

GREEN CONTRACTING IN HIGHWAY CONSTRUCTION: STATE OF PRACTICE

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ABSTRACT

Growing public awareness of climate change requires transportation professionals to integrate green concepts into the transportation planning, design, construction, and operation processes. For the past decade, while many studies have been done regarding carbon emission reduction strategies for on-road and off-road operations, very few have dealt with emission reduction issues in highway project delivery. This paper, based on a survey of 39 State Departments of Transportation, reports the green contracting practice for delivering highway projects in the U.S. Four levels of green contracting strategies and their application procedures are identified. Organizational reasons for successful implementation of green contracting are presented and discussed. More importantly, the study discovers there is a substantial lack of consistent methodology and processes for implementing green contracting. Nor is there a common vocabulary in this field. In an effort to promote green contracting in highway construction, the study suggests that state highway agencies, 1) establish organization-wide green initiatives; 2) develop green specifications and standards; 3) encourage broader industry participation

INTRODUCTION

There is overwhelming evidence that global warming exists as a man-made phenomenon. According to the Intergovernmental Panel on Climate Change (IPCC), the warming is predominately due to the increased concentration of greenhouse gases (GHG), mainly carbon dioxide, in the atmosphere as a result of fossil fuel use and land use change (1). Since 1997, various global efforts have been made to curb greenhouse gas emissions and adapt to climate change resulting from global warming. At the Copenhagen climate summit in December 2009, both developed and developing countries made strong commitments on mitigating and adapting to the climate challenge. The United States officially pledged to cut its greenhouse gases emissions by 17% from the 2005 level by 2020. Many state and local governments have adopted even more aggressive reduction targets to tackle climate change. For example, AB 32, passed in 2006, requires the state of California to reduce greenhouse gas emissions by 25% by 2020. Similarly, in Maryland, the Greenhouse Gas Emissions Reduction Act of 2009 sets the target at 25% below 2006 levels by 2020.

The transportation sector is the second largest source of carbon dioxide in the U.S., and accounts for almost 30% of carbon emissions, which is only 5% lower than that of electricity generation. Therefore, to reach the federal and states' emission reduction target, transportation agencies must achieve a substantial carbon emissions reduction from both on-road and off-road transportation sources. While many studies have been done regarding emission reduction from on-road operations, very few have focused on carbon emissions from highway infrastructure development and construction. Additionally, there have been no comprehensive studies exploring the strategies to integrate emission reduction into highway project delivery. To reduce carbon emissions by construction and maintenance activities, transportation agencies need to develop innovative contracting strategies and integrate construction firms' equipment and material usage into agencies' carbon emission reduction programs.

This paper is aimed to investigate various contracting strategies for tackling climate change in highway construction. The paper briefly reviews early studies on construction emissions and sustainable practices, and then defines green contracting in highway projects. A survey of state Departments of Transportation is reported in which information was gathered regarding current practices and the implementation status for green contracting strategies. The research furthermore identifies the forms and procedures to integrate green contracting strategies into the existing project delivery system. Challenges and recommendations for organizational and specification change are also discussed.

CONSTRUCTION EMISSIONS

Total U.S. greenhouse gas emissions have risen by 17% from 1990 to 2007 and reached 7,150 Million Metric Tons of carbon dioxide equivalents (MMT CO_2e) in 2007. This represents a 0.6% growth (41.5 MMT CO_2e) from the 2005 emission level of 7,109 MMT CO_2e (2). The majority of U.S. greenhouse gas emissions come from energy production, electricity generation, and petroleum usage, which generate about 34% of the total emissions. Transportation activities account for the second largest portion (29%). Emissions from industry processes contribute 20%, while the remaining 18% comes from the residential, agriculture, and commercial sectors.

