Appendix 5

Center for Climate Strategies (CCS)
Analysis of Potential Greenhouse Gas Emission Reductions and Costs of Supporting Recommendations and Related Actions

Center for Climate Strategies
Helping States and the Nation Tackle Climate Change

Analysis of Potential Greenhouse Gas Emission Reductions and Costs of Supporting Recommendations and Related Actions for New Jersey

New Jersey Department of Environmental Protection
and the Center for Climate Strategies
November 2009

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Acronyms and Abbreviations

\$/kWh	dollars per kilowatt-hour
\$/MtCO_2e	dollars per million metric ton of carbon dioxide equivalent
\$/tCO_2e	dollars per metric ton of carbon dioxide equivalent
AASHTO	American Association of State Highway and Transportation Officials
AEO2008	Annual Energy Outlook 2008
ANL	Argonne National Laboratory
APTA	American Public Transportation Association
ARB	[California] Air Resources Board
BAU	business as usual
BBtu	billion British thermal units
Btu	British thermal unit
C	carbon
CA LEV	California Low Emission Vehicle Program
CAFE	corporate average fuel economy
CCS	Center for Climate Strategies
CESA	Clean Energy and Security Act of 2009
CH_4	methane
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CWNS	Clean Watershed Needs Survey
DCA	New Jersey Division of Codes and Standards
EGU	Electricity Generating Unit
EIA	Energy Information Administration [US DOE]
EMP	New Jersey Energy Master Plan
EPA	[United States] Environmental Protection Agency
FTA	United States Federal Transit Administration
GB	Green Buildings
GB	Green Buildings
GHG	greenhouse gas
GREET	Greenhouse gases, Regulated Emissions and Energy use in Transportation [model]
GSPT	Garden State Preservation Trust

GWP	global warming potential
GWRA	New Jersey Global Warming Response Act
HDV	heavy-duty vehicle
HFC	hydrofluorocarbon
HOT	High Occupancy Toll
HOV	high-occupancy vehicle
HWA	Federal Highway Administration (US DOT)
ICC	International Code Council
IECC	International Energy Conservation Code
IGCC	integrated gasification combined cycle
IPM	Integrated Planning Model
km	kilometer
kWh	kilowatt-hour
LCFS	low-carbon fuel standard
LDAR	Leak Detection and Repair
LDV	light-duty vehicle
LEED	Leadership in Energy and Environmental Design [Green Building Rating System™]
LFG	landfill gas
LPG	liquefied petroleum gas
metric ton	1,000 kilograms or 22,051 pounds
MG	million gallons
MGD	million gallons per day
MM	million
MMBtu	millions of British thermal units
MMT	million metric ton
$MMtCO_2e$	million metric tons of carbon dioxide equivalent
MRF	Materials recovery facility
MSW	municipal solid waste
$MtCO_2e$	metric tons of carbon dioxide equivalent
MW	megawatt [one thousand kilowatts]
MWh	megawatt-hour [one thousand kilowatt-hours]
NETL	National Energy Technology Laboratory [US DOE]
NG	natural gas
NGCC	natural gas combined cycle
NJDEP	New Jersey Department of Environmental Protection
NPV	net present value

NRC	National Research Council
NYSERDA	New York State Energy Research and Development Authority
NYSERDA	New York State Energy Research and Development Authority
ODS	ozone-depleting substance
POTWs	Publicly Owned Wastewater Treatment Works (Plants)
R/AC	refrigeration and air conditioning
RCA	Recycling Enhancement Act
RCI	Residential, Commercial, and Industrial [Technical Work Group]
RGGI	Regional Greenhouse Gas Initiative
RPS	renewable portfolio standard
SEM	structural equation modeling
SFMTA	San Francisco Municipal Transportation Agency
SI PHEV	spark ignition plug-in hybrid electric vehicles
SOCCR	First State of Carbon Cycle Report (2007)
SOTA	State of the Art
t	metric ton
T&D	transmission and distribution
tCe	tons of Carbon equivalent
tCO_2	metric tons of carbon dioxide
tCO_2e	metric tons of carbon dioxide equivalent
tCO_2e/MWh	metric tons of carbon dioxide equivalent per megawatt-hour
TCRB	Transit Cooperative Research Program
TDM	travel demand management
TLU	Transportation and Land Use [Technical Work Group]
TRB	Transportation Research Board
TRU	trailer refrigeration unit
TS	Terrestrial Carbon Sequestration
TSE	truck stop electrification
TSM	Transportation System Management
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
VISION	Voluntary Innovative Sector Initiatives: Opportunities Now Program [US DOE]
VMT	vehicle miles traveled
WARM	WAste Reduction Model [US EPA]
WWTP	wastewater treatment plant
yr	year

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Chapter 1
Introduction and Overview

Introduction

New Jersey's Global Warming Response Act (GWRA) requires the state to reduce greenhouse gas (GHG) emissions to 1990 levels by 2020 (about a 24% reduction below estimated 2020 business-as-usual (BAU) emissions on a gross emissions, consumption basis). The Act also sets a long-term goal for New Jersey to further reduce statewide emissions to 80% below 2006 levels by 2050.[1] The State of New Jersey has adopted several core recommendations needed for the State to meet its 2020 statewide GHG emission limit. The State also has underway a number of additional "related actions" which together with the core recommendations will help ensure early emission reductions to set the state on a path toward achieving its long-term goal. However, the state recognizes the need to identify and adopt additional measures to provide further assurance that it will achieve its 2020 goal and to keep the state on course to meet its 2050 goal. Thus, New Jersey has identified several "supporting recommendations" that, if fully implemented, will provide assurance that the State will achieve its 2020 limit on its way to meeting its 2050 limit.

This report presents the results of an assessment of the GHG emission reductions and costs or cost savings associated with supporting recommendations and additional related actions identified by New Jersey on the basis of data availability. The supporting recommendations were analyzed incrementally to the core recommendations and related actions adopted by New Jersey for the following sectors:

- Residential and Commercial Energy Use (i.e., Green Buildings [GB]);
- Waste Management;
- Industrial Sector – Highly Global Warming Gases;
- Terrestrial Carbon Sequestration (TS) by Forestry and Agriculture;
- Transportation and Land Use (TLU); and
- Electricity generation.

For the electricity generation sector, the recommendation to establish a minimum carbon dioxide (CO_2) emissions performance standard was analyzed but not included in the overall results because it is considered a potential implementation mechanism for securing emission reductions under the Regional Greenhouse Gas Initiative (RGGI). The remainder of this chapter provides a summary of the analytical results for each of the supporting recommendations and related actions and describes the overall analytical framework for the analysis. Chapters 2 through 7 of this report provide details on the analytical design parameters, data sources, methods, assumptions, and results for the recommendations and actions analyzed for each sector; for completeness, actions with GHG reduction potential but without incremental costs were included in the detailed economic analyses as though they were being implemented solely to achieve GHG reductions;

[1] Taking initiative on a statewide level, Governor Jon S. Corzine signed the Global Warming Response Act (GWRA) (P.L. 2007, c.112) on July 6, 2007. This new law embodies the proactive and ambitious limits for the reduction of GHG emissions in New Jersey that were set forth previously in the Governor's Executive Order 54.

however, such actions are not included in the summary monetary figures presented in the current chapter.

The remainder of this introductory chapter provides a brief overview of the emission reductions associated with New Jersey's core recommendations followed by summaries of the results for the related actions and supporting recommendations analyzed and the overall methodology and guidelines applied to quantify the GHG emission reductions and costs or cost savings for the related actions and supporting recommendations.

Core Recommendations – Summary of Emission Reductions

The emission reductions associated with the core recommendations serve as the starting point for quantification of the related actions and supporting recommendations; therefore, the following provides a brief overview of the core recommendations. Table 1.1 lists the core recommendations that New Jersey has adopted for each sector. These core recommendations will enable New Jersey to meet its near-term statewide GHG reduction goal to reduce GHG emissions to 1990 levels by 2020. Several of these core recommendations also represent the most cost-effective methods for reducing GHG emissions in the state and will achieve significant savings through more efficient use of energy by residential, commercial, and industrial buildings and fuel by on-road vehicles.

Table 1.1. Core Recommendations – Net Annual GHG Emission Reductions in 2020

Core Recommendation	Sector	Net Annual GHG Reductions in 2020 ($MMtCO_2e$)*
Whole-building energy efficiency	Green buildings	11.7
California Low Emission Vehicle (CA LEV) Program	Transp./land use	10.0
Regional Greenhouse Gas Initiative (RGGI)	Electricity gen.	8.5
Wind power	Electricity gen.	5.9
Appliance standards	Green buildings	1.9
Imported electricity – Renewable Portfolio Standard (RPS)	Electricity gen.	1.9
HERS70 building code	Green buildings	1.6
Photovoltaics	Electricity gen.	1.3
2006 IECC building code upgrade	Green buildings	0.9
Biofuels combustion	Electricity gen.	-1.4
Combined heat and power (net)	Green buildings	-4.4
Total		**37.8**

* The negative values in the last column of this table represent net GHG emissions increases.

Additional Related Actions - Summary of Emissions Reductions

In additional to the core recommendations, New Jersey has underway a number of related actions that were not expressly designed for GHG reduction purposes but that are expected to produce such reductions as an added benefit. Table 1.2 summarizes the emissions reductions projected for these measures. Because the GHG reductions are not the express purpose of these measures, the marginal monetary costs or benefits of these measures are not included in our summary of the monetary impacts of the supporting recommendations.

Table 1.2. Related Actions – Net Annual GHG Emission Reductions in 2020

Additional Related Action	Sector	Net Annual GHG Reductions in 2020 ($MMtCO_2e$)*
Increase recycling rate to 70% from 50%	Waste management	5.00
Improve landfill gas management	Waste management	0.19
Increase recycling rate to 50%	Waste management	2.61
Preserve additional green infrastructure	Terrestrial sequestration	0.75
Adopt forest stewardship legislation	Terrestrial sequestration	0.03
Encourage low-carbon goods movement	Transportation & land use	1.40
Good state of road repair/maintenance	Transportation & land use	0.01
Double public transit ridership	Transportation & land use	0.65
Total		**10.64**

Because these actions were implemented for purposes other than GHG reduction, the marginal cost of such reductions is technically zero. However, they are expected to contribute to New Jersey's ability to surpass its 2020 GHG reduction goals on the way to meeting its 2050 goals.

Supporting Recommendations - Summary of Results

A total of 11 supporting recommendations were analyzed; 7 of the recommendations mitigate GHG emissions, 3 of the recommendations are designed to sequester carbon, and one recommendation represents a potential implementation mechanism under RGGI. The analytical results for each supporting recommendation reflect incremental GHG emission reductions and costs (or savings) relative to New Jersey's core recommendations and related actions. Each of the supporting recommendations was evaluated for potential overlap with other supporting recommendations within the same sector as well as with other sectors and adjusted to remove potential double-counting of emission reductions and costs (or cost savings). Table 1.3 provides a summary of the estimated GHG emission reductions and net costs (or savings) associated with the supporting recommendations analyzed for each sector after adjusting for overlaps. Table 1.4 shows the estimated GHG emission reductions and net costs (or savings) for each of the supporting recommendations and the adjustments for overlaps made for the TLU and electricity generation sectors.

Table 1.3. Supporting Recommendations - Estimated GHG Emission Reductions and Net Costs (or Cost Savings) by Sector (Adjusted for Overlaps)

Sector / No. Supporting Recommendations Analyzed[1]	Annual Results (2020)		Cumulative Results (2009-2020)		
	GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
Green Buildings (Residential and Commercial) / 2 Recommendations	3.9	-$285	22	–$1,176	-$53
Highly Warming Gases (Commercial & Industrial) / 1 Recommendation	1.05	-$1.3	9.4	-$14	-$1.5
Waste / 1 Recommendation	0.4	-$89	2.0	-$483	-$238
Terrestrial Carbon Sequestration (Agriculture & Forestry) / 3 Recommendations	0.37	$38.2	2.03	$244	$120
Transportation and Land Use (TLU) / 3 Recommendations	10.14	$109	51.9	-$3,558	-$69
Totals	**15.85**	**-$228**	**87.3**	**-$4,987**	**-$57**

[1] The results for the one measure analyzed for the electricity sector are excluded from Table 1.3 because its emission reductions and costs would otherwise be double counted under RGGI. See Table 1.4 for the estimated impacts associated with this supporting recommendation.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Costs are discounted to year 2009 in 2007 dollars using a 3% real discount rate. Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings. The values shown in the Cost-Effectiveness column are calculated by dividing the value in the Cost column by value in the GHG Reduction column; these values represent the weighted average cost-effectiveness of the Supporting Recommendations within each sector after adjusting for overlaps between the measures and with recent actions (i.e., for the waste sector).

The order of the sectors presented in this table does not reflect or imply prioritization of the sectors based on the results presented in this table.

Table 1.4. Supporting Recommendations - Estimated GHG Emission Reductions and Net Costs (or Cost Savings) by Recommendation (Adjusted for Overlaps)

Sector / Supporting Recommendation	Annual Results (2020)		Cumulative Results (2009-2020)		
	GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)
Green Buildings (Residential and Commercial)					
GB-1 (new buildings)	1.7	-$68	9.8	-$299	-$30
GB-2 (existing buildings)	2.1	-$217	12.2	-$877	-$72
Highly Warming Gases (Commercial & Industrial Refrigeration and Air Conditioning)					
HWG-E (LDAR for refrigerants)	1.1	-$1.3	9.4	-$14	-$1.5
Waste Management					
W-1 (POTW anaerobic digesters)	0.4	-$89	2.0	-$483	-$238
Terrestrial Carbon Sequestration (Agriculture & Forestry)					
TS-3 (no net loss of forest land) *	0.004	$2	0.021	$11.1	$520.3
TS-4 (urban forest cover requirement) *	0.35	$36	1.9	$231	$121.6
TS-7 (sustainable agriculture)	0.019	$0.2	0.11	$1.88	$16.4
Transportation and Land Use					
TLU-1 (low- and zero-emission	4.52	$825	20.8	$2,861	$138
TLU-2 (low-carbon fuels)	4.53	$991	21.7	$3,728	$171
TLU-5 (reduce vehicle miles traveled)	3.41	-$1,445	20.5	-$9,598	-$469
Electricity Generation					
EGU-1 (performance standard for electricity generating units)	1.4	$75.6	4.7	$162	$35
Grand Total Before Adjusting for Overlaps	19.5	$109.5	103.1	-$4,276	-$42
Adjustments (Subtractions) for Overlaps	-$3.68	-$337.6	-15.8	-$711	NA
TLU overlaps with CA LEV	-2.32	-$262	-11.1	-$549	NA
EGU-1 overlaps with RGGI	-1.4	-$75.6	-4.7	-$162	NA
Grand Total After Adjusting for Overlaps	**15.85**	**-$228**	**87.3**	**-$4,987**	**-$57**

* Figures reflect costs and cost savings through 2020 only; actual costs and savings extend well beyond 2020.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; POTW = Publicly Owned Treatment Works; LDAR = leak detection and repair; NA = Not applicable.

Costs are discounted to year 2009 in 2007 dollars using a 3% real discount rate. Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above supporting recommendations is for reference purposes only; it does not reflect prioritization among these recommendations.

Figure 1.1 presents a graphical summary of the potential cumulative emission reductions associated with the core and supporting recommendations relative to the BAU reference case projections for New Jersey.

- The blue line shows actual (for 1990, 1995, 2000, and 2004) and projected (for 2010, 2015, and 2020) levels of New Jersey's gross GHG emissions on a BAU basis. This consumption-based approach accounts for emissions associated with the generation of electricity in New Jersey to meet the state's demand for electricity.
- The red line shows the projected emissions associated with the implementation of the core recommendations described in Table 1.1.
- The green line shows the projected emissions if all of the recommendations and related actions are implemented and the estimated reductions are fully achieved.
- Projected emissions associated with New Jersey's statewide GHG reduction targets are shown by the black line.

Figure 1.1. Annual GHG Emissions: Reference Case Projections and Core and Supporting Recommendations (consumption basis, gross emissions)

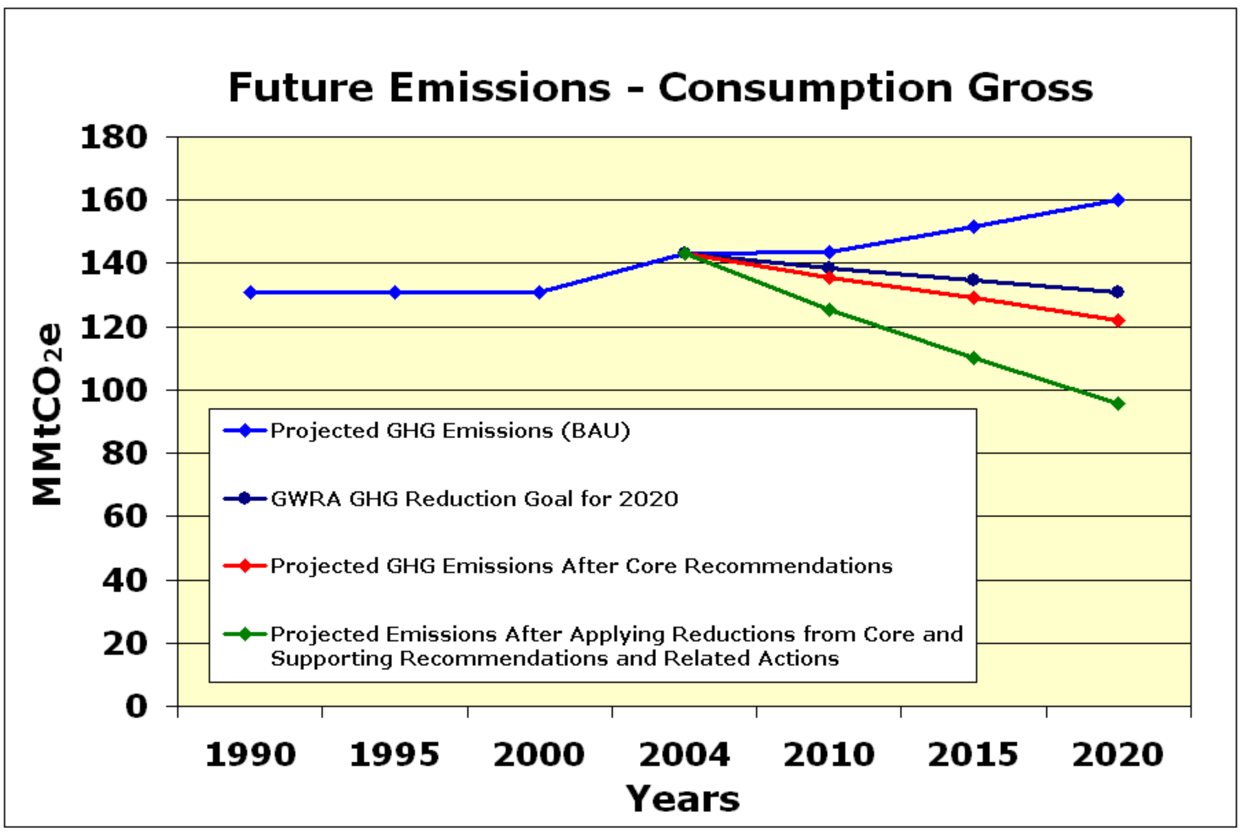

Table 1.5 provides the numeric estimates underlying Figure 1-1. In summary, if all of the core recommendations are fully implemented and achieve all of the GHG reductions projected, then New Jersey will be able to over-achieve its statewide GHG emissions reduction goal of 5% below 1990 levels by 8.7 $MMtCO_2e$ (6.6% below 1990 levels). Should the core measures not fully achieve their projected emission reduction levels, the related actions and supporting

recommendations will provide reductions by 2020 to ensure that New Jersey meets its 2020 goal. The related actions and supporting recommendations will also place the state well on its way toward achieving its long-term goal to further reduce statewide emissions to 80% below 2006 levels by 2050. Analysis of the related actions and supporting recommendations indicates that if fully implemented they have the potential to reduce GHG emissions by an additional 26.5 $MMtCO_2e$ in 2020. By 2020, emission reductions associated with both the core and supporting recommendations and the related actions would place New Jersey at 27% below 1990 levels and 33% below 2006 levels.

Table 1.5. Annual emissions: Reference Case Projections and Impact of Recommendations and Related Actions (consumption basis, gross emissions)

Consumption Basis - Gross Emissions	1990	1995	2000	2004	2010	2015	2020
Projected GHG Emissions (BAU)	130.8	130.8	130.8	143.3	143.4	151.6	159.9
Reductions from NJ's Core Recommendations							37.8
Projected GHG Emissions After Core Recommendations				143.3	135.5	129.0	122.1
GWRA GHG Reduction Goal for 2020				143.3	138.5	134.5	130.8
Total GHG Reductions from Supporting Recommendations and Related Actions							26.5
Projected Emissions After Applying Reductions from NJ's Recommendations and Related Actions				143.3	125.3	110.3	95.6
Percent below 1990 Levels							27%
Amount of Emissions Reduction Below GWRA Goal							35.1

It is important to note that, to yield these emission reductions from the core and supporting recommendations and the related actions, implementation must be timely, aggressive, and thorough. Evaluation of key factors such as cost-effectiveness, economic impacts, and harmonization with other New Jersey programs and policies will be critical to effective implementation of these recommendations and actions.

Overall, the supporting recommendations are projected to result in a net *benefit* of approximately \$228 million *in 2020* (about \$14/tCO_2e of emissions reduced, on average) after adjusting for overlaps and interactions between the supporting and core recommendations and related actions. Over the *entire* period of analysis (2009-2020), the supporting recommendations are projected to result in a net *cost* of about \$1.57 billion or, on average, about \$18/tCO_2e of emissions reduced.

As shown in Tables 1.3 and 1.4, net cost savings are attributed to improving the efficient use of (1) energy by existing and new residential and commercial buildings, (2) highly warming gases used in commercial and industrial refrigeration, (3) waste products in the waste sector, and (4) reduction in vehicle miles traveled in the transportation sector. Cumulative net costs are attributed to the supporting recommendations for managing forest and agricultural lands as carbon sinks and other transportation recommendations. For the recommendations designed to maintain and enhance carbon sequestration, some investment is required to acquire and manage lands while the emission reduction benefits are not significantly realized for several years past 2020. Thus, the constraint of the analysis period significantly understates the long-term benefits of these recommendations which are needed to keep New Jersey on its path toward meeting its long-term GHG reduction goal by 2050.

For the transportation sector, the costs associated with increasing the use of low- and zero-emission vehicles and low-carbon fuels in New Jersey are estimated incremental to the California low-emission vehicle (CA LEV) standards that New Jersey has adopted as a core recommendation. These standards include both tailpipe emission standards as well as requirements to improve the corporate average fuel economy (CAFE) of the on-road vehicle fleet. The net effect of these two supporting recommendations is that the net cost-effectiveness of electric vehicle and low-carbon fuels strategies is higher than the CAFE and state clean car tailpipe standards already adopted by New Jersey and also higher than potential additional incremental vehicle efficiency improvements.

Overall Methodology and Guidelines for Quantifying Supporting Recommendations

The following explains the overall methodology and guidelines applied to quantify the GHG emission reductions and costs / cost savings for the supporting recommendations. This overall methodology was then customized to incorporate specific design parameters and data sources for each supporting recommendation analyzed based on information provided by New Jersey Department of Environmental Protection (NJDEP) and other New Jersey State agencies. Due to time and resource constraints, it was not possible to incorporate all costs and benefits associated with the recommendations analyzed. To the extent possible, direct costs / cost savings were quantified. The sector-specific chapters included in this report provide details on how the following overall methodology was customized to quantify GHG emission reductions and costs / cost savings for each recommendation.

