JUNE 14, 2023

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

METRICS FOR ASSESSING THE IMPACTS OF ENERGY-EFFICIENT MOBILITY SYSTEMS

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DOE Vehicle Technologies Office
2023 Vehicle Technologies Office Annual Merit Review

Project ID# eems099

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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OVERVIEW

Timeline

- Project start date: 10/1/2020
- Project end date: 09/30/2023
- Percent complete: 80%

Budget

- Total project funding: NREL (LBNL)
  - DOE share: **$1.81M ($290K)**
  - Contractor share: $0
- Funding for FY22: $585K ($60K)
- Funding for FY23: $525K ($50K)
- Funding received so far in FY23: $260K ($35K)

Barriers

- Lack of **open and practical metrics** to quantify energy productivity of mobility.
- Need for new tools and core capabilities to **accurately measure the transportation system-wide energy impacts** of new mobility technologies.

Partners

- SMART Mobility Laboratory Consortium
  - Lawrence Berkeley National Laboratory (LBNL)
  - Argonne National Laboratory (ANL)
- American Council for an Energy-Efficient Economy (ACEEE)
- Delaware Department of Transportation (DDOT)
- Colorado Department of Transportation (CDOT)
- Florida International University (FIU)

RELEVANCE

MEP is Being Leveraged for Research and Deployment within and Outside DOE

While the relevance of the Mobility Energy Productivity (MEP) metric has already been established through SMART 1.0 research activities, it is corroborated by its applications across a variety of entities in SMART 2.0.

- SMART 1.0 (Initial Development) ➔ SMART 2.0 (Enhancement and Robust Implementation)

CORE Metric for **DOE-EEMS** research:

- MEP metric will help in decisions regarding billions of dollars of infrastructure investment

Independent **DOT** Collaborations

- Exploring potential commercialization for use by local and state agencies

Partnering with **Industry** (Street Light Data)

- ACEEE to include MEP metric in their clean energy scorecard

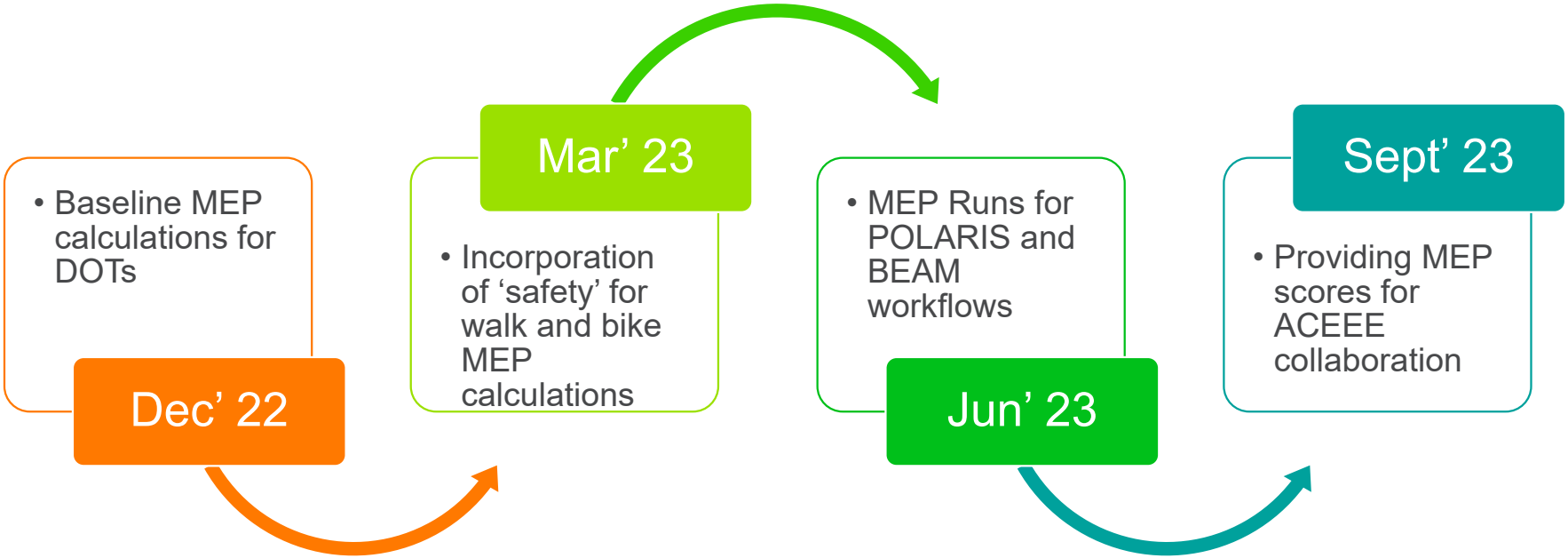
Partnering with **Non-profit** Organizations

MILESTONES

Month/Year	Description of Milestone or Go/No-Go Decision	Status
June 2022	Document alternative default synthesis methods for the output of the individual-level metric	Complete
September 2022	Implementation of an automated Socio-demographic-incorporated MEP calculation for POLARIS and BEAM workflows	Complete
September 2022	Finish baseline MEP calculations using outputs of DelDOT travel demand model	Complete
March 2023	Demonstrate the impact of adding ‘safety’ as an additional factor in MEP calculations.	Complete
June 2023	Demonstrate the benefit of multimodal routing feature in MEP calculations through illustrative scenarios.	On-track
June 2023	Final report for Task 2.2 summarizing the final method and illustrative results of the INEXUS	On-track
August 2023	Summarize bike and transit scenario analysis results from DOT projects.	On-track
September 2023	Compute MEP scores for cities identified by ACEEE.	On-track

APPROACH

Project Timeline for FY23



APPROACH

E-bike Impacts on the MEP Scores of Low-income Essential Workers

- NREL partnered with the Colorado Energy Office (CEO) starting in 2020 to execute a pilot program where e-bikes and equipment were distributed to low-income essential workers in Colorado (CEO, 2021).

