses for the New Haven and Waterbury Divisions.
2. A stationary fuel cell to replace diesel backup generators at the Hartford Division. The stationary fuel cell will provide combined heat and power to the Hartford facility.

Project Status: Project 1 is complete. TIGGER funding enabled the agency to upgrade an existing order of buses from diesel to diesel hybrid-electric. The agency received 31 hybrid buses—14 40-foot buses that seat 38 passengers, and 17 35-foot buses that seat 30 passengers. The buses were placed in service at two of CTTRANSIT's divisions: New Haven received the 14 40-foot hybrid buses and Waterbury received the 17 35-foot hybrids. The hybrid buses replaced older diesel buses that had reached the end of their useful lives. The specifications of the New Haven buses are provided in Table 7-2. NREL is working with the agency to collect the data on the Waterbury buses.

Table 7-2

Specifications for CTTRANSIT 40-Foot Buses

	Baseline	New Technology
Number of Vehicles	3	14
Model Year	2007	
Manufacturer	New Flyer	New Flyer
Model	DL-40	Xcelcior
Length (ft)	40	40
Weight (lb)	28,850	
Engine OEM	Cummins	
Engine: Rated Power (hp)	280	
Hybrid System Manufacturer	N/A	Allison
Hybrid Model	N/A	EV 40
Hybrid Configuration	N/A	Parallel
Energy Storage Type	N/A	NiMH Batteries
Energy Storage Manufacturer	N/A	Allison

Project 2 also is complete. The agency selected ClearEdge Power[11] through a competitive bid process to supply a 400-kW stationary fuel cell power system. The system installation was completed and the unit was generating power in October 2012. Figure 7-2 shows the fuel cell installed at the CTTRANSIT Hartford Division.

Figure 7-2

Stationary Fuel Cell during Installation at CTTRANSIT

Summary of Results for Project 1: CTTRANSIT submitted the data for the 40-foot hybrid buses in operation at the New Haven Division. The baseline data were from buses similar to those that were replaced. Table 7-3 provides a summary of energy and GHG results for the project. The new buses resulted in an estimated fuel savings of 21,816 gallons during the first year of operation, saving CTTRANSIT an average of $85,519 in fuel costs.

[11] In February 2013, ClearEdge Power completed its acquisition of UTC Power, formerly a subsidiary of United Technologies Corporation.

Table 7-3

Summary of Energy Use and GHG Emissions for CTTRANSIT

	Hybrid	Baseline	Savings	Unit
Total Fuel Used	91,741	113,557	21,816	gal
Annual GHG Emissions	1,015.8	1,257.3	242	tons CO_2^e
Annual Energy Use	11,784	14,586	2,802	MBtu
Lifetime of Technology			12	years
Projected Lifetime GHG Savings			2,899	tons CO_2^e
Projected Lifetime Energy Savings			33,627	MBtu

Figure 7-3 shows an energy savings of 19% from reducing fuel consumption. GHG emissions were reduced by 19%, shown in Figure 7-4. This is a reduction of 242 tons of CO_2 emissions annually.

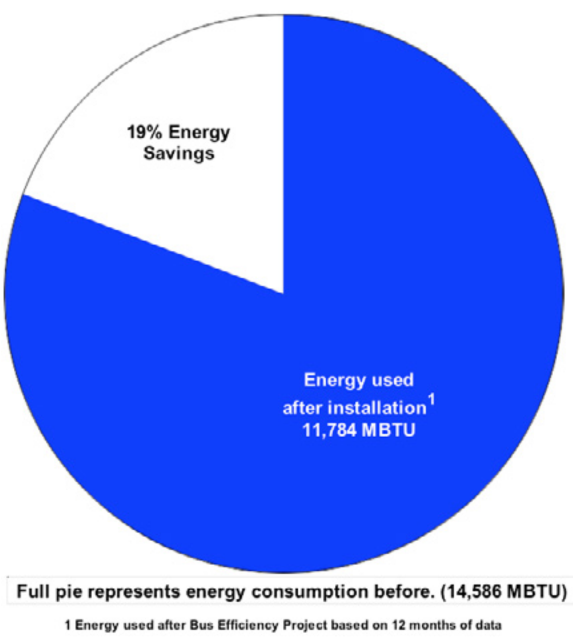


Figure 7-3

Annual Energy Use for CTTRANSIT 40-Foot Hybrid Buses

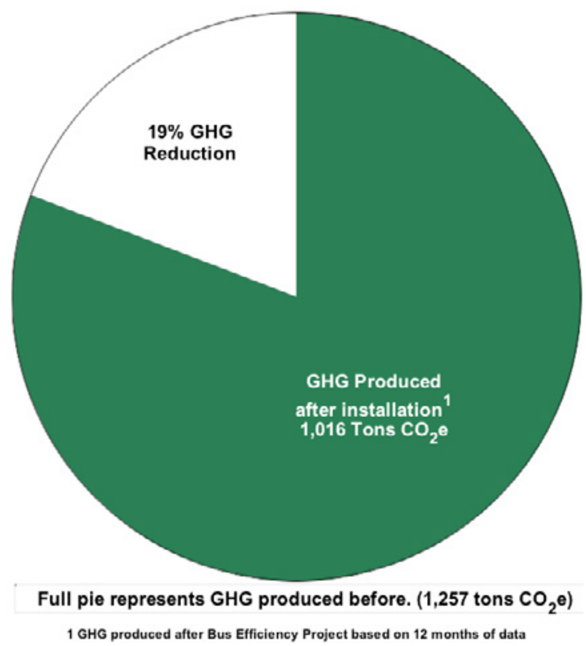


Figure 7-4

Annual GHG Emissions for CTTRANSIT 40-Foot Hybrid Buses

Figure 7-5 shows the monthly fuel economy comparison between the older buses and the hybrids. The hybrid buses have an average fuel economy that is 24% higher than that of the baseline diesel buses.

Figure 7-5

Monthly Average Fuel Economy for CTTRANSIT 40-Foot Buses

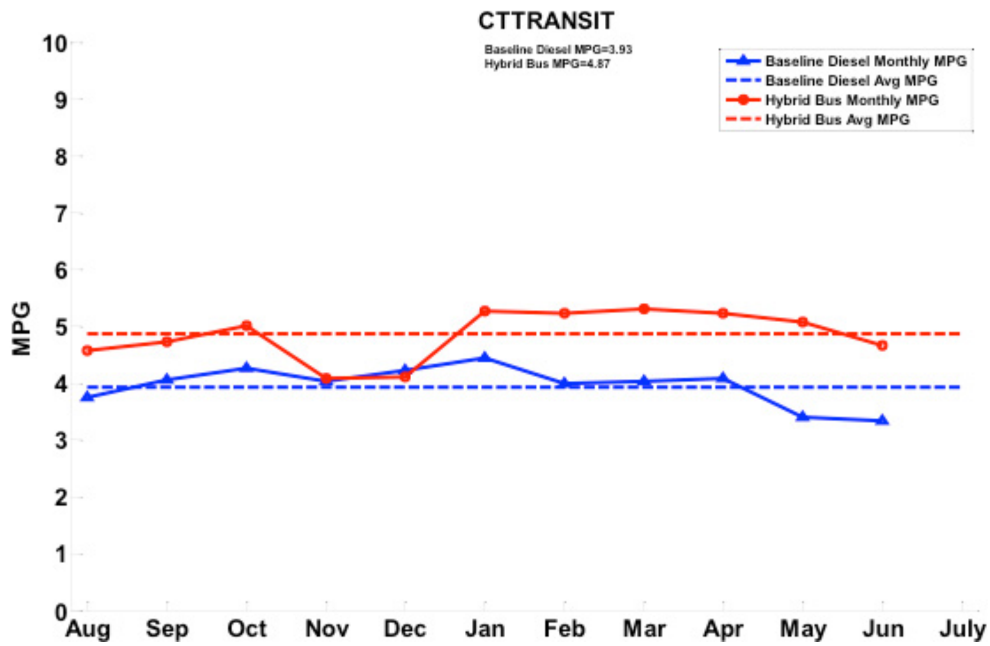


Table 7-4 summarizes the operational costs of the hybrid and diesel baseline buses. The maintenance costs for the hybrid buses were 68% lower than for the diesel buses. Most of the maintenance costs for the diesel baseline buses were for unscheduled repairs. CTTRANSIT provided very detailed maintenance records. Costs for accident-related repair, which would be extremely variable from bus to bus, were eliminated from the analysis. The level of detail also allowed NREL to categorize the repair by system. The propulsion-related-only maintenance costs are provided in the table. These costs for the hybrid buses were only 27% of the total unscheduled maintenance costs; for the baseline diesel buses these were more than 50% of the total unscheduled maintenance costs.

Table 7-4

Summary of Operational Costs for CTTRANSIT 40-Foot Buses

	Hybrid	Baseline
Total Miles	471,307	114,414
Parts Cost	$49,278.81	$68,891.28
Labor Cost	$78,750.61	$27,266.85
Total Maintenance Cost	$128,029.42	$96,158.13
Maintenance Cost per Mile	$0.27	$0.84
Scheduled Maintenance Cost	$47,246.77	$12,198.85
Scheduled Maintenance Cost per Mile	$0.10	$0.11
Unscheduled Maintenance Cost	$80,782.65	$49,513.64
Unscheduled Maintenance Cost per Mile	$0.17	$0.43
Propulsion-Related Unscheduled Maintenance Costs	$21,621.57	$26,882.76
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.05	$0.23
Fuel Economy (mpg)	4.87	3.93
Total Fuel Used (gal)	96,777.6	29,113.0
Fuel Cost (at $3.99/gal)	$386,142.70	$116,160.78
Fuel Cost per Mile	$0.82	$1.02
Total Cost per Mile	$1.09	$1.86

Using the mileage of the buses after retrofit as the baseline, the operational cost savings are summarized in Table 7-5. By replacing the older diesel buses with new hybrid buses, CTTRANSIT estimates it will save nearly $730,000 each year they are in service.

Table 7-5

Operational Cost Difference for CTTRANSIT 40-Foot Buses

	Hybrid	Baseline	Difference
Total Maintenance Cost	$128,029.42	$396,105.37	$268,075.95
Total Fuel Cost	$386,142.70	$478,502.53	$92,359.83
Total Cost	*$514,172.12*	*$874,607.90*	*$360,435.78*

Project Name: **CTTRANSIT Stationary Fuel Cell Installation – New Haven**

Transit Agency: Connecticut Department of Transportation
Location: New Haven, Connecticut
Award Amount: $5,702,298
Award Year: 2011
TIGGER Goal: Energy reduction

Transit Agency Profile: Connecticut Transit (CTTRANSIT), owned by the Connecticut Department of Transportation, provides fixed-route transportation services to metro Hartford, New Haven, and Stamford. The Hartford division is the largest of the three areas, operating 237 buses over 30 local routes and 12 express routes.

Project Description: Under this TIGGER III project, CTTRANSIT will install a 400 kilowatt stationary fuel cell system at its New Haven Division, similar to what was done for the Hartford Division (see previous project).

Project Status: This project is in progress. ClearEdge Power was awarded the contract for the fuel cell system installation at CTTRANSIT in New Haven. Southern Connecticut Gas has installed a new natural gas line to provide fuel for the installation once in place. ClearEdge Power has provided a 75% complete design, and the agency provided comments for the completion. CTTRANSIT has filed a utility interconnection agreement and put the design work on hold until project bonding issues are resolved with ClearEdge Power. CTTRANSIT anticipates construction of this project to begin in June 2014.

Project Name:	**Hale Street Photovoltaic System**
Transit Agency:	Lowell Regional Transit Authority
Location:	Lowell, Massachusetts
Award Amount:	$1,500,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Energy reduction

Results Summary:

First Year Energy Savings: 1,514 MBtu
First Year Energy Cost Savings: $43,896
Projected Lifetime Energy Savings: 28,741 MBtu

Transit Agency Profile: Lowell Regional Transit Authority (LRTA) provides public transportation services for its 13 member communities. It offers fixed-route bus service to 6 communities, demand-response service for older adults and persons with disabilities to 10 communities, special minibus service to 6 regional councils on aging, and shuttle service for 12 business and tourist sites in the city of Lowell.

Project Description: LRTA installed a PV system on the roof of its Hale Street garage. Table 7-6 provides selected specifications for the LRTA solar installation. A total of 600 American Choice Solar Panels were installed covering 1,800 square feet of the roof. Because the peak power rating of the new solar panels is two times higher than that of the panels originally planned, the agency was able to install fewer than half the number of the panels on the roof, allowing for future expansion and staying within budget constraints. The inverter for the system has a 95% efficiency rating, and the panels are rated at 90% efficiency for the first 10 years of operation. Each panel is 3 square feet, comes with a 5-year warranty, and has an estimated lifetime of 20 years. The panels are at a 3% angle and are available 75% of the time.

Table 7-6

LRTA PV System Specifications

Solar System Specifications	
PV Manufacturer	American Choice Solar Panels
PV Panel Nameplate Power (W)	250
PV Area Per Panel (sq ft)	18
Number of PV Panels Installed	1,911
Total PV Area (sq ft)	33,634
Panel Estimated Lifetime (yrs)	25

Project Status: The installation of the PV system was completed on November 21, 2011.

Summary of Results: LRTA provided a full year of data before and after the solar system began operation. Table 7-7 summarizes the results. Figure 7-6 provides a comparison of the energy consumption at the facility. The analysis showed the agency reduced energy consumption by 84% in the first year of operation using only 296 MBtu annually compared to the 1,810 MBtu annually consumed prior to the installation. This is enough energy to power an average of 40 homes in the United States[12] each year.

Table 7-7

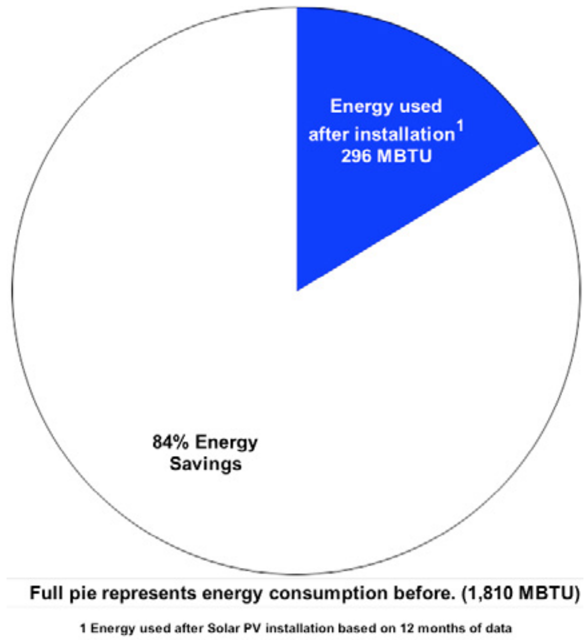
Summary of Results for LRTA Solar Project

	kWh	MBtu
Estimated Energy Savings	489,698	1,672
Actual Energy Use Before	530,081	1,810
Actual Energy Use After	86,692	296
Annual Energy Savings	443,390	1,514
Technology Lifetime (yrs)	25	25
Projected Lifetime Savings	10,394,210	35,486
Projected Lifetime Savings per TIGGER $	6.93	0.02

[12] Based on the 2011 average electricity cost for the continental United States, $0.099/kWh (EIA).

Figure 7-6

Annual Energy Savings for LRTA Solar Project



Project Name: MART Renewable Energy Project

Transit Agency:	Montachusett Regional Transit Authority
Location:	Fitchburg, Massachusetts
Award Amount:	$1,687,500
Award Year:	2010
TIGGER Goal:	Energy reduction

Results Summary:

First Year Energy Savings: 515 MBtu
First Year Energy Cost Savings: $30,146
Projected Lifetime Energy Savings: 12,063 MBtu

Transit Agency Profile: Montachusett Regional Transit Authority (MART) is a regional transit authority of MassDOT, providing transit services to Fitchburg, Leominster, Gardner, and some areas of Lancaster and Lunenburg in north central Massachusetts.

Project Description: Solar panels and battery systems will be installed at two MART locations and will be connected to an energy management system. These systems are designed to provide mission critical power for 2–3 days during power outages. The systems will monitor power consumption and will conserve power via smart switches to shut down idle equipment. The PV power will offset grid power during normal operating hours. This project will reduce the electrical energy use at two MART facilities. The complete project is MART's Green Initiative for Energy Production, Preservation and Proliferation (EP3). It will provide an energy management model consisting of three components: 1) local energy production;

2) energy preservation; and 3) proliferation of excess capacity.[13] Table 7-8 lists the MART PV system specifications.

Table 7-8

MART Solar System Specifications

Solar System Specifications	
PV Manufacturer	Solar World
PV Panel Nameplate Power (W)	250
PV Area Per Panel (sq ft)	17
Number of PV Panels Installed	672
Total PV Area (sq ft)	11,544
Panel Estimated Lifetime (yrs)	25

Project Status: The first phase of this project was completed in November 2012, and the partial dataset has been submitted for analysis. A detailed analysis performed to assess the solar potential at the offices and garage location revealed poor solar capture conditions at the facility. The planned solar array has been replaced by lighting fixture upgrades, which were completed at the beginning of 2014; the agency currently is collecting data on this portion of the project for analysis. A partial system deployment is estimated by June 2014. MART anticipates issuing a Request for Proposals (RFP) for a scaled-down version of this system on the storage facility in March 2014. It will include the energy management control system and energy conservation measures. MART plans to issue a separate RFP for a solar array installation at its Gardner Main Street Maintenance Facility in February 2014, with an estimated completion date of June 2014.

Summary of Results: The Fitchburg Water Street Maintenance Facility had a solar array, battery backup power, and an energy management system fully deployed in November 2012. MART provided data for the first completed phase of its project for preliminary analysis; the results are provided in Table 7-9 and Figure 7-7. Solar World supplied the panels for this project, installing 672 panels on the roof of the facility. The first phase shows a 41% reduction in energy consumption, slightly more than 150,000 kWh during the first year of operation. The estimated cost savings to MART during the first year is $30,146.

Table 7-9

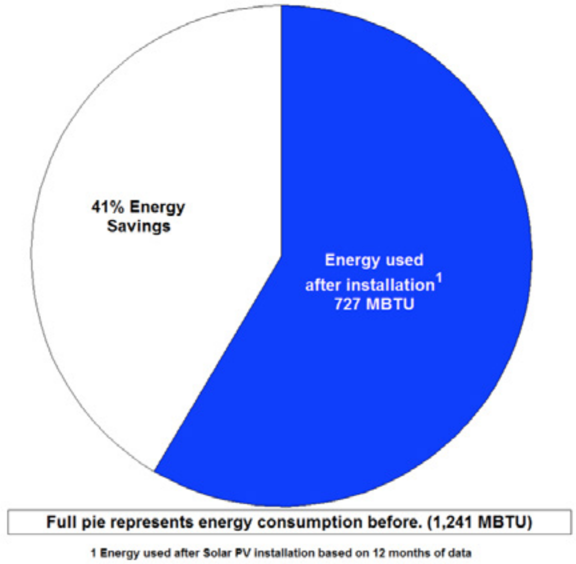
Summary of Results for MART Project

	kWh	MBtu
Estimated Energy Savings	220,082	751
Actual Energy Use Before	363,540	1,241
Actual Energy Use After	212,809	727
Annual Energy Savings	150,731	515
Technology Lifetime (yrs)	25	25
Projected Lifetime Savings	3,533,535	12,063
Projected Lifetime Savings per TIGGER $	2.09	0.01

[13] http://www.mrta.us/CapitalProjects.html/.

Figure 7-7

Annual Energy Savings for MART Solar Project



Project Name: Rhode Island Facility Lighting Conversion

Transit Agency:	Rhode Island Public Transit Authority
Location:	Rhode Island, statewide
Award Amount:	$345,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Energy reduction

Transit Agency Profile: Rhode Island Public Transit Authority (RIPTA) provides transit services to all five counties in Rhode Island (Providence, Bristol, Kent, Washington, and Newport). RIPTA operates fixed-route service, human service paratransit, and flex service with a fleet of 370 revenue vehicles over 60 routes.

Project Description: The project will replace the lights at four RIPTA facilities with new high-efficiency compact fluorescent lighting, a proven technology with widespread use showing a net energy savings. In addition to reducing the electrical energy use, efficient lighting has the added advantage of decreasing the heat load on the building's air cooling system.

Project Status: The RIPTA facility lighting project was completed by the end of 2010. NREL is working with the agency to collect the data needed to complete the analysis and will include it in the next report.

Project Name: Rhode Island Public Transit Solar Project

Transit Agency: Rhode Island Public Transit Authority
Location: Providence, Rhode Island
Award Amount: $1,200,000
Award Year: 2010
TIGGER Goal: Energy reduction

Transit Agency Profile: Rhode Island Public Transit Authority (RIPTA) provides transit services to all five counties in Rhode Island (Providence, Bristol, Kent, Washington, and Newport). RIPTA operates a fleet of 370 revenue vehicles over 60 routes. RIPTA also operates flex Service, human services paratransit, and contracted seasonal ferry service.

Project Description: The RIPTA solar project incorporates solar PV panels installed on RIPTA facilities. The PV panel design includes 1,134 panels covering more than 37,000 square feet of roof space.

Project Status: This project is in progress. RIPTA completed the architectural and engineering plans in the spring of 2012; a contract was awarded in September 2012. Project construction and procurement began with winter work that includes minor electrical upgrades. Roof construction and panel installation were completed in the spring of 2013. NREL is working with the agency to collect the data needed to complete the analysis and will include it in the next report.

Project Name: STSI Transit Facility Energy Efficiency Improvements

Transit Agency: Stagecoach Transportation Services, Inc.
Location: Randolph, Vermont
Award Amount: $95,769
Award Year: 2011
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Stagecoach Transportation Services, Inc. (STSI) provides transportation services to a 29-town area in central Vermont. The agency operates five deviated and commuter routes as well as programs that focus on specialized populations, including older adults, persons with disabilities, and low-income families and individuals.

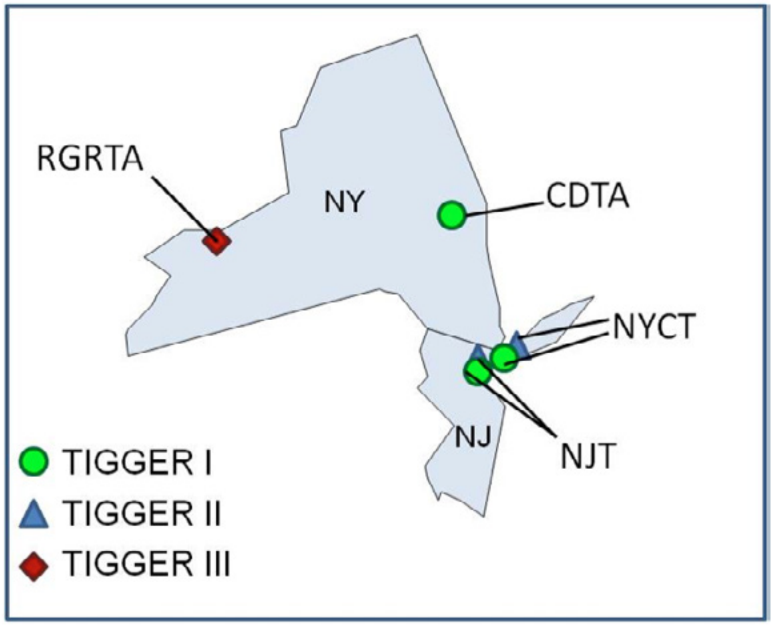
Project Description: The STSI project will improve the energy efficiency of the agency's administrative and vehicle facilities in Randolph, Vermont. The administration facility, known as the Freight House, is a former railroad building built in 1848. An energy audit conducted in 2011 outlined several modifications and upgrades that would significantly cut energy losses and lower the cost to heat this historic building. The facilities also include a metal-sided 12-bay garage that is costly to heat. The TIGGER project will implement recommendations from the energy audit that will tighten the building envelope and lower energy and fuel use.

Project Status: This project includes insulation and sealing of the administrative building in addition to renovations of the Hedding Drive facilities. STSI issued an RFP for the work in April 2012; a contract was awarded in May 2012. The expected completion date is December 2014.

Region II

Figure 7-8

Map of FTA Region II Project Locations



Region II projects:

1. New Jersey Transit (NJT), facility air compressor upgrade
2. New Jersey Transit (NJT), electric switch heaters and controls for rail
3. Capital District Transportation Authority (CDTA), hybrid bus project
4. New York City Transit (NYCT), remote third rail heaters
5. New York City Transit (NYCT), wayside energy storage system
6. Rochester-Genesee Regional Transportation Authority (RGRTA), facility efficiency project

Project Name: New Jersey Transit Efficient Air Compressors

Transit Agency: New Jersey Transit
Location: Newark, New Jersey
Award Amount: $250,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Results Summary:

First Year Energy Savings: 3,621 MBtu
First Year Energy Cost Savings: $105,000
Projected Lifetime Energy Savings: 36,209 MBtu

Transit Agency Profile: New Jersey Transit (NJT) serves the state of New Jersey and Orange and Rockland counties in New York. The agency operates a fleet of 2,027 buses, 711 trains, and 45 light rail vehicles over a service area of 5,325 square miles. NJT also connects to major commercial and employment centers in New Jersey, New York City, and Philadelphia.

Project Description: NJT is improving four of its facilities by upgrading air compressor systems with energy efficient equipment. This project involves the purchase and installation of energy-efficient systems, monitoring and verification services, and spare parts at the four NJT maintenance facilities in New Jersey. The electric motors will be replaced with variable-frequency drive motors. Dryers that are incorrectly sized or operating poorly also will be replaced. The capacity of the air storage tanks will be increased, where possible, to maximize energy efficiency.

Project Status: This project is complete, and NJT provided data for one year before and one year after the new technology installation for analysis.

Summary of Results: Table 7-10 shows a summary of the energy savings of NJT's project. During the first year of operation, energy consumption was reduced by more than 1 million kWh. The technology has an expected useful life of 10 years, which will provide an estimated lifetime energy savings of 10.6 million kWh. Figure 7-9 shows a 6% reduction in energy use during the first year of operation, enough to power 94 homes. The new technology provided a cost savings of $105,000 to the agency the first year.[14]

Table 7-10

Summary of Results for NJT Facility Project

	kWh	MBtu
Estimated Energy Savings	1,021,090	3,486
Actual Energy Use Before	16,400,351	55,991
Actual Energy Use After	15,339,739	52,370
Annual Energy Savings	1,060,612	3,621
Technology Lifetime (yrs)	10	10
Projected Lifetime Savings	10,606,119	36,209
Projected Lifetime Savings per TIGGER $	42.42	0.14

[14] Based on average U.S. utility rates for 2011 (EIA).

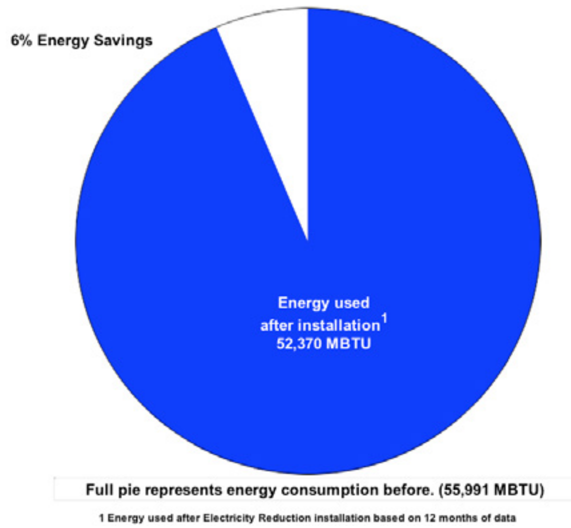


Figure 7-9
Annual Energy Savings for NJT Facility Project

Project Name: NJT Energy Efficient Electric Switch Heaters and Controls for Rail

Transit Agency: New Jersey Transit
Location: Newark, New Jersey
Award Amount: $2,484,766
Award Year: 2010
TIGGER Goal: Energy reduction

Results Summary:

First Year Energy Savings: 16,887 MBtu
First Year Energy Cost Savings: $489,697
Projected Lifetime Energy Savings: 168,871 MBtu

Transit Agency Profile: New Jersey Transit (NJT) operates one of the largest transit systems in the country. New Jersey has the third-highest public transit use in the country: roughly 10% of commuters use mass transit every weekday. Its fleet includes more than 1,800 buses, 1,200 railcars, and other purchased services, allowing NJT to provide more than 3.2 billion passenger miles annually.

Project Description: NJT is using TIGGER funds to replace 390 switch heaters with new flat heaters that have better heat transfer characteristics and will heat the track only during freezing conditions. The heaters maintain proper switching of commuter rail trains in the winter by heating the track switches to prevent snow and ice buildup. The older heaters were configured to heat the track during the entire fall and winter season, wasting a significant amount of energy. The new track heaters also carry a 10-year warranty that vastly exceeds the expected lifetime of the old heaters. This is expected to save millions of dollars by eliminating two heater replacements over the next decade.

Project Status: The RFP for this project was released in January 2012, and an award was made in May 2012. In total, 50% of the installations (187) were completed by March 2014, and a partial data set, which included 147 installations, was provided for analysis in January 2014.

Summary of Results: NJT replaced old switch heaters for the commuter trains with new flat switch heaters that provide heat during freezing conditions. The new technology reduced energy consumption by almost 5 million kWh during the first year of operation, as shown in Table 7-11. The reduction is due to the ability of the new switch heaters to be turned on only at freezing temperatures rather than for the entire cold season.

Table 7-11

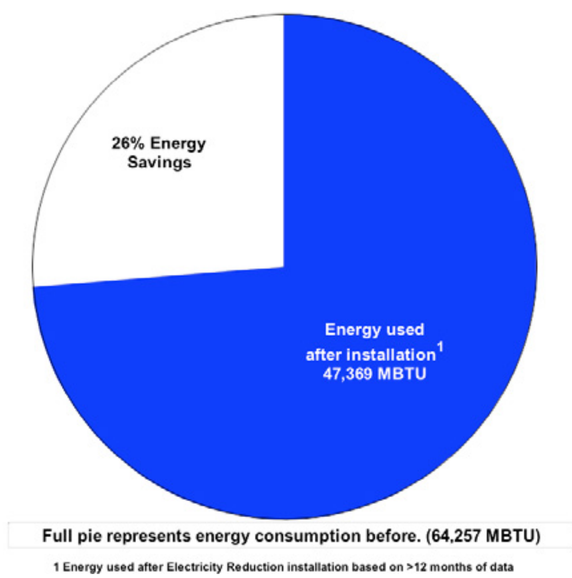
Summary of Results for NJT Rail Switch Heater Project

	kWh	MBtu
Estimated Energy Savings	5,203,925	17,766
Actual Energy Use Before	18,821,507	64,257
Actual Energy Use After	13,875,073	47,369
Annual Energy Savings	4,946,435	16,887
Technology Lifetime (yrs)	10	10
Projected Lifetime Savings	49,464,346	168,871
Projected Lifetime Savings per TIGGER $	19.91	0.07

Figure 7-10 shows that the agency reduced energy consumption by 26% the first year, saving an average of $489,697. The energy saved is enough to power 439 homes annually.

Figure 7-10

Annual Energy Savings for NJT Switch Heater Project



Project Name: CDTA Hybrid Bus Project

Transit Agency: Capital District Transportation Authority
Location: Albany, New York
Award Amount: $3,520,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: GHG emissions reduction

Transit Agency Profile: Capital District Transportation Authority (CDTA), based in Albany, New York, provides transit services to a four-county region covering 2,300 square miles. The transit agency offers 58 regular routes with 50,000 passenger trips each weekday on its local, limited stop express, park-and-ride, and suburban shuttle services. CDTA also provides demand-response service in selected communities.

Project Description: CDTA used TIGGER funds to cover the incremental cost for 20 hybrid buses. CDTA purchased 43 new buses to replace older buses at the end of their service lives. The original order included three hybrid-electric buses. TIGGER funding was used to cover the incremental cost of upgrading 20 of the remaining transit buses on order to include hybrid-electric propulsion systems. By leveraging funding in this way, CDTA added 23 new clean-burning hybrid-electric buses to its fleet. Table 7-12 provides some specifications for the hybrid and baseline buses.

Table 7-12

Summary of Vehicle Specifications for CDTA Project

	Baseline	New Technology
Number of Vehicles	20	20
Model Year	1998	2010
Manufacturer	Orion	Gillig
Model	VI	
Length (ft)	40	40
Weight (lb)	30	25,600
Engine OEM	Cummins	Cummins
Engine: Rated Power (hp)	320	280
Hybrid System Manufacturer		Allison
Hybrid Model		EV 40
Hybrid Configuration		Parallel
Energy Storage Type		NiMH Batteries
Energy Storage Manufacturer		Allison

Project Status: This project is complete. The 20 hybrid buses have been in service since June 2010.

Summary of Results: CDTA has provided some preliminary data on the new hybrid and baseline buses. NREL is working with the agency to collect the remaining data needed to complete the analysis. Results will be included in the next report.

Project Name: NYCT Remote Third-Rail Heaters

Transit Agency: New York City Transit Department of Subways
Location: New York, New York
Award Amount: $2,000,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Transit Agency Profile: New York City Transit (NYCT) is an agency of the Metropolitan Transportation Authority, operating in New York City and surrounding communities. NYCT is the largest public transit agency in North America. The NYCT subway provides service to Brooklyn, the Bronx, Manhattan, and Queens with a fleet of 6,380 subway cars traveling 345 million miles per year.

Project Description: NYCT is installing about 350 wireless control points that will link to about 600 of the third-rail heaters used to keep the third-rail ice-free during inclement weather. This enables the agency to monitor, activate, and deactivate the heaters from a central location, as weather conditions require. These heaters are typically left on from fall through late spring, using excess power when not needed. The TIGGER funds are being used to cover the labor cost.

Project Status: The NYCT third-rail heater project encountered implementation issues due to Hurricane Sandy, slowing progress and causing schedule delays from the original proposed completion date. NYCT completed installation of all 350 control points in October 2013. Completion of construction and testing is expected to be completed in July 2014.

Project Name: Wayside Energy Storage Project

Transit Agency: New York State Metropolitan Transportation Authority
Location: New York, New York
Award Amount: $4,000,000
Award Year: 2010
TIGGER Goal: Energy reduction

Transit Agency Profile: New York City Transit (NYCT) is an agency of the Metropolitan Transportation Authority, operating in New York City and surrounding communities. NYCT is the largest public transit agency in North America. The NYCT subway provides service to Brooklyn, the Bronx, Manhattan, and Queens with a fleet of 6,380 subway cars traveling 345 million miles per year.

Project Description: NYCT is installing a wayside energy storage system that will store subway braking energy in a nickel metal hydride battery power system. This technology has been pilot tested on the Rockaway line and has shown the best overall capability compared to alternatives such as ultracapacitors and flywheel energy storage.

Project Status: This project is in progress. The funding received will be used to install five or six units instead of the eight units that were originally proposed. TransPower Inc. was awarded the construction contract in April 2013. The first battery string unit was damaged during transport. A replacement is expected in June 2014, with the remaining two units delivered by October 2014. During this time, the agency is continuing site construction and testing activities.

Project Name: Facility Efficiency Upgrade

Transit Agency:	Rochester-Genesee Regional Transportation Authority
Location:	Rochester-Genesee, New York
Award Amount:	$352,140
Award Year:	2011
TIGGER Goal:	Energy reduction

Transit Agency Profile: The Rochester-Genesee Regional Transportation Authority (RGRTA) provides fixed-route urban transit service and paratransit service for the city of Rochester and the surrounding area in Monroe County, as well as fixed-route and demand-response rural services in Genesee, Livingston, Orleans, Seneca, Wayne, and Wyoming counties. These 7 counties cover 3,700 square miles and have a combined population of nearly 1.1 million.

Project Description: RGRTA's TIGGER project consists of four energy-efficiency improvements to its facility:

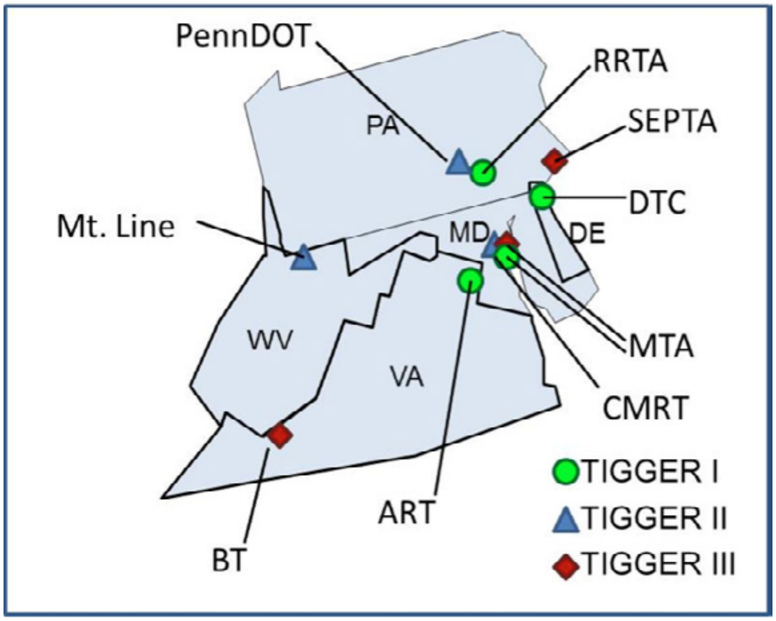
1. Unit heater efficiency—replace existing unit heaters with energy-efficient unit heaters.
2. Boiler replacement—replace the existing boilers that have surpassed end of life with new-technology, condensing-type boilers with a computer-based control system. The new boilers are expected to have an efficiency of 94% compared to the 80-87% efficiency of the older boilers.
3. Pavement ice control—install temperature sensors and a controller to the existing pavement ice control system that will allow it to be used only when needed. RGRTA's existing system is generally turned on from October through May and operates 24 hours per day.
4. HVAC controls–install temperature sensors, carbon monoxide sensors, and controllers in the Operations and Service building to more efficiently control heated spaces.

Project Status: Awarded in TIGGER III, this project is in the early implementation stage. The agency has incorporated the TIGGER upgrades into the 2013 Campus Improvement Plan to avoid coordination issues during construction. RGRTA expects to have all upgrades completed by early 2015.

Region III

Figure 7-11

Map of FTA Region III Project Locations



Region III projects:

1. Delaware Transit Corporation (DTC), solar panel project
2. Maryland Transit Administration (MTA), halon replacement
3. Howard County/Central Maryland Regional Transit (CMRT), electric bus project
4. Red Rose Transit Authority (RRTA), facility improvement
5. Pennsylvania DOT (PennDOT), hybrid transit vehicle project
6. Arlington Transit (ART), CNG hybrid bus project
7. Mountain Line Transit (Mt. Line), solar power plant
8. Maryland Transit Administration (MTA), electric radiator retrofit
9. Southeastern Pennsylvania Transportation Authority (SEPTA), wayside energy storage system
10. Blacksburg Transit (BT), dynamic bus routing and scheduling study

Project Name: Delaware Solar Panel Project

Transit Agency:	Delaware Transit Corporation
Location:	Wilmington, Delaware
Award Amount:	$1,500,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Energy reduction

Results Summary:

First Year Energy Savings: 1,767 MBtu
First Year Energy Cost Savings: $51,234
Projected Lifetime Energy Savings: 41,419 MBtu

Transit Agency Profile: Delaware Transit Corporation (DTC) operates the DART First State transit agency. DART First State provides transportation services in Delaware with more than 400 buses and 57 year-round bus routes. It also runs the Sussex County Resort Summer Service and paratransit service. DART provides New Castle County with commuter rail service to and from Philadelphia.

Project Description: Two DTC facilities were retrofitted with solar PV systems for this TIGGER project. At the Dover Administration Building, DTC installed a 181.4-kW direct-current PV system estimated to produce 221,271 kWh of electricity annually. At the second site, the Wilmington Paratransit Maintenance Garage in Wilmington, DTC installed a 158.4-kW PV system. The solar panels were manufactured in Delaware by Motech Industries. Table 7-13 lists the DTC PV system specifications.

Table 7-13

DTC Solar System Specifications

Solar System Specifications	
PV Manufacturer	Motech (DE)
PV Panel Nameplate Power (W)	235
PV Area Per Panel (sq ft)	3
Number of PV Panels Installed	1,456
Total PV Area (sq ft)	48,000
Panel Estimated Lifetime (yrs)	25

Project Status: The construction on the PV panels was completed and the system was activated in early 2012.

Summary of Results: DTC provided a full year of data before and after the solar system began operation. Table 7-14 summarizes the results. Figure 7-12 presents the energy savings graphically. The entire pie represents the total energy use for the DTC facilities before the solar installation. The blue portion shows the total energy use after the system was completed, resulting in an energy savings of 41%. The project resulted in energy savings of more than 517,000 kWh, which would be the equivalent of powering 46 homes for an entire year. This adds up to significant economic savings of more than $51,000 each year.[15]

[15] Based on 2011 average U.S. electricity costs of $0.099/kWh (EIA).

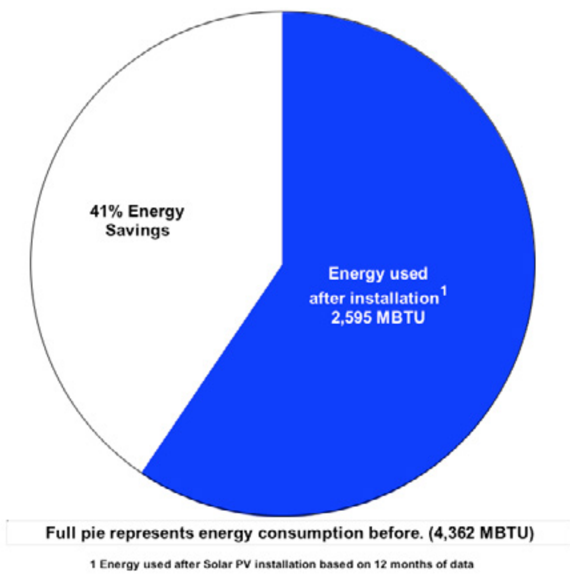
Table 7-14

Summary of Results for DTC Solar Panel Project

	kWh	MBtu
Estimated Energy Savings	415,870	1,420
Actual Energy Use Before	1,277,613	4,362
Actual Energy Use After	760,094	2,595
Annual Energy Savings	517,519	1,767
Technology Lifetime (yrs)	25	25
Projected Lifetime Savings	12,131,996	41,419
Projected Lifetime Savings per TIGGER $	8.09	0.03

Figure 7-12

Energy Savings for DTC Solar Panel Project



Project Name: MTA Halon Replacement

Transit Agency: Maryland Transit Administration
Location: Baltimore, Maryland
Award Amount: $522,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: GHG emissions reduction

Summary of Results:

Projected GHG Savings: 27,462 tons of CO_2e

Transit Agency Profile: The Maryland Transit Administration (MTA) owns and operates many transit- and railroad-related structures and facilities throughout Maryland. MTA's multimodal transit systems include buses, light rail, heavy rail, regional commuter trains, paratransit, and freight.

Project Description: MTA replaced Halon fire suppression systems across the transit agency with StatX fire suppression systems—an alternative to reduce the potential GHG emissions release. Halon 1301 is characterized as a GHG with "high global warming potential."

Project Status: This project was completed in June 2011.

Summary of Results: MTA originally proposed to replace the Halon fire suppression compound with Novec 1230; however, the StatX fire suppression compound was ultimately selected because of project economics and the characteristics shown in Table 7-15.

Table 7-15

Summary of Environmental Properties of Fire Suppression Compounds

Fire Suppression Compound	Property	Compound Value	Baseline Property Value and Basis Compound
Halon 1301[16]	Ozone Depletion Potential (ODP)	10	$CCl_3F = 1$
Halon 1301	Global Warming Potential (GWP)	6,900	$CO_2 = 1$
Novec 1230[17]	Ozone Depletion Potential (ODP)	0	$CCl_3F = 1$
Novec 1230	Global Warming Potential (GWP)	1	$CO_2 = 1$
StatX[18]	Ozone Depletion Potential (ODP)	0	$CCl_3F = 1$
StatX	Global Warming Potential (GWP)	0	$CO_2 = 1$

StatX fire suppression systems are an environmentally friendly alternative to Halon systems. StatX systems produce no GHG emissions in the event of a system release. StatX fire suppression systems use a potassium-based aerosol that suppresses fire by chemically interfering with free radicals that are essential elements in the propagation of fire (see Figure 7-13). The StatX fire suppression compound has an ODP of zero and no GWP. This offers a significant environmental advantage over Halon systems, which use bromotrifluoromethane as the fire suppression compound with ODP=10 and GWP=6,900.

[16] EPA website: http://www.epa.gov/ozone/science/ods/classone.html.

[17] 3M Technical Brief: http://multimedia.3m.com/mws/mediawebserver?aaaaaaKIUmpavEbaoEbaaB2IfMYAAAA_-/.

[18] Stat-X product website, whitepaper: http://www.statx.com/pdf/351StatX_WhiteP_Tox.pdf.

Figure 7-13

StatX Fire Suppression System Installed at MTA Facility

Photo courtesy of MTA

Based on the consultant's original survey of MTA's fire suppression systems, 4.98 metric tons of Halon were available for removal and destruction. However, a more detailed survey during the design phase of the project revealed that a few sites in the MTA system had already replaced the original Halon with an acceptable Halon replacement, so those sites were excluded from this project. Thus, 3.98 metric tons of Halon were documented as removed from service and destroyed in an environmentally acceptable manner. Removal of this Halon from the MTA fire suppression systems equates to preventing the release of 27,462 tons of CO_2^e in the unlikely event that all of the MTA fire suppression systems were to release.

The unique characteristics of the MTA Halon Replacement project fall outside the standard GHG emissions calculations applied to other TIGGER projects. It is important to note that none of the MTA fire suppression systems have been triggered to date. Thus, the avoidance of 27,462 tons of CO_2^e represents the maximum potential impact of this project on reducing GHG emissions in the unlikely event that all of these fire suppression systems were to be triggered.

