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REDUCING CARBON EMISSIONS ON I-64 CAPACITY IMPROVEMENT PROJECT WITH THE USE OF FSB AND EMULSION ASPHALT MIXTURES

Document Prepared by:

Global Emissionairy, LLC

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Prepared By	Global Emissionairy, LLC
Contact	Ben Devine, PE PO Box 6, Phoenix, MD 21131 443-616-3010 / ben@globalemissionairy.com www.globalemissionairy.com

CONTENTS

1 PROJECT DETAILS.. 4
1.1 Summary Description of the Project 4
1.2 Sectoral Scope and Project Type 5
1.3 Project Eligibility 5
1.4 Project Design 6
1.5 Project Proponent 7
1.6 Other Entities Involved in the Project 8
1.7 Ownership.. 10
1.8 Project Start Date 10
1.9 Project Crediting Period 10
1.10 Project Scale and Estimated GHG Emission Reductions or Removals 10
1.11 Description of the Project Activity 12
1.12 Project Location 16
1.13 Conditions Prior to Project Initiation 16
1.14 Compliance with Laws, Statutes and Other Regulatory Frameworks 17
1.15 Participation under Other GHG Programs 18
1.16 Other Forms of Credit.. 18
1.17 Sustainable Development Contributions 19
1.18 Additional Information Relevant to the Project 22

2 SAFEGUARDS.. 22
2.1 No Net Harm 22
2.2 Local Stakeholder Consultation 23
2.3 Environmental Impact 24
2.4 Public Comments 24
2.5 AFOLU-Specific Safeguards 24

3 APPLICATION OF METHODOLOGY.. 25
3.1 Title and Reference of Methodology 25
3.2 Applicability of Methodology 25
3.3 Project Boundary 25
3.4 Baseline Scenario 32

3.5 Additionality 33
3.6 Methodology Deviations 34

4 IMPLEMENTATION STATUS 34
4.1 Implementation Status of the Project Activity 34

5 ESTIMATED GHG EMISSION REDUCTIONS AND REMOVALS............................ 35
5.1 Baseline Emissions 35
5.2 Project Emissions 38
5.3 Leakage..51
5.4 Estimated Net GHG Emission Reductions and Removals..52

6 MONITORING 58
6.1 Data and Parameters Available at Validation 58
6.2 Data and Parameters Monitored...64
6.3 Monitoring Plan 79

7 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS 80
7.1 Data and Parameters Monitored...80
7.2 Baseline Emissions 90
7.3 Project Emissions 92
7.4 Leakage..94
7.5 Net GHG Emission Reductions and Removals 95

1 PROJECT DETAILS

1.1 Summary Description of the Project

The foam stabilized base (FSB) and asphalt emulsion mixtures project aims to enlist road construction contractors in the United States of America with the purpose of reducing greenhouse gas (GHG) emissions during the asphalt installation process by using FSB and asphalt emulsions in place of Hot Mix Asphalt (HMA). Prior to project implementation, the road construction projects would have utilized typical HMA or Warm Mix Asphalt (WMA) installation which has a significant GHG emission footprint associated with the mining of virgin aggregates, trucking the virgin aggregate to the mix plant, heating the mix to 310°F, and then trucking the mixed product at high temperatures to the job site (further detailed in Sections 1.11 and 3.4).

FSB and asphalt emulsions, as compared to the baseline HMA or WMA scenario, greatly reduce GHG emissions by (further detailed in Section 1.11):

1. Recycling the existing roadway and eliminating the need for virgin aggregate mining.
2. Eliminating the need for long distance trucking of virgin aggregates.
3. FSB and asphalt emulsions do not need to be heated to high temperatures like HMA which reduces GHG emissions related to electricity, diesel, or natural gas consumption at the mix plant and to-site delivery.

FSB and asphalt emulsions are utilized in three pavement application processes known as Cold-in-Place Recycling (CIR), Cold Central Plant Recycling (CCPR), and Full Depth Reclamation (FDR). CIR is a method of producing FSB/asphalt emulsion pavement mixtures using one or more mobile recycling machines for milling, asphalt production, and placement in a continuous operation at the project job site that generally uses 100% RAP generated from the existing pavement at the site. CCPR is a method of producing FSB/asphalt emulsion pavement mixtures at a central mixing plant and transporting that mixture to the jobsite for installation. FDR is a method of producing FSB/asphalt emulsion pavement mixtures that is very similar to CIR, however the full depth of existing pavement and a predetermined depth of the underlying subbase is recycling and mixed on-site to produce the asphalt mixture.

These pavement recycling techniques enable agencies to optimize the value of in-place materials and minimize the construction time and traffic flow disruptions, as well as to reduce vehicle emissions from long traffic queues. In-place recycling reclamation also reduces the number of construction vehicles moving in and out of the construction area and neighborhood truck traffic.

NCHRP Synthesis 421 documented the following benefits of pavement recycling to fix the structural distress in pavements; (a) reduces the use of natural resources; (b) eliminates materials generated for disposal; (c) reduces fuel consumption; (d) reduces greenhouse gas emissions by between 50% and 85%; (e) minimizes lane closure times; (f) improves driver safety by improving friction, providing lane widening, and eliminating overlay edge drop off; (g) maintains height clearances, which eliminates the need to adjust appurtenances; (h) addresses existing material deficiencies such as moisture damage; (i) reduces costs of preservation, maintenance, and rehabilitation; and (j) improves base support with a minimum of needed wearing course.

The project activity quantifies the reduced GHG emissions associated with the use of FSB and/or asphalt emulsions as substitutes for HMA on asphalt construction projects. The project instances consist of existing highway roads in need of repair to extend the usable lifespan for conveying vehicular traffic. The initial project instance is located in the State of Virginia on Interstate Highway 64 (I-64) which began construction in April 2018.

This group of projects is submitted following VCS methodology VM0039, Methodology for Use of Foam Stabilized Base and Emulsion Asphalt Mixtures in Pavement Application V1.0, which provides the requirements for pavement projects within the United States that utilize FSB and asphalt emulsions in place of traditional HMA to issue verified carbon unit credits (VCUs). This group of projects will include completed pavement projects that utilized FSB and asphalt emulsions and are located within the continental United States. Global Emissionairy, LLC is the project proponent. Ultimately, projects currently under design, construction, and future projects would be added under this project description. An estimated annual average GHG emission reduction is 7,379 tonnes of CO_2 per year with an estimated total GHG emission reduction of 73,790 tonnes of CO_2 over the 10-year crediting period.

Audit Type	**Period**	**Program**	**VVB Name**	**Number of years**
Validation/ Verification	2018-2021 (17-April-2018 – 13-September-2021)	VCS	Ruby Canyon Environmental Inc.	3.41
Total	2018-2021 (17-April-2018 – 13-September-2021)	VCS	Ruby Canyon Environmental Inc.	3.41

1.2 Sectoral Scope and Project Type

The project falls under Sectoral Scope 6: Construction and should be considered a grouped project.

1.3 Project Eligibility

This project meets all requirements set out in the VCS Standard, VCS Program Guide, and the approved VCS methodology VM0039. The asphalt paving project activities described herein generate GHG reductions through the production and installation of FSB and/or asphalt emulsions using Cold Central Plant Recycling (CCPR), Cold In-place Recycling (CIR), and/or Full Depth Reclamation (FDR) processes and are located within the United States of America.

Section 2.1 of the VCS Standard (v4.4) lays out the scope of the VCS program, including the following:

1. The seven Kyoto Protocol greenhouse gases (this project has will reduce CO2 emissions as detailed in Section 5 of this document)
2. Ozone-depleting substances (not applicable)
3. Project activities supported by a methodology approved under the VCS Program through the methodology development and review process (this project utilizes VM0039 as explained in Section 3 of this document)
4. Project activities supported by a methodology approved under an approved GHG program, unless explicitly excluded (not applicable)
5. Jurisdictional REDD+ programs and nested REDD+ projects as set out in the VCS Program document Jurisdictional and Nested REDD+ Requirements (not applicable)

1.4 Project Design

The project has been designed as a grouped project. New project instances will comply with the set of criteria listed below.

Eligibility Criteria

As a grouped project, additional project instances may be included in this project description if the following requirements are met:

1. Project activities include the construction of any type of road and/or parking lot (including parking lot patching projects) in the United States.
2. Project activities must apply one or more of the following processes for road construction:
    a. FSB produced using the CCPR process
    b. FSB produced using the CIR process
    c. FSB produced using the FDR process
    d. Asphalt emulsions produced using the CCPR process
    e. Asphalt emulsions produced using the CIR process
    f. Asphalt emulsions produced using the FDR process
3. Production plants where the project activity occurs may serve multiple pavement types, including, but not limited to, roadways and parking lots.

4. Project activities may have an HMA or WMA surface *layer but* must have at least one FSB or asphalt emulsions base layer.
5. Are subject to the baseline scenario determined in the project description for the specified project activity and geographic area, which in this case (as specified in VM0039) is the continuation of reconstructing roadways with HMA pavement in the United States
6. Have characteristics with respect to additionality that are consistent with the initial instances for the specified project activity and geographic area. For example, the new project activity instances have financial, technical and/or other parameters (such as the size/scale of the instances) consistent with the initial instances, or face the same investment, technological, and/or other barriers as the initial instances.
7. Occur within one of the designated geographic areas (The United States) specified in the project description.
8. Conform with at least one complete set of eligibility criteria for the inclusion of new project activity instances. Partial conformance with multiple sets of eligibility criteria is insufficient.
9. Be validated at the time of verification against the applicable set of eligibility criteria.
10. Be included in the monitoring report with sufficient technical, financial, geographic, and other relevant information to demonstrate conformance with the applicable set of eligibility criteria and enable evidence gathering by the validation/verification body.
11. Have evidence of project ownership, in respect of each project activity instance, held by the project proponent from the respective start date of each project activity instance (i.e., the date upon which the project activity instance began reducing or removing GHG emissions).
12. Have a project start date that is the same as or later than April 17, 2018.
13. Be eligible for crediting from the start date of the project activity instance through to the end of the project crediting period (only).
14. Only eligible for crediting from the start of the verification period in which they were added to the grouped project.
15. Not be or have been enrolled in another VCS project.
16. Adhere to the clustering and capacity limit requirements for multiple project activity instances set out in 3.6.8 - 3.6.9 of the VCS Standard (v4.4).

1.5 Project Proponent

Organization name	Global Emissionairy, LLC
Contact person	Harold Green

Title	CEO
Address	PO Box 6, Phoenix, Maryland 21131
Telephone	202-288-4130
Email	hg@globalemissionairy.com

1.6 Other Entities Involved in the Project

Organization name	Allan Myers, Inc.
Role in the project	Contractor
Contact person	Tim Peffer
Title	Director, Quality Control
Address	1805 Berks Road Worcester, PA 19490
Telephone	610-584-6020
Email	tim.peffer@allanmyers.com

Organization name	University of Maryland, Smart Construction Center
Role in the project	Technical Consultants, Methodology development
Contact person	Dr. Qingbin Cui
Title	Professor of Civil Engineering
Address	1173 Glen Martin Hall 4298 Campus Drive College Park, MD 20742

Telephone	301-405-8104
Email	cui@umd.edu

Organization name	King Cow Interactive LLC
Role in the project	Methodology and application development
Contact person	David F. Choy
Title	Partner
Address	Kingcow.com
Telephone	202-470-6045
Email	david@globalemissionairy.com

Name	Dr. Chandra Akesitty
Role in the project	Technical Consultant, Methodology development
Title	Structural Engineer
Address	7035 Southmoor Street Hanover, MD 21076
Telephone	202-740-3812
Email	chandra@globalemissionairy.com

Organization name	Global Emissionairy, LLC
Role in the project	Verra Registry Account Administrator

Contact person	Jim Peacock
Address	PO Box 6, Phoenix, Maryland 21131
Telephone	443-864-3683
Email	jp@globalemissionairy.com

1.7 Ownership

The Project Proponent, Global Emissionairy, LLC, holds the rights of the GHG emissions savings achieved in the asphalt pavement construction projects performed by Allan Myers, Inc. using FSB and/or asphalt emulsion through an Emission Reductions Sales and Service Legal Agreement. This is consistent with VCS Standard Section 3.6.1 Ownership, clause 3 which states:

3. Project ownership arising by virtue of a statutory, property or contractual right in the plant, equipment or process that generates GHG emission reductions and/or removals (where the project proponent has not been divested of such project ownership).

1.8 Project Start Date

The Project start date is April 17, 2018, the date that CCPR and FDR asphalt installation first began.

1.9 Project Crediting Period

The Project's crediting period is 10 years-fixed, beginning on the Project start date of April 17, 2018, and ending on April 16, 2028.

1.10 Project Scale and Estimated GHG Emission Reductions or Removals

For the purposes of assessing materiality, VCS projects are disclosed across two project categories:

1. *Projects:* Less than or equal to 300,000 tonnes of CO_2e per year.
2. *Large Projects*: Greater than 300,000 tonnes of CO_2e per year.

The grouped project is anticipated to be under the annual 300,000 tCO_2e threshold for *Large Project* scale and is therefore classified as *Project* category. In addition, a 10-year fixed crediting period has been selected for the Grouped Projects.

Table 1: Project Scale

Project Scale	
Project	X
Large project	

Table 2: Estimated Annual GHG Emission Reductions for Project Crediting Period

Year	Estimated GHG emission reductions (tCO_2e)
2018 (17-April-2018 – 31-December-2018)	9,181
2019 (1-January-2019– 31-December-2019)	2,390
2020 (1-January-2020– 31-December-2020)	3,581
2021 (1-January-2021– 13-September-2021)	2,638
2021 (14-September-2021– 31-December-2021)	-
2022 (1-January-2022–	-

31-December-2022)	
2023 (1-January-2023–31-December-2023)	-
2024 (1-January-2024–31-December-2024)	10,500
2025 (1-January-2025–31-December-2025)	12,500
2026 (1-January-2026–31-December-2026)	15,000
2027 (1-January-2027–31-December-2027)	18,000
2028 (1-January-2028–16-April-2028)	-
Total estimated ERs	73,790
Total number of crediting years	10
Average annual ERs	7,379

1.11 Description of the Project Activity

For over 40 years, FSB and asphalt emulsions have been used in road projects around the world when natural resources for virgin aggregate or funding to construct and maintain roads using HMA have been limited. In North America, where virgin aggregate has historically been easily accessible within proximity to project sites, FSB has not been as widely implemented as it has in other parts of the world. FSB has, therefore, been used on a very limited basis in the United States for the last 10 to 15 years. Most projects using FSB and asphalt emulsions in the United States are pilot projects funded by various state highway agencies. While these projects have proven successful, state highway administrations have been slow to accept and develop the protocol and practices for this approach in North America. Presently there are no national or regional standards for the production or application of FSB and asphalt emulsions, which serves as a major impediment to the acceptance and application of FSB and asphalt emulsions beyond the testing phase.

The project activity includes roadway paving projects that utilize FSB and/or asphalt emulsion instead of HMA in the production and installation of asphalt pavement construction. GHG emission reductions are generated from producing and installing FSB and asphalt emulsions instead of HMA as follows:

- FSB and asphalt emulsions consist of 50% less liquid asphalt/bitumen by weight and 2.5% less asphalt/bitumen by volume than required for HMA production, reducing the reliance on resources. No virgin aggregates are required, eliminating the energy and resources needed for excavating machines and trucking. In most applications, but especially in rural areas, the GHG emissions from trucking are significantly reduced. This is due to the fact that FSB and asphalt emulsions can be manufactured on or close to the project site.
- Aggregates in FSB and asphalt emulsions do not have to be heated, while HMA liquid, which is roughly 2.2% of the total weight of the mix, needs to be heated up to 310 °F and kept at high temperatures during storage and transport resulting in significant GHG emissions from the electricity, natural gas, or diesel fuel used to heat, mix, store, and transport the HMA.

The project instances in the first monitoring period (April 17, 2018, through September 13, 2021) described in this project description use Cold Central Plant Recycling (CCPR) and Full-Depth Reclamation (FDR) paving processes.

Introduction to the CCPR Process

The CCPR process rehabilitates roads by reusing reclaimed aggregate pavement (RAP) at a central plant location. Figure 1 below shows the typical arrangement of the main manufacturing/production technologies, systems and equipment involved in the CCPR paving process. The CCPR process begins by using a front loader to feed RAP into a mobile mixing plant that crushes, screens, then blends the unheated RAP with FSB or asphalt emulsions with a small amount of Portland cement (if applicable to the mix design) in a cold mixing process. This process creates an asphalt mixture that is transported to the jobsite using dump trucks. Once at the jobsite, the dump trucks pour the asphalt mixture into a paving machine that lays the mixture down onto the ground surface in a uniform layer. The final step in this paving process is compaction which is performed by rollers following behind the paving machine that perform multiple passes until the proper density is obtained.

The cold recycling mix plant is the primary piece of equipment in this process that controls production rates. A typical diesel-powered mobile mixing plant can produce 220 tonnes/hour of recycled mix. When operating at a mixing capacity of 200 tonnes/hour, one truck load of 20 tonnes of cold recycling mix is produced every 6 minutes. This amount of material enables an approximately 560 foot long, 12 feet wide, and 6-inch-thick section of road to be paved every hour, or roughly one lane-mile per 10-hour workday at a 6-inch depth.

The mobile mix plant includes a screen deck to receive the appropriate gradation required by the specification, and an oversized particles removal system to ensure that all particles are of acceptable specification sizes. The calibrated conveyer collects the crushed aggregate particles from the screen deck, weighs the particles based on the mix design batches, and transfers them to the pugmill.

