MATERIAL PROGRESS:

Advancing Maryland's Carbon Reduction Strategy Through Low-Carbon Transportation Materials

JUNE 10, 2024

MDOT MARYLAND DEPARTMENT OF TRANSPORTATION

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1.1 Introduction

The Maryland Department of Transportation (MDOT) is requesting $48,417,000 from the Federal Highway Administration (FHWA) Low-Carbon Transportation Materials (LCTM) program[1] to support ***Material Progress: Advancing Maryland's Carbon Reduction Strategy Through Low-Carbon Transportation Materials.*** The purpose of this program is to **advance the comprehensive utilization of construction materials, products, and treatments that have substantially lower levels of embodied carbon associated with the production stage as compared to the estimated industry averages of similar materials or products.** This investment will support Maryland's efforts to reduce greenhouse gas (GHG) emissions, strongly aligning with the State of Maryland's goal set in its Climate Solutions Now Act (CSNA) to reduce GHG emissions by 60 percent over 2006 levels by 2031 and achieve net-zero emissions by 2045. In alignment with **MDOT's Carbon Reduction Strategy** and building upon the work supported through FHWA's Climate Challenge Project, MDOT is seeking methods to reduce carbon emissions generated from construction materials. MDOT is building upon the funding provided by the FHWA Climate Challenge Project to develop Environmental Product Declarations (EPD) for our producers and moving to deployment. **The funding requested in this application will advance the sustainability of federal-aid eligible construction in Maryland by pursuing the Project Objectives shown in** Figure 1-1**.** In practice, key activities supported by this funding may include:

Figure 1-1 | Project Objectives

- **Identify, test, and deploy** lower embodied carbon construction materials;
- **Confirm the efficacy of engineering performance** in LCTM applications;
- **Assess alternate binders, rejuvenators, manufacturing processes, etc.** to ensure appropriate use in construction projects;
- **Develop and maintain an LCTM source of supply review and materials clearance** to support increased use of LCTMs at the local and municipal levels in Maryland; and
- **Promote technology transfer and workforce development** to increase the use of LCTMs and to support quantification and analysis to inform material selection for transportation projects.

- Optimizing high reclaimed asphalt pavement (RAP) and concrete mixes; using rejuvenating agents, crumb rubber modifiers, reducing GHG emissions by as much as 30% by increasing RAP to 30-50%;
- Improving chemical warm mix asphalt, the use of supplementary cementitious materials, and blended cement with up to 15% limestone addition
- Identifying opportunities for low carbon in steel, concrete, and cement applications;
- Reviewing and incorporating applications for glass and recycled plastics in mixes to reduce environmental impacts; and
- Adopting materials and products with lower embodied GHG emissions in road construction projects.

Material Progress **will accelerate the adoption of low-carbon materials and products with lower embodied GHG emissions on federal-aid eligible construction projects in Maryland.** With support from FHWA, MDOT can expedite decarbonization by launching pilot projects that will position Maryland to scale up its use of these materials. **MDOT is requesting LCTM funding to promote and facilitate the use of the following eligible material categories: asphalt mixtures, concrete (and cement), steel, and glass.**

[1] The FHWA LCTM program was created in the Inflation Reduction Act (IRA, Pub. L. 117-169, August 16, 2022) and included in Title 23, United States Code (U.S.C.), Section 179. It provides funding for the use of construction materials that have substantially lower levels of GHG emissions.

As industry innovates, materials improve, and price differentials with conventional materials come down, this program will **establish and utilize operational processes and product databases; support technology development improvement and transfer programs and activities; facilitate stakeholder engagement and collaboration; collect stakeholder input; identify eligible construction projects; and incentivize the usage of LCTM.** The program will support all five of the LCTM program goals as shown in **Table 1-1**. A more detailed version of this table can be found in Appendix A.

Table 1-1| Alignment of Material Progress Proposed Activities with FHWA LCTM Program Goals

Program Goals	MDOT Proposed Activities
Increase the Use of LCTM and Products	• Develop new low-carbon materials and products with lower embodied carbon emissions; • Conduct studies to inform policy and specification documents; • Construct pavements with asphalt and concrete mixtures that meet stringent Global Warming Potential (GWP) emission thresholds; and • Build a replicable framework for LCTM implementation processes.
Facilitate the Use of LCTM and Products	• Develop comparative cost analyses and innovative contracting methods to support and incentivize LCTM use; and • Partner with academia, consultants, construction industry and trade associations to identify training needs, procure testing equipment, and develop curricula to support continuous improvement.
Develop LCTM identification frameworks with EPDs	• Leverage data from existing EPDs and performance metrics; • Develop EPD protocols for LCTM; • Promote development and harmonization of EPDs for construction materials; and • Collaborate with other DOTs to collect and store EPDs and identify regional, ISO-compliant "substantially lower" embodied carbon thresholds.
Promote Technology Transfer and Enhance Workforce Development	• Continue to foster interagency and interoffice collaboration in the areas of asphalt and cement/concrete materials/products development and use with entities and consultants to develop local thresholds for GHG emissions • Facilitate LCTM trainings, workshops, and peer engagement to enhance skills of DOT personnel and contractors in partnership with industry experts; and • Develop training materials, conduct stakeholder outreach, and develop implementation process report(s) to foster LCTM proliferation.
Prepare specifications to allow use of LCTM in eligible construction projects	• Implement change order processes for LCTM use on eligible projects; • Update existing specifications or develop new specifications for the use of LCTM; • Establish quality assurance protocols; and • Establish procedures to monitor and report performance after construction.

The cement industry alone accounts for about **8 percent** of global carbon emissions. During the last three years, MDOT has placed an annual average of **1.3 million tons** of asphalt mix with an average of **44 percent** eco-friendly warm mix asphalt and **25 percent** reclaimed asphalt pavement (RAP). An annual average of 128,000 cubic yards of concrete was used in ready mix and precast concrete applications. Almost 19,000 precast concrete pieces were produced annually during the last five years. **FHWA's LCTM program aligns with Maryland's commitment to sustainable infrastructure development by creating pathways to increase the share of sustainable materials, mixes, and inputs throughout MDOT's network of assets.**

Based on SHA's January 2024 Price Index Sheet, there is a tremendous opportunity to increase the use of LCTMs in cement, concrete, asphalt, and steel applications. This grant involves identifying appropriate uses in the context of risk and resilience. Pilot projects and monitoring will highlight opportunities as the development of product specific and facility specific EPDs for these materials become more available.

The inclusion of LCTM into the SHA's regular operations will:

- **Provide opportunities** to identify, research, utilize, and promote the usage of LCTM, with a keen focus on regional applicability, cost-effectiveness, and robust stakeholder and community engagement;
- **Develop workforce capacity** for the agency and stakeholders, facilitating technology and knowledge transfer, and stakeholder outreach and engagement in construction with sustainable materials;
- **Support federal sustainability goals** to reduce the transportation sector's environmental impact;
- **Leverage collaborative partnerships** with academic institutions, construction experts, and materials industries to deploy a phased approach meeting LCTM program goals;
- **Advance Administration Priorities** including safety, climate change and sustainability, equity, environmental justice, workforce development, job quality and wealth creation; and
- **Leverage SHA expertise with federal-aid programs** to enable and guide LCTM implementation efforts at agencies like the Maryland Transportation Authority (MDTA) and Maryland Port Administration (MPA).

Relevant Agency History

Formed in 1971, MDOT is an organization comprising one authority and five modal administrations, including the SHA, Maryland Transit Administration (MTA), Motor Vehicle Administration, Maryland Aviation Administration (MDOT MAA), MDTA, and MPA. This structure and coordinated, balanced approach to transportation enables MDOT to work together as a unified team to advance its mission to provide safe, reliable, accessible, equitable, and sustainable transportation options across the State. **This overarching, holistic approach to managing the transportation system will facilitate the deployment of LCTM into numerous areas of construction projects eligible for federal-aid funding in the future.**

The State of Maryland is a leader in sustainable transportation policy. In 2022, the Maryland General Assembly enacted the Climate Solutions Now Act (CSNA) requiring the state to reduce GHG emissions by 60 percent (from 2006 levels) by 2031 and achieve net-zero emissions by 2045. MDOT developed a Climate Pollution Reduction Plan in 2023 to determine effective and efficient GHG reduction strategies, emphasizing the importance of sustainable design and material strategies. MDOT is committed to advancing asphalt and concrete materials production, mix design and construction quality assurance (see Section A.2). With support from FHWA, ***Material Progress*** **will speed the implementation of these plans, improve sustainability and mitigate the environmental impacts of the transportation sector by increasing the use of LCTM.**

1.2 Technical Description

Scope of Work and Planned Major Activities

MDOT is requesting LCTM funding to implement innovative and low-carbon asphalt and concrete (and cement) materials and products, and steel across its eligible facilities. Additionally, MDOT is investigating opportunities to utilize low-carbon glass beads in the production of pavement striping products. MDOT also looks forward to collaborating with FHWA as the sustainable glass materials industry and construction applicability matures. The ***Material Progress*** program will be delivered using a **Seven Task Structure,** aligned with the Example LCTM Eligible Activities listed in **Table 1 of the LCTM RFA.** Within each task, MDOT will conduct activities associated with each eligible material to accomplish the **Project Objectives** shown in Figure 1-1 and the **Program Goals** presented in Table 2-1.

