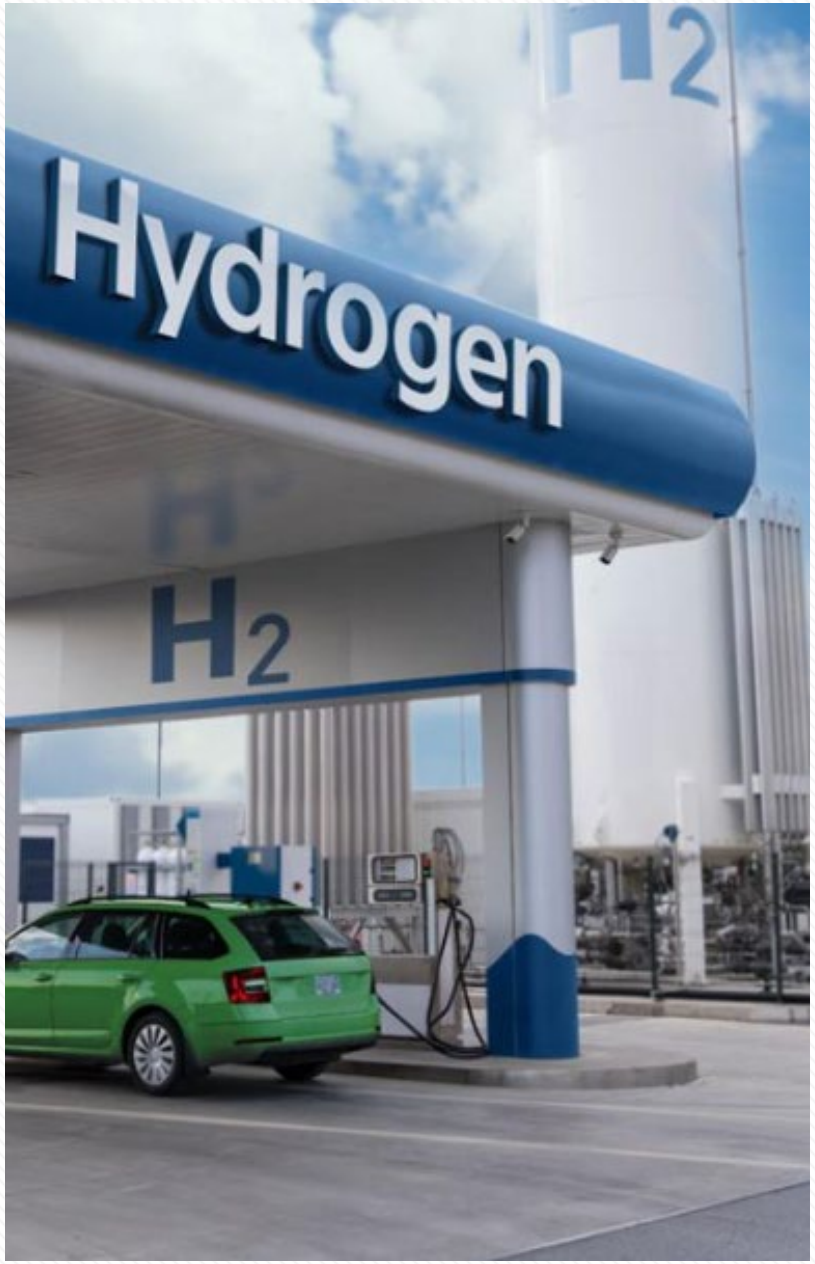
ENERGY FUTURES & HYDROGEN PROGRAM UPDATE