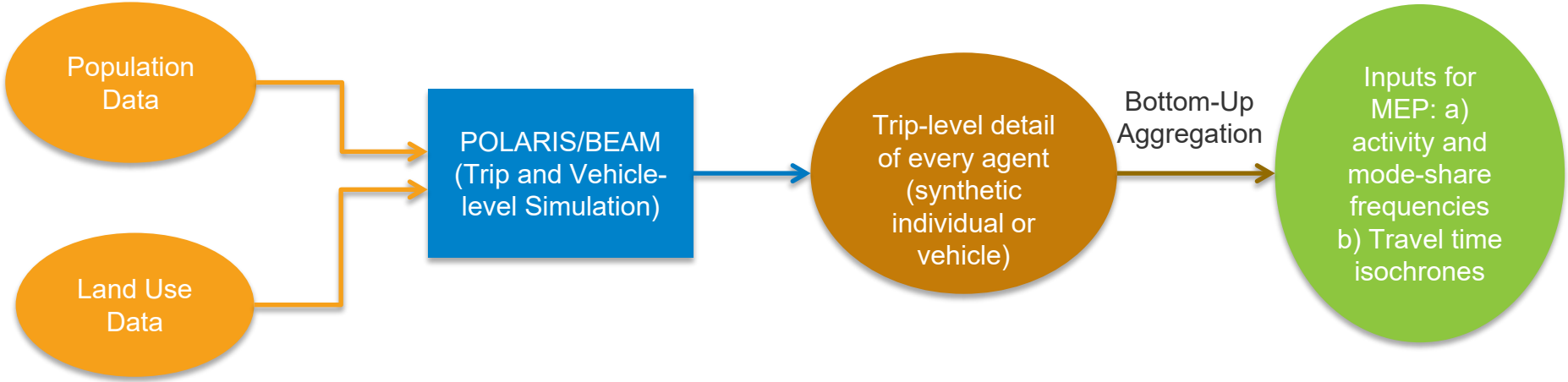
- We utilize data collected across all pilots' participants for the travel period of May 2021 to May 2022 for analysis and integration with the MEP metric.

Mode	Trips	Unique uses	Mean trip distance	Mean trip duration	Mean speed (mph)
Drive	25,708	194	6.1 mi	24 min	22
E-bike	14,177	155	2.7 mi	24 min	9.9
Bike	1,563	82	2.5 mi	23 min	7.4
Walk	8,018	159	0.84 mi	26 min	3.0

APPROACH

Estimating SD-MEP Inputs from POLARIS and BEAM Model Outputs

- **POLARIS and BEAM** models simulate travel at the level of each (synthetic) individual for a given study region (Chicago Metro for POLARIS and San Francisco Bay Area for BEAM)
- MEP activity and mode-share inputs estimated from POLARIS/BEAM output by bottom-up aggregation
- Aggregation methodology allows estimation of activity and mode-share frequencies for total population, as well as different socio-demographic groups.



APPROACH

INEXUS Agent-Trip Accessibility Metrics

INEXUS Suite of Metrics
***In**dividual **ex**perienced **u**tility-based **s**ynthesis*

Potential INEXUS
Captures the full utility of modal options available to the individual

Realized INEXUS
Measures the utility experienced by the agent for the mode they actually chose

Social INEXUS
Measures the utility experienced by and the externalities associated with the agent for the mode chosen

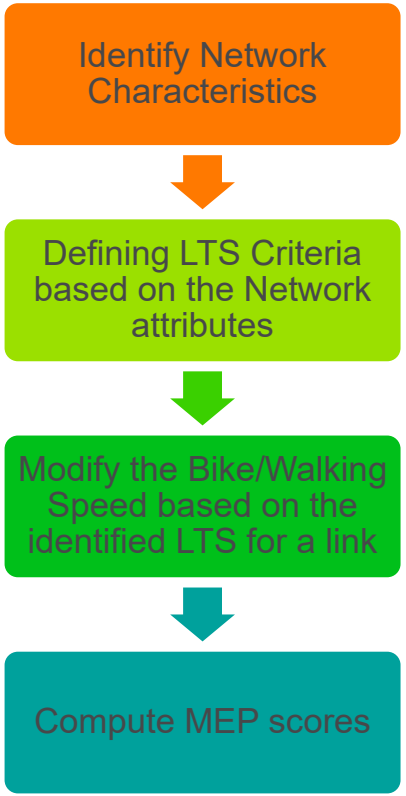
- High-resolution agent-based modeling frameworks are powerful tools for exploring alternative transportation system policy, design, and technology deployment scenarios.
- Gaining multi-faceted insights from these scenario outcomes requires a range of innovative ways of processing the results, including development of informative metrics.
- We demonstrate an example of this using a sensitivity analysis in the BEAM CORE integrated agent-based modeling framework:
  - price of ride-hailing is varied from 0% to 800% of the baseline.
  - This makes a flexible backup option more or less affordable and accessible.

APPROACH

Incorporating Safety in MEP Calculations

Level of traffic stress (LTS) is an approach that quantifies the amount of discomfort that people feel when they bicycle close to traffic.

