Core Modeling & Decision Support Capabilities: FASTSim, RouteE, T3CO & OpenPATH

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National Renewable Energy Laboratory
Wednesday June 14, 2023

DOE Vehicle Technologies Office
2023 Annual Merit Review and Peer Evaluation Meeting

EEMS112

Tool Leads
FASTSim: Aaron Brooker & Chad Baker
RouteE: Jake Holden
T3CO: Jason Lustbader & Chad Baker
OpenPATH: K. Shankari

Overview

Timeline

- Project start: December 2021
- Project end: December 2024
- Percent complete: 45%

Budget

- Total project funding: $1.2 million per year for FY22–FY24
  - DOE share: 100%
- Funding for FY22: $1.2 million
- Funding for FY23: $600,000 received so far.

Barriers

- Improved model and data availability to support enhanced RD&D of advanced mobility solutions
- Quantify technology impacts
- High uncertainty and rapid changes in mobility technology and behaviors.

Numerous Partners/Collaborators

- OEMs and suppliers, fleets, federal agencies
- Research partners at other labs, universities, state agencies, industry
- Mapping, logistics, and information providers
- MPOs, local agencies, mobility providers
- Livewire for data dissemination (EEMS066).

MPO = metropolitan planning organization; OEM = original equipment manufacturer; RD&D = research, development, and deployment

Project Objectives and Relevance

- Support tools for quantifying energy impacts and identifying strategies to achieve maximum impact.
- Enable collaborations for implementing and deploying tools to realize real-world benefits.
- Facilitate data collection that informs actions to promote equitable and energy-efficient mobility.

- Directly relevant to DOE goals of advancing equitable pathways to reduce transportation energy and carbon emissions, and to improve mobility.
- Extensive stakeholder collaboration and coordination helps to advance an array of energy-efficient transportation activities.
  - Capabilities leveraged by many other projects within and beyond EEMS/VTO/DOE.
  - Tools, analyses, and data outputs made broadly available.
- Efforts to increase efficiency, reduce costs, and improve mobility + energy security span passenger and freight movements across LD + MDHD and pedestrian + micromobility modes.

LD = light-duty; MDHD = medium- and heavy-duty

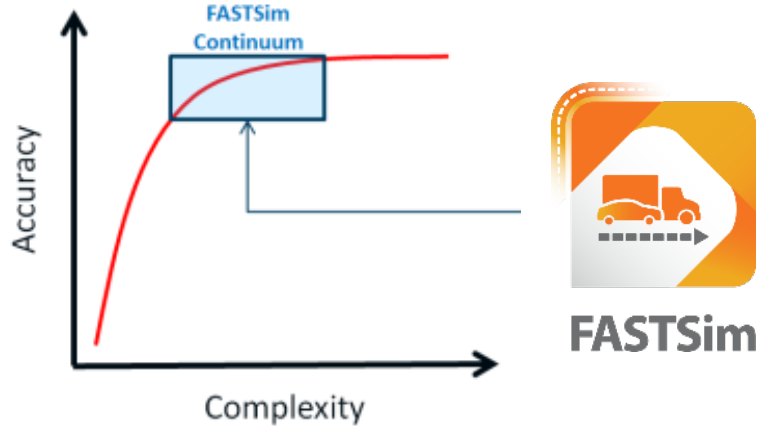
Overall Approach

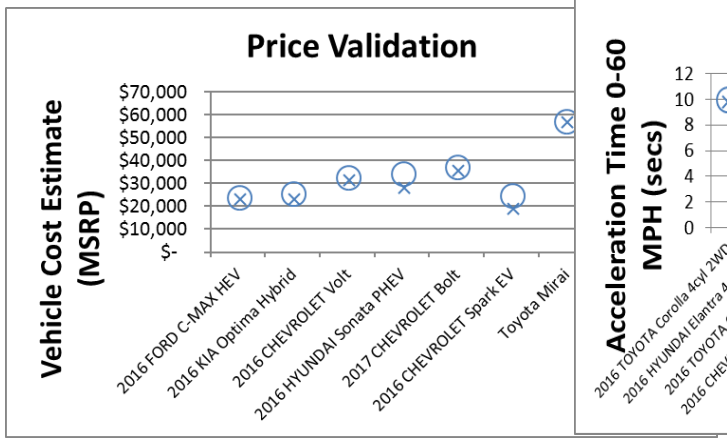
- Maintain, update/enhance, and broaden the reach of core capabilities for streamlined vehicle energy + cost modeling, as well as mobility data collection + analysis (of existing and advanced tech).
- Further expand representation of emerging technologies (e.g., CAVs and real-world advanced powertrain performance) and equity considerations.
- Provide a foundation for impactful lab research and for industry/practitioner collaborations leveraging core tools.

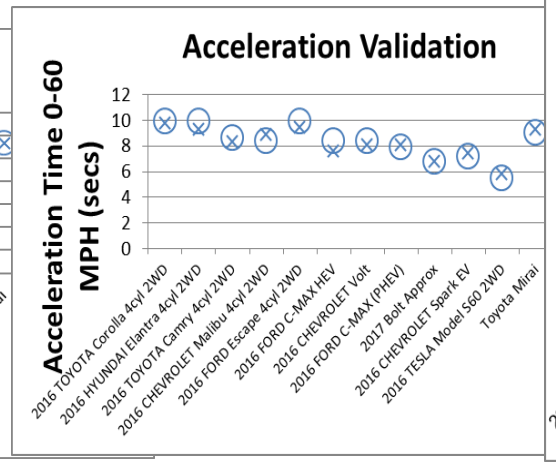
CAV = connected and automated vehicle

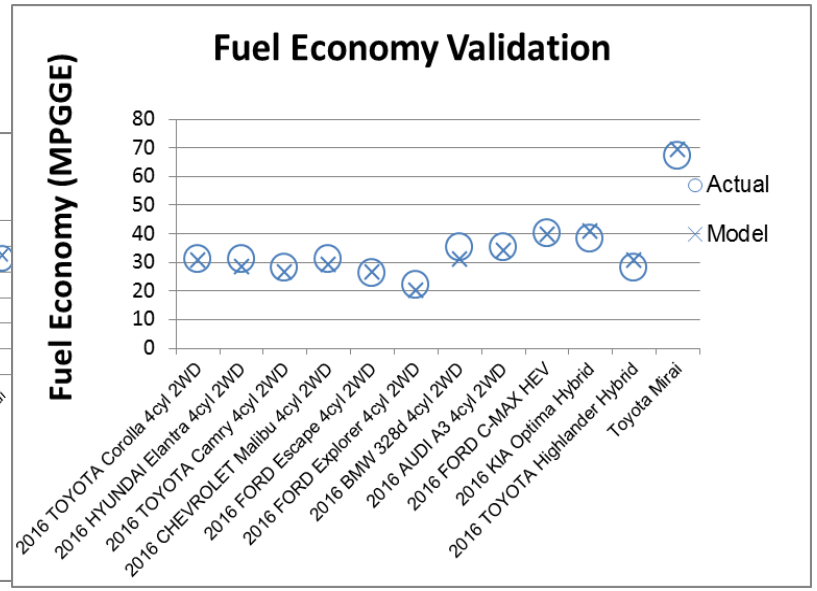
Approach: Vehicle Powertrain Modeling in FASTSim

- **FASTSim's balance of accuracy vs. complexity**
  - Model captures most important factors influencing vehicle energy use, performance, and cost.
  - Useful for evaluating tech improvement impacts.
- **Well validated and widely accepted**
  - Simplest version with generic components gives good large-scale agreement.
  - Complexity can be added to capture a range of real-world considerations.



