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STATE HIGHWAY ADMINISTRATION

RESEARCH REPORT

INNOVATIVE CONTRACTING STRATEGIES FOR COMBATING CLIMATE CHANGE

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16. Abstract

The state of Maryland has made a strong commitment to combating climate change and reducing greenhouse gas emissions. This research investigated the state of practice of innovative contracting solutions to reduce emissions from highway construction activities. Implementation methods and challenges were identified and reported. Specifically, the report presents a framework of green performance contracting (GPC) that includes four levels of strategies, namely material related strategies, equipment and energy efficiency related strategies, green life-cycle strategies, and clean energy development strategies. A total of 19 GPC strategies and their application procedures and cases were identified and documented. An optimization model based on the Data Envelopment Analysis was developed to assist state highway agencies in selecting appropriate green performance contracting strategies in accordance with environmental performance, organizational readiness, cost effectiveness, and other criteria. Implementation recommendations were provided to tackle climate change at the project level.

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EXECUTIVE SUMMARY

With the growing public awareness of climate change and the need to take action against it, an increasing number of state highway agencies have started to integrate climate change considerations into their transportation system development and operation activities. While many studies over the past decade have been done regarding emission reduction and adaptation strategies for operations, very few have dealt with these challenges in the highway project development and delivery process. This report describes the state of the practice of green performance contracting strategies on highway development and construction projects. Green performance contracting is defined in this report as contract specifications, contracting methods, and delivery strategies that help reduce emissions and improve adaptation to climate change. A broader definition covers sustainability's economic, environmental, and social aspects. This report documents 19 green performance contracting strategies used in highway development and construction projects. Major research findings include:

- State highway agencies have various levels of experience in applying green performance contracting strategies to highway projects, ranging from material related strategies, to equipment and energy efficiency, to life-cycle green strategies.
- Contract specification is the primary method for integrating green performance contracting strategies into highway development and construction projects, although other methods have been successfully implemented in a few states.
- Green performance contracting strategies can be incorporated into variously-sized projects and different project delivery systems.
- Numerous challenges exist for implementing green performance contracting strategies on highway projects, including the lack of common terminology and established guidelines for green highway evaluation and climate impact analysis.
- The study of existing green strategies can be used to develop a framework for green performance contracting that combines green concepts with performance specifications.

The Maryland State Highway Administration (SHA) has been successful in developing and incorporating design-build and other innovative contracting methods into highway construction. SHA can be a national leader in promoting sustainability in transportation project development. This research recommends that the agency:

- Establish project-level green initiatives with quantifiable goals for achievement. The initiatives need to be integrated into an SHA climate action plan.
- Define common terminology and develop a set of green specifications for highway development and construction projects.

- Introduce guidelines for implementing green performance contracting, evaluating the sustainability of design and construction plans, and analyzing climate impacts at the project level.
- Establish guidelines for quantifying the emission reductions from innovative techniques and contracting strategies.
- Create a rating system by which the agency can recognize and evaluate a project's use of sustainable practices.
- Explore renewable energy options and innovations in sustainability.
- Lead by example through integrating sustainability and green performance contracting concepts into SHA's operations, policies, and functions.

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1 GREEN HOUSE GAS EMISSIONS FROM HIGHWAY CONSTRUCTION

1.1. CLIMATE CHANGE

According to the United Nations Framework Convention on Climate Change (UNFCCC), climate change refers to "a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods." The basis of climate change is radiative forcing, which alters Earth's energy balance and, therefore, temperature. Under stable conditions, the total amount of energy entering the Earth's climate system from solar radiation will exactly balance the amount being radiated into space, thus allowing the Earth to maintain a constant average temperature over time. However, recent measurements indicate that the Earth is presently absorbing more energy than it emits into space due to the increasing concentration of greenhouse gases.[1] This asymmetry in the flow of energy would cause the Earth's surface temperature to rise and lead to global climate change.

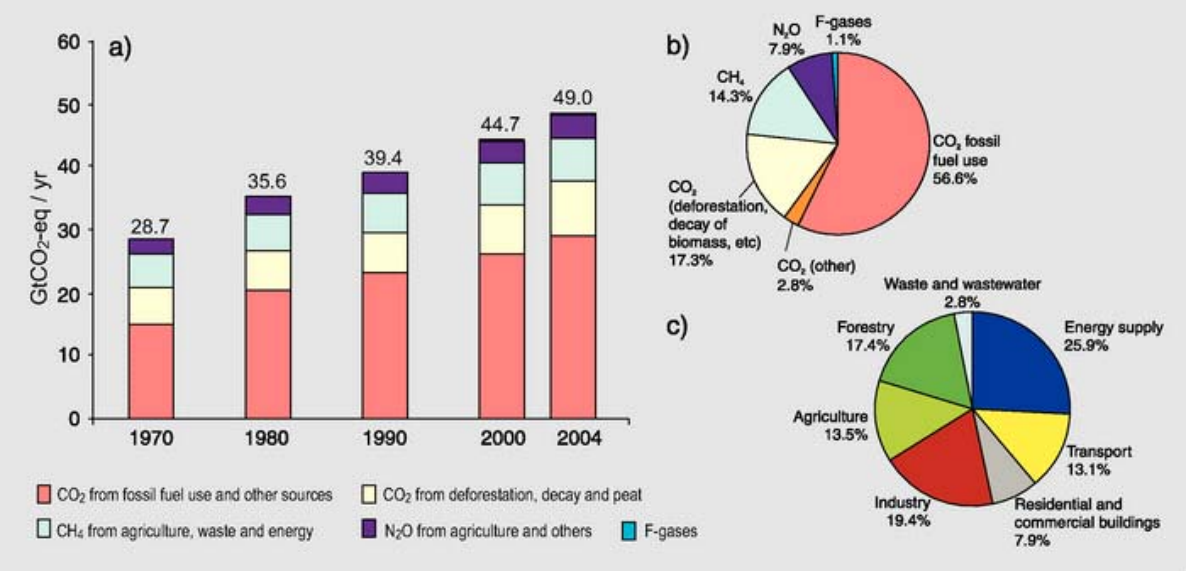
According to the fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), the existence of warming in the climate system is unequivocal, as is evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels.[2] Moreover, an overwhelming majority of climate scientists believe that human activities have significantly increased, and continue to increase the concentration of greenhouse gases at a far greater rate than would occur through natural processes.

1.2. GREENHOUSE GAS EMISSIONS

While water vapor (H_2O) and ozone (O_3) contribute to more than half of the greenhouse gas effect, their presence is primarily related to natural reactions, rather than human activities. The United Nations lists six direct greenhouse gases (GHGs) that are closely connected to human activities and should be carefully tracked and controlled, including CO_2-carbon dioxide, CH_4-methane, N_2O-nitrous oxide, PFCs-perfluorocarbons, HFCs-hydrofluorocarbons, and SF_6-sulfur hexafluoride. Because each of these GHGs has different radiative properties, atmospheric lifetime, and warming influence on the global climate, the comprehensive climate impact of all GHGs is commonly measured in global warming potential as expressed in unit of CO_2-equivalent (CO_2-eq or CO_2e). CO_2-equivalent emission is the amount of CO_2 emission that would cause the same time-integrated radiative forcing, over a given time horizon, as the emitted amount of a long lived GHG or a mixture of GHGs.

As shown in AR4, global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004. Among all GHG emissions, CO_2 is the most predominant manmade GHG. Annual CO_2 emissions have grown between 1970

and 2004 by about 80%, and represented 77% of total manmade GHG emissions in 2004. The growth of manmade GHG emissions was much higher from 1995-2004 than it was from 1970-1994 (Figure 1-1).



(a) Global annual emissions of anthropogenic GHGs from 1970 to 2004. (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO_2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO_2-eq. (Forestry includes deforestation)

Figure 1-1 Global Manmade GHG Emissions (source: IPCC AR4)

In the United States (US), total GHG emissions rose by 17% from 1990 to 2007 and reached 7,150 Million Metric Tons of carbon dioxide-equivalent ($MMTCO_2$-eq) in 2007. This represented a 0.6% increase (41.5 $MMTCO_2$-eq) from the 2005 emission level. [3] The vast majority of US GHG emissions come from energy production and petroleum consumption that generate about 34% of the total emissions. Transportation activities account for the second largest portion (28%). Emissions from industry represent approximately 20%, while the remaining 18% comes from residential, agriculture, and commercial sectors.[4]

On June 26, 2009, the US House of Representative passed climate bill H.R. 2454, [5] The American Clean Energy and Security Act. Although the Senate failed to pass meaningful climate legislation, H.R. 2454 represents a comprehensive approach to America's energy policy that would create clean energy jobs, save energy costs, enhance energy independence, and cut global warming pollution. As mandated in the resolution, President Obama submitted the greenhouse gas emission reduction target to the United Nation Framework Convention on Climate Change Secretariat under the Copenhagen Accord in January 2010. The reduction target commits the United States to reduce its GHG emissions levels by 17% below 2005 levels by 2020, 42% below 2005 levels by 2030, and 83% below 2005 levels by 2050.

Maryland is among the states most vulnerable to climate change, and its government, therefore, has taken strong actions to address climate change. [6] In April 2007, Governor Martin O'Malley signed an Executive Order that established the Maryland Commission on Climate

Change. In the same year, Maryland joined the Regional Greenhouse Gas Initiative, a regional trading program to limit CO_2 emissions. The Greenhouse Gas Emissions Reduction Act of 2009 mandates a 25% reduction of GHG emissions by 2020 from the 2006 levels and by at least 80% by 2050.

1.3. GHG EMISSIONS REDUCTION IN THE TRANSPORTATION SECTOR

The transportation sector is a vital part of the economy and essential to everyday activities. However, its rapid growth makes it the fastest-growing source of GHGs. According to an analysis conducted by the Environmental Protection Agency (EPA), transportation GHG emissions grew from 1,509 $MMTCO_2$-eq to 1,866 $MMTCO_2$-eq during the period of 1990 to 2003. [7] This represents a 24% increase in the transportation sector's GHG emissions, and compares to the average increase of 13% in the US GHG emissions over the same time (Figure 1-2).

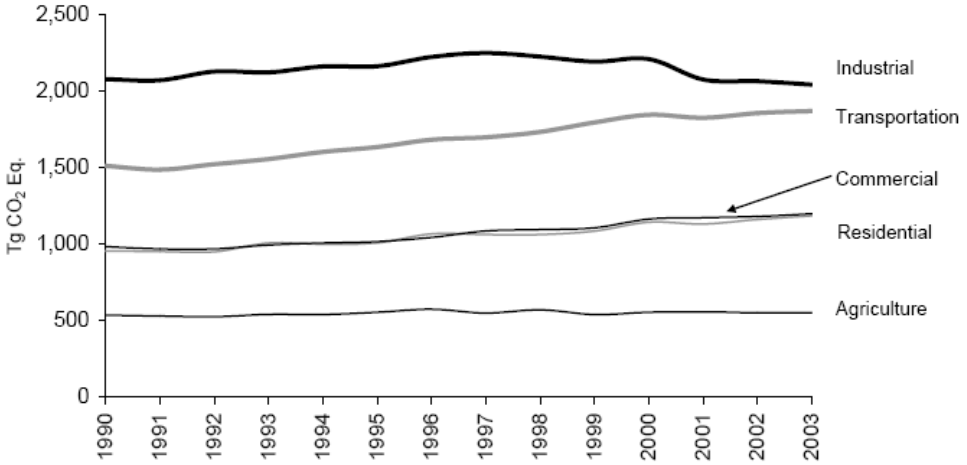


Figure 1-2 US Greenhouse Gas Emissions by End-Use Economic Sector (source: EPA "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003)

Total transportation GHG emissions are approximately proportional to fossil fuel use. In 2003, approximately 81% of transportation emissions in the United States came from on-road vehicles. Other modes transportation including aircraft, rail, boats, and pipelines, accounted for 16% of all transportation GHG emissions. Furthermore, off-road emission sources, primarily construction and agriculture equipment, produced more than 145 MMT CO_2-eq in 2003 (or 2.1% of the total U.S. GHG emissions).

In addition to being a major contributor to GHG emissions, the transportation sector is highly vulnerable to climate change. Indeed, a major concern is the potential flooding of roads, railways, transit systems, and airport runways in coastal areas due to rising sea levels and surges brought on by more intense storms. The effects of climate change on the transportation systems are expected to be widespread and costly in both human and economic terms, and therefore

require major changes in the planning, design, construction, operation, and maintenance of transportation infrastructure.

1.4. GHG EMISSIONS REDUCTION IN THE CONSTRUCTION SECTOR

The construction sector contributes a smaller portion of the total GHG emissions than does the transportation industry. Construction, however, still ranks as the third-highest emission source among all end-use industry sectors (Figure 1-3). According to the EPA, 131 $MMTCO_2$-eq were produced by construction site activities in 2002. This represents approximately 6% of US industrial GHG emissions, or 1.7% of total US emissions. Within the 131 $MMTCO_2$-eq emissions from the construction industry, 76% came from fossil fuel combustion in construction equipment, while the balance was from purchased electricity. Construction of highways, bridges, and water and sewer line structures is typically considered to be equipment-intensive to produce far more GHG emissions than vertical construction activities.[8]

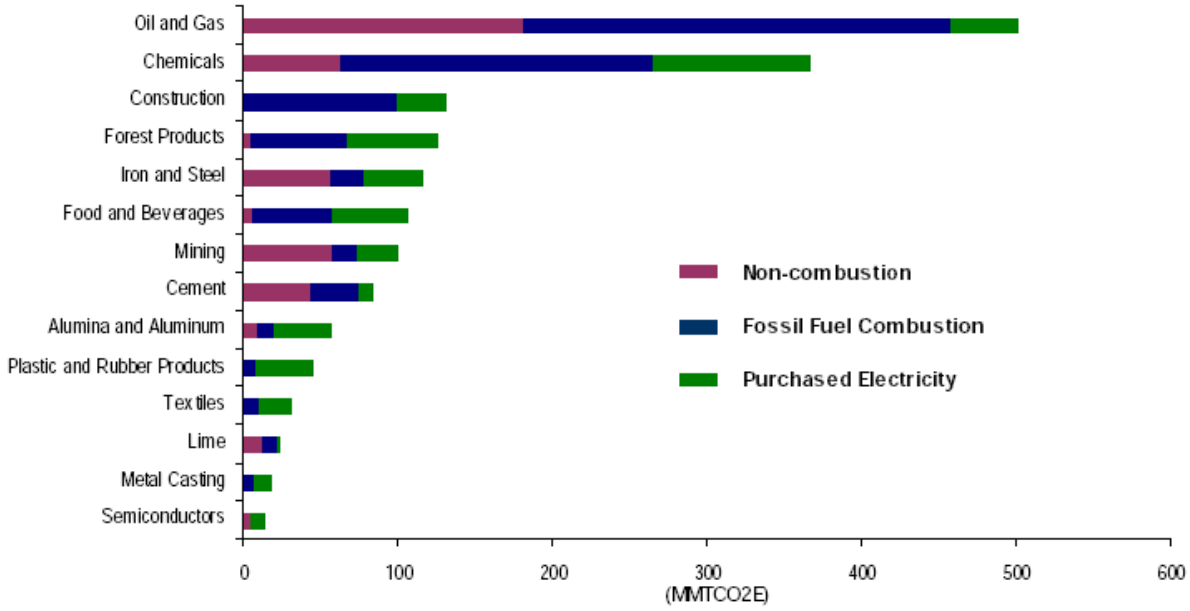


Figure 1-3 2002 Greenhouse Gas Emissions from Industrial Sectors (source: EPA report "Quantifying Greenhouse Gas Emissions from Key Industrial Sectors in the United States" 2008)

One must note that EPA estimates do not include embodied emissions from construction materials (including the extraction, production, transportation, use and disposal of construction materials). A significant amount of materials are consumed in construction projects, which makes a significant contribution to the magnitude of GHG emissions due to embodied energy. For example, the US construction industry used more than 110 million tons of cement in 2000.[9] Total GHG emissions from cement manufacturing and processing were 76.9 $MMTCO_2$-eq in 2001.[10] The US Geological Survey estimated that the construction industry produced more than 20 $MMTCO_2$-eq emissions by consuming approximately 16% of total iron and steel production in 2002 (Table 1-1). Considering that 54% of energy consumption is directly or indirectly related

to facility construction and operations, embodied emissions created through the extraction, processing, transportation, construction, and disposal of materials should be counted in the construction GHG emissions. The Green Design Institute at Carnegie Mellon University (CMU-GDI) developed an Economic Input-Output Life Cycle Assessment (EIO-LCA) model to estimate indirect (embodied) energy use and GHG emissions in addition to direct emissions by construction activities. The model includes 485 commodity sectors and traces all supply chain inputs into construction.[11] Based on the 2002 US benchmark input-output (I-O) accounts, the EIO-LCA model calculates life-cycle carbon emissions by the construction sector ranging from 41.7 to 67.6 $MMTCO_2$-eq per $100 billion in economic activity.[12] Given that construction was valued at $861 billion in 2002, total life-cycle GHG emissions by the construction industry for that year were approximately 470 $MMTCO_2$-eq, of which one-fourth were from indirect emissions.[13,14,15]

Table 1-1 Greenhouse Gas Emissions in the Construction Industry

Sectors	Data Date	GHG Emissions ($MMTCO_2$-eq)	% of US Emissions	Data Source
Construction Site	2002	131	1.7%	EPA
Fossil Fuel Combustion		100		
Purchased Electricity		31		
Upstream – Material Manufacturing				
Cement	2001	76.9	1.1%	EIA
Combustion related CO_2		35.5		
Cement Production related CO_2		41.4		
Iron and steel	2002	20.2	0.3%	EIA, USGS
Limestone	2006	19.6	0.3%	EIA
Construction – Life Cycle	2002	470	6.8%	CMU-GDI
Buildings	2002	2236	32.2%	DOE

1.5. INNOVATIVE CONTRACTING TO REDUCE EMISSIONS

The State of Maryland has already taken concrete actions to reduce GHG emissions and address climate change. Aligned with Governor O'Malley's "Smart, Green, and Growing" initiatives, the Maryland Department of Transportation (MDOT) made a commitment to reduce GHG emissions associated with Vehicle Miles Traveled (VMT) by 15% of 2006 levels by 2015, and at least 25% by 2020. MDOT also committed to reducing emissions from off-road transportation sources, including highways, railways, construction equipment etc., by 15% by 2020.[16]

To meet these commitments, the Maryland State Highway Administration (SHA) must integrate policies to prevent/reduce climate change into all aspects of transportation system development and operations. In particular, to reduce GHG emissions from highway construction and maintenance activities, SHA needs to develop innovative contracting strategies and integrate construction firms' equipment and material use into SHA's GHG emission reduction program and climate action plan.

This report presents the state of practice of innovative contracting strategies to reduce GHG emissions and tackle climate change. A new green performance contracting framework is proposed and its implementation strategy is discussed. The report is organized into six chapters. Chapter 2 defines the Green Performance Contracting framework and details four levels of contracting strategies. Chapter 3 provides a review of the state of practice of green performance contracting strategies in highway construction projects. In Chapter 4, nine case studies are reported and discussed to illustrate the application of those green performance contracting strategies. Chapter 5 presents a decision analysis model to assess the efficiency of various green performance contracting strategies using the Data Envelopment Analysis technique. An implementation strategy for SHA is discussed based on the analysis. The last chapter summarizes the findings and recommendations to SHA.

2 GREEN PERFORMANCE CONTRACTING

2.1. DEFINITION OF GREEN PERFORMANCE CONTRACTING

Leadership in Energy & Environmental Design (LEED) is an internationally recognized green certification system for the building sector. However, there are no universally agreed-upon definitions of what "going green" or sustainability means for highway construction projects. Nor is there a clear definition of green contracting for highway project delivery. Molenaar et. al evaluated the performance of various project delivery methods (design-build, design-bid-build, and construction manager at risk) in delivering LEED certified building projects.[17] Klotz et. al proposed a detailed modeling protocol for evaluating the delivery processes of green projects.[18] However, green project delivery remains undefined.

Many organizations use the triple bottom line of economic, environmental, and social aspects to measure "being green" and sustainability. Similar to this approach, green performance contracting in highway projects could be examined through three configuration scopes. Green performance contracting, then, is defined as any contract provisions, contracting methods, and delivery strategies that help to:

1) Reduce emissions and improve adaptation to climate change (scope 1);

2) Benefit the environment at large (scope 2); or

3) Improve the quality of life of the public through a direct economic, ecological, or social benefit (scope 3).

The research objectives for this project focus on the green performance contracting strategies within the scope covering contracting strategies related to GHG emissions and climate change. Such strategies should contribute to GHG emission reductions throughout the life-cycle of a project. Specifically, reductions should target: upstream material processing and transportation; construction site equipment operations and energy use; facility operation and maintenance; and finally demolition (Figure 2-1).

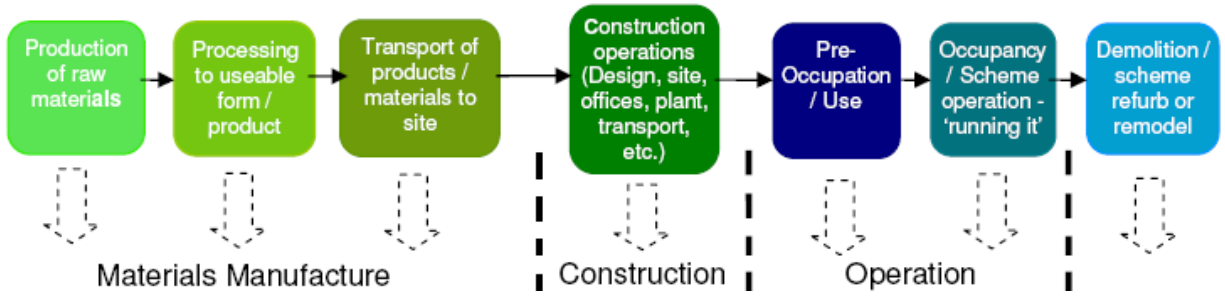


Figure 2-1 Construction Project Lifecycle CO_2 Emissions (source: ENCORD)

A number of green performance contracting strategies either have been or could be incorporated into highway construction. Furthermore, these strategies directly or indirectly contribute to emission mitigation and/or climate change adaptation. For example, diesel engine

retrofit and use of alternative fuels in construction equipment would reduce the consumption of fossil fuels, which directly lowers emissions from highway construction operations. Use of reclaimed asphalt pavement reduces the demand for virgin materials and limits energy use and emissions resulting from the production and delivery of virgin materials. These green performance contracting strategies can be classified into four levels in accordance with applied project phase and emission sources addressed by the strategies.

- **Level I: Material Related Strategies**

Material related strategies are commonly used green methods in highway construction projects. These strategies include the recycling and reuse of construction materials (e.g. slag cement, steel, and scrap tires), pavement materials (e.g. recycle asphalt pavement), new paving technologies (e.g. warm mix asphalt pavement), material life cycle management (e.g. the shipment model FLEET), and material waste management (e.g. WaRM). Each of the preceding strategies was significantly driven by cost saving initiatives rather than environmental consideration. The use of these strategies does contribute to considerable GHG emission reductions during the course of a highway construction project.

- **Level II: Equipment and Energy Efficiency Strategies**

Fuel consumption and electricity use are two primary sources of GHG emissions at construction job sites. Level II covers all relevant contracting strategies that reduce emissions from equipment fuel combustion and purchased electricity during the construction process. Equipment related strategies could either result in low emission intensity (e.g. through equipment retrofit technologies), or reduce the use of fossil fuel (e.g. idling reduction and engine upgrade). In the US, more than 85% of the power generation is from power plants that consume fossil fuel. Therefore, a large amount of embodied GHG emissions are due to on-site electricity use for powering construction equipment and lighting the facility.[19] Contracting strategies grouped in this category also include those that improve the efficiency of electricity use at construction sites. Some example strategies are the use of LED lighting, operation and maintenance management, etc.

- **Level III: Green Life Cycle Strategies**

In business management, Life-Cycle Management (LCM) was developed as an approach to manage the total life-cycle of products and services. LCM addresses a broad range of activities, beginning with the initial identification of a problem, continuing through the building or acquisition of a solution, and ending with the final disposition of the solution at the end of its useful life.[20] Similarly, level III extends these strategies beyond the construction phase to cover all innovative contracting methods used to forestall/prevent climate change in the planning, development, and design phases. These green life cycle strategies can help by first, analyzing the environmental effects at early stages of highway project development; second. by identifying potential environmental, economic, and social risks, in addition to alternative plans and designs to reduce emissions; and finally, by establishing standard procedures for evaluating project sustainability at the earliest possible stage.

- **Level IV: Clean Energy Development**

Renewable energy is an essential part of the US low-emission energy portfolio and is important for energy security. Clean power (generated from wind, solar, and geothermal sources) does not produce GHGs and therefore, is identified as the most effective means of reducing energy-related GHG emissions. Pilot projects have been implemented by several leading states to integrate renewable energy sources into highway development projects, such as Oregon and Massachusetts. Level IV strategies document all contracting practices and integrated delivery methods in this area.

2.2. GREEN PERFORMANCE CONTRACTING STRATEGY LIST

The 19 green performance contracting strategies identified in this study are classified into four groups described above and listed in Table 2-1. The list is by no means complete, but provides an overview and some guidelines for current best practices. State highway agencies are encouraged to develop more innovative strategies based on new practices and processes.

Table 2-1 Green Performance Contracting Strategy

Level	Strategy
I	L1-01 Reclaimed Asphalt Pavement (RAP)
	L1-02 Other Material Recycling or Reusing
	L1-03 Sustainable Material Treatment
	L1-04 Material Waste Management
	L1-05 Material Life-Cycle Management
II	L2-01 Equipment Retrofit Technology
	L2-02 Engine Repower and Upgrade
	L2-03 Idling Reduction
	L2-04 Alternative Fuels
	L2-05 LED Lighting
	L2-06 Equipment Operation and Maintenance
	L2-07 Equipment Selection and Vehicle Electrification
	L2-08 Work Zone Traffic Management
	L2-09 Employee Commuting Reduction
III	L3-01 Green Road Rating System
	L3-02 Climate Impact Analyses
	L3-03 Climate Adaptation Design
IV	L4-01 Highway-related Solar Energy
	L4-02 Highway-related Wind Turbine

L1-01: Reclaimed Asphalt Pavement (RAP)

Reclaimed asphalt pavement (RAP) is generated when pavement is removed for reconstruction or resurfacing and depending upon material and construction specification, is then used in the base course or surface course s. If properly crushed and screened, RAP consists of high-quality, well-graded aggregate coated in asphalt cement. A contracting strategy typically includes such requirements as RAP sources, limits on RAP usage (e.g. maximum amount and application area), testing and acceptance, measurement, and payment.

L1-02: Other Material Recycling or Reusing

In addition to asphalt pavement, many other non-hazardous byproduct materials are generated from industrial processes but usually wasted or disposed. These materials are also recommended to be reused or recycled as substitutions for raw materials in manufacturing. Steel bars from concrete pavements, for example, can be melted down and recycled as new steel products. Scrap tires, a huge source of waste and disposal in the United States, could become a significant rubber material resource that if properly recycled, could be used in the construction process. Some other recycled or reused materials include slag cement, fly ash, shingles, and recycled foundry sand (RFS). A typical specification for other material recycling/reusing follows the same format as a RAP specification.

L1-03: Sustainable Material Treatment

Material treatment contributes a large amount of GHG emissions both in the process of construction and the operation of facilities. There are several improved methods and technologies available as substitutions for traditional hot-mixed asphalt treatment, which could be required or incentivized as contracting strategies for a project. Warm-mix asphalt, for example, is the generic term for a variety of technologies that allow the producers of hot-mix asphalt pavement material to lower the temperatures at which the material is mixed and placed on the road. Concrete additives, such as slag cement and light fly ash, can be used to create lighter pavements. There are some other technologies available for greener material treatment, such as thin/ ultra-thin white topping, roller compacted concrete pavement, and light-color aggregate in asphalt concrete pavements and asphalt chip sealing. A warm-mix asphalt specification should cover requirements on materials, mix design, additives, sampling and testing, construction process, and equipment requirements.

L1-04: Material Waste Management

Waste management involves the collection, transport, processing, recycling, or disposal, and monitoring of waste materials. It can involve solid, liquid, gaseous, or radioactive substances, with different management methods used for each. On construction sites, it is suggested that a waste management program be created that details the following: how to prevent waste; identification of materials to be recycled and reused; an outlines of the procedures and expectations for monitoring, handling, and collecting waste; hazardous waste considerations; and estimates of costs and savings. Once such a program is developed, it is important that everyone

on the construction site is aware of the program and has received education about waste handling requirements. A material waste management specification typically includes a management plan, waste analysis, materials targeted for recycling and reuse, waste handling and sorting, and recycling service selection and responsibilities.

L1-05: Material Life-Cycle Management

Material life-cycle management is a broader perspective of material management, which refers to the whole life cycle of materials as they flow through the process of selection, production, procurement, shipment, recycling/reusing, and disposal. Material life-cycle management generally reflects the whole picture of project material use in reducing cost, increasing performance, and all associated environmental effects.

L2-01: Equipment Retrofit Technology

The second level of environmental performance contracting strategies is defined as strategies related to equipment and energy use. One such strategy is to use diesel retrofit technologies. Devices are attached to equipment to remove pollutants from a diesel engine's exhaust. The two most common diesel retrofit technologies are diesel oxidation catalysts (DOCs) and diesel particulate filters (DPFs).[21] These two technologies often require a significant initial investment. Selection of the most appropriate technology depends on the type of equipment being retrofitted and the conditions in which it will be operated. Installation needs to take into account severe environmental conditions, operator visibility, space and weight constraints, and placement issues. EPA's National Clean Diesel Campaign and California Air Resources Board (CARB) have technology verification programs that evaluate the emission reduction performance of retrofit technologies and their durability, and identify conditions that must exist for these technologies to achieve those reductions. The lists of verified technologies can be found on the EPA and CARB websites.[22] An example equipment retrofitting specification developed by Mass DOT includes detailed requirements and information on construction equipment in excess of 50 horsepower. The elements in the specification are certification requirement and exemption, reporting and compliance, non-compliance penalty, cost, schedule, and payment.

