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How to estimate lifecycle GHG emissions of transportation infrastructure

Seth Hartley, ICF | Tim Sexton, MnDOT
Karin Landsberg, WSDOT | Pritpall Bhullar, Caltrans

Welcome!

Seth Hartley

Senior Air Quality Specialist, ICF

Seth focuses on the air quality, climate, and public health impacts of transportation. He is an Atmospheric Scientist with 18 years of experience working with various clients including the U.S. EPA, FHWA, and various state and local agencies on planning, modeling, and mitigation of air pollution.

Some ground rules

Lines will be muted.

Submit questions in the chat box.

We're recording!

How did we do?

Tell us what you want to hear next.

Today's presenters + agenda

Tim Sexton

Assistant Commissioner and Chief Sustainability Officer, MNDOT

Pritpall Bhullar

Senior Transportation Engineer, Caltrans

Karin Landsberg

Senior Policy Specialist, WSDOT

- Introduction and background: What is ICE 2.1 and what does it solve?
- The pooled fund study
- Tool overview
- User experiences
- Questions

1. Background and the ICE tool for transportation infrastructure

What is ICE?

The Infrastructure Carbon Estimator (ICE) is a spreadsheet tool that estimates the "ballpark" energy and GHG emissions associated with transportation facilities.

- Covers full lifecycle of materials and fuels.
- Addresses the lifetime of facilities, including construction, routine maintenance, rehabilitation, and (in some cases) use.

ICE was created to solve the problem of "planning-level" estimation of embodied carbon emissions in transportation infrastructure.

- Designed for pre-engineering analyses of the energy and GHG emissions impacts of constructing and maintaining infrastructure.
- Estimates the construction and maintenance impacts of long-range transportation decisions.
- ICE helps answer: How much carbon will be embodied in the building, modification, maintenance, and/or use of a transportation project(s) without needing engineering studies?

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ICE may be used for…

National Environmental Policy Act and comparative analysis

- Functionality has been included to facilitate build versus no-build or alternatives comparisons off-model.

Planning or system-level analysis from a full lifecycle perspective

- Footprint energy use and GHG emissions estimation for planned projects.
- System-level estimates for construction / maintenance over the duration of a plan.
- Analyses where only simple project inputs are available.

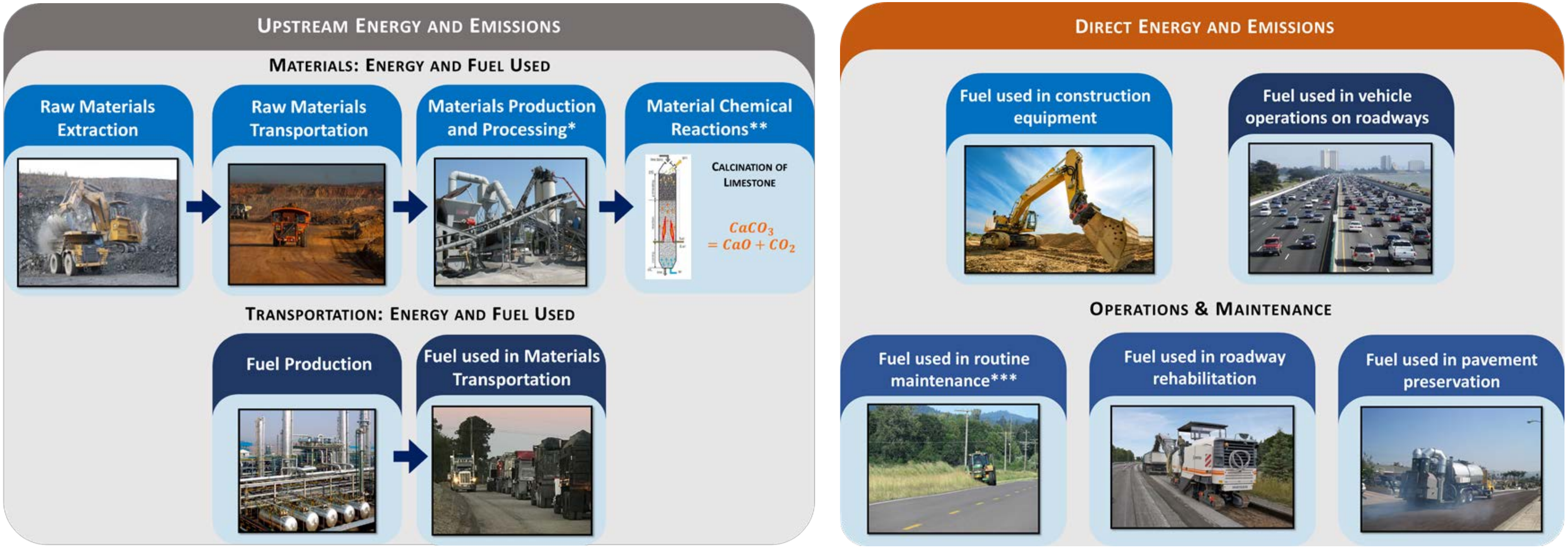
Supporting agency sustainability practices and user education

- Graphics and tables added to illustrate the relative contribution of different phases of the infrastructure, different materials, different infrastructure components (in a combined plan), and different mitigation options that may be available.
- Exploring the types of strategies that are most effective to reduce infrastructure's energy use and GHG emissions and by how much.

Estimations of the net energy and GHG impacts of projects

- Evaluations made before detailed engineering studies are available.
- ICE relies on a pavement neutral approach, representing a typical mix of asphalt and concrete surfaces, which remains fixed in all ICE calculations.
- Functionality has been added to integrate with more sophisticated pavement tools.
- ICE operates with simple inputs to describe most projects, with inputs based on national average factors.

ICE conducts full lifecycle analysis



Infrastructure types included in ICE 2.1

Types carried over from ICE 1.0

- Roadways
- Bridges and overpasses (new)
- Transit
  - Light rail
  - Heavy rail
  - Bus Rapid Transit (BRT)
- Parking
- Pathways
- Vehicle operations

New project types in ICE 2.1

- Roadway rehabilitation (standalone)
- Roadway lighting
- Roadway signage
- Culverts
- Custom pavement

How to get ICE 2.1?