Construction activities contribute a small portion of the U.S. carbon emissions. According to the U.S. Environmental Protection Agency (EPA), 131 MMT CO_2e were produced by construction site activities in 2002. This represents about 1.7% of total U.S. emissions, or 6% of U.S. industrial carbon emissions. Within the 131 MMT of carbon emissions from the construction industry, 76% resulted from fossil fuel combustion for on- and off-road construction equipment, and 24% came from purchased electricity. Highway and bridge construction, specialty trade contractors, and water and sewer line structures construction are typically considered as being emission intensive and produce far more carbon dioxide than vertical construction activities (3).

One must note that the EPA estimates do not include emissions from materials extraction, production, transportation, use, and disposal. A large amount of materials are being consumed by the

construction industry, which signifies the magnitude of carbon emissions due to embodied energy. For example, the U.S. construction industry used more than 110 million tons of cement in 2000 (4). Total carbon emissions from cement manufacturing and processing reached 76.9 MMTCO₂e in 2001 (5). The U.S. Geological Survey estimated that the construction industry consumes 16% of total iron and steel production annually, which accounted for over 20 MMTCO₂e in 2002.

Considering the fact that 54% of energy consumption is directly or indirectly related to facility construction and operation, embodied emissions created through the extraction, processing, transportation, construction, and disposal of materials should be counted in the construction carbon emissions (4). The Green Design Institute at Carnegie Mellon University (CMU-GDI) developed an Economic Input-Output Life Cycle Assessment (EIO-LCA) model that can estimate indirect (embodied) carbon emissions in addition to direct emissions by construction activities. The model includes 485 commodity sectors and traces all supply chain inputs into construction (6). Based on the 2002 U.S. benchmark input-output (I-O) accounts, the EIO-LCA model calculates life-cycle carbon emissions by construction sectors ranging from 41.7 to 67.6 MMTCO₂e per \$100 billion of economic activity. Given the construction value put in place at \$861 billion in 2002, the total life-cycle carbon emissions by the construction industry were 470 MMTCO₂e, of which one-fourth were from indirect emissions (7, 8) (Table 1).

<Insert Table 1 here>

GREEN CONTRACTING

There is no universally agreed upon definition of “going green” or sustainability. Nor is there a clear definition of green contracting in highway construction. Molenaar et. al (9) evaluated the performance of various project delivery methods (design-build, design-bid-build, and construction manager at risk) in delivering LEED certified building projects. Klotz et. al (10) proposed a detailed modeling protocol for evaluating the delivery processes of green projects. However, green project delivery remains undefined.

In this paper, we define green contracting in highway projects using the idea of “triple bottom line” approach to measure “being green” and sustainability. Specifically, the green contracting is defined as contract provisions, contracting methods, and delivery strategies at three configuration scopes: 1) reduce emissions and improve adaption to climate change (scope 1); 2) benefit the environment (scope 2); 3) improve the quality of public lives through a direct economic, ecological, or social benefit (scope 3). To align with the research objective, this paper focuses on the green contracting strategies within scope 1. A broader definition could cover sustainability’s triple bottom line of economic, environmental, and social aspects.

As to the definition, a great number of contracting strategies could be identified as green due to their direct or indirect contribution to emission mitigation and adaptation. For example, diesel engine retrofit and use of alternative fuels in construction equipment would reduce the consumption of fossil fuels, directly lowering the emissions from highway construction operations. Use of reclaimed asphalt pavement, on the other hand, reduces the demand for virgin materials and limits energy use and emissions resulting from the production and delivery of virgin materials. Green contracting strategies were further classified into four levels in accordance with the applied project phases and emission sources addressed by the strategies. Table 2 shows some examples of green contracting strategies for each level.