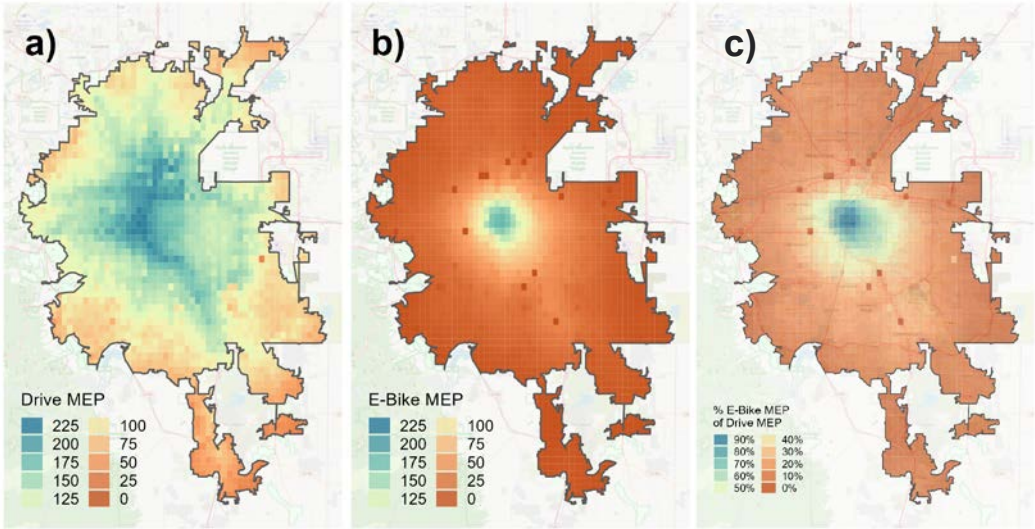
Speed Limit	Width of Street Being Crossed		
	Up to 3 lanes	4-5 lanes	6+ lanes
Up to 25 mph	LTS 1	LTS 2	LTS 4
30 mph	LTS 1	LTS 2	LTS 4
35 mph	LTS 2	LTS 3	LTS 4
40 + mph	LTS 3	LTS 4	LTS 4



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

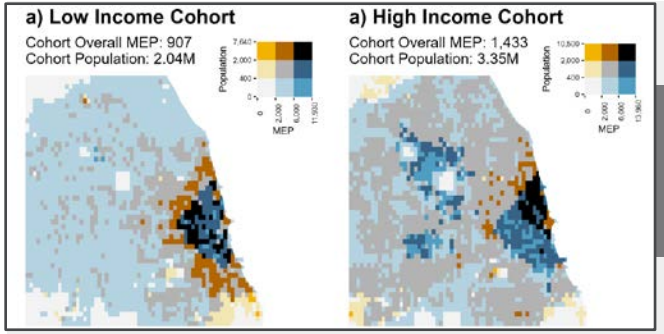
E-BIKES Improve Efficient access

Taking the energy, cost, and speed tradeoffs of e-bikes and cars into account, it was found that **personal e-bikes can provide access that is comparable to cars** in some areas (~9% of the cities population or 4% of its area) in Denver



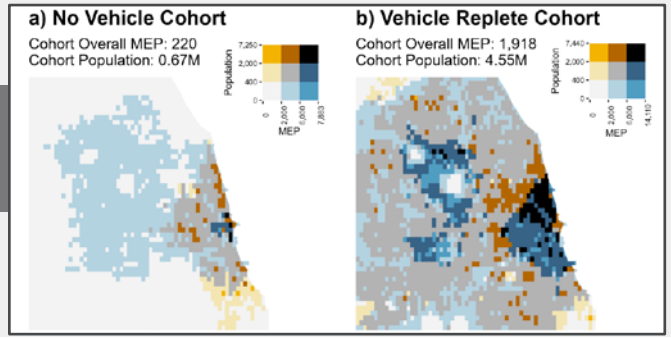
TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Vehicle Ownership Has an outsized impact on time, energy, and cost-efficient accessibility



Low-Income:
Household Annual Income < $36.9K

High-Income:
Household Annual Income ≥ $83K

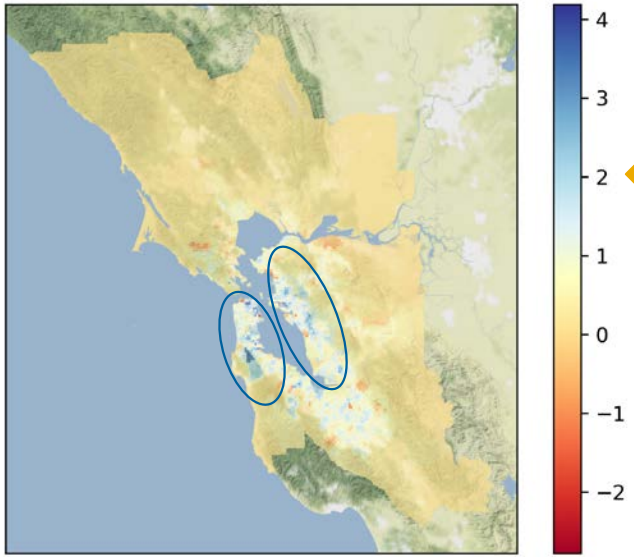


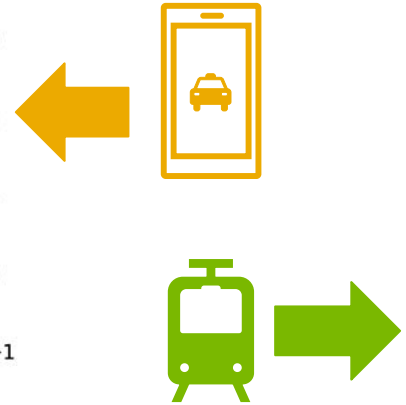
Vehicle-replete:
Number of drivers (age 16+) >=
Number of vehicles in household

