APPENDIX G

Greenhouse Gas and Climate Change Analysis

GHG Running Exhaust and Fuel Cycle Emissions (CO2e)

Year	Emission Factor (g/mi)*	ADT (vehicles per day)	Length (mi)	g/day	MT/day	MT/year
2015	638.13	17,700	4.2	47,438,743.92	47.44	17,315.14
2040 (No Build)	444.43	23,300	4.2	43,491,976.66	43.49	15,874.57
2040 (Build)	444.43	23,300	4.2	43,491,976.66	43.49	15,874.57

*Since only posted speed is provided, the rate for average speed and roadtype was used as a conservative estimate

Conversion factor g 1000000

Greenhouse Gas Analysis Assumptions

Roadway		
AADT in 2040 – 23,300	AADT per lane mile reconstructed/resurfaced	5,825 AADT per lane mile in 2040
Total existing centerline miles	4.8 miles (includes bridge)	
Total existing lane miles	8.4 miles	
Total newly-constructed centerline miles	0	
Total newly-constructed additional lane miles	8.4 miles	
Rural Principal Arterial – analysis timeframe will be 25 years (2042)		
Year 1 – new const and reconstruct existing	8.4 miles new construct additional lanes; 8.4 miles reconstruct existing lanes	4.2 miles – centerline, new const. of shoulders 8.4 lane miles of new bike/ped const
Year 15 - resurface	16.8 lane miles resurface + 2.5 miles of bridges resurfaced = 19.3 miles	4.2 –centerline miles shoulder improvement resurface 8.4 lane miles bike/ped resurface
Bridge		
Construct New	3,289 feet	2 12-foot travel lanes
	New multi-span	2- 10 foot wide shoulders
	Counted as 6 total lanes (travel lanes, shoulders, multi-use path)	1 – 10 foot wide multi-use path
Year 15 maintenance:	New bridge and Existing bridge would both have maintenance year 15	Resurface bridge decks (included in year 15 resurface above)
Total New Const	0	
Total construct additional lane	8.4 miles	
Total reconst existing lanes	8.4 miles	
Total shoulder improvements	8.4 miles	
Total Resurface	19.3 lane miles road	
Total Bike/Ped	16.8 miles (construct and resurface)	
Total project-days of lane closure	Construction:	Assume two years for project construction (widening and bridge)
	Rehab – assume 90 days	Total: 90
		Total: 820 days
Mitigation Inputs	Preventative Maintenance	50% assumed planned deployment

ICE Tool - Project Inputs

General Information

Infrastructure location (state)	SC
Analysis timeframe (years)	25
Average daily traffic per lane mile - for facilities that will be reconstructed or resurfaced	5,825

Roadway System

Total existing centerline miles	4.2
Total existing lane miles	8.4
Total newly-constructed centerline miles	0
Total newly-constructed lane miles	8.4

Rail, Bus, and Bicycle Infrastructure

Total existing track miles of light rail	0
Total existing track miles of heavy rail	0
Total newly-constructed track miles of rail	0
Total existing lane miles of bus rapid transit	0
Total newly-constructed lane miles of bus rapid transit	0
Total existing lane miles of bicycle lanes	0
Total newly-constructed lane miles of bicycle lanes	0

Roadways

Roadway Projects

	Roadway Construction					Roadway Rehabilitation	
Facility type	New Roadway (lane miles)	Construct Additional Lane (lane miles)	Re-Alignment (lane miles)	Lane Widening (lane miles)	Shoulder Improvement (centerline miles)	Re-construct Pavement (lane miles)	Resurface Pavement (lane miles)
Rural Interstates	0	0	0	0	0	0	0
Rural Principal Arterials	0	8.4	0	0	8.4	8.4	19.3

Infrastructure location (state)	SC
Analysis timeframe (years)	25
Average daily traffic per lane mile - for facilities that	5,825

Parking

Total existing centerline miles	4.2

Accounting for the Full Roadway Lifespan

The estimator tool accounts for construction, rehabilitation, routine maintenance, and preventive maintenance in different ways:

- **New Construction (user provided):** The user enters lane miles of construction projects.
- **Rehabilitation (user provided):** The user enters expected reconstruction and resurfacing projects on all existing and new roadways for the length of the analysis period. As a general rule of thumb, new roadways require resurfacing after 15 years and reconstruction after 30 years.
- **Routine Maintenance (automatically estimated):** The tool automatically estimates routine maintenance activity, such as sweeping, striping, bridge deck repair, litter pickup, and maintenance of appurtenances, per lane mile of existing and new roadway.
- **Preventive Maintenance (user provided):** The user has the option to specify a preventive maintenance program as a mitigation strategy (in the Mitigation Inputs tab). Preventive maintenance techniques include crack sealing, patching, chip seals, and micro-surfacing.