- Cost-Effectiveness: Because the monetized dollar value of GHG reduction benefits for New Jersey is not available, physical benefits are used instead, measured as dollars per $MMtCO_2e$ (cost per ton) or "cost-effectiveness" evaluation. Both positive costs and cost savings (negative costs) are estimated as a part of compliance cost.
- Focus of analysis: Net GHG reduction potential in physical units of million metric tons (MMt) of carbon dioxide equivalent (CO_2e) and net cost per metric ton reduced in units of dollars per metric ton of carbon dioxide equivalent ($\$/MtCO_2e$). Where possible, full life cycle analysis is used to evaluate the net energy performance of actions (taking into account all energy inputs and outputs to production). Net analysis of the effects of carbon sequestration is conducted where applicable.
- Geographic inclusion: Measure GHG impacts of activities that occur within New Jersey, regardless of the actual location of emissions reductions.
- Direct vs. Indirect Effects: Define "direct effects" as those borne by the entities implementing the recommendation. For example, direct costs are net of any benefits or savings to the entity. Define "indirect effects" as those borne by the entities other than those implementing the recommendation. For the quantification of the supporting recommendations, the following lists indirect cost and/or benefits that were not generally quantified due to time and resource constraints:
    - Re-spending effect on the economy

- Net value of employment impacts
    - Net value of health benefits/impacts (except for TLU-5 and TLU-6)
    - Higher cost of electricity reverberating through the economy
    - Energy security
    - Health benefits of reduced air and water pollution
    - Ecosystem benefits of reduced air and water pollution
    - Value of quality-of-life improvements
    - Value of improved road safety (except for TLU-5 and TLU-6)
    - Value of net environmental benefits/impacts (value of damage by air pollutants to structures, crops, etc.)
    - Net savings on the embodied energy of materials used in buildings, appliances, equipment, relative to standard practice
    - Improved productivity as a result of an improved working environment, such as improved office productivity through improved lighting (though the inclusion of this as indirect rather than direct might be argued in some cases)

- <u>Non-GHG (external) impacts and costs:</u> Include in qualitative terms where deemed important. Quantify on a case-by-case basis as needed depending on need and where data are readily available.

- <u>Discounted and "Levelized" Costs:</u> Discount a multi-year stream of net costs (total costs net of any savings) to arrive at the "net present value cost" of a recommendation. Discount costs in constant 2007 dollars using a 3% annual real discount rate for the period 2009 through 2020. Capital investments are represented in terms of levelized or amortized costs through 2020. Create a "levelized" cost per ton by dividing the "present value cost" by the cumulative reduction in tons of GHG emissions. This is a widely used method to estimate the "dollars per ton" cost or cost savings of reducing GHG emission (all in CO_2e). A "levelized" cost is a "present value average" used in a variety of financial cost applications.

- <u>Time period of analysis:</u> Count the impacts of actions that occur during the project time period and, using levelized emissions reduction and cost analysis, report emissions reductions and costs for 2020. Where additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, show these for comparison and potential inclusion.

- <u>Aggregation of cumulative impacts of recommendations:</u> In addition to "stand alone" results for each recommendation, estimate cumulative impacts of all recommendations combined. In this process avoid simple double counting of GHG reduction potential and cost when adding emission reductions and costs associated with all of the recommendations. Note and/or estimate interactive effects between recommendations using simple analytical methods where overlap is likely.

- <u>Recommendation design specifications and other key assumptions:</u> Include assumptions on timing, goal levels, implementing parties, types of implementation mechanism, and other key assumptions as determined by New Jersey.

- Transparency: Clearly identify recommendation design choices (above) as well as data sources, methods, key assumptions, and key uncertainties. Use data and comments provided by New Jersey to ensure best available data sources, methods, and key assumptions using their expertise and knowledge to address specific issues in New Jersey. Modifications will be made through decisions with New Jersey technical experts, as needed, to improve analysis.

All projections of future emissions, costs, and cost savings are subject to uncertainty, the key source of which is the uncertainty associated with the data inputs and assumptions. Due to constraints on time and resources, we elected to present point estimates of the future values of emissions, costs and cost savings, and other factors rather than attempt to do a formal uncertainty analysis. It should also be noted that our results are in the nature of projections rather than forecasts, the difference being that the former trace out the logical effects of given assumptions on the future, while the latter make explicit predictions about future states of affairs. New Jersey's future emissions reductions, costs, and cost savings will probably differ from those portrayed in this report, and the differences could be significant. Nonetheless, we believe that our results provide a reasonable basis for decision making, especially when taken as indicators of direction of change (increase or decrease), algebraic sign (positive or negative), and order of magnitude.

For additional reference see the economic analysis guidelines developed by the Science Advisory Board of the US EPA available at:
http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html.

Chapter 2
Green Buildings for the Residential and Commercial Sectors

Introduction

Two supporting recommendations for implementing "Green Building" initiatives to mitigate direct-energy use and GHG emissions by the residential and commercial sectors were analyzed for their emission reductions and costs / savings. The two recommendations are designed to be incremental to core recommendations included in New Jersey's Energy Master Plan (EMP). The recommendations analyzed include:

- GB-1 - Develop and facilitate the use of a State Green Building Standard for all New Residential and Commercial Buildings through existing and emerging state programs; and
- GB-2 - Develop and facilitate State Green Building Remodeling, Operations and Maintenance Program for all Existing Residential and Commercial Buildings through existing and emerging state programs.

Table 2.1 summarizes the estimated GHG emission reductions and costs (savings) for each recommendation. The remainder of this chapter provides information on the parameters for analysis, methods, data sources, and assumptions used to prepare the analysis for each of the supporting recommendations.

Table 2.1. Estimated GHG Emission Reductions and Net Costs (or Cost Savings)

No.	Supporting Recommendation Name	Annual Results (2020)		Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
GB-1	Green Buildings – New	1.73	-$68	9.84	-$299	-$30.4
	Residential (Subtotal)	1.38	-$54	7.84	-$239	-$30.4
	Commercial (Subtotal)	0.35	-$14	2.00	-$61	-$30.4
GB-2	Green Buildings – Existing	2.14	-$217	12.17	-$877	-$72.0
	Residential (Subtotal)	1.72	-$176	9.77	-$711	-$72.8
	Commercial (Subtotal)	0.42	-$41	2.40	-$165	-$69.0
Sector Total (No adjustments for overlaps needed)		**3.87**	**-$285**	**22.0**	**-$1,176**	**-$53.4**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Costs are discounted to year 2009 in 2007 dollars using a 3% real discount rate. Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above recommendations is for reference purposes only; it does not reflect prioritization among the recommendations.

Design of Recommendations

For new buildings (GB-1), the goal is for the State of New Jersey to develop and facilitate the use of a State Green Building Standard for all New Residential and Commercial Buildings through existing and emerging state programs. In anticipation of the release of the New Jersey's Green Building Manual in the Summer of 2010, which will be used by State agencies to identify specific actions to incorporate into regulatory and / or incentive-based programs to facilitate new and existing green buildings, the next 18 months will be used to build capacity in the emerging green building industry in New Jersey.

For existing buildings (GB-2), the goal is for the State of New Jersey to develop and facilitate State Green Building Remodeling, Operation, and Maintenance Programs for all Existing Residential and Commercial Buildings through existing and emerging state programs. In anticipation of the release of the New Jersey's Green Building Manual in the Summer of 2010, which will be used by State agencies to identify specific actions to incorporate into regulatory and / or incentive-based programs to facilitate new and existing green buildings, the next 18 months will be used to build capacity in the emerging green building industry in New Jersey.

Analytical Approach and Data Sources

A spreadsheet model developed to analyze a similar policy for the state of Maryland was modified to incorporate New Jersey-specific data sources and assumptions to estimate GHG emission reductions, costs and cost savings, and the cost-effectiveness of the green building recommendations for New Jersey.[2] The modifications to the spreadsheet model include the following:

Emission Reductions:

- The timing and level of future building codes were determined.
- The compliance rate of new and renovated homes and buildings to the new building codes was assumed.
- Total energy savings from the new building codes were computed based on the number of participating buildings, average energy use per building, and energy saving rates resulted from the new building codes.
- The total energy savings were broken out by electricity and natural gas.
- The GHG emission reductions were calculated by using the emission factors of electricity and natural gas.

Savings:

- This is computed by multiplying energy savings of electricity and natural gas by the avoided delivered cost of electricity and natural gas, respectively, and then adding them together.

[2] The spreadsheet model is based on the model developed to analyze the impacts associated with RCI-1 (Improved Building and Trade Codes and Beyond-Code Building Design and Construction in the Private Sector) adopted by the Maryland Climate Change Commission and included in the Maryland Climate Action Plan, see Appendix D-3 for details, August 2008, http://www.mde.state.md.us/assets/document/Air/ClimateChange/Appendix_D_Mitigation.pdf.

Costs:

- Average construction cost of a New Jersey home or commercial building was calculated.
- The incremental costs for new and renovated buildings from future building code improvements as percentages of the average construction cost were assumed.
- The total incremental costs were computed by multiplying the costs for an individual building by the total number of participating buildings.

The analyses of the "Green Building" recommendations are designed to be incremental to the building codes policy in the New Jersey's EMP. Table 2.1 shows the energy efficiency goals of the improved building codes in the EMP and the incremental goals included in the analysis of GB-1/GB-2.

Table 2.1. Energy Efficiency Goals of Improved Building Codes in New Jersey Energy Master Plan and in GB-1/GB-2

	New Jersey 's Energy Master Plan	GB-1/GB-2	LEED
New (vs. Code)	30%	10-20% (incremental to EMP)	40-50%
Existing (vs. actual)	20%	10-20% (incremental to EMP)	30-40%

Table 2.2 presents the key assumptions used to compute the emission reductions and associated savings. Table 2.3 presents the key assumptions used to compute the costs.

Table 2.2. Key Assumptions for the Calculation of Emission Reductions and Associated Savings

Assumption	Residential Sector	Commercial Sector	Notes
Number or total square feet of new homes/buildings	314,109 (2009-2020 cumulative)	158,334,633 (2009-2020 cumulative)	Residential buildings: the total "housing units authorized by building permits for new construction" in 2007 from the New Jersey Division of Codes and Standards (DCA) website (http://www.state.nj.us/dca/codes/) is used as the base year value. The numbers of new residential buildings in the forecast years are projected based on the population growth rate of New Jersey. Commercial buildings: the total square feet of new office space and retail space authorized by building permits in 2007 from the New Jersey DCA website is used as the base year value. The total square feet of new commercial buildings in the forecast years are projected based on the population growth rate of New Jersey.
Ratio of new vs. renovated homes/buildings	1.00	1.00	Assumption used in Maryland;
Building code compliance rate	100%	100%	Assumption provided by New Jersey DCA
Number or total square feet of new homes/buildings participating in building code updates	314,109 (2009-2020 cumulative)	158,334,633 (2009-2020 cumulative)	Calculated by multiplying the number or total square feet of new homes/buildings by the building code compliance rate.
Number of renovated homes/buildings participating in building code updates	314,109 (2009-2020 cumulative)	158,334,633 (2009-2020 cumulative)	Calculated by multiplying the number or total square feet of renovated homes/buildings by the building code compliance rate.
Average square footage per new/renovated building	2,438	18,339	Residential: 2008 national average square footage. Commercial: calculation of projected square footage of buildings divided by the projected number of buildings for the Middle Atlantic Region.
Average energy use for a new/renovated home/building under current building code	106,645 Btu/sq. ft./year	131,875 Btu/sq. ft./year	Residential: average residential energy use per household (from EMP) divided by average square footage per home. Commercial: average level between 2009 and 2020 (from EMP).
Percentage difference between the energy use in the new homes/buildings constructed under the current code and the average energy use in all the existing building stock.	20%	16%	Adopted the data used in the Maryland Climate Action Plan which are calculated using Gulf Coast studies on building codes.

Assumption	Residential Sector	Commercial Sector	Notes
Energy savings goals for improved building code	2010: 10% energy savings incremental to EMP 30% (new) and 20% (existing) goal 2015: 20% energy savings incremental to EMP 30% (new) and 20% (existing) goal	2010: 10% energy savings incremental to EMP 30% (new) and 20% (existing) goal 2015: 20% energy savings incremental to EMP 30% (new) and 20% (existing) goal	Assumptions provided by New Jersey Department of Environmental Protection (NJDEP).
Proportion of energy savings by fuel type	37.5% Electricity 62.5% Natural gas	37.5% Electricity 62.5% Natural gas	The percentages are computed based on the data provided by NJDEP.
Emissions factors	Electricity average (2008–2020): 0.569 tCO_2e/MWh, or the equivalent in (tCO_2/BBtu), Natural Gas: 54 tCO_2e/Bbtu		Electricity: provided by NJDEP. Natural Gas: EPA 2003 U.S. GHG inventory, Appendix A
Transmission and distribution (T&D) electricity loss	7%		Assumption for New Jersey provided by NJDEP.
Avoided energy costs (utility avoided costs)	Electricity: $28,375/BBtu (2007$) Natural Gas: $7,514/BBtu (2007$)	Electricity: $26,766/BBtu (2007$) Natural Gas: $7,744/BBtu (2007$)	The data used in the Maryland Climate Action Plan are adjusted by the ratio of delivered electricity and NG prices in Maryland and New Jersey.

Table 2.3. Key Assumptions for the Calculation of Costs

Assumption	Residential Sector	Commercial Sector	Notes
Real Discount Rate	3%		Assumption provided by NJDEP.
Capital Recovery Factor for Levelization	4.95% Interest rate: 3% Period: 30 years	4.95% Interest rate: 3% Period: 30 years	Calculated based on assumed interest rate and levelization period. The Capital Recovery Factor is used to generate equal annual capital costs.
Average Construction Cost of Home/Building	$319,698/home	$155.5/sq. ft.	Average cost per Sq. Ft. is based on national estimates from ICC and adjusted by the ratio of New Jersey to national average weekly wage in the construction sector. Average construction cost of a home is computed by multiplying the average cost per Sq. Ft. by the average square footage per home.
Incremental Costs from Building Code Improvements (as percentage of the construction cost of a Home/Building)	Existing: 2010: 2% (corresponding to 10% incremental energy savings to EMP 20% goal) 2015: 2% (corresponding to 20% incremental energy savings to EMP 20% goal) New: 2010: 2% (corresponding to 10% incremental energy savings to EMP 30% goal) 2015: 4% (corresponding to 20% incremental energy savings to EMP 30% goal)	Existing: 2010: 2% (corresponding to 10% incremental energy savings to EMP 20% goal) 2015: 2% (corresponding to 20% incremental energy savings to EMP 20% goal) New: 2010: 2% (corresponding to 10% incremental energy savings to EMP 30% goal) 2015: 4% (corresponding to 20% incremental energy savings to EMP 30% goal)	Adopted the data used in the Maryland Climate Action Plan, which are based on the incremental costs of LEED levels with equivalent energy savings.

ICC = International Code Council; LEED = Leadership in Energy and Environmental Design Green Building Rating System™.

Chapter 3
Waste Management Sector

Introduction

One supporting recommendation and two related actions for the waste sector were analyzed for their emission reductions and costs / savings. These include:

- W-1 - Improved Efficiency at Publicly Owned Wastewater Treatment Plants (POTWs);
- W-2 - Increase Municipal Solid Waste (MSW) Diversion Rate; and
- W-3 - State of the Art Guidelines for Landfill Gas (LFG) Control.

Table 3.1 summarizes the estimated GHG emission reductions and costs (savings) for each of the three supporting recommendations/related actions. The remainder of this chapter provides information on the parameters for analysis, methods, data sources, and assumptions used to prepare the analysis for each of the supporting recommendations/related actions.

Table 3.1. Total Estimated GHG Emission Reductions and Net Costs and Cost Savings for All Recommendations and Actions for the Waste Management Sector

No.	Name of Supporting Recommendation or Related Action	Annual Results (2020)		Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
W-1	Improved Efficiency at Publicly Owned Wastewater Treatment Plants (POTWs)	0.39	-$88.9	2	-$483	-$238
W-2	Increase Municipal Solid Waste (MSW) Diversion Rate	4.98	-$44.0	27.4	-$242	-$8.8
W-3	State of the Art Guidelines for Landfill Gas (LFG) Control	0.19	$0.23	1.5	$2.3	$1.5
Sector Total (No adjustments for overlaps needed)		5.56	-$133	31	-$723	-$23
Reductions From Recent Actions (i.e., 50% MSW Recycling Statutory Mandate)		2.61	-$23.1	14.4	-$127	-$8.8
Sector Total Plus Recent Actions		8.2	-$156	45.3	-$850	-$19

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Costs are discounted to year 2009 in 2007 dollars using a 3% real discount rate. Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above recommendations is for reference purposes only; it does not reflect prioritization among the recommendations.

Improved Efficiency at Publicly Owned Wastewater Treatment Plants (POTWs) (W-1)

Design of Recommendation

The goal of this supporting recommendation is to provide favorable financing from the New Jersey Environmental Infrastructure Financing Program to local government units (such as municipal utilities authorities) to install energy efficiency and/or greenhouse gas (GHG) reduction measures at Publicly Owned Treatment Works (POTWs) and public water supply systems. Two states for which CCS has provided facilitation and technical support, South Carolina and Vermont, have set efficiency targets to reduce the amount of electricity at POTWs by 25%. Therefore, the goal proposed by CCS is a 25% reduction in the amount of electricity used at POTWs by 2020. A linear ramp-up between 2010 and 2020 is assumed.

POTWs will be encouraged to undertake energy audits to identify processes/equipment that can be changed or upgraded to reduce energy use and/or greenhouse gas emissions. As part of the survey discussed below, information will be provided to the POTWs regarding the local government energy audit program administered by the New Jersey Board of Public Utilities.

The Department intends to increase the practice of using anaerobic digester gases generated at POTWs for energy generation. As a first step, the Department will be conducting a survey of approximately 100 POTWs with a design flow of greater than one million gallons per day to obtain targeted information on digester gas management, the extent to which energy recovery is utilized, and under what operating conditions. The Department plans to partner with selected POTWs to develop and refine case studies documenting energy savings, costs and cost savings, as well as greenhouse gas reductions for different operating scenarios. These studies will be used to demonstrate how the practice can be effectively applied across a range of POTW sizes and designs. The Department will use the energy audit data and the case study data to encourage the use of anaerobic digestion at suitable POTWs.

The Department will develop an education and outreach program to inform POTWs across the state about the effectiveness and benefits of digester gas energy recovery. The Department will also take steps to partner with groups representing the wastewater treatment sector, along with the New Jersey Board of Public Utilities in these activities.

To facilitate implementation of beneficial equipment and process changes identified in the energy audits and the case study results, the New Jersey Environmental Infrastructure Financing Program will develop a protocol to provide additional priority points for projects that incorporate measures to reduce energy usage and/or greenhouse gases at POTWs. In addition, the loan program will place increased emphasis on compliance with N.J.A.C. 7:22-11(d)5iii(7), which requires that all wastewater, water and stormwater projects consider opportunities to reduce the use of energy or recover energy, as part of their facilities plan/project report.

Public water supply systems will be encouraged to conduct energy audits and to replace inefficient energy-consuming equipment. The New Jersey Environmental Infrastructure

Financing Program will develop protocols for providing additional priority points for projects that incorporate measures to reduce energy usage.

Analytical Approach and Data Sources

This analysis relied on data from EPA's Clean Watershed Needs Survey (CWNS).[3] The existing municipal flow for the year 2004 (1,045 MGD)[4] was used as the baseline flow rate for POTWs in New Jersey. The energy use per million gallons is determined from the median of a survey of 12 Wastewater Treatment Plants (WWTPs) (2,286 kWh/MG).[5] The annual BAU WWTP electricity consumption is estimated by taking the product of the annual municipal flow and the electricity use (in kWh/MG treated). The goal of 25% electricity use reduction is applied to the BAU WWTP electricity consumption to yield the amount of electricity avoided in 2020. The carbon intensity of New Jersey electricity production is multiplied by the electricity avoided to calculate GHG emission reductions.

The cost-effectiveness estimate is based on the aforementioned analyses completed for similar GHG mitigation recommendations in South Carolina and Vermont. The basis for the cost estimates are several case studies of various efficiency improvements at POTWs in Vermont. These case studies were updated to include 3% interest and discount rates. The energy-saving technologies considered include variable frequency drives for pumping and aeration motors, high efficiency aeration motors, improved lighting at buildings, rotary solids dewatering (as opposed to centrifugal), and implementation of anaerobic digestion for combined heat and power (where feasible). CCS extracted the per-kWh (avoided) cost of such upgrades at POTWs, as they were utilized to meet the goals set in South Carolina and Vermont. The average upgrade cost between the two states is applied to the avoided electricity in New Jersey to calculate the upgrade cost. The cost savings from avoided electricity is calculated by multiplying the energy avoided by the projected electricity prices in New Jersey (provided by NJDEP). It is assumed that there is a one year lag between the incurrence of upgrade cost and the realization of GHG emission reductions.

These key data inputs, including the assumed New Jersey electricity carbon intensity and electricity prices, are presented in Table 3.2. The electricity carbon intensity is incorporated from the Electricity Sector Appendix of the New Jersey GHG Inventory and Forecast.

Results

Table 3.3 presents the projected GHG emission reductions due to improved energy efficiency at POTWs in New Jersey. The cumulative emission reductions (2010-2020) are 2.03 $MMtCO_2e$ and the annual emission reductions in 2020 are 0.39 $MMtCO_2e$. The GHG emission reductions are estimated by multiplying the kWh avoided through increased energy efficiency at POTWs by the New Jersey electricity production carbon intensity for each year.

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[3] U.S. EPA. Clean Watersheds Needs Survey. "Select CWNS 2004 Data of Interest: Ask WATERS Simple Query Tool." Available at: http://www.epa.gov/cwns/2004data.htm.
[4] MGD – Million Gallons per Day.
[5] SBW Consulting, Inc. *Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes at Various Municipal Wastewater Treatment Facilities*. San Francisco, CA: Pacific Gas and Electric Company, February 28, 2002. Available at: http://www.cee1.org/ind/mot-sys/ww/pge2.pdf.

Table 3.2. Key Data Inputs and Assumptions

Year	Electricity usage reduced through increased efficiency (kWh)	Electricity Generation Carbon Intensity (tCO_2e/MWh)	Upgrade Cost per kWh Saved (South Carolina)	Upgrade Cost per kWh Saved (Vermont)	Electricity Price ($/kWh)
2010	-	0.42	$0.00033	$0.00072	$0.13
2011	65,402,638	0.47	$0.00024	$0.00057	$0.14
2012	130,805,276	0.43	$0.00043	$0.00096	$0.14
2013	196,207,914	0.46	$0.00040	$0.00097	$0.15
2014	261,610,552	0.50	$0.00037	$0.00098	$0.15
2015	327,013,190	0.54	$0.00035	$0.00099	$0.16
2016	392,415,828	0.56	$0.00021	$0.00100	$0.16
2017	457,818,466	0.58	$0.00019	$0.00101	$0.17
2018	523,221,104	0.61	$0.00017	$0.00102	$0.17
2019	588,623,742	0.60	$0.00015	$0.00103	$0.18
2020	654,026,380	0.59	$0.00014	$0.00103	$0.19

Table 3.3. GHG Emission Reductions Associated with Improving the Energy Efficiency at POTWs

Year	GHG Emission Reductions from Avoided Electricity ($MMtCO_2e$)
2010	-
2011	0.03
2012	0.06
2013	0.09
2014	0.13
2015	0.18
2016	0.22
2017	0.27
2018	0.32
2019	0.35
2020	0.39
Total	**2.03**

The cost-effectiveness is estimated by applying the factors in Table 3.2 to the GHG emission reduction estimates in Table 3.3. Table 3.4 presents the levelized (discounted) cost results assuming a 3% discount rate. The upgrade costs are calculated by adding the levelized upgrade cost from the previous year (assumed to be zero for 2010) by the product of the average upgrade cost from the South Carolina and Vermont analyses and the kWh saved in the previous year. This is done to implement the assumption that there is a one year lag between the incurrence of upgrade costs and the accrual of GHG emission reductions from that expenditure.