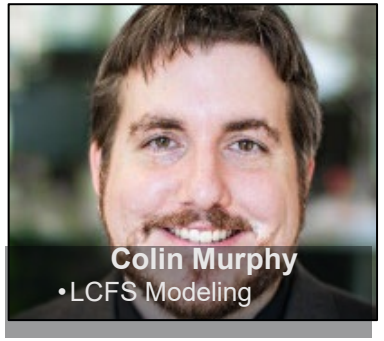
With Initial 2024 Projects

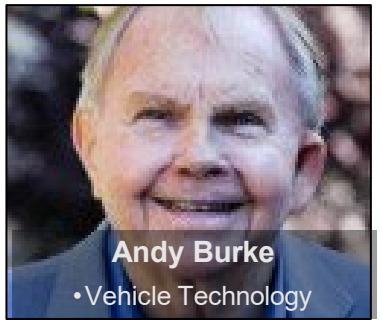


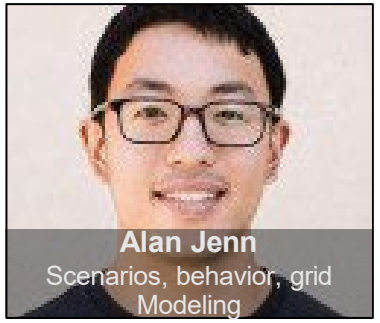
December 2023

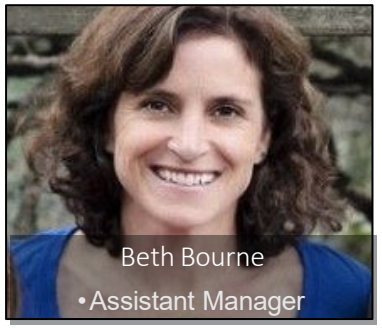
Lew Fulton, Director STEPS+ Energy Futures Program
Institute of Transportation Studies, UC Davis