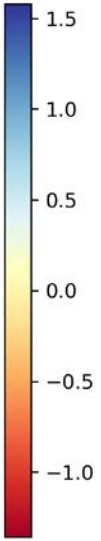
The spatial disparity in locations with high MEP scores vs. places of residence **was stark for vehicle-ownership based cohorts compared income-based cohorts.**

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Ridehail pricing and transit enhancement scenarios for SF Bay Region







Ride hail $: 2.24 ➔ 2.08/pax-mile
Ride hail MEP: 3,174 ➔ 3,954 (25%↑)

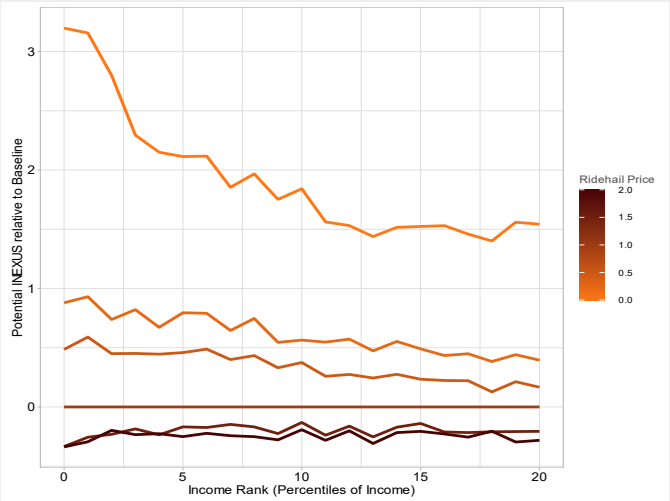
Transit enhancements: SF downtown
Transit MEP: 135 ➔ 206 (52%↑)

TECHNICAL ACCOMPLISHMENTS

Potential INEXUS Can highlight inequities in the baseline transportation system

- A multitude of factors (residence location, mode availability, budget constraints, vehicle ownership, etc.) contribute to systematic inequities in the current transportation system.
  - Potential INEXUS for mandatory trips for highest income travelers is 16% higher than for lowest income travelers.
- Moving from baseline price to no-cost ridehail results in a 44% improvement in the median Potential INEXUS for the lowest income group compared to a 13% improvement for the highest income group.

Distribution of Potential INEXUS across ridehail price scenarios by the income of travelers

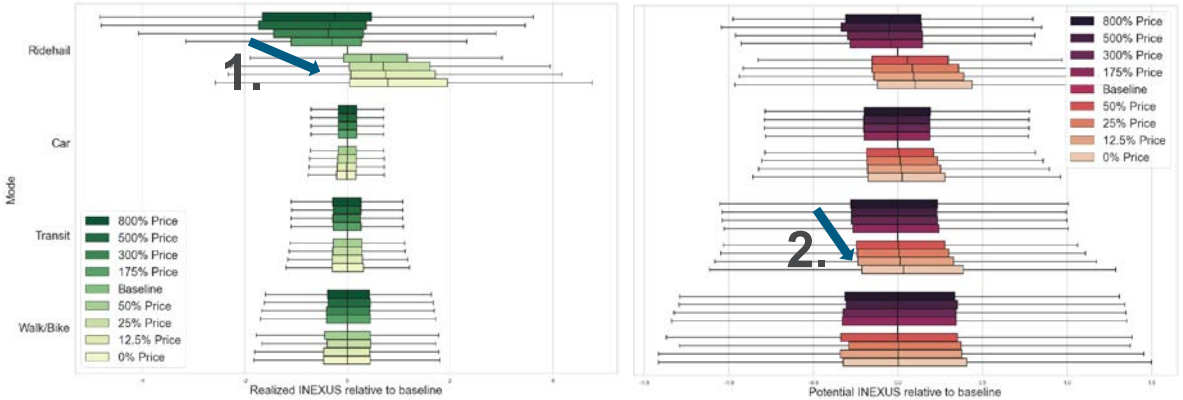


TECHNICAL ACCOMPLISHMENTS

INEXUS can capture a range of Potential benefits from a system change even without behavior change

- **Freeride direct benefit:** travelers that use ridehail in both the baseline and the lower ridehail price scenario receive benefits without any induced behavior change
- **Backup option indirect benefit:** some travelers that don't reoptimize are still better off because they have a more appealing backup option available