L2-02: Engine Repowering and Upgrading

Engine repowering is the replacement of an older diesel engine with a new, lower-emission engine. Upgrading occurs when emission reducing parts are added, most often during an engine rebuild.[23] The emissions reduction benefits of engine replacement or upgrading depend on the original certified emissions level of the vehicle and the certified emissions level of the replacement engine. The cost of repowering a piece of equipment depends on the make and model. For example, installing a new engine in a typical D6H track-type tractor costs approximately $27,000. Engines for smaller equipment should have a lower repowering cost. Installing an emission upgrade kit during the engine rebuild for a typical track-type tractor could add several thousand dollars to the cost of an engine rebuild. In most cases, engine repowering and upgrading will be combined with equipment retrofitting specifications and incorporated into the standard/supplementary construction specifications.

L2-03: Idling Reduction

Unnecessary idling occurs when trucks wait for extended periods of time to load or unload, or when unused equipment is left on to maintain heating or cooling for driver comfort. Some equipment comes with automatic shutdown features; however, these features are not universal. For example, one can program a shutdown if the clutch, brake, or accelerator pedals are not touched for five minutes. In addition to employing idling reduction equipment, agencies could also require or give incentives to contractors to increase their operational efficiency. Idling reduction is typically included in the standard equipment retrofitting specifications and defines the compliance requirement and penalty.

L2-04: Alternative Fuels

At its broadest definition, an alternative fuel is any fuel other than conventional fuels such as gasoline and diesel, that is used to produce energy or power. Emissions and energy output provided by alternative fuels vary depending on the fuel source. The four most common types of alternative fuels are ultra-low sulfur diesel (ULSD), biodiesel, emulsified diesel fuel, and compressed natural gas (CNG). There are many other innovative alternative fuels technologies, although some are still in the research and development phase and require further evaluation. Agencies can add available strategies to the list based on a comprehensive evaluation of the strategy's cost efficiency, maturity, and environmental impact.

L2-05: LED Lighting

A light-emitting diode (LED) is a semiconductor light source that provides energy-efficient lighting. Recent advances in LED technology have resulted in new options for highway use, including outdoor area lighting, traffic lights, signals, and information display systems. The use of LED lights is a logical and cost-effective strategy for future use in the transportation sector. To integrate LED lighting into the construction contracting process, LED lights and other relevant processes must be required in the project contract and standard material and construction specifications.

L2-06: Equipment Operation and Maintenance Management

Preventive maintenance seeks to maintain engines at their original level of performance, to improve their efficiency and life, and to prevent catastrophic failures. A systematic maintenance program can include the use of fuel monitoring systems, software, or a database/inventory of equipment and periodic maintenance requirements. Equipment training addresses a broad range of issues, including operating equipment in a safe and efficient manner, maximizing the productive capacity of equipment to do work, and being knowledgeable of the capability and limits of equipment. It is important to train operators in preventive maintenance strategies – that is, to inspect their vehicles daily for tire pressure, fluid leaks, fluid levels (engine oil, coolant level, and transmission fluid), oil color, or other elements recommended in the owner's manual.

L2-07: Equipment Selection and Vehicle Electrification

Identifying the proper size of equipment for a task can also provide fuel savings and associated reductions in GHG emissions. Possible GHG emission reductions vary based on the difference between the horsepower used and the horsepower required for the task. Vehicle electrification involves employing electric or hybrid electric equipment. Future technological advances may allow the use of fuel cells to generate clean electric power at construction sites.

L2-08: Staging Zone and Work Zone Mobility

A construction staging zone is a designated area where vehicles, supplies, and construction equipment are positioned for access and use. A well run staging zone can help reduce the congestion at the construction site, increase the efficiency of equipment loading and unloading, reduce the corresponding GHG emissions, and provide an interim storage location for waste. Work zone traffic management strategies should be identified based on the project constraints, construction phasing/staging plan, type of work zone, and anticipated work zone impacts. Once these strategies are implemented, they need to be consistently monitored to ensure they are effective in managing work zone impacts.

L2-09: Employee Commuting Reduction

Given the number of workers on a job site, worker commuting may be a significant, yet often overlooked, source of GHG emissions in a highway construction project. GHG emissions associated with worker commuting vary by project and location. No data has been found on the average distance workers travel to a construction site; so no quantitative estimate of the national GHG outputs from employee commuting could be calculated. Opportunities for reducing emissions associated with commuting include establishing carpools or shuttle vans. This strategy typically provides an incentive to contractors to develop a carpool program when a long distance commute is needed for projects.

L3-01: Green Road Rating System

Leadership in Energy & Environmental Design (LEED) is an internationally recognized green building certification system. Similarly, a green road rating system is intended to provide third-party verification that a highway or road is designed and built using strategies for more sustainable practices, such as energy efficiency, material conservation, or GHG emissions reduction. The Greenroads Sustainability Performance Metric was developed to award points to new and reconstructed roadways projects based on a listing of Greenroads credits.[24,25] After the verification process, a silver, gold, or evergreen level certification maybe awarded to the project. This strategy addresses GHG emissions through the entire design and construction process rather than reducing emissions via a supplementary specification.

L3-02: Climate Impact Analysis

Climate impact analysis is used to investigate and evaluate the environmental effects of the whole production process of a given product. Carbon footprint (CF) modeling is the fundamental methodology for the project climate impact analysis. CF modeling estimates the overall amount

of carbon dioxide and other GHG emissions associated with a product, service, or project along its supply-chain. CF modeling sometimes includes emissions from use and end-of-life recovery and disposal. There are a large number of methodologies, tools, and analysis software for calculating the climate impact of the transportation sector. This strategy is also a process-oriented method and represents a process innovation at the planning phase of the project delivery cycle.

L3-03: Climate Adaptation Design

Climate Adaptation Design is a strategy that involves climate assessment and GHG emission reductions in the stages of project planning, design, and technology/methodology incorporation during the construction process. The aim of climate adaption design is to communicate the importance of adapting to some degree of inevitable climate change, and to show how such adaptation can be integrated into the whole life cycle of the project. Some adaptation designs include temperature adaptation, water/flood adaptation, and wind adaptation.

L4-01: Highway-Related Solar Energy

Sunlight is the most abundant energy source readily available. Additionally, sunlight is free from geopolitical tension, and poses no threat to the environment. In recent years, the worldwide photovoltaic (PV) market has grown by an average of 30% annually. PV technology can be deployed in any location, with output roughly proportional to the amount of sunlight to which it is exposed. Furthermore, there are two broad approaches for energy transmission. Off-grid use, the first, requires that PV cells have module in the system for storing electricity. The second, grid-connected technology, could connect the system directly to the grid and calculate the transmission of electricity by meters mounted on the connector.

L4-02: Highway-Related Wind Turbine

Wind technology is driven by the nature of the resource harvested. Current US land-based and offshore wind resources are estimated to be sufficient to supply the electrical energy needs of the entire country several times over. Wind turbine technology is promoted at both the federal and state levels with tax credits and other incentives. Similar to the use of solar energy, placing wind turbine in a highway right-of-way or rest areas represents an innovative project delivery approach that could significantly improve energy efficiency along the highway infrastructure.

2.3. GREEN PERFORMANCE CONTRACTING CARD

To better assist highway agencies in understanding and applying these strategies, a set of Green Performance Contracting (GPC) strategy cards were developed by this research team. A sample card is shown on page 16; all GPC strategy cards are attached in Appendix C. Each GPC card follows a similar format and covers the following elements if applicable.

- **Name.** This is the name of the strategy that will be further discussed.
- **Description.** A short definition or description of the strategy is given to help agencies better understand the strategy being discussed on the card.

- **Implementation.** This section describes how the strategy could be implemented into highway projects. It may include requirements for compliance, state or federal standards associated with the strategy, and how the strategy may be paid for if used, (e.g., using grants or incentives). Take the following GPC Card L1-02, "Other Material Recycling or Reusing," as an example. The implementation section of this card tells agencies what EPA and FHWA standards need to be followed.

- **Technological Options.** This section lists various options or methods that agencies may choose from for the specific strategy. In the case of L1-02, there are various byproduct materials that can be used during manufacturing and construction.

- **Technological Requirements.** The technological requirements section includes what is required of the agencies when they implement a certain strategy (e.g., state and federal laws that must be followed).

- **Green Benefits.** The Green Benefit section lists some of the benefits that can come from implementing the strategy. The sample GPC Card includes such benefits for L1-02 as cost and energy savings or conserving natural resources.

- **Barriers.** This section includes possible barriers, problems, or risks associated with the strategy implementation.

- **Sample Provisions.** This section includes state or federal contract specifications and provisions associated with each strategy. The specifications and provisions may be from a state DOT or from a federal organization, such as EPA.

- **Project Application.** This section includes examples of the strategies that have been applied in highway projects, such as using recycled materials in the construction of a bridge in California, shown in the example GPC Card.

These cards provide a quick reference for transportation engineers to obtain important information about GPC strategies. The cards also include various references and examples so that one can review further information if needed.

GPC CARD ---- L1-02

NAME:
Other Material Recycling or Reusing

DESCRIPTION:
Non-hazardous byproduct materials generated from industrial processes, which were usually wasted and disposed, are now recommended to be reused or recycled as substitutions for raw materials in manufacturing.

IMPLEMENTATION:
Recycled or reused materials are usually requested by contractors in order to save money. To control the quality of the material recycled, the project owner needs to set a ceiling or a performance standard in the contract specification or follow standards regulated by EPA or FHWA.

TECHNOLOGICAL OPTIONS:
- Recycled Concrete Pavement (RCP)
- Steel Recycling
- Slag Cement Recycling
- Fly Ash Recycling
- Crushed Glass or Glass Cullet Recycling
- Scrap Tires Recycling
- Shingles Recycling
- Foundry Sand Recycling
- Others

GREEN BENEFIT:
Using industrial materials can conserve natural resources, and reduce the energy use and pollution associated with the energy-intensive manufacturing processes. It can also save money by reducing waste and decreasing disposal costs for end users.

SAMPLE PROVISIONS:
The Wisconsin Department of Natural Resources has conducted a Beneficial Use of Industrial Byproducts Program that encourages the safe and beneficial use of fly ash, bottom ash, paper mill sludge, foundry sand, and slag as alternatives to placing those materials in landfills. See Administrative Code NR538. The EPA and states have certain specifications and provisions for implementing recycled and reused materials.

PROJECT APPLICATION:
In 2002, Caltrans used fly ash and granulated blast furnace slag to reconstruct the east span of the San Francisco Oakland Bay Bridge.

3 GREEN PERFORMANCE CONTRACTING: STATE OF PRACTICE

3.1. STATE OF PRACTICE SURVEY

3.1.1. SURVEY DESIGN AND IMPLEMENTATION

To identify the current practice of green performance contracting in highway construction projects in the United States, the research team developed a survey targeting state highway contract engineers. The survey was conducted from April to June 2010 and was developed through collaborative efforts between SHA officials and University of Maryland researchers. In addition to questions on respondents' background data and their general interest in green performance contracting, there were 12 questions covering the following topics:

- What green performance contracting strategies have been incorporated into highway projects?
- How is green performance contracting used in relation to project size, delivery method, form, and contractor compliance?
- What are the primary reasons for implementing green performance contracting strategies?
- How is climate change impact analysis conducted at the project level?
- What types and sources of emissions are addressed by the green performance contracting?
- What are the challenges of implementing green performance contracting?

The survey was conducted via email and an online form, with follow-up phone interviews with 12 officials from seven state DOTs. The survey results are summarized in Figures 3-1 through 3-5, with observations and recommendations discussed afterwards.

The survey originally targeted, and was sent to, state contract engineers. The final responses, however, came from a diverse set of DOT officials. Of the 39 completed surveys, only one-third were filled out by contract engineers. The majority of respondents had varied professional backgrounds and were involved in various phases and aspects of highway project development. These respondents included construction engineers, design engineers, planning engineers, environmental engineers, public communication officials, and DOT executive and special program officials (Figure 3-1). In follow-up interviews, most interviewees reported that although only the coordinator was listed on the survey, the survey responses actually came from collaborations among several individuals.

Observation 1: *Green performance contracting affects not only contracting, but the entire project life cycle.*

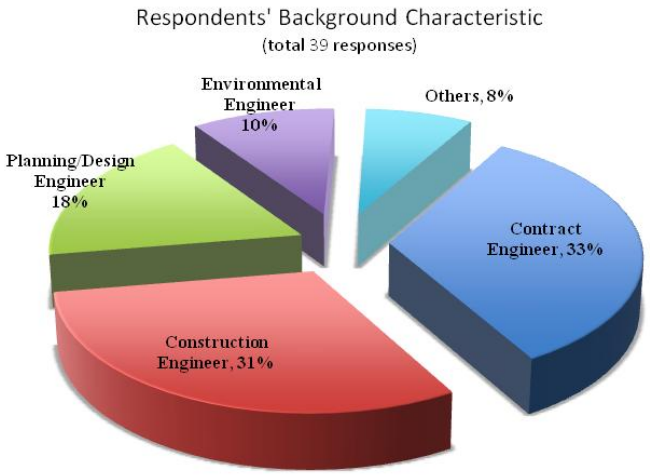


Figure 3-1 Respondent Profile

3.1.2. GREEN PERFORMANCE CONTRACTING PRACTICES

Although 14 out of 39 state respondents indicated no green strategies were used in their states, the other 25 respondents reported Level I strategies, particularly recycled materials, were used in highway construction (Figure 3-2). Approximately half of these 25 state respondents also reported incorporating warm-mix asphalt into their construction specifications. Respondents from 12 states indicated their state implemented at least one Level II green strategy in addition to various Level I strategies. Of the Level II strategies, ten states adopted idling reduction policies, nine utilized alternative fuels, seven launched engine retrofit programs, and four established energy efficiency programs. In addition, California, Illinois, New York, Oregon, and Washington integrated green road rating or energy and emission analysis-Level III strategies- into their highway project development processes.

Furthermore, many states are beginning to investigate and implement clean energy strategies. In 2008 the Oregon DOT developed its first solar highway project and had plans to continue to install solar panels in unused highway right-of-way to generate power for highway lighting. Although the Massachusetts Highway Department has not completed any clean energy projects, the Massachusetts Turnpike Authority was scheduled to build a wind turbine near a turnpike rest area.[26] In 2009, the Maryland SHA developed a wind turbine pilot project to investigate wind energy options and help power an agency facility. Several state DOTs (e.g. CA, IL, MI) were in pursuit of federal grants for renewable energy projects such as green rest areas and solar powered interchanges.

Observation 2: *State DOTs use a wide range of green performance contracting strategies in highway projects, from material related strategies, to equipment and energy efficiency, to life-cycle green strategies.*

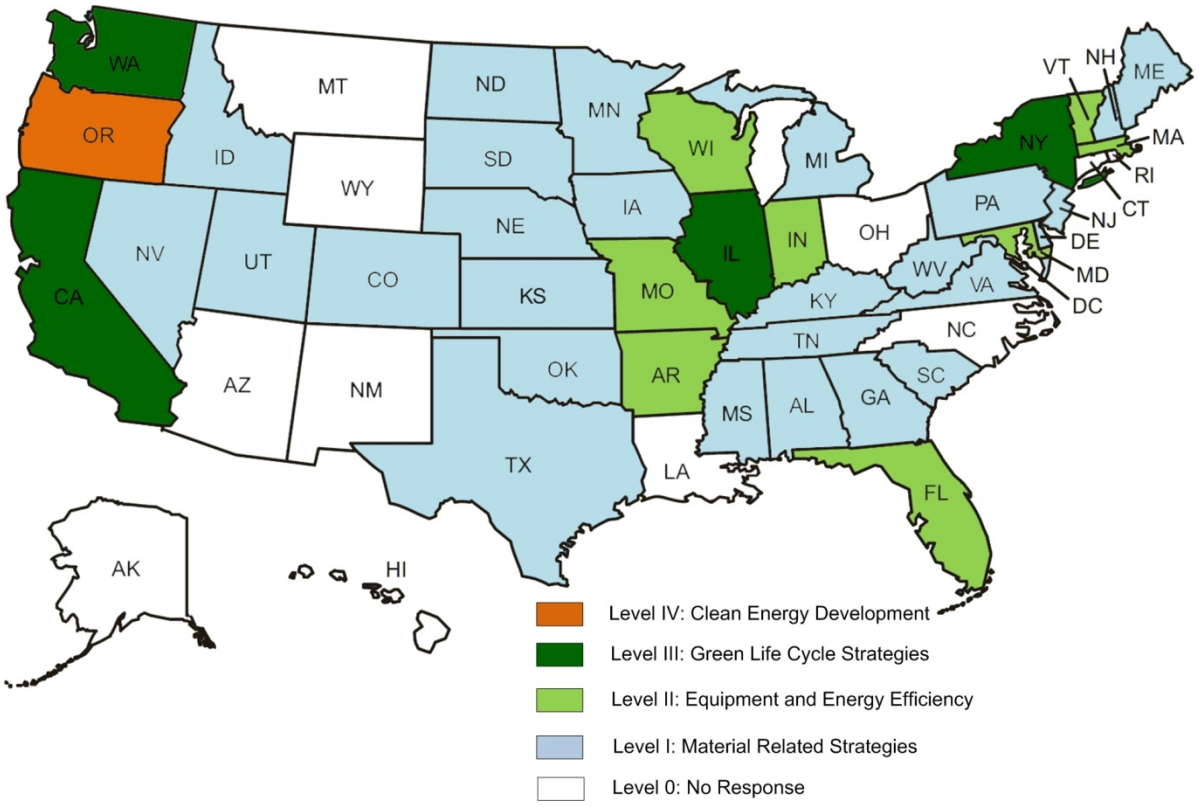


Figure 3-2 State DOTs Green performance contracting Practice

It should be noted that respondents' preconceived notions about implement green performance contracting strategies affected the results presented here. For example, the respondents from the fourteen states in which no green contract provisions were used in highway construction projects may have failed to include agency practices with regard to material recycling and reuse. According to FHWA, reclaimed asphalt pavement was permitted as an aggregate in the hot recycling of asphalt paving mixtures in nearly every states. [27] This discrepancy may be explained by respondents' comments about the challenges in implementing green performance contracting. Their comments suggest a widespread perception that going green is expensive. Indeed, two-thirds of comments listed extra cost as a critical concern preventing the implementation of green performance contracting. Because of a lack of common vocabulary on what exactly green performance contracting means, many transportation professionals may be unaware that some green performance contracting strategies are predominantly cost-driven and have already been integrated into design and construction specifications (e.g. recycled materials, traffic control plans and nighttime construction all can reduce emissions resulting from reduced work zone congestion). This focus on cost also indicates that reducing greenhouse gas emissions has not been a principal factor in state DOT construction and maintenance decisions.

Observation 3: *There is a lack of common vocabulary on green performance contracting, which may lead to misunderstandings about green performance contracting strategies.*

3.1.3. GREEN PERFORMANCE CONTRACTING PROCEDURES

Green performance contracting can take a number of forms, including contract requirements, bidding preferences, and contract allowances.[28] The survey results show that the majority of state agencies implemented green performance contracting strategies by incorporating green requirements into standard specifications or by issuing special provisions (Figure 3-3). Under its green and sustainability initiative, Massachusetts DOT issued standard special provisions that required all contractors and sub-contractors to use EPA/CARB certified equipment during the bidding process. In most states, the use of recycled materials is an option for contractors, not a requirement. Contractors often choose to use recycled materials because they are more cost effective. To ensure quality structural performance, standards for recycled materials often specify the maximum allowable percentages of recycled materials that can be used in a project.

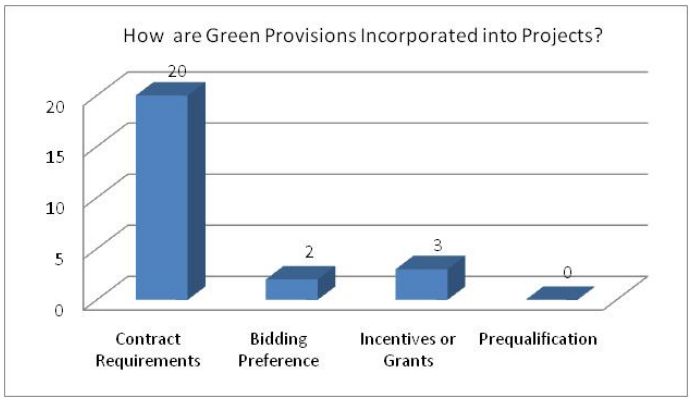


Figure 3-3 Green performance contracting Procedure

Bidding preference gives a contractor bonus points during the evaluation of bids for a project if the contractor commits to using green construction equipment, materials, or techniques during the construction phase. An example is the Arkansas Highway and Transportation Department (AHTD), which considered construction schedule methods (e.g. full closures, nighttime construction, and alternative project phasing) in bid evaluation procedures. By using bidding preference on an interstate reconstruction project in central Arkansas, AHTD selected a highly productive paving company. The result of this selection was expedited project delivery and improved work zone mobility.[29] Current bidding preference is only given for a few limited aspects of construction, including work zone mobility strategies, cost-plus-time bidding or the lane rental method. This limited biding preference is due in part to strong industrial resistance to the use of bidding preferences for engine retrofitting.

Contract allowances and government grants provide opportunities to offset part or all of the initial cost of green equipment, technologies, and products. Furthermore, government grants have been used successfully in California and Texas to spur an increased use of cleaner off-road

equipment. Texas DOT Special Specification 5018 (December 2004) provides contract allowances for the use of cleaner engines and fuels on roadway and maintenance projects.[30] In compliance with this specification, until November 1, 2007, eligible non-road engines received an incentive payment based on two factors, namely engine horsepower and on-site operation time.

Observation 4: *Contract specification is the primary form of green performance contracting, although other forms have been successfully used in a few states.*

3.1.4. OTHER IMPLEMENTATION ISSUES

Three questions on the questionnaire pertained to project type, delivery method, and contractor compliance issues for the implementation of green performance contracting strategies. There has been a concern that green performance contracting may be unaffordable for small projects because of a perceived extra cost. Our results, however, do not indicate that this is an issue (Figure 3-4). Currently, green performance contracting strategies have been applied to both small and large projects. More than 10 states use green performance contracting strategies on highway projects of various size. This finding indicates that green strategies are viable for projects of all sizes. Additionally, it is important to remember that green performance contracting does not have established construction industry buy-in and that there are extras costs associated with the implementation of green performance contracting strategies. According to Massachusetts DOT, the extra cost associated with an engine retrofit requirement is almost incidental primarily because of the current global recession. Since the recent economic downturn, Massachusetts DOT has received increased competition and received bid price decrease by up to 20% compared to previous bids. However, the long term cost impact of green performance contracting remains unclear.

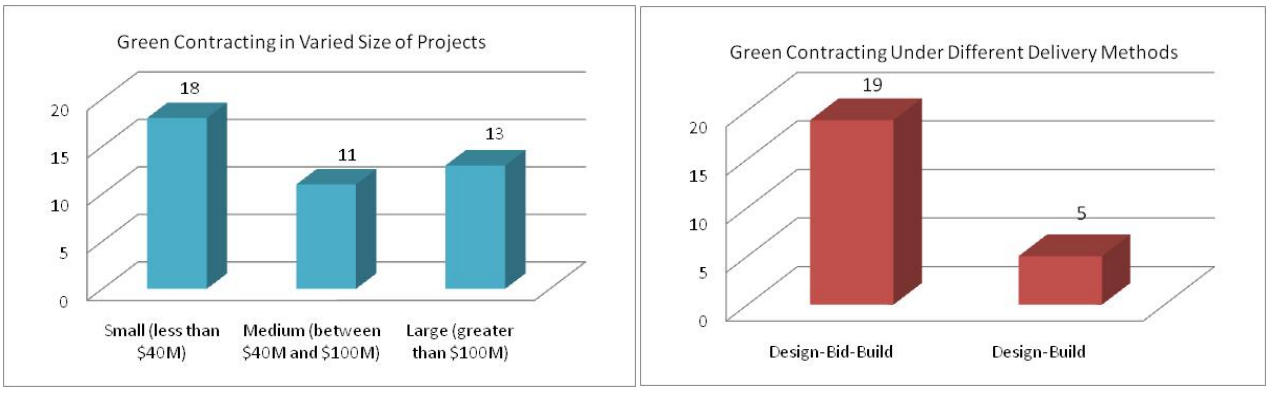


Figure 3-4 Green performance contracting Implementation Issues

Observation 5: *Green performance contracting can be incorporated into projects of various sizes and different project delivery systems.*

Green performance contracting fits easily into all the major project delivery systems, Design-Bid-Build (DBB), Design-Build (DB), and even Construction Manager at Risk (CM@Risk). Five out of 19 states adopted green performance contracting strategies through both DBB and DB procurement routes; the other 14 states used green performance contracting strategies only on traditional DBB projects (Figure 3-4). Within these 14 states, however, ten had none or very little of legislated Design-Build procurement authority according to the Design-Build Institute America's 2010 report.[31] CM@Risk, which is also called Construction Manager/General Contractor (CM/GC), is a process that allows the owner to choose the Construction Manager (CM) before the design phase is complete. The CM serves as a consultant to the owner in the development and design phases, provides a guaranteed maximum price for the project, and then coordinates subcontractors during the construction phase. As one of the most experienced agencies on CM@Risk for highways, Utah DOT allows the optional use of recycled materials on all CM@Risk contracts provided they meet specified engineering properties.

Because most green performance contracting strategies are integrated into contract specifications, contractor compliance is commonly verified through field inspection and documentation. On-site construction inspectors can be state staff or consultants. Similar to other contract provisions, non-compliance with green contract provisions causes a range of consequences including warnings, work shutdown, fines, withheld payment, and termination of the contract.

3.1.5. PRIMARY REASONS FOR GREEN PERFORMANCE CONTRACTING

Green strategies benefit the environment and help preserve natural resources. However, additional incentives are required to encourage green performance contracting strategies in highway projects because there are often additional costs associated with their implementation. These results indicate that nine out of 13 states use material related strategies primarily for economic reasons. At the contractor's request, these state agencies allow the use of recycled materials or warm mix asphalt as a substitute for hot mix asphalt. The other four states (Delaware, Kansas, Mississippi, and Utah) use recycled materials mainly due to agency wide green initiatives or to enhance the agency's public image (Figure 3-5).

Equipment and energy efficiency-related contracting strategies result in incremental increases in the costs of project construction and, therefore, require extra organizational support through agency policies, initiatives, regulations, or legislation. Missouri DOT established a green initiative program to award green contractors with green credits. Under this program, the agency assigns a green credit to the contractor for using various environmentally friendly practices that include using alternative fuels and recycling. Vermont has, in addition to a green initiative within the state's highway agency, a state climate change commission established in 2007 by the governor to promote both energy efficiency and to create a Green Standard for pricing carbon reduction efforts. In Massachusetts, a GreenDOT sustainability initiative was created to position the Massachusetts DOT as a national leader in promoting sustainability in the transportation

sector. The GreenDOT supports the implementation of all existing "green" state laws, executive orders, and agency policies. Moreover, the GreenDOT initiative sets a clear target for greenhouse gas reductions. By 2020, the initiative aims for a reduction of 7.3% below 1990 transportation greenhouse gas emissions, or 30% below the "business as usual" level.

Observation 6: *Some green performance contracting strategies are primarily cost-driven and easily integrated into contract specifications. However, higher levels of green performance contracting strategies may require local green initiatives, mandates, or legislation.*

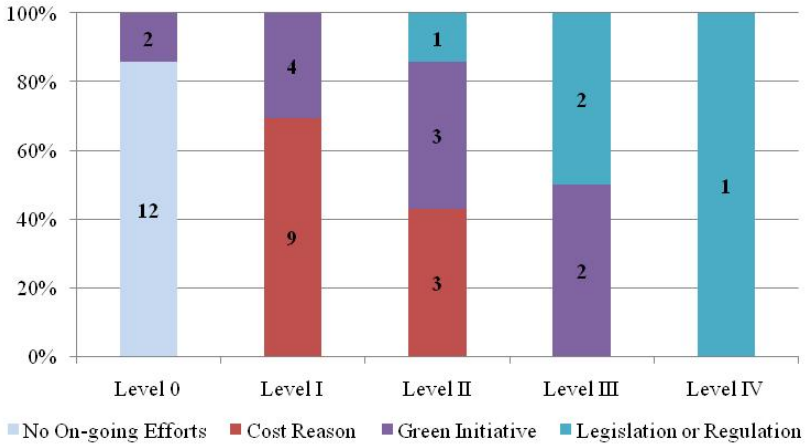


Figure 3-5 Primary Reasons for Green performance contracting

Green life-cycle strategies are generally driven by state policy and legislation, and were, at the time of data collection, used for green highway rating and project-level emission and energy analysis. In New York, the State Energy Plan required the state DOT and Metropolitan Planning Organizations (MPOs) to conduct a greenhouse gas/energy analysis of their transportation plans. As one of its major climate change and energy initiatives, the New York State DOT developed a transportation environmental sustainability rating and self-certification program for all projects whose designs require full Plans, Specifications and Estimates (PS&Es) in 2008. In California, a climate action program was established to respond to legislative requirements of the Assembly Bill (AB) 32 California Global Warming Solution Act of 2006 and the Governor's Executive Order S-3-05. In Washington, Executive Orders 05-01, 04-01, and 02-03 direct Washington DOT to develop Sustainability Plans that report on sustainable business practices and track progress. Similarly, Oregon DOT developed a sustainability program to respond to Oregon statute ORS 184.421 and Executive Order 06-02. Under this sustainability program, Oregon DOT performed a greenhouse gas impact analysis on the Columbia River Crossing project and was, at the time of data collection, evaluating three pilot projects based on the Greenroads sustainability performance metric. The agency also provides guidance for project level greenhouse gas and climate change evaluations. The Office of Sustainable Practice was established in Illinois to guide the agency's sustainable practices in the areas of planning, design, construction, maintenance, operations, and other activities. Of the 14 states that had no green performance contracting experience, 12 reported no on-going green efforts within their highway

agencies, although two-thirds of these respondents expressed interest in involving green perspectives in their agency operation and construction projects.