EF-HYDROGEN PROGRAM TEAM

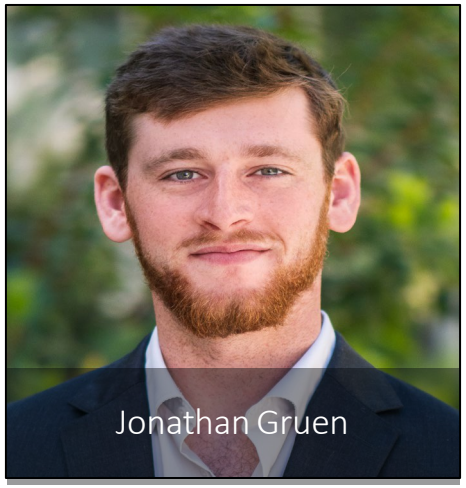


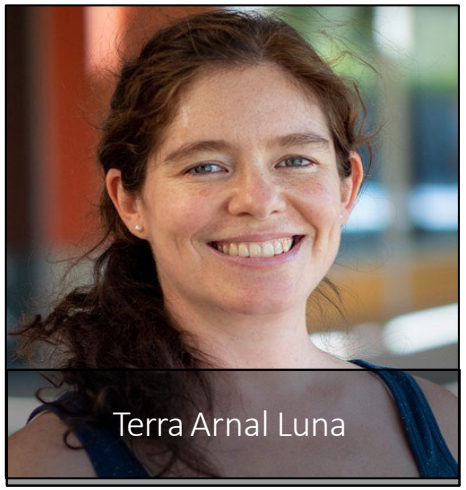


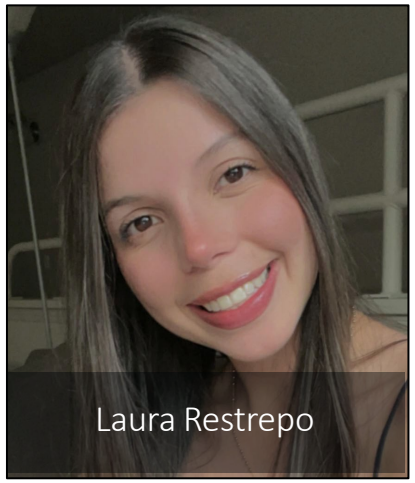


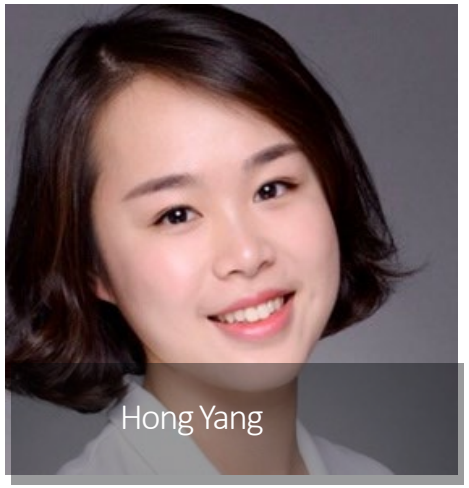


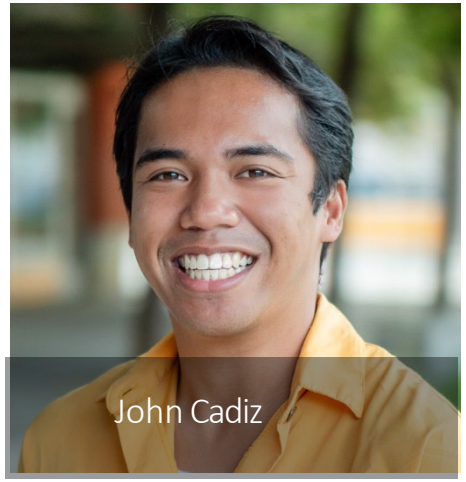
EF-HYDROGEN PROGRAM TEAM STUDENTS











LOW CARBON FUEL POLICY RESEARCH INITIATIVE

Colin Murphy Ph.D. Co-Lead
Deputy Director, Policy Institute

Julie Witcover Ph.D. Co-Lead
Associate Project Scientist, Policy Institute

Jin Wook Ro Ph.D.
Postdoctoral Researcher, Policy Institute

Pedro Liedo Orozco
Ph.D. Student, Ag. Resource Economics

Laedon (Ray) Kang MBA
M.S. Student Trans. Tech. & Policy

Lucas Salgado
M.S. Student Trans. Tech. & Policy

EF MODELING PUBLICATIONS 2022/2023

Transitions and Hydrogen Modeling:

- California Hydrogen Analysis Project: The Future Role of Hydrogen in a Carbon-neutral California: Final Synthesis Modeling Report
- Technology and Fuel Transition: Pathways to Low Greenhouse Gas Futures for Cars and Trucks in the United States (California report coming mid-2024)
- The Role of Clean Fuel Systems in California Hydrogen Transition: A Comparison of Hydrogen, Synthetic Natural Gas, Related Fuels
- Fuel-cell vehicle and hydrogen transitions in California: Scenarios, cost analysis, and workforce implications (February 2024)
- California FCEV and Hydrogen Refueling Station Deployment: Requirements and costs to 2050 (February 2024)
- Modeling future hydrogen supply chains in the western United States under uncertainties: an optimization-based approach focusing on California as a hydrogen hub
- Evaluation of the Economics of Light-Duty Battery-Electric and Fuel Cell Passenger Cars, SUVs, and Trucks: Methods, Issues, and Infrastructure
- Creating a Global Hydrogen Economy: Review of International Strategies, Targets, and Policies with a Focus on Japan, Germany, South Korea, and California
- Use Of Liquid Hydrogen in Heavy-Duty Vehicle Applications: Station And Vehicle Technology and Cost Considerations

EF MODELING PUBLICATIONS 2022/2023

Policy Briefs:

- Potential Uses of Hydrogen in California's Clean Energy Transition
- The Carbon Intensity and Greenhouse Gas Reduction Potential of Different Hydrogen Production Pathways.
- Tech Brief: Pipelines for a Hydrogen System in California
- Tech Brief: Hydrogen Storage (February 2024)

