UCDAVIS
Sustainable Transportation Energy Pathways
An Institute of Transportation Studies Program

STEPS+ Project Portfolio for 2024

The following outlines our list of priority projects by research center for STEPS+ for 2024.

UCDAVIS
Electric Vehicle Research Center
Institute of Transportation Studies

EV Center Lead Researchers: Gil Tal, Alan Jenn, Ken Kurani, Scott Hardman, Debapriya (Priya) Chakraborty, Minal Chandra, Aaron Rabinowitz, Angela Sanguinetti, Sina Nordoff, Dahlia Garas (PM)

New 2024 projects in addition to 2023 projects below

1. **Development of a Downtime Detection tool for public DCFC locations**
2. **ClimateWorks – evaluation of global supply regulations**
3. **EV Resistors**

2023 projects

1. **Exploring the motivations for the co-adoption of home solar and electric vehicles**
2. **Do electric vehicle owners recover the premium they pay for an electric vehicle in total cost savings?**
3. **Sustainable Electric Vehicle Charging Business Models**
4. **What comes before awareness? What impels engagement with EVs?**
5. **Identifying Opportunity for Multimodality through Integrating Public EV Charging Infrastructure and Transit Systems.**
6. **Energy implications of Co-adoption of EVs and Renewable Energy Technologies**
7. **EV transition and the equity implications of the CalGreen building codes**
8. **Examining the shift towards larger vehicles: implications for the environment and vehicle electrification**
9. **Price Benchmarking of Used EVs from Buyer's Perspective**
10. **Understanding EV Charger Reliability: Problems and Solution**

SF Lead Researchers: Lew Fulton, Miguel Jaller, Marshall Miller, Andrew Burke, Jingyuan Zhao, Guihua Wang

Project 1. HDV Charger Deployment in the Next Four Years

Project Description: Thousands of charges will need to be installed in California over the next four years to support a rapid update of ZEV trucks and buses. These chargers will have varying power levels, support different types of vehicles, and be installed in different types of locations (depots, public charging, etc.). We are well positioned to estimate the numbers and types of charges needed within depots. For fleets needing public charging, we will model locations and power requirements needed around the state. We will begin with a lit review of recent studies, then we will perform our own analysis on the numbers. We may extend this to a spatial study as the year progresses.

Project 2. FCEV Market Penetration Conditions

Project Description: Our current report on this subject provides considerable detail on our approach, assumptions, vehicle data and projections, and some scenarios for market penetration for all types of ZEVs across all vehicle types. This follow-up study will focus on FCEVs and the requirements needed to achieve specific market shares and sales across various types by specific years. We will concentrate on the price of trucks and hydrogen needed to rapidly build the market, both as "choice variables" and in relation to what can be expected to happen with these prices over the next few years. We will also examine policy implications and develop recommendations based on those implications.

Project 3. On-Going Updates to Data & Projections of Battery and Fuel Cell Truck Characteristics and Prices

Project Description: Most of our SF Program work relies on good estimates of vehicle production cost and characteristics. We last did a detailed update on this in 2018 and have done minor adjustments since then. With many vehicle models now hitting service, there is considerable additional data to inform such estimates. We will review the pricing on currently available models but, more importantly, look at recent studies of component costs and how these may affect prices going forward. We will use a technology component cost model to build up to vehicle production costs and prices. We will consider current actual prices and project to large volume, learned out prices into the future. This will reflect market growth, and we will consider both fast and slow market growth in terms of how long it may take to get to "long run" prices. Fuel cost assumptions will also be updated.

Project 4. Study of MHDV Fuel Cell Market Barriers

Project Description: This is a project initiated by the CEC and co-funded with Sustainable Freight Funds. The project aims to obtain a better understanding of the barriers surrounding the medium-duty and heavy-duty (MDHD) fuel cell truck (FCET) market. We will conduct interviews with truck OEMs, trucking fleets, hydrogen suppliers, and equipment providers, and ask them questions about fleet experience, experience with hydrogen fuels, barriers to FCET adoptions, and expectations for necessary hydrogen infrastructure. We will conduct a Delphi Study, with participants representing multiple perspectives on

this issue to estimate barriers, impacts, and consequences of fleet acquisition and use of FCETs.

Project 5. Port Drayage Purchases: New vs. Second Hand and Role of Stock Turnover

Project Description: Port drayage operators are being targeted to adopt only ZEV trucks starting in Jan 2024. These operators commonly do not drive long distances and do not buy new trucks, but rather purchase second or third hand trucks, at relatively low costs. This project will look at the impacts of purchasing new ZEVs on port operators and consider options to make secondhand ZEV trucks available more rapidly. We will investigate a policy idea to create a "ZEV truck buy-back/secondhand resale" program, where the state (or program funded by the state) arranges to purchase ZEV trucks from original owners after some period (e.g., 3 years) and sell these into secondhand markets. The program could guarantee buy back prices from first owners, helping them get financing to purchase new trucks. The program could then guarantee a lower price to secondhand purchases to make these vehicles more affordable. The project effort will include an external working group and lead to a specific policy proposal that can be directed to the legislature.