Available via MnDOT's sustainability website. Includes:

- The most current version of ICE 2.1.
- The final report and user's guide.
- Links to additional resources from FHWA and Minnesota specific version of the tool.

http://www.dot.state.mn.us/sustainability/ghg-analysis.html

ICE tool and Minnesota Department of Transportation

Tim Sexton
Minnesota Department of Transportation

Why it's important to analyze infrastructure GHG emissions

Air quality considerations

- Impacts of criteria pollutants and mobile source air toxics are short-lived and localized in the atmosphere.
- Primary focus is on tailpipe emissions from vehicles using transportation facilities, rather than emissions associated with the facilities themselves.
  - Emissions from the construction and maintenance are less relevant since they're temporary.
  - Once construction is over, emissions don't matter anymore.

GHG considerations

- Impacts of CO2 and other GHGs are global and long-lived.
- They increase atmospheric concentrations regardless of where or when they occur.
- Need to analyze emissions on a cumulative rather than "snapshot" basis.
- Need to account for the entire "footprint" of transportation facilities through lifecycle analysis (addressing roadway materials).
- **Transportation agencies have significant control over decisions related to infrastructure and can significantly influence GHG emissions in this area.**

Tools to analyze transportation infrastructure energy/GHGs

Bottom-up

- Based estimates of material quantities and construction vehicle activity (from engineering analysis).
- Able to evaluate impacts of specific pavement types.
- Most accurate but require detailed inputs.
- Examples
  - Road Construction Model (RCM)
  - California Emissions Estimator Model (CalEEMod)
  - Pavement Lifecycle Assessment Tool for Environmental and Economic Effects (PaLATE)
  - GreenDOT
  - Greenhouse Gas Assessment Spreadsheet for CAPital Projects (GasCAP)
  - LCA PAVE (forthcoming from FHWA)

Top-down

- Based on facility lane-miles and project type.
- Less accurate and not pavement-specific, but easier to use.
- Provide useful information for long-range planning, NEPA, and other pre-engineering purposes.
- Examples
  - New York State Energy Use Factors (NYSDOT, based on Department of Energy Analysis)
  - Infrastructure Carbon Estimator Version 1.0 (FHWA)

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ICE pooled fund study

ICE 2.1 was developed as part of a transportation pooled fund study.

- Minnesota DOT (pooled fund study lead)
- New York State DOT
- Caltrans
- Colorado DOT
- Iowa DOT
- Washington State DOT
- Texas DOT
- Federal Highway Administration

Project objectives:

- Updating the model's energy use and emissions factors to reflect recent research.
- Expanding the range of infrastructure types included in the model.
- Updating the tool interface and improving model outputs.

ICF selected by pooled fund panel to serve as project consultant.

2. Using ICE

ICE 2.1 major updates

- Remaining an Excel based tool for familiarity but adding a completely reworked interface to maximize utility and facilitate future updates.
- Maintaining its existing “pre-engineering” planning scope but allowing for additional customization in cases where users may have additional information through a new “project” mode.
- Increasing output and results options to facilitate comparisons and enhance educational value.
- Retaining the useful analysis scope (e.g., by project phases, activity types, direct vs upstream energy).
- Updating material, fuel, and use phase energy and emission factors to values current (at the time of publication) that continue to rely on point estimates of primary material’s energy and carbon intensity for national applicability.
- Including logic in mitigation measures to avoid selecting incompatible options.
- Keeping the most typical infrastructure categories and added new requested categories.
- Continuing to prioritize ease of use, applying a user-centered design approach.
- Adding functionality for comparative analyses.
- Complying with Section 508.

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The ICE approach: Project vs. planning modes

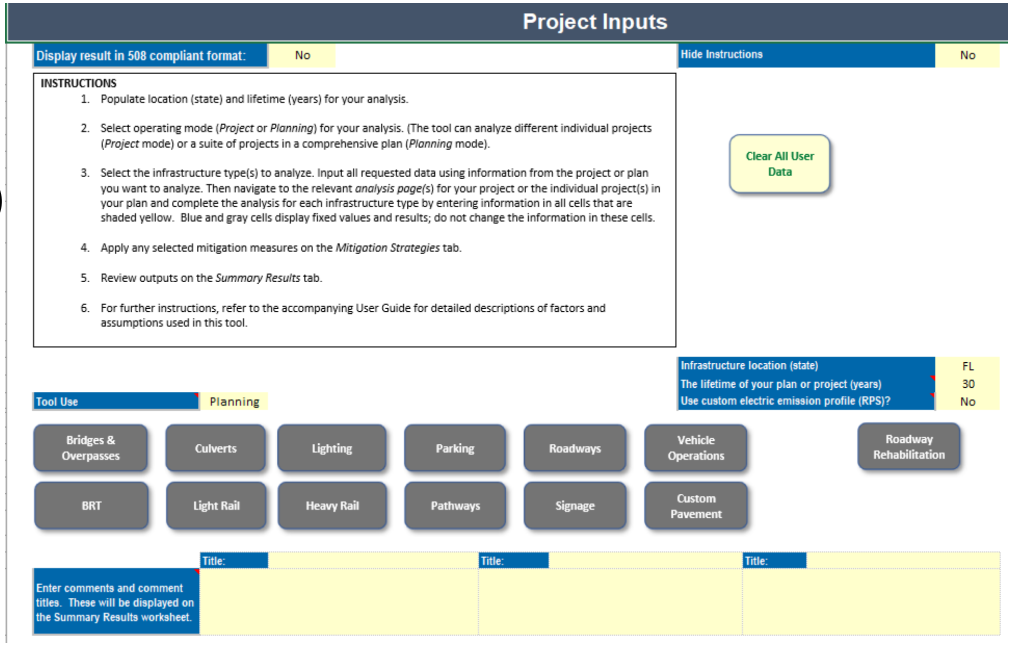
Planning mode (1)

- Operates with fewer input details.
- Allows combined analysis of multiple infrastructure types.
- Designed for use in planning applications with suite of projects.
- Turn on (green) / off (grey/white) infrastructure types on project inputs tab.