EF LCFS 2023 PRODUCTS

- **FPSM Modeling of LCFS Targets in 2030 and Beyond:** Proposed 30% 2030 target is appropriate, auto acceleration mechanism should help support stable credit prices
- **Forecasting Credit Supply Demand Balance for the Low-Carbon Fuel Standard Program** (collaboration with Econ and Ag & Natural Resource Econ faculty)
- Collaboration w/ ORNL moving forward to update BioTRANS model
- First paper for LCFS Credit Market Model in review; Phase 2 work moving forward
- SAF vs. RD air quality trade-off analysis done, paper being finalized
- EPA National Center of Environmental Economics seminar presented in July, follow-up blog posted in October
- Workshop report from NY & Brussels aviation and marine fuel panels released through CGEP
- **Modeling expected air quality impacts of Oregon's proposed expanded clean fuels program**
- **Aviation Fuels – Exploring Low Carbon Options Under Current Policy**

EF AND SF WEBINAR SERIES RECAP

Aug 10: EF updates, including California Transition Analysis, Low-carbon Fuels

Aug 24: SF updates and truck choice, depot scalability and logistic studies
Call Recording Slide Presentation

Sept 7: Hydrogen plans and updates on supply chain and station analysis
Call Recording Slide Presentation

Oct 19: Sustainable Freight updates and discussion of 2024 topics
Call Recording Slide Presentation

Oct 26: Energy Futures updates and discussion of 2024 topics

Nov 2: H2 updates and discussion of 2024 topics
Call Recording Slide Presentation

EF RESEARCH: 2023-24 PRIORITY AREAS

- **ZEV Transition study for California**; how to achieve state targets to 2035 and beyond. Our US transition study was published in Spring 2023;
  - California update from our 2020 study will reflect latest targets and policies and evaluate costs and challenges to meet California's ZEV targets.
- **LCFS Modeling/Low-carbon fuels analysis**: have published extensively on optimizing Low-Carbon Fuel Standard (LCFS) in the 2030 time frame and beyond;
  - Working with CARB staff to identify strategies for adjusting 2030 targets
  - Evaluating long-term fuel pathway transitions and program needs
- **Hydrogen system modeling:** major report published in Spring 2023 on optimizing a California hydrogen system, developing infrastructure, and serving transportation vehicles along with other end uses;
  - We are connected to (and our work feeds into) the state's ARCHES California hydrogen partnership, including applying for over $1B of funding from US DOE

EF: TRANSITIONS – KEY FINDINGS 2023

- **ZEV Transition study for California**; how to achieve state targets to 2035 and beyond. Our US transition study was published in Spring 2023;
  - Nearly every new car and truck sold in California by 2035 must be zero emission
  - LDVs continue to make strong progress, reaching 25% ZEV sales in some months in 2023, but trucks are at a very early phase
  - High fuel/energy prices (electricity/hydrogen) will not help with TCOs
  - The cost of incentivizing sales for both cars and trucks could be very high if TCO's are set to match gasoline/diesel
  - New sources of funds will be needed, such as the dreaded F word… (feebates)
  - We continue to count on hitting TCO and first cost parity for all ZEV vehicle types by 2030, but this will require large volume production, not clearly going to be achieved for trucks
  - National programs and other state programs will help with achieving scale

LFCS: KEY FINDINGS 2023

- **LCFS Modeling/Low-carbon fuels analysis**: have published extensively on optimizing Low-Carbon Fuel Standard (LCFS) in the 2030 time frame and beyond;
  - Proposed 30% 2030 target appears appropriate. Higher targets possible, but would require potentially unsustainable levels of biofuel consumption.
  - Auto acceleration mechanism likely to support strong, stable credit price.
- **Comparison of Air Quality Impacts from SAF and RD in California**: No significant difference in regional air quality impacts for SAF vs. RD in CA through 2030.
  - Small (non-significant) benefits for SAF, including reduction in air pollutant EJ disparities
  - Higher (50%) SAF blending yields significant air quality benefits
- **LCFS Credit Market Model Shows Importance of Higher, Long-term Targets**
  - Model calibrated to LCFS parameters through 2019. Paper under review at *Applied Energy*.
  - Update underway to improve modeling of lipid-based fuels & SAF