Project 6. Extension of H2 ICE vs. FCEVs to Additional Topics

Project Description: This project builds off an existing paper comparing H2 ICE vs FCEV trucks in terms of economics, practicability, emissions, etc. The project will consider other ZEV truck technologies emerging around the world including, battery swapping programs (advancing in China), catenary and roadway electrification systems (advancing in Europe/Nordic countries), on-board capture of CO2 (Middle East concept), and others. The initial and main effort will concentrate on literature review and basic comparison of technologies and system options. Possible extension would be to compare costs in specific contexts like California, with specifically designed systems for this context. This also could be completed at US level.

Project 7. Comparison of Hydrogen Fuel Cell & Battery Electric Powertrains for Heavy Duty Vocational Truck Applications

Project Description: Refuse trucks and concrete mixer trucks have significant Power Take Off (PTO) demands when operating the hydraulic equipment on-board, and thus, require additional energy when compared to a similarly sized truck without PTO demands. Since model availability is currently limited (especially for concrete mixer trucks), this project will explore the relevant factors that must be considered for the development and implementation of these vehicles. We plan to perform a total cost of ownership analysis and duty cycle modeling. We will also analyze the potential disruptions to operations and evaluate infrastructure needs. We will identify optimal power train types and configurations for each vehicle type. We will determine if similar vehicle types could require different powertrain technologies to be successful.

Project 8. International Truck TCO Study

Project Description: We plan to perform a total cost of ownership study with a focus on the United States, Europe, and India (with the potential to include China). We will compare factors that influence truck purchases and potential demands for ZEVs. We will consider the drive cycles of trucks, the typical types and sizes of trucks doing specific jobs, range and battery requirements, and upfront costs. We expect to model some example vehicle types using our Advisor model, to evaluate battery requirements, efficiency impacts, and costs. We will also examine implications for market uptake of ZEVs in each market by vehicle type and compare time required for attaining cost parities in the markets. We will focus on battery-electric trucks but may also extend this to fuel cell or hydrogen ICE trucks.

Project 9. Freight Flow Patterns, Electrification, and Infrastructure Requirements in the Central Valley

Project Description: This project builds on a previous study that evaluated the trade-offs between charging infrastructure coverage, battery electric truck (BET) specifications, and fleet adoption of BETs. The project will enhance previous research by analyzing a sample of load data within the Central Valley to generate origin-destination flow requirements and develop an explicit routing model of vehicle flows to transport those loads. We will use the proposed model to evaluate charging infrastructure requirements when electrifying the fleets to transport the simulated loads. We will also add spatial resolution to the infrastructure requirement analyses conducted in previous work. This study leverages funding and data from a project funded by the SB1 program at UC Davis.

Project 10. Evaluation of Vehicle Form Factors for Last-Mile Distribution

Project Description: This project focuses on the last mile and will evaluate and compare the use of different vehicle form factors and powertrains such as electric three-wheelers and quad vehicles, cargo bikes, and regular electric vans. This project will use the team's last-mile distribution optimization models and TCO frameworks to evaluate the operational and economic performance of the various vehicles. The goal of the project is to identify the use cases for the different form factors and benchmark the vehicles.

UCDAVIS
Energy Futures
Institute of Transportation Studies

EF Lead Researchers: Lew Fulton, Colin Murphy, Marshall Miller, Julie Witcover, Stefania Mitova, Guihua Wang

Project 1. Analysis of California ZEV Transitions and Costs

Project Description: This project builds on previous papers and research on CA and US ZEV transitions. The project creates new, updated scenarios and will document all vehicle and fuel related costs, compared to business as usual. We will also link these vehicle scenarios to needed refueling scenarios and estimate charging and H2 refueling infrastructure costs considering LDVs and MHDVs separately. We will assess costs of policies such as the Low Carbon Fuel Standard and the Inflation Reduction Act. We will also evaluate environmental costs such as greenhouse gas and air quality impacts. Lastly, we will evaluate impacts from direct air capture and job-related impacts.