Example: The user enters new construction of 10 lane miles of new freeway, with an analysis period of 40 years. Assuming that all construction takes place in year 1

Options	
% roadway construction on rocky / mountainous terrain	0%

an analysis period of 40 years. Assuming that all construction takes place in year 1, the user enters 10 lane miles of freeway resurfacing (assumed to take place in year 15) and 10 lane miles of freeway reconstruction (assumed to take place in year 30). The tool automatically includes routine maintenance of the 10 newly constructed lane miles. The user has the option of specifying a preventive maintenance strategy, which will increase the longevity of the pavement surface and therefore reduce the amount of energy and emissions associated with resurfacing and rehabilitation.

Bridge Structures

	Construct New Bridge				Reconstruct Bridge				Add Lane to Bridge			
Bridge Structure	Number of bridges	Average number of spans per bridge	Average number of lanes per bridge	Total number of lane-spans	Number of bridges	Average number of spans per bridge	Average number of lanes per bridge	Total number of lane-spans	Number of bridges	Average number of spans per bridge	Average number of new lanes per bridge	Total number of lane-spans
Single-Span	0	1	0	0	0	1	0	0	0	1	0	0
Two-Span	0	2	0	0	0	2	0	0	0	2	0	0
Multi-Span (over land)	0	0	0	0	0	0	0	0	0	0	0	0
Multi-Span (over water)	1	3	6	18	0	0	0	0	0	0	0	0

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Rail, bus, bicycle, and pedestrian facilities

Rail construction

Project Type	Light rail	Heavy rail
New construction (underground - hard rock) - track miles	0	0
New construction (underground - soft soil) - track miles	0	0
New construction (elevated) - track miles	0	0
New construction (at grade) - track miles	0	0
Converted or upgraded existing facility - track miles	0	N/A
New rail station (underground) - stations	0	0
New rail station (elevated) - stations	0	0
New rail station (at grade) - stations	0	0

Bus rapid transit construction

New lane or right-of-way - lane miles	0
Converted or upgraded lane/facility - lane miles	0
New BRT Stations	0

Bicycle and Pedestrian Facilities

Project Type	New Construction	Resurfacing	Restriping
Off-Street Bicycle or Pedestrian Path - miles	0	0	N/A

On-Street Bicycle Lane - lane miles	8.4	8.4	0
On-Street Sidewalk - miles	0	N/A	N/A

Construction - Delay

Total project-days of lane closure	820
Average daily traffic per directional segment for facilities requiring lane closure	5,800
Percentage of facility lanes closed during construction	50%

Estimating Project-Days of Lane Closure

Estimates of project-days of lane closure may be available from project documents. The tool assumes that lane closures occur in one-mile increments. Average values for construction schedules (e.g., daytime versus overnight) are incorporated in the calculations. Estimates of emissions from construction delay are meant to provide a rough sense of the scale of emissions relative to the construction processes themselves, and are not meant to replace estimates derived from traffic

