Appendix N
Construction Phase Life Cycle Analysis Report
(Parsons & Hatch - May 2019)

City of Kingston
Third Crossing

Construction Phase Life Cycle Assessment Report

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City of Kingston
Third Crossing Bridge

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1. Introduction

The City of Kingston (City) has retained a project team consisting of Peter Kiewit Sons ULC (Kiewit), Hatch Ltd. (Hatch) and SYSTRA International Bridge Technologies (SYSTRA) as the primary proponents (Integrated Project Delivery (IPD) Team) to prepare the Parks Canada Detailed Impact Analysis (DIA) Report of the Third Crossing of the Cataraqui River (Report). The IPD Team is supplemented by specialized industry experts Brownlie Ernst and Marks (BEaM), Vertechs Designs, Moon-Matz, Tulloch and Bergman.

The Construction Phase Life Cycle Report was originally completed by Parsons as part of the Preliminary Design of the Third Crossing of the Cataraqui River. This version of the report updates the information used for the assessment to reflect the bridge design developed during the validation design phase while using the estimation approach from the preliminary design.

2. Purpose

This purpose of this report is to describe the scope, inputs, analysis, and output of a preliminary, planning level Life Cycle Assessment (LCA) for the construction phase of the City of Kingston Third Crossing of the Cataraqui River Project.

Detailed design documents not available at this stage of the Third Crossing project. As such, the U.S. Federal Highway Administration (FHWA) Infrastructure Carbon Estimator (ICE) tool was selected during the preliminary design for the analysis because it provides approximate energy use and emissions outputs for projects that have not progressed to more detailed levels of design and construction planning. The tool and its capabilities are described in more detail in the “LCA Analysis Tools” section below.

As is explained in more detail, below, a whole-project LCA would estimate carbon emissions caused by materials extraction and processing, transportation of materials to be used during construction and operation, and project maintenance and operation, including vehicle traffic. Although the boundary of this LCA is limited to the construction phase, its relationship to a whole project LCA is discussed to demonstrate context and relationship of this analysis to the energy and carbon impacts that may be performed for other phases of the project.

3. Life Cycle Assessment Overview

3.1 Relevant Standards

A standardized, internationally accepted, method for evaluate the environmental footprint via a LCA is outlined in ISO Standard 14040: “Environmental management -- Life cycle assessment -- Principles and framework” and ISO Standard and 14044: “Environmental management -- Life cycle assessment – Requirements and guidelines.” The foundations for these standards were developed in the mid=1990’s and the original “Principles and framework” document was published in 1997. In 2006, ISO 14040 was revised and expanded to include Standard 14044.[1]

3.2 LCA Process Steps

The following sections describe the standard steps in the process of performing an LCA as defined by ISO Standards 14040. Section 4 details how these steps were applied to the Third Crossing Project Construction Phase.

3.2.1 Define Goal & Scope

Defining the LCA goals includes establishing the intended audience and reasons for carrying out the analysis, and whether the nature of the analysis will be comparative or absolute. Establishing the scope of the LCA includes defining the:

- General system to be studied, e.g. “New cable-stay bridge construction” or “Highway Rehabilitation”; and
- LCA boundary, or the processes within the system to be included:
    - Impact categories, e.g. water, energy consumption, greenhouse gas emissions, other emissions; and
    - Associated functional units, e.g. gallons, kBTU, tons of CO_2 equivalent, tons of other emissions to the air such as Sulfur Oxides (SOx) or Nitrogen Oxides (NOx).

3.2.2 Perform Life Cycle Inventory

The steps of performing the Life Cycle Inventory (LCI) include:

[1] Du, Guiangli. Life cycle assessment of bridges, model development and case studies

- Data collection (energy, raw material, and other ancillary or physical inputs; products, co-products and waste; emissions to air, discharges to water and soil; and other environmental aspects;
- Data calculation (validation of collected data; relating of data to unit processes; relating of data to the reference flow of the functional unit); and
- Data allocation (allocating input flows and outputs released to the relevant materials and flows).

3.2.3 Perform Life Cycle Impact Assessment

The steps of performing the Life Cycle Impact Assessment (LCIA) include:

- Determine the relevant impact categories;
- Establish indicators for each impact category;
- Assign LCI results to the appropriate impact categories;
- Normalize relative to reference information (if applicable);
- Group results (if applicable);
- Apply weighting to results (if applicable); and
- Review goal and scope to determine if objectives have been met, summarize.

3.2.4 Interpret Results & Prepare LCA Report

The LCA interpretation includes a critical review of the LCI and LCIA, that:

- Describes the basis of the interpretation (i.e. relative approach, potential environmental impacts, no assessment of risk or safety margins, etc.);
- Describes results as they relate to the goal and scope;
- Describes the limitations of the LCA, such as:
  - system boundary limitations;
  - inadequate LCI data availability or quality limitations;
  - differences in allocation and aggregation procedures; and
  - uncertainty analysis, sensitivity analysis.
- Draws conclusions and provide recommendations.

A report is then prepared to summarize all of the steps of the LCA, the interpretation of results and next steps.

3.3 LCA Analysis Tools

Although several tools are available to assist with performing LCAs, their applicability to planning for civil infrastructure and transportation projects is often limited because:

1. They focus on building systems and associated products rather than transportation facilities.
2. They require detailed information regarding project design, materials, and construction means and methods in order to produce a meaningful result.

This does not prevent a project team from performing a detailed LCA without the assistance of software or tools, but it can lead to a more time-consuming process that requires collecting and analyzing project and location- specific data. Furthermore, if a project is in the planning stages, such as the Third Crossing, assumptions must be made regarding material quantities, location of extraction and manufacture, construction processes, durations, and other complex data inputs.

A survey of available tools was performed by Parsons with the goal of finding one with the following attributes:

- Applicable to transportation infrastructure projects;
- Does not require detailed project inputs;
- Analyzes the impacts of activities related to a project's construction phase;
- Rather than comparing specific design alternatives such as pavement or bridge types, estimates total energy and emissions of a transportation construction project, which could include rehabilitation of existing transportation system components and/or the construction of new elements;
- Provides an opportunity to analyze different environmental mitigation strategies on the overall energy and emissions outputs of the project in question; and
- Uses an estimation methodology based on widespread data and validated emissions factors.

An overview of the ICE tool is provided in Section 3.4. More detailed information can be found on FHWA's online version of the FWHA Infrastructure Carbon Estimator, Final Report and User's Guide, September 2014 (User's Guide).

3.4 FHWA's Infrastructure Construction Estimator

3.4.1 Overview

The FHWA's Infrastructure Construction Estimator (ICE) tool is "designed to allow users to create "ballpark" estimates of energy and GHG emissions" using data collected from various state's Department of Transportation (DOT), a nationwide database of construction bid documents, and consultation with transportation engineers and lifecycle analysis experts. The calculation methodologies, including energy and emissions factors embedded in the tool are based on empirical data gathered from a broad sample of projects throughout the United States.

For example, assumptions about the proportions of asphalt and concrete, travel distances, and material production practices, come from representative sample of projects out of the whole, rather than requiring detailed information about project quantities and location of production that is not available at the planning stage. As such, the exercise can be done without the detailed information from engineering documents and construction plans. This makes it an appropriate tool to use at this stage of the Third Crossing project, prior to detailed design.

3.4.2 Inputs

The ICE tool accept inputs for a variety of facility types, including roadways, parking facilities, bridges, rail and bus rapid transit infrastructure, and bicycle and pedestrian facilities. Project types within each facility type vary, but generally include both new construction and repair or upgrading of existing facilities. All available facility and project types in the ICE tool are shown in Figure 3-1, with ones applicable to the Third Crossing project highlighted with green boxes.

Project scope inputs allow for differentiation among terrain types (e.g. bridges over water vs. on land) and type of construction (e.g. rehabilitation/reconstruction, new construction, roadway widening) to account for differing labor and material intensities.

3.4.3 Outputs

Per the User's Guide, the tool is capable of estimating energy consumption and associated emissions for the following categories of activities:

- Construction/Rehabilitation – Construction of a new facility or rehabilitation of an existing facility, including reconstruction and repaving;

- Materials – Embodied energy and emissions associated with the extraction, transportation, and production of materials;
- Construction equipment and transportation – Fuel use on site in construction and routine maintenance equipment, as well as fuel used to transport materials to the site;
- Routine Maintenance – Periodic maintenance activities including vegetation and snow management, sweeping, restriping, and crack sealing;
- Construction equipment and transportation – Fuel used in maintenance equipment;
- Facility Use (partial), i.e. Impacts on Vehicle Operation;
- Traffic delay during construction– Excess fuel consumption by vehicles using existing facilities due to delays caused by construction activity; and
- Efficiency gains from pavement smoothness – Fuel saved in vehicles traveling on recently improved roadway surfaces.

As further described in the section entitled “Scope” below, the scope of this LCA only includes the first category: Construction/Rehabilitation.

Category	Facility type	Project type
Roadways	Rural interstates Rural principal arterials Rural minor arterials Rural collectors Urban interstates / expressways Urban principal arterials Urban minor arterials / collectors	Roadway construction New facility Re-alignment Construct additional lane Lane widening Shoulder improvement Roadway rehabilitation Re-construct pavement Resurface pavement
Parking	Surface parking Structured parking	New construction
Bridge structures	Single-span Two-span Multi-span (over land) Multi-span (over water)	New construction Reconstruction Lane addition
Rail	Light rail Heavy rail Rail station	New construction, underground (hard rock, soft soil) New construction, elevated New construction, at grade Convert/upgrade existing facility (light rail only)
Bus rapid transit	BRT lane or right-of-way BRT station	New construction Convert/upgrade lane
Bicycle	Off-street paths On-street bicycle lanes	New construction Resurfacing Restriping (on-street only)
Pedestrian	Off-street paths On-street (sidewalks)	New construction Resurfacing (off-street only)

Input Category relevant to the Third Crossing project

Figure 3-1: FHWA ICE Facility and Project Types

4. Third Crossing Construction LCA

4.1 Goal & Scope Definition

4.1.1 Goal

The goal of this LCA is to evaluate carbon emissions for the construction phase of the City of Kingston Third Crossing project and in doing so, to determine the impact of the current project configuration, including planning level design and material choices impact energy consumption and greenhouse gas emissions. A definition of the processes included in the construction phase can be found in the “Scope” section below.

The audience for the study is the City of Kingston itself and the reason for carrying out the study is to analyze the carbon impact of the construction phase of the Third Crossing, which, together with analyses performed for other project phases, will constitute an overall project greenhouse gas emissions analysis.

The preferred alignment, which connects John Counter Boulevard and Gore Road, was evaluated in this LCA. The results of the study are expressed with an upper and lower limit to the energy and emissions calculation. The upper limit (or "Unmitigated" result), represents the energy consumption and emissions associated with standard practice, the worst-case scenario as informed by Ontario Province Standard Specifications (OPSS). The lower limit (or "Mitigated") result represents the energy and emissions calculated when various mitigation strategies have been applied. The mitigation categories are described in more detail in the Section 4.2.1 and assumptions made regarding the Unmitigated and Mitigated conditions for this study are provided in the Section 4.2.5.