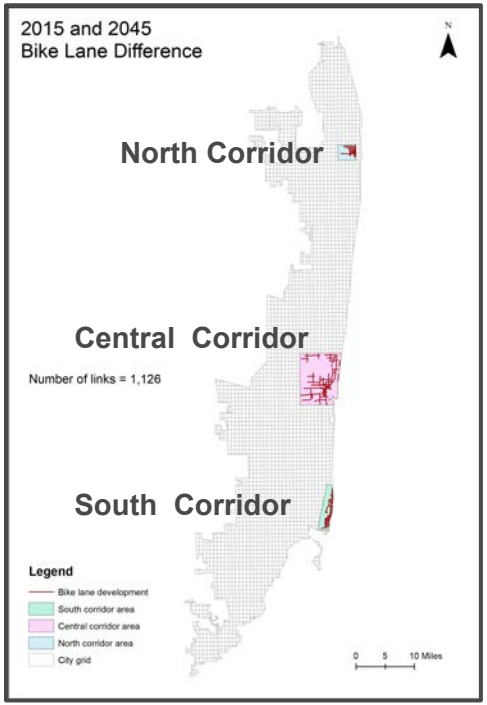
REALIZED INEXUS | **POTENTIAL INEXUS**

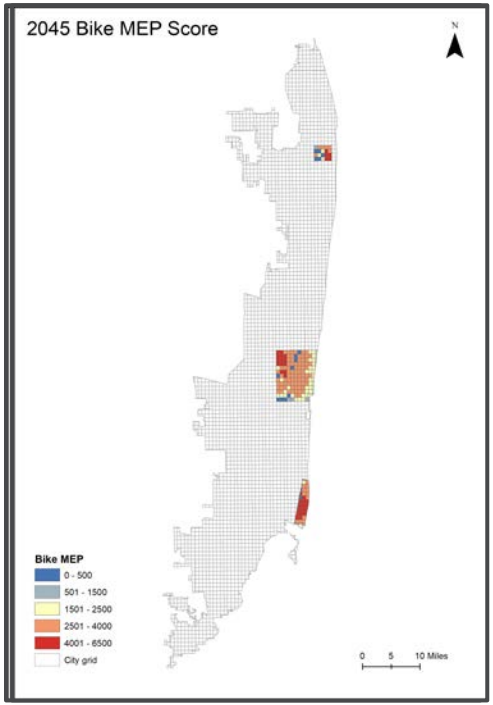


Realized and Potential INEXUS for travelers who **do not change** their mode from the baseline

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

MEP utilized to Prioritize Bike Infrastructure Investments in Miami, FL

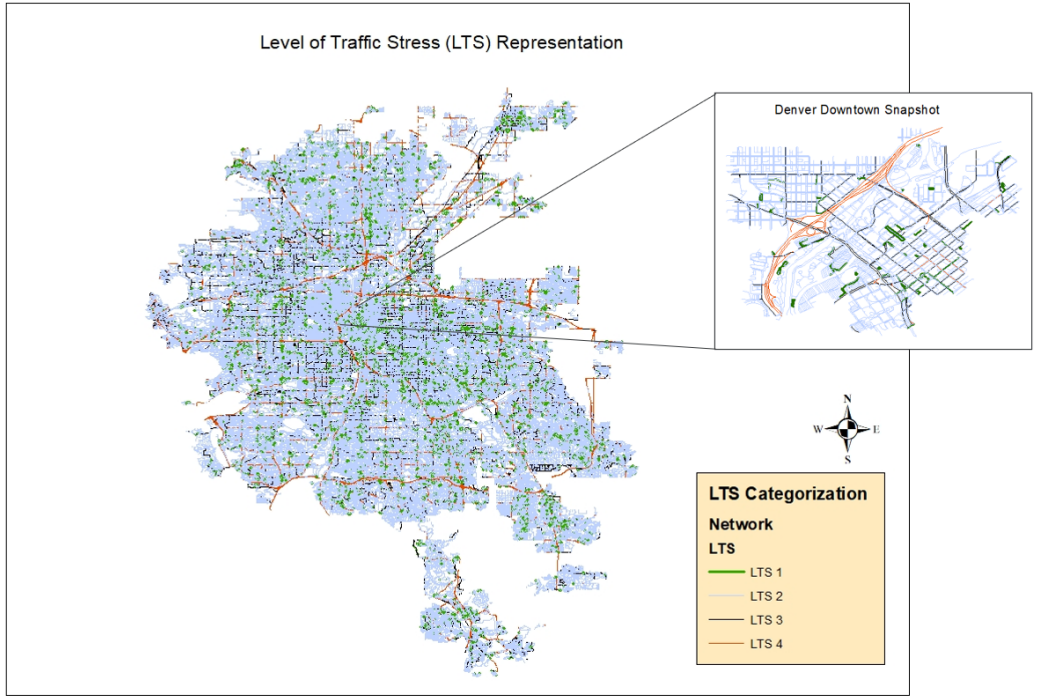




Corridor	2015 Opportunity Count per Grid/Total Lane Miles*	2045 Opportunity Count per Grid/Total Lane Miles	Opportunity Increment/ Lane-Mile
North	68,590/10	88,987/44	1,233
Central	68,044/114	112,470/260	304
South	52267/26	70,585/85	312

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Incorporation of Safety in MEP calculations



LTS incorporation will increase behavioral realism in MEP calculations

RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

Question 1: Approach to Performing the Work.

Reviewer 1: The person-based Individual Experienced Utility-based Synthesis (INEXUS) metric is an interesting concept and is intended to complement the location-based MEP metric. There are three related but different types of INEXUS metrics. It will be important to clearly explain the purpose and interpretation of these different INEXUS values.