Project Name: Howard County Electric Bus Project

Transit Agency:	Maryland Department of Transportation
Location:	Columbia, Maryland
Award Amount:	$3,777,826
Award Year:	2010
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: Howard Transit provides public transit service to Howard County, Maryland, and is provided by the Howard County government. Managed by Central Maryland Regional Transit (CMRT), Howard Transit operates eight fixed routes around the county.

Project Description: This project will replace three worn diesel-on-chassis buses that currently are operated by CMRT and serve the major traffic generators in Columbia, Maryland. The buses will be replaced with three battery-electric buses. Supporting the buses will be an inductive charging system and associated infrastructure, an energy information station, and a transit shelter. The electric buses will serve the Green route, which includes the Mall in Columbia, the Village of Wilde Lake, Howard Community College, and Howard County General Hospital.

The energy information station will be created in conjunction with the University of Maryland and Howard Community College. It will provide real-time information on vehicle charging, energy use, emissions reductions, and cost savings.

Project Status: This project is in the early stage of implementation. The Center for Transportation and the Environment (CTE) is providing the project management services. An RFP was issued in June 2013. The bids received were considered non-responsive, and a new RFP was issued in December 2013.

Project Name: Red Rose Facility Improvement

Transit Agency:	Red Rose Transit Authority
Location:	Lancaster, Pennsylvania
Award Amount:	$2,450,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Energy reduction

Results Summary:

First Year Energy Savings: 1,992 MBtu
First Year Energy Cost Savings: $50,236
Projected Lifetime Energy Savings: 59,748 MBtu

Transit Agency Profile: Red Rose Transit Authority (RRTA) is a regional transit authority that has provided transit services throughout Lancaster County, Pennsylvania, for more than 35 years. Currently, RRTA operates a fleet of 42 fixed-route buses on 17 routes, employs 100 full-time employees, and carries approximately 2 million passengers each year.

Project Description: RRTA completed several energy-efficient technology upgrades as part of a facility expansion and complete renovation project. The sustainable building design included geothermal heating, ventilation, and air conditioning; daylighting features; rooftop PV panels; a green roof; waste oil burners; and upgraded energy-efficient electrical fixtures. Table 7-16 lists the Red Rose PV system specifications.

Table 7-16

Red Rose Solar System Specifications

Solar System Specifications	
PV Manufacturer	Sharp
PV Panel Nameplate Power (kW)	235
PV Area per Panel (sq ft)	18
Number of PV Panels Installed	641
Total PV Area (sq ft)	16,465
Panel Estimated Lifetime (yrs)	30
Panel Efficiency Rating (%)	14

Project Status: The RRTA facility improvement project was completed in October 2010.

Summary of Results: RRTA has seen a substantial energy savings, even though the upgrade added more square footage to its usable space. The data presented in Table 7-17 were obtained from energy use at the facility one year before and one year after the improvements were operational. RRTA's TIGGER project resulted in a 72% reduction in energy use, as shown in Figure 7-14. Using a waste oil burner for heating specific areas of the facility as well as geothermal heating has eliminated all heating oil use and reduced the need to dispose of used oil. The project resulted in annual savings of more than 190,000 kWh of electricity and more than 10,000 gallons of heating oil, which would be the equivalent of powering 52 homes for an entire year. This saves more than $50,000 each year.

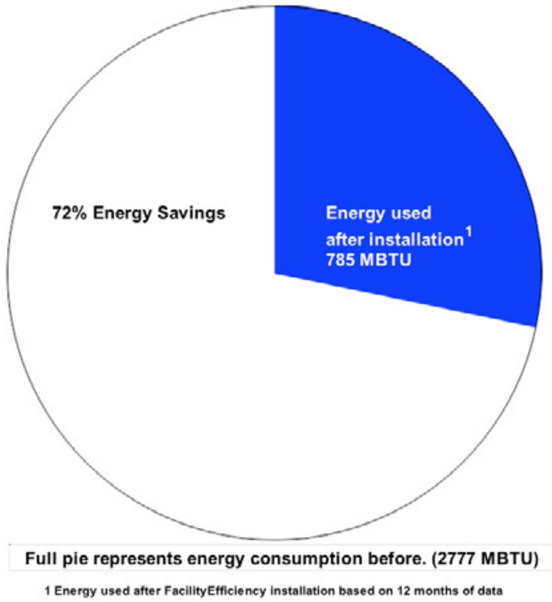
Table 7-17

Summary of Results for Red Rose Facility Project

	kWh	Gallons (heating oil)	MBtu
Estimated Energy Savings			2,260
Actual Energy Use Before	420,520	10,441	2,777
Actual Energy Use After	229,998	0	785
Annual Energy Savings	190,521	10,441	1,992
Technology Lifetime (yrs)	30	30	30
Projected Lifetime Savings	5,715,641	313,235	59,748
Projected Lifetime Savings per TIGGER $	2.33	0.13	0.02

Figure 7-14

Annual Energy Savings for Red Rose Facility Project



Project Name:	**Pennsylvania Hybrid Transit Vehicle Project**
Transit Agency:	PennDOT Bureau of Public Transportation
Location:	Harrisburg, Pennsylvania
Award Amount:	$5,000,000
Award Year:	2010
TIGGER Goal:	GHG emissions reduction

Transit Agency Profile: The PennDOT Bureau of Public Transportation supports and oversees 37 individual transit systems in the commonwealth, including the 4th and 16th largest in the country. Combined, these systems operate more than 4,200 fixed-route vehicles and provide more than 430 million passenger trips annually.

Project Description: PennDOT is providing diesel-electric hybrids to small rural or urban transit agencies in the commonwealth to replace aging vehicles. TIGGER funds will be used to purchase approximately 40 hybrid vehicles.

Project Status: This project is in progress. By the end of 2013, 16 of the 40 hybrid buses had been delivered; the remaining buses should be delivered between 2014 and 2016. PennDOT currently is working with six transit agencies in the state. Table 7-18 lists the agencies purchasing hybrid buses under the TIGGER project. The agencies that have received the hybrid buses are in the process of collecting and compiling data for analysis.

Table 7-18

List of Participating Agencies and Hybrid Buses on Order

Agency	Number of Buses	Bus OEM	Length (ft)	Hybrid
Transportation & Motor Buses for Public Use Authority (AMTRAN)	3	Gillig	35	Allison
Area Transportation Authority of North Central PA (ATA)	20	Ford (E450)	23	Crosspoint Kinetics
Lebanon Transit	3	Gillig	29	Allison
New Castle Area Transit Authority	5	Gillig	35	Allison
River Valley Transit (RVT)	6	Gillig	40, 35	Allison
York Adams Transportation Authority (York)	3	Gillig	40	Allison
Total	*40*			

Project Name: ART CNG Hybrid Bus Project

Transit Agency: Arlington Transit
Location: Arlington, Virginia
Award Amount: $1,500,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Arlington Transit (ART) is a local public transit fixed-route service provided by Arlington County, Virginia. ART operates 13 routes with a fleet of 46 vehicles, serving more than 2.5 million passengers annually.

Project Description: ART purchased three compressed natural gas (CNG)-electric hybrid buses to replace three conventional diesel engine vehicles that had reached the end of their useful service lives and were scheduled for replacement. The TIGGER funds covered approximately 80% of the purchase cost of the CNG-electric hybrid buses; locally-raised funds covered the remaining cost. The CNG-electric hybrid buses are rated as heavy-duty vehicles and are larger than the light-duty vehicles they are replacing. ART has contracted with DesignLine USA of Charlotte, North Carolina, to provide the three 30-foot buses. The buses have a CNG-electric hybrid system that uses a turbine.

Project Status: All three buses were delivered to ART in mid-2012 and were in service by September 2012 (see Figure 7-15). The agency has been collecting data on the buses; however, there have been issues with the project. Because of issues with heating, the buses have not been operated during the winter months. The early design included an air conditioning system but did not include heating. A supplemental heater was added; however, the heating system was not sufficient to meet the agency requirements. In 2013, DesignLine declared bankruptcy, compounding the problem. ART is investigating its options to have the buses modified so they can be put back into service. NREL will complete an analysis for the next report.

Figure 7-15

CNG Hybrid Bus in Service at ART

Photo courtesy of ART

Project Name: **Mountain Line Transit Solar Power Plant**

Transit Agency: Mountain Line Transit
Location: Morgantown, West Virginia
Award Amount: $1,100,000
Award Year: 2010
TIGGER Goal: Energy reduction

Results Summary:

First Year Energy Savings: 643 MBtu
First Year Energy Cost Savings: $18,647
Projected Lifetime Energy Savings: 15,074 MBtu

Transit Agency Profile: Monongalia County Urban Mass Transit Authority, or Mountain Line Transit, operates transit services in the greater Morgantown, West Virginia, area. Mountain Line Transit operates a fleet of 22 passenger buses and 4 paratransit demand-response vehicles. Mountain Line Transit provides more than one million passenger miles per year in Morgantown and nearby Fairmont and Clarksburg, West Virginia, and provides connecting service to Waynesburg and Pittsburgh, Pennsylvania.

Project Description: Mountain Line Transit outfitted its 30,000 square feet of roof space with 572 solar PV panels that cover 10,296 square feet. These panels are expected to generate more than 37 MWh of electricity each year. This energy will offset electricity demand at Mountain Line Transit facilities; any excess energy will be sold back to the electricity grid through a net-metering arrangement. An automated monitoring system will track power generation and aid in data collection. Table 7-19 provides the specifications of the PV system, which was manufactured by Solarworld, Inc.

Table 7-19

Mountain Line Solar System Specifications

Solar System Specifications	
PV Manufacturer	Solarworld
PV Panel Nameplate Power (W)	245
PV Area per Panel (sq ft)	18
Number of PV Panels Installed	572
Total PV Area (sq ft)	10,296
Panel Estimated Lifetime (yrs)	25

Project Status: The West Virginia Design-Build Board approved the installation contractor for construction of the solar power plant in early November 2011. Mountain Line Transit broke ground on the project in April 2012 and began operation of the system in October 2012. A net-metering agreement was established with the local utility. Excess power generated from the system is fed into the electricity grid and sold back to the utility.

Project Results: Table 7-20 provides the energy savings from the Mountain Line solar installation in the first year of operation. Figure 7-16 presents the information graphically. Mountain Line has reduced its energy purchased from the grid by 64%, translating to an average reduction in electricity costs of $18,532 and enough energy to power 17 homes annually.[19] The system comes with a 20-year warranty and has a lifetime expectancy of 25 years.

Table 7-20

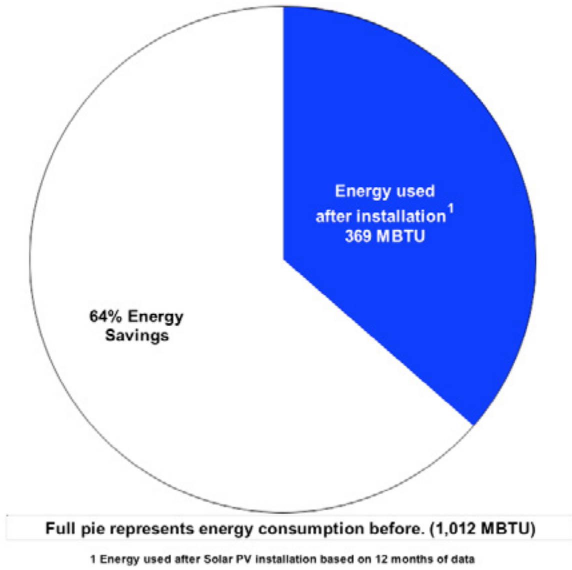
Summary of Results for Mountain Line Transit Solar Project

	kWh	MBtu
Estimated Energy Savings	372,519	1,272
Actual Energy Use Before	296,410	1,012
Actual Energy Use After	108,060	369
Annual Energy Savings	188,350	643
Technology Lifetime (yrs)	25	25
Projected Lifetime Savings	4,415,418	15,074
Projected Lifetime Savings per TIGGER $	4.01	0.01

[19] Based on 2011 average U.S. electricity costs of $0.099/kWh (EIA).

Figure 7-16

Annual Energy Savings for Mountain Line Transit Solar Project



Project Name:	**Bus Electric Radiator Retrofit**
Transit Agency:	Maryland Transit Administration
Location:	Baltimore, Maryland
Award Amount:	$1,544,580
Award Year:	2011
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: The Maryland Transit Administration (MTA) owns and operates many transit- and railroad-related structures and facilities throughout Maryland. MTA's multimodal transit systems include buses, light rail, heavy rail, regional commuter trains, paratransit, and freight.

Project Description: MTA will replace hydraulic fan drives and radiators on some vehicles in its bus fleet. MTA experienced issues with hydraulic leaks and alternators; the agency determined that the EMP MiniHybrid MH8 Thermal System was a suitable replacement for the radiators and solved the problem with the alternators. MTA selected the EMP MiniHybrid as its standard radiator and has installed the system in approximately 100 buses on a "replace as fails" basis. MTA also has had the system installed by the OEM on 141 new buses since late 2009. For the TIGGER III project, MTA will retrofit 100 buses in its legacy fleet with the EMP system.

Project Status: Awarded in TIGGER III, this project is underway and is expected to be complete in the summer of 2014.

Project Name: Wayside Energy Storage Project

Transit Agency:	Southeastern Pennsylvania Transportation Authority
Location:	Philadelphia, Pennsylvania
Award Amount:	$1,440,000
Award Year:	2011
TIGGER Goal:	Energy reduction

Transit Agency Profile: The Southeastern Pennsylvania Transportation Authority (SEPTA) is currently the sixth largest transit system in the United States and the largest in Pennsylvania. SEPTA's service area covers 2,220 square miles in the 5-county area, with service extending into New Jersey and Delaware. SEPTA is a multimodal transit agency operating heavy rail, light rail, commuter rail, buses, trolley buses, and paratransit.

Project Description: SEPTA will use TIGGER funds to add a WESS along its busiest rail corridor to capture and use braking energy along the line. SEPTA has already tested the technology through a pilot project that is showing great potential for reducing energy use. The project will also use two-way smart grid technology to maximize the impact and save significant energy.

Project Status: SEPTA completed the technical performance criteria in September 2012. The RFP for the purchase of the WESS also was completed and advertised with the proposals that were due by the end of February 2013. The agency awarded contracts to ABB and Viridity in November 2013. The project is in the final design and manufacturing phase. Installation of the WESS is expected to begin in June 2014; completion is expected in August 2014.

Project Name: Dynamic Bus Routing and Scheduling Study

Transit Agency:	Blacksburg Transit
Location:	Blacksburg, Virginia
Award Amount:	$1,858,680
Award Year:	2011
TIGGER Goal:	GHG emissions reduction

Transit Agency Profile: Blacksburg Transit, a division of the town of Blacksburg, provides fixed-route, paratransit, deviated fixed-route, demand-response, and commuter services to the citizens of Blacksburg, Virginia Tech, and the partnering communities in the New River Valley of Virginia. Ninety percent of the agency's ridership consists of Virginia Tech students.

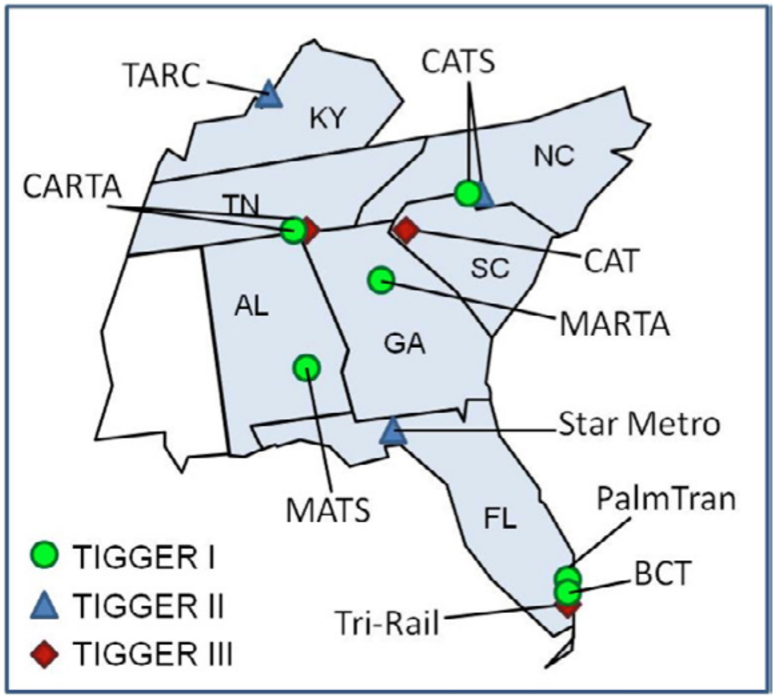
Project Description: This project will use a range of intelligent transportation systems (ITS) solutions to enhance operational efficiency and reduce fuel use. ITS solutions encompass a wide range of wireless and wired communications-based information technologies. Blacksburg Transit plans to use a suite of computer-based technologies to collect real-time data to connect transit buses, infrastructure, and commuters and to optimize bus routes and scheduling to meet customers' needs in the most efficient manner.

Project Status: Awarded in TIGGER III, this project is in the early implementation stage. A Memorandum of Understanding was established with Virginia Tech Transportation Institute, and a contract was awarded to Kimley-Horn and Associates for the project. They have developed an optimization concept of bus operations and have started purchasing equipment. An RFP was released in October 2013 for software, and Animations Creation was selected. The estimated completion date of this project is the end of 2014.

Region IV

Figure 7-17

Map of FTA Region IV Project Locations



Region IV projects:

1. Montgomery Area Transit System (MATS), hybrid bus project
2. Palm Tran, thermal motor fan retrofit
3. Broward County Transit (BCT), MiniHybrid thermal system
4. Tri-Rail, green station demonstration
5. Star Metro, electric bus project
6. Metropolitan Atlanta Rapid Transit Authority (MARTA), Laredo Bus Facility solar canopy—see case study in Section 8
7. Transit Authority of River City (TARC), Union Station energy efficiency improvements
8. Charlotte Area Transit System (CATS), hybrid bus project
9. Charlotte Area Transit System (CATS), solar project
10. Chattanooga Area Regional Transportation Authority (CARTA), facility lighting upgrade
11. Chattanooga Area Regional Transportation Authority (CARTA), wayside inductive power system for electric buses
12. City of Seneca/Clemson Area Transit (CAT), electric bus project

Project Name: Montgomery Area Transit System Hybrid Bus Project

Transit Agency: Montgomery Area Transit System
Location: Montgomery, Alabama
Award Amount: $2,675,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: -513 MBtu / -44 tons CO_2^e
Projected Lifetime Energy/GHG Savings: -6,156 MBtu / -528 tons CO_2^e

Transit Agency Profile: The Montgomery Area Transit System (MATS) offers 14 fixed routes in its 135-square-mile service area. Owned by the City of Montgomery and operated by the First Transit Group, the MATS fleet includes 35 fixed-route buses and 11 paratransit buses.

Project Description: MATS replaced eight older Thomas diesel buses with hybrid buses; the TIGGER grant funded four of the eight buses. These are the first hybrid buses for the agency and the first in Alabama. The 35-foot Gillig buses feature the Allison diesel hybrid propulsion system. Table 7-21 provides selected specifications of the hybrid and older diesel buses.

Table 7-21

MATS Bus Specifications

	Baseline	New Technology
Number of Vehicles	4	4
Model Year	2003	2011
Manufacturer	Thomas	Gillig
Model	SLF	30B102N4
Length (ft)	30	35
Number of Seats	28	32
Weight (lb)	28,580	39,600
Engine OEM	Cummins	Cummins, ISB
Engine: Rated Power (hp)	N/A	280
Hybrid System Manufacturer	N/A	Allison
Hybrid Model	N/A	H40EP
Hybrid Configuration	N/A	Parallel
Energy Storage Type	N/A	Nickel Metal Hydride

Project Status: The buses were delivered in July 2011 and are now in service.

Project Summary Results: MATS provided data on four of the hybrid buses and four baseline buses. The baseline data were from buses that were the same type as the replaced buses, because the buses that were replaced had been out of service for some time and the data were not available. Table 7-22 summarizes the analysis results for the project. The results show an energy and GHG emissions increase for the hybrid buses compared to the baseline buses because the hybrid buses have a lower fuel economy than the baseline buses. This is due to the difference in size for the two types of buses—the hybrid buses are longer and heavier than the buses they replaced. Figure 7-18 presents the energy results and Figure 7-19 presents the GHG emissions results for the MATS project.

Table 7-22

Summary of Energy and GHG Savings for MATS Hybrid Bus Project

	Hybrid	Baseline	Savings	Units
Total Fuel Used	28,406	25,543	-4,950	gal
Annual GHG Emissions	393	437	-44	tons CO_2^e
Annual Energy Use	4,561	5,074	-513	MBtu
Lifetime of Technology			12	years
Projected Lifetime GHG Reduction			-528	tons CO_2^e
Projected Lifetime Energy Savings			-6,156	MBtu
Lifetime GHG Reduction per TIGGER $			-0.4	lb CO_2^e
Lifetime Energy Savings per TIGGER $			-2,301	Btu

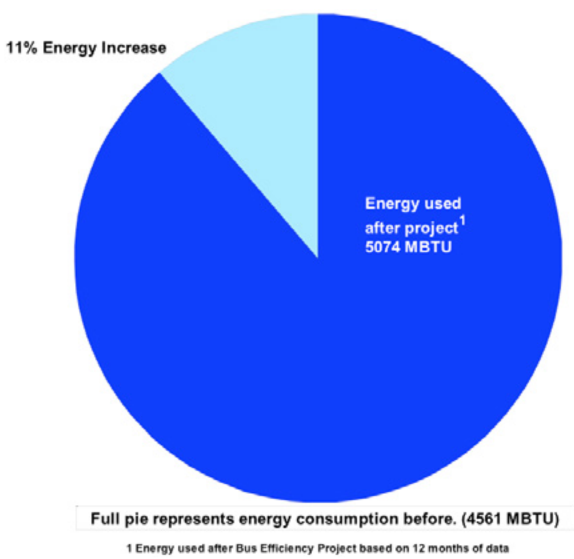


Figure 7-18

Annual Energy Use for MATS Hybrid Bus Project

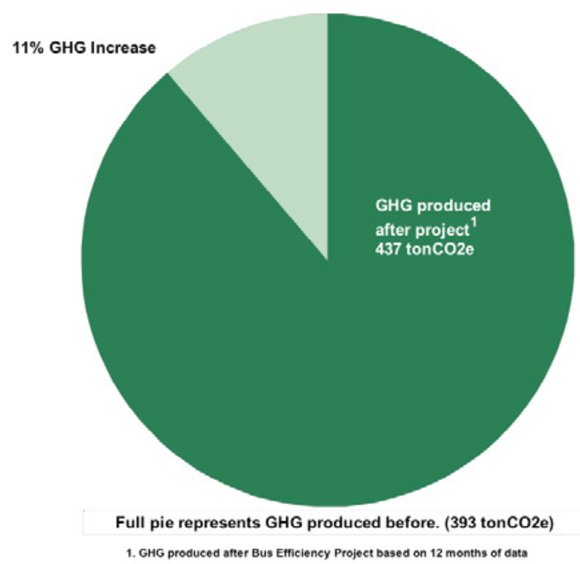


Figure 7-19

Annual GHG Emissions for MATS Hybrid Bus Project

According to MATS, without the TIGGER grant the agency would have purchased 35-foot standard diesel buses instead of the hybrids. Similar-sized standard diesel buses would have a lower fuel economy and, therefore, would emit more GHGs than a hybrid bus. To determine the savings for the agency had it purchased standard buses, NREL requested additional data on a similar-sized set of buses in service at MATS. Figure 7-20 shows the monthly average fuel economy for the hybrid and diesel baseline buses, including the smaller buses that were replaced and similar-sized diesel buses. The hybrid buses have a fuel economy that is 10% lower than that of the baseline buses that were replaced. When comparing the hybrid buses to similar-sized standard diesel buses, the hybrids had a fuel economy that was 17% higher. Taking into account these data, the MATS hybrid buses are using 15% less energy and GHG emissions are 15% lower than for standard buses of similar size.

Figure 7-20

Monthly Average Fuel Economy for MATS Hybrid and Diesel Buses

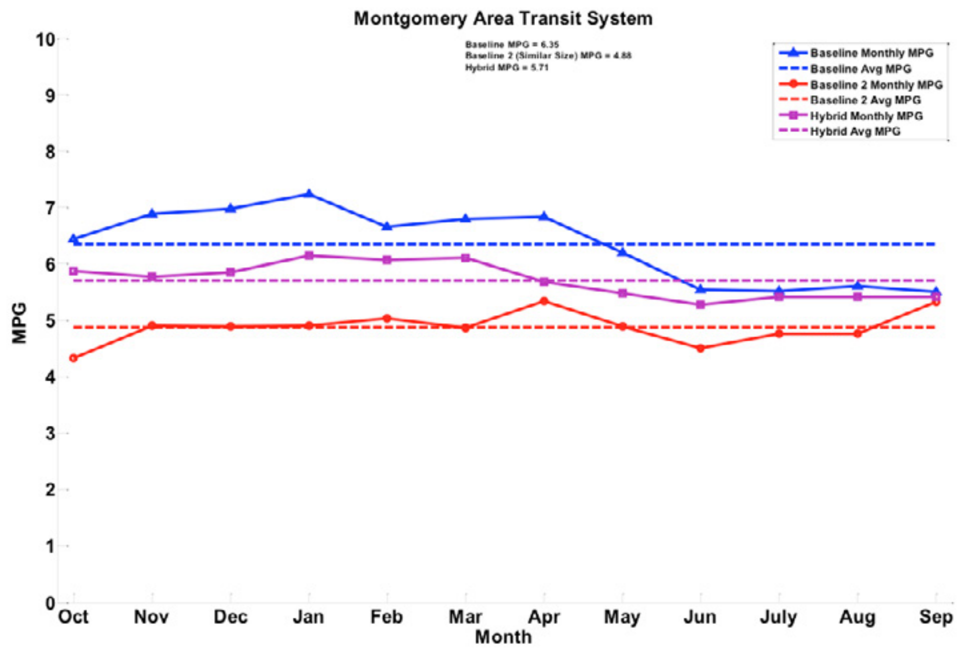


Table 7-23 provides an overall summary of the operational costs of the hybrid and baseline buses. The total maintenance cost for the hybrids is 81% lower than that of the baseline diesel buses. This results in a cost savings for the agency.

Table 7-23

Summary of Operational Costs for MATS Hybrid Bus Project

	Hybrid	Baseline
Total Miles	162,197	127,559
Total Maintenance Cost	$10,322.04	$43,493.28
Maintenance Cost per Mile	$0.06	$0.34
Scheduled Maintenance Cost	$2,398.78	$1,914.25
Scheduled Maintenance Cost per Mile	$0.01	$0.02
Unscheduled Maintenance Cost	$7,923.26	$41,579.04
Unscheduled Maintenance Cost per Mile	$0.05	$0.33
Propulsion-Related Unscheduled Maintenance Costs	$737.34	$10,346.54
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.00	$0.08
Fuel Economy (mpg)	5.71	6.35
Total Fuel Used (gal)	28,405.8	20,088.0
Fuel Cost (at $3.09/gal)	$87,773.86	$62,072.02
Fuel Cost per Mile	$0.54	$0.49
Total Cost per Mile	$0.60	$0.83

Table 7-24 shows the resulting operational cost differences for the project. These results indicate an increase in fueling costs for the new hybrid buses, but a decrease in maintenance costs. The overall savings for the first year of the project is more than $36,000.

Table 7-24

Operational Cost Differences for MATS Hybrid Bus Project

	Hybrid	Baseline	Difference
Total Maintenance Cost	$10,322.04	$55,303.66	$44,981.62
Total Fuel Cost	$87,773.86	$78,927.36	-$8,846.50
Total Cost	$98,095.89	$134,231.02	$36,135.12

Project Name: Palm Tran Thermal Motor Fan Retrofit

Transit Agency: Palm Tran
Location: West Palm Beach, Florida
Award Amount: $320,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: GHG emissions reduction

Results Summary:

First Year GHG Savings: 86 tons CO_2^e
First Year Fuel Savings: $22,023
Estimated Lifetime GHG Savings: 1,032 tons CO_2^e

Transit Agency Profile: Palm Tran, Palm Beach County's public transportation agency, provides service to Florida's largest county, which has more than one million residents. The transit agency connects Jupiter, West Palm Beach, and Boca Raton with a fleet of 146 buses running 35 fixed routes.

Project Description: Palm Tran's TIGGER project consisted of replacing the cooling systems on 15 conventional diesel buses with electrically-driven MiniHybrid Thermal Systems from Engineered Machined Products (EMP). The agency had two types of buses retrofitted with the EMP system: standard diesel buses and diesel hybrid buses. Table 7-25 provides selected specifications for the buses.

Table 7-25

Summary of Vehicle Specifications for Palm Tran Buses

	Hybrid Buses	Diesel Buses
Number of Vehicles	9	6
Model Year	2010	2011
Manufacturer	Gillig	Gillig
Model	G30D102N4—Low Floor	G27D102N—Low Floor
Length (ft)	40	40
Weight (lb)	29,420	28,060
Engine OEM	Cummins	Cummins
Engine: Rated Power (hp)	280	280
Hybrid System Manufacturer	Allison	
Hybrid Model	H40EP	
Hybrid Configuration	Parallel	
Energy Storage Type	Lithium Ion Battery	
Energy Storage Manufacturer	Allison	

Project Status: This project is complete. Palm Tran had all the units installed by the end of December 2011.

Summary of Results: Palm Tran installed the EMP system on standard diesel buses and hybrid buses. NREL created charts for each bus type to show the difference in savings. The totals for the project as a whole are included in the tables. As with the other bus retrofit projects, the installation for each bus was completed over a period of time. Thus, the monthly data from each bus do not align with the same calendar months. Data for these projects are time-aligned with the date of retrofit. Table 7-26 summarizes the GHG emissions for the Palm Tran buses before and after retrofit. The data are normalized to the mileage for the buses after the EMP systems were installed. Figure 7-21 graphically represents the GHG emissions for the diesel buses at Palm Tran and shows a 4.95% savings for the diesel buses after the EMP systems were installed. Figure 7-22 shows a 2.02% savings in GHG emissions for Palm Tran's hybrid buses after retrofit.

Table 7-26

Summary of GHG Emissions for Palm Tran Buses

	Before	After	Savings	Unit
Total Fuel Used	188,506	182,059	6,448	gal
Annual GHG Emissions	2,184.0	2,098.0	86	tons CO_2e
Lifetime of Technology			12	years
Projected Lifetime GHG Savings			1,032	tons CO_2e
Lifetime GHG Savings per TIGGER $			6.5	lb CO_2e

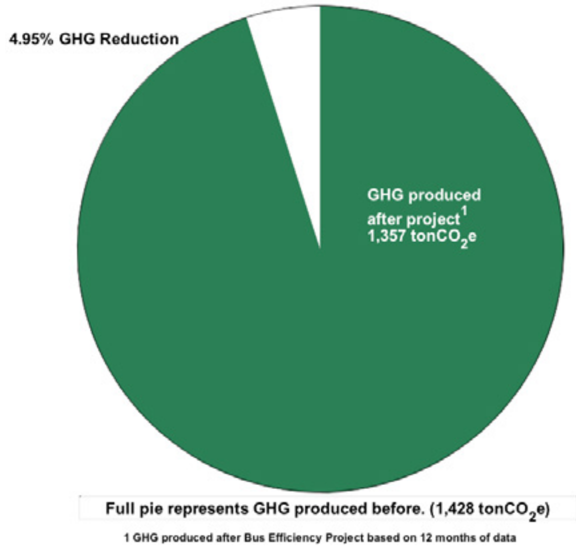


Figure 7-21

Annual GHG Emissions for Palm Tran Diesel Buses

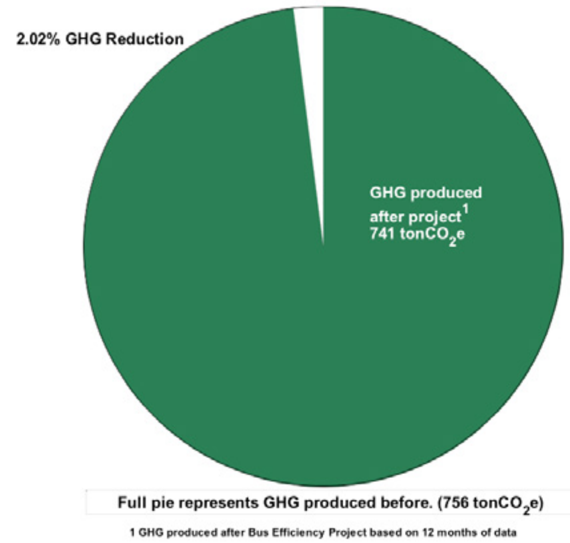


Figure 7-22

Annual GHG Emissions for Palm Tran Hybrid Buses

Figure 7-23 provides the monthly average fuel economy for the hybrid and diesel buses before and after the EMP systems were installed. The average fuel economy of the hybrid buses increased by 2% after the EMP system was installed. The improvement for the conventional diesel buses was even better, showing a 5.3% increase with the EMP system.

Figure 7-23

Monthly Average Fuel Economy for Palm Tran Hybrid and Diesel Buses

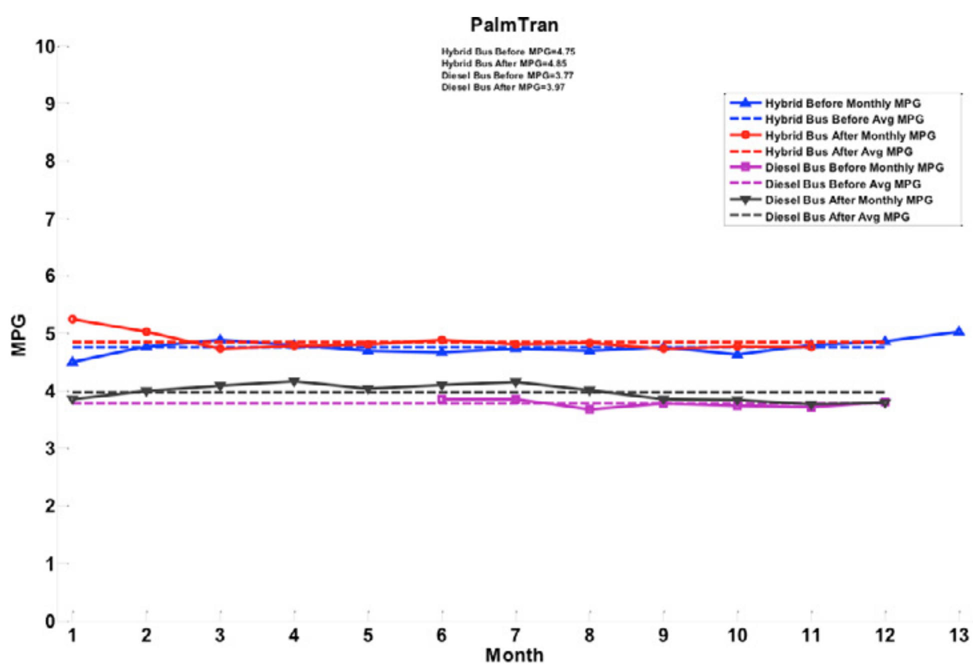


Table 7-27 summarizes the costs for the hybrid and diesel buses before and after retrofit. The maintenance costs for the hybrid buses before and after retrofit were similar. The maintenance cost for the diesel buses before the retrofit was slightly higher than the costs after retrofit. Because Palm Tran provided very detailed maintenance records, NREL was able to eliminate any costs for accident-related repair, which would be extremely variable from bus to bus. The level of detail also allowed NREL to categorize the repair by system. The propulsion-related-only maintenance costs are provided in the table.

Table 7-27 *Summary of Operational Costs for Palm Tran Thermal Motor Fan Project*

	Hybrid Before	Hybrid After	Diesel Before	Diesel After
Total Miles	482,677	451,849	118,960	359,222
Parts Cost	$26,456.08	$40,498.14	$39,031.04	$23,672.03
Labor Cost	$83,543.20	$86,991.45	$17,340.70	$62,794.55
Total Maintenance Cost	$109,999.28	$127,489.59	$56,371.74	$86,466.58
Maintenance Cost Per Mile	$0.23	$0.28	$0.47	$0.24
Scheduled Maintenance Cost	$60,300.13	$58,125.53	$15,742.90	$46,660.41
Scheduled Maintenance Cost per Mile	$0.12	$0.13	$0.13	$0.13
Unscheduled Maintenance Cost	$49,699.16	$69,364.06	$40,628.84	$39,806.17
Unscheduled Maintenance Cost per Mile	$0.10	$0.15	$0.34	$0.11
Propulsion-Related Unscheduled Maintenance Costs	$35,058.15	$57,154.71	$5,264.14	$31,736.99
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.07	$0.13	$0.04	$0.09
Fuel Economy (mpg)	4.75	4.85	3.77	3.97
Total Fuel Used (gal)	101,616.2	93,164.7	31,554.4	90,484.1
Fuel Cost (at $3.54/gal)	$359,790.37	$329,866.43	$111,723.91	$320,375.25
Fuel Cost per Mile	$0.75	$0.73	$0.94	$0.89
Total Cost per Mile	$0.97	$1.01	$1.41	$1.13

Using the mileage of the buses after retrofit as the baseline, the operational cost savings are summarized in Table 7-28. After retrofit with the EMP system, the buses were estimated to save Palm Tran more than $72,000 the first year in service.

Table 7-28

Operational Cost Differences for Palm Tran Thermal Motor Fan Project

	Before	After	Savings
Total Maintenance Cost	$264,640.35	$215,398.21	$49,242.14
Total Fuel Cost	$667,440.45	$644,611.32	$22,829.14
Total Cost	$932,080.81	$860,009.53	$72,071.27

Project Name: Broward County MiniHybrid Thermal System

Transit Agency: Broward County Transit
Location: Pompano Beach, Florida
Award Amount: $2,000,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Broward County Transit (BCT) covers a service area of 410 square miles in Broward County, Florida. BCT buses connect to Palm Beach and Miami-Dade transit systems and to Tri-Rail. BCT operates 288 fixed-route buses and 72 community buses and provides paratransit service.

Project Description: BCT used TIGGER funds to replace mechanically- and hydraulically-driven cooling systems on 80 of its 288 buses with MiniHybrid Thermal Systems from Engineered Machined Products (EMP). Early tests by BCT showed the potential for this retrofit to increase the efficiency of the buses and result in reduced fuel use.

Project Status: This project was completed in January 2011. The buses are all in service; however, BCT experienced challenges providing the data needed for the analysis. The overall results will be included in the next report.

Project Name: Pompano Beach Green Station Demonstration

Transit Agency: South Florida Regional Transportation Authority
Location: Pompano Beach, Florida
Award Amount: $5,713,549
Award Year: 2011
TIGGER Goal: Energy reduction

Transit Agency Profile: The South Florida Regional Transportation Authority (SFRTA) operates Tri-Rail, a commuter rail service, with 18 stations along a 72-mile corridor in southeast Florida. Tri-Rail's service area covers Palm Beach, Broward, and Miami-Dade counties—a population of more than 5.5 million people. All Tri-Rail stations connect to bus transit systems and local shuttles in Miami-Dade, Broward, and Palm Beach counties and to Metrorail, a heavy rail system in Miami-Dade County.

Project Description: The Pompano Beach Green Station Demonstration will showcase Tri-Rail's first green, Leadership in Energy and Environmental Design (LEED)-certified, sustainable station, which is expected to generate more than 100% of the station's energy demand through solar panels. The green station will include the following elements:

- Platform canopies partially covered with PV panels
- Parking lot PV canopies for energy production and shaded parking

- LED lights
- Machine-room-less elevators

The PV panels will be connected to the electricity grid with a smart meter that will store surplus energy generated during the day to be drawn from at night.

Project Status: This project, awarded in TIGGER III, is in the early implementation stage. The design plan is complete, and SFRTA plans to issue an RFP for construction in June 2014. SFRTA expects the project to be complete by the end of 2016.

Project Name: StarMetro Electric Bus Project

Transit Agency:	City of Tallahassee, StarMetro
Location:	Tallahassee, Florida
Award Amount:	$7,241,003
Award Year:	2010
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: StarMetro, part of the Department of Public Works for the City of Tallahassee, is the public transit system serving Tallahassee, Florida. StarMetro operates 12 fixed routes as well as shuttles for the local universities, paratransit, and dial-a-ride services in the area.

Project Description: StarMetro is using TIGGER funds to replace three older diesel buses with fast-charge battery electric buses. These zero-emission buses were built by Proterra and feature an electric drive propulsion system powered by lithium titanate batteries. The 35-foot bus chassis is built of lightweight composites but seats a similar number of passengers as a 40-foot bus. The agency plans to operate the buses on its Canopy route, a main east to west route that services downtown Tallahassee. The project includes installation of a fast charger on the route at a layover point. During every circuit, the buses will be fully charged in less than 10 minutes. In 2012, StarMetro was awarded additional funding from another TIGGER project that was canceled. The funds are being used to purchase two more buses, bringing the fleet to five electric buses.

Project Status: This project is in progress. StarMetro received all five buses from Proterra between June and July 2013 and the fast charger installation was completed in July 2013 (see Figure 7-24). The agency is working with CTE to manage the project and handle the data collection requirements. During the deployment StarMetro held a media event to unveil the new charging equipment and had a mystery bus campaign that eventually showcased the new bus designs. The agency also made two public service announcements online and in local advertisements about the new buses. StarMetro accepted the buses and put them in service August 2013 along the Canopy route. The route schedule was modified to accommodate the new bus technology. The agency is assessing options for increasing service consistency and fully realizing the benefits of the new bus technology.

Figure 7-24

StarMetro Fast-Charge Electric Bus

Photo courtesy of StarMetro

Project Name: Union Station Energy Efficiency Improvements

Transit Agency: Transit Authority of River City
Location: Louisville, Kentucky
Award Amount: $2,658,600
Award Year: 2010
TIGGER Goal: Energy reduction

Transit Agency Profile: The Transit Authority of River City (TARC) has provided transit services to the Louisville, Kentucky, greater metropolitan area, including three counties in Kentucky and two in Indiana, since 1974. Service each year includes more than 11 million miles encompassing 46 routes. TARC has a fleet of 315 vehicles, 89 of which are in demand-response paratransit service. TARC also operates 14 historic replica trolleys in Louisville.

Project Description: TARC operates out of historic Union Station in Louisville. Union Station was originally built in the 1890s and is listed in the National Register of Historic Places. Although several upgrades have been completed over the station's long history, including the addition of storm windows on the first floor in the mid-1980s and a boiler/chiller upgrade in 1979, there has never been a comprehensive project to upgrade the energy efficiency of the landmark while maintaining its historic authenticity. This project will address two major areas of energy inefficiency: leaky, single-pane, and stained glass windows from the original construction in the 1890s will be restored, and the inefficient (80%) and outdated boiler and chiller system will be replaced.

Project Status: TARC signed a contract for the window restoration on November 14, 2011. The window upgrades were completed during the summer of 2012. The door restorations are also complete. The HVAC system upgrades are being negotiated. There are challenges in keeping the scope within budget. In addition to the TIGGER upgrades, TARC also has other funding for a skylight window replacement and an insulation project. The skylight replacement was completed in October 2013. Part of the building envelope project includes new insulation, which has proved to be problematic for the agency. It has been split into two pieces. The first includes a skylight well or skylight curb that was completed in March 2014. The second part, insulation for the attic floor, is near completion. This piece includes sealing chases that vent into or through the attic to the roof. The HVAC contract is anticipated to be awarded in June 2014. A second air barrier test was conducted in the fall of 2013 and showed minimal improvement over the first test. The agency has since redoubled efforts to identify leaks in the building envelope. Asbestos and lead paint abatement work is scheduled to begin in May 2014. The agency plans to issue an RFP to install floor insulation on the third floor when the abatement work starts.

Project Name: Charlotte Hybrid Bus Project

Transit Agency:	Charlotte Area Transit System
Location:	Charlotte, North Carolina
Award Amount:	$2,858,289
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: 3,029 MBtu / 261 tons CO_2^e
First Year Fuel Cost Savings: $123,373
Projected Lifetime Energy/GHG Savings: 36,552 MBtu / 3,134 tons CO_2^e

Transit Agency Profile: The Charlotte Area Transit System (CATS) provides transit services to 1,725,000 people in a 5-county, 2-state metropolitan area. CATS operates 73 bus routes and 324 buses—255 40-foot buses, 42 30-foot buses, 7 40-foot hybrid buses, and 19 rubber-wheel trolley buses. In addition to its bus service, CATS operates the LYNX light rail service, which includes 9.6 miles of rail and 15 passenger stations.

Project Description: CATS replaced six older diesel buses with more efficient hybrid buses from Gillig. Table 7-29 provides some of the specifications for the new hybrid and baseline diesel buses that were replaced.

Table 7-29

Specifications for CATS Hybrid and Diesel Buses

	Baseline	New Technology
Number of Vehicles	6	6
Model Year	1998, 1999	2011
Manufacturer	Nova	Gillig
Model	Low Floor	Low Floor Hybrid
Length (ft)	40	40
Weight (lb)	27,500	30,400
Engine OEM	Detroit Diesel	Cummins
Engine: Rated Power (hp)	280	280
Hybrid System Manufacturer	N/A	Allison
Hybrid Model	N/A	EP-40
Hybrid Configuration	N/A	Parallel
Energy Storage Type	N/A	Nickel Metal Hydride

Project Status: This project is complete. All of the hybrid buses were delivered by October 2011 and were placed into service. One of the new TIGGER hybrid buses is pictured in Figure 7-25.

Figure 7-25

Hybrid Bus in Service at CATS

Project Results: CATS submitted more than one year of data on the baseline and hybrid buses. Table 7-30 summarizes the energy use and GHG emissions for the project. Figure 7-26 and Figure 7-27 present the results graphically. Based on the data analysis, CATS has an annual energy savings of 28% and GHG emissions are 28% lower. This is the equivalent of removing approximately 46 cars from the road each year.