4.1.2 Scope

The scope of the LCA is as follows:

- System to be studied: City of Kingston Third Crossing of the Cataraqui River, Construction Phase;
- System boundary: Refer to Figure 2 for a visual representation of the Construction Phase LCA boundary within the context of a whole-project LCA. Processes and materials included in this LCA are driven by the configuration of FHWA's ICE tool and the boundary defined by the City of Kingston. They are:
    - Extraction, transportation, and production of materials; and
    - Operation of on-site by construction vehicles and equipment.
- Impact categories: This LCA focuses on energy and greenhouse gas emissions and only includes the following impact categories:
    - Energy consumption; (functional unit: millions of British Thermal Units (MMBTU); and
    - Greenhouse gas emissions; functional unit: and metric tons of CO2 equivalent (MT CO2e).

4.2 Life Cycle Inventory

4.2.1 Data Collection & Calculation

Detailed project inputs that show the data requirements for the ICE tool are included in Appendix A.1: Project Inputs and Appendix A.2: Mitigations Inputs. Project information inputs fall into to the following three categories:

- General project information;
- Existing transportation system details; and
- Project scope of work, e.g. lane-miles of new or rehabilitation work (including roadway and bicycle/pedestrian lanes, bridge(s), rail, public transit, and bus rapid transit, if applicable).

Available mitigation inputs are defined by the ICE tool and fall into the four categories shown below. Options for evaluating the impacts of other project variables such as detailed construction means and methods or bridge structural system options, are not included, due to the nature of ICE as a high level planning phase tool:

- Construction and Maintenance vehicle attributes (% hybrid vehicles in fleet, use of B20 and B100 in place of diesel fuel by vehicles and equipment);
- In-place road reconstruction practices (cold in-place recycling and/or full-depth reclamation);
- Paving practices (use of warm mix asphalt, recycled aggregate in asphalt and concrete, use of Portland Cement substitutes such as fly ash, silica fume, and blast furnace slag);
- Maintenance practices, such as alternative vegetation management and alternative snow removal methods.

Details regarding which mitigations were applied in the analysis can be found in the Section 4.2.5.

4.2.2 General Project Information

General project information is described below:

- Project Location: The ICE tool only includes a drop-down menu of U. S. states to select for the project location. Since this information is “only “used to estimate the level of effort associated with vegetation and snow management which are operational practices that were not evaluated as part of this LCA. Nonetheless, New York state was selected, as it is the closest to the City of Kingston, and it is assumed that the data used by the tool to calculate materials and production impacts, would be drawn from a regionally relevant set of projects;

- Analysis Timeframe (years): Since the scope of this LCA only includes the construction phase, the Project Lifetime was entered into the ICE tool "1" as recommended by the User's Guide, which states, "If you only want to estimate the total emissions associated with a construction project, set this cell to 1. However, we recommend filling in this cell if you are interested in estimating impacts related both to construction and routine maintenance.";
- None of the project is located in difficult terrain that would increase the energy use or emissions impacts of construction phase, due to more difficult earthwork and more materials needed for roadway base and structural elements.

4.2.3 Existing Transportation System

- Existing components of the transportation system are described below and summarized in Table 1;
- The existing roadway consists of John Counter Boulevard to the west of the river and Gore Road east of the river;
- Currently there is no light or heavy rail, no existing Bus Rapid Transit (BRT), nor any existing bicycle lanes, or multi-use pathways; and
- There is an existing sidewalk, located on the south side of Gore Road.

Table 1: Existing Transportation Facility ICE Tool Inputs

EXISTING ROADWAY INFRASTRUCTURE		NOTES
Existing roadway	400 (0.249) Centerline-meters (Centerline-miles)	West: 240 m; East: 160 m
	800 (0.497) Lane-meters (Lane-miles)	West; 240 m; East: 160 m; 2 lanes

4.2.4 Project Scope of Work

- The construction scope of work is described below and summarized in Table 2, Table 3and Table 4;
- The bridge and its east and west approaches are considered to be "Undivided Urban Arterial" type roadway according to the project's design criteria. In the ICE , the equivalent category was determined to be "Urban Principal Arterial"; and

- None of the roadway rehabilitation or new construction work falls into the following input categories: Rural interstate, Rural Principal Arterial, Rural Minor Arterial, Rural Collector, Urban Interstate, or Urban Minor Arterial/ Collector.

Roadway work:

- On the West side of the new bridge, replacement (not overlay of existing pavement) and widening of existing pavement using a conventional pavement structure on John Counter Boulevard to the east of Montreal Street. The length of this segment is approximately 240 m (from Sta. 10+030 to Sta. 10+270);
- On the east side of the new bridge, widening and extension of the roadway on Gore Road, west of Highway 15 to the Bridge, including significant fill in order to provide a road base that will link the onshore road to the abutment as it approaches the bridge from the east. The length of the reconstructed segment is approximately 160 m (from Sta. 11+640 to Sta. 11+800). The length of the new roadway extension begins west of Point St. Mark Drive and is approximately 190 m long (from Sta. 11+450 to Sta. 11+640);
- Both existing road segments will require widening, formalization of traffic lanes, and introduction of new traffic patterns through both signalized and unsignalized intersections;
- A new 15 m long left turn bay will be provided for westbound travelers at Point St. Mark Drive;
- A new 15 m long left turn bay will be provided for westbound travelers at the Gore Road Library;
- A new 60 m long access road to the Gore Road Library; and
- A new 80 m long left turn bay will be provided for eastbound travelers at Highway 15 east of Point St. Mark Drive.

On-Street Bicycle Lanes:

- A commuter bicycle lane 1,770 m in length will be provided on the north and south sides of the roadway, beginning on John Counter Boulevard at Montreal St, continuing along the bridge, and extending eastward on Gore Road to Highway 15 (Sta. 10+030 to Sta. 11+800).

Off-Street Bicycle/Pedestrian Paths:

- There will be a new multi-use path provided along the south side of the roadway for the entire 1,180 m length of the bridge (Sta. 10+270 to Sta. 11+450);
- The multi-use path will extend approximately 160 m eastward from the bridge along the south side of Gore Road to connect to the existing sidewalk east of Point St. Mark Drive (from Sta. 11+640 to Sta. 11+800). The multi-use path will also extend under the bridge to connect to the trail network on the Gore Road Library property, with an estimated length of 400 m;
- The multi-use path will extend approximately 95 m westward from the bridge (Sta. 10+270) along the south side of John Counter Boulevard until it reaches Ascot Lane (Sta. 10+175). At Ascot lane, a multi- use path is provided on the north side of John Counter Blvd (via crosswalk) and on the south side of John Counter Blvd, both of which lead to the existing Elliott Avenue Parklet, with an estimated length of 225 m.

Sidewalks:

- A new sidewalk will be provided on the east side of the bridge from the north end of the crosswalk at Point St. Mark Drive to the library parking lot, with an estimated length of 60 m; and
- A new 145 m long sidewalk will be provided on the north side of John Counter Boulevard from the connection to the multi-use trail at Ascot Lane (Sta.10+175) westward to Montreal Street (Sta. 10+030).

Bridge:

- The bridge preliminary bridge design consists of 22 spans, 18 spans on west side, the main navigation channel arch span, and 3 spans on east side, with 19 conventional piers and two main span piers. The approach spans from the west shore to the arch are 48 m long (measured centre-to-centre of the pier). The spans to the east of the arch measure 43 m, The main navigation channel arch span measures 94.88 m with 71.75 m and 61.69 m back spans to Pier 17 and 20, respectively. Refer to Appendix B for a drawing depicting the general arrangement of the bridge.

Rail: There is no new rail infrastructure in the scope of work.

Bus Rapid Transit: There is no new BRT infrastructure in the scope of work.

Parking: There is no new structured or surface parking in the scope of work.

Table 2: Roadway Rehabilitation and New Construction Scope of Work

ROADWAY CONSTRUCTION (REHABILITATION)		QUANTITY	UNITS	NOTES
Existing Urban	Re-constructed	800 (0.497)	Lane-meters (Lane-miles)	
Principal Arterial	Re-surfaced	0	Lane-meters (Lane-miles)	
ROADWAY CONSTRUCTION (NEW)		**QUANTITY**	**UNITS**	**NOTES**
New Urban Principal Arterial	New Roadway	360 (0.224)	Lane-meters (Lane-miles)	East: 190 m; 2 lanes
	Additional Lanes	170 (0.106)	Lane-meters (Lane-miles)	East: 170 m, turning lanes
	Lane Re-Alignment	0	Lane-meters (Lane-miles)	
	Lane Widening	800 (0.497)	Lane-meters (Lane-miles)	West: 240m; East: 160m; 2 lanes
	Shoulder Improvement	0	Centerline-meters (Centerline-miles)	

Table 3: New Bridge Structure Scope of Work

BRIDGE TYPE	NUMBER OR BRIDGES	AVERAGE NUMBER OF SPANS PER BRIDGE	AVERAGE NUMBER OF LANES PER BRIDGE
Single -Span	0	1	NA
Two-Span	0	2	NA
Multi-Span (overland)	0	NA	NA
Multi-Span (overwater)	1	22	2

Table 4: New or Rehabilitated Bicycle and Pedestrian Scope of Work

BRIDGE	QUANTITY	UNITS	NOTES
Existing pavement resurfaced to create/rehabilitate Off-Street bike lanes	0	Lane-meters (Lane-miles)	

BRIDGE	QUANTITY	UNITS	NOTES
Existing pavement resurfaced to create/rehabilitate On-Street bike lanes	0	Lane-meters (Lane-miles)	
Existing pavement re-striped (but not resurfaced) for On-Street bike lanes	0	Lane-meters (Lane-miles)	
New Off-Street Bicycle or Pedestrian Path	2,060 Meters (1.28 miles)	Meters (miles)	West: 95 m; Bridge: 1,180 m; East: 160 m; Under Bridge West: 225m; Under Bridge East: 400 m
New On-Street Bicycle Lanes	3,540 (2.20)	Lane-meters (Lane-miles)	North and south-bound, 1,770 m
New sidewalk	205 (0.127)	Meters (miles)	West 145m; East: 60m

4.2.5 Mitigation Inputs

As stated previously, reduction to energy consumption and emissions can be calculated using a limited number of mitigation practices available in the ICE tool. The Unmitigated and Mitigated condition assumptions made for this LCA are described below and summarized in Table 5. In general, the "Unmitigated" condition reflects standard practice when adhering to OPSS and the "Mitigated" condition reflects the maximum extent to which a certain practices is permitted by OPSS and by City of Kingston practices. The City of Kingston is currently updating its pavement technologies, historical pavement performance, and other innovations that may influence the range of mitigation that could be utilized on the project. Some mitigation strategies have been found to be detrimental to the performance of particular asphalt materials leading to poor performance of pavements in Kingston. For the purpose of this planning level exercise, it is assumed that none of the mitigation strategies poses a risk to the structural performance of the bridge and pavements.