As the aggregate is transported on the conveyor, aggregate and cement weights are measured and transmitted from the conveyor to the pug mill by built-in calibrated mix plant computer. The computer also controls nozzles, which releases foam bitumen or asphalt emulsion that is proportional to the mix design, into the pug mill with the proportion of sprayed foamed bitumen or asphalt emulsion by percent weight of the aggregate that enters the pug mill.

The components are mixed in the pug mill before they exit the mix plant through the slewing conveyor that dumps the mix into a stockpile or directly into a waiting dump truck that transports the material to the job site. Once at the job site, the dump trucks unload the mix material into a paver, which is calibrated to adjust the rate of pavement application based on the level of smoothness, desired layer thickness, and cross slope of the required pavement profile. The rollers follow the paver to compact the mix according to a pre-determined rolling pattern that dictates how many passes of each roller are required to achieve optimum density according to the approved mix design.

The quality control technician on the job site records the number of rollers passes, depth of material, gradation of crushed and screened aggregates from the calibrated conveyor belts, and density of the paved mat according to the pre-approved quality control plan.

Generally, two hours after the paving is completed using the CCPR process, traffic is allowed on to the pavement. The CIR mat is open for 3 to 10 days for complete curing before it receives surface treatment such as chip seal, micro surface, or HMA pavement.

Introduction to FDR and CIR Processes

The FDR and CIR processes rehabilitate roads by reusing existing pavement “in-place” which eliminates the need to procure and haul new aggregate compared to traditional baseline projects. Figure 2 below shows the typical arrangement of the main manufacturing/production technologies, systems and equipment involved in the FDR and CIR paving processes. The FDR and CIR process use the same machinery which consists of milling existing pavement into reclaimed aggregate pavement (RAP), sizing the RAP, mixing the new RAP with asphalt emulsions, placing the new material down, and compacting it. This process is executed with a “train” of equipment that drives down a roadway.

A cement spreader truck leads the train and applies a uniform layer of cement to the road surface at a specific rate determined by the project mix design. Then, there is a water truck and an optional bitumen tank, as determined by the mix design, that are hooked up to a cold recycling machine. For CIR, the cold recycling machine mills up just a portion of the existing pavement, while for FDR applications this machine mills up all the existing pavement and a specified depth of the underlying sub-base. The milled material is then crushed, screened, mixed with the required additives (water/bitumen), and placed back down on the ground surface by the same cold recycling machine. The last step in this process is compaction which is achieved by rollers following behind the cold recycler to achieve final compaction and complete the road construction.

The cold recycling machine is the primary piece of equipment in these processes that control production rates. The FDR and CIR process can pave a 2-mile-long stretch of lane on a good day with reasonable pavement hardness. However, if the existing pavement contains a hard rock like granite, the length of the lane that can be paved may be reduced to a minimum of one mile.

The cold recycler includes a milling machine that can cut 3 to 13.8 inches deep and is connected to a crushing unit to size up the aggregate from millings. Typical CIR projects cut down approximately 3 to 6 inches, while FDR projects typically cut down 6 to 12 inches. The treatment train also includes a screen deck to receive the appropriate gradation required by the specification, and an oversized particles removal system to ensure that all particles are of acceptable specification sizes. The calibrated conveyer collects the crushed aggregate particles from the screen deck, weighs the particles based on the mix design batches, and transfers them to the pugmill.

As the aggregate is transported on the conveyor, aggregate weights are measured and transmitted from the conveyor to the pug mill by built-in calibrated cold recycler computer. The computer also controls nozzles, which releases foam bitumen or asphalt emulsion that is proportional to the mix design, into the pug mill with the proportion of sprayed foamed bitumen or asphalt emulsion by percent weight of the aggregate that enters the pug mill. The Portland cement is already sprayed proportionately on the road before the train, and it is combined with the aggregate from the milling machine.

The components are mixed in the pug mill before they are conveyed to the paver, which is calibrated to adjust the rate of pavement application based on the level of smoothness and cross slope of the required pavement profile. The rollers follow the paver to compact the mix according to a pre-determined rolling pattern that dictates how many passes of each roller are required to achieve optimum density according to the approved mix design.

The quality control technician on the job site records the number of rollers passes, depth of milling at random locations, gradation of crushed and screened aggregates from the calibrated conveyor belts, and density of the paved mat according to the pre-approved quality control plan.

Generally, two hours after the paving is completed using the CIR process, traffic is allowed on to the pavement. The CIR mat is open for 3 to 10 days for complete curing before it receives surface treatment such as chip seal, micro surface, or HMA pavement.

Average Lifetime of Equipment

A 12’ cold recycler is the standard and has an average life expectancy of about 5,000 operating hours or 5 years assuming an average use of 1,000 hours per year. All other equipment in the FDR/CIR train and the CCPR mix plant has an average life expectancy of 10 to 15 years however this can vary greatly based on the use (hours per year) and the quality of maintenance performed on the machinery. The age of equipment in specific project instances may vary.

1.12 Project Location

The Grouped Projects have been or will be constructed within the continental United States of America. The first project instance is located within the City of Newport News, James City County, and York County in the Commonwealth of Virginia on Interstate Highway 64. The project instance was part of Segment 2 and 3 of the I-64 capacity improvements.

Table 3: Project Instance Coordinates

Project	Start Coordinates	End Coordinates
I-64 Segment 2	37°15'25.5"N, 76°38'44.3"W	37°12'58.8"N, 76°35'48.6"W
I-64 Segment 3	37°21'20.7"N, 76°44'05.4"W	37°15'25.5"N, 76°38'44.3"W

1.13 Conditions Prior to Project Initiation

A project becomes an ideal candidate for repair using recycling techniques when it has major structural distresses, such as alligator (bottom-up) or longitudinal (top-down) cracking in existing HMA pavements or when the project has an extensive patching history and cannot restore ride quality to the desired value with nominal HMA overlay. Cold in-place recycling (CIR) or Cold Central Plant Recycling (CCPR) are recycling techniques to fix the structural distresses in the pavements to extend the pavement life with minimal costs, traffic interruptions, and carbon emissions. The project becomes a good candidate for full depth reclamation (FDR) if the structural distress is caused by a poor existing subgrade condition. FDR will expose the subgrade and fix the entire pavement from the bottom layer up.

Pavement condition index (PCI), a commonly used rating system to evaluate ride quality, is measured by using either cores or a falling weight deflectometer (FWD) before making the decision on rehabilitation. CIR will be used if the PCI is within the fair range and FDR will be used if the PCI is in the poor to very poor range. State and local departments of transportation use PCI to evaluate and prioritize roadway construction projects with available funding to fix damaged roadways, which ensure safe and efficient transportation for public use. The decision to initiate a project is completely independent of the contractor that ultimately performs the roadway improvements, which ensures that a project is never implemented to generate GHG emissions for the purpose of their subsequent reduction, removal, or destruction. Every project instance included within this grouped project description was initiated by an independent party for the purposes of rehabilitating an existing roadway to improve its value to the public. The baseline scenario has the same existing conditions prior to project initiation and is further detailed in Section 3.4.

In-place recycling enables agencies to optimize the value of in-place materials and minimize the construction time and traffic flow disruptions, as well as to reduce vehicle emissions from long traffic queues. In-place recycling/ reclamation also reduces the number of construction vehicles moving in and out of the construction area and neighborhood truck traffic.

NCHRP Synthesis 421 documented the following benefits of in-place recycling to fix the structural distress in pavements; (a) reduces the use of natural resources; (b) eliminates materials generated for disposal; (c) reduces fuel consumption; (d) reduces greenhouse gas emissions by between 50% and 85%; (e) minimizes lane closure times; (f) improves driver safety by improving friction, providing lane widening, and eliminating overlay edge drop off; (g) maintains height clearances, which eliminates the need to adjust appurtenances; (h) addresses existing material deficiencies such as moisture damage; (i) reduces costs of preservation, maintenance, and rehabilitation; and (j) improves base support with a minimum of needed wearing *course.*

1.14 Compliance with Laws, Statutes and Other Regulatory Frameworks

The incremental level of activity, the use of alternative asphalt mix designs and cold recycling installation, requires no new compliance with national, regional and local laws, statutes or regulatory frameworks as none of these currently exist in the United States.

However, in most cases, roadway owners establish construction specifications that offer detailed instructions on materials, procedures, and quality standards for individual projects. These specifications are distinct from legal or regulatory mandates. The specific construction specifications vary from project to project but typically include the following common procedures:

- Materials: The construction specifications define the allowable materials to be used in the cold recycling mix which typically includes RAP, portland cement, bituminous stabilizer, and water. Other additives may be applicable to future project instances. Evidence of materials used in the mix will be provided to the VVB.

- Mix design: The construction specifications outline laboratory procedures for testing various mix designs to determine the ideal composition in terms of raw material percentages that yield optimal density and tensile strength. The contractor or an independent third-party laboratory submits the recommended mix design to the roadway owner for approval. This step is crucial for stakeholder engagement, ensuring consensus on the project mix design. All project-specific mix designs will be provided to the VVB.

- Installation Equipment: The construction specifications outline the necessary equipment for installation, including an in-place recycling unit, a paver, a vibratory double steel drum roller, and a second roller, a pneumatic tire roller. While other equipment is commonly used on projects, these four pieces of equipment are typically specified by the construction specifications. All installation equipment will be provided to the VVB.

For this initial project instance, the construction specifications were part of the Virginia Department of Transportation 2016 Road and Bridge Specification (revised March 2020) including special provision SP315-000400-00 (CCPR) and SP315-000420-00 (FDR). Global Emissionairy provided the VVB with the contractor's quality control plan which documented the process and step taken to ensure compliance with the specifications.

1.15 Participation under Other GHG Programs

1.15.1 Projects Registered (or seeking registration) under Other GHG Program(s)

The project instances under this grouped project are not registered and have not pursued registration under any other GHG program.

1.15.2 Projects Rejected by Other GHG Programs

The project instances under this grouped project have not been rejected by any other GHG Program.

1.16 Other Forms of Credit

1.16.1 Emissions Trading Programs and Other Binding Limits

The project instances under this grouped project have not and will not be used in activities that are included in an emissions trading program or any other mechanism that includes GHG allowance trading.

1.16.2 Other Forms of Environmental Credit

The project instances under this grouped project have not received or tried to receive other environmental credits.

1.16.3 Supply Chain (Scope 3) Emissions

This section is not applicable as all claimed emission reductions and removals related to this project occurred prior to 1 January 2024.

1.17 Sustainable Development Contributions

1.17.1 Sustainable Development Contributions Activity Description

The United Nations (UN) Sustainable Development Goals (SDGs) provide a global sustainability framework for all developed and developing countries to implement which contributes to a more sustainable future for all. While the United States has committed to the UN SDGs, it does not have any specific national target goals established for each SDG. However, several of the SDGs align with the grouped project instance, including SDG 9 – Target 9.4, SGD 12 – Target 12.5, and SDG 13.

- SDG 9 – Target 9.4 aims to upgrade infrastructure and retrofit industries to make them sustainable using increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes. The grouped project instance utilizes CCPR and FDR/CIR process technology to rehabilitate roadways through recycling of the existing roadway aggregate resulting in a significant reduction of virgin aggregate mining and greater resource-use efficiency.
- SDG 12 – Target 12.5 aims to substantially reduce waste generation through prevention, reduction, recycling, and reuse by 2030. The grouped project instance meets this design criteria through the CCPR and FDR/CIR processes by re-using asphalt millings, greatly reducing wasted material.
- SDG 13 – aims to take urgent action to combat climate change and its impacts. While the grouped project instances do not directly correspond with an official SDG indicator, the very nature of the VCS Program aligns with this SDG through quantification of GHG emission reductions. The grouped project instance uses CCPR and FDR processes to greatly reduce CO_2 emissions as compared to the baseline HMA scenario as described in Section 5.

1.17.2 Sustainable Development Contributions Activity Monitoring

The grouped project instance implements CCPR and FDR/CIR technology to rehabilitate roadway infrastructure by recycling the aggregate material of the existing roadway. This process results in significant reductions in waste material, reductions in virgin aggregate mining and trucking, and reductions in CO_2 emissions as compared to the baseline HMA scenario. The project instance rehabilitated 15.33 miles of roadway infrastructure, reused 395,925 tonnes of asphalt millings which prevented mining of virgin aggregate, and prevented 17,790 tonnes of carbon from being released into the atmosphere. Since this is the initial monitoring period for the project, there have been no prior contributions towards the SDGs included in previous monitoring periods. Table 4 below summarizes and quantifies the specific SDG targets met by the grouped project instance. Due to the absence of specific national target goals established for each SDG in the United States, it is not possible to compare project contributions against official targets. Evidence of the project instance SDG contributions are included in Appendix A.

Table 4: Sustainable Development Contributions

Row number	SDG Target	SDG Indicator	Net Impact on SDG Indicator	Current Project Contributions	Contributions Over Project Lifetime
1)	9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	Implemented activities to increase	The project has upgraded 15.33 miles of roadway infrastructure using more sustainable construction processes than the typical baseline scenario project.	The project has upgraded 15.33 miles of roadway infrastructure using more sustainable construction processes than the typical baseline scenario project.
2)	12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse	Implemented activities to increase	The project has reduced 395,925 tonnes of waste through the recycling and reuse of asphalt millings in roadway construction.	The project has reduced 395,925 tonnes of waste through the recycling and reuse of asphalt millings in roadway construction.
3)	13.0	Tonnes of greenhouse gas emissions avoided or removed	Implemented activities to increase	The project has prevented the release of 17,790 tonnes of carbon into the atmosphere during the monitoring period.	The project has prevented the release of 17,790 tonnes of carbon into the atmosphere during the monitoring period.

1.18 Additional Information Relevant to the Project

Leakage Management

According to the applicable methodology, VM0039 Methodology for Use of Foam Stabilized Base and Emulsion Asphalt Mixtures in Pavement Application, it is reasonable to assume zero leakage because there is no difference in site preparation activities between baseline and project scenarios. Replacing HMA with FSB or asphalt emulsions for the pavement base layer does not entail a change in carbon efflux or carbon sink at the construction site.

Commercially Sensitive Information

This section is not applicable as there is has not been any commercially sensitive information withheld from the project record.

Further Information

Not applicable.

2 SAFEGUARDS

2.1 No Net Harm

The proposed project involves substituting a layer of Hot Mix Asphalt (HMA) for a layer of FSB or asphalt emulsion cold recycled mix, a process that contributes to reducing environmental and socio-economic impacts compared to conventional practices. However, it is essential to acknowledge and address any potential negative consequences.

Environmental Impacts and Mitigation:

- *Energy Consumption*: The construction process, including equipment operation and transportation, consumes energy. However, this energy consumption is mitigated because cold recycling uses significantly less energy than traditional methods due to the reduced need for virgin materials and the lower temperature requirements for cold recycling as discussed in VM0039, v1.0.
- *Air Quality*: Any construction project involving heavy machinery will have associated emissions and could pose localized air quality impacts. This is mitigated through project implementation because the project emits significantly less emissions than the standard baseline practice as demonstrated by the project emission reductions quantified in this report.

Socio-Economic Impacts:

- *Traffic Disruptions:* Roadway construction projects often pose traffic disruptions to the public using the roadways due to the required trucking of significant amounts of aggregates to rehabilitate the roadway. The project activities mitigate traffic disruptions because virgin aggregate trucking is greatly reduced, and construction times are 20%-40% faster (RoadResource). The project activities cause no net harm because construction traffic is significantly reduced compared to the business-as-usual scenario.

In summary, this project consistently demonstrates its commitment to the principle of "No Net Harm." Through efficient resource utilization, a substantial reduction in aggregate trucking, and proactive measures to mitigate air quality impacts, it effectively mitigates any environmental and socio-economic impacts. The tangible evidence of reduced emissions reinforces the assertion that this project causes no net harm. It is a practical example of more sustainable construction practices that not only minimize adverse impacts but also contributes positively to the environment and society.

2.2 Local Stakeholder Consultation

Local Stakeholders consultation was achieved in several ways during the project's NEPA process which requires public outreach and through direct correspondence. The Project Proponent has identified the following stakeholders:

- Asphalt Contractor and Construction personnel (Allan Myers)
- Virginia Transportation Research Council, Virginia Department of Transportation
- Virginia Department of Transportation
- General public/road users

Stakeholder consultation for the project activity took place during the project implementation as part of the I-64 Peninsula Study Environmental Impact Statement. The public was informed about the road construction projects, including aspects of the use of recycled asphalt pavement (RAP) and FSB, via public meetings, project mailings, and a project website that included videos that displayed the asphalt installation process. Open forum citizen information meetings were held in March 2011 and April 2021 and input was collected from the public for a duration of one month after each of the two meetings.

No updates were made to the project design related to the use of CCPR or FDR since no related comments were received or recorded in the I-64 Peninsula Study Environmental Impact Statement. https://www.virginiadot.org/projects/hamptonroads/i-64_peninsula_study.asp

The Project Proponent has been in consultation about the use of FSB and asphalt emulsions with VDOT staff prior to, during, and after the construction of the I-64, Segment 2. Dr. Brian Diefenderfer of the VDOT Virginia Transportation Research Council has discussed the use of FSB and asphalt emulsions, and quantifying the reduction in emissions versus HMA, with the Project Proponent periodically over the last decade. Allan Myers, the asphalt contractor, developed the asphalt mix design, pavement layer typical section, and structural coefficient in consultation with VDOT personnel.

The project instance has been featured in numerous local and national publications for its innovative use of RAP, asphalt emulsion, CCRP and FDR. The I-64 Project has received a 2021 Roads & Bridges / ARRA Recycling Award.

