

Innovative Clean Transit – Comprehensive Review

Summary Presentation for California Air Resources Board
Program Readiness – Large Transit Agency, Standard Bus Purchase Requirements

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About NREL & UC-Berkeley



National Renewable Energy Laboratory Center for Integrated Mobility Sciences

U.S. Department of Energy National Laboratory

Main campus in Golden, CO

>3,000 professionals dedicated to creating a clean energy future for the world



tsrc.berkeley.edu



University of California Berkeley Transportation Sustainability Research Center

Created in 2006 to combine six of UC Berkeley's campus research centers.

TSRC was formed to study the economic, social, environmental, and technological aspects of sustainable transportation.

ICT Comprehensive Review

Objective

Provide a comprehensive assessment of Innovative Clean Transit program readiness for 2023 ZEB standard bus purchase requirements.

Approach

1. Conduct literature reviews for the latest information on ZEBs and infrastructure.
2. Interview ZEB stakeholders—transit agencies, OEMs and technology providers, utilities, and fuel providers.
3. Combine analyzed data from NREL’s detailed fleet evaluations and other published ZEB studies.
4. Utilize modeling tools to compare economics of ZEBs to conventional bus purchases and to estimate the economic impact of the ZEB transition in California.



Key Components of Comprehensive Review

Literature Review

ZEB Models and Infrastructure

ZEB Incentive Program Inventory

ZEB Fleet Performance and Economics

Macroeconomic Assessment of ZEB Deployments

Pandemic Impacts on ZEB Deployment

Stakeholder Input and Outreach

Literature Review

Objective

Develop an understanding of existing ZEB roll-out plans in California as well as recent findings in academic literature.

Approach

Completed a review of key literature on zero emission bus (ZEB) technology deployment, including ZEB roll-out plans and highlight major findings.



Over 180 references and information sources cited in the Comprehensive Review Report

Review of Commercially Available ZEBs and Infrastructure

Power source	OEM	Type	Model	Length (ft)	Width (in)	Wheelbase (ft)	Curb weight (lb.)	Turning radius (ft)	Seated passengers	Total Energy kWh	Drivetrain	Nominal range (mi)	Fuel Economy (projected at SLW w/o HVAC) kWh/mi
Electric	Proterra	Standard	ZX5 35ft	36.9	102	20.25	26,359	36	29	220	Duopower	95-125	1.5-2.0
Electric	Proterra	Standard	ZX5+ 35ft	36.9	102	20.25	29,658	36	29	440	Duopower	172-240	1.6-2.3

Objective

Identify available ZEB models as well as hydrogen fueling and charging infrastructure.

Approach

NREL and UC-Berkeley updated and expanded existing database of ZEB technologies that were gathered through years of transit evaluations to include new models introduced to the market.

Provided listing of available ZEBs and Infrastructure including basic specifications

Note: actual vehicle and infrastructure availability is continually changing

ZEB Incentive Program Inventory

Objective

Evaluate adequacy and efficacy of existing ZEB incentives to meet the objectives of the ICT regulation.

Approach

NREL and UC-Berkeley evaluated a variety of local, regional, state, and national incentive programs supporting the deployment of zero emission buses and infrastructure in California.

Identified all major funding programs available to CA transit agencies, highlighting recent improvements and remaining needs/challenges

Federal and State Laws and Incentives

Find federal and state laws and incentives for alternative fuels and vehicles, air quality, fuel efficiency, and other transportation-related topics.

The screenshot displays a user interface for finding federal and state laws and incentives. It features two main navigation buttons: 'Federal' (with a classical building icon) and 'State' (with a map of the United States icon). Below the 'State' button is a dropdown menu labeled 'select a state'. To the right of these buttons are links for 'Recent Federal Actions', 'Key Federal Legislation', 'Recent State Updates', 'Local Examples', and 'Utility Examples'. On the far right, there are two yellow buttons: 'Search' (with a magnifying glass icon) and 'See All' (with a grid icon), both with subtext indicating search by category or keyword and viewing in summary tables.

ZEB Fleet Performance and Economics



Objective

Review operational performance and costs of existing ZEB deployments to assess the economics of ZEB transitions.