ICE Tool - Mitigation Inputs

Energy / GHG reduction strategies

Strategy	Baseline deployment	Planned deployment	Maximum potential deployment	Applied to
Alternative fuels and vehicle hybridization				
Hybrid maintenance vehicles and equipment	0%	0%	44%	Fuel use by maintenance equipment
Switch from diesel to B20 in maintenance vehicles and equipment	0%	0%	100%	Fuel use by maintenance equipment
Switch from diesel to B100 in maintenance vehicles and equipment	0%	0%	100%	Fuel use by maintenance equipment
Combined hybridization/B20 in maintenance vehicles and equipment	0%	0%	44%	Fuel use by maintenance equipment
Hybrid construction vehicles and equipment	0%	0%	44%	Fuel use by construction equipment
Switch from diesel to B20 in construction vehicles and equipment	0%	0%	100%	Fuel use by construction equipment
Switch from diesel to B100 in construction vehicles and equipment	0%	0%	100%	Fuel use by construction equipment
Combined hybridization/B20 in construction vehicles and equipment	0%	0%	44%	Fuel use by construction equipment
Vegetation management				
Alternative vegetation management strategies (hardscaping, alternative mowing, integrated roadway/vegetation management)	No	No	N/A	Fuel use by vegetation management equipment
Snow fencing and removal strategies				
Alternative snow removal strategies (snow fencing, wing plows)	No	No	N/A	Fuel use by snow removal equipment
In-place roadway recycling				
Cold In-place recycling	0%	0%	99%	Asphalt and fuel use by construction equipment in roadway resurfacing and BRT conversions
Full depth reclamation	0%	0%	99%	Base stone and fuel use by construction equipment in roadway reconstruction and BRT conversions
Warm-mix asphalt				
Warm-mix asphalt	0%	0%	100%	Asphalt use in all projects
Recycled and reclaimed materials				
Use recycled asphalt pavement as a substitute for virgin asphalt aggregate	0%	0%	25%	Asphalt use in all projects
Use recycled asphalt pavement as a substitute for virgin asphalt bitumen	0%	0%	40%	Asphalt use in all projects
Use industrial byproducts as substitutes for Portland cement	0%	0%	33%	Concrete use in all projects
Use recycled concrete aggregate as a substitute for base stone	0%	0%	100%	Base stone use in all projects
Preventive maintenance				

Preventive maintenance	0%	50%	100%	Materials and construction fuel use in roadway resurfacing and reconstruction projects

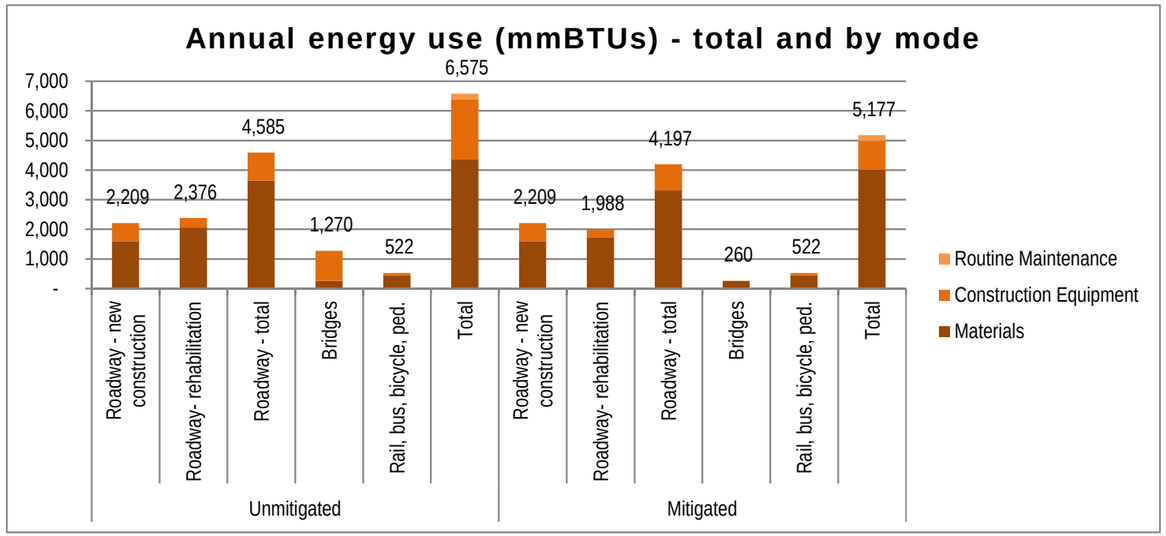
ICE Tool Results

	Annualized energy use (mmBTUs), per year over 25 years											
	Unmitigated						Mitigated					
	Roadway - new construction	Roadway-rehabilitation	Roadway - total	Bridges	Rail, bus, bicycle, ped.	Total	Roadway - new construction	Roadway-rehabilitation	Roadway - total	Bridges	Rail, bus, bicycle, ped.	Total
Upstream Energy												
Materials	1,593	2,051	3,644	260	440	4,344	1,593	1,716	3,309	260	440	4,009
Direct Energy												
Construction Equipment	616	325	941	1,010	82	2,033	616	272	888	-	82	970
Routine Maintenance						198						198
Total	2,209	2,376	4,585	1,270	522	6,575	2,209	1,988	4,197	260	522	5,177