Note that no mitigations related to maintenance vehicles, alternative vegetation management, alternative snow removal methods, or preventive maintenance were evaluated, as they apply to the Operations & Maintenance Phase, which is outside the scope of this LCA.

Alternative Fuels & Vehicle Hybridization

The OPSS do not address the use of hybrid or biofuel construction vehicles. Therefore, the “Unmitigated” condition assumes that 0% of construction vehicles will be hybrid, use B20 fuel, use B100 fuel, or be combined hybrid/alternative fuel vehicles. The “Mitigated” condition was assumed, conservatively, to be 10% use of each vehicle type.

In-Place Roadway Recycling

City of Kingston does not permit in-place recycling of asphalt in new asphalt for road projects. While the existing asphalt will be disposed of and may be recycled for non-City paving projects.. The “Unmitigated” condition is therefore assumed to be 0% and the “Mitigated” condition is assumed to be 0%.

Warm Mix Asphalt

Warm Mix Asphalt (WMA): Per the report by Lou Politano, P.Eng. “MTO Warm Mix Asphalt - A Greener Alternative to Hot Mix Asphalt” MTO specified 10% WMA on all of its contracts in 2011. It should be noted that the City of Kingston is currently not using WMA, hence the “Mitigated” condition with respect to WMA is 0%.

Recycled and Reclaimed Materials

The OPSS state that values “up to” a certain % of Reclaimed Asphalt Pavement (RAP), Recycled Concrete Material (RCM), and cementitious material substitutes are allowed, which means that the minimum amount of recycled and reclaimed materials that would be incorporated into a standard project is 0%. This is used as the “Unmitigated” condition, or the worst-case energy and emissions scenario for the incorporation of recycled and reclaimed materials.

The “Mitigated” condition reflects the following:

- OPSS Section 1003: Allows for the use of RAP as a substitute for virgin asphalt aggregate, but does not specify a maximum amount. The City of Kingston does not use RAP to replace virgin asphalt aggregate in new paving projects. The mitigated condition was therefore assumed to be 0%.
- OPSS Section 1150: Allows a maximum of 30% RAP as a substitute for virgin asphalt bitumen in asphalt mix. . The City of Kingston does not use

RAP to replace virgin asphalt bitumen in new paving projects. The mitigated condition was therefore assumed to be 0%.

- OPSS Section 1350: Allows a maximum 25% combined industrial by-products as cementitious substitutes in concrete mixes.
- OPSS Section 1001: Allows for the use of RCM as aggregate as a substitute for base stone, but does not specify a maximum amount. The maximum allowed by the ICE tool is 100%, but availability of RCM is unknown at this time. As such, the mitigated condition was assumed to be 0%.

Table 5: Emissions Mitigation Practices

STRATEGY	UNMITIGATED (STANDARD PRACTICE PER OPSS)	MITIGATED (PLANED IMPLEME-NTATION)	THRESHOLD (DEFINED BY ICE TOOL)
ALTERNATIVE FUELS AND VEHICLE HYBRIDIZATION			
Hybrid construction vehicles and equipment – as a % of all construction vehicles/equipment	0%	25%	44%
Switch from diesel to B20 in construction vehicles and equipment – as a % of total fuel used by construction vehicles	0%	10%	100%
Switch from diesel to B100 in construction vehicles and equipment – as a % of total fuel used by construction vehicles	0%	10%	100%
Combined hybridization/B20 in construction vehicles and equipment – as a % of all construction vehicles/equipment	0%	10%	44%
IN -PLACE ROADWAY RECYCLING			
Cold In-place recycling - % of total roadway resurfacing and BRT conversion lane miles that are resurfaced using cold in-place recycling	0%	0%	99%
Full depth reclamation - % of total roadway resurfacing and BRT	0%	0%	99%

STRATEGY	UNMITIGATED (STANDARD PRACTICE PER OPSS)	MITIGATED (PLANED IMPLEME-NTATION)	THRESHOLD (DEFINED BY ICE TOOL)
conversion lane miles that are reconstructed using full depth reclamation			
WARM-MIX ASPHALT			
Warm-mix asphalt - % by mass of warm mix asphalt used in the project	0%	0%	100%
RECYCLED AND RECLAIMED MATERIALS			
Use recycled asphalt pavement as a substitute for virgin asphalt aggregate - % by mass of recycled aggregates used in the project	0%	0%	25%
Use recycled asphalt pavement as a substitute for virgin asphalt bitumen - % by mass of bitumen used that comes from recycled asphalt pavement	0%	0%	25%
Use industrial byproducts as substitutes for Portland cement - % by mass of Portland cement substitutes are used (e.g. fly ash, blast furnace slag, silica fume)	0%	25%	33%
Use recycled concrete aggregate as a substitute for base stone - % by mass of aggregate that comes from recycled concrete	0%	0%	100%

4.2.6 Data Validation

Project data input collection and calculations were validated by the Hatch Design Manager, Kiewit construction team as well as the City of Kingston, and reflects the latest project information available at the time of this analysis.

4.2.7 Data Allocation

The ICE tool automatically allocates the input data to the following output flows relevant to the scope of this LCA:

- Construction Materials: These outputs include the upstream energy and emissions from raw materials extraction and transportation, as well as materials productions; and
- Construction Equipment: These outputs include the direct energy and emissions from transport of materials to the construction site, and the operation of construction vehicles and equipment on site.

4.3 Life Cycle Impact Analysis

The ICE tool was used to calculate the energy and emissions impacts, based on the validated input data. As previously discussed, the relevant impact categories are energy use and greenhouse gas emissions, measured in millions of British Thermal Units (MMBTU) and metric tons of CO2 equivalent (MT CO2e), respectively. The energy and emissions savings associated with each mitigation strategy was first evaluated separately and then a combined impact is calculated, as shown in the scenarios below:

- Scenario 1: Unmitigated Baseline Performance
- Scenario 2A: Mitigated (Alternative Fuels only)
- Scenario 2B: Mitigated (Recycled and Reclaimed Materials only)
- Scenario 3: Mitigated (All mitigations combined)

Since In-place Roadway Recycling and Warm Mix Asphalt mitigation levels noted in Table 5 are 0% these mitigations were not evaluated separately.

As stated earlier, no mitigation practices related to operations and maintenance were evaluated within the scope of the study. Detailed outputs for each Scenario are included in Appendix C. Summary result tables and discussion are provided in the Section 4.3 below.

4.4 Interpretation

The Unmitigated, or worst case scenario energy and emissions outputs are shown in Figure 4-1 and Figure 4-2 below.

The unmitigated energy and emissions outputs are summarized in Table 6 and Table 7, respectively.

Mitigation category, and the impact of all Mitigations combined are shown in Table 8 and Table 9 below.

A summary of energy and emissions outputs by project component from all Mitigations combined are shown in Table 10 and Table 11.

Figure 4-1: Unmitigated and Mitigated Construction Phase Energy Use

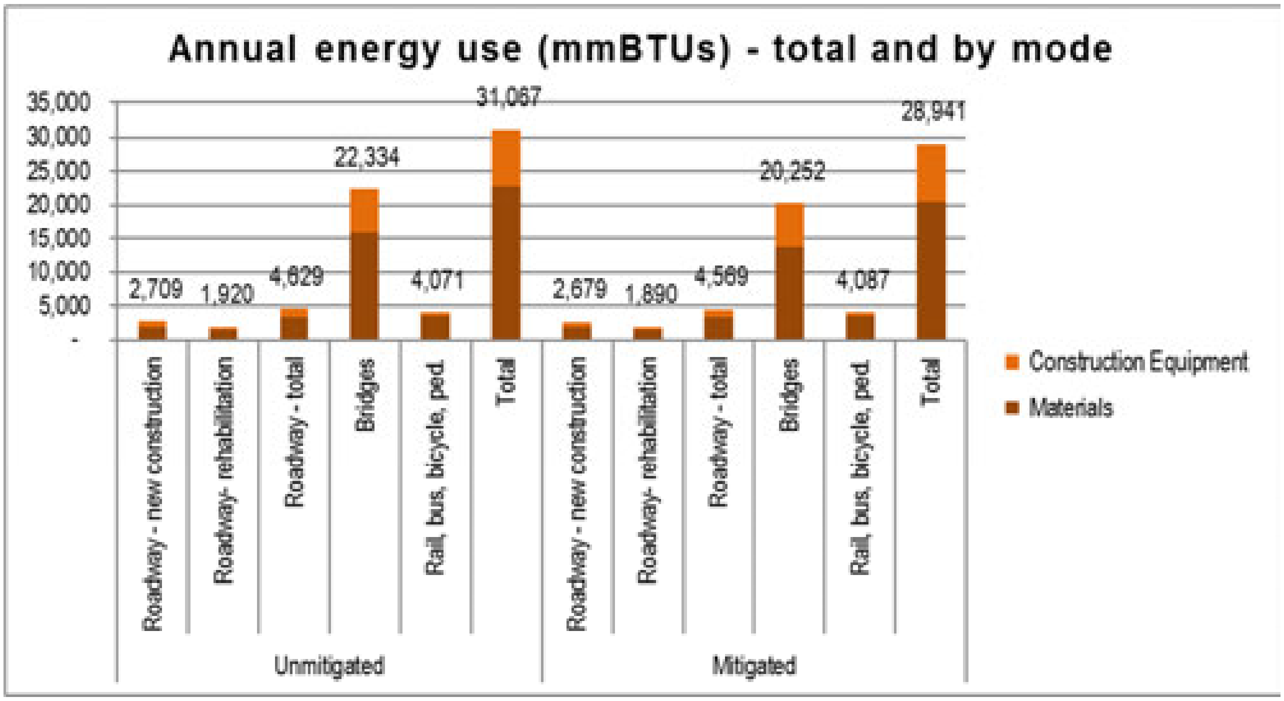


Table 6: Unmitigated Construction Phase Energy Use

ENERGY (MMBTU)	NEW ROAD CONSTRUCTION	ROADWAY REHAB	BRIDGES	RAIL, BUS, BIKE, PED.	TOTAL
UPSTREAM: MATERIALS	1,908	1,508	15,964	3,487	22,464
DIRECT: CONSTRUCTION EQUIPMENT	618	412	6,370	584	7,984
ROUTINE MAINTENANCE					33
TOTAL	2,709	1,920	22,334	4,071	31,067
% CONTRIBUTION	8.7%	6.1%	72%	13.1%	

Figure 4-2: Unmitigated and Mitigated Construction Phase Greenhouse Gas Emissions