MDOT has developed a detailed **Workplan** to implement ***Material Progress,*** the seven task structure is detailed with 52 subtasks, see Table 1-2. This plan embraces three pathways to LCTM implementation outlined by FHWA Sustainable Pavement Program Cooperative Center: (1) Introduce the use of LCTM, (2) Expand the use of LCTM, and (3) Institutionalize the use of LCTM. The seven major tasks include: (1) Process for Lower Embodied Carbon, (2) LCTM Quality Assurance (QA) and LCTM Specifications, (3) Construction Project Identification, (4) Use of LCTM on Projects, (5) Substantially Lower Embodied Carbon, (6) Quality Assurance and Acceptance and (7) Use of LCTM on Construction. MDOT applied expertise and creativity to prepare a thorough approach for ***Material Progress.***

Table 1-2 | Material Progress Workplan Tasks

Task	Subtask
1. Process for Lower Embodied Carbon	1.1 Develop a series of Implementation Process Reports (IPRs) with specific details on each task
	1.2 Identify eligible existing and new asphalt, concrete (and cement), and steel materials and products
	1.3 Stakeholder Outreach and Engagement for asphalt and concrete (and cement) and steel industries
	1.4 Develop materials to procure consultant services to support the development and administration
	1.5 Assess existing EPDs, identify EPD Gaps and develop additional EPDs with stakeholders
	1.6 Develop/update or procure a functional web-based database for the collection of EPDs
	1.7 Develop specifications and policy guidance documentation for collection of EPDs
	1.8 Workforce Development and facilitation of knowledge transfer
2. LCTM Quality Assurance (QA) and LCTM Specifications	2.1 Develop IPR for material quality assurance and developing specifications
	2.2 Laboratory evaluation of the performance of eligible material mixes
	2.3 Document processes to build a replicable framework for LCTM activities
	2.4 Preparation of preliminary mixture design and testing evaluation methods and test strip locations
	2.5 Perform a preliminary statistical analysis of available EPD data to establish GWP levels for LCTM
	2.6 Review and update existing LCTM specifications; develop specifications for new LCTM
	2.7 Evaluate the performance of eligible material mixes across the state through pilot projects
	2.8 Conduct cost comparisons between LCTM and conventional materials.
	2.9 Develop LCTM benchmarks – industry, regional and state
	2.10 Provide stakeholder training and certification on LCTM testing and field placement, including QA
	2.11 Share Piloting and Test Results
3. Construction Project Identification	3.1 Develop IPR
	3.2 Prepare a plan for incorporation of LCTM on construction projects
	3.3 Identify eligible construction projects
	3.4 Develop project-specific contract language for construction and design
	3.5 Publish formal guidance on LCTM implementation on projects
	3.6 Industry outreach and coordination
	3.7 Provide stakeholder training related to packaging of advertisement / construction
4. Use of LCTM on Projects	4.1 Develop of IPR for calculating incentives
	4.2 Identify eligible Federal-aid projects for implementation
	4.3 Establish estimates of LCTM use costs
	4.4 Develop a comparative cost analysis between the use of LCTM and conventional materials
	4.5 Establish LCTM bid items
	4.6 Provide resources to support change orders or incentives to accommodate eligible LCTM
	4.7 Examine the financial implications of the grant coverage for cost differences
	4.8 Collaborate with stakeholders to evaluate methodologies to maximize potential incentives
	4.9 Training for practitioners on sustainable material practices, sourcing, and quality assurance
5. Substantially Lower Embodied Carbon	5.1 Develop IPR for material use on construction projects
	5.2 Add an EPD pay item in standard construction contract language for EPD collection
	5.3 Partner to identify efficient prices, record unit pricing in e-bidding and construction management
	5.4 Establish and refine criteria for quality, performance, and usage incentives for LCTM
	5.5 Identify additional costs to implement LCTM to facilitate efficient requests for reimbursement
	5.6 Report Energy Star performance scores by material suppliers, as required by EPA's ID
6. Quality Assurance and Acceptance	6.1 Development of IPRs
	6.2 Placement of LCTM test strips at project sites and in research environments
	6.3 Identification of third-party QA resources
	6.4 Verification of material thresholds for substantially lower embodied carbon
	6.5 Verification of engineering properties of LCTM
	6.6 Publish long-term performance reporting commitments
	6.7 Update SHA standards, Manuals and Specifications
7. Use of LCTM on Construction Projects	7.1 Development of IPR
	7.2 Establishing detailed performance monitoring schedules and reporting mechanisms
	7.3 Development of project-specific performance monitoring plan
	7.4 Reporting of project-specific long-term data on LCTM deployments

Task 1 – Process for Substantially Lower Embodied Carbon

The initial step in the LCTM program is developing a series of Implementation Process Reports (IPRs) that will provide specific details on each Task and its activities. After receiving notification of award for this grant, MDOT will collaborate with partners like the **University of Maryland, College Park (UMD), American Concrete Institute (ACI), Maryland Asphalt Association (MAA), National Center for Asphalt Technology (NCAT) and the American Concrete Pavement Association (ACPA)**, as needed. These partners will assist the agency in developing the IPRs to launch the program and will be engaged starting at the earliest stages of the program to achieve the tightest possible schedule and expedite the program. Additional IPRs will be developed, if needed, as the program evolves. MDOT will work diligently to send IPRs for approval to FHWA and be responsive in addressing comments to obtain the required approval. Additionally, MDOT will commit to revising IPRs as needed. **MDOT acknowledges that IPR approval is required before construction projects can be obligated using LCTM funds and that all funds requested (including construction projects) will be obligated before September 30, 2026.**

Task 1 Highlights

Milestones

- Develop Implementation Process Reports (IPRs) early and often;
- Establish academic partnerships to identify eligible materials, training needs, and data availability; and
- Initiate stakeholder outreach.

Deliverables

- Processes to collect and store EPDs;
- Local or regional "substantially lower" embodied carbon thresholds that meet ISO acceptable practices;
- Resources to support training programs and workshops; and
- Functional EPD Database.

MDOT will engage its partners to identify the eligible existing and new low-carbon materials that would reduce carbon footprint on MDOT projects, develop specifications and required federal reports, training materials, and policy guidance. It will assess existing EPDs, develop additional EPDs, and share piloting and testing results. **As early as possible in the process, MDOT will develop materials to procure consultant services to support the development and administration of *Material Progress*, either through task orders for existing contracts or solicitations for new services.**

MDOT will focus on adding High Recycled Asphalt Pavement (RAP) mixes, rejuvenators, Crumb Rubber Modifiers (CRMs), and eco-friendly additives into asphalt mix designs. For concrete mixes, the focus will be repurposed cementitious materials such as fly ash, slag cement, silica fume, metakaolin, calcined clay, and other low carbon materials. With MPA, MDOT SHA will explore the potential of Titanium Dioxide nanoparticles to degrade pollutants without compromising material performance; potentially sequestering public-health harming emissions for historically overburdened communities near the Port of Baltimore.

MDOT will facilitate knowledge transfer through development of **training programs, technical support, workshops, and peer engagement** to educate stakeholders on sustainable material practices and learn from best practices across the country. MDOT anticipates sharing findings from the data analysis and refining goals with stakeholders, aiming to enhance the skillset of DOT personnel, contractors, and other relevant stakeholders. Training will be conducted to align with the evolving LCTM goals, thus fostering technology transfer and workforce development, stakeholder Outreach and Coordination, and LCTM Training development of Implementation Process Report(s).

The inclusion of LCTM into the SHA's regular operations will contribute to broader climate resilience and sustainability goals by reducing the carbon footprint of infrastructure projects. This aligns with federal sustainability mandates and supports the reduction of the transportation sector's environmental impact. Stakeholders may include the **MAA, NCAT, UMD, National Ready Mixed Concrete Association (NRMCA), ACI, Designers, Local Public Agencies, Material Producers, Material Testing Labs, and Contractors.**

MDOT will develop/update or procure a functional web-based database to catalog environmental product declarations (EPDs) of asphalt, concrete, and steel products in Maryland, including standardization for digital information format for digital submission. MDOT will collaborate with other State DOTs, MDOT modal

agencies, and NAPA, Maryland RMCA, NRMCA, and the Mid-Atlantic Chapter of the American Concrete Pavement Association (ACPA) to establish Mid-Atlantic Region (regional) sustainability benchmarks.