<Insert Table 2 here>

SURVEY DESIGN AND IMPLEMENTATION

From April to June 2010, all state Departments of Transportation (DOTs) were surveyed about their use of green contracting in highway development and improvement projects. The survey was part of a research project sponsored by the Maryland State Highway Administration (MSHA). The overall objective of the research project was aimed to identify, evaluate, and develop innovative contracting

strategies for managing climate change and sustainability at the project level. In cooperation with MSHA officials, the University of Maryland researchers prepared the survey questionnaire to investigate and document the state of practice of green contracting. In addition to respondents' background data and their general interest in green contracting, the questionnaire consisted of 12 questions and covered the following topics:

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

The survey was conducted via email and an online form, with follow-up phone interviews with 12 officials from 7 state DOTs to gain additional information. The survey results are summarized in Figures 1 through 5, with observations and recommendations discussed thereafter.

The survey was originally targeted at and sent to state contract engineers. The final responses, however, came from a diverse set of DOT officials. Of the total 39 completed questionnaires, only one-third were filled out by contract engineers. The majority of the respondents have varied professional backgrounds that cover all phases and aspects of highway project development, including construction engineers, design engineers, planning engineers, environmental engineers, public communication officials, and DOT executive and special program officials (Figure 1). During the follow-up interviews, most interviewees reported that the responses actually came from a group of state engineers, although only the coordinator was listed on the survey.

Observation 1: *Green contracting is not just contracting, but an issue throughout the project life cycle.*

<Insert Figure 1 here>

GREEN CONTRACTING PRACTICES

While 14 out of 39 respondents indicated no green strategies had been used in their states, the remaining 25 states reported the use of Level I strategies, particularly using recycled materials in highway construction (Figure 2). About half of the 25 states also incorporated warm mix asphalt into their construction specifications. There are a total of 12 states that have implemented at least one Level II green strategy in addition to Level I strategies. Within all Level II strategies, 10 states adopted idling reduction policies, 9 utilized alternative fuels, 7 launched engine retrofit programs, and 4 established energy efficiency programs. Additionally, California, Illinois, New York, Oregon, and Washington have integrated green road rating or energy and emission analysis (Level III strategies) into their highway project development processes.

Furthermore, Oregon DOT developed its first solar highway project in 2008, and continues to expand the installation of solar panels in the highway right-of-way to generate power for highway lighting. Although the Massachusetts Highway Department has not developed any clean energy projects, the Massachusetts Turnpike Authority is currently building a wind turbine near the turnpike rest area (11). The Maryland SHA also installed a wind turbine in 2009 to power an agency facility. Several state DOTs (e.g. CA, IL, MI) are pursuing federal grants for renewable energy projects, including green rest areas and solar powered interchanges.

<Insert Figure 2 here>

Observation 2: *State DOTs have various levels of experience in applying green contracting to highway projects, from material related strategies, to equipment and energy efficiency, to life-cycle green strategies.*

It should be noted that 14 respondents who stated that no green contract provisions were used in their highway construction projects, may fail to include agency practices in the area of material recycling and reuse. According to FHWA (12), reclaimed asphalt pavement was permitted as an aggregate in the hot recycling of asphalt paving mixtures in almost all 50 states. The discrepancy may be explained by respondents' comments about the challenges in implementing green contracting. Their comments suggest a widespread perception among transportation professionals that going green is expensive. 12 out of 18 comments listed extra cost as a critical concern for implementing green contracting. Because of a lack of common vocabulary on what exactly green contracting means, many transportation professionals may be unaware that some green contracting strategies are in essence cost-driven and have already been integrated into their design and construction specifications, e.g. recycled materials, traffic control plans, and nighttime construction, that help reduce emissions resulting from work zone congestion. The discrepancy also indicates that reducing greenhouse gas emissions has not been a principal factor in their construction and maintenance decisions.

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

GREEN CONTRACTING PROCEDURES

Green contracting can take a number of forms: contract requirements, bidding preferences, or contract allowances (13). The survey results show that a majority of state agencies implemented green contracting strategies effectively by including green requirements into standard specifications or issuing special provisions (Figure 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 for cost reasons. Therefore, standard specifications do indicate the maximum allowable percentages of recycled materials to ensure quality of structural performance.