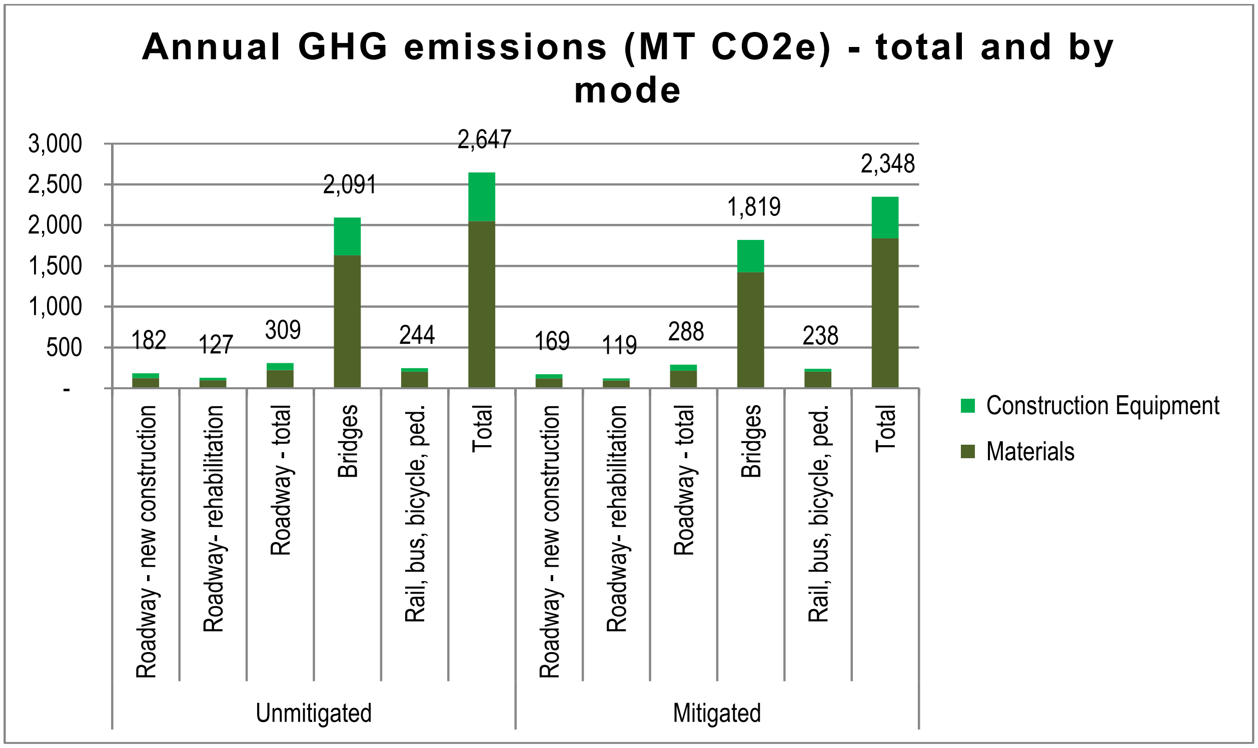


Table 7: Unmitigated Construction Phase Greenhouse Gas Emissions

EMISSIONS ($MT\ CO_2E$)	NEW ROAD CONSTRUCTION	ROADWAY REHAB	BRIDGES	RAIL, BUS, BIKE, PED.	TOTAL
UPSTREAM: MATERIALS	124	97	1,627	201	2,049
DIRECT CONSTRUCTION EQUIPMENT	58	30	464	43	595
ROUTINE MAINTENANCE					3
TOTAL	182	127	2,091	244	2,647
% CONTRIBUTION	6.8%	4.7%	79%	9.2%	-

Table 8: Energy Use & % Savings by Mitigation Scenario

ENERGY (MMBTU)	UNMITIGATED	ALTERNATIVE FUELS	RECYCLED/ RECLAIMED MATERIAL	COMBINED MITIGATIONS
UPSTREAM: MATERIALS	22,867	22,867	20,491	20,491
DIRECT: CONSTRUCTION EQUIPMENT	8,167	8,417	8,167	8,417
TOTAL	31,034	31,284	28,658	28,908
% SAVINGS	-	-0.8%	7.7%	6.9%

Table 9: Emissions Output & % Savings by Mitigation Scenario

ENERGY (MMBTU)	UNMITIGATED	ALTERNATIVE FUELS	RECYCLED/ RECLAIMED MATERIAL	COMBINED MITIGATIONS
UPSTREAM: MATERIALS	2,049	2,049	1,835	1,835
DIRECT CONSTRUCTION EQUIPMENT	595	510	595	510
TOTAL	2,644	2,559	2,430	2,345
% SAVINGS	-	3.2%	8.1%	11.3%

Table 10: Energy Use & % Savings by Project Component

Energy (MMBTU)	NEW ROAD CONST	ROAD WAY REHAB	BRIDGES	RAIL, BUS, BIKE, PED.	TOTAL	NEW ROAD CONST	ROAD WAY REHAB	BRIDGES	RAIL, BUS, BIKE, PED.	TOTAL
UPSTEAM: MATERIALS	1,853	1,465	13,688	3,485	20,491	3%	3%	14%	0%	10%
DIRECT CONSTRUCTION EQUIPMENT	826	425	6,564	602	8,228	-3%	-3%	-3%	-3%	-3%
ROUTINE MAINTENANCE					33					
TOTAL & % SAVINGS WITHIN CATEGORY	2,679	1,890	20,252	4,087	28,941	1%	2%	9%	0%	7%
% CONTRIBUTION TO OVERALL SAVINGS						1%	1%	98%	-1%	-

Table 11: Emissions Output & % Savings by Project Component

	COMBINED MITIGATIONS GHS EMISSION (MT CO_2E)					COMBINED MITIGATIONS (% SAVINGS WITHIN CATEGORY)				
Energy (MMBTU)	**NEW ROAD CONSTR**	**ROAD WAY REHAB**	**BRIDGES**	**RAIL, BUS, BIKE, PED.**	**TOTAL**	**NEW ROAD CONSTR**	**ROAD WAY REHAB**	**BRIDGES**	**RAIL, BUS, BIKE, PED.**	**TOTAL**
UPSTEAM: MATERIALS	119	93	1,422	201	1,835	4%	4%	13%	0%	10%
DIRECT CONSTRUCTION EQUIPMENT	50	26	397	37	510	13%	13%	14%	14%	14%
ROUTINE MAINTENANCE					3					
TOTAL & % SAVINGS WITHIN CATEGORY	169	119	1,819	238	2,348	7%	6%	13%	2%	11%
% CONTRIBUTION TO OVERALL SAVINGS						4%	3%	91%	2%	-

4.4.1 Discussion of Results

Overall unmitigated energy use and emissions for the construction phase are dominated by the contribution of the Bridge portion of the scope (72% and 79%, respectively). This is to be expected since the bridge comprises the largest portion of the scope of work and associated materials. As such, the mitigation measures that have a large impact on the bridge materials and transport greatly influence the overall energy and emissions outputs for the Third Crossing Project. Ultimately the combined mitigations for the bridge component comprise over 98% of the total energy savings and over 92% of the total emissions reduction.

Mitigation 2B, Recycled/Reclaimed Materials has the most significant impact to energy use and emissions (7.7% and 8.1%, respectively). The decreased need for extraction and transport of virgin materials leads this significant decrease in Upstream Materials energy and emissions for all project components.

Mitigation 2A, the use of alternate fuel/hybrid vehicles, also contributes 3.2% to overall emissions reduction (likely due to lower emissions factors for biofuels and electricity), which is significant because even though this mitigation only influences the Direct emissions from construction vehicles, it still has the second largest impact overall with respect to emission. It should be noted that alternative fuels/hybrid vehicles are expected to slightly increase energy use due to the upstream processing to manufacture the fuels.

4.4.2 Limitations

Data source limitations: LCIA as performed by the ICE tool is limited to the methodologies and assumptions used by the creators of the tool. Data sources, calculation methodologies, and assumptions used to quantify energy and GHG emissions factors are summarized in Section 5 (p. 44) and the Appendix (p. A-1) of the User's Guide.

System boundary limitations: As shown in Figure 2, the LCIA is limited to the construction phase of the project. Energy and emissions associated with operations and maintenance are excluded from the scope of this LCA.

Analysis tool limitations:

U.S. Based – no Canadian states/provinces are available as choices in project information section of the ICE tool. However, the state selection only impacts the output for the winter maintenance requirements and the emissions factors for electricity used in construction. Maintenance is outside the scope of this LCA, none of the Third Crossing project elements uses any electricity in construction, and all other emissions factors (i.e. for road base, asphalt, concrete, steel, diesel fuel, from manufacture and combustion have no regional variations. As such, the ICE tool still produces good estimates for a project in Canada and the state selection will not impact the outcome.

Bridge length – The User's Guide states that the ICE tool is not as reliable for long span bridges (> 1,000 ft) due to the different types of materials and construction practices involved in those projects. Further discussion with the creators of the tool clarified that very long bridges tend to be one-of-a-kind customized structures, which "could be slab-on-pier, or cable-stay, or suspension, or steel truss, all of which would involve different materials, construction activity and emissions." Due to the fact that the majority of the bridge reflects a standard flat slab-on-pier bridge, the estimates are still considered to be reasonable. In order to account for the main navigation channel arch span, a contingency factor of 15% could be applied to the overall unmitigated energy and emissions outputs to obtain an upper end estimate of project impacts. This would not change the relative impacts of the mitigations described above or the recommendations below.

4.5 Conclusion & Recommendations

The use of recycled materials (e.g. fly ash and blast furnace slag), have a significant impact on overall energy use and emissions. It is recommended that the project specifications encourage maximizing the use of these materials, without compromising structural performance, by providing specific % minima for recycled and reclaimed content.

Means of transportation, fuels used, and the associated emissions factors have a noticeable influence on emissions for material transport and construction equipment operation, even if the total energy consumption is not significantly reduced. As construction means and methods progress, the focus should be on minimizing distance travelled and using fuels with low emissions factors.

During detailed design, it is recommended that a more detailed LCA be performed based on estimates of material quantities, raw material source and manufacturing locations, transportation distances, and anticipated transportation modes, and likely construction means, methods, and equipment.

Appendix A

Project & Mitigations Inputs

Appendix A.1

Project Inputs

Project Inputs

Mitigation Inputs | Results Summary | Impacts on Vehicle Operation

Instructions:

1. Using information from the project or plan you want to analyze, complete the inputs on this page and on the Mitigation Inputs page by entering information in the cells that are shaded orange. Gray cells display results; do not change the information in these cells. (The tool uses the term "project" not just to refer to individual projects, but also to long-range transportation plans or other plans that consist of a suite of projects.)

2. Click on the gray buttons at the top of the page to navigate between input pages, the results page, and the impacts on vehicle operation page.

3. For further instructions, refer to the accompanying user guide for detailed descriptions of factors and assumptions used in this tool.