Approach

NREL's Vehicle and Infrastructure Cash-Flow Evaluation (VICE) model was customized for California-specific inputs and expanded to include fuel cell electric buses. Sensitivity analysis was used to identify key parameters that influence ZEB economics in California.

VICE Model Overview

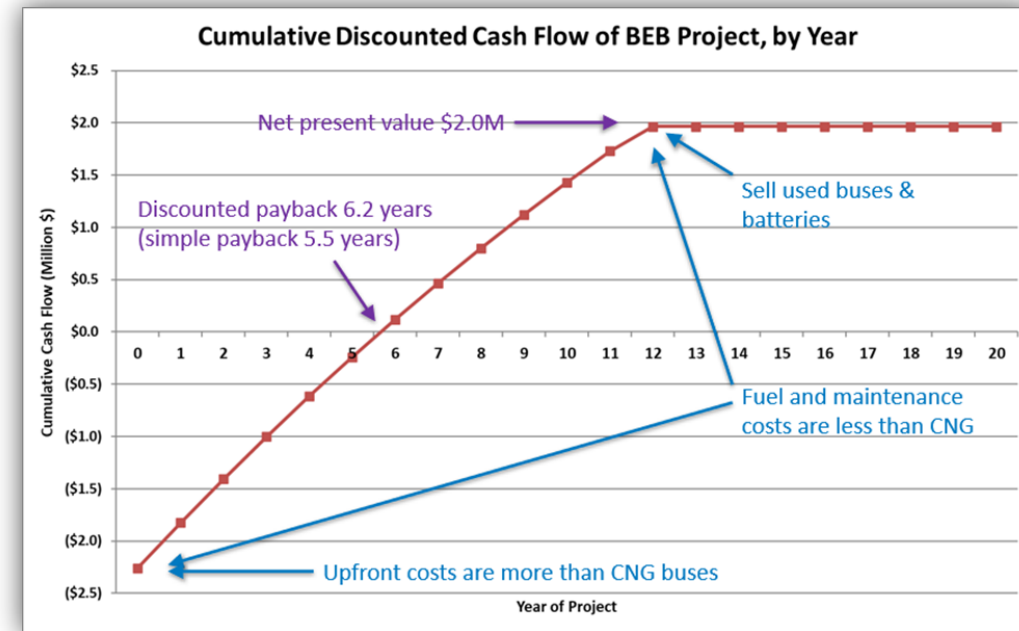
Discounted cashflow analysis that considers up-front capital costs and long-term operational costs

- Results are reported in payback period and net present value (NPV)
- Operating parameters are gathered from real-world deployments

NREL Nationwide Baseline Electric Transit Bus Analysis

- Modeled example fleet scenario for BEBs and FCEBs compared to conventional buses
- Conducted sensitivity analyses to determine which input parameters are most influential

VICE model was used to evaluate “typical” ZEB economics with a focus on relative sensitivities to key economic parameters using California-based inputs