On-going communication with stakeholders involved with projects and interested stakeholders can be achieved by accessing the Project Proponents website (https://globalemissionairy.com/). Any comments can be sent through the websites comment form or via email (contact@globalemissionairy.com). To date, Global Emissionairy has not received any comments on the project.

2.3 Environmental Impact

The project activity includes applying FSB and/or asphalt emulsion layers in place of HMA layers in asphalt paving applications. The first project instance was conducted as part of the Interstate 64 Peninsula Study Final Environmental Impact Statement (FEIS) and Record of Decision.

The FEIS identified five separate highway build alternatives that were evaluated to determine whether they would address the purpose and need for the project. Alternatives were either not carried forward for further study or retained for detailed study. The results of the FEIS and record of decision document that alternative 1 was chosen to move forward because it kept the proposed improvements within the existing right of way to the greatest extent practical. The FEIS also identified pavement recycling as an environmental impact mitigation measure. Thus, the project implementation aided the reduction in environmental impacts.

The FEIS identified five distinct highway build alternatives, which were assessed to determine their alignment with the project's purpose and necessity. Alternatives were either excluded from further investigation or retained for in-depth study. The FEIS and the record of the decision revealed that Alternative 1 was selected to proceed as it primarily confined proposed improvements within the existing right-of-way to the greatest practical extent. Additionally, the FEIS highlighted pavement recycling as a potential measure to mitigate environmental impacts. Therefore, the project's implementation contributed to reducing environmental impacts.

2.4 Public Comments

This Project Description was listed on the Verra Registry and available for public comment from August 17, 2022 – September 16, 2022. No public comments were received.

2.5 AFOLU-Specific Safeguards

Not applicable.

3 APPLICATION OF METHODOLOGY

3.1 Title and Reference of Methodology

The project is conducted under VCS methodology VM0039, "Methodology for Use of Foam Stabilized Base and Emulsion Asphalt Mixtures in Pavement Application," version 1.0 (VM0039). This methodology is located at https://verra.org/methodology/vm0039-methodology-for-us-of-fsb-in-pavement-application-v1-0/.

3.2 Applicability of Methodology

This project meets all of the eligibility criteria under VM0039, as indicated below (italics indicate how each requirement is met):

1) Project activities include the construction of any type of road and/or parking lot (including parking lot patching projects) in the United States – *The project instance consists of a road construction project.*
2) Project activities must apply one or more of the following processes for road construction:
   a) FSB produced using the CCPR process – *The project instance utilizes CCPR with FSB.*
   b) FSB produced using the CIR process
   c) FSB produced using the FDR process
   d) Asphalt emulsions produced using the CCPR process
   e) Asphalt emulsions produced using the CIR process
   f) Asphalt emulsions produced using the FDR process
3) Production plants where the project activity occurs may serve multiple pavement types, including, but not limited to, roadways and parking lots. – *The production plant that was used to make the CCPR mix also made HMA mix for the projects surface layer (using different machinery).*
4) Project activities may have an HMA or WMA surface layer but must have at least one FSB or asphalt emulsions base layer. – *The project instance includes an HMA surface layer but uses CCPR with FSB as a base layer.*

3.3 Project Boundary

The spatial extent of the project boundary encompasses the stages from raw material acquisition to product installation and complies with the cradle-to-gate assessment principle. The GHG impact of producing an asphalt mixture should be calculated by adding up the following emission sources: 1) GHG associated with manufacturing each of the constituent and ancillary materials; 2) GHG from transporting materials from factory to mix plant; 3) GHG from all forms of energy involved in producing the asphalt at mixing plant; and 4) GHG from all forms of energy involved in milling the existing pavement and placing new pavement, including relevant transport activities.

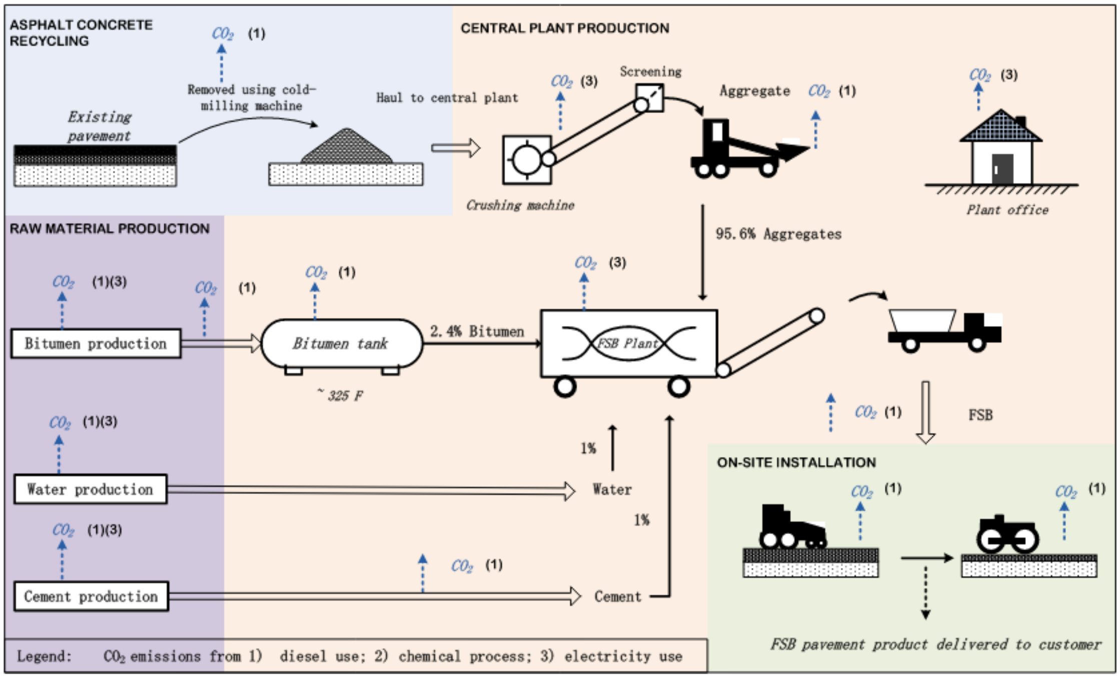
Maintenance and excavation of the new pavement are not included due to the high variability of practices in each region. The boundary also excludes GHG emissions associated with the production of capital goods having lifetimes longer than one year and the transportation of employees to and from their normal place of work.

There are three processes that the Grouped Projects can utilize: 1) Cold Central Plant Recycling (CCPR), 2) Cold in-place Recycling (CIR), 3) Full-Depth Reclamation (FDR). CIR and FDR have the same boundary.

<u>Boundary for CCPR</u>

CCPR transports milled materials from an existing jobsite to a central plant where FSB or asphalt emulsions are processed through a pug mill. Production of FSB begins with the crushing of RAP, which diverts waste from landfills. Once the crushed pavement is sized, the unheated RAP is then blended with foamed bitumen (or asphalt emulsion) and a small amount of Portland cement in a cold mixing process. Table 5 shows the major processes included in the CCPR project. The boundary consists of energy consumption for milling the existing pavement, producing bitumen binder and water, transportation to and at the FSB production plant, heating of bitumen binder, mixing, transportation of materials and resources to the project site, and installation of the mix.

Figure 1: CCPR Boundary



Boundary for CIR or FDR

CIR or FDR uses one or more mobile recycling machine for milling, production, and placement in a continuous operation at the pavement site. It reconstructs the roadways by using special equipment to mill up the existing pavement, mix it with hot bitumen oil (or asphalt emulsion) and additives, and then immediately place it back down on the road by permanent placement with a paver and rollers. CIR or FDR allows a paving contractor to use the aggregate from the existing road and, by adding liquid asphalt cement (consisting of under 3% of total volume), it reduces the emissions of new aggregate materials and new liquid asphalt cement that must be shipped from the producer's plant site. Table 5 shows the major activities included in the CIR or FDR system. The project boundary includes production of bitumen, water, and cement, operation of recycler and rollers, and transportation and storage of input materials.

Project instances must incorporate FSB and/or asphalt emulsions in place of traditional asphalt mixes while delivering or exceeding the baseline project structural strength design parameters. For example, the project boundary for the first project instance (I-64 highway) replaces the third layer (HMA) and fourth layer (cement treated base, CTB) in the pavement design with FSB. Although other GHGs have been reduced in this first project instance, methodology VM0039 only calculates the reduction of CO_2 emissions.

Figure 2: Typical Arrangement of Equipment for FDR and CIR

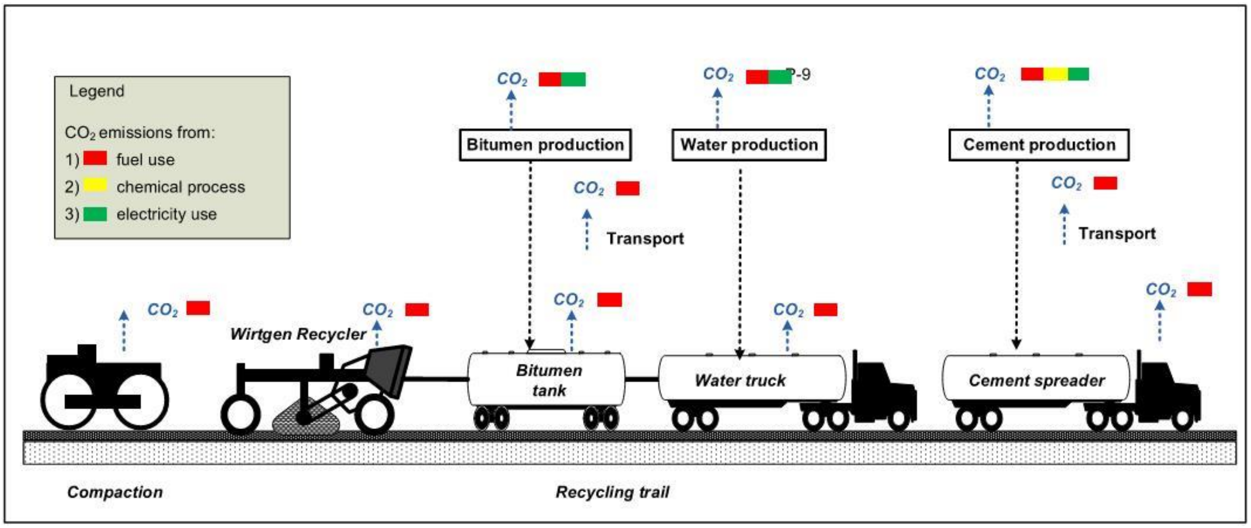


Table 5: GHG Sources Included in Baseline and Project Scenario

Source		Gas	Included?	Justification/Explanation
HMA (Baseline)	Raw material acquisition	CO_2	Yes	GHGs are released from energy consumption in material manufacture process.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Raw material transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from producers to central plant.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	In-plant production	CO_2	Yes	GHGs are generated from the usage of natural gas by the drum mixer, plant electricity (including electricity for plant office), and diesel equipment/vehicles operated for producing HMA at central plant.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	To site transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from the central plant to construction site.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Installation	CO_2	Yes	GHGs are released from diesel consumption by construction equipment/vehicles, including asphalt paving machine, backhoe, bobcat/loader, sweeper/broom, air compressor, roller, trucks, etc.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	

Source		Gas	Included?	Justification/Explanation
	Maintenance	CO_2	No	GHGs from maintenance and rehabilitation are excluded due to uncertain traffic volume, failure type and repair options.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Excavation	CO_2	No	GHGs from excavation are excluded due to the uncertainty in determining pavement disposal options (e.g., landfill, recycling, remain in place).
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
CCPR (Project Scenario 1)	Raw material acquisition	CO_2	Yes	GHGs are released from energy consumption in material manufacture process.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Raw material transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from producers to central plant.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	FSB/Asphalt emulsions production	CO_2	Yes	GHGs are generated from the usage of electricity by plant office, bitumen heater and crusher and diesel equipment/vehicles operated for producing asphalt emulsions at the central plant.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	To-site transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from the central plant to construction site.

Source		Gas	Included?	Justification/Explanation
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Installation	CO_2	Yes	GHGs are released from diesel consumption by construction equipment/vehicles, including asphalt paving machine, backhoe, bobcat/loader, sweeper/broom, air compressor, roller, trucks, etc.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Maintenance	CO_2	No	GHGs from maintenance and rehabilitation are excluded due to uncertain traffic volume, failure type and repair options.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Excavation	CO_2	No	GHGs from excavation are excluded due to the uncertainty in determining pavement disposal options (e.g., landfill, recycling, remain in place).
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
CIR or FDR (Project Scenario 2)	Raw material acquisition	CO_2	Yes	GHGs are released from energy consumption in material manufacture process.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Raw material transport	CO_2	Yes	GHGs are released from fuel consumption for transporting materials from producers to the job site.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	

Source		Gas	Included?	Justification/Explanation
	FSB/Asphalt emulsions Production & Placement	CO_2	Yes	GHGs are released from fuel consumption by construction equipment/vehicles, including, but not limited to a cold recycler (e.g., Wirtgen 3800 CR), a cement spreader, a water truck, a bitumen truck, a vibratory roller and a pneumatic roller.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Maintenance	CO_2	No	GHGs from maintenance and rehabilitation are excluded due to uncertain traffic volume, failure type and repair options.
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	
	Excavation	CO_2	No	GHGs from excavation are excluded due to the uncertainty in determining pavement disposal options (e.g., landfill, recycling, remain in place).
		CH_4	No	Not Applicable under methodology VM0039.
		N_2O	No	

The Grouped Projects have been or will be constructed within the continental United States of America. The first project instance, the widening of I-64, Segment 2 & 3, took place in Newport News, James City, and York Counties in Virginia as shown in Figure 3 below.

Figure 3: Geographical Boundary and Project Instance Location

Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

3.4 Baseline Scenario

The baseline scenario is the use of HMA technique in pavement application. The emission estimation starts with the production of raw materials at manufacturer sites and ends with the delivery of the final pavement product to the customer. It includes all energy-consuming activities of equipment and machinery at supplier sites, the hot mix facility, the job site, and associated transportation. The emission sources covered within the system boundary include production materials, manufacturing equipment/vehicles, operation of the plant office, and transport and storage of input material. Specifically, the boundary for HMA system consists of energy consumption for quarrying/producing the mineral aggregates and bitumen binder, transportation to and at the HMA production plant, storage, heating of the individual components (including aggregates and bitumen binder), mixing, and the transportation and installation of the mix at the job site.

The baseline scenario for projects applying this methodology is the project where HMA, or the subcategory warm mix asphalt (WMA), is applied to both the surface and base layers. More than 94% of the U.S. roads are paved with HMA. The National Asphalt Pavement Association (NAPA) statistics show that approximately one third of HMA projects in the U.S. in 2014 used WMA technologies. HMA and WMA typically require that more than 70% virgin aggregates are used in HMA production. They need to be quarried, transported to the hot mix plant, sorted into cold bins, dried by the heaters, blended with hot bitumen binders, and then fed into a mixer. The emissions associated with a series of these processes serve as performance benchmarks.

CCPR and CIR (or FDR) projects replace HMA or WMA base layers with FSB or asphalt emulsions. They typically outperform the performance benchmarks because they can reduce the emissions from producing bitumen and producing, transporting, and heating virgin aggregates.

For this first project instance, the baseline scenario includes the application of HMA in four asphalt layers installed over six traffic lanes and four shoulders of I-64.

3.5 Additionality

Project proponents follow two steps described in Section 6 of VM0039 to determine additionality. First, proponents must demonstrate regulatory surplus in accordance with the rules and requirements described in the latest version of the VCS Standard. No rules or regulations mandating the use of FSB or asphalt emulsions to reduce CO_2e emissions exist. Therefore, all CO_2e reductions are regulatory surplus.

Step 1: Regulatory Surplus

Regulatory surplus is established in this project through the following aspects: 1) CCPR was not a typical practice in Virginia. The I-64 Widening Project Segment 2 & 3 is one of only a few experimental highway projects in Virginia where CCPR was installed. 2) There is no regulatory requirement in Virginia to apply CCPR in highway construction. The selection of CCPR in Segment 2 & 3 was based on a design-build selection process, where the contractor voluntarily proposed innovative design and construction methods, including selection of low-emission materials. The I-64 Segment 1 project serves as a comparison case where the contractor voluntarily selected to follow traditional methods and materials, and therefore didn’t produce the same environmental benefits as the I-64 Segment 2 & 3 projects.

Step 2: Performance Benchmark

A performance benchmark determines baseline emissions for patching and roadway scenarios. This performance benchmark depends on whether a project is a parking lot or roadway, the distance materials need to be hauled, and the year a project has been completed. When a project emits less than the relevant predetermined benchmark set out in Table 3 of VM0039 (Table 7 of this document), the project is deemed to be additional. This is determined by comparing the project emission intensity (EI), derived in Section 5.2, to the Performance Benchmark/Crediting Baseline. Section 5.2.1 provides an explanation and example calculation for a CCPR project instance which is defined by Eq. 3. Section 5.2.2 provides an explanation and example calculation for a CIR (or FDR) project which is defined by Eq. 12. The detailed calculations for all project instances in this monitoring period are provided in Appendix A.

Table 6 below provides this comparison showing that the project emission intensity is less than the performance benchmark and therefore emission reductions are achieved.