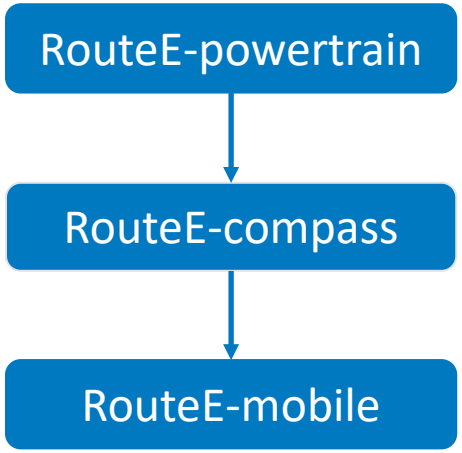






FASTSim = Future Automotive Systems Technology Simulator

Approach: RouteE – Route Energy Prediction Model



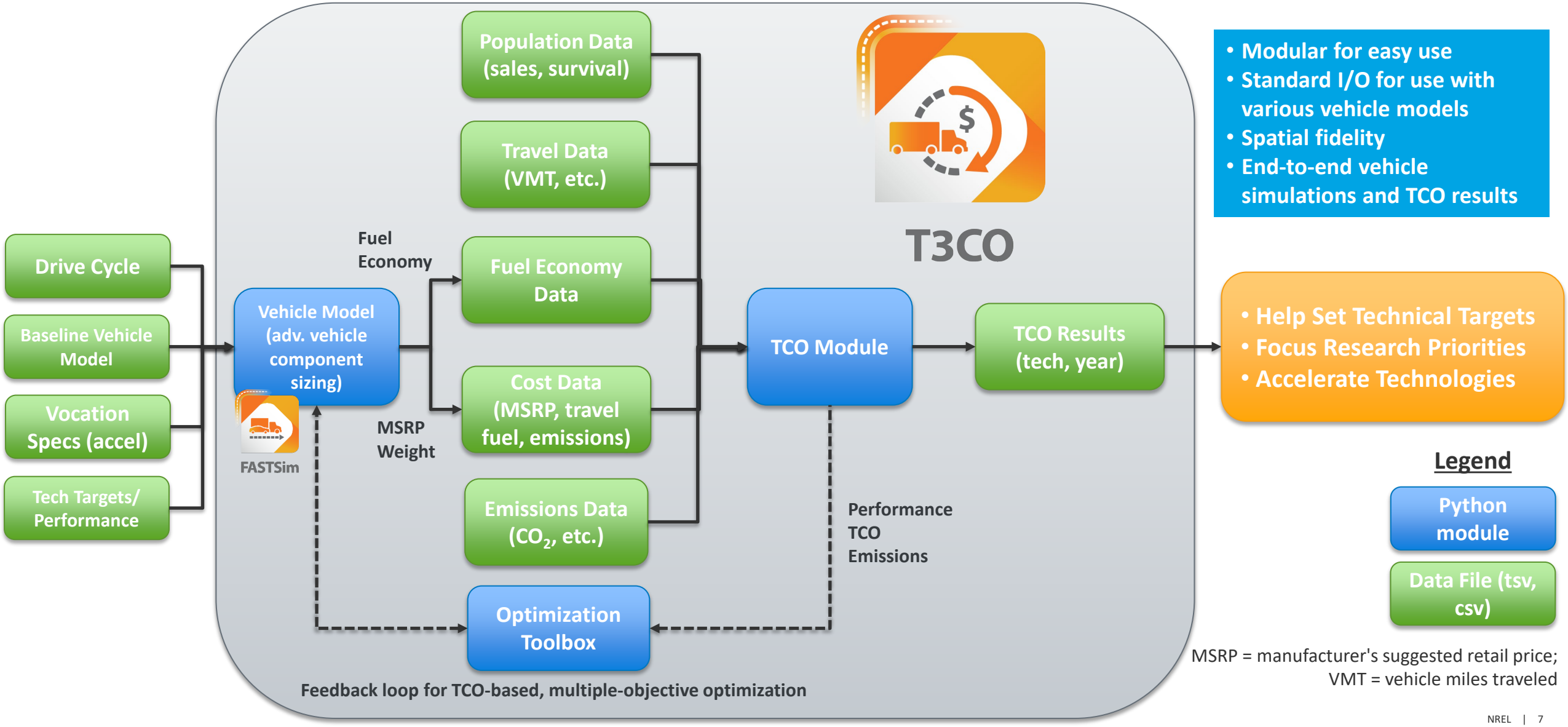
Model Overview

- A modular, **energy-optimal routing and navigation** platform that allows users to co-optimize travel time and energy consumption for individual **vehicles, fleets, or entire transportation networks**.
- Components can also be implemented as stand-alone packages. For example, RouteE-powertrain can perform accurate energy predictions for a variety of powertrain technologies where high-frequency drive cycle data are unavailable.