If a contractor commits to using green construction equipment, materials, and techniques, a bidding preference is given to the contractor during the evaluation of bids. Probably due to a strong industrial resistance against the use of bidding preferences for engine retrofitting, the current practice of giving bidding preference to green companies in highway projects is limited to the area of work zone mobility strategies, and in the format of cost-plus-time bidding or the lane rental method. An example is the Arkansas Highway and Transportation Department (AHTD) that considered construction schedule methods (i.e. full closures, nighttime construction, alternative project phasing, etc.) in bid evaluation procedures. It was reported that by using bidding preference on an interstate reconstruction project in central Arkansas, AHTD selected a highly productive paving company, which expedited project delivery and improved work zone mobility (14).

Contract allowance and government grants provide an opportunity to offset part or all of the initial cost of green equipment, technologies, and products. Government grants have been used successfully in California and Texas to spur cleaner off-road equipment. Texas DOT Special Specification 5018 provides contract allowances for the use of cleaner engines and fuels on roadway and maintenance projects. Until November 1, 2007, eligible off-road engines had been qualified to receive an incentive payment that was based on two factors, namely engine horsepower and operation time of equipment on-site.

<Insert Figure 3 here>

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

OTHER IMPLEMENTATION ISSUES

Three questions were asked about the project type, delivery method, and contractor compliance issue for the implementation of green contracting strategies. There has been a concern that green contracting is unaffordable for small projects, considering the extra cost of going green. The survey results, however, do not support the concern (Figure 4). Currently, green contracting strategies have been applied to both small and large projects. More than 10 states used green contracting strategies on various sizes of highway projects. Within the five states implementing Level III green contracting strategies, New York implemented greenhouse gas emission and energy analysis on all sizes of highway projects. However, one should not conclude that there is no extra cost of green contracting. Nor might one conclude that green contracting already has construction industry buy-in. According to Massachusetts DOT, the extra cost associated with an engine retrofit requirement is almost incidental, primarily because of the current global recession. Similar for Massachusetts DOT, the economic downturn resulted in an obvious increase of contractor competition, and the bid prices dropped up to 20% compared to previous bids. However, the long-term cost impact of green contracting remains unclear.

Green contracting appears to fit easily into all the major project delivery systems: Design-Bid-Build (DBB), Design-Build (DB), and even Construction Manager at Risk (CM@Risk). 5 out of the 39 states that responded adopted green contracting strategies through both DBB and DB procurement routes, while the other 14 states used green contracting strategies only on traditional DBB projects (Figure 4). Within these 14 states; however, 10 states have very limited or no form of legislated Design-Build procurement authority, according to the Design-Build Institute America's 2010 report (15). 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.

<Insert Figure 4 here>

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

Since most green 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, payment withheld, and even termination of the contract.

PRIMARY REASONS FOR GREEN CONTRACTING

Everyone agrees that going green benefits the environment and preserves natural resources. However, the implementation of green contracting strategies in highway projects still needs compelling reasons because of their potential cost impact. The survey finds that 9 out of 13 states use material-related strategies primarily for economic reasons. At the contractor's request, state agencies allow the use of recycled materials or warm-mix asphalt as a substitute for hot mix asphalt. The other 4 states (Delaware, Kansas, Mississippi, and Utah) use recycled materials mainly due to agency-wide green initiatives or to enhance the agency's public image.

Equipment and energy efficiency related contracting strategies, on the other hand, are expected to result in incremental costs in project construction, and therefore need extra organizational support through agency policies, initiatives, regulations, or even legislations. Missouri DOT established its green initiative program to award green contractors. Under this program, the agency assigns a "green credit" goal for the contractor and appoints a "green credit" value for the use of various environmentally friendly practices, including alternative fuels and recycling. In Vermont, besides a green initiative within the highway agency, a state climate change commission was established three years ago by the governor to both promote energy efficiency and 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 initiative was aimed to support 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 should produce a reduction of 7.3% below 1990 transportation greenhouse gas emissions, or 30% below the “business as usual” level.