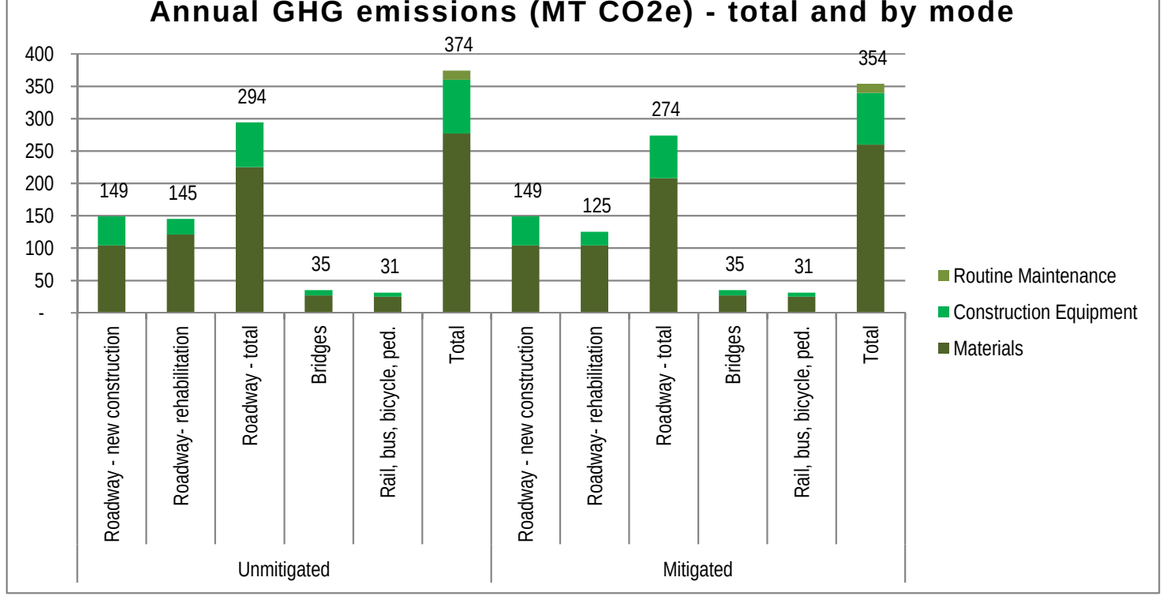
Note: To convert mmBTU to the equivalent gallons of US conventional diesel, use the conversion factor of 7.785 gallons of diesel / mmBTU. Please keep in mind that this conversion represents the equivalent amount of energy required, which can be useful for informational purposes, but it does not necessarily represent actual gallons of diesel required.

	Annual GHG emissions (MT CO2e), per year over 25 years											
	Unmitigated						Mitigated					
	Roadway - new construction	Roadway-rehabilitation	Roadway - total	Bridges	Rail, bus, bicycle, ped.	Total	Roadway - new construction	Roadway-rehabilitation	Roadway - total	Bridges	Rail, bus, bicycle, ped.	Total
Upstream Emissions												
Materials	104	121	225	27	25	277	104	104	208	27	25	260
Direct Emissions												
Construction Equipment	45	24	69	8	6	83	45	21	66	8	6	80
Routine Maintenance						14						14
Total	149	145	294	35	31	374	149	125	274	35	31	354

Annualized over 25 Years



Annualized over 25 Years



Construction delay	Result	Energy use (mmBTUs)	GHG emissions (MT CO2e)
Total project-days of construction/lane closure	820		
Project lifetime (years)	25		
Additional energy use / emissions due to delay (per project-day)		6.5	0.6
Total energy use / GHG emissions due to construction delay		5,321	474
Annual energy use / GHG emissions due to construction delay, per year		212.8	18.9

Pavement smoothness	Result	Energy use (mmBTUs)	GHG emissions (MT CO2e)
Total lane miles of roadway reconstruction / resurfacing	28		
Project lifetime (years)	25		
Reduced Energy use / GHG emissions due to smooth pavement		448	33
Annual energy / emissions savings due to pavement smoothness		17.9	1.3

Note: Energy and emission savings from pavement smoothness are automatically calculated for all resurfacing and reconstruction projects. Savings accrue after project completion.

Total	Energy use (mmBTUs)	GHG emissions (MT CO2e)
Total Annualized Delay and Pavement Smoothness Impacts	194.9	17.6