ENERGY I-CORPS
U.S. Department Of Energy

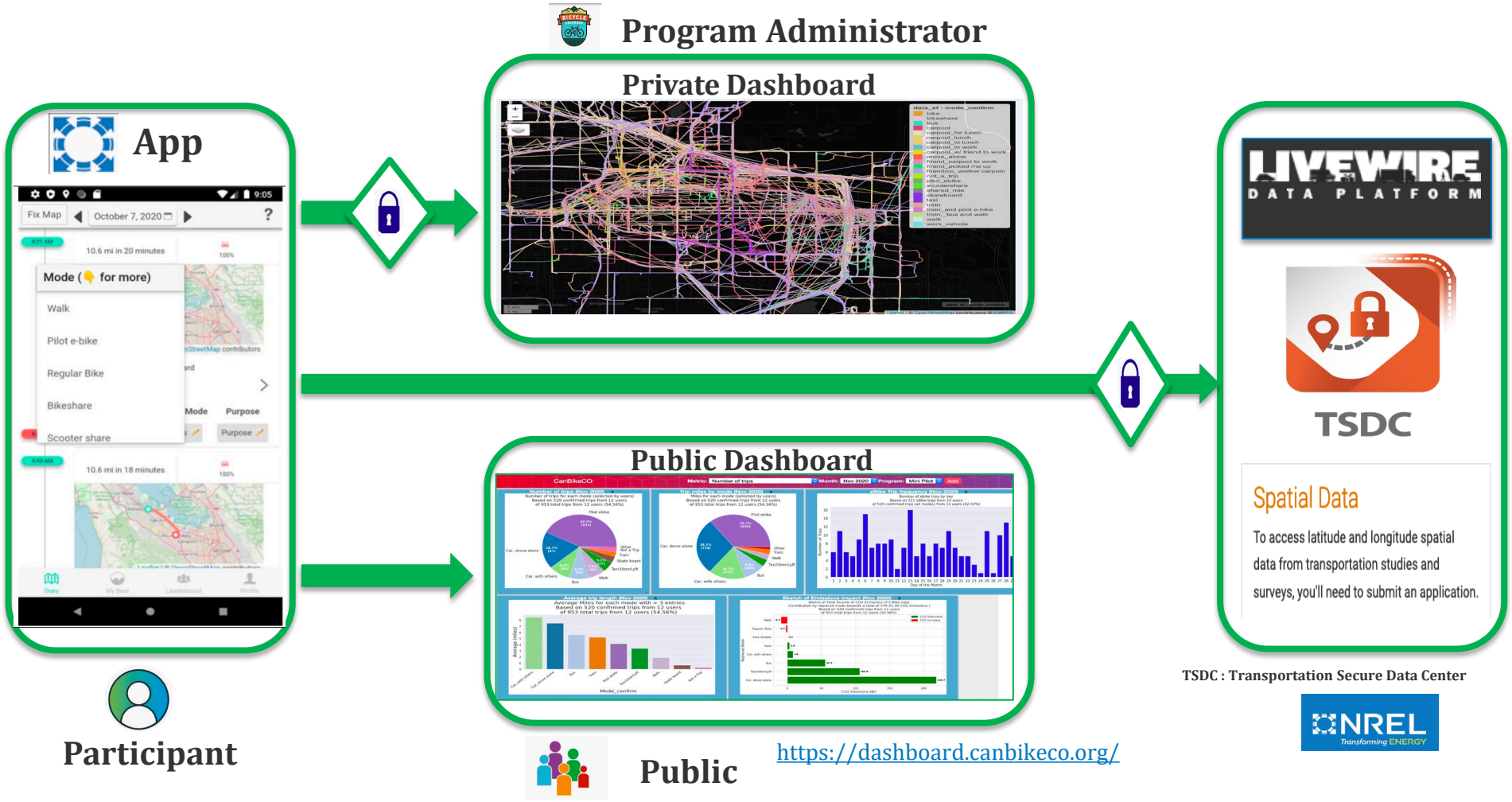
Supported through I-Corps in 2018

Approach: Transportation Technology Total Cost of Ownership (T3CO) Modeling Flow



MSRP = manufacturer's suggested retail price;
VMT = vehicle miles traveled

Approach: Instrumenting Human Mobility with OpenPATH



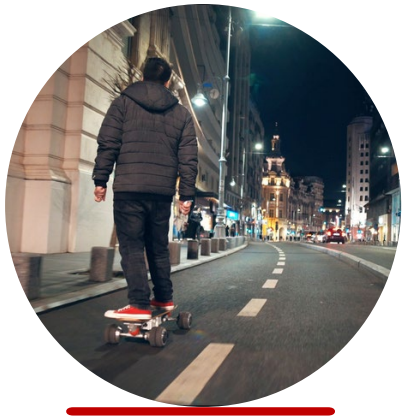
OpenPATH = Open Platform for Agile Trip Heuristics

Supported through I-Corps in 2021

Approach: OpenPATH Helps Include Underrepresented Groups in Analysis and Decision-Making

Speak through behavior

- Partner in communities
- Capture unusual hours and modes
- Provide for privacy and transparency



OpenPATH

"If you cannot measure it, you cannot improve it"

Alternatives fall short

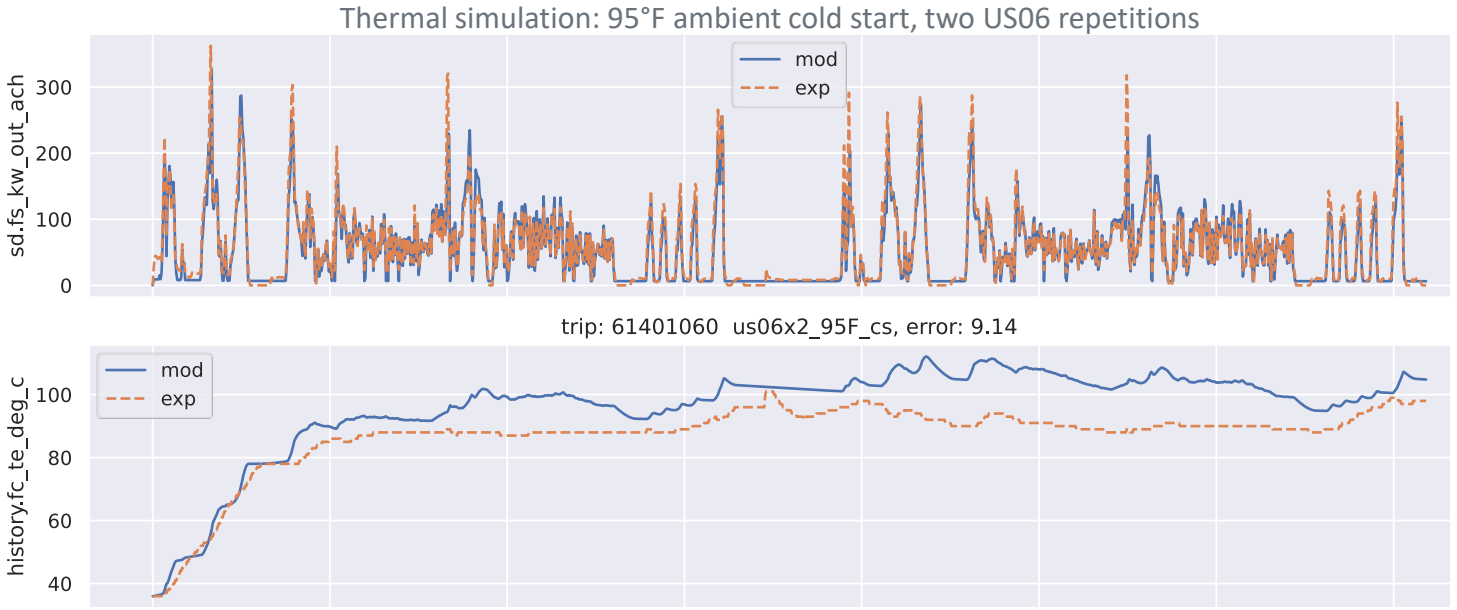
- City council and town hall meetings struggle to reach low-income residents
- Online surveys are overly simplistic and prone to reporting error