***Observation 6:** Some green contracting strategies are primarily cost-driven and easily integrated into contract specifications. However, higher levels of green contracting strategies may be demanded by local green initiatives, mandates, or legislations (Figure 5).*

<Insert Figure 5 here>

The green life-cycle strategies are entirely driven by state policy and legislation, and are currently used in the area of green highway rating and project-level emission and energy analysis. In New York, the State Energy Plan requires the state DOT to conduct a greenhouse gas energy analysis of its transportation plans. As one of its major climate change and energy initiatives, New York State DOT developed a transportation environmental sustainability rating program and began self-certification for all project designs submitted 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 its sustainability program to respond to Oregon statute ORS 184.421 and Executive Order 06-02. Under this program, Oregon DOT undertook a greenhouse gas impact analysis on the Columbia River Crossing project and is currently evaluating three pilot projects based on the Greenroads sustainability performance metric. The agency has also produced guidance for project level greenhouse gas and climate change evaluations. In Illinois, along with the agency’s green initiative, an Office of Sustainable Practice was established to guide the agency’s sustainable practices in the areas of planning, design, construction, maintenance, operations, and others. On the other hand, 12 out of 14 states that had no green contracting experience also reported no on-going green efforts within their highway agencies, although two-thirds of these respondents expressed their interest in involving green perspectives in their agency operation and construction projects.

EMISSION TYPES AND SOURCES

Highway construction activities have the potential to generate a substantial amount of air pollution. Therefore, the emissions from construction activities must be assessed, and when necessary, mitigated if the emissions cause a significant air quality impact. These emissions include fugitive dust generated from grading, exhaust emissions of particulate matter (PM), nitrogen oxide (NO_x) from construction equipment, and evaporative emissions of reactive organic compounds (ROG) from paving activities. More recently, levels of exhaust emissions of greenhouse gases (GHG), such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), have also become an increasing concern due to the role they play in climate change.

Many states DOTs have 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 to most state DOTs, and therefore, have not been widely integrated into environmental impact assessments. The survey shows that only three state DOTs (NY, OR, WA) have addressed the greenhouse gas impacts of highway construction activities. Many transportation professionals may also not be aware that most green contracting strategies can reduce greenhouse gas emissions, in addition to addressing other construction-related emissions. Table 3 lists typical construction-related emission sources and green contracting strategies for GHG mitigation.

<Insert Table 3 here>

CLIMATE CHANGE IMPACT ANALYSIS

Quantifying climate change impacts at the project level is relatively new and lacks a consistent format and language. Currently, only California, New York, and Washington have developed guidance or a methodology for project-level GHG and climate change evaluation. In New York, a GHG analysis is performed and included in the environmental project documentation for major projects during the project design phase. The GHG analysis is integrated into the project-level energy analysis. Indirect energy use as the energy required to construct and maintain transportation facilities is quantified, and then the carbon dioxide emissions from roadway projects can be determined by multiplying a carbon emission coefficient. 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 emissions and lifecycle emissions. In California, comprehensive guidelines and procedures for evaluating project-level GHG emissions from highway construction are still under development. However, the California DOT has been able to estimate GHG emissions from construction equipment operations, and then 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 ones are EPA's Motor Vehicle Emission Simulator (MOVES) model and NONROAD model. While the MOVES model estimates emissions from highway operation, the NONROAD model can calculate the emissions from non-road engines, equipment, and vehicles. Several metropolitan planning organizations did project-level analysis of GHG emissions using EPA's MOVES and NONROAD models. The Sacramento Metropolitan Air Quality Management District developed a road construction emission model (RCEM) to assess highway construction emissions. Another EPA recommended tool, called Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE), is also available to estimate construction emissions and evaluate the life-cycle cost impact of varied pavement designs. Additionally, Michigan and Maryland have on-going research efforts to develop their own guidance and methodologies for project-level GHG emissions. Although all of these models are available, there is no federal guidance on how to address project-level GHG emissions. Nor are there federal or state 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 brings green standards to highway construction. It also helps develop a list of best practices in constructing sustainable roads. The survey identified three rating systems currently used in the U.S., namely, GreenLITES, Greenroads, and I-LAST. The Green Leadership in Transportation Environmental Sustainability (GreenLITES) is the only rating system endorsed by a state highway agency. According to New York State DOT, all project Plans, Specifications & Estimates (PS&Es) submittals 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 Illinois-Livable and Sustainable Transportation (I-LAST) rating system is also voluntary in nature. The purpose, 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 4.