Table 7-30

Summary of Energy and GHG Savings for CATS Hybrid Bus Project

	Baseline	Hybrid	Savings	Units
Total Fuel Used	84,987	61,403	23,584	gal
Annual GHG Emissions	941	680	261	tons CO_2^e
Annual Energy Use	10,917	7,887	3,029	MBtu
Lifetime of Technology			12	years
Projected Lifetime GHG Reduction			3,134	tons CO_2^e
Projected Lifetime Energy Savings			36,352	MBtu
Lifetime GHG Reduction per TIGGER $			2.1	lb CO_2^e
Lifetime Energy Savings per TIGGER $			12,117	Btu

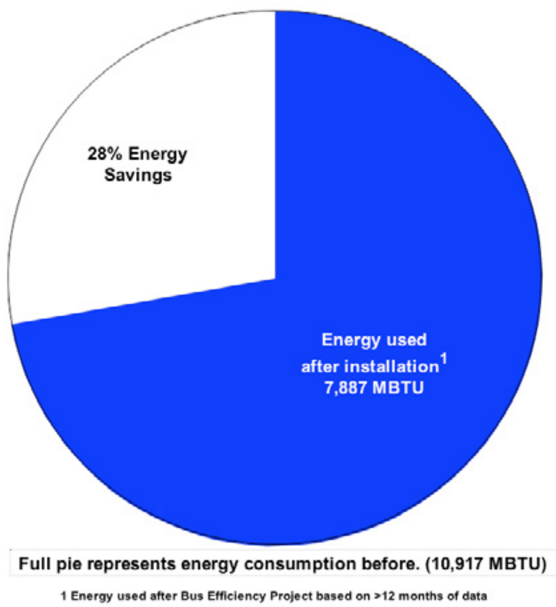


Figure 7-26

Annual Energy Use for CATS Hybrid Bus Project

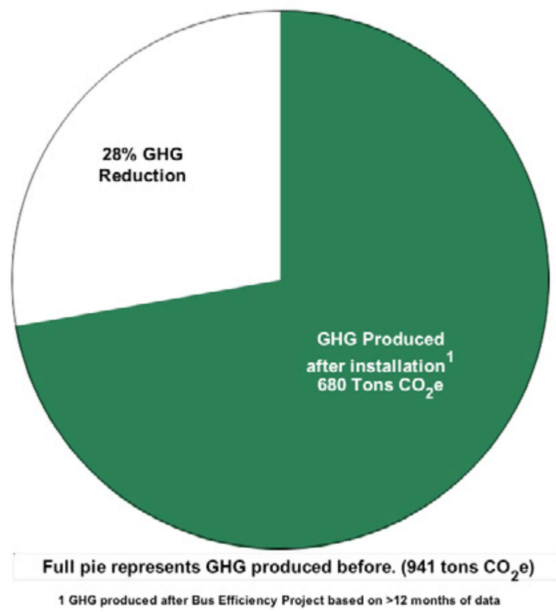


Figure 7-27

Annual GHG Emissions for CATS Hybrid Bus Project

Figure 7-28 shows the monthly fuel economy for the baseline and hybrid buses. The hybrid buses have an average fuel economy that is 38% higher than that of the baseline diesel buses. This is estimated to save the agency more than $123,000 each year in fuel costs.

Figure 7-28

Monthly Average Fuel Economy for CATS Hybrid and Baseline Buses

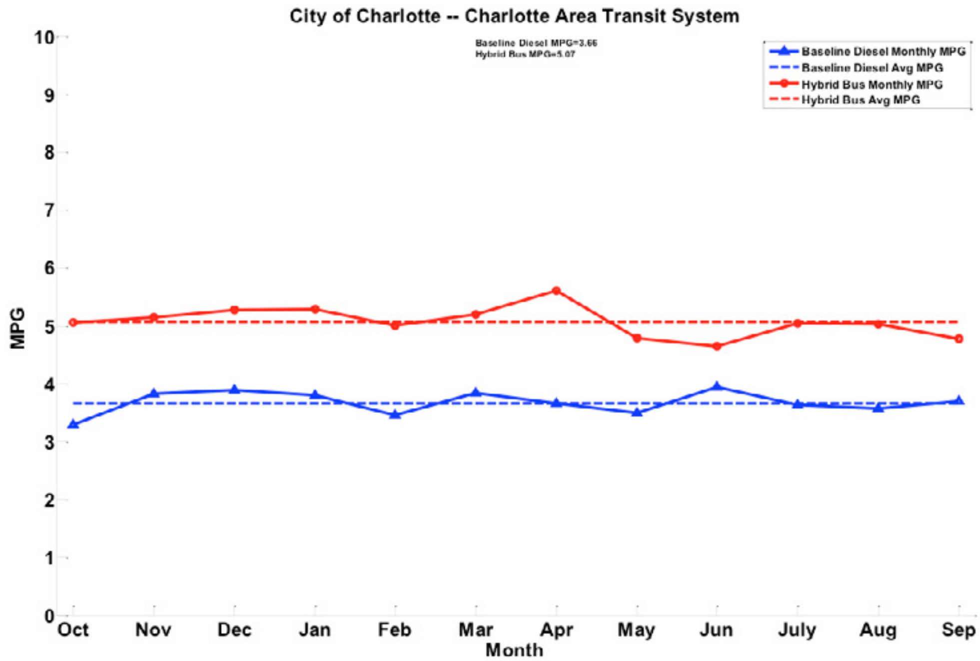


Table 7-31 summarizes the costs for the new hybrid and baseline diesel buses at CATS. The maintenance costs for the hybrid buses were significantly lower than for the diesel buses. Most of the maintenance costs for the diesel baseline buses were for unscheduled repairs. CATS provided detailed maintenance records that allowed NREL to eliminate costs such as accident-related repairs from the analysis. This is important because accidents are extremely variable from bus to bus. The level of detail also allowed NREL to categorize the repair by system. The propulsion-related-only maintenance costs are provided in the table. For the hybrid buses, these costs were only 34% of the total unscheduled maintenance costs; for the baseline diesel buses, these costs were 55% of the total unscheduled maintenance costs.

Table 7-31

Summary of Operational Costs for CATS Hybrid Bus Project

	Hybrid	Baseline
Total Miles	428,673	217,268
Parts Cost	$8,651.16	$106,308.27
Labor Cost	$44,794.74	$102,396.39
Total Maintenance Cost	$53,445.90	$208,704.66
Maintenance Cost per Mile	$0.12	$0.96
Scheduled Maintenance Cost	$26,798.59	$38,619.02
Scheduled Maintenance Cost per Mile	$0.06	$0.18
Unscheduled Maintenance Cost	$26,647.31	$170,085.64
Unscheduled Maintenance Cost per Mile	$0.06	$0.78
Propulsion-Related Unscheduled Maintenance Costs	$9,127.34	$92,938.21
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.02	$0.43
Fuel Economy (mpg)	5.07	3.66
Total Fuel Used (gal)	84,530.6	59,298.6
Fuel Cost (at $3.80 per gallon)	$321,216.42	$225,334.82
Fuel Cost per Mile	$0.75	$1.04
Total Cost per Mile	$0.87	$2.00

Using the mileage of the hybrid buses as the baseline, the operational cost savings are summarized in Table 7-32. By replacing the older diesel buses with new hybrid buses CATS is estimated to save more than $481,000 the first year in service.

Table 7-32

Operational Cost Differences for CATS Hybrid Bus Project

	Hybrid	Baseline	Difference
Total Maintenance Cost	$53,445.90	$411,777.40	$358,331.50
Total Fuel Cost	$321,216.42	$444,588.96	$123,372.54
Total Cost	$374,662.32	$856,366.36	$481,704.04

Project Name: CATS Solar Project

Transit Agency: Charlotte Area Transit System
Location: Charlotte, North Carolina
Award Amount: $1,000,000
Award Year: 2010
TIGGER Goal: Energy reduction

Results Summary:

First Year Energy Savings: 542 MBtu
First Year Energy Cost Savings: $9,809
Projected Lifetime Energy Savings: 12,712 MBtu

Transit Agency Profile: The Charlotte Area Transit System (CATS) provides transit services to 1,725,000 people in a 5-county, 2-state metropolitan area. CATS operates 73 bus routes and 324 buses—255 40-foot buses, 42 30-foot buses, 7 40-foot hybrid buses, and 19 rubber-wheel trolley buses. CATS also operates the LYNX light rail service, which includes 9.6 miles of rail and 15 passenger stations.

Project Description: CATS installed PV panels at its South Tryon Maintenance Facility. The PV panel installation covers approximately half the available space on nine peaked canopies in the parking area. The installation was completed such that the system easily could be modified to cover all usable space should additional funding be made available. Table 7-33 provides selected specifications for the solar system. CATS installed 1,134 Sharp PV panels on top of the canopies covering close to 20,000 square feet. Each panel has a 14.10% efficiency and peak power rating of 260.82 kW with a nameplate power of 230 kW. Each panel covers 17.54 square feet, is angled at 3 degrees, and is available about 19% of the time. The inverter has an efficiency rating of 97.6, which contributes to the 20% energy savings experienced at the facility. The panels come with a 25-year warranty and have a life expectancy of 35 years. Figure 7-29 shows the solar system installed at the CATS maintenance facility.

Table 7-33

CATS Solar System Specifications

Solar System Specifications	
PV Manufacturer	Sharp
PV Panel Nameplate Power (W)	200
PV Area per Panel (square feet)	18
Number of PV Panels Installed	1,134
Total PV Area (square feet)	19,890
Panel Estimated Lifetime (years)	25
Panel Efficiency Rating (%)	14
Inverter Efficiency Rating (%)	98
Warranty (years)	25

Project Status: This project was completed in late December 2012. The agency has collected the requested data on energy savings and transferred the data to NREL for analysis.

Figure 7-29

Solar Canopies Installed at CATS Facility

Project Results Summary: CATS installed 1,134 PV panels covering nearly 20,000 square feet of canopy tops. Prior to the PV installation, power for the CATS facility came from the electric grid supplemented by a generator. The baseline data provided by CATS did not include the additional generator power used. Table 7-34 provides a summary of the energy savings results. The annual energy savings resulted in a $9,809 cost savings during the first year of operation. Figure 7-30 shows a 3% reduction in energy consumption; however, this does not account for the added energy from the generator during the baseline year. Had the generator use been included, the energy reduction is estimated to be 6%-7%.

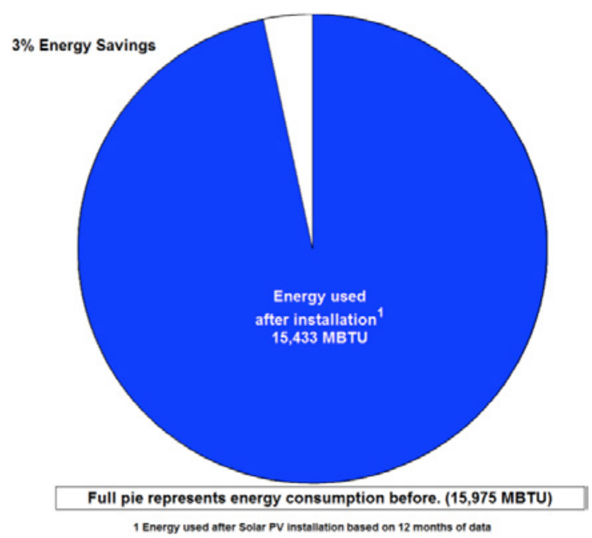
Table 7-34

Summary of Results for CATS Solar Project

	kWh	MBtu
Estimated Energy Savings	201,931	689
Actual Energy Use Before	4,679,403	15,975
Actual Energy Use After	4,520,570	15,433
Annual Energy Savings	158,833	542
Technology Lifetime (years)	25	25
Projected Lifetime Savings	3,723,470	12,712
Projected Lifetime Savings per TIGGER $	3.72	0.01

Figure 7-30

Annual Energy Use for CATS Solar Project



Project Name: CARTA Facility Lighting Conversion

Transit Agency: Chattanooga Area Regional Transportation Authority
Location: Chattanooga, Tennessee
Award Amount: $650,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Results Summary:
First Year Energy Savings: 1,461 MBtu
First Year Energy Cost Savings: $42,370
Projected Lifetime Energy Savings: 26,300 MBtu

Transit Agency Profile: The Chattanooga Area Regional Transportation Authority (CARTA) provides transit services to Chattanooga and surrounding Hamilton County in Tennessee. CARTA operates a diverse fleet of vehicles on 17 fixed-route bus lines and in paratransit and demand-response services. CARTA operates 15 electric shuttle buses in the downtown area as well as 2 incline railcars.

Project Description: CARTA replaced the fluorescent lights in 1,724 fixtures with new high-efficiency LED lights. This involved seven operating areas in CARTA's facilities, including parking garages associated with CARTA's downtown shuttle service and the bus barn and shop, service lane, steam room, and maintenance shop located at CARTA headquarters.

Project Status: This project is complete. Installation of the energy-efficient lighting at the various CARTA facilities was completed in September 2011.

Summary of Results: CARTA provided one year of data before and after the lighting retrofit project. Table 7-35 provides a summary of results for the project. The agency reduced energy consumption by 427,978 kWh annually.

Table 7-35

Summary of Results for CARTA Facility Efficiency Project

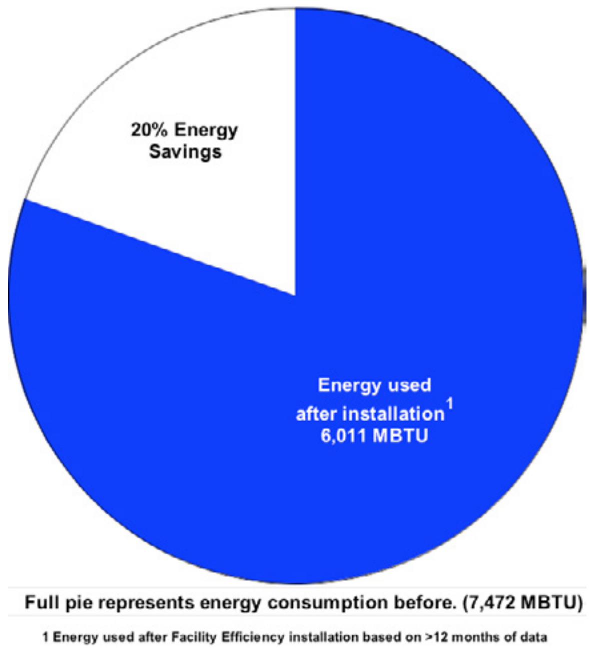
	kWh	MBtu
Estimated Energy Savings	1,356,766	4,632
Actual Energy Use Before	2,188,691	7,472
Actual Energy Use After	1,760,713	6,011
Annual Energy Savings	427,978	1,461
Technology Lifetime (years)	18	18
Projected Lifetime Savings	7,703,606	26,300
Projected Lifetime Savings per TIGGER $	11.85	0.04

Figure 7-31 shows the annual energy savings graphically. The 20% reduction is expected to save the agency an estimated $42,370 in yearly energy costs.[20]

[20] Based on 2011 average U.S. electricity costs of $0.099/kWh (EIA).

Figure 7-31

Annual Energy Savings for CARTA Facility Project



Project Name: Wayside Inductive Power Transfer System for Electric Buses

Transit Agency:	Chattanooga Area Regional Transportation Authority
Location:	Chattanooga, Tennessee
Award Amount:	$2,502,400
Award Year:	2011
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: The Chattanooga Area Regional Transportation Authority (CARTA) provides transit services to Chattanooga and surrounding Hamilton County in Tennessee. CARTA operates a diverse fleet of vehicles on 17 fixed-route bus lines and in paratransit and demand-response services. CARTA operates 15 electric shuttle buses in the downtown area as well as 2 incline railcars.

Project Description: CARTA will replace three older diesel buses with three battery-electric buses outfitted with a Wampfler wayside inductive power transfer system. This system charges the bus wirelessly through a power device embedded in the pavement at a bus layover point or parking area. When these devices are installed along the selected route, the bus could operate all day without being plugged in. CARTA has been working in partnership with the University of Tennessee at Chattanooga's Center for Energy, Transportation, and the Environment (CETE) for several years to test this inductive technology. Leveraging this earlier research, CARTA plans to deploy these electric buses on a traditional fixed-route service. Inductive charging is expected to greatly extend the range of a pure electric bus; low range is the primary issue with electric buses.

Project Status: This TIGGER III project has been initiated. CARTA will use in-house expertise to develop specifications for the equipment. Delays on this project have pushed the expected release of an RFP to July 2014 for the new battery-electric buses.

Project Name: Seneca Electric Bus Project

Transit Agency:	City of Seneca/Clemson Area Transit
Location:	Seneca, South Carolina
Award Amount:	$4,118,000
Award Year:	2011
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: The City of Seneca, South Carolina, provides three fare-free transit routes in the city and surrounding area. These routes include a business circulator route, a residential circulator route, and an express service linking downtown Seneca to the city of Clemson, Clemson University, and the Amtrak station. Clemson Area Transit (CAT) operates these routes for Seneca. In addition to serving Seneca, CAT provides fixed-route bus service to Clemson University, the city of Clemson, the towns of Central and Pendleton, and Anderson County.

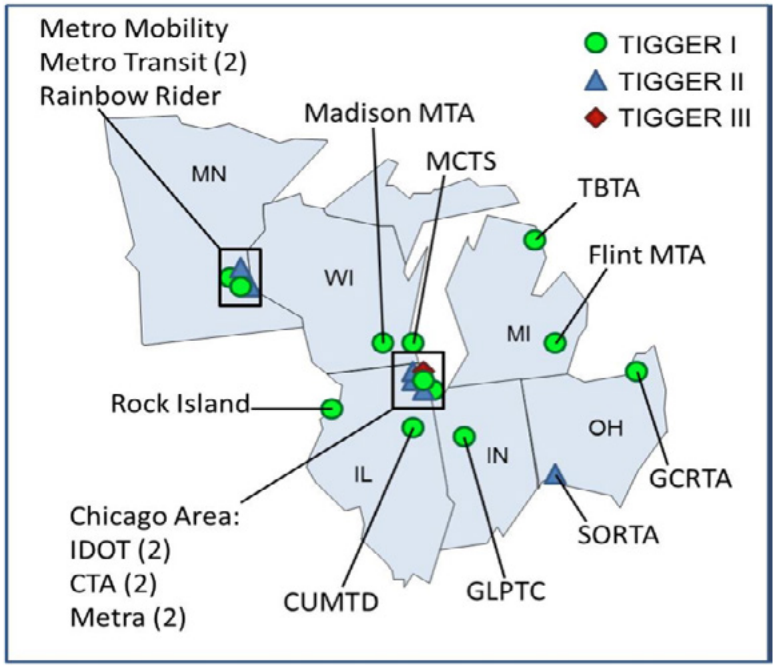
Project Description: The project will replace all three of Seneca's diesel transit buses with 35-foot fast-charge electric buses from Proterra with an additional one that will be used a spare. The spare bus is provided through a paid agreement with CAT. The buses will be charged using two fast-charge stations funded by the local power provider as a cost match for the project.

Project Status: This project is in progress. Proterra delivered all four buses in December 2013 following the completion of two fast-charge station installations in November 2013. The City of Seneca has contracted CTE to manage the project, including completing the reporting requirements and data collection. Operator training was completed in early 2014 and shadow testing began. The agency has experienced intermittent issues with the buses and charging stations that are being resolved by Proterra. CAT expects the buses to be in full service by June 2014.

Region V

Figure 7-32

Map of FTA Region V Project Locations



Region V projects:

1. Illinois DOT (IDOT), paratransit hybrid bus program (TIGGER I)
2. Illinois DOT (IDOT), paratransit hybrid bus program (TIGGER II)
3. Chicago Transit Authority (CTA), outdoor electric power system
4. Rock Island Metro, solar thermal system
5. Champaign-Urbana Mass Transit District (CUMTD), geothermal HVAC system
6. Chicago Transit Authority (CTA), electric bus project
7. Metra, locomotive efficiency project (TIGGER III)
8. Metra, locomotive efficiency project (TIGGER II)
9. Greater Lafayette Public Transportation Corporation (GLPTC), wind energy project
10. Thunder Bay Transportation Authority (TBTA), plug-in electric bus project
11. Flint Mass Transportation Authority (Flint MTA), ultra-light zero-emission buses
12. Suburban Mobility Authority for Regional Transportation (SMART), Detroit hydraulic hybrid bus project (not shown on map—project canceled)

13. Rainbow Rider Transit System, hybrid bus project
14. Minneapolis Metro Mobility, hybrid bus project
15. Minneapolis Metro Transit, hybrid bus and geothermal project
16. Greater Cleveland Regional Transportation Authority (GCRTA), energy conservation project—see case study in Section 8
17. Southwest Ohio Regional Transit Authority (SORTA), Bond Hill Division facility improvement
18. Madison Metro Transit (Madison MTA), energy efficient lighting project
19. Milwaukee County Transit System (MCTS), hybrid vehicle project

Project Name: IDOT Paratransit Hybrid Bus Program

Transit Agency:	Illinois Department of Transportation
Location:	Statewide, Illinois
Award Amount:	$4,030,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Both energy and GHG emissions reduction

Project Name: IDOT Paratransit Hybrid Bus Program

Transit Agency:	Illinois Department of Transportation
Location:	Chicago, Illinois
Award Amount:	$144,000
Award Year:	2010
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: The Illinois Department of Transportation (IDOT) oversees 52 public transportation systems in Illinois. Its services include 600 million passenger miles per year using 7,300 transit vehicles, of which 4,650 are buses or van pools. The agency provides key services for the 14% of Illinois residents without private vehicles.

Project Description: IDOT provided 34 medium-duty hybrid buses for paratransit and demand response transit use by nine transit districts in the state. IDOT purchased Ford 450 cutaway buses with an Azure Dynamics hybrid system powered by a gasoline engine. The project partners received a second award under TIGGER II that added another hybrid bus to the original fleet. The two projects are included in this status update.

Project Status: By June 2011, all 34 TIGGER hybrid paratransit buses were delivered and placed in revenue service with nine urban or small urban transit organizations across Illinois. The fleet had many technical issues that were compounded when Azure filed for bankruptcy in March 2012. This resulted in a lack of parts, maintenance, service, and technical support availability. More than half the buses are inoperable at this time.

Work is continuing on the preparation of a project manual, “A Guidebook to Implementing Hybrid Paratransit Buses, IDOT/TIGGER.” This manual is included in the scope of the TIGGER grant and will be made available for future use by other agencies or transit entities. A copy of the report has been provided to NREL; however, the data provided are not sufficient for a full analysis.

Project Name: CTA Outdoor Electric Power System

Transit Agency: Chicago Transit Authority
Location: Chicago, Illinois
Award Amount: $1,500,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: 15,595 MBtu / 1,248 tons CO_2^e
First Year Energy and Fuel Cost Savings: $295,396
Projected Lifetime Energy/GHG Savings: 1,713,440 MBtu / 24,963 tons CO_2^e

Transit Agency Profile: Chicago Transit Authority (CTA) operates the second largest public transportation system in the United States with more than 1.6 million rides on an average weekday. CTA serves a 6-county region in northeastern Illinois that includes Chicago and 40 Chicago suburban locations. CTA operates a fleet of 1,780 buses on more than 150 fixed routes serving more than 11,000 stops, and it operates 1,200 railcars on 225 miles of track serving more than 140 stations. CTA is committed to cost-effective alternatives to reducing energy consumption and is currently operating more than 200 diesel hybrid buses.

Project Description: CTA installed electrified stalls that will reduce bus idle emissions, which is a major concern for the agency. A study of operational data showed that CTA buses idled for up to one million hours annually, consuming one gallon of diesel fuel for every hour spent idling. This equates to 27,000 metric tons of carbon dioxide emissions. The CTA outdoor electric power system allows buses to plug into grid-generated power instead of consuming diesel fuel while the bus engines are idling. The grid power will be used to preheat the engine without running onboard electronics, including heating or air conditioning. In this way, buses will be ready for the start of their route without consuming diesel fuel during winter months. Eighty vehicles will be served by this electrical power installation in the North Park region. The reduction in diesel fuel use will improve air quality and provide a cost savings to the transit agency.

Project Status: The construction for this project has been completed, and electrified stalls were operational in March 2012. The agency expects to use the system mainly for preheating in the winter months. Thus, significant use of the system did not begin until November 2012. Results collected during the fall/winter season are included in this report.

Summary of Results: Table 7-36 summarizes the energy savings results for the CTA project. Figure 7-33 shows the annual energy savings graphically. The 6% annual energy savings includes the reduction of annual fuel costs incurred by the agency by an estimated $295,396. The reduced energy consumption includes the fuel consumption of the buses, which represents a decrease of 3,908 gallons of diesel fuel annually.

Table 7-36

Summary of Energy Savings for CTA Facility Project

	kWh	MBtu
Estimated Energy Savings	4,567,955	15,595
Actual Energy Use Before	44,074,287	150,470
Actual Energy Use After	41,245,228	140,811
Annual Energy Savings	2,829,059	9,658
Technology Lifetime (yrs)	20	20
Projected Lifetime Savings	56,581,190	193,168
Projected Lifetime Savings per TIGGER $	37.7	0.13

Figure 7-33

Annual Energy Savings for CTA Facility Project

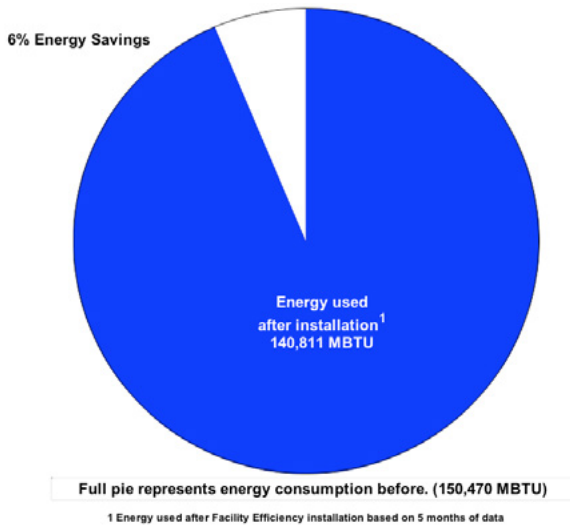


Table 7-37 provides the summary results for GHG savings attributed to the project. The stalls enabled a reduction in idle time for the buses, which not only reduced the fuel consumption, saving CTA money, but also reduced the GHG emissions by 7%, as shown in Figure 7-34.

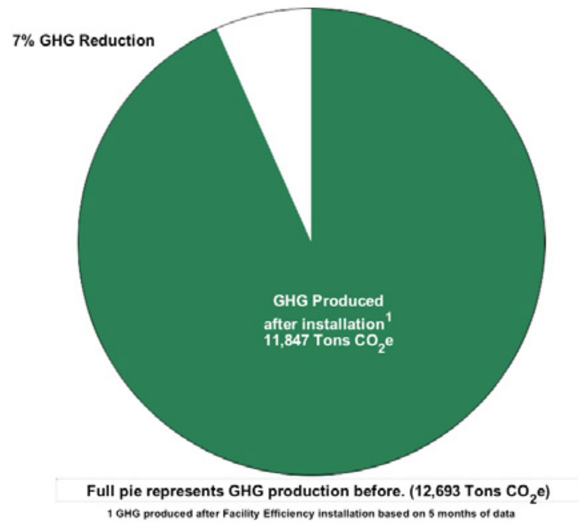
Table 7-37

Summary of GHG Savings for CTA Facility Project

	Tons CO_2e
Estimated GHG Reduction	1,248
Actual GHG Emissions Before	12,693
Actual GHG Emissions After	11,847
Annual GHG Reduction	846
Technology Lifetime (yrs)	20
Projected Lifetime Reduction	16,916
Projected Lifetime Reduction per TIGGER $	0.01

Figure 7-34

Annual GHG Savings for CTA Facility Project



Project Name: Rock Island Solar Thermal System

Transit Agency:	Rock Island Metro
Location:	Moline, Illinois
Award Amount:	$600,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Energy reduction

Transit Agency Profile: Rock Island County Metropolitan Mass Transit District, or MetroLINK, serves communities in Rock Island County in western Illinois, including Carbon Cliff, Colona, East Moline, Hampton, Milan, Moline, Rock Island, and Silvas. Its bus system connects to Bettendorf Transit and Davenport CitiBus on the Iowa side of the Mississippi River to serve the entire Quad City region, which has a population of nearly 400,000. The transit agency also operates the channel cat water taxi, which serves four landings along the Mississippi River during the summer months.

Project Description: MetroLINK is using TIGGER funding to add a hot water system with 200 roof-mounted solar thermal panels to its new $33 million LEED-platinum sustainable design facility. The system will provide hot water for bus washing and for the facility, which will house the agency's maintenance, administration, and operations functions. The solar-heated water also will be used for supplemental facility heating during the colder months.

Project Status: This project is in process. The solar thermal hot water system construction contract was awarded to Heliadyne during the fourth quarter of 2012. The original bid exceeded the TIGGER award amount, but the contractor has agreed to complete the project for the TIGGER project dollars allocated. Final system testing was scheduled for February 2014. Project results will be included in the next assessment report.

Project Name: Champaign-Urbana Geothermal HVAC System

Transit Agency: Champaign-Urbana Mass Transit District (CUMTD)
Location: Champaign-Urbana, Illinois
Award Amount: $450,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: GHG emissions reduction

Results Summary:

First Year GHG Savings: 97 tons CO_2e
First Year Fuel Cost Savings: $13,275
Projected Lifetime GHG Savings: 2,916 tons CO_2e

Transit Agency Profile: The Champaign-Urbana Mass Transit District (CUMTD) operates buses in the twin cities of Champaign-Urbana, home to the University of Illinois. CUMTD serves an urbanized population of approximately 145,000 and provides more than 11 million rides annually, in part because of its close relationship with the university.

Project Description: CUMTD installed a geothermal HVAC system in its administration building.

Project Status: The CUMTD facilities improvement project was completed in December 2010.

Summary of Results: CUMTD provided an annual comparison of electric utility data for the facility. Table 7 38 summarizes the GHG emissions results for the project. Figure 7-35 shows the GHG savings graphically. The agency greatly reduced its natural gas use once the geothermal system went online, resulting in a 67% annual reduction of GHG emissions. Based on current natural gas prices, this is estimated to have saved the agency approximately $13,275 in the first year of the project.

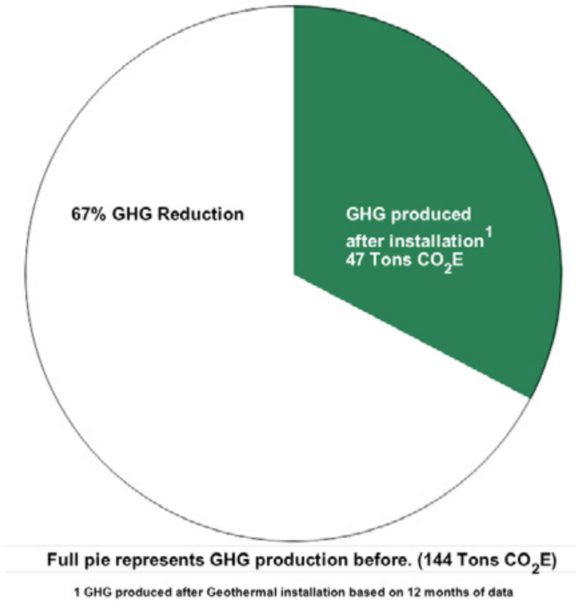
Table 7-38

Summary of GHG Emissions Results for CUMTD Geothermal Project

	Tons CO_2e
Estimated GHG Reduction	67.0
Actual GHG Emission Before	144.5
Actual GHG Emission After	47.3
Annual GHG Reduction	97.2
Technology Lifetime (yrs)	30
Projected Lifetime GHG Reduction	2,916
Projected Lifetime GHG Reduction per TIGGER $	0.0065

Figure 7-35

Annual GHG Emissions for CUMTD Geothermal Project



Project Name: CTA Electric Bus Project

Transit Agency: Chicago Transit Authority
Location: Chicago, Illinois
Award Amount: $2,210,490
Award Year: 2010
TIGGER Goal: GHG emissions reduction

Transit Agency Profile: Chicago Transit Authority (CTA) operates the second largest public transportation system in the country with more than 1.6 million rides on an average weekday. CTA serves a 6-county region in northeastern Illinois that includes Chicago and 40 Chicago suburban locations. CTA operates a fleet of 1,780 buses on more than 150 fixed routes serving more than 11,000 stops, and it operates 1,200 railcars on 225 miles of track serving more than 140 stations.

Project Description: This TIGGER project will provide two new all-electric battery-powered buses to replace older diesel buses. CTA is planning to use this project as a demonstration for the new technology. The agency will use the results of the evaluation to determine the feasibility for adoption of the technology on a larger scale.

Project Status: This project is in process. CTA experienced some delays early in the project as a result of lithium ion battery supplier issues. The buses have been delivered and will be placed in service in mid-2014.

Project Name: Locomotive Efficiency Project

Transit Agency: Metra, Commuter Rail Division of the RTA
Location: Chicago, Illinois
Award Amount: $2,208,000
Award Year: 2011
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Metra, the commuter railroad in northeastern Illinois, provides rail service to Chicago and the six counties of the Greater Chicago area. Metra's 11 rail lines provide more than 81 million passenger trips each year, serving 240 stations in its service area. The railroad has more than 1,000 pieces of rolling stock that are used on the 702 trains each weekday.

Project Description: Metra's TIGGER project will upgrade 22 locomotives to supply "hotel" power with new engine/generator sets. Hotel power provides amenities for passenger comfort such as lighting, heating, and air conditioning. This power is often needed when the train is stopped. Currently, the locomotive's main engine provides power for both locomotion and hotel power. During standby mode at a stop, the engine must provide power even when passengers are not present. The upgrade will add a separate engine/generator set to provide the hotel power. The engine can then be powered down to idle or even shut down.

Project Status: Awarded in TIGGER III, this project has not started. The agency has finalized the grant agreement and issued an RFP for the upgrades.

Project Name: Locomotive Efficiency Project

Transit Agency: Metra, Commuter Rail Division of the RTA
Location: Chicago, Illinois
Award Amount: $341,694
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Metra, the commuter railroad in northeastern Illinois, provides rail service to Chicago and the six counties of the Greater Chicago area. Metra's 11 rail lines provide more than 81 million passenger trips each year, serving 240 stations in its service area. The railroad has more than 1,000 pieces of rolling stock that are used on the 702 trains each weekday.

Project Description: This TIGGER project grant will provide funding for Metra to modify 27 locomotives to include automatic engine start-stop (AESS) technology to reduce idling time, thereby lowering fuel consumption and GHG emissions. The use of an AESS will be controlled by a set of predetermined parameters that will also turn the engine back on if required to maintain engine or environmental conditions (e.g., battery charge or cabin temperature).

Project Status: IDOT is currently negotiating the terms and conditions with its supplier on this project. The expected project completion date is December 2014.

Project Name: **Greater Lafayette Wind Energy Project**

Transit Agency: Greater Lafayette Public Transportation Corporation
Location: Lafayette, Indiana
Award Amount: $2,180,750
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Results Summary:

First Year Energy Savings: 505 MBtu
First Year Energy Cost Savings: $14,600
Projected Lifetime Energy Savings: 10,099 MBtu

Transit Agency Profile: The Greater Lafayette Public Transportation Corporation (GLPTC) operates in northwestern Indiana, serving the Lafayette metropolitan area, and provides nearly 5 million rides annually. Because Lafayette is home to Purdue University, the area has the second highest ridership of any transit agency in Indiana. GLPTC operates 70 buses, 6 demand-response vehicles, and 10 support vehicles. In total, 20 of the buses are hybrid diesel-electric and 2 vehicles are trolleys.

Project Description: For its TIGGER project, GLPTC installed three wind turbines to offset power at its administrative and maintenance facilities. The agency originally proposed four roof-mounted turbines for the facility. Working with consultants during the early phase of implementation, the agency determined the original plan was not feasible. GLPTC reviewed several options for standalone turbines. Based on availability of specific turbine technology, budget, and space considerations, the agency selected Northwind to provide the turbines. The turbines provide power directly to the facility but were set up for net metering to put excess power back onto the grid when not needed by the facility. Table 7-39 provides selected specifications for the turbines installed.

Table 7-39

Turbine Specifications for GLPTC Wind Project

Turbine Specifications	
Manufacturer	Northwind
Nameplate Power (W)	100
Hub Height (m)	36.70
Rotor Diameter (m)	20.9
Total Height (m)	47.15
Maximum Rotation Speed (rpm)	58.6
Rated Wind Speed (m/sec)	15
Estimated Lifetime (yrs)	20

Project Status: This project is complete. The three ground-mounted turbines came online July 15, 2011. GLPTC has collected operational data for a one-year time period.

Summary of Results: Table 7-40 provides a summary of the results from the GLPTC TIGGER project in kWh and MBtu. In the first year of operation, the wind turbines have shown an annual energy savings of almost 148,000 kWh. At current energy prices, this could save the agency more than $14,600 each year. Figure 7-36 shows the energy savings for the first year of the project.

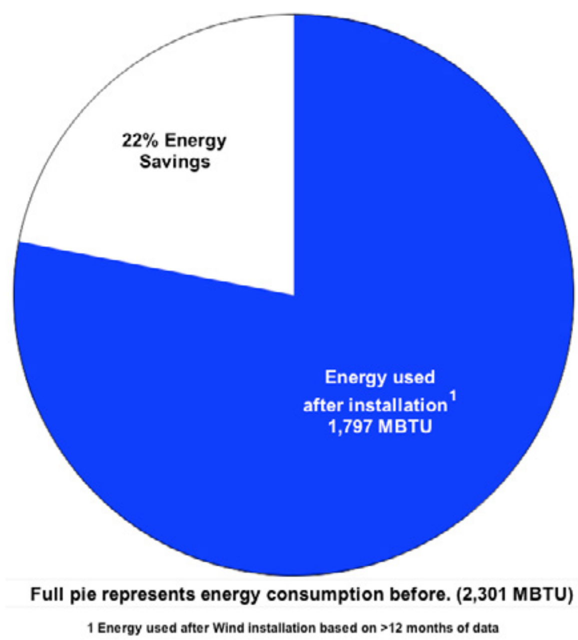
Table 7-40

Summary of Energy Savings Results for GLPTC Wind Project

	kWh	MBtu
Estimated Energy Savings	381,198	1,301
Actual Energy Use Before	674,124	2,301
Actual Energy Use After	525,543	1,794
Annual Energy Savings	148,578	507
Technology Lifetime (yrs)	20	20
Projected Lifetime Savings	2,971,558	10,145
Projected Lifetime Savings per TIGGER $	1.36	0.00

Figure 7-36

Annual Energy Savings for GLPTC Wind Project



GLPTC based its original estimate on four roof-mounted turbines. Once the project scope changed to a different type of turbine, the original estimate no longer applied. Therefore, the estimated energy savings for the project have been modified to reflect the expected savings for three standalone turbines. GLPTC estimated its wind project would save more than 1,301 MBtu each year. The actual energy saved during the first year of operation was a little less than half the estimated savings. This could be due to several factors. Wind energy is highly variable. The predicted energy for the turbines was based on the mean wind speed of 11 mph for the area; however, the average wind speed for that area during the year of data collection was 7 mph (Weather Underground, Inc.).

Project Name: Thunder Bay Series Hybrid Buses

Transit Agency:	Thunder Bay Transportation Authority
Location:	Alpena, Michigan
Award Amount:	$2,590,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: The Thunder Bay Transportation Authority (TBTA) in northeastern Michigan serves the 50,000 residents of Alpena, Alcona, and Montmorency counties. TBTA operates a fleet of 35 vehicles, provides more than 118,000 rides per year, and employs 55 people.

Project Description: TBTA is replacing four diesel paratransit buses with more efficient series hybrid-electric buses. The battery dominant buses are capable of running in all-electric mode for part of their route. The buses will plug in overnight at the depot to fully recharge the batteries. TBTA selected trolley-style buses that have been shown to provide an incentive for attracting ridership.

Project Status: A third-party contract was awarded to CTE to provide technical and consulting services in support of the hybrid-electric bus project. TBTA selected Double K, Inc. as the supplier for the new buses. The buses are currently under construction, and TBTA expects the first trolley to be delivered in June 2014 with the remaining trolleys to be delivered by the end of the year (see Figure 7-37).

Figure 7-37

TBTA New Hybrid Bus

Photo Courtesy of CTE

Project Name: Flint Ultra-Light Zero-Emission Buses

Transit Agency: Flint Mass Transportation Authority
Location: Flint, Michigan
Award Amount: $2,200,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: The Flint Mass Transportation Authority (Flint MTA) provides public transportation to Flint and Genesee counties in Michigan. Flint MTA services include fixed routes, peak routes, regional routes, and paratransit and specialized services for older adults and people with disabilities.

Project Description: The original proposal included the purchase of two 40-foot zero-emission buses and an upgrade to an electrical charging supply. Flint MTA based its proposal on an ultra-light chassis with plug-in electric drive. Due to circumstances out of Flint MTA's control, the supplier that was used as a basis for the cost estimation is no longer providing this product.

Project Status: Flint MTA has identified hydrogen fuel cell buses as the technology that can meet the zero-emission requirement. It has submitted specifications for the purchase to FTA for approval; upon approval Flint MTA plans to issue an RFP for two new hydrogen fuel cell buses. Flint MTA anticipates delivery of the buses in 2015.

Project Name: Detroit Hydraulic Hybrid Bus Project

Transit Agency: Suburban Mobility Authority for Regional Transportation
Location: Detroit, Michigan
Award Amount: $2,000,000
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Project Status: This TIGGER project was canceled due to unforeseen issues that arose with the initial manufacturer of the hybrid buses and the ability of the project sponsor to fully participate. Project funds were transferred to an existing StarMetro project that had not previously received the full funding amount requested in the original proposal.

Project Name: Rainbow Rider Transit System Hybrid Bus Project

Transit Agency: Minnesota Department of Transportation
Location: St. Paul, Minnesota
Award Amount: $845,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: -442 MBtu / -37 tons CO_2^e
Projected Lifetime Energy/GHG Savings: -3,095 MBtu / -259 tons CO_2^e

Transit Agency Profile: The Rainbow Rider Transit System serves the west central Minnesota counties of Douglas, Grant, Pope, Stevens, Todd, and Traverse with handicapped-accessible buses as well as a Volunteer Driver Program.

Project Description: Rainbow Rider replaced eight older paratransit vehicles with new gasoline hybrid paratransit vehicles. The buses are being used in a combination of urban and rural route service. Two are on a Glaval bus platform and the remaining six were built by Turtle Top. Both manufacturers used a Variable Torque Motors (VTM) hybrid system, which is an add-on component that works in combination with the engine to create a hybrid system. The primary components include a motor/generator installed in the vehicle driveline, ultracapacitors to store braking energy, and a controller. If the system develops a problem, it can be turned off and operated using the original engine and transmission. The system was installed on the buses as they were built at the bus manufacturer facility.

Project Status: This project is complete. All eight buses were delivered and were placed in service between October 2010 and February 2011.

Summary of Results: Rainbow Rider provided one year of data from the baseline and new hybrid buses. Although the hybrid buses were built by two different manufacturers, the buses are similar in size and weight and were combined into a group for comparison. The baseline buses consisted of three distinct vehicle types: six gasoline-fueled cutaway buses, one diesel-fueled cutaway bus, and one gasoline-fueled van. To calculate the energy use for the baseline buses, NREL combined the six gasoline cutaway buses to determine the average energy use for that group and then added the results for the other two vehicle types for total energy use and GHG emissions.

Table 7-41 summarizes the analysis results for the project. The results show an actual energy increase for the hybrid buses compared to the baseline buses. Figure 7-38 presents the GHG results, and Figure 7-39 presents the energy results for the Rainbow Rider project. The savings were much lower than estimated, due to several factors. Two of the baseline vehicles were already more efficient than the hybrids—the gasoline van is a much lighter vehicle and averaged over 14 mpg, and the diesel-fueled cutaway averaged around 10 mpg. The hybrid buses averaged 6.52 mpg, which was slightly less than the similarly-sized baseline buses at 6.96 mpg. Also, the Rainbow Rider service is primarily demand response in a rural area without set stops. This type of duty cycle does not benefit from the regenerative braking of a hybrid system as much as a more urban stop-and-go route does. Rainbow Rider reported major issues with the buses that sometimes resulted in a need to deactivate the hybrid system. During those times the bus would perform as a standard bus and not benefit from regenerative braking. All these factors would be expected to lower the fuel economy for the new buses.

Table 7-41

Summary of Annual Energy Use and GHG Emissions for Rainbow Rider

	Hybrid	Baseline	Savings	Unit
Total Fuel Used	24,966	20,941	-4,025	Gal
Annual GHG Emissions	245	208	-37	tons CO_2e
Annual Energy Use	2,898	2,456	-442	MBtu
Lifetime of Technology			7	years
Projected Lifetime GHG Savings			-259	tons CO_2e
Projected Lifetime Energy Savings			-3,095	MBtu
Lifetime GHG Savings per TIGGER $			-0.6	lb CO_2e
Lifetime Energy Savings per TIGGER $			-3,662.5	Btu

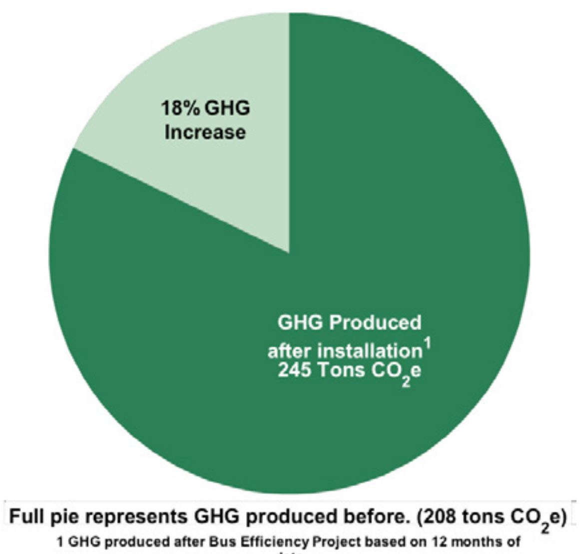


Figure 7-38

Annual GHG Emissions for Rainbow Rider Hybrid Bus Project

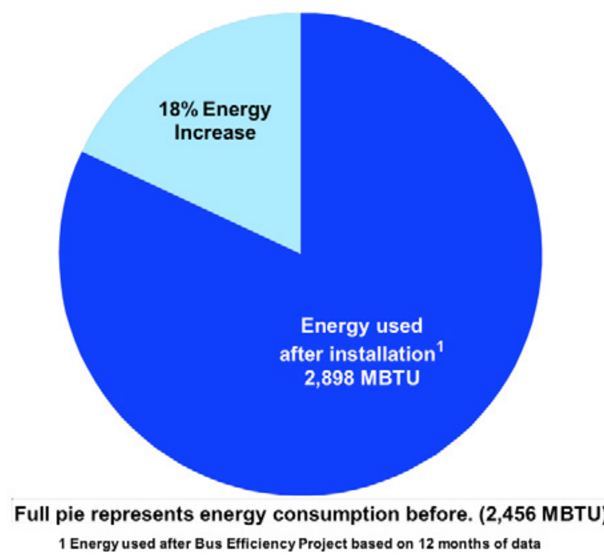


Figure 7-39

Annual Energy Use for Rainbow Rider Hybrid Bus Project

Figure 7-40 shows the monthly fuel economy for the baseline and hybrid buses in service. The fuel economies for the van and diesel baseline vehicles are significantly different than for the other baseline vehicles and are shown separately.