Table 3.4. Levelized (Discounted) Cost of Improved Energy Efficiency at POTWs

Year	GHG Emission Reductions ($MMtCO_2e$)	Upgrade Cost ($MM)	Electricity Cost Savings ($MM)	Net Program Cost ($MM)	Discounted Net Cost ($2007MM)
2010	-	$0.03	$0.00	$0.0	$0.0
2011	0.03	$0.09	$8.97	-$8.9	-$8.6
2012	0.06	$0.22	$18.56	-$18.3	-$17.3
2013	0.09	$0.40	$28.80	-$28.4	-$26.0
2014	0.13	$0.62	$39.72	-$39.1	-$34.7
2015	0.18	$0.89	$51.36	-$50.5	-$43.5
2016	0.22	$1.16	$63.75	-$62.6	-$52.4
2017	0.27	$1.48	$76.94	-$75.5	-$61.4
2018	0.32	$1.83	$90.95	-$89.1	-$70.4
2019	0.35	$2.21	$105.84	-$103.6	-$79.4
2020	0.39	$2.21	$121.65	-$119.4	-$88.9
Total	**2.03**	**$11.12**	**$607**	**-$595**	**-$483**
				Cost-Effectiveness ($/$tCO_2e$)	**-$238**
				2020 Cost-Effectiveness ($/$tCO_2e$)	**-$229**

Increase Municipal Solid Waste (MSW) Diversion Rate (W-2)

Design of Action

This related action is designed to achieve the statutorily required 50% MSW diversion goal and exceed the goal to achieve a 70% MSW recycling rate by 2020,[6] with an ultimate goal of zero waste production by 2050. According to the most recent county-level recycling statistics documented on the NJDEP website, the 2006 MSW diversion rate was about 36%, not including bulky waste (i.e., Class B recyclables, C&D waste). CCS utilized the estimates in the material-specific recycling statistics document to develop a waste characterization profile for New Jersey. This step was necessary to generate inputs for the EPA Waste Reduction Model (WARM), which was used to estimate GHG emission reductions.

The 50% diversion target is statutorily required, but was not included in the business-as-usual scenario. The quantification of this related action will therefore assess the GHG emission reduction and cost-effectiveness implications of the 50% BAU target, as compared to the baseline recycling rate. Additionally, this assessment will estimate the GHG emission reductions and cost-effectiveness of the 70% target diversion rate, as compared to both the baseline diversion rate and the 50% BAU target. The goal of zero waste by 2050 is not quantified.

The achievement of the aforementioned diversion targets is dependent on the implementation of several policy, funding, and outreach mechanisms, many of which have already been identified and implemented by NJDEP. For example, the New Jersey Solid Waste Management Act (NJSA 13:1E-1 et. seq.), and New Jersey Statewide Mandatory Source Separation and Recycling Act (NJSA 13:1E-99.11 et. seq.) establish a regulatory system of statewide oversight of county-level plans to manage solid waste and recycling programs. Substantial funding will also be necessary for the construction and operation of additional materials recovery facilities (MRF) and additional recyclable and compostable waste collection efforts. The Recycling Enhancement Act (REA) provides approximately $20 million annually to counties and municipalities for recycling assistance. The NJDEP will utilize recycling research or demonstration, education and professional training money contained in the REA fund to focus on those activities that will maximize the GHG emissions reductions that can be achieved through recycling, specifically targeting those materials in the waste stream for which increased recycling will yield the largest GHG reductions.

[6] "Diversion" is equal to the sum of MSW recycled plus MSW composted. New Jersey DEP considers composting to be a form of recycling. Therefore, recycling and composting will not be considered separately in this analysis. Source reduction, also a method of waste diversion, is not considered in this analysis.

Analytical Approach and Data Sources

The key source of data for the New Jersey baseline waste management scenario was the "New Jersey Generation, Disposal and Recycling Statistics" webpage.[7] The "Generation, Disposal and Recycling Rates by County" 2006 data file was used to determine both the baseline diversion rate and the breakdown of waste diverted and disposed. The total amount of waste generated was multiplied by 0.50 and 0.70 to determine the tonnage of waste diverted under the two scenarios, respectively.

The 2006 baseline breakdown of waste generated and diverted, by material (from the "Material Specific Recycling Rates" data set),[8] was applied to the tonnages under the BAU and policy scenarios. The resulting material-specific MSW characterization was entered into EPA's Waste Reduction Model (WARM) in order to determine the GHG emission reductions above the baseline (2006) waste management scenario.[9] A linear ramp-up is assumed from zero incremental diversion in 2010 through full implementation of each scenario in 2020.
The cost-effectiveness estimate is based on the average cost-effectiveness of waste diversion GHG mitigation recommendations from several other states assisted by CCS. In each of the selected reference state-level analyses, similar cost and revenue variables were considered in the quantitative assessment of the recommendations. These analyses have been updated to reflect a 3% discount rate for costs and savings and a 3% real interest rate for capital costs. The cost variables include capital and operation cost for additional MRF or composting capacity and additional curbside collection cost. The revenue variables include avoided landfill tipping fees and revenue from recycled or composted materials. It is known that some costs may be borne in 2010 in order to yield emission reductions beginning in 2011. However, the approach of applying cost-effectiveness estimates from other states does not allow for costs to be counted for years in which zero GHG reductions accrue.

Table 3.5 shows the total levelized net cost ($2007 NPV) of GHG mitigation recommendations in the reference analyses using a 3% discount rate. As the data in this table show, waste diversion measures in other states assisted by CCS have presented a net cost savings. The average cost-effectiveness ($2007/t$CO_2$e) of these states is applied to the GHG emission reduction estimate to yield the estimated cost-effectiveness of the New Jersey related action.

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[7] New Jersey Department of Environmental Protection. "New Jersey Generation, Disposal, and Recycling Statistics: 2006 Generation, Disposal and Recycling Rates by County." Available at: http://www.state.nj.us/dep/dshw/recycle/stats.htm.
[8] New Jersey Department of Environmental Protection. "New Jersey Generation, Disposal, and Recycling Statistics: 2006 Material Specific Recycling Rates." Available at: http://www.state.nj.us/dep/dshw/recycle/ stats.htm.
[9] U.S. Environmental Protection Agency. WAste Reduction Model (WARM)." Version 8, May 2006. Available at: http://www.epa.gov/climatechange//wycd/waste/calculators/WARM_home.html. EPA created WARM to help solid waste planners and organizations track and voluntarily report GHG emission reductions from several different waste management practices. WARM is available as a web-based calculator and as a Microsoft Excel spreadsheet. WARM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in tCe, tCO_2e, and energy units (MMBtu) across a wide range of material types commonly found in MSW. For an explanation of the methodology, see the EPA report *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*, EPA530-R-02-006, May 2002. Available at: http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html.

The cumulative emission reductions and cost-effectiveness values in Table 3.5 are based on the projected life-cycle emission reductions of the recycling GHG mitigation recommendations in each state. In Michigan, the Climate Action Council chose to report only in-state emissions in the final summary table (e.g., direct emissions from landfills and waste combustion), which is why the results in that report differ from those reported in Table 3.5.[10] The nature of recycling as a mitigation strategy is such that most of the GHG emission reductions are indirect (i.e., emissions avoided due to reduced extraction of raw materials and energy consumption during manufacturing of the products and packaging that are not needed due to recycling). These indirect GHG emission reductions may or may not take place within a given state's borders, as it is very difficult to model the entire manufacturing supply chain for all materials recycled in a given state). Therefore, the only emissions that are known to be reduced in-state through recycling are the direct emissions from MSW landfills. Based on the WARM outputs, the MSW landfill emission reductions are much smaller than the indirect emission reductions. The total cost of recycling is the same regardless of the estimated emission reductions. Therefore, the absolute value of the cost-effectiveness estimate will be much higher when only in-state emission reductions are counted.

Table 3.5. Reference Case Analytical Results of State GHG Mitigation Recommendations

State	Cumulative Emission Reductions ($MMtCO_2e$)	Analysis Period (years)	Avg. Annual GHG Emission Reduction ($MMtCO_2e/yr$)	NPV (3% Discount Rate) ($MM)	Cost-Effectiveness (3% Discount Rate) ($/tCO_2e$)
Arkansas	35.8	15	2.4	-$360	-$10.0
Iowa	26.5	10	2.6	-$264	-$10.0
Maryland	183.7	10	18.4	-$1,309	-$7.1
Michigan	313.8	15	20.9	-$4,090	-$13.0
Pennsylvania	65.06	15	4.3	-$615	-$9.5
South Carolina	20.1	10	2.0	-$68	-$3.4
				Average Cost-Effectiveness	**-$8.8**

Results

Table 3.6 presents the projected GHG emission reductions due to an increase above the baseline waste diversion practices in New Jersey. The cumulative emission reductions (2010-2020) of the 50% (BAU) scenario are 14.4 $MMtCO_2e$ and the annual emission reductions in 2020 are 2.61 $MMtCO_2e$. The cumulative emission reductions of the 70% (policy) scenario are 41.8 $MMtCO_2e$ and the annual emission reductions in 2020 are 7.60 $MMtCO_2e$. The difference between the BAU and policy scenario (identified as GHG Emission Reductions Incremental to BAU) represents the potential GHG emission reduction due to achieving the 70% goal, as compared to the statutorily required 50% diversion rate goal.

[10] Michigan Climate Action Council, Michigan Climate Action Plan, MCAC Final Report - March 2009, see Appendix J for Agriculture, Forestry, and Waste Management Policy Recommendations, http://www.miclimatechange.us/stakeholder.cfm.

Table 3.6. GHG Emission Reduction from Additional Waste Diversion

Year	Incremental GHG Emission Reductions - 50% Diversion Rate ($MMtCO_2e$)	Incremental GHG Emission Reductions - 70% Diversion Rate ($MMtCO_2e$)	GHG Emission Reductions Incremental to Recent Action (50% Diversion Rate) ($MMtCO_2e$)
2010	-	-	-
2011	0.26	0.76	0.50
2012	0.52	1.52	1.00
2013	0.78	2.28	1.50
2014	1.04	3.04	1.99
2015	1.31	3.80	2.49
2016	1.57	4.56	2.99
2017	1.83	5.32	3.49
2018	2.09	6.08	3.99
2019	2.35	6.84	4.49
2020	2.61	7.60	4.98
Total	**14.4**	**41.8**	**27.4**

The cost-effectiveness of waste diversion under the two New Jersey scenarios is estimated by applying the average cost-effectiveness from the reference analysis in Table 3.5 to the GHG emission reduction estimates in Table 3.6. Table 3.7 presents the levelized (discounted) cost results assuming a 3% discount rate.

Table 3.7. Levelized (Discounted) Cost of Additional Waste Diversion

Year	Levelized Annual Cost - 50% Diversion Rate (million $2007)	Levelized Annual Cost - 70% Diversion Rate (million $2007)	Levelized Annual Cost - Incremental to Recent Action (million $2007)
2010	$0.0	$0.0	$0.0
2011	-$2.3	-$6.7	-$4.4
2012	-$4.6	-$13.4	-$8.8
2013	-$6.9	-$20.1	-$13.2
2014	-$9.2	-$26.8	-$17.6
2015	-$11.5	-$33.6	-$22.0
2016	-$13.8	-$40.3	-$26.4
2017	-$16.2	-$47.0	-$30.8
2018	-$18.5	-$53.7	-$35.2
2019	-$20.8	-$60.4	-$39.6
2020	-$23.1	-$67.1	-$44.0
Total ($2007 NPV)	**-$127**	**-$369**	**-$242**

State of the Art Guidelines for Landfill Gas (LFG) Control (W-3)

Design of Action

The Department will propose State of the Art (SOTA) guidelines for LFG control pursuant to N.J.A.C 7:27C 8.12 and 22.35., and is also planning to propose amendments to the design standards and construction requirements for sanitary landfills gas collection and venting systems. This analysis addresses the control of methane at landfill sites that currently are not required to collect and control LFG and are currently venting methane.

Analytical Approach and Data Sources

Data were provided by NJDEP on current LFG control and utilization in the state.[11] These data included whether the site currently collected and utilized its LFG for energy purposes, collected and controlled via flaring, vented LFG with passive vents, or was currently not controlled nor vented. This analysis focused on the sites with passive vents (19 sites). For each site, NJDEP provided information on the waste in place, year opened, year closed, estimated methane (CH_4) generated, and estimated CH_4 emitted.

Of the 19 sites, 10 sites that were closed after 1980 were selected for analysis, since the older sites could be getting toward the end of their life in terms of methane generation. It was assumed that 50% of the methane emitted from each site could be collected by the vents and would be combusted via the use of solar flares attached to each vent. This might appear to be a conservatively low assumption; however, the US EPA considers the default collection efficiency for active LFG collection at non-state of the art sites to be 75%.[12] Passive vents are likely to be less efficient at gas collection than an active gas collection system. Solar flares consist of a stand-alone unit at each vent of a small open flare that is assisted by spark ignition powered by a battery and solar panel. In addition to this equipment, it was assumed that a thermocouple and data logger would be needed for each flare (for monitoring purposes to assure that the flare is always operational).

For each site, the surface area of the landfill was obtained from NJDEP's website.[13] For one of the 10 sites assessed, the area had to be estimated using the average area per cubic yard of waste in place. Typical LFG design of passive vents suggests a minimum of 1 vent per acre of landfill surface. Information on the cost of solar flares was taken from the list sheet for Solar Spark Vent Flares™ sold by Landfill Service Incorporated (www.landfill.com). The cost of each solar flare, data logger and thermocouple is estimated to be $4,050. Installation and maintenance costs were not readily available but are estimated at $300 each for installation and $15,600 per landfill site

[11] B. Kettig, NJDEP, personal communication with S. Roe, CCS, June 2009.
[12] US EPA, AP-42 Section 2.4, http://www.epa.gov/ttn/chief/ap42/ch02/draft/d02s04.pdf.
[13] http://www.state.nj.us/dep/dshw/lrm/landfill.htm.

annually for maintenance.[14] Estimates of equipment life were not available but were assumed to be 15 years.

Results

Table 3.8 provides an overall summary of the reductions and costs for this recommendation. The cost-effectiveness was estimate to be less than $2/t$CO_2$e. The recommendation is estimated to achieve 0.19 MMtCO_2e of GHG reductions annually by 2020.

Table 3.8. Landfill Gas Mitigation from Passively Vented Sites

Year	GHG Reductions (tCO_2e)	Capital Costs ($)	Maintenance Costs ($)	Annualized Capital Costs ($)	Total Annual Costs ($)	Discounted Costs (2007$)
2010	-	$419,411	$31,200	$35,133	$66,333	$60,704
2011	37,750	$419,411	$62,400	$70,265	$132,665	$117,871
2012	75,500	$419,411	$93,600	$105,398	$198,998	$171,657
2013	113,249	$419,411	$124,800	$140,531	$265,331	$222,210
2014	150,999	$419,411	$156,000	$175,663	$331,663	$269,672
2015	188,749	$0	$156,000	$175,663	$331,663	$261,818
2016	188,749	$0	$156,000	$175,663	$331,663	$254,192
2017	188,749	$0	$156,000	$175,663	$331,663	$246,789
2018	188,749	$0	$156,000	$175,663	$331,663	$239,601
2019	188,749	$0	$156,000	$175,663	$331,663	$232,622
2020	188,749	$0	$156,000	$175,663	$331,663	$225,846
2021	188,749	$0	$156,000	$175,663	$331,663	$219,268
2022	188,749	$0	$156,000	$175,663	$331,663	$212,882
2023	188,749	$0	$156,000	$175,663	$331,663	$206,682
2024	188,749	$0	$156,000	$175,663	$331,663	$200,662
2025	188,749	$0	$156,000	$175,663	$331,663	$194,817
2026	188,749	$0	$124,800	$140,531	$265,331	$151,314
2027	188,749	$0	$93,600	$105,398	$198,998	$110,180
2028	188,749	$0	$62,400	$70,265	$132,665	$71,314
2029	188,749	$0	$31,200	$35,133	$66,333	$34,619
2030	188,749	$0	$0	$0	$0	$0
Total (2010-2030)	**3,397,481**					**$3,704,720**
Total (2010-2020)	**1,509,992**					**$2,302,983**
2020 CE =	**$1.53**	**$2007/t$CO_2$e**	**3% Discount Rate**			

Note: assumes that 50% of the methane emitted is available for collection; also assumes one vent per acre based on an estimate of the average surface area per cubic yard of waste.

[14] Installation costs assume 4 man-hours each @ $75/hr. Maintenance costs assume 8 hours per site for each bi-monthly visit to assure proper operation and $75/hr.

Chapter 4
Control of Highly Warming Gases from Commercial and Industrial Refrigeration and Air Conditioning

Introduction

This supporting recommendation involves developing a state regulation establishing a Leak Detection and Repair (LDAR) program for highly warming gases used in commercial and industrial refrigeration equipment that exceed a threshold size.

Table 4.1 summarizes the estimated GHG emission reductions and costs for this recommendation. The remainder of this chapter provides information on the parameters for analysis, methods, data sources, and assumptions used to prepare the analysis for this supporting recommendation.

Table 4.1. Estimated GHG Emission Reductions and Net Cost Savings

No.	Supporting Recommendation Name	Annual Results (2020)		Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
HWG-1	Reducing HWG emissions from commercial and industrial refrigeration and air conditioning equipment	1.05	-$1.3	9.4	-$14	-$1.5
Sector Total (No adjustments for overlaps needed)		1.05	-$1.3	9.4	-$14	-$1.5

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Costs are discounted to year 2008 in 2007 dollars using a 3% real discount rate. Negative values in the Cost and the Cost-Effectiveness columns represent net savings.

Design of Recommendation

This recommendation would essentially extend many of the current federal requirements for Ozone Depleting Substances (ODSs) under Title VI of the federal Clean Air Act to cover hydrofluorocarbons (HFCs), which are used as replacements for ODSs but are currently not regulated under Title VI. The commercial and industrial refrigeration sector in New Jersey is projected to release 2.09 $MMtCO_2e$ in 2020, which will account for 1.35% of total Statewide releases of greenhouse gases (GHGs) in that year (based on 2020 BAU without projected reductions).

Analytical Approach and Data Sources

The analysis for this action is based on a similar analysis undertaken by staff of the California Air Resources Board (ARB).[15] The ARB analysis drew on data from a survey of 26,000 California businesses with HFC-emitting refrigeration systems; cost data from the survey are summarized in Table 4.2.[16] ARB staff divided survey respondents into three categories based on the size of their refrigeration systems; larger facilities tended to have fewer but larger systems than small or medium facilities.

Most of the costs shown in Table 4.2 vary with the number of systems for which HFC leaks are to be detected and repaired; a few costs depend solely on the size of the facility. The bulk of the facilities surveyed were small or medium-sized. Overall, the average facility had an annual cost (including amortization of capital costs) of just under $1,700 before savings on refrigerant and net savings of just under $500 net of refrigerant savings.

The total annual cost for the HFC-only facilities came to about $44 million. That cost would be offset in part by the savings on HFC refrigerant compounds due to earlier leak detection and repair, estimated by ARB staff at $56.8 million annually, leaving a net savings of $12.8 million.

ARB staff estimated that the 26,000 HFC-emitting facilities emit a total of about 14.3 $MMtCO_2e$ annually, and that about half of that or 7.2 $MMtCO_2e$ could be avoided through the proposed LDAR program. Based on a net savings statewide of $12.8 million, the savings per metric ton comes to about $1.79. That figure will vary as the price of HFC refrigerants fluctuates on the world market.

As noted above, it is projected that by 2020 under a BAU scenario, New Jersey's HFC-emitting facilities will emit some 2.09 million $MtCO_2e$, or about 15% of California's statewide emissions. Assuming that half of New Jersey's HCF emissions can be avoided through an LDAR program comparable to that proposed by ARB, about 1.045 million $MtCO_2e$ could be avoided. At $1.79 per Mt, the total net savings of a New Jersey LDAR program for HFCs would come to about $1.87 million.

The annual projected emissions from the New Jersey HFC-emitting facilities between 2009 and 2020 are computed by interpolating between the emission level in 2004 (0.58 million $MtCO_2e$) and the 2020 projected emission level before reductions of 2.09 million $MtCO_2e$. It is assumed that half of the annual emissions can be avoided through the program at the savings of $1.79 per metric ton. All costs were discounted to 2008 using an annual discount rate of 3%.

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[15] California Air Resources Board , High-GWP Refrigerant Management Program for Stationary Sources, Refrigerant Management Program, Presentation at Technical Workgroup Meeting, Sacramento, July 7, 2009.
[16] Other facilities had ODS-emitting refrigeration systems already covered under Title VI.

Table 4.2. CA HWG Leak Detection and Repair Program and Extrapolation to NJ (HFC-Emitting Refrigeration Systems Only)

Annual CA LDAR Costs	HFC only
Periodic inspections or audits	$19,700,000
Leak repair (incl. refrigerant recharge)	10,200,000
Annual reporting/recordkeeping costs	6,400,000
Equipment (amortized) & maintenance	5,700,000
Annual implementation fees	2,000,000
Total gross cost/yr	**44,000,000**
Annual savings on refrigerant (net)	56,800,000
Total net cost/year	**-12,800,000**
Total CA facilities subject to rule	26,000
Gross cost (savings)/facility/yr	$1,692
Net cost (savings)/facility/yr	-$492
Projected 2020 BAU $MtCO_2e$ (HFCs)	14,300,000
Pct. of 2020 $MtCO_2e$ avoided	50.0%
2020 $MtCO_2e$ avoided	7,150,000
Total net cost/$MTCO_2e$ avoided	**-$1.79**
Extrapolation to NJ	**HFC only**
NJ 2020 BAU $MtCO_2e$ (HFCs)	2,090,000
Pct. 2020 $MtCO_2e$ avoided	50.0%
2020 $MtCO_2e$ avoided (HFCs)	1,045,000
Total net cost/$MtCO_2e$ avoided	-$1.79
Total NJ cost (savings)	**-$1,870,769**

Chapter 5
Terrestrial Sequestration of Carbon by the Forestry and Agriculture Sectors

Introduction

Three supporting recommendations and two related actions for sequestering carbon by forest and agricultural management practices were analyzed for their emission reductions and costs. These include:

- TS-1 - Expansion of Green Infrastructure/Garden State Preservation Trust (GSPT)
- TS-2 - Forest Stewardship;
- TS-3 - No Net Loss of Forest Reforestation;
- TS-4 - Forest Canopy/Cover Requirement; and
- TS-7 - Sustainable Agriculture.

Table 5.1 summarizes the estimated GHG emission reductions and costs for each of the five recommendations or actions. The remainder of this chapter provides information on the parameters for analysis, methods, data sources, and assumptions used to prepare the analysis for each of the supporting recommendations and related actions.