Key to Cell Colors
User Input
Results Automatically Calculated

General Information

Infrastructure location (state)	CO
Analysis timeframe (years)	30

Average daily traffic per lane mile - for facilities that will be reconstructed or resurfaced	

Roadway System	
Total existing centerline miles	0
Total existing lane miles	0
Total newly-constructed centerline miles	#DIV/0!
Total newly-constructed lane miles	0

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	0	0	0	0	0	0
Rural Minor Arterials	0	0	0	0	0	0	0
Rural Collectors	0	0	0	0	0	0	0
Urban Interstates / Expressways	0	0	0	0	0	0	0
Urban Principal Arterials	0	0	0	0	0	0	0
Urban Minor Arterials / Collectors	0	0	0	0	0	0	0

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

Parking

Surface Parking (spaces)	0
Structured Parking (spaces)	0

Options	
% roadway construction on rocky / mountainous terrain	0%

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, 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)	0	0	0	0	0	0	0	0	0	0	0	0

How Many Bridge Spans?

Approximately half of short bridges in the U.S. (less than 1000 feet long) are single-span or double-span. If information about number of spans is not available, it is reasonable to assume a mix of single-span and two-span bridges. Note that the number of spans is an important factor in energy use and GHG emissions. You may want to test a few different assumptions to see the effects. Longer bridges (more than 1000 feet) can't be reliably estimated in the tool.

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	0	0	0
On-Street Sidewalk - miles	0	N/A	N/A

Construction - Delay

Total project-days of lane closure	0
Average daily traffic per directional segment for facilities requiring lane closure	0
Percentage of facility lanes closed during construction	

Impacts on Vehicle Operation

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 modeling software. Planned construction projects that will result in significant lane closures on high volume roads should be evaluated using traffic modeling software.

Appendix A.2

Mitigations Inputs

Mitigation Inputs

Project Inputs | Results Summary | Impacts on Vehicle Operation

Instructions: Follow the steps below to calculate the impact of energy and GHG mitigation strategies:

1. Enter the baseline deployment (i.e., the extent to which the strategy is currently deployed) in Column B.

2. Enter the planned deployment (i.e., the extent to which the strategy will be deployed in the project that you are examining) in Column C.

Column D displays the maximum potential deployment of the strategy, based on research. If you enter a value in Column B or C that is greater than the value shown in Column D, the cell will appear highlighted in light red with dark red text as a warning. The calculations in the sheet will continue to function.

Some reduction strategies (i.e., biodiesel/hybrid maintenance vehicles and equipment; biodiesel/hybrid construction vehicles and equipment; and in-place roadway recycling for BRT conversions) apply to the same activities. Care must be taken to make sure you do not input a total deployment greater than 100% for overlapping strategies. For example, the tool does **not** prevent you from applying a combined deployment of B20 and B100 maintenance vehicles exceeding 100% of the maintenance fleet.

3. Compare the mitigated and unmitigated results on the *Results* page to assess the impact of mitigation strategies. Energy/GHG reductions are calculated based on the difference between planned and baseline deployment and the energy/GHG reduction potential of each strategy. If the planned deployment of a strategy is less than the baseline deployment, energy/GHG reductions will

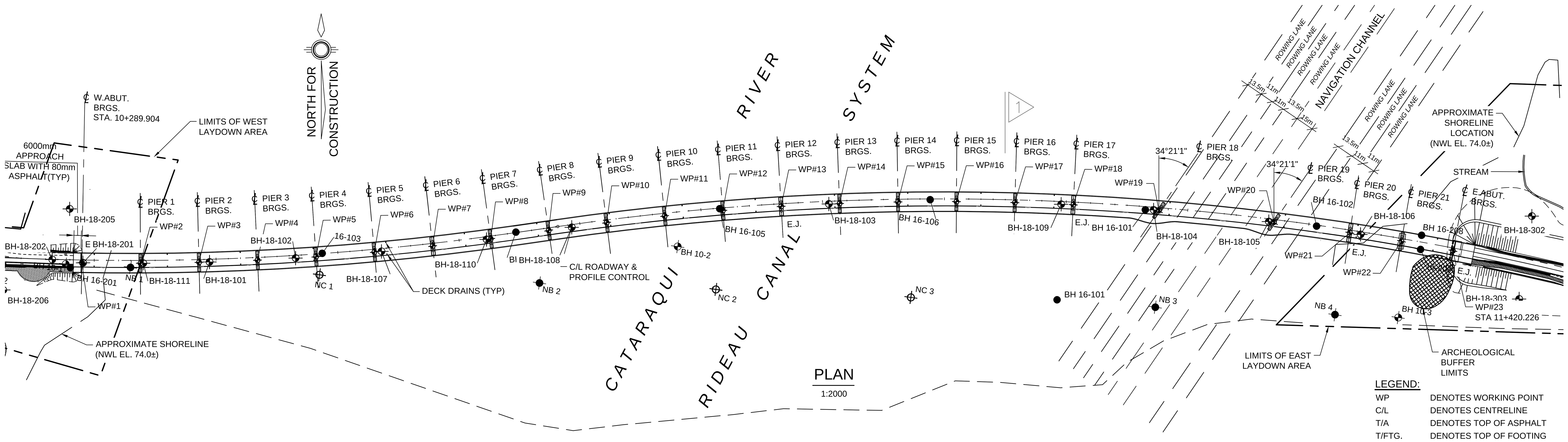
Energy / GHG reduction strategies

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

Appendix B

General Arrangements

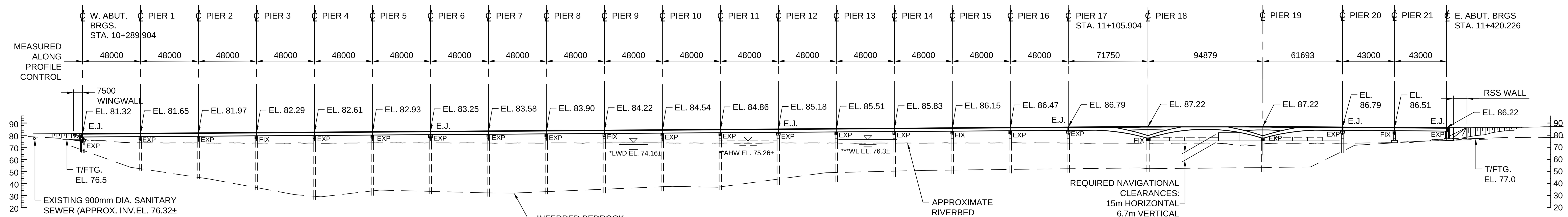
METRIC



PLAN
1:2000

LEGEND:

WP	DENOTES WORKING POINT
C/L	DENOTES CENTRELINE
T/A	DENOTES TOP OF ASPHALT
T/FTG.	DENOTES TOP OF FOOTING
T/CAISSON	DENOTES TOP OF CAISSON
- - -	DENOTES NOISE BARRIER



ELEVATION
1:2000

GENERAL NOTES:

DESIGN LOADS

BRIDGE: CL-625-ONT TRUCK LOAD, CL-625-ONT LANE LOAD OF CHBDC.

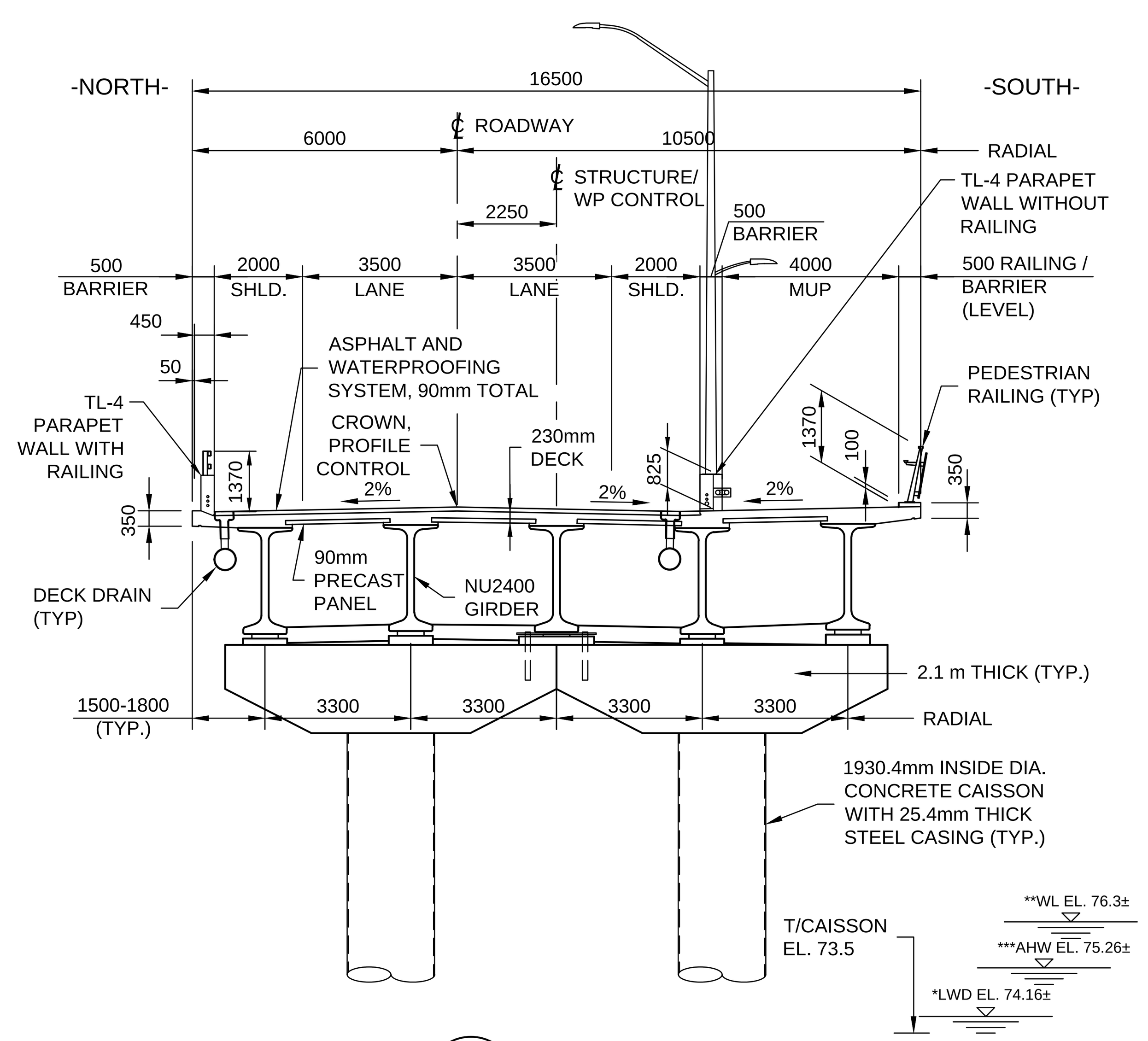
SIDEWALK: PEDESTRIAN LOADS AND MAINTENANCE VEHICLE OF CHBDC S6-14.