Project 2. Global ZEV Transitions – Model Development and Outlook Report

Project Description: We have begun developing a new UC Davis global sustainable transportation model that will include analysis for up to 30 countries/regions. We will have the initial road vehicle model done in Q1 of 2024, then extend this model to other modes and consider supply chain aspects over the rest of the year. The model will provide us with strong capabilities to model a range of global/regional transportation/energy/materials questions. The first phase of analysis will center on vehicle demand/sales/stock projections for cars and trucks, technology market share projections, vehicle use/energy impacts; later analysis will include battery requirements, materials requirements, materials flows, vehicle secondhand market trade, vehicle end-of-lie projections, vehicle production/trade scenarios by region to match demand, cost considerations, and policy implications. The goal is to have

the model fully developed in 2024 with related papers; We will then produce a major "sustainable transportation outlook report" in 2025.

Project 3. Critical Minerals and Supply Chains

Project Description: This modeling project reviews critical minerals and supply chain implications for the US, EU, and global south regions. We will assess mineral supply risks focusing five key minerals (Li, Ni, Co, Mn, Gr). We recently published our first of these papers, on Graphite. We will be analyzing the impacts of the US IRA and the EU CRM Act on these specific mineral supply chains as well. We are working with key partners to create a multilateral framework for a global south council on critical materials. This will focus on creating downstream diversification for critical mineral-rich countries, enabling participation of developing countries in global mineral value chains. We will do specific India-focused work, such as helping develop a lithium sourcing strategy and inform India's long-term critical mineral policy. This work will then be broadened out to cover a range of "global south" countries later in the year or in 2025.

Project 4. Ongoing Modeling of CA LCFS Market Developments

Project Description: This project builds on previous LCFS market modeling and focuses on current and future LCFS program development in California. 2023 draft rules are limited in scope, and while we are on target to reach CARB's projected 2030 target of 30%, increasing supply of hydrotreated lipid-based fuels (with HEFA renewable diesel, HEFA alternative jet fuel dominating) is likely to keep credit prices low while posing serious sustainability risks. We are using FPSM to engage with the current rulemaking proposal, with a brief paper updating our December 2023 report. RNG continues to be a controversial topic; EF researchers are currently working on a RIMI-supported project to explore approaches to additionality assessment in this space. The UC Davis LCFS Web Data tool is still being updated; we plan a California or multi-jurisdictional status review for 2024.

Project 5. LCFS Research & Modeling Needs

Project Description: EF researchers continue to model low carbon fuels market developments surrounding the LCFS and related policies in other jurisdictions. This includes work on EV credit quantification, additionality determination, credit market modeling, and feedstock sourcing and supply (and land use change risks). We are also collaborating with ORNL to update their BioTrans biofuel supply model to include the effect of state-level alternative fuel policies and continue to engage with stakeholders in jurisdictions considering adopting an LCFS or similar program (e.g., U.S. Midwest, New York, New Jersey, New Mexico, and Hawaii), or with one (California, Oregon, British Columbia, Canada). Lastly, indirect land use change remains a concern with few solutions; we have begun examining how framing in terms of uncertainties, especially but not exclusively in the absence of more in-depth research and modeling in this area, can inform policy.

Project 6. LCFS Transitions in Shipping and Aviation: CA and International

Project Description: This project is a transition study of on-road fuels to aviation, and extension of CA LCFS credit model to include aviation. Funded by Climateworks, this project will identify merit order of end uses for alternative fuels. It will consider hydrogen, and the difference between directly fueling vehicles vs. input to liquid fuel vs. stationary sources. It will also consider biofuels, including those derived from existing on-road fuels as well as new technologies to better understand prioritization of on-road ICE applications or aviation/marine over time. There will also be some international work in this area, building on a US/EU policy landscape study with potential to include a fuel policy evaluation in

India and Brazil. Note also that the ORNL work mentioned in the LCFS research and modeling project includes biofuels used in aviation and shipping.

Project 7. Extension of Hydrogen Modeling and Scenarios to Cover Non-Road Models

Project Description: This project builds on 2023 hydrogen spatial modeling work published here, to update and deepen this work in several respects. This will include integrating new vehicle travel and hydrogen fueling demand analysis, supply chain work, and electricity sector analysis of hydrogen (as described in the following project blurbs). It will also particularly extend previous work with a particular "deep dive" analysis of ports/shipping, airports/aviation, and rail in California. If resources permit, it will also include addition of some industrial H2 demand, such as refining and chemicals, based on hydrogen price analysis. The analysis will consider hydrogen both as a direct end-use fuel and feedstock for other fuels (e.g. shipping fuel) and will have a spatial component. This work is funded in part by the California SB1 program and completed in cooperation with UC Berkeley and the Energy Efficiency Institute.