Figure 7-40

Monthly Average Fuel Economy for Rainbow Rider Baseline and Hybrid Vehicles

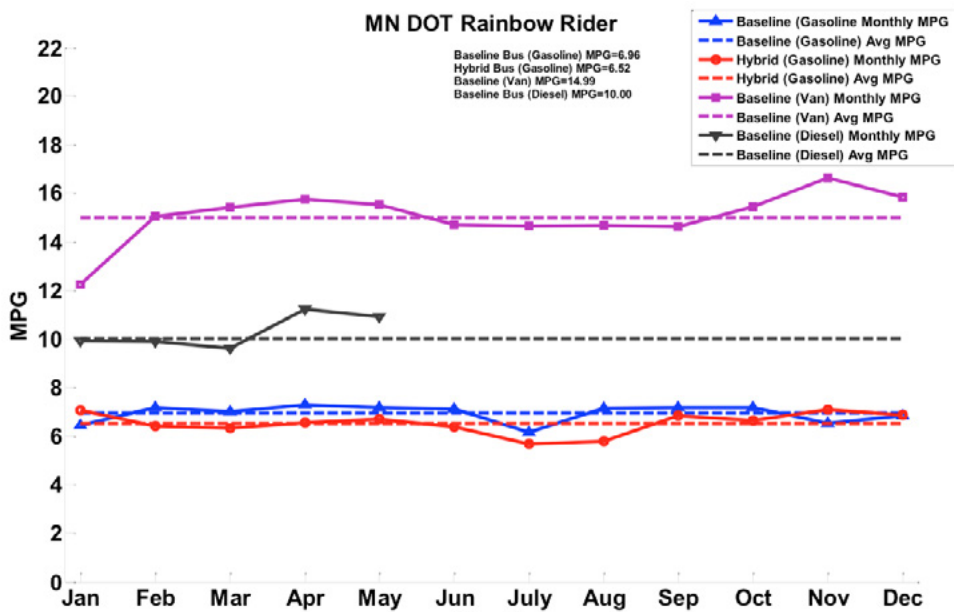


Table 7-42 provides an overall summary of the operational costs of the hybrid and baseline buses and Table 7-43 shows the resulting operational cost difference for the project. These results indicate a net increase in cost for the new hybrid buses.

Table 7-42

Summary of Operational Costs for Rainbow Rider Hybrid Bus Project

	Hybrid	Baseline
Total Miles	162,803	186,086
Total Maintenance Cost	$26,346.84	$21,114.07
Maintenance Cost per Mile	$0.16	$0.11
Fuel Economy (mpg)	6.52	6.96
Total Fuel Used (gal)	24,966.4	20,941.3
Fuel Cost ($3.48/gal gasoline, $3.8/gal diesel[21])	$86,883.04	$84,803.30
Fuel Cost per Mile	$0.53	$0.46
Total Cost per Mile	$0.70	$0.57

[21] Per-gallon fuel cost was not available. NREL used the 2011 average fuel cost for the Midwest from EIA, www.eia.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html.

Table 7-43

Operational Cost Differences for Rainbow Rider Hybrid Bus Project

	Hybrid	Baseline	Savings
Total Maintenance Cost	$26,346.84	$18,472.29	-$7,874.55
Total Fuel Cost	$86,883.04	$73,547.31	-$13,335.73
Total Cost	$113,229.88	$92,019.59	-$21,210.28

Rainbow Rider reports that the project proved to be a challenge and the hybrids did not perform as originally expected. The agency worked closely with VTM and Cummins Crosspoint (the master distributor of the VTM system) installing four versions of the system on the buses over the first two years of operation. In late 2012, Cummins Crosspoint purchased the design from VTM and currently is working on an upgrade to the system. VTM is no longer in operation. Rainbow Rider elected to remove the system and operate the buses as standard gasoline vehicles. Once the new design has been completed and tested, Cummins Crosspoint could reinstall it on the Rainbow Rider buses.

Project Name: **Minneapolis-St. Paul Hybrid Buses**

Transit Agency: Metro Mobility
Location: Minneapolis, Minnesota
Award Amount: $1,100,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: -476 MBtu / -35 tons CO_2^e
Projected Lifetime Energy/GHG Savings: -3,332 MBtu / -245 tons CO_2^e

Transit Agency Profile: Metro Mobility is the oversight division for the Americans with Disabilities Act (ADA) paratransit service operating through the Metropolitan Council in the Minneapolis–St. Paul region. Metro Mobility provides shared public transportation to certified riders who, because of a disability or health condition, cannot use regular fixed-route buses. With a peak fleet of 265 small buses and 18 automobiles, the service delivered 1.22 million rides in 2008.

Project Description: Metro Mobility used TIGGER funds to replace 10 small diesel buses with gasoline hybrid-electric buses. The older buses had surpassed 225,000 miles and were scheduled for replacement. Table 7-44 provides selected specifications for the baseline and hybrid buses. The gasoline hybrid buses are integrated on Ford E350 chassis and feature a parallel hybrid propulsion system from Azure Dynamics.

Table 7-44

Vehicle Specifications for Metro Mobility Buses

	Baseline	New Technology
Number of Vehicles	10	10
Model Year	2006	2010
Manufacturer	Ford	Ford
Model	E350	E450
Length (ft)	18	22
Weight (lb)	10,700	14,500
Engine OEM	International	Ford
Engine: Rated Power (hp)	350	310
Hybrid System Manufacturer		Azure
Hybrid Model		Balance
Hybrid Configuration		Parallel
Energy Storage Type		Lithium Ion Battery
Energy Storage Manufacturer		Johnson Control

Project Status: This project is complete. All 10 vehicles were delivered and placed in service by the end of November 2010.

Summary of Results: Metro Mobility provided a full year of data on the baseline and new hybrid buses for the analysis. Table 7-45 provides a summary of energy use and GHG emissions. Figure 7-41 depicts the energy use and Figure 7-42 depicts the GHG emissions for the project. The project resulted in a net increase in energy use and GHG emissions over the baseline buses. This increase is primarily due to the lower than expected fuel economy for the hybrid buses. The baseline buses are smaller and are powered by a diesel engine. While the new buses are hybrids, they are larger, heavier, and powered by gasoline engines. The agency anticipated a lower fuel economy for the hybrids compared to the diesel baseline buses; however, gasoline produces fewer pounds of CO_2 per gallon than diesel does.

Table 7-45

Summary of Annual Energy Use and GHG Emissions for Metro Mobility Hybrid Bus Project

	Hybrid	Baseline	Savings	Unit
Total Fuel Used	36,906	29,646	-7,260	gal
Annual GHG Emissions	362	327	-35	tons CO_2^e
Annual Energy Use	4,271	3,795	-476	MBtu
Lifetime of Technology			7	years
Projected Lifetime GHG Savings			-245	tons CO_2^e
Projected Lifetime Energy Savings			-3,332	MBtu
Lifetime GHG Savings per TIGGER $			-0.3	lb CO_2^e
Lifetime Energy Savings per TIGGER $			-2,163.6	Btu

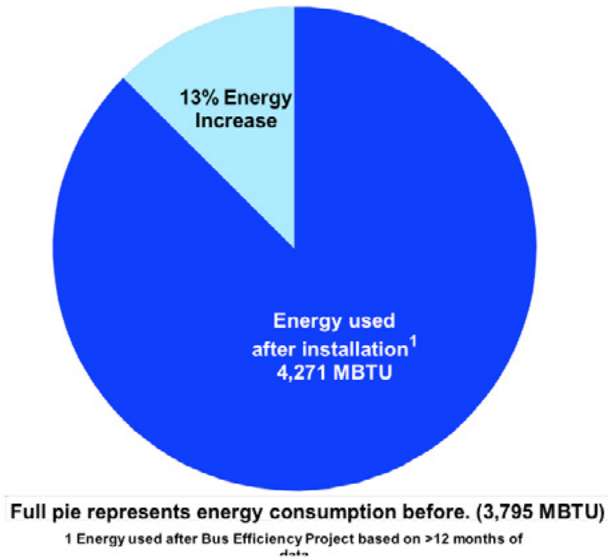


Figure 7-41

Annual Energy Savings for Metro Mobility Hybrid Bus Project

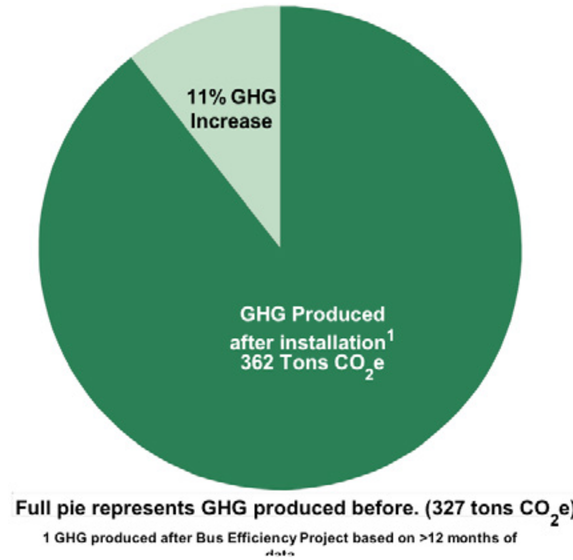


Figure 7-42

Annual GHG Savings for Metro Mobility Hybrid Bus Project

Figure 7-43 shows the monthly fuel economy for the baseline and hybrid buses in service. The baseline buses averaged 10.98 mpg and the gasoline-hybrid buses averaged 8.82 mpg. Metro Mobility estimated the buses would average 10.08 and 9.77 mpg for the diesel and gasoline-hybrid buses, respectively. The difference in fuel economies for the two groups resulted in a net increase in energy use and GHG emissions attributed to the project.

Figure 7-43

Monthly Fuel Economy for Metro Mobility Hybrid and Baseline Buses

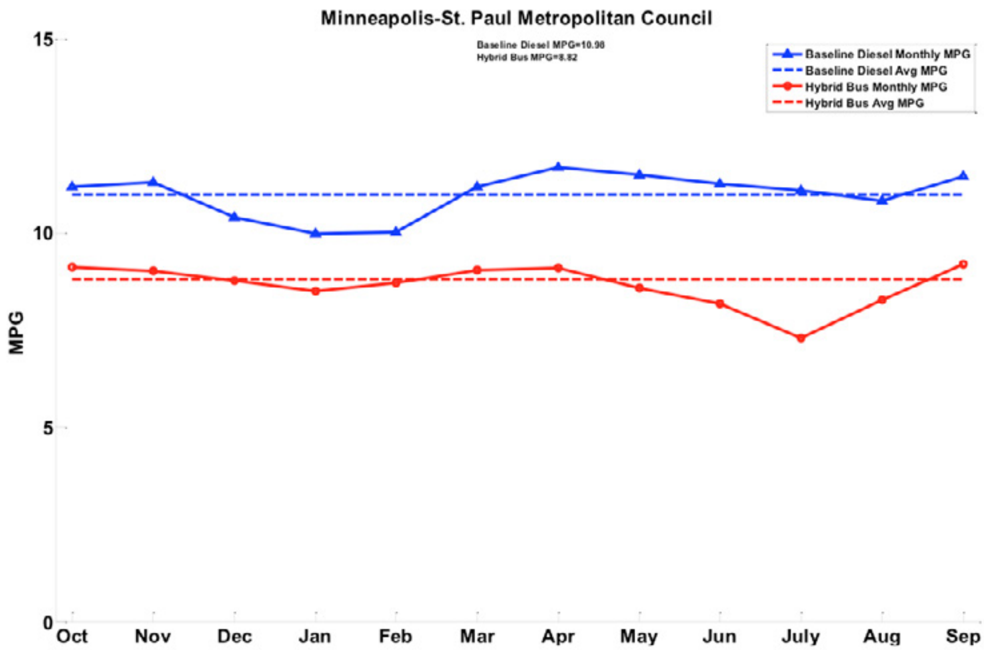


Table 7-46 summarizes the operational costs for the baseline and hybrid buses in service at Metro Mobility. The hybrid buses have a total cost per mile that is slightly higher than that of the baseline buses. Metro Mobility reports it experienced many issues with the new buses that reduced reliability. Much of the early maintenance on the buses was covered under warranty and, thus, is not included in the total cost. Table 7-47 outlines the overall cost differences normalized to the hybrid bus total mileage. The analysis of the first year of operation shows a cost increase compared to the baseline buses. These buses are the same model as those purchased for the IDOT paratransit bus project (see earlier project summary). Like IDOT, Metro Mobility had many technical issues with the buses. Azure filed for bankruptcy in March 2012, resulting in a lack of availability of parts, maintenance, service, and technical support.

Table 7-46

Summary of Operational Costs for Metro Mobility Hybrid and Baseline Buses

	Hybrid	Baseline
Total Miles	325,508	584,839
Parts Cost	$18,285.60	$50,086.92
Labor Cost	$19,385.00	$35,132.00
Total Maintenance Cost	$37,670.60	$85,218.92
Maintenance Cost per Mile	$0.12	$0.15
Scheduled Maintenance Cost	$17,774.25	$36,686.21
Scheduled Maintenance Cost per Mile	$0.05	$0.06
Unscheduled Maintenance Cost	$19,896.35	$48,532.71
Unscheduled Maintenance Cost per Mile	$0.06	$0.08
Propulsion-Related Unscheduled Maintenance Costs	$24,131.43	$29,553.24
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.07	$0.05
Fuel Economy (mpg)	8.82	10.98
Total Fuel Used (gal)	37,221.4	54,020.2
Fuel Cost (at $3.54/gal gasoline; $3.90/gal diesel)	$131,763.86	$210,678.78
Fuel Cost per Mile	$0.41	$0.36
Total Cost per Mile	$0.52	$0.50

Table 7-47

Operational Cost Differences for Metro Mobility Hybrid Bus Project

	Hybrid	Baseline	Savings
Total Maintenance Cost	$37,670.60	$47,430.90	$9,760.31
Total Fuel Cost	$132,170.72	$116,202.35	-$15,968.37
Total Cost	$169,841.31	$163,633.25	-$6,208.07

Project Name: Metro Transit Hybrid Bus and Geothermal Project

Transit Agency: Metropolitan Council (Metro Transit)
Location: Minneapolis, Minnesota
Award Amount: $2,400,000
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Summary of Results (Project 1):
First Year Energy/GHG Savings: 796 MBtu / 69 tons CO_2^e
First Year Fuel Cost Savings: $19,609
Estimated Lifetime Energy/GHG Savings: 9,552 MBtu / 828 tons CO_2^e

Transit Agency Profile: Metro Transit operates 910 transit buses in the greater Minneapolis-St. Paul metropolitan area. Metro Transit also operates the Twin Cities' light rail system comprising 27 railcars, 6 locomotives, and 18 rail coaches. With these combined services, Metro Transit provides more than 76 million passenger trips annually.

Project Description: Metro Transit's TIGGER project consists of two distinct parts:

1. Replacing two older buses with new diesel-electric hybrid buses that have additional electrification of the passenger cabin air conditioning and engine cooling systems. These changes will reduce fuel use on these buses by an estimated 25%. These buses also will be able to operate indoors purely on electric power, without running the diesel engine. This feature could save on emissions from garage heating if deployed across the entire Metro Transit fleet. Table 7-48 provides selected specifications for the baseline and hybrid buses. Figure 7-44 shows a Metro Transit hybrid bus.
2. Installation of a geothermal ground source heat pump to replace the heating system for two planned expansions: one for the Rail Support Group Facility and one for the Light Rail Transit Operations and Maintenance building. Rather than heating these buildings with traditional gas and/or oil fired systems, Metro Transit will install a ground source heat pump system. This system will use the earth nearby the buildings as a heat source/sink, providing heat in the winter and precooling air to the office air conditioning system in the summer.

Figure 7-44

Metro Transit Hybrid Bus on Display at 2013 APTA Bus Conference

Table 7-48 *Vehicle Specifications for Metro Transit Buses*

	Baseline	New Technology 1	New Technology 2
Number of Vehicles	2	1	1
Model Year	1999	2012	
Manufacturer	Gillig	New Flyer	New Flyer
Model	Phantom	Xcelsior (XDE40)	Xcelsior (XDE40)
Length (ft)	40	40	40
Weight (lb)	30,700	29,180	
Engine OEM	Detroit Diesel	Cummins	Cummins (2014)
Engine: Rated Power (hp)	275	280	
Hybrid System Manufacturer		BAE Systems	BAE Systems
Hybrid Model		Electric Drive	Electric Drive
Hybrid Configuration		Series	Series
Energy Storage Type		Lithium Ion Battery	Lithium Ion Battery
Energy Storage Manufacturer		A123	A123
Energy Saving Features		Electric accessories—BAE Systems APS	Electric accessories—BAE Systems APS plus start-stop control of engine

Project Status: The hybrid buses for the first project were delivered in the fall of 2012. The buses are in service and the agency has purchased specialized tools from BAE Control Systems, Inc., for maintenance on the buses. The second project was completed in March 2013. Metro Transit is currently compiling the data on the geothermal system. The final results will be included in the next assessment report.

Summary of Results (Project 1): The two hybrid buses have different configurations. The first bus included a BAE Systems electric accessory package (auxiliary power system, or APS) as part of the hybrid propulsion system. In addition to the APS, the second bus also included a Cummins 2014 engine and was configured to allow start-stop capability.
During the first year of operation, the agency reduced fuel consumption by 6,217 gallons. Table 7-49 summarizes the results for the buses. Metro Transit was able to achieve a fuel reduction of 6,217 gallons during the first year of operation and is estimated to save a total of 824 tons of CO_2 emissions over the lifetime of the buses. This is a 32% reduction in both energy consumption and GHG emissions for this project during the first year, as shown in Figure 7-45 and Figure 7-46.

Table 7-49

Summary of Energy/ GHG Savings for Metro Transit Hybrid Bus Project

	Baseline	Hybrid	Savings	Units
Total Fuel Used	19,727	13,511	6,217	gal
Annual GHG Emissions	218	149	69	tons CO_2e
Annual Energy Use	2,525	1,729	796	MBtu
Lifetime of Technology			12	years
Projected Lifetime GHG Reduction			824	tons CO_2e
Projected Lifetime Energy Savings			9,549	MBtu
Lifetime GHG Reduction per TIGGER $			1.4	lb CO_2e
Lifetime Energy Savings per TIGGER $			7,958	Btu

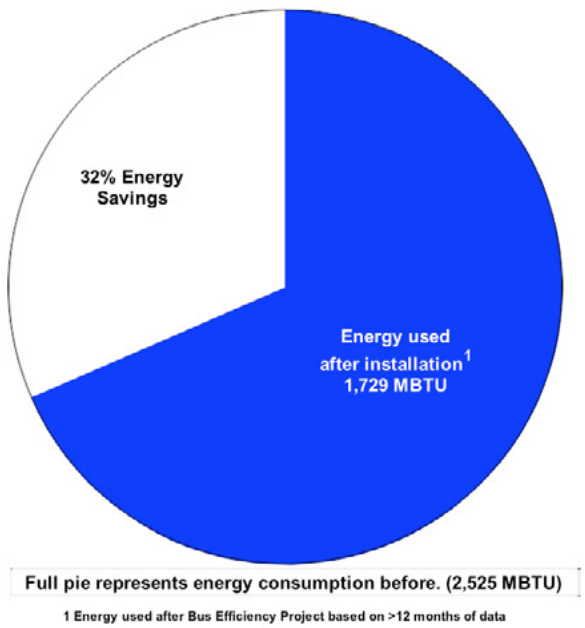


Figure 7-45

Annual Energy Use for Metro Transit Bus Project

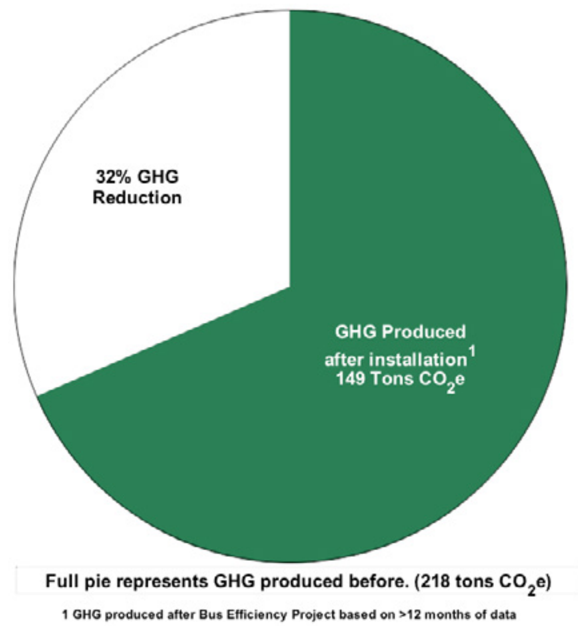


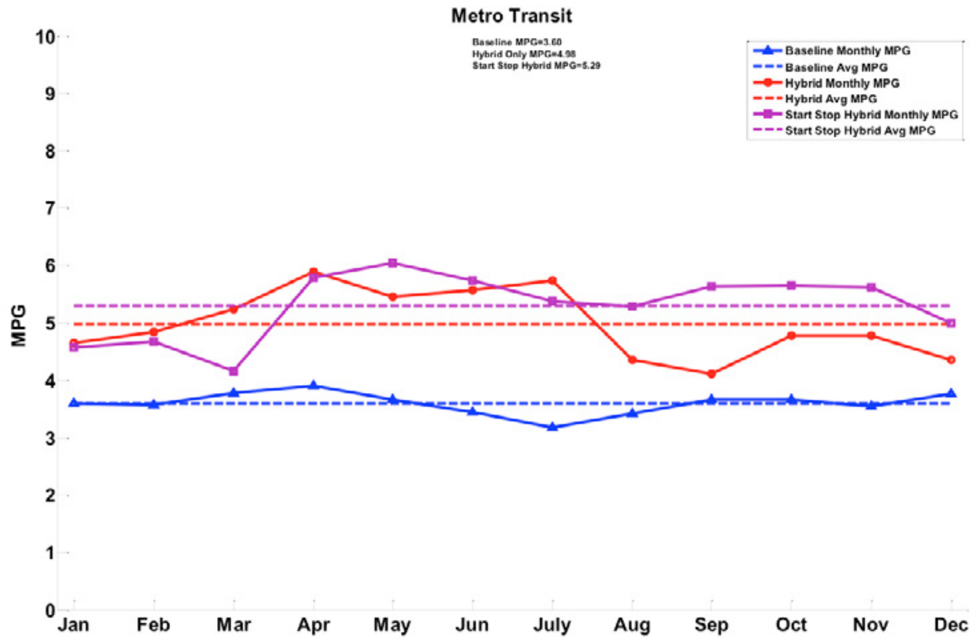
Figure 7-46

Summary of GHG Emissions for Metro Transit Bus Project

Figure 7-47 shows the fuel economy of the buses in miles per gallon. The data collected for each bus show that the new buses achieved a fuel economy that was as much as 46% higher than that of the baseline diesel buses. The data for the two types of hybrid bus are graphed separately to show the difference in fuel economy for the different hybrid systems. Based on the data provided, the hybrid with the start-stop capability has a fuel economy 6% better than the hybrid without that capability.

Figure 7-47

Monthly Average Fuel Economy for Metro Transit Bus Project



The maintenance costs for the buses are summarized in Table 7-50. The maintenance costs for the hybrid buses were significantly lower—70% less—than the costs for the diesel buses. Most of the maintenance costs for the diesel baseline buses were for unscheduled repairs. Metro Transit provided very detailed maintenance records. Costs for accident-related repairs, which would be extremely variable from bus to bus, were eliminated from the analysis. The level of detail also allowed NREL to categorize the repair by system. The propulsion-related-only maintenance costs are provided in the table. The hybrid buses had propulsion-related-only maintenance costs that were only 23% of the total unscheduled maintenance costs; the baseline diesel buses had propulsion-related-only maintenance costs that were 48% of the total unscheduled maintenance costs.

Table 7-50

Summary of Operational Costs for Metro Transit Bus Project

	Hybrid	Baseline
Total Miles	71,131	47,132
Parts Cost	$7,349.95	$19,998.35
Labor Cost	$18,306.68	$37,333.86
Total Maintenance Cost	$25,656.63	$57,332.21
Maintenance Cost per Mile	$0.36	$1.22
Scheduled Maintenance Cost	$6,208.84	$2,825.96
Scheduled Maintenance Cost per Mile	$0.09	$0.06
Unscheduled Maintenance Cost	$19,447.79	$54,506.25
Unscheduled Maintenance Cost per Mile	$0.27	$1.16
Propulsion-Related Unscheduled Maintenance Costs	$4,411.60	$26,194.55
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.06	$0.56
Fuel Economy (mpg)	5.29	3.63
Total Fuel Used (gal)	13,446.3	12,984.0
Fuel Cost (at $3.19/gal)	$42,879.92	$41,405.68
Fuel Cost per Mile	$0.60	$0.88
Total Cost per Mile	$0.96	$2.09

Using the mileage of the buses after retrofit as the baseline, the operational cost savings are summarized in Table 7-51. Metro Transit is estimated to save more than $80,000 for the first year in service.

Table 7-51

Operational Cost Differences for Metro Transit Bus Project

	Hybrid	Baseline	Difference
Total Maintenance Cost	$25,656.63	$86,525.02	$60,868.38
Total Fuel Cost	$42,879.92	$62,488.92	$19,609.00
Total Cost	$68,536.55	$149,013.94	$80,477.38

Project Name: SORTA Bond Hill Division Facility Improvements

Transit Agency: Southwest Ohio Regional Transit Authority
Location: Cincinnati, Ohio
Award Amount: $776,418
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: The Southwest Ohio Regional Transit Authority (SORTA) provides public transportation services for Cincinnati, Hamilton County, and parts of Butler, Clermont, and Warren counties in southwestern Ohio. SORTA operates 50 fixed routes as well as paratransit services.

Project Description: SORTA is making efficiency upgrades to its Bond Hill facility under the TIGGER Program. Upgrades include several improvements to increase efficiency, such as installation of new heating systems, incorporation of heat recovery, and upgrades to the lighting systems with sensor-controlled fixtures.

Project Status: This project is in progress. Due to reduced funding, lighting and sensor-controlled fixtures are not part of this project. Arctic was awarded the contract for this project in May 2013. Renovations in the front office area have been completed, and two HVAC units have been installed. All upgrades have been completed and are operational. A low gas pressure issue at both large rooftop units has been identified and is being addressed with Duke Energy Corporation. Commissioning and owner control training are expected to begin in June 2014. Once all upgrades have been completed at the facility, SORTA will begin data collection and submit the data for analysis.

Project Name: Madison Energy Efficient Lighting Project

Transit Agency: Madison Metro Transit
Location: Madison, Wisconsin
Award Amount: $150,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Results Summary:
First Year Energy Savings: 1,024 MBtu
First Year Energy Cost Savings: $29,693
Projected Lifetime Energy Savings: 10,240 MBtu

Transit Agency Profile: Madison Metro Transit provides transit services throughout Madison, Wisconsin, and to the surrounding communities of Middleton, Fitchburg, and Verona. The agency operates a fleet of vehicles on 61 fixed-route bus lines as well as paratransit services and campus shuttles.

Project Description: For its TIGGER project, Madison Metro Transit upgraded the lighting systems at its bus storage and maintenance garage facilities. The project replaced existing 250-watt high-pressure sodium lighting with efficient T8 fluorescent lighting. T8 fluorescent lighting uses high-efficiency electronic ballasts for reduced energy consumption. These lights are controlled by motion sensors and dimmers to conserve energy during off hours.

Project Status: Madison Metro Transit has completed this project, which began in September 2010 and passed final inspection in September 2011 and has provided utility data for the one year before and after comparison.

Project Summary Results: The TIGGER project results have shown an overall improvement in lighting levels with a corresponding decrease in electric power consumption. The annual energy savings are summarized in Table 7-52 and presented graphically in Figure 7-48. Madison Metro Transit reduced its energy use by 299,933 kWh, which saved an estimated $29,693 in energy costs.

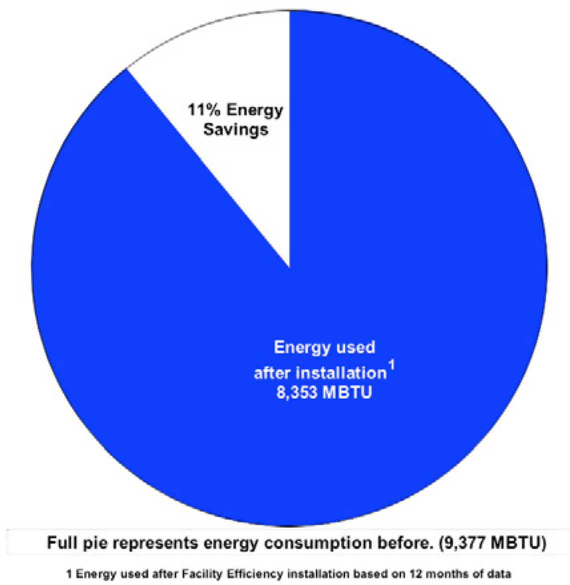
Table 7-52

Summary of Results for Madison Metro Transit Facility Project

	kWh	MBtu
Estimated Energy Savings	233,199	796
Actual Energy Use Before	2,746,593	9,377
Actual Energy Use After	2,446,660	8,353
Annual Energy Savings	299,933	1,024
Technology Lifetime (yrs)	10	10
Projected Lifetime Savings	2,999,326	10,240
Projected Lifetime Savings per TIGGER $	20.00	0.07

Figure 7-48

Annual Energy Savings for Madison Metro Transit Facility Project



Project Name: Milwaukee Hybrid Vehicle Project

Transit Agency: Milwaukee County Department of Transportation and Public Works
Location: Milwaukee, Wisconsin
Award Amount: $210,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: GHG emissions reduction

Results Summary:

First Year GHG Savings: 42 tons CO_2^e
First Year Fuel Cost Savings: $14,764
Projected Lifetime GHG Savings: 336 tons CO_2^e

Transit Agency Profile: The Milwaukee County Transit System (MCTS) provides transit services in Milwaukee County and parts of Ozaukee and Waukesha counties. The transit agency operates a fleet of 483 diesel buses and offers 58 regular fixed-route bus lines as well as door-to-door paratransit service. Approximately 90% of Milwaukee County's one million residents are served by the fixed-route buses.

Project Description: MCTS replaced seven older vans with new hybrid-electric vehicles manufactured by Ford.

Project Status: This project is complete. A purchase order was issued on February 17, 2010, and the vehicles were delivered on June 10, 2010. The transit agency has provided fleet data for fueling.

Summary of Results: MCTS replaced seven Ford Explorers with Hybrid Ford Escapes. The data for the Ford Explorers were not available, so the agency provided data for similar vehicles to use as the baseline for the analysis. The baseline vehicles do not have the same use pattern as the hybrid vehicles; however, the data are compared on a mile per gallon basis. The results summarized in Table 7-53 show an annual fuel reduction of 4,292 gallons. GHG emissions were reduced by 38%, as shown in Figure 7-49, equivalent to 42 tons of CO_2 annually. Figure 7-50 shows the monthly average fuel economy for the vehicles. The hybrids resulted in more than $14,000 in fuel cost savings.

Table 7-53

Summary of Results for MCTS Hybrid Vehicle Project

	Baseline	Hybrid	Savings	Units
Total Fuel Used	11,419	7,128	4,292	gal
Annual GHG Emissions	112	70	42	tons CO_2e
Annual Energy Use			8	years
Lifetime of Technology			338	tons CO_2e
Projected Lifetime GHG Reduction			3.2	lb CO_2e

Figure 7-49

Annual GHG Emissions for MCTS Hybrid Vehicle Project

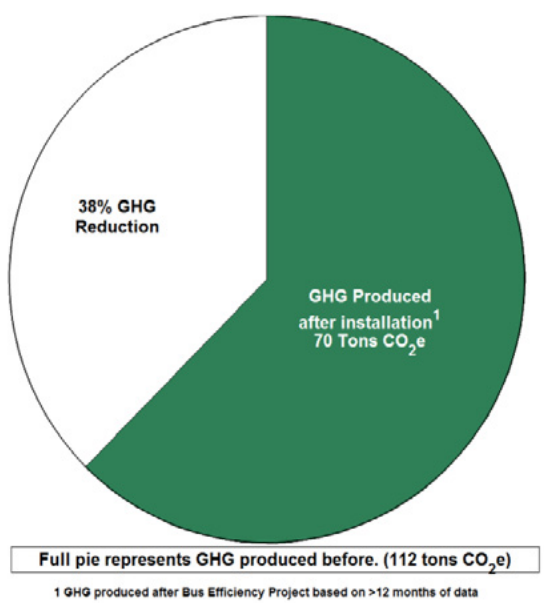
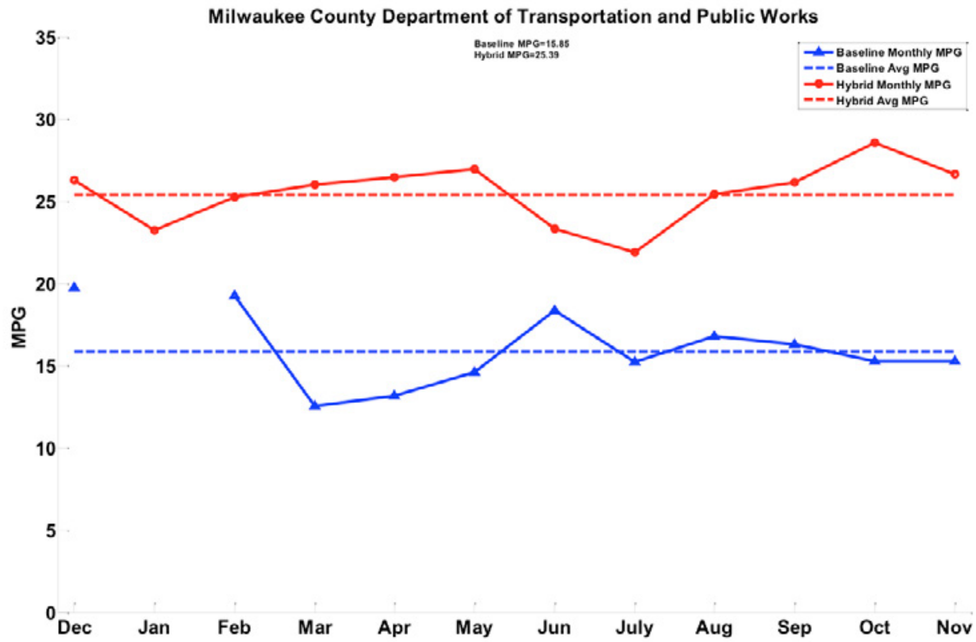


Figure 7-50

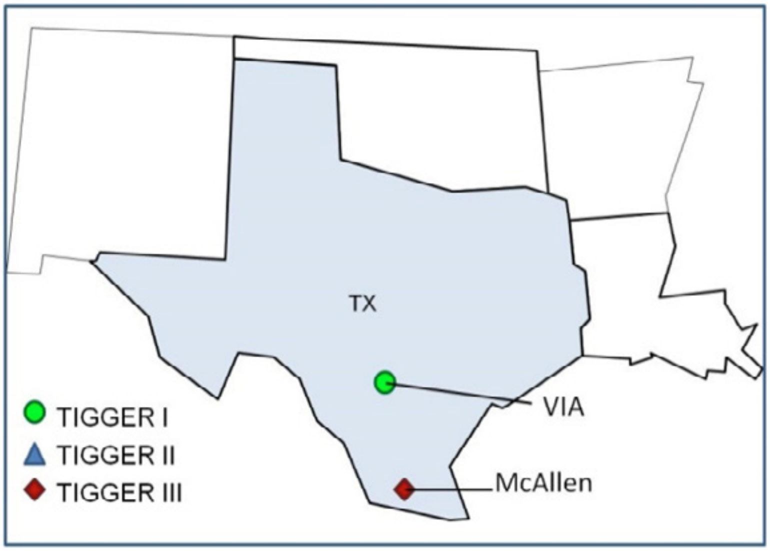
Monthly Average Fuel Economy for MCTS Hybrid Vehicle Project



Region VI

Figure 7-51

Map of FTA Region VI Project Locations



Region VI projects:

1. VIA Metropolitan Transit, fast-charge electric bus project
2. City of McAllen, on-line electric vehicle project

Project Name: VIA Fast-Charge Electric Bus Project

Transit Agency: VIA Metropolitan Transit of San Antonio, Texas
Location: San Antonio, Texas
Award Amount: $5,000,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: VIA Metropolitan Transit covers a service area comprising 1,213 square miles in Bexar County, Texas, and includes San Antonio. VIA's fixed-route services are accomplished with a fleet of 446 buses. These buses are predominantly 40-foot coaches operating with a range of propulsion technologies and fuels, including diesel-electric hybrid, conventional diesel, propane, and CNG.

Project Description: VIA replaced three older diesel buses with battery-electric buses from Proterra. The buses use a quick-charge station that can fully charge the batteries in less than 10 minutes (see Figure 7 52). VIA contracted with its local energy provider, CPS Energy, to receive 100% of the electricity used by the buses through its Windtricity program. Windtricity uses wind-powered turbines to generate grid electricity. VIA also installed solar PV panels at the bus charging station for supplemental power.

Project Status: This project is in progress. The buses have been delivered and were placed into service in early 2013. The buses are being used in a downtown circulator service. As of the end of 2013, the buses accumulated in excess of 11,000 on-road miles. VIA has contracted CTE to support the project, including collecting data to be submitted for analysis; the results will be included in the next assessment report.

Figure 7-52

VIA Quick-Charge Battery Bus

Project Name: On-Line Electric Vehicle Project

Transit Agency: City of McAllen
Location: McAllen, Texas
Award Amount: $1,906,908
Award Year: 2011
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: The City of McAllen Transit Department provides public transportation services within the McAllen city limits. The City operates seven intracity bus routes as well as complimentary paratransit services.

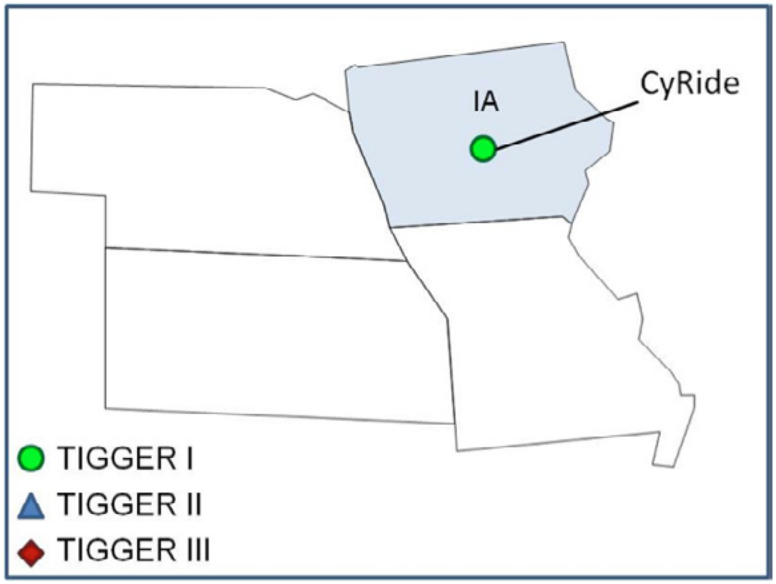
Project Description: For its TIGGER project, the City of McAllen will implement inductively charged electric bus technology on part of its fixed-route fleet. Three of McAllen's older diesel buses will be retrofitted as electric buses capable of charging through an electric roadway. This electric roadway will be installed on one of the City of McAllen's current bus routes.

Project Status: Awarded in TIGGER III, this project has not started. After the project was awarded, the manufacturer for the inductive charging technology pulled out of the project, resulting in a schedule delay. The City of McAllen issued an RFP in July 2013 for the work and awarded the contract to WAVE, Inc., in November 2013. Contract negotiations are underway and, once finalized, the project will begin.

Region VII

Figure 7-53

Map of FTA Region VII Project Locations



Region VII project:

1. Ames Transit Agency (CyRide), hybrid bus project

Project Name: Ames Transit Agency Hybrid Buses

Transit Agency: Ames Transit Agency
Location: Ames. Iowa
Award Amount: $1,600,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary:
First Year Energy/GHG Savings: 1,147 MBtu / 99 tons CO_2^e
First Year Fuel Cost Savings: $29,202
Projected Lifetime Energy/GHG Savings: 20,646 MBtu / 1,782 tons CO_2^e

Transit Agency Profile: Ames Transit Agency, or CyRide, is the public transit agency for the 59,000 residents of Ames, Iowa, and serves the greater Ames community and Iowa State University with its fleet of 70 large buses and 8 small buses. The transit agency operates 12 fixed routes 18 hours per day, seven days per week and offers extended service (until 3:00 AM) on Friday and Saturday nights as well as dial-a-ride service for older adults and people with disabilities.

Project Description: At the time of the original call for proposals for TIGGER, CyRide was in the process of replacing older buses and expanding its fleet and already had an order for new buses. CyRide used funding from several sources to purchase 12 hybrid buses. The TIGGER funding covered the incremental cost for making 10 of the buses hybrids. CyRide purchased 40-foot Gillig buses with a Voith hybrid system. Table 7 54 provides vehicle specifications for the baseline and hybrid buses.

Table 7-54

Vehicle Specifications for CyRide Buses

	Baseline 1	Baseline 2	Baseline 3	New Technology
Number of Vehicles	2	1	3	10
Model Year	1993	1988	2010	2010
Manufacturer	Gillig	Orion	Gillig	Gillig Hybrid
Model	35/96	1.508	Low-Floor	Low Floor
Length (ft)	35	40	40	40
Weight (lb)	29,500	29,500	25,000	29,500
Engine OEM	Cummins	Cummins	Cummins	Cummins
Engine: rated rower (hp)	280	280	280	280
Hybrid System Manufacturer				Voith DIWA
Hybrid Model				Preproduction Model
Hybrid Configuration				Parallel
Energy Storage Type				High Voltage Capacitor
Energy Storage Manufacturer				Maxwell

Project Status: This project is complete. CyRide purchased diesel hybrid buses and they have been in service since August 2010.

Summary of Results: CyRide purchased 10 hybrid buses with TIGGER funding. This bus order also included three new standard diesel buses to replace three older diesel buses that had reached the end of their useful lives. Without TIGGER funds, the agency would have purchased only standard diesel buses. To determine energy and GHG emissions savings, results from the new hybrids are being compared to performance results of the older diesel buses and new diesel buses. CyRide provided one year of data on the three diesel buses that were replaced and one year of records on the hybrid and new diesel baseline buses. These data were used to determine the average fuel economy and cost per mile for each group of buses. The averages were used to calculate the before and after energy use and GHG emissions as follows:

Before = old diesel bus average × 3 buses + new diesel bus average × 7 buses

New = hybrid bus average × 10 buses

CyRide used the older buses less during the data year because of their lower reliability. To normalize the results, NREL used the mileage for the new hybrid buses as the multiplier for all three groups. Table 7-55 provides a summary of annual savings and projects the lifetime savings based on the expected useful life for the agency. CyRide reports that buses are typically used for 18 years.

Table 7-55

Summary of Energy and GHG Savings for CyRide Hybrid Bus Project

	Baseline	Hybrid	Savings	Unit
Total Fuel Used	75,027	65,637	9,390	gal
Annual GHG Emissions	790	691	99	tons CO_2e
Annual Energy Use	9,157	8,010	1,147	MBtu
Lifetime of Technology			18	years
Projected Lifetime GHG Savings			1,782	tons CO_2e
Projected Lifetime Energy Savings			20,646	MBtu
Lifetime GHG Savings per TIGGER $			2.2	lb CO_2e
Lifetime Energy Savings per TIGGER $			12,904	Btu

The annual energy savings for the CyRide TIGGER project is shown in Figure 7-54 and the GHG emissions savings is shown in Figure 7-55. CyRide's hybrid buses are using 13% less energy and have GHG emissions 13% lower than do the baseline buses.