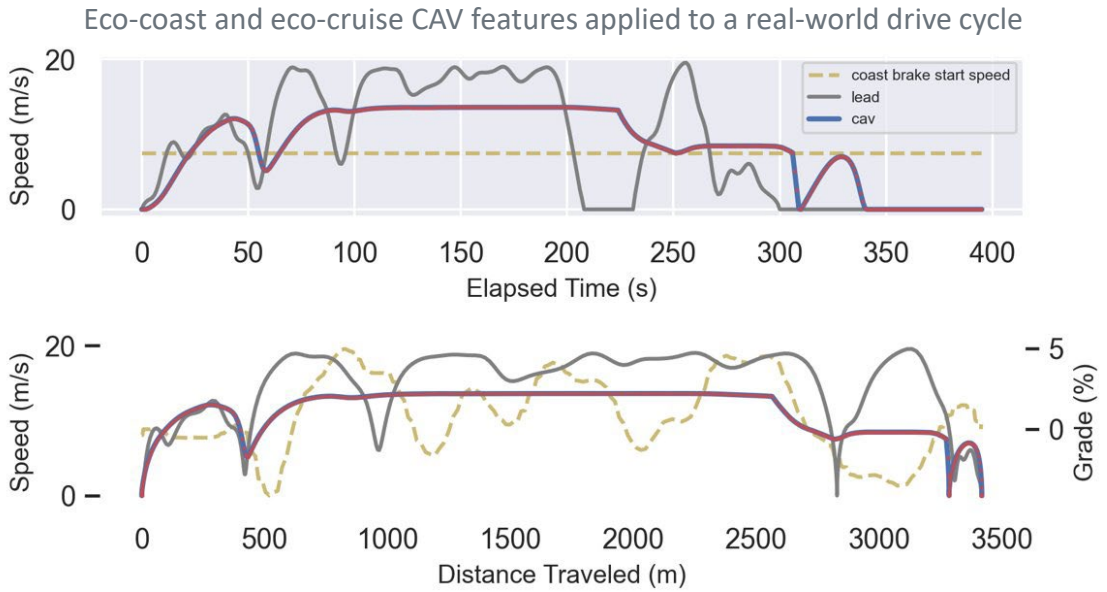
FY23 Milestones

Description	Due	Status
Prepare and submit draft RouteE validation report to DOE for review ahead of publication as a lab technical report	12/31/22	Complete
Prepare and submit one or more draft papers on OpenPATH enhancements and/or applications to DOE and publishing venue review	3/31/23	Complete
Complete initial version of all supporting components for the “Easy Button” NREL-hosted instance of OpenPATH—to include an admin dashboard in addition to the join page, core data collection, and public dashboard	3/31/23	Complete
Leverage improved automation of the FASTSim vehicle import process to complete a full update of the FASTSim base light-duty vehicle database, along with addition to medium- and heavy-duty vehicle modeling	6/30/22	On track
Complete update to T3CO, including streamlining use of FASTSim Rust and improving parameter, objective, and constraint handling to be more modular	9/30/22	On track

Tool Enhancement Accomplishments

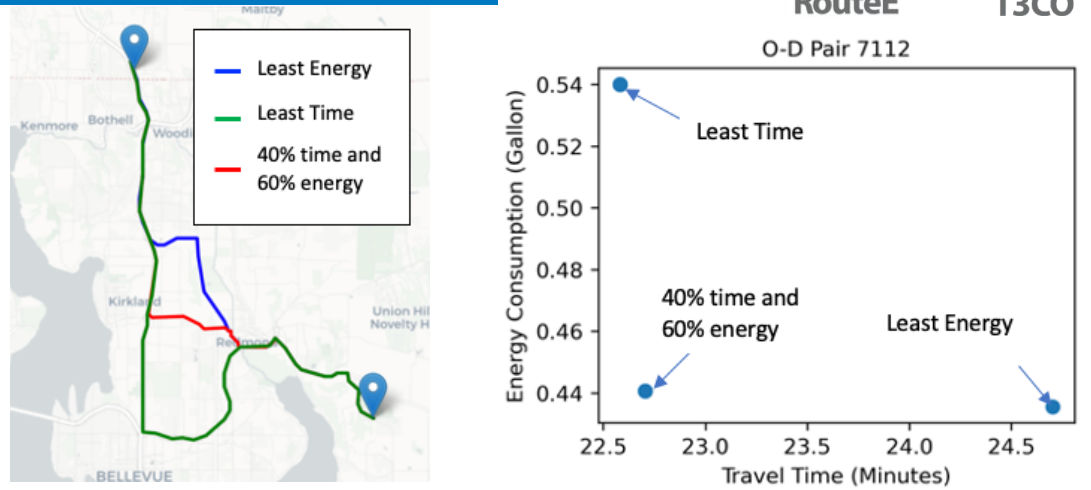
- **FASTSim**
  - Published updated validation report
  - Set up process for tracking FASTSim-supported publications; >140 identified so far
  - Implemented coding enhancements for further 10–100x speed improvement
  - Developed new thermally sensitive component models, enhancing analyses of temperature impacts on energy use
  - Integrated modules to capture impacts of different eco-driving feature implementations
  - Added multiple models to the vehicle database
  - Prototyped an import tool to facilitate adding numerous additional vehicle models
  - Expanded modeling to include 2-wheel vehicles
  - Refined scale deployment to support simulation and training of RouteE models for entire fleets of vehicles.



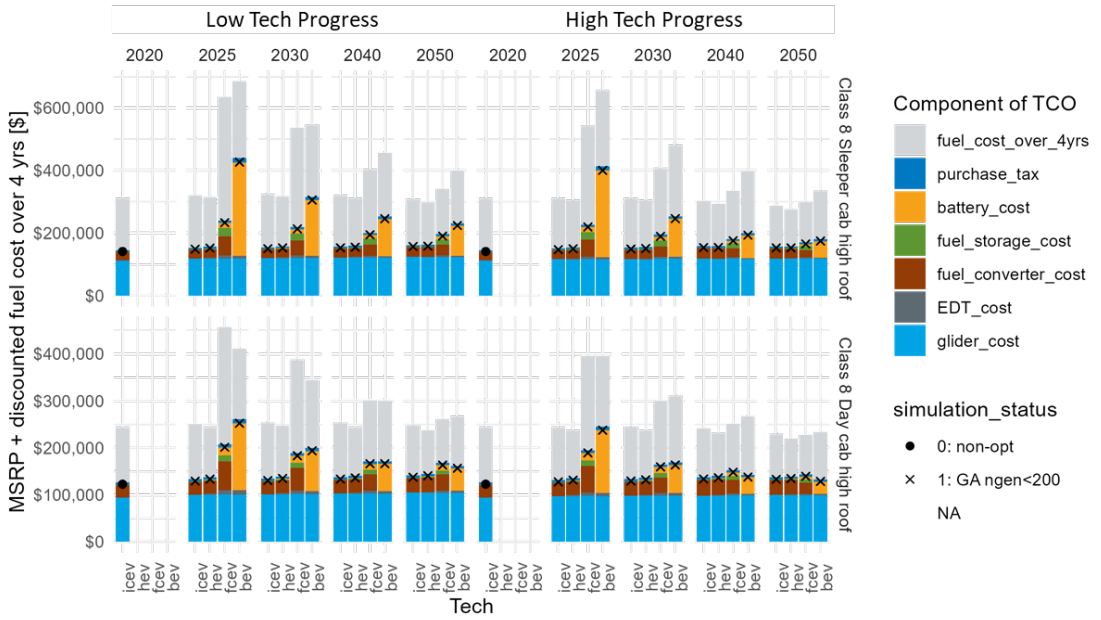


Tool Enhancement Accomplishments

- **RouteE**
  - Integrated composite weighting, enabling co-optimization of time and energy in RouteE-Compass
  - Added heavy-duty truck and transit bus models to the publicly available web API
  - Updated documentation and available demonstration notebooks
  - Drafted a RouteE validation report
  - Leveraging Wejo-connected car movements data as a scaled-up training data set—further improving model accuracy and robustness; also enables exploration of deep learning techniques that require larger training data.
- **T3CO**
  - Refactored to leverage FASTSim speed enhancements
  - Improved optimization methods, speed, and powertrain coverage
  - Implemented "sweep" functionality to analyze hundreds of vehicle/vocation scenarios
  - Added thorough methodology documentation
  - Developed payload capacity cost approach for medium-duty vehicles.