Table 6: Additionality Evaluation

Vintage	Project	Crediting Baseline, CB (Kg CO_2e/tonne CIR)	Relation	Emission Intensity (EI) (Kg CO2e / Tonne Installed)	Result
2018 (17-April-2018 – 31-December-2018)	I-64 Segment 2 – Layer 1 CCPR	94.7	>	60.14	Additional
	I-64 Segment 2 – Layer 2 FDR	94.7	>	52.92	Additional
2019 (1-January-2019– 31-December-2019)	I-64 Segment 3 – Layer 1 CCPR	94.6	>	51.03	Additional
	I-64 Segment 3 – Layer 2 FDR	94.6	>	52.29	Additional
2020 (1-January-2020– 31-December-2020)	I-64 Segment 3 – Layer 1 CCPR	94.5	>	50.92	Additional
	I-64 Segment 3 – Layer 2 FDR	94.5	>	52.22	Additional
2021 (1-January-2021– 13-September-2021)	I-64 Segment 3 – Layer 1 CCPR	94.4	>	54.62	Additional
	I-64 Segment 3 – Layer 2 FDR	94.4	>	52.29	Additional

3.6 Methodology Deviations

The Project Description does not include any deviations from methodology VM0039.

4 IMPLEMENTATION STATUS

4.1 Implementation Status of the Project Activity

The project focuses on implementing cold recycling paving technology to substitute HMA in asphalt paving projects. It's important to note that the realization of emission reductions is contingent upon the full implementation of the project. Emission reductions are achieved during road construction; however, these reductions are only established post-full project implementation and upon the final acceptance of the road by the relevant road owner before being opened to the public.

Throughout the first monitoring period, all projects detailed in this project description had been fully implemented, thereby achieving the intended emission reductions. Nevertheless, road construction is not an ongoing, continual process. Instead, it occurs based on specific road conditions, local requirements, and the availability of funding.

Cold recycling, the technology employed in this project, is underutilized in the United States. Its implementation necessitates extensive coordination among the project proponent, the contractor, and the road owner before the decision to utilize cold recycling is made. In this context, during the first monitoring period, the completion of Segments 2 and 3 of I-64 constituted the entire extent of the road projects within this period. Therefore, the absence of other ongoing road construction during this monitoring period results in a recorded zero emission claim for the duration spanning 2020 to 2021.

Leakage is not considered an issue under VM0039 methodology and is therefore set at zero, refer to Section 5.3 for more information related to leakage.

5 ESTIMATED GHG EMISSION REDUCTIONS AND REMOVALS

5.1 Baseline Emissions

As described in VM0039, baseline emissions have been predetermined by the performance benchmark for the crediting baseline, which have three strata of performance benchmarks based on project types and one-way distances between the HMA plant and job site. Stratum 1 is for patching projects with hauling distances less than 40 miles, while Stratum 2 is for patching projects with hauling distances greater than 40 miles. Stratum 3 is for roadway projects. The performance benchmark for the crediting baseline is adjusted annually based on the expected changes in the use of RAP for conventional HMA projects. Based on NAPA (2017), the use of RAP in HMA is expected to increase by 1.1% every year. This increase can reduce carbon emissions by 0.1 kg CO_2e/t (NAPA, 2012). Therefore, as shown in Table 7, the performance benchmark decreases by 0.1 kg CO_2e/t annually for all three strata of performance benchmarks.

Table 7: Crediting Baseline/Performance Benchmark from 2014 to 2025

Year	Patching Project (<40mile)	Patching Project (>40mile)	Roadway Project
2014	121.9	142.4	95.1
2015	121.8	142.3	95.0
2016	121.7	142.2	94.9
2017	121.5	142.1	94.8
2018	121.6	142.0	94.7
2019	121.4	141.9	94.6
2020	121.3	141.8	94.5
2021	121.2	141.7	94.4
2022	121.1	141.6	94.3
2023	121.0	141.5	94.2
2024	120.9	141.4	94.1
2025	120.8	141.3	94.0
Note: Unit: kg CO_2e/t. 1 kg CO_2e per tonne of output = 0.001 tCO_2e per tonne of output			

The I-64 Segment 2 project was a roadway project that began construction in 2018. Therefore, 94.7 kg CO_2e/t was used as the crediting baseline. The I-64 Segment 3 project was a roadway project that began construction in 2019 and ended in 2021. Therefore, 94.6, 94.5, and 94.4 kg CO_2e/t was used as the crediting baseline based on the project tonnage installed in each respective year.

Segment 2 of the first project instance is used as an example calculation to demonstrate how the baseline emissions are determined.

Baseline emissions are calculated using Eq. 1 and Eq. 2 below. The crediting baseline (CB) and correction factors (θ_{AE} or Θ_{FSB}) variables are determined and available at validation as defined in Section 6.1. The Project Amount variables are monitored and have been defined in Section 6.2 for each project instance.

Baseline GHG emission reductions for a single FSB project using the CCPR process must be calculated as follows:

$$BE_{FSB-CCPR} = \left(\frac{CB}{\Theta_{FSB}}\right) * \frac{Project\ Amount}{1{,}000} \quad Eq.1$$

Where:

BE $_{FSB\text{-}CCPR}$ = *Baseline Emissions of FSB using CCPR (tCO$_2$e)*

CB = *Crediting baseline (kgCO$_2$e/tonne)*

θ_{FSB} = *Correction factor for FSB (default value is 1.02)*

Project amount = *Amount of FSB manufactured (tonne)*

Baseline GHG emission reductions for a single FSB project using the FDR process must be calculated as follows:

$$BE_{FSB-FDR} = \left(\frac{CB}{\Theta_{FSB}}\right) * \frac{Project\ Amount}{1{,}000} \quad Eq.2$$

Where:

BE $_{FSB\text{-}FDR}$ = *Baseline Emissions of FSB using FDR (tCO$_2$e)*

CB = *Crediting baseline (kgCO$_2$e/tonne)*

Θ_{FSB} = *Correction factor for asphalt emulsion (default value is 1.02)*

Project amount = *Amount of asphalt emulsions manufactured (tonne)*

Table 8: Baseline Emissions

Project	Crediting Baseline, CB (Kg CO$_2$e/tonne CIR)	Correction Factor, $\boldsymbol{\Theta}$ (unitless)	Project Amount (Tonnes)	Baseline Emissions (Tonnes CO$_2$)
I-64 Segment 2 – Layer 1 CCPR	*94.7*	*1.02*	*92,326.84*	*8,571*
I-64 Segment 2 – Layer 2 FDR	94.7	1.02	154,391.86	14,334
			Total Baseline Emissions (tonnes CO$_2$e) =	22,905

5.2 Project Emissions

Segment 2 of the first project instance is used as an example calculation throughout Section 5 to demonstrate how the emission reduction numbers are determined. Since Segment 3 was constructed in the same way as Segment 2 (with different amounts and materials), we did not include detailed Segment 3 calculations in Section 5.

Project emissions are calculated in one of two ways, depending on the production method. I-64 Segment 2 consisted of two separate pavement layers that replaced traditional HMA. Table 9 below summarizes the pavement typical sections applied on the I-64 Segment 2 project. For the project's pavement work on Reconstructed Roadway, only Pavement Section 3 (CCPR) and Section 5 (FDR) are applicable for emission reductions under VM0039. For the project's pavement work on New Roadway, only Pavement Section 3 (CCPR) is applicable for emission reductions under VM0039. Per the VM0039 procedures, emission reduction calculations can only be applied to the layers that replace conventional HMA, which are the layers previously mentioned above and have bolded text in Table 9 below. All other remaining pavement layers are excluded from calculations as they fall under a conventional pavement design and are not replaced by CCPR, FDR, or CIR technologies. Therefore, for simplicity, the CCPR layer will be referred to as Layer 1 – CCPR and the FDR Layer will be referred to as Layer 2 – FDR in the subsequent calculations. Each of these two layers have separate methods to calculate emission reductions as summarized in Sections 4.2.1 and 4.2.2 below.

Table 9: Pavement Typical Sections

Pavement Design Category	Reconstructed Roadway	New Roadway
Pavement Section 1	2” asphalt concrete	2” asphalt concrete
Pavement Section 2	2” asphalt concrete	2” asphalt concrete
Pavement Section 3 **(Layer 1 – CCPR)**	**6” cold central plant recycled mix (CCPR)**	**6” cold central plant recycled mix (CCPR)**
Pavement Section 4	2” drainage layer	2” drainage layer
Pavement Section 5 **(Layer 2 – FDR)**	**12” full depth reclamation (FDR)**	12” cement treated base (CTB)

5.2.1 Layer 1 - CCPR Project Emissions

The first method is Central Cold Plant Recycling (CCPR) and includes the transportation of raw and recycled materials to a central plant and ends with the delivery of the final pavement product to the job site. CCPR projects transport milled materials from an existing jobsite to a central plant where FSB or asphalt emulsions are processed through a pug mill mix plant. Production of FSB begins with the crushing of RAP, which diverts waste from landfills. Once the crushed pavement is sized, the unheated RAP is then blended with foamed bitumen (or asphalt emulsions) and a small amount of Portland cement in a cold mixing process. The boundary consists of the energy consumption for milling the existing pavement, producing bitumen binder and water, transportation to and at the FSB and asphalt emulsions production plant, heating of bitumen binder, mixing, transportation of materials and resources to the project site, and installation of the mix.

For I-64 Segment 2, CCPR was installed on both the reconstructed and new construction roadways, including all travel lanes and shoulders, at a thickness of six inches. The total roadway width for Layer 1 – CCPR was 116 ft to 120 ft (due to varying shoulder width) which included both Eastbound and Westbound sides of I-64 for a total length of 7.08 miles.

Layer 1 – CCPR emission intensity (CCPR EI) represents the quantity of GHGs emitted from producing and installing one metric ton of FSB and asphalt emulsions using CCPR. It is the summation of raw material production emission intensity (EI_M), to-plant delivery emissions intensity (EI_{PD}), to-site delivery emissions intensity (EI_{SD}), in-plant production emission intensity (EI_P), and on-site installation emission intensity (EI_I). CCPR EI is calculated using the following equation below:

$$CCPR\ EI = EI_M + EI_{PD} + EI_{SD} + EI_P + EI_I \ (Eq.\ 3)$$

Where:

CCPR EI = Emission intensity of CCPR (kgCO$_2$e/tonne)

EI_M = Emission intensity of raw material production (kgCO$_2$e/tonne)

EI_{PD} = Emission intensity of to-plant delivery (kgCO$_2$e/tonne)

EI_{SD} = Emission intensity of to-site delivery (kgCO$_2$e/tonne)

EI_P = Emission intensity of in-plant production (kgCO$_2$e/tonne)

EI_I = Emission intensity on-site installation (kgCO$_2$e/tonne)

Five materials are used in the production and installation of FSB/asphalt emulsions using CCPR: Recycled Asphalt Pavement (RAP), cement, bitumen, water, and manufactured aggregates. To calculate the emission intensity of raw material production, each raw materials emission factor and weight are multiplied together and divided by the amount of FSB or asphalt emulsions manufactured (project amount).

Emission Intensity of raw material production (EI_M) is calculated using the following equation below:

$$EI_M = \frac{EF_M \times W_M}{Project\ Amount}\ (Eq.4)$$

Where:

EI_M (kgCO$_2$e/tonne) = Emission intensity of raw material production

EF_M = Raw material emission factor (kgCO$_2$e/tonne)

W_M = Raw material weight (kg)

Project amount (tonnes) = Amount of FSB/asphalt emulsions manufactured

For I-64 Segment 2, EI_M is calculated for RAP, cement, bitumen, water, and manufactured aggregates. During the CCPR process, RAP is recycled and diverted from landfills and is reused in the FSB/asphalt emulsion mixture. Therefore, the materials emission factor for RAP is zero. Similarly, water is not a manufactured material and therefore has a materials emission factor of zero.

$$EI_M\ (RAP) = \frac{0.00\ \frac{kgCO_2e}{kg} \times\ 71{,}968{,}771\ kg}{92{,}326.84\ tonnes} = 0.00\ \frac{kg\ CO_2e}{tonne}$$

$$EI_M\ (cement) = \frac{0.83\ \frac{kgCO_2e}{kg} \times\ 923{,}268\ \ kg}{92{,}326.84\ tonnes} = 8.30\ \frac{kg\ CO_2e}{tonne}$$

$$EI_M\ (bitumen) = \frac{0.48\ \frac{kgCO_2e}{kg} \times\ 2{,}308{,}171\ kg}{92{,}326.84\ tonnes} = 12.00\ \frac{kg\ CO_2e}{tonne}$$

$$EI_M\ (water) = \frac{0.00\ \frac{kgCO_2e}{kg} \times\ 4{,}431{,}688\ \ kg}{92{,}326.84\ tonnes} = 0.00\ \frac{kg\ CO_2e}{tonne}$$

$$EI_M\ (manufactured\ aggregates) = \frac{0.01\ \frac{kgCO_2e}{kg} \times\ 12{,}694{,}940\ \ kg}{92{,}326.84\ tonnes} = 0.83\ \frac{kg\ CO_2e}{tonne}$$

$$\boldsymbol{Total\ EI_M = 0.00 + 8.30 + 12.00 + 0.00 + 0.83 =\ 21.13\ \frac{kg\ CO_2e}{tonne}}$$

To calculate the to-plant delivery emission intensity, the number of trips and distance from the raw material supplier to CCPR mix plant, discount factor, and truck emission factor are multiplied together and divided by the amount of the FSB or asphalt emulsions manufactured using CCPR for the project. When hauling distance is not directly monitored, the distance is estimated using a map distance calculator. For conservativeness, a discount factor (DF) of 0.1 is applied when a map distance calculator is used to estimate hauling distance.

Emission Intensity of to-plant delivery (EI_{PD}) is calculated using the following equation below:

$$EI_{PD} = \frac{Trip_P \times Distance_P \times (1 + DF) \times EF_T}{Project\ Amount} \quad (Eq. 5)$$

Where:

EI_{PD} = Emission Intensity of to-plant delivery (kg CO_2e/tonne)

$Trip_P$ = Number of trips from raw material supplier to job site

$Distance_P$ (miles) = Distance from raw material supplier to CCPR mix plant

DF = Discount factor

EF_T = Truck emission factor (kg CO_2e/mile)

Project amount (tonnes) = Amount of FSB/asphalt emulsions manufactured

For I-64 Segment 2, there were three materials delivered to the site: cement, bitumen, and manufactured aggregates. RAP is also used in the CCPR process however it is recycled from other traditional HMA projects and commonly stockpiled at the CCPR mix plant to divert from the landfill, resulting in to-site delivery distance of zero. In addition, water was available directly at the CCPR mix plant and therefore had a trip distance of zero.

$$EI_{PD}(RAP) = \frac{0\ trips \times 0 \frac{miles}{trip} \times (1 + 0.1) \times 10.2 \frac{kgCO_2e}{mile}}{92{,}326.84\ tonnes} = 0.00 \frac{kgCO_2e}{tonne}$$

$$EI_{PD}(cement) = \frac{51\ trips \times 145 \frac{miles}{trip} \times (1 + 0.1) \times 10.2 \frac{kgCO_2e}{mile}}{92{,}326.84\ tonnes} = 0.90 \frac{kgCO_2e}{tonne}$$

$$EI_{PD}(bitumen) = \frac{127\ trips \times 100 \frac{miles}{trip} \times (1 + 0.1) \times 10.2 \frac{kgCO_2e}{mile}}{92{,}326.84\ tonnes} = 1.55 \frac{kgCO_2e}{tonne}$$

$$EI_{PD}(water) = \frac{0\ trips \times 0 \frac{miles}{trip} \times (1 + 0.1) \times 10.2 \frac{kgCO2e}{mile}}{92{,}326.84\ tonnes} = 0.00 \frac{kgCO_2e}{tonne}$$

$$EI_{PD}(manufac. agg.) = \frac{700\ trips \times 45 \frac{miles}{trip} \times (1 + 0.1) \times 10.2 \frac{kgCO2e}{mile}}{92{,}326.84\ tonnes} = 3.83 \frac{kgCO_2e}{tonne}$$

$$\boldsymbol{Total\ EI_{PD} = 0.00 + 0.90 + 1.55 + 0.00 + 3.83\ = 6.27\ \frac{kgCO_2e}{tonne}}$$

To calculate the emission intensity of raw material to-site delivery, the number of trips from production plant to job site, discount factor, and truck emission factor are multiplied together and divided by the amount of the FSB or asphalt emulsions manufactured using CCPR for the project. When hauling distance is not directly monitored, the distance is estimated using a map distance calculator. For conservativeness, a discount factor (DF) of 0.1 is applied when a map distance calculator is used to estimate hauling distance.

Emission Intensity of to-site delivery (EI_{SD}) is calculated using the following equation below:

$$EI_{SD} = \frac{Trips_S \times Distance_S\ \times\ (1 + DF)\ \times\ EF_T}{Project\ Amount}\quad (Eq. 6)$$

Where:

EI_{SD} = Emission Intensity of to-site delivery ($kgCO_2e$/tonne)

$Trips_S$ = Number of trips from production plant to job site

$Distances_S$ = Distance to site from CCPR mix plant (miles)

DF = Discount factor

EF_T = Truck emission factor ($kgCO_2e$/mile)

Project amount (tonnes) = Amount of FSB/asphalt emulsions manufactured

For I-64 Segment 2, the total CCPR mix used on the project was transported from the CCPR mix plant to the project site.

$$EI_{SD}(CCPR\ Mix) = \frac{5{,}616\ trips\ \times\ 32.7\frac{miles}{trip}\ \times\ (1 + 0.1)\ \times\ 10.2\frac{kgCO_2e}{mile}}{92{,}326.84\ tonnes}\ = 22.32\ \frac{kgCO_2e}{tonne}$$

$$\boldsymbol{Total\ EI_{SD}\ = 22.32\ \frac{kgCO_2e}{tonne}}$$

In-plant production emission intensity (EI_P) includes the emissions from diesel and or electricity consumption by mix plant equipment, vehicles, and plant office. The diesel consumption emissions are typically attributed to mixing machines, loaders, and dump trucks. Their emissions are calculated using equations 6 and 7. A list of common emission factors used for FSB and asphalt emulsion FDR or CIR projects are provided in Appendix B of VM0039 as well as those used in this project as presented in Section 6.1. Electricity consumption emissions are typically attributed to the bitumen heater, RAP crusher, and plant office. Their emissions are calculated using equation 8.