3.1.6. EMISSION TYPES AND SOURCES

Highway construction activities have the potential to generate a substantial amount of air pollution. These emissions include dust generated from grading, exhaust emissions of particulate matter (PM), nitrogen oxides (NO_X) from construction equipment, and evaporative emissions of reactive organic compounds (ROG) from paving activities. More recently, emissions of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have also become an increasing concern due to the role they play in climate change. Therefore, emissions from construction activities must be assessed and, when necessary, mitigated.

Many state DOTs established air quality programs to assess and address the potential impacts of construction-related emissions including ROG, NO_X, PM, etc. However, analyzing GHG emissions is new for most state DOTs and , at the time of data collection, was not widely integrated into environmental impact assessments. Our findings indicates that only three state DOTs (those in New York, Oregon, and Washington) addressed the greenhouse gas impact of highway construction activities. Many transportation professionals may also not be aware that most green performance contracting strategies can reduce greenhouse gases emissions in addition to addressing other construction related emissions. Table 3-1 lists typical construction-related emission sources and green performance contracting strategies for GHG mitigation.

Table 3-1 Emission Sources and Green Strategies

Emission source	Contracting strategy
Material production and transportation	Material recycle and reuse; Use of local material; Warm mix asphalt; Waste management; Low carbon shipping modes
Off-road diesel equipment	Engine retrofit; Idling reduction; Alternative fuels;
Electric-powered equipment	Energy efficiency;
Worker commute Trips	Alternative fuels; Bike/ped accessibility
Work zone congestion	Work zone mobility, lane rental, A+B
Post-construction Operation	Solar highway, LED lighting
Land use change	Green road rating

3.1.7. CLIMATE CHANGE IMPACT ANALYSIS

Quantifying climate change effects at the project level is a relatively new analysis and lacks a consistent format and language. As of 2010, only California, New York, and Washington developed guidance or methodology for evaluating project-level GHG and climate change effects. In New York, a GHG analysis is performed and included in the environmental assessment documentation for major projects during the project design phase. The GHG analysis is integrated into the project-level energy analysis. Indirect energy use (the energy required to construct and maintain transportation facilities) and direct energy use (the on-road operational energy consumption for the transportation facility) are quantified, As a consequence, the carbon

dioxide emissions from roadway projects can be determined by applying carbon emission coefficients. Washington DOT conducts a GHG and climate change evaluation for all projects that require Environmental Assessments (EAs) and Environmental Impact Statements (EISs). The analysis focuses on highway construction and operational emissions, while also acknowledging material related emission and lifecycle emission. In California, comprehensive guidelines and procedures for evaluating project-level GHG emissions from highway construction were, at the time of data collection, under development. However, California DOT was able to estimate GHG emissions from construction equipment operations and determine the emission reduction benefits of retrofitting or replacing high-emitting construction equipment used to build transportation projects.

There are other models available for project-level GHG analysis. The most popular are EPA's Motor Vehicle Emission Simulator (MOVES) model and NONROAD model. Whereas the MOVES model estimates emissions from highway operation, the NONROAD model calculates the emissions from off-road engines, equipment, and vehicles. Several metropolitan planning organizations did project-level analysis of GHG emissions using EPA's MOVES and NONROAD models. Sacramento Metropolitan Air Quality Management District developed a road construction emission model (RCEM) to assess highway construction emissions. Another EPA recommended tool is the Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE). PaLATE allows users to estimate construction emissions and evaluate life-cycle cost impact of varied pavement designs. Additionally, Michigan and Maryland had on-going research efforts to develop their own guidance and methodology for project-level GHG emissions. Although all of these models are available, there is no federal guidance about which best addresses project-level GHG emissions, nor does there exist federal or state reporting thresholds for project level GHG emissions.

Another area associated with green actions and sustainability is the green highway rating system. Similar to the LEED standard for green buildings, the green highway rating system standardizes metrics of the greenness of highway construction. The rating system allows officials to develop a list of best practices for constructing sustainable roads. The survey identified three rating systems used in the United States: Green Leadership in Transportation Environmental Sustainability, Greenroads, and Illinois-Livable and Sustainable Transportation. The GreenLITES is the only rating system endorsed by a state highway agency. According to New York DOT, all project PS&Es submissions must be GreenLITES-certified. Greenroads was developed by the University of Washington and Ch2MHILL, and has been used for evaluating several pilot projects in Washington and Oregon. The I-LAST rating system is also voluntary. The purpose of I-LAST, according to Illinois DOT, is to provide a list of best practices to bring sustainability to highway projects. A comparison of the three rating systems is given in Table 3-2.

Table 3-2 Green Highway Rating Systems

	GreenLITES	Greenroads	I-LAST
Endorsed State	NY	Not yet, pilot evaluation in WA and OR	IL
Certification Levels	Certified, Silver, Gold, Evergreen	Certified, Silver, Gold, Evergreen	Not a certification program, advisory in nature
Certification Requirement	Required for all PS&E submissions	Voluntary	Voluntary
Evaluation Category	Sustainable Sites, Water Quality, Materials & Resources, Energy & Atmosphere, Innovation/Unlisted	Project Requirements, Environment & Water, Access & Equity, Construction Activities, Materials & Resources, Pavement Technologies, Custom Credit	Planning, Design. Environmental, Water Quality, Transportation, Lighting, Materials, Innovation.
Elements	158	50	150
Total Points	251	118	233
Minimum Certification Points (%)	15	32	NA
Info Source	https://www.nysdot.gov/programs/greenlites	www.greenroads.us	www.dot.il.gov/green/documents/I-LASTGuidebook.pdf

Observation 7: *Many green highway rating and climate change impact analysis systems are available, but there is no widely endorsed or standardized method.*

3.1.8. CHALLENGES

Respondents identified challenges associated with the use of green performance contracting strategies. These comments are summarized below.

- There are high costs associated with going green. There could be higher bid prices and a reduction in the number of bidders.
- It is difficult to get policies written and in place.
- Lack of staff resources and leadership focus.
- Do we have industry buy-in?
- There is no legislative incentive.
- Lack of compelling technology or research
- There are varied levels of implementation or enforcement and contractor compliance between different locations (like urban and rural areas).
- It is difficult to specify measurable standards and limits.

3.2. PRACTICES IN LEADING STATES

3.2.1. NEW YORK

In 2002, New York State adopted one of the first Energy Plans in the nation that integrates transportation planning, energy conservation, greenhouse gases mitigation, and air quality planning. Under the plan, New York State is to:

- Reduce primary energy use per unit of gross state product by 25% below 1990 levels by 2010.
- Increase renewable energy use from 10% to 15% by 2020.

Then-Gov. David A. Paterson signed Executive Order No. 24, [32] in August 2009, which set a goal to reduce greenhouse gas emissions in New York State by 80% below the levels emitted in 1990 by the year 2050. The Executive Order also created the New York Climate Action Council (CAC) and tasked it with drafting a climate action plan by September 30, 2010. NYSDOT is one of 15 member agencies that comprise the Council. At NYSDOT, all the major offices from the Operations, Engineering and Administration divisions were, at the time of data collection, involved in green initiatives. Indeed, the Operations Division, with substantial involvement by the Office of Environment, was the executive sponsor of climate change initiatives.

The New York legislature passed the Diesel Emissions Reduction Act in 2006, which required state-owned diesel vehicles and those working on state contracts to use ULSD fuel and the best diesel retrofit emission control technology to reduce diesel PM emissions. In June 2009, the New York State Environmental Board approved regulations that require all engines in heavy-duty diesel vehicles owned by state agencies, authorities and contractors working on behalf of the State be retrofitted or replaced to decrease diesel PM emissions by December 2010. The regulations also require the use of ULSD fuel in state-owned or contracted heavy-duty vehicles, including on and off-road vehicles. The regulations require application of best available retrofit technology. Compliance options included replacement of a vehicle newer than 2007 that is equipped with a DPF or to retrofit an existing vehicle with the highest-level verified PM retrofit technology.[33] On the operational side, agency-owned fleet equipment used 5% biodiesel. This biodiesel percentage was selected based on the concern that higher percentages could increase NOx emissions in ozone nonattainment areas of the state.

In Section 3008 of the Transportation Equity Act for the 21st Century (TEA-21), put into effect in 1998, there was the Clean Fuels Formula Grant Program, which facilitates transit operators to buy or lease low-emissions buses and related equipment, construct alternative fueling facilities, modify garage facilities to accommodate clean-fuel vehicles, and assist in the use of biodiesel fuel. Currently, the State does not have any funding or grant programs for green construction equipment, but the NYSDOT routinely applies for funding and grants through the USEPA Clean Diesel program.

The NYSDOT is supporting an application for a $3 million grant for the Transportation and Climate Initiative's (TCI's) electric vehicle planning project where electric vehicle charging stations would be installed across the Northeastern United States. This will reduce carbon emissions by making electric vehicles more commonplace and decreasing our dependency on imported petroleum.

The Central New York Regional Transportation Authority used the Congestion Mitigation and Air Quality Improvement Program funding sources to build a compressed natural gas refueling facility and a fueling station. This initiative encouraged the use of compressed natural gas by public and private vehicles, reduced air pollutants, and helped improve the air quality by minimizing congestion and providing public transportation.

According to New York's environmental policy, recycling is their first choice in dealing with solid waste. The NYSDOT promoted using recycled tires in highway embankments, using glass, plastics, and aggregates in pavement mixes, and plastic, rubber, and aggregate in noise walls. The use of recyclable materials is always allowed on NYSDOT's construction projects and is typically incorporated by contractors when materials are available and cost effective in comparison to the non-recyclable materials.

A green initiative adopted by NYSDOT is the GreenLITES Project Design Certification Program. This program is similar to the LEED rating system, but applies to NYSDOT projects and awards Department project designers with certification recognition for incorporating green design practices (i.e., permeable pavements, solar fixtures, truckstop electrification, etc.) into their projects. Since GreenLITES is a certification program, it could be treated as an incentive or prequalification initiative. Furthermore, the NYSDOT requires project-level energy analysis and GHG estimation for all highway projects. The estimation tool is a part of the New York State Energy Plan (SEP),[34] and contractors could conduct the analysis according to the NYSDOT's guidelines.[35]

Engine retrofit devices are mainly monitored visually on job sites, and mechanical devices that conduct automatic inspection like idling monitors are still under development. Responses from contractors have been mainly positive because the three required provisions (idling, dust control, and ULSD) are not cost-prohibitive. For projects that specify construction exhaust retrofits and/or engine replacements, the response was mixed because contractors were aware of these requirements before placing their bids, and therefore, adjust their prices accordingly. The biggest challenge associated with statewide implementation of green construction practices has been the variation of those responses between urban and rural areas. In urban areas, acceptance appears to be coming more quickly, whereas in rural areas, contractors do not necessarily understand the need for such provisions and are somewhat slower to accept them.

3.2.2. OREGON

The Oregon Governor's Advisory Group on Global Warming developed the Oregon Strategy for Greenhouse Gas Reduction in 2004.[36] According to the strategy, the Advisory Group proposed the GHG reduction goals for Oregon:

- By 2010, arrest the growth of Oregon's greenhouse gas emissions and begin to reduce them, making measurable progress toward meeting the existing benchmark for CO_2 of not exceeding 1990 levels.
- By 2020, achieve a 10% reduction below 1990 greenhouse gas levels.
- By 2050, achieve "climate stabilization" emissions level at least 75% below 1990 levels.

In February 2007, the governors of Washington, Oregon, California, Arizona and New Mexico launched the Western Climate Initiative (WCI). WCI requires partners to set an overall regional goal to reduce emissions, develop a market-based, multi-sector mechanism to help achieve that goal, and participate in a cross-border greenhouse gas registry. As the core of the Western Climate Initiative, a cap-and-trade system would go into effect in January 2012, gradually decreasing emissions levels.

The State of Oregon developed a Business Energy Tax Credit (BETC) program in 2008 to give incentives to those who used renewable energy in various business projects, including conservation, renewable resources, high performance homes, homebuilder-installed renewable energy projects, renewable energy resource equipment manufacturing, sustainable buildings, transportation, alternative fuels, rental dwelling weatherization, and recycling.[37] The program credits 50% of eligible project costs for qualifying renewable resource projects. The program has been successfully conducted, and Oregon's government committed to strengthen the incentive by creating a BETC Energy Fund that would create up-front funding options under the BETC.

The Oregon Department of Transportation (ODOT) has been an active part of its state's green initiatives. The ODOT developed a specific sustainability council that was responsible for analyzing all aspects of the agency's internal and external operations and to identify opportunities to integrate sustainability principles into agency decision-making, management and operations. The council consists of two teams. Conservation and Alternative Resource Teams (CARTs) supported the overall sustainability program by implementing on-the-ground initiatives in ODOT facilities. Sustainability Project Teams worked on internal greenhouse gas emission tracking, neighborhood electric vehicles use, fleet use of biodiesel, vehicle emissions issues and other initiatives.[38]

The ODOT also established a bicycle and pedestrian program to create pedestrian and bicycle facilities on state highways and provide support to local governments, governmental and non-governmental organizations, and private citizens, in planning, designing and constructing pedestrian and bicycle facilities.[39]

Turning now to highway construction, ODOT finished the nation's first solar demonstration project in 2008.[40] The project installed 594 solar panels along DOT right-of-way at the Interstate 5 and Interstate 205 interchange in Tualatin, Oregon. The solar array supplies about one-third of the energy needed for illumination at the site, which could reduce around 43 metric tons of CO_2-eq emissions per year. It is important to consider cost effectiveness, as well. ODOT's Region 1 (Portland Metro Area) annual electric bill was more than $1.2 million, with 50% coming from signals and flashers. Region 1 has retrofitted 95% of its signals and flashers with power-saving LEDs, which resulted in a savings of $110,000 per year on Oregon's electric bill, and energy consumption reductions equivalent to the annual power needed for over 140 Oregon homes. At the time of data collection, ODOT continued to research and test innovative highway lighting technologies that will reduce energy.

The ODOT is leading several innovative pilot projects such as Electronic Vehicle Charging Stations and Truck Road Use Electronics (TRUE).[41,42] Oregon also implemented Green Light Weigh Stations which use a "preclearance" system that uses palm-sized transponders mounted inside truck windshields to identify the trucks. A computer receives all the information, verifies truck size and weight, checks the carrier´s registration and safety records, and sends a green light signal back to the transponder if the truck is cleared to past the station. Truckers save time, money, and fuel by continuing through weight states. In August 2010, this system precleared its 13-millionth truck, and as of October 2010, it served 4,751 trucking companies with 38,337 trucks equipped with transponders. Emission testing done by the Oregon Department of Environmental Quality (DEQ) showed a 36% to 67% reduction in particulate matter, carbon dioxide, nitrogen oxides, carbon monoxide, and hydrocarbons. Trucks using this system also experienced a 57% improvement in fuel economy. So far, truckers have saved 1.083 million hours of travel time and $127 million in operating costs. Trucks have emitted 8,671 pounds less particulate matter, 17,329 pounds less hydrocarbons, 41,600 pounds less carbon monoxide, 138,671 pounds less nitrogen oxides, and 24,843,000 pounds less carbon dioxide.

The ODOT is currently using Greenroad sustainability performance metric to evaluate its pilot projects. The Greenroad rating system was developed by the University of Washington, intended to award points for more sustainable practices during the design and construction phases of roadway projects and award a certification level based on the number of points earned. Another green strategy used in Oregon has to do with the OTIA III Materials and Contamination Performance Standards, which require extensive reuse and recycling of bridge materials. For example, in 2009, 44,800 tons of asphalt pavement, 21,500 tons of clean fill, 40,200 tons of concrete, 2,700 tons of metal, and 400 tons of wood were captured, reused, and recycled.

Meanwhile, ODOT has developed a GHG analysis model GreenSTEP to help the Global Warming Commission evaluate GHG emission's contributing factors and their interrelationships, and to develop a strategy for reducing transportation sector GHG emissions. The GreenSTEP model includes models of household travel, vehicle ownership and vehicle characteristics

operating at the household level along with simple truck, fuels and emissions models to estimate the effects of land use, transportation pricing, and other policies on GHG emissions.

3.2.3. CALIFORNIA

The California Department of Transportation (Caltrans) and the California Transportation Commission (CTC) moved rapidly to integrate climate change into the state's transportation planning framework. At the time of data collection, California was the only state to adopt mandatory greenhouse gas (GHG) reduction targets and to create an administrative and regulatory framework in response.

On June 1, 2005, then California Governor Arnold Schwarzenegger issued Executive Order S-3-05,[43] which established statewide GHG emission reduction targets to 2000 levels by 2010, to 1990 levels by 2020, and to 80% below 1990 levels by 2050. On September 27, 2006, Gov. Schwarzenegger signed the Global Warming Solutions Act, Assembly Bill (AB) 32,[44] which capped the state's GHG emissions at 1990 levels by 2020. This is the first statewide program in the United States to mandate an economy-wide emissions cap that includes enforceable penalties.

California's climate strategies regulate about 95% of all emissions.[45] With respect to transportation emissions, Assembly Bill 32 requires retrofits to improve the fuel efficiency of heavy duty vehicles. It also required energy efficiency and co-benefits audits for large industrial sources such as cement plants that manufacture a widely used product in highway construction.

California's legislature passed AB 1007 in 2005. This legislation imposed various limitations on emissions from vehicular and non-vehicular sources of air contaminants for the control of air pollution.[46] The legislation directed the California Energy Commission (CEC), in partnership with the California Air Resources Board (CARB), to develop and adopt a state alternative fuels plan to increase the use of alternative fuels without adversely affecting air quality and water quality or causing negative health effects.[47]

According to the plan, certain alternative fuels and technologies are specifically identified to be subject to evaluation, including ethanol, biodiesel, hydrogen, methanol, propane, natural gas, electricity and other fuels. CARB also proposed a Low Carbon Fuel Standard Program (LCFS). The goal of which was to reduce greenhouse gas emissions by reducing the full fuel-cycle carbon intensity of the transportation fuel pool used in California.[48] Through the Department's energy conservation program, dealing with facilities and roadway related electrical and LPG/natural gas consumption loads, the Department saved approximately 125,000,000 KWH.

The legislation required comparative evaluations of full fuel cycle impacts, including criteria on air pollutants, GHG emissions, toxic chemicals, and water pollutants. Additionally, AB1007 also requires no net material increase in air, water, and toxic pollution. To complete this analysis, both the CEC and the CARB used a publicly available fuel cycle model, the GHG

Emissions, Criteria Air Emissions, and Energy Efficiency in Transportation (GREET) model, which has been modified to reflect California conditions.

In January 2008, the California Air Pollution Control Officers Association (CAPCOA) prepared a resource document for reviewing GHG emissions from projects under the California Environmental Quality Act (CEQA). According to the executive white paper,[49] CEQA required that public agencies refrain from approving projects with significant adverse environmental outcomes if there are feasible alternatives or mitigation measures that can substantially reduce or avoid those adverse environmental consequences. The white paper also evaluated various analytical methods and modeling tools that could estimate the greenhouse gas emissions from different project types subject to CEQA. In addition, the suitability of the methods and tools to accurately characterize a project's emissions were discussed and the paper provided recommendations for the most appropriate methodologies and tools available.

The CARB approved a mandatory reporting regulation of greenhouse gases by major sources. For most industrial sectors, the mandatory reporting regulation specified a reporting threshold of 25,000 metric tons of carbon dioxide. A wide range of industries were required to submit GHG reports regularly, including electricity retail providers and marketers, petroleum refineries, cement plants, hydrogen plants, and co-generation or electricity generation facilities.[50]

Caltrans' goal was to reduce the amount of cement used in pavements and bridges by up to 50% and have stronger, longer-lasting concrete. The typical concrete mix is about 25% fly ash, which produces 25% less GHG in its production statewide. The objective is to increase the amount of fly ash in concrete mixes to 60% fly ash and 50% slag. Caltrans also changed its specification to allow 2.5% limestone concrete mix in future cements use. Additionally, Caltrans is researching 100-year pavement, designed to last 100 years, to significantly reduce maintenance, congestion, GHG emissions, and construction material costs.

In addition to incorporating climate change mitigation strategies, California proposed a California Climate Adaptation Strategy (CAS) in 2009 to analyze the best known science on climate change impacts in the state, to assess vulnerability, and to outline possible solutions that can be implemented within and across State agencies to promote resiliency.[51] This is the first step in an ongoing, evolving process to reduce California's vulnerability to climate impacts. The adaptation strategy was lead by the California Natural Resources Agency (CNRA) working with 12 other state agencies through the Climate Action Team (CAT).

3.2.4. MASSACHUSETTS

In 2007, Massachusetts' legislature passed the Global Warming Solutions Act (GWSA). It was designed to reduce energy costs to ratepayers, expand clean energy jobs, attract clean energy businesses, increase the state's energy independence and reduce greenhouse gas emissions.[52] The GWSA made Massachusetts one of the first states in the nation to begin with a comprehensive program to address climate change. As mandated by the Act, the Climate

Protection and Green Economy Advisory Committee includes members from various sectors of the state, including industry and manufacturing, transportation, energy generation and distribution, and environmental protection. The Act requires the state, on an economy-wide basis, to:

- Reduce statewide GHG emissions between 10% and 25% below the statewide GHG emissions level in 1990 by 2020, and
- Reduce statewide GHG emissions at least 80% below the statewide GHG emissions level in 1990 by 2050.

In order to reach these goals, Massachusetts Department of Transportation (MassDOT) was charged with implementing a number of actions to reduce the consumption of energy and fuel, and thereby the emissions of GHGs.

The Massachusetts Executive Office of Energy and Environmental Affairs (EEA) developed a greenhouse gas emissions policy and protocol in 2007. It requires certain projects undergoing review by the Massachusetts Environmental Policy Act (MEPA) office to quantity the project's GHG emissions and to identify measures that avoid, minimize, or mitigate such emissions. In addition to quantifying project-related GHG emissions, the policy also required proponents to quantify the impact of proposed mitigation in terms of emissions and energy savings.[53]

In 2004, Massachusetts adopted the California Low Emission Vehicle (LEV) standards for light-duty diesel powered passenger vehicles and trucks. According to the standard, manufacturers can obtain credits through special projects providing alternate-fuel vehicle refueling, fuel cell vehicles, personal electric vehicle use or Transportation System projects that result in placing vehicles with advanced technology in innovative transportation systems in Massachusetts. The LEV program determines the credit awarded for these projects by evaluating project cost and the number and use of advanced technology vehicles placed as a result of the project.[54]

Massachusetts Department of Environmental Protection (MassDEP) adopted an Environmental Results Program (ERP) requiring ERP certification for all owners or operators of ERP facilities, which includes engines, combustion turbines, and industrial facility users, among others.[55] The certification process was designed to ensure that the ERP facilities and units were compliance with the performance-based requirements of MassDEP and to provide protection for public health, safety, welfare and the environment.

At the time of data collection, Massachusetts began a new green initiative, Smart Growth and Smart Energy Toolkit . The toolkit was designed to incorporate the 10 sustainable development principles[56] into the policies and programs of all agencies in order to lead by example on clean energy and other issues, and to ensure that state infrastructure investments encourage smart growth instead of subsidizing sprawl.[57]

Massachusetts proposed the State Revolving Fund (SRF) program to provide financial assistance for municipal wastewater treatment and drinking water infrastructure projects.

Beginning in 2001.[58] The SRF program required that diesel oxidation catalyst (DOC) technology be installed in at least half of construction equipment used on SRF projects. A year later the retrofit requirement was expanded to encompass all equipment. In January 2008, MassDEP amended the retrofit requirement to apply only to engines rated 50 horsepower or greater and will be used on a project site for 30 days or more. The SRF program's retrofit requirement is part of the larger Massachusetts Diesel Retrofit Program (MDRP), which was developed to respond to excessive diesel emissions from state-funded construction projects.

On June 4, 2009, the EEA launched the Climate Change Adaptation Advisory Committee, which was formed under the Global Warming Solutions Act of 2008. The Advisory Committee was charged by the legislature with evaluating strategies for adapting to the predicted effects of climate change. These effects include increased sea levels, warming temperatures, and increased incidences of floods and droughts.

MassDOT undertook an agency-based green and sustainability initiative called GreenDOT in 2010. GreenDOT was designed to help MassDOT comply with several existing state laws, executive orders, and MassDOT policies, which include the 2009 Transportation Reform Law, the Global Warming Solutions Act, and MassDOT's Complete Streets design approach. GreenDOT's goal was to reduce GHG emissions by more than 2 million tons by 2020, which represents a 7.3% decrease below 1990 transportation sector emission levels. GreenDOT called for MassDOT to incorporate sustainability into all of its activities, from strategic planning to project design and construction to system operation.[59] The main objectives of this program were to reduce GHG emissions, promote the healthy transportation options of walking, bicycling, and public transit, and support smart growth development.

3.2.5. WASHINGTON

Under the authority of the State of Washington Executive Order 07-02,[60] the state's target for greenhouse gas emissions reduction and clean energy economy are:

- By 2020, to reduce greenhouse gas emissions in Washington to 1990 levels, a reduction of 10 million metric tons below 2004 emissions;
- By 2035, to reduce greenhouse gas emissions in the State of Washington to 25% below 1990 levels, a reduction of 30 million metric tons below 2004 levels;
- By 2050, that Washington will do its part to reach global climate stabilization levels by reducing emissions to 50% below 1990 levels or 70% below its expected emissions that year, an absolute reduction in emissions of nearly 50 million metric tons below 2004 levels;
- By 2020, to increase the number of clean energy sector jobs to 25,000 from the 8,400 jobs the State had in 2004; and
- By 2020, to reduce expenditures by 20% on fuel imported into the state by developing Washington resources and supporting efficient energy use.

The Washington State Department of Transportation (WSDOT) and the Washington State Transportation Commission (WSTC) are acting to prevent climate change both in a long-range plan and through participation in inter-agency efforts, including the Washington Climate Advisory Team. The Washington Climate Advisory Team (CAT) is a multi-disciplinary stakeholder group tasked by then Governor Christine Gregoire with proposing policies to reduce the state's GHG emissions. The effort was led by the Department of Ecology and the Department of Community, Trade, and Economic Development. Transportation is a major target area for emissions reductions. Representatives from both WSTC and WSDOT served on the Transportation Technical Working Group that supported this effort. The 2008 CAT report "Leading the Way: Implementing Practical Solutions to the Climate Change Challenge," emphasized the importance of land-use decisions, transportation choices, and development patterns working together to achieve the GHG emission and VMT reduction targets.[61]

The report requires agencies to maximize energy efficiency when designing, building, upgrading, and when operating new and existing buildings by energy delivery from lower or non-carbon sources and more efficient use of fuels. The report recommended using the Energy Efficiency Quality Investment Program (EEQUIP), tax incentives to encourage the use of combined heat and power, renewable energy, and the Washington State Energy Code (WSEC).[62]

The WSDOT has proposed an evaluation tool for Greenhouse Gas and Climate Change estimates at the project level.[63] The guidance of the tool outlines a standard analytical process and provides template language for projects' emission evaluations. The evaluation process follows the State Environmental Policy Act (SEPA) which was adopted in 1971 to ensure that environmental values were considered during decision-making by state and local agencies.[64] In the Estimation Guidance, emissions from the operation and construction phases are considered to be significant and therefore are required to be quantitatively reported. The embodied/lifecycle emissions, however, need only to be qualitatively reported. The evaluation process is not mandatory, although it is highly recommended and has been performed in many projects.

The State of Washington encouraged incorporating the use of emerging technologies and practices in climate change adaptation design strategies. Led by the Department of Commerce, the global warming mitigation and adaptation program selected three counties and six cities through a competitive process to provide grants and technical assistance for their efforts to anticipate, mitigate, and adapt to global warming and its associated problems.

Additionally, WSDOT cooperated with California and Oregon to develop the nation's first electric highway along Interstate 5 through the West Coast Green Highway project.[65] This project was designed to provide clean transportation and emerging technologies to a regional market of 10 million consumers travelling throughout the Interstate 5 corridor. The project would also attract commuters and green-technology industries looking to locate or expand their business opportunities in an electric vehicle-ready region.

At the time of data collection, the WSDOT used smarter highways, known also as active traffic management technology (ATM), to improve traffic flow. These smarter highway tools

include: overhead gantries that display speed limits and real-time traffic information for each lane; alerts for drivers to slow down when approaching congestion; warnings for back-ups, junction control, and hard shoulder running to allow drivers to use the shoulder as a traffic lane during congested periods or to move around a collision or stalled vehicle; dynamic rerouting to alert drivers to change their route based on current traffic conditions,; and travel time signs.

WSDOT switched to an electronic tolling system known as Good To Go!, which allows drivers to pay without stopping. WSDOT is also used high occupancy toll (HOT) lanes to give drivers lane choice by allowing a small proportion of single-passenger cars to use underused carpool lanes. These HOT lanes include an electronic toll that fluctuates with the level of congestion letting solo drivers use carpool lanes reserved for vehicles with at least two occupants. Additionally, respondents indicated WSDOT officials were considering using express toll lanes to reduce congestion.

In order to promote travelling by walking and bicycling, WSDOT on average added more than 20 miles of new sidewalk, trails, and paths each year. These investments can mean savings of more than $23 million in fuel costs, and can mean a 67,000 metric tons of reductions in CO_2 emissions.

By using LED lights in traffic signals, WSDOT reduced its electricity consumption annually from 31,600 kilowatt hours (KWH) to 4,744 KWH. LED lights are also being used in the arrow boards, warning beacons, and even vehicles, which save an estimated 121,000 gallons of fuel, 4.4 tons of air pollutants, and 800 tons of carbon dioxide annually.

In order to improve air emission performance, WSDOT retrofitted maintenance vehicles and equipment with tailpipe diesel catalysts and engine filters using US EPA and Ecology grants in 2005 and, in 2006. These retrofits reduced diesel pollution by 20-40% from each engine. Additionally, WSDOT usually replaces engines and equipment every 12-15 years with cleaner models. Engines manufactured after 2007 pollute 90-99% less particulate matter and NOx.