Task 2 - LCTM Quality Assurance and LCTM Specifications

Task 2 will support MDOT in **developing a quality assurance (QA) program suitable for use with LCTM**, which will include the construction of test sections with LCTM on projects with diverse, environmental and traffic conditions across Maryland. Determining the strength, applicability, and availability of LCTMs will require consultation with numerous stakeholders. To organize that effort, MDOT will **leverage LCTM program funding to position itself as a leader for the state and Mid-Atlantic region by**:

- **Developing IPRs** for material quality assurance and specifications;
- **Laboratory evaluation of eligible material mixes.** MDOT may procure testing equipment, as necessary to account for the increase volume of testing and new testing;
- **Documenting the processes** to build a replicable framework for LCTM activities, including the development of a verification process for LCTM and EPDs. MDOT will document the implementation process, quality assurance protocols, and monitoring requirements to serve as a reference for MDOT and other DOTs in developing processes to collect and store EPDs and identifying local or regional "substantially lower" embodied carbon thresholds that meet ISO acceptable practices;
- **Preparation of preliminary mixture design and testing evaluation methods and test strip locations** across the state through pilot projects within four zones: Eastern Shore, Western MD, Central MD, and Southern MD. The distinct terrain and climate characteristics found in the four zones will provide FHWA insights into performance from the mountains to the ocean and in both urban and rural contexts.
- **Conducting cost comparisons** of LCTM with conventional materials. If LCTM proves to be more costly, the delta cost is covered under the grant;
- **Analyzing and defining GWP levels** for different asphalt mixes to be analyzed and defined following ISO standards, using available EPDs from Maryland's producers.

Task 2 Highlights

Milestones

- Development of IPRs;
- Developing QA and Performance Plans;
- Convening stakeholder workshop;
- Updating material specifications to facilitate LCTM use on projects; and
- Preparation of preliminary mixture design and testing evaluation methods and test strip locations.

Deliverables

- Testing equipment to accept and verify LCTM;
- Completed LCTM Test Strips; and
- Verification process for LCTM and EPDs.

Currently, MDOT has available EPD data from Asphalt and Concrete Producers operating in Maryland. NCAT has already performed a preliminary statistical analysis with available data so far for asphalt, in Maryland, and NRMCA is also developing regional thresholds for concrete materials. As the marketplace continues to develop, MDOT and SHA will follow a similar process for steel and glass materials. This task will draw upon **robust stakeholder outreach** to gauge the level of readiness for LCTM implementation in Maryland. **MDOT has had preliminary discussions with UMD and NCAT on workshops, peer exchanges, and development of certifications to disseminate knowledge on sustainable asphalt practices among stakeholders.** When MDOT receives LCTM funding, that process will accelerate rapidly. Other activities in this task will include **the development of a verification process for LCTM and EPDs.** All the activities related to the task and its activities will be submitted to FHWA in the Implementation Process Report. More details about planned activities are described in Appendix B.

Task 3 - Construction Project Identification

Under Task 3, SHA's Office of Construction (OOC) and Office of Highway Development (OHD) will collaborate to identify suitable construction projects, which have already completed the National Environmental Policy Act (NEPA) process and are advancing on the State Transportation Improvement Plan (STIP). This team will

work with other SHA teams to adjust project financing, letting, contracting, and performance evaluation information accordingly, along with material producers, and contractors to deliver the projects and support the development of a sustainable marketplace for LCTM. The team will set standards for the use of LCTM on SHA projects.

MDOT will review guidance and best practices, support partners and stakeholders, and develop an implementation process for the incorporation of LCTM on construction projects. For example, SHA might assess asphalt mixture design using balanced mix design (BMD). QA specifications will be updated to assess GWP and BMD criteria. **Construction will include test strips to assess and validate the performance of selected LCTM**, potentially leading to full-project construction based on performance. **From all this analysis, Task 3 will also produce a scalable list of investments in LCTMs across the state, including identification of potential partnership and pilot projects with other MDOT agencies and partners in state government.** Examples of **scalable investments** may include, but are not limited to, studying applications for **Titanium Dioxide** with the MPA and investigating usage of **LCTM Glass in Solar Panels and Canopies** for energy collection and storage with local, state, and regional partners like transit providers.

Task 3 Highlights

Milestones

- Development of IPRs;
- Identification of eligible construction projects; and
- Preparation of plan for incorporation of LCTM on construction projects.

Deliverables

- Project-specific contract language for construction and design;
- Publication of formal guidance on LCTM implementation; and
- Analysis of data from test strip areas across all four Maryland regions.

Task 4 - Application of LCTM on Projects

Task 4 includes the identification of eligible projects for implementation using the preliminary projects list. It will:

- Provide resources to support change orders or incentives to accommodate the use of eligible LCTM;
- Establish estimates of LCTM use costs;
- Develop a **comparative cost analysis** between the use of LCTM and conventional materials;
- Collaborate with industry partners and contractors to evaluate methodologies to maximize the return of potential incentives; and
- Support training for practitioners on sustainable material practices, material sourcing, and quality assurance.

Task 4 Highlights

Milestones

- Development of IPRs;
- Confirm LCTM usage on list of proposed projects from Task 3;
- Secure resources to initiate and accelerate change orders;
- Establish LCTM use costs; and
- Finalize LCTM use incentive procedures.

Deliverables

- Comparative cost analyses; and
- Training and certification courses for practitioners.

Task 5 - Substantially Lower Embodied Carbon

This task will include collection of available **ENERGY STAR Energy Performance Scores** for all plants in the supply chain for eligible materials. The score will be provided in the EPD or through the relevant Energy Performance Indicator (EPI) EPA's ID. MDOT will focus its efforts in this task on incorporating High Recycled Asphalt Pavement (RAP) mixes, rejuvenators, Crumb Rubber Modifiers (CRMs), and eco-friendly additives into asphalt mix designs. For concrete mixes, activities will include use of repurposed cementitious materials such as fly ash, slag cement, silica fume, metakaolin, calcined clay, and other low carbon materials. In Partnership with MDOT MPA, MDOT SHA will also explore the incorporation of Titanium Dioxide nanoparticles on asphalt or concrete pavements to degrade pollutants without compromising material performance. This application could

Task 5 Highlights

Milestones

- Development of IPRs;
- Adding an EPD Bid Item; and
- Formalizing partnerships with stakeholders and industry partners to record, capture, and utilize unit pricing data.

Deliverables

- Policies governing incentives for environmental performance;
- Submission of standard implementation cost guidance to inform reimbursements; and
- Other costs for the use of substantially lower carbon materials.

potentially sequester public-health harming emissions near historically overburdened communities adjacent to the Port of Baltimore.

MDOT's principal activities in **Task 5** will include:

- Adding a pay item in standard construction contract language to determine if the material meets the low carbon material definition;
- Partnering with stakeholders and industry partners to determine most efficient prices, recording unit pricing in e-bidding, and construction management programs;
- Establishing and refining criteria for quality, performance, and usage incentives offered to contractors;
- Identifying any additional costs to implement LCTM to facilitate efficient requests for reimbursement in accordance with all Federal regulations and cost control provisions; and
- Reporting of Energy Star performance scores by material suppliers, as required by EPA's ID.

Task 6 - Quality Assurance and Acceptance

Task 6 Highlights

Milestones

- Development of IPRs;
- Placement of LCTM Test Strips at project sites and in research environments; and
- Identification of QA testing resources.

Deliverables

- Verify that materials meet thresholds for substantially lower carbon;
- Verify engineering properties of LCTMs; and
- Publish long-term performance reporting commitments.

Task 6 will support **QA testing requirements, verification of materials, and verification of engineering properties.** SHA will leverage and amend the following resources:

- Material Quality Assurance Manual
- Standard and Supplemental Specifications for Construction and Materials; and
- Book of Standards for Highway and Incidental Structures ("greybook")

As necessary, SHA will involve consultants and subject matter experts to conduct additional testing necessary to accept LCTM, to ensure material meet LCMT criteria, and to assess if in-place low-carbon materials meet design criteria. Additionally, SHA will offer quality incentives to facilitate LCTM usage.

Task 7 – Monitor and Report use of Materials and Products on Construction Projects

Task 7 will support the conclusion and ongoing implementation of the goals, strategies, objectives, and work products developed for ***Material Progress***. This task will involve developing strategies for studying and supporting construction and post-construction activities. SHA will contract with a third-party entity—potentially a university, research institution or non-profit industry association—to establish detailed performance monitoring schedules and reporting mechanisms. For example, for asphalt pavements, the focus may be on tracking smoothness (IRI), rutting, and cracking over multiple years. MDOT and its partner will develop a comprehensive project-specific performance monitoring plan to track, collect, and report data on LCTM deployments over time.

Task 7 Highlights

Milestones

- Development of IPRs; and
- Contracting with third party to establish detailed performance monitoring schedules and reporting mechanisms

Deliverables

- Development of Project-Specific Performance Monitoring Plan; and
- Reporting of project-specific long-term data on LCTM deployments

1.3 Team Information

About Maryland Department of Transportation

The Maryland Department of Transportation is a consolidated, multi-modal transportation agency that mirrors USDOT's structure. MDOT is comprised of five modal agencies (State Highway Administration, Maryland Transit Administration, Maryland Aviation Administration, Maryland Port Authority, and Maryland Motor

Vehicle Agency) and Secretary Paul Wiedefeld serves as Chair of the Maryland Transportation Authority. MDOT's unique and consolidated structure provides FHWA a unique opportunity to advance LCTM utilization and understanding across multi-modal applications that are eligible for federal-aid funding.