Emission intensity of in-plant production (EI_P) is calculated using the following equation below:

$$EI_P = EI_D + EI_E \ (Eq. 7)$$

Where:

EI_P = Emission Intensity of in-plant production (kgCO$_2$e/tonne)

EI_D = Emission intensity of diesel consumption (kgCO$_2$e/tonne)

EI_E = Emission intensity of electric consumption (kgCO$_2$e/tonne)

Emission Intensity of in-plant diesel consumption (EI_D) is calculated using the following equation below:

$$EI_D = \frac{EF_{EQ} * HR_{EQ}}{Project\ Amount} \ (Eq. 8)$$

Where:

EI_D = Emission intensity of diesel consumption (kgCO$_2$e/tonne)

EF_{EQ} = Equipment emission factor (kgCO$_2$e/tonne)

HR_{EQ} = Equipment operation hours (hour)

Project amount = Amount of asphalt emulsions manufactured (tonne)

Where equipment operation hours are not available, labor hours (HR_{LA}) can be used to approximate equipment operation hours according to the below equation. Conversion factors (CF) for commonly used equipment are listed in Section 6.1.

$$HR_{EQ} = HR_{LA} \times CF \ (Eq. 9)$$

Where:

HR_{EQ} = Equipment operation hours (hour)

HR_{LA} = Labor hours (hour)

CF = Conversion factor

For I-64 Segment 2, there were a total of three pieces of equipment used at the CCPR mix plant including a Wirtgen KMA 220i mobile cold recycling mixing plant, a Caterpillar 952 Front Loader, and a Caterpillar 973 Front Loader. First, the labor hours reported in the project logs were summed together for each piece of construction equipment over the entire project duration. Then, to calculate the emission intensity of in-plant diesel consumption, the equipment emission factor and the corresponding equipment operating hours were multiplied by together and divided by the amount of the FSB or asphalt emulsions manufactured for the project. Table 10 summarizes the diesel consuming equipment used at the CCPR mix plant and their data inputs for HR_{EQ}, EF_{EQ}, and EI_D for the I-64 Segment 2 project. Each of the individual diesel consuming equipment emission intensities were then summed together to obtain the total in-plant diesel consuming equipment emission intensity.

$$\boldsymbol{Total\ EI_D = 8.24 + 1.45 + 1.45 = 8.24\ \frac{kgCO_2e}{tonne}}$$

Table 10: Emission Intensity of In-Plant Diesel Consumption

Equipment	Equipment Operating Hours, HR_{EQ}	Equipment Emission Factor, EF_{EQ}	In-plant Diesel Consumption Emission Intensity, EI_D (Eq. 8)
	(Hours)	(Kg CO_2e/Hr)	(Kg CO_2e/Hr)
Cold Recycler, Other	920	535.9	5.34
Rubber Tired Loaders, Others	920	145.7	1.45
Rubber Tired Loaders, Others	920	145.7	1.45

Emission Intensity of in-plant electricity consumption (EI_E) is calculated using the following equation below:

$$EI_E = \frac{EF_{EL} * C_{EL}}{Project\ Amount}\ (Eq.10)$$

Where:

EI_E = Emission intensity of electricity consumption (kgCO_2e/tonne)

EF_{EL} = Electricity emission factor (kgCO_2e/kWh)

C_{EL} = Electricity consumption (kWh)

CCPR Project amount = Amount of CCPR mix manufactured (tonne)

For I-64 Segment 2, all the CCPR mix plant equipment used for the project was diesel powered machinery and there was no applicable electric consumption, which resulted in an EI_E of zero.

$$\boldsymbol{Total\ EI_E = 0\ \frac{kgCO_2e}{tonne}}$$

Using Eq. 7, the total in-plant production emission intensity for I-64 Segment 2 is the sum of the in-plant diesel consumption and in-plant electricity emission intensities.

$$\boldsymbol{EI_P = 8.24 + 0.00 = 8.24 \frac{kgCO_2e}{tonne}}$$

On-site installation emissions intensity (EI_I) is derived from diesel consumption from the equipment used for the installation of the CCPR pavement layer. For CCPR installation, this equipment typically includes milling machines, loaders, pavers, rollers, and trucks. A list of common emission factors used for FSB and asphalt emulsion projects are provided in Appendix B of VM0039 as well as those used in this project as presented in Section 6.1.

Emission Intensity of on-site installation equipment (EI_I) is calculated using the following equation below:

$$EI_I = \frac{EF_{EQ} * HR_{EQ}}{Project\ Amount}\ (Eq.11)$$

Where:

EI_I (kgCO$_2$e/tonne) = Emission intensity of pavement installation

EF_{EQ} = Equipment emission factor (kgCO$_2$e/tonne)

HR_{EQ} = Equipment operation hours (hour)

Project amount = Amount of asphalt emulsions manufactured (tonne)

For I-64 Segment 2, there were a total of three pieces of construction equipment used during the CCPR installation process. The equipment operating hours reported in the project logs were summed together for each piece of construction equipment over the entire project duration. To calculate the emission intensity of CCPR pavement installation, the equipment emission factor and the corresponding equipment operating hours were multiplied by together and divided by the amount of the FSB or asphalt emulsions manufactured using CCPR for the project. Table 11 summarizes the equipment used during the on-site installation and their data inputs for HR_{EQ}, EF_{EQ}, and EI_I. Each of the individual installation equipment emission intensities were then summed together to obtain the total installation equipment emission intensity.

$$\boldsymbol{Total\ EI_I = 1.26 + 0.46 + 0.46 = 2.18\ \frac{kgCO_2e}{tonne}}$$

Table 11: Emission Intensity of Installation Equipment Summary

Equipment	Equipment Operating Hours, HR_{EQ}	Equipment Emission Factor, EF_{EQ}	On-site installation Emission Intensity, EI_I (Eq. 11)
	(Hours)	(Kg CO_2e/Hr)	(Kg CO_2e/Hr)
Paver, Others	920	126.5	1.26
Roller, Others	920	46.4	0.46
Roller, Others	920	46.4	0.46

Using Eq. 3, the total CCPR emission intensity for I-64 Segment 2 is the sum of the raw material emission intensity, the to-plant delivery emission intensity, the to-site delivery emission intensity, the in-plant production emission intensity, and the installation equipment emission intensity.

$$\boldsymbol{CCPR\ EI = 21.13 + 6.27 + 22.32 + 8.24 + 2.18 = 60.14\,\frac{kgCO_2e}{tonne}}$$

Note that CCPR projects may include more than one installation project because FSB and asphalt emulsions produced in central plants could be placed in a number of road areas. Where there are *I = 1,…, N* installation projects using FSB and asphalt emulsions from the same manufacturing process, the emission intensity of multiple CCPR projects (MCCPR EI) must be calculated according to Eq. 12 below. Please note that this equation may only be applied if the multiple road sections utilize the same constituent mix design and are installed within the same vintage, otherwise the road sections shall be treated as individual projects according to Eq, 3. In the case of this first monitoring period, Segment 2 and 3 used the same mix design. However, since they occurred at different times in separate vintages they are treated as separate installations according to Eq. 3.

$$MCCPR\ EI = EI_M + EI_{PD} + EI_P + \frac{\sum_i^N EI_{SD,i} \cdot project\ amount_i + \sum_I^N EI_{I,i} \cdot project\ amount_i}{\sum_I^N project\ amount_i} \text{(Eq. 12)}$$

Where:

$MCCPR\ EI$ = Emission intensity of multiple CCPR projects (kgCO_2e/t)

EI_M = Emission intensity of raw material production (kgCO_2e/t)

EI_{PD} = Emission intensity of to-plant delivery (kgCO_2e/t)

EI_P = Emission intensity of in-plant production (kgCO_2e/t)

EI_{SD} = To-site delivery emission intensity (kgCO_2e/t)

EI_I = On-site installation emission intensity (kgCO_2e/t)

Project amount = Amount of FSB and asphalt emulsions manufactured (t)

5.2.2 Layer 2 – FDR or CIR Project Emissions

The second and third production method of asphalt installation is cold in-place recycling (CIR) and full depth reclamation (FDR) which have emission reductions calculated using the same equations. CIR and FDR include the transportation of raw materials to a job site and ends with the installation of the final pavement surface. CIR and FDR use one or more mobile recycling machines for milling, production, and placement in a continuous operation at the pavement site. It reconstructs the roadways by using special equipment to mill up the existing pavement, mix it with hot bitumen oil (or asphalt emulsions) and additives, and then immediately place it back down on the road by permanent placement with a paver and rollers. CIR and FDR allow a paving contractor to use the aggregate from the existing road and, by adding liquid asphalt cement (consisting of under 3% of the total volume), it reduces the emissions of new aggregate materials and new liquid asphalt cement that must be shipped from the producer's plant site.

FDR or CIR emission intensity (FDR EI or CIR EI) represents the quantity of GHGs emitted from producing and installing one metric ton of FSB or asphalt emulsions using FDR or CIR. FDR EI or CIR EI is calculated using the following equation below:

$$FDR\ EI\ (or\ CIR\ EI) = EI_M + \mathrm{EI}_{\mathrm{SD}} + EI_I\ (Eq.13)$$

Where:

FDR or CIR EI = Emission intensity of FDR or CIR (kgCO$_2$e/tonne)

EI_M = Emission intensity of raw material production (kgCO$_2$e/tonne)

EI_{SD} = To-site delivery emission intensity (kgCO$_2$e/tonne)

EI_I = On-site installation emission intensity (kgCO$_2$e/tonne)

Four materials are used in the production and installation of FSB/asphalt emulsions using FDR or CIR: Recycled Asphalt Pavement (RAP), cement, bitumen, and water. To calculate the emission intensity of raw material production, each raw materials emission factor and weight are multiplied together and divided by the amount of FSB or asphalt emulsions manufactured (project amount).

Emission Intensity of raw material production (EI_M) is calculated using the following equation below:

$$EI_M = \frac{EF_M \times W_M}{Project\ Amount}\ (Eq.14)$$

Where:

EI_M = Emission intensity of raw material production (kgCO$_2$e/tonne)

EF_M = Raw material emission factor (kgCO$_2$e/tonne)

W_M = Raw material weight (kg)

Project amount = Amount of FSB/asphalt emulsions manufactured (tonnes)

For I-64 Segment 2, EI_M is calculated for RAP, cement, bitumen, and water. During the FDR or CIR process, RAP is recycled on-site by milling the existing asphalt pavement which is reused in the FSB/asphalt emulsion mixture. Therefore, the materials emission factor for RAP is zero. Similarly, water is not a manufactured material and therefore, has a materials emission factor of zero.

$$EI_M\ (RAP) = \frac{0.00\ \frac{kgCO_2e}{kg} \times\ 145{,}128{,}353\ kg}{154{,}391.86\ \ tonnes} = 0.00\ \frac{kg\ CO_2e}{tonne}$$

$$EI_M\ (cement) = \frac{0.83\ \frac{kgCO_2e}{kg} \times\ 7{,}719{,}593\ \ kg}{154{,}391.86\ \ tonnes} = 41.50\ \frac{kg\ CO_2e}{tonne}$$

$$EI_M\ (bitumen) = \frac{0.48\ \ \frac{kgCO_2e}{kg} \times 0\ kg}{154{,}391.86\ \ tonnes} = 0.00\ \frac{kg\ CO_2e}{tonne}$$

$$EI_M\ (water) = \frac{0.00\ \frac{kgCO_2e}{kg} \times\ 1{,}543{,}919\ kg}{154{,}391.86\ \ tonnes} = 0.00\ \frac{kg\ CO_2e}{tonne}$$

$$\boldsymbol{Total\ EI_M = 0.00 + 41.50 + 0.00 + 0.00 =\ 41.50\ \frac{kg\ CO_2e}{tonne}}$$

To calculate the emission intensity of raw material to-site delivery, the number of trips and distance from production plant to job site, discount factor, and truck emission factor are multiplied together and divided by the amount of the FSB or asphalt emulsions manufactured for the project. When hauling distance is not directly monitored, the distance is estimated using a map distance calculator. For conservativeness, a discount factor (DF) of 0.1 is applied when a map distance calculator is used to estimate hauling distance.

Emission Intensity of to-site delivery (EI_{SD}) is calculated using the following equation below:

$$EI_{SD} = \frac{Trips_S \times Distance_S\ \times\ (1 + DF)\ \times\ EF_T}{Project\ Amount} \quad (Eq. 15)$$

Where:

$Trips_S$ = Number of trips from production plant to job site

$Distances_S$ = Distance to site (miles)

DF = Discount factor

EF_T = Truck emission factor ($kgCO_2e$/mile)

Project amount = Amount of FSB/asphalt emulsions manufactured (tonnes)

For I-64 Segment 2, there were three materials delivered to the site: cement, bitumen, and water. RAP, also used in the FDR or CIR process, is recycled on-site through milling of existing pavement, resulting in to-site delivery emission intensity of zero.

$$EI_{SD}(RAP) = \frac{0\,trips \times 0\,\frac{miles}{trip} \times (1+0.1) \times 10.2\,\frac{kgCO_2e}{mile}}{154{,}391.86\ \ tonnes} = 0.00\ \frac{kgCO_2e}{tonne}$$

$$EI_{SD}(cement) = \frac{425\,trips \times 177.7\ \frac{miles}{trip} \times (1+0.1) \times 10.2\,\frac{kgCO_2e}{mile}}{154{,}391.86\ \ tonnes} = 5.49\ \frac{kgCO_2e}{tonne}$$

$$EI_{SD}(bitumen) = \frac{0\,trips \times 132.7\,\frac{miles}{trip} \times (1+0.1) \times 10.2\,\frac{kgCO_2e}{mile}}{154{,}391.86\ \ tonnes} = 0.00\ \frac{kgCO_2e}{tonne}$$

$$EI_{SD}(water) = \frac{0\,trips \times 0\ \frac{miles}{trip} \times (1+0.1) \times 10.2\,\frac{kgCO_2e}{mile}}{154{,}391.86\ \ tonnes} = 0.00\ \frac{kgCO_2e}{tonne}$$

$$\boldsymbol{Total\ EI_{SD} = 0.00 + 5.49 + 0.00 + 0.00\ = 5.49\ \frac{kgCO_2e}{tonne}}$$

On-site installation emissions intensity (EI_I) is derived from diesel consumption from the equipment used for the installation project. For FDR or CIR installation, this equipment typically includes a cold recycler (e.g., Wirtgen 3800 CR), cement spreader, water truck, bitumen truck, vibratory roller, pneumatic roller, skid steer, etc. A list of common emission factors used for FSB and asphalt emulsion FDR or CIR projects are provided in Appendix B of VM0039 as well as those used in this project as presented in Section 6.1.

Emission Intensity of on-site installation equipment (EI_I) is calculated using the following equation below:

$$EI_I = \frac{EF_{EQ} * HR_{EQ}}{Project\ Amount}\ (Eq. 16)$$

Where:

EI_I = Emission intensity of pavement installation ($kgCO_2e$/tonne)

EF_{EQ} = Equipment emission factor ($kgCO_2e$/tonne)

HR_{EQ} = Equipment operation hours (hour)

Project amount = Amount of asphalt emulsions manufactured (tonne)

Where equipment operation hours are not directly available, labor hours (HR_{LA}) or running speed of cold recycler (S) may be used to approximate equipment operation hours according to the two equations below. Labor hours must be documented in the project daily log for verification. Conversion factors (CF) for commonly used equipment are listed in Section 5.1.

$$HR_{EQ} = HR_{LA} \times CF \ (Eq. 17)$$

Where:

HR_{EQ} = Equipment operation hours (hour)

HR_{LA} = Labor hours (hour)

CF = Conversion factor

The running speed of the cold recycler can be read from the screen on the machine. The water truck and bitumen truck are connected to the cold recycler to supply it with binding agents, and the rollers normally follow the train of equipment to compact the newly produced layer. Therefore, they can be assumed to run at the same speed as the cold recycler.

$$HR_{CR} = \frac{L}{S} \ (Eq. 18)$$

Where:

HR_{CR} = Operation hours of the cold recycler (hour)

S = Running speed of the cold recycler (mile/hour)

L = Project Length (lane-miles)

For I-64 Segment 2, there were a total of three pieces of construction equipment used during the FDR or CIR installation process. To calculate the emission intensity of pavement installation, the equipment emission factor and the corresponding equipment operating hours were multiplied together and divided by the amount of the FSB or asphalt emulsions manufactured for the project. Table 12 summarizes the equipment used during the on-site installation and their data inputs for HR_{EQ}, EF_{EQ}, and EI_I for the I-64 Segment 2 project. Each of the individual installation equipment emission intensities were then summed together to obtain the total installation equipment emission intensity.

$$\boldsymbol{Total\ EI_I = 5.37 + 0.28 + 0.28 = 5.92 \frac{kgCO_2e}{tonne}}$$

Table 12: Emission Intensity of Installation Equipment Summary

Equipment	Equipment Operating Hours, HR_{EQ}	Equipment Emission Factor, EF_{EQ}	On-site installation Emission Intensity, EI_I (Eq. 15)
	(Hours)	(Kg CO_2e/Hr)	(Kg CO_2e/Hr)
Cold recycler, Wirtgen 12'	920	901.4	5.37
Rollers, Other	920	46.4	0.28
Rollers, Other	920	46.4	0.28

Using Eq. 13, the overall FDR or CIR emission intensity for I-64 Segment 2 is the sum of the raw material emission intensity, the to-site delivery emission intensity, and the installation equipment emission intensity.

$$\boldsymbol{CIR\ or\ FDR\ EI = 41.50 + 5.49 + 5.92 = 52.92\,\frac{kgCO_2e}{tonne}}$$

Note that CIR and FDR projects may include more than one installation project because FSB and asphalt emulsion produced from CIR or FDR could be placed in a number of road sections. Where there are I = 1,…, N road sections using FSB and asphalt emulsion using the same CIR or FDR machinery, the emission intensity of multiple CIR or FDR projects (MCIR EI or MFDR EI) must be calculated according to Eq. 19 below. Please note that this equation may only be applied if the multiple road sections utilize the same constituent mix design and are installed in the same vintage. In the case of this first monitoring period, Segment 2 and 3 used the same mix design however since they occurred at different times in separate vintages they are treated as separate installations according to Eq. 13.

$$MCIR\ EI\ (or\ MFDR\ EI) = \ EI_M + \frac{\sum_i^N EI_{SD,i}\cdot project\ amount_i + \sum_I^N EI_{I,i}\cdot project\ amount_i}{\sum_I^N project\ amount_i}\ (Eq. 19)$$

As future project instances are incorporated into this grouped project description, additional appendices will be added to define and document all required variables.