HYDROGEN: KEY FINDINGS 2023

- ARCHES and other H2 hubs provide the opportunity for a national H2 system and true scale economies in hydrogen production and distribution.
- Unclear if it will lead to scale economies in fuel cell electric cars, trucks, and buses
- California's goal of 5000 FC HD trucks by 2030 will be challenging, while not enough by itself to guarantee cost reductions to bring prices close to diesel trucks
- The state's goal to produce hydrogen within the state may prove expensive
- DOE's $1B plus a state match will help, but investments by 2030 will likely be in the $1B range just for trucks.
- Hydrogen prices before subsidies must be brought down to $10/kg by 2028, far below today's levels of $25+
- Larger scale production and distribution for trucks should also help LDV systems, but not before 2028 or so.

PLANNED 2024 TOPICS

TRANSITION MODELING

1) Analysis of transition costs in more detail (Follow on paper to US and CA transition paper)
2) Global ZEV transitions – model development and outlook report
3) Critical materials and supply chains

LOW-CARBON FUELS

4) Ongoing modeling of LCFS market developments, in California and elsewhere
5) New approaches to additionality to improve LCFS credit quantification (esp. for RNG)
6) Low-carbon fuels transitions in shipping and aviation – moving on-road biofuels to non-road sectors

HYDROGEN

7) Revised H2 transition study including Rail/shipping/air
8) On-going spatial and infrastructure siting work
9) On-going supply chain study
10) Ongoing LCA work including Leakage
11) DEI/equity study
12) Next electric power/H2 study

1. ANALYSIS OF CALIFORNIA AND/OR US TRANSITION COSTS

Follow on paper to US and CA transition paper

- Update of all vehicle and fuel cost (including infrastructure costs), with assumptions and projections, to use in scenarios
- New CA model scenarios for vehicle/fuel transitions with comparison to a BAU
- Assessing costs of policies such as LCFS and IRA
- Assessing environmental costs such as GHG and air quality impacts (simplified approaches)
- (if resources permit): assessing disadvantaged community (DAC) and job-related impacts

2. GLOBAL ZEV TRANSITIONS – GLOBAL MODEL DEVELOPMENT AND OUTLOOK REPORT

- We are creating a new UC Davis global sustainable transportation/energy/policy model (current name G-STEP)
- Model and analysis will include (for world and up to 10 countries/regions):

- Vehicle demand/sales/stock projections (cars & trucks)
- Technology market share projections
- Vehicle 2nd hand market trade
- Cost considerations
- Vehicle production/trade scenarios by region to match demand
- Vehicle use/energy impacts
- Vehicle end-of-lie projections
- Policy implications

- Key features: good regional detail and vehicle movement projections, separation of new and 2nd hand vehicles, tracking of battery requirements and resources in that supply chain (see next project)
- Hope to create a major "sustainable transportation outlook report" for 2025 (some smaller reports and documentation by end 2024).
- Other deep dive analysis will be spring boarded from this, tbd.

3. CRITICAL MINERALS AND SUPPLY CHAINS

Implications for the US, EU, and Global South

- Linked to global modeling project and our work on projecting EV sales, stocks, and battery requirements to 2030 and beyond
- Identify potential critical materials needs, and assess critical mineral supply risks*
  - 5 focus minerals: Li, Ni, Co, Mn, Gr
  - Defining resource 'criticality'; Mine-wise analysis
- Multilateral Framework for a Global South Council on Critical Minerals
  - Downstream Diversification of Critical Mineral-Rich Countries
  - Enabling participation of developing countries in global mineral value chains
- Lithium sourcing strategy for India
  - Devising a strategic sourcing plan for India from global markets
  - Inform India's long term critical mineral policy

** Briefing to EU Secretariat of Mineral Security Partnership; India is also now a formal member of MSP*

4. ONGOING MODELING OF LCFS MARKET DEVELOPMENTS

In California and elsewhere

- 2023 rulemaking is limited in scope
  - 30% 2030 Target likely, w/ 4.5%/year increases thereafter
  - Auto acceleration mechanism, intra-state jet fuel compliance obligation, MD/HD infrastructure capacity credits
  - RNG restrictions
- STEPS+ support allowed significant additional use of Fuel Portfolio Scenario Model (FPSM) to engage w/ current rulemaking
  - Auto-acceleration mechanism analysis presented in July
  - Comparison w/ ICF model included in FPSM report
- LCFS Web Data tool is continuing to be updated
- Thinking of subject for next Status Review