<Insert Table 4 here>

Observation 7: A number of green highway rating and climate change impact analysis systems are available. Yet there is currently no widely endorsed method.

CHALLENGES

The respondents at many of the state DOTs provided very useful comments and challenges associated with the use of green contracting strategies. These comments are summarized below.

- It is expensive to go green. 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.

CONCLUSION AND RECOMMENDATIONS

In summary, state DOTs have various degrees of experience regarding the use of green contracting strategies in highway projects. It seems feasible and promising to integrate green elements into highway construction contracts. The survey clearly shows an increasing interest in green contracting by transportation agencies and professionals, but more collaborative research and outreach work is required. The biggest challenge facing public agencies is that there are no consistent methodologies and processes for implementing green contracting, nor is there a common language in this field. Some of the recommendations from the research include the following:

- Transportation agencies are recommended to create an agency-wide green initiative to promote green practices at the project level. Many green contracting strategies require strong organizational support and collaboration from other areas beyond contracting and the construction administration for successful implementation. The initiative could be led by an environmental division (e.g. NY), a planning division (e.g. CA), or a special office (e.g. IL).
- The highway construction community needs to develop shared vocabulary and guidance for green contracting. This common vocabulary should be able to cover existing green strategies and may be under an integrated framework of environmental performance contracting.
- Green contracting strategies should be integrated into the states' highway development, design, and construction guidelines. The state agencies should work toward green specifications and standards as guidelines for highway development.
- The implementation of green contracting strategies should involve broader industry participation and follow a path from cost-driven strategies toward results-oriented strategies.
- A federal-endorsed rating system will align all on-going efforts in this area. Guidance, procedures, and methodologies for energy and GHG emission analysis should be developed based on the best practices in leading states.

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TABLE 1: Greenhouse Gas Emissions in the Construction Industry

Sectors	Data Date	GHG Emission (MMTCO ₂ e)	% 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

TABLE 2: Example Green Contracting Strategies

Level	Green Contracting Strategy
I: Material Related Strategies	Material Recycling And Reuse
	Warm Mix Asphalt
	Waste Management
II: Equipment and Energy Efficiency	Equipment Retrofit
	Engine Replacement and Upgrade
	Idling Reduction
	Alternative Fuels
	Truck Staging Zone
	LED Lighting
	Work Zone Mobility
III: Green Life Cycle Strategies	Green Road Rating System
	Climate Impact Analyses
	Climate Adaptation Design
IV: Clean Energy Development	Solar Highway
	Highway-Based Wind Turbines