CONSTRUCTION NOTES

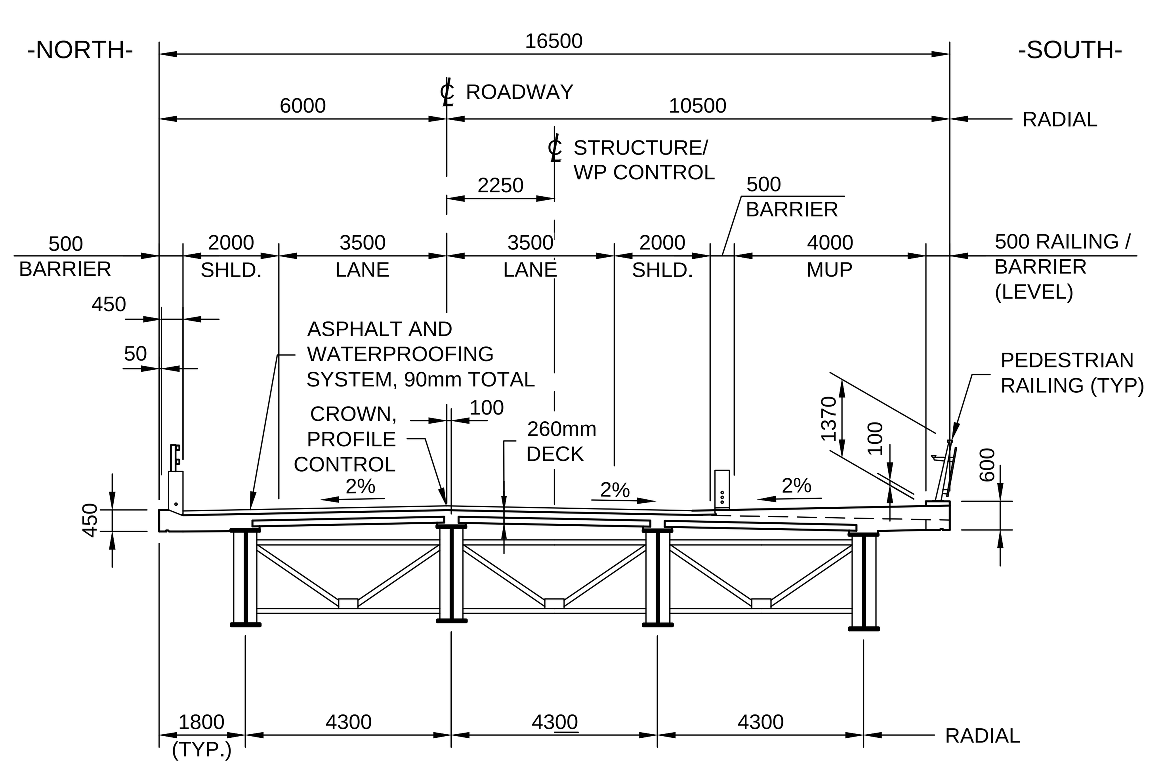
1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE. CHAINAGES AND ELEVATIONS ARE IN METRES.
2. MAINTAIN FULL NAVIGATIONAL CLEARANCE THROUGHOUT CONSTRUCTION.
3. INFERRED BEDROCK PROFILE IS BASED ON BOREHOLE LOGS FROM GOLDER ASSOCIATES REPORT ENTITLED "PRELIMINARY GEOTECHNICAL INVESTIGATION - THIRD CROSSING OF CATARAQUI RIVER - JOHN COUNTER BOULEVARD TO GORE ROAD, KINGSTON, ONTARIO", DATED MARCH 2017, REPORT NO. 1541774/2000/003.

NOTE:

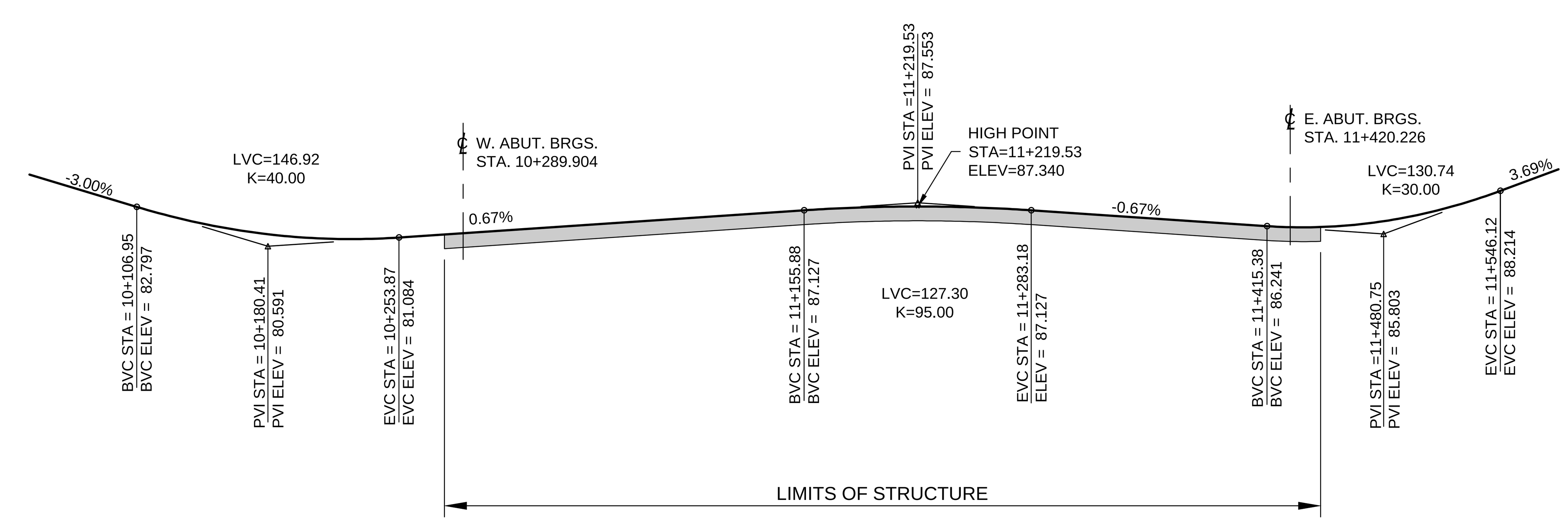
*	LOW WATER DATUM	EL. 74.16	CANADIAN HYDROGRAPHIC SERVICE (LAKE ONTARIO)
**	AVERAGE HIGH WATER	EL. 75.26	MINISTRY OF NATURAL RESOURCES (LAKE ONTARIO)
***	REGULATORY WATER LEVEL	EL. 76.3	CATARAQUI REGION CONSERVATION AUTHORITY "REGULATORY LIMIT WITHIN THE STUDY AREA"



SECTION 1 APPROACH SPANS
1:125



SECTION 2 MAIN SPAN
1:125



CROWN PROFILE CONTROL (ROADWAY)
N.T.S.

INTEGRATED PROJECT DELIVERY TEAM: HATCH, SYSTRA INTERNATIONAL BRIDGE TECHNOLOGIES, Kiewit, KINGSTON

No.	DATE	REVISIONS	BY	CHECKED

DESIGN COMPANY: HATCH

DESIGN:	MA
DRAWN:	YZ
CHECKED:	MA

KINGSTON THIRD CROSSING

DIA REPORT

GENERAL ARRANGEMENT

DATE: 18-12-19

SCALE: N.T.S.

DRAWING NO. 3.1.14.1

SHEET NO.

REVISION

DRAWING NAME: Drawing 3.1.14.1.dwg SAVE DATE: 5/10/2019 10:06 AM PLOT DATE: 5/10/2019 10:06 AM
SAVED BY: zhao857409

Appendix C

Mitigations Scenarios

Appendix C.1

Fuel Mitigations Scenario

Project Inputs

Mitigation Inputs | Results Summary | Impacts on Vehicle Operation

Instructions:

1. Using information from the project or plan you want to analyze, complete the inputs on this page and on the Mitigation Inputs page by entering information in the cells that are shaded orange. Gray cells display results; do not change the information in these cells. (The tool uses the term "project" not just to refer to individual projects, but also to long-range transportation plans or other plans that consist of a suite of projects.)

2. Click on the gray buttons at the top of the page to navigate between input pages, the results page, and the impacts on vehicle operation page.

3. For further instructions, refer to the accompanying user guide for detailed descriptions of factors and assumptions used in this tool.

Key to Cell Colors
User Input
Results Automatically Calculated

General Information

Infrastructure location (state)	NY
Analysis timeframe (years)	1

Average daily traffic per lane mile - for facilities that will be reconstructed or resurfaced	

Roadway System	
Total existing centerline miles	0.249
Total existing lane miles	0.497
Total newly-constructed centerline miles	0.112225352
Total newly-constructed lane miles	0.224

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	1.28

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	0	0	0	0	0	0
Rural Minor Arterials	0	0	0	0	0	0	0
Rural Collectors	0	0	0	0	0	0	0
Urban Interstates / Expressways	0	0	0	0	0	0	0
Urban Principal Arterials	0.224	0	0	0.497	0	0.497	0
Urban Minor Arterials / Collectors	0	0	0	0	0	0	0

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, 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.

Parking	
Surface Parking (spaces)	0
Structured Parking (spaces)	0

Options	
% roadway construction on rocky / mountainous terrain	0%

Bridge Structures

Bridge Structure	Construct New Bridge				Reconstruct Bridge				Add Lane to Bridge			
	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	22	2	0	0	0	0	0	0	0	0	0

How Many Bridge Spans?

Approximately half of short bridges in the U.S. (less than 1000 feet long) are single-span or double-span. If information about number of spans is not available, it is reasonable to assume a mix of single-span and two-span bridges. Note that the number of spans is an important factor in energy use and GHG emissions. You may want to test a few different assumptions to see the effects. Longer bridges (more than 1000 feet) can't be reliably estimated in the tool.

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	1.28	0	N/A
On-Street Bicycle Lane - lane miles	2.2	0	0
On-Street Sidewalk - miles	0.127	N/A	N/A

Construction - Delay

Total project-days of lane closure	0
Average daily traffic per directional segment for facilities requiring lane closure	0
Percentage of facility lanes closed during construction	<50%

Impacts on Vehicle Operation

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 modeling software. Planned construction projects that will result in significant lane closures on high volume roads should be evaluated using traffic modeling software.

Mitigation Inputs

Project Inputs | Results Summary | Impacts on Vehicle Operation

Instructions: Follow the steps below to calculate the impact of energy and GHG mitigation strategies:

1. Enter the baseline deployment (i.e., the extent to which the strategy is currently deployed) in Column B.

2. Enter the planned deployment (i.e., the extent to which the strategy will be deployed in the project that you are examining) in Column C.

Column D displays the maximum potential deployment of the strategy, based on research. If you enter a value in Column B or C that is greater than the value shown in Column D, the cell will appear highlighted in light red with dark red text as a warning. The calculations in the sheet will continue to function.

Some reduction strategies (i.e., biodiesel/hybrid maintenance vehicles and equipment; biodiesel/hybrid construction vehicles and equipment; and in-place roadway recycling for BRT conversions) apply to the same activities. Care must be taken to make sure you do not input a total deployment greater than 100% for overlapping strategies. For example, the tool does **not** prevent you from applying a combined deployment of B20 and B100 maintenance vehicles exceeding 100% of the maintenance fleet.