Project mode (2)

- Offers additional specificity options
- Limited to one infrastructure type per simulation.
- Option to be guided through infrastructure tabs ("walk me through the estimate").
- Additional inputs for many infrastructure types on individual infrastructure tabs.

(1)



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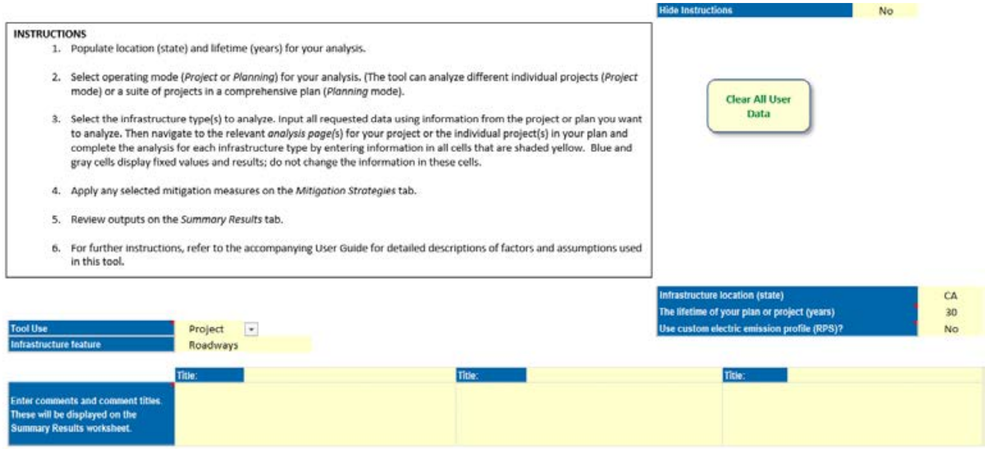

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Example case study walk-through 1: Planning level

- **Infrastructure location:** FL
- **Project lifetime:** 30 years
- **Infrastructure types:**
  1. New roadway construction and lifetime maintenance.
- **Mitigation measures applied:**
  1. Partially switch from diesel to Soybean-based RDII 100.
  2. Partially switch from diesel to E-Diesel (Corn).
  3. Vegetation management.
  4. Use of industrial byproducts as substitutes for Portland cement.
  5. Use of recycled concrete aggregate as substitute for base stone.
  6. Include pavement preservation.

Note: This project is similar to the Project Level Case Study in the User's Guide (Section 3.2) but simplified to correspond to a more "traditional" project by excluding impacts of any existing road network and custom rehabilitation schedule. See the User's Guide for that example.

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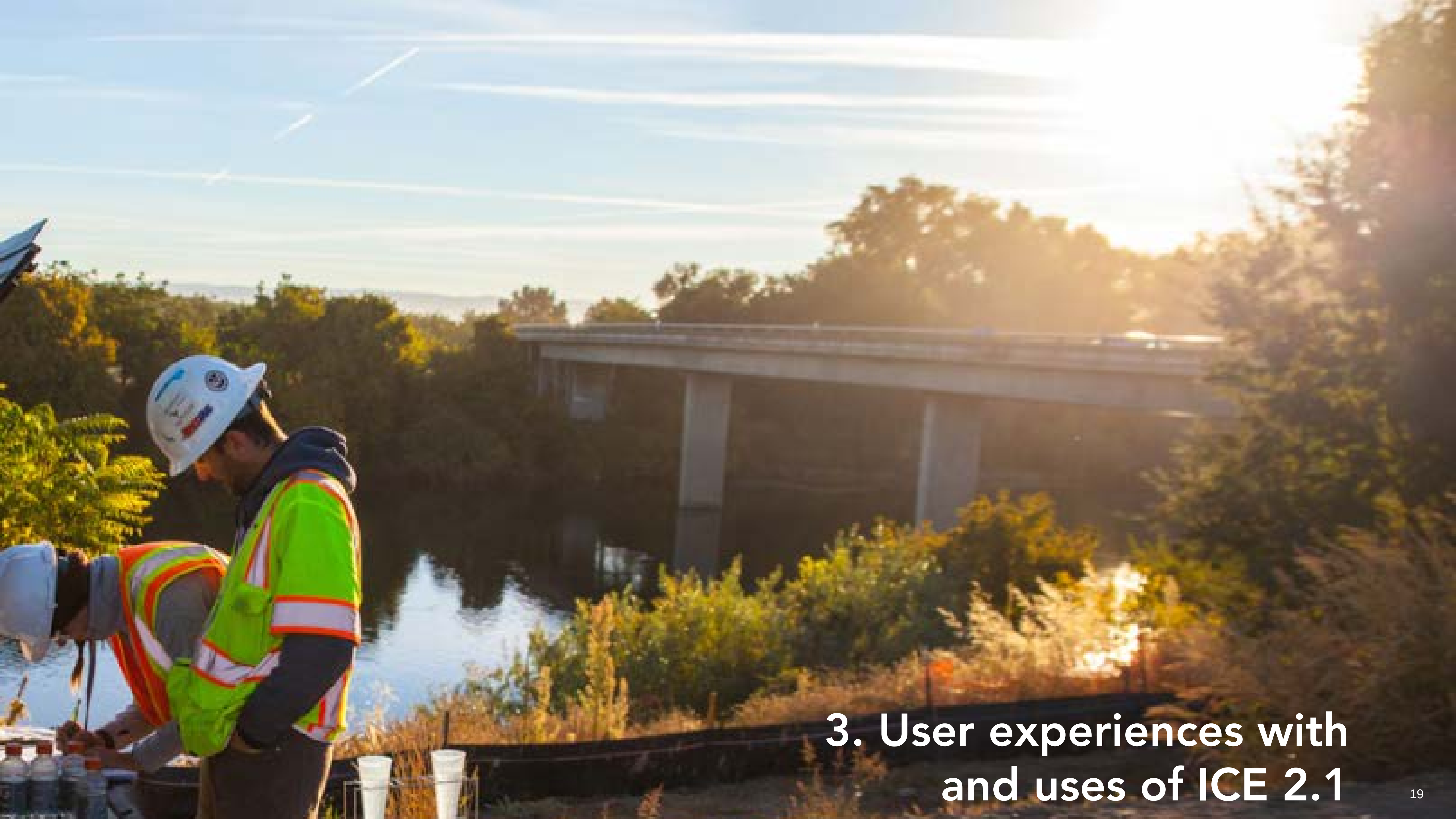