Table 5.1. Total Estimated GHG Emission Reductions and Net Costs for Supporting Recommendations and Related Actions for Terrestrial Sequestration

No.	Name of Supporting Recommendation or Related Action	Annual Results (2020)		Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)
TS-1	Green Infrastructure	0.75	$50	4.5	$463	$103
TS-2	Forest Stewardship	0.032	$0.37	0.18	$2.9	$17
TS-3	No Net Loss of Forest Reforestation	0.004	$1.6	0.021	$11	$520
TS-4	Forest Canopy/Cover Requirement	0.35	$36	1.94	$231	$119
TS-7	Sustainable Agriculture[1]	0.019	$0.15	0.11	$1.9	$16
Sector Total (No adjustments for overlaps needed)		1.16	$88	6.7	$710	$106

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Costs are discounted to year 2009 in 2007 dollars using a 3% real discount rate.

[1] Covers just the terrestrial carbon storage (no-till cultivation) component of this plan.

The numbering used above to denote the supporting recommendations and related actions is for reference purposes only; it does not reflect prioritization among these recommendations.

Design of Recommendations and Actions

The overall purpose of these supporting recommendations and related actions is to enhance terrestrial carbon sequestration via a set of five supporting recommendations and related actions for interventions in forest and agricultural land uses, and the state's green infrastructure as a whole. In forestry, the recommendation is for expansion of the forest stewardship program to cover 4,000 acres/yr. Forest stewardship plans would be developed to identify, among others, the best mechanisms for enhancing carbon sinks in forests which currently have less-than-optimal carbon stocks (e.g., via forest stand improvement or other forest management approaches). The other forestry options are: 1) a “no net loss” reforestation program that would require all state-funded projects to replace all trees lost in areas impacted by project development; and 2) forest canopy/cover goals for development areas across the state. In agriculture, a sustainable agriculture program would expand the use of “no till” practices or other approaches to enhance levels of soil carbon, thereby indirectly sequestering carbon dioxide from the atmosphere. Finally, the continued preservation of the state's land assets would be pursued and expanded with support from the Garden State Preservation Trust (GSPT). The main component of this recommendation is the Green Acres program, which covers acquisition of conservation lands comprising the green infrastructure of forests, watersheds and wildlife habitats, freshwater wetlands, tidal marshes, and agricultural landscapes of environmental significance. A total of 10,000 acres is assumed to be acquired annually and preserved for posterity.

Analytical Approach and Data Sources

Forest Stewardship (TS-2)

The GHG emission reductions for this recommendation were estimated by assessing the carbon accumulation that would occur over a 45-yr period as forested areas with less than optimal stocking are improved by one “stocking level” as defined by the U.S. Forest Service. The targeted acreage is 4,000 acres/yr over 10 years. An estimate of the 45-yr carbon accumulation achieved by treatment of less than optimally stocked areas was taken from a recent CCS analysis for New York State Energy Research and Development Authority (NYSERDA) (0.80 tCO_2/acre-yr).

Costs assume that the emission reductions would be achieved by development of stewardship plans with oversight by New Jersey Department of Environmental Protection (NJDEP) or other state staff and that the treatment would include plantings with disease resistant species appropriate for each area. The average cost of plantings ($137/acre) was also taken from the recent work conducted for NYSERDA. The estimated GHG reductions (carbon sequestration) and cost estimates are provided in Attachment 1.

No Net Loss Program (TS-3)

The recommendation calls for achieving no net loss of forested land (e.g., at the urban fringe and along transportation corridors). The GHG emission reductions were estimated by using an

NJDEP estimate of 5.8 tCO_2e/acre-yr of net GHG emission reductions provided by urban forests. This includes both the GHG emission reductions associated with carbon sequestration as well as the energy savings provided by urban trees via shading and wind protection. The recommendation calls for trees to be either retained or an equivalent number replanted in a nearby location. Under the recommendation, an estimated 67 acres/yr would be covered. NJDEP estimated that there is an average of 204 trees/acre. The number of trees retained or planted was used along with the net GHG emission reduction estimate above to estimate GHG reductions in each year.

The length of the No Net Loss program was assumed to be through 2020; however, the emission reductions continue to accrue over the life of the urban trees covered by the program (assumed at 30 years on average). To estimate the costs of the program, CCS assumed that all of the trees would need to be replanted. Of the trees that would need to be replanted, CCS assumed that one-third would be strategically located to provide energy savings to buildings. NJDEP provided an estimate of tree replacement cost of $300 per tree. To estimate the value of energy savings, an average per-tree estimate of emissions reduction from energy savings was taken from the CCS analysis for NYSERDA (0.0034 tCO_2/yr). Most of this would be associated with shading effects which would reduce electricity consumption. Using the per-tree emission reduction estimate and the carbon content of NJ electricity (0.569 tCO_2e/MWh), an estimated energy savings of 5.98 kWh/tree-yr was derived. NJDEP provided estimates of average electricity prices (ranging from $0.112/kWh in 2005 to $0.186/kWh in 2020). Total costs in each year were the sum of the annualized tree planting and administrative costs, offset in part by the energy savings. The estimated GHG reductions and costs are provided in Attachment 2.

Forest Canopy/Cover Requirement (TS-4)

Here the program goals are to retain urban tree canopy coverage and rural forest cover in all developable areas of the state including those that are not environmentally sensitive. The targeted area for enhancing canopy cover is much larger at 30,000 acres/yr (estimate provided by NJDEP) with a goal of retaining 50% of all forest canopy/cover. As the program will cover both rural and urban areas, the same net emission reduction estimate for carbon sequestration was used here (5.8 tCO_2e/acre-yr) for the both the rural forest cover and urban forest canopy components. Key assumptions used in the analysis are that under BAU all of the trees on developed acres would be removed (NJDEP estimates an average statewide forest cover of 40% covering both rural and urban areas). GHG reductions in both the rural and urban areas were estimated using a value of 5.8 tCO_2/acre-yr provided by NJDEP as a statewide average estimate of carbon sequestration. In the urban areas, it was assumed that the replacement trees would be strategically planted to reduce energy use, resulting in energy savings (from shading and wind protection for buildings). The avoided CO_2 due to these energy savings was taken from the CCS analysis for NY (0.0034 tCO_2/tree-yr).

Costs were estimated separately for rural and urban development. The break-out of lands to be developed through 2020 was assumed to be 60% urban and 40% rural. For rural costs, an estimated reforestation cost of $550/acre was used, which is the average cost estimated in the CCS analysis for NY state. For urban costs, a similar approach to that described above for the No Net Loss Program was used, except that it was assumed that all replanted trees in urban areas would be strategically placed to achieve energy savings. Based on data from 4 NJ cities, the average number of mature urban trees per acre is 45.[17] The same replanting costs as the No Net Loss Program ($300/tree) were applied. Costs for the incremental urban tree maintenance were also included, since there would be an increase in the number of trees above baseline ($8.50/tree taken from the CCS analysis for NYSERDA). The annual GHG reductions and costs are shown in Attachment 3.

Sustainable Agriculture (TS-7)

This analysis focused on achieving soil carbon gains (indirectly sequestering carbon dioxide from the atmosphere) through no till farming (the recommendation also addresses other sustainable agricultural practices that can achieve GHG emission reductions). The incremental annual cultivated area brought into continuous no-till farming targeted by NJDEP is assumed to be 3,500 acres, and the program is assumed to last for 10 years. From a similar analysis conducted by CCS for NYSERDA, it is estimated that continuous no-till practices can sequester 0.454 tCO_2/acre annually. Also, from the same analysis, there are additional GHG reductions via lower diesel fuel consumption of 0.043 tCO_2/acre-yr.

Under the program, farmers would receive an incentive of $10/acre-yr. Fuel cost savings of 3.5 gallons/acre are estimated at a current cost of $2.46/gallon (fuel costs are estimated to increase by 2.4%/yr based on data from the U.S. Department of Energy's Energy Information Administration). Total annual costs are the cost of no-till practices net of payments to farmers, fuel savings, and administrative costs. The annual GHG reductions and costs are shown in Attachment 4.

Green Infrastructure (TS-1)

This program is primarily concerned with acquisition and conservation management of priority protected landscapes and open spaces throughout the state. Sequestering these lands maintains and enhances their ecosystem functions and services, which include carbon uptake and accumulation in vegetation and soils. The GHG emission reductions (associated with carbon sequestration of lands to be conserved) were estimated following a two-step process. First, the typology of lands acquired under the Green Acres program was determined and the percentage share of each type was applied to the to the total target area of lands assumed to be purchased annually (10,000 acres). The percentage composition as determined from Green Acres and GSPT program reports is as follows: 55% forestlands, 30% wetlands including tidal wetlands, 5% farmlands, and 7% others (open space, urban, barren lands). Open waters comprise 3%, but these are assumed to have no significant sequestration. Second, carbon removal coefficients appropriate for each land type were used to estimate the carbon sequestration to be expected from land preservation.[18] The amount of sequestration is cumulative as acreage is added every

[17] Average of 4 NJ cities (Woodbridge, Moorestown, Freehold, and Jersey City) from Nowak et al, "A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services", Arboriculture & Urban Forestry, 34(6): November 2008.

[18] All coefficients, except for wetlands, are from Northeast Carbon Feasibility Project ("Terrestrial Carbon Sequestration in the Northeast: Quantities and Costs". 2007, The Nature Conservancy, The Sampson Group, and Winrock International). Wetland coefficient calculated from data of the First State of Carbon Cycle Report

year through 2020. The lands continue sequestering carbon through time, at least until individual trees die (for simplicity this has been ignored since the projection only goes out to 2020).

The cost of land acquisition is assumed to average $15,000 per acre based on Green Acres data. It should be noted that the program is contingent on the re-authorization of Garden State Preservation Trust funding. Legislation is currently pending gubernatorial approval for a voter referendum on the bond issue this year, and approval of the legislation by the Governor and voters is assumed for analytic purposes. The bill proposes funding for Green Acres at the level of $218 million. At the specified cost of acquisition, the proposed funding would be exhausted in less than two years' time. Historically, however such referenda have been held every 3 to 4 years, and the 2007 bond issue will be exhausted in 2010. The current legislation does not indicate which years the bond issue covers, so the estimates assume constant annual funding will be available for 2010 to 2020 at the level of $150 million annually, i.e., 10,000 acres times $15,000 per acre.

Based on the foregoing assumptions, the NJDEP estimates that a total of about 4.5 million metric tons of CO_2 equivalents would be sequestered from 2010 through 2020 (see Tables 5.2 and 5.3). The annual cost of $150 million is discounted to 2009 using an annual discount rate of 3%; this treatment is in keeping with that used for the other recommendations considered in this report, and it results in a present value cost (in real 2007 dollars) of about $1.3 billion. The direct cost of this related action is therefore $308 per $MtCO_2e$. The relatively high direct cost is attributable to the cost of the land being preserved. This estimated cost does ***not*** reflect the value of the ecosystem services preserved through the program.

The true economic cost of preserved land is less than the annual cost used here when the avoided cost of community infrastructure and other services (sewer, waste, water, schools, etc.) is taken into account. Certain studies indicate that preserved land requires, on a per dollar basis, from 35 to 37 cents of these services as against $1 to $1.19 for residential development[19] (Compton, 2007; American Farm Trust). This translates to a 1:3 ratio. When the avoided cost of community infrastructure services is accounted for, the actual cost of preserved land is reduced accordingly. Based on the 1:3 ratio, the actual cost is $5,000 annually. Taking this approach reduces the direct cost of this related action to $103 per $MtCO_2e$ (see Table 5.3). As in the original analysis, this cost does not reflect the value of the ecosystem services preserved through the program.

(SOCCR) The North American Carbon Budget and Implications for the Global Carbon Cycle. 2007. U.S. Climate Change Science Program.

[19] It is estimated that open space requires only 35 cents in services and that open space reduces the cost of services and Taxes (Crompton, J.L., 2004. The proximate principle: the impact of parks, open space and water features on residential property values and the property tax base). Other studies show that residential development required an average of $1.19 in municipal services vs. farmland that required only 37 cents in services (American Farmland Trust http://www.farmlandinfo.org/documents/27757/COCS_09-2007.pdf).

Table 5.2. Garden State Preservation Trust - Estimated CO_2 Storage and Sequestration (Green Acres Component Only)

			2010		2011 - 2020	Cumulative Total		
Land Type	**Share**	**Area (acres)**	**Storage (tonnes)**	**Seq (tonnes/yr**	**Same as 2010**	**Area (acres)**	**Storage (tonnes)**	**Seq (tonnes/yr**
Forest	55%	5,500	1,251,250	64,350		60,500	13,763,750	707,850
Wetland*	30%	3,000	885,000	2,100		33,000	9,735,000	23,100
Farmland	5%	500	39,500	1,650		5,500	434,500	18,150
Other	7%	700	51,100	280		7,700	562,100	3,080
Open water	3%	300	0	0		3,300	0	0
Total	**100%**	**10,000**	**2,226,850**	**68,380**		**110,000**	**24,495,350**	**752,180**
*includes tidal wetlands								
Carbon Removal Factors	**CO_2 storage**	**CO_2 seq'n**						
Land Type	*MT/acre*	*MT/acre/yr*						
Forest	227.5	11.7						
Wetland	295.0	0.7						
Farmland	79.0	3.3						
Other	73.0	0.4						
Open water	0.0	0.0						

Notes: Funding proposed for Green Acres under GSPT Bill (A3901) is $218 million. For analytic purposes, approval by Governor and voters is assumed. Historically, referenda have been held every 3 to 4 years. Since A3901 is silent on which years the bond issue covers, the above calculations assume constant annual funding will be available for 2010 - 2020.

Table 5.3. Garden State Preservation Trust - Estimated Costs (Green Acres Component Only)

Year	Assumed Expenditure*	PV Factor	PV at 3.00%	Acres Acquired	Cumulative Acreage	$MtCO_2e$ Sequestered	6.838 MT/acre/yr
2009		**1.0000**					
2010	$50,000,000	0.9709	$48,543,689	10,000	10,000	68,380	
2011	$50,000,000	0.9426	$47,129,795	10,000	20,000	136,760	
2012	$50,000,000	0.9151	$45,757,083	10,000	30,000	205,140	
2013	$50,000,000	0.8885	$44,424,352	10,000	40,000	273,520	
2014	$50,000,000	0.8626	$43,130,439	10,000	50,000	341,900	
2015	$50,000,000	0.8375	$41,874,213	10,000	60,000	410,280	
2016	$50,000,000	0.8131	$40,654,576	10,000	70,000	478,660	
2017	$50,000,000	0.7894	$39,470,462	10,000	80,000	547,040	
2018	$50,000,000	0.7664	$38,320,837	10,000	90,000	615,420	
2019	$50,000,000	0.7441	$37,204,696	10,000	100,000	683,800	
2020	$50,000,000	0.7224	$36,121,064	10,000	110,000	752,180	
	$550,000,000		**$462,631,206**	**110,000**		**4,513,080**	
			4,513,080				
			$103	**per $MtCO_2e$**			

* Net of $100 million/yr in avoided costs of development.

Results

Table 5.4 provides an overall summary of the GHG reductions and costs for the five components of the terrestrial carbon sequestration sector. Combined, these five recommendations and actions are estimated to achieve 1.16 $MMtCO_2e$ of GHG reductions annually by 2020. The overall cost-effectiveness is $106/metric ton in 2007 dollars.

Table 5.4. Annual GHG Emission Reductions and Net Costs Associated with Supporting Recommendations and Related Actions for Terrestrial Sequestration

	Forest Stewardship		No Net Loss Program		Forest Canopy/Cover Requirement		Sustainable Agriculture	
Year	**Reductions**	**Discounted Costs**	**Reductions**	**Discounted Costs**	**Reductions**	**Discounted Costs**	**Reductions**	**Discounted Costs**
2010	-	$134,458	-	$288,979	-	$2,623,603	1,740	$196,632
2011	3,200	$166,393	389	$459,863	35,351	$7,020,959	3,479	$188,266
2012	6,400	$196,353	777	$623,407	70,702	$11,144,171	5,219	$183,600
2013	9,600	$224,427	1,166	$776,807	106,052	$15,028,892	6,958	$179,046
2014	12,800	$250,698	1,554	$920,510	141,403	$18,677,864	8,698	$174,601
2015	16,000	$275,249	1,943	$1,054,945	176,754	$22,101,525	10,437	$170,263
2016	19,200	$298,158	2,332	$1,180,527	212,105	$25,309,904	12,177	$166,031
2017	22,400	$319,498	2,720	$1,297,652	247,456	$28,312,638	13,916	$161,900
2018	25,600	$339,342	3,109	$1,406,701	282,806	$31,118,984	15,656	$157,869
2019	28,800	$357,759	3,497	$1,508,041	318,157	$33,737,835	17,395	$153,935
2020	32,000	$374,815	3,886	$1,602,024	353,508	$36,177,732	19,135	$150,097
Totals	**176,000**	**$2,937,150**	**21,373**	**$11,119,457**	**19,442,944**	**$231,254,107**	**114,807**	**$1,882,238**
	TS-2 CE=	**$17**	**TS-3 CE=**	**$520**	**TS-4 CE=**	**$119**	**TS-7 CE=**	**$16**
Total 2020 Reductions =			**1,160,709**					
Cumulative GHG Reductions =			**6,769,554**					
Cumulative Discounted Costs =			**$709,824,158**					
Cost-Effectiveness =			**$106**					

Green Infrastructure (GSPT)		
	Reductions	**Discounted Costs**
2010	68,380	48,543,689
2011	136,760	47,129,795
2012	205,140	45,757,083
2013	273,520	44,424,352
2014	341,900	43,130,439
2015	410,280	41,874,213
2016	478,660	40,654,576
2017	547,040	39,470,462
2018	615,420	38,320,837
2019	683,800	37,204,696
2020	752,180	36,121,064
Total	**4,513,080**	**462,631,206**
	TS-1 CE=	**103**

Sensitivity Analysis

The results shown for Forest Stewardship, the No Net Loss Program, and the Forest Canopy/Cover Requirement are based on total emissions and total net present value costs through 2020. That year was chosen to make the results of these analyses comparable to those for the other supporting recommendations and related actions considered in this report. However, barring such events as disease, fire, land clearing, etc., trees are inherently long-lived assets, and therefore choosing such a relatively short time horizon understates both the emissions reductions and the costs. Because most of the implementation costs for these three programs are incurred in the early years, the net result is to overstate the cost per $MtCO_2e$ for shorter versus longer time horizons. The effect of time horizon on the cost-effectiveness of the supporting recommendations and related actions is presented in Table 5.5. As Table 5.5 shows, the cost per $MtCO_2e$ is cut roughly in half when the longer time horizon is used. While the results from the 2020 analysis are presented in Chapter 1, it is important to keep in mind the very different results that use of a longer time horizon would produce.

Table 5.5. Effect of Time Horizon on Cost-Effectiveness of Cost-Effectiveness of Supporting Recommendations and Related Actions for Terrestrial Sequestration

	Forest Stewardship	No Net Loss	Forest Canopy/Cover
2020 GHG reduction ($MtCO_2e$)	176,000	21,373	1,944,294
2020 NPV cost	$2,937,150	$11,119,457	$231,254,106
2020 $/MtCO2e	**$17**	**$520**	**$119**
Adjusted time horizon	**2065**	**2050**	**2050**
GHG reduction ($MtCO_2e$)	1,616,000	137,953	12,549,534
NPV cost	$6,753,264	$36.340,900	$860,548,793
$/$MtCO_2e$	**$4**	**$263**	**$69**

Attachment 1. Forest Stewardship

Year	GHG Reductions (tCO_2e)	Acres in Program	Plan Costs ($)	Admin Costs ($)	Enhanced Stocking Capital Costs ($)	Annualized Capital Costs ($)	Total Annual Costs ($)	Discounted Costs (2007$)
2010	-	4,000	$ 18,000	$ 106,576	$ 548,000	$ 22,350	$ 146,926	$ 134,458
2011	3,200	8,000	$ 36,000	$ 106,576	$ 548,000	$ 44,701	$ 187,277	$ 166,393
2012	6,400	12,000	$ 54,000	$ 106,576	$ 548,000	$ 67,051	$ 227,627	$ 196,353
2013	9,600	16,000	$ 72,000	$ 106,576	$ 548,000	$ 89,401	$ 267,977	$ 224,427
2014	12,800	20,000	$ 90,000	$ 106,576	$ 548,000	$ 111,751	$ 308,327	$ 250,698
2015	16,000	24,000	$ 108,000	$ 106,576	$ 548,000	$ 134,102	$ 348,678	$ 275,249
2016	19,200	28,000	$ 126,000	$ 106,576	$ 548,000	$ 156,452	$ 389,028	$ 298,158
2017	22,400	32,000	$ 144,000	$ 106,576	$ 548,000	$ 178,802	$ 429,378	$ 319,498
2018	25,600	36,000	$ 162,000	$ 106,576	$ 548,000	$ 201,152	$ 469,728	$ 339,342
2019	28,800	40,000	$ 180,000	$ 106,576	$ 548,000	$ 223,503	$ 510,079	$ 357,759
2020	32,000	44,000	$ 198,000	$ 106,576	$ 548,000	$ 245,853	$ 550,429	$ 374,815
2021	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 162,538
2022	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 157,804
2023	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 153,207
2024	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 148,745
2025	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 144,413
2026	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 140,207
2027	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 136,123
2028	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 132,158
2029	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 128,309
2030	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 124,572
2031	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 120,943
2032	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 117,421
2033	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 114,001
2034	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 110,680
2035	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 107,457
2036	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 104,327
2037	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 101,288
2038	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 98,338
2039	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 95,474
2040	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 92,693
2041	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 89,993
2042	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 87,372
2043	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 84,827
2044	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 82,357
2045	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 79,958
2046	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 77,629
2047	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 75,368
2048	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 73,173
2049	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 71,042
2050	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 68,972
2051	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 66,963
2052	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 65,013
2053	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 63,119
2054	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 61,281
2055	32,000	44,000	$ -	$ -	$ -	$ 245,853	$ 245,853	$ 59,496
2056	32,000	44,000	$ -	$ -	$ -	$ 201,152	$ 201,152	$ 47,261
2057	32,000	44,000	$ -	$ -	$ -	$ 178,802	$ 178,802	$ 40,786
2058	32,000	44,000	$ -	$ -	$ -	$ 156,452	$ 156,452	$ 34,648
2059	32,000	44,000	$ -	$ -	$ -	$ 134,102	$ 134,102	$ 28,834
2060	32,000	44,000	$ -	$ -	$ -	$ 111,751	$ 111,751	$ 23,328
2061	32,000	44,000	$ -	$ -	$ -	$ 89,401	$ 89,401	$ 18,119
2062	32,000	44,000	$ -	$ -	$ -	$ 67,051	$ 67,051	$ 13,193
2063	32,000	44,000	$ -	$ -	$ -	$ 44,701	$ 44,701	$ 8,539
2064	32,000	44,000	$ -	$ -	$ -	$ 22,350	$ 22,350	$ 4,145
2065	32,000	44,000	$ -	$ -	$ -	$ -	$ -	$ -
Total	1,616,000							**$ 6,753,264**
2020 Total	**176,000**							**$ 2,937,150**
2020 CE =	$ **17**	$2007/tCO2e	3% Discount Rate					