MDOT is a customer-driven leader that delivers safe, sustainable, intelligent, exceptional, and inclusive transportation solutions in order to connect its customers to life's opportunities. MDOT serves residents, visitors, and businesses in the state of Maryland by operating and maintaining Maryland's state highways, bridges, tollways, transit systems, motor vehicle licensing, Baltimore/Washington International Thurgood Marshall Airport and the Helen Delich Bentley Port of Baltimore. MDOT seeks to provide safe, reliable, equitable, and sustainable transportation options to Marylanders across the state, prioritizing **equity, preservation, resilience, modernization, and experience** to guide its decision-making process to support the State's goals for the transportation system.

State DOT Staffing Structure

MDOT has extensive experience administering Federal funds and programs. MDOT annually administers over $3 billion in federal and state capital funding to make multimodal transportation investments to enhance safety, state of good repair, connectivity, commerce, and mobility. MDOT is a committed public steward of taxpayer funding and maintains numerous controls and best practices to ensure compliance with state and federal regulations, effective and transparent management of public resources, and best practices to watchfully oversee major public procurements.. MDOT SHA has 3,000 employees across Maryland, responsible for construction, operations, and maintenance of Maryland's State highway systems. ***Material Progress*** will be led by the **Office of Materials Technology (OMT)**. SHA support offices will include the seven Engineering Districts, OHD, OOC, Asset Management Office, Office of Structures, Office of Procurement and Contract Management, Office of Maintenance and Office of Traffic and Safety.

Office of Materials Technology (OMT)

OMT includes two Sections: five Material Quality Divisions and three Material Engineering Divisions. The Material Quality Divisions conduct laboratory, office, and field operations for all the major materials used in the construction and maintenance of roads, bridges, and other structures. The materials include asphalt, concrete, cement, soils, aggregate, metals, structural materials, and coatings and pavement markings. Field operations involve material sampling and inspections, audits of material fabrication/plant production, onsite construction support, and material testing. OMT carries out material testing and other laboratory functions at a central laboratory situated in Hanover, MD in support of material quality operations. These services include rending approval of material sources and final approval of all materials used in the construction and maintenance of roads, bridges, and other structures in Maryland. These services are available to other MDOT Modals, Counties, Local Public Agencies, and Municipalities. OMT also provides oversight and review of a private lab that performs tests for MD projects.

The Material Engineering Divisions are responsible for pavement, geotechnical and engineering geology services that provide technical expertise, field testing services, emergency response to geo-hazards, and advisory recommendations in the planning, design, construction, and maintenance phases of highway transportation projects.

Maryland Port Administration (MPA)

The MPA owns six cargo terminals and one cruise terminal within the Port of Baltimore. It focuses on supporting Maryland's economy by stimulating waterborne commerce. The MPA is the state's leading creator of wetlands through its industry-renowned coastal restoration dredging work, the Innovative Reuse and Beneficial Use Program. This program may have applicability in materials mixes. Additionally, MPA's Clean Diesel initiative is removing thousands of tons of emissions by upgrading dray trucks and cargo-handling equipment.

Maryland Transportation Authority (MDTA)

The MDTA is responsible for constructing, managing, operating, and improving the State's toll facilities, as well as for financing new revenue producing transportation projects. The MDTA's eight toll facilities include two turnpikes, two tunnels, and four bridges. All of the MDTA's projects and services are funded through tolls paid by the customers who use the MDTA's facilities. MDTA's Office of Engineering and Construction (OEC) uses OMT/SHA approved materials and mixes. The MDTA's consolidated transportation program (CTP) is approximately $3 billion over six years. Additionally several of MDTA's facilities are federal aid eligible and may serve as potential LCTM deployment opportunities.

Anticipated Partners

SHA anticipates a phased approach to the program development vision, through collaborative partnerships with academia, consultants, MDTA and other MDOT modal agencies, and industry to meet the LCTM program goals. It plans to collaborate with the entities and organizations listed below.

Consultants

Consultants can be selected to support LCTM projects following MDOT's current procedures. MDOT does not have a list of specifically qualified consultants, but many frequent collaborators have the expertise to support a variety of planning and engineering tasks related to ***Material Progress***. Specific attributes which may be considered for each consultant may include: experience with the Mechanistic-Empirical Pavement Design Guide; strong demonstration of laboratory testing facilities and capabilities; field evaluation of materials; construction monitoring; experience and familiarity with MDOT's specification books; and experience organizing certification courses and workshops, especially ones relevant to the development of a LCTM course and/or workshop. The consultant selection process will follow MDOT Specifications for Consulting Services.

Universities and Research Institutions

Another collection of anticipated partners includes universities and institutions of higher education. MDOT is fortunate to be located near several world-class institutions of higher education and cutting-edge research in the fields of planning, engineering, and data analytics. For specific knowledge and expertise, it may also partner with academic institutions from across the nation. Frequent collaborators are included in the table below; MDOT will take an active role in seeking and collaborating with partners to advance ***Material Progress*****.** A list of anticipated university partners is provided in the appendices.

Other Partners

MDOT would also welcome the opportunity to collaborate with other entities and organizations interested in LCTM production, research, and usage. Potential partners include: NCAT National, NRMCA (Maryland Chapter), ACI (Maryland Chapter), MAA , American Institute of Steel Construction (AISC), local municipal partners, and others.

1.4 Overall Readiness

Material Progress will be managed by SHA, specifically the Offices of Materials Technology and Highway Development. These offices will work with the 7 SHA Engineering Districts, Other SHA Offices, other modal units within MDOT using a technical management approach to ensure successful completion of the scoped work. The cost estimate is $48,417,000 based on the budget provided in Volume 2 of this application. A **summary schedule** is provided below, along with a consideration of project risks and mitigation strategies. **A complete Gantt Chart of proposed activities is included as an attachment.**

Schedule

Table 1-3 | Summary Project Schedule

Milestone	Start Date	End Date
Task 1 | Process for Lower Embodied Carbon	**10/1/2024**	**10/1/2030**
MILESTONE: Approval of Request for Proposals	10/1/2024	3/1/2025
Task 2 | LCTM Quality Assurance (QA) and LCTM Specifications	**10/1/2024**	**5/1/2031**
MILESTONE: IPR Approval Process Complete	10/1/2024	6/30/2026
MILESTONE: Project Partnership and Implementation Agreements	10/1/2024	6/1/2025
Task 3 |Construction Project Identification	**6/1/2025**	**5/1/2027**
Task 4 |Use of LCTM on Projects	**3/1/2025**	**8/31/2031**
MILESTONE: Procurement Authorization	3/1/2025	7/31/2025
Task 5 | Substantially Lower Embodied Carbon	**10/1/2024**	**3/1/2031**
Task 6 |Quality Assurance and Acceptance	**5/1/2026**	**2/1/2027**
Task 7 | Use of Materials and Products on Construction Projects	**10/1/2025**	**8/31/2031**
MILESTONE: LCTM Placement	6/1/2026	3/1/2027

Project Risks and Mitigation Strategies

MDOT has considered a range of project risks that have the potential to impact successful initiative and completion of this program. The program has received political support and numerous elected officials and others have provided letters of support. For each task, MDOT will consider an expansive range of potential risks and mitigation strategies to the likelihood of effective commencement and completion of each task.

The table below provides a summary of the primary anticipated risks to ***Material Progress*****,** along with mitigation strategies to address them and ensure that all project funds are obligated and expended on time.

Table 1-4 | Project Risks and Mitigation Strategies

Risk	Likelihood	Impact	Mitigation Strategy
Obligations Risk	Medium	Medium	• Coordinate across agencies and with FHWA
Project Approval and Permitting Delays	Medium	High	• Coordinate across agencies to encourage parallel reviews • Develop detailed schedule and adequate contingencies and redundancies • Phasing of projects
LCTM Cost Escalation and Variability	Medium	Medium	• Monitor incoming bids • Deploy plan to address potential cost overruns
Procurement Delays and LCTM Materials Risk	Medium	High	• Engagement with industry • Procurement from multiple suppliers
Contractor Availability	Medium	High	• Engagement with industry • Incentives

1.5 Eligible Application Factors

Factor #1: Substantially Lower Embodied Carbon Identification

MDOT plans to incorporate many types of materials in accordance with EPA Interim Determination (EPA ID) (2022). The agency has a history of investigating new materials and processes that can improve the performance and sustainability of transportation materials, such as those outlined in MDOT's 2018 Pavement & Geotechnical Design Guide which shows examples of new materials being researched and piloted. MDOT may identify additional materials by partnering with local universities, local chapters of professional organizations, consultants, and other industry stakeholders.

MDOT is forward thinking in this arena and prepared to meet the EPA ID guidance of the best performing 20 percent of products. The Maryland Port Administration (MPA) is interested in partnering on eligible Title 23 activities to explore the incorporation of Titanium Dioxide nanoparticles on asphalt or concrete pavements to degrade pollutants without compromising material performance. This application would potentially sequester public-health harming emissions near historically overburdened communities adjacent to the Port of Baltimore and known truck idling hot spots on federal-aid eligible facilities. There is also potential for this pilot to inform efforts of local DOTs, like Baltimore City DOT, in their own LCTM application efforts. However, MDOT is presenting this as scalable option for implementation, and our budgeted focus will remain on more traditional highway federal aid activities.