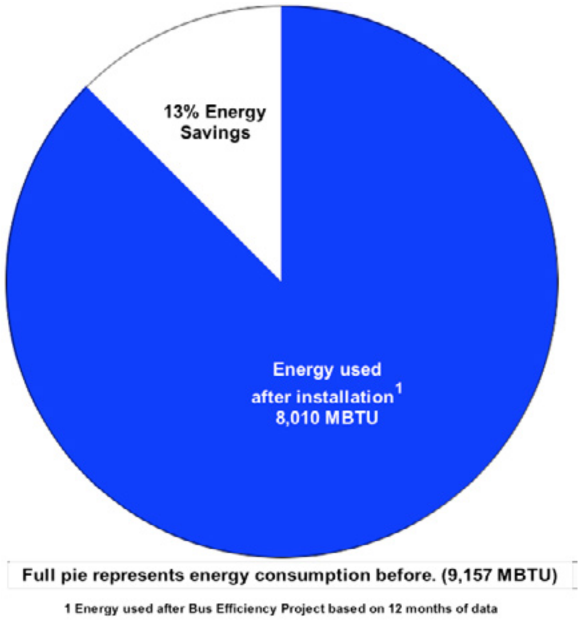


Figure 7-54

Annual Energy Savings for CyRide Hybrid Bus Project

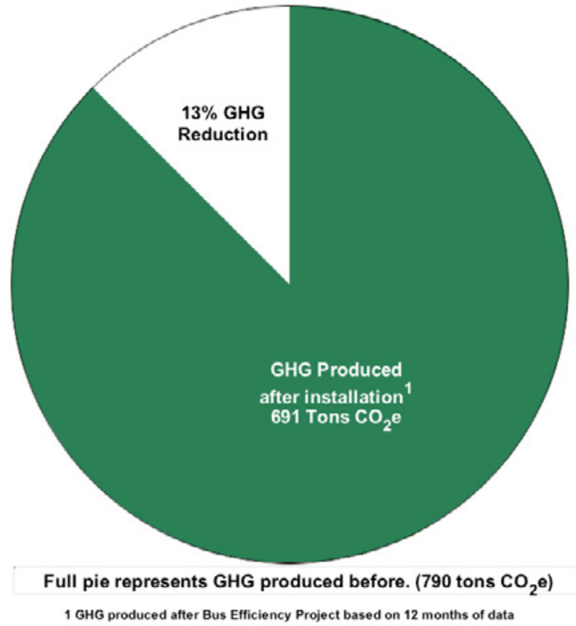


Figure 7-55

Annual GHG Savings for CyRide Hybrid Bus Project

Figure 7-56 provides the monthly average fuel economy for the hybrid and diesel baseline buses. The average fuel economy of the hybrid buses is 4.69 mpg, which is 9.8% higher than that of the new diesel buses and 24.7% higher than that of the older diesel buses.

Figure 7-56

Monthly Fuel Economy for CyRide Hybrid and Baseline Buses

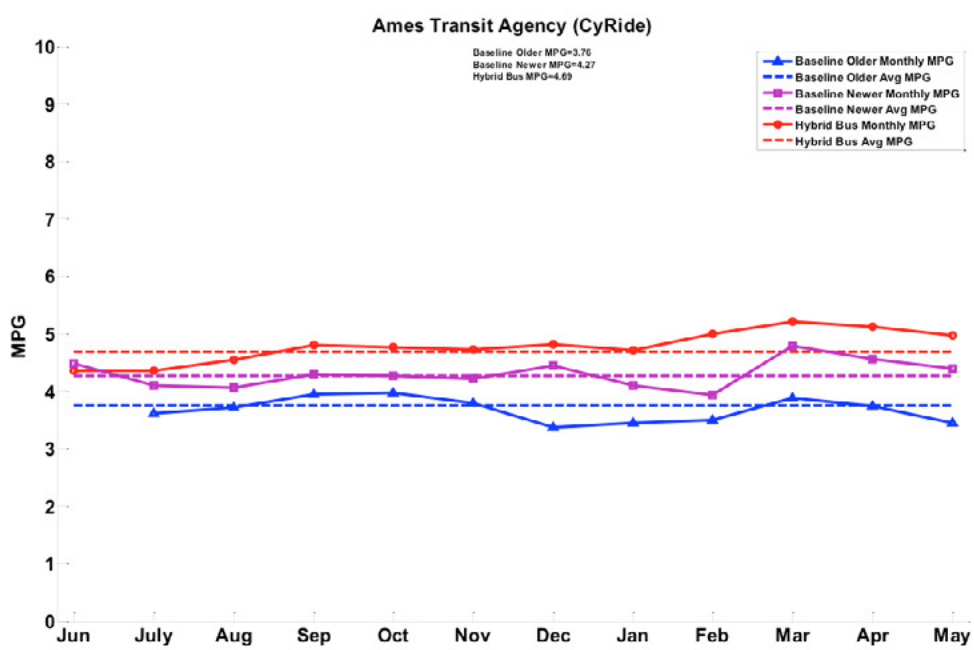


Table 7-56 summarizes the costs for the hybrid and diesel buses. The maintenance costs for the new hybrid and diesel buses were essentially the same, at $0.20 per mile. The older diesel buses cost 3.6 times more than the new buses to maintain. Because CyRide provided very detailed maintenance records, NREL was able to eliminate any costs for accident-related repair, which would be extremely variable from bus to bus. The level of detail also allowed NREL to categorize the repair by system. The propulsion-related-only maintenance is provided in the table.

Table 7-56 *Summary of Operational Costs for CyRide Hybrid and Baseline Buses*

	Hybrids	New Diesel Baseline	Old Diesel Baseline
Total Miles	307,837	159,167	26,579
Parts Cost	$10,163.89	$3,844.81	$3,157.26
Labor Cost	$50,372.89	$27,287.50	$15,403.10
Total Maintenance Cost	$60,536.78	$31,132.31	$18,560.36
Maintenance Cost per Mile	$0.20	$0.20	$0.70
Scheduled Maintenance Cost	$32,664.58	$16,594.39	$4,765.01
Scheduled Maintenance Cost per Mile	$0.11	$0.10	$0.18
Unscheduled Maintenance Cost	$27,872.20	$14,537.92	$13,795.34
Unscheduled Maintenance Cost per Mile	$0.09	$0.09	$0.52
Propulsion-Related Unscheduled Maintenance Costs	$8,574.98	$4,308.19	$1,927.61
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.03	$0.03	$0.07
Fuel Economy (mpg)	4.69	4.27	3.76
Total Fuel Used (gal)	65,636.9	37,275.6	7,068.9
Fuel Cost (at $3.11/gal)	$204,130.72	$115,927.25	$21,984.23
Fuel Cost per Mile	$0.66	$0.73	$0.83
Total Cost per Mile	$0.86	$0.92	$1.53

Using the hybrid bus mileage as the baseline, the operational cost savings are summarized in Table 7-57. The hybrid buses are estimated to save CyRide more than $75,000 each year in service.

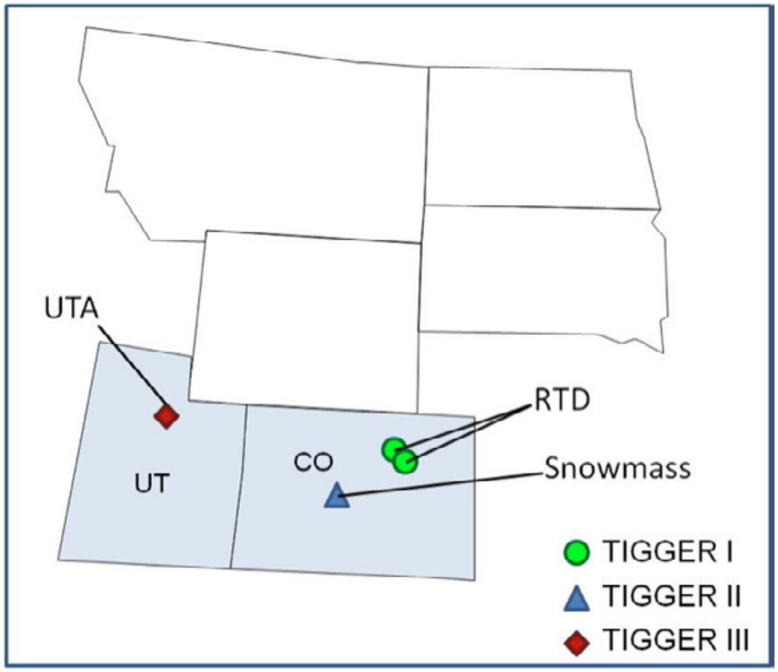
Table 7-57 *Operational Cost Differences for CyRide Hybrid Bus Project*

	Hybrid Total	Baseline Total	Savings
Annual Maintenance Cost	$60,536.78	$106,637.63	$46,100.85
Annual Fuel Cost	$204,130.72	$233,332.55	$29,201.84
Annual Total Cost	$264,667.50	$339,970.18	$75,302.68

Region VIII

Figure 7-57

Map of FTA Region VIII Project Locations



Region VIII projects:

1. Denver Regional Transportation District (RTD), efficient boiler at East Metro
2. Denver Regional Transportation District (RTD), efficient boiler at Boulder
3. Snowmass Village, Daly Lane facility efficiency improvement
4. Utah Transit Authority (UTA), University of Utah campus shuttle electrification

Project Name: Denver RTD Efficient Boiler at East Metro

Transit Agency: Denver Regional Transportation District
Location: Aurora, Colorado
Award Amount: $770,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Transit Agency Profile: Denver Regional Transportation District (RTD) is a regional transit authority that has been providing transit services to 8 counties throughout the Denver–Aurora–Boulder region of central Colorado for more than 40 years. Denver RTD currently operates 165 fixed routes, with 1,039 fixed-route buses and 117 light rail vehicles.

Project Description: Denver RTD is improving energy efficiency by refurbishing the existing boiler components at its East Metro maintenance facility in Aurora, Colorado. The upgrade includes replacing these components and related pipes and valves with newer, energy-efficient versions. Additionally, RTD will install an integrated climate control system that can be programmed to turn on based on the outside air temperature.

Project Status: This project is near completion. RTD has experienced numerous delays on this project, primarily administrative- and design-related. RTD will install the remaining valves and the de-aerator tank in May 2014 so the boilers can be in place before the 2014 heating season.

Project Name: Denver RTD Efficient Boiler at Boulder

Transit Agency: Denver Regional Transportation District
Location: Boulder, Colorado
Award Amount: $325,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Transit Agency Profile: Denver Regional Transportation District (RTD) is a regional transit authority that has been providing transit services to 8 counties throughout the Denver–Aurora–Boulder region of central Colorado for more than 40 years. Denver RTD currently operates 165 fixed routes, with 1,039 fixed-route buses and 117 light rail vehicles.

Project Description: RTD is replacing the two existing boilers at its Boulder maintenance facility with four high-efficiency hot water boilers that also include clean-burning technology to reduce nitrogen oxide emission levels compared to the current level. These new boilers also use an advanced, integrated control system for improved climate control—the boilers can be set to turn on and off based on the outside air temperature.

Project Status: This project is in process, and the materials have been ordered. RTD has experienced some delays due to administrative processes. Materials and parts will be delivered in May 2014. Construction will begin during the warm months, and RTD is working toward putting the boilers in place before the 2014 heating season.

Project Name: Colorado Daly Lane Facility Efficiency Improvement

Transit Agency:	Snowmass Village
Location:	Snowmass, Colorado
Award Amount:	$73,936
Award Year:	2010
TIGGER Goal:	Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: 4,571 MBtu / 280 tons CO_2^e
First Year Energy and Fuel Cost Savings: $47,723
Projected Lifetime Energy/GHG Savings: 91,418 MBtu / 5,603 tons CO_2^e

Transit Agency Profile: The town of Snowmass Village is located on the Western Slope of Colorado at an elevation of around 8,000 feet. It provides free shuttle service around the village with eight fixed winter routes. Designed to get people out of their cars, these routes transfer passengers between parking lots and lodging areas to the ski slopes, shopping, and employers.

Project Description: Snowmass Village upgraded its Daly Lane Bus Facility with technologies to lower energy use and decrease emissions. Because of cold winter conditions, diesel buses must be stored indoors. Multiple open/close cycles of the garage doors make heating a challenge. Facility upgrades included installing fast-close garage doors and replacing existing lighting fixtures with LED lamps.

Project Status: This project was completed in November 2011. The garage door overlays and 28 LED lamps were purchased and installed.

Summary of Results: Snowmass Village used TIGGER funding to install two fast-close garage door overlays with weather sealing over the existing garage doors and replace 28 metal halide light fixtures inside the facility with LED lamps. Both the garage door overlays and the maintenance bay lighting employ sensor technology. This enables the agency to set the timing for the doors and ensure that they close after use and prevent accidents. The lights in the maintenance area use motion sensors and come on when movement is detected.

Table 7-58 summarizes the energy use at the facility before and after implementation of the TIGGER project. Data were collected for one year of facility operation before the installation of the upgrades and for one year after installation. The upgrades resulted in a 60,519-kWh decrease in electricity use and 43,643 fewer therms of natural gas used annually, which is equal to the average annual energy use of 119 homes. These upgrades have resulted in a 41% decrease in energy use at the facility, as shown in Figure 7-58. The Daly Lane Facility has expanded its energy efficiency efforts because of this project by replacing additional lights with LED lamps. The facility not only saves money but also has better lighting conditions and requires less maintenance for the fixtures.

Table 7-58

Summary of Energy Use for Snowmass Village Facility Project

	kWh	NG therms	MBtu
Estimated Energy Savings			1,616
Actual Energy Use Before	265,524	102,880	11,194
Actual Energy Use After	212,201	59,237	6,648
Annual Energy Savings	53,323	43,643	4,546
Technology Lifetime (years)	20	20	20
Projected Lifetime Savings	1,066,464	872,857	90,927
Projected Lifetime Savings per TIGGER $	14.42	11.81	1.23

Figure 7-58

Annual Energy Savings for Snowmass Village Facility Project

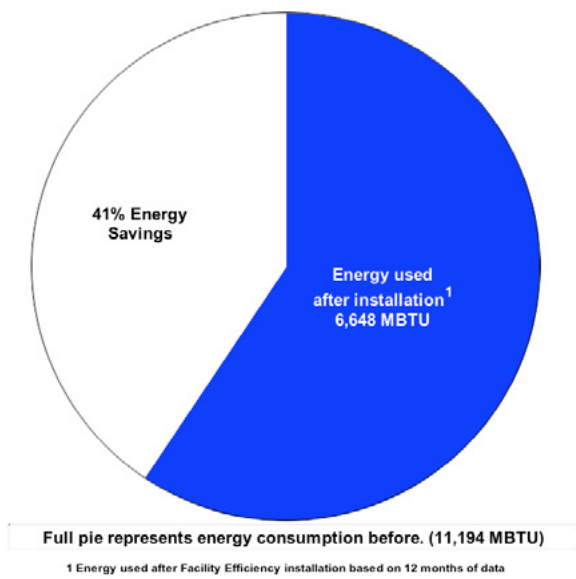


Table 7-59 summarizes the GHG emission results for the project. The fast roll-up doors prevented heat loss, reducing the need for natural gas to heat the facility. This lower natural gas use added up to a 42% reduction in GHG emissions, as shown in Figure 7-59. This project has proved to be very beneficial for Snowmass Village. With the lower electricity and natural gas use, as well as lower maintenance costs, the project is estimated to save as much as $47,700 each year. Figure 7-60 shows the fast-roll-up doors installed at the Snowmass Village facility.

Table 7-59

Summary of GHG Emissions for Snowmass Village Facility Project

Snowmass Village	Tons CO_2e
Estimated GHG Reduction	83.0
Actual GHG Emissions Before	660
Actual GHG Emissions After	380
Annual GHG Reduction	280
Technology Lifetime (yrs)	20
Projected Lifetime GHG Reduction	5,603
Projected Lifetime GHG Reduction per TIGGER $	0.08

Figure 7-59

Annual GHG Emissions for Snowmass Village Facility Project

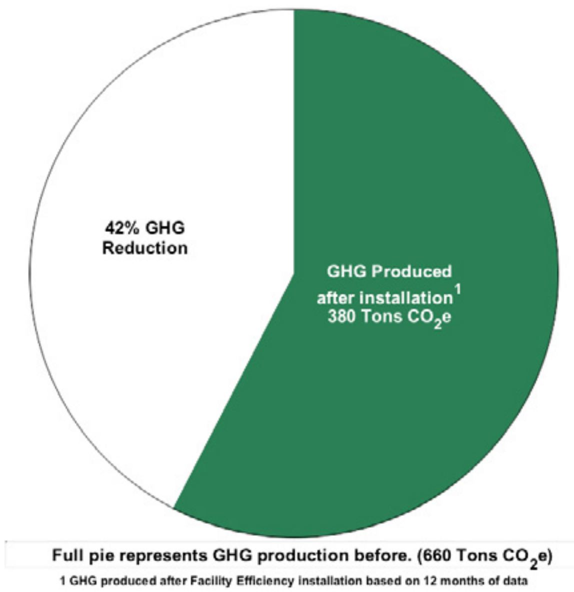


Figure 7-60

Fast-Roll-Up Doors Installed at Snowmass Village Facility

Project Name: University of Utah Campus Shuttle Electrification

Transit Agency: Utah Transit Authority
Location: Salt Lake City, Utah
Award Amount: $2,692,000
Award Year: 2011
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: The University of Utah operates a free shuttle system that serves the campus and the adjacent research park. The University is collaborating with the Utah Transit Authority (UTA), the multimodal transportation company that serves the greater Salt Lake City area. UTA provides fixed-route service, commuter bus service, bus rapid transit, light rail, commuter rail, paratransit, and transportation demand-response service to the district, a six-county area along the Wasatch Mountains.

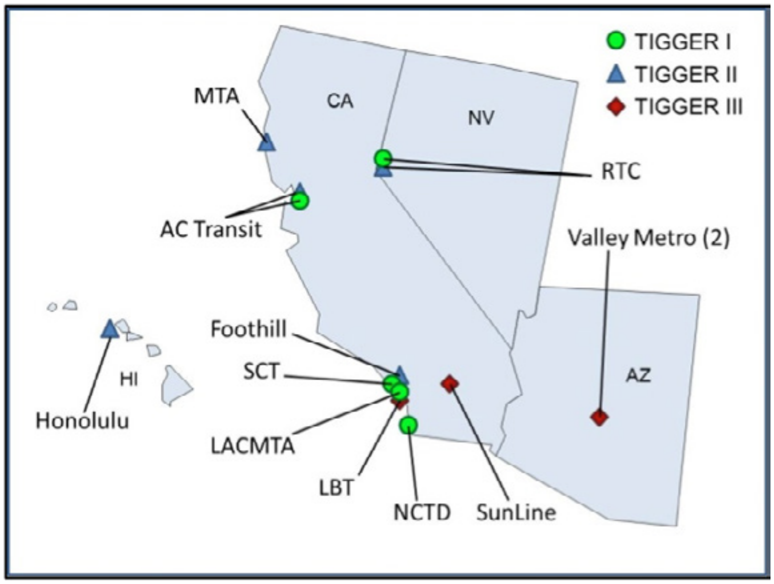
Project Description: For this project, a public-private partnership between UTA, Wireless Advanced Vehicle Electrification (WAVE), the University of Utah, and Utah State's Energy Dynamics Laboratory will implement an electric trolley bus powered by wireless power transfer technology. In this approach, electrical infrastructure embedded in roadways and receiver coils mounted on the bus work together to transfer power to the bus only as needed. Demonstrating this new approach to powering electric buses will allow the team to evaluate the feasibility of the technology for future implementation at the University of Utah and in the UTA service area.

Project Status: This project is in progress. A contract with UTA, the University of Utah, and WAVE was completed in June 2012. The bus has been delivered, and the charging pads have been installed. The bus has demonstrated inductive charging capability and upon further testing performed by UTA, technical issues were identified. The project vehicle was sent back to the manufacturer to complete minor modifications and has been returned to the university. Testing continues and the agency anticipates full service operation in the summer of 2014.

Region IX

Figure 7-61

Map of FTA Region IX Project Locations



Region IX projects:

1. AC Transit, photovoltaic installation
2. AC Transit, fuel cell power system
3. Santa Clarita Transit (SCT), solar canopy
4. Los Angeles County Metropolitan Transportation Authority (LACMTA), Red Line Westlake rail WESS—see case study in Section 8
5. North County Transit District (NCTD), PV installation
6. Mendocino Transit Authority (MTA), solar canopy project
7. Foothill Transit, fast-charge electric bus project—see case study in Section 8
8. SunLine, American fuel cell buses
9. Long Beach Transit (LBT), zero-emission bus project
10. Regional Transportation Commission of Washoe County (RTC), hybrid bus project
11. Regional Transportation Commission of Washoe County (RTC), electric bus circulator
12. Valley Metro, electric fan retrofit
13. Valley Metro, solar shade canopy
14. City and County of Honolulu Department of Transportation Services, hybrid bus project

Project Name: AC Transit Photovoltaic Installation

Transit Agency:	Alameda-Contra Costa Transit District
Location:	Oakland, California
Award Amount:	$6,400,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Both energy and GHG emissions reduction

Results Summary (preliminary):

First Year Energy/GHG Savings: 1,910 MBtu / 593 tons CO_2^e
First Year Energy Cost Savings: $53,000
Projected Lifetime Energy/GHG Savings: 36,264 MBtu / 7,115 tons CO_2^e

Transit Agency Profile: The Alameda-Contra Costa Transit District (AC Transit) serves 13 cities in the San Francisco Bay Area, carrying more than 61 million people annually with nearly 600 buses. Since 1999, AC Transit has been building the most comprehensive zero-emission fuel cell program in North America, complete with zero-emission vehicles, on-site fuel production and dispensing, public outreach and education, and on-site maintenance. AC Transit currently leads the Zero Emission Bay Area, a coalition of regional transit agencies operating fuel cell buses in real-world service.

Project Description: AC Transit installed a 500-kW PV system on the roof of its Central Maintenance Facility (CMF) in Oakland. The electricity generated will be used to renewably generate hydrogen for fueling fuel cell-powered buses. Because the cost of solar equipment dropped significantly during this first phase of this project, AC Transit realized a $2 million savings. This savings enabled the transit agency to purchase an additional 200-kW PV system for one of its other operating divisions. Table 7-60 lists the AC Transit PV system specifications.

Table 7-60

AC Transit CMF PV System Specifications

Solar System Specifications	
PV Manufacturer	Solyndra
PV Panel Nameplate Power (W)	191
PV Area per Panel (square feet)	21
Number of PV Panels Installed	2,672
Total PV Area (square feet)	56,593
Panel Estimated Lifetime (years)	30

Project Status: The PV installation at the agency's CMF was completed, and the system began producing power on August 1, 2011. AC Transit is in the construction stage for the second PV installation, which is expected to be at its Hayward Division. The agency has selected a firm for the architecture and engineering of the installation from six proposers. The contract was awarded in October 2013, with an expected completion date of April 2014.

Summary of Results: The first phase of this project attained annual energy savings of 536,957 kWh, a 63% energy reduction. This is the equivalent of powering

48 homes for an entire year and is estimated to have saved the agency more than $53,000 in electricity costs during the first year. The summary of energy savings is shown in Table 7-61, representing energy data for one year before and one year after operation of the solar installation. Figure 7-62 graphically presents the energy savings achieved to date on the first phase of the solar installation. This total will increase once the second phase is complete.

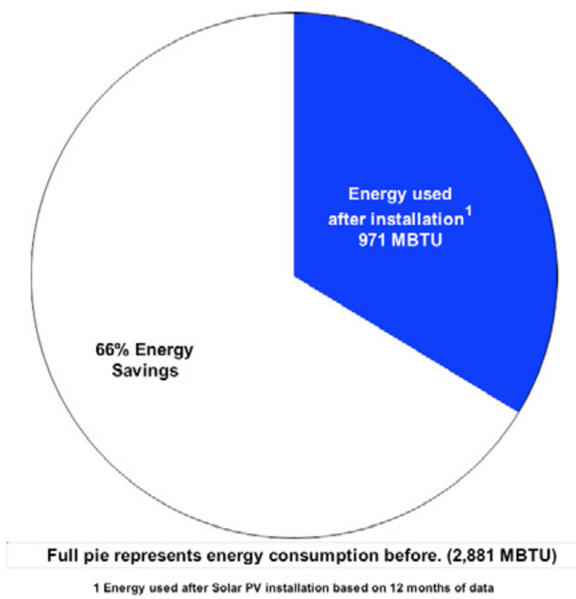
Table 7-61

Summary of Energy Savings for AC Transit Solar Project

	kWh	MBtu
Estimated Energy Savings	951,377	3,248
Actual Energy Use Before	843,981	2,881
Actual Energy Use After	284,546	971
Annual Energy Savings	559,436	1,910
Technology Lifetime (yrs)	30	30
Projected Lifetime Savings	15,545,531	53,072
Projected Lifetime Savings per TIGGER $	2.43	0.01

Figure 7-62

Energy Savings for the AC Transit Solar Project



AC transit completed the second phase of this project in April 2014 and currently is collecting the requested data for NREL's analysis.

AC Transit's solar project provides power to offset hydrogen production for its fleet of 12 fuel cell electric buses (FCEBs). Thus, the agency can claim the GHG savings for diesel fuel displaced by operating the FCEBs in place of standard diesel buses. Table 7-62 provides the summary calculations for this savings based on the most recent data collected on the FCEBs. The FCEBs are estimated to displace more than 53,000 gallons of diesel fuel during a year of service. This calculates to annual GHG reductions of 593 tons CO_2^e. The estimated lifetime GHG reductions are based on a 12-year life expectancy for the buses, not the expected life of the solar project. Should AC Transit continue operating these FCEBs (or other zero-emission buses) for a longer period, the potential GHG savings would increase.

Table 7-62

Summary of GHG Savings for AC Transit Solar Project

	FCEB
Miles Accumulated (Mar–Oct 2013)	259,171
Average Miles per Month	32,396
Estimated Annual Miles	388,757
Average Miles per Diesel Gallon Equivalent	7.26
Estimated Annual Diesel Gallons Displaced	53,548
Estimated Annual GHG Savings (tons CO_2^e)	593
Technology Lifetime (yrs)	12
Projected Lifetime Savings	7,115

Project Name: AC Transit Fuel Cell Power System

Transit Agency: Alameda-Contra Costa Transit District
Location: Oakland, California
Award Amount: $6,000,000
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: The Alameda-Contra Costa Transit District (AC Transit) serves 13 cities in the San Francisco Bay Area, carrying more than 61 million people annually with nearly 600 buses. Since 1999, AC Transit has been building the most comprehensive zero-emission fuel cell program in North America, complete with zero-emission vehicles, on-site fuel production and dispensing, public outreach and education, and on-site maintenance. AC Transit currently leads the Zero Emission Bay Area, a coalition of regional transit agencies operating fuel cell buses in real-world service.

Project Description: AC Transit's project involves three major components: 1) installation of a 400-kW solid oxide fuel cell (SOFC) power generating system at its Seminary Operating Division to allow its largest division to operate independent of electricity grid power; 2) installation of a 65-kg/day proton exchange membrane (PEM) electrolyzer at the new hydrogen fueling station, which is replacing an existing station; and 3) contracting for the required amount of biomethane renewable offset credits to operate the SOFC system.

Project Status: The SOFC installation was completed in March 2013 and connected to the local electricity grid. The remaining TIGGER funds will be used to install a PEM electrolyzer at the hydrogen fueling station. AC Transit released an RFP in April 2014 for this work, with an estimated award date of June 2014. Once the electrolyzer is installed and operational, AC Transit will compile the requested data for NREL's analysis.

Project Name: Santa Clarita Transit Solar Canopy

Transit Agency: Santa Clarita Transit
Location: Santa Clarita, California
Award Amount: $4,617,598
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Summary of Results:
First Year Energy Savings: 3,837 MBtu
First Year Energy Cost Savings: $111.267
Projected Lifetime Energy Savings: 82,575 MBtu

Transit Agency Profile: Santa Clarita Transit (SCT) serves Santa Clarita, California, and surrounding communities with a fleet that includes more than 100 transit buses ranging in length from 23 to 60 feet. The agency has eight local fixed routes, eight express routes, and two station link routes.

Project Description: Santa Clarita Transit installed a 49,000-square-foot PV system on the roof of its Transit Maintenance Facility. Table 7-63 provides selected specifications for the solar system installation. More than 3,200 PV panels cover the facility's bus wash and four bus ports. The system provides about 97% of the facility's energy needs. Real-time data on the system can be found online at http://www.santaclaritatransit.com/resources/solar-energy/.

Table 7-63

SCT Solar System Specifications

Solar System Specifications	
PV Manufacturer	Sharp
PV Panel Nameplate Power (W)	240
PV Area per Panel (square feet)	18
Number of PV Panels Installed	1,842
Total PV Area (square feet)	49,851
Panel Estimated Lifetime (years)	25
Panel Efficiency Rating (%)	15
Inverter Efficiency Rating (%)	97
Warranty (years)	5

Project Status: This project was completed in July 2011. The agency has submitted data for analysis, and the results are included in this report.

Summary of Results: Santa Clarita Transit submitted data for one year before the project was implemented and one year after the solar panels were operational. The installation saved the agency 1,123,913 kWh during the first year of operation, as shown in Table 7-64, reducing energy consumption by 95% (Figure 7-63). This provides a significant cost savings to the agency over the lifetime of the system, an estimated 21,339,809 kWh.

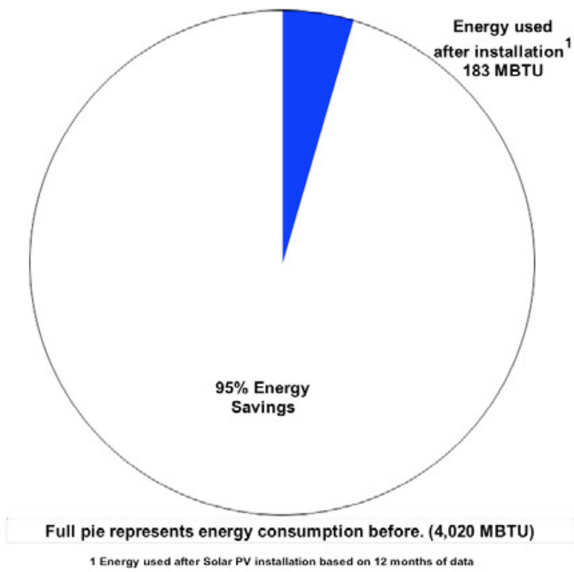
Table 7-64

Summary of Energy Savings for Santa Clarita Transit Solar Project

	kWh	MBtu
Estimated Energy Savings	967,487	3,303
Actual Energy Use Before	1,177,431	4,020
Actual Energy Use After	53,518	183
Annual Energy Savings	1,123,913	3,837
Technology Lifetime (yrs)	25	25
Projected Lifetime Savings	26,347,455	89,950
Projected Lifetime Savings per TIGGER $	5.70	0.02

Figure 7-63

Annual Energy Use for Santa Clarita Transit Solar Project



Project Name: NCTD PV Installation

Transit Agency:	North County Transit District
Location:	Oceanside, California
Award Amount:	$1,999,694
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Energy reduction

Estimated Energy Savings per Year: 1,957 MBtu

Estimated Lifetime Energy Savings: 32,656 MBtu

Transit Agency Profile: The North County Transit District (NCTD) is the multimodal transit agency that provides transit services to North San Diego County. The four modes of service include bus (BREEZE), light rail (SPRINTER), commuter rail (COASTER), and paratransit (LIFT). NCTD's service area covers approximately 1,000 square miles just north of San Diego and serves 12 million passengers annually.

Project Description: NCTD's TIGGER project focuses on installing solar panels for generating power and is part of its overall sustainability plan. Table 7-65 lists the NCTD PV system specifications. The project includes four installations:

1. SPRINTER Maintenance Facility–220-kW PV panel system mounted on the roof and ground (Figure 7-64)
2. BREEZE Maintenance Facility–180-kW PV panel system mounted on the building roof
3. Rail right-of-way solar installation–20-kW PV laminate system mounted directly in the rail right-of-way (Figure 7-65)
4. Transit Center carport parking canopy–75-kW PV panel system covering the parking area that includes charging ports for electric vehicles (Figure 7-66).

Table 7-65

NCTD Solar System Specifications

Solar System Specifications	Rail Right of Way	SPRINTER	Carport	BREEZE
PV Manufacturer	Uni-Solar	SolarWorld	Suniva	SolarWorld
PV Panel Nameplate Power (W)	136	240	255	245
PV Area per Panel (sq ft)	23	18	17	16
Number of PV Panels Installed	165	1,204	300	826
Total PV Area (sq ft)	3,836	21,732	5,241	12,976
Panel Estimated Lifetime (yrs)	25	25	25	25

Project Status: This project is complete. The first three installations were all completed in 2011, and the fourth system was completed in January 2012.

Figure 7-64

NCTD SPRINTER Facility Solar Installation

Figure 7-65

NCTD Solar Installation along Rail Right-of-Way

Figure 7-66

NCTD Solar Installation at Transit Center includes Electric Vehicle Chargers

Summary of Results: NCTD installed PV systems at four of its facilities. The data are summarized in Table 7-66. During the first year of operation the installations produced more than 773,000 kWh of energy, saving an estimated 13.4 million kWh over the lifetime of the systems. Figure 7-67 shows that all four systems provided a 29% reduction in energy consumption during the first year of operation, reducing the electricity cost by an average of $56,747.[22] Three solar panel manufacturers were used for these installations and each site used a different power rating for the panels.

Table 7-66

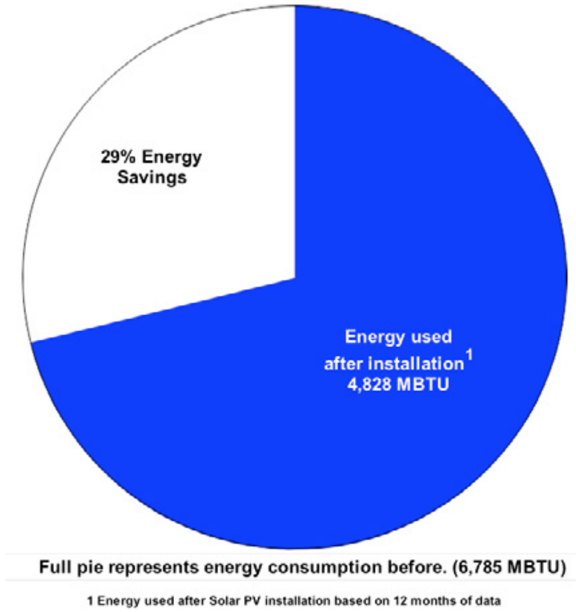
Summary of Energy Savings Results for NCTD Solar Project

	kWh	MBtu
Estimated Energy Savings	697,802	2,382
Actual Energy Use Before	1,987,423	6,785
Actual Energy Use After	1,414,222	4,828
Annual Energy Savings	573,202	1,957
Technology Lifetime (yrs)	25	25
Projected Lifetime Savings	13,437,340	45,875
Projected Lifetime Savings per TIGGER $	6.72	0.02

[22] Based on average U.S. electricity costs in 2011 of $0.099/kWh (EIA).

Figure 7-67

Annual Energy Use for NCTD Solar Project



Project Name: Mendocino Solar Canopy Project

Transit Agency: Mendocino Transit Authority
Location: Ukiah, California
Award Amount: $470,000
Award Year: 2010
TIGGER Goal: Energy reduction

Transit Agency Profile: The Mendocino Transit Authority (MTA) has provided public transit services for Mendocino County in California since 1976. MTA's service area encompasses about 2,800 square miles and provides a diverse system of long-distance, commuter, and local fixed routes, plus two dial-a-rides and two flex routes.

Project Description: This TIGGER project is part of MTA's larger Facility Solarization and Modernization Program, which currently is composed of two separately-funded projects. The TIGGER-funded portion consists of a solar canopy system that will provide power and protect vehicles from sun and weather year round. The 107-kW PV canopy system is expected to provide the electricity needed to operate the existing Administrative and Operations building located next to the canopy system.

Project Status: This project is complete and operational. A canopy composed of about 3,600 square feet of solar canopies was installed and connected to the existing electrical system at the administrative offices and the new maintenance building in November 2013. MTA is collecting data on the new system to submit for analysis; the results will be included in the next assessment report.

Project Name: American Fuel Cell Hybrid Buses for SunLine

Transit Agency: SunLine Transit Agency
Location: Thousand Palms, California
Award Amount: $4,917,876
Award Year: 2011
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: SunLine Transit Agency provides public transit services to southern California's Coachella Valley (including Palm Springs). SunLine's headquarters are in Thousand Palms, California, and its service area of more than 1,100 square miles includes 9 member cities and part of Riverside County. SunLine operates 11 fixed routes (SunBus) and provides paratransit services (SunDial).

Project Description: SunLine began operating its newest fuel cell electric bus, the American Fuel Cell Bus (AFCB), in December 2011. This bus was developed as part of another FTA-funded program (National Fuel Cell Bus Program). The AFCB—a 40-foot ElDorado bus that features a BAE Systems hybrid drive, advanced lithium ion batteries, and a Ballard fuel cell—meets "Buy America" requirements. SunLine and its partners will use TIGGER III funds to add two more of these buses to its fleet. Figure 7-68 shows one of the new TIGGER-funded AFCBs.

Project Status: This project is in progress. SunLine expects the first bus to be delivered by April 2014 and the second shortly after in June 2014.

Figure 7-68

American Fuel Cell Bus at SunLine Transit Agency

Photo courtesy of SunLine

Project Name: LBT Zero Emission/All Electric Bus Pilot Project

Transit Agency: Long Beach Transit
Location: Long Beach, California
Award Amount: $6,700,000
Award Year: 2011
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Long Beach Transit (LBT) provides public transit service in a 98-square-mile area of southern California, including the cities of Long Beach, Signal Hill, and Lakewood, and parts of Artesia, Bellflower, Carson, Cerritos, Compton, Hawaiian Gardens, Norwalk, and Paramount. LBT operates a variety of services, including fixed-route bus service, shuttle service, demand-response service, paratransit service, and water taxi service.

Project Description: For its TIGGER project, LBT will replace 10 40-foot diesel buses with 10 battery-electric buses and supporting charging infrastructure. The buses are intended to completely electrify LBT's Passport route, a free downtown circulator route that is heavily traveled by residents and tourists. Two en route charging units and an overnight charging station are planned as part of this project.

Project Status: This project is in progress. LBT issued two RFPs in October 2012—the first for the buses and charging equipment and the second for the design of bus shelters and charging stations. In early 2013, LBT selected BYD Motors, Inc., to build 10 electric buses and provide the charging equipment in California. The BYD procurement also includes the WAVE inductive charging system for en route charging. The contract was subsequently canceled because of issues with BYD's Disadvantaged Business Enterprise (DBE) certification at the time of its bid. LBT plans to reissue a solicitation for zero-emission buses in 2014. LBT also selected STV, Inc. to provide architectural and engineering services for the design of the en route and depot charging stations. The current plan is to issue awards in July 2014.

Project Name: RTC Hybrid Bus Project

Transit Agency: Regional Transportation Commission of Washoe County
Location: Reno, Nevada
Award Amount: $3,000,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: 581 MBtu / 50 tons CO_2^e
First Year Fuel Cost Savings: $4,142
Projected Lifetime Energy/GHG Savings: 6,972 MBtu / 600 tons CO_2^e

Transit Agency Profile: The Regional Transportation Commission of Washoe County (RTC) is the metropolitan planning organization for the Reno/Sparks metropolitan region. Public transit services include fixed-route, paratransit, commuter, vanpool, and bus rapid transit (BRT) services. Its fixed-route bus service—RTC RIDE—offers 28 routes with a fleet of 70 buses, covering a 136-square-mile area surrounding Reno/Sparks.

Project Description: RTC used TIGGER funds to replace two standard diesel buses at the end of their service lives with more efficient hybrid buses. The new 60-foot hybrid buses have about 50% more seating capacity than the older 40-foot buses that are being replaced. RTC purchased eight hybrid buses, three of which were funded with the TIGGER grant. Table 7-67 provides selected specifications on the old diesel and new hybrid buses.

Table 7-67

Vehicle Specifications for RTC Baseline and Hybrid Buses

	Baseline 1	Baseline 2	New Technology
Number of Vehicles	1	1	3
Model Year	1997	1998	2009
Manufacturer	NOVA	NOVA	New Flyer
Model	T80606 1	T80606 1	DE60LFA
Length (ft)	40	40	60
Weight (lb)	26,620	26,620	48,750
Passengers	44 seats, 22 standees	44 seats, 22 standees	57 seats, 45 standees
Engine OEM	Detroit Diesel	Detroit Diesel	Cummins
Engine: Rated Power (hp)	275	275	330
Hybrid System Manufacturer			Allison
Hybrid Model			EP 40
Hybrid Configuration			Parallel
Hybrid Model			EP 40

Project Status: This project is complete. The buses were delivered in August 2010, and all were placed in service by the end of October 2010.

Summary of Results: RTC purchased three 60-foot articulated buses to replace 40-foot standard transit buses. A one-to-one replacement of a lighter bus with a much heavier bus results in a net increase in fuel use, even if the heavier bus is a hybrid. Using three articulated buses allowed RTC to carry the same number of passengers as with four 40-foot buses. To determine actual energy and GHG savings, NREL compared the fuel use of the three new hybrid buses to that of four 40-foot buses. RTC provided one year of data on the older, 40-foot diesel buses and six months of data on the new hybrids. During the project, RTC entered into a new contract with a fuel provider. As a result, individual fueling records for the buses were available for only the first six months of operation. NREL used the actual data to project a full year of fuel use for the calculations.

To normalize the results, NREL used the mileage for the new hybrid buses as the multiplier for both groups. Table 7-68 provides a summary of annual savings and projects the lifetime savings based on the agency's expected useful bus life. RTC reports that buses are typically used for 12 years.

Table 7-68

Summary of Energy and GHG Savings for RTC Hybrid Bus Project

	Baseline	Hybrid	Savings	Unit
Total Fuel Used	25,974	24,485	1,489	gal
Annual GHG Emissions	321	271	50	tons CO_2e
Annual Energy Use	3,719	3,138	581	MBtu
Lifetime of Technology			12	years
Projected Lifetime GHG Savings			600	tons CO_2e
Projected Lifetime Energy Savings			6,972	MBtu
Lifetime GHG Savings per TIGGER $			0.4	lb CO_2e
Lifetime Energy Savings per TIGGER $			2,324	Btu

The annual energy savings for the RTC TIGGER project is shown in Figure 7-69, and the GHG savings is shown in Figure 7 70. RTC's hybrid buses are using 16% less energy and have GHG emissions 16% lower than the baseline buses do.

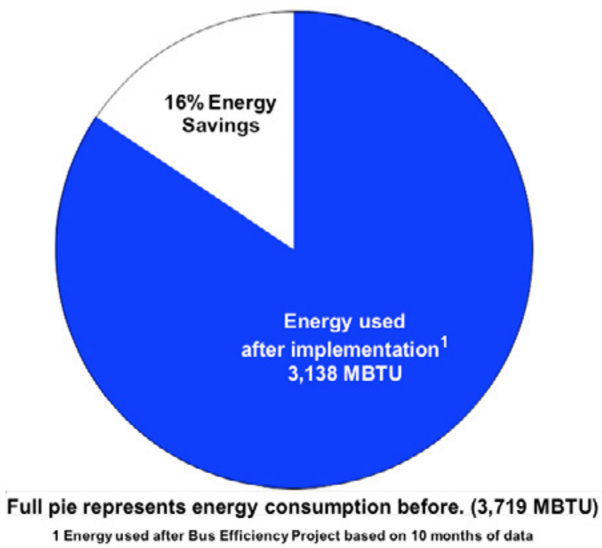


Figure 7-69

Annual Energy Savings for RTC Hybrid Bus Project

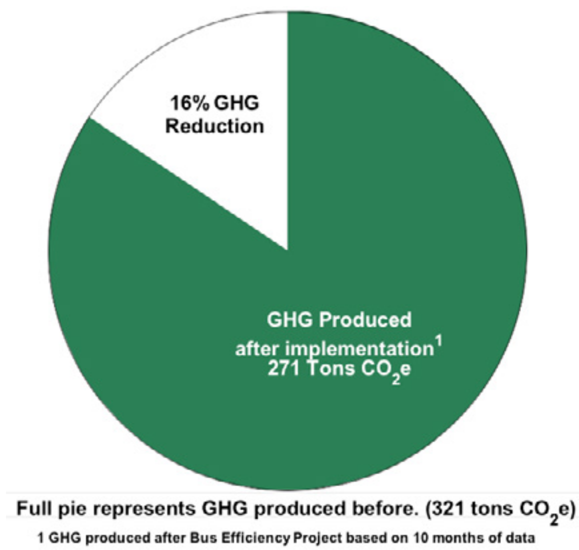


Figure 7-70

Annual GHG Savings for RTC Hybrid Bus Project

Figure 7-71 provides the monthly average fuel economy for the hybrid and diesel baseline buses. As expected, the fuel economy of the larger articulated buses is lower than that of the lighter 40-foot diesel baseline buses. The average fuel economy of the hybrid buses is 3.08 mpg, which is 26% lower than that of the baseline diesel buses.

Figure 7-71

Monthly Fuel Economy for RTC Hybrid and Baseline Buses

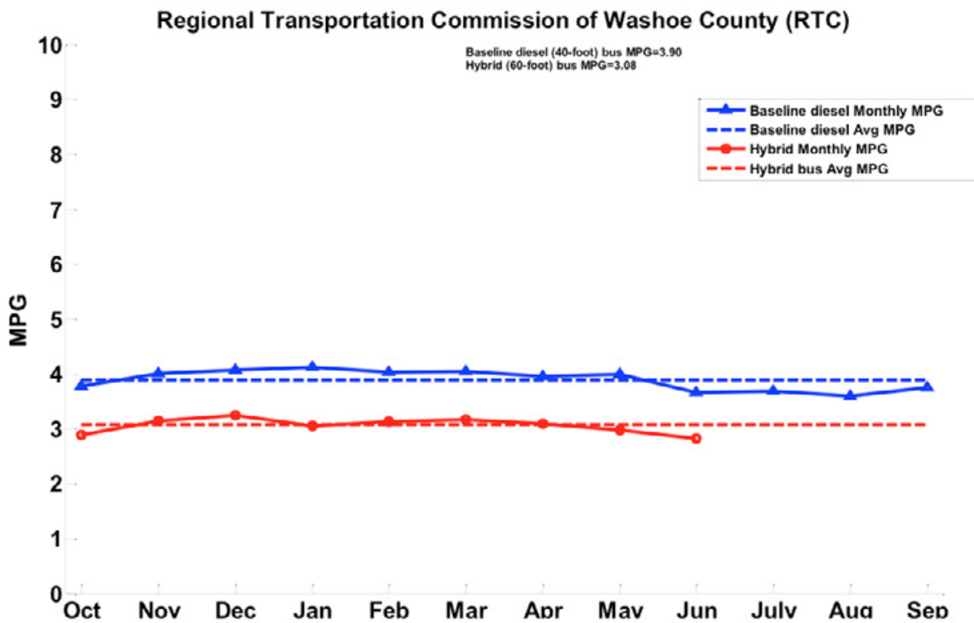


Table 7-69 summarizes the costs for the hybrid and diesel buses. The maintenance costs for the new hybrid buses are approximately 45% lower than those of the diesel buses. The level of detail provided allowed NREL to categorize the repair by system. The propulsion-related-only maintenance is provided in the table. The propulsion-related-only costs for the new hybrid buses are less than $0.001 per mile.