3. Compare the mitigated and unmitigated results on the *Results* page to assess the impact of mitigation strategies. Energy/GHG reductions are calculated based on the difference between planned and baseline deployment and the energy/GHG reduction potential of each strategy. If the planned deployment of a strategy is less than the baseline deployment, energy/GHG reductions will

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%	25%	44%	Fuel use by construction equipment
Switch from diesel to B20 in construction vehicles and equipment	0%	10%	100%	Fuel use by construction equipment
Switch from diesel to B100 in construction vehicles and equipment	0%	10%	100%	Fuel use by construction equipment
Combined hybridization/B20 in construction vehicles and equipment	0%	10%	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%	0%	100%	Materials and construction fuel use in roadway resurfacing and reconstruction projects

Results Summary

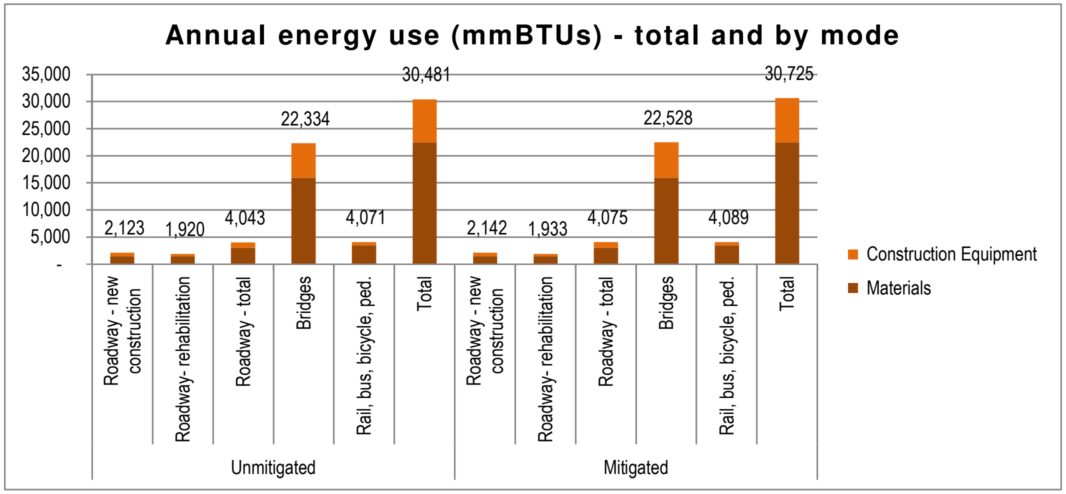
Project Inputs | Mitigation Inputs | Impacts on Vehicle Operation

	Annualized energy use (mmBTUs), per year over 1 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	1,505	1,508	3,013	15,964	3,487	**22,464**	1,505	1,508	3,013	15,964	3,487	**22,464**
Direct Energy												
Construction Equipment	618	412	1,030	6,370	584	**7,984**	637	425	1,062	6,564	602	**8,228**
Routine Maintenance						**33**						**33**
Total	**2,123**	**1,920**	**4,043**	**22,334**	**4,071**	**30,481**	**2,142**	**1,933**	**4,075**	**22,528**	**4,089**	**30,725**

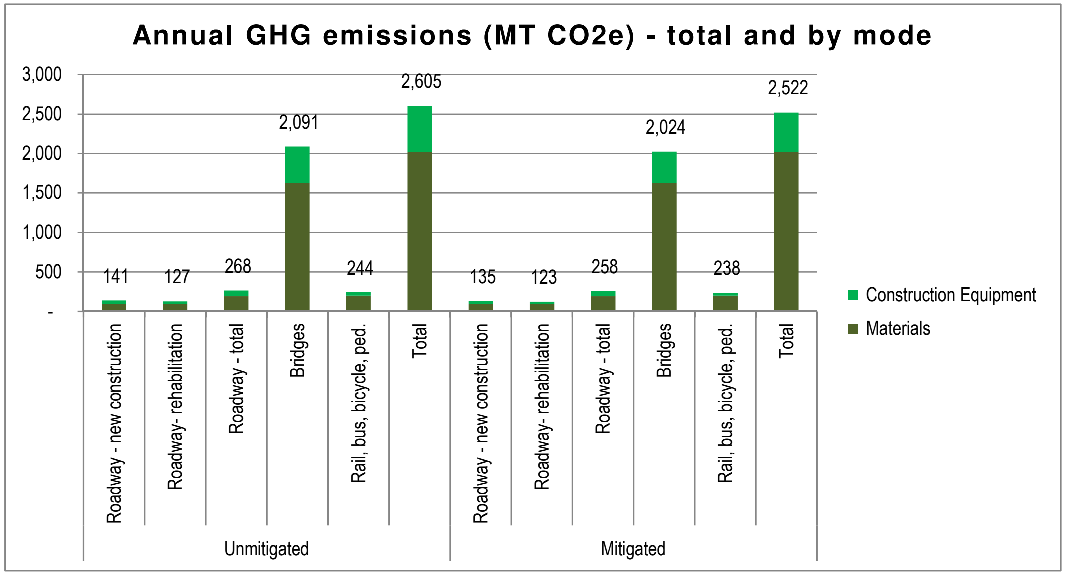
Note: To convert mmBTU to the equivalent gallons of US conventional diesel, use the conversion factor of 7.785 gallons of diesel / mmBTU. Please keep in mind that this conversion represents the equivalent amount of energy required, which can be useful for informational purposes, but it does not necessarily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

	Annual GHG emissions (MT CO2e), per year over 1 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	96	97	193	1,627	201	**2,021**	96	97	193	1,627	201	**2,021**
Direct Emissions												
Construction Equipment	45	30	75	464	43	**582**	39	26	65	397	37	**499**
Routine Maintenance						**2**						**2**
Total	**141**	**127**	**268**	**2,091**	**244**	**2,605**	**135**	**123**	**258**	**2,024**	**238**	**2,522**

Annualized over 1 Years



Annualized over 1 Years



Appendix C.2

Recycled Material Mitigation Scenario

Project Inputs

Mitigation Inputs | Results Summary | Impacts on Vehicle Operation

Instructions:

1. Using information from the project or plan you want to analyze, complete the inputs on this page and on the Mitigation Inputs page by entering information in the cells that are shaded orange. Gray cells display results; do not change the information in these cells. (The tool uses the term "project" not just to refer to individual projects, but also to long-range transportation plans or other plans that consist of a suite of projects.)

2. Click on the gray buttons at the top of the page to navigate between input pages, the results page, and the impacts on vehicle operation page.

3. For further instructions, refer to the accompanying user guide for detailed descriptions of factors and assumptions used in this tool.

Key to Cell Colors
User Input
Results Automatically Calculated

General Information

Infrastructure location (state)	NY
Analysis timeframe (years)	1

Average daily traffic per lane mile - for facilities that will be reconstructed or resurfaced	

Roadway System	
Total existing centerline miles	0.249
Total existing lane miles	0.497
Total newly-constructed centerline miles	0.112225352
Total newly-constructed lane miles	0.224

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	1.28

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	0	0	0	0	0	0
Rural Minor Arterials	0	0	0	0	0	0	0
Rural Collectors	0	0	0	0	0	0	0
Urban Interstates / Expressways	0	0	0	0	0	0	0
Urban Principal Arterials	0.224	0	0	0.497	0	0.497	0
Urban Minor Arterials / Collectors	0	0	0	0	0	0	0

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, 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.

Parking	
Surface Parking (spaces)	0
Structured Parking (spaces)	0

Options	
% roadway construction on rocky / mountainous terrain	0%

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	22	2	0	0	0	0	0	0	0	0	0

How Many Bridge Spans?

Approximately half of short bridges in the U.S. (less than 1000 feet long) are single-span or double-span. If information about number of spans is not available, it is reasonable to assume a mix of single-span and two-span bridges. Note that the number of spans is an important factor in energy use and GHG emissions. You may want to test a few different assumptions to see the effects. Longer bridges (more than 1000 feet) can't be reliably estimated in the tool.

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	1.28	0	N/A
On-Street Bicycle Lane - lane miles	2.2	0	0
On-Street Sidewalk - miles	0.127	N/A	N/A

Construction - Delay

Total project-days of lane closure	0
Average daily traffic per directional segment for facilities requiring lane closure	0
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 modeling software. Planned construction projects that will result in significant lane closures on high volume roads should be evaluated using traffic modeling software.

Impacts on Vehicle Operation

Mitigation Inputs

Project Inputs | Results Summary | Impacts on Vehicle Operation

Instructions: Follow the steps below to calculate the impact of energy and GHG mitigation strategies:

1. Enter the baseline deployment (i.e., the extent to which the strategy is currently deployed) in Column B.

2. Enter the planned deployment (i.e., the extent to which the strategy will be deployed in the project that you are examining) in Column C.

Column D displays the maximum potential deployment of the strategy, based on research. If you enter a value in Column B or C that is greater than the value shown in Column D, the cell will appear highlighted in light red with dark red text as a warning. The calculations in the sheet will continue to function.

Some reduction strategies (i.e., biodiesel/hybrid maintenance vehicles and equipment; biodiesel/hybrid construction vehicles and equipment; and in-place roadway recycling for BRT conversions) apply to the same activities. Care must be taken to make sure you do not input a total deployment greater than 100% for overlapping strategies. For example, the tool does **not** prevent you from applying a combined deployment of B20 and B100 maintenance vehicles exceeding 100% of the maintenance fleet.