5.3 Leakage

There is no leakage. As described in the project methodology VM0039: “Leakage is not considered an issue under this methodology and is therefore set at zero. It is reasonable to assume zero leakage because there is no difference in site preparation activities between baseline and project scenarios. Replacing HMA with FSB or asphalt emulsions for the pavement base layer does not entail a change in carbon efflux or carbon sink at the construction site.

5.4 Estimated Net GHG Emission Reductions and Removals

Net GHG emission reductions for FSB and asphalt emulsions are the emission intensity differences adjusted by the weight differences. A correction factor (θ) of 1.02 for FSB and 1.17 for asphalt emulsions is applied for all project instances. I-64 Segment 2, utilized FSB installed through CCPR and FDR or CIR processes which uses a default Correction Factor, θ_{FSB}=1.02. This project started generating emission reductions in the year 2018 which corresponds to a Crediting Baseline value of 94.7 per Table 7 of Section 5.1.

For projects that have a different structural layer coefficient and material density, the correction factor must be calculated as follows:

A correction factor (θ) Is calculated as follows:

$$\Theta = \frac{0.0025 * DE}{LC} \; Eq. 20$$

Where:

DE = Density of FSB or Asphalt Emulsions (lb/cu. Ft)

LC = Layer coefficient of FSB or Asphalt Emulsions

5.4.1 Layer 1 - CCPR Net GHG Emission Reductions and Removals

Net GHG emission reductions for an FSB project using CCPR must be calculated as follows:

$$ER_{FSB-CCPR} = \left(\frac{CB}{\Theta_{FSB}} - CCPR\ EI\right) * \frac{Project\ Amount}{1{,}000} \; Eq. 21$$

Where:

$ER_{FSB-CCPR}$ = Net emission reductions of FSB using CCPR (tCO_2e)

CB = Crediting baseline ($kgCO_2e/t$)

Θ_{FSB} = Correction factor for FSB (default value is 1.02)

CCPR EI = Emission intensity of CCPR project ($kgCO_2e/t$)

Project amount = Amount of FSB manufactured (t)

Applying the values summarized in the preceding sections to Eq. 21, results in a net emission reduction of 3,760.92 tonnes of CO_2 for Layer 1 of the I-64 Segment 2 project.

$$\boldsymbol{ER_{FSB-CCPR} = \left(\frac{94.7}{1.02} - 60.14\right) * \frac{92,326.84}{1,000} = 3,018\ tonnes\ of\ CO_2\ (net\ reduction)}$$

Net GHG emission reductions for multiple FSB projects with the same project mix design occurring in the same vintage must be calculated as follows:

$$ER_{FSB-CCPR} = \left(\frac{CB}{\theta_{FSB}} - MCCPR\ EI\right) \cdot \Sigma\ \frac{project\ amount_i}{1{,}000} \qquad \text{Eq. 22}$$

Where:

$ER_{FSB\text{-}CCPR}$ = Net emission reductions of FSB using CCPR (tCO_2e)

CB = Crediting baseline ($kgCO_2e/t$)

Θ_{FSB} = Correction factor for FSB (default value is 1.02)

MCCPR EI = Emission intensity of multiple CCPR projects ($kgCO_2e/t$)

Project amount = Amount of FSB manufactured (t)

Net GHG emission reductions for a single asphalt emulsion project must be calculated as follows:

$$ER_{AE-CCPR} = \left(\frac{CB}{\Theta_{AE}} - CCPR\ EI\right) * \frac{Project\ Amount}{1{,}000}\ Eq. 23$$

Where:

$ER_{FSB\text{-}CCPR}$ = Net emission reductions of asphalt emulsions using CCPR (tCO_2e)

CB = Crediting baseline ($kgCO_2e/t$)

Θ_{AE} = Correction factor

CCPR EI = Emission intensity of CCPR project ($kgCO_2e/t$)

Project amount = Amount of FSB or asphalt emulsion manufactured (t)

Net GHG emission reductions for multiple asphalt emulsion projects with the same project mix design occurring in the same vintage must be calculated as follows:

$$ER_{AE-CCPR} = \left(\frac{CB}{\theta_{AE}} - MCCPR\ El\right) \cdot \Sigma\ \frac{project\ amount_i}{1{,}000} \qquad \text{Eq.24}$$

Where:

$ER_{AE\text{-}CCPR}$ = Net emission reductions of asphalt emulsions using CCPR (tCO_2e)

CB = Crediting baseline ($kgCO_2e/t$)

θ_{AE} = Correction factor for asphalt emulsion (default value is 1.17)

MCCPR EI = Emission intensity of multiple CCPR projects ($kgCO_2e/t$)

Project amount = Amount of asphalt emulsions manufactured (t)

5.4.2 Layer 2 - FDR Net GHG Emission Reductions and Removals

Net GHG emission reductions for an FSB project using FDR or CIR must be calculated as follows:

$$ER_{FSB-FDR\ or\ CIR} = \left(\frac{CB}{\Theta_{FSB}} - FDR\ EI\ (or\ CIR\ EI)\right) * \frac{Project\ Amount}{1{,}000}\quad Eq.25$$

Where:

$ER_{FSB\text{-}FDR\ or\ CIR}$ = Net emission reductions of FSB using FDR or CIR (tCO_2e)

CB = Crediting baseline ($kgCO_2e/t$)

Θ_{FSB} = Correction factor for FSB (default value is 1.02)

FDR or CIR EI = Emission intensity of FDR or CIR project ($kgCO_2e/t$)

Project amount = Amount of FSB manufactured (t)

Applying the values summarized in the preceding sections to Eq. 25, results in a net emission reduction of 6,164.12 tonnes of CO_2 for Layer 2 of the I-64 Segment 2 project.

$$\boldsymbol{ER_{FSB-FDR\ (or\ CIR)} = \left(\frac{94.7}{1.02} - 52.92\right) * \frac{154{,}391.86}{1{,}000} = 6{,}163\ tonnes\ of\ CO_2\ (net\ reduction)}$$

Net GHG emission reductions for multiple FSB projects with the same project mix design occurring in the same vintage must be calculated as follows:

$$ER_{FSB-FDR\ or\ CIR} = \left(\frac{CB}{\theta_{FSB}} - MFDR\ (or\ MCIR)\ EI\right) \cdot \Sigma\ \frac{project\ amount_i}{1{,}000}\qquad \text{Eq. 26}$$

Where:

$ER_{FSB\text{-}FDR\ or\ CIR}$ = Net emission reductions of FSB using FDR or CIR (tCO_2e)
CB = Crediting baseline ($kgCO_2e/t$)
Θ_{FSB} = Correction factor for FSB (default value is 1.02)
MFDR (orMCIR) EI = Emission intensity of multiple FDR projects ($kgCO_2e/t$)
Project amount = Amount of FSB manufactured (t)

Net GHG emission reductions for a single asphalt emulsion project must be calculated as follows:

$$ER_{AE-FDR\ or\ CIR} = \left(\frac{CB}{\Theta_{AE}} - FDR\ or\ CIR\ \ EI\right) * \frac{Project\ Amount}{1{,}000}\quad Eq.27$$

Where:

$ER_{FDR\ or\ CIR}$ = Net emission reductions of FDR or CIR (tCO_2e)

CB = Crediting baseline ($kgCO_2e/t$)

Θ_{AE} = Correction factor

FDR or CIR EI = Emission intensity of FDR or CIR project ($kgCO_2e/t$)

Project amount = Amount of asphalt emulsions manufactured (t)

Net GHG emission reductions for multiple asphalt emulsion projects with the same project mix design must be calculated as follows:

$$ER_{AE-FDR\ or\ CIR} = \left(\frac{CB}{\theta_{AE}} - MFDR\ or\ MCIR\ El\right) \cdot \Sigma\ \frac{project\ amount_i}{1{,}000} \qquad \text{Eq. 28}$$

Where:

$ER_{AE\text{-}FDR\ or\ CIR}$ = Net emission reductions of asphalt emulsions using FDR or CIR (tCO_2e)

CB = Crediting baseline ($kgCO_2e/t$)

θ_{AE} = Correction factor for asphalt emulsion (default value is 1.17)

MFDR or MCIR EI = Emission intensity of multiple FDR or CIR projects ($kgCO_2e/t$)

Project amount = Amount of asphalt emulsions manufactured (t)

5.4.3 Total Net GHG Emission Reductions and Removals

The total net GHG reductions and removals generated in the I-64 Segment 2 is the sum of the removals from each individual layer installed on the project. Layer 1 – CCPR generated 3,444.20 tonnes of CO_2 reductions while Layer 2 – FDR generated 6,164.12 tonnes of CO_2 reductions. Therefore, the total net GHG emission reductions and removals generated in the first project monitoring period by I-64 Segment 2 was 14,428.62 tonnes of CO_2.

$$\boldsymbol{Total\ ER_{SEGMENT\ 2} = 3,018 + 6,163 = 9,181\ tonnes\ of\ CO_2\ (net\ reduction)}$$

The same procedure outlined in Section 5.2 and 5.4 will be applied to all future project instances to be incorporated in future monitoring periods. Table 13 below provides ex-ante estimate of net GHG emission reductions from the potential expansion of the project activity including the first project instance.

Ex-Ante Calculations

Predicting future monitored project variables in roadway projects presents challenges due to the dynamic nature of such endeavors. Accurate estimations rely on implementing the project, gathering necessary data, and understanding critical factors like road dimensions, location specifics, structural profiles, and contractor equipment. Until these elements are known through project implementation and data collection, assumptions are essential for estimating key variables in the Emission Reduction (ER) calculations.

The following assumptions are made to derive rough estimations for essential variables:

1. Project Emission Intensity (EI): The average of ex-post instances within this first monitoring period is assumed for CCPR (Cold Central Plant Recycling), CIR (Cold In-Place Recycling), or FDR (Full Depth Reclamation) EI. Given the unpredictability of the proportion of future instances between CCPR, FDR , and CIR, an average emission intensity is applied to the overall tonnage (project amount), encompassing all other variables needed to compute the project's emission intensity.
2. Correction Factor for FSB Pavement Applications: A correction factor of 1.02 is assumed for FSB projects in the future.
3. Overall Annual Project Amount: An assumed increase of 20% is projected for the years 2024 through 2027. Notably, zero project instances occurred between 2020 and 2023, hence resulting in zero ERs for these years. Additionally, for 2028, considering the winter months, it is assumed no relevant paving activities will occur, resulting in an ER of zero.
4. Crediting Baseline Adjustment: The annual adjustment of the crediting baseline adheres to the applied methodology.

The accompanying ex-ante ER spreadsheet contains necessary inputs for reproducing estimated net GHG emission reductions. As future project activities unfold, all variables will be precisely defined and submitted to the VVB along with ex-post calculations.

Table 13: Ex-ante (Estimated) Crediting Period Project Emissions and Reductions

Year	Estimated baseline emissions (tCO_2e)	Estimated project emissions (tCO_2e)	Estimated leakage emissions (tCO_2e)	Estimated net GHG emission reductions or removals (tCO_2e)
2018 (17-April-2018 – 31-December-2018)	22,905	13,724	0	9,181
2019 (01-January-2019 – 31-December-2019)	5,378	2,988	0	2,390
2020	8,054	4,473	0	3,581

(01-January-2020 – 31-December-2020)				
2021 (01-January-2021 – 13-September-2021)	6,298	3,660	0	2,638
2021 (14-September-2021 – 31-December-2021)	-	-		-
2022 (01-January-2022 – 31-December-2022)	-	-	0	-
2023 (01-January-2023 – 31-December-2023)	-	-	0	-
2024 (01-January-2024 – 31-December-2024)	25,500	15,000	0	10,500
2025 (01-January-2025 – 31-December-2025)	30,500	18,000	0	12,500

2026 (01-January-2026 – 31-December-2026)	36,500	21,500	0	15,000
2027 (01-January-2027 – 31-December-2027)	43,750	25,750	0	18,000
2028 (01-January-2028 – 16-April-2028)	-	-	0	-
Total	**178,885**	**105,095**	**0**	**73,790**

6 MONITORING

6.1 Data and Parameters Available at Validation

6.1.1 Parameters Available at Validation for HMA and CCPR

Data / Parameter	EF_M
Data unit	$kgCO_2e/kg$
Description	Material emission factor
Source of data	CMUGDI (2008)
Value applied:	RAP: 0 Cement: 0.83 Bitumen: 0.48 Water: 0

	Crushed rock: 0.056 Sand: 0.005 Manufactured aggregates: 0.006
Justification of choice of data or description of measurement methods and procedures applied	CMUGDI (2008) is comprised of national economic input-output models and publicly available resources use and emission data, which has been accessed over 1 million times by researchers or business users.
Purpose of Data	Calculation of project emissions
Comments	Data to be updated when the material emissions factor is updated.

Data / Parameter	EF_T
Data unit	$kgCO_2e/mile$
Description	Truck's emission per mile travelled
Source of data	The Climate Registry (TCR 2023)
Value applied:	10.2
Justification of choice of data or description of measurement methods and procedures applied	Emission factors from The Climate Registry are compiled from publicly available data sources and updated each year to ensure that project proponents have the most accurate and up-to-date greenhouse gas data.
Purpose of Data	Calculation of project emissions
Comments	Data to be updated when the diesel emissions factor is updated.

Data / Parameter	EF_{EQ}
Data unit	$kgCO_2e/hr$
Description	Equipment emissions per hour

Source of data	VM0039 Appendix B
Value applied:	Cold Recycler, Other: 535.9 Rubber Tired Loaders, Other: 145.7 Paver, Others: 126.5 Rollers, Other: 46.4
Justification of choice of data or description of measurement methods and procedures applied	The engine emission information is obtained from the EPA off-road engine certification database and further stratified equipment types by engine maker and horsepower rating. The database created for equipment emission estimation is presented in Appendix B of the methodology
Purpose of Data	Calculation of project emissions
Comments	Data was collected one time and must be updated when more strict emission standard is implemented nationwide

Data / Parameter	EF_{EL}
Data unit	$kgCO_2e/kWh$
Description	Electricity emission factor
Source of data	EPA (2017)
Value applied:	Refer to EPA's eGRID summary tables for electricity emission factors for different regions. (Please note that no electric consumption is applicable to the first monitoring period as all equipment used diesel fuel)
Justification of choice of data or description of measurement methods and procedures applied	Emission factors from eGRID summary tables are compiled by the EPA and updated each year to ensure that project proponents have the most accurate and up-to-date greenhouse gas data. The calculation of electricity emission must use region-specific emission factors.
Purpose of Data	Calculation of project emissions

Comments	The project proponent must use the most recent eGRID summary tables available. Please note that no electric consumption is applicable to the first monitoring period as all equipment used diesel fuel.

Data / Parameter	CF
Data unit	Between 0 and 1
Description	Conversion factor: the percentage of equipment operating time in the total labor time
Source of data	Liu et al. (2016)
Value applied:	Milling machine: 0.66 Backhoe: 0.33 Loader: 0.33 Sweeper: 0.55 Paver: 0.50 Roller: 0.59 Truck: 1
Justification of choice of data or description of measurement methods and procedures applied	Three projects were observed on-site to count the effective operation time of each piece of equipment. The percentage utilization (PU) was calculated using the effective operation time divided by the total labor hours. The average PU values are 0.55 for the asphalt-milling machine; 0.10 for the backhoe; 0.10 for the bobcat/loader; 0.4 for the sweeper/broom; 0.10 for the excavator; 0.33 for the paver and 0.45 for the roller. Different Pus will produce different amounts of GHG emissions. According to a study by Lewis et al. (2009), the emission rate of idling equipment is about one quarter of the emission rate of the operating equipment. This difference is simplified and incorporated into the emission calculation as an average conversion factor (CF), which equals PU+0.25(1-PU).
Purpose of Data	Calculation of project emissions

Comments	Please note that this variable was not used in the first monitoring period as the contractor provided equipment operating hours rather than labor hours.