3. User experiences with and uses of ICE 2.1

ICE Tool & Caltrans

Pritpall Bhullar
Senior Transportation Engineer,
Division of Transportation Planning,
California Department of Transportation

Caltrans Project Delivery

(TYPICAL)

PID	PR	PS&E	
PLANNING	ENVIRON	DESIGN	CONSTRUCTION
ICE TOOL (GHG)	Cal BC/ EMFAC (GHG)		

ICE tool and Caltrans

What is a PID?

- Project Initiation Document (PID) is an engineering document / technology report that develops a planning level scope, cost estimate, and delivery schedule.

Why GHG analysis in PIDs?

- Executive Order B-30-15 requires state agencies to consider climate change in planning and investment decisions.

Why select ICE tool to perform GHG analyses in PID?

- It is a simplified, easy-to-use tool.
- Educates planners and decision makers in employing various mitigation strategies.

North Spokane Corridor

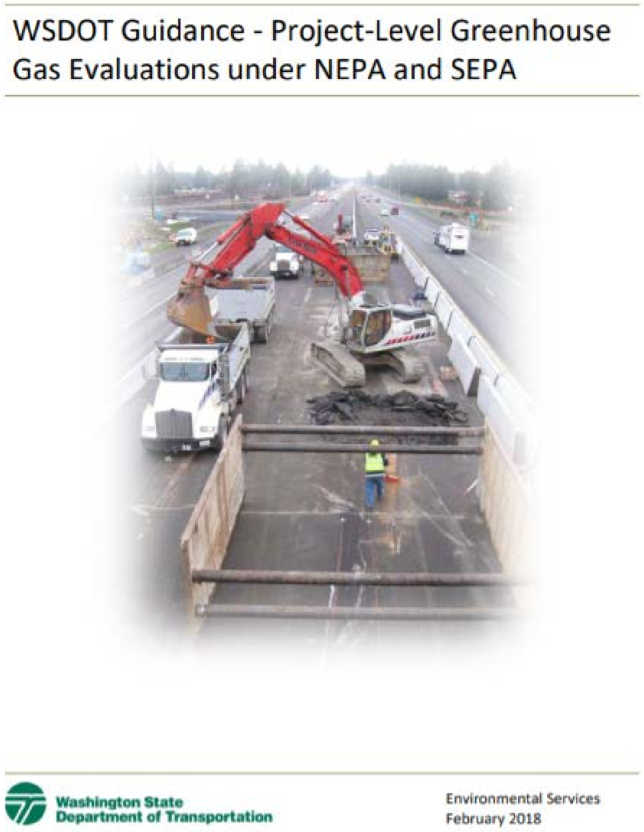
ICE analysis of GHGs

Karin Landsberg, Senior Policy Specialist – Air Quality and Climate

WSDOT Project GHG Policy

[WSDOT Guidance – Project-Level Greenhouse Gas Evaluations under NEPA and SEPA]

- First published in 2009, updated as requirements, tools, and resources change.
- Identifies what types of analysis we do.
- Analysis is generally based on level of documentation (CE, EA, EIS).
- With the release of FHWA's ICE tool, began doing quantitative construction and maintenance analyses.