Currently, MDOT has available EPD data from Asphalt and Concrete Plants/Producers operating in Maryland. The agency will continue to collaborate with industry and strategic partners to gather more EPDs and analyze these data to inform and establish sustainability benchmarks and guidelines that can identify products that meet the substantially lower embodied carbon threshold. **MDOT is working to formalize and streamline information by coordinating EPD codes with concrete mix design codes.** Regionally, MDOT is developing a comprehensive database to catalog EPDs of various asphalt and concrete materials in Maryland in collaboration with other entities - State DOTs, MAA and NAPA, Maryland RMCA, NRMCA - to establish Mid-Atlantic Region (regional) benchmarks for sustainability.

For collecting EPDs and use of LCTM in construction projects MDOT will collaborate with entities like universities and consultants with capabilities and prior experience in EPDs and life-cycle assessments (LCAs) to develop implementation process reports (IPRs) as per the federal guidelines for projects. MDOT will add a line item pay item for EPD collection to determine if materials meet LCTM requirements. MDOT is considering strategies similar to the following to ensure eligible construction projects utilize these materials:

- Implementation of green public procurement strategies such as EPD requirements, emission reduction incentives (or GWP thresholds with incentives), and carbon pricing;
- Identification of projects and life-cycle emissions analysis at the project level;
- Design of green contracting strategies, including contract provisions and specifications;
- Developing Standard of procedure to ensure federal compliance; and
- Tracking and evaluation of emissions from construction materials and operations.

MDOT will work with a consultant and develop regional thresholds for our low carbon concrete and asphalt materials in conformance with ISO standards. NCAT has already performed a preliminary statistical analysis with available data so far for asphalt materials produced in Maryland, which can help identify products that are in the top 20 percent in GHG emission reduction. NRMCA is also developing regional thresholds for concrete materials.

Factor #2: Quality Assurance and Materials Acceptance

Quality assurance and material acceptance will be tied into the above processes for identifying EPDs for construction projects. **As the products move forward and receive EPD status, MDOT will develop draft technical specifications for any materials identified and incorporation of those materials into highway and structural construction practices.** Generally, this will involve the drafting of quality assurance and

materials acceptance IPR for the materials of interest. The IPRs will be submitted to the FHWA for approval before MDOT obligates any funding for construction projects, as established in the RFA requirements.

Ensuring that material placed on construction projects conform with engineering specifications and the EPA ID goals will be facilitated through strategic partnerships with local universities, research institutes, and professional organizations. MDOT will contract with these entities to establish detailed performance monitoring schedules and reporting mechanism. MDOT utilizes a practice of placing short test strips of concrete and asphalt in the field to ensure that LCTM can be produced at production scale, is placeable/workable, and meets all engineering requirements and environmental benefits in a production environment. Continued monitoring of test strips can be performed by agency or research partners. To assist in these and other assessments MDOT plans to purchase new testing equipment which may include:

- Asphalt extractor which can help perform binder extraction frequently and test the PG grade of asphalt binder for high RAP mixes;
- Asphalt pavement analyzer (APA) to assist in asphalt mixture performance tests (AMPT) to perform simple moisture sensitivity and rutting tests and perform more scientific four corner methods to compare the surrogate testing of asphalt mixes and develop correlations between AMPT and surrogate testing;
- X-ray diffraction instrument (XRD) to characterize the components used in the concrete mixes – including the aggregates. This testing would be used in conjunction with the current SHA owned X-ray fluorescence (XRF) used for compositional analysis of the cementitious materials; and
- Resistivity test equipment to assess low carbon concrete in accordance with the agency special provision.

Factor #3: Use of Materials and Products on Construction Projects

LCTM will be incorporated into projects that are identified through a collaboration of MDOT's OMT, OOC, and OHD along with other internal stakeholders. This team will work with material producers and contractors to facilitate the use of LCTM on construction projects in the state. The following is a general outline of the steps needed to incorporate LCTM on a construction project:

- Identify eligible projects from the Statewide Transportation Improvement Program, including the Consolidated Transportation Program;
- Submit change orders to accommodate the use of LCTM;
- Implement project-specific construction contract language through special provision inserts to incorporate eligible materials into the project proposal documents;
- Use developed EPD protocols to identify the construction bid item categories that will encompass the materials requiring EPDs to facilitate EPD use of the same on projects;
- Provide developed IPRs for EPDs to contractors; and
- Develop special provisions with the goal of providing incentives to contractors for the utilization of eligible LCTM. The incentives may be related to the carbon footprint reduction and cost-savings when compared with construction with conventional materials. As Maryland incurs reimbursable additional costs related to LCTM, they will request reimbursement through the grant fund.

Through established partnerships, MDOT will engage stakeholders across the state and internally within the agency to build statewide capacity for incorporating LCTM. These activities may include: developing workshop and training materials; conducting industry outreach through training programs, workshops, or certification courses that educate stakeholders on sustainable practices in asphalt and concrete, material sourcing, and QA processes; creating case studies and success stories on state LCTM and EPD applications; and sharing new specifications via clearinghouse for stakeholder comment in advance of procurement.

MDOT commits to identifying and utilizing asphalt mixes that fall within the "best performing 20th percentile" of GWP and "better performing 40th percentile" of GWP, as per the guidelines. MDOT, in partnership with consultants and academia, will identify and/or design suitable local materials that have a verified lower GWP, using EPDs as a benchmark.

MDOT will also develop special provisions with the goal of providing incentives to contractors for the utilization of eligible LCTMs that result in the construction of quality projects. Incentives may account for carbon footprint reduction and cost-savings compared with construction using conventional materials.

Factor #4: Schedule and Budget

Material Progress will distribute funds from October 2024 (assuming award by that date) to August 2031. Each major activity is shown in the budget below for the funding request amount of $48,417,000. MDOT plans to obligate all funding in advance of the 2026 obligation deadline.

The schedule summarized above and budget included in Volume 2 satisfy the following requirements:

- Description of start and end dates and budget for each major activity, milestone, and deliverable;
- Estimated budget appears commensurate with the application's technical narrative; and
- Activities are explicitly described as being completed by the expiration of funds.

In addition, specific numbers from the budget appear throughout this application, which also identifies opportunities for application of risk mitigation strategies. Finally, the budgeted amount includes 9.09% allocated to contingencies in the event of unanticipated cost overruns.

1.6 Administration Priorities

Safety

Safety is an overarching priority for MDOT. **The program proposed in this application will align with the National Roadway Safety Strategy (NRSS) and the Fiscal Years 2022-2026 DOT Strategic Plan with respect to advancing safe and efficient transportation.** The NRSS outlines the US DOT's comprehensive approach to significantly reducing serious injuries and deaths on our nation's highways, roads, and streets. It is also a first step in working toward an ambitious long-term goal of reaching zero roadway fatalities. **MDOT is committed to its goal for zero traffic deaths and remains an** Ally in Action**.** In addition, some of the construction projects on which LCTM will be used involve intersection safety improvements.

Climate Change and Sustainability

The Administration has undertaken several activities to reduce GHG emissions in all sectors of industry. Specific programs include the Federal Buy Clean Initiative and Executive Order (E.O.) 14057, and Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability (86 FR 70935);

Material Progress will adhere to the tenets of these programs and others. Maryland has been at the forefront of identifying and deploying carbon reduction strategies. The State of Maryland and MDOT have sought to reduce carbon through strategic investments in projects, programs, policies, and infrastructure. In 2016, State's Greenhouse Gas Reduction Act (GGRA) required Maryland to achieve a minimum of 40 percent reduction in statewide GHG emissions from 2006 levels by 2040 across all economic sectors. In 2021, the Maryland Department of the Environment set comprehensive strategies to reduce GHGs. In 2022, the State's Climate Solutions Now Act (CSNA), set the most aggressive emissions reduction goals in the nation, to reduce emissions by 60 percent (over the 2006 level) by 2031, and reach net zero emissions by 2045. Following the establishment of the Carbon Reduction Program (CRP), under the Infrastructure Investment and Jobs Act (IIJA), MDOT developed a Carbon Pollution Reduction Strategy (CRS), a core strategy is to lower embodied materials. This application also aligns with EPA's Buy Clean Strategy. As one potential eligible example of activities, SHA increasing RAP to 30-50% may reduce asphalt lifecycle GHG emissions by as much as 30%.

MDOT is currently participating in two FHWA Climate Challenge Projects, after receiving a total grant award of $312,000. One of these projects is titled *Informed Emissions Reduction Strategies for Asphalt and Concrete Paving Projects*. MDOT apply its experience to advance ***Material Progress***.