Attachment 2. No Net Loss Program

Year	GHG Reductions (tCO_2e)	Tree Planting Costs ($)	Annualized Capital Costs ($)	Trees in Place for Energy Savings	Electricity Saved per Year (kWh)	Energy Savings ($)	Admin Costs ($)	Total Annual Costs ($)	Discounted Costs (2007$)
2010	-	4,100,400	$ 209,199	4,510	0	0	$ 106,576	$ 315,775	$ 288,979
2011	389	4,100,400	$ 418,399	9,021	$ 53,903	$ 7,395	$ 106,576	$ 517,580	$ 459,863
2012	777	4,100,400	$ 627,598	13,531	$ 80,855	$ 11,474	$ 106,576	$ 722,700	$ 623,407
2013	1,166	4,100,400	$ 836,797	18,042	$ 107,807	$ 15,825	$ 106,576	$ 927,548	$ 776,807
2014	1,554	4,100,400	$ 1,045,997	22,552	$ 134,758	$ 20,462	$ 106,576	$ 1,132,111	$ 920,510
2015	1,943	4,100,400	$ 1,255,196	27,063	$ 161,710	$ 25,399	$ 106,576	$ 1,336,373	$ 1,054,945
2016	2,332	4,100,400	$ 1,464,396	31,573	$ 188,662	$ 30,651	$ 106,576	$ 1,540,320	$ 1,180,527
2017	2,720	4,100,400	$ 1,673,595	36,084	$ 215,613	$ 36,235	$ 106,576	$ 1,743,936	$ 1,297,652
2018	3,109	4,100,400	$ 1,882,794	40,594	$ 242,565	$ 42,167	$ 106,576	$ 1,947,204	$ 1,406,701
2019	3,497	4,100,400	$ 2,091,994	45,104	$ 269,517	$ 48,463	$ 106,576	$ 2,150,106	$ 1,508,041
2020	3,886	4,100,400	$ 2,301,193	49,615	$ 296,468	$ 55,143	$ 106,576	$ 2,352,626	$ 1,602,024
2021	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 57,040	$ -	$ 2,244,153	$ 1,483,650
2022	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 59,002	$ -	$ 2,242,191	$ 1,439,177
2023	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 61,031	$ -	$ 2,240,162	$ 1,395,995
2024	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 63,130	$ -	$ 2,238,063	$ 1,354,065
2025	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 65,301	$ -	$ 2,235,892	$ 1,313,351
2026	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 67,547	$ -	$ 2,233,646	$ 1,273,817
2027	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 69,871	$ -	$ 2,231,322	$ 1,235,429
2028	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 72,274	$ -	$ 2,228,919	$ 1,198,154
2029	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 74,760	$ -	$ 2,226,433	$ 1,161,959
2030	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 77,331	$ -	$ 2,223,862	$ 1,126,812
2031	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 79,991	$ -	$ 2,221,202	$ 1,092,684
2032	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 82,742	$ -	$ 2,218,451	$ 1,059,544
2033	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 85,588	$ -	$ 2,215,605	$ 1,027,364
2034	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 88,532	$ -	$ 2,212,661	$ 996,116
2035	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 91,577	$ -	$ 2,209,616	$ 965,772
2036	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 94,727	$ -	$ 2,206,466	$ 936,306
2037	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 97,985	$ -	$ 2,203,208	$ 907,693
2038	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 101,355	$ -	$ 2,199,838	$ 879,907
2039	3,886	-	$ 2,301,193	49,615	$ 296,468	$ 104,841	$ -	$ 2,196,352	$ 852,925
2040	3,886	-	$ 2,091,994	49,615	$ 296,468	$ 108,447	$ -	$ 1,983,547	$ 747,849
2041	3,886	-	$ 1,882,794	49,615	$ 296,468	$ 112,177	$ -	$ 1,770,617	$ 648,125
2042	3,886	-	$ 1,673,595	49,615	$ 296,468	$ 116,035	$ -	$ 1,557,560	$ 553,531
2043	3,886	-	$ 1,464,396	49,615	$ 296,468	$ 120,026	$ -	$ 1,344,369	$ 463,851
2044	3,886	-	$ 1,255,196	49,615	$ 296,468	$ 124,155	$ -	$ 1,131,042	$ 378,880
2045	3,886	-	$ 1,045,997	49,615	$ 296,468	$ 128,425	$ -	$ 917,572	$ 298,418
2046	3,886	-	$ 836,797	49,615	$ 296,468	$ 132,842	$ -	$ 703,955	$ 222,276
2047	3,886	-	$ 627,598	49,615	$ 296,468	$ 137,411	$ -	$ 490,187	$ 150,270
2048	3,886	-	$ 418,399	49,615	$ 296,468	$ 142,137	$ -	$ 276,261	$ 82,223
2049	3,886	-	$ 209,199	49,615	$ 296,468	$ 147,026	$ -	$ 62,173	$ 17,966
2050	3,886	-	$ -	49,615	$ 296,468	$ 152,083	$ -	$ (152,083)	$ (42,666)
Total	137,953								$ **36,340,900**
2020 Total	**21,373**								$ **11,119,457**
2020 CE =	$ **520**	$2007/tCO2e	3% Discount Rate						

Attachment 3. Forest Canopy/Cover Requirement

Year	GHG Reductions (tCO_2e)	Tree Replacement Cap Costs ($)	Annualized Cap Costs ($)	Energy Savings ($)	Urban Tree Maintenance ($)	Admin Costs	Total Annual Costs ($)	Discounted Costs (2007$)
2010	-	$49,920,000	$2,546,881	$0	$0	$320,000	$2,866,881	$2,623,603
2011	35,351	$49,920,000	$5,093,763	$265,612	$2,754,000	$320,000	$7,902,151	$7,020,959
2012	70,702	$49,920,000	$7,640,644	$549,495	$5,508,000	$320,000	$12,919,149	$11,144,171
2013	106,052	$49,920,000	$10,187,526	$824,243	$8,262,000	$320,000	$17,945,283	$15,028,892
2014	141,403	$49,920,000	$12,734,407	$1,098,991	$11,016,000	$320,000	$22,971,417	$18,677,864
2015	176,754	$49,920,000	$15,281,289	$1,373,738	$13,770,000	$320,000	$27,997,550	$22,101,525
2016	212,105	$49,920,000	$17,828,170	$1,648,486	$16,524,000	$320,000	$33,023,684	$25,309,904
2017	247,456	$49,920,000	$20,375,051	$1,923,234	$19,278,000	$320,000	$38,049,818	$28,312,638
2018	282,806	$49,920,000	$22,921,933	$2,197,981	$22,032,000	$320,000	$43,075,952	$31,118,984
2019	318,157	$49,920,000	$25,468,814	$2,472,729	$24,786,000	$320,000	$48,102,085	$33,737,835
2020	353,508	$49,920,000	$28,015,696	$2,747,476	$27,540,000	$320,000	$53,128,219	$36,177,732
2021	353,508	$0	$28,015,696	$2,841,975	$27,540,000	$0	$52,713,720	$34,849,979
2022	353,508	$0	$28,015,696	$2,939,725	$27,540,000	$0	$52,615,971	$33,772,190
2023	353,508	$0	$28,015,696	$3,040,836	$27,540,000	$0	$52,514,860	$32,725,525
2024	353,508	$0	$28,015,696	$3,145,425	$27,540,000	$0	$52,410,271	$31,709,076
2025	353,508	$0	$28,015,696	$3,253,611	$27,540,000	$0	$52,302,085	$30,721,963
2026	353,508	$0	$28,015,696	$3,365,518	$27,540,000	$0	$52,190,177	$29,763,329
2027	353,508	$0	$28,015,696	$3,481,275	$27,540,000	$0	$52,074,421	$28,832,344
2028	353,508	$0	$28,015,696	$3,601,012	$27,540,000	$0	$51,954,683	$27,928,202
2029	353,508	$0	$28,015,696	$3,724,868	$27,540,000	$0	$51,830,827	$27,050,120
2030	353,508	$0	$28,015,696	$3,852,984	$27,540,000	$0	$51,702,711	$26,197,337
2031	353,508	$0	$28,015,696	$3,985,507	$27,540,000	$0	$51,570,189	$25,369,116
2032	353,508	$0	$28,015,696	$4,122,588	$27,540,000	$0	$51,433,108	$24,564,739
2033	353,508	$0	$28,015,696	$4,264,383	$27,540,000	$0	$51,291,312	$23,783,511
2034	353,508	$0	$28,015,696	$4,411,056	$27,540,000	$0	$51,144,640	$23,024,757
2035	353,508	$0	$28,015,696	$4,562,773	$27,540,000	$0	$50,992,922	$22,287,821
2036	353,508	$0	$28,015,696	$4,719,709	$27,540,000	$0	$50,835,987	$21,572,066
2037	353,508	$0	$28,015,696	$4,882,043	$27,540,000	$0	$50,673,653	$20,876,874
2038	353,508	$0	$28,015,696	$5,049,959	$27,540,000	$0	$50,505,736	$20,201,645
2039	353,508	$0	$28,015,696	$5,223,652	$27,540,000	$0	$50,332,044	$19,545,797
2040	353,508	$0	$25,468,814	$5,403,318	$27,540,000	$0	$47,605,496	$17,948,522
2041	353,508	$0	$22,921,933	$5,589,164	$27,540,000	$0	$44,872,769	$16,425,448
2042	353,508	$0	$20,375,051	$5,781,402	$27,540,000	$0	$42,133,649	$14,973,599
2043	353,508	$0	$17,828,170	$5,980,253	$27,540,000	$0	$39,387,917	$13,590,109
2044	353,508	$0	$15,281,289	$6,185,942	$27,540,000	$0	$36,635,346	$12,272,216
2045	353,508	$0	$12,734,407	$6,398,706	$27,540,000	$0	$33,875,701	$11,017,264
2046	353,508	$0	$10,187,526	$6,618,789	$27,540,000	$0	$31,108,737	$9,822,694
2047	353,508	$0	$7,640,644	$6,846,441	$27,540,000	$0	$28,334,204	$8,686,044
2048	353,508	$0	$5,093,763	$7,081,922	$27,540,000	$0	$25,551,840	$7,604,943
2049	353,508	$0	$2,546,881	$7,325,504	$27,540,000	$0	$22,761,378	$6,577,110
2050	353,508	$0	$0	$7,577,463	$27,540,000	$0	$19,962,537	$5,600,349
Totals	**12,549,534**							**$860,548,793**
			2020 CE =	**$119**	**$2007/$tCO_2e$**	**3% Discount Rate**		

Attachment 4. Sustainable Agriculture							
Year	GHG Reductions (tCO_2e)	Program Acres	Payments ($)	Admin. Costs ($)	Fuel Savings ($)	Annualized Costs ($)	Discounted Costs (2007$)
2010	1,740	3,500	$ 35,000	$ 210,000	$ 30,135	$ 214,865	$ 196,632
2011	3,479	7,000	$ 70,000	$ 210,000	$ 68,105	$ 211,895	$ 188,266
2012	5,219	10,500	$ 105,000	$ 210,000	$ 102,158	$ 212,842	$ 183,600
2013	6,958	14,000	$ 140,000	$ 210,000	$ 136,210	$ 213,790	$ 179,046
2014	8,698	17,500	$ 175,000	$ 210,000	$ 170,263	$ 214,737	$ 174,601
2015	10,437	21,000	$ 210,000	$ 210,000	$ 204,315	$ 215,685	$ 170,263
2016	12,177	24,500	$ 245,000	$ 210,000	$ 238,368	$ 216,632	$ 166,031
2017	13,916	28,000	$ 280,000	$ 210,000	$ 272,420	$ 217,580	$ 161,900
2018	15,656	31,500	$ 315,000	$ 210,000	$ 306,473	$ 218,527	$ 157,869
2019	17,395	35,000	$ 350,000	$ 210,000	$ 340,526	$ 219,475	$ 153,935
2020	19,135	38,500	$ 385,000	$ 210,000	$ 374,578	$ 220,422	$ 150,097
Total	**114,807**	**38,500**					**$ 1,882,238**
2020 CE =	**$ 16.39**	$2007/tCO2e	3% Discount Rate				

Chapter 6
Transportation and Land Use

Introduction

Six supporting recommendations or related actions for mitigating carbon by transportation and land use measures were analyzed for their emission reductions and/or costs. These include:

- TLU-1 - Facilitate Widespread use of Low-Emission and Zero-Emission Vehicles
- TLU-2 - Require Low-Carbon Fuels;
- TLU-3 - Transition to Low-Carbon Methods of Goods Movement;
- TLU-4 - Maintain Good State-of-Repair in Roads Infrastructure and Operation while mitigating greenhouse gas (GHG) Impacts;
- TLU-5 - Reduce vehicle-miles traveled (VMT); and
- TLU-6 - Double Transit Ridership and Enhance Greenhouse Commuting Programs.

Table 6.1 summarizes the estimated GHG emission reductions and costs for each of the six recommendations or actions. The remainder of this chapter provides information on the parameters for analysis, methods, data sources, and assumptions used to prepare the analysis for each of the supporting recommendations or related actions.

Overview of Analytical Approach

Analysis of transportation and land use issues is inherently complex, given the inter-relationships among transportation systems, land use, and other important aspects of societal well-being. Several issues arise in any assessment of the GHG emissions impacts associated with changes to the transportation system. The variables and assumptions used have a significant impact on the outcome. Key variables include but are not limited to (1) future growth rates for VMT, (2) average fuel prices, and (3) discount rates. Evaluation of the baseline scenario is also as important as is an evaluation of the validity of changes to the baseline.

For any specific analysis of changes to the transportation system, a number of analytical questions arise. Some of these questions include:

(1) What is the affected population?
(2) What portion of the population is affected?
(3) What is the market penetration rate for any changes to business as usual?
(4) How quickly is the population affected (i.e., is the pattern linear, exponential, or asymptotic)?

The analytic methods and the results they produce are often dependent upon professional judgments by stakeholders and the timing and sequencing of programs and projects:

(1) When do the programs start?

(2) How long is the ramp-up period?

(3) What is the shape of ramp-up period to the horizon year?

(4) What horizon year is used?

(5) Is peer group comparison data used? (e.g., data related to the size of urbanized areas, patterns of baseline development, and stages in pathway upon technology curves).

Table 6.1. Total Estimated GHG Emission Reductions and Net Costs and Cost Savings for All TLU Supporting Recommendations and Related Actions

No.	Name of Supporting Recommendation or Related Action	Annual Results (2020)		Cumulative Results (2009-2020)			
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)	Fuel Savings (million gallons)
1	Facilitate widespread use of low and zero emissions vehicles	4.52	$825	20.77	$2,861	$138	1,459
2	Require low carbon fuels	4.53	$991	21.74	$3,728	$171	1,727
3	Transition to low carbon methods of goods movement	1.40	-$54	8.13	-$417	-$51	686
4	Maintain good state of repair in roads infrastructure and operation while mitigating GHG impacts	0.006	-$6	0.07	-$58	-$831	8
5	Reduce vehicle-miles traveled (VMT)	3.41	-$1,445	20.48	-$9,598	-$469	1,925
6	Double transit ridership and enhance greenhouse commuting programs	0.65	n/a	3.92	n/a	n/a	337
Sector Total Before Adjusting for Overlaps		14.52	$311	75.11	-$3,484	-$46	6,142
Sector Total After Adjusting for Overlaps		12.24	$49	64.00	-$4,033	-$63	5,281

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; TBD = to be determined; NA = Not available.

Costs are discounted to year 2009 in 2007 dollars using a 3% real discount rate. Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above supporting recommendations and related actions is for reference purposes only; it does not reflect prioritization among these recommendations.

To ensure consistent results across recommendations, common factors and assumptions are used for the following items:

- ***Independent and integrated analyses*—**Each recommendation is first analyzed individually and then addressed as part of an overall integrated analysis.
- ***Fuel costs and projected escalation*—**Fuel cost estimates are based on common sources wherever possible. For example, fossil fuel price escalation is indexed to the U.S. Department of Energy (U.S. DOE), Energy Information Administration (EIA) projections as indicated in their most recent Annual Energy Outlook 2008 (AEO2008).[20]
- ***Consumption-based approach*—**The analysis uses a consumption-based approach where emissions are calculated on the basis of the consumption of transportation fuels (regardless of where produced) to provide energy to consumers, as opposed to a production-based approach, which considers the emissions from in-state production of transportation fuels (regardless of where the fuels are consumed).
- ***Life-cycle GHG approach*—**Life-cycle GHG emissions are considered to the extent feasible. The use of the U.S. DOE life-cycle emissions analysis tools (i.e., GREET and VISION) facilitates these analyses of the life-cycle GHG emissions of Transportation and Land Use sector activities.

In addition to estimating the impacts of each individual policy recommendation, the combined impacts of the TLU policy recommendations are estimated, assuming that all policies are implemented together. This “overlap analysis” involves adjusting gross totals for the TLU sector to avoid double-counting of impacts. In addition, overlaps between policy recommendations in the TLU sector and policies in other sectors were identified. The following section identifies where these overlaps occur and summarizes the methods used to adjust the impacts analysis to avoid double-counting of impacts. Potential synergies between TLU policies may not be fully accounted for, and so the results are best interpreted as *conservative* estimates of GHG reductions.

Method for Analyzing the Potentially Overlapping Impacts of Combined TLU Policies

It is widely accepted that there are three general categories of factors that impact the emission of GHGs from the transportation sector. These three general categories are often described as “the three-legged stool.” The three categories (or three legs of the stool) are vehicle characteristics, fuels, and travel activity or travel demand.

These three factors interact in a complex fashion to affect on GHG emission levels. The following formula summarizes this interaction in a simplified fashion:

(1) Vehicle miles traveled per year divided by

(2) Miles per gallon multiplied by

(3) Million metric tons of carbon equivalent ($MMtCO_2e$) per gallon yields

(4) $MMtCO_2e$ per year.

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[20] U.S. Department of Energy (U.S. DOE), Energy Information Administration (EIA), Annual Energy Outlook 2008, http://www.eia.doe.gov/oiaf/archive/aeo08/index.html.

Thus, the GHG emissions reductions resulting from individual stand-alone policies are not simply additive. For example, a policy that reduces VMT will *reduce* the GHG benefits of a policy that improves fuel economy or one that reduces fuel carbon intensity and vice versa.

The cumulative GHG emissions reduction that would result if all TLU policies described below were implemented as a package was estimated by identifying the potential for overlap between the policies as follows:

- TLU Categories 1 and 2 and the New Jersey LEV program affect both the light-duty vehicle (LDV) and heavy-duty vehicle (HDV) fleets, while TLU-3 affects the HDV fleet. Overlaps between TLU-3 and the other measures were not assessed because TLU-3 relates to the operation and use of HDVs and does not relate to the vehicle technologies themselves.
- TLU Category 1 and the New Jersey LEV program affect vehicle fuel economy. TLU-2 and TLU-3 affect the carbon intensity of fuels. TLU-4 affects traffic flow and operations in urban areas, which primarily impact vehicle fuel economy. TLU Categories 5 and 6 affect primarily LDV VMT. The overlap within each of these three groups was first determined.
- As a final step, the overlap between each of the three categories of the three-legged stool was estimated and applied. The use of the VISION model was a critical tool in this step in the overlap analysis. Consecutive and alternative VISION model runs provided an estimate of the overlap between Categories 1, 2, and NJ LEV. In addition, alternative VMT inputs into VISION with subsequent runs of the model provided an estimate of the overlap between the VMT categories and other categories.

Facilitating Widespread Use of Low and Zero Emissions Vehicles (TLU-1)

To quantify the GHG emission reductions and cost-effectiveness of low and zero emissions vehicles, a target of 10% reduction in carbon intensity over predicted levels in 2020 was assumed. This target is based on New Jersey's stated commitment to developing an approach to implementing a low-carbon fuel standard (LCFS) that would reduce carbon intensity by 10% by 2020. There are many approaches and combinations of approaches to achieving this goal, and analysis of all of the approaches is beyond the scope of this study. Therefore a single well-defined scenario was selected for investigation.

In this analysis, new electric vehicles powered by zero-emission energy sources are assumed to displace new gasoline internal combustion engine LDVs so that the target is met. The analysis was performed with the VISION spreadsheet modeling tool.[21] VISION provides estimates of the potential energy use, oil use and carbon emission impacts through 2100 of advanced LDV and HDV vehicle technologies and alternative fuels. The VISION model reflects data from EIA's AEO2008 report and includes vehicle fleet characteristics for the entire United States. To generate emission estimates, the VISION model uses full fuel-cycle carbon emissions rates from Argonne National Laboratory's GREET model.

The VISION model default values used in the present study reflect the characteristics of the U.S. vehicle fleet and fuel prices. These characteristics were not altered, with the exception of the proportions of electricity derived from various sources, which were based on the New Jersey energy profile for February 2009.[22] On-road fuel consumption in New Jersey was derived from VMT estimates and the U.S. fleet fuel efficiency characteristics. Forecasted State fuel consumption as a percentage of the U.S. was used as a scaling factor to scale the VISION U.S. results to New Jersey. Vehicle costs were scaled using the share of vehicle registrations in New Jersey to the U.S. total.[23]

Other Assumptions

- 100% of the electricity necessary to power new electric vehicles was assumed to be derived from wind, solar and geothermal. Many other blends of energy sources are possible, but this one was selected for analysis because it is assumed that additional electrical power for electric vehicles would be fully powered by renewable energy sources.
- The new electric LDV market share of new car sales was assumed to increase linearly from 2010 to 2020 when it reaches 22.55% and attains a 10% reduction in carbon equivalent emissions against forecasted emissions.
- New electric vehicles were assumed to displace gasoline internal combustion engine market share.

[21] ANL, http://www.transportation.anl.gov/modeling_simulation/VISION/index.html.
[22] EIA, http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=NJ.
[23] HWA, Policy Information, http://www.fhwa.dot.gov/policy/ohpi/hss/index.cfm.

- Annual percentage reductions in carbon equivalent emissions were applied to a baseline forecast of GHG emissions for New Jersey to determine the reduction in carbon dioxide equivalent (CO_2e) emissions.

Savings
- Avoided gasoline and ethanol sales were based on forecasted U.S. fuel prices and multiplied by a scaling factor for New Jersey.

Costs
- Vehicle costs were calculated by multiplying the cost of an electric vehicle over the cost of a conventional gasoline vehicle by the number of vehicles sold, scaled to New Jersey.
- To calculate fuel costs, an average of U.S. renewable electricity prices for solar, geothermal, and wind was multiplied by the electricity consumption necessary to power the New Jersey fleet of electric vehicles. [24]

Table 6.2 provides a summary of the emission reductions and net discounted costs estimated for this supporting recommendation.

Table 6.2. Estimated GHG Emission Reductions and Net Cost Savings for TLU-1

Year	Additional Vehicle Cost (millions)	Additional Electricity Cost (millions)	Gasoline & Ethanol Cost (millions)	Total Cost (millions)	GHG Reduction ($MMtCO_2e$)	Cost-Effectiveness (mil. $/MMtCO_2e$)	Gasoline Reduction (million gallons)
2009	$0.00	$0.00	$0.00	$0.00	0.00	$0.00	0.00
2010	$14.99	$10.09	-$14.29	$10.79	0.07	$148.03	5.22
2011	$46.56	$31.40	-$43.34	$34.61	0.23	$150.93	16.22
2012	$95.31	$63.91	-$86.47	$72.75	0.47	$154.45	33.15
2013	$160.63	$106.16	-$139.79	$127.00	0.79	$160.46	55.21
2014	$241.35	$157.29	-$204.86	$193.79	1.18	$164.85	81.77
2015	$338.10	$217.11	-$272.71	$282.51	1.62	$174.48	112.60
2016	$451.07	$285.78	-$348.81	$388.04	2.12	$183.17	147.78
2017	$578.63	$361.78	-$440.06	$500.36	2.66	$187.95	186.27
2018	$720.62	$445.62	-$545.21	$621.03	3.25	$191.28	228.14
2019	$862.47	$536.08	-$675.27	$723.27	3.87	$186.95	273.07
2020	$1,002.45	$631.59	-$808.93	$825.11	4.52	$182.65	319.97
Total				**$2,861.18**	**20.77**	**$137.73**	**1,459.40**

[24] Smith, Rebecca. "The New Math of Alternative Energy." Wall Street Journal. February 12, 2007.