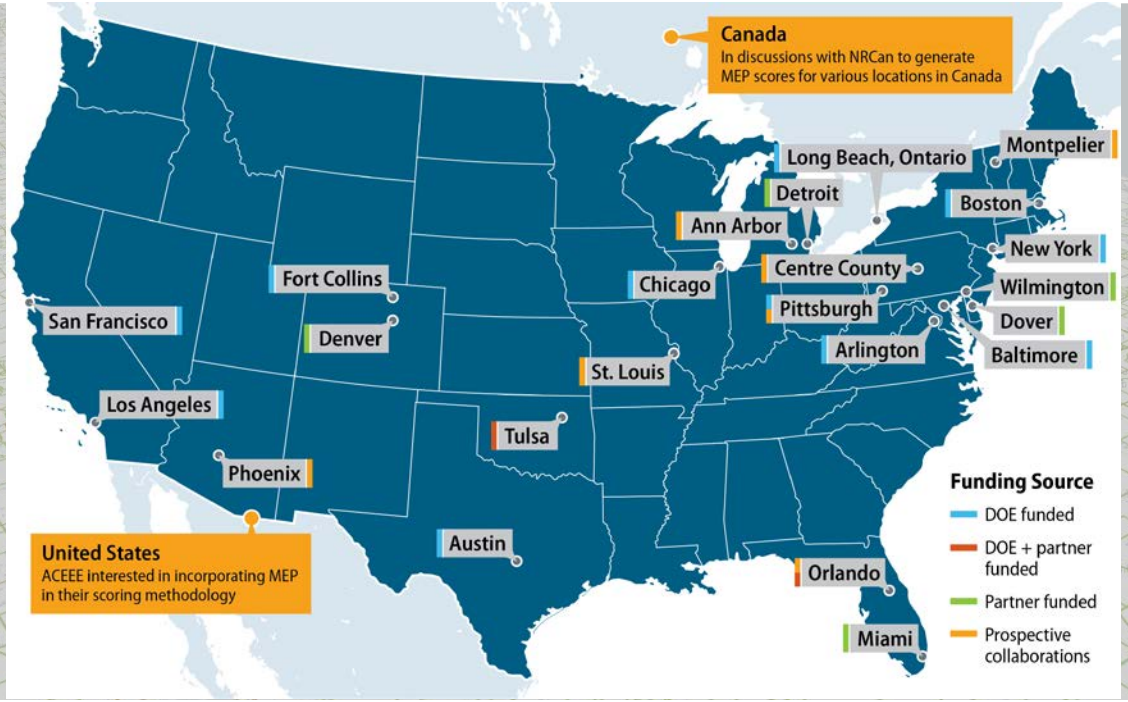
AS: Thanks for the comments. The team has made significant progress on the INEXUS metric since last AMR including presenting INEXUS at the 2022 TRB annual meeting. The LBNL team is currently in the process of finalizing a journal article that articulates the differences between these three variations of the INEXUS metric. Sample results on potential and realized INEXUS are included in this year's AMR slides with more explanation on the metrics as well as interpretation of the results.

Reviewer 2: This area is so important that getting in-depth technical review by outsiders should be part of the activity. Part of the plan that may be missing is to dumb down some of the technical presentations to more clearly explain critical relationships that are included in the work. Does the project produce technical papers to explain the processes and cost functions that are being applied?

VG: Excellent point. Increasing interpretability of the metric is an aspect that the team has also identified as an important next step for the metric. A few activities have already been undertaken to this effect. A description of the MEP metric has been included in the 2021 ACEEE scorecard and sent out for feedback to ~100 cities across the US. The MEP team is also getting feedback on the metric from our DOT collaborators engaging on integrating the MEP metric into their transportation planning processes.

COLLABORATIONS AND COORDINATION WITH OTHER INSTITUTIONS

- SMART Mobility Consortium Laboratory Partners: LBNL and ANL.



REMAINING CHALLENGES AND BARRIERS

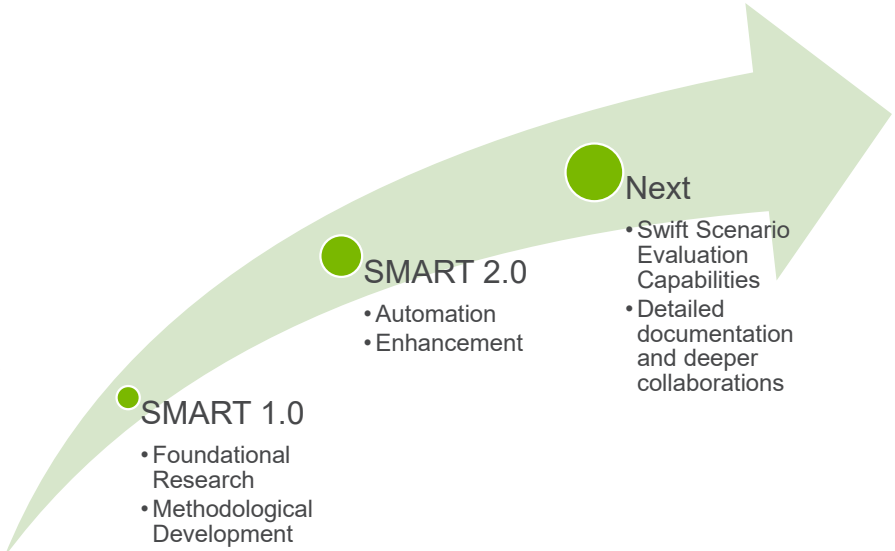
- Lowering the threshold for adoption and use of the MEP tool and metric
- Switching to open-source datasets to compute MEP scores for any location
- Scaling the MEP calculations to the national level
- Standardizing data i/o to facilitate in-depth collaborations with transportation planning agencies
- Deploying a clou-based MEP calculation that anyone can use

PROPOSED FUTURE RESEARCH

Leveraging data from OpenStreetMap to standardize MEP calculations

Producing a MEP scorecard for each city

Path-based MEP calculations



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

SUMMARY

- **Objective**: Build on the current strengths of the MEP metric and enhance its capabilities to answer a wider range of questions associated with emerging transportation alternatives.
- **Efforts** in FY23 focused on:
  - Finalizing multimodal routing methodology
  - Moving from MEP 1.0 to MEP 2.0 (16x faster run times)
  - Strengthening DOT collaborations
  - Final version of the MEP visualization dashboard
- **Future efforts** will aim at:
  - Increasing interpretability of the metric
  - Lowering the threshold for adoption (envisioning three tiers of partnership)