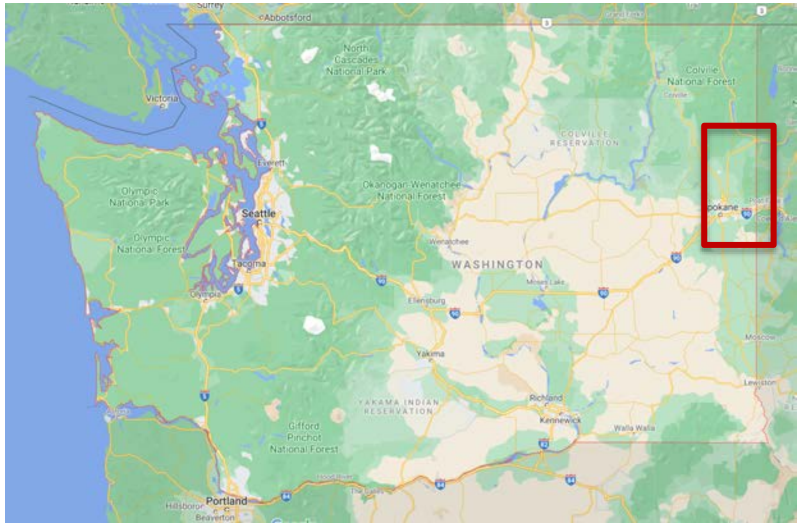

WSDOT Guidance - Project-Level Greenhouse Gas Evaluations under NEPA and SEPA

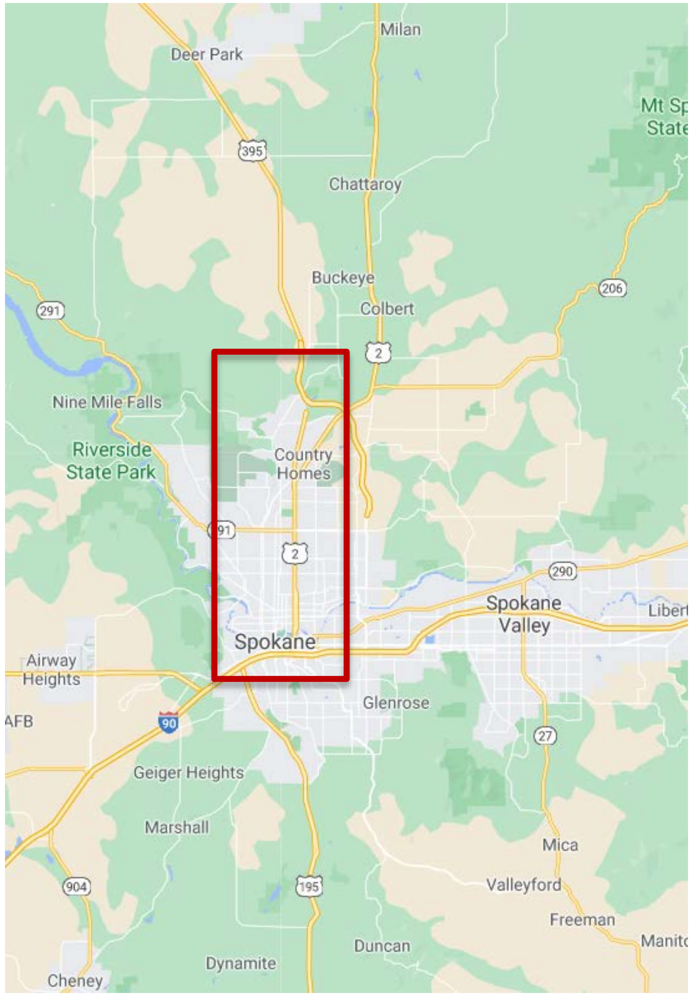
Washington State Department of Transportation

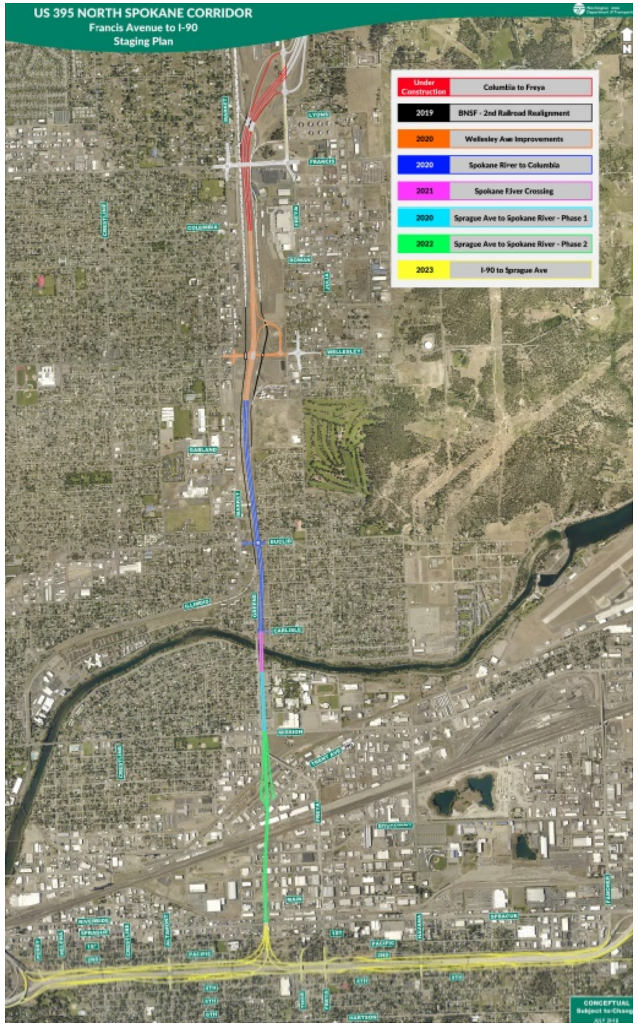
Environmental Services
February 2018

North Spokane corridor

Limited access corridor linking I-90 to existing US 2 and US 395 – 10.5 miles.