Requiring Low-Carbon Fuels in the Transportation Sector (TLU-2)

To quantify the GHG emission reductions and cost-effectiveness of a LCFS, a target of 10% reduction in carbon intensity over predicted levels in 2020 was assumed. This target is based on New Jersey's stated commitment to developing an approach to implementing a low-carbon fuel standard that would reduce carbon intensity by 10% by 2020. The standard is assumed to be met by fuel providers: refiners, importers, and blenders of on-road vehicle fuels. The LCFS is assumed not to specify a particular mix of fuel types—the fuel formulations are left to fuel providers, who decide how to meet the standard. The possible fuels that could be used to meet the standard are assumed to include ethanol, biodiesel, compressed natural gas (CNG), liquefied petroleum gas (LPG), hydrogen, and electricity.

As with TLU-1, many approaches could lead to achievement of the 10% goal, and a single one was selected for investigation. The analysis here was performed by examining the impact of increased sales of spark ignition plug-in hybrid electric vehicles (SI PHEV). (Note: according to AEO 2008 forecasts of greenhouse gas emissions, biofuels were not sufficiently low in emissions to achieve the 10% goal.) Previous analyses have been conducted using the methods described below for several other states, including Washington, Montana, South Carolina, Iowa, and Arkansas.

The analysis was performed with the VISION spreadsheet modeling tool (see TLU-1 for a description). The VISION model default values used here reflect the characteristics of the U.S. vehicle fleet and fuel prices. These characteristics were not altered, with the exception of the proportions of electricity derived from various sources, which were based on the New Jersey energy profile for February 2009.[25] On-road fuel consumption in New Jersey was derived from VMT estimates and the U.S. fleet fuel efficiency characteristics. The forecasted State fuel consumption as a percentage of the U.S. fuel consumption was used as a scaling factor to scale the VISION U.S. results to New Jersey. Vehicle costs were scaled to New Jersey using the ratio of vehicle registrations in New Jersey to the U.S. total.[26]

<u>Other Assumptions</u>

- According to default carbon coefficients in the VISION model, New Jersey electricity produces 24.64 $MMtCO_2e$ per quadrillion British thermal unit (Btu), and gasoline produces 26.87. The majority of the decrease in emissions in the present study is thus from the increased mileage per gallon of the vehicles rather than from fuel switching.
- To reach the goal of a 10% decrease in carbon intensity by 2020, sales of new gasoline internal combustion engine vehicles were assumed to be phased out entirely by 2018 in favor of SI PHEVs. (In the individual analyses for TLU-1 and TLU-2, CCS assumed that the new vehicle technologies (ZEV and SI PHEV) replaced the most fuel inefficient technology, which was gasoline, and the model was able to increase new sales penetration to meet the 10% reduction goals by subtracting the corresponding new sales market penetration from the gasoline-only vehicle sales percentage forecast. However, when the two technologies were

[25] EIA, http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=NJ.
[26] HWA, Policy Information, http://www.fhwa.dot.gov/policy/ohpi/hss/index.cfm.

combined for the overlap analysis, the combined new sales percentage of ZEVs and SI PHEVs went beyond the forecasted new sales percentage of gasoline-only vehicles in 2017.)

- Annual percentage reductions in carbon-equivalent emissions were applied to a baseline forecast of GHG emissions for New Jersey to determine the forecasted reduction in CO_2e emissions.

Savings
- Avoided gasoline and ethanol sales were based on forecasted U.S. fuel prices and multiplied by a scaling factor for New Jersey.

Costs
- Vehicle costs were calculated by multiplying the cost of SI PHEV over the cost of a conventional gasoline vehicle by the number of vehicles sold, scaled to New Jersey.
- Increased electricity consumption was multiplied by the forecasted U.S. price of electricity and scaled to New Jersey.

Table 6.3 provides a summary of the emission reductions and net discounted costs estimated for this supporting recommendation.

Table 6.3. Estimated GHG Emission Reductions and Net Costs for TLU-2

Year	Additional Vehicle Cost (millions)	Additional Electricity Cost (millions)	Gasoline & Ethanol Cost (millions)	Total Cost (millions)	GHG Reduction ($MMtCO_2e$)	Cost-Effectiveness (mil. $/MMtCO_2e$)	Gasoline Reduction (million gallons)
2009	$0.00	$0.00	$0.00	$0.00	0.00	$0.00	0.00
2010	$32.71	$1.53	-$18.05	$16.19	0.08	$193.60	6.59
2011	$98.50	$4.56	-$53.00	$50.06	0.26	$196.26	19.83
2012	$197.62	$9.42	-$104.39	$102.66	0.52	$199.06	40.02
2013	$327.78	$16.16	-$167.61	$176.33	0.86	$205.71	66.20
2014	$485.79	$24.16	-$243.38	$266.57	1.26	$211.84	97.14
2015	$671.81	$34.89	-$324.29	$382.41	1.73	$221.66	133.88
2016	$885.23	$47.70	-$414.43	$518.50	2.24	$231.03	175.54
2017	$1,122.28	$63.26	-$523.01	$662.54	2.80	$236.22	221.33
2018	$1,394.51	$82.61	-$656.42	$820.70	3.44	$238.40	274.63
2019	$1,622.75	$101.76	-$802.05	$922.46	4.03	$229.18	324.27
2020	$1,802.47	$118.90	-$930.24	$991.13	4.53	$218.83	367.88
Total				**$3,727.90**	**21.74**	**$171.47**	**1,727.31**

Transition to Low-Carbon Methods of Goods Movement (TLU-3)

To quantify the GHG emission reductions and net costs of a transition to low-carbon methods of goods movement, the following three approaches were examined:

- Encouraging truck stop electrification;
- Promoting the use of plug-in trailer refrigeration units; and
- Encouraging increased use of shuttle rail to move goods.

The effects of encouraging truck stop electrification (TSE) were calculated by estimating the number of expected TSE units during the policy analysis period (i.e., 2009 to 2020), the GHG reductions attributed to a TSE unit relative to traditional engine idling, and the cost of expanding TSE units on a per unit basis. The 2009 count of TSE units in New Jersey was estimated using information from the U.S. DOE.[27] The number of truck stops in New Jersey is assumed to increase at the same growth rate as TSE units in New York, as estimated in a recently completed NYSERDA study. GHG emissions relative to traditional idling practices and TSE unit costs were obtained from a 2004 TRB study.[28]

There is a lack of readily available data on the number of trailer refrigeration units (TRUs) in New Jersey. Accordingly, the number of TRUs in New Jersey was estimated by scaling the number of TRUs in New York, according to a recently completed NYSERDA study, by the population ratio for the two states. Plug-in TRU GHG emissions relative to traditional idling practices and TRU unit costs were obtained from a 2004 TRB study.[29] The analysis utilizes a perpetual inventory of TRUs that enter and exit the TRU population as old units are phased out and new units are purchased over time.

The effects of encouraging increased use of freight rail diversion were estimated from a national level estimate of the impacts of freight rail diversion. New Jersey's share of the estimated GHG reduction and cost estimates were scaled using New Jersey's current share of national rail freight movement, which is estimated to be 1.3% of all national rail-transported freight and available rail lines.[30]

Other Assumptions

- The annual percentage reductions in carbon-equivalent emissions were applied to a baseline forecast of GHG emissions for New Jersey to determine the reductions in CO_2e emissions.

Savings

- Avoided gasoline and ethanol sales were obtained by multiplying a scaling factor for New Jersey by forecasted U.S. fuel prices.

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[27] Department of Energy, http://www.afdc.energy.gov/afdc/locator/tse/state.
[28] TBR. 2004. "Long-Haul Tractor Idling Alternative." Table 1. http://epa.gov/smartway/documents/dewitt-study.pdf.
[29] TBR. 2004. "Long-Haul Tractor Idling Alternative." Table 1. http://epa.gov/smartway/documents/dewitt-study.pdf.
[30] New Jersey State Rail Plan. 2009. http://www.state.nj.us/transportation/freight/rail/pdf/railplan.pdf.

Costs

- TRU and TSE program costs are calculated by multiplying the cost of a TRU or TSE unit by the number of TRUs and TSEs expected to be sold in New Jersey over time minus the fuel savings expected from introducing the new technology. The number of TSEs sold is based on a growth rate assigned to the number of TSEs currently in New Jersey. The number of TRUs is scaled down from the number of TRUs in New York based on the population ratio for the two states.

- Rail freight diversion costs were estimated by scaling down the national-level costs of rail freight diversion based on the current share of rail freight that is transported through New Jersey according to the Association of American Railroads.[31] To calculate the costs and levels of rail diversion that might be realized, a credible source is AASHTO's Bottom Line report for rail.[32]

Table 6.4 provides a summary of the emission reductions and net costs and cost savings estimated for this related action.

Table 6.4. Estimated GHG Emission Reductions and Net Costs and Savings for TLU-3

	Annual Results (2020)		Cumulative Results (2009-2020)			
	GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/$tCO_2e$)	Fuel Savings (million gallons)
Trailer Refrigeration Units (TRU)	0.38	-$68.64	2.63	-$382.00	-$145.16	231.07
Truck Stop Electrification (TSE)	0.52	$15.03	1.45	$30.91	$21.35	126.53
TRU + TSE (Anti-idling)	0.90	-$53.61	4.08	-$351.09	-$86.06	357.60
Rail Diversion	0.49	-$0.01	4.05	-$66.18	-$16.36	328.06
Total (TRU + TSE + Rail)	**1.40**	**-$53.62**	**8.13**	**-$417.27**	**-$51.35**	**685.66**

[31] "State Rankings: 2007" Association of American Railroads. http://www.aar.org/~/media/AAR/2007_RailroadsAndStates/State%20Rankings%202007.ashx

[32] "Transportation Invest in America Freight-Rail Bottom Line Report," American Association of State Highway and Transportation Officials (AASHTO).

Maintaining a Good State of Repair in Roads Infrastructure and Operation while Mitigating Greenhouse Gas Impacts (TLU-4)

Transportation System Management (TSM), the key concept here, means managing and operating the transportation system to help transportation networks meet demand in an effective and efficient manner. Effective system management may utilize a variety of strategies based on advanced technologies, market-based incentives, regulations, and design standards. Each strategy provides a relatively small benefit in terms of GHG reduction, but when applied in concert, significant gains can be achieved.

Technological improvements include traffic signal coordination, lane management, traveler information displays, and other “intelligent” transportation system applications. Incentives can include policies that financially favor desired behavior or that allow users to gain a time advantage and include value pricing and smart parking strategies. System design is also important since infrastructure and technology can be adapted to encourage less driving; system design includes access management applications and intersection improvements. Finally, users can be barred from performing certain actions that would negatively impact the efficiency of the transportation system. TSM policies can be instituted at every level of government; some can have a virtually instant effect, while others require many decades to reap the full benefits.

For this related action, the emission reductions and costs associated with expansion of emergency service patrols and of signal synchronization were estimated using data that was provided by various New Jersey state and local agencies. Analysis of the cumulative impacts was conducted using simple spreadsheet analysis techniques; given the relatively small size of the projects involved, no ramp-up was assumed within the eleven-year period from 2009 to 2020. Cost estimates were based on information provided by New Jersey Department of Environmental Protection (NJDEP). Table 6.5 provides a summary of the emission reductions and net cost savings estimated for this related action.

Table 6.5. Estimated GHG Emission Reductions and Net Cost Savings for TLU-4

	Annual Results (2020)		Cumulative Results (2009-2020)			
	GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)	Fuel Savings (million gallons)
Emergency service patrols	0.001	-$0.5	0.014	-$4.7	-$338	1.6
Signal Synchronization	0.005	-$-5.8	0.056	-$53.6	-$954	6.4
Total	0.006	-$6.3	0.070	-$58.3	-$831	8.0

Reducing Vehicle Miles of Travel (TLU-5)

The most common approach for reducing travel activity is to reduce VMT; therefore, for this supporting recommendation, methods for reducing VMT were analyzed. The baseline forecast of VMT in the absence of new technologies and institution of certain “best practices” is based on VMT data provided by the New Jersey Department of Transportation (NJDOT). Based on historical trends, VMT are increasing at an annual rate of 1.7% over the 2005 baseline value of 64.2 billion VMT and at that rate would reach 82.6 billion VMT in 2020. If instead VMT increases were held to 1%/year, the level would reach 74.5 billion VMT in 2020, or about 8.1 billion VMT/year less. GHG emissions associated with vehicle travel would decline accordingly. This comparison raises the following questions:

1. Is a reduction of 8.1 billion VMT/year by 2020 realistic?
2. What policy measures would be needed to achieve that reduction?
3. What would be the net costs or benefits of those measures?

A variety of state, regional, and municipal land use planning and development practices and expansion of travel mode options can affect the number and length of vehicle trips. There is no one program or approach that can achieve New Jersey’s VMT and GHG reduction goals, but over the long term, a suite of approaches can substantially reduce the state’s GHG emissions by reducing the growth in VMT. It should be noted that within any group of approaches, the strength of implementation is a key variable.

- Estimating the impact of all of the many potential VMT-reducing mechanisms is beyond the scope of this study. The analysis presented in this section and the next simplifies by dividing the potential mechanisms into those producing *primary or direct* VMT reductions due to (e.g., expanding public transit) and those resulting in *secondary or indirect* reductions (e.g., stemming from a shift towards more compact development patterns).[33] The terminology is widely used in the field and does not imply relative importance.

- The analysis of the potential for VMT reduction relies upon a well-established body of research and policy analysis that incorporates the concept of ‘transit leverage’. Statistical studies of cities around the world have shown that those with significant transit investments show a more energy-efficient use of the transportation system that is not fully accounted for simply by 'mode shift' from private automobiles to bus and rail transit. There has been increasing understanding that transit networks also allow for more trip chaining (see below), shorter driving trips, and more walking trips. As a result, researchers have recognized in the last decade that some cities have been able to “leverage” transit investments in a manner that augments their impact.

Newman describes the operation of transit leverage as follows: “The phenomenon of ‘transit leverage’ is where people who switch from a car to transit actually save more than just one

[33] More compact development can reduce truck trip lengths, but the vast majority of the literature examines light-duty vehicle (LDV) VMT only. This study therefore considers potential GHG reductions from reductions in VMT for personal (non-commercial) travel.

passenger km [kilometer] for one passenger km as an engineer would calculate. For a start trains go straighter than cars and hence even for the same destination there will be extra passenger km saved. Then passengers tend to do 'trip chaining' where several functions are combined like shopping, collecting dry cleaning, picking up children, when they take a transit trip which means even more passenger km are saved. Then as is often the case with quality transit, households save on (i.e., eliminate) one car and hence even more trips are saved. Finally, transit tends to attract land use around it and hence even fewer passenger km are generated."[34]

The American Public Transportation Association (APTA) and the United States Federal Transit Administration (FTA) have both recognized the role and contribution of transit leverage and have provided information to assist transit agencies and policy analysts to consider the effects of transit leverage. As Johnston states, "[t]he most effective policy sets combine land use policies, such as compact growth, with strong transit provision and not expanding highway capacity. The addition of auto pricing policies, such as fuel taxes, work trip parking charges, or all-day tolls increases the effectiveness of land use and transit policies." In reviewing one study of U.S. scenario exercises, Johnston found that "[t]hese studies generally evaluated modest growth management policies and did not employ the pricing of parking or fuels or roadways. So, these results may be viewed as lower bounds on what VMT reductions could occur in scenario exercises."[35]

The concept of "transit leverage" (or the "land use multiplier" as it is sometimes called) is backed by significant scientific evidence based on international comparisons of cities. For example, a Canadian study suggested that "capital investment in expanded transit systems appears to have relatively little impact on GHG reductions on its own unless accompanied by highly integrated and effective travel demand management (TDM) measures. Effective TDM may also require the gradual introduction of road pricing. In other words, achieving transit ridership goals and associated emissions reductions requires appropriate TDM policies (probably eventually including road pricing) and real land use initiatives. At the same time, if appropriate TDM policies are implemented, considerable capital investment in expanded transit services will be required to accommodate the anticipated modal shifts."[36]

Strength of the "Transit Leverage" Effect

A large body of literature now documents the effects of compact, transit-oriented land-use patterns on reducing vehicle trips and vehicle travel (for a recent synthesis, see Ewing, Bartholomew et al. 2008). Appendix A describes some of the more noteworthy studies. Evidence for the transit leverage or land-use multiplier is considerably strengthened by the fact that the studies generate results that are at least the same order of magnitude. This is

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[34] Peter Newman, "Saving Transport Greenhouse—Some basic principles and data", unpublished paper, Curtin University.

[35] Johnston, Robert A., Department of Environmental Science & Policy, University of California – Davis, "Review of U.S. and European Regional Modeling Studies of Policies Intended to Reduce Transportation Greenhouse Gas Emissions," July 30, 2007, for presentation at the Transportation Research Board (TRB) Annual Meeting, Washington, D.C., January, 2008.

[36] "The Impact of Transit Improvements on GHG Emissions: A National Perspective: Final Report," (March 2005) Prepared for Transport Canada, prepared by Cansult and TSi Consultants, p. 29.

despite significant differences in methodologies, geographic context and the method of computing the multiplier (some studies report it as the reduction in vehicle travel per transit passenger mile, while others report it as a multiple of the primary mode shift effect).[37]

The research shows an overall consensus on the general range of the transit leverage effect, namely somewhere between 2 and 7 times for North American urban areas. This means that for every mile reduction in VMT due to increased transit options and mode shift, between 2 and 7 *additional* miles are reduced due to indirect or secondary effects. It is plausible that the international comparisons show a higher range of values because cities and countries in other parts of the world have been able to successfully 'leverage' transit to a higher degree than most American cities have to date. Some results are based on U.S. transit, including bus-based systems, while other studies use data are from global cities with higher densities and a higher proportion of rail systems; given this, it is not surprising that the multiplier effects reported in the latter are sometimes stronger.

The transit leverage research and other related regional modeling research provide the basis for the following general method of quantifying and allocating the indirect effects of transit on VMT:

(1) An urban growth boundary can provide an impact roughly equal to the direct transit effect (i.e., it has a leverage of 1.0 "units" or 1.0 times the direct effect).

(2) A low level of travel demand management (TDM) programs can produce an effect roughly half as large as direct transit investment or 0.5x the direct effect.

(3) A high level of TDM programs can produce an additional 1.0 unit effect, for a total potential of 1.5x the direct effect from TDM programs.

(4) A program of significant auto use pricing (some combination of fuel taxes, tolls and other facility charges, parking charges, etc) can have an effect equal to the overall TDM effect.

(5) Congestion reduction associated with transit has an estimated effect that is 0.2x the direct transit effect.

(6) The remaining indirect effects may be considered to be mainly related to land use, including overall residential and job density, as well as transit-oriented development and other aspects of 'smart growth'.

Strategies that seek to result in avoided travel and trips are usually referred to "travel demand management" or TDM. Some TDM strategies being considered by New Jersey for implementation do not yet have sufficient data to provide an estimate of GHG emission and energy savings. For example, a regional network of High Occupancy Toll (HOT) lanes involves converting existing High Occupancy Vehicle (HOV) lanes to HOT and using the revenue generated to finance completion of the HOV/HOT system as well as other improvements within the HOT corridors. HOT lanes could provide for reduced congestion and emissions and provide faster and more predictable travel times for carpools and buses. Funds from HOT lanes could allow the region to complete its HOV network without having to rely on outside funds. Such a program could have a significant impact on VMT, but its extent and cost have not been developed in sufficient detail to include in the present analysis.

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[37] Recommended Practice for Quantifying Greenhouse Gas Emissions from Transit, APTA Climate Change Standards Working Group, Prepared for APTA Climate Change Standards Working Group (April 2008).

Application to New Jersey

In applying the transit leverage analysis to the state of New Jersey, several factors were considered:

(1) Are there urban limit lines (growth boundaries) that are in place or being considered?
(2) Does New Jersey as a state have a 'low TDM' or a 'high TDM' program level?
(3) Is a system of auto use pricing (including HOT lanes and New Jersey Transit parking charges) being considered for the horizon year of 2020?

Based on information provided by various state and local agencies about programs and policies in place and being considered, the indirect effects were assessed qualitatively as follows:

1. Urban growth boundaries were judged not to be in effect, but a program of growth management exists in terms of infrastructure investment and channeling of development toward locations where infrastructure is already available.
2. The level of TDM was judged to be high in suburban areas and medium in urban areas; the latter is lower because there tend to be more transit options in urban areas and where such options are available, people tend to use them without special TDM measures. The state as a whole can be characterized as medium to high in terms of TDM level.
3. Auto use pricing approaches, including parking taxes, pay-as-you-drive insurance, and other mechanisms, are being analyzed as possible ways of reducing auto use. Whether and when such measures might be adopted cannot be predicted with certainty at this time.

Based on these assumptions, the transit leverage effect for New Jersey and its components were estimated using the assumptions provided in Table 6.6. The land use factor of just under 4x and the overall factor of about 5.2x are in line with the range of results for North American cities (see above), especially given the highly urbanized nature of the northeastern New Jersey/New York transit service area, as summarized in Table 6.7. This analysis implies that holding the rate of VMT increase to 1%/year is a realistic goal for New Jersey. Table 6.8 shows the calculation of fuel savings (based on an assumed mileage of 23.31 mpg from 2009 through 2020) and $MMtCO_2e$ (based on 0.0005 Mt per VMT) saved per year.

Costs and Benefits of the Indirect Effects

The literature on the cost per ton associated with reducing GHG emissions through the use of pricing measures and travel demand management is somewhat uncertain. Growth management and land use change are obviously very complex policies with many components and therefore very more complicated cost structures. The cost for TLU-5 is, therefore, a rough estimate that considers selected study results for the cost of regional pricing, TDM, and land use/growth management measures.

Two studies of regional pricing measures include cost-effectiveness estimates:

(1) An unpublished study for the NYC metro area conducted for NYSERDA that CCS completed using the U.S. DOT's TRUCE model for the tri-state metro region.

(2) San Francisco Bay Area Metropolitan Transportation Commission results from Regional Transportation Plan documents.

Table 6.6. Transit Land Use Leverage Analysis Showing Estimated Direct and Indirect VMT Reduction Impacts

Savings in 2020 VMT from reducing VMT growth to 1.0%/yr from 1.7%/yr over 2005		8,133,370,190	100%
Transit leverage estimates:			
-direct transit effect*		1,307,700,774	16%
-total indirect transit effect		6,825,669,416	84%
Transit leverage factor		5.22	
Allocation of indirect effects	**Leverage factor**		
Urban growth boundaries with significant 'leakage'	0.25	326,925,194	4%
Medium (assumed) TDM programs	0.50	653,850,387	8%
Low (assumed) auto use pricing programs (including assumed New Jersey Transit parking tax)	0.50	653,850,387	8%
Land use leverage factor	3.97	5,191,043,449	64%
Total of non-transit VMT allocations	5.22	6,825,669,416	84%

* New Jersey Transit estimate pro-rated to 2020 based on New Jersey Transit capital expenditure data.

Table 6.7. Data on New Jersey Transit Service Area and Urban Area

Year	Service Area Population	Service Area Population Density	Urban Area Population	Population Density	Percent of Residents in Transit-Supportive Areas
2006	17,799,861	5,308.64	18,213,825	5,432	19%

Source: National Transit Database" of the U.S. Department of Transportation, Federal Transit Administration, http://204.68.195.57/ntdprogram/.