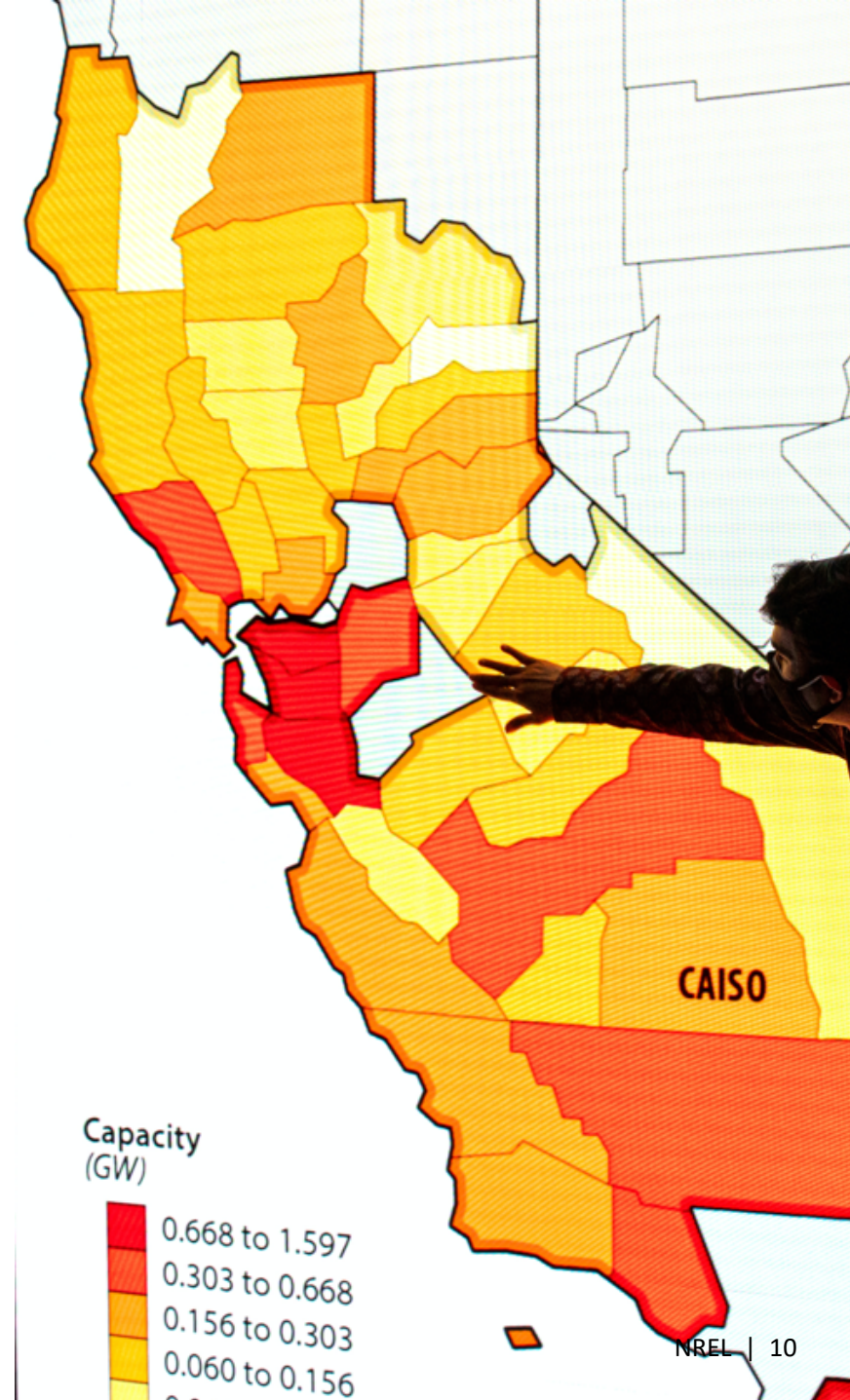
Macroeconomic Assessment of ZEB Deployments

Objective

Quantify the economic additive benefits of ZEB deployments on the California economy.

Approach

The economic assessment built on assumptions made in fleet economics modeling to estimate direct, indirect, and induced economic activity in California through use of the IMPLAN model.