Sample RouteE output for an example origin-destination pair using different prioritization weighting between travel time and energy consumption

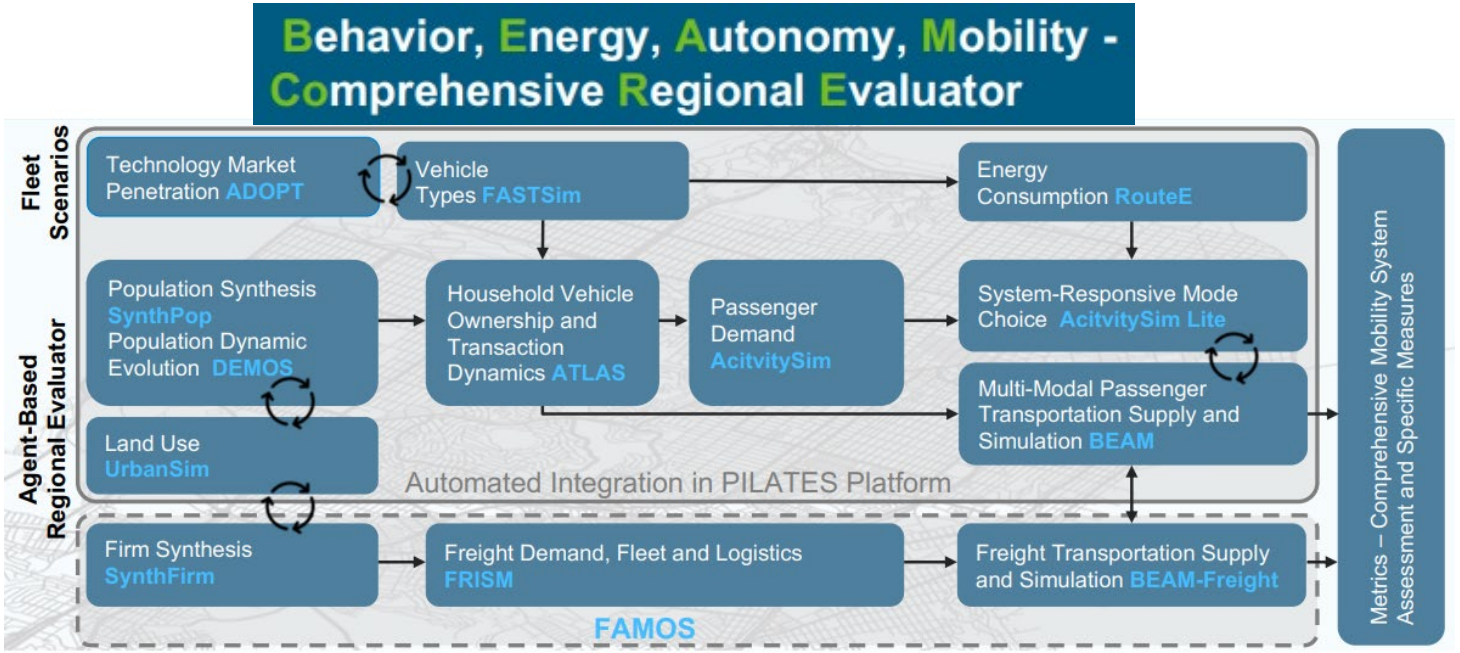


Sample output from the new T3CO sweep capability

Tool Application Accomplishments

FASTSim RouteE T3CO

- EEMS examples
  - BEAM CORE within SMART
  - Optimizing Regional Mobility
  - Big Data Solutions for Mobility
  - Transit Electrification
  - Co-Optimization of Vehicles and Routes.



- Broader VTO/DOE examples
  - Benefits/Transportation Decarbonization Analysis [+ADOPT speedup]
  - Transportation Energy Analytics Dashboard
  - Class 8 tractor & Class 4 delivery total cost of ownership analysis
  - Collaborations with 21CTP & SuperTruck 3.

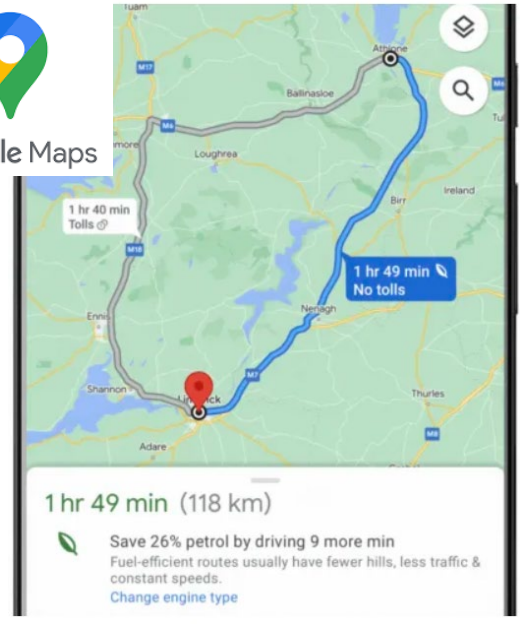
ADOPT

Spatial and Temporal Analysis of the Total Cost of Ownership for Class 8 Tractors and Class 4 Parcel Delivery Trucks