In 2010, Washington legislature approved Bill 6373 that requires people operating the following sources to report to the Department of Ecology their emissions of certain greenhouse gases: (1) A single facility, source, or site that emits at least 10,000 metric tons of greenhouse gases annually; or (2) A supplier of liquid motor vehicle fuel, special fuel, or aircraft fuel that supplies products equivalent to at least 10,000 metric tons of carbon dioxide annually.[66] The Department of Ecology must report to the Governor and the appropriate committees of the State Senate and House of Representatives the total emissions of greenhouse gases for the preceding two years, and totals in each major source sector.

4 GREEN PERFORMANCE CONTRACTING: CASE STUDIES

4.1. LEVEL I CASE: MATERIAL RECYCLE AND REUSE

Case 1: Fly Ash used in San Francisco Bay Bridge Reconstruction

The San Francisco Oakland Bay Bridge was damaged in the 1989 Loma Prieta Earthquake and then underwent a major seismic safety improvement project. California Department of Transportation (Caltrans) began reconstruction in 2002, starting with the San Francisco side of the Bay Bridge (the West Span) and working East. The West Span required seismic retrofit work, and the most cost-effective solution required the complete replacement of the existing span.[67]

The construction of the new East Span of the San Francisco Bay Bridge took advantage of the unique properties of fly ash and ground granulated blast furnace slag to enhance concrete durability and strength. The chemical and physical properties of fly ash concrete helped mitigate the corrosive effects of seawater and salt fog and the structural requirements of an earthquake zone.[68] For durable concrete, Caltrans required that at least 25% of the cementitious material be fly ash in almost all of its structural concrete to mitigate Alkali Silica Reactivity (ASR) since 1997. Cement cracking as it hardens is a common problem in a salt-water environment, so the high-salt zones of the bridge used a concrete mix containing 50% fly ash to prevent cracking. The round fly ash particles also improved flow and workability of the mix. The fly ash concrete used was also denser and stronger than traditional concrete and could better carry heavy loads.

Figure 4-1 San Francisco Bay Bridge

For the pier concrete, the contractor used 50% ground granulated blast-furnace slag, which was the maximum percentage allowed by the 2001 specifications. Although there was no requirement or even encouragement for its use, bid prices indicated that using this material could be a financial benefit for the contractor. In 2006, Caltrans received an award for Innovation from

EPA's Coal Combustion Products Partnership (C2P2), in part based on its work on the new Bay Bridge.

Case 2: Beneficial Use of Industrial Byproduct Program in Wisconsin

The Wisconsin Department of Transportation (WisDOT) is recognized as a national leader in beneficially using fly ash and foundry sand in transportation improvement projects and in recycling asphalt and concrete pavements. It is WisDOT's policy to encourage the use of industrial byproducts and recycled or reclaimed materials when those materials deliver performance equivalent to that of traditional materials at a comparable or lower cost. WisDOT has worked closely with the Wisconsin Department of Natural Resources (DNR) in its approval process for the use of industrial byproducts such as fly ash, bottom ash, paper mill sludge, and foundry sand and slag as alternatives. WisDOT or Wisconsin DNR established the Beneficial Use of Industrial Byproducts Program to streamline a self-implementing process and encourage the beneficial use of industrial byproducts. According to the Wisconsin Administrative Code Chapter NR 538, which governs the program, five categories of industrial byproducts are established according to their chemical characteristics and twelve pre-approved beneficial uses based upon those categories are provided [69,70]. The definitions of the five categories in the NR 538 are provided below. For more information, refer to the file of Administrative Code Chapter NR 538.

- **Category 1:** Industrial byproducts that have been determined to contain less than the concentration specified for the parameters listed in NR 538, Appendix I, Tables 1A and 1B.
- **Category 2:** Industrial byproducts that have been determined to contain less than the concentration specified for the parameters listed in NR 538, Appendix I, Tables 2A and 2B. If in the total elemental analysis total polyaromatic hydrocarbons exceed 100 mg/kg, department concurrence is necessary prior to classification as a Category 2 industrial byproduct. …
- **Category 3:** Industrial byproducts that have been determined to contain less than the concentration specified for the parameters listed in NR 538, Appendix I, Table 2A. Coal ashes are Category 3 industrial byproducts if the concentration of boron is less than 3.4 mg/l ...
- **Category 4:** Industrial byproducts that have been determined to contain less than the concentration specified for the parameters listed in NR 538, Appendix I, Table 3.
- **Category 5:** Industrial byproducts that have been determined not to be a hazardous waste as defined in s. NR 660.10 (52) and are not Category 1 to 4 industrial byproducts.

The WisDOT rewrote its Standard Specifications as "performance-based specifications," facilitating the use of recycled materials. Accordingly, contractors should follow several steps[47] to participate in the program and incorporate industrial byproducts:

- The first step to participate in the program is to characterize the byproduct materials that intend to be beneficially used.
- Once the byproduct material has been characterized properly and the results of the characterization are sent to the Department, the contractor may proceed to beneficially use this material.
- Most beneficial uses allowed under the NR 538 can proceed without specific departmental approval; however, regional staff assigned to the beneficial use program review larger proposed projects to allow for the evaluation of potential impacts to human health or the environment. The regional office staffs of the program also review and approve beneficial uses for industrial byproducts which are not specified and evaluate other waste materials for beneficial uses.
- Once the contractors qualify for participation in the program they will be required to keep records of their beneficial use projects, report the amount of material they generate and beneficially use to the department annually, and retest their byproduct material at designated yearly intervals.

Industry estimates indicate that the beneficial use of industrial byproducts in Wisconsin is well above the national average, with approximately 72% of coal ash, 45% of foundry byproducts, and 63% of paper mill sludge being used in Wisconsin in 2000.[71]

4.2. LEVEL II CASE: EQUIPMENT RETROFIT TECHNOLOGY

Case 3: Maryland State Highway Administration Inter-county Connector Project (ICC)

The Maryland State Highway Administration (SHA) partnered with the Maryland Transportation Authority (MDTA) and the Federal Highway Administration (FHWA) to initiate the Inter-County Connector Project (ICC) in June 2003. The ICC project provided a multi-modal 6-lane divided east-west highway to link existing and planned development between I-270 and I-95/US 1 corridors in Maryland. The ICC project is located in Montgomery and Prince George counties and covers approximately 18 miles. The project would be completed via a total of five design-build contracts. Each contract takes into consideration numerous environmental concerns including heavy-duty emission reductions, using low sulfur diesel fuel, environmental mitigation, and environmental stewardship.

Figure 4-2 Maryland SHA Inter-county Connector Project (ICC)

Aligned with the project purposes and needs, the ICC study team proposed a project-level conformity determination for air quality in regards to fine particulate matter (PM2.5), which was applied on April 5, 2006.[72] The conformity documents were required under the Clean Air Act to ensure that federally supported highway and transit projects are consistent with the purpose of the state air quality implementation plan (SIP). For the ICC project, project-level PM2.5 conformity required an assessment of localized emissions impacts, which is called a hotspot analysis.

In addition, the ICC project followed a series of national vehicle control programs proposed by EPA to substantially reduce vehicle emissions. These programs include the Tier II vehicle and fuel sulfur standards for light-duty vehicles, the 2007 Highway Rule for heavy-duty diesel vehicles, and related programs. Started in 2007, heavy-duty engine standards resulted in the introduction of new, highly effective control technologies for heavy-duty engines. Due to the 2007 diesel engine and fuel program, particulate matter emission levels are expected to be 90% lower on a per vehicle basis than 2000 standards levels.

The ICC project also conducted an environmental impact statement evaluation (EIS) for public review and the final version was approved on January 3, 2006. According to the EIS Air Quality Technical Report,[73] various project commitments were listed for managing the ICC project heavy-duty equipment. The following includes some of the sample language. For more information, refer to the Final EIS Air Quality Technical Report.

> "…The Lead Agencies will require the implementation of a Diesel Emission Reduction Plan for construction purposes. Mobile source emissions can be reduced during construction by use of retrofits-oxidation catalysts on equipment and not permitting idling of delivery trucks or other equipment during long periods of time for unloading. This will be monitored during project construction…"
>
> "…Construction equipment will be maintained to minimize noise emissions caused by inefficiently tuned engines, poorly lubricated moving parts and poor-ineffective muffling/exhaust systems…"

Case 4: Massachusetts DOT's Standard Special Provision

On June 2, 2010, a Massachusetts DOT green and sustainability initiative called GreenDOT was signed and began to be enforced within the agency. The main objectives of this program were to reduce greenhouse gas (GHG) emissions, to promote the healthy transportation options of walking, bicycling, and public transit, and to support smart growth development. As shown in the directive, the projected reduction objective of GHG emissions under the GreenDOT innitiative are 7.3% below 1990 emission levels by 2020 and 12.3% below 1990 emission levels by 2050. To align with the emission reduction target, the MassDOT specifications committee developed a set of standard special provisions of pollution prevention that specifically require the implementation of diesel retrofit technologies in highway construction.[74]

All MassDOT projects were required to install diesel engine retrofit devices. As part of the bidding process, contractors and sub-contractors are required to use EPA or CARB certified equipment, and must submit the following information:

- Identified owned/rental equipment;
- Equipment type, equipment make, model, and VIN;
- Engine model, year of manufacture, and horsepower rating;
- Type of fuel used;
- Emission control device (ECD) type;
- ECD manufacturer, make and model;
- ECD EPA/CARB verification number or certification;
- ECD installation date.

In order to ensure specification compliance, contractors and subcontractors were to keep records of all equipment used on the project. MassDOT tasked staff member to inspect and monitor project equipment use to make sure all required ECD were properly installed. Upon confirming the equipment was in compliance, MassDOT would issue a compliance label assigning a tracking number to the device. Random checking was conducted by MassDOT staff during the project construction and penalties were assessed if the contractor breached the contract. The following is an example of the compliance language used in the contract provisions.[75]

State Contract No. _____

CERTIFICATION OF CONSTRUCTION EQUIPMENT STANDARD COMPLIANCE

I, _____ authorized signatory for

_____

whose principal place of business is at

_____

do hereby certify that any and all large non-road (greater than 50 horsepower) diesel construction equipment (DCE) to be used in this contract has emission control devices installed, such as oxidation catalysts or particulate filters, on the exhaust system side of the diesel combustion engine equipment.

I also hereby agree on behalf of _____
to provide a list of said DCE to the Massachusetts Highway Department prior to its actual use in connection with this contract, including but not limited to the number of vehicles subject to this certification and the number of vehicles retrofitted by vehicle type.

I acknowledge that this certificate is being furnished as a requirement under this contract, and is subject to applicable, State and Federal Laws, both criminal and civil.

Date _____ Signature _____

4.3. LEVEL III CASE: GREEN ROAD RATING SYSTEM

Case 5: Mercer Corridor Project of Greenroad Rating System

Figure 4-3 Greenroad Rating Certification

Greenroads is a voluntary sustainability rating system for roadway design and construction that is modeled after the LEED system for certifying green and sustainable building projects.[76] Greenroads, in its fourth year of implementation during the time data were collected, was developed through collaboration between the University of Washington and CH2M HILL. A project earns voluntary credit points for meeting the system's 11 project requirements for certification. Once a project is assessed, the project can be classified into one of the four certification levels: Certified, Silver, Gold, or Evergreen. To be certified, a project must have earned a minimum of 32 voluntary credit points in addition to the project requirements. To earn a Silver rating the project must attain between 43 and 53 points; Gold, between 54 and 63. Evergreen indicates a project has received more 64 points. Voluntary credits are awarded in 5 categories: access and equity, environment and water, construction, materials and resources, and pavement technologies. There are also 10 custom credits available for sustainable practices that do not fit within the established categories. Credits are weighted so that they are awarded based on a project's lifetime sustainability impact. An activity that contributes to sustainability over several years carries more weight than an activity that has a one-time benefit.

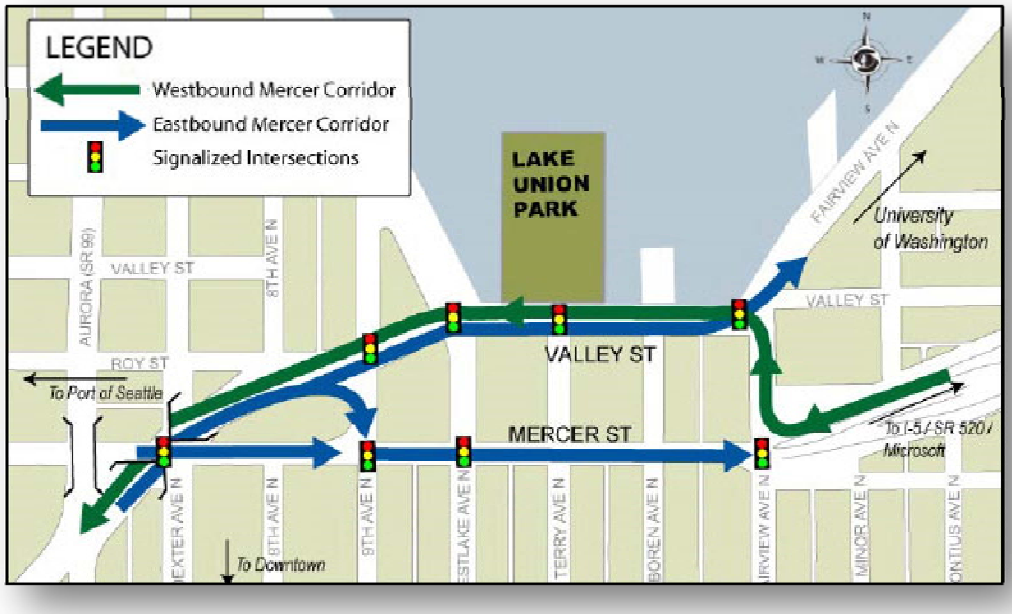
The Mercer Corridor Project was, at the time of data collection, undergoing the process of earning Greenroads certification. The Mercer Street corridor stretches from I-5 to Elliot Avenue in Seattle and affects more than 80,000 people moving through this area.[77] The project causes heavy traffic congestion on Aurora Avenue as well as I-5.

Figure 4-4 The Mercer Corridor Project

According to the Greenroads website, "the [Mercer Street] project is intended to reconstruct pavements, replace infrastructure and utilities, increase mobility and transportation with improved modal access, improve congestion and safety, integrate land development, and strengthen economic connections." While the project has yet to meet all 11 requirements for certification, it remains a Greenroads pilot project that is in the process of implementing several sustainable practices supported by the Greenroads rating system. Because this project is

targeted toward encouraging urban development through improved area access, the project had earned the most points in the access and equity category.

The Problem



The Solution

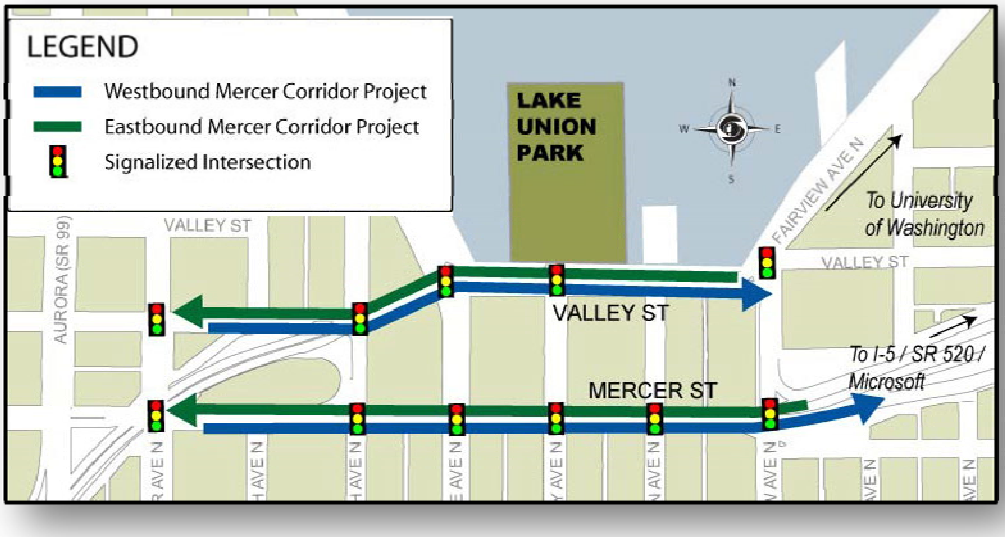


Figure 4-5 The Mercer Corridor Project

Case 6: GreenLITE Program in New York

The New York State Department of Transportation (NYSDOT) implemented its GreenLITES program (Green Leadership In Transportation Environmental Sustainability) in September 2008.[78] GreenLITES is a transportation environmental sustainability self-certification rating program that distinguishes transportation projects and operations based on their holistic approach to the "triple bottom line" of economy, society, and environment that has been adopted by NYSDOT. The program is another model after the US Green Building Council's LEEDs building certification system as well as the University of Washington's Greenroads program. The GreenLITES Project Design Certification program was implemented in 2008 and followed in 2009 by GreenLITES Maintenance/Operations Plan Spreadsheet, in 2010 by the Regional Pilot Sustainability Assessment Program, and the GreenLITES Planning program.

Figure 4-6 GreenLITES Rating Certification

Like the Greenroads program, the GreenLITES Project Design Certification program has four certification levels.[79] The levels are Certified, Silver, Gold and Evergreen. Certified is the basic level of certification and indicates that a project has 15-29 points and has incorporated a number of sustainable practices while the Silver certification indicates that the project has 30-44 points and several of these sustainable practices have a high level of impact or change the state of practice. The Gold certification indicates that many of the sustainable practices have a high level of impact or change the state of practice, earning the project 45-60 points. To achieve the Evergreen certification the project has earned above 60 points and the design must have the highest number of sustainable practices with an extremely high level of impact. The projects are evaluated in five areas: sustainable sites, water quality, materials and resources, energy and atmosphere and innovation/unlisted. Projects are assessed using a scorecard that subdivides each of these categories that consist of several sustainable practices. A project can earn one or two points depending on the existence of a sustainable practice and the extent to which the practice was implemented. In the materials and resources category, for example, there is a recycled content subcategory that lists nine sustainable practices for which a project could earn up to two points each. A distinct advantage of the Greenroads program is that projects that earn an Evergreen rating usually significantly advance the state of practice or approach environmental sustainability in a particularly innovative manner.

The NYSDOT also has two other self-certification programs, the Operations Certification Program and the Local Projects Certification Program. The OCP encourages sustainability through "careful roadside work practices and enhancements." The LPC program allows local, non-NYSDOT, project sponsors to rate their federally funded projects according to GreenLITES criteria. As the majority of NYSDOT's responsibilities pertain to the maintenance of the transportation system, this program is an internal management tool that distinguishes transportation maintenance residencies, regional bridge maintenance groups, main office and

regional operations program areas based on the extent to which projects incorporate sustainable operations practices. This program is implemented as a part of NYSDOT's established Maintenance and Operations Plan (MOP). Sustainable operations activities are listed in MOP and points are awarded upon completion. Each department can estimate an expected GreenLITES score in the beginning of a fiscal year and then report actual progress made at the end of the year. Points awarded are evaluated by quality assurance to ensure proper rating.

4.4. LEVEL IV CASE: HIGHWAY-RELATED SOLAR ENERGY

Case 7: Solar Highway Pilot Project in Oregon

Figure 4-7 Oregon Solar Highway Pilot Project

In 2007, the Oregon legislature enacted Senate Bill 838 established a Renewable Portfolio Standard. The standard requires Oregon to supply 25% of its electricity needs from renewable sources by 2025. In light of this mandate, Allison Hamilton, a Project Director at the Oregon Department of Transportation's (ODOT) Office of Innovative Partnerships, conceived the concept for Oregon's Solar Highway. She was inspired by Germany's use of highway margins for renewable energy generation and sought to offset ODOT's electricity consumption while adding value to existing public assets. Construction began in August 2009 and was completed by December of that year. The solar highway is located outside Tualatin, Oregon. The solar panels power the interchange between I-5 and I-205, which is on a commonly traveled route into Portland. The 104-kilowatt solar photovoltaic system consists of 594 solar panels and covers about 8,000 square feet. The array produces about 112,000 kilowatt hours a year, or 28% of the 400,000 kilowatt hours used to light the interchange. The generated solar power is handled through a net metering arrangement in which the solar panels produce electricity during the day, supplying power onto the PGE grid, and PGE subsequently returns an equivalent amount of power at night to light the interchange.[80]

The implementation of this $1.3 million project required the use of several innovative financing strategies. While this project embodies the essence of projects eligible for sustainable energy tax credits, its proprietor, the Oregon DOT, is tax exempt. It was therefore necessary for ODOT to form a public-private partnership to be able to capitalize on these tax incentives to fund

the project. The ODOT worked with SolarWay, a consortium comprised of Advanced Energy Systems, PGE, US Bank, Aadland Evans, Moyano Group, Good Company, Energy Trust of Oregon, Oregon Department of Energy, SolarWorld, PV Powered, and United Fund Advisors.[81] The ODOT was able to capitalize on both federal and state renewable energy incentives. Expanded by the American Recovery and Reinvestment Act of 2009, the Business Energy Investment Tax Credit (ITC) provided a corporate tax credit of 30% for solar and small wind installations for the commercial, industrial, utility, agricultural sectors. In addition to this Oregon had its own Business Energy Tax credit that was expanded to cover up to 50% of certified renewable energy project costs.[82]

4.5. LEVEL IV CASE: HIGHWAY-RELATED WIND TURBINE

Case 8: Wind Turbine Pilot Project, Westminster, MD

Figure 4-8 Maryland Westminster Wind Turbine

Maryland Governor Martin O'Malley introduced the Maryland: Smart, Green and Growing initiative in 2008.[83] This initiative grew out of his support of the EmPOWER Maryland Act aimed to reduce energy consumption by 15% by 2015 and to increase Maryland's renewable portfolio standard to require that utilities purchase 20% of their power from clean energy sources by 2022. Furthermore in July 2009, the Maryland State Highway Administration (SHA) launched a pilot project to install a residential sized wind turbine at the Westminster Maintenance Facility to provide a sustainable offset to the facility's energy consumption.[84] The facility is near MD 97 in a lightly populated area of Westminster in northern central Maryland. The complete installation cost $25,000, the majority of which was provided by SHA. In addition to internal funding, the Maryland Energy Administration contributed $6,000 through the Windswept Grant Program that encourages the deployment of small-scale wind turbines.

The wind turbine is a residential sized horizontal-axis turbine situated on state-owned land and is connected directly to the facility's power grid to offset power consumption. The rated capacity of the turbine is 2.4kW and can produce 400kWh per month at average wind speed of 12 mph. The SHA's ability to determine the energy savings associated with the turbine has been limited due to a lump sum billing system for the entire 7th Engineering District including its district office in Frederick and other maintenance facilities including the Westminster facility.

Case 9: Blandford Service Area in Massachusetts

On April 28, 2009, the Massachusetts Turnpike Authority issued a Request for Proposals (RFP) for the installation of a utility sized wind turbine in the Blandford Rest Area. Prior to that, extensive feasibility studies were performed by the Massachusetts Renewable Energy Research Lab (RERL). They accumulated wind resource data in the Blandford area from 2006 through 2009. These studies indicated the Blandord section of Massachusetts experienced a mean wind speed of approximately 13.5 mph with west being the prevailing direction of the wind. As the studies indicated there were sufficient wind resources and few obstructions in this area, so the Blandford Rest Area was deemed an appropriate location for wind turbines as part of a new "Greening the Turnpike" initiative.

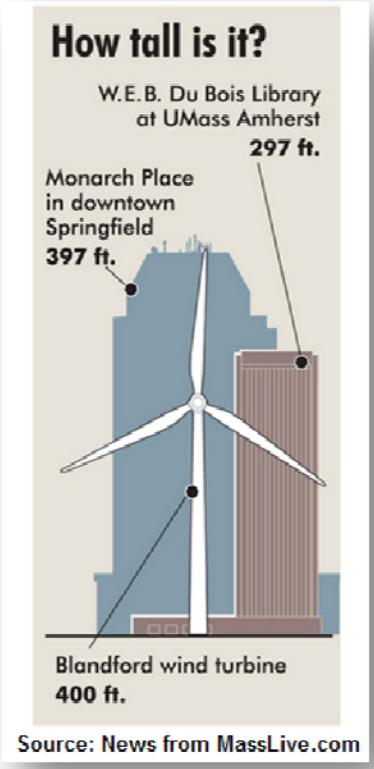


Figure 4-9 Blandford Wind Turbine

It was announced in 2010 that Solaya Renewable Energy will install a 1.65 MW turbine at the Blandford Rest Area located along the Massachusetts Turnpike (I-90) in Hampden County. This utility grade turbine will be nearly 400 feet tall; a kiosk at the rest area will accompany the turbine to provide motorists information about the turbine and its operation. The project has received a $40,000 grant from the Massachusetts Clean Energy Center (MassCEC) under the Massachusetts Commonwealth Wind Community Scale Wind Initiative. The turbine will be able to provide up to 3,000 MW hours of electricity annually, so the electricity generated will be sold to a retail electricity provider. The Massachusets DOT rents the land to Solaya for 3.5% of Solaya's annual power sales. Rent is expected to be approximately $16,600 in the first full year of operations and was expected to increase over time through long-term power purchase agreements. The Commonwealth of Massachusetts is guaranteed an annual rent of $15,000 per year for a term of 20 years.) Initial plans indicate that Solaya plans to form a Special Purpose Entity, called Blandford Wind LLC, to manage the project's finances.

5 EVALUATION OF GREEN PERFORMANCE CONTRACTING STRATEGIES

5.1. INTRODUCTION

Based on the preceding review of existing models for green and sustainable performance contracting, it is clear that although the specifics of some standards converge, there still is no widely agreed-upon standard. A decision model, then, is needed to assist highway agencies in selecting the appropriate green performance contracting (GPC) strategy or portfolio of strategies. First, the GPC strategies identified in the previous chapters address diverse emission sources, impose distinct contract requirements, result in unequal implementation costs, and yield varied environmental benefits. It is obvious that some strategies are complementary to others, while others are competitive or mutually exclusive. Second, a state highway agency has to operate within the constraints of its existing capacity including authority, cost, and staffing. Furthermore, other factors, such as organizational complexity and industrial acceptance, also play an important role in the successful implementation of GPC strategies in highway construction projects. Given limited resources and budgetary constraints, the agency should determine an optimal strategy portfolio that offers the maximum benefit at the lowest cost and risk.

When considering the features and characteristics of a problem, the decision-making model must be well designed to satisfy internal organizational requirements, integrate both qualitative and quantitative data, and remain flexible to new advances. After all, highway agencies show vastly different levels of experience on innovations and emission management. In this report, a Data Envelopment Analysis (DEA)-based decision-making model was developed to evaluate the efficiency of GPC strategies in terms of yielding the maximum benefits at the lowest costs (tangible and intangible). The model follows a four-stage process to calculate the relative efficiency of a specific GPC strategy compared to other strategies (Figure 5-1).

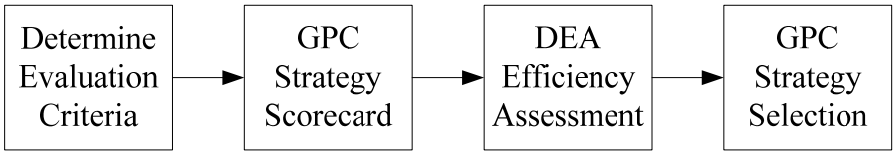


Figure 5-1 DEA Efficiency Evaluation Process

5.2. EVALUATION CRITERIA

Seven evaluation criteria were identified and defined in the decision-making model, namely, emission reduction potential, financial consideration, technological maturity, organizational readiness, industrial and public acceptance, risk, and impact on project performance. These criteria are discussed below and an assessment is made thereafter.

1) Emission Reduction Potential

An agency needs to evaluate the potential of GPC strategies to reduce GHG emissions both in the short and long terms. Some strategies can be adopted immediately without considerable investments or major process change, but their potential to contribute to the reduction target is limited. The potential of clean energy development and other strategies seems promising, but the high cost and requirement for major process changes make them hard to be easily implemented. Issues should be considered in this category include the following:

- Emission reduction target
- Existing emission inventory
- Emission type, source, and volume addressed by GPC strategies
- Long term emission reduction due to GPC strategies
- Emission reduction estimation method and accuracy, and
- Application condition

2) Financial Consideration

Cost of implementation is one of the driving factors behind the desire to select appropriate GPC strategies in highway project construction. The financial consideration encompasses all direct and indirect costs associated with the implementation of a GPC strategy, as well as the availability and accessibility of external financial resources. Implementation costs cover activities as varied as the acquisition and installation of engine retrofit devices to the entire project. One should note that the implementation costs are calculated from a project life-cycle perspective. If a GPC strategy incurs additional costs during project operation and maintenance, those incremental costs should also be considered. It is also important to note there are numerous federal and state programs to encourage the use of green technologies and clean energy. Some GPC strategies may also create valuable emission credits that are tradable in the market. These government and market incentives are important determinants influencing the adopting large scale and costly green strategies, as they can dramatically reduce the total implementation cost. Issues that should be assessed include:

- Implementation costs, e.g.: new materials and equipment, labor and other resources, development and evaluation, additional administrative and overhead costs, transaction fees, relevant consulting and legal services, and changes in organization and management systems
- Other incremental costs over the project life cycle and associated with GPC strategies
- Benefits associated with the implementation, e.g.: savings in labor and materials, less energy consumption, or less transaction fees.
- External Financial Resources, e.g.: Federal and state grants, low interest credit assistance, tax incentives, renewable energy credit, or carbon reduction credits.
- Other cost items

3) Technological Maturity

Technological Maturity refers to the theoretical, technical, and practical issues of the strategies during implementation. Technological maturity is a method of evaluating whether a GPC strategy and its underlying technology are functional and ready for immediate implementation by a highway agency. Some technologies are mature and ready for commercial use, while others are under development or in pilot phase and hence require a relatively long duration for implementation. Because climate change-related technologies continue to evolve, it is critical to continually updating the analysis of technological maturity with new data and applications. Issues covered in this category include:

- Underlying technologies
- Technology effectiveness and efficiency
- Acceptance and popularity
- Availability of commercial products
- Best practices
- Learning curve
- Concerns and risks

4) Organizational Readiness

The implementation of GPC strategies typically requires changes in organizational structure, innovation in business processes and operations, and evolution of regulations and specifications. For example, an agency may need to establish a specific task team, launch new initiative or program, or redevelop standard construction specifications to implement certain GPC strategies. The more changes thare are needed means the less an agency is ready to immediately implement GPC strategies. Organizational readiness describes how likely it is that an organization can successfully incorporate new GPC strategies into its business operations. To evaluate organizational readiness, one should consider the following items.

