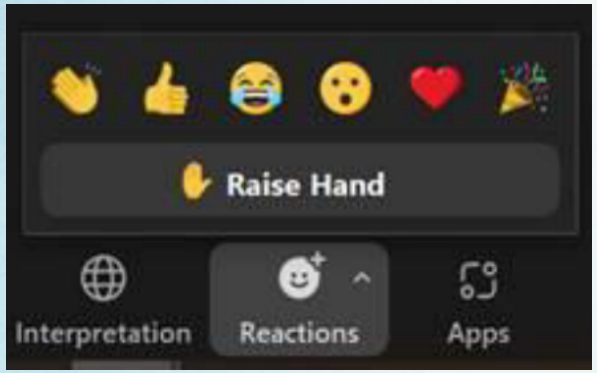
CALIFORNIA
AIR RESOURCES BOARD

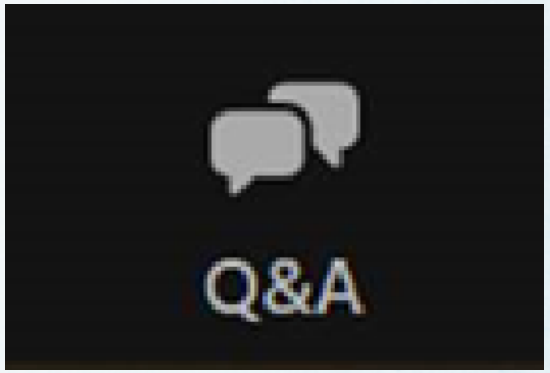
Public Workshop for the Draft 2025 Cargo Handling Equipment Technology Assessment

November 13, 2025

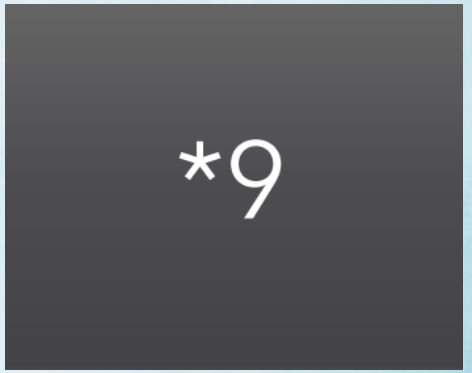
How to Participate During the Workshop



Zoom: To be added to the speaking queue, use the Raise Hand feature



Zoom: Submit questions using the Zoom Q&A box

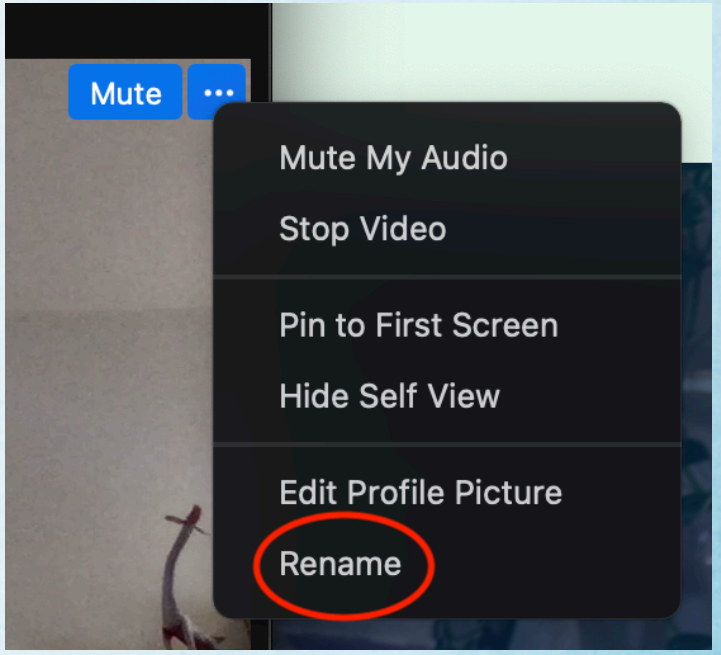


Phone: Press *9 to Raise Hand and *6 to Unmute

Check Your Zoom Name

- To rename, click the dots on the top right side of your picture/video
- Use this naming convention:
  - First Last - Affiliation

(e.g., Joelle Howe - CARB)