Table 7-69

Summary of Operational Costs for RTC Hybrid and Baseline Buses

	Hybrid	Baseline
Total Miles	75,514	126,072
Total Maintenance Cost	$14,776.88	$44,610.77
Maintenance Cost per Mile	$0.20	$0.35
Scheduled Maintenance Cost	$9,356.95	$5,655.27
Scheduled Maintenance Cost per Mile	$0.12	$0.04
Unscheduled Maintenance Cost	$5,419.93	$38,955.50
Unscheduled Maintenance Cost per Mile	$0.07	$0.31
Propulsion-Related Unscheduled Maintenance Costs	$335.65	$16,728.59
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.00	$0.13
Fuel Economy (mpg)	3.08	3.88
Total Fuel Used (gal)	24,175.2	30,882.9
Fuel Cost (at $2.78/gal)	$67,232.02	$85,886.35
Fuel Cost per Mile	$0.90	$0.72
Total Cost per Mile	$1.09	$1.04

Using the hybrid bus mileage as the baseline, the operational cost savings are summarized in Table 7-70. The hybrid buses saved RTC more than $24,000 in the first year of service.

Table 7-70

Operational Cost Difference for RTC Hybrid Bus Project

	Hybrid Total	Baseline Total	Savings
Annual Maintenance Cost	$14,776.88	$35,627.66	$20,850.78
Annual Fuel Cost	$68,094.09	$72,235.83	$4,141.75
Annual Total Cost	$82,870.97	$107,863.49	$24,992.52

Project Name: RTC Electric Bus Circulator

Transit Agency: Regional Transportation Commission of Washoe County
Location: Reno, Nevada
Award Amount: $4,650,523
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: The Regional Transportation Commission of Washoe County (RTC) is the metropolitan planning organization for the Reno/Sparks metropolitan region. Public transit services include fixed-route, paratransit, commuter, vanpool, and bus rapid transit (BRT) services. Its fixed-route bus service—RTC RIDE—offers 28 routes with a fleet of 70 buses, covering a 136-square-mile area surrounding Reno/Sparks.

Project Description: RTC is replacing four diesel buses with four battery-electric buses capable of taking a fast charge. The agency will operate the buses on a downtown circulator.

Project Status: A contract with Transit Resource Center to perform vehicle inspections and acceptance testing was awarded in August 2012. Proterra was selected as the manufacturer for the fast-charge electric buses and charging station. All buses have been delivered and began service operation in March 2014. Proterra also will supply and install one shop charger and one fast-charge station at a bus station along the planned route. RTC is currently in negotiations with Transit Resource Center to provide additional support for reporting requirements.

Project Name: Valley Metro Electric Fan Retrofit

Transit Agency:	Regional Public Transportation Authority (Valley Metro)
Location:	Phoenix, Arizona
Award Amount:	$1,349,715
Award Year:	2011
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: The Regional Public Transportation Authority, known locally as Valley Metro, provides transit service to 16 neighboring cities and towns within Maricopa County. Valley Metro delivers an integrated regional transit system. Regional transit services include Local, Express, and RAPID commuter bus service, neighborhood circulators, paratransit service, and METRO light rail.

Project Description: For this TIGGER project, Valley Metro will retrofit some vehicles in the existing transit bus fleet with an electric cooling fan system (MiniHybrid Thermal System) that is expected to increase efficiency and lower operations cost.

Project Status: Valley Metro worked with EMP to install its MiniHybrid thermal system in 21 of Valley Metro's buses. The installations were done as the buses were built. All installations were completed at the end of January 2014, and the agency is in the process of collecting data for analysis.

Project Name: Valley Metro Solar Shade Canopy Project

Transit Agency:	Regional Public Transportation Authority (Valley Metro)
Location:	Phoenix, Arizona
Award Amount:	$2,715,000
Award Year:	2011
TIGGER Goal:	Energy reduction

Transit Agency Profile: The Regional Public Transportation Authority, known locally as Valley Metro, provides transit service to 16 neighboring cities and towns in Maricopa County. Valley Metro delivers an integrated regional transit system. Regional transit services include Local, Express, and RAPID commuter bus service, neighborhood circulators, paratransit service, and METRO light rail.

Project Description: For this project, Valley Metro is installing a solar canopy at the Operations and Maintenance Center (OMC) facility that will include the construction of approximately 142,000 square feet of steel canopy structures over existing rail tracks and yard. Approximately 19,000 square feet of free-standing "tracking" solar panels will be installed on the northwest corner of the OMC lot. It is estimated that both the free-standing and shade canopy configurations of solar panels will produce about 780 kW of electricity annually.

Project Status: This project is located on airport property and requires coordination with the Federal Aviation Administration (FAA) before installation. A Categorical Exclusion and a glare study on the proposed solar canopy project were completed, and final approval from the FAA to move forward with the installation was received. A new glare analysis was completed to accommodate the adjusted placement and tilt of the solar panel installation. The bidding process for equipment and installation is complete, and Natural Power and Energy LLC has been selected. Valley Metro intended to use a third-party purchase agreement for the installation; however, the local utility is no longer participating in a solar incentive program. Valley Metro will proceed with a scaled-down solar installation to remain within budget.

Project Name: Honolulu Turbine Hybrid Bus Project

Transit Agency:	City and County of Honolulu Department of Transportation Services
Location:	Honolulu, Hawaii
Award Amount:	$5,061,000
Award Year:	2010
TIGGER Goal:	Both energy and GHG emissions reduction

Transit Agency Profile: The City and County of Honolulu operates 531 buses on 105 fixed routes and a fleet of 166 vehicles in paratransit service. Paratransit service is operated by the Department of Transportation Services (The Handi-Van service). The transit agency provides fixed-route service (referred to as The Bus) to the island of Oahu, which has almost one million residents. Operations include eight transit centers and five designated park-and-ride lots.

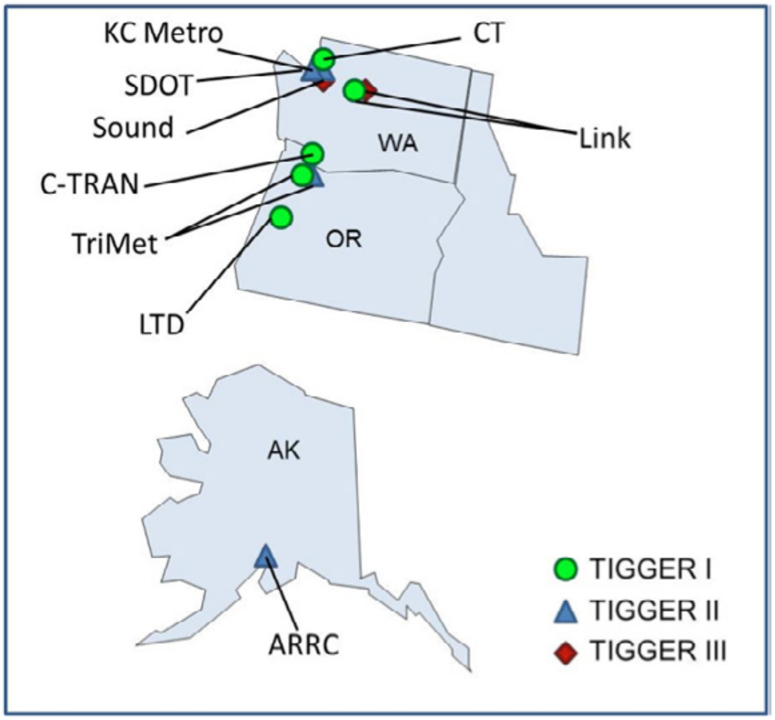
Project Description: This project will provide 8 new-technology 45-foot turbine low floor buses fueled with ultra-low sulfur diesel fuel. These eight buses will be used on the highly visible Route 8 with service between downtown Waikiki and the Ala Moana shopping district and suburban bus depot. The 45-foot buses have a higher carrying capacity for the nearly 5,000 passengers per day who use this route. The City and County of Honolulu will compare data from three existing bus platforms: an older diesel bus, a newer, more efficient diesel bus, and a hybrid diesel bus. These buses will be run for three-month periods on the Route 8 corridor to capture data that can then be compared with turbine engine performance.

Project Status: This project is in the early stages. The original plans were to have the buses in service by mid-year 2012, but the transit agency has experienced delays. It made a conditional award to DesignLine in June 2013; however, the company filed for bankruptcy in August 2013, causing the award to be canceled. Honolulu consulted with FTA regarding potential for changing the scope of this project, but it is now committed to the original direction and plans to issue a new RFP in mid-2014 for four 40-foot battery dominant hybrid-electric buses.

Region X

Figure 7-72

Map of FTA Region X Project Locations



Region X projects:

1. Alaska Railroad Corporation (ARRC), locomotive upgrades
2. Lane Transit District (LTD), hybrid bus project
3. TriMet, bus efficiency improvement project–see case study in Section 8
4. TriMet, light rail on-board energy storage system
5. Community Transit (CT), hybrid bus project
6. Link Transit, battery electric bus project
7. Link Transit, battery electric bus fleet expansion
8. Clark County Public Transportation Benefit Area (C-TRAN), facility improvement
9. King County Metro (KC Metro), zero-emission, fast charge bus project
10. Seattle Department of Transportation (SDOT), King Street Station efficiency improvements–see case study in Section 8
11. Sound Transit, light rail on-board energy storage system

Project Name: Alaska Railroad Locomotive Upgrades

Transit Agency:	Alaska Railroad Corporation
Location:	Anchorage, Alaska
Award Amount:	$1,035,000
Award Year:	2010
TIGGER Goal:	GHG emissions reduction

Transit Agency Profile: The Alaska Railroad Corporation (ARRC) is a full-service (offering both freight and passenger services) railroad serving ports and communities from the Gulf of Alaska to Fairbanks. ARRC owns and operates a fleet of 30 passenger railcars, 6 baggage cars, 8 diner/café cars, and 2 general purpose cars. In addition to passenger service, ARRC provides freight hauling service, moving more than 90,000 carloads of freight each calendar year. ARRC owns a fleet of 51 locomotives.

Project Description: ARRC is using the TIGGER grant to help fund the overhaul of three GP40 locomotives to bring the locomotive engines into EPA compliance for lower emissions and improved fuel efficiency. This project will retrofit three existing locomotives in the ARRC fleet with emission reduction kits and automatic engine stop-start idling reduction systems.

Project Status: Work began on the project in 2011, and ARRC has procured all of the materials to complete the upgrades. ARRC is using internal labor to install the emission reduction kits on the locomotives. The first installation was completed in October 2013. Assembly of the second and third units is in progress, with an expected completion date of December 2014.

Project Name: Lane Transit Hybrid Bus Project

Transit Agency:	Lane Transit District
Location:	Eugene, Oregon
Award Amount:	$3,000,000
Award Year:	2009 (Recovery Act)
TIGGER Goal:	Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: 5,209 MBtu / 449 tons CO_2^e
First Year Fuel Cost Savings: $149,811
Projected Lifetime Energy/GHG Savings: 83,344 MBtu / 7,184 tons CO_2^e

Transit Agency Profile: Lane Transit District (LTD) is the designated transit service provider in Lane County, Oregon. LTD provides fixed-route bus service, bus rapid transit, and paratransit services to the Eugene–Springfield, Oregon, metropolitan area and surrounding communities. LTD operates 115 buses, each of which travels an average of 3,700 miles per year. In 2008, LTD provided 11,408,000 passenger trips.

Project Description: LTD used TIGGER funds to cover the incremental cost of purchasing 24 40-foot diesel hybrid buses. These buses replaced older standard diesel buses that had surpassed their useful lives. Allison Transmission, Inc. provided the hybrid technology systems in the buses, which were built by Gillig. Table 7-71 provides selected specifications for the baseline and new hybrid buses.

Table 7-71

Summary of Vehicle Specifications for LTD Hybrid Bus Project

	Baseline	New Technology
Number of Vehicles	24	24
Model Year	1994	2011
Manufacturer	Gillig	Gillig
Model	Phantom	G30D102N4
Length (ft)	40	40
Weight (lb)	29,140	27,300
Engine OEM	Cummins (M11)	Cummins (ISB)
Engine: Rated Power (hp)	180	280
Hybrid System Manufacturer		Allison
Hybrid Model		EV-40
Hybrid Configuration		Parallel
Energy Storage Type		Nickel Metal Hydride
Energy Storage Manufacturer		Panasonic

Project Status: This project is complete. LTD was able to stretch the funding for this project to include hybrid propulsion technology on all 24 buses that were purchased. The first set of buses (15) was delivered and put into service in November and December 2011. The remaining nine buses were delivered in January–February 2012 and placed into service March–May 2012.

Summary of Results: LTD submitted data on the baseline and hybrid buses. Table 7-72 summarizes the energy use and GHG emissions for the project. Figure 7-73 and Figure 7-74 present the results graphically. Based on the data analysis, LTD has an annual energy savings of 19% and emits 19% fewer GHG emissions. This is the equivalent of removing approximately 80 cars from the road each year. Figure 7-75 shows the monthly fuel economy for the baseline and hybrid buses. The hybrid buses have an average fuel economy that is 24% higher than that of the baseline diesel buses. This is estimated to save the agency nearly $155,000 each year in fuel costs.

Table 7-72

Summary of Energy Use and GHG Emissions for LTD Hybrid Bus Project

	Hybrid	Baseline	Savings	Unit
Total Fuel Used	170,433	211,277	40,844	gal
Annual GHG Emissions	1,889.0	2,338.0	449	tons CO_2e
Annual Energy Use	21,909	27,118	5,209	MBtu
Lifetime of Technology			16	years
Projected Lifetime GHG Savings			7,184	tons CO_2e
Projected Lifetime Energy Savings			83,344	MBtu
Lifetime GHG Savings per TIGGER $			4.8	lb CO_2e
Lifetime Energy Savings per TIGGER $			27,781	Btu

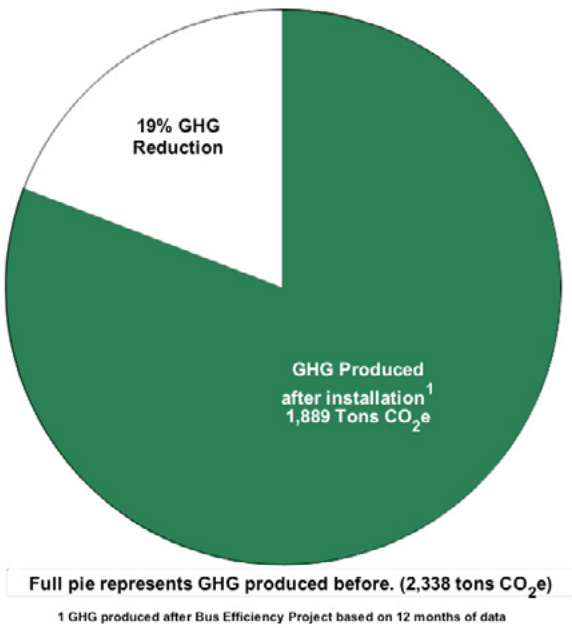


Figure 7-73

Annual GHG Emissions for LTD Hybrid Bus Project

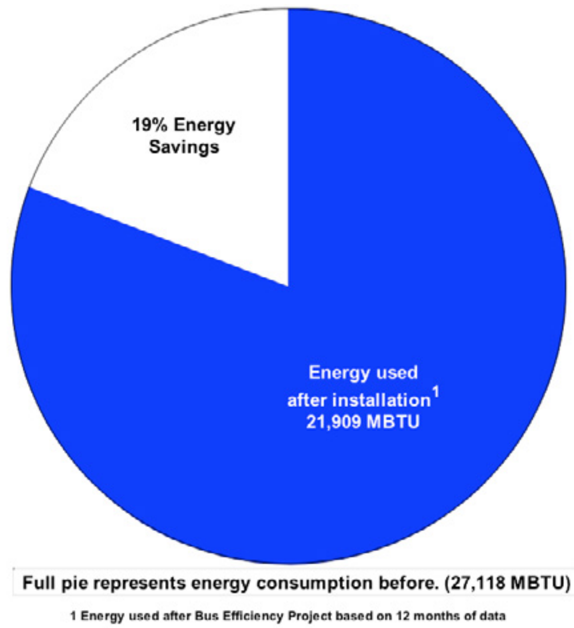


Figure 7-74

Annual Energy Use for LTD Hybrid Bus Project

Figure 7-75

Monthly Average Fuel Economy for LTD Baseline and Hybrid Buses

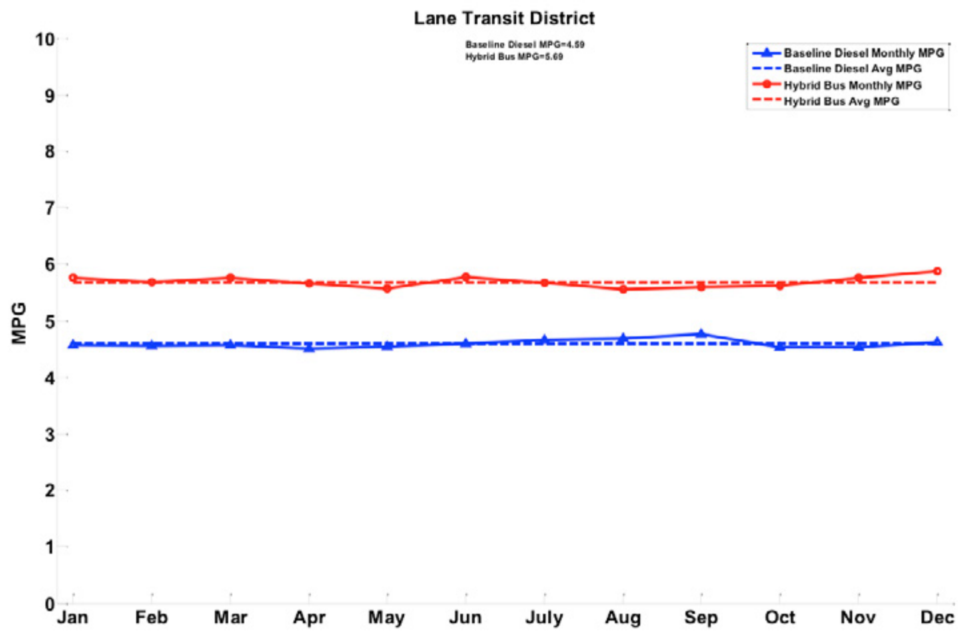


Table 7-73 summarizes the costs for the new hybrid and baseline diesel buses at LTD. The maintenance costs for the hybrid buses were significantly lower than for the diesel buses. Most of the maintenance costs for the diesel baseline buses were for unscheduled repairs. Like several other agencies, LTD provided very detailed maintenance records. Costs for accident-related repairs, which would be extremely variable from bus to bus, were eliminated from the analysis. The level of detail also allowed NREL to categorize the repair by system. The propulsion-related-only maintenance costs are provided in the table.

Table 7-73

Summary of Operational Costs for LTD Hybrid and Baseline Buses

	Hybrid	Baseline
Total Miles	942,676	909,460
Parts Cost	$36,863.87	$341,208.51
Labor Cost	$166,938.07	$415,067.35
Total Maintenance Cost	$203,801.94	$756,275.86
Maintenance Cost per Mile	$0.22	$0.83
Scheduled Maintenance Cost	$72,291.11	$19,572.10
Scheduled Maintenance Cost per Mile	$0.08	$0.02
Unscheduled Maintenance Cost	$131,510.83	$664,415.26
Unscheduled Maintenance Cost per Mile	$0.14	$0.73
Propulsion-Related Unscheduled Maintenance Costs	$30,154.90	$256,723.81
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.03	$0.28
Fuel Economy (mpg)	5.69	4.59
Total Fuel Used (gal)	165,800.0	197,991.3
Fuel Cost (at $3.80/gal)	$630,063.11	$752,394.60
Fuel Cost per Mile	$0.67	$0.83
Total Cost per Mile	$0.88	$1.66

The hybrid buses had propulsion-related-only maintenance costs that were only 23% of the total unscheduled maintenance costs; the baseline diesel buses had propulsion-related-only maintenance costs that were nearly 40% of the total unscheduled maintenance costs.

Using the mileage of the buses after retrofit as the baseline, the operational cost savings are summarized in Table 7-74. By replacing the older diesel buses with new hybrid buses LTD is estimated to save nearly $730,000 each year they are in service.

Table 7-74

Operational Cost Difference for LTD Hybrid Bus Project

	Hybrid	Baseline	Savings
Total Maintenance Cost	$203,801.94	$783,897.15	$580,095.21
Total Fuel Cost	$630,063.11	$779,874.14	$149,811.03
Total Cost	$833,865.05	$1,563,771.29	$729,906.24

Project Name: TriMet Light Rail On-Board Energy Storage System

Transit Agency: Tri-County Metropolitan Transportation District of Oregon
Location: Portland, Oregon
Award Amount: $4,200,000
Award Year: 2010
TIGGER Goal: Energy reduction

Transit Agency Profile: The Tri-County Metropolitan Transportation District of Oregon (TriMet) provides public transportation for much of Multnomah, Clackamas, and Washington counties in the Portland, Oregon, metro area. TriMet operates a comprehensive public transit network including a 51-mile, 85-station MAX light rail system, 79 bus lines, and door-to-door service for older adults and people with disabilities.

Project Description: TriMet is using TIGGER funds to upgrade 27 light rail vehicles (LRVs) with double-layer capacitors for better on-board energy storage to recover braking energy that would otherwise be lost. TriMet currently operates a fleet of next-generation light rail vehicles that feature regenerative braking, meaning that upon deceleration the vehicle motors function as generators and make power available to the traction electrification system. Agency studies indicated that only 70% of that regenerated power was being captured and used when there were no nearby trains. To maximize the energy saving benefits, the capacitor-equipped vehicles will be paired with non-capacitor-equipped vehicles in service. These capacitor units release previously stored electrical energy upon acceleration, thus using close to 100% of the regenerated power captured from braking trains.

Project Status: The production prototype unit was completed and was tested in a vehicle during 2012. Installation is complete on all 27 LRVs; Figure 7-76 shows one of the installed units. An additional spare unit was received in August 2013, and two portable discharge units were designed to aid in discharging energy from the storage units during maintenance. A warranty is in place for the new units, and TriMet's project staff is the administrator. System performance data are being recorded and will be submitted to NREL for analysis.

Figure 7-76

Ultracap Energy Storage Installed on TriMet LRV

Photo Courtesy of TriMet

Project Name: Community Transit Hybrid Bus Project

Transit Agency: Snohomish County Public Transit Benefit Area (Community Transit)
Location: Everett, Washington
Award Amount: $3,000,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Results Summary:

First Year Energy/GHG Savings: 2,341 MBtu / 201 tons CO_2^e
First Year Fuel Cost Savings: $58,552
Projected Lifetime Energy/GHG Savings: 28,092 MBtu / 2,412 tons CO_2^e

Transit Agency Profile: Community Transit provides service within Snohomish County in Washington State. The service area covers 1,305 square miles and serves 516,099 people. Community Transit operates 30 local routes, including the Swift bus rapid transit system, the transit agency's highest ridership route. Community Transit also operates 23 commuter routes with service to Seattle and a vanpool program with 396 active groups that carry approximately 3,000 passengers each weekday.

Project Description: Community Transit used TIGGER funds to cover the incremental cost of hybrid buses. The agency replaced 15 older 40-foot buses with more fuel efficient hybrid buses. Table 7-75 provides specifications for the old diesel and new hybrid buses.

Table 7-75

Vehicle Specifications for Community Transit Buses

Community Transit	Baseline	New Technology
Number of Vehicles	15	15
Model Year	1995	2011
Manufacturer	New Flyer	New Flyer
Model	D40LF	XDE40
Length (ft)	40	40
Weight (lb)	27,500	42,540
Engine OEM	Detroit Diesel	Cummins
Engine: Rated Power (hp)	275	280
Hybrid System Manufacturer		BAE Systems
Hybrid Model		TB200
Hybrid Configuration		Series
Energy Storage Type		Lithium-Ion Battery
Energy Storage Manufacturer		A123

Project Status: This project is complete. All the buses were delivered and placed into service by early October 2011.

Summary of Results: Community Transit provided a full year of data on the new hybrid and baseline buses. Table 7-76 summarizes the energy use and GHG emissions for the project. Figure 7-77 and Figure 7-78 present the results graphically. Based on the data analysis, Community Transit has an annual energy savings of 16% and emits 16% fewer GHG emissions.

Table 7-76

Summary of Energy and GHG Savings for Community Transit Hybrid Bus Project

Community Transit	Hybrid	Baseline	Savings	Unit
Total Fuel Used	93,211	111,452	18,241	gal
Annual GHG Emissions	1,032	1,233	201	tons CO_2^e
Annual Energy Use	11,967	14,308	2,341	MBtu
Lifetime of Technology			12	years
Projected Lifetime GHG Savings			2,412	tons CO_2^e
Projected Lifetime Energy Savings			28,092	MBtu
Lifetime GHG Savings per TIGGER $			1.6	lb CO_2^e
Lifetime Energy Savings per TIGGER $			9,364	Btu

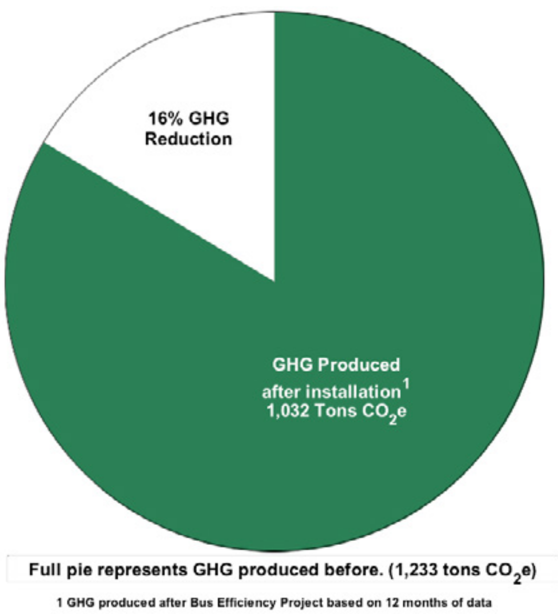


Figure 7-77

Annual GHG Savings for Community Transit Hybrid Bus Project

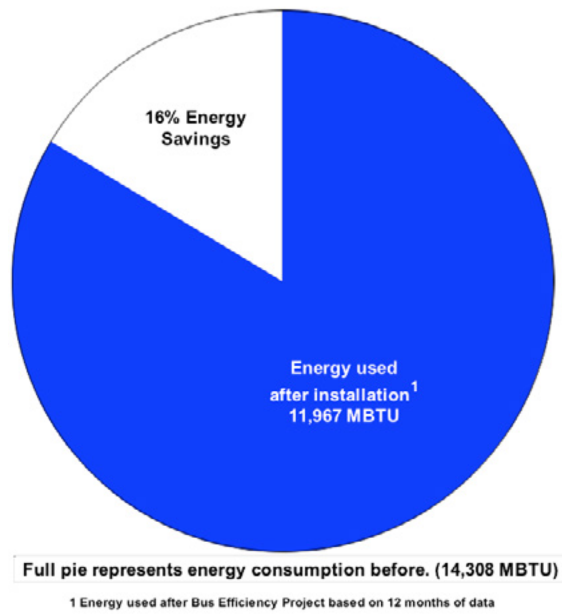


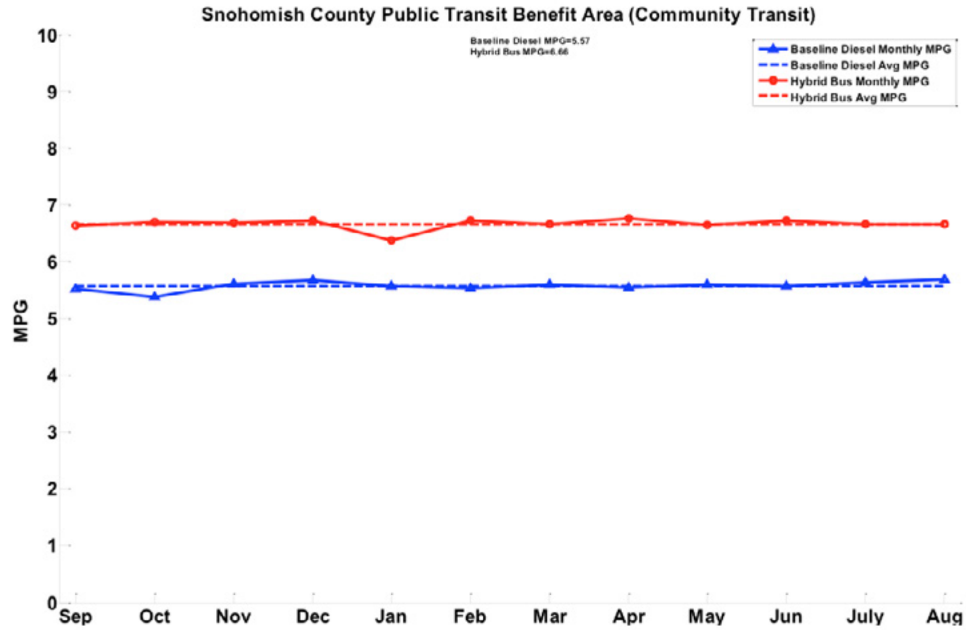
Figure 7-78

Annual Energy Savings for Community Transit Hybrid Bus Project

Figure 7-79 shows the monthly fuel economy for the baseline and hybrid buses. The hybrid buses have an average fuel economy that is 20% higher than that of the baseline diesel buses.

Figure 7-79

Monthly Fuel Economy for Community Transit Hybrid and Baseline Buses



Community Transit provided monthly totals for maintenance costs on the baseline and hybrid buses. These data did not allow for differentiating details of the maintenance records by system, so some warranty or accident costs may be included in the results. Costs were separated by scheduled and unscheduled maintenance. The level of detail also did not allow for separating out the costs associated with the propulsion system. Table 7-77 summarizes the operational costs for the hybrid and baseline buses for Community Transit's TIGGER project. Table 7-78 provides the annual cost difference based on the total mileage of the hybrid buses. Based on the data analysis, Community Transit saved nearly $72,000 in operational costs by replacing the older diesel buses with hybrid buses.

Table 7-77

Summary of Operational Costs for Community Transit Hybrid and Baseline Buses

Community Transit	Hybrid	Baseline
Total Miles	620,786	780,889
Total Maintenance Cost	$323,912.15	$424,306.41
Maintenance Cost per Mile	$0.52	$0.54
Scheduled Maintenance Cost	$38,232.61	$56,223.67
Scheduled Maintenance Cost per Mile	$0.06	$0.07
Unscheduled Maintenance Cost	$285,679.54	$368,082.74
Unscheduled Maintenance Cost per Mile	$0.46	$0.47
Fuel Economy (mpg)	6.66	5.57
Total Fuel Used (gal)	93,211.1	140,195.5
Fuel Cost (at $3.21/gal)	$299,207.67	$450,027.59
Fuel Cost per Mile	$0.48	$0.58
Total Cost per Mile	$1.00	$1.12

Table 7-78

Operational Cost Difference for Community Transit Hybrid Bus Project

Community Transit	Hybrid	Baseline	Savings
Total Maintenance Cost	$323,912.15	$337,312.32	$13,400.17
Total Fuel Cost	$299,207.67	$357,759.97	$58,552.31
Total Cost	$623,119.82	$695,072.29	$71,952.48

Project Name: Link Transit Electric Bus Project

Transit Agency: Link Transit
Location: Wenatchee, Washington
Award Amount: $2,925,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Link Transit provides year-round service for 17 communities in Chelan and Douglas counties in the state of Washington, with 12 urban fixed routes, 11 rural flex routes, 2 long-distance commuter routes, and 1 seasonal route to the Mission Ridge Ski Resort. Link Transit's fixed-route fleet consists of 57 diesel-powered buses, replica trolleys, and cutaways (body on van chassis). Paratransit service is operated with 16 gas-powered vans and 6 diesel-powered cutaways.

Project Description: Link Transit purchased five 22-foot, low floor battery electric trolley style buses along with two Ultra-Fast Charge "Gamma" chargers and one overnight charging station for its Wenatchee bus fleet. The buses, built by Ebus, replaced five older diesel buses.
Project Status: The agency has received three EBus trolleys to date. The fast-charging stations for the buses were installed and approved for operation in March 2013, allowing the two trolleys the agency had received to run full service routes. During the initial deployment with limited service, a redesign of the batteries was determined necessary to accommodate the needs of the agency. The trolleys currently use nickel cadmium batteries, but the batteries will be changed to lithium titanate for improved performance when used in conjunction with the Gamma chargers. All five buses are expected to be delivered in May 2014.

There have been issues with using the new charging systems, which will be resolved by EBus when the final two trolleys are delivered. All trolleys will be upgraded to the newer batteries during the final delivery as well.

Project Name: Link Transit Electric Bus Fleet Expansion

Transit Agency: Link Transit
Location: Wenatchee, Washington
Award Amount: $2,500,000
Award Year: 2011
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: Link Transit provides year-round service for 17 communities in Chelan and Douglas counties in the state of Washington, with 12 urban fixed routes, 11 rural flex routes, two long-distance commuter routes, and one seasonal route to the Mission Ridge Ski Resort. Link Transit's fixed-route fleet consists of 57 diesel-powered buses, replica trolleys, and cutaways (body on van chassis). Paratransit service is operated with 16 gas-powered vans and 6 diesel-powered cutaways.

Project Description: Link Transit will expand its electric bus fleet from five buses (awarded in TIGGER I) to eight buses. The project will also add three fast-charge stations, to extend the limit of coverage for the fleet, and five additional overnight charge ports at the depot.

Project Status: This project will not begin until the first project is successfully completed. Successful completion will result in the delivery of all five trolleys with new battery systems, improved charging capability with the Gamma chargers, and full service deployment.

Project Name: C-TRAN Facility Improvement

Transit Agency: Clark County Public Transportation Benefit Area
Location: Vancouver, Washington
Award Amount: $1,500,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Summary of Results:

- First Year Energy/GHG Savings: 571 MBtu / -8.3 tons CO_2^e
- First Year Energy Cost Savings: $3,915
- Projected Lifetime Energy/GHG Savings: 11,418 MBtu / -166 tons CO_2^e

Transit Agency Profile: The Clark County Public Transportation Benefit Area (C-TRAN) provides fixed-route, commuter express, demand-response, and vanpool services to more than 335,000 residents in Clark County, Washington. Its fleet includes 108 coaches, 58 demand-response vehicles, and 20 vanpool vehicles. The transit agency also operates 16 diesel-electric hybrid buses, which use 30% less fuel than do conventional diesel buses.

Project Description: C-TRAN's project involved installing PV systems and retrofitting its buildings with lighting upgrades and advanced temperature-control systems along with new, high-efficiency mechanical equipment. Its PV system consists of two rooftop PV systems—a 10-kW system at Fisher's Landing Transit Center and a 10-kW system at the maintenance building. The agency replaced lights inside the facility as well as outdoors with more efficient fixtures and bulbs. HVAC system improvements included installing a new digital-direct control system, variable-speed ventilation, and demand-controlled ventilation. Figure 7-80 shows some of the upgrades.

Figure 7-80

C-TRAN Upgrades include Solar (upper left), New HVAC (lower left), and Outdoor Lighting (right)

Project Status: This project was completed in November 2011. The agency has provided the requested data to NREL for analysis.

Summary of Results: The facility improvement project at C-TRAN resulted in an energy savings of 167,221 kWh during the first year of operation. The energy information is summarized in Table 7-79. The savings resulted in an electricity cost savings of $8,133.04. Figure 7-81 shows this is an 8% reduction in overall energy use at the facilities.

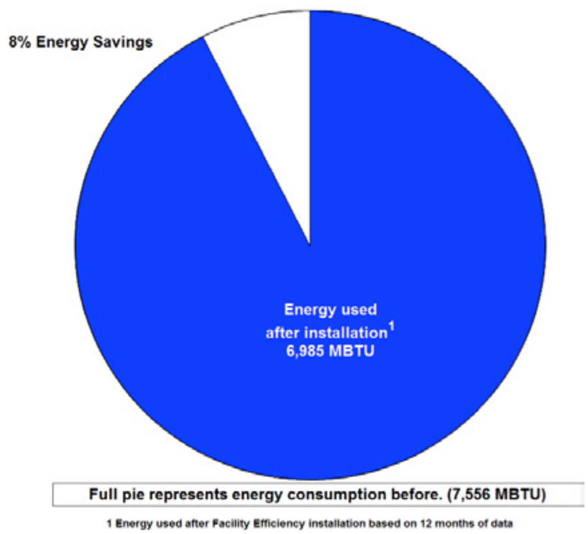
Table 7-79

Summary of Energy Savings for C-TRAN Facility Improvement Project

	kWh	therms	MBtu
Estimated Energy Savings			2,181
Actual Energy Use Before	192,772	1,795.5	7,556
Actual Energy Use After	151,062	2,039.4	6,985
Annual Energy Savings	41,710	-243.9	571
Technology Lifetime (yrs)	20	20	20
Projected Lifetime Savings	834,204	-4,878.6	11,418
Projected Lifetime Savings per TIGGER $	0.56	0.00	0.01

Figure 7-81

Annual Energy Use for C-TRAN Facility Improvement Project



The GHG emissions calculation for this project is based on natural gas consumption. C-TRAN experienced an increase in natural gas consumption despite the new HVAC system installation. Many factors could contribute to these results during one year of operation—it could be that the new lighting will not produce the same level of heat as the old bulbs, or weather patterns may have caused a colder winter than usual. The building use also could have changed. The data collected during the first year of operation showed a 6% increase in GHG emissions as presented in Figure 7-82. This is an annual increase of 8.3 tons of CO_2 emissions. Table 7-79 shows the actual natural gas use before and after the project was complete. The increase resulted in an additional $1,573 cost for natural gas, making the overall cost savings to C-TRAN approximately $6,560.

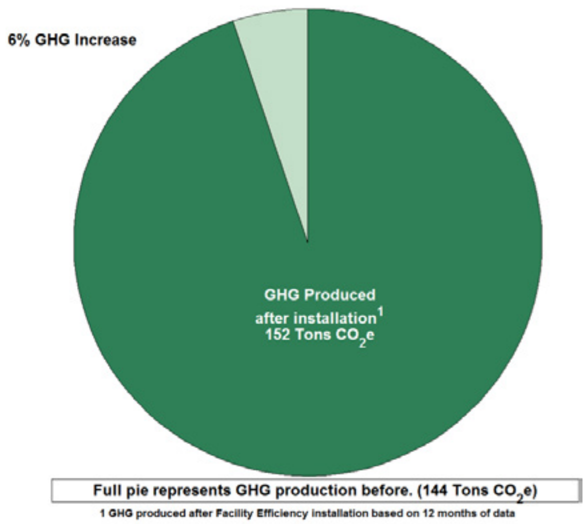
Table 7-80

Summary of GHG Emissions Savings for C-TRAN Facility Improvement Project

	Tons CO_2e
Estimated GHG Reduction	357
Actual GHG Emissions Before	143.5
Actual GHG Emissions After	151.8
Annual GHG Reduction	-8.3
Technology Lifetime (yrs)	20
Projected Lifetime Reduction	-166.0
Projected Lifetime Reduction per TIGGER $	-0.0001

Figure 7-82

GHG Emissions for C-TRAN Facility Improvement Project



Project Name: **King County Zero-Emission, Fast Charge Bus Project**

Transit Agency: King County Metro
Location: Seattle, Washington
Award Amount: $4,761,900
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Transit Agency Profile: King County Metro (KCM) provides public transit service to all of King County, Washington, an area of 2,134 square miles that includes Seattle. The agency operates a fleet of 2,614 vehicles, including 155 electric trolley buses, 1,291 diesel coaches and articulated buses, 336 demand-response vans, and 1,154 vanpool vans.

Project Description: This project was intended to leverage the existing electric trolley infrastructure in Seattle, operated by KCM, to provide fast-charging capabilities for one or two battery electric buses. The buses could operate along trolley routes while connected to the overhead wire grid but could leave the infrastructure for up to 30 miles of off-grid operation. The buses would return to the trolley route to recharge using an on-board fast-charging system that could use power from the overhead trolley wires or from a standalone fast charger. If the design proved feasible, KCM would be able to replace current 40-foot diesel buses with an all-electric fleet with little or no impact on service.

Project Status: At the onset of the project, KCM issued a request for interest to determine whether the concept was feasible, what improvements could be made to the initial concept, and the level of interest from the bus building community. After reviewing the responses, KCM issued an RFP with the goal of acquiring one or two all-electric buses that were required to operate as electric trolleys using poles connected to the existing overhead wire grid and to operate as electric buses off the grid. During early discussions with the respondents, KCM realized that the proposers could not meet the requirements of the RFP. The primary challenges were with the charging time and operating range of the bus while off the grid:

- Charging time: Charging with the overhead grid was possible, but not within the time necessary to meet service schedules. Acceleration of the charge time would require additional equipment that would increase cost and stress the existing overhead wire beyond its capacity.
- Bus operating range: The 30-mile range requirements could be met but would require a battery pack that would add weight and reduce seating capacity.

Based on these discussions, KCM determined that using the existing overhead trolley system was not feasible. The agency has initiated a new RFP for up to two battery-electric buses with fast-charge stations. This type of bus should meet KCM's operating needs and stay within the scope of the original TIGGER grant proposal. In December 2012, FTA agreed to the revised strategy, and KCM has moved forward with a new RFP. The agency expects the buses to be delivered in mid-2015.

Project Name: **Central Link Light Rail On-Board Energy Storage Project**

Transit Agency: Central Puget Sound Regional Transit Authority (Sound Transit)
Location: Seattle, Washington
Award Amount: $1,583,085
Award Year: 2011
TIGGER Goal: Energy reduction

Transit Agency Profile: Central Puget Sound Regional Transit Authority (Sound Transit) provides regional express bus, commuter rail, and light rail service in King, Pierce, and Snohomish counties within the central Puget Sound Region. Sound Transit's geographic area encompasses 3 urban counties and 1,100 square miles. Sound Transit operates a fleet of 35 light rail vehicles (LRVs) for the Central Link light rail line, connecting downtown Seattle and Sea-Tac International Airport.

Project Description: Sound Transit's TIGGER project will reduce power consumption by adding an on-board energy storage system to some of its LRVs. The agency's LRVs already feature regenerative braking, which captures energy typically expended during braking and returns the energy back to the power distribution system. The on-board energy storage system will use capacitors to capture the remaining 60% of the energy generated from braking that otherwise dissipates into wasted heat or is lost if not used immediately. Figure 7-83 shows an LRV operating at Sound Transit.

Figure 7-83

Sound Transit Light Rail Vehicle

Project Status: Sound Transit issued an RFP for procurement, design, and installation of five on-board energy storage units for LRVs. The award was made to Kinkisharyo International, LLC in October 2012. Equipment testing was completed, and it was determined that new bus bars for the capacitor models were needed. This issue was resolved and installation of the roof-mounted brackets for the Energy Management Storage System (EMSS) units was completed on three of the LRVs in October 2013. The first EMSS installation was completed in January 2014. The static and dynamic testing of the first EMSS unit was completed successfully the week of January 20, 2014. Installation of the remaining two EMSS units was completed in March 2014. Full operation of all three EMSS units is scheduled for April 2014.

SECTION
8

Case Studies

Bus Efficiency Case Study: TriMet Bus Efficiency Improvement Project

Prepared by Leslie Eudy, Michael Lammert, Melanie Caton, and Matthew Post, National Renewable Energy Laboratory

Transit Agency: Tri-County Metropolitan Transportation District of Oregon
Location: Portland, Oregon
Award Amount: $750,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Both energy and GHG emissions reduction

Summary of Savings:
First Year Energy/GHG Savings: 2,447 MBtu / 211 tons CO2e
First Year Fuel Cost Savings: $57,089
Estimated Lifetime Energy/GHG Savings: 39,152 MBtu / 3,376 tons CO2e

Background

The Tri-County Metropolitan Transportation District of Oregon (TriMet) provides public transportation for much of Multnomah, Clackamas, and Washington counties in the Portland, Oregon, metro area. About 1.5 million people live in the 570-square-mile service area. TriMet operates a comprehensive public transit network including a 51-mile, 85-station MAX light rail system, 79 bus lines, and door-to-door service for older adults and people with disabilities. Riders make an average of 252,000 weekday trips on TriMet's fixed routes. TriMet operates and maintains 625 transit buses, 119 light rail vehicles, and 4 commuter rail cars. A contractor for TriMet operates an additional 252 LIFT vehicles and 15 minivans for door-to-door service.

TriMet is committed to the environment and actively seeks ways to reduce fuel use and lower emissions. In 2006, the agency partnered with Engineered Machined Products (EMP) on a pilot demonstration of a new cooling system to enhance bus performance, reduce emissions, and increase average fuel efficiency. The electrically-controlled cooling system had been designed for other diesel engine applications, and TriMet wanted to investigate the impact of the system for transit buses. The project successfully demonstrated lower fuel use as well as other benefits. EMP went on to commercialize the product—the MiniHybrid Thermal System—for the transit market.