Data / Parameter	DF
Data unit	Between 0 and 1
Description	For conservativeness, a discount factor (DF) must be applied when a map distance calculator is used to estimate hauling distance. DF is equal to 0 if using actual logged miles.
Source of data	On-site observations
Value applied:	0.1
Justification of choice of data or description of measurement methods and procedures applied	Ten projects were observed on site to count the distance between the map and equipment odometer. Hauling distance = Map distance × (1+DF)
Purpose of Data	Calculation of project emissions
Comments	Data does not need to be updated

6.1.2 Parameters Available at Validation for FDR or CIR

Data / Parameter	EF_T
Data unit	$kgCO_2e/mile$
Description	Truck’s emission per mile travelled
Source of data	The Climate Registry (TCR 2023)
Value applied:	10.2
Justification of choice of data or description of	Emission factors from The Climate Registry are compiled from publicly available data sources and updated each year to ensure

measurement methods and procedures applied	that project proponents have the most accurate and up-to-date greenhouse gas data.
Purpose of Data	Calculation of project emissions
Comments	Data to be updated when the diesel emissions factor is updated

Data / Parameter	EF_M
Data unit	$kgCO_2e/kg$
Description	Material emission factor
Source of data	Carnegie Mellon University Green Design Institute (CMUGDI 2008)
Value applied:	RAP: 0 Cement: 0.83 Bitumen: 0.48 Water: 0
Justification of choice of data or description of measurement methods and procedures applied	CMUGDI (2008) is comprised of national economic input-output models and publicly available resources use and emission data, which has been accessed over 1 million times by researchers or business users.
Purpose of Data	Calculation of project emissions
Comments	Data to be updated when the material emissions factor is updated

Data / Parameter	EF_{EQ}
Data unit	$kgCO_2e/hr$
Description	Equipment emission per hour
Source of data	VM0039 Appendix B

Value applied:	Cold Recycler, Wirtgen, 12': 901.4 Roller, Others: 46.4
Justification of choice of data or description of measurement methods and procedures applied	The engine emission information is from the EPA off-road engine certification database and stratified by equipment type, engine make, and horsepower rating. The database created for equipment emission estimation is presented in Appendix B.
Purpose of Data	Calculation of project emissions
Comments	Data was collected one time and must be updated when more strict emissions standards are implemented nationwide

6.2 Data and Parameters Monitored

6.2.1 Data and Parameters Monitored for HMA and CCPR

Data / Parameter	W_M
Data unit	Kg
Description	Quantity of each raw material used to produce HMA or FSB or asphalt emulsions
Source of data	Plant production records
Description of measurement methods and procedures applied	The W_M variable is an indirect measurement. The CCPR asphalt mix design provides the percent composition of each raw material. The contractor reports the total amount of mix produced through production records and trucking reports. Using the overall tonnage installed and the % composition of each raw material, the quantity of each raw material component is calculated. The truck scale used for trucking reports on the project was a Class III L scale which meets or exceed NIST Handbook 44 standards.
Frequency of monitoring/recording	The quantity of each raw material is calculated once per project instance at final completion. However, the trucking reports are monitored for every truck leaving the mix plant through the entire duration of the project and summed together once upon project instance competition.

Value applied:	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	Truck scales at the CCPR plant measure the tonnage of mix leaving the plant. The truck scale is a Cardinal PRC, accuracy class III L, serial number B30089. The CCPR mix design was performed by a certified independent third-party laboratory following ASTM D6926, AASHTO T-283, AASHTO T-180 Method D, AASHTO T 248 (Method A), and AASHTO T 27 (Dry) testing procedures.
QA/QC procedures applied	Cross-checking of contractor reported CCPR quantity versus trucking manifests was performed for each project instance and will be performed for all future instances at the completion of each project. Truck scale calibrations were performed at a minimum every 6 months according to industry standards to meet NIST Handbook 44 standards.
Purpose of data	Calculation of project emissions
Calculation method	Percent composition of each raw material multiplied by total weight of mix produced.
Comments	N/A

Data / Parameter	$Distance_P$
Data unit	Miles
Description	The total miles that trucks travelled to supply raw materials to HMA plant or FSB plant
Source of data	Data derived from monitoring, supplied by Allan Myers
Description of measurement methods and procedures to be applied	Distance can be measured by approximation through number of truck loads and map distance between project site and mix plant.

Frequency of monitoring/recording	Once per project
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	Distance from raw material suppliers to CCPR mix plant measured using online mapping software
QA/QC procedures to be applied	Cross-checking of reported mileage versus trucking manifests to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	Summation of total miles traveled
Comments	N/A

Data / Parameter	Distance$_s$
Data unit	Miles
Description	The total miles that trucks travelled to transport CCPR mix from mix plant to jobsite.
Source of data	Approximated by applying map distance between mix plant and jobsite and number of trips to transport all CCPR mix material.
Description of measurement methods and procedures to be applied	Distance can be obtained from the daily report of truck drivers or measured by approximation
Frequency of monitoring/recording	Once per project
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.

Monitoring equipment	Distance from the asphalt plant to the job site measured using online mapping software
QA/QC procedures to be applied	Cross-checking of reported mileage versus trucking manifests to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	Summation of total miles traveled
Comments	N/A

Data / Parameter	C_{EL}
Data unit	kWh
Description	Electricity consumption of the mix plant
Source of data	Data derived through monitoring
Description of measurement methods and procedures to be applied	The use of electricity can be obtained from the mix plant's utility bills
Frequency of monitoring/recording	Utility bills must be collected monthly or quarterly
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	Utility provider electricity meters
QA/QC procedures to be applied	Cross-checking reported consumption versus utility bills to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	Not applicable – the consumption is reported directly on utility bills.

Comments	N/A

Data / Parameter	Project amount
Data unit	tonnes
Description	Output quantity of FSB or asphalt emulsions
Source of data	Plant production records
Description of measurement methods and procedures to be applied	The contractor reports the total amount of mix produced through production records and trucking reports. The truck scale used for trucking reports on the project was a Class III L scale which meets or exceed NIST Handbook 44 standards.
Frequency of monitoring/recording	The trucking reports are monitored for every truck leaving the mix plant through the entire duration of the project and summed together once upon project instance competition.
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. For the purposes of ex-ante estimates the following values have been applied to calculations (see section 5.4.3 for assumptions): 2018: 246,719 2019: 57,994 2020: 86,941 2021: 68,055 2022: 0 2023: 0 2024: 275,826 2025: 330,991 2026: 397,189 2027: 476,627 2028: 0
Monitoring equipment	Truck scales at the CCPR plant measure the tonnage of mix leaving the plant. The truck scale is a Cardinal PRC, accuracy class III L, serial number B30089.
QA/QC procedures to be applied	Cross-checking of contractor reported CCPR quantity versus trucking manifests was performed for each project instance and will be performed for all future instances at the completion of each project. Truck scale

	calibrations were performed at a minimum every 6 months according to industry standards to meet NIST Handbook 44 standards.
Purpose of data	Calculation of project emissions
Calculation method	Summation of all trucking reports upon project completion
Comments	N/A

Data / Parameter	HR_{EQ}
Data unit	Hour
Description	Total operating hours of on-site use of equipment
Source of data	Data derived through monitoring
Description of measurement methods and procedures to be applied	Where equipment operation hours are not available, labor hours can be used to approximate equipment operation hours. Labor hours are documented in the project daily log for verification.
Frequency of monitoring/recording	Once per project instance
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	Print outs of internal time keeping data.
QA/QC procedures to be applied	Cross-checking of reported data versus labor hours to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	Summation of operating hours to complete CCPR installation.
Comments	N/A

Data / Parameter	HR_{LA}
Data unit	Hours
Description	The total labor hours of on-site installation equipment use
Source of data	Road contractor
Description of measurement methods and procedures to be applied	Can be obtained from daily timesheet logs.
Frequency of monitoring/recording	Once per project instance
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	N/A
QA/QC procedures to be applied	Cross-checking reported values versus daily logs to confirm quality measurement
Purpose of data	Calculation of project emissions
Calculation method	Summing the daily logs across the duration of the project.
Comments	N/A

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Source of data	Laboratory testing reports or VM0039 reported industry standards
Description of measurement methods and procedures to be applied	Density data can be obtained from project records or specifications. Commonly applied testing includes AASHTO T-180 Method D however the specific test method applied can depend on the locality of the project instances.

Frequency of monitoring/recording	Once per project instance
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	The density testing is performed in a laboratory prior to project implementation to find the proper mix that achieves the optimum density based on the testing of the existing roadway aggregates. The CCPR mix designs are performed by a certified independent third-party laboratory following ASTM D6926, AASHTO T-283, AASHTO T-180 Method D, AASHTO T 248 (Method A), and AASHTO T 27 (Dry) testing procedures.
QA/QC procedures to be applied	Cross-checking of reported data versus theoretical density to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data / Parameter	LC
Data unit	Unitless
Description	Layer coefficient of FSB or asphalt emulsions
Source of data	Data derived from industry standards or VM0039 default values
Description of measurement methods and procedures to be applied	Calculation of project specific layer coefficients is not feasible due to the need for post installation monitoring of the pavement performance. Therefore, layer coefficients must be pulled from industry technical research such as the American Association of State Highway Transportation Officials (AASHTO) Design Guide as was done for the development of VM0039.
Frequency of monitoring/recording	Once per project instance
Value applied	FSB: 0.32 Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.

Monitoring equipment	N/A
QA/QC procedures to be applied	Cross-checking of contractor reported data versus DOT commonly used coefficients to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

6.2.2 Data and Parameters Monitored for FDR or CIR

Data / Parameter	W_M
Data unit	Kg
Description	The weight of each raw material used to produce FSB or asphalt emulsions
Source of data	Derived through project records
Description of measurement methods and procedures applied	The W_M variable is an indirect measurement. The FDR or CIR asphalt mix design provides the percent composition of each raw material. Using the overall tonnage installed (project amount) and the % composition of each raw material, the quantity of each raw material component is calculated.
Frequency of monitoring/recording	The quantity of each raw material is calculated once per project instance at final completion.
Value applied:	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CIR or FDR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	The FDR or CIR mix design is performed by a certified independent third-party laboratory following ASTM D6926,

	AASHTO T-283, AASHTO T-180 Method D, AASHTO T 248 (Method A), and AASHTO T 27 (Dry) testing procedures.
QA/QC procedures applied	Ensuring that the project instance raw material tonnage reported by Allan Myers is cross-checked and aligns with the calculated values from the mix design % composition.
Purpose of data	Calculation of project emissions
Calculation method	Percent composition of each raw material multiplied by total weight of mix produced.
Comments	N/A

Data / Parameter	Project amount
Data unit	tonnes
Description	Output quantity of FSB and asphalt emulsions
Source of data	Data derived through project records
Description of measurement methods and procedures to be applied	The measurement of project amount is theoretical based on project area, depth, and density. The construction equipment performing this work is not directly metered therefore project records must be used to perform the calculation.
Frequency of monitoring/recording	Once per project
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future CCPR instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. For the purposes of ex-ante estimates the following values have been applied to calculations (see section 5.4.3 for assumptions): 2018: 246,719 2019: 57,994 2020: 86,941 2021: 68,055 2022: 0 2023: 0 2024: 275,826 2025: 330,991

	2026: 397,189 2027: 476,627 2028: 0
Monitoring equipment	Project records including density, engineering plans, and mix design.
QA/QC procedures to be applied	Cross-checking of contractor reported amount versus calculated tonnage based on project dimensions, density, and mix design.
Purpose of data	Calculation of project emissions
Calculation method	Product of project installation area, FDR layer depth, and FDR mix density.
Comments	N/A

Data / Parameter	L
Data unit	Miles
Description	Length of damaged pavement
Source of data	Data derived from monitoring
Description of measurement methods and procedures to be applied	Data obtained from project records – Design Plans, Typical Pavement Sections
Frequency of monitoring/recording	Once per project
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	N/A
QA/QC procedures to be applied	Cross-checking engineering plans to reported length.
Purpose of data	Calculation of project emissions
Calculation method	Project lengths are reported in engineering plan documents.

Comments	N/A

Data / Parameter	$Distance_s$
Data unit	Miles
Description	The total miles that trucks travelled to supply raw materials to the job site
Source of data	Approximated by applying map distance between raw material suppliers to jobsite and number of trips to transport all raw materials.
Description of measurement methods and procedures to be applied	Distance can be obtained from the daily report of truck drivers or measured by approximation
Frequency of monitoring/recording	Once per project
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	Distance that trucks travelled to supply raw materials to the job site measured using online mapping software
QA/QC procedures to be applied	Cross-checking of reported mileage versus trucking manifests to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	Summation of total miles traveled
Comments	N/A

Data / Parameter	S
Data unit	Miles per hour
Description	Running speed of the cold recycler
Source of data	Road contractor

Description of measurement methods and procedures to be applied	The data can be obtained from project records. The contractor forman records the speed of the cold recycler throughout the project.
Frequency of monitoring/recording	Daily logs are kept to document running speed and averages over the project duration are used in the final calculations.
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	N/A
QA/QC procedures to be applied	Cross-checking reported speed versus drivers log to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	Averaging out reported cold recycler speeds.
Comments	All projects within the first monitoring period were able to track labor hours to estimate equipment operating hours therefore this variable was not used but may be used in future monitoring periods.

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Source of data	Laboratory testing reports or VM0039 reported industry standards
Description of measurement methods and procedures to be applied	Density data can be obtained from project records or specifications. Commonly applied testing includes AASHTO T-180 Method D however the specific test method applied can depend on the locality of the project instances.
Frequency of monitoring/recording	Once per project
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future instances added over the project crediting period however the values cannot be accurately

	estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	The density testing is performed in a laboratory prior to project implementation to find the proper mix that achieves the optimum density based on the testing of the existing roadway aggregates. The CCPR mix designs are performed by a certified independent third-party laboratory following ASTM D6926, AASHTO T-283, AASHTO T-180 Method D, AASHTO T 248 (Method A), and AASHTO T 27 (Dry) testing procedures.
QA/QC procedures to be applied	Cross-checking of reported data versus theoretical density to confirm quality measurement.
Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data / Parameter	LC
Data unit	Unitless
Description	Layer coefficient of FSB or asphalt emulsions
Source of data	Data derived from industry standards or VM0039 default values
Description of measurement methods and procedures to be applied	Calculation of project specific layer coefficients is not feasible due to the need for post installation monitoring of the pavement performance. Therefore, layer coefficients must be pulled from industry technical research such as the American Association of State Highway Transportation Officials (AASHTO) Design Guide as was done for the development of VM0039.
Frequency of monitoring/recording	Once per project instance
Value applied	FSB: 0.32 Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	N/A
QA/QC procedures to be applied	Cross-checking of reported data versus DOT commonly used coefficients to confirm quality measurement.

Purpose of data	Calculation of project emissions
Calculation method	N/A
Comments	N/A

Data / Parameter	HR_{EQ}
Data unit	Hours
Description	The total operating hours of on-site installation equipment
Source of data	Equipment operating hours are approximated by labor hours reported on equipment operator timesheets and conversion factors defined in the VM0039 Methodology
Description of measurement methods and procedures to be applied	Where equipment operation hours are not available, labor hours can be used to approximate equipment operation hours. Labor hours are documented in the project daily log for verification.
Frequency of monitoring/recording	Once per project instance
Value applied	The values applied will vary based on each individual project instance. With this being a grouped project there will be future instances added over the project crediting period however the values cannot be accurately estimated until those projects are completed and incorporated into future monitoring periods. Refer to Section 5.4.3 for assumptions made in the ex-ante calculations.
Monitoring equipment	Print outs of internal time keeping data.
QA/QC procedures to be applied	Cross-checking reported values versus operator timesheet documents
Purpose of data	Calculation of project emissions
Calculation method	Summing the labor hours reported for each piece of installation equipment and multiplying by the conversion factors (CF) defined in Section 5.1.1
Comments	N/A

6.3 Monitoring Plan

The monitoring plan details the procedures for collecting and reporting all data and parameters listed in Section 6.2. Monitored data and parameters will depend on the materials used (FSB or asphalt emulsions), and the process used (CCPR, CIR, or FDR) for the calculations. The project proponents monitoring plan consists of the collection of project data relating to travel distances, energy and equipment usage, quantity of asphalt materials produced; asphalt material composition; and equipment type and usage.

Project Proponent and Data Collection Control:

The data required for the calculation of net carbon emissions reductions were collected by the asphalt contractor in electronic form through the asphalt contractor's internal software system or as electronic copies of design documentation (Design files, asphalt mix tickets). The asphalt mix composition undergoes thorough testing before and during its production and before, during, and after it is installed. The asphalt contractor personnel are responsible for collecting data monitored at the asphalt production facility and at the construction site. The project proponent provides a spreadsheet that can be filled out by the asphalt contractors and access to a web based protected folder for uploading all project documentation.

The project proponent reviews data for typical errors, including inconsistent physical units, unit conversion errors, transcription errors, and missing data for specific time periods or physical units. This stage of the data intake is when the project proponent performs all required QA/QC procedures as discussed in the Section 6.1 data tables and then performs the project ER calculations. For example, Global Emissionairy uses the trucking manifests to calculate percent compositions and cross checks this against the project mix design to ensure compliance project specifications. This process ensures that contractor reported values are accurate and in line with industry standards. If the data provided by the contractor had any discrepancies or missing information, the Global Emissionairy team communicates with the contractor to obtain the corrected data and revises calculations as applicable. These procedures are performed by an engineering manager or technical experts at Global Emissionairy whom, at a minimum, are licensed professional engineers or have advanced degrees in the civil and environmental engineering field.

The asphalt contractor also provided the project QA/QC plan (included in Appendix A) which was required, reviewed, and approved by VDOT.

All project data inputs were reviewed by the project proponent. Project data values were input into the project proponent's proprietary software PaveNext Application which performs the GHG quantification equations present in the methodology.

All data collected as a part of monitoring process is archived electronically and be kept stored indefinitely within both the project proponent and asphalt contractor's server.