Before We Get Started

- Need help? Use the Q&A function in Zoom to request assistance
- Slides are available on the CHE Technology Assessment webpage
  - https://ww2.arb.ca.gov/our-work/programs/cargo-handling-equipment/che-technology-assessments
- Zoom recording will be made available at the link above

Workshop Agenda

- Background
- Draft CHE Technology Assessment
  - **Introduction and Approach**
  - **Results**
  - Conclusion
  - Appendices
- **Wrap-up**

Discussion/Q & A after bolded topics

Background

- CHE Definition
- Current CHE Regulation
- CHE Population and Emissions Inventory

CHE Definition

"Any off-road, self-propelled vehicle or equipment used at a port or intermodal rail yard to lift or move container, bulk, or liquid cargo carried by ship, train, or another vehicle to perform maintenance and repair activities that are routinely scheduled or that are due to predictable process upsets …"

Mobile Cargo Handling Equipment Regulation
13 CCR § 2479

CARB Mobile CHE Regulation

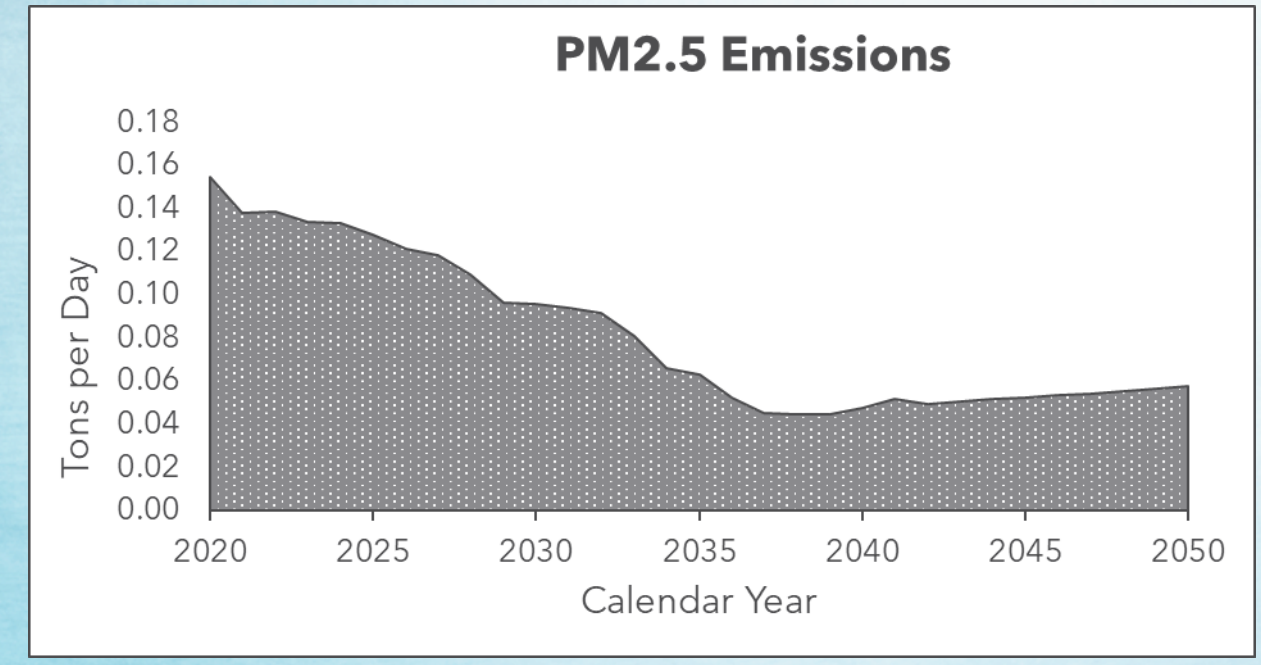
- Adopted in 2005 and amended in 2011
- Fully implemented in 2017
- Requires diesel-powered CHE to meet NOx and PM standards
- Fuel trucks, mobile cranes, and sweepers are exempt from the current requirements
- No zero-emission requirements