TABLE 3: 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

TABLE 4: 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

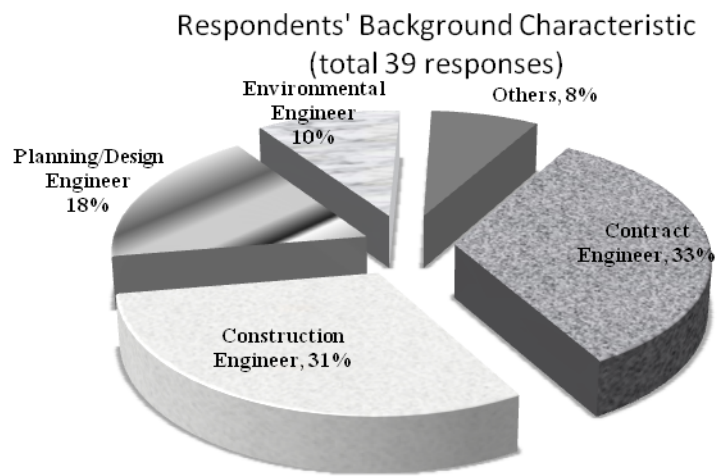


FIGURE 1: Respondent Profile

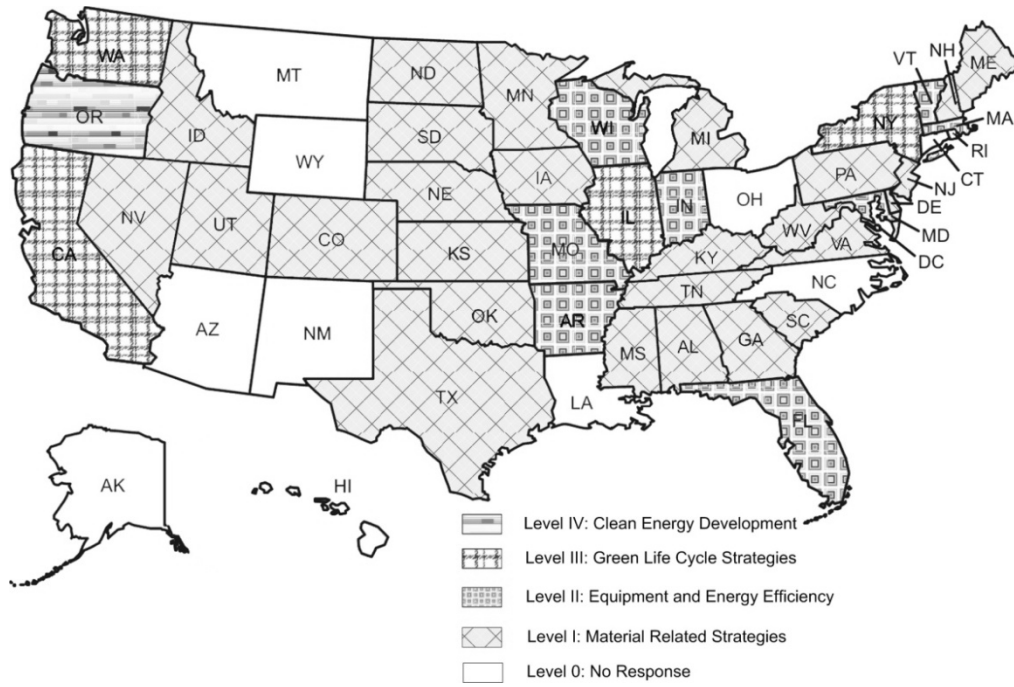


FIGURE 2: State DOTs' Green Contracting Practices

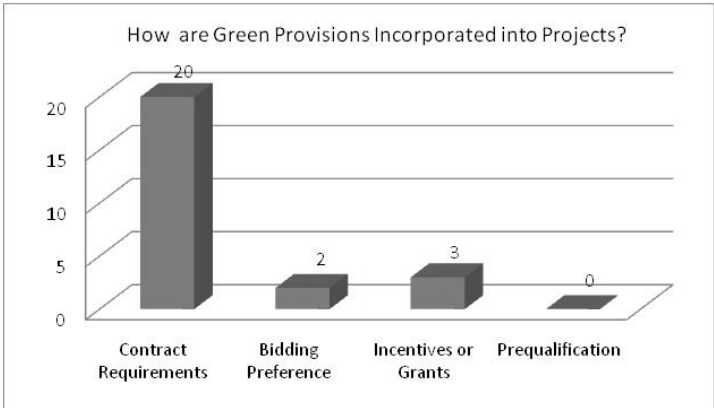