Table 6.8. Fuel Savings Calculated for TLU-5

Component of VMT Reduction	2020 Value (Billion VMT)	2020 Million Gallons Gasoline	$MMtCO_2e$ Saved (2020)
Savings in 2020 VMT from reducing VMT growth	8.1	349	4.07
Transit leverage estimates:			
-direct transit effect*	1.3	56	0.65
-total indirect transit effect	6.8	293	3.41
Allocation of indirect effects:			
Urban growth boundaries	0.3	14	0.16
Medium (assumed) TDM programs	0.7	28	0.33
Low (assumed) auto use pricing programs (including assumed New Jersey Transit parking tax)	0.7	28	0.33
Land use leverage	**5.2**	**223**	**2.60**
Total of non-transit VMT allocations	**6.8**	**293**	**3.41**

Based on these two studies, the cost of reducing VMT using auto use pricing mechanisms could be estimated at about $300/ton. However the federal Congestion Management and Air Quality (CMAQ) program reports an average for two categories of pricing measures of $399/ton (converted from 2005 dollars by CCS), without considering benefits. The average of these two estimates is $350/ton. CMAQ also reports a cost of $311/ton for regional TDM measures.

The cost of policies such as urban growth boundaries and other land use measures is harder to estimate. Some previous analyses have used a qualitative "less than zero" determination in other state climate action plans based upon extended stakeholder discussions of the issues in qualitative terms. There are several studies (most commonly, TRB TCRP "Cost of Sprawl" study by several authors at Rutgers University) to give basis for this qualitative judgment. In quite a few states, the stakeholders are comfortable with this assessment which translates numerically into a 'conservative' estimate of $0/ton.

The recent Moving Cooler report estimates a 'positive cost' associated with local planning efforts related to rezoning. A "zero" or even negative (cost savings) conclusion could be based upon an operating assumption that all measures undertaken are 'deregulatory' and relate to release existing market demand for development that is currently restricted by zoning. Two examples of deregulatory zoning would be (1) relaxation of height limits on development and (2) changes from single use zoning to zoning where mixed use development would be allowed occur. A positive cost, zero cost, and net cost savings are not necessarily inconsistent. The value used in any given situation would depend on whether or not and to what degree there is a belief that 'upzoning' or removal of a 'single use zoning' district or some other deregulatory zoning would have the effect of releasing pre-existing market demand for development. Of course results also depend upon the market conditions for specific locations in question

The staff of the California Air Resources Board has estimated this cost at a "conservative" $100 per MTCO2e, while other studies argue that the cost of such measures is nil. Rather than a cost of $100 (which we believe is high) or $0 per ton, we elect to use the midpoint of this range or $50 per ton, recognizing that this is a subject of active research and controversy and that new findings are likely to appear regularly.

Using the leverage factors from Table 6.6, the average cost per ton of the indirect transit leverage effects can be estimated as shown in Table 6.9.

Table 6.9. Weighted Average Cost per Ton for TLU-5 Indirect Transit Leverage Effects

Indirect effect	Leverage factor	Share of total	Cost/ton	Weight
Urban growth boundaries and land use measures	4.00 (approx.)	80%	$50	$40
TDM programs	0.50	10%	$311	$31
Auto use pricing programs	0.50	10%	$350	$35
Total or average	**5.00**	**100%**		**$106**

Using the weighted average of about $106/ton, we can then estimate the total cost of the TLU-5 measures, from which we need to subtract the indirect effects' share of the benefits described below in the discussion of TLU-6 (see Table 6.12).

Combining the costs and the benefits produces the results shown in Table 6.10. The estimated net cost savings of \$484/tCO_2e is conservative; Moving Cooler, for example, shows net cost savings for land use measures of \$728/tCO_2e.

Table 6.10. Estimated GHG Emission Reductions and Net Cost Savings for TLU-5

	Annual Results (2020)		Cumulative Results (2009-2020)			
	GHG Reductions (MMtCO_2e)	**Costs (Million \$)**	**GHG Reductions (MMtCO_2e)**	**Costs (NPV, Million \$)**	**Cost-Effectiveness (\$/tCO_2e)**	**Fuel Savings (million gallons)**
Total	3.41	-\$1,445	20.48	-\$9,598	-\$469	1,925

Doubling transit ridership and enhancing greenhouse commuting programs (TLU-6)

Improvement and expansion of existing transit service and implementation of new, innovative transit services can shift passenger transportation from single-occupant vehicles to public transit, thereby reducing VMT, fuel consumed, and emissions. Public transportation improvements are also critical to support Smart Growth initiatives, which as discussed above accounts for even greater reductions in VMT, fuel consumption, and emissions. This mitigation policy involves action by all levels of government. Table 6.11 summarizes New Jersey Transit's service levels for 2006.

Table 6.11. New Jersey Transit Data on Passenger Miles, Passenger Trips, and Revenue Miles for 2006

Mode	Passenger Miles	Passenger Trips	Revenue Miles
Commuter Rail – Directly Operated	2,116,307,617	75,067,220	58,787,082
Commuter Rail – Privately Operated	12,298,425	327,475	218,022
Demand Responsive – Publically Operated	9,789,981	1,264,368	9,752,353
Light Rail – Directly Operated	13,427,835	5,537,710	584,128
Light Rail – Privately Operated	59,471,684	10,229,366	2,808,158
Motor Bus – Directly Operated	915,684,027	149,587,799	68,014,358
Motor Bus – Privately Operated	50,305,881	12,678,685	8,946,086
Van Pool - Total	24,381,685	601,655	3,383,309

In recent years, several states in the United States have established an official policy goal of doubling transit ridership. This goal of doubling ridership has been included in the official state climate and energy action plans for Florida[38], Iowa[39], and in the draft state climate and energy plan for the State of New Jersey[40]. The next section examines the feasibility of this goal.

Feasibility of Doubling Transit Ridership

The goal of doubling transit ridership in certain parts of the United States is more than a rhetorical goal. Increasing concern with petroleum dependence, the growth of GHG emissions, and associated global climate change have motivated the official adoption of this goal. The goal of doubling transit ridership may be traced to an influential special report of the National Research Council's (NRC) Transportation Research Board (TRB). The report "Making Transit

[38] (http://www.flclimatechange.us/documents.cfm).
[39] (http://www.iaclimatechange.us/capag.cfm).
[40] (http://www.state.nj.us/globalwarming/home/documents/pdf/final_report20081215.pdf).

Work: Insight from Western Europe, Canada, and the United States," was published by the National Academy Press as Special Report 257. [41]

TRB Special Report 257 included a comparison of public transportation systems in cities in the United States, Canada, and Western Europe. The report finds that "Ridership levels in Canadian cities are roughly double those of American cities."[42] Since the report was released in 2001, transportation professionals are increasingly recognizing that some of best practices and results from Canadian cities seem within reach for American cities.

The goal of 'doubling transit ridership' can be interpreted in two ways – either as an absolute ridership goal, or a standardized ridership goal. An example of doubling absolute transit ridership would be moving from 100,000 to 200,000 total transit trips in a year. Such a goal would include a 'natural' increase in absolute ridership that might be associated with population growth. An example of doubling standardized transit ridership would be moving from 25 annual rides per capita to 50 rides per capita. Such a standardized goal would look for ridership increases over and above those natural increases that might occur from population growth alone.

Neither the 'absolute' nor the 'standardized' formulation of the doubling goal takes into account the economic cycle. Commuter traffic increases as a result of higher employment, and to the extent that the economic cycle results in different levels of employment, both absolute and standardized ridership would change to some extent as a result. These 'cyclical' increases in transit ridership may be viewed as differing from increases due to structural changes in the urban environment, although some are influenced by the changing price associated with the cost of travel.

Based upon a review of standardized transit system ridership data during the 1990s, the TRB special report found that most Canadian cities have annual transit ridership of between 50 and 100 rides per capita. In contrast, most United States cities have annual transit ridership of between 0 and 50 rides per capita. This difference in the experience of the two countries suggests that if some United States cities were to follow a more 'Canadian' path, they could double their standardized transit ridership and have travel patterns more like their counterparts north of the border.

Six major urban areas in the United States already meet or exceed the Canadian patterns of public transit usage. The greater New York City region averages 140 transit rides per year per capita. Five other urban areas in the U.S. – Boston, Chicago, San Francisco, Philadelphia, and Washington, DC – have transit ridership greater than 75 rides per capita annually. These five relatively transit-intensive American cities seem more comparable to Canadian cities, while the New York City region seems more comparable to the largest urban regions in Canada—Montreal and Toronto-- and to major western European cities reviewed in the TRB special report, almost all of which have per capita transit usage levels greater than 100 rides per capita.

[41] Making Transit Work: Insight From Western Europe, Canada, and the United States—Special Report 257. Transportation Research Board: Washington, DC, 2001**.**

[42] Ibid, page 31.

As examples of the standardized transit ridership levels of some other cities and urban regions, the southeast Florida region has about 30 annual transit trips per capita, comparable with the Atlanta region and southern California. The Orlando area has 15 annual trips per capita, and the Jacksonville and Tampa-St. Petersburg regions have about 10 annual trips per capita. This data suggests that there is significant room to grow per capita transit ridership in Florida cities.[43]

Just as some U.S. cities and states are envisioning the possibility of following a more "Canadian" path when it comes to travel patterns, the most transit-intensive American cities may set a goal of become more like Western European cities in their levels of public transit use, just as New York City has already done.

For example the greater San Francisco Bay Area metropolitan region shows transit ridership greater than 75 rides per capita annually, and the City of San Francisco, the most 'transit-rich' portion of the metropolitan region, demonstrated transit usage levels of 272 rides per capita in 2005, according to the San Francisco Municipal Transportation Agency (SFMTA). The SFMTA's recent Climate Action Plan includes a summary of a plan to increase ridership by up to 32% in ten years, assuming the availability of additional funding to increase service hours by 25% over 2005 levels. If successful, this increased ridership would result in a per capita ridership of 334 rides annually. The SFMTA climate plan compares its increased ridership plan to the example of Zurich, Switzerland, which has a per capita annual ridership of 560. The Zurich level of per capita transit ridership is roughly two times San Francisco's 2005 level of 272.

In summary, it appears that the policy goal of 'doubling transit ridership' has a resonance and usefulness for consideration by more cities, urban regions, and states in the U.S. The goal is flexible in that it takes into account the 'starting point' of transit ridership for a given city or urban region and attempts to build on this starting point. In addition, it implicitly recognizes the need for expansion of transit service, since it is rarely if ever possible to double ridership with the existing supply of transit capacity and service.

For this related action, doubling transit ridership by 2020 was analyzed based on data provided by various New Jersey state and local agencies; the 2020 annual estimates of GHG savings were also obtained from New Jersey agency reports. Analysis of the cumulative impacts was conducted using simple spreadsheet techniques with a linear annual ramp-up assumed for the eleven-year period from 2009 to 2020. Table 6.12 shows the emission reductions estimated for TLU-6. As noted in Chapter 1, New Jersey Transit's capital program is being undertaken for many reasons in addition to GHG reduction, and there is no easy way to allocate that budget among the various purposes. Since it would be misleading to attribute the entire capital budget to GHG reduction, no analysis of the costs and benefits of TLU-6 was performed.

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[43] APTA Transit Ridership Report, as cited in "South Florida Economic Trends" (2006) http://www.edri-research.org/clientuploads/EDRI_Study_files/SEFLWeb.pdf.

Table 6.12. Estimated GHG Emission Reductions for TLU-6

	Annual Results (2020)		Cumulative Results (2009-2020)			
	GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO_2e$)	Fuel Savings (million gallons)
Total	0.65		3.92			337

Economic Benefits of Transit Investment

There is a broad literature on the role of transit as a part of a modern economy and as a key contributor to creating and maintaining certain aspects of quality of life. Overarching reviews of that literature are done only periodically. One of the most comprehensive reviews is Cambridge Systematics, Inc.'s, *Public Transportation and the Nation's Economy: A Quantitative Analysis of Public Transportation's Economic Impact*, 1999. The study demonstrates that transit produces net economic returns on investment nationally:

> "Transit capital investment is a significant source of job creation. This analysis indicates that in the year following the investment 314 jobs are created for each $10 million invested in transit capital funding.
>
> "Transit operations spending provides a direct infusion to the local economy. Over 570 jobs are created for each $10 million invested in the short run.
>
> "Businesses would realize a gain in sales 3 times the public sector investment in transit capital; a $10 million investment results in a $30 million gain in sales.
>
> "Businesses benefit as well from transit operations spending, with a $32 million increase in business sales for each $10 million in transit operations spending.
>
> "Business output and personal income are positively impacted by transit investment, growing rapidly over time. These transportation user impacts create savings to business operations, and increase the overall efficiency of the economy, positively affecting business sales and household incomes. A sustained program of transit capital investment will generate an increase of $2 million in business output and $0.8 million in personal income for each $10 million in the short run (during year one). In the long term (during year 20), these benefits increase to $31 million and $18 million for business output and personal income respectively.
>
> "Transit capital and operating investment generates personal income and business profits that produce positive fiscal impacts. On average, a typical state/local government could realize a 4% to 16% gain in revenues due to the increases in income and employment generated by investments in transit.
>
> "Additional economic benefits which would improve the assessment of transit's economic impact are difficult to quantify and require a different analytical methodology from that employed in this report. They include "quality of life" benefits, changes in land use, social welfare benefits and reductions in the cost of other public sector functions.
>
> "The findings of this report complement studies of local economic impacts, which carry a positive message that builds upon the body of evidence that shows transit is a sound public investment. [L]ocal studies have shown benefit/cost ratios as high as 9 to 1."

Other Benefits of New Jersey Transit Improvements

Transit services have a large number of other impacts which provide additional benefits. Transit service provides mobility, accessibility, and safety benefits that are not included in the analysis above. Other important co-benefits include improved air quality, public health (e.g., due to walking), and quality of life. Transit benefits from reducing congestion and facilitating land use patterns such as transit-oriented development and smart growth are very significant and as noted are partially reflected in the analysis above.

The provision of transit service provides other more direct benefits and cost impacts. Most importantly are travel time benefits that accrue to transit users, reduced air pollution, and congestion relief that affect road users on parallel routes. Reducing VMT and increasing reliance on public transit will also result in reduced parking demand, lower household costs for transportation, decreased traffic congestion, improved air quality, reduced need and cost for roadway expansion, and improved health for new transit riders who walk or bicycle to transit.

Because consideration of New Jersey Transit' capital and operating expenditures in isolation could produce a misleading picture of the overall balance of costs and benefits, this analysis examines certain of the benefits of the New Jersey Transit capital program and the related land use measures. The benefits examined are those that are most readily quantifiable using spreadsheet methods.

Many of the benefits of New Jersey Transit's capital program and the related land use measures discussed above under TLU-5 stem from the ability of public transit to reduce the use of private automobiles, as measured by the change in VMT. VMT-related benefits are as follows:

- Savings on fuel and vehicle maintenance costs;
- Reduction in time lost from traffic delays;
- Reduction in number of highway fatalities and injuries;
- Reduction in amount of accident-related property damage;
- Improvements in air quality, as measured by emissions of PM_{10} and $PM_{2.5}$; and
- Reduction in GHG emissions, especially carbon dioxide.

Several other benefits cannot readily be measured and are therefore omitted from this analysis:

- Gains in quality of life from reduced traffic noise, driving stress, etc.;
- Savings on costs of vehicle ownership for those who decide to forego vehicle ownership (e.g., of second cars); and
- Economic multiplier effects (e.g., stimulus to businesses from transit construction projects (see above)). This gain will be offset to an unknown extent by losses to businesses that service the highway sector, and a separate study would be needed to evaluate these trade-offs.

Table 6.12 summarizes the estimated magnitude of the quantifiable direct and indirect benefits based on New Jersey Transit's projection of the effect of its capital program on aggregate VMT in New Jersey. It should be noted that the savings in gasoline consumption depend on the price of gasoline (assumed here at $2.50/gallon). As recent years have shown, that price can fluctuate by a dollar or more within a relatively short time period, and the magnitude of this particular benefit is therefore highly volatile.

As Table 6.13 shows the New Jersey Transit capital program and the related land use measures clearly have very substantial economic benefits that go far to balance the large costs of the measures and, therefore, improve the cost-effectiveness in terms of mitigating GHG emissions.

Table 6.13. Benefits of New Jersey Transit Capital Program

	Direct Effects	**Indirect Effects**	**Total Effects**
1. Fuel saved	$140,612,986	$733,942,948	$874,555,934
2. Fatalities avoided	$97,816,018	$510,560,072	$608,376,090
3. Vehicle maintenance	$78,532,924	$409,910,116	$488,443,040
4. $PM_{2.5}$ avoided	$44,860,389	$234,153,095	$279,013,484
5. CO_2 avoided	$17,353,401	$90,577,740	$107,931,142
6. PM_{10} avoided	$9,910,955	$51,731,178	$61,642,132
7. Avoided injuries	$1,137,700	$5,938,332	$7,076,032
8. Property damage avoided	$846,736	$4,419,621	$5,266,357
9. Delay avoided	$54,984,738	$286,998,108	$341,982,846
10. Quality of life gains	not quantified	not quantified	not quantified
11. Ownership cost savings	not quantified	not quantified	not quantified
12. Multiplier effects (net)	not quantified	not quantified	not quantified
GRAND TOTAL	**$446,055,847**	**$2,328,231,210**	**$2,774,287,058**

Appendix A: Strength of the Transit Leverage Effect

This appendix reports results of some of the more noteworthy studies of the transit leverage or land use multiplier effect. The studies are listed in order of the magnitude of the effect found in the study; where a study provided a range of results, the ordering is based on the low end of the range.

Holtzclaw (2000) compared three prototypical cities in the San Francisco Bay Area (San Francisco, Walnut Creek and San Ramon), and computed a reduction in vehicle travel of between 1.4 and 9 for every mile of transit passenger travel.

The most recent major study in this area was done for APTA by ICF and Patricia Mokhtarian of UC Davis (Bailey, Mokhtarian et al. 2008). This study applied multivariate statistical analysis using structural equation modeling (SEM) to National Household Travel Survey data to produce estimates of the 'direct' and 'indirect' effects of transit on VMT, energy consumption, and by extension, GHG emissions. In contrast to other techniques, which mainly identify correlations between auto and transit travel, SEM can help explain the extent to which transit causes denser, more walkable land-use patterns, and conversely the extent to which these land-use patterns create a need for improved transit service. This study concludes (p. 12) that "the magnitude of the secondary effect is approximately twice as large as [1.9 times] the primary effect of actual public transit trips," The study also found (p. 1) "a significant correlation between transit availability and reduced automobile travel, independent of transit use."

After reviewing three major reports of the European Commission on regional scenario analyses that used "state-of-the-practice methods", Johnson found that the combination of either auto use pricing policies or urban growth boundaries with transit provision appears to approximately double the VMT reduction effect of additional transit investment as compared with transit investment undertaken alone. Johnston concluded that "we may view these [European] projections as the upper bounds of what could be achieved in most regions in the U.S." It is not clear from the from the Johnston review what would be a reasonable conclusion regarding the expected combined VMT reduction effect of transit investment and land use intensification near transit stations.

Bailey and Mokhtarian (2008) found that their model "confirms the hypothesis that public transportation availability has a significant secondary effect on VMT beyond the primary effect of using transit. The secondary effect is mainly generated through land use patterns. The magnitude of the secondary effect is approximately twice as large as the primary effect of actual public transit trips. This result suggests that public transit is a significant enabler of an efficient built environment."[44]

[44] TCRP Project J-11/Task 3, Transit Cooperative Research Program, Transportation Research Board, "The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction, " (February 2008) Requested by the American Public Transportation Association, project managed by ICF International. Authors: Linda Bailey, Patricia Mokhtarian, Ph.D. (UC Davis), Andrew Little, p. 12.

The indirect "leverage effect" of public transportation was estimated at three to four times the direct effect of transit service by the American Public Transportation Association, "Public Transportation Reduces Greenhouse Gases and Conserves Energy" (4/2008) http://www.apta.com/research/info/online/greenhouse_brochure.cfm.

In a study of U.S. metropolitan areas with populations of at least 2 million, Pushkarev and Zupan (1982) documented the empirical observation that cities with high public transit use show far lower rates of auto travel than would be implied by the direct substitution of auto with transit trips alone; they found a leverage effect of 4:1.

One of the most influential studies in this area (Newman and Kenworthy, 1999, Sustainability and Cities, page 87) used a worldwide statistical analysis of cities in a World Bank study to estimate that the transit leverage effect is between 5:1 and 7:1. In other words, for every one unit of direct effect from transit investment that results in mode shift, there are between 5 and 7 units of indirect effect that shows up in the entire transportation system. A good proportion of this indirect effect is related to the patterns of land development and land use.

In a study of 32 global cities, Newman and Kenworthy (1999) estimate a land-use multiplier of between 5 and 7, meaning that for every extra passenger mile on transit per capita, vehicle miles per capita decline by five to seven miles.

Neff (1996) used travel time budget theory to analyze the substitution of transit travel for auto travel in U.S. urbanized areas. He concluded that every mile of transit travel replaces 5.4 to 7.5 miles of auto travel.

Newman concluded that transit leverage in the U.S. has been found to be 1 in 6 to 7: "[t]hat is, for every passenger km added to a new transit system that replaces cars there are 6 to 7 passenger km [kilometers] of car use removed from the city. If the quality of the transit is not as good and there are large numbers of park and ride facilities provided then it may reduce to 1 in 3. But it is always more than one."

More recent, as-yet-unpublished work by Newman, Kenworthy and Glazebrook identifies an exponential relationship between transit and auto travel: As the use of public transport increases linearly, auto travel decreases exponentially.

In addition to the empirical research on transit leverage in urban regions around the world and around the United States, a corroborating body of research from regional modeling and scenario forecasting studies has made similar findings about the integrative impacts of combinations of policies, expressed in terms of the percentage reduction in VMT obtainable under various policy scenarios.

The Sacramento region conducted regional scenario analyses and adopted a plan that reduces VMT per day by 12.3 miles per household in 2050, with 1.5 million more people in the region and fuel savings estimate of 75 million gallons per year, with dollar value equivalent of $180 million per year. The California Energy Commission survey of Metropolitan Planning Organizations in California found results that indicate potential low range estimate for 2.6%

reduction in VMT per capita (59,573 billion Btu energy savings) and potential high range estimate for 10.2 reduction in VMT per capita (233,621 billion Btu energy savings) between 2000 and 2020.

The Center for Climate Strategies, during the course of review of studies, surveyed metropolitan region results from around the United States. The Center for Climate Strategies' review found ranges of estimated VMT reductions for 12 metro regions, including a 4.6% reduction in VMT for San Francisco Bay Area (Regional Livability Footprint) and a 31.7% VMT reduction in Sacramento region for Sacramento Blueprint. As a result, Center for Climate Strategies' analyses have used a range of 3% to 11% of urban VMT below baseline for the 2020 time frame.

A 2005 Canadian study concluded that "[h]igh transit investment could reduce annual GHG emissions by approximately 2% relative to the BAU case (2020 year). In terms of TDM measures, low TDM measures could further reduce annual GHG emissions by approximately 1% while an annual GHG emissions reduction of approximately 3% could be achieved with high TDM measures. Therefore, a total of approximately 5% of annual GHG emissions could be achieved with the implementation of both high transit investment and high TDM measures."[45]

A study sponsored by the U.S. Department of Transportation Federal Highway Administration found in the Bartholemew study (2005, 2007) results showing potential for compact development to on average result in 8% fewer VMT as compared with BAU scenario.

One of the important reviews of regional modeling studies around the world presents good evidence about the integrated effects of alternative strategies to reduce VMT, fuel use, and associated emissions. Professor Robert Johnston conducted the review entitled; "Review of U.S. and European Regional Modeling Studies of Policies Intended to Reduce Congestion, Fuel Use, and Emissions" The Johnston review looks at 40 long range scenario exercises performed in the United States and Europe. The main conclusion of the Johnston review is that VMT reductions for the 20 year time horizon are achievable in the range from 10% to 20% for U.S. regions, compared to the future trend scenario, while supporting the same level of future job and housing growth.