Tool Application Accomplishments

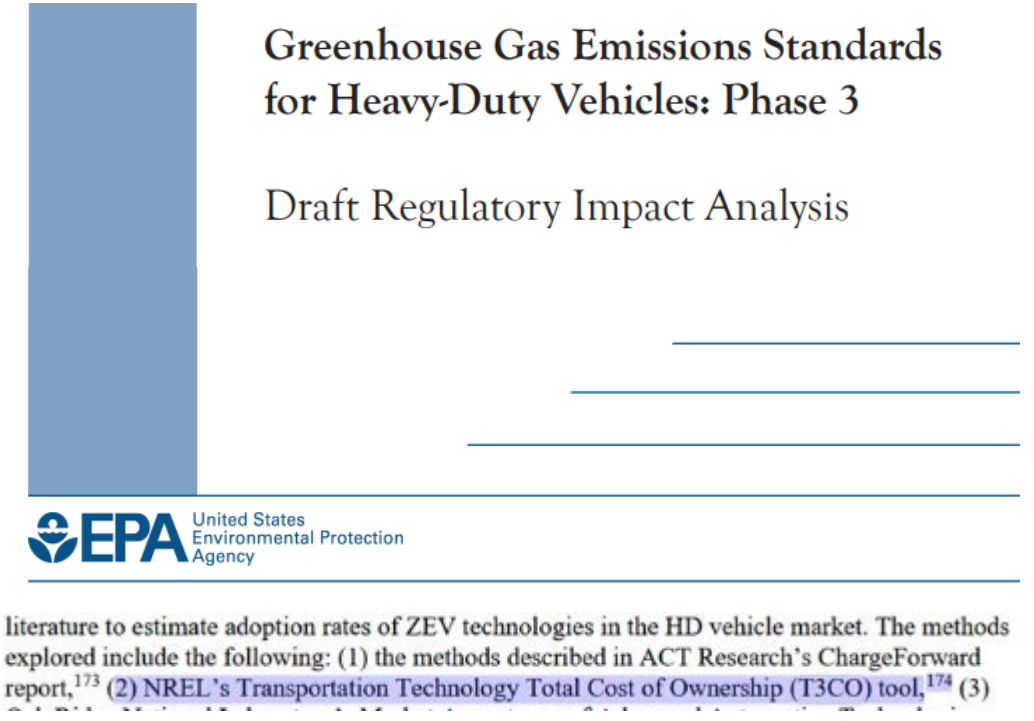
FASTSim RouteE T3CO

- Industry examples
  - Eco-routing (multiple)
  - Informing fleet electrification opportunities/strategy and GHG emissions standards
  - Off-cycle tech benefits evaluation
  - Large-scale analyses of info-rich controls, GHG emissions, and TCO scenarios.
- Thousands of FASTSim users from range of organizations
  - Growing base of active and interested users for each tool.



Google Maps eco-friendly directions are coming to 40 European countries

The feature, which launched in the US last fall, is getting a major expansion.



GHG = greenhouse gas emissions
TCO = total cost of ownership

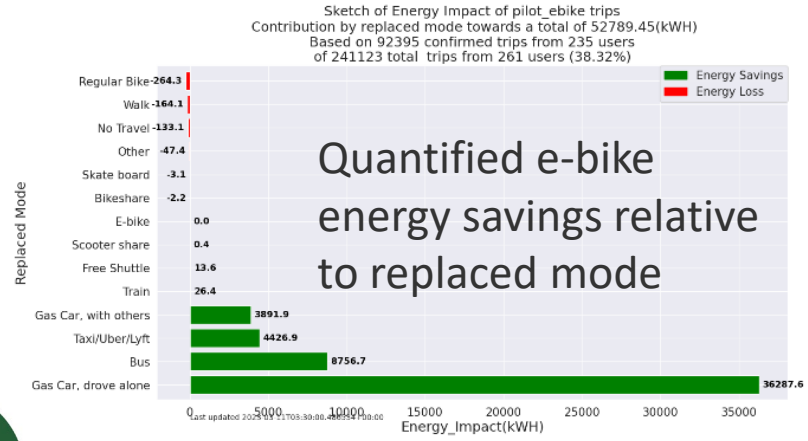
Tool Enhancement Accomplishments

- Facilitating deployment
  - Established NREL-hosted and configurable version of OpenPATH
  - Including NREL-branded smartphone apps in Apple and Google Play stores, plus an NREL-hosted public dashboard
  - Established workflow from MOU through deployment and ultimately to data integration into the TSDC/Livewire.
- Improving app features and user interface
  - Ensuring users accept all required phone settings
  - Improving ability to infer labels for trips
  - Providing a dashboard for carbon footprint calcs
  - Other user interface improvements such as color scheme, map interface, and faster responsiveness
  - Adding trip survey functionality such as time-use components to support activity-based modeling
  - Adding two-factor authentication plus enhanced visualization, export, and other admin dashboard features so admins can monitor their own programs.

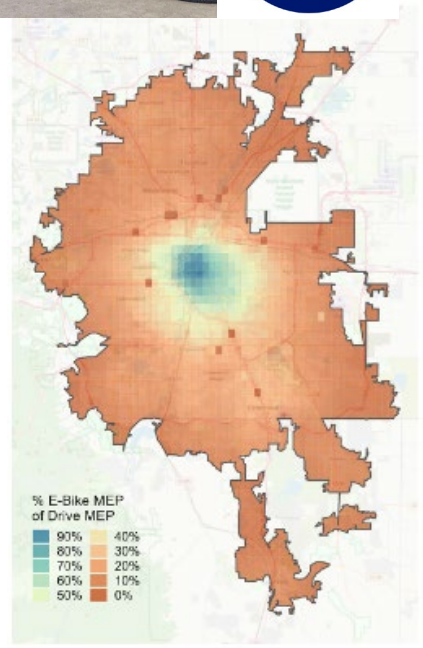
MOU = memorandum of understanding

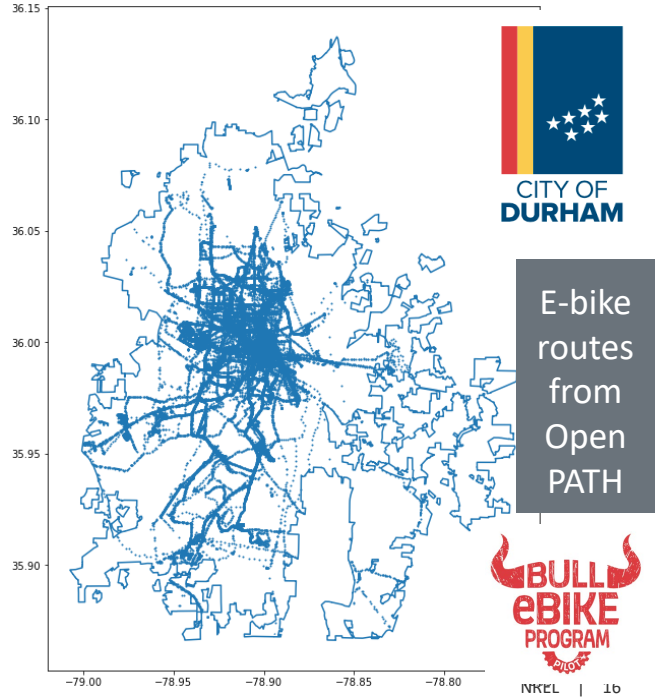
Tool Application Accomplishments: Many Related to E-bikes

- Colorado Energy Office (CEO) next round of the low-income e-bike pilot
- Denver, CO, and New Haven, CT, cited OpenPATH data in designing rebate programs
  - Collaborating with Denver CASR and customizing OpenPATH for evaluating program
- Data collection in Durham, NC, informing proposed bike infrastructure expansion
- SMART Mobility MITIE project leveraging data for energy and mobility analyses
- Agreement with Vail, CO, to evaluate both shared and ownership micromobility
- New study agreements (in NC, MA, WY, and more).