Calibration of Equipment:

All direct measurements are conducted with calibrated measurement equipment according to relevant industry standards. Equipment calibration procedures following manufacturers' procedures, are as follows:

- The truck scales at the CCPR mix plant are calibrated at a minimum every six months.
- Pumps and injectors are calibrated at the shop at the end of each season to ensure accurate measurement of weights and proportions of liquids.
- The totalizer on the computer is verified with a pre-known density of the RAP for every hour of the operation of the machine as it moves on the road to verify tolerances of weights and rate of pre-spread Portland cement on the pavement.
- Quality control and assurance practices are used to verify weights, densities, amount of asphalt, and water added to further justify the calibration of the equipment.
- A third-party independent lab is hired to perform quality control testing on these jobs and the results are documented.
- Calibration of all contractor's equipment is the contractor's responsibility to ensure all quantities are measured correctly and the product meets project specifications. Project specifications are the main method that owners use to hold contractors accountable. Only when project specifications are met do contractors get paid.
- Superintendents of the team are trained by vendors on calibrating the equipment, and they train some of the crew who operate the equipment on a regular basis.

For indirect measurements for all project instances, the structural layer coefficient comes from the VM0039 Methodology and is a reasonably conservative estimate used by state Departments of Transportation. (See the footnote on page 25 of the methodology).

7 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

7.1 Data and Parameters Monitored

Sections 7.1.1 through 7.1.2 summarize all data and parameters monitored during the first monitoring period running from April 17, 2018, through September 13, 2021. Data and parameters determined or available at validation which remain fixed throughout the project crediting period are included in Section 6.1 and 6.2 (Data and Parameters Available at Validation) above.

7.1.1 I-64 Segment 2 Data and Parameters Monitored

Data and Parameters Monitored for CCPR

Data / Parameter	W_M
Data unit	Kg
Description	Quantity of each raw material used to produce HMA or FSB or asphalt emulsions
Value applied:	RAP: 71,968,771 Cement: 923,268 Bitumen: 2,308,171 Water: 4,431,688 Crushed Rock: 0 Sand: 0 Manufactured Aggregate: 12,694,940
Comments	N/A

Data / Parameter	$Distance_P$
Data unit	Miles
Description	The total miles that trucks travelled to supply raw materials to HMA plant or FSB plant
Value applied	RAP: 0 Cement: 145 Bitumen: 100 Water: 0 Crushed Rock: 0 Sand: 0 Manufactured Aggregate: 45
Comments	N/A

Data / Parameter	$Distance_S$

Data unit	Miles
Description	The total miles that trucks travelled to transport CCPR mix from mix plant to jobsite.
Value applied	32.7
Comments	N/A

Data / Parameter	Project amount
Data unit	tonnes
Description	Output quantity of FSB or asphalt emulsions
Value applied	CCPR = 92,326.84
Comments	N/A

Data / Parameter	HR_{EQ}
Data unit	Hour
Description	Total operating hours of on-site use of equipment
Value applied	Wirtgen KMA 220 Plant: 920 hours Rubber Tired Loaders, CAT 952: 920 hours Rubber Tired Loaders, CAT 973: 920 hours Paver - Caterpillar, 1055: 920 hours Roller – Others, >10t: 1,840 hours
Comments	N/A

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Value applied	130
Comments	N/A

Data / Parameter	LC
Data unit	Unitless
Description	Layer coefficient of FSB or asphalt emulsions
Value applied	0.32
Comments	Source is from the VM0039 published default value of 0.32 for FSB.

<u>Data and Parameters Monitored for FDR</u>

Data / Parameter	W_M
Data unit	Kg
Description	The weight of each raw material used to produce FSB or asphalt emulsions
Value applied:	RAP: 145,128,353 Cement: 7,719,593 Bitumen: 0 Water: 1,543,919
Comments	N/A

Data / Parameter	Project amount
Data unit	tonnes
Description	Output quantity of FSB and asphalt emulsions
Value applied	154,391.86
Comments	N/A

Data / Parameter	L
Data unit	Miles
Description	Length of damaged pavement

Value applied	7.08
Comments	N/A

Data / Parameter	Distances
Data unit	Miles
Description	The total miles that trucks travelled to supply raw materials to the job site
Value applied	RAP: 0 Cement: 177.7 Bitumen: 132.7 Water: 0
Comments	N/A

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Value applied	130
Comments	N/A

Data / Parameter	LC
Data unit	Unitless
Description	Layer coefficient of FSB or asphalt emulsions
Value applied	0.32
Comments	Source is from the VM0039 published default value of 0.32 for FSB.

7.1.2 I-64 Segment 3 Data and Parameters Monitored

Data and Parameters Monitored for CCPR

Data / Parameter	W_M
Data unit	Kg
Description	Quantity of each raw material used to produce HMA or FSB or asphalt emulsions
Value applied:	2019 RAP: 28,419,496 Cement: 364,586 Bitumen: 911,466 Water: 1,750,014 Crushed Rock: 0 Sand: 0 Manufactured Aggregate: 5,013,061 2020 RAP: 42,278,773 Cement: 542,383 Bitumen: 1,355,958 Water: 2,603,440 Crushed Rock: 0 Sand: 0 Manufactured Aggregate: 7,457,769 2021 RAP: 33,153,191 Cement: 425,314 Bitumen: 1,063,284 Water: 2,041,505 Crushed Rock: 0 Sand: 0 Manufactured Aggregate: 5,848,061

Comments	N/A

Data / Parameter	Distance_{P}
Data unit	Miles
Description	The miles that trucks travelled to supply raw materials to HMA plant or FSB plant
Value applied	RAP: 0 Cement: 145 Bitumen: 100 Water: 0 Crushed Rock: 0 Sand: 0 Manufactured Aggregate: 45
Comments	N/A

Data / Parameter	Distance_{S}
Data unit	Miles
Description	The total miles that trucks travelled to transport CCPR mix from mix plant to jobsite.
Value applied	22.7
Comments	N/A

Data / Parameter	Project amount
Data unit	tonnes
Description	Output quantity of FSB or asphalt emulsions
Value applied	2019 = 36,458.62 2020 = 54,238.32

	2021 = 42,531.35
Comments	N/A

Data / Parameter	HR_{EQ}
Data unit	Hour
Description	Total operating hours of on-site use of equipment
Value applied	2019 Cold Recycler, Other: 320 hours Rubber Tired Loaders, Others: 320 hours Rubber Tired Loaders, Others: 320 hours Paver - Caterpillar, Others: 320 hours Roller – Others: 320 hours Roller – Others: 320 hours 2020 Cold Recycler, Other: 470 hours Rubber Tired Loaders, Others: 470 hours Rubber Tired Loaders, Others: 470 hours Paver - Caterpillar, Others: 470 hours Roller – Others: 470 hours Roller – Others: 470 hours 2021 Cold Recycler, Other: 520 hours Rubber Tired Loaders, Others: 520 hours Rubber Tired Loaders, Others: 520 hours Paver - Caterpillar, Others: 520 hours Roller – Others: 520 hours Roller – Others: 520 hours
Comments	N/A

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Value applied	130

Comments	N/A

Data / Parameter	LC
Data unit	Unitless
Description	Layer coefficient of FSB or asphalt emulsions
Value applied	0.32
Comments	Source is from the VM0039 published default value of 0.32 for FSB.

Data and Parameters Monitored for FDR

Data / Parameter	W_M
Data unit	Kg
Description	The weight of each raw material used to produce FSB or asphalt emulsions
Value applied:	2019 RAP: 20,243,673 Cement: 1,076,791 Bitumen: 0 Water: 215,358 2020 RAP: 30,740,392 Cement: 1,635,127 Bitumen: 0 Water: 327,025 2021 RAP: 23,992,501 Cement: 1,276,197 Bitumen: 0 Water: 255,239

Comments	N/A

Data / Parameter	Project amount
Data unit	tonnes
Description	Output quantity of FSB and asphalt emulsions
Value applied	2019 = 21,535.82 2020 = 32,702.54 2021 = 25,523.94
Comments	N/A

Data / Parameter	L
Data unit	Miles
Description	Length of damaged pavement
Value applied	8.25
Comments	N/A

Data / Parameter	HR_{EQ}
Data unit	Hour
Description	Total operating hours of on-site use of equipment
Value applied	2019 Cold recycler, Wirtgen 12': 121.5 hours Roller – Others: 121.5 hours Roller – Others: 121.5 hours 2020 Cold recycler, Wirtgen 12': 184.5 hours Roller – Others: 184.5 hours Roller – Others: 184.5 hours 2021 Cold recycler, Wirtgen 12': 144 hours Roller – Others: 144 hours

	Roller – Others: 144 hours
Comments	N/A

Data / Parameter	Distances
Data unit	Miles
Description	The total miles that trucks travelled to supply raw materials to the job site
Value applied	RAP: 0 Cement: 167.7 Bitumen: 122.7 Water: 0
Comments	N/A

Data / Parameter	DE
Data unit	lb/cu.ft
Description	Density of FSB or asphalt emulsions
Value applied	130
Comments	N/A

Data / Parameter	LC
Data unit	Unitless
Description	Layer coefficient of FSB or asphalt emulsions
Value applied	0.32
Comments	Source is from the VM0039 published default value of 0.32 for FSB.

7.2 Baseline Emissions

Baseline emissions for the first monitoring period running from April 17, 2018, through September 13, 2021, are calculated using Eq. 29 and Eq. 30 below. The crediting baseline (CB) and correction factors (θ_{AE} or Θ_{FSB}) variables are determined and available at validation as defined in Section 6.1. The Project Amount variables are monitored and have been defined in Section 6.2 above for each project instance.

Baseline GHG emission reductions for a single FSB project using the CCPR process must be calculated as follows:

$$BE_{FSB-CCPR} = \left(\frac{CB}{\Theta_{FSB}}\right) * \frac{Project\ Amount}{1{,}000} \quad Eq. 29$$

Where:

$BE_{FSB\text{-}CCPR}$ = Baseline Emissions of FSB using CCPR (tCO_2e)

CB = Crediting baseline ($kgCO_2e$/tonne)

θ_{FSB} = Correction factor for FSB (default value is 1.02)

Project amount = Amount of FSB manufactured (tonne)

Baseline GHG emission reductions for a single FSB project using the FDR process must be calculated as follows:

$$BE_{FSB-FDR} = \left(\frac{CB}{\Theta_{FSB}}\right) * \frac{Project\ Amount}{1{,}000} \quad Eq. 30$$

Where:

$BE_{FSB\text{-}FDR}$ = Baseline Emissions of FSB using FDR (tCO_2e)

CB = Crediting baseline ($kgCO_2e$/tonne)

Θ_{FSB} = Correction factor for asphalt emulsion (default value is 1.02)

Project amount = Amount of asphalt emulsions manufactured (tonne)

Table 14: Baseline Emissions

Vintage	Project	Crediting Baseline, CB (Kg CO_2e/tonne CIR)	Correction Factor, Θ (unitless)	Project Amount (Tonnes)	Baseline Emissions (Tonnes CO_2)
2018 (17-April-2018 – 31-December-2018)	I-64 Segment 2 – Layer 1 CCPR	94.7	1.02	92,326.84	8,571
	I-64 Segment 2 – Layer 2 FDR	94.7	1.02	154,391.86	14,334

Vintage	Project	Crediting Baseline, CB (Kg CO_2e/tonne CIR)	Correction Factor, Θ (unitless)	Project Amount (Tonnes)	Baseline Emissions (Tonnes CO_2)
2019 (1-January-2019– 31-December-2019)	I-64 Segment 3 – Layer 1 CCPR	94.6	1.02	36,458.62	3,381
	I-64 Segment 3 – Layer 2 FDR	94.6	1.02	21,535.82	1,997
2020 (1-January-2020– 31-December-2020)	I-64 Segment 3 – Layer 1 CCPR	94.5	1.02	54,238.32	5,025
	I-64 Segment 3 – Layer 2 FDR	94.5	1.02	32,702.54	3,029
2021 (1-January-2021– 13-September-2021)	I-64 Segment 3 – Layer 1 CCPR	94.4	1.02	42,531.35	3,936
	I-64 Segment 3 – Layer 2 FDR	94.4	1.02	25,523.94	2,362
	Total Baseline Emissions (tonnes CO_2e) =				42,635

7.3 Project Emissions

Project emissions for the first monitoring period running from April 17, 2018, through September 13, 2021, are calculated using Eq. 31 below. The Project Amount variables are monitored and have been defined in Section 6.1 above for each project instance.

Project GHG emission reductions for a single CCPR or FDR project must be calculated as follows:

$$PE_{CIR} = (CCPR\ or\ FDR\ EI) * \frac{Project\ Amount}{1{,}000} \quad Eq. 31$$

Where:

PE $_{CIR}$ = *Project Emissions of CCPR or FDR projects (tCO_2e)*

Project amount = *Amount of asphalt emulsions manufactured (tonne)*

Table 15: Project Emission Intensity

Vintage	Project	EI_M kg CO_2e/tonne	EI_{PD} kg CO_2e/tonne	EI_{SD} kg CO_2e/tonne	EI_P kg CO_2e/tonne	EI_I kg CO_2e/tonne	Total Project EI kg CO_2e/tonne
2018 (17-April-2018 – 31-December-2018)	I-64 Segment 2 – Layer 1 CCPR	21.13	6.27	22.32	8.24	2.18	60.14
	I-64 Segment 2 – Layer 2 FDR	41.50	-	5.49	-	5.92	52.92
2019 (1-January-2019– 31-December-2019)	I-64 Segment 3 – Layer 1 CCPR	21.13	6.27	14.45	7.26	1.92	51.03
	I-64 Segment 3 – Layer 2 FDR	41.50	-	5.19	-	5.61	52.29
2020 (1-January-2020– 31-December-2020)	I-64 Segment 3 – Layer 1 CCPR	21.13	6.27	14.45	7.17	1.90	50.92
	I-64 Segment 3 – Layer 2 FDR	41.50	-	5.19	-	5.61	52.29
2021 (1-January-2021– 13-September-2021)	I-64 Segment 3 – Layer 1 CCPR	21.13	6.27	14.45	10.11	2.68	54.64
	I-64 Segment 3 – Layer 2 FDR	41.50	-	5.19	-	5.61	52.29

Note: The calculation process for CCPR EI and FDR EI is documented in Section 5.2 above. All step-by-step calculations are provided in the attached ER spreadsheet and are therefore summarized in the table above.

Table 16: Project Emissions

Vintage	Project	Emission Intensity (EI) (Kg CO2e / Tonne Installed)	Project Amount (Tonnes)	Project Emissions (Tonnes CO_2e)
2018	I-64 Segment 2 –	60.14	92,326.84	5,553

Vintage	Project	Emission Intensity (EI) (Kg CO2e / Tonne Installed)	Project Amount (Tonnes)	Project Emissions (Tonnes CO_2e)
(17-April-2018 – 31-December-2018)	Layer 1 CCPR			
	I-64 Segment 2 – Layer 2 FDR	52.92	154,391.86	8,171
2019 (1-January-2019– 31-December-2019)	I-64 Segment 3 – Layer 1 CCPR	51.03	36,458.62	1,861
	I-64 Segment 3 – Layer 2 FDR	52.29	21,535.82	1,127
2020 (1-January-2020– 31-December-2020)	I-64 Segment 3 – Layer 1 CCPR	50.92	54,238.32	2,762
	I-64 Segment 3 – Layer 2 FDR	52.29	32,702.54	1,711
2021 (1-January-2021– 13-September-2021)	I-64 Segment 3 – Layer 1 CCPR	54.64	42,531.35	2,325
	I-64 Segment 3 – Layer 2 FDR	52.29	25,523.94	1,335
	Total Project Emissions (tonnes CO_2e) =			24,845

7.4 Leakage

Leakage is not considered an issue under VM0039 methodology and is therefore set at zero. It is reasonable to assume zero leakage because there is no difference in site preparation activities between baseline and project scenarios. Replacing HMA with FSB or asphalt emulsions for the pavement base layer does not entail a change in carbon efflux or carbon sink at the construction site.

7.5 Net GHG Emission Reductions and Removals

The net GHG emission reductions and removals for the first monitoring period running from April 17, 2018, through September 13, 2021, are summarized in Table 17 below.

Table 17: Net GHG Emission Reductions and Removals

Year	Project	Baseline emissions (tCO_2e)	Project emissions (tCO_2e)	Leakage emissions (tCO_2e)	Net GHG emission reductions (tCO_2e)
2018 (17-April-2018 – 31-December-2018)	I-64 Segment 2	22,905	13,724	0	9,181
2019 (1-January-2019– 31-December-2019)	I-64 Segment 3	5,378	2,988	0	2,390
2020 (1-January-2020– 31-December-2020)	I-64 Segment 3	8,054	4,473	0	3,581
2021 (1-January-2021– 13-September-2021)	I-64 Segment 3	6,298	3,660	0	2,638
Total		**42,635**	**24,845**	**0**	**17,790**

The estimated ex-ante GHG emission reductions and the achieved emission reductions for this monitoring period are below.

Table 18: Ex-ante versus Achieved Emission Reduction Comparison

Year	Ex-ante emissions reductions/removals	Achieved emissions reductions/removals	Percent difference	Justification for the difference
2018 (17-April-2018 – 31-December-2018)	9,181	9,181	0.0	No difference.

2019 (1-January-2019– 31-December-2019)	2,390	2,390	0.0	No difference.
2020 (1-January-2020– 31-December-2020)	3,581	3,581	0.0	No difference.
2021 (1-January-2021– 13-September-2021)	2,638	2,638	0.0	No difference.