FIGURE 3: Green Contracting Procedures

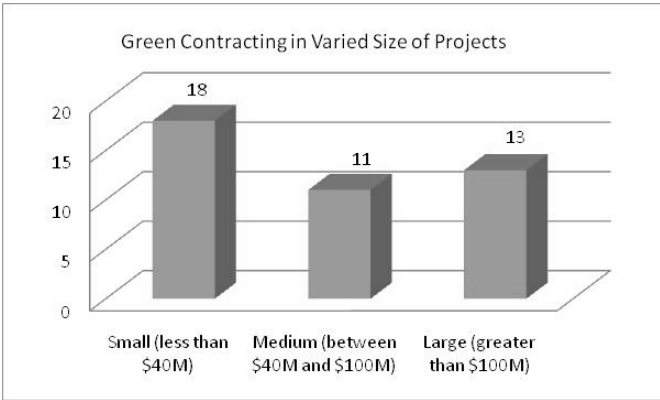


FIGURE 4 (a): Green Contracting Implementation Issues, Size of Projects

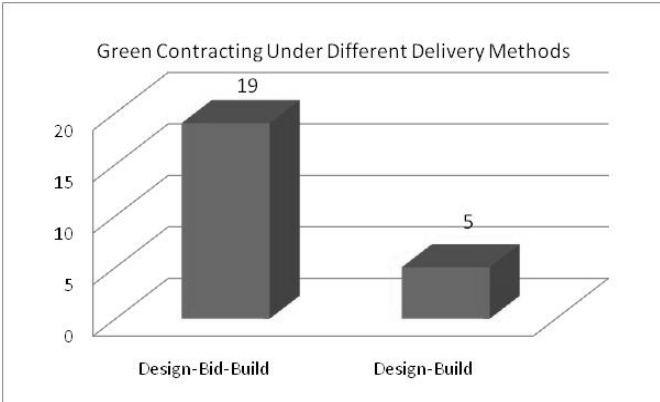


FIGURE 4 (b): Green Contracting Implementation Issues, Delivery Methods

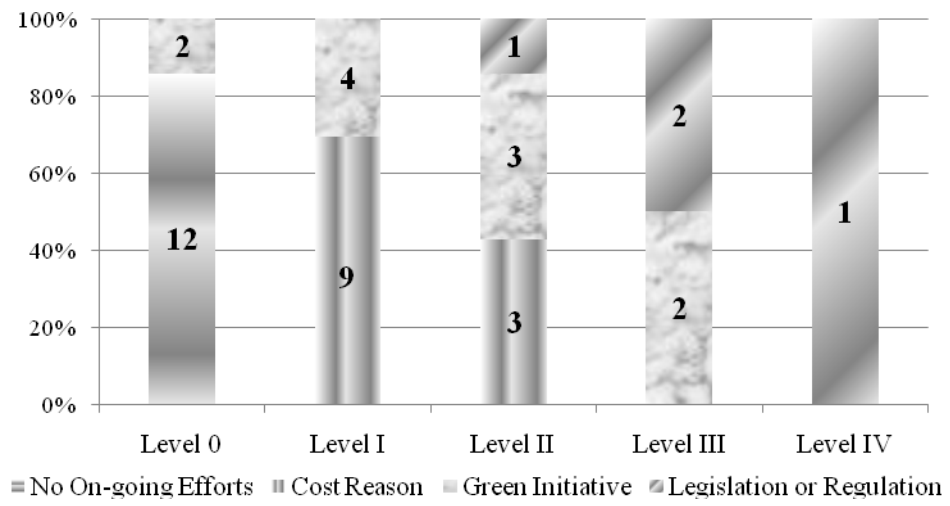


FIGURE 5: Primary Reasons for Green Contracting