3. Compare the mitigated and unmitigated results on the *Results* page to assess the impact of mitigation strategies. Energy/GHG reductions are calculated based on the difference between planned and baseline deployment and the energy/GHG reduction potential of each strategy. If the planned deployment of a strategy is less than the baseline deployment, energy/GHG reductions will

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%	25%	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%	0%	100%	Materials and construction fuel use in roadway resurfacing and reconstruction projects

Results Summary

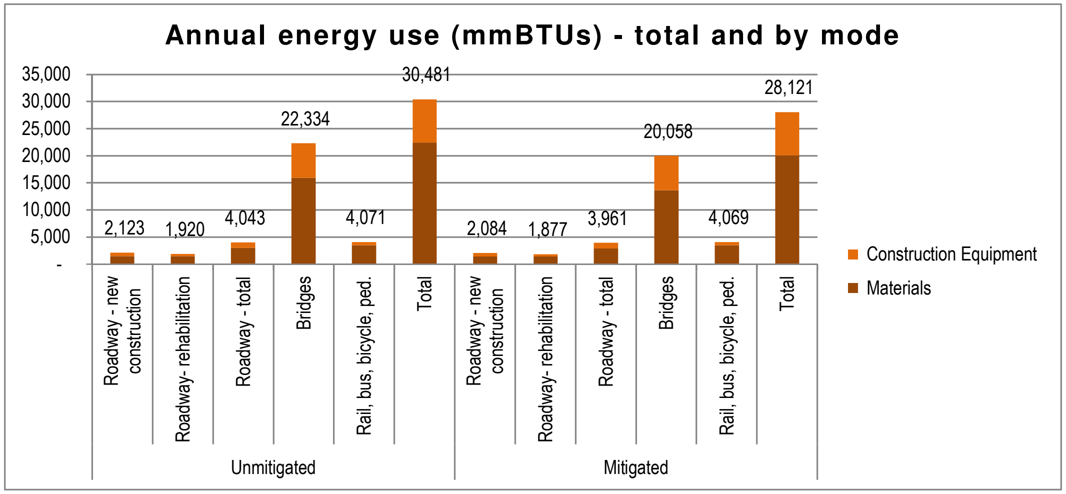
Project Inputs | Mitigation Inputs | Impacts on Vehicle Operation

	Annualized energy use (mmBTUs), per year over 1 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	1,505	1,508	3,013	15,964	3,487	**22,464**	1,466	1,465	2,931	13,688	3,485	**20,104**
Direct Energy												
Construction Equipment	618	412	1,030	6,370	584	**7,984**	618	412	1,030	6,370	584	**7,984**
Routine Maintenance						**33**						**33**
Total	**2,123**	**1,920**	**4,043**	**22,334**	**4,071**	**30,481**	**2,084**	**1,877**	**3,961**	**20,058**	**4,069**	**28,121**

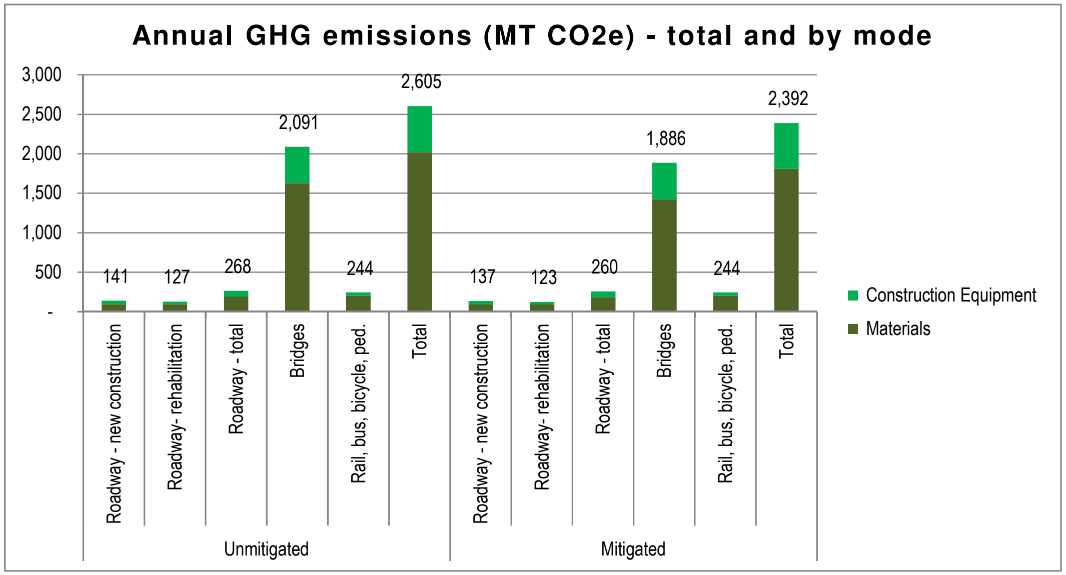
Note: To convert mmBTU to the equivalent gallons of US conventional diesel, use the conversion factor of 7.785 gallons of diesel / mmBTU. Please keep in mind that this conversion represents the equivalent amount of energy required, which can be useful for informational purposes, but it does not necessarily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

	Annual GHG emissions (MT CO2e), per year over 1 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	96	97	193	1,627	201	**2,021**	92	93	185	1,422	201	**1,808**
Direct Emissions												
Construction Equipment	45	30	75	464	43	**582**	45	30	75	464	43	**582**
Routine Maintenance						**2**						**2**
Total	**141**	**127**	**268**	**2,091**	**244**	**2,605**	**137**	**123**	**260**	**1,886**	**244**	**2,392**

Annualized over 1 Years



Annualized over 1 Years



Appendix C.3

Mitigated (All Mitigations Combined)

Project Inputs

Mitigation Inputs | Results Summary | Impacts on Vehicle Operation

Instructions:

1. Using information from the project or plan you want to analyze, complete the inputs on this page and on the Mitigation Inputs page by entering information in the cells that are shaded orange. Gray cells display results; do not change the information in these cells. (The tool uses the term "project" not just to refer to individual projects, but also to long-range transportation plans or other plans that consist of a suite of projects.)

2. Click on the gray buttons at the top of the page to navigate between input pages, the results page, and the impacts on vehicle operation page.

3. For further instructions, refer to the accompanying user guide for detailed descriptions of factors and assumptions used in this tool.

Key to Cell Colors
User Input
Results Automatically Calculated

General Information

Infrastructure location (state)	NY
Analysis timeframe (years)	1

Average daily traffic per lane mile - for facilities that will be reconstructed or resurfaced	

Roadway System	
Total existing centerline miles	0.249
Total existing lane miles	0.497
Total newly-constructed centerline miles	0.112225352
Total newly-constructed lane miles	0.33

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	1.28

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	0	0	0	0	0	0
Rural Minor Arterials	0	0	0	0	0	0	0
Rural Collectors	0	0	0	0	0	0	0
Urban Interstates / Expressways	0	0	0	0	0	0	0
Urban Principal Arterials	0.224	0.106	0	0.497	0	0.497	0
Urban Minor Arterials / Collectors	0	0	0	0	0	0	0

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

Parking

Surface Parking (spaces)	0
Structured Parking (spaces)	0

Options

% roadway construction on rocky / mountainous terrain	0%

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, 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	22	2	0	0	0	0	0	0	0	0	0

How Many Bridge Spans?

Approximately half of short bridges in the U.S. (less than 1000 feet long) are single-span or double-span. If information about number of spans is not available, it is reasonable to assume a mix of single-span and two-span bridges. Note that the number of spans is an important factor in energy use and GHG emissions. You may want to test a few different assumptions to see the effects. Longer bridges (more than 1000 feet) can't be reliably estimated in the tool.

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	1.28	0	N/A
On-Street Bicycle Lane - lane miles	2.2	0	0
On-Street Sidewalk - miles	0.127	N/A	N/A

Construction - Delay

Total project-days of lane closure	0
Average daily traffic per directional segment for facilities requiring lane closure	0
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 modeling software. Planned construction projects that will result in significant lane closures on high volume roads should be evaluated using traffic modeling software.

Impacts on Vehicle Operation

Mitigation Inputs

Project Inputs | Results Summary | Impacts on Vehicle Operation

Instructions: Follow the steps below to calculate the impact of energy and GHG mitigation strategies:

1. Enter the baseline deployment (i.e., the extent to which the strategy is currently deployed) in Column B.

2. Enter the planned deployment (i.e., the extent to which the strategy will be deployed in the project that you are examining) in Column C.

Column D displays the maximum potential deployment of the strategy, based on research. If you enter a value in Column B or C that is greater than the value shown in Column D, the cell will appear highlighted in light red with dark red text as a warning. The calculations in the sheet will continue to function.

Some reduction strategies (i.e., biodiesel/hybrid maintenance vehicles and equipment; biodiesel/hybrid construction vehicles and equipment; and in-place roadway recycling for BRT conversions) apply to the same activities. Care must be taken to make sure you do not input a total deployment greater than 100% for overlapping strategies. For example, the tool does **not** prevent you from applying a combined deployment of B20 and B100 maintenance vehicles exceeding 100% of the maintenance fleet.

3. Compare the mitigated and unmitigated results on the *Results* page to assess the impact of mitigation strategies. Energy/GHG reductions are calculated based on the difference between planned and baseline deployment and the energy/GHG reduction potential of each strategy. If the planned deployment of a strategy is less than the baseline deployment, energy/GHG reductions will

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%	25%	44%	Fuel use by construction equipment
Switch from diesel to B20 in construction vehicles and equipment	0%	10%	100%	Fuel use by construction equipment
Switch from diesel to B100 in construction vehicles and equipment	0%	10%	100%	Fuel use by construction equipment
Combined hybridization/B20 in construction vehicles and equipment	0%	10%	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%	25%	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%	0%	100%	Materials and construction fuel use in roadway resurfacing and reconstruction projects

Results Summary

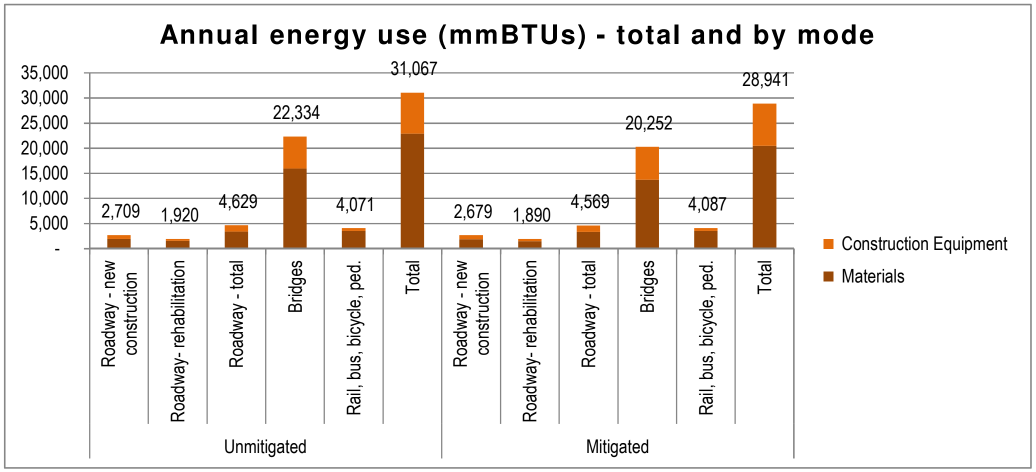
Project Inputs | Mitigation Inputs | Impacts on Vehicle Operation

	Annualized energy use (mmBTUs), per year over 1 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	1,908	1,508	3,416	15,964	3,487	**22,867**	1,853	1,465	3,318	13,688	3,485	**20,491**
Direct Energy												
Construction Equipment	801	412	1,213	6,370	584	**8,167**	826	425	1,251	6,564	602	**8,417**
Routine Maintenance						**33**						**33**
Total	**2,709**	**1,920**	**4,629**	**22,334**	**4,071**	**31,067**	**2,679**	**1,890**	**4,569**	**20,252**	**4,087**	**28,941**

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 1 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	124	97	221	1,627	201	**2,049**	119	93	212	1,422	201	**1,835**
Direct Emissions												
Construction Equipment	58	30	88	464	43	**595**	50	26	76	397	37	**510**
Routine Maintenance						**3**						**3**
Total	**182**	**127**	**309**	**2,091**	**244**	**2,647**	**169**	**119**	**288**	**1,819**	**238**	**2,348**

Annualized over 1 Years



Annualized over 1 Years