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

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

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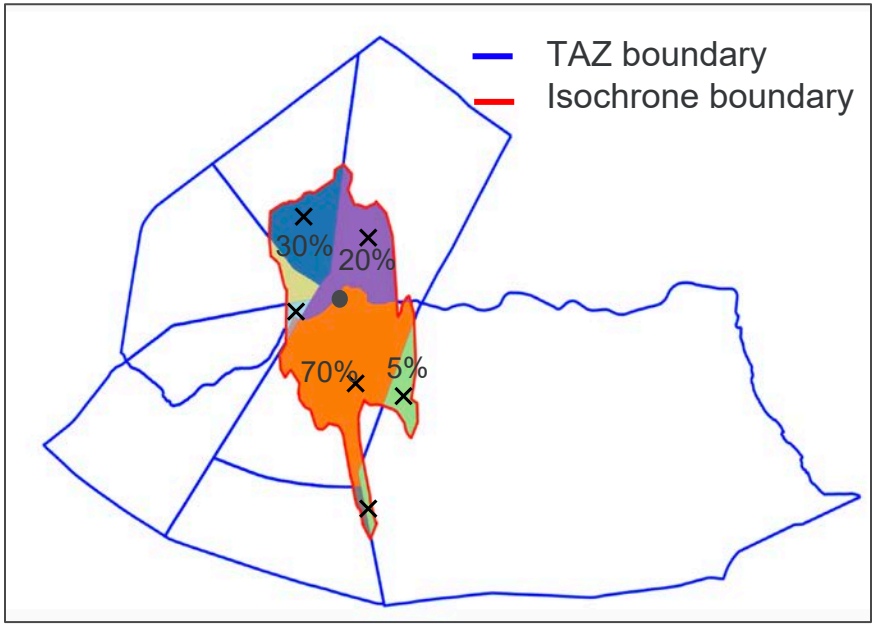
TECHNICAL BACKUP SLIDES

APPROACH

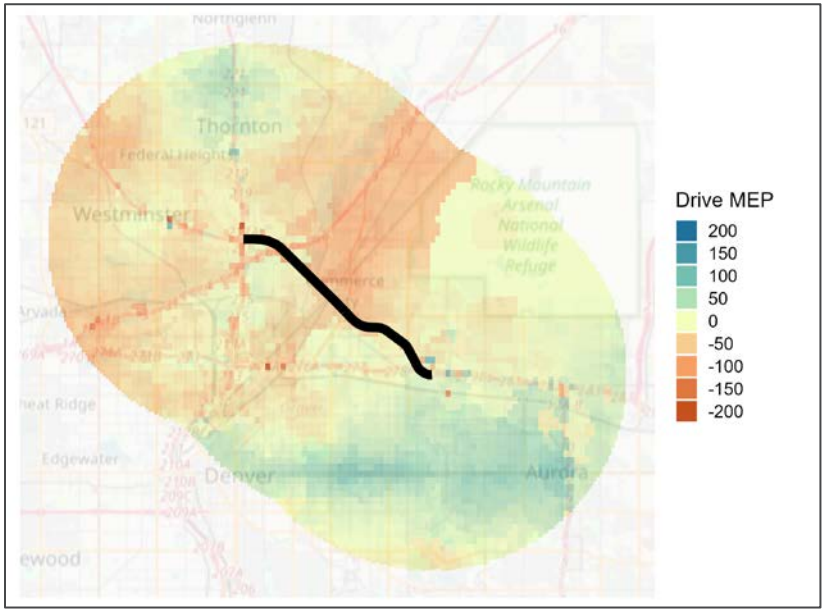
DOT Collaborations

- NREL Team worked with Colorado, Florida, and Delaware departments of transportation (DOT) to integrate the MEP calculation process into transportation planning process for each of the DOTs.
- As a part of these collaborations, the NREL team had to modify the MEP calculation process to work with (aggregate and non-standard) data formats of DOTs travel demand models (TDMs). Specifically
  - A Spatial Allocation method was developed to work with aggregate level land use inputs
  - A tool was created to take transit networks from TDMs as input and output the Generalized Transit Feed Specification (GTFS) which is the gold standard for representing transit networks.



TECHNICAL ACCOMPLISHMENTS AND PROGRESS

CDOT I-270 Drive MEP: Baseline Increase in MEP from 2015 to 2030



- Map is showing the increase from 2015 to 2030 (negative means scores went down)
- Lower scores north and west of **I-270 corridor** (Commerce City primarily, some around Westminster/Arvada)
- Higher scores south of corridor (especially around Colfax between Downtown Denver and Aurora)

2015 Drive MEP (pop-weighted): 387 → **+2.0% increase** → **2030 Drive MEP (pop-weighted): 395**

TECHNICAL ACCOMPLISHMENTS AND PROGRESS

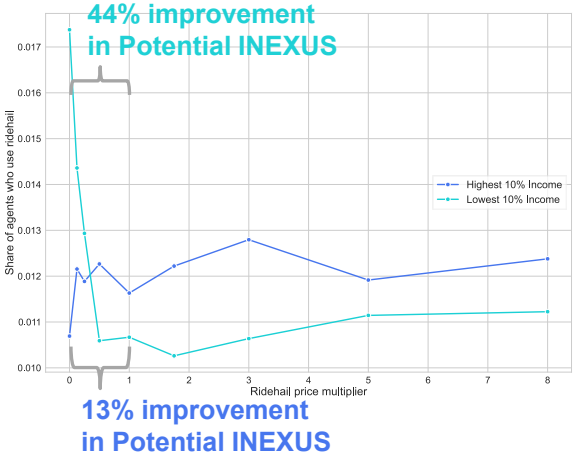
Scenario Analysis Capability in the Visualization Dashboard

- A new capability has been introduced in the MEP visualization dashboard to **adjust the EV penetration rate** (for car and transit modes) in a city.
- When users move the EV proportion slider, the MEP computation is updated based on the **new energy intensity factor**.