Quantified e-bike energy savings relative to replaced mode





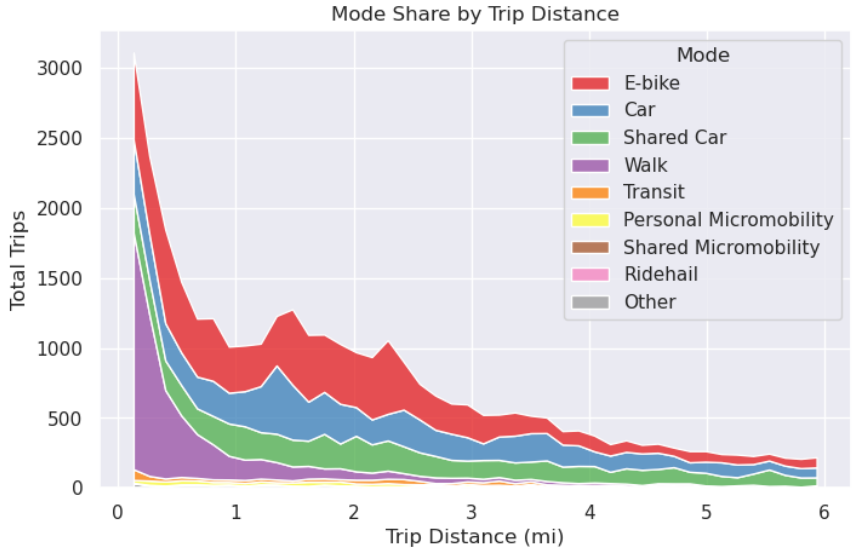
E-bike routes from Open PATH

CASR = Climate Action, Sustainability & Resiliency
MITIE = Micromobility-Integrated Transit & Infrastructure for Efficiency

Tool Application Accomplishments: For Other Modes, in U.S. and Internationally

OpenPATH

- Capture all user travel modes
- Puerto Rico collaborations
  - On-demand transit project baseline data
  - Congestion reduction project to discourage driving alone
- Sacramento, CA, to partner on mode shift and VMT reduction evaluation
- Laos interested in OpenPATH for travel survey data collection to inform electric vehicle infrastructure planning with EVI-Pro.



Responses to Previous Year Reviewers' Comments

- Minor request for further detail on objectives/expected impacts to overcome barriers

Added text to the Objectives & Relevance slide to address this

- Commended for what was shown so far after just starting the project

Thank you!

- Flesh out the Collaboration and Coordination slides to explicitly show connections of activities for each tool mapped to work and coordination plans with key collaborators

Built out the pair of Collaboration and Coordination slides that follow to address this

- Good future work plans covering both technical aspects and potential engagement activities aligned with the project objectives

Thank you!

Collaboration and Coordination

Numerous examples noted in application accomplishment slides; highlighting several:

	Project Activities		Benefit to Various Collaborations
FASTSim	Validated energy estimation for expanded applications	→	Quantifying energy impacts and strategies for maximum impact
FASTSim	Thermal capability enhancements	→	Support for industry off-cycle benefits analyses and implementations
RouteE	Expanded vehicle coverage and composite weighting enhancements	→	Multiple energy-saving eco-routing and electrification opportunity analysis applications
T3CO	Tool speed and coverage enhancements	→	Improved TCO analysis support for EPA, 21CTP, and under SuperTruck3

U.S. DEPARTMENT OF ENERGY SMARTMOBILITY Systems and Modeling for Accelerated Research in Transportation

AI HPC BIG DATA

2023-01-0942 Published 11 Apr 2023

Assessing the National Off-Cycle Benefits of 2-Layer HVAC Technology Using Dynamometer Testing and a National Simulation Framework

Google Maps

Bus Electrification

CoVAR

EPA United States Environmental Protection Agency

21st CENTURY TRUCK PARTNERSHIP℠

Posted FASTSim versions also independently leveraged by thousands of users

Collaboration and Coordination

Numerous examples noted in application accomplishment slides; highlighting several:

Project Activities	Benefit to Various Collaborations
NREL-hosting + app improvements	Facilitates deployment partnering
Enabling data collection/ revealed travel behavior and preferences + Publication of data analyses and findings	Inform strategies for incentives and investments to advance sustainable and equitable mobility goals

OpenPATH

Additionally archiving data via the Transportation Secure Data Center and Livewire

TSDC

LIVEWIRE DATA PLATFORM

COLORADO Energy Office

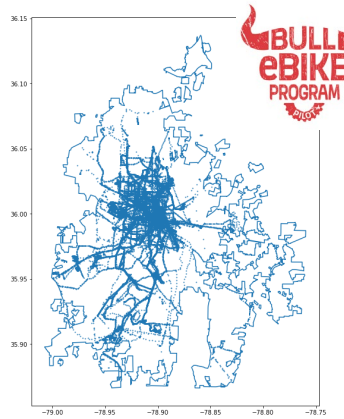
MASSACHUSETTS CLEAN ENERGY CENTER

RECINTO UNIVERSITARIO DE MAYAGÜEZ · UNIVERSIDAD DE PUERTO RICO · CAAM

DENVER THE MILE HIGH CITY

CITY OF DURHAM

BULL eBIKE PROGRAM



Remaining Challenges/Barriers → Proposed Future Work

- Further updating needed to have latest model year vehicles represented → FY22 milestone to update full FASTSim base light-duty vehicle database plus add additional medium- and heavy-duty models.
- Expand reach of the further FASTSim speed improvements from code refactoring → connect user interface to refactored code and update public posting.
- Continue increasing confidence in the tools → complete publication of RouteE validation paper as a lab technical report.
- External accessibility of RouteE and T3CO modeling → leverage FASTSim updates to further expand number of models available through the web API, plus explore options for open sourcing or packaging for streamlined closed-source license deployment.
- Now that initial version of OpenPATH "easy button" components implemented, need to address enhancement requests from partners → prioritize and implement enhancements such as automated, anonymized spatial visualization in the public dashboard to see where people are riding their bikes.
- Partnering critical to maximize impacts → build upon current successes by establishing new collaborative applications for the tools.

Any proposed future work is subject to change based on funding levels.

Summary

- Project providing maintenance, updates, and enhancements to core capabilities supporting numerous EEMS/DOE and external efforts
- Tools plus data and research outputs made externally accessible
- Overall helping to advance transportation efficiency, emissions reductions, and equitable mobility improvements.