- Existing green initiatives and programs
- Organization structure and complexity
- Current contract standards, conditions, and specifications
- Project delivery systems and processes
- Consultancy availability
- Project Management.

5) Industrial and Public Acceptance

The successful implementation of the strategies depends on close collaboration between public agencies and the construction industry. The reactions from local communities may also play an important role in the acceptance of certain GPC strategies because many of the strategies directly influence the quality of life. Therefore, the implementation of these strategies will be strongly dictated by the local communities and special interest groups. Public outreach efforts

regarding sustainable or green practices in transportation projects may also create a positive public image for the organization. The following issues should be considered when evaluating the industrial and public acceptance.

- Market conditions and competitiveness
- Industrial structure and contractor profile
- Opinions from professional associations and private companies
- Public awareness and opinions
- Outreach efforts and public involvement

6) Impact on Project Performance

Adoption of GPC strategies may affect a project's cost, schedule, or overall performance. Some strategies may provide positive outcomes by encouraging energy efficiency, or by using low-cost recycled materials. Other strategies require extensive time and cost for contractors to ensure compliance with regulations and specifications, and, hence, pose a significant potential conflict with other project objectives. An agency should recognize and balance competing project objectives while selecting appropriate GPC strategies for highway construction. Issues to be considered regarding project performance include:

- Project objectives and priority
- Performance evaluation method
- Impact of GPC strategies on project delivery process
- Impact of GPC strategies on project time and cost
- Impact on compliance inspection
- Other aspects of project performance, e.g. safety, environment, etc.

7) Risk and Uncertainty

The implementation of GPC strategies is an agency-wide endeavor with significant risk and uncertainty. The risk stems from various factors that include, but are not limited to, technical failures, institutional resistance, market volatility, and public suspicion. Overstated GHG emission reductions, underestimated implementation cost, and inaccurate assessment of project performance impacts can also pose significant challenges for a highway agency to optimize strategy selection and decision making. The agency should evaluate the reliability and robustness of GPC strategies under uncertain conditions. The evaluation should cover the following issues.

- Technical, organizational, market risks
- Inaccuracy in emission reduction estimation
- Low industrial capacity and competition
- Specification, manual, and guidance related risks
- Policy and regulation change

5.3. EVALUATION METHODOLOGY

The decision model for identifying appropriate GPC strategies was based on the Data Envelopment Analysis (DEA) technique. The DEA technique is a non-parametric linear programming approach that produces a single measure of efficiency for each evaluation unit (called decision making unit or DMU) relative to its peers.[85] In this study, DMUs are the GPC strategies. The DEA decision model enables a highway agency to measure the input-output efficiency of each GPC strategy compared to other strategies in terms of seven evaluation criteria identified in the previous section.

Strategy Scorecard

An analyst or an expert group first collects data and tabulates statistics by strategy and evaluation criteria in a consistent manner. Both numeric and plain-text data should be included in this step. One could use numeric data directly in the DEA analysis or use rating scales that embrace both numeric data and plain-text information regarding GPC strategies. A 5-point Likert scale is a preferred method in this study. Score may range from the most favorable rating (=1) to least favorable rating (=5). Detailed definition of the 5-point Likert scale for each GPC evaluation criterion is described in Table 5-1. Then all assigned ratings should be tabulated in the GPC strategy scorecard in Table 5-2. A complete GPC strategy scorecard template for practical use is provided in Appendix D.

Table 5-1 5-Point Likert Scale

Score	Financial Consideration	Technological Maturity	Organizational Readiness	Industrial and Public Acceptance	Emission Reduction	Impact on Project Performance	Risks
1	Cost Effective/ significant benefits	Practiced by the Agency	Completely Prepared	Completely Acceptable	Great Extent	Highly Positive	Low Risk
2	Little or Negligible Effectiveness	Slightly Different Practice	Mostly	Somewhat Acceptable	Much	Somewhat Positive	Some Risks
3	Slightly Cost Ineffective	Practiced by Others	Somewhat	Neutral	Somewhat	Negligible	Risky
4	Cost Ineffective	Limited Use by Others	Minimally	Somewhat Concerned	Very Little	Somewhat Negative	Very Risky
5	Highly Cost Ineffective	New Technology	Not At All	Serious Problem	Not At All	Highly Negative	High Risk

Table 5-2 GPC Strategy Scorecard

	Input				Output		
Strategy	Financial Consideration	Technical Implementation Readiness	Organizational Readiness	Industrial and Public Acceptance	GHG Reduction Potential	Impact on Project Performance	Risks
L1-01							
L1-02							
L1-03							
…							
L3-03							
L4-01							
L4-02							

Efficiency Assessment

After the scorecard is completed, one can apply the DEA decision model to calculate the efficiency frontier of all GPC strategies. The formation of the optimization model is shown in the Appendix E. The basic idea of the DEA decision model is to find the set of GPC strategies that form a frontier surface that represents all evaluation criteria. This envelopment surface is referred to as the efficiency frontier. The efficiency of each GPC strategy is determined based on a comprehensive analysis of measuring the distance to the efficiency frontier (Figure 5-2)

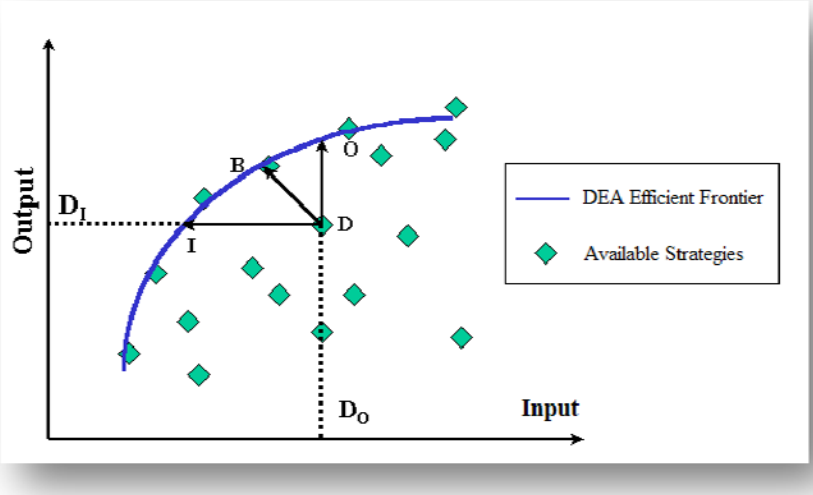


Figure 5-2 DEA Model Demonstration

The DEA decision model can be solved with optimization software packages, e.g. DEAFrontier, Excel Solver, or Matlab. The solution will be a set of efficiency rankings in the form of percentage (*Ei* for GPC strategy *i*). The efficiency ranking measures the efficiency of a certain strategy compared to other strategies with regard to all seven criteria. A score of 100% indicates a GPC perfectly aligns with the highway agency's criteria and is highly efficient. If a GPC strategy is rated below 100%, the strategy is less efficient compared to other strategies.

5.4. STRATEGY SELECTION FOR SHA

The State of Maryland has already developed a climate action plan. This plan calls for dramatical GHG emissions reductions from the transportation sector. Given various strategies at the project level, SHA needs to understand the potential of each strategy in terms of effectiveness and efficiency to achieve the emission reduction target at the lowest cost and risk. The DEA decision model was used in this study to evaluate all GPC strategies for implementation. The evaluation was assumed to be conducted during the project development phase with relevant information collected including

- SHA business plan and organizational structure
- Project development manual, standards, and specifications
- Emission inventory and climate action plan implementation status
- GPC implementation cost
- Federal and state grants for energy efficiency and green transportation
- Engineers' opinions on implementing GPC strategies

The scores were determined by the team's understanding and knowledge about existing practices and SHA operations. A complete score tabulation is summarized in Table 5.3. It should be noted that the DEA decision model can incorporate numeric/ratio data in addition to ordinary Likert scale data used in this case. If such data on GPC strategy implementation cost or estimated GHG emission reduction is available, the analyst could use these numeric cost and emission data directly in the DEA efficiency assessment. The mathematical optimization was conducted to determine the efficiency ranking for GPC strategies. The results are shown in Figure 5-3.

Table 5-3 Strategy Scorecard for SHA

Strategy	Input				Output		
	Financial Consideration	Technical Implementation Readiness	Organizational Readiness	Industrial and Public Acceptance	Emission Reduction Potential	Impact on Project Performance	Risks
L1-01	1	1	2	1	4	2	1
L1-02	2	2	3	1	4	2	2
L1-03	4	2	2	2	3	3	3
L1-04	3	2	3	2	3	3	3
L1-05	4	4	4	4	2	3	4
L2-01	4	1	1	4	2	3	2
L2-02	5	2	1	5	2	3	2
L2-03	2	2	2	2	4	3	2
L2-04	2	1	2	2	3	2	2
L2-05	4	3	2	2	4	3	2
L2-06	3	2	3	2	4	3	1
L2-07	4	5	4	4	2	3	4
L2-08	4	3	4	2	4	4	3
L2-09	1	1	3	2	4	3	3
L3-01	3	4	5	5	3	5	4
L3-02	3	3	3	4	2	4	3
L3-03	5	5	4	4	1	5	5
L4-01	5	4	4	3	1	4	4
L4-02	5	4	5	3	1	4	5

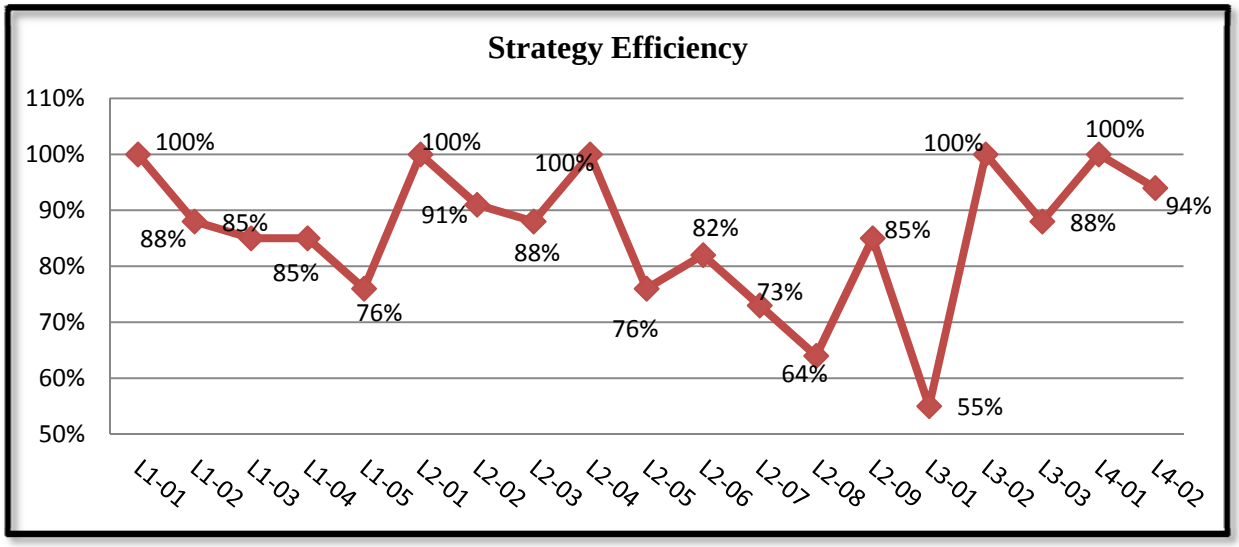


Figure 5-3 GPC Strategy Efficiency

The analysis demonstrated that five GPC strategies provide the maximum emission reduction benefit at the lowest cost and risk. These five strategies are found to be efficient as compared to other strategies. These five optimal GPC strategies are indifferent in terms of implementation efficiency.

L1-01 Reclaimed Asphalt Pavement (RAP)

L2-01 Equipment Retrofitting

L2-04 Alternative Fuels

L3-02 Climate Impact Analyses

L4-01 Highway-related Solar Energy

SHA could select one or more of these GPC strategies to satisfy its budgetary and resource constraints. Without an observable increase in project cost, the SHA can achieve, for example, a considerable reduction on GHG emissions from construction materials by requiring use of RAP in construction. The agency can also cut more emissions from construction operations, primarily from equipment operations, by incorporating retrofitting and alternative fuel requirements in the construction specifications. At the project development and planning phase, the agency can conduct life-cycle climate impact analysis so that low-emission design alternatives are identified, evaluated, and selected. This strategy is especially important because it offers an opportunity to reduce emissions and adapt to climate change at the early phase when life-cycle benefits can be realized. The SHA should explore opportunities to use renewable energy at its facilities. It is also economic and technically possible to deploy solar energy in maintenance facilities and for roadway lighting.

Other GPC strategies can also be included for supplementary benefits. It should be noted that the strategy assessment and selection is a dynamic process and should be adjusted while new information, knowledge, or strategy is available. The agency should also monitor and evaluate the strategy implementation to improve the decision model and strategy assessment process.

6 SUMMARY AND RECOMMENDATIONS

6.1. RESEARCH SUMMARY

With the growing awareness of global climate change and the need for sustainability, state highway agencies are taking essential steps to reduce carbon emissions and life cycle impact of highway infrastructure. While many strategies are known to assist highway agencies to mitigate and adapt to climate change during highway operations, little is known about how climate change issues should be integrated into highway planning, delivery, and construction processes.

This research defined a Green Performance Contracting (GPC) framework with nineteen available green performance contracting strategies that were classified into four levels:

- Level I: Material Related Strategies
- Level II: Equipment and Energy Efficiency Strategies
- Level III: Green Life Cycle Strategies
- Level IV: Clean Energy Development

Definitions and classifications for each strategy level were discussed. A series of GPC cards were included as appendices to assist transportation professionals to better understand, evaluate, and implement these strategies.

A survey of the GPC strategies implemented by various state Departments of Transportation (DOTs) was conducted. According to the results of the survey, State DOTs have varying degrees of experience regarding the use of green performance contracting strategies in highway projects. The findings also indicated it is feasible and promising to integrate green elements into highway construction contracts. The results showed an increasing interest in green performance contracting among transportation agencies and professionals – but results also indicated that more collaborative research and aggressive outreach efforts are required. The biggest challenge facing public agencies is that there is a substantial lack of consistent methodologies and guidelines for implementing green performance contracting. Related to this is the absence of a common terminology to describe and evaluate sustainable strategies.

Seven evaluation criteria were proposed to assist state highway agencies in better assessing the strategies and incorporating green and sustainability principles into their project delivery processes. The criteria were:

- Emission Reduction Potential
- Financial Consideration
- Technological Maturity
- Organizational Readiness
- Industrial and Public Acceptance
- Impact on Project Performance

- Risk and Uncertainty

An optimization model based on the Data Envelopment Analysis (DEA) technique was used to determine the efficiency frontier of all GPC strategies. The efficiency frontier shows a set of GPC strategies that are input-output efficient compared to the rest of GPC strategies in terms of above-mentioned evaluation criteria. Based on an evaluation using a 5-point Likert scale, the most efficient strategies were identified for SHA to determine the optimal GPC strategies. The following strategies were expected to provide greater input-output efficiency at all aspects of seven evaluation criteria.

L1-01 Reclaimed Asphalt Pavement (RAP),

L2-01 Equipment Retrofit Technology,

L2-04 Alternative Fuels,

L3-02 Climate Impact Analyses, and

L4-01 Highway-related Solar Energy.

6.2. RECOMMENDATIONS

To integrate these strategies, transportation agencies are recommended to create agency-wide initiatives to promote green practices at the project level. The successful implementation of sustainable practices requires strong organizational support and collaboration from other areas beyond contracting and construction administration. As shown by the examples of many states, these initiatives can be led by an environmental division (New York), a planning division (California), or a special office (Illinois). In addition, it is critical that the successful implementation of green performance contracting strategies requires a widespread industry support for results-oriented strategies over those that are predominantly cost-driven.

An integrated framework for green performance contracting should be originated in the State's goals and modeled after the successful practices of other agencies. Green performance contracting strategies should be integrated into highway development, design, and construction guidelines. The state highway agencies need to work with the construction industry to establish terminology and guidelines for green performance contracting. Common vocabulary must sufficiently describe and evaluate existing green strategies as well as expand additional innovations in sustainable practices. Similarly, guidelines for implementing and assessing green performance contracting should be based on the most current best practices in green and sustainable strategies.

Subsequently, standardized and quantitative methods for evaluating the extent to which a sustainable practice has been successfully implemented should be developed based on the current state of practice and any federal or expert guidelines that may be available. Target emissions reduction rates, energy and resource savings or other quantifiable criteria should be established to encourage early adoption and to evaluate effectiveness. Climate impact analysis will aid in

this process, as it allows for the life cycle evaluation of sustainable practices. Furthermore, a transportation rating system, similar to the LEEDs building certification program or New York's GreenLITES program, should be created to recognize "green and sustainable" projects for all sustainable practices proposed and implemented. It is critical that regular and consistent evaluations are conducted of sustainable practices to ensure effectiveness.

It is very important for the SHA to establish guidelines for quantifying the emission reductions from innovative green contracting practices. Existing green rating systems are primarily qualitative and cannot provide quantitative climate impact analysis for design alternatives and delivery method selection. The development of quantification methods and toolkit for emission reductions will promote green practices at the project level, especially from the early stage of project development when design changes and decisions are of major importance to environmental and climate impact.

There are several sustainable technologies that are immediately applicable to the agency. The use of alternative fuels, engine retrofit technologies, and renewable energy will greatly reduce GHG emissions. In addition, the integration of renewable energy sources, particularly solar energy on highway right-of-way, will significantly reduce reliance on energy from fossil fuels and represent a potential cost savings. Furthermore, a widespread use of reclaimed asphalt in highway construction and maintenance will conserve resources. These technologies all provide significant sustainable benefit, as shown by Maryland SHA and other state agencies. It is therefore important that the SHA continues to pursue the integration of sustainable practices into transportation construction and operations by establishing green performance contracting guidelines and continuing sustainability research and development.

REFERENCES

[1] Board on Atmospheric Sciences and Climate. (2008). "Earth Observations from Space." National Academy of Sciences, 27. <http://www.nap.edu/openbook.php?record_id=11991&page=27>.

[2] "Climate Change 2007: Synthesis Report." (2007). Intergovernmental Panel on Climate Change (IPCC). <http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf>.

[3] US Environmental Protection Agency. (2009). Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2007. April 15, 2009, Washington DC

[4] "Inventory of US Greenhouse Gas Emissions and Sinks, 1990-2008." (April 2010). U.S. Environmental Protection Agency. <http://www.epa.gov/climatechange/emissions/downloads10/US-GHG-Inventory-2010_Report.pdf>.

[5] "Comparison of Transportation Provisions in House and Senate Climate Change Legislation." Rev. of *House Climate Bill HR 2454 and Senate Climate Bill S 1733*. 16 Oct. 2009. Print.

[6] Maryland. Maryland Commission on Climate Change. Greenhouse Gas and Carbon Mitigation Working Group. *Comprehensive Greenhouse Gas and Carbon Footprint Reduction Strategy*. 2008. Print.

[7] "Greenhouse Gas Emissions from the US Transportation Sector, 1990-2003." (March 2006). U.S. Environmental Protection Agency. Office of Transportation and Air Quality. <http://www.epa.gov/otaq/climate/420r06003.pdf>.

[8] Truitt, P. (2009). Potential of Reducing Greenhouse Gas Emissions in the Construction Sector. US Environmental Protection Agency, February 2009, Washington DC

[9] Horvath, A. (2004). "Construction Materials and the Environment". Annu. Rev. Environ. Resour. 29: 181-204

[10] Hanle, L.J., Jayaraman, K., and Smith, J.S. (2004). CO_2 Emissions profile of the US Cement Industry, 13th International Emission Inventory Conference, Clearwater, FL, June 8 - 10, 2004 < http://www.epa.gov/ttnchie1/conference/ei13/>

[11] Handrickson, C. and Horvath, A. (2000). "Resource Use and Environmental Emissions from US Construction Sectors". Journal of Construction Engineering and Management. ASCE, 126(1), pp-38-44

[12] Carnegie Mellon University Green Design Institute. (2009) Economic Input-Output Life Cycle Assessment (EIO-LCA) US 1997 (491) model [Internet], Available from: <http://www.eiolca.net/> [Accessed 22 Oct, 2009]

[13] Energy Information Administration (2008). Emissions of Greenhouse Gases Report, Report # DOE/EIA-0573, Department of Energy, Washington DC http://www.eia.doe.gov/oiaf/1605/ggrpt/carbon.html

[14] Energy Information Administration (2006). Energy-Related Carbon Dioxide Emissions in US Manufacturing, Report # DOE/EIA-0573, Department of Energy, Washington DC <http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/industry_mecs.pdf>

[15] D&R International, (2008). 2008 Buildings Energy Data Book, Department of Energy, Washington, DC

[16] "Climate Action Plan Executive Summary." (August 2008). Maryland Commission on Climate Change. <http://www.mde.state.md.us/programs/Air/ClimateChange/Documents/www.mde.state.md.us/assets/document/Air/ClimateChange/Executive_Summary.pdf>.

[17] Molenaar, K., Sobin, N., Gransberg, D., McCuen, T., Korkmaz, S., and Horman, M. (2009). Sustainable, High Performance Projects and Project Delivery Methods: A State-of-Practice Report. Charles Pankow Foundation.

[18] Klotz, L., Horman, M., and Bodenschatz. M. (2007). "A Lean Modeling Protocol for Evaluating Green Project Delivery". Lean Construction Journal, 3(1). April 2007

[19] Sharrard A. L., Matthews H. S., and Roth, M. (2008) "Environmental Implications of Construction Site Energy Use and Electricity Generation" ASCE, Journal of Construction Engineering and Management, 133(11). pp846-854

[20] "OSWER Life Cycle Management Guidance." (2008). U.S. Environmental Protection Agency. <http://www.epa.gov/oswer/oswerlcm.htm>.

[21] EPA-Diesel, R. (2000). Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements. United States Environmental Protection Agency, Air and Radiation EPA420-R-00-026

[22] "Verified Technologies List." (February 2011). National Clean Diesel Campaign (NCDC). U.S. Environmental Protection Agency. <http://www.epa.gov/dieselretrofit/verif-list.htm>.

[23] "Cleaner Diesels: Low Cost Ways to Reduce Emissions from Construction Equipment." (March 2007). U.S. Environmental Protection Agency. <http://www.epa.gov/cleandiesel/documents/100r07002.pdf >.

[24] "The Greenroads Rating System." (2007-2011). Greenroads. <http://www.greenroads.us/1/home.html>.

[25] "Greenroads Project Checklist." Greenroads. <www.greenroads.us/files/162.xlsx>.

[26] Ailworth, E. "Wind Turbine Set for Turnpike." (April 28, 2009). *The Boston Globe.* <http://www.boston.com/business/technology/articles/2009/04/28/wind_turbine_set_for_turnpike/>.

[27] "User Guidelines for Byproduct and Secondary Use Materials in Pavement Construction." (2008). U.S. Department of Transportation Federal Highway Administration (FHWA). <http://www.fhwa.dot.gov/pavement/pub_details.cfm?id=384>.

[28] ICF Consulting. (May 2005). "Emission Reduction Incentives for Off-Road Diesel Equipment Used in the Port and Construction Sectors." U.S. Environmental Protection Agency. <http://westcoastcollaborative.org/files/sector-marine/ICF%20Emission%20Reduction%20Incentives.pdf>.

[29] Maze, T, Burchett, G and Hochstein, J. (2005). "Synthesis of Procedures to Forecast and Monitor Work Zone Safety and Mobility Impacts." The Center for Transportation Research and Education. Iowa State University. <http://www.intrans.iastate.edu/reports/work_zone_mobility.pdf>.

[30] "TxDOT Equipment Spec 5018." (2004). Texas Department of Transportation. <http://www.epa.gov/cleandiesel/documents/cl-txdot-equip-5018.pdf>.

[31] "Legislation and Advocacy, State Legislation." (2011). Design-Build Institute of America (DBIA). <http://www.dbia.org/advocacy/state/>.

[32] "Executive Order No. 24 (2009): Establishing a Goal to Reduce Greenhouse Gas Emissions Eighty Percent by the Year 2050 and Preparing a Climate Action Plan." (2009). New York State Department of Environmental Conservation. <http://www.dec.ny.gov/energy/71394.html>.

[33] "New York State Diesel Emission Reduction Act 2006." (June 2006). New York State. <http://www.cleanaircarolina.org/wp-content/uploads/2010/06/State-of-New-York-Diesel-Emission-Reduction-Act-2006.pdf>.

[34] "2013 New York State Energy Plan." New York State. <http://www.nysenergyplan.com/>.

[35] "Final Supplemental Environmental Impact Statement (FSEIS) Route 9A Project." (2005). Federal Highway Administration (FHWA). <https://www.nysdot.gov/portal/page/portal/regional-offices/region11/projects/project-repository/files/fseis/14_energy.pdf>.

[36] "Oregon Strategy for Greenhouse Gas Reductions." (December 2004). Governor's Advisory Group on Global Warming. <http://www.oregon.gov/ENERGY/GBLWRM/docs/GWReport-FInal.pdf?ga=t>.

[37] "Oregon Business Energy Tax Credit." (March 2008). Oregon Department of Energy. <http://www.oregon.gov/ENERGY/CONS/BUS/docs/betcbro.pdf?ga=t>.

[38] "The Oregon Department of Transportation Sustainability Plan, Volume 1: Setting the Context." (September 2008). Oregon Department of Transportation (ODOT). <http://www.oregon.gov/ODOT/SUS/docs/Sustain_Plan_Volume1.pdf>.

[39] "Bicycle & Pedestrian Program." Oregon Department of Transportation (ODOT). <http://www.oregon.gov/ODOT/HWY/BIKEPED/>.

[40] "Innovative Partnerships Program." (March 2010). ODOT Office of Innovative Partnerships and Alternative Funding. <http://www.oregon.gov/ODOT/HWY/OIPP/inn_solarhighway.shtml>.

[41] "Innovative Partnerships Program." (2011). Oregon Department of Transportation. <http://www.oregon.gov/ODOT/HWY/OIPP/inn_ev-charging.shtml>.

[42] "Truck Road Use Electronics Pilot Project (TRUE)." (2011). ODOT Office of Innovative Partnerships and Alternative Funding. <http://www.oregon.gov/ODOT/HWY/OIPP/TRUE.shtml>.

[43] "California Executive Order S-3-05." (June 2005). State of California. <http://gov.ca.gov/executive-order/1861/>.

[44] "Assembly Bill 32: Global Warming Solutions Act." (2006). California Air Resources Board (CARB). <http://www.arb.ca.gov/cc/ab32/ab32.htm>.

[45] California. California Environmental Protection Agency. Air Resources Board. *Climate Change Scoping Plan*. 2008. Print.

[46] "Assembly Bill No. 1007: Chapter 371." (September 2005). State of California. <http://www.arb.ca.gov/fuels/lcfs/ab1007.pdf>.

[47] "State Alternative Fuels Plan." (December 2007). CARB and California Energy Commission. <http://www.energy.ca.gov/2007publications/CEC-600-2007-011/CEC-600-2007-011-CMF.PDF>.

[48] "Final Regulation Order." California Air Resources Board. California Code of Regulations (CCR). <http://www.arb.ca.gov/regact/2009/lcfs09/lcfscombofinal.pdf>.

[49] "CEQA & Climate Change." (January 2008). California Air Pollution Control Officers Association. <http://www.capcoa.org/wp-content/uploads/downloads/2010/05/CAPCOA-White-Paper.pdf>.

[50] "Regulation for the Mandatory Reporting of Greenhouse Gas Emissions." California Air Resources Board. California Code of Regulations (CCR). <http://www.arb.ca.gov/regact/2007/ghg2007/frofinoal.pdf>.

[51] "2009 California Climate Adaptation Strategy." (2009). California Natural Resources Agency. <http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF>.

[52] "Global Warming Solutions Act of 2007: Senate No. 534." (2007). State of Massachusetts. < http://www.mass.gov/legis/bills/senate/185/st00pdf/st00534.pdf>.

[53] "MEPA Greenhouse Gas Emissions Policy and Protocol." (2008). Executive Office of Energy and Environmental Affairs (EEA)." <http://www.env.state.ma.us/mepa/downloads/RevisedGHGPolicy.pdf>.

[54] "Low Emission Vehicle Program." State of Massachusetts. <http://www.mass.gov/dep/air/laws/levregs.pdf>.

[55] "Environmental Results Program Certification." Massachusetts Department of Environmental Protection (MassDEP). <http://www.mass.gov/dep/service/regulations/310cmr70.pdf>.

[56] "Sustainable Development Principles." State of Massachusetts. <http://www.mass.gov/Agov3/docs/smart_growth/patrick-principles.pdf>.

[57] "The Patrick Administration's Smart Growth/Smart Energy Program." The Patrick Administration of Massachusetts. <http://www.mass.gov/envir/smart_growth_toolkit/pages/state-policy.html>.

[58] "Reducing Air Emissions from Diesel Construction Engines." Massachusetts Department of Environmental Protection (MassDEP). <http://www.mass.gov/dep/water/wastewater/diesel.htm>.

[59] "GreenDOT Policy Directive." (June 2010). MassDOT. <http://www.massdot.state.ma.us/main/Documents/HealthyTransportationCompact/P-10-002.pdf>.

[60] Gregoire, C. (February 2007). "Executive Order 07-02: Washington Climate Change Challenge." <http://www.governor.wa.gov/execorders/eo_07-02.pdf>.

[61] "Implementing Practical Solutions to the Climate Change Challenge." (November 2008). 2008 Washington Climate Action Team.

<http://www.ecy.wa.gov/climatechange/2008CATdocs/ltw_app_v2.pdf>.