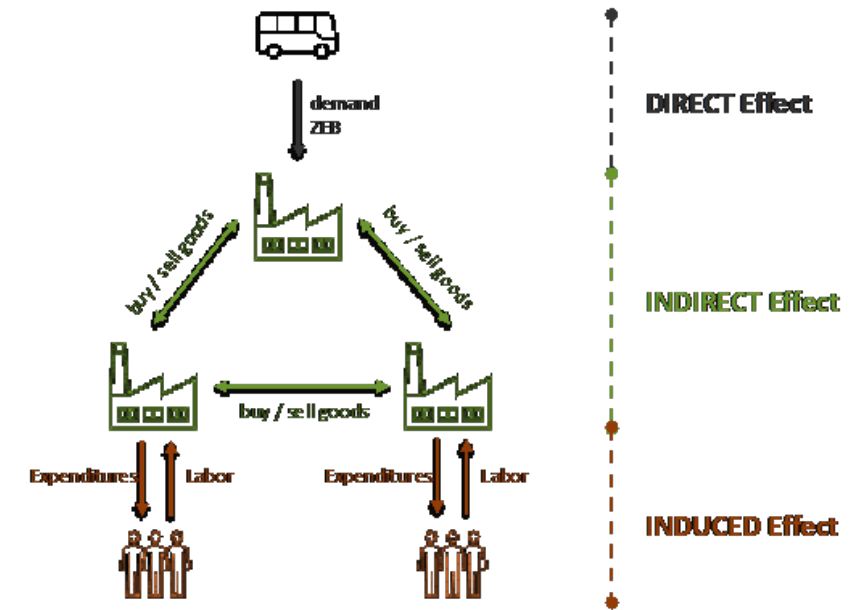


Macroeconomic Modeling Framework

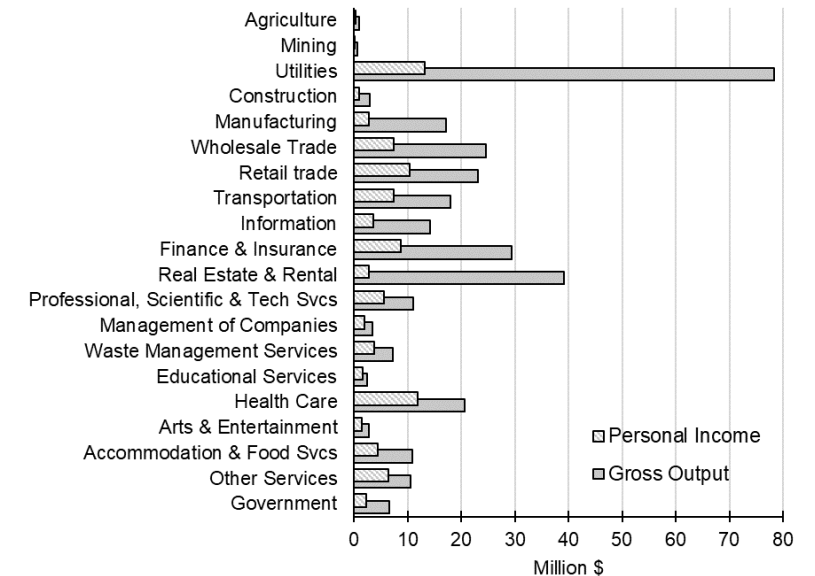
The accounting system describes the structure of the economy as a network of sectors. Impacts on all sectors in the region are estimated, as all supply chains are considered simultaneously.

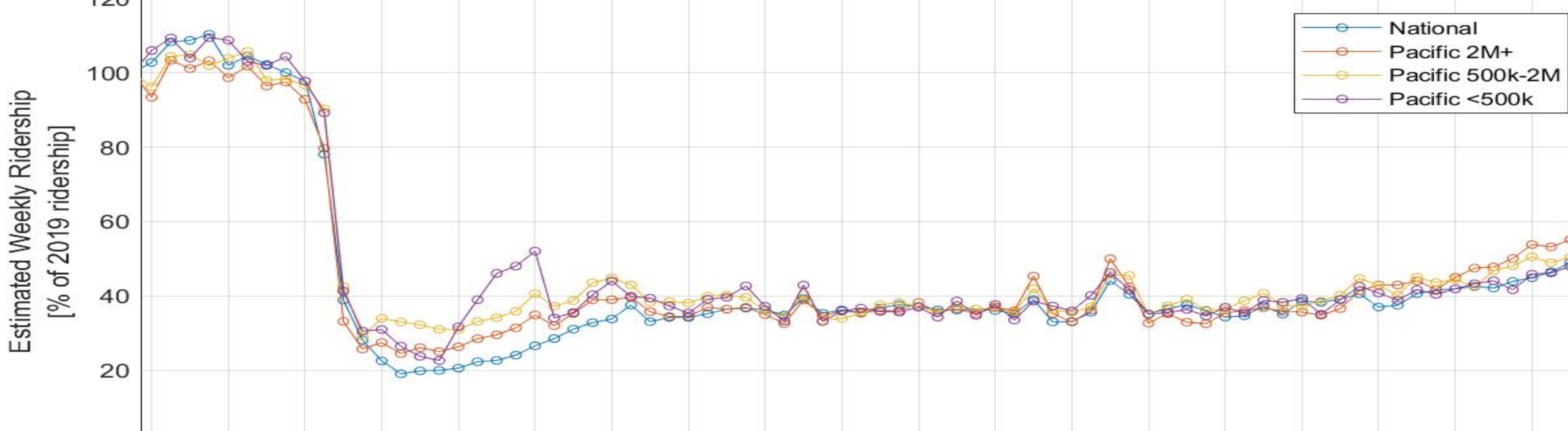
Modeling estimated direct, indirect and induced effects on:

- Jobs (total number)
- Occupations (types and characteristics)
- Personal Income (wages and proprietor income)
- Gross Regional Product (wealth generation)
- Federal, State/County Taxes
- Industry Output (production by sector)



Impacts by Sector (2040)





Pandemic Effects on ZEB Deployment

Objective

Quantitatively and qualitatively identify impacts of the COVID-19 pandemic on ZEB deployment in California.

Approach

National data on COVID-19 impacts to transit ridership was evaluated as a baseline. Interviews with transit agencies put this in the context of impacts to ZEB deployment in California.

The pandemic had dramatic impacts on transit ridership, operations, and revenues, which impacted many agency ZEB transitions plans

Stakeholder Interviews and Feedback

Objective

Inform and validate analysis through stakeholder input and review.

Approach

NREL and UC-Berkeley used a multi-pronged approach to stakeholder input and review:

- Targeted interviews with key, representative ZEB stakeholders
- Project briefings with California Transit Association's ZEB task force
- Public comment and review of the draft ICT comprehensive review



These outreach efforts ensured that all ZEB stakeholder perspectives were represented

Summary of Key Findings

Details are provided in the Comprehensive Review Report

ICT 2023 – Readiness Summary Statement

2023 Purchase Requirement for Standard 40-ft Buses, Large Transit Agencies

Based on the information collected and evaluated under this comprehensive review, the California transit industry appears to be well positioned to proceed with the 2023 requirement of 25% of new bus purchases being ZEBs for large transit agencies.

This is supported by:

- Large transit agencies' ZEB Rollout Plans,
- Momentum developed from over a decade of ZEB demonstrations and deployments,
- Continued product development and refinement led by the transit industry,
- Progress made since 2018 adoption of ICT,
- Successful partnerships and collaboration of California transit agencies, vehicle manufacturers, charging and fuel equipment suppliers, utility providers and others.

Significant CA ZEB Progress Made Since 2018 Adoption of ICT

- Increased number of Altoona-tested ZEB models
- Increased number of commercially-available ZEB models
- Enhanced policy and increased legislation supporting the ZEB deployment
- Increased amount of state funding for ZEBs and ZEB infrastructure
- Increased group procurement opportunities on ZEBs
- Economic impact and environmental justice
- Increased electric charging and hydrogen fueling standardization
- Positive impacts of increased investments on the job market

Summary of Key Needs Moving to 100% ZEB Fleets

To achieve a successful transition to 100% ZEB transit fleets in the coming years, some of the greatest needs include:

1. Sustained progress from the vehicle, equipment, and infrastructure manufacturing base is needed to continue ***driving down costs, improve reliability and optimize performance.***
2. ***Expansion of charging and fueling infrastructure*** is a fundamental need that will require coordinated efforts and forward-looking planning by transit agencies, utilities, and developers.
3. Comprehensive and standardized training programs to ***develop a highly skilled workforce*** that can improve the efficiency and cost of maintaining ZEB equipment while creating new jobs and ensuring safety.
4. ***Financial support*** for purchasing, installing, and operating ZEBs and the necessary fueling/charging equipment. Federal and State funding for ZEBs and related charging/fueling infrastructure are critical to achieving reasonable payback on the upfront costs, especially in the early years.

These “Key Needs” are supported by the detailed technical discussion throughout the body of the Comprehensive Review

Questions and Discussion

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NREL and UC-Berkeley would like to acknowledge and thank CARB staff for continuous support during the ICT Comprehensive Review.