[45] "The Impact of Transit Improvements on GHG Emissions: A National Perspective: Final Report," (March 2005) Prepared for Transport Canada, prepared by Cansult and TSi Consultants, p. 31.

Chapter 7
Electricity Generating Units

Introduction

Under this supporting recommendation, the New Jersey Department of Environmental Protection (NJDEP) will develop an electricity generating unit (EGU) – related rulemaking to establish a maximum carbon dioxide (CO_2) emissions performance standard expressed in pounds of CO_2 emitted per megawatt-hour of electricity generated. The proposed performance standard (amount of CO_2 per megawatt (MW) hour of net electricity) would apply to all in-state new fossil fuel-fired EGUs and reconstructed EGUs.

Table 7.1 summarizes the estimated greenhouse gas (GHG) emission reductions and net costs for this supporting recommendation. The supporting recommendation is assumed to totally overlap in the short run with the Regional Greenhouse Gas Initiative (RGGI), which is one of New Jersey's core GHG mitigation recommendations. Therefore, the emission reductions and costs are estimated here for the purpose of understanding the potential impacts of a minimum CO_2 performance standard but are not included in the aggregated costs associated with the other supporting recommendations to avoid double-counting of the emission reductions and costs associated with RGGI. The remainder of this chapter provides information on the parameters for analysis, methods, data sources, and assumptions used to prepare the analysis for this supporting recommendation.

Table 7.1. Estimated GHG Emission Reductions and Net Costs for EGU Supporting Recommendation

No.	Supporting Recommendation Name	Annual Results (2020)		Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	GHG Reduction s ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO_2e$)
EGU-1	Generation Performance Standard	1.40	$75.8	4.70	$162.2	34.52
Sector Total [sum of results before adjusting for overlaps]		1.40	$75.8	4.70	$162.2	34.52
Sector Total After Adjusting for Overlaps with RGGI		0.0	$0	$0.0	$0	$0

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Costs are discounted to year 2009 in 2007 dollars using a 3% real discount rate.

It is likely that the improved air pollution control of new coal-fired integrated gasification combined cycle (IGCC) units would result in significant reductions in the emissions of criteria air pollutants, provided existing coal units are retired and replaced with new IGCC units. The benefits associated with such reductions are not reflected above.

Quantification Methods

The business-as-usual (BAU) scenario for this analysis was defined as the result of the prior Rutgers projections associated with the development of the Energy Master Plan and was provided to CCS in order to prepare the analysis. The results of that scenario for generation and GHG emissions are summarized in Tables 7.2 through 7.4.

New coal generation was defined as incremental generation in excess of 2010 levels. This generation is assumed to be the subject of the performance standard and would need to be replaced with baseload power from a facility in compliance with the standard, assumed in the analysis to be a suitably-sized natural gas combined cycle (NGCC) unit having a CO_2e intensity equal to 0.57 metric tons of carbon dioxide equivalent emissions per megawatt hour (tCO_2e/MWh). The source for the coal-fired generation displaced was assumed to be a supercritical pulverized coal steam unit. The starting year for the analysis is assumed to be 2011.

Levelized costs were calculated using cost and performance assumptions from a variety of sources, including the U.S. Department of Energy's National Energy Technology Laboratory (NETL), ICF International assumptions for Integrated Planning Model (IPM) modeling in the northeast U.S., and Black & Veatch, an engineering firm. Fuel prices were taken from the US Department of Energy/Energy Information Administration's Annual Energy Outlook (AEO) 2009 results for the mid-Atlantic region. A summary of assumptions appears in the Annex using a 3% real discount rate. The results are presented in Table 7.4. NPV costs are equal to $162 million, cumulative GHG emission reductions reach 4.7 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) by 2020, and the cost of avoided GHG is $34.5/$tCO_2e$.

Table 7.2. Business-as-Usual (BAU) Generation

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BAU generation																	
Coal (pulverized)	10,322	10,649	10,975	11,302	11,628	11,955	12,282	12,328	12,374	12,420	12,466	12,513	13,116	13,720	14,323	14,927	15,531
Waste coal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas	16,036	14,338	12,641	10,943	9,245	7,547	5,850	6,404	6,957	7,511	8,065	8,619	11,232	13,845	16,458	19,072	21,685
Other Gases	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroleum	1,391	1,159	927	696	464	232	0	0	0	0	0	0	3	6	8	11	14
Nuclear	27,082	28,167	29,252	30,337	31,422	32,507	33,592	33,592	33,592	33,592	33,591	33,591	33,611	33,631	33,651	33,671	33,691
Hydroelectric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solar/PV	10	111	212	314	415	516	617	761	905	1,049	1,193	1,337	1,472	1,606	1,741	1,875	2,010
Wind	0	5	9	14	19	23	28	259	490	721	952	1,183	1,211	1,240	1,269	1,298	1,326
MSW	1,051	1,025	1,000	974	948	923	897	894	891	888	885	881	885	888	892	895	899
Landfill Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass	0	61	122	182	243	304	365	590	815	1,039	1,264	1,489	1,863	2,237	2,612	2,986	3,360
Other wastes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
On-site	1,227	1,227	1,227	1,227	1,227	1,227	1,227	1,227	1,227	1,227	1,227	1,227	1,294	1,361	1,428	1,495	1,562
Exports	0	0	0	0	0	0	0	5	9	14	19	23	169	315	461	607	753
Imports	21,710	23,176	24,641	26,107	27,573	29,039	30,504	30,252	30,000	29,748	29,496	29,244	27,093	24,942	22,791	20,640	18,489
Total (production-based)	57,119	56,742	56,365	55,988	55,611	55,234	54,857	56,054	57,250	58,447	59,643	60,840	64,687	68,535	72,382	76,230	80,077
Total (consumption-based)	78,829	79,918	81,007	82,095	83,184	84,273	85,362	86,301	87,241	88,181	89,121	90,060	91,611	93,161	94,712	96,263	97,813

Table 7.3. Business-as-Usual (BAU) GHG Emissions*

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BAU CO2e emissions																	
Coal (pulverized)	10.38	10.71	11.04	11.37	11.69	12.02	12.35	12.40	12.44	12.49	12.54	12.58	13.19	13.80	14.40	15.01	15.62
Waste coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural Gas	9.21	8.24	7.26	6.29	5.31	4.34	3.36	3.68	4.00	4.32	4.63	4.95	6.45	7.96	9.46	10.96	12.46
Other Gases	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petroleum	1.10	0.92	0.73	0.55	0.37	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Nuclear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydroelectric	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar/PV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MSW	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Landfill Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biomass	0.00	0.02	0.05	0.07	0.10	0.12	0.15	0.12	0.09	0.06	0.03	0.00	0.27	0.55	0.82	1.09	1.37
Other wastes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
On-site	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.77	0.81	0.85	0.89	0.93
Exports	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Imports	0.00	3.13	6.26	9.39	12.52	15.65	18.78	18.62	18.46	18.30	18.15	17.99	16.57	15.16	13.75	12.33	10.92
Total (production-based)	22.72	21.92	21.11	20.31	19.50	18.70	17.89	18.23	18.56	18.90	19.23	19.57	21.99	24.41	26.84	29.26	31.69
Total (consumption-based)	22.72	25.05	27.37	29.70	32.02	34.35	36.67	36.85	37.02	37.20	37.38	37.55	38.56	39.58	40.59	41.60	42.61

*GHG emissions are a million metric tons of carbon dioxide equivalent ($MMtCO_2$) basis.

Table 7.4. Incremental Emissions and Costs associated with the Generation Performance Standard (3% discount rate)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
New coal																		
Generation (GWh)	0	0	0	0	0	0	0	46	92	139	185	231	835	1,438	2,042	2,645	3,249	
CO2e emissions (MMtCO2e)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.09	0.14	0.19	0.23	0.84	1.45	2.05	2.66	3.27	
Replacement generation (NGCC)																		
Generation (GWh)	0	0	0	0	0	0	0	46	92	139	185	231	835	1,438	2,042	2,645	3,249	
CO2e emissions (MMtCO2e)	0	0	0	0	0	0	0	0.0265	0.0531	0.0796	0.1062	0.1327	0.4796	0.8264	1.1733	1.5201	1.867	
Annual Reductions																		
Generation (GWh)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2e emissions (MMtCO2e)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.06	0.08	0.10	0.36	0.62	0.88	1.14	1.40	
Costs of Annual Reductions																		**NPV (million 2006$)**
New Coal Generation (million 2006$)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	3.4	5.1	6.8	8.6	30.9	53.3	75.7	98.1	120.4	$257.61
New NGCC Generation (million 2006$)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	5.6	8.4	11.2	14.0	50.4	86.9	123.3	159.8	196.3	$419.82
Incremental cost (million 2006$)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	2.2	3.2	4.3	5.4	19.5	33.6	47.7	61.7	75.8	**$162.21**
Cumulative Reductions																		**CSC (2006$/TCO2e avoided)**
Generation (GWh)	0	0	0	0	0	0	0	46	92	139	185	231	835	1,438	2,042	2,645	3,249	
CO2e emissions (MMtCO2e)	0	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.12	0.20	0.30	0.66	1.28	2.16	3.30	4.70	**$34.52**
Impact of GPS (consumption basis)																		
BAU CO2e emissions (MMtCO2	22.72	25.05	27.37	29.70	32.02	34.35	36.67	36.85	37.02	37.20	37.38	37.55	38.56	39.58	40.59	41.60	42.61	
Alternative CO2e emissions (MI	22.72	25.05	27.37	29.70	32.02	34.35	36.67	36.83	36.98	37.14	37.30	37.45	38.21	38.96	39.71	40.46	41.21	

References

Black & Veatch, "20 Percent Wind Energy Penetration in the United States", p. 52 http://www.20percentwind.org/Black_Veatch_20_Percent_Report.pdf

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NETL, 2007. "Cost and Performance Baseline for Fossil Energy Plants," U.S. Department of Energy’s National Energy Technology Laboratory, DOE/NETL-2007/1281, Volume 1: Bituminous Coal and Natural Gas to Electricity, Final Report (Original Issue Date, May 2007), Revision 1, August 2007. Report available from: http://www.netl.doe.gov/energy-analyses/pubs/Bituminous%20Baseline_Final%20Report.pdf.

Annex: Assumptions – Supercritical Coal

Technology type & description				
Type	Supercritical pulverized coal steam cycle			
Size	580	MW		
Online year	2008			
Description	Coal introduced into a pulverized coal plant is combusted in a furnace to heat water to the gas phase to power a steam turbine and generator. The supercritical stage operates at 21.4 Mpa and 1100 degrees celcius.			
Heat rate				Source:
Central estimate	8,721	btu/kWh	**(default)**	Central Estimate: ICF International, General Assumptions for IPM Modeling, slide 80
Low estimate	7,849	btu/kWh		
High estimate	9,593	btu/kWh		
Selected	**8,721**	**btu/kWh**		
Capacity factor				Source:
Central estimate	85%	percent	**(default)**	Central estimate: Black & Veatch, "20 Percent Wind Energy Penetration in the United States", p. 52 http://www.20percentwind.org/Black_Veatch_20_Percent_Report.pdf
Low estimate	77%	percent		
High estimate	94%	percent		
Selected	**85.0%**	**percent**		
Financial parameters				
Book life				Source:
Central estimate	30	years	**(default)**	Assumption
Low estimate	27	years		
High estimate	33	years		
Selected	**30**	**years**		
Real discount rate				
Central estimate	3.0%	%	**(default)**	Source:
Low estimate	4.0%	%		N/A
High estimate	6.0%	%		
Selected	**3.0%**	**percent**		
Capacity credit				Source:
Central estimate	100%	%	**(default)**	N/A
Low estimate	100%	%		
High estimate	100%	%		
Selected	**100.0%**	**percent**		
Capital recovery factor				Source:
Calculated	**5.10%**	**percent**		Calculation
Overnight facility capital cost				Source
Central estimate	1,575	2006 $/kW	**(default)**	Central Estimate: ICF International, General Assumptions for IPM Modeling, slide 80, High Estimate: Black & Veatch, "20 Percent Wind Energy Penetration in the United States", p. 5-15, Table 5-5 http://www.20percentwind.org/Black_Veatch_20_Percent_Report.p
Low estimate	1,418	2006 $/kW		
High estimate	1,733	2006 $/kW		
Selected	**1,575**	**2006 $/kW**		
Overnight T&D capital cost				Source
Central estimate	80	2006 $/kW	**(default)**	Assumption
Low estimate	60	2006 $/kW		
High estimate	100	2006 $/kW		
Selected	**80**	**2006 $/kW**		
Start-up costs (i.e., contingency)				Source
Central estimate	2.0%	% of capital cost	**(default)**	Central Estimate: NETL, "Cost and Performance Baseline for Fossil Energy Plants," p.52 Exhibit 2-15
Low estimate	1.8%	% of capital cost		
High estimate	2.2%	% of capital cost		
Selected	**2.0%**	**% of capital cost**		

	Subbituminous coal			return to list
Fuel prices (2006$/mmbtu)				
	Central	Low	High	Selected
2006	1.94	1.94	1.94	**1.94**
2007	1.78	2.18	1.78	**1.78**
2008	1.79	2.19	1.79	**1.79**
2009	1.83	2.23	1.83	**1.83**
2010	1.90	2.32	1.90	**1.90**
2011	1.92	2.35	1.92	**1.92**
2012	1.90	2.32	1.90	**1.90**
2013	1.89	2.31	1.89	**1.89**
2014	1.87	2.29	1.87	**1.87**
2015	1.86	2.28	1.86	**1.86**
2016	1.85	2.27	1.85	**1.85**
2017	1.85	2.26	1.85	**1.85**
2018	1.86	2.27	1.86	**1.86**
2019	1.86	2.27	1.86	**1.86**
2020	1.86	2.28	1.86	**1.86**
2021	1.86	2.28	1.86	**1.86**
2022	1.86	2.27	1.86	**1.86**
2023	1.86	2.27	1.86	**1.86**
2024	1.85	2.27	1.85	**1.85**
2025	1.85	2.26	1.85	**1.85**
2026	1.84	2.25	1.84	**1.84**
2027	1.84	2.25	1.84	**1.84**
2028	1.84	2.25	1.84	**1.84**
2029	1.84	2.25	1.84	**1.84**
2030	1.85	2.26	1.85	**1.85**

Source	
central	AEO 2009 fuel price assumptions to the electric sector in the Mid-Atlantic census region
Low	AEO 2009 fuel price assumptions to the electric sector in the Mid-Atlantic census region
High	AEO 2009 fuel price assumptions to the electric sector in the Mid-Atlantic census region

Fixed Operations & Maintenance (O&M) cost				Source
Central estimate	35.62	2006 $/kW-yr	**default**	Central Estimate: NREL, "Gas-Fired Distributed Energy Resource Technology Characterizations," p. 3-9, Table 1, System 5
Low estimate	30.67	2006 $/kW-yr		
High estimate	40.56	2006 $/kW-yr		
Selected	**35.62**	**2006 $/kW-yr**		

Variable Operations & Maintenance (O&M) cost				Source
Central estimate	3.10	2006 mills/kWh	**(default)**	Central Estimate: NETL, "Cost and Performance Baseline for Fossil Energy Plants," p.462, Exhibit 5-14
Low estimate	2.66	2006 mills/kWh		
High estimate	3.53	2006 mills/kWh		
Selected	**3.10**	**2006 mills/kWh**		

Regional construction multiplier				Source
central estimate	1.04	dimensionless	**(default)**	Central Estimate: ICF International, General Assumptions for IPM Modeling, slide 83 for "Rest of State" High Estimate: Average of Long Island and NYC costs
low estimate	1.00	dimensionless		
high estimate	1.93	dimensionless		
Selected	**1.04**	**dimensionless**		

Levelized costs		
Capital costs		
overnight facility cost	1,575.00	2006 $/kW
overnight T&D cost	80.00	2006 $/kW
EPC	33.10	2006 $/kW
Regional multiplier	72.59	2006 $/kW
Total capital (unlevelized)	1,760.69	2006 $/kW
Total capital (levelized)	89.83	2006 $/kW
Capital (levelized)	**12.06**	**2006 $/MWh**
Fuel costs		
NPV (2009-2030)	32.39	2006 $/mmbtu
Fuel cost (levelized)	1.86	2006 $/mmbtu
Fuel (levelized)	**16.22**	**2006 $/MWh**
Fixed O&M costs		
Fixed O&M (levelized)	35.62	2006 $/kW-yr
Fixed O&M (levelized)	**4.78**	**2006 $/MWh**
Variable O&M costs		
Variable O&M (levelized)	3.10	2006 mills/kWh
Variable O&M (levelized)	**3.10**	**2006 $/MWh**
Total levelized costs		
Capital (levelized)	12.06	2006 $/MWh
Fuel (levelized)	16.22	2006 $/MWh
Fixed O&M (levelized)	4.78	2006 $/MWh
Variable O&M (levelized)	3.10	2006 $/MWh
Total (levelized)	**36.16**	**2006 $/MWh**

Annex: Assumptions – NGCC

Technology type & description				
Type	Conventional natural gas combined cycle			
Size	540	MW		
Online year	2008			
Description	A combined-cycle gas turbine power plant consists of one or more gas turbine generators equipped with heat recovery steam generators to capture heat from the gas turbine exhaust. The steam that is produced powers a steam turbine.			
Heat rate				
Central estimate	7,064	btu/kWh	**(default)**	Central Estimate: ICF International, General Assumptions for IPM Modeling, slide 80
Low estimate	6,880	btu/kWh		
High estimate	7,770	btu/kWh		
Selected	**7,064**	**btu/kWh**		
Capacity factor				Source:
Central estimate	65%	percent	**(default)**	Central estimate: Black & Veatch, "20 Percent Wind Energy Penetration in the United States", p. 52 http://www.20percentwind.org/Black_Veatch_20_Percent_Report.pdf
Low estimate	59%	percent		
High estimate	72%	percent		
Selected	**65.0%**	**percent**		
Financial parameters				
Book life				Source:
Central estimate	30	years	**(default)**	Assumption
Low estimate	27	years		
High estimate	33	years		
Selected	**30**	**years**		
Real discount rate				
Central estimate	3.0%	%	**(default)**	NA
Low estimate	4.0%	%		
High estimate	6.0%	%		
Selected	**3.0%**	**percent**		
Capacity credit				Source:
Central estimate	100%	%	**(default)**	N/A
Low estimate	100%	%		
High estimate	100%	%		
Selected	**100.0%**	**percent**		
Capital recovery factor				
Calculated	**5.10%**	**percent**		
Overnight facility capital cost				Source
Central estimate	703	2006 $/kW	**(default)**	Central Estimate: ICF International, General Assumptions for IPM Modeling, slide 80, High Estimate: Black & Veatch, "20 Percent Wind Energy Penetration in the United States", p. 5-15, Table 5-5
Low estimate	633	2006 $/kW		
High estimate	780	2006 $/kW		
Selected	**703**	**2006 $/kW**		
Overnight T&D capital cost				
Central estimate	80	2006 $/kW	**(default)**	Assumption
Low estimate	60	2006 $/kW		
High estimate	100	2006 $/kW		
Selected	**80**	**2006 $/kW**		
Start-up costs (i.e., contingency)				Source
Central estimate	2.0%	% of capital cost	**(default)**	Central Estimate: NETL, "Cost and Performance Baseline for Fossil Energy Plants," p.52 Exhibit 2-15
Low estimate	1.8%	% of capital cost		
High estimate	2.2%	% of capital cost		
Selected	**2.0%**	**% of capital cost**		

	Natural gas				
Fuel prices (2006$/mmbtu)					
	Central	Low	High	**Selected**	
2006	7.57	7.57	7.57	**7.57**	
2007	7.12	7.12	7.12	**7.12**	
2008	7.54	7.54	7.54	**7.54**	
2009	7.77	7.77	7.77	**7.77**	
2010	7.30	7.30	7.30	**7.30**	
2011	7.01	7.01	7.01	**7.01**	
2012	6.77	6.77	6.77	**6.77**	
2013	6.47	6.47	6.47	**6.47**	
2014	6.26	6.26	6.26	**6.26**	
2015	6.14	6.14	6.14	**6.14**	
2016	6.09	6.09	6.09	**6.09**	
2017	6.14	6.14	6.14	**6.14**	
2018	6.20	6.20	6.20	**6.20**	
2019	6.25	6.25	6.25	**6.25**	
2020	6.16	6.16	6.16	**6.16**	
2021	6.06	6.06	6.06	**6.06**	
2022	6.18	6.18	6.18	**6.18**	
2023	6.25	6.25	6.25	**6.25**	
2024	6.36	6.36	6.36	**6.36**	
2025	6.46	6.46	6.46	**6.46**	
2026	6.57	6.57	6.57	**6.57**	
2027	6.61	6.61	6.61	**6.61**	
2028	6.83	6.83	6.83	**6.83**	
2029	6.96	6.96	6.96	**6.96**	
2030	7.09	7.09	7.09	**7.09**	

Source	
central	AEO 2009 fuel price assumptions to the electric sector in the Mid-Atlantic census region
Low	AEO 2009 fuel price assumptions to the electric sector in the Mid-Atlantic census region
High	AEO 2009 fuel price assumptions to the electric sector in the Mid-Atlantic census region

Fixed Operations & Maintenance (O&M) cost				Source
Central estimate	12.14	2006 $/kW-yr	**default**	Central Estimate: NREL, "Gas-Fired Distributed Energy Resource Technology Characterizations," p. 3-9, Table 1, System 5
Low estimate	10.93	2006 $/kW-yr		
High estimate	13.35	2006 $/kW-yr		
Selected	**12.14**	**2006 $/kW-yr**		

Variable Operations & Maintenance (O&M) cost				Source
Central estimate	2.01	2006 mills/kWh	**(default)**	Central Estimate: NETL, "Cost and Performance Baseline for Fossil Energy Plants," p.462, Exhibit 5-14
Low estimate	1.81	2006 mills/kWh		
High estimate	2.21	2006 mills/kWh		
Selected	**2.01**	**2006 mills/kWh**		

Regional construction multiplier				Source
central estimate	1.04	dimensionless	**(default)**	Central Estimate: ICF International, General Assumptions for IPM Modeling, slide 83 for "Rest of State" High Estimate: Average of Long Island and NYC costs
low estimate	1.00	dimensionless		
high estimate	1.93	dimensionless		
Selected	**1.04**	**dimensionless**		

Levelized costs		
Capital costs		
overnight facility cost	703.00	2006 $/kW
overnight T&D cost	80.00	2006 $/kW
EPC	15.66	2006 $/kW
Regional multiplier	34.34	2006 $/kW
Total capital (unlevelized)	833.00	2006 $/kW
Total capital (levelized)	42.50	2006 $/kW
Capital (levelized)	**7.46**	**2006 $/MWh**
Fuel costs		
NPV (2009-2030)	116.67	2006 $/mmbtu
Fuel cost (levelized)	6.70	2006 $/mmbtu
Fuel (levelized)	**47.33**	**2006 $/MWh**
Fixed O&M costs		
Fixed O&M (levelized)	12.14	2006 $/kW-yr
Fixed O&M (levelized)	**2.13**	**2006 $/MWh**
Variable O&M costs		
Variable O&M (levelized)	2.01	2006 mills/kWh
Variable O&M (levelized)	**2.01**	**2006 $/MWh**
Total levelized costs		
Capital (levelized)	7.46	2006 $/MWh
Fuel (levelized)	47.33	2006 $/MWh
Fixed O&M (levelized)	2.13	2006 $/MWh
Variable O&M (levelized)	2.01	2006 $/MWh
Total (levelized)	**58.93**	**2006 $/MWh**