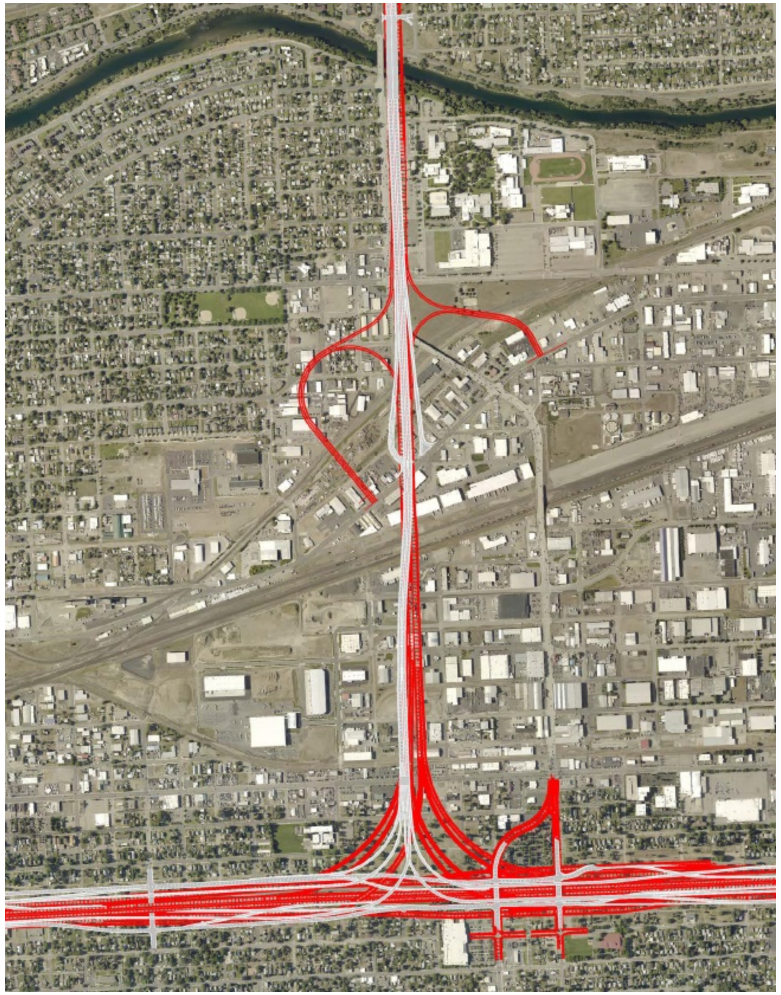






NSC ICE analysis

- Multi-decade project, 5.5 miles of 10.5 miles completed.
- Air quality analysis needed to be updated in 2019 as part of a NEPA reevaluation.
- Updated energy and greenhouse gases analysis at the same time.
  - Operational analysis used MOVES.
  - Construction and maintenance analysis used ICE 2.1.



ICE inputs

Tool Use	Planning

Infrastructure location (state)	WA
The lifetime of your plan or project (years)	30
Use custom electric emission profile (RPS)?	No

Bridges & Overpasses
Culverts
Lighting
Parking
Roadways
Vehicle Operations
Roadway Rehabilitation
BRT
Light Rail
Heavy Rail
Pathways
Signage
Custom Pavement

Bridges & Overpasses

	Construct New Bridge/Overpass				Reconstruct Bridge/Overpass				Add Lane to Bridge/Overpass			
Bridge/Overpass Structure	Number of bridges & overpasses	Average number of spans per structure	Average number of lanes per structure	Total number of lane-spans	Number of bridges & overpasses	Average number of spans per structure	Average number of lanes recon-structed per structure	Total number of lane-spans	Number of bridges & overpasses	Average number of spans per structure	Average number of lanes per structure added	Total number of lane-spans
Single-Span		1		0		1		0		1		0
Two-Span		2		0		2		0		2		0
Multi-Span (over land)	1	40	4	160				0				0
Multi-Span (over water)				0				0				0

ICE inputs

Roadway System	
Total existing centerline miles	
Total newly constructed centerline miles	1.7

Roadway Projects

Facility type	Roadway System	Roadway Construction				
	Existing Roadway (lane miles)	New Roadway (lane miles)	Construct Additional Lane (lane miles)	Realignment (lane miles)	Lane Widening (lane miles)	Shou Improvement (centerline miles)
Rural Interstates						
Rural Principal Arterials						
Rural Minor Arterials						
Rural Collectors						
Urban Interstates / Expressways		1.7				
Urban Principal Arterials						
Urban Minor Arterials / Collectors				7		

Include roadway rehabilitation activities (reconstruct and resurface)	Yes
% roadway construction on rocky / mountainous terrain	

Pathways

Bicycle and Pedestrian Facilities

Project Type	New Construction	Resurfacing
Off-Street Bicycle or Pedestrian Path - miles	3	
On-Street Bicycle Lane - lane miles	1	
On-Street Sidewalk - miles		N/A

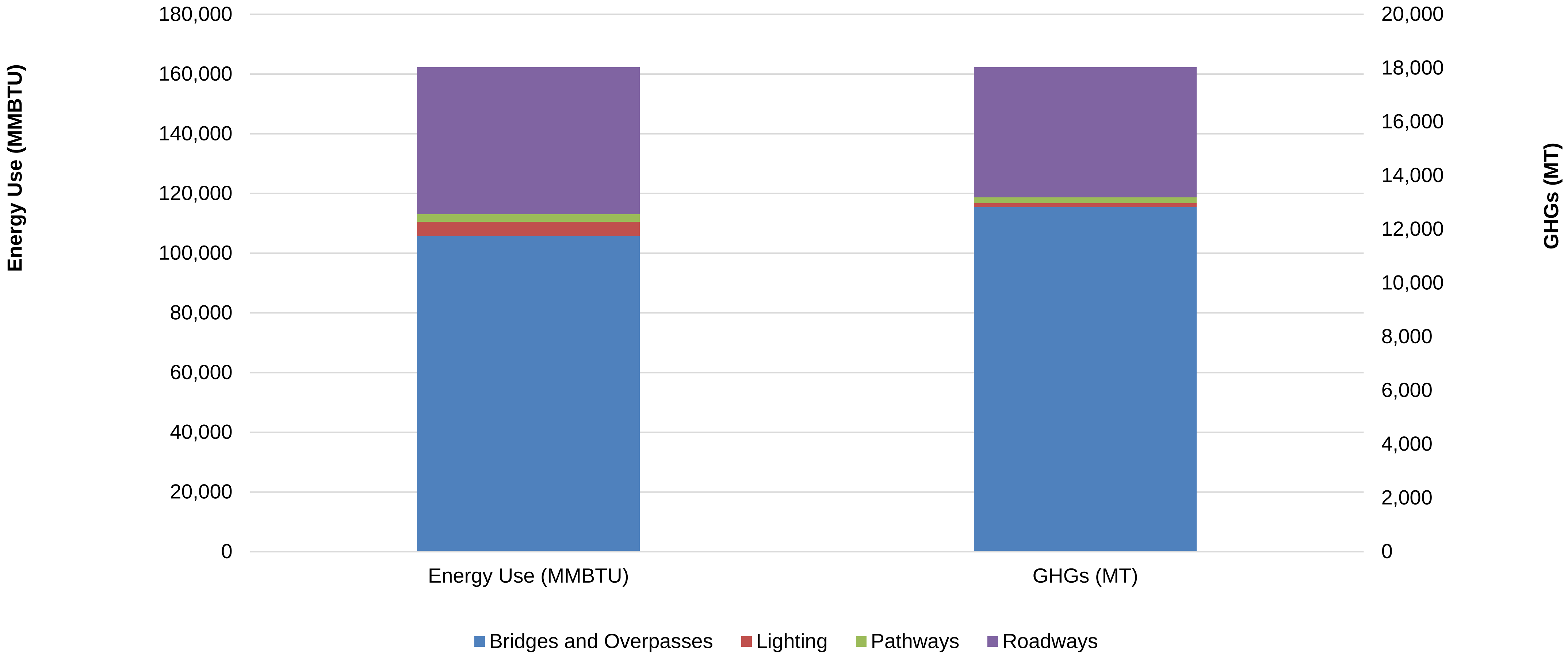
Lighting

Number of roadway miles	1.7

Lighting Structures

Support Structure Type	Lumen Range	Ave. number of HPS lights per roadway mile	Ave. number of LED lights per roadway mile
Vertical	4000-5000		
Vertical	7000-8800		
Vertical	8500-11500		
Vertical	11500-14000		45
Vertical	21000-28000		

Results: Total energy & GHGs



Questions?