www.nrel.gov/fastsim

www.nrel.gov/routee

www.nrel.gov/t3co

www.nrel.gov/openpath

www.nrel.gov/tsdc

livewire.energy.gov

Thank You

www.nrel.gov

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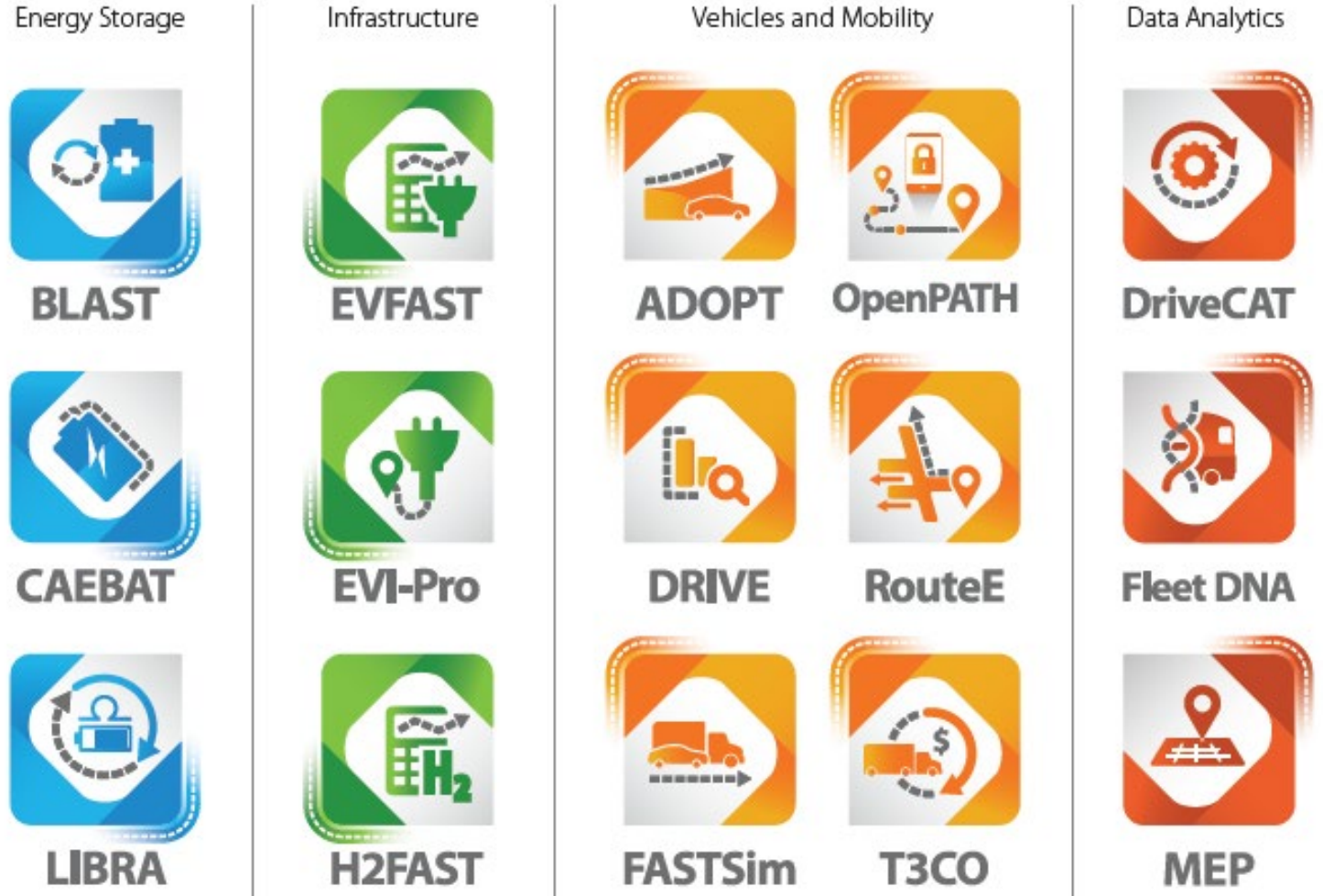
Technical Backup Slides

Further NREL Transportation Data and Tool Resources

Supporting a wide range of transportation-related topics



See:

www.nrel.gov/transportation/data-tools.html

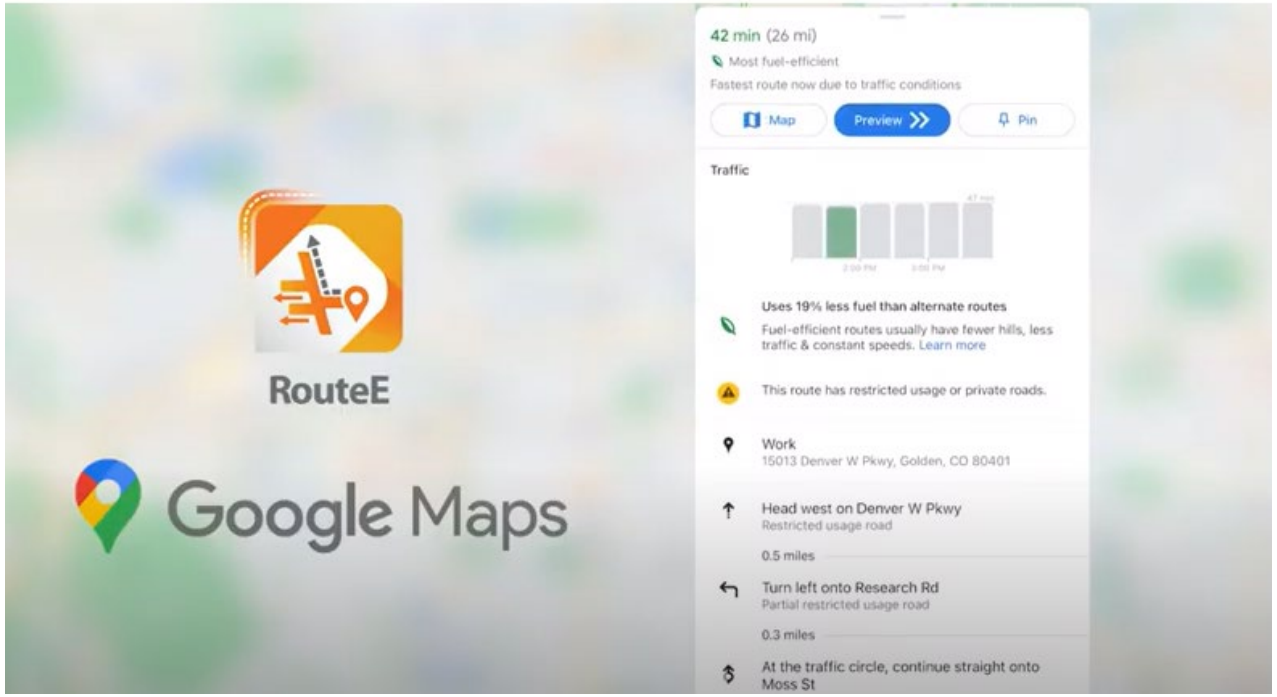
FY22 Milestones

Description	Due	Status
Hold project kickoff meetings with DOE.	12/31/21	Complete
Update/refactor the OpenPATH CO_2 dashboard to include data from user labels.	3/31/22	Complete
Complete priority FASTSim maintenance/updates, such as cleaning up the motor and fuel converter efficiency map interface and preparing added thermal features for public release—including thermally sensitive powertrain models with an automated validation process and data for a conventional vehicle.	6/30/22	Complete
Complete updated integration and analysis of user-optimal eco-routing algorithms for multiple powertrain types in RouteE.	9/30/22	Complete
Complete priority T3CO updates, such as simulation speed up, improving optimization method options, adding unit testing, expanding spatial features, and creating documentation.	9/30/22	Complete

Further Details on Eco-Friendly Routing Collaboration with Google Maps

FASTSim RouteE

[Video describing RouteE and the Google Maps collaboration]



- Announcement of U.S. launch, with estimate of saving >1 million tons of carbon emissions per year, equivalent of removing 200,000 cars from the road.
- Paper on Google Maps Eco-Friendly Routing highlighting further details on the use of FASTSim and RouteE and the expectation to eventually reach 1 billion users.
- Announcement of expansion to Europe in 2022.
- Related, RouteE was recognized as an R&D 100 Award Finalist in 2022.
- Lots of mentions in the popular press, including by The New York Times and Fortune magazine.