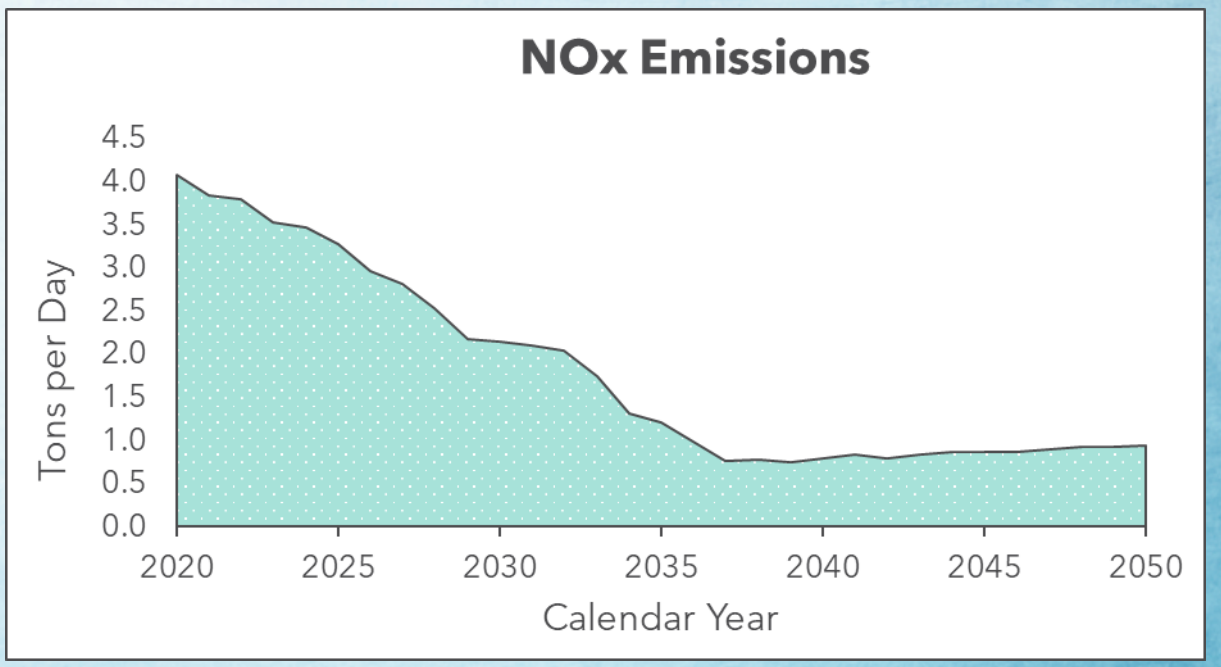
CHE Population and Emissions Inventory

- Over 5,000 CHE statewide
  - Population is expected to double by 2050
- Largest populations are at the Ports of Long Beach, Los Angeles, and Oakland
- Most equipment is diesel-powered

Statewide CHE Population and Emissions Inventory (continued)

- Current regulation and natural turnover reduce PM2.5 and NOx emissions until about 2037
- Emissions remain steady through 2050 and beyond





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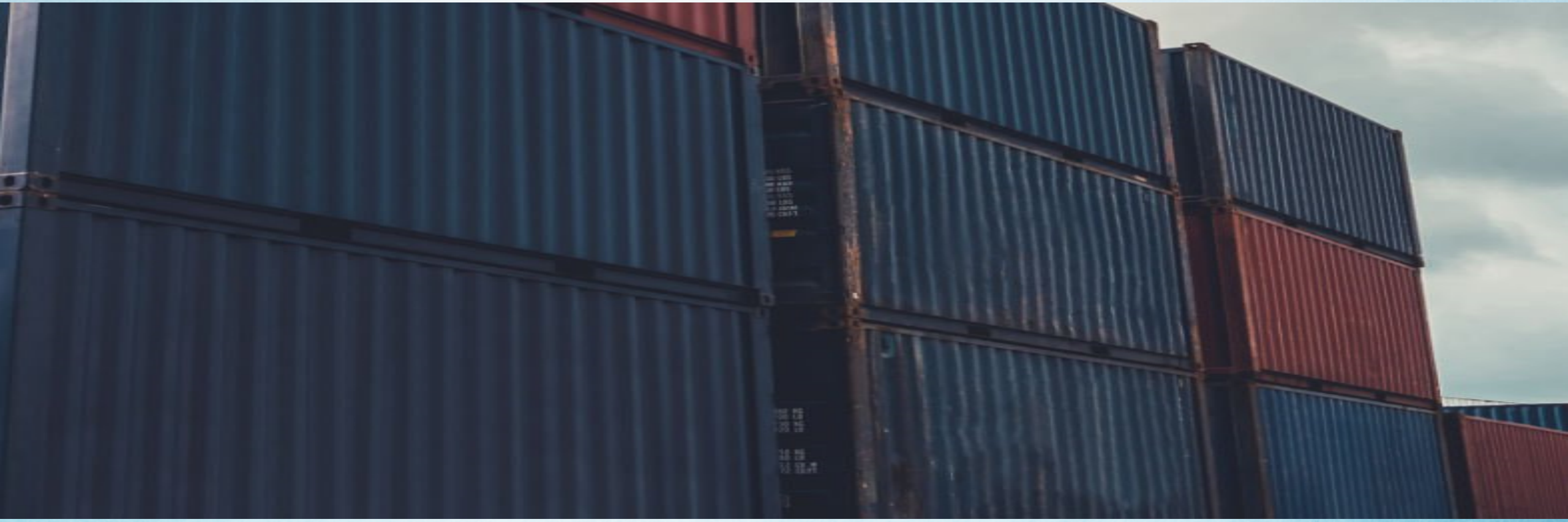
Draft CHE Technology Assessment