Equity and Environmental Justice

To the fullest extent possible, this program seeks to fund activities and projects that will create proportional impacts to all populations in a project area, remove transportation-related disparities to all populations in a project area, and increase equitable access to project benefits, consistent with E.O. 13985, Advancing Racial Equity and Support for Underserved Communities Through the Federal Government (86 FR 7009).MDOT will use tools like the Climate and Economic Justice Screening Tool and/or DOT Equitable Transportation Community Explorer to evaluate and prioritize projects. For example, the Maryland Port Administration would like to pilot titanium dioxide applications to asphalt and concrete to reduce public-health harming emissions from trucks. This will maximize the potential of reducing public-health harming emissions at some of the most environmentally overburdened communities in the State. The entire City of Baltimore is designated as an Area of Persistent Poverty (AOPP) according to USDOT definitions. Additionally, SHA commitment to pilot LCTMs in its four unique zones will ensure an equitable approach to deployment that considers both rural and urban contexts.

Workforce Development, Job Quality, and Wealth Creation

The program proposed will incorporate the components of E.O. 14052, Implementation of the Infrastructure Investment and Jobs Act (86 FR 64335) that apply, and will, where possible, and applicable, include the participation of Disadvantaged Business Enterprises, Minority-owned Businesses, Women-owned Businesses, or 8(a) firms. This program also intends to support Made in America goals consistent with E.O. 14005, Ensuring the Future Is Made in All of America by All of America's Workers (86 FR 7475). Maryland supports the creation of good-paying jobs with the free and fair choice to join a union and the incorporation of strong labor standards and training and placement programs, especially registered apprenticeships, in project planning stages, consistent with E.O. 14025, Worker Organizing and Empowerment (86 FR 22829), and E.O. 14052, Implementation of the Infrastructure Investment and Jobs Act (86 FR 64335)].

The increased use of LCTM materials will benefit producers and stimulate job creation. The development of EPDs by Maryland-based producers will be a significant step in the advancement of a local market for LCTM. Currently, there are twelve concrete plants in the state of Maryland that are operated by three companies that have produced or developed concrete mixes with an EPD. Maryland's Buy Clean Maryland Act will send demand signals to concrete producers in the region that the State is a committed buyer of alternative concrete products, which will encourage their production and use. MDOT maintains a robust, multi-part Minority Business Enterprise (MBE) Program that includes: the Disadvantaged Business Enterprise (DBE) Program, the Airport Concessions Disadvantaged Business Enterprise (ACDBE) Program, and Small Business Enterprise (SBE) Program(s). The program was established in 1978 and is believed to be the oldest in the country. Its purpose is to ensure that small, minority- and women-owned firms can participate fully and fairly in both state and U.S. DOT federally funded projects. SHA maintains a 29% DBE goal on federally funded activities.

1.7 Scalable Project Options

Material Progress is designed to develop tools, processes, and training materials to support LCTM adoption throughout Maryland, including scalable investment options such as: testing, monitoring of performance, and a control site for LCTM; collaborating with MDTA on various projects; studying applications for **Titanium Dioxide** with the MPA; investigating usage of **LCTM Glass in Solar Panels and Canopies** for energy collection and storage with local, state, and regional partners like transit providers.

1.8 Implementation Process Reports (IPRs)

MDOT is committed to developing IPRs to document all relevant process(es) the Department plans to implement LCTM activities and increase the adoption of low carbon transportation materials. To ensure that LCTM funds are obligated and expended by stated deadlines, MDOT will develop IPRs on a rolling basis. MDOT will leveraging third party consultants, academic institutions, and industry partners to conduct research necessary for each IPR. All seven tasks identified in the Scope of Work include development and submission of IPRs, functions which are also accounted for in the attached Budget Application.

2. Volume 2 Budget Application

2.1 Budget Application

MDOT is requesting $48,417,000 from the LCTM program to support ***Material Progress*****.** This Budget Application has been prepared in accordance with the FHWA Request for Applications (RFA) for the Low Carbon Transportation Materials (LCTM) grant program.

The activities defined in this application are scalable and should additional funding be made available, can be increased to support further implementation. Contingencies associated with unanticipated cost increases are included. The costs contained in this application are the best estimates that could be made at this time given the uncertainty in costing out a multi-task, multi-year project. Throughout ***Material Progress***, MDOT will draw from its robust, publicly available business standards and specifications, including its price index. Updated budget information, including estimated hours and labor rates, equipment costs, itemized travel costs, and other costs, will be provided early and often as part of subsequent Implementation Process Reports (IPRs) to be prepared and submitted to FHWA for approval as discussed in Volume 1. MDOT will commit to revising IPRs as needed.

In accordance with Section 5 of the RFA, MDOT SHA will target submitting all IPRs within one year of when the funds become available for obligation, but no later than June 30, 2026. In accordance with Section 5 of the RFA, all LCTM funds shall be expended prior to September 30, 2031.

Budget Justification

The budget tables in Section 2.2 of this Volume 2 present the cost estimate for each Task identified in Volume 1. Expected costs have been grouped into the following general budget items:

- SHA Personnel - The SHA labor costs have been estimated based on using a single loaded labor rate ($139.58), representing a best estimate of a weighted rate for all classes of agency personnel expected to work on the LCTM program, incorporating annual increases in the labor rate over the duration of the program. MDOT SHA anticipates 6.45% of LCTM program funding will be used to support these costs.
- Consultant labor - The consultant labor costs have been estimated based on using a single loaded labor rate ($287.92), representing a best estimate of a weighted rate for all classes of consultant personnel expected to work on the LCTM program, incorporating annual increases in the labor rate over the duration of the program. A variety of consultants will be required to complete the work required to execute the Tasks in the proposed LCTM project.
- Universities and Research Institutions - The academic labor costs have been estimated based on using a single loaded labor rate ($145.88), representing a best estimate of a weighted rate for academic personnel expected to work on the LCTM program, incorporating annual increases in the labor rate over the duration of the program. In addition, an average annual rate for graduate students that includes compensation, fringe benefits, and overhead has been estimated, representing a best estimate of a weighted annual rate for students expected to work on the LCTM program, incorporating annual increases in the rate over the duration of the program.
- Other Direct costs - Other direct costs include project-related travel, equipment, training materials, and testing. The specific needs will be documented in the appropriate IPRs.
- Construction-related costs - Construction will be a major cost, but until specific projects have been identified for LCTM use, it is not possible to provide exact estimates. At this point it is only possible to estimate construction costs based on bid item costs for existing projects and extrapolating to account for new materials and methods required for construction using LCTMs.
- Contingency - To account for unexpected costs (e.g., inflation, extreme weather events, material supply issues), a contingency of 9.09% has been included. For ease of consideration, the contingency is only applied to the overall requested amount within each parent task.

Task Highlights

This section provides the summary and cost for each task as discussed in Volume 1.

Task 1 – Process for Substantially Lower Embodied Carbon | Cost: $2.94M

1.1 Develop a series of Implementation Process Reports (IPRs) that will provide specific details on each task and its activities

1.2 Identify existing asphalt and concrete (and cement) and steel materials and products eligible for LCTM and develop alternative materials, including reviews and updates

1.3 Stakeholder Outreach and Engagement - Update of LCTM Program for asphalt and concrete (and cement) and steel industries

1.4 Develop materials to procure consultant services to support the development and administration

1.5 Assess existing EPDs, identify EPD Gaps and develop additional EPDs in partnership with other stakeholders

1.6 Develop/update or procure a functional web-based database for the collection of EPDs

1.7 Develop specifications and policy guidance documentation for collection of EPDs

1.8 Workforce Development and facilitation of knowledge transfer

Task 2 - LCTM Quality Assurance and LCTM Specifications | Cost: $6.24M

2.1 Develop IPR for material quality assurance and developing specifications

2.2 Laboratory evaluation of the performance of eligible material mixes

2.3 Document the processes to build a replicable framework for LCTM activities, including the development of a verification process for LCTM and EPDs

2.4 Preparation of preliminary mixture design and testing evaluation methods and test strip locations

2.5 Perform a preliminary statistical analysis of available EPD data to establish GWP levels for LCTM (asphalt, concrete (and cement) and steel)

2.6 Review and update existing LCTM specifications and develop specifications for new LCTM in partnership with stakeholders

2.7 Evaluate the performance of eligible material mixes across the state through pilot projects

2.8 Conduct cost comparisons between LCTM and conventional materials. If LCTM proves to be more costly, the delta cost is covered under the grant

2.9 Develop LCTM benchmarks – industry, regional and state

2.10 Workforce development – Provide stakeholder training and certification on LCTM testing and field placement for QA of LCTM testing and field placement

2.11 Share Piloting and Test Results Detailed performance monitoring schedules and reporting mechanisms will be established

Task 3 - Construction Project Identification | Cost: $2.44M

3.1 Develop IPR

3.2 Prepare a plan for incorporation of LCTM on construction projects

3.3 Identify eligible construction projects

3.4 Develop project-specific contract language for construction and design

3.5 Publish formal guidance on LCTM implementation on projects

3.6 Industry outreach and coordination

3.7 Provide stakeholder training related to packaging of advertisement / construction

Task 4 - Use of LCTM on Projects | Cost: $32.13M

4.1 Develop of IPR for calculating incentives

4.2 Identify eligible Federal-aid projects for implementation

4.3 Establish estimates of LCTM use costs

4.4 Develop a comparative cost analysis between the use of LCTM and conventional materials

4.5 Establish LCTM bid items

4.6 Provide resources to support change orders or incentives to accommodate the use of eligible LCTM

4.7 Examine the financial implications of the grant coverage for cost differences

4.8 Collaborate with industry partners and contractors to evaluate methodologies to maximize the return of potential incentives