Project Overview

For its TIGGER project, TriMet replaced the existing bus cooling system in 39 buses in its fleet with the EMP MiniHybrid system. Table 8-1 provides the specifications of the buses that were retrofit with the TIGGER funding.

Table 8-1

Summary of Vehicle Specifications for TriMet Buses

TriMet	Baseline
Number of Vehicles	39
Model Year	2005
Manufacturer	New Flyer
Model	DE40
Length (ft)	40
Weight (lb)	26,800
Engine OEM	Cummins
Engine: Rated Power (hp)	280

Technology Details

The EMP MiniHybrid thermal system is a fully-contained cooling system that replaces the hydraulically-driven cooling system in a bus. A high-output alternator and a system of heat exchangers and eight electronically-controlled electric fans replace the original bus alternator and cooling system. The MiniHybrid system is much smaller than the traditional hydraulic system, saving space and weight. It also eliminates the need for a large hydraulic fluid tank necessary to operate the older-style hydraulic fan system. The MiniHybrid kit includes temperature sensors for the engine charge air and engine jacket water flow paths to separately optimize cooling of those systems.

EMP advertises a number of advantages for installing this cooling system. Replacing mechanically- or hydraulically-driven components with an electrically-driven system increases the efficiency, which can lower fuel use. Because the eight fans are individually controlled, the system can use the minimum number necessary to reduce the temperature to the optimal level. The electric fan motors also can be operated in the reverse direction. Operating the system of fans in reverse can blow out any debris accumulated in the radiator; this could save maintenance staff time by reducing the need for regular steam cleaning. Hydraulic cooling systems are prone to leaks, which can lead to fires. The EMP system eliminates hydraulic fluid, which increases safety and potentially lowers maintenance costs.

The system can be installed on a new bus as the bus is built or can be retrofitted on an existing bus. Figure 8-1 shows the EMP system installed on one of TriMet's buses.

Figure 8-1

EMP System Installed on TriMet Bus

Project Results

TriMet began installation of the EMP cooling systems in November 2009. Installation on all 39 buses was completed in October 2010. TriMet provided data for the buses from one year prior to and one year after retrofit. As with the other bus retrofit projects, the installation for each bus was completed over a period of time. Because of this, the monthly data from each bus do not align with the same calendar months. Data for these projects are time-aligned with the date of retrofit.

Table 8-2 summarizes the energy use and GHG emissions for the TriMet buses before and after retrofit. The data are normalized to the mileage for the buses after the EMP systems were installed. Figure 8-2 and Figure 8-3 graphically represent the energy use and GHG emissions, respectively, for the buses at TriMet and show a 4.35% savings for the buses after the EMP systems were installed.

Table 8-2

Summary of Energy Use and GHG Emissions for TriMet Bus Efficiency Project

TriMet	Before	After	Savings	Unit
Total Fuel Used	478,088	456,606	21,482	gal
Annual GHG Emissions	4,856.0	4,645.0	211	tons CO_2^e
Annual Energy Use	56,272	53,825	2,447	MBtu
Lifetime of Technology			16	years
Projected Lifetime GHG Savings			3,376	tons CO_2^e
Projected Lifetime Energy Savings			39,152	MBtu
Lifetime GHG Savings per TIGGER $			9.0	tons CO_2^e
Lifetime Energy Savings per TIGGER $			52,203	Btu

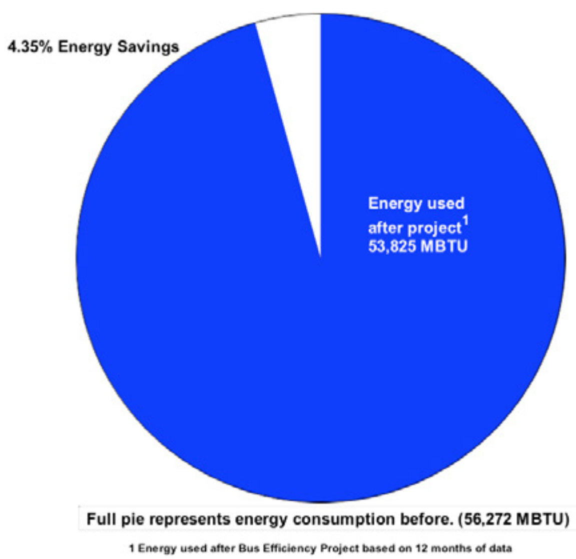


Figure 8-2

Annual Energy Use for TriMet Bus Efficiency Project

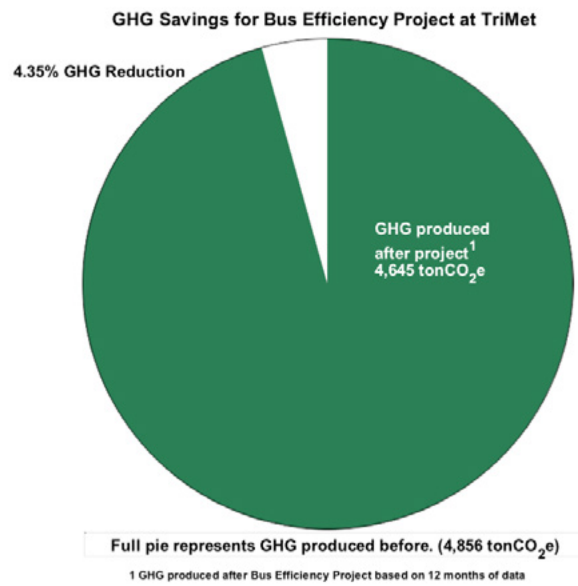


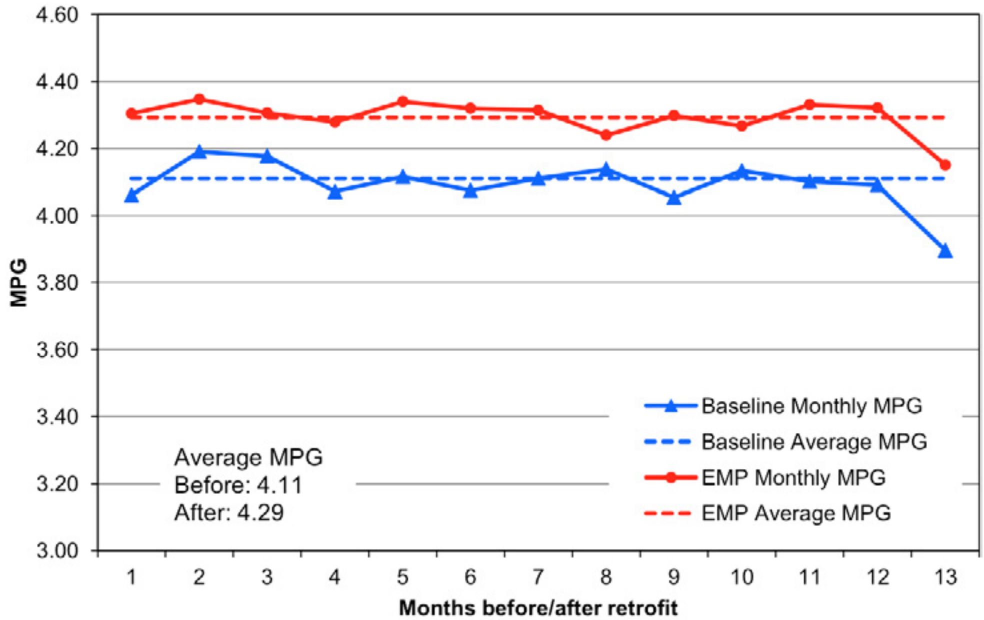
Figure 8-3

Annual GHG Emissions for TriMet Bus Efficiency Project

Figure 8-4 shows the monthly fuel economy before and after retrofit. The buses had an average fuel economy of 4.11 mpg before and 4.30 mpg after the retrofit of the EMP system, a 4.7% improvement. Based on the data provided, TriMet is estimated to save more than $57,000 each year in fuel costs.

Figure 8-4

Monthly Average Fuel Economy for TriMet Buses Before and After Retrofit



TriMet provided detailed maintenance data on 10 of the 39 project buses. Table 8-3 summarizes the cost for the buses before and after the retrofit. Costs for accident-related repair, which would be extremely variable from bus to bus, were eliminated from the analysis. The total maintenance costs were slightly less for the buses after the EMP system was installed. TriMet provided a level of detail that allowed NREL to categorize the repairs by system. The propulsion-related-only maintenance costs are provided in the table and were higher for the buses after the retrofit. The primary driver for this difference was costs for the exhaust system, which were 42% of the total cost for the EMP-equipped buses but only 30% of the total costs for the buses before retrofit. During the time period covered, diesel particulate filters (DPF) were replaced on several of the buses. The cost for a DPF was around $7,800. Because the numbers of DPFs replaced were not equal for the before and after time periods, the parts costs were significantly different. If the DPF costs are removed from the analysis, the total cost drops to $0.30 per mile before retrofit and $0.27 per mile after retrofit. That is a 9% savings in maintenance costs.

Table 8-3 *Summary of Operational Costs for TriMet Bus Efficiency Project*

TriMet (10 of 39 buses)	Baseline	EMP
Total Miles	522,388	514,793
Parts Cost	$156,171.07	$155,780.11
Labor Cost	$158,749.42	$140,279.33
Total Maintenance Cost	$314,920.49	$296,059.44
Maintenance Cost per Mile	$0.60	$0.58
Scheduled Maintenance Cost	$93,258.86	$61,309.91
Scheduled Maintenance Cost per Mile	$0.18	$0.12
Unscheduled Maintenance Cost	$221,661.63	$234,749.53
Unscheduled Maintenance Cost per Mile	$0.42	$0.46
Propulsion-Related Unscheduled Maintenance Costs	$106,281.34	$131,205.06
Propulsion-Related Unscheduled Maintenance Costs per Mile	$0.20	$0.25
Propulsion-Related Unscheduled Maintenance Costs (without DPF costs)	$51,611.34	$45,070.06
Propulsion-Related Unscheduled Maintenance Costs per Mile (without DPF costs)	$0.10	$0.09
Fuel Economy (mpg)	4.11	4.30
Total Fuel Used (gal)	476,263.3	456,606.1
Fuel Cost (at $2.72/gal)	$1,265,673.29	$1,213,434.14
Fuel Cost per Mile	$0.65	$0.62
Total Cost per Mile	$3.03	$2.93
Total Cost per Mile (without DPF costs)	$2.72	$2.63

Table 8-4 lists the maintenance costs per mile by system along with the percent of the total for each category. The vehicle systems shown in the table are as follows:

- Cab, body, and accessories – includes body, glass, and paint repairs following accidents; cab and sheet metal repairs on seats and doors; and accessory repairs such as hubodometers, fareboxes, and radios
- Propulsion-related systems – repairs for exhaust, fuel, engine, propulsion control, non-lighting electrical (charging, cranking, and ignition), air intake, cooling, and transmission
- Preventive maintenance inspections (PMI) – labor for inspections during preventive maintenance
- Brakes
- Frame, steering, and suspension
- Heating, ventilation, and air conditioning (HVAC)
- Lighting
- Air system, general
- Axles, wheels, and drive shaft
- Tires

Table 8-4

Maintenance Costs per Mile for TriMet Bus Efficiency Project by System

System	Baseline Cost per Mile ($)	Baseline Percent of Total (%)	EMP Cost per Mile ($)	EMP Percent of Total (%)
Propulsion-Related	0.21	48	0.25	56
Cab, Body, and Accessories	0.10	23	0.09	19
Frame, Steering, And Suspension	0.02	5	0.01	3
Brakes	0.02	5	0.03	7
HVAC	0.02	4	0.02	5
Lighting	0.01	2	0.01	2
General Air System Repairs	0.03	6	0.02	5
Axles, Wheels, and Drive Shaft	0.03	7	0.02	3
Tires	0.00	0	0.00	0
Total	*0.43*	*100*	*0.45*	*100*

The buses before and after the EMP retrofit had the same two systems with the highest percentage of maintenance costs—propulsion-related and cab, body, and accessories. Before the EMP retrofit, the propulsion-related costs were 48% of the total maintenance costs; after retrofit, these costs made up 56% of the total. As mentioned, the reason for the difference was the exhaust repairs that included replacing high-cost DPFs.

Table 8-5 provides a summary of maintenance costs for systems related to the retrofit. These systems include the cooling system, non-lighting electrical, and the hydraulic system. For the 10 buses for which TriMet provided detailed maintenance data, there was not a significant difference in costs for the retrofit-related systems. Maintenance cost totaled $0.01 per mile both before and after the retrofit. After the retrofit, there were no repair costs associated with the hydraulic system.

Table 8-5

Summary of Retro-fit-Related Costs for TriMet Bus Efficiency Project

Maintenance System Costs	Baseline	EMP
Mileage	514,793	522,388
Cooling System		
Parts Cost ($)	1,670.51	1,068.07
Labor Cost ($)	2,798.09	3,245.07
Total Cost ($)	4,468.60	4,313.14
Total Cost ($) Per Mile	0.01	0.01
Non Lighting Electrical System (General Electrical, Charging, Cranking, Ignition)		
Parts Cost ($)	577.46	4,458.83
Labor Cost ($)	3,273.11	4,440.31
Total Cost ($)	3,850.57	8,899.14
Total Cost ($) per Mile	0.01	0.02
Hydraulic System		
Parts Cost ($)	1,512.42	0.00
Labor Cost ($)	294.06	0.00
Total Cost ($)	1,806.48	0.00
Total Cost ($) per Mile	0.00	0.00

Using the mileage of the buses after retrofit as the baseline, the operational cost savings are summarized in Table 8-6. Based on the data provided, TriMet is estimated to have saved more than $57,000 in fuel costs during the first year of the project. Adding in the maintenance cost savings, the agency is estimated to have saved more than $111,000 by retrofitting the buses with the EMP system.

Table 8-6

Operational Cost Difference for TriMet Bus Efficiency Project

TriMet	Baseline	EMP	Difference
Total Maintenance Cost	$1,183,576.34	$1,129,106.30	$54,470.05
Total Fuel Cost	$1,270,523.24	$1,213,434.14	$57,089.10
Total Cost	$2,454,099.58	$2,342,540.43	$111,559.15

Figure 8-5 provides a comparison of the estimated energy savings to the actual energy savings for the first year of operation. Figure 8-6 provides a comparison of the GHG savings. The actual energy saved during the first year of operation is 14% lower than the estimate. Actual GHG savings were essentially the same as what was estimated.

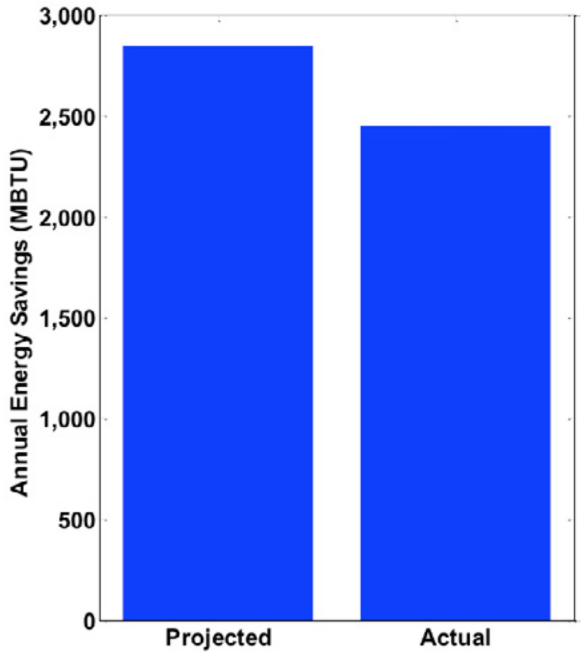


Figure 8-5

Comparison of Annual Energy Savings to Estimated Savings for TriMet Bus Efficiency Project

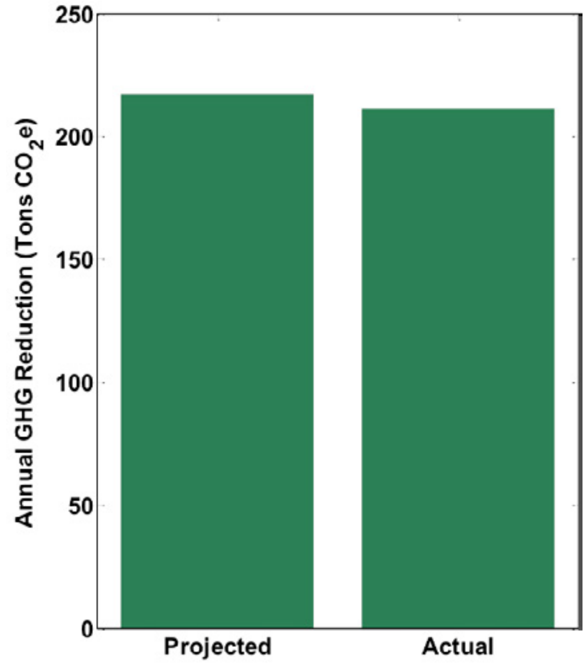


Figure 8-6

Comparison of Annual GHG Savings to Estimated Savings for TriMet Bus Efficiency Project

Project Experience and Lessons Learned

TriMet reports that the project went well, and the resulting fuel savings will have a significant impact on future budgets. The agency also completed retrofits on another fleet of buses during this timeframe with funding from outside the TIGGER program. TriMet's experiences and lessons learned could help other agencies plan for retrofits to existing bus fleets. This section summarizes some of these experiences.

Review existing bus fleets to determine which will provide the best return on investment for retrofit. An agency needs to consider factors such as age and mileage for each bus type within its fleet before deciding whether to install an electric cooling package. The older buses at an agency might not last long enough to benefit from a retrofit. Many agencies are electing to retrofit buses that have not passed the mid-point for expected life and are purchasing replacement buses with an electronic cooling package already installed.

Plan ahead to ensure the work can be completed within the desired timeframe. TriMet elected to retrofit the buses with in-house labor as opposed to contracting with an outside company. Because of a tight workforce, the agency was able to assign only one maintenance technician for the project.

TriMet reports that it took 8–15 hours to complete each retrofit. As a result, the retrofits for all the buses took about a year to complete.

Review the engine layout for each bus fleet to ensure that the cooling system manufacturer understands the plumbing necessary for retrofit. TriMet reports that it experienced some delays in the project because not all the buses had the same configuration of components within the engine compartment. Plumbing for the retrofit that was designed for one configuration would not work in all the buses. As a result, the agency had to have new plumbing and connections built for the other configurations.

Electric cooling retrofits can reduce the risk of fires and avoid costly repairs. Hydraulic fluid leaks on heated engine components can lead to fires. Electric cooling retrofits, such as the EMP MiniHybrid system, involve replacing the hydraulic system and large hydraulic fluid reservoirs in a bus. Transit agencies that have retrofit buses report lower maintenance costs because hydraulic systems require more time to maintain and to repair leaks. With a lower chance of hydraulic leaks, roadcall rates can also be reduced.

National Applicability

The EMP system, like other electric cooling systems, can be retrofitted on existing buses, which makes it a technology that is applicable to all transit agencies. These systems can be a cost-effective solution to increase efficiency and lower fuel and maintenance costs.

Project Contribution to TIGGER Program Goals

The TIGGER Program was instituted to promote energy saving and sustainable technologies to the transit industry by funding capital investments that would reduce GHG emissions or lower the energy use of public transportation systems. TriMet's TIGGER project contributed to those goals by saving more than 21,000 gallons of diesel fuel in the first year of operation. This fuel savings means 211 fewer tons of GHG emissions were released into the atmosphere—the equivalent of removing 37 cars from the road each year the fleet is operated. This equates to a savings of 9 lb CO_2^e per TIGGER dollar invested.

Bus Efficiency Case Study: Foothill Fast-Charge Electric Bus Project

Prepared by Leslie Eudy, Melanie Caton, and Matthew Post, National Renewable Energy Laboratory

Transit Agency: Foothill Transit
Location: West Covina, California
Award Amount: $10,170,000
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Background

Foothill Transit is a Joint Powers Authority comprising 22 member cities in the San Gabriel and Pomona Valleys and three appointees form the Board of Supervisors in the County of Los Angeles. Foothill Transit operates 300-plus buses on 33 fixed-route local and express lines, covers more than 300 square miles in the eastern Los Angeles County, and serves approximately 14 million customers each year.

Project Description

Building on an earlier ARRA-funded project, Foothill Transit will deploy a fleet of fast-charge electric buses to completely electrify line 291 that serves the cities of Pomona and La Verne. The agency currently has three electric buses and one fast-charge station located at the Pomona Transit Center, which is mid-way on Line 291. The TIGGER grant will add 12 more buses to the fleet.

Project Status

This project is in progress. At the April 26, 2013, Executive Board Meeting, Foothill Transit's Executive Board approved a sole-source procurement with Proterra LLC for 12 Ecoride electric buses. The Ecoride buses and charging equipment have decreased in cost per bus since the original bid, enabling the agency to purchase three additional buses. The all-electric buses are replacing 40-foot CNG buses that have reached or exceeded their useful lives. The new buses will be used on Line 291 as well as other local commuting service lines that can use the fast charging equipment at the Pomona Transit Center (PTC).

Foothill Transit has been monitoring its original three electric buses (funded through the U.S. Department of Transportation's TIGER program) from September 2010 through June 2012. Additional time was taken to monitor the buses following manufacturer upgrades to the equipment. Foothill Transit has received, inspected, and accepted all 12 buses. Three of these buses have been put into full revenue service on Line 291. The remaining nine buses are undergoing operating tests to ensure compliance standards are met before being deployed into revenue service.

The fast charging station equipment used for the installation at PTC uses Bluetooth wireless technology, which has presented some challenges for the buses. Wireless communication issues arising from heavily populated areas is a common problem. To resolve these issues in its current and future electric buses, Proterra will use Eaton-manufactured equipment to provide the charging technology.

Facility Efficiency Case Study: Cleveland Energy Conservation Project

Prepared by Leslie Eudy, Melanie Caton, and Matthew Post, National Renewable Energy Laboratory

Photo Courtesy of GCRTA

Transit Agency: Greater Cleveland Regional Transit Authority
Location: Cleveland, Ohio
Award Amount: $2,257,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Summary of Savings:

First Year Energy Savings: 33,313 MBtu
First Year Energy Cost Savings: $722,552
Projected Lifetime Energy Savings: 832,835 MBtu

Background

The Greater Cleveland Regional Transit Authority (GCRTA) provides transit services to Cleveland and surrounding communities in Cuyahoga County, Ohio. Its service area includes 458 square miles and 59 municipalities, with a population of 1.3 million. GCRTA maintains 492 buses for 70 fixed routes. It operates 21 vehicles that are part of the RTA HealthLine bus rapid transit system and 80 paratransit vehicles that provide more than 540,000 trips each year. GCRTA also manages rail service consisting of heavy rail, light rail, and a downtown trolley service. Overall, GCRTA makes 57.3 million passenger trips annually.

Because of the magnitude of its operations, GCRTA uses a large amount of energy; it is the second-largest energy user in the region. The agency is committed to sustainability with a goal of identifying ways to increase efficiency that will result in cost savings as well as create a healthier environment. To this end, the agency has taken steps such as washing buses at night after high peak electricity pricing, capturing water with rain barrels to reuse natural supplies when possible, adjusting air conditioning units for better efficiency, and recycling. Each year, the agency participates in the federal energy audit program to ensure it is operating at a high efficiency rate and to identify areas for improvement. As technology improves and funding becomes available, additional energy reductions and cost savings are realized through the use of this program.

During the summer of 2009, in response to the Demand Side management and Energy Efficiency Rider (DSE2) mandate,[23] GCRTA's Internal Audit Department began an inventory of its utility meters, 125 of which were electric utility meters. The agency hired an energy-consulting firm to assess its facilities and develop a comprehensive Energy Conservation Plan. C. J. Brown Energy, P.C. performed the energy audit for a cost of $77,545, which GCRTA paid for using its capital budget. The results of the assessments showed that GCRTA could potentially reduce its energy use by more than 31% by investing in energy efficient retrofits to its facilities. Eight buildings were selected for modifications that would give the greatest savings for the agency. The estimated payback time for the modifications was 4.5 years.

GCRTA was already planning for these energy reduction modifications when the TIGGER Program funding availability was announced. The TIGGER grant allowed GCRTA to accelerate its implementation plan and take advantage of bulk purchase prices. In addition, the agency was able to standardize the upgrades across the facilities, which will lower maintenance costs in the future.

Project Overview

GCRTA's energy audit found that more than 60% of energy use was occurring in 8 operation facilities. Lighting at these facilities accounted for 45% of the total energy consumption, which presented a prime opportunity for achieving maximum energy reductions with a short payback period through lighting upgrades. The building modifications included lighting retrofits, addition of lighting controls, a partial roof replacement, changes to building use patterns, and replacement of overhead doors. These energy upgrades were surveyed using Energy Conservation Measures to achieve the greatest energy savings at

[23] Ohio Senate Bill 221 set annual, cumulative efficiency standards to reach 22.2% reduction in energy consumption by 2025, http://www.legislature.state.oh.us/analysis.cfm?hf=analyses127/s0221-i-127.htm. The Ohio Public Utilities Commission approved the DSE2 Rider for Ohio utility companies to fully recover the cost of implementing these efficiency standards from customers.

the facilities while supporting long-term energy conservation goals. Table 8-7 provides an overview of the upgrades for each facility location. The Central Rail Maintenance Facility and Rail Service Building are combined because there is one utility meter for all buildings at that site.

Table 8-7

List of Upgrades for Each GCRTA Facility

GCRTA Facility	Summary of Upgrades
Central Bus Maintenance/Woodhill Garage	Lighting retrofit, controls, usage pattern change, and partial roof replacement
Harvard Bus Garage	Lighting retrofit and controls
Hayden Bus Garage	Lighting retrofit
Central Rail Maintenance Facility and Rail Service Building	Lighting retrofit, controls, and overhead door replacement
GCRTA Main Office	Lighting retrofit
Triskett Bus Garage	Lighting retrofit
Paratransit Bus Garage	Lighting retrofit and controls

The energy retrofits included replacing 6,417 lighting fixtures with new, more efficient fixtures and bulbs. Exchanging fluorescent magnetic ballasts for electronic ballasts and replacing incandescent bulbs with compact fluorescents or LED lighting provided better task lighting in some locations; in some cases, the lighting was brighter than needed and light levels were adjusted based on employee feedback. The use of natural lighting and improved control measures including motion sensors and timers further reduced energy consumption at the facilities. GCRTA was able to upgrade approximately 65% of the facility lighting using TIGGER funds. The facilities that received lighting upgrades were the highest priority projects identified by the audit as providing the highest savings with the best payback.

Technology Details

GCRTA used several types of upgrades to improve efficiency at its facilities. The primary modification was the lighting retrofit. The addition of controls and sensors helped maximize the savings. This section describes the technologies and benefits.

Efficient Lighting

Most of the lighting improvements were made by replacing older light fixtures with newer technology. The upgrades in the office areas involved replacing T-12 fluorescent luminaires using magnetic ballasts with T-8 fluorescent lights using electronic ballasts. The newer T-8 lamps provide more lumens per watt (efficacy). The light output of the T-8 fixtures does not degrade as much over time, which lowers maintenance costs, and the fixtures are smaller in diameter (1 inch versus 1.25 inch), allowing for more efficient use of reflective fixtures. The end result of these attributes is that more light is delivered to the task, with less energy expended over time. In the maintenance areas, the primary lighting source was high intensity discharge (HID) light fixtures that cast a yellow light. These fixtures took about 30 minutes to come up to full intensity and another 30 minutes to shut down. During the start-up and shut-down period, the light was not sufficient for working. These light fixtures were replaced with high intensity T-8 fixtures that are instant-on and instant-off. The majority of the upgrade did not require rewiring—the older fixtures were replaced with the new ones. In a few areas, the fixtures were relocated due to obstruction issues. The new fixtures all use standard four-foot fluorescent tubes; the number of tubes per fixture ranges from one to six depending on the amount of light needed for the area.

In the Energy Policy Act of 1992, the U.S. Department of Energy (DOE) put in place efficiency requirements for lighting. These requirements essentially prohibit installation of T-12 fixtures because they do not meet the new regulations.[24, 25] There are also T-5 fixtures, which are more efficient than T-8 fixtures in some respects; however, the cost/benefit tradeoffs do not always favor the more energy efficient T-5 device.

Natural Lighting

GCRTA incorporated natural lighting, also referred to as daylighting, in select areas with daylight-responsive electric lighting controls. The sensor lighting controls are designed to use electric lighting when low natural light conditions exist. A common area in the Hayden facility and skylights in the Central Rail Maintenance Facility both are leveraging daylighting in this manner.

Task Lighting and Motion Sensors

Several locations identified a potential benefit from motion sensor and timer controls—automatically turning the lights off in spaces when not in use. One example is a poorly-lit parts storage area, which received new lighting and controls that provide a well-lit space with sensor controls that turn the lights off when the area is not in use. Lavatories are another area where GCRTA installed motion sensors.

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[24] U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy lighting regulation fact sheet: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_fluorescent_factsheet.pdf.

[25] DOE report on the performance of T-12 and T-8 fluorescent lamps, report number PNNL-18076, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/troffer_benchmark_01-09.pdf.

Building Improvements

Thermal imaging identified moisture issues that had caused the insulation for the roof of the Woodhill Maintenance Garage to become compacted. To fix this problem, GCRTA replaced part of the roof and added new insulation that would be able to withstand any potential moisture issues. The thermal imaging also detected garage doors that were not well sealed in the Central Rail Maintenance Facility. To correct this issue, the agency installed new fast acting doors that improved the door seals and minimized the time the doors spent in the open position. These upgrades help reduce heat loss and therefore lower energy use in the space.

Project Results

All of the project work using TIGGER funds was completed by late 2011. GCRTA provided the utility data that was available for each of its facilities to NREL, which used these data to determine the energy savings achieved as a result of the building modifications. There are several project variables that introduce uncertainty into the calculations. For several of the facilities, the data prior to retrofit were limited to less than a year. NREL used the available data to project energy use for a full year before the project was completed. For these facilities, the results do not take into account any seasonal variations and the potential cost differences. Also, GCRTA was in the process of consolidating operations within and between facilities. The use of some facilities increased after the project was implemented. For other facilities, the operations were drastically reduced. These changes have an effect on facility energy use that is not directly attributed to the TIGGER project modifications. Another variable is the cost of electricity at the different facilities. GCRTA reports that its facilities are located in areas that are supplied by two different power companies, and the electricity rates vary between areas and from month to month. To normalize the cost savings estimates, NREL calculated the average cost per kWh for the year after retrofit for each facility and used that to determine the savings for each site.

The data analysis showed that GCRTA reduced the energy use in each of the facilities that were retrofit under the project. Table 8-8 summarizes the energy savings and estimated cost reductions for each facility.

Table 8-8

GCRTA Energy Conservation Project Annual Energy and Cost Savings by Facility

GCRTA Facility	Energy Savings, kWh	Estimated Cost Savings, $
Central Bus Maintenance / Woodhill Garage*	1,485,266	$129,918
Harvard Bus Garage*	552,770	$45,230
Hayden Bus Garage	1,190,006	$81,420
Central Rail Maintenance Facility and Rail Service Building*	4,869,906	$310,776
GCRTA Main Office	89,159	$7,904
Triskett Bus Garage*	1,427,423	$132,901
Paratransit Bus Garage*	143,154	$14,403
Total	*9,757,684*	*$722,552*

*Facilities with less than a year of "before" data.

Central Bus Maintenance/Woodhill Garage

The Central Bus Maintenance facility and Woodhill Division Garage are co-located at this site. The Central Bus Maintenance facility is a 30-year-old building that houses the major repair work for the agency. GCTRA upgraded the lighting from HID and T-12 fluorescent fixtures to more efficient T-8 fixtures. Lighting controls and occupancy sensors were also added to increase efficiency. The Woodhill Division facility was originally used as a bus garage, but the agency repurposed it because the layout was not set up well for moving buses through the daily process for transit operation. GCRTA moved other operations into the building and also consolidated several work areas to maximize use and reduce the total square footage that needed to be heated. GCRTA changed out the lighting fixtures to account for the new use of the building. The audit also identified a section of the roof that needed to be replaced. The analysis of the upgrades at these two buildings showed a 37% reduction in energy use.

Harvard Bus Garage

GCRTA closed the Harvard Bus Garage in 2010 and moved the operations to several other divisions. Even though the agency was not using the facility, it elected to complete the planned upgrades to make the building more attractive for leasing to another party. Because the building was empty, the upgrades were accomplished quickly. The agency upgraded the lighting and controls in the building. GCRTA provided 2 months of before and after data, which were used to project a full year of energy use. The analysis showed a 59% reduction in energy use.

Hayden Bus Garage

The Hayden Bus Garage facility is a major bus operating division and is in use 24 hours a day and 7 days a week. The agency replaced the old HID and T-12 fixtures with T-8 fixtures and added lighting controls. GCRTA provided a full year of data before and after the retrofit. The analysis showed an energy savings of 20%. Figure 8-7 shows the difference of the lighting quality in the maintenance area after the retrofit was completed.

Figure 8-7

Lighting in Hayden Bus Garage Before (left) and After (right) Retrofit

Photo Courtesy of GCRTA

Central Rail Maintenance Facility and Rail Service Building

The buildings at this location were lit primarily with HID lights in the maintenance areas and older T-12 fluorescent lights in the office areas. The agency replaced the lights in the office area with T-8 lamps and the lights in the maintenance area with high efficiency T-8 fixtures. Lighting controls were installed in areas that were not occupied continually. Two older overhead doors were also replaced to minimize heat loss in the Rail Service Building. Only 6 months of data were available for this location. The analysis projection for a full year of operations at this facility showed an energy reduction of more than 4.8 million kWh, a 21% reduction in energy use. GCRTA reports that this number is likely overestimated based on several site variables including weather differences and changing train patterns. The agency estimates the actual savings will be closer to 1.7 million kWh.

Figure 8-8

Updated Lighting in Central Rail Facility

Figure 8-9

Central Rail Facility Fast-Roll-Up Doors

GCRTA Main Office

The energy audit showed that the GCRTA Main Office was more efficient than the agency's other buildings because of previous retrofits. One item identified for improvement was a section of the office with can lighting in high-ceilinged areas. These can lights used compact fluorescent bulbs, but they were difficult to reach and highly labor-intensive to change. The agency replaced the bulbs with longer lasting, lower wattage LED bulbs. This simple change resulted in an energy savings of 4% based on the analysis of the data. GCRTA reports that this could be underestimated because the summer after the retrofit was unnaturally warm and humid, causing higher air conditioning use.

Triskett Bus Garage

The Triskett Bus Garage is GCRTA's newest bus division facility; however, the audit identified upgrades that could improve efficiency. The office areas were already equipped with T-8 lighting, but the maintenance area had HID lighting. The upgrade for this building focused on replacing the HID fixtures with T-8 fixtures. GCRTA provided 4 months of before and after data for this facility, and analysis showed a 23% energy savings.

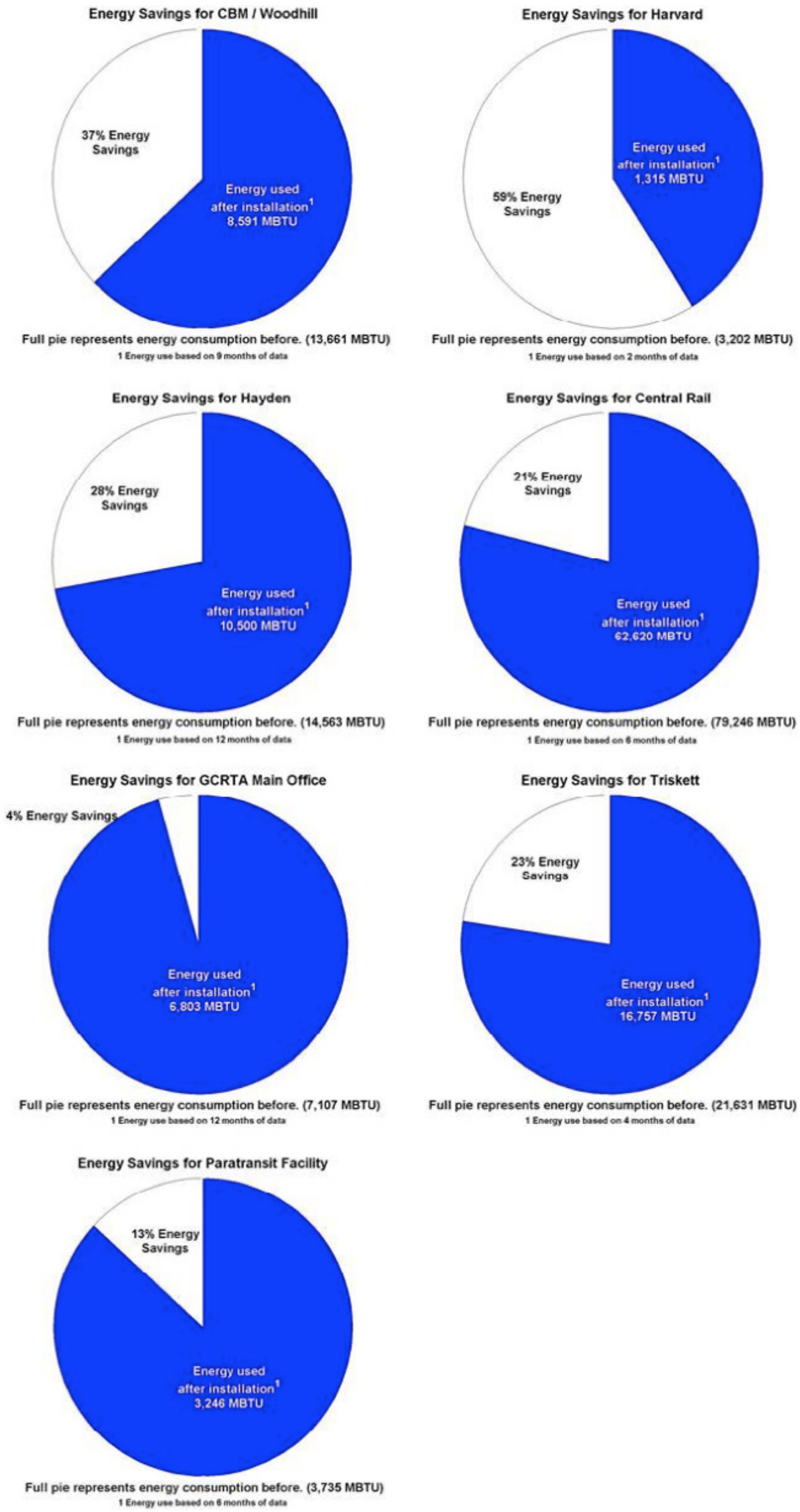
Paratransit Bus Garage

The Paratransit Bus Garage facility operates about 17 hours a day and 7 days a week. HID lighting fixtures in the maintenance area and in the office area were replaced with T-8 fixtures with lighting controls. The analysis included 6 months of data and showed a 13% reduction in energy use.

Figure 8-8 presents the savings graphically and illustrates the differences in savings from facility to facility.

Figure 8-10

Energy Savings for Each GCRTA Facility



GCRTA provided extensive documentation for the lighting upgrades that were analyzed and validated by NREL. The analyses showed that GCRTA was able to reduce energy use in all of its upgraded facilities, resulting in an overall energy savings of 23% for the project as a whole. Table 8-9 summarizes the total energy savings for the GCRTA project. The project resulted in an annual energy savings of more than 9.7 million kWh, which is equal to powering 865 homes for an entire year.[26] Figure 8-9 shows the energy savings graphically.

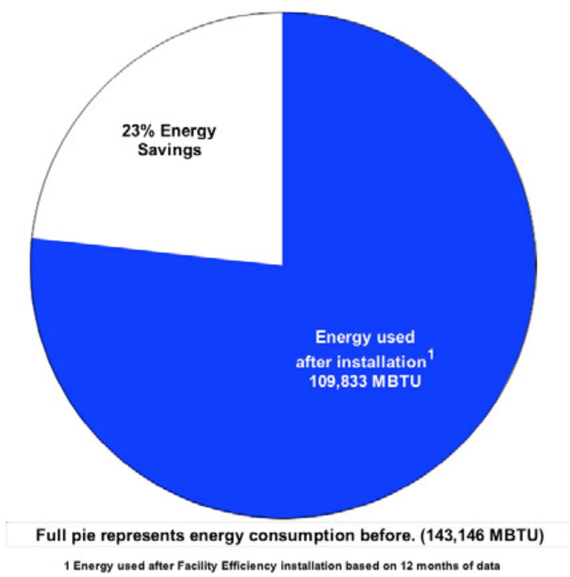
Table 8-9

Summary of Energy Savings for GCRTA TIGGER Project

	kWh	MBtu
Estimated Energy Savings	6,310,009	21,542
Actual Energy Use Before	41,929,152	143,146
Actual Energy Use After	32,171,467	109,833
Annual Energy Savings	9,757,685	33,313
Technology Lifetime (yrs)	25	25
Projected Lifetime Savings	243,942,116	832,818
Projected Lifetime Savings per TIGGER $	108.08	0.37

Figure 8-11

Annual Energy Savings for GCRTA Energy Conservation Project



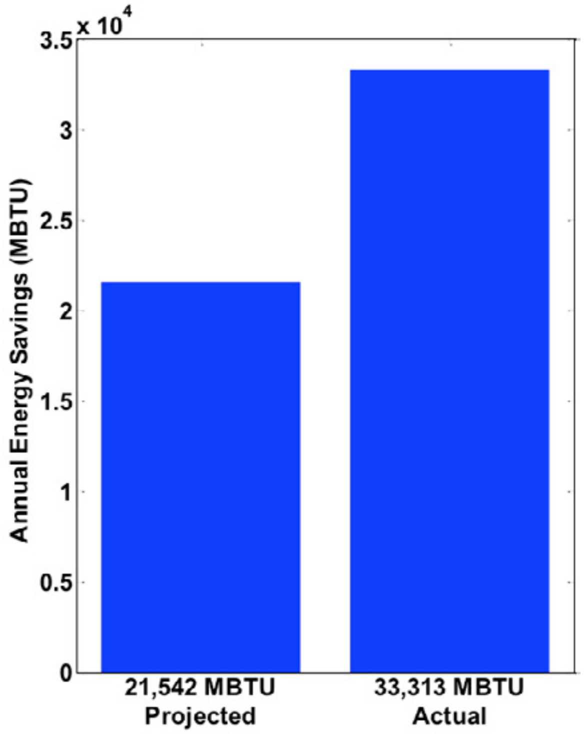
The 23% reduction in energy use exceeds the reduction mandated by DSE2, which exempts the agency from further reductions and brings it in compliance with the current mandate for 2025. Eight buildings received upgrades to achieve the greatest energy reductions with the available funding. After completing those upgrades, the agency was able to upgrade an additional building using the remaining TIGGER funds, increasing its energy savings over what was planned.

[26] Based on the EIA estimate of annual energy use in an average home in the United States in 2011 of 940 kWh.

Figure 8-10 compares the estimated energy savings with the actual energy savings for the first year of operation. The actual energy saved during the first year of operation was 55% higher than the estimate, making the GCRTA facility project one of the most successful projects to date. The actual annual energy savings is close to 9.7 million kWh, providing a cost savings of more than $722,000 in operation expenses.

Figure 8-12

Comparison of Annual Energy Used to Estimated Savings for GCRTA Energy Conservation Project



Project Experience and Lessons Learned

GCRTA reports that the project went well, and the resulting energy savings will have a positive impact on future budgets. The agency's experiences and lessons learned could help other agencies plan for similar upgrades. This section summarizes some of these experiences.

Conduct an energy audit to identify and prioritize improvements. The audit of the utility meters provided details regarding billing as well as consumption. GCRTA spent extra effort to understand the energy savings by reviewing the audit information and factoring in facility operations at each location. This empowered the agency to streamline and consolidate its use of facilities, specifically in high tariff areas. Understanding the billing and the suppliers involved in providing power needs is important when determining where to implement facility upgrades for the best impact on budget. Combining this knowledge with the annual federal energy audits can support continuous energy reductions and operational cost savings. The operational changes made by GCRTA resulted in increased personnel at some facilities, which reduced the expected energy savings for those locations. At other buildings, GCRTA was able to consolidate space and shut down sections, resulting in energy savings that were higher than expected if you factor in only the building modifications.

Lighting upgrades are cost-effective and improve working conditions. GCRTA identified facility lighting upgrades as providing the fastest return on investment. The energy audit found numerous locations using old HID lighting that not only used a lot of energy per square foot of floor space but also imposed difficulties in start-up time, which led to added energy usage and reduced productivity. GCRTA provided illuminance calculations indicating the light levels to be expected from the retrofit, information that often is neglected when the primary goal is energy reduction. The new lights improved lighting in critical task areas with a lower overall electrical usage. Many of the lighting upgrades provided instant-on lighting while also improving task lighting. In some places employees complained that the new lighting was too bright, so the agency replaced the light bulbs with lower wattage bulbs, further increasing savings. Sensor-based light switches were employed in areas that had intermittent use and daylighting upgrades. Additional lighting controls were used in other areas to automatically turn off the lights after working hours.

When selecting a contractor, go for best value as opposed to lowest bid. GCRTA developed a Request for Proposals for the lighting retrofit contract that included performance-based criteria and was to be scored for best value. The agency had a good idea from the audit of what was needed but asked for the bidders to suggest better ways to further improve efficiency. Potential contractors have an in-depth knowledge of the technology and the most recent advances in lighting efficiency improvements and could identify other modifications of which the agency might not be aware.

"Going big" with a project has its advantages. The agency planned to complete the facility upgrades over a span of time, doing one building retrofit each year based on the availability of funding. With its available budget at the time, GCRTA would have been able to complete about 22% of this project. However, due to the TIGGER grant, GCRTA executed the complete project, and energy savings are being realized now. Because the agency was able to complete the entire project in a short time period, it was able to standardize fixtures across all of its facilities. This will lower cost and reduce the number of different parts needed for inventory storage. The agency also was able to take advantage of bulk prices for fixtures and bulbs. Bulk prices for standard 4-foot fluorescent bulbs were less than $1 per bulb, while smaller lot prices were around $4 per bulb.