Thank you!

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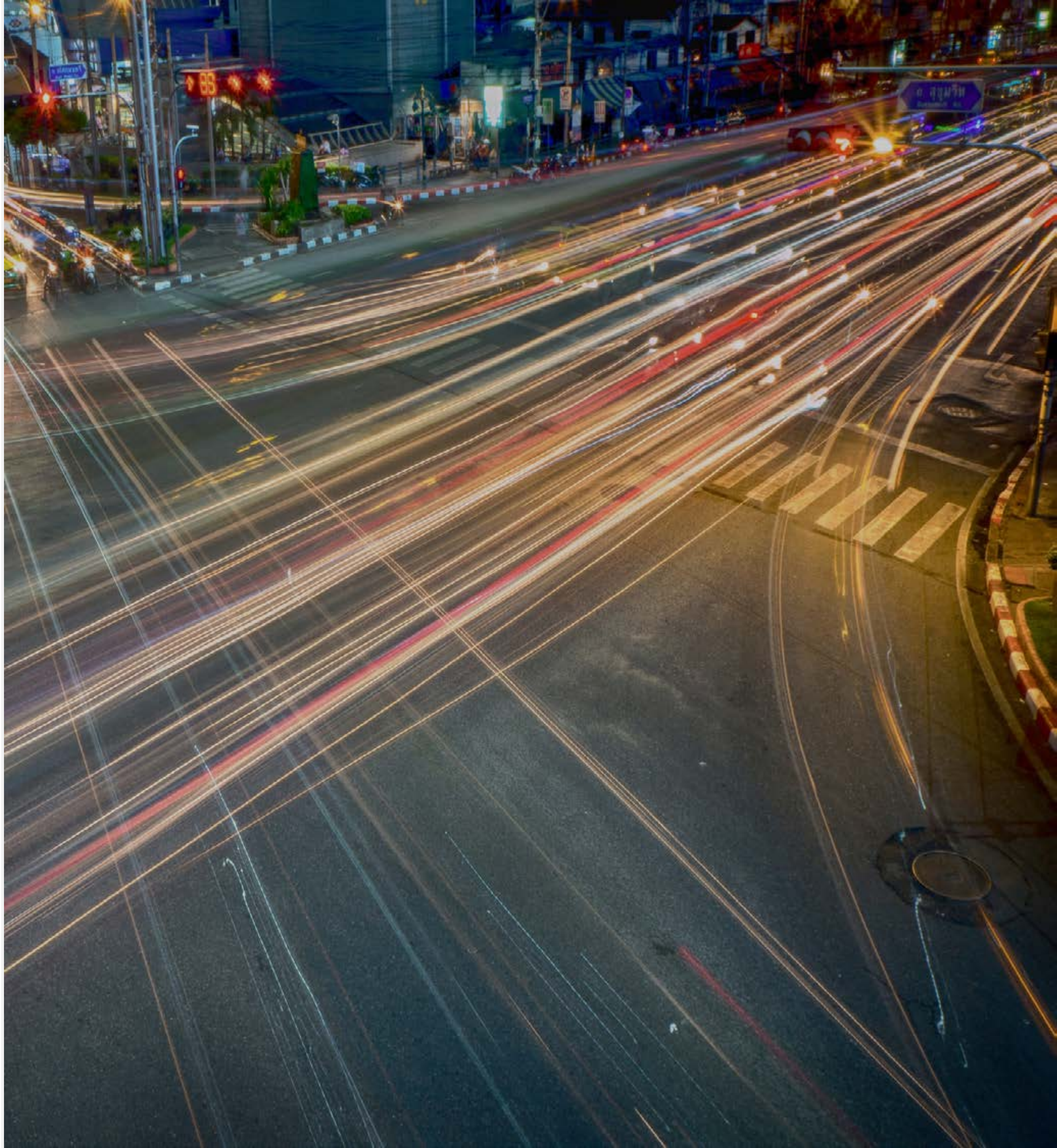
Download ICE 2.1 at

http://www.dot.state.mn.us/sustainability/ghg-analysis.html



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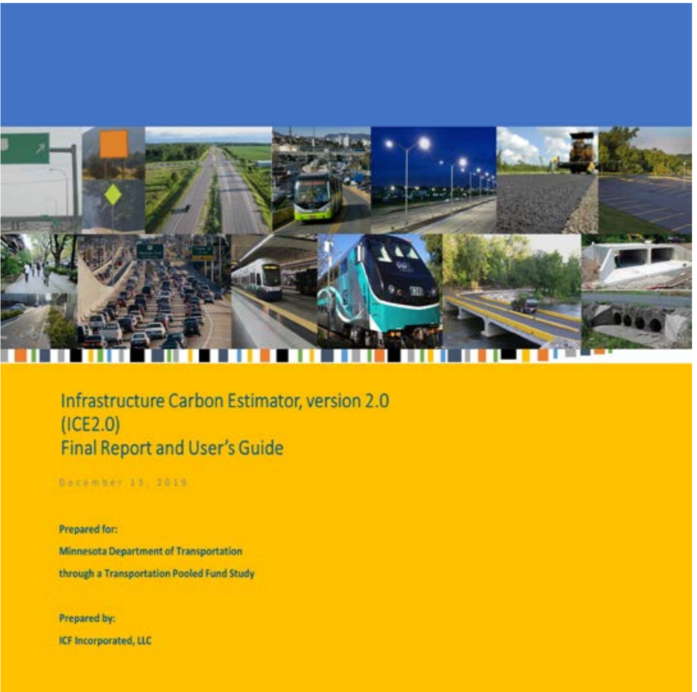
Resources for ICE 2.1 users



ICE 2.1 user's guide

Updated, detailed user's guide with:

- Instructions on how to use ICE.
- Example use cases.
- Details on prototypes, materials, and mitigation strategies.