4.9 Support training for practitioners on sustainable material practices, material sourcing, and quality assurance

Task 5 – Use of Substantially Lower Embodied Carbon Materials on Construction Projects | Cost: $1.81M

5.1 Developing IPR for material use on construction projects

5.2 Adding an EPD pay item in standard construction contract language for EPD collection to determine if the material meets the low carbon material definition

5.3 Partnering with stakeholders and industry partners to determine most efficient prices, recording unit pricing in e-bidding, and construction management programs

5.4 Establishing and refining criteria for quality, performance, and usage incentives for LCTM offered to contractors

5.5 Identifying any additional costs to implement LCTM to facilitate efficient requests for reimbursement in accordance with all Federal regulations and cost control provisions; and

5.6 Reporting of Energy Star performance scores by material suppliers, as required by EPA's ID

Task 6 - Quality Assurance and Acceptance | Cost: $1.79M

6.1 Development of IPRs

6.2 Placement of LCTM test strips at project sites and in research environments

6.3 Identification of third-party QA resources

6.4 Verification of material thresholds for substantially lower embodied carbon

6.5 Verification of engineering properties of LCTM

6.6 Publish long-term performance reporting commitments

6.7 Update SHA standards, Manuals and Specifications

Task 7 – Monitor and Report Use of Materials and Products on Construction Projects | Cost: $1.05M

7.1 Development of IPR

7.2 Establishing detailed performance monitoring schedules and reporting mechanisms

7.3 Development of project-specific performance monitoring plan

7.4 Reporting of project-specific long-term data on LCTM deployments

2.2 Budget Table(s)

Table 2-1 | Budget by Cost Type and Task

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Total
Equipment Procurement		$711,000	$450,000					$1,161,000
Information Technology Services	$1,065,000	$350,000	$350,000		$350,000			$2,115,000
Internal Staff Time	$393,884	$1,152,476	$366,166	$248,001	$310,731	$433,273	$218,825	$3,123,356
Other	$267,563	$567,442	$346,957	$31,121,337	$164,674	$163,128	$95,446	$32,726,547
Professional Services	$889,665	$2,359,484	$619,023	$475,064	$662,210	$734,190	$446,272	$6,185,907
Travel and Supplies	$20,000	$100,000	$40,000	$60,000	$60,000	$140,000	$80,000	$500,000
University Resources	$307,068	$1,001,460	$269,382	$230,301	$263,799	$323,817	$209,364	$2,605,191
Grand Total	$2,943,180	$6,241,861	$2,441,528	$32,134,702	$1,811,414	$1,794,407	$1,049,907	$48,417,000

Table 2-2 | Budget by Cost Type

Cost Type	Total Cost		Share of Total
Construction	$	28,200,000.00	58.24%
Contractual	$	10,906,097.68	22.53%
Equipment	$	1,161,000.00	2.40%
Other	$	125,000.00	0.26%
Personnel	$	3,123,355.55	6.45%
Travel	$	500,000.00	1.03%
Contingency	$	4,401,546.77	9.09%
Grand Total	**$**	**48,417,000.00**	**100.00%**

Table 2-3 | Budget by Resource Type

Resource Type	Sum of Total Cost		Sum of Total Cost2
Equipment Procurement	$	1,161,000.00	2.40%
Information Technology Services	$	2,115,000.00	4.37%
Internal Staff Time	$	3,123,355.55	6.45%
Other	$	32,726,546.77	67.59%
Professional Services	$	6,185,907.05	12.78%
Travel and Supplies	$	500,000.00	1.03%
University Resources	$	2,605,190.62	5.38%
Grand Total	**$**	**48,417,000.00**	**100.00%**

Appendix A. Schedule and LCTM Goals and Proposed Actions

A.1 Schedule

MDOT has prepared a detailed example schedule below. The Gantt chart developed provides a high-level overview of the overall project timeline. This kind of resource will be utilized to help manage resources during the project and support efficient tracking of tasks. This will help keep all parties aligned in the process and ensure coordination across the MDOT offices and visions involved.

A.2 LCTM Goals and MDOT Proposed Activities

As mentioned in the introduction, the program will support all five of the LCTM program goals. MDOT has multiple proposed actions to support each goal as shown in Table A-1.

Table A-2-4 LCTM Program Goals

LCTM Goal	MDOT Proposed Activities
Increasing the Use of Low-Carbon Materials and Products that are used in Title 23 funded projects	• Identify construction projects eligible for federal-aid funding under the STIP, including the Consolidated Transportation Program; issue change orders to accommodate the use of eligible LCTM; • Prepare comparative cost analyses for traditional and LCTM; • Develop an EPD protocol to identify and utilize LCTM on projects; and • Provide incentives to contractors to use eligible LCTM.
Facilitating the Use of Low-Carbon Materials and Products while ensuring appropriateness for use in projects funded under Title 23	• Collaborate with local contractors and industry partners to assess existing EPDs and develop additional EPDs as needed; • Host and facilitate training, technical support workshops, and peer engagement activities to advance the use of LCTM; • Identify suitable projects, which have already completed the NEPA process advancing on the STIP • Develop special provisions or other suitable contracting approaches to incorporate LCTM in upcoming projects; • Partner with the **University of Maryland's Build America Center** and other academic and industry research partners to: – Identify eligible materials, training, data, and special provision development needs; – Preliminary mixture design and testing to evaluate materials; – Procure testing equipment to properly accept and verify LCTM; – Construct LCTM Test Strips; – Develop standards and guidance for the utilization of LCTM on SHA projects; – With the support of National Center for Asphalt Technology (NCAT); – Analyze data from various mix types to define GWP levels according to ISO standards; – Use simulation data to determine mixes that fall into the 20th and 40th percentiles of GWP;

LCTM Goal	MDOT Proposed Activities
	– Include mixes in test strips and subsequent projects, monitoring their performance over time; and – Apply BMD test criteria to ensure the success of advancing LCTM materials into practices. Use the IDEAL-CT in combination with GWP to identify optimal LCTM asphalt mixtures.
Promoting Technology Transfer and Enhancing Workforce Development to increase the adoption of environmental quantification techniques used in decision-making by transportation agencies	• With the support of NCAT; • Share findings from the data analysis and refine goals with stakeholders; • Enhance the skillset of DOT personnel, contractors, and other relevant stakeholders; and • Conduct training, stakeholder outreach and coordination, and develop implementation process report(s) to foster LCTM technology transfer and workforce development.
Encouraging State DOTs to Begin LCTM Activities and building successful low carbon transportation material identification frameworks that eventually may be replicated by non-State recipients eligible to apply for LCTM funding	• Develop LCTM training materials; • Share piloting and testing results with industry and local stakeholders; • Build a replicable framework for LCTM activities; • Document processes and results of the test strips and full-project implementations; • Document the implementation process, QA protocols, and monitoring requirements; • Serve as a reference for future projects and for other DOTs, to facilitate development of processes to collect and store EPDs, and to identify local or regional "substantially lower" embodied carbon thresholds that meet ISO acceptable practices; • Conduct cost comparisons of LCTM with conventional materials; • Analyze and define GWP levels for different asphalt mixes following ISO standards; and • Select LCTM across the state to assess climatic and regional material availability effects.

Appendix B. Asphalt and Concrete Materials Details

B.1 Asphalt Mixes in Maryland Today

MDOT SHA is committed to advancing asphalt materials production, mix design and construction quality assurance. MDOT has already begun exploring the use of asphalt mix improvements such as high Recycled Asphalt Pavement (RAP) mixes, asphalt rejuvenators, and eco-friendly additives.

Asphalt is a mix of mineral aggregates, asphalt binder, and various additives. The material requirements for low embodied carbon asphalt, using the threshold of the top 20% of product performers, are featured in the table below.

Table B-1 | Low Embodied Carbon Asphalt

Top 20% Threshold	**Top 40% Threshold**	**Better than Industry Average Threshold**
55.4	64.8	72.6

Note: EPD-reported GWPs, in kilograms of carbon dioxide equivalent per cubic meter

Source: https://www.gsa.gov/system/files/Asphalt%20-%20GSA%20IRA%20Low%20Embodied%20Carbon%20Requirements%20%28Dec.%202023%29_508.pd

An asphalt mix of 25% RAP is considered High RAP[2] by FHWA, Maryland does not have any cap on RAP usage in dense graded mixes. However, the state requires contractors to follow AASHTO blending charts for those mixes that have more than 30% asphalt binder replacement (ABR). Even higher ratios have been explored successfully in the US. Neighboring New Jersey (NJDOT) currently allows up to 100% RAP in certain applications. Vermont (VTrans) guidelines use 50% RAP in most applications.[3] MDOT is currently piloting the use of rejuvenators in RAP mixes, which allow for higher ratios of RAP without reducing the performance of the asphalt as well as Crumb Rubber Modifiers (CRMs), and other eco-friendly additives into asphalt mix designs.