[62] "Washington State Energy Code 2006 Edition: Chapter 51-11 WAC." (2006). Washington State Building Code Council. <http://ftp.resource.org/codes.gov/wa_energy.pdf>.

[63] "Washington State Department of Transportation Guidance for Project-Level Greenhouse Gas and Climate Change Evaluations." (October 2010). WSDOT. <http://www.wsdot.wa.gov/NR/rdonlyres/73ADB679-BDA6-4947-93CA-87C157862DD7/0/WSDOTprojectLevelGHG.pdf>.

[64] "Greenhouse Gas Emissions and SEPA." Washington State Department of Ecology. <http://www.ecy.wa.gov/climatechange/sepa.htm>.

[65] "Transforming I-5 with Cleaner and Smarter Transportation." (2010). *West Coast Green Highway*. WSDOT. <http://www.westcoastgreenhighway.com/>.

[66] "Substitute Senate Bill 6373: Chapter 146, Laws of 2010." (2010). State of Washington. <http://apps.leg.wa.gov/documents/billdocs/2009-10/Pdf/Bills/Session%20Law%202010/6373-S.SL.pdf>.

[67] "The San Francisco-Oakland Bay Bridge Seismic Safety Projects." (2011). Bay Bridge Public Information Office. <http://baybridgeinfo.org/>.

[68] "Using Recycled Industrial Materials in Roadways." (July 2009). U.S. Environmental Protection Agency. <http://www.epa.gov/osw/conserve/rrr/imr/pdfs/roadways.pdf>.

[69] "Beneficial Use of Industrial Byproducts." (2007). Wisconsin Department of Natural Resources. < http://www.dnr.state.wi.us/org/aw/wm/solid/beneficial/>.

[70] "Wisconsin Administrative Code, Chapter NR 538: Beneficial Use of Industrial Byproducts." (February 2010). Wisconsin Department of Natural Resources. <http://legis.wisconsin.gov/rsb/code/nr/nr538.pdf>.

[71] "Wastes – Resource Conservation Challenge." (November 2010). U.S. Environmental Protection Agency. < http://www.epa.gov/epawaste/rcc/index.htm>.

[72] "Project-level Conformity Determination for the Intercounty Connector Project in Maryland." (2006). MDOT, SHA, MdTA, USDOT, FHWA. <http://www.iccproject.com/PDFs/PM25Report.pdf>.

[73] "FEIS Air Quality Technical Report." (2006). FHWA, Maryland SHA, MdTA. <http://pdf.iccstudy.org/FEIS/pdf.php>.

[74] "Standard Special Provisions." (February 2011). MassDOT. <http://www.mhd.state.ma.us/downloads/manuals/stdspc.pdf>.

[75] "MHD Certification of Construction Equipment Compliance." Massachusetts Department of Environment Protection (MDEP). <http://www.epa.gov/diesel/construction/documents/cl-mhd-compliance.pdf>.

[76] "The Greenroads Rating System." Greenroads. <http://www.greenroads.us/>.

[77] "Greenroads Pilot Project: Mercer Corridor East – Phase I." Greenroads. <http://www.greenroads.us/141/21/pilot-project.html>.

[78] "GreenLITES." (2011). NYSDOT. <https://www.nysdot.gov/programs/greenlites>.

[79] "GreenLITES Project Design Certification Program." (2008-2010). NYSDOT. <https://www.nysdot.gov/programs/greenlites/repository/Green%20LITES%20Certification%20Program%20Document%20-%20April%202010.pdf>.

[80] "First U.S. Solar Highway Installation Starts in Oregon." (August 2009). Environment News Service. <http://www.ens-newswire.com/ens/aug2008/2008-08-09-091.html>.

[81] "Oregon Department of Transportation 104 KW Demonstration Project." Advanced Energy Systems. <http://www.aesrenew.com/odot104kw.html>.

[82] "Database of State Incentives for Renewables & Efficiency." (2009-2011). North Carolina State University. <http://www.dsireusa.org/>.

[83] "Smart, Green & Growing." State of Maryland. <http://www.green.maryland.gov/>.

[84] "Board Votes to Allow Small Wind Turbines." (May 2008). Carroll County Government. <http://ccgovernment.carr.org/ccg/releases/windmills.pdf>.

[85] Cook, W. D., & Zhu, J. (2006). *Rank order data in DEA: A general framework.* European Journal of Operational Research, 174(2), 1021-1038.

APPENDIX A: SURVEY QUESTIONNAIRE

Respondent: _____ ***Designation:*** _____
Address: _____
Telephone: _____ ***Fax:*** _____ ***Email:*** _____
(Please note that your name will not be used in the final report)

1. Has your agency incorporated **any** green contracting provisions in highway (or capital) projects?
   ☐ Yes ☐ No (If you answered no, go to question 11.)

2. Please select all green contracting provisions that have been incorporated in your highway (capital) projects.

- ☐ Construction equipment retrofit program
- ☐ Engine replacement and upgrade
- ☐ Idling reduction program
- ☐ Use of recycled materials
- ☐ Alternative fuels
- ☐ Energy efficiency program
- ☐ Truck staging zone
- ☐ Green road rating system
- ☐ Climate impact analyses from contractors (e.g. emission estimation, carbon profiling)
- ☐ Climate adaptation strategies (e.g. climate adaptation planning, design and engineering standards)
- ☐ Others: Please specify _____

3. How has your agency incorporated these green contracting strategies into your projects?

- ☐ Contract requirements
- ☐ Bidding preference to green contractors
- ☐ Contract incentives or grants
- ☐ Green prequalification
- ☐ Other: Please specify _____

4. What is the primary reason for your agency to implement these strategies?

- ☐ Legislative requirements
- ☐ Regulatory requirements
- ☐ Green Initiatives
- ☐ Public Image
- ☐ Other: Please specify _____

5. At what stage and by what method does your agency evaluate a project's impact on climate change? (Please provide a copy of the evaluation guidelines/methodology if available)

6. What type of emissions do these contract provisions address? (Please select all that apply)

- ☐ Carbon dioxide (CO2)
- ☐ Other green house gasses
  Methane (CH_4), Nitrous oxide (N_2O), Hydro-fluorocarbons (HFCs), Per-fluorocarbons (PFCs), and Sulfur hexafluoride (SF_6)

- ☐ Other pollutants (e.g. particulate matter (PM))
- ☐ None

7. What types of emission sources do these contract provisions address? (Please select all that apply)
   - ☐ Off-road diesel equipment
   - ☐ Construction site electric utility
   - ☐ Material production and transportation
   - ☐ Construction worker commute trip
   - ☐ Road congestion due to construction job
   - ☐ Infrastructure (facility) operation after construction
   - ☐ Others, Please specify _____

8. How is contractor compliance verified when implementing new green contracting provisions? And what is the consequence of non-compliance with these provisions?

9. What size highway (capital) projects incorporate green contracting provisions in your agency? (Please select all that apply)
   - ☐ Small (less than $40M)
   - ☐ Medium (between $40M and $100M)
   - ☐ Large (greater than $100M)

10. What type of project delivery method(s) have been used on those projects with green contracting provisions?
   - ☐ Design-bid-build
   - ☐ Design-Build
   - ☐ Other innovative methods (Please specify.) _____

11. What are some existing or ongoing efforts in your agency or state (city) to address climate change issues at the project level? (Please select all that apply)
   - ☐ Climate legislation or Executive Order
   - ☐ Local incentives (e.g. tax credit, grants, and credit support)
   - ☐ Green initiatives
   - ☐ Broad research
   - ☐ Others: Please specify _____
   - ☐ None

12. What are the challenges for your agency to implement green contracting provisions in highway (capital) projects?

Additional comments on these issues:

We would appreciate it if you could provide a copy of specific green contracting provisions used by your agency. Thank you for your response.

Are you interested in obtaining a copy of the survey results? ☐ Yes ☐ No

Are you willing to participate in the follow-up interview? ☐ Yes ☐ No

APPENDIX B: INTERVIEW QUESTIONS

1.0. Climate change legislation

1.1. Are there any local legislations or initiatives dealing with climate change in your state?

1.2. Are there any agency wide strategy plans or programs addressing climate change? If yes, please describe the plan.

1.3. Are there any targets or performance requirements for your agency/office to reduce carbon and other emissions? If yes, please describe.

2.0. Contracting for climate change

2.1. Does your agency use any innovative contracting methods to reduce emissions from capital projects?

2.2. What emission sources do you address?

2.3. What method is used to estimate the emission inventory and emissions from a capital project?

2.4. Please describe the requirement and practice of using recycled materials in construction? (what types, allowable percentage, design requirement, etc)

2.5. Does your agency implement diesel engine retrofit program? If yes, please describe the process and requirement.

2.6. What types of alternative fuels does your agency encourage contractors to use during construction? How did contractors get paid for the use of alternative fuels? Was there any incentives?

2.7. How does your organization incorporate green contracting provisions into design-build and design-bid-build projects?

2.8. Does project size create barriers to implement green provisions? If yes, how.

2.9. Does your organization seek green road certification for any projects? If yes, what rate system is used?

2.10. What are challenges and barriers for your organization to implement green contracting?

2.11. What climate adaptation strategies has your organization implemented or will your organization implement soon?

2.12. How do you see the new EPA ruling regarding carbon dioxide to be an endangerment for public health affect capital project delivery in the future?

2.13. Does your organization have any green contractor rating process?

3.0. Performance and Dispute Issues

3.1. What were the cost, time, and quality impacts of green contracting method and provisions?

3.2. Are there any adverse impacts on project performance due to the implementation of green contracting provisions? If yes, please describe in detail.

3.3. How does your organization monitor, track, and verify contractors' compliance?

3.4. How do you evaluate the performance of the method(s) adopted for going green? Are you satisfied with these green strategies?

3.5. How did contractors evaluate green provisions? How was the industry acceptance for green provisions?

3.6. What performance measures were used?

3.7. What is the format of compliance report? How often does your agency require contractors to report compliance?

3.8. What is the procedure for addressing non-compliance? What is the dispute resolution process?

3.9. How do you evaluate the effectiveness of current green provisions in terms of reducing emissions and tackling climate change?

3.10. What areas could be improved and how?

APPENDIX C: GPC CARD

GPC CARD ---- L1-01

NAME

Reclaimed Asphalt Pavement (RAP)

DESCRIPTION

Reclaimed asphalt pavement (RAP) is defined as salvaged, milled, pulverized, broken, or crushed asphalt pavement (AASHTO, 2005).

IMPLEMENTATION

Recycled RAP can be returned back to the roadway structure in some form, usually incorporated into asphalt paving by means of hot or cold recycling. Sometimes it is also used as an aggregate in base or sub-base construction.

TECHNOLOGICAL REQUIREMENTS

RAP is now widely accepted in asphalt paving mixtures in almost all 50 states. Substitution rates in pavement usually vary from 10-50% depending on the wearing surface, binder and base courses according to different state specifications.

GREEN BENEFIT

Benefits of RAP include cost savings, conservation of asphalt and aggregate resources, conservation of energy, preservation of existing highway geometrics, and preservation of the environment.

SAMPLE PROVISIONS

See FHWA's guide book for detailed RAP specifications [1]. Each state has its own specifications for the use of RAP as well[2].

[1] Federal Highway Administration: http://www.fhwa.dot.gov/pavement/recycling/98042/
[2] State Specifications on RAP:
http://www.morerap.us/RAP%20Resources/State%20Practices/RAP_StatesSpecificationreviewfinal.pdf

GPC CARD ---- L1-02

NAME

Other Material Recycling or Reusing

DESCRIPTION

Non-hazardous byproduct materials generated from industrial processes, which were usually wasted and disposed, are now recommended to be reused or recycled as substitutions for raw materials in manufacturing.

IMPLEMENTATION

Recycled or reused materials are usually requested by contractors in order to save money. To control the quality of the material recycled, the owner needs to set a ceiling or a performance standard in the contract specification or follow standards regulated by EPA or FHWA.

TECHNOLOGICAL OPTIONS

- **Recycled Concrete Pavement (RCP)**: RCP is reclaimed Portland cement concrete pavement material that can be used as a new base or filling material.
- **Steel Recycling**: Steel barely loses its properties and strength (95% can be reused), so steel bars in concrete pavements can be melted down and recycled as new steel products.
- **Slag Cement Recycling**: Slag cement, or ground granulated blast furnace slag, is a material that comes from the processing of molten slag from an iron blast furnace and can be used to partially replace Portland cement in concrete.
- **Fly Ash Recycling**: Fly ash is a combustion material remaining in the combustion of coal consumed to generate electricity, and it can be used to replace some Portland cement, replace fine aggregate in asphalt pavements, and used in stabilized base course, flowable fills, and embankments.
- **Crushed Glass or Glass Cullet Recycling**: Crushed glass, or glass cullet, is made of recycled glass products that can be used as a substitution for aggregates in base courses or fills, and has also been used as an aggregate substitute in asphalt pavements.
- **Scrap Tires Recycling**: Scrap tires are a huge source of waste and disposal in the US, so it could become a significant rubber material resource if properly recycled and used in the construction process.
- **Shingles Recycling**: Shingles can be used to modify the asphalt binder, but can also work as an aggregate substitute.
- **Foundry Sand Recycling**: Recycled foundry sand (RFS) or Waste Foundry Sand (WFS) is silica sand that can be used in many roadway construction applications such as embankments, flowable fill, HMA, and PCC, or can be blended with either coarse or fine aggregates and used as a road base or sub-base material.

- **Others**: Other industrial materials can include blast furnace slag, carpet fiber wastes, coal bottom ash or bottom slag, flue gas desulfurization waste, mill tailings, municipal waste combustion ash, etc.

GREEN BENEFIT

Using industrial materials can conserve natural resources, and reduce the energy use and pollution associated with the energy intensive manufacturing processes. It can also save money by reducing waste and decreasing disposal costs for end users.

SAMPLE PROVISIONS

The Wisconsin Department of Natural Resources has conducted a Beneficial Use of Industrial Byproducts Program that encourages the safe and beneficial use of fly ash, bottom ash, paper mill sludge, foundry sand, and slag as alternatives to placing those materials in landfills. See Administrative Code NR538[3]. The EPA and states have certain specifications and provisions for implementing recycled and reused materials[4]. For specific limitation requirements of the materials used in different states, please also refer to FHWA's research summary[5].

PROJECT APPLICATION

In 2002, Caltrans used fly ash and granulated blast furnace slag to reconstruct the east span of the San Francisco Oakland Bay Bridge[6].

[3] Department of Natural Resources: http://legis.wisconsin.gov/rsb/code/nr/nr538.pdf
[4] Environmental Protection Agency: http://www.epa.gov/osw/conserve/rrr/imr/road.htm
[5] Federal Highway Administration: http://www.fhwa.dot.gov/publications/publicroads/94fall/p94au32.cfm
[6] Environmental Protection Agency: http://www.epa.gov/osw/conserve/rrr/imr/pdfs/roadways.pdf

GPC CARD ---- L1-03

NAME
Sustainable Material Treatment

DESCRIPTION
Non-hazardous byproduct materials from industrial processes were usually wasted and disposed of, but are now recommended to be reused or recycled to replace raw materials in manufacturing.

TECHNOLOGICAL OPTIONS
- Warm/Cool pavement
- Concrete Additives
- Others, like Thin/Ultra-Thin White Topping (TWT/UTW), Roller Compacted Concrete Pavement (RCC), light aggregate in asphalt concrete pavements, and asphalt chip sealing

TECHNOLOGICAL REQUIREMENTS

Warm/Cool pavement
Warm-mix asphalt is the generic term for a variety of technologies that allow the producers of hot-mix asphalt pavement material to lower the temperatures at which the material is mixed and placed on the road. Reductions of 50 to 100 degrees Fahrenheit have been documented.

Concrete Additives
Concrete additives can be used to create lighter pavements. The most common additives are slag cement and light fly ash. When substituted for Portland cement in quantities between 25% and 65%, slag cement plays a critical role in reducing the permeability of concrete. This reduces its evaporative cooling.

GREEN BENEFIT

Warm/Cool pavement
Drastic reductions of temperatures in pavement have the benefits of cutting fuel consumption and decreasing the production of greenhouse gases. Potential engineering benefits include reduced emissions from burning fuels, fumes and odors generated at the plant and the paving site, better compaction on the road, and the ability to haul paving mixes for longer distances.

Concrete Additives
Slag cement can be used to replace or used with Portland cement. Slag cement makes concrete lighter, increases reflectivity of the finished surface, and aids with workability and performance. Light fly ash has higher strength, increased workability, durability, reduced shrinkage, and reduces more greenhouse gas emissions and embodied energy than Portland cement concrete.

SAMPLE PROVISIONS
See the New Mexico State Highway and Transportation Department's Standard Specifications for Cold-Mix Pavement in Highway and Bridge Construction.[7]

[7] Federal Highway Administration: http://www.fhwa.dot.gov/pavement/recycling/98042/21.cfm

GPC CARD ---- L1-04

NAME

Material Waste Management

DESCRIPTION

Waste management is the collection, transport, processing, recycling or disposal, and monitoring of waste materials. The term usually relates to man-made materials, and is generally carried out to reduce the wastes' effect on health, the environment, or aesthetics. It is also used to recover resources from the waste.

IMPLEMENTATION

Waste management can involve solid, liquid, gaseous, or radioactive substances, with different methods used for each. Management for non-hazardous waste, residential waste, and institutional waste in metropolitan areas is usually the responsibility of local government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator. Each state and local government has its own requirements for management.

TECHNOLOGICAL OPTIONS

- **RFID tags**

Technologies, like RFID tags, are now being used to collect data on presentation rates for curb-side pick-ups, which is useful when examining the usage of recycling bins or similar items.

- **GPS tracking**

Benefits of GPS tracking are particularly evident when considering the efficiency of ad hoc pick-ups (like skip bins or dumpsters) where the collection is done on a consumer request basis.

- **Integrated software packages**

Integrated software packages are useful in aggregating this data for use in the optimization of operations for waste collection operations.

- **Rear vision cameras**

Rear vision cameras are commonly used for OH&S reasons and video recording devices are becoming more widely used, particularly concerning residential services and contaminations of the waste stream.

TECHNOLOGICAL REQUIREMENTS

Technologies, like RFID tags, are now being used to collect data on presentation rates for curb-side pick-ups, which is useful when examining the usage of recycling bins or similar items.

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Rear vision cameras are commonly used for OH&S reasons and video recording devices are becoming more widely used, particularly concerning residential services and contaminations of the waste stream.

GREEN BENEFIT

The management of waste is a key component in a business' ability to maintain ISO14001 accreditation. Companies are encouraged to improve their environmental efficiencies each year, and one method is by improving a company's waste management with a new recycling service.

PROJECT APPLICATION

See the case of Life Cycle Assessment (LCA) of Municipal Solid Waste Management in the State of Kuwait in UK.[8]

[8] European Journal of Scientific Research: http://www.eurojournals.com/ejsr_34_3_11.pdf

GPC CARD ---- L1-05

NAME

Material Life Cycle Management

DESCRIPTION

Material life-cycle management is a broader perspective of material management, which refers to the whole life cycle of materials as they flow through the process of selection, production, procurement, shipment, recycling/reusing, and disposal. Material life-cycle management generally considers the whole picture of project material use in the cost reducing, performance, and associated environmental impacts. It is a complicated process and is usually conducted with different software and tools.

TECHNOLOGICAL OPTIONS

- Shipment Model: FLEET
- Design Model: PaLATE
- Material Estimation Tool: ReCon
- Material Waste Management Tool: WaRM
- Material Life Cycle Tool: BEES

GREEN BENEFIT

EPA's Freight Logistics Environmental and Energy Tracking (FLEET) Performance Model can help quantify the current fuel use and emissions of shipments, as well as help evaluate the costs and effectiveness of future emission reduction strategies.

The Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE) assists decision-makers in evaluating the use of recycled materials in highway construction and maintenance activities.

EPA's ReCon tool, designed to compare the GHG impacts of material purchasing and manufacturing, offers an option to evaluate the benefits of using common materials with various recycled contents.

EPA's Waste Reduction Model (WaRM), designed to calculate emissions related to alternative waste management practices, offers a wide range of materials and practices. It also estimates emissions related to waste transportation.

The Building for Environmental and Economic Sustainability tool (BEES) measures the environmental performance of building products using the environmental life-cycle assessment approach specified in International Organization for Standardization (ISO) 14040 standards.

GPC CARD ---- L2-01

NAME:

Equipment Retrofit Technology

DESCRIPTION

Retrofit technologies are devices that are attached to equipment engines to reduce emissions from the exhaust.

IMPLEMENTATION

Some of the retrofit strategies are required in the standard or special contract specifications. Many equipment retrofits must be verified by EPA or CARB, and if not, must meet certain standards listed under certain state specifications, such as the MassDOT Revised Diesel Retrofit Specification (MassDOT "MassDOT Revised Diesel Retrofit Specification" 2009), the New Jersey Department of Environmental Protection's (NJDEP's) Mandatory Diesel Retrofit Program,[9] or the New York State Diesel Emissions Reduction Act (DERA) (NYS Department of Environmental Conservation).

Some federal and state programs provide credit or grants incentive for engine retrofitting. By submitting required materials and proving the actual cost, the equipment owner can be reimbursed by tax credit or some other grants or funds, such as through the Congestion Mitigation and Air Quality Improvement Program (CMAQ), EPA's Clean Diesel Emerging Technologies Funding Assistance Program, and the Oregon Air Quality Diesel Program.

TECHNOLOGICAL OPTIONS

<u>The main 2:</u>

- Diesel Oxidation Catalysts (DOCs)
- Diesel Particulate Filters (DPFs)

<u>Others:</u>

- Cetane enhancers
- Diesel Catalytic Converter
- Catalytic mufflers
- Closed Crankcase Filtration or Ventilation Systems (CCFs or CCVs)
- Diesel Multistage Filtration Systems (DMFs)
- Flow-through filters (FTFs)
- Selective Catalyst Reduction (SCR) technology

TECHNOLOGICAL REQUIREMENTS

Before installing the best retrofit device for the particular vehicle, it has to be made certain that the device is verified by the EPA, CARB, or any other state agencies, and the engine of the vehicle must be inspected before installation. The EPA has a verification process for retrofit technology manufacturers, such as the verification requirements as well as testing requirements.[10] The device must be installed by trained personnel and information about the installation and

[9] New Jersey Department of Environmental Protection: http://www.nj.gov/dep/stopthesoot/retrofit.htm
[10] Environmental Protection Agency: http://www.epa.gov/otaq/retrofit/verif-process.htm

vehicle must be documented. The device may have to be custom-designed if there is not enough space available for the installation. Periodic inspections and maintenance should be made if required as well.

GREEN BENEFIT

Diesel Oxidation Catalysts

- Reduce hydrocarbon emissions by 50%, carbon monoxide by 40%, and particulate matter by at least 20%.
- Can be used on almost any engine, rarely require maintenance, and can last 7-15 years[11].

Diesel Particulate Filters

- Reduce emissions of particulate matter, hydrocarbons, and carbon monoxide by 60-90%.
- Can last 7-15 years[12].

BARRIERS

For DPFs, they must be used with ultra-low sulfur diesel fuel, they are expensive, they cannot be used on any engine (work best on engines built after 1995), and they must be cleaned out every 100,000 miles.

SAMPLE PROVISIONS

The Massachusetts Department of Transportation (MassDOT) has certain specifications in its contracts for retrofitting off-road diesel powered construction equipment operating on MassDOT job sites. One of the requirements of the MassDOT specifications is that the retrofits have to be verified by the EPA or by CARB. Other standards are listed under Section 3.00 in 3.041 – Certification of Construction Equipment Standard Compliance Requirement.[13]

PROJECT APPLICATION

1. In 2009-10, EPA awarded $77 million in grants to promote diesel emission reduction strategies utilizing the deployment of EPA or California Air Resource Board (CARB) verified and certified technologies.
2. Connecticut DOT's I-95 New Haven Harbor Crossing (I-95 NHHC) requires all contractors and subcontractors to use emission control devices, such as oxidation catalysts, and/or alternative fuels[14].
3. In 2006 using EPA and Ecology grants, Washington State Department of Transportation (WSDOT) retrofitted construction equipment using diesel catalysts, and in 2007, retrofitted 150 more vehicles using federal transportation dollars targeted for air quality[15].

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[11] Environmental Protection Agency: http://epa.gov/cleandiesel/documents/420f03016.pdf
[12] Environmental Protection Agency: http://epa.gov/cleandiesel/documents/420f03017.pdf
[13] Massachusetts DOT: http://www.mhd.state.ma.us/default.asp?pgid=content/publications_diesel_spec&sid=about
[14] Connecticut DOT: http://www.i95newhaven.com/commute/clean_air.aspx
[15] Washington DOT: http://www.wsdot.wa.gov/NR/rdonlyres/FC06ED88-C40C-4B09-82AE-061F687E5D1B/0/PublicFleetFactSheet.pdf

GPC CARD ---- L2-02

NAME

Engine Repowering and Upgrading

DESCRIPTION

Engine "repowering" is the replacement of an older diesel engine with a new, lower emission engine system. "Upgrading" means adding emissions-reducing parts, most often during an engine rebuild[16].

IMPLEMENTATION

Standards of the EPA, CARB, the Clean Air Act, and other state regulations must be followed before engines are replaced or upgraded.

Some federal and state programs provide credits, grants, or other incentives for engine repowering and upgrading, such as the New York & New Jersey Regional Truck Replacement Program (TRP)[17] and the Wisconsin non-Road Construction Legacy Fleet Diesel Engine Repower Grant Program[18]. Grant programs are available to subsidize the repowering of equipment. US DOT and some states like California, Texas, New Jersey, Oregon and Tennessee have established grants programs to encourage retrofitting, rebuilding and replacement of non-road engines[19].

TECHNOLOGICAL REQUIREMENTS

When repowering, owners need to take the following steps:

- Consult with the equipment and engine manufacturers to select a repower engine arrangement to match power and torque curves for application
- Address installation issues and re-engineering needs
- Maintain inlet manifold temperature and other parameters for the repowered engine's original certification
- Modify the software and electrical system of the older vehicle to adapt to the newer engine

GREEN BENEFIT

Emission reduction benefits of engine replacement or upgrades depend on the original certified emission level of the vehicle and replacement engine. For example, Caterpillar's upgrade model 3306 diesel engine has been verified by the EPA to reduce PM emissions by 22%, CO by 13%, HC by 71%, and NOx by 37%. Replacing an engine can also extend equipment life, improve fuel economy and lower maintenance costs, thus reducing overall equipment operating costs.

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[16] Environmental Protection Agency: http://www.epa.gov/cleandiesel/documents/100r07002.pdf
[17] The Port Authority of New York & New Jersey: http://www.panynj.gov/truckers-resources/truck-replacement.html
[18] Wisconsin DOT: http://www.dot.wisconsin.gov/safety/vehicle/dera-grant-prog.htm
[19] EPA Grants and Funds: http://epa.gov/otaq/diesel/grantfund.htm

BARRIERS

Initial cost is expensive, but overall cost ends up being cheaper in the long run.

SAMPLE PROVISIONS

The EPA enforces the tampering prohibition part of the Clean Air Act through the Mobile Source Enforcement Memorandum No. 1A[20] .

Specifications from Section 203(a)(3) of the Clean Air Act need to be followed, which deals with removing and installing engines or any other emission control devices[21].

CARB has regulations for add-on parts and the replacement of engines and other parts on vehicles[22].

PROJECT APPLICATION

1. Washington State Department of Transportation (WSDOT) replaces most of its equipment every 12-15 years so that it can update to the cleanest air emission control equipment. Purchased on-road engines manufactured after 2007 will pollute 90-99% less particulate matter, and engines purchased after 2010 will pollute 90-99% less nitrogen oxides than engines manufactured in the 1980s[23].
2. The Dan Ryan Expressway project in Illinois addresses the reduction of carbon monoxide, hydrocarbons, nitrogen oxides, and particulate matter through emission control devices verified by the EPA[24].

[20] Environmental Protection Agency: http://www.epa.gov/Compliance/resources/policies/civil/caa/mobile/tamper-memo1a.pdf
[21] Environmental Protection Agency: http://www.epa.gov/compliance/resources/policies/civil/caa/mobile/engswitch.pdf
[22] California Air Resources Board: http://www.arb.ca.gov/msprog/aftermkt/replace.htm
[23] Washington State DOT: http://www.wsdot.wa.gov/NR/rdonlyres/FC06ED88-C40C-4B09-82AE-061F687E5D1B/0/PublicFleetFactSheet.pdf
[24] Environmental Protection Agency: http://www.epa.gov/diesel/construction/documents/cl-idot-dust.pdf

GPC CARD ---- L2-03

NAME

Idling Reduction

DESCRIPTION

Unnecessary idling occurs when trucks wait for extended periods of time to load or unload, or when equipment that is not being used is left on, such as heating or air conditioning for the driver. A 2005 study of California construction equipment shows that an average heavy-duty diesel truck idles 29.4% of its operational time.[25]

IMPLEMENTATION

- The lowest cost of an idling reduction strategy would be to implement a company idling policy that involves raising awareness among equipment operators and advising them to turn off equipment that is not being used.
- CARB has strict requirements for idling alternatives and various compliance options for idling reduction strategies as well.[26]
- Auxiliary power units (APU) give truck drivers amenities, such as air conditioning, during driving breaks while eliminating idling. To help expand the use of idle reduction technologies, the EPA has partnered with the Small Business Administration to set up attractive loan packages for trucking companies that implement SmartWay strategies, such as the use of APUs.
- There are many state and federal incentives for using idling reduction strategies.[27]

TECHNOLOGICAL OPTIONS

- Cab and block heaters
- Automatic engine start-stop controls
- Battery-powered air conditioning systems
- Direct-fired heaters
- On-and-off truck electrification
- Auxiliary power units

TECHNOLOGICAL REQUIREMENTS

There are various state and local vehicle idling laws that must be followed[28].