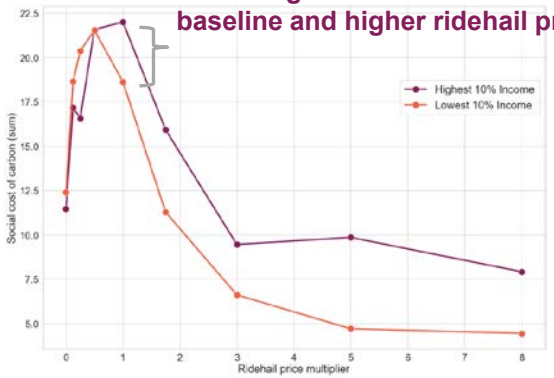
With a 60% EV fleet (from 0%), Overall MEP increases by 20%, compared to baseline Drive MEP 24% ↑ , and Transit MEP 13% ↑

TECHNICAL ACCOMPLISHMENTS

Social INEXUS can reveal differences in the share of carbon emissions across subpopulations



Each higher income traveler contributes on average more to carbon emissions baseline and higher ridehail prices



At lower ridehail prices, more low-income households switch to ridehail, resulting in a 44% improvement in their accessibility and experience.

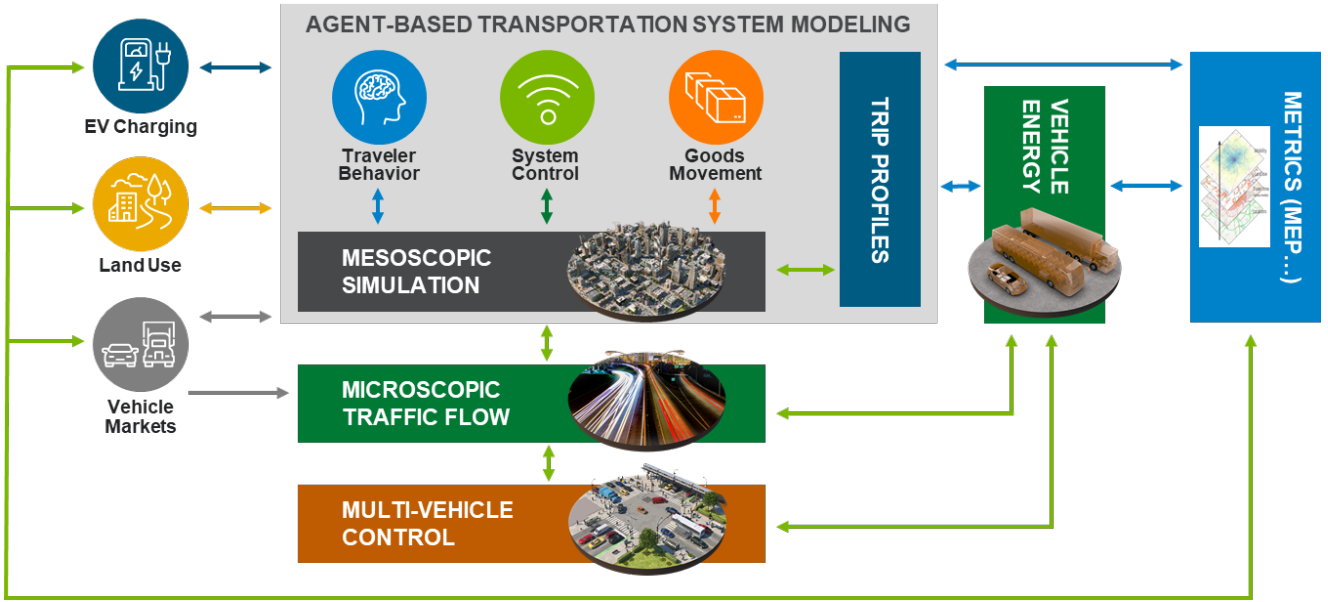
This improvement in accessibility comes with a trade-off →lower income traveler more similar to their higher income counterparts in terms of carbon emissions contributions

Improving equity and environmental outcomes can often be difficult to achieve simultaneously, but tools like these can help understand the mechanisms underlying these tradeoffs

REVIEWER ONLY SLIDES

RELEVANCE

DOE Smart 1.0 Workflow Modeling Process



This project addressees the critical need for a metric that can quantify changes in the quality of mobility and accessibility resulting from changes to the transportation system, especially coupled with changes in energy efficiency

RESPONSES TO PREVIOUS YEAR REVIEWERS' COMMENTS

Question 2: Technical Accomplishments and Progress.

Reviewer 1: Can data from the Whole Traveler survey be used to support or augment the estimation of the energy decay coefficient?
VG: That is a great suggestion. We are looking into the whole traveler survey to update energy decay coefficients for modes other than driving. For driving, we feel that leveraging third party data (through providers such as INRIX and Wejo) would be better as they are able to provide a greater sample of data than that is available in WholeTraveler.

Question 4: Proposed Future Research.

Reviewer 4: Carrying out assessment of additional factors to include the MEP metric calculation' is of strong interest. This work deserves to be validated and refined further.
VG: Thanks for the suggestion. We have compared MEP scores (using only time weights) for select cities with walk, bike, and transit scores from: https://www.walkscore.com/. The team plans to update MEP scores for ~100 cities across the US using fully open-source data (as a part of a parallel TCF project). Once done, we can carry out similar assessments with EPA's national walkability index, and mode-specific access scores published by the accessibility observatory (http://access.umn.edu/).