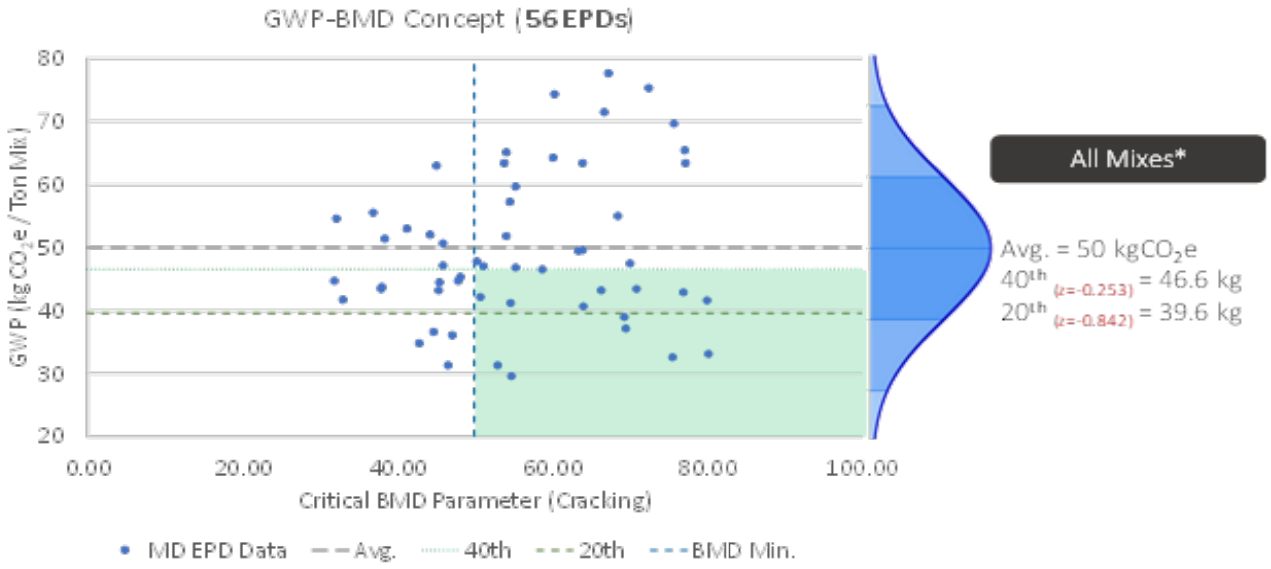
SHA follows the Superpave® method for volumetric design of dense-graded asphalt mixtures. The volumetric analysis is based on 4.0 percent design air voids at 50 to 100 gyrations depending on the design traffic level, except that 3.0 percent design air voids is required for 4.75 mm NMAS mixtures. The minimum voids in mineral aggregates (VMA) criteria vary from 11 to 16 percent depending on the NMAS

The data in the figures below demonstrate the depth of MDOT's engagement in this policy space to date. Figure B-1 shows how the actual EPD data can be compared to BMD criteria for cracking, and Table B-2 identifies EPDS for existing Maryland asphalt mixture producers.

[2] https://www.fhwa.dot.gov/pavement/recycling/rap/

[3] Omranian et al., 2022. https://www.sciencedirect.com/science/article/abs/pii/S0950061822025168

Figure B-1 | Idealized Example of Assessing Asphalt Mixtures by GWP and BMD



Note: The cracking data simulated and does not represent actual data. SHA will work with industry partners like the National Center for Asphalt Technology to advance this concept into realization for this effort.

Table B-2-5 | Breakdown of Existing Maryland Producers' EPD by NMAS

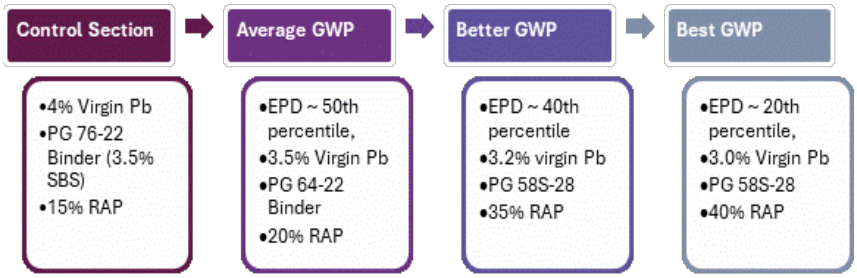
Asphalt Mixture, NMAS	Existing EPDs	Percentage of Data
4.75 mm	1	2%
9.5 mm	14	25%
12.5 mm	21	38%
19.0 mm	12	21%
25.0 mm	7	13%
37.5 mm	0	-

Plans for Asphalt Quality Assurance and Specifications

This section provides additional detail about the plans for Task 2 - LCTM Quality Assurance and LCTM Specifications. With the support of NCAT, MDOT will analyze data from various mix types to define GWP levels according to ISO standards. Using simulation data, the administration will determine mixes that fall into the 20th and 40th percentiles of GWP and include them in test strips and subsequent projects, monitoring their performance over time. Asphalt mixture performance testing will also be utilized in the assessment of eligible materials. MDOT is in the process of advancing balanced mixed design (BMD) for asphalt materials design and production quality assurance.

MDOT is planning to implement the High-temperature Indirect Tensile Strength (HT-IDT) test and the Indirect Tensile Asphalt Cracking Test (IDEAL-CT) for the evaluation of rutting resistance and cracking resistance,

Figure B-2 Illustrative Concept, Asphalt Pavement Test Strips



respectively, toward balanced mix design in the future. Research is currently underway to select the preliminary HT-IDT and IDEAL-CT test criteria for mixture design approval. In this task, BMD test criteria will be used to ensure the success of advancing LCTM materials into practices.

Initial focus will be on 12.5 mm NMAS surface asphalt mixtures, based on the available data. A similar concept can be used in concrete and cement applications.

MDOT will leverage its own resources and its partners to identify challenges to deployment and collaborate on mitigation strategies to address them. Outside entities like McCormick Taylor, UMD, NMRC, and NCAT will be able to provide consulting services on EPD collection, evaluation, benchmarking, and assessment of eligibility of low-carbon materials for use on identified projects.

B.2 Concrete Mixes in Maryland Today

Concrete is a composite mixture of hydraulic cement, aggregates, and water, and sometimes include other admixtures, fibers, and cementitious materials. Concrete can be mixed in situ, or "ready mixed" and delivered to the construction site from the manufacturing facility. As the table below demonstrates, the embodied carbon thresholds for concrete vary by material strength classification: as the strength class rises, the corresponding embodied carbon threshold also increases.

Table B-2-6 | Low Embodied Carbon Concrete

Concrete Strength Class	Top 20% Threshold	Top 40% Threshold	Better than Industry Average Threshold
≤ 2,499	228	261	277
3,000	257	291	318
4,000	284	326	352
5,000	305	357	382
6,000	319	372	407
≥ 7,200	321	362	402

EPD-reported GWPs, in kilograms of carbon dioxide equivalent per cubic meter

Maryland currently optimizes concrete mixes by including repurposed supplementary cementitious materials (SCM) and concrete admixtures to lower the embodied carbon content and increase the durability and service life of the concrete pavements and structures. The optimized concrete mixes include the use of Type 1L cement, and other cementitious materials such as fly ash, ponded fly ash, slag cement, silica fume, metakaolin, and calcined clay for durable low carbon mixes. These mixes could be binary or ternary, provided they are durable, and achieve a longer service.

Appendix C. Anticipated University Partners

Table C-2-7 List of Anticipated University Partners

Partner University	Details About Anticipated Partnership
University of Maryland, College Park (UMD) – Build America Center (BAC)	SHA has a long-standing working relationship with the Civil Engineering Department and Build America Center (BAC) at the University of Maryland (UMD). BAC is a center for excellence established by FHWA. The center focuses on mobilizing the use of innovative finance, funding, and project delivery solutions to advance transportation infrastructure development. BAC may identify the eligible existing and new low carbon materials suitable for projects such as titanium dioxide. It also has capabilities to organize certification courses and workshops.
Morgan State University – National Transportation Center	The National Transportation Center (NTC) at Morgan State University is a distinguished research institution focused on transportation and its vital role in human and economic development.
Michigan State University – National Center for Pavement Preservation	The National Center for Pavement Preservation (NCPP) was established by Michigan State University and the Foundation for Pavement Preservation to lead collaborative efforts among government, industry, and academia in the advancement of pavement preservation. It can optimize concrete mixes and identifying the eligible existing and new low carbon materials suitable for projects, such as titanium dioxide.
Auburn University – Transportation Research Institute	Established in 2021, the Auburn University Transportation Research Institute is home to the National Center for Asphalt Technology (NCAT), its affiliated asphalt test track, and four other research units. NCAT mission is to provide innovative, relevant and implementable research, technology development and education that advances safe, durable and sustainable asphalt pavements.