GREEN BENEFIT

- Saves fuel consumption, which saves drivers money
- Prolongs engine life

[25] Grading & Excavation Contractor: http://www.gradingandexcavation.com/november-december-2009/ghg-emissions-reduction.aspx
[26] California Air Resources Board: http://www.arb.ca.gov/msprog/cabcomfort/cabcomfort.htm
[27] US Department of Energy: http://www.afdc.energy.gov/afdc/vehicles/idle_reduction_laws.html
[28] Environmental Protection Agency: http://www.epa.gov/smartway/documents/420b06004.pdf

- Reduces associated greenhouse gas emissions
- APUs could help eliminate 11 million tons of carbon dioxide emissions from truck idling in the United States each year.
- Current APUs save an average of 8% in fuel costs each year, according to the EPA.[29]

BARRIERS

- There is a high initial cost and high weight of APUs.
- Automatic start-stop controls are noisy and have minimal benefit in the winter.
- Truck stop electrification requires equipped location.[30]

SAMPLE PROVISIONS

- CARB has regulations for engines and emission performance requirements for technologies used as alternatives to idling,[31] such as:
    - 2008 and newer model year heavy-duty diesel engines must be equipped with a non-programmable engine shutdown system that automatically shuts down the engine after five minutes of idling or they can meet a stringent oxides of nitrogen idling emission standard.
    - In-use truck requirements require some operators to manually shut down their engine when idling more than five minutes at any location within California.
    - Emission producing alternative technologies, like the diesel-fueled auxiliary power systems (APS) and fuel-fired heaters, must meet emission performance requirements that ensure emissions are not exceeding the emissions of a truck engine operating at idle.

PROJECT APPLICATION

Electrified truck parking spaces (EPS) have been built in 140 locations across the US to provide parked trucks with heating, air conditioning, and other services so that no diesel is consumed and no emissions from the trucks are produced.[32]

[29] Center on Globalization Governance & Competitiveness: http://www.cggc.duke.edu/environment/climatesolutions/greeneconomy_Ch3_AuxiliaryPowerUnits.pdf
[30] Center for Transportation Research: http://www.intrans.iastate.edu/pubs/truck_idling/gaines.pdf
[31] California Air Resources Board: http://www.arb.ca.gov/msprog/truck-idling/truck-idling.htm
[32] US Department of Energy: http://www1.eere.energy.gov/cleancities/pdfs/idling_reduction_primer.pdf

GPC CARD ---- L2-04

NAME

Alternative Fuels

DESCRIPTION

An alternative fuel, most generally defined, is any fuel other than the traditional selections: gasoline and diesel, which is used to produce energy or power. Emissions and energy output provided by alternative fuels varies, depending on the fuel source.

IMPLEMENTATION

- According to the Energy Policy Act (EPAct) of 1992, under Standard Compliance:
    - Each year, covered fleets must acquire a certain percentage of alternative fuel vehicles (AFVs) based on the number of light-duty vehicles (LDVs) they purchase.
    - 75% of new covered LDVs that state fleets acquire must be AFVs, and 90% AFVs for alternative fuel providers.
    - Fleets also may meet up to 50% of the AFV acquisition requirements through the purchase and use of biodiesel.
- Under Alternative Compliance, covered fleets can obtain a waiver from the AFV acquisition requirements of the Standard Compliance to implement petroleum reduction measures instead.[33]
- According to the Clean Air Act, inspection and maintenance (I/M) programs are mandatory in several areas across the country.[34]
- Conventional original equipment manufacturer (OEM) vehicles being converted to alternative fuel vehicles (AFVs) must meet US Environmental Protection Agency (EPA) standards.
- Vehicles operating in California must follow conversion rules issued by the California Air Resources Board (CARB).
- The Clean Air Act enforces an operating permit program for commercial and industrial sources that release pollutants into the air.
- Grant programs, funding, and tax incentives are implemented in the American Recovery and Reinvestment Act of 2009, Surface Transportation Acts, Alternative Motor Fuels Act, and the Energy Policy Act of 2005 to promote the use of alternative fuels and vehicles and improve air quality. Loans are also given out by the US Department of Energy.[35]

TECHNOLOGICAL OPTIONS

The main 4:

- Compressed Natural Gas (CNG)

[33] US Department of Energy: http://www1.eere.energy.gov/vehiclesandfuels/epact/pdfs/fleet_compliance.pdf
[34] Environmental Protection Agency: http://www.epa.gov/oms/epg/regs.htm
[35] US Department of Energy: http://www.afdc.energy.gov/afdc/laws/key_legislation

- Biodiesel
- Emulsified Diesel Fuel
- Ultra-low Sulfur Diesel (ULSD)

Others:

- Pure methanol, ethanol, and other alcohols
- Blends of 85% or more of alcohol with gasoline
- Liquid fuels domestically produced from natural gas; liquefied petroleum gas (propane)
- Coal-derived liquid fuels
- Hydrogen
- Electricity
- Fuels, other than alcohol, derived from biological materials
- P-series fuels

In addition, the US Department of Energy (DOE) is authorized to designate other fuels as alternative fuels, provided that the fuel is substantially nonpetroleum, yielding substantial energy security benefits and offering substantial environmental benefits. For more information about the alternative fuels defined by EPAct 1992 as well as DOE's alternative fuel designation authority, visit the EPAct website. (Reference 42 US Code13211)

TECHNOLOGICAL REQUIREMENTS

ULSD

ULSD enables the use of advanced emission-control devices in equipment. As for EPA's regulations, advanced emission control systems required for the 2007 highway engines and future non-road engines will not operate properly without ULSD. All non-road diesel fuel was required to move to 500 ppm sulfur in 2007, and further to ULSD by December 1, 2010. There are exemptions for small refiners of locomotive and marine diesel fuel that allow for 500 ppm diesel to remain in the system until December 1, 2014, when all highway, non-road, locomotive and marine diesel fuel produced and imported will be ULSD.[36]

Biodiesel

Most non-road vehicles can run on B5 with little modification. B20 is also commonly used in larger equipment. Biodiesel has a high gel point, hence some users in very cold environments need to use fuel heaters and cold flow additives. Biodiesel can be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems. Pure blends of biodiesel may not be suitable for the winter season.[37]

Emulsified diesel fuels

Emulsified diesel fuels generally do not require engine modifications, but the addition of water reduces the energy content of the fuel, so some reduction in power and fuel economy can be expected. Meanwhile, fleet operators should check with OEMs before using a fill-and-go

[36] Clean Diesel Fuel Alliance: http://www.clean-diesel.org/images/ULSD_issue_paper.pdf
[37] Environmental Protection Agency: http://www.epa.gov/ne/eco/diesel/pdfs/biodiesel-factsheet.pdf

system. Emulsified diesel and fleet operators should confirm warranty compatibility with the equipment/engine manufacturer before using emulsified fuels.[38]

CNG

CNG buses require special refueling facilities as well as special maintenance facilities, both of which can be expensive.[39]

GREEN BENEFIT

Ultra-Low Sulfur Diesel

- Using ULSD fuel on its own, without particulate filters or oxidation catalysts, can reduce PM emissions 5-9% depending on the baseline fuel sulfur levels.
- If ULSD is used with particulate filters, PM reductions of 55-90% can be achieved.
- When ULSD is used with oxidation catalysts, PM reductions of 10-50% are possible.
- ULSD can reduce engine wear, deposits and oil degradation. These savings result from companies' ability to extend oil change intervals.

Biodiesel

- According to the US Department of Energy, in comparison to petroleum diesel, the process of biodiesel production and use produces 78% less carbon dioxide emissions. Although carbon dioxide is released when biodiesel made from soybeans is combusted, the production of soybean crops helps remove carbon dioxide from the atmosphere.
- B20 reduces emissions of particulate matter and carbon monoxide by about 10%, as well as lowers emissions of hydrocarbons (including some toxic air pollutants) by more than 20%.
- B100 reduces emissions of particulate matter and carbon monoxide by 47%, while lowering emissions of hydrocarbons by 67%.

Emulsified Diesel Fuel

- Emulsified fuels have been tested for many on-road and non-road diesel engines, although only Lubrizol's PuriNOx summer blend has received EPA verification.
- EPA has confirmed a 16.8–23.3% reduction in PM and a 17–20.2% reduction in NOx for non-road applications.

Compressed Natural Gas

- Vehicles powered by natural gas perform just like vehicles powered by diesel fuel.
- Natural gas buses can reduce emissions of particulate matter (PM) by about 70- 90% if they meet Clean Fueled Fleet requirements or have catalysts. CNG engines that do not have catalysts may have higher PM emissions than Clean Diesel engines meeting EPA's 2007 emission standard.
- Using natural gas can reduce nitrogen oxide emissions by 32-73% and non-methane hydrocarbons by 69-83%.

BARRIERS

For ultra-low sulfur diesel, the availability is limited, it can be more expensive than other fuels, and its liability decreases in cold weather.

[38] Environmental Defense: http://www.edf.org/documents/4941_cleanerdieselhandbook.pdf
[39] Environmental Protection Agency: http://www.epa.gov/region1/eco/diesel/retrofits.html#edf

For biodiesel, it can soften and dissolve some rubber, including vehicle fuel lines and pump seals. Therefore, on older vehicles, it may be necessary to replace the fuel filters, fuel lines, and other components after the first couple tanks of biodiesel.

Natural gas is a non-renewable energy source, it is toxic, the pipelines are expensive, and it is more expensive to operate compared to diesels.

SAMPLE PROVISIONS

Fleets interested in acquiring AFVs must obtain a waiver from the US Department of Energy proving they will achieve petroleum reductions equivalent to that achieved having AFVs run on alternative fuels 100% of the time.

The EPA has a specific protocol for alternative fuel conversions, and one can see the EPA regulations and information on alternative fuels on the EPA website.[40]

Other examples of provisions include the DOE Energy Policy Act 1992[41] and the Nevada Alternative Fuels Provision.[42]

PROJECT APPLICATION

1. In September of 2007, USDOT announced that Interstate-5 had been designated as a Corridor of the Future. The purpose of the Corridors of the Future Program is to develop innovative national and regional approaches to reduce congestion and improve the efficiency of freight delivery. Part of the application submitted by Washington, Oregon, and California included the development of alternative fuels distribution along the corridor as a possible interstate initiative for a future focused and sustainable transportation corridor.

In furtherance of this interstate initiative, Washington, Oregon, and California signed a tri-state Memorandum of Understanding (MOU) in September 2008. The three states have agreed to work together to foster the use of alternative fuel vehicles by developing the distribution network for alternative fuels throughout the I-5 Corridor. The memorandum lays out common goals, a work plan, and activities designed to further the development of this alternative fuels corridor.[43, 44]

[40] Environmental Protection Agency: http://www.epa.gov/oms/consumer/fuels/altfuels/altfuels.htm
[41] Energy Policy Act of 1992: http://www.afdc.energy.gov/afdc/pdfs/2527.pdf
[42] Nevada State Legislature: http://www.leg.state.nv.us/nrs/nrs-486a.html
[43] West Coast Green Highway: http://www.westcoastgreenhighway.com/images/Tri-StateMOUAlternativeFuelsCorridor.pdf
[44] West Coast Green Highway: http://www.westcoastgreenhighway.com/alternativefuels.htm

GPC CARD ---- L2-05

NAME
LED Lighting

DESCRIPTION
A light emitting diode (LED) is a semiconductor light source that provides energy-efficient lighting. LEDs are a logical and cost-effective strategy for future transportation use. Compared to fluorescent and incandescent lights, LEDs are very durable, turn on instantly, and are not sensitive to humidity or low temperatures.[45]

IMPLEMENTATION
LED lighting is made up of hundreds of small diodes that can be used in traffic signals, information display systems, toll lighting, rest area lighting, and highway lighting along the road. If agencies decide to use LED lights for traffic signals, they still have to follow the requirements for the signals, such as the amount of wattage that needs to be used for specific types of signals.

GREEN BENEFIT
- LEDs do not contain any mercury, lead, or other known disposal hazards, and they come on instantly without run-up time or re-strike delay.
- LEDs can last for years, while halogen bulbs last for months, thereby reducing the long-term cost for the agency as well as reducing the time, work, and traffic associated with replacing the lights. Less traffic caused by replacing lights and by burnt out lights will reduce overall emissions from vehicles as well.[46]
- For 30 bulbs per year, the CO_2 emissions of LEDs would be about 451 pounds/year, 4500 pounds/year for incandescent, and 1051 pounds/year for compact fluorescents.[35]
- LED fixtures are brighter than traditional incandescent lights and can use 90% less electricity than traditional bulbs, which drastically reduces electricity consumption, long-term costs, and associated greenhouse gas emissions. LED lights also have a significantly longer life than traditional bulbs – 25,000 to 100,000 hours compared to 15,000 hours of traditional lighting.[36]

BARRIERS
- During snowstorms, LEDs used in traffic lights and signals may not generate enough heat to melt the snow accumulated on the lenses, so LEDs should be used in areas where snowstorms do not occur often.
- Agencies will be required to pay much more money for the initial cost of LEDs than for traditional bulbs, but they will save more money in the long-term

PROJECT APPLICATION
In 2001, the City of Portland in Oregon replaced over 13,300 red and green incandescent traffic lights with LED lights, with thousands of dollars in maintenance and energy savings.[47]

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[45] Lighting Comparison Chart: http://www.designrecycleinc.com/led%20comp%20chart.html
[46] US Department of Energy: http://www1.eere.energy.gov/buildings/ssl/using_leds.html
[47] City of Portland, Oregon: http://www.portlandonline.com/bps/index.cfm?a=111737&c=41888

GPC CARD ---- L2-06

NAME

Equipment Operation and Maintenance Management

DESCRIPTION

Preventive maintenance seeks to maintain engines at their original level of performance and improve equipment efficiency and engine life. Equipment training addresses a broad range of issues, including operating equipment in a safe and efficient manner, maximizing the productive capacity of equipment to do work, and being knowledgeable of the capability and limits of equipment.

IMPLEMENTATION

Companies are recommended to do systematic inspection, detection, and correction of potential equipment failure. A systematic maintenance program can prevent unnecessary or premature maintenance as well as the need for repairs after catastrophic failures. Many companies use fuel monitoring systems, software, or a database/inventory of equipment and periodic maintenance requirements. It is important to train operators to inspect their vehicles daily for tire pressure, fluid leaks, fluid levels (engine oil, coolant level, and transmission fluid), oil color, or other elements recommended in the owner's manual.

TECHNOLOGICAL OPTIONS

Preventive maintenance can include:

- air, fuel, and oil filter replacement
- battery replacement before failure
- regular oil changes
- other simple repairs and abnormality detection

TECHNOLOGICAL REQUIREMENTS

Construction equipment operators must have a commercial driver's license, which is issued by states according to each state's rules and regulations. They also need to be in good physical condition with a sense of balance, ability to judge distance, eye-hand-foot coordination, and sometimes the ability to work at heights. Many operators are required to be certified and have experience with computers through schools, on-the-job training, or apprenticeship and paid training programs. Operating new equipment may require additional electronics or computer science[48].

GREEN BENEFIT

Proper maintenance reduces fuel consumption, reduces particulate matter emissions, increases the longevity of the equipment, and saves time and money.

[48] US Department of Labor: http://www.bls.gov/oco/ocos255.htm

Effective operator training could increase productivity, provide for a safe work environment, reduce maintenance costs, and lower machine fuel consumption.

BARRIERS

With preventive maintenance, there are risks with equipment failure or human error, and the cost may be high for fleet management software.

SAMPLE PROVISIONS

There are equipment inspection and maintenance (I/M) programs for cars and light trucks that were made mandatory in several areas across the country by the 1990 Amendments to the Clean Air Act. These programs include regulations by the EPA regarding requirements for the programs and for air quality standards[49].

[49] Environmental Protection Agency: http://www.epa.gov/otaq/epg/regs.htm

GPC CARD ---- L2-07

NAME:

Equipment Selection and Vehicle Electrification

DESCRIPTION

Equipment selection deals with wisely choosing the proper equipment and finding the proper size and weight of equipment for a task. Vehicle electrification involves employing electric or hybrid electric equipment.

IMPLEMENTATION

There are state and federal incentives to encourage the use of electric vehicles.[50]

TECHNOLOGICAL REQUIREMENTS

Along with the incentives offered, companies still have to follow state and federal laws, such as alternative fuel vehicles (AFV) or low emission vehicle standards and requirements.[51]

GREEN BENEFIT

Choosing the proper equipment, energy efficient equipment, and electric vehicles can provide fuel savings and reduce GHG emissions. Using electric vehicles also lowers operating costs and they are quieter.

BARRIERS

Truck engines that are too large will add unnecessary weight which will burn more fuel. However, under-sized engines can easily become overworked, leading to excess fuel consumption and accelerated engine wear. For electric vehicles, charging stations are needed.

SAMPLE PROVISIONS

Power requirements of the machines must still be met when choosing certain equipment and electric vehicles. Engines still need to meet the EPA standards for engines and emissions.[52]

PROJECT APPLICATION

1. By June 1, 2015, Washington State plans to have 100% of its publicly owned vehicles and construction equipment to run on electricity or biofuel.[53]
2. Volvo Construction Equipment (Volvo CE) produced a diesel hybrid loader. By combining diesel power with electric torque, the electric motor supports the diesel engine, providing more power, better performance, and a 10% reduction in fuel consumption.[54]

[50] US Department of Energy: http://www.consenseus.org/downloads/policy/StateIncentives.pdf
[51] US Department of Energy: http://www.afdc.energy.gov/afdc/laws/laws/NY
[52] Environmental Protection Agency: http://www.epa.gov/oms/hd-hwy.htm
[53] State of Washington: http://www.nissanusa.com/ev/media/pdf/incentives/nissan-leaf-incentive-55.pdf
[54] Volvo: http://www.volvo.com/constructionequipment/asia/en-gb/newsmedia/pressreleases/2008/NewsItemPage.htm?channelId=4578&ItemID=41180&sl=en-gb

GPC CARD ---- L2-08

NAME

Staging Zone and Work Zone Mobility

DESCRIPTION

A construction staging zone is a designated area where vehicles, supplies, and construction equipment are positioned for access and use. Work zone mobility is important for traffic control and safety.

IMPLEMENTATION

To better plan and operate the staging zone, the construction company should establish a system to track resources and personnel for organization, efficiency, and safety.

Work zone traffic management strategies should be identified based on the project constraints, construction phasing/staging plan, type of work zone and anticipated work zone impacts. Once implemented, they need to be monitored to ensure effectiveness.

Each state has to work with the Federal Highway Administration in the implementation of its policies and procedures to improve work zone mobility. The FHWA must also review the states' policies and procedures. Additionally, each state must have a Transportation Management Plan (TMP), trained personnel, and may need a Temporary Traffic Control (TTC) plan for significant projects[55].

TECHNOLOGICAL REQUIREMENTS

There are federal laws and codes, and each state has its own laws and guidance, such as laws about worker safety and guidebooks on best work zone practices and traffic control[56].

The Federal Highway Administration also has the Work Zone Safety and Mobility Rule, which was published on September 9, 2004. This required all state and local governments that receive federal-aid funding to comply with the provisions by October 12, 2007[57].

GREEN BENEFIT

- Construction staging zones reduce the congestion of the construction site, increase efficiency of equipment loading and unloading, and reduce the corresponding GHG emissions. They may also provide interim waste storage locations.
- Work zone mobility minimizes traffic delays, maintains or improves motorist and worker safety, and allows roadwork to be completed in a timely manner.

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[55] Electronic Code of Federal Regulations: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=4326b3462801c075d9d260366f1f811e&rgn=div5&view=text&node=23:1.0.1.7.21&idno=23#23:1.0.1.7.21.9

[56] Washington State DOT: http://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/1010.pdf

[57] Federal Highway Administration: http://ops.fhwa.dot.gov/wz/resources/final_rule.htm

SAMPLE PROVISIONS

There are various federal laws for work zones that companies have to follow dealing with traffic control devices, worker visibility, and work zone safety[58].

PROJECT APPLICATION

1. Many transportation agencies are using Intelligent Transportation Systems (ITS) to manage work zones. WSDOT uses ITS for basically their entire state highway network. It is used for communications, traffic cameras, variable message signs, highway advisory radios, and road/weather information systems[59].
2. The Illinois Department of Transportation used a Real-Time Work Zone Traffic Control System in the construction zone management of the I-55 Lake Springfield Bridge[60].

[58] The National Work Zone Safety Information Clearinghouse: http://www.workzonesafety.org/laws/
[59] Washington State DOT: http://www.wsdot.wa.gov/Operations/ITS/
[60] Intelligent Transportation Systems in Work Zones Case Study: http://ntl.bts.gov/lib/jpodocs/repts_te/13984.htm#project

GPC CARD ---- L2-09

NAME

Employee Commuting Reduction

DESCRIPTION

There is a large number of commuting employees in the construction industry, which may possibly be a significant source of greenhouse gas emissions in the industry.

IMPLEMENTATION

Emissions associated with employee commuting vary by projects. Very little data has been found on the average distance employees travel to construction sites; therefore, no calculations could be made on the national GHG impacts from employee commuting. One way to reduce these emissions is by using carpools, shuttle vans, or shuttle buses.

GREEN BENEFIT

- Using carpools or shuttle vans will reduce GHG emissions produced from all employees travelling separately to sites. One study in July 2010 shows that the use of buses and carpooling for construction workers can avoid about 3,384 metric tons of $C0_2$ emissions as well as lesser amounts of ozone precursors and diesel particulate matter. Implementing a bus carpooling program is predicted to reduce projected trips from 1,040 to 655 per day and vehicle miles traveled from 55,730 to 30,750. This would reduce adverse effects from worker commutes by reducing worker trips about 37% to sites.[61]

- Will save fuel and money on fuel costs.

BARRIERS

Carpooling may not be the most feasible method for all workers depending on their initial location. Workers also may not be able to leave the site early for emergencies.

[61] California Valley Solar Ranch (CVSR): http://www.californiavalleysolarranch.com/deir/Air%20Quality/CVSR%20AQ%20Emissions%20Avoidance%20List%207-6-10.pdf

GPC CARD ---- L3-01

NAME

Green Roads Rating System

DESCRIPTION

This is a rating system used to determine the extent to which sustainable practices such as energy efficiency, material conservation, or GHG emissions reduction, are being implemented in transportation system construction and operational activities.

IMPLEMENTATION

It is necessary to develop an evaluation framework to integrate and develop sustainable practices in transportation systems. Central to the evaluation of sustainable practices is the development of goals and criteria. In terms of criteria it is necessary to determine reasonable measures of improvement to ensure that there is tangible progress. These goals and criteria can then be assigned numerical values and assessed with a scorecard to allow for fair and objective evaluation. It is also necessary that the state of practice constantly be re-evaluated to consider new innovations.

GREEN BENEFIT

This strategy is designed to facilitate the integration of sustainable practices into transportation systems development and management. The rating system allows agencies to determine areas that need improvement as well as recognize areas that are successfully implementing sustainable practices, allowing the agency to distinguish innovative sustainable techniques and reward the use of these techniques in the field.

PROJECT APPLICATION

Greenroads[62] was developed by the University of Washington and CH2M hill and modeled after the LEEDs building certification program. If a project meets the system's 11 project requirements for certification, points are then awarded for meeting criteria from voluntary credit evaluation categories and tallied on a score card. Voluntary credits can be accumulated in five categories: access & equity, environment & water, construction, materials & resources, and pavement technologies. Once a project has been assessed it can be classified into one of the four certification levels: Certified, Silver, Gold, or Evergreen.

GreenLITES[63] was developed by New York DOT in September 2008. GreenLITES is a self-certification rating program that uses a scorecard system to distinguish transportation projects and operations implementing sustainable practices. The operations section of the GreenLITES program is integrated into the NYSDOT Maintenance & Operations Plan (MOP) to be evaluated in an updated MOP score card.

[62] The Greenroads Rating System http://www.greenroads.us/
[63] GreenLITES program https://www.nysdot.gov/programs/greenlites

GPC CARD ---- L3-02

NAME

Climate Impact Analysis

DESCRIPTION

Climate impact analysis is used to investigate and evaluate the environmental impacts of the whole process of a given project. The analysis should be conducted for the whole project lifecycle, thus resulting in an overview of the project sustainability performance.

IMPLEMENTATION

Carbon footprint (CF) modeling is the fundamental methodology for the project climate impact analysis, which is the overall amount of carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions associated with a product, a service or a project, along its supply-chain and sometimes even including emissions from use and end-of-life recovery and disposal.

The GHG analysis could also be integrated into the project-level energy analysis. Indirect energy use (the energy required to construct and maintain transportation facilities) and Direct energy use (the on-road operational energy consumption for the transportation facility) are quantified, and then the carbon dioxide emissions from roadway projects can be determined by applying carbon emission coefficients.

TECHNOLOGICAL OPTIONS

Based on the carbon footprint calculation, there are a large number of methodologies, tools, and analysis software for calculating the climate impact of the transportation sector. Examples of the technology are listed below. For more information, refer to AASHTO's report "Assessment of Greenhouse Gas Analysis Techniques for Transportation Projects"[64]

- State Inventory Tool (SIT) And State Inventory Projection Tool[65]
- MOBILE6 by EPA
- NONROAD Model[66] by EPA
- National Mobile Inventory Model (NMIM)[67] by EPA
- EMFACmodel[68] by The California Air Resources Board (CARB)
- Climate Leadership In Parks (CLIP) Tool[69] by EPA
- GREETMODEL[70] by Argonne National Laboratory (Sponsored By US DOE)
- LIFECYCLE EMISSIONS MODEL (LEM)[71]

[64] Assessment of Greenhouse Gas Analysis Techniques for Transportation Projects http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25(17)_FR.pdf
[65] SIT http://www.epa.gov/statelocalclimate/resources/tool.html
[66] EPA NONROAD model http://www.epa.gov/OMS/nonrdmdl.htm
[67] EPA NMIM model http://www.epa.gov/oms/nmim.htm
[68] CARB EMFACMODEL software http://www.dot.ca.gov/hq/env/air/pages/emfac.htm
[69] CLIP tool http://www.nps.gov/climatefriendlyparks/CLIPtool/index.html
[70] GREETMODEL http://www.transportation.anl.gov/modeling_simulation/GREET/index.html

- Motor Vehicle Emissions Simulator (MOVES)[72] by EPA
- COMMUTERMODEL[73] by EPA
- VISIONMODEL[74] by Argonne National Laboratory (sponsored by US DOE)
- Systems For The Analysis Of Global Energy Markets (SAGE)[75] by DOE
- …

GREEN BENEFIT

Life cycle emission analysis could help agencies to measure the green performance on a project basis. Involving analysis tools or software into the decision making would also provide incentive to contractors for being green.

BARRIERS

It takes long time for developing an integrated system. A possible learning curve is expected in the early period of implementation.

PROJECT APPLICATION

Sacramento Metropolitan Air Quality Management District developed a road construction emission model (RCEM)[76] to assess highway construction emissions.

Another EPA recommended tool called Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE)[77] is also available to estimate construction emissions and evaluate life-cycle cost impact of varied pavement designs.

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[71] US Davis LEM model http://www.its.ucdavis.edu/publications/2003/UCD-ITS-RR-03-17-MAIN.pdf
[72] EPA MOVES model http://www.epa.gov/otaq/models/moves/index.htm
[73] EPA COMMUTORMODEL http://www.epa.gov/oms/stateresources/policy/transp/commuter/420b05017.pdf
[74] Argonne VISION Model http://www.transportation.anl.gov/modeling_simulation/VISION/
[75] US DOE SAGE model http://tonto.eia.doe.gov/ftproot/modeldoc/m072(2003)1.pdf
http://tonto.eia.doe.gov/ftproot/modeldoc/m072(2003)2.pdf
[76] RCEM http://www.airquality.org/ceqa/RoadConstructionModelVer6.3-2.xls
[77] PaLATE http://www.ce.berkeley.edu/~horvath/palate.html

GPC CARD ---- L3-03

NAME

Climate Adaptation Design

DESCRIPTION

Climate Adaptation Design is a strategy that involves climate assessment and GHG emissions reductions in the stages of project planning, product design, and technology or methodology incorporation during the construction process.

IMPLEMENTATION

In addition to emission mitigation strategies, adaptation strategies such as climate adaptation design should be taken into full consideration especially for new facility construction. According to the EPA's report "Impacts of Climate Variability and Change on Transportation Systems and Infrastructure"[78], vulnerability to the impacts of climate change is a function of exposure to climate conditions, sensitivity to those conditions, and the capacity to adapt to the changes.

TECHNOLOGICAL OPTIONS

In order to increase the vulnerability of infrastructures, adaptation designs include but are not limited to:

- Temperature Adaptation -- Cooling and ventilation systems, shade design, vegetation and soil management, and light paint,
- Water/Flood Adaption -- Stormwater management, alternative road layout, rainwater collection system, grey water recycling, sustainable drainage systems, and permeable/porous asphalt pavements,
- Wind Adaption-- Long-term resilience design

PROJECT APPLICATION:

Washington State is encouraging the use of emerging technologies and practices in climate change adaptation design strategies. Lead by the Department of Commerce, the global warming mitigation and adaptation program selected three counties and six cities through a competitive process to provide grants and technical assistance for their efforts to anticipate, mitigate, and adapt to global warming and its associated problems. WSDOT also sponsors annual excellent environmental design awards for competitive Environmental Improvement Projects. The 2010 winners are the Nile Valley Landslide project[79] and US 97A Wildlife Fence project[80].

[78] EPA adaptation report http://www.climatescience.gov/Library/sap/sap4-7/final-report/sap4-7-final-all.pdf
[79] Nile Valley Landslide project http://www.wsdot.wa.gov/projects/sr410/landslide/
[80] Wildlife Fence project http://www.wsdot.wa.gov/projects/us97a/wildlifefence/

GPC CARD ---- L4-01

NAME

Highway-Related Solar Energy

DESCRIPTION

As solar power is abundant, it is recommended that photovoltaic panel arrays are used to provide environmentally friendly renewable energy.

IMPLEMENTATION

To ensure the most efficient energy generation, it is critical that the solar arrays be placed in a location with optimal sun exposure. Initial purchase and installation costs are significant; however the arrays require little life-cycle maintenance.

TECHNOLOGICAL OPTIONS

- **Monocrystalline Silicon Panels**

These are the most efficient type of panels available with an efficiency of 14-18%. Comprised of a single silicon crystal, these panels are more expensive to purchase and maintain.