ICE 2.1 tool in-line help

The tool has pop-up windows within it that guide users through data entry and outputs.

All fields we identified as needing explanation have help attached.

Old ICE 1.0 materials

The old version of ICE also had:

- Detailed user guide.
- Website hosted by FHWA with extensive background information, much of which is still relevant for reference. Start with:

  https://www.fhwa.dot.gov/environment/sustainability/energy/tools/carbon_estimator/

Other tools

FHWA's comprehensive pavement lifecycle assessment tool will provide more detailed analyses on many of the topics in ICE.

GreenDOT, PaLATE, and GasCAP also provide some LCA capabilities.

Other tools provide tailpipe equipment or construction emissions.

Mitigations and caveats with ICE

- **What ICE can/cannot do**
  - Screening level or pre-engineering analysis.
  - Limited pavement mix/design ability. Only pavement-neutral approach available in the tool.
  - Inputs based on composite from multiple studies (e.g., BidTabs data) and literature values including EPDs.
  - Limited customization available for infrastructure.
  - Simple approach to mitigation.
- **For specialized or detailed analyses, users should refer to FHWA's infrastructure tool.**
- **Users should be cautious when using the simplified mitigation strategies in ICE.**

Mitigation Strategies

Return To Project Inputs

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

The user will enter both the business as usual (BAU) deployment (i.e., the extent to which the strategy is deployed through standard agency practices) in Column F and the planned deployment (i.e., the extent to which the strategy will be deployed in the project that you are examining) in Column G. (Baseline refers to values without any mitigations.) For Pavement Preservation strategies, enter both the schedule change and application frequency.

Column H displays the increase in deployment from implementation of the strategy. Some reduction strategies (e.g., Switch from diesel to Soy bean-based BD20 and biodiesel/hybrid maintenance vehicles and equipment) may be incompatible. The user should take care that inputs do not describe a total deployment greater than 100% for overlapping strategies. The tool will warn if "excess" energy savings from mitigation are predicted or incompatible strategies are selected.

For a more refined mitigation analysis, please refer to FHWA's upcoming Pavement LCA Tool.

						BAU Reductions		Planned Reductions	
Strategy	BAU deployment	Planned deployment	Deployment increase	Energy reduction factor	GHG reduction factor	Energy reductions	GHG reductions	Energy reductions	GHG reductions
Alternative fuels and vehicle hybridization									
Switch from diesel to Soy bean-based BD20			0.0%	-5%	12%	0.0%	0.0%	0.0%	0.0%
Switch from diesel to Soy bean-based RDII 100			0.0%	-20%	66%	0.0%	0.0%	0.0%	0.0%
Switch from diesel to Forest Residue-based RDII 100			0.0%	-61%	71%	0.0%	0.0%	0.0%	0.0%
Switch from diesel to E-Diesel, Corn			0.0%	-3%	0%	0.0%	0.0%	0.0%	0.0%
Switch from diesel to PHEV: Diesel and Electricity (U.S. Mix)			0.0%	41%	44%	0.0%	0.0%	0.0%	0.0%
Switch from diesel to CNG, NA NG			0.0%	-6%	11%	0.0%	0.0%	0.0%	0.0%
Switch from diesel to LNG, NA NG			0.0%	-11%	7%	0.0%	0.0%	0.0%	0.0%
Hybrid maintenance vehicles and equipment			0.0%	11%	11%	0.0%	0.0%	0.0%	0.0%
Combined hybridization/B20 in maintenance vehicles and equipment			0.0%	1%	27%	0.0%	0.0%	0.0%	0.0%
Hybrid construction vehicles and equipment			0.0%	11%	11%	0.0%	0.0%	0.0%	0.0%
Combined hybridization/B20 in construction vehicles and equipment			0.0%	1%	27%	0.0%	0.0%	0.0%	0.0%
Vegetation management									
Alternative vegetation management strategies (hardscaping, alternative mowing, integrated roadway/vegetation management)			N/A	25%	25%	0.0%	0.0%	0.0%	0.0%
Snow fencing and removal strategies									
Alternative snow removal strategies (snow fencing, wing plows)			N/A	50%	50%	0.0%	0.0%	0.0%	0.0%
In-place roadway recycling									
Cold In-place recycling			0.0%	33%	37%	0.0%	0.0%	0.0%	0.0%
Full depth reclamation			0.0%	68%	68%	0.0%	0.0%	0.0%	0.0%
Warm-mix asphalt									
Warm-mix asphalt			0.0%	37%	37%	0.0%	0.0%	0.0%	0.0%
Recycled and reclaimed materials									
Use recycled asphalt pavement as a substitute for virgin asphalt			0.0%	12%	12%	0.0%	0.0%	0.0%	0.0%
Use recycled asphalt pavement as a substitute for virgin asphalt			0.0%	84%	84%	0.0%	0.0%	0.0%	0.0%
Use industrial byproducts as substitutes for Portland cement			0.0%	59%	59%	0.0%	0.0%	0.0%	0.0%
Use recycled concrete aggregate as a substitute for base stone			0.0%	58%	58%	0.0%	0.0%	0.0%	0.0%
Pavement preservation									
Pavement preservation extends roadway life by (years)			N/A	N/A	N/A	N/A	N/A	N/A	N/A
Pavement preservation frequency (every N years, for entire roadway			N/A	N/A	N/A	N/A	N/A	N/A	N/A

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