Project 8. Spatial and End-Use Infrastructure Siting Work

Project Description: This project concentrates on a detailed analysis if hydrogen station design, siting, and growth in numbers, particularly for heavy-duty vehicle stations. While we will pay particular attention to the HDV stations, we will also examine LDV and the interactions that exist between the two types. Analysis will be conducted with GIS tools and our STIEVE spatial model. We will include ongoing analysis of technologies and systems (e.g. liquid vs gas transport/storage), and the implications for full pathways, costs, and emissions.

Project 9: Hydrogen System Supply Chain Study

Project Description: This project is linked with the previous project (#8). We will use SERA to track pathways from hydrogen production to end use, including all production for use within the state. Other scenarios will also be explored including H2 produced near or far, connected, or unconnected to grid, storage issues and transportation options. We will also explore production technology alternatives and roles (electrolysis vs. biomass).

Project 10: LCA Work Including Leakage

Project Description: This project assesses the current understanding of hydrogen leakage, reviews the literature, reports on leakage estimates for different parts of the supply system and different design factors, and identifies current areas of concern. We then will assess the potential for cutting leakage in the future via technologies and system design. We will use the information derived from this work to better track the hydrogen leakage associated with our spatial modeling and estimate atmospheric warming implications.

Project 11: H2 DEI and Equity Study

Project Description: This project will perform a DEI/Equity study for H2 systems. The primary research will be conducted through interviews and potential surveys targeting individuals in position of influence (e.g. community leaders), various stakeholders, and public. Questions aim to better understand views on H2 and H2 plans, and what influences these views. We will use the learnings to suggest strategies for addressing concerns and increase support for plans and specific actions and investments.

Project 12: Next Electric Power/H2 Study

Project Description: This project is a follow up on 2021-2022 electric power and H2 study. We are upgrading our GOOD electric power/dispatch model (changing it from GAMS to a pure python model) to allow for deeper H2 analysis within electric sector. This is part of our on-going work to understand the potential role of H2 for energy storage with the electricity system. We will also examine the potential and cost of producing electrolytic H2 for end use as it relates to the storage role, and for "soaking up" excess renewables in the process.

UCDAVIS
3 Revolutions Future Mobility
Institute of Transportation Studies

2024 projects

1. **What are the Early Impacts of the Clean Miles Standard on California Ridehailing Drivers?**
   Lead Research: Giovanni Circella, Yongsung Lee

2. **Impacts of Remote/Hybrid Work and Remote Services on Activity and Transportation Patterns**
   Lead Researchers: Giovanni Circella, Yongsung Lee

3. **Postpandemic Travel for Low-Income and Disadvantaged Communities**
   Lead Researchers: Giovanni Circella, Yongsung Lee

4. **Transatlantic Cooperation for Leveling Up MaaS**
   Lead Researchers: Giovanni Circella, Yongsung Lee

5. **VMT Measurement Methods and Pilot Test for Collecting Odometer Readings**
   Lead Researchers: Siddhartha Gulhare, Giovanni Circella

6. **Providing Electric Vehicle Carsharing to Rural Regions in the Central Valley of California**
   Lead Researcher: Caroline Rodier

7. **What Are the Needs of Individuals with Disabilities? How Can Technology Solutions Address Those?**
   Lead Researcher: Prashanth Venkataram

8. **Forecasting the Impacts of Emerging Technologies on Infrastructure, Transportation Systems, and Access in California**
   Lead Researchers: Yongsung Lee, Giovanni Circella, Miguel Jaller

9. **Lessons Learned from the Longitudinal UC Davis COVID-19 Mobility Study**
   Lead Researchers: Basar Ozbilen, Giovanni Circella

10. **Studying Car Dependence and Opportunities to Increase Travel Multimodality in Los Angeles**
    Lead Researchers: Basar Ozbilen, Giovanni Circella

11. **Mobility Wallets and Payment Systems**
    Lead Researcher: Caroline Rodier

12. **Last Mile Delivery and Cargo Bikes**
    Lead Researchers: Giovanni Circella, Yongsung Lee

UCDAVIS
China Center for Energy and Transportation
Institute of Transportation Studies

2023 projects

1. **Update of China's transportation carbon neutrality pathway**
   Lead Researchers: Xiuli Zhang, Lewis Fulton, Yunshi Wang, and Yan Xing

2. **California – Hainan, China MOU: high-level cooperation opportunities and challenges**
   Lead Researchers: Yunshi Wang, Xiuli Zhang, and Yan Xing

3. **Total Cost of Ownership (TCO) Analysis of Imported Battery Swap Trucks**
   Lead Researchers: Yunshi Wang, Timothy Hughes, and Yan Xing

4. **Exploring Microtransit Adoption and Impacts on Transportation Access of Underserved Populations (Cooperate with Public Transit Research Center)**
   Lead Researcher: Yan Xing, Susan Pike, Susan Handy, and Yunshi Wang