- **Polycrystalline Silicon Panels**

These panels are comprised of many photovoltaic wafers and have an energy return rate of 12-14%. They are cheaper to manufacture than monocrystalline panels, and therefore are cheaper to purchase. These panels are also less expensive to maintain as damages to one of the cells on a polycrystalline panel can be fixed by the replacement of that individual cell rather than the entire panel. [81]

GREEN BENEFIT

The main benefit of solar power is that it reduces the reliance on energy generated using fossil fuels. Using solar panels to generate power using the sun's energy avoids the release of greenhouses gases, carcinogens, and carbon dioxide that is associated with traditional energy generation techniques. As energy from the sun is completely renewable, solar power can also help preserve resources. In addition solar panels are recyclable further reducing resource consumption and manufacturing emissions.

PROJECT APPLICATION

A solar highway was built right outside Tualatin, Oregon in 2009 to power the interchange between I-5 and I-205. The solar photovoltaic system consists of 594 solar panels and covers about 8,000 square feet.

[81] Types of Solar Panels http://www.solarpanelcenter.net/Types-of-Solar-Panels.php

GPC CARD ---- L4-02

NAME

Highway-Related Wind Turbine

DESCRIPTION

Wind energy is a renewable resource that occurs naturally, and wind turbines can be used to generate electricity continuously in appropriate locations. The largest wind turbines can generate up to 5MW of power, and can be used jointly to form wind farms.

IMPLEMENTATION

It is important that turbines are placed in locations with appropriate wind resources. It is necessary that feasibility studies be conducted before the installation of a wind turbine. Studies should include environmental considerations as well wind direction and availability data.

TECHNOLOGICAL OPTIONS

- **Horizontal Axis Wind Turbines (HAWTs)**

More traditional turbines are situated at the top of a tower with the rotor spinning about a horizontal axis. These turbines have well-established designs and criteria. They are significantly more efficient than vertical axis turbines.

- **Vertical Axis Wind Turbines (VAWT's)**

These structures do not require a tower, so they are considered to be easier to maintain. However, they are approximately 50% less efficient than horizontal axis turbines, and due to low starting torque, they consume initial energy resources to start the turning of the blades.

GREEN BENEFIT

Wind resources are completely renewable. Furthermore, wind turbines require little operation and maintenance, as most are designed to shut off in high winds. As with solar energy, the majority of the environmental benefits stem from the offset of the use of energy from fossil fuels. There are no greenhouse gas emissions or waste associated with the operation of wind turbines.

APPENDIX D: GPC STRATEGY EVALUATION TEMPLATE

Evaluator: _____ ***Date:*** _____

Strategy	Financial Consideration	Technical Implementation Readiness	Organizational Readiness	Industrial and Public Acceptance	Emission Reduction Potential	Impact on Project Performance	Risks
L1-01 Reclaimed Asphalt Pavement							
L1-02 Other Material Recycling/Reusing							
L1-03 Sustainable Material Treatment							
L1-04 Material Waste Management							
L1-05 Material Life-Cycle Management							
L2-01 Equipment Retrofit Technology							
L2-02 Engine Repower and Upgrade							
L2-03 Idling Reduction							
L2-04 Alternative Fuels							
L2-05 LED Lighting							
L2-06 Equipment Maintenance Mgmt							
L2-07 Equipment Vehicle Electrification							
L2-08 Work Zone Traffic Management							
L2-09 Employee Commuting Reduction							
L3-01 Green Road Rating System							
L3-02 Climate Impact Analyses							
L3-03 Climate Adaptation Design							
L4-01 Highway-related Solar Energy							
L4-02 Highway-related Wind Turbine							

APPENDIX E: DEA OPTIMIZATION MODEL

Assume that we have *N* Decision Making Units (DMU) for evaluation. Each DMU has *I* different inputs and *R* outputs. *L* is the total level of Likert's scale scores assigned for each criterion. The efficient score for a certain DMU could be solved through the following model:

$$E_0 = \min(\theta - \varepsilon^2 \sum_{r \in R} \sum_{l\text{-}1}^{L} \alpha_{rl} - \varepsilon^2 \sum_{i \in I} \sum_{l\text{-}1}^{L} \alpha_{il})$$

s.t.

$$\sum_{k=1}^{K} \lambda_k \bar{\gamma}_{rk}(l) - \alpha_{rl} = \bar{\gamma}_{r0}(l), r \in R, l = 1...L$$

$$\theta \bar{\delta}_{i0}(l) - \sum_{j=1}^{N} \lambda_k \bar{\delta}_{ik}(l) - \alpha_{il} = 0, i \in I, l = 1...L$$

$$\sum_{k=1}^{N} \lambda_k = 1$$

$$\lambda_k, \alpha_{rl}, \alpha_{il} \geq 0$$

Where

$$\gamma_{rk}(l) = \begin{cases} 1 & if\ DMU\ k\ is\ ranked\ in\ the\ lth\ position\ on\ output\ r, \\ 0 & otherwise, \end{cases}$$

$$\delta_{ik}(l) = \begin{cases} 1 & if\ DMU\ k\ is\ ranked\ in\ the\ lth\ position\ on\ output\ i, \\ 0 & otherwise. \end{cases}$$

$$\bar{\gamma}_{rk}(l) = \sum_{n=1}^{l} \gamma_{rk} = \gamma_{rk}(1) + \gamma_{rk}(2) + \cdots + \gamma_{rk}(l)$$

$$\bar{\delta}_{ik}(\mathrm{l}) = \sum_{n=l}^{L} \delta_{ik} = \delta_{ik}(L) + \delta_{ik}(L-1) + \cdots + \delta_{ik}(l)$$

This model could be solved by any linear optimization software, and will generate K correspondent efficiency scores after running K times for each strategy.

APPENDIX F: CLIMATE POLICIES

F.1. INTERNATIONAL APPROACHES

The beginning of a global-wide approach to deal with climate change was with the United Nations Framework Convention on Climate Change (UNFCCC or FCCC), produced at the United Nations Conference on Environment and Development (UNCED), in June 1992. Originally, this framework was an international environmental treaty to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The UNFCCC entered into force on March 1994, and as of December 2009, it had 192 parties.

The treaty itself is considered non-legally binding because it sets no mandatory limits on greenhouse gas emissions for individual countries and contains no enforcement mechanisms. Instead, the framework provides basic foundation for further updates (called "protocols") that would set mandatory emission limits.

Since 1995, the parties agree to hold annual meetings called Conferences of the Parties (COP) to assess progress in dealing with climate change. Several important COPs and conference agreements are listed as follows:

- COP 3, 1997, The Kyoto Protocol on Climate Change

COP3 took place in December 1997 in Kyoto, Japan. After intensive negotiations, it adopted the Kyoto Protocol, which is a legally binding international agreement, whereby all participating nations commit themselves to tackling the issues of global warming and greenhouse gas emissions. The target agreed upon was an average reduction of 6 to 8% below 1990 levels between the years 2008-2012, defined as the first emissions budget period. The United States would be required to reduce its total emissions an average of 7% below 1990 levels. However, the Bush administration explicitly rejected the protocol in 2001.

The Kyoto Protocol provides several "flexible mechanisms" which enable Annex I countries (most are developed countries) to meet their GHG emission targets by acquiring GHG emission reductions credits. The credits are acquired by an Annex I country financing projects that reduce emissions in non-Annex I countries (most are developing countries) or other Annex I countries or by purchasing credits from Annex I countries with excess credits. The three flexible mechanisms are emissions trading, the clean development mechanism (CDM) and joint implementation (JI).

- COP 6, 2001, Bonn, Germany, COP 7, 2001, Marrakech, Morocco

COP 6 took place on July 17-27, 2001, in Bonn, Germany, just after President George W. Bush had become the US President, and had rejected the Kyoto Protocol in March. As a result the United States delegation to this meeting declined to participate in the negotiations related to the Protocol, and chose to act as observers at that meeting, as well as the COP 7 meeting, which was held in Marrakech, Morocco October 29-November 10, 2001.

In COP6 and COP7, the other parties negotiated the key proposals, and reached agreements on most of the major detailed political issues of Kyoto Protocol. The issues included (1) Operational rules among parties to the Protocol, (2) Accounting procedures for the three flexible mechanisms, (3) Legally binding requirements that outline consequences for failure to meet

emissions targets and (4) A target date for bringing the Protocol into force: the August-September 2002 World Summit on Sustainable Development (WSSD) to be held in Johannesburg, South Africa.

- COP 11/MOP 1, 2005, Montreal, Canada

COP 11 took place between November 28 and December 9, 2005, in Montreal, Quebec, Canada. It was also the first Meeting of the Parties (MOP) to the Kyoto Protocol since the initial meeting in Kyoto in 1997. It was therefore one of the largest intergovernmental conferences on climate change ever. The event marked the entry into force of the Kyoto Protocol by launching the Montreal Action Plan, which is an agreement hammered out to "extend the life of the Kyoto Protocol beyond its 2012 expiration date and negotiate deeper cuts in greenhouse-gas emissions."[82] Cop 11 was closed with the adoption of more than forty decisions within the Kyoto Protocol framework.

- COP 15/MOP 5, 2009, Copenhagen, Denmark

COP 15 took place in Copenhagen, Denmark from 7 December to 18 December 2009. The overall goal for the COP 15/MOP 5 was to establish an ambitious global climate agreement for the period from 2012 when the first Kyoto Protocol commitment period (2008-2012) expires. However, in the end of the conference, although a 13-paragraph 'political accord' was negotiated by approximately 25 parties including US and China, it was only 'noted' by the COP as there was no consensus. Ministers and officials from 192 countries had to decide to put off the difficult task of reaching a climate change agreement to after the COP 15 with ad hoc meetings.

Nevertheless, the Copenhagen Accord made progress referring to a collective commitment by developed countries for new and additional resources, including forestry and investments through international institutions, which will approach USD 30 billion for the period 2010 - 2012. Meanwhile, it established the timeframe for big emitters to register their emissions reduction actions. By the end of January 2010, key countries announced their actions towards reducing their global warming pollution, and agreed to implement commitments by launching new programs of laws, policies and projects.

Among all the announcements, United States agreed to reduce emissions by 17% below 2005 levels by 2020, 42% below 2005 levels by 2030, and 83% below 2005 levels by 2050. China committed to reduce emissions per unit of GDP by 40 to 45% below 2005 levels by 2020 and to increase energy from non-fossil fuels to supply 15% of China's primary energy consumption by 2020. India agreed to reduce emissions per unit of GDP by 20 to 25% below 2005 levels by 2020. European Union committed to reduce emissions to 20% below 1990 levels by 2020 and would increase their commitment to 30% if other countries also committed to ambitious efforts.

F.2. US APPROACHES

F.2.1 REGULATION INITIATIVES

- US House of Representatives Climate Bill HR 2454

H.R. 2454, introduced in May 2009 and passed by the House of Representatives in June 2009, was created in efforts to create clean energy jobs, achieve energy independence, reduce global

[82] CBC news. http://www.cbc.ca/canada/story/2005/12/10/climate051210.html

warming pollution, and transition to a clean energy economy. Title II, Subtitle C, Section 222 of the bill requires the promulgation of national transportation-related greenhouse gas reduction goals, as well as models and methodologies to incorporate these goals into transportation planning. In addition to promulgation of these goals, the section requires the Secretary of Transportation to establish performance measures to ensure that transportation plans meet requirements and achieve progress toward national goals.

In relation to construction fleets, the bill allows federal, state, and fuel provider fleets to earn credits from the conversion of existing vehicles to operate on alternative fuels. It also requires the EPA to establish GHG emission standards for new heavy-duty vehicles and engines. This bill will therefore support fixing old machines and building new ones that are better for the environment.

There are also provisions that relate to industries that manufacture the products used in highway construction. The bill calls for industrial plant efficiency standards and also discusses how to ensure real reductions from the industries. Another important provision is a product carbon disclosure program. This program, similar to the EPA's current carbon labeling program, would require industries to report the emissions due to the manufacturing of the material. With this information, contract specifications could require that the project use a material whose manufacturing emissions are less than a certain amount.

- US Senate Climate Bill S 1733

S 1733, backed by Senators Kerry, Graham, and Lieberman, is similar to the House's bill. The bill, which is still on the table, was introduced on September 30, 2009. It too includes provisions for heavy-duty vehicle emission standards, a product carbon disclosure program, and a discussion of how to ensure real industrial emissions. One of two differences to note is that this bill provides for grants from the DOT to states and municipal planning organizations to help implement and finance transportation-related greenhouse gas reduction goals. The other major difference is that the Senate's bill grants more power to the EPA while the House's bill would supersede the EPA.

- Maryland Climate Action Plan

Maryland's Climate Action Plan of 2008 already has a few provisions that could easily be implemented into highway planning. Provision TLU-10 would require state regulation, led by MDOT and MDE, as well as legislative action to promote transportation options with reduced emissions and to improve transportation system management policies to reduce emissions. This includes incentives to increase purchases of fuel-efficient or low GHG vehicles, increasing the use of alternate fuels or low sulfur diesel to reduce GHG emissions, and reducing idling time, all three of which can be applied to construction equipment. The provision also includes the adoption of state contracting and fleet standards for low GHG equipment procurements. In addition to fleet specifications, TLU-10 also mentions how the use of managed lanes can encourage more fuel efficient vehicles, more carpooling, and less driving overall. These managed lanes include, but are not limited to, HOV lanes, green lanes for use only by vehicles with certain emission standards, and toll roads. Through planned use of features like these, the planning would in turn reduce emissions during the operation phase.

Provision TLU-11 would require state agencies to conduct an evaluation of the resulting transportation and land use GHG emissions related to state and local major capital projects such

as major road construction or modifications. The aforementioned ideas of measuring emissions from product manufacture and construction equipment emissions would both be useful in fulfilling this requirement.

- California Assembly Bill 32

Currently, California has one of the nation's most developed policies on climate change. While many state governments are focusing on power plant emissions, which comprise about 30% of all emissions, California's climate strategies regulate about 95% of all emissions. In response to transportation emissions, California Assembly Bill 32 requires retrofits to improve the fuel efficiency of heavy-duty vehicles. It also calls for energy efficiency and co-benefits audits for large industrial sources such as cement plants, a widely used product in highway construction.

The United Nations Climate Change Conference COP15, held in December 2009, sent a message out to the world that global warming and climate change are issues that need to be dealt with sooner rather than later. The United States, led by President Barack Obama, committed to reducing emissions to 17% below 2005 levels by the year 2020, and 80% below 2005 levels by 2050. Incorporating climate change into highway development is just one of many ways to start working towards these goals. The Copenhagen Accord states that developing countries are not subject to emissions abatement commitments and international consultations and analysis, but through the United States' reductions policies we hope to lead by example. The same is true for states within the United States. Should Maryland develop an effective way in which to incorporate climate change into highway development, the state may influence others to do the same.

F.2.2. CARBON TAX

Another way to control GHG emissions is to impose a tax on the carbon content of energy sources. When a tax is charged on producers of fossil fuels or first purchasers, they will in turn pass a portion of tax on to refiners, distributors, or industrial utilities in the case of oil, coal, and natural gas. Accordingly, customer will experience higher prices for using electricity, gas and services that utilize these energy inputs in the production process. Over time, consumers will be given incentives to use less energy such as driving less or purchasing more fuel-efficient vehicles. Similarly, suppliers will also consider using alternative fuels or renewable energy.

The level of carbon tax could be set on the basis of different countries conditions, energy resources, and supply and demand relations. World-wide, the carbon tax ranges from 4.4 cent per ton of CO_2 (San Francisco Bay Area) [83] to 150 dollars per ton (Sweden)[84]. The relationship between the price of carbon emissions and the economic potential for emissions reduction by technological innovations could provide some methods to set the price of the carbon tax. Carbon tax could generate substantial revenue, and some portion of the revenue could be used to develop advanced energy technology or energy efficiency programs, these related programs will obtain increased supports.

[83] San Francisco Chronicle, May 22, 2008
http://articles.sfgate.com/2008-05-22/news/17155215_1_carbon-dioxide-greenhouse-gas-emissions
[84] Review of Sweden Carbon Tax
http://www.colby.edu/personal/t/thtieten/eco-taxation.htm

F.2.3. CAP AND TRADE

In cap and trade (also known as emissions trading) program, the central authority (usually a governmental body) distributes or auctions allowances for emissions within a given period, and sets a limit or cap for regulated entities on the amount of pollutants that can be emitted. In the prescribed period, the emitters would be required to hold an equivalent number of allowances (or credits) to represent the legal right to emit a specific amount of GHGs.

Emitters that need to increase their number of emission allowances must buy credits from those who pollute less and offer their excess credits. The transfer of allowances is referred to as a trade, and is conducted through organized exchanges. The price of the trade is determined by the demand for permits by CO_2 emission sources and the supply of CO_2 emission permits issued by the government.

Cap and trade systems are intended to provide an economically efficient means to reduce overall carbon emissions by encouraging those who can cut emissions most cheaply to do so. Beginning in 1990s, there were several SO_2 and NO_x trading markets under the Clean Air Act (CAA) program, these trading systems have been proved to be effective in saving much of the cost of a regulatory approach to achieve the same outcomes.

- The European Union Emission Trading Scheme (EU ETS)

The European Union Emission Trading Scheme (EU ETS) is the biggest international carbon trading system. Its first 3-year phase ran from 2005 to 2007, and the second phase is now underway (2008-2012). EU ETS includes all 27 EU member states and other 3 non-EU members, with about 12,000 firms in six major industrial sectors (power, steel, cement, refining, ceramics, lime and glass). Combined, these sectors contribute 40% of all EU greenhouse gas emissions. The European Commission creates a cap for each member state, through a scheme called national allocation plans (NAPs). A company's allowance could be traded on the Cap-and-Trade market. Similar to a stock market, companies and private individuals can buy and sell allowances, through the following methods: (1) privately, moving allowances between operators within a company and across national borders, (2) over the counter, using a broker to privately match buyers and sellers, or (3) trading on the spot market of one of Europe's climate exchanges (the most liquid being the European Climate Exchange).

- US Regional Cap and Trade Programs for CO_2 and GHGs

- The Regional Greenhouse Gas Initiative (RGGI) includes ten states in the Northeast and Mid-Atlantic, as well as five observer states and Canadian provinces. The main sectors covered by the program are fossil fuel-fired electricity generating units having a rated capacity equal to or greater than 25 megawatts. Emissions of each plant are tracked by the RGGI CO_2 Allowance Tracking System (RGGI COATS). The regional emission cap was set slightly above 2005 levels through 2014. Beginning with the year 2015, the scheduled annual CO_2 emission budget will decline by 2.5% per year for each state, so that each state's base annual emissions budget for 2018 will be 10 below its initial base annual CO_2 emissions budget. The first three year compliance period began on January 1, 2009.

- Western Climate Initiative (WCI) Regional Cap-and-Trade Program emerged in Fab.2007, with seven US states and four Canadian provinces. The industries included in the program are electric utilities, industrial and commercial facilities, industrial processing (including oil and

gas), residential, commercial and fuel combustion facilities, and transportation fuel combustion. In terms of its size and scope, this program is the most comprehensive compliance market in the United States. The program will start on 1st Jan. 2012. Participants committed to an overall 15% decrease in total annual GHG emissions by 2020 below 2005 level. And by 2020, the WCI will be expected to extend its scope to cover nearly 90% of the regional GHG emissions.

The WCI employs four implementation tools to achieve the goal of reducing emissions. The first tool is capping carbon emissions, then auctioning or allocating permits to firms allowing the right to emit a ton of carbon dioxide equivalent. The WCI also calls for the implementation of three "complementary" tools used to help achieve the goal, including the implementation of California Clean Car Standards, energy efficiency programs aimed at reducing energy demand growth by 1%, and programs designed to reduce annual vehicle miles traveled growth by 2%.

- Chicago Climate Exchange (CCX) is a voluntary, legally binding integrated trading system to reduce emissions of GHGs. It has around 400 members ranging from States and municipalities such as Oakland and Chicago, to companies such as Ford, DuPont, and Motorola, to educational institutions such as the University of California, San Diego, and University of Minnesota.

The tradable instrument on CCX is called the Carbon Financial Instrument® (CFI®) contract, which represents 100 metric tons of Exchange Allowances or Exchange Offsets. Members are allocated annual emission allowances by CCX in accordance with the CCX Emission Reduction Schedule, which requires a 6% reduction in absolute GHG emissions from a standardized emission baseline. The program design allows Members who reduce beyond their targets to sell their surplus allowances or bank them for future use; those who do not meet the targets must comply by purchasing CFI contracts. Members' baselines and annual emissions data are independently verified by the Financial Industry Regulatory Authority (FINRA), which provides independent regulatory oversight to CCX. Entities or individuals who trade on CCX for purposes other than complying with the emissions reduction requirements, may join the Exchange as Liquidity Providers.

- The Midwestern Greenhouse Gas Accord (MGGA) is a regional agreement signed by mid-western US states and Canadian provinces calling for a reduction in greenhouse gas emissions and productive responses to climate change. The MGGA's members are states Iowa, Illinois, Kansas, Michigan, Minnesota, Wisconsin and the province Manitoba, while its observers are Indiana, Ohio, Ontario and South Dakota. The Midwest's industrial and agricultural sectors make it the most coal-dependent region in North America.

The Accord was signed on November 15, 2007. It establishes the Midwestern Greenhouse Gas Reduction Program, which aims to establish greenhouse gas reduction targets and time frames consistent with signing states' targets; develop a market-based and multi-sector cap-and-trade mechanism to help achieve those reduction targets; establish a system to enable tracking, management, and crediting for entities that reduce greenhouse gas emissions; and develop and implement additional steps as needed to achieve the reduction targets, such as a low-carbon fuel standards and regional incentives and funding mechanisms.

Table F-1 Major Carbon Trading Schemes

	EU	CCX	RGGI	WCI	MGGA
Participants	27 EU member states and 3 non-EU members (Norway, Iceland, and Liechtenstein)	Over 400 members ranging from states and municipalities, to companies, to educational institutions	CT, DE, MA, MD, ME, NH, NJ, NY, RI, VT	AZ, CA, MT, NM, OR, UT, WA, British Columbia, Manitoba, Ontario, and Québec	KS, IL, IO, MI, MN, WI, and Manitoba (Canada)
Observers	-	-	PA, DC, Québec, New Brunswick, Ontario	AK, CO, ID, KS, NE, WY, Saskatchewan (Canada),and the Mexican states of Baja California, Chihuahua, Coahuila, Nuevo Leon, Sonora and Tamaulipas	IN, OH, SD
Timeline	January 2005	December 2003	January 2009	Start date: Jan 1, 2012	Start date: Jan 1,2011
GHG Coverage	CO_2	CO_2, CH_4, N_2O, HFC, PFC, SF_6	CO_2	CO_2, CH_4, N_2O, HFC, PFC, SF_6	CO_2, CH_4, N_2O, HFC, PFC, SF_6
Industrial Cap	2200 $MMTCO_2$-eq	585 $MMTCO_2$-eq	188 $MMTCO_2$-eq	N/A	N/A
Instrument	European Union Allowance (EUA),	Carbon Financial Instrument (CFI)	RGGI CO_2 Allowance	N/A	N/A
Contract size	1 $MTCO_2$-eq on spot 1000 $MTCO_2$-eq future and option	100 $MTCO_2$-eq	1000 $MTCO_2$-eq	N/A	N/A
Target	20% below 1990 level by 2020	6% below 2000 baseline emissions level by 2010.	2009–2014 equal to historical emissions. 2015–2018 cap declines 2.5% per year.	Regional average reduction of 15% below 2005 levels by 2020 (jurisdiction targets vary).	20% below 2005 levels by 2020 and 80% below 2005 levels by 2050.

	EU	CCX	RGGI	WCI	MGGA
Scope	Mainly large stationary sources in the power, steel, cement, refining, ceramics, lime, and glass sectors as well as combustion installations (e.g. chemical crackers, dryers)	Voluntary, rule-based registry	Large electric generators. Covers 28% of regional CO_2 emissions	In 2012 — electricity generators and large industrial sources. Covers 50% of regional CO_2 emissions In 2015 — expanded to emissions from residential, commercial, and other industrial combustion, and transportation fuels. Covers nearly 90% of regional CO_2 emissions.	Electric, industrial, residential, commercial, transportation combustion and industrial process emissions. Covers nearly 90% of regional CO_2 emissions.
Allowance distribution	Based on the National Allocation Plan (NAP). Only 4% are auctioned. From 2013 on, auctioning will be a far greater share (at least 50%) of emission permits.	Based on member emissions baseline and the CCX Emission Reduction Schedule	Nearly 100% auction	Partner allowance budget. Minimum of 10% the allowance will be allocation auctioned in the first compliance period. The minimum percentage increases to 25% in 2020.	N/A
Value and volume (2008)	3100 MT of carbon credits traded with a total value of $90B	69.2 MT of carbon credits with a total value of $307M	N/A	N/A	N/A
Offset limits	No more than 50% of emission reductions, EU-wide, typically implemented by member states as a percentage of covered entities' emissions	No more than 50% of required program-wide emission reductions	3.3% initially, expands to 5% and 10% if price triggers met ($7 and $10 per ton).International offsets allowed if price is above $10	Limited to less than 49% of emissions reductions relative to starting cap	20% of compliance obligation, may expand if allowance prices rise above price thresholds

APPENDIX G: SAMPLE GPC PROVISION AND SPECIFICATION

Level I - Material Related Strategies:

Document 1:
Pavement Recycling Guidelines for State and Local Governments Participant's Reference Book
(Note: Guide book from Federal Highway Administration about pavement recycling. There are example specifications for cold-mix recycling found at the end of the document.)
http://www.fhwa.dot.gov/pavement/recycling/98042/Frontpg.pdf

Document 2:
Wisconsin Administrative Code Chapter NR 538
(Note: These are the standards for the use of industrial byproducts in Wisconsin.)
http://legis.wisconsin.gov/rsb/code/nr/nr538.pdf

Document 3:
INDOT Special Provision 200-R-401. Recycled Foundry Sand
(Note: These are requirements for the use of recycled foundry sand from Indiana DOT)
http://www.in.gov/dot/div/contracts/standards/rsp/sep07/200/200-R-401%20070901.pdf

Level II - Equipment and Energy Efficiency Strategies

Document 1:
FEIS Air Quality Technical Report
(Note: This is an air quality analysis for the Inter-county Connector (ICC) in Maryland.)
http://pdf.iccstudy.org/FEIS/pdfs/tech/AQReport.pdf

Document 2:
MHD Certification of Construction Equipment Compliance
(Note: This is a contract for companies in Massachusetts signing that they agree to use retrofit equipment verified by EPA and CARB.)
http://www.epa.gov/diesel/construction/documents/cl-mhd-compliance.pdf

Document 3:
IDOT Dan Ryan Vehicle Emissions Spec
(Note: The Dan Ryan Expressway project in Illinois focuses on emission reduction through idle-reduction practices, EPA verified emission control devices, and by using ULSD fuel.)
http://www.epa.gov/cleandiesel/documents/cl-idot-emissions.pdf

Document 4:
Destiny USA Idle-Reduction Policy
(Note: This is an EPA policy put into place to control unnecessary idling from onsite equipment and vehicles.)
http://www.epa.gov/diesel/construction/documents/cl-destiny-usa-idle-reduction.pdf

Level III: Green Life Cycle Strategies

Document 1:

GreenLITES Score Card
(Note: This is the self-evaluation score card of NYDOT GreenLITES program)
https://www.nysdot.gov/programs/greenlites/repository/GREENLITES_Scorecard_2%201%200.xls

Document 2:
GreenLITES Project Design Certification Program
(Note: This is the handbook of NYDOT GreenLITES project design certification program)
https://www.nysdot.gov/programs/greenlites/repository/Green%20LITES%20Certification%20Program%20Document%20-%20April%202010.pdf

Document 3:
Greenroads Rating System Manual
(Note: This is the Washington Greenroads Rating System version 1.5 manual.)
http://www.greenroads.us/files/236.pdf

Document 4:
Assessment of Greenhouse Gas Analysis Techniques for Transportation Projects
(Note: This is an AASHTO's report for GHG analysis techniques, including a long list of available methodologies for GHG emission analysis.)
http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/25-25(17)_FR.pdf

Level IV – Clean Energy Development

Document 1:
Oregon Business Energy Tax Credit (BETC) Overview
(Note: This is the overview of the energy credit used in the Oregon Solar Highway pilot project)
http://www.oregon.gov/ODOT/HWY/OIPP/docs/BETCoverview2007sept.pdf

Document 2:
Summary of Proposed West Linn Solar Highway Project Site Feasibility Analysis
(Note: This is the feasibility analysis report of Oregon West Linn Solar Highway Project)
http://www.oregon.gov/ODOT/HWY/OIPP/docs/WestLinnSummary_031710.pdf

Document 3:
Life-Cycle Greenhouse Gas Analysis for the Proposed West Linn Solar Highway Project
(Note: This is the environment review report especially for GHG emissions for Oregon West Linn Solar Highway Project)
http://www.oregon.gov/ODOT/HWY/OIPP/docs/Solar_WestLinnGHGanalysis.pdf

APPENDIX H: CLIMATE CHANGE WEBSITE IN OTHER STATE DOTS

Below is a list of the official websites built specially for climate change issues from different states.

California:
http://www.dot.ca.gov/climateaction.htm

Maryland:
http://www.green.maryland.gov/climate.html

Massachusetts
http://www.mass.gov/?pageID=eoeeasubtopic&L=3&L0=Home&L1=Air,+Water+%26+Climate+Change&L2=Climate+Change&sid=Eoeea

Michigan:
http://www.michigan.gov/documents/deq/deq-miclimateactionplan-part1_276563_7.pdf

New York:
https://www.nysdot.gov/programs/climate-change

Oregon:
http://www.oregon.gov/ODOT/TD/CLIMATECHANGE/index.shtml

Vermont:
http://www.aot.state.vt.us/planning/Documents/Planning/VTransClimateActionPlanfinal1.pdf

Washington:
http://www.wsdot.wa.gov/environment/climatechange/

Wisconsin
http://dnr.wi.gov/climatechange/