Longer-lasting light bulbs can save on labor costs. The project is also expected to result in lower maintenance costs over time. The newer bulbs last longer and, therefore, do not need to be changed as often. In addition, lights in the high-ceilinged maintenance areas are harder to reach and require more time and personnel for changing bulbs. In some cases, such as at the rail maintenance facility, changing bulbs requires a special rig to help workers reach the lights. This adds labor time and results in the need to shut down a maintenance bay during the process.

Planning for future technology changes can decrease costs even more. When selecting the fixtures for retrofit, the agency chose those that could also use LED bulbs. LED bulbs use even less energy than fluorescent bulbs, but currently they are much more expensive. By installing fixtures that can use either type of bulb, the agency can switch to the LED bulbs once the costs come down without having to change out the fixtures again.

National Applicability

This project has excellent applicability not only to the transit industry but to any industry that uses similar buildings. A lighting retrofit is often the first measure taken when reducing energy consumption because it is often the most cost-effective choice. This is especially true in older buildings; however, it frequently requires installing new light fixtures in addition to replacing the bulbs. It is helpful to do a little upfront research to determine what type of lighting is needed for the facility and evaluate the options available. Energy audits can be obtained a number of ways such as from consultants, utility companies, software packages, Web tools, and government entities in the energy sector. The Clinton Climate Initiative established the Energy Efficiency Building Retrofit Program[27] to provide support to building projects worldwide, including free energy efficiency master planning and project support. There are many resources available on the Office of Energy Efficiency and Renewable Energy[28] website that can provide useful information about retrofits and other energy reduction measures for a variety of building types. Project managers can explore available state and federal funding through the Database of State Incentives for Renewables and Efficiency.[29]

Project Contribution to TIGGER Program Goals

The TIGGER Program was instituted to promote energy saving and sustainable technologies to the transit industry by funding capital investments that would reduce GHG emissions or lower the energy use of public transportation systems. GCRTA's facility efficiency project contributed to those goals by saving

[27] http://www.presidentsclimatecommitment.org/resources/eebrp/.

[28] http://energy.gov/eere/buildings/improving-energy-efficiency-commercial-buildings.

[29] http://www.dsireusa.org/.

more than 9.8 million kWh in the first year of operation, the equivalent of powering 865 homes for a year. This equates to 4.32 kWh per TIGGER dollar invested.

Although GCRTA initiated its energy reduction project prior to the TIGGER award, the agency did not have funds available to complete all of the upgrades and would not have been able to upgrade all of the buildings as planned without the TIGGER funding. TIGGER allowed GCRTA to realize the benefits much earlier than planned. The annual cost savings realized from this project were $966,011 with a projected lifetime savings of $24,150,270. This project has an estimated payback period of 2.3 years with a return on investment of 970% and a per-TIGGER-dollar cost savings of $10.70.

Facility Efficiency Project: King Street Station Efficiency Improvements

Prepared by Leslie Eudy, Melanie Caton, and Matthew Post, National Renewable Energy Laboratory

Transit Agency: Seattle Department of Transportation
Location: Seattle, Washington
Award Amount: $2,555,344
Award Year: 2010
TIGGER Goal: Both energy and GHG emissions reduction

Background

The City of Seattle Department of Transportation (SDOT) is a multi-modal transportation agency responsible for roadways and bridges in the Seattle area. SDOT owns and operates two transit systems—Seattle South Lake Union Streetcar and Seattle Center Monorail—as well as the King Street Station. This station, built in 1906, is an historic train station that is a hub for commuter train, Amtrak, and buses.

Project Description

SDOT is using TIGGER funds to help restore King Street Station. This is a major reconstruction project funded by a variety of federal and state grants as well as a city levy that was initiated in 2008. Phase I of the restoration¬, replacement of the roof and refurbishment of the clock tower, was completed in 2011. The funding from TIGGER will go toward Phase II, which includes a number of technologies to improve efficiency and reduce energy use. Upgrades include an expansion of the geothermal heating/cooling system, insulation, efficient windows, and lighting upgrades.

Project Status

The restoration was completed in June 2013. The restoration will result in a significant increase in usable space in the facility. LEED certification and building commissioning activities are underway. SDOT is collecting data to submit for the detailed case study analysis that will be included in the next assessment report.

Renewable Energy–Solar Project Case Study: MARTA Laredo Bus Facility Solar Canopies

Prepared by Leslie Eudy, Melanie Caton, Matthew Post, and Nate Blair, National Renewable Energy Laboratory

Transit Agency: Metropolitan Atlanta Rapid Transit Authority
Location: Decatur, Georgia
Award Amount: $10,800,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Summary of Savings
First Year Energy Savings: 4,545 MBtu
First Year Energy Cost Savings: $78,223
Projected Lifetime Energy Savings: 106,553 MBtu

Background

The Metropolitan Atlanta Rapid Transit Authority (MARTA) is the ninth largest transit system in the United States. MARTA provides comprehensive fixed-route bus, heavy rail, and paratransit service, with nearly 500,000 passenger boardings each weekday. It serves as the backbone for the greater-Atlanta regional transit network. MARTA currently operates a fleet of 537 buses. The rail system consists of four lines with a total of 47.6 miles and 318 railcars serving 38 stations.

MARTA's commitment to sustainability and environmentally-conscious practices stretches back to the early 1990s. The agency joined with the city of Atlanta to form a coalition in 1993 and was the first 'clean city' designated by the U.S. Department of Energy. The bulk of MARTA's bus fleet is comprised of compressed natural gas buses. Since that time, the agency has implemented a number of programs to reduce energy use, lower emissions, and protect the local environment. Programs include:

- Promoting recycling at its facilities and transit and rail stops
- Instituting a no-idle policy
- Upgrading lights to lower-energy-use LED lights
- Installing motion detection sensor light switches to turn off the lights in areas when not in use
- Capturing and filtering water from the bus wash for reuse
- Collecting, filtering, and storing rain water to reduce the need for municipal water.

In response to the notice of funding availability for the FTA's TIGGER Program, MARTA developed a proposal to take on a major project to generate energy with a photovoltaic (PV) system at the Laredo Bus Facility. The agency's goals for the project were to generate energy to offset the power needs of the facility and to provide shading for the buses to reduce the need for excessive air conditioning during the hot summer months. Maximum monthly mean temperatures in the Atlanta region range from 82 to 96 degrees Fahrenheit during the summer months and can reach as high as 106 degrees.[30] Having a shaded area would not only keep the buses cooler, but would provide better working conditions for staff.

MARTA decided a design/build strategy would work best for the project because its staff did not have expertise in solar technologies. The agency released a request for qualifications to pre-qualify interested firms. From 12 original proposals, MARTA down selected 4 firms to submit full proposals, eventually awarding the contract to the team of New South LLC (engineering) and Circle D (construction).

Project Overview

MARTA constructed PV-integrated canopies on the bus storage lot at the Laredo Bus Operations and Maintenance Facility. The steel and concrete structures cover bus parking areas, protecting vehicles from sun and weather, and allow natural lighting during the day. The structure was designed with a minimum

[30] NOAA, National Climate Data Center, monthly temperature data from 2000 to 2013 for station COOP:090451 Atlanta Hartsfield International Airport, http://www.ncdc.noaa.gov/.

number of columns to allow buses to maneuver. The canopy lighting includes energy-efficient LED lamps to provide ample night lighting for safety and maintenance. Figure 8-11 shows the shaded parking area under the canopy.

Figure 8-13

Solar Canopy Provides Shaded Parking for MARTA Bus Fleet

The agency's project goals were to provide 1) power generation to offset energy use, 2) protection for the buses from the elements, 3) relief from the heat, and 4) lighting. MARTA reports that the construction went very well, although there were challenges that required active management by the project team. The agency began meetings with the local utility company, Georgia Power, early in the process to ensure there would be no issues with integrating the PV system into the electric grid. The older transformers at the site needed to be replaced with a bi-directional meter for net metering. During the day, excess electricity is exported to the grid. At night, MARTA imports electricity from the grid to meet power needs of the staff.

Because the Laredo facility was an existing operating facility, constructing a large canopy over the parking area created a logistical challenge. MARTA could not shut down the facility, so staff had to develop a plan to keep the bus operations moving while the construction was going on. The agency operates and maintains 262 buses out of this facility. The majority of the buses are parked in the outside lot when not in service or being maintained inside the facility. MARTA had to find a temporary solution for parking the buses during construction. The best option was to convert the employee parking lot to a temporary parking area for the buses (Figure 8-12). The pavement had to be repainted for efficient entry, exit, and parking for buses. Employees were asked to park in another off-site location. MARTA operated shuttle buses between this parking lot and the facility to bring the employees to work. The agency used its operation expense budget to pay the $500,000 cost for the temporary shuttle services. Two inspectors were employed to direct traffic and monitor progress.

Figure 8-14

Employee Parking Area Temporarily Repurposed for Buses during Construction

Technology Details

After a rigorous selection process, MARTA chose New South Construction and Circle D Enterprises to complete the project. A total of 4,903 solar panels were installed above the newly-constructed canopy at the bus maintenance facility, covering 855,557 square feet. The design called for 14 panels to be linked together and then wired back to a Smart Sub-Combiner box; 31 of these boxes were used to complete this project. The panels are tilted at a 2° angle and face south. The ideal angle for this latitude is 30°; however, to accommodate the canopy structure, it was not feasible to use the optimal tilt. Two stand-alone inverters were installed that are located on the east side of the canopies.

Suniva Solar Panels

The Suniva solar panels are rated to perform at a temperature range between 185°F and -40°F. Lightning protection was installed on the canopy system. The specifications for the Suniva panels installed at the facility are presented in Table 8-10. Maintenance is required for the panels as well as the electrical connections. The agency planned for the periodic cleaning of the panels and inspections of the wiring connections by strategically placing access panels in the canopy. A one-year maintenance contract with New South cost the agency $26,684 for the first year. They requested that staff be trained as part of this contract to provide the skill set needed to maintain the system internally in the future. The first-year contract was paid for using TIGGER funds; however, following years are expected to cost more due to inflation and will require funds from the operation budget. Maintenance of the system consists of checking the electrical and mechanical connections annually and washing the panels on an as-needed basis to ensure no debris collects on them because it minimizes the efficiency and production capability of the panels.

Table 8-10

Specifications of MARTA Solar Project

Solar System Specifications	
PV Manufacturer	Suniva
PV Panel Nameplate Power (W)	240
PV Area per Panel (sq ft)	17.45
Number of PV Panels Installed	4,903
Total PV Area (sq ft)	855,557
Panel Estimated Lifetime (yrs)	25

Smart Sub-Combiner

Thirty-one combiner boxes were installed in the canopy for this project. These boxes monitor the solar string currents as well as the temperature and send the information to the inverters. Each Satcon Smart Sub-Combiner accommodates the individual strings of solar panels on the canopy, can handle up to 10 amps of power, and does not require external power. The units operate in a temperature range from 131°F to -4°F and require less than 20 W of power, which is drawn from the solar array. Information collected from the arrays is sent to the inverter using a Modbus connection that sends the information electronically. The boxes have a natural convection cooling.

PowerGate Plus Inverters

Two inverters (pictured in Figure 8-13) used in the MARTA solar installation convert the DC power produced by the panels into three-phase AC power suitable for grid integration. They function independent of one another, minimizing any power loss due to malfunction of equipment or other issues that would cause power loss, and provide grounding for the solar array using a galvanized isolation transformer to ensure that the power being placed on the grid matches the specifications required by the Georgia Power utility grid. The PowerGate Plus 500 kW uses an open communication protocol that is compatible with third-party monitoring systems.

Figure 8-15

MARTA Solar Canopy Feeds Power Into Two Inverters

Remote System Monitoring

MARTA uses PV View® Plus software to monitor the performance of the solar system at the facility. Information from the system equipment is transmitted to the PV View server using a secure internet connection. This software allows for real-time remote monitoring of the power production and many other aspects of the system from MARTA's communication room at the facility. The weather station is pictured in Figure 8-14.

Figure 8-16

Installation includes Weather Station to Collect Additional Data for Determining System Performance

Project Results

The system installation was completed in March 2012; however, the agency had not worked out the final details in a net metering agreement with the local utility company. This agreement was in place by the end of March 2012, and data analysis begins with April. Table 8-11 provides a summary of the data results. The project resulted in an energy savings of more than 1.3 million kWh for the first year, a little over one-third of the agency's total electrical use. This equates to 4,545 MBtu, which is the equivalent of powering 118 homes for an entire year.[31] An average of 50,000 kWh of electricity was placed on the grid and sold back to the utility company through a net metering agreement.

[31] Based on the average energy use for a home in the continental U.S. during 2011 (EIA).

Table 8-11

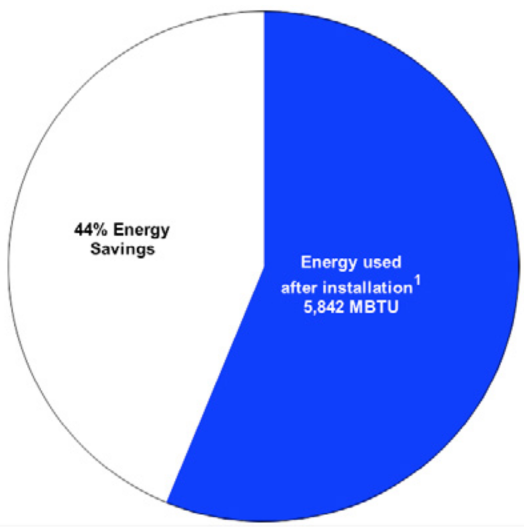
Summary of Energy Savings from MARTA Solar Project

	kWh	MBtu
Estimated Energy Savings	1,199,180	4,094
Actual Energy Use Before	3,042,604	10,387
Actual Energy Use After	1,711,238	5,842
Annual Energy Savings	1,331,366	4,545
Technology Lifetime (years)	25	25
Projected Lifetime Savings	31,210,689	106,553
Projected Lifetime Savings per TIGGER $	2.89	0.01

Figure 8-15 illustrates the annual energy savings for the project. The agency reduced its energy use by 44% over the previous year of operation. This resulted in a savings of $78,233 in electricity costs the first year of system operation.

Figure 8-17

Annual Energy Savings for MARTA Solar Project



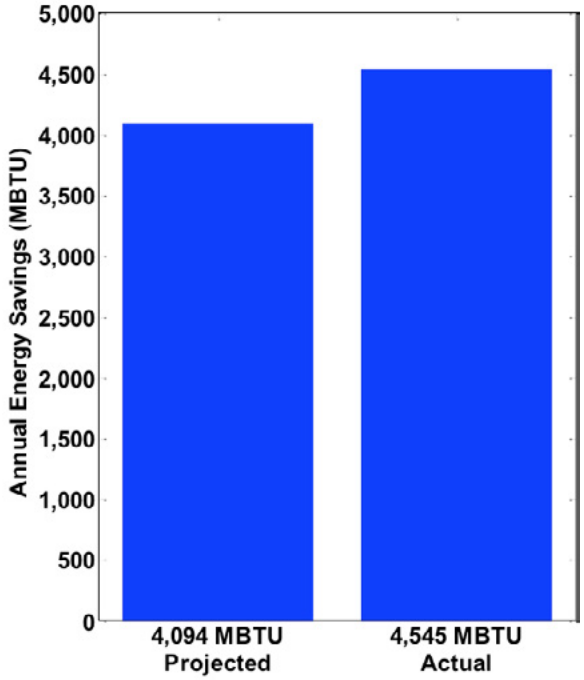
Full pie represents energy consumption before. (10,387 MBTU)

1 Energy used after Solar PV installation based on 12 months of data

Figure 8-16 provides a comparison of the estimated energy savings to the actual energy savings for the first year of operation. The energy savings during the first year of operation was 20% greater than the original savings estimate. The typical annual AC electrical output from this system is 1,192,793 kWh, which is what the projection was in the original estimate. A number of factors can have an impact on PV solar array performance such as the number of sunny days, shade patterns, debris accumulating on the panels, the efficiency of the inverters used, and many others. These factors should all be evaluated prior to installing a PV system.

Figure 8-18

Comparison of Annual Energy Savings to Estimated Savings for MARTA Solar Project



Project Experience and Lessons Learned

MARTA reports that the solar canopy continues to show energy savings. The agency would not have taken on the project if it had not received the TIGGER funding. The agency's experiences and lessons learned could help other agencies plan for adding PV systems to their facilities. This section summarizes some of these experiences and provides advice on what other transit agencies could do to facilitate a similar project.

Review similar projects to gain an understanding of what might be possible. MARTA staff researched the technology and reviewed available requests for proposals to find out what other organizations were asking for with respect to PV installations. The Internet was invaluable in conducting this research. The agency also worked with the PV manufacturer to develop specifications before going out to bid for the project.

Be rigorous in the pre-qualification and selection process for proposers. MARTA reports that the pre-qualification process helped weed out less qualified or less committed bidders. Once the bidders were down-selected to the most qualified, MARTA pulled together a diverse team to evaluate proposals. This team included staff from management as well as depot operations and maintenance. This ensured cooperation and good coordination between departments once the project was started.

Using a design/build process was the best option and had good payoff. In-house staff did not have the expertise in PV systems to determine what would meet the needs for the facility. During the selection process, MARTA could take advantage of the knowledge base of the proposers and select the best value for the work.

Keep communications open with internal stakeholders. Listening to internal stakeholder's needs and addressing them helped the project go smoothly.

Initiate discussions with utility companies and permitting officials early on to streamline the process. MARTA reports that its early coordination with Georgia Power was important to determine what the utility company needed to do to prepare the site for metering a large PV installation.

Select qualified in-house project management to ensure coordination between departments for an operating facility. Because the facility was operational, MARTA needed a strong manager and team to plan and coordinate the logistics between construction activities and bus operations. Keeping everyone at the facility informed was important to avoid confusion with changing conditions and procedures as construction progressed.

Plan for functionality. The agency reports that the canopy design featured several aspects that facilitate easy maintenance and convenience for staff. Access panels were built into the system to allow maintenance workers to easily clean the PV panels (see Figure 8 17). Several electric plugs were added in case power was needed for minor work in or around a bus under the canopy. LED lighting provided energy efficient light that was more uniform and covered the area better than the pole lighting used previously. The canopy support poles were spaced so that MARTA's buses could easily negotiate around and between them. MARTA even planned for the optimal turning radius of articulated buses, should the agency elect to add that type of buses to its fleet.

A scalable construction allows for future growth. MARTA had funding to cover half the available canopy space with PV panels. The installation included all the prep work and connections to complete the second half of the space. This will make it easy and more cost-effective for the agency to add on to the system.

Consider upgrading the monitoring software to provide long-term storage of data. Monitoring software systems often provide real-time data but do not store historical data on system performance. Access to historical data allows an agency to see how the system performs over time. Transit agencies could add an automatic back-up capability to the system, as MARTA did, or they could request that the installer include software to provide storage.

Figure 8-19

Solar Canopy Equipped with Access Panels to Facilitate Cleaning PV Panels

National Applicability

The project has a good national applicability for agencies in areas with high solar potential. Studies have been conducted to estimate the technical potential of solar and other renewable resources in the United States. In a recent NREL study, renewable energy technical potential is defined as the achievable energy generation of a particular technology given system performance, topographic limitations, environmental considerations, and land-use constraints.[32] (See http://www.nrel.gov/gis/maps.html for detailed maps showing the renewable energy potential for various energy technologies.)

Project Contribution to TIGGER Program Goals

The TIGGER Program was instituted to promote energy saving and sustainable technologies to the transit industry by funding capital investments that would reduce GHG emissions or lower the energy use of public transportation systems. MARTA's solar project contributed to those goals by saving more than 1.3 million kWh in the first year of operation, the equivalent of powering 118 homes for a year. This equates to 2.89 kWh per TIGGER dollar invested.

MARTA does not have state or local credits available for solar installations and would not have been able to install the PV system without the TIGGER funding. The annual cost savings realized from this project in the first year was $78,223, and the projected lifetime cost savings to the agency is $1,894,183. Using the TIGGER funding and the projected lifetime cost savings of the agency, the per-TIGGER-dollar cost savings is $0.18. The calculations do not include any cost share contributed to the project by the agency or tax credits. The TIGGER award was used to construct a large canopy area that also provides fuel savings due to minimizing idle time for the bus fleet, further increasing the value of the TIGGER dollars to the agency and achievement of the goals of the initiative. These cost savings were not accounted for in this analysis. However, NREL is working with MARTA to obtain these savings for inclusion in the next report.

[32] *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis Technical Report*, NREL/TP-6A20-51946, July 2012, http://www.nrel.gov/docs/fy12osti/51946.pdf.

Renewable Energy—Wind Project: MBTA Wind Energy Project

Prepared by Leslie Eudy, Robi Robichaud, Melanie Caton, and Matthew Post, National Renewable Energy Laboratory

Transit Agency: Massachusetts Bay Transit Authority
Location: Boston, Massachusetts
Award Amount: $2,500,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Estimated Energy Savings per Year: 1,105 MBtu
Estimated Lifetime Energy Savings: 22,104 MBtu

Background

Greater Massachusetts Bay Transportation Authority (MBTA) is a multi-modal transit agency operating in eastern Massachusetts. MBTA service includes subway, commuter rail, bus ferry, and trolley service.

Project Description

MBTA is constructing two wind turbines to provide a sustainable source of renewable energy. The first wind turbine, a Northwind 100 rated at 100 kW, is located at the Kingston station on the Plymouth Commuter Rail Line that serves 972 passengers each day. The turbine was produced by Northern Power Systems, which is headquartered in Barre, Vermont. The second wind turbine, a 600 kW machine, is slated to be installed next to the MBTA Right-of-Way near the Old Colony Correctional Center.

Rail Efficiency Project: Red Line Westlake Rail Wayside Energy Storage System

Prepared by Leslie Eudy, Melanie Caton, and Matthew Post, National Renewable Energy Laboratory

Transit Agency: Los Angeles County Metropolitan Transportation Authority
Location: Los Angeles, California
Award Amount: $4,466,000
Award Year: 2009 (Recovery Act)
TIGGER Goal: Energy reduction

Estimated Energy Savings per Year: 1,366 MBtu
Estimated Lifetime Energy Savings: 27,312 MBtu

Background

The Los Angeles County Metropolitan Transportation Authority (LACMTA) is the county-chartered, regional transportation planning and public transportation agency for Los Angeles County. LACMTA's 1,400-square-mile service area accounts for more than 9.6 million people—one third of California's residents. LACMTA's metro bus fleet of more than 2,000 vehicles transported 366 million passengers in 2010. Its metro rail system features more than 70 miles of track and 65 passenger stations along five service lines.

Project Description

LACMTA is installing a wayside energy storage system (WESS) at its Westlake station on the Red Line heavy rail. WESS technology uses a flywheel to capture and store the energy that is usually lost to resistors or friction when a train decelerates, and then it transfers that energy to a train as it starts or accelerates.

Project Status

This project is in progress. The initial invitation for bid was cancelled and reissued with an alternative scope. The new scope satisfies the objectives of the project and is within the budget. LACMTA is using in-house labor to support the installation of the system. The project has been delayed due to contract negotiations, procurements, and increased maintenance work. However, despite the challenges experienced during this project, LACMTA expects to have the system operational during the first quarter of 2015.

SECTION
9

Index of TIGGER Projects

Table 9-1 *TIGGER I Projects*

ID	Location	Project Name	Transit Agency	Category	Sub Category	Page #
D2009-TGGR-001	Montgomery, AL	MATS Hybrid Bus Project	Montgomery Area Transit System (MATS)	Bus	Hybrid	
D2009-TGGR-002	Oakland, CA	AC Transit Photovoltaic System Installation	AC Transit	Facility	Renewable—PV	
D2009-TGGR-003	Santa Clarita, CA	Santa Clarita Transit Solar Canopy	Santa Clarita Transit	Facility	Renewable—PV	
D2009-TGGR-004	Los Angeles, CA	Red Line Westlake Rail Wayside Energy Storage System	Los Angeles County Metropolitan Transportation Authority (LACMTA)	Rail	WESS	
D2009-TGGR-005	Oceanside, CA	NCTD PV Installation	North County Transit District (NCTD)	Facility	Renewable—PV	
D2009-TGGR-006	Denver, CO	Denver RTD Efficient Boiler at East Metro	Denver Regional Transportation District (RTD)	Facility	Upgrades	
D2009-TGGR-007	Boulder, CO	Denver RTD Efficient Boiler at Boulder	Denver Regional Transportation District (RTD)	Facility	Upgrades	
D2009-TGGR-008	Statewide, CT	CTTRANSIT Hybrid Bus and Stationary FC Installation	Connecticut Department of Transportation	Bus, Facility	Hybrid, Renewable—PV	
D2009-TGGR-009	Wilmington, DE	Delaware Solar Panel Project	Delaware Transit Corporation	Facility	Renewable—PV	
D2009-TGGR-010	West Palm Beach, FL	Palm Tran Thermal Motor Fan Retrofit	Palm Tran—Palm Beach County	Bus	Retrofit	
D2009-TGGR-011	Pompano Beach, FL	Broward County MiniHybrid Thermal System	Broward County Transit	Bus	Retrofit	
D2009-TGGR-012	Decatur, GA	Laredo Bus Facility Solar Canopies	Metropolitan Atlanta Rapid Transit Authority	Facility	Renewable—PV	

ID	Location	Project Name	Transit Agency	Category	Sub Category	Page #
D2009-TGGR-013	Ames, IA	Ames Transit Agency Hybrid Buses	Ames Transit Agency (CyRide)	Bus	Hybrid	
D2009-TGGR-014	Statewide, IL	IDOT Paratransit Hybrid Bus Program	Illinois DOT (IDOT) on behalf of seven transit agencies	Bus	Hybrid	
D2009-TGGR-015	Chicago, IL	CTA Outdoor Electric Power System	Chicago Transit Authority (CTA)	Facility	Upgrades	
D2009-TGGR-016	Moline, IL	Rock Island Solar Thermal System	Rock Island Metro	Facility	Renewable—PV	
D2009-TGGR-017	Champaign-Urbana, IL	Champaign-Urbana Geothermal HVAC System	Champaign-Urbana Mass Transit District (CUMTD)	Facility	Geothermal	
D2009-TGGR-018	Lafayette, IN	Greater Lafayette Wind Energy Project	Greater Lafayette Public Transportation Corporation	Facility	Renewable—Wind	
D2009-TGGR-019	Lowell, MA	Hale Street PV System	Lowell Regional Transit Authority	Facility	Renewable—PV	
D2009-TGGR-020	Several, MA	MBTA Wind Energy Project	Massachusetts Bay Transportation Authority (MBTA)	Facility	Renewable—Wind	
D2009-TGGR-021	Baltimore, MD	MTA Halon Replacement	Maryland Transit Administration (MTA)	Facility	Upgrades	
D2009-TGGR-022	Alpena, MI	Thunder Bay Plug-In Hybrid Buses	Thunder Bay Transportation Authority (TBTA)	Bus	Hybrid	
D2009-TGGR-023	Flint, MI	Flint Ultra-light Zero-Emission Buses	Flint Mass Transportation Authority	Bus	Zero-emission	
D2009-TGGR-024	St Paul, MN	Rainbow Rider Transit System Hybrid Bus Project	Minnesota Department of Transportation	Bus	Hybrid	

ID	Location	Project Name	Transit Agency	Category	Sub Category	Page #
D2009-TGGR-025	Minneapolis, MN	Minneapolis-St Paul Hybrid Buses	Metro Mobility Minneapolis-St. Paul Metropolitan Council	Bus	Hybrid	
D2009-TGGR-026	Charlotte, NC	Charlotte Hybrid Bus Project	City of Charlotte—Charlotte Area Transit System	Bus	Hybrid	
D2009-TGGR-027	Newark, NJ	NJT Efficient Air Compressors	New Jersey Transit (NJT)	Facility	Upgrades	
D2009-TGGR-028	Reno, NV	RTC Hybrid Bus Project	Regional Transportation Commission of Washoe County (RTC)	Bus	Hybrid	
D2009-TGGR-029	Albany, NY	CDTA Hybrid Bus Project	Capital District Transportation Authority (CDTA), Albany, New York	Bus	Hybrid	
D2009-TGGR-030	New York, NY	NYCT Remote Third Rail Heaters	New York City Transit (NYCT) Department of Subways	Rail	Controls	
D2009-TGGR-031	Cleveland, OH	Cleveland Energy Conservation Project	Greater Cleveland Regional Transit Authority	Facility	Upgrades	
D2009-TGGR-032	Eugene, OR	Lane Transit Hybrid Bus Project	Lane Transit District	Bus	Hybrid	
D2009-TGGR-033	Portland, OR	TriMet Bus Efficiency Improvement Project	Tri-County Metropolitan Transportation District of Oregon (TriMet)	Bus	Retrofit	
D2009-TGGR-034	Lancaster, PA	Red Rose Facility Improvement	Red Rose Transit Authority (RRTA)	Facility	Upgrades	
D2009-TGGR-035	Statewide, RI	Rhode Island Facility Lighting Conversion	Rhode Island Public Transit Authority	Facility	Upgrades	
D2009-TGGR-036	Chattanooga, TN	CARTA Facility Lighting Conversion	Chattanooga Area Regional Transportation Authority (CARTA)	Facility	Upgrades	

ID	Location	Project Name	Transit Agency	Category	Sub Category	Page #
D2009-TGGR-037	San Antonio, TX	VIA Fast-Charge Electric Bus Project	VIA Metropolitan Transit of San Antonio, Texas	Bus	Zero-emission	
D2009-TGGR-038	Arlington, VA	ART CNG Hybrid Bus Project	Arlington Transit (ART)	Bus	Hybrid	
D2009-TGGR-039	Everett, WA	Community Transit Hybrid Bus Project	Snohomish County Public Transit Benefit Area (Community Transit)	Bus	Hybrid	
D2009-TGGR-040	Wenatchee, WA	Link Transit Electric Bus Project	Link Transit	Bus	Zero-emission	
D2009-TGGR-041	Vancouver, WA	C-TRAN Facility Improvement	Clark County Public Transportation Benefit Area (C-TRAN)	Facility	Renewable—PV	
D2009-TGGR-042	Madison, WI	Madison Energy Efficient Lighting Project	Madison Metro Transit	Facility	Upgrades	
D2009-TGGR-043	Milwaukee, WI	Milwaukee Hybrid Vehicle Project	Milwaukee County Department of Transportation and Public Works	Bus	Hybrid	

Table 9-2 *TIGGER II Projects*

ID	City	Project Name	Transit Agency	Category	Sub Category	Page #
D2010-GGER-001	Anchorage, AK	Alaska Railroad Locomotive Upgrades	Alaska Railroad Corporation	Rail	Locomotive upgrades	
D2010-GGER-002	Oakland, CA	AC Transit Fuel Cell Power System	Alameda-Contra Costa Transit District (AC Transit)	Facility	Renewable—FC	
D2010-GGER-003	Ukiah, CA	Mendocino Solar Canopy Project	Mendocino Transit Authority	Facility	Renewable—PV	
D2010-GGER-004	West Covina, CA	Foothill Fast-Charge Electric Bus Project	Foothill Transit	Bus	Zero-emission	
D2010-GGER-005	Snowmass, CO	Colorado Daly Lane Facility Efficiency Improvement	State of Colorado, Snowmass Village	Facility	Upgrades	
D2010-GGER-006	Tallahassee, FL	Star Metro Electric Bus Project	City of Tallahassee	Bus	Zero-emission	
D2010-GGER-007	Honolulu, HI	Honolulu Turbine Hybrid Bus Project	City and County of Honolulu Department of Transportation Services	Bus	Hybrid	
D2010-GGER-008	Chicago, IL	IDOT Paratransit Hybrid Bus Program	Illinois Department of Transportation (IDOT)	Bus	Hybrid	
D2010-GGER-009	Chicago, IL	CTA Electric Bus Project	Chicago Transit Authority (CTA)	Bus	Zero-emission	
D2010-GGER-010	Chicago, IL	IDOT Locomotive Efficiency Project	Illinois Department of Transportation (IDOT)	Rail	Locomotive upgrades	
D2010-GGER-011	Louisville, KY	Union Station Energy Efficiency Improvements	Transit Authority of River City	Facility	Upgrades	
D2010-GGER-012	Fitchburg, MA	MART Renewable Energy Project	Montachusett Regional Transit Authority (MART)	Facility	Renewable—PV	
D2010-GGER-013	Baltimore, MD	Howard County Electric Bus Project	Maryland Department of Transportation	Bus	Zero-emission	

ID	City	Project Name	Transit Agency	Category	Sub Category	Page #
D2010-GGER-014	Detroit, MI	Cancelled				
D2010-GGER-015	Minneapolis, MN	Metro Transit Hybrid Bus Retrofit	Metropolitan Council (Metro Transit)	Bus	Hybrid	
D2010-GGER-016	Minneapolis, MN	Metro Transit Geothermal Project	Metropolitan Council (Metro Transit)	Facility	Geothermal	
D2010-GGER-017	Charlotte, NC	CATS Solar Power Project	City of Charlotte—Charlotte Area Transit System (CATS)	Facility	Renewable—PV	
D2010-GGER-018	Newark, NJ	NJT Energy Efficient Electric Switch Heaters and Controls for Rail	New Jersey Transit (NJT)	Rail	Controls	
D2010-GGER-019	Reno, NV	RTC Electric Bus Circulator	Regional Transportation Commission of Washoe County (RTC)	Bus	Zero-emission	
D2010-GGER-020	New York, NY	NYCT Wayside Energy Storage Project	New York State Metropolitan Transportation Authority/New York City Transit (NYCT)	Rail	WESS	
D2010-GGER-021	Cincinnati, OH	SORTA Bond Hill Division Facility Improvements	Southwest Ohio Regional Transit Authority (SORTA)	Facility	Upgrades	
D2010-GGER-022	Portland, OR	TriMet Light Rail On-Board Energy Storage System	Tri-County Metropolitan Transportation District of Oregon (TriMet)	Rail	On-board energy storage	
D2010-GGER-023	Harrisburg, PA	Pennsylvania Hybrid Transit Vehicle Project	PennDOT Bureau of Public Transportation	Bus	Hybrid	
D2010-GGER-024	Providence, RI	Rhode Island Public Transit Solar Project	Rhode Island Public Transit Authority	Facility	Renewable—PV	
D2010-GGER-025	Seattle , WA	King County Zero-Emission, Fast Charge Bus Project	King County Department of Transportation	Bus	Zero-emission	

ID	City	Project Name	Transit Agency	Category	Sub Category	Page #
D2010-GGER-026	Seattle, WA	King Street Station Efficiency Improvements	Seattle Department of Transportation	Facility	Upgrades	
D2010-GGER-027	Morgantown, WV	Mountain Line Transit Solar Power Plant	Monongalia County Urban Mass Transit Authority d/b/a. Mountain Line Transit Authority	Facility	Renewable—PV	

Table 9-3 *TIGGER III Projects*

ID	City	Project Name	Transit Agency	Category	Sub Category	Page #
D2011-GGER-001	Phoenix, AZ	Electric Fan Retrofit and Solar Canopy Project	Regional Public Transportation Authority	Bus, Facility	Retrofit, Renewable—PV	
D2011-GGER-002	Long Beach, CA	Long Beach Transit Zero Emission/All Electric Bus Pilot Project	Long Beach Public Transportation Company	Bus	Zero-emission	
D2011-GGER-003	Thousand Palms, CA	American Fuel Cell Hybrid Buses for SunLine Transit	SunLine Transit Agency	Bus	Zero-emission	
D2011-GGER-004	New Haven, CT	CTTRANSIT Stationary Fuel Cell Installation—New Haven Division	Connecticut Department of Transportation	Facility	Renewable—FC	
D2011-GGER-005	Pompano Beach, FL	Pompano Beach Green Station Demonstration	South Florida Regional Transportation Authority	Facility	Renewable—PV	
D2011-GGER-006	Chicago, IL	Locomotive Energy Efficiency Project	Commuter Rail Division of the RTA d/b/a Metra	Rail	Locomotive upgrades	
D2011-GGER-007	Baltimore, MD	Bus Electric Radiator Retrofit	Maryland Department of Transportation	Bus	Retrofit	
D2011-GGER-008	Rochester-Genesee, NY	Facility Efficiency Project	Rochester Genesee Regional Transportation Authority	Facility	Upgrades	
D2011-GGER-009	Philadelphia, PA	SEPTA's Wayside Energy Storage Project	Southeastern Pennsylvania Transportation Authority (SEPTA)	Rail	WESS	

ID	City	Project Name	Transit Agency	Category	Sub Category	Page #
D2011-GGER-010	Seneca, SC	Seneca Electric Bus Project	South Carolina Department of Transportation	Bus	Zero-emission	
D2011-GGER-011	Chattanooga, TN	Wayside Inductive Power Transfer System for Electric Buses	Chattanooga Area Regional Transportation Authority	Bus	Zero-emission	
D2011-GGER-012	McAllen, TX	On-line Electric Vehicle Bus Project	City of McAllen	Bus	Zero-emission	
D2011-GGER-013	Salt Lake City, UT	University of Utah Campus Shuttle Electrification	Utah Transit Authority	Bus	Zero-emission	
D2011-GGER-014	Blacksburg, VA	Blacksburg Transit Dynamic Bus Routing and Scheduling Study	Town of Blacksburg—Blacksburg Transit	Facility	ITS	
D2011-GGER-015	Randolph, VT	STSI Transit Facility Energy-Efficient Improvements	Vermont Agency of Transportation	Facility	Upgrades	
D2011-GGER-016	Wenatchee, WA	Link Transit Electric Bus Fleet Expansion	Link Transit	Bus	Zero-emission	
D2011-GGER-017	Seattle, WA	Central Link Light Rail On-board Energy Storage Project	Central Puget Sound Regional Transit Authority	Rail	On-board energy storage	

Table 10-1 *Conversion Factors Used in Calculating Energy and GHG Emissions*

Fuel or Energy Type	Units	Btu/unit	lb CO_2/unit
Diesel fuel	gal	128,450	22.1447
Gasoline	gal	116090	19.6658
E10 Ethanol	gal	112,114	16.9935
E85 Ethanol	gal	82,294	13.6669
E100 Ethanol	gal	76,330	12.6083
Compressed Natural Gas	scf	930	0.1194
Compressed Natural Gas	therms	100,000	12.8378
Compressed Natural Gas	gge	114,717	14.7272
Compressed Natural Gas	lb	20,268	2.6020
Liquefied Natural Gas	gal	74720	10.5497
Liquefied Petroleum Gas / Propane	gal	84,950	12.7467
B2 Biodiesel	gal	128,272	22.1235
B5 Biodiesel	gal	128,005	22.0916
B10 Biodiesel	gal	127560	22.0385
B20 Biodiesel	gal	126,670	21.9324
B50 Biodiesel	gal	124,000	21.6139
B80 Biodiesel	gal	121,330	21.2955
B100 Biodiesel	gal	119550	21.0832
Hydrogen	kg	113,724	0.0000
Hydrogen	scf	289	0.0000
Dimethyl Ether	gal	68,930	10.6251
Heating Oil	gal	128450	22.1447
Kerosene	gal	128,450	22.1447
M100 Methanol	gal	57,250	9.1123
Electricity	kWh	3,414	N/A

SECTION

11

List of Data Collected

All project partners were asked to submit one year of data prior to the installation of the new technology and one year of data after the new technology was operational for analysis. The data collected included the following.

General Site Information on All Projects

- Transit agency
- Location
- Project type
- Project implementation date

Building Efficiency Projects

Technologies Implemented

- Building envelope improvements
  - Wall R-value
  - Roof R-value
  - Window paning
  - Wall area insulated
  - Roof area insulated
  - Area of all windows
  - Insulation manufacturer
  - Insulation type
  - Insulation thickness
  - Window manufacturer
  - Window frame type
  - Window glass type
  - Window purge gas
- HVAC
  - Heat source fuel type
  - Heat source type
  - Heat source efficiency
  - Heat source size
  - Heated area
  - Summer temperature setpoint–day time

- Summer temperature setpoint–night time
- Winter temperature setpoint–day time
- Winter temperature setpoint–night time
- AC efficiency
- AC size
- Cooled area (if different from heated area above)
- Management control system
- Waste heat used
- Waste heat temperature

• PV installations
- PV manufacturer
- PV panel nameplate power
- Panel efficiency rating
- PV area per panel
- Number of PV panels installed
- Total PV area
- Peak power rating
- Inverter efficiency rating
- Total system efficiency
- Warranty
- Panel estimated lifetime

• Wind turbine
- Turbine manufacturer
- Model number
- Nameplate capacity
- Hub height
- Rotor diameter
- Total height
- Maximum rotation speed
- Rated wind speed
- Efficiency rating
- Warranty
- Turbine estimated lifetime

• Lighting upgrades
- Lighting manufacturer
- Light power per fixture

  - Light luminous flux
  - Light specific luminous flux
  - Light cost per fixture
  - Lighting utilization
  - Number of fixtures
  - Light type
  - Estimated light lifetime
- Door replacements
  - Door manufacturer
  - New door opening time
  - Door area
  - Time door remains open
  - Approximate number of opening events per day
  - Indoor temperature

Electricity Use

- Date/month
- Electricity consumed
- Electricity sold to grid
- Cost per unit
- Demand charge

Heating Fuel Use:

- Date/month
- Fuel type
- Amount consumed
- Cost per unit

Maintenance/Repairs Associated with the Technology:

- Date of service
- Type of service
- Description of work
- Cost

Bus Efficiency Projects

- Specifications for replaced and new vehicles
  - Bus OEM, model, year
  - Length, weight, height

- Number of seats/standees
- Fuel used
- Technology type
- Engine OEM, model, rated power
- Technology manufacturer
- List of vehicles replaced
- List of new vehicles

• Fueling records for replaced and new vehicles for one year
  - Date
  - Fuel type
  - Odometer reading
  - Fuel amount
  - Fuel cost

• Maintenance records for replaced and new vehicles for one year
  - Date
  - Work order number
  - Bus number
  - Odometer
  - Work description
  - Vehicle system
  - Labor hours
  - Labor cost
  - Part
  - Part quantity
  - Part cost
  - Work type (scheduled, unscheduled, road call)

The Halon project was analyzed using weight measurements of the material that was replaced.

ACRONYMS

AESS	automatic engine start-stop
AFCB	American Fuel Cell Bus
APS	auxiliary power system
ARRA	American Recovery and Reinvestment Act of 2009
ARRC	Alaska Railroad Corporation
ART	Arlington Transit
BCT	Broward County Transit
BRT	bus rapid transit
BT	Blacksburg Transit
CAT	Clemson Area Transit
CATS	Charlotte Area Transit System
CARTA	Chattanooga Area Regional Transportation Authority
CDTA	Capital District Transportation Authority
CETE	Center for Energy, Transportation, and the Environment
CHP	combined heat and power
CMF	Central Maintenance Facility (AC Transit)
CMRT	Central Maryland Regional Transit
CNG	compressed natural gas
CO_2e	carbon dioxide equivalent
CT	Community Transit
CTA	Chicago Transit Authority
CTE	Center for Transportation and the Environment
C-TRAN	Clark County Public Transportation Benefit Area
CTTRANSIT	Connecticut Transit
CUMTD	Champaign-Urbana Mass Transit District
DTC	Delaware Transit Corporation
EIA	U.S. Energy Information Administration
EMP	Engineered Machined Products
EMSS	Energy Management Storage Unit
EO	executive order
EPA	Environmental Protection Agency
FC	fuel cell
FCEB	fuel cell electric bus
FTA	Federal Transit Administration
FY	fiscal year
GCRTA	Greater Cleveland Regional Transit Authority
GHG	greenhouse gas
GLPTC	Greater Lafayette Public Transportation Corporation
GWP	global warming potential
HLA	hydraulic launch-assist
HVAC	heating, ventilation, and air conditioning
IDOT	Illinois Department of Transportation
ITS	intelligent transportation systems
kW	kilowatt

LACMTA	Los Angeles County Metropolitan Transportation Authority
LBT	Long Beach Transit
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LRTA	Lowell Regional Transit Authority
LRV	light rail vehicle
LTD	Lane Transit District
MARTA	Metropolitan Atlanta Rapid Transit Authority
MART	Montachusett Regional Transit Authority
MATS	Montgomery Area Transit System
MBTA	Massachusetts Bay Transportation Authority
MBtu	million British thermal units
MCTS	Milwaukee County Transit System
MTA	Maryland Transit Administration
Flint MTA	Mass Transportation Authority (Flint, Michigan)
MTA	Mendocino Transit Authority
NCTD	North County Transit District
NJT	New Jersey Transit
NOFA	notice of funding availability
NREL	National Renewable Energy Laboratory
NYCT	New York City Transit
ODP	ozone depletion potential
OEM	original equipment manufacturer
OMC	Operations and Maintenance Center
PEM	proton exchange membrane (fuel cell)
PV	photovoltaic
RFP	request for proposals
ROI	return on investment
RRTA	Red Rose Transit Authority
RIPTA	Rhode Island Public Transit Authority
RGRTA	Rochester-Genesee Regional Transportation Authority
RTC	Regional Transportation Commission of Washoe County
RTD	Regional Transportation District (Denver)
SCC	Social Cost of Carbon
SCT	Santa Clarita Transit
SDOT	Seattle Department of Transportation
SEPTA	Southeastern Pennsylvania Transportation Authority
SFRTA	South Florida Regional Transportation Authority
SMART	Suburban Mobility Authority for Regional Transportation
SOFC	solid oxide fuel cell
SORTA	Southwest Ohio Regional Transit Authority
STSI	Stagecoach Transportation Services, Inc.
TARC	Transit Authority of River City
TBTA	Thunder Bay Transportation Authority

TIGER	Transportation Investment Generating Economic Recovery
TIGGER	Transit Investments for Greenhouse Gas and Energy Reduction
TMF	Transit Maintenance Facility
TriMet	Tri-County Metropolitan Transportation District of Oregon
UTA	Utah Transit Authority
UV	ultraviolet
VTM	Variable Torque Motors
WESS	wayside energy storage system

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