5. LCFS RESEARCH & MODELING NEEDS

- Medium/Long Term LCFS revisions:
  - EERs, additionality determination, EV credit quantification
- Avoided Methane Credits, esp. from livestock digesters are still controversial
  - Possible collaboration w/ UCSC on drone-based sensing method
  - RIMI project evaluating RNG additionality determination
- Expansion of LCFS to other states
  - U.S. Midwest, New York, New Jersey, New Mexico, and Hawaii
- Indirect Land Use Change: Still a problem with few good solutions
  - July EPA Webinar offered new framing, next step is develop quantified guidance

6. LCFS TRANISTIONS IN SHIPPING AND AVIATION: CA & INTERNATIONAL PERSPECTIVES

- Transition study of on-road fuels to aviation, and extension of CA LCFS credit model to include aviation, funded by Climateworks
- Identifying merit order of end uses for alternative fuels
  - Hydrogen – directly fueling vehicles vs. input to liquid fuel vs. stationary sources?
  - Biofuels – Prioritize on-road ICE applications or aviation/marine?
- Draw on hydrogen work in this area
- International studies in these areas (led by our European Center, ETERC)
  - US/EU Policy Landscape study
  - India, Brazil fuel policy evaluations

7. REVISED H2 TRANSITION STUDY INCLUDING RAIL/SHIIPING/AIR

- Funded in part by California SB1 program
- Will update our vehicle market modeling, spatial modeling including station analysis, and supply chain work.
- Will expand on our modeling scope to include rail/shipping and air (and ports and airports) in the same spatial framework.
- (If resources permit) will consider some stationary demand for hydrogen (electric sector, industry) to add to the modeling and supply chain analysis.

8-9. HYDROGEN STUDIES

8) On-going spatial and end-use infrastructure siting work

- Detailed analysis of station design, siting, growth in numbers, particularly heavy-duty vehicle stations
- Use of GIS tools and our STIEVE spatial model
- Particular attention to HDV stations, but also LDV and the interaction between them
- Ongoing analysis of technologies and systems (e.g. liquid vs gas transport/storage), implications for full pathways, costs, emissions.

9) On-going supply chain study

- Linked to 8); using SERA to track pathways from hydrogen production to end use, including production in and outside the state for use within the state.
- Looking at scenarios with H2 produced nearby or far away; connected or unconnected to grid; storage issues; transportation options. Levels of foresight; production technology alternatives and roles (electrolysis vs biomass), etc

10-11. HYDROGEN STUDIES

10) Ongoing LCA work including Leakage

- Assess current understanding of leakage, identify areas of concern
- Assess potential for cutting leakage in the future via technologies and system design
- Keep track of the understanding of hydrogen leakage and atmospheric concentrations relative to warming impacts
- Main goal is a lit review paper during 2024

11) DEI/equity study of H2

- Interviews and potential surveys of individuals in positions of influence (e.g. community leaders), various stakeholders, and regular folks, to better understand views on H2 and on H2 plans (such as ARCHES), and what influences these views.
- Use learnings to suggest strategies for addressing concerns and increase support for plans and specific actions and investments

12. ELECTRIC POWER/H2 STUDY

- Follow up from 2021-22 electric power/H2 study as presented in Spring 2023 modeling report
- Upgrade our GOOD model for deeper H2 analysis within electric sector
- On-going work to understand the potential role of H2 as a grid storage system
- Potential and cost of producing H2 for end use functions, and soaking up excess renewables in the process
- Economics of H2 production from electrolysis connected to or off-grid, potential of mini-grids for this, location of production (e.g. in-state or out-of-state) relative to end uses, and cost tradeoffs between production and transportation/distribution
- Exploration of hydrogen storage options and locations.