Draft CHE Technology Assessment Introduction and Approach

- Purpose of the Technology Assessment
- Technology Assessment Elements
- Technology Assessment Development
- CHE Types and Categories
- Zero-Emission CHE Technologies
- Technology Assessment Approach

Purpose of the Technology Assessment

- Help meet California's risk reduction, air quality, and climate goals, and the directives of EO N-79-20 and EO N-27-25
- Evaluate the availability and operational feasibility of zero-emission CHE technologies
  - CARB published previous CHE Technology Assessment in 2015
- Inform and support various planning and regulatory actions:
  - Mobile Source Strategy and State Implementation Plan
  - Scoping Plan updates
  - Funding plans for clean transportation incentives

Technology Assessment Elements

- Technology Description
- Technology Readiness
- Emissions Benefits
- Infrastructure Requirements and Considerations
- Economics
- Technology Outlook

Technology Assessment Development

- Staff conducted extensive research and outreach including:
  - Site visits to California seaports and intermodal railyards
  - Meetings with CHE manufacturers, operators, mechanics, and facility managers
  - Review of technology assessments, including those from the Ports of Long Beach, Los Angeles, and Oakland
  - Analysis of news articles, journals, and demonstration reports
  - Technical research on CHE duty cycles, use-cases, lifespan, etc.
- Assessment reflects data available through January 2025

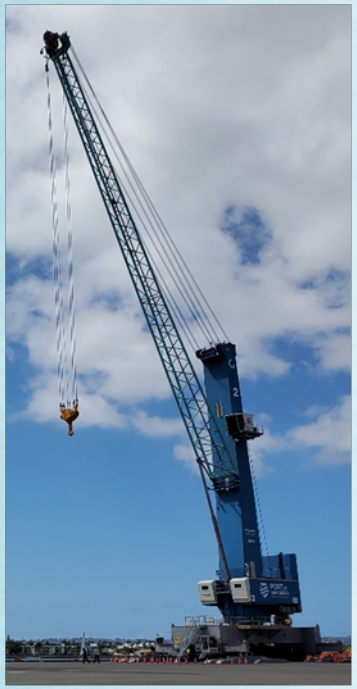
CHE Types and Categories

The Technology Assessment includes 25 of the most common "types" of CHE, separated into 3 "categories"

Bulk Material CHE	Container CHE	Facility Support CHE
• Crane, Material Handling • Crane, Mobile • Crane, Mobile Harbor • Crane, Off-Road • Dozer • Excavator • Forklift, Heavy Lift • Forklift, Telehandler • Haul Truck • Loader or Loader-Excavator • Log Stacker	• AGV • Rail-Mounted Gantry Crane • Reach Stacker • Rubber-Tired Gantry Crane • Ship-to-Shore Crane • Shuttle and Straddle Carriers • Side Handler • Top Handler • Yard Truck	• Aerial Lift • Cone Vehicle • Railcar Mover • Utility Truck, Other (fuel trucks, water trucks, etc.) • Utility Truck, Sweeper

CHE Types and Categories (continued)

Bulk Material CHE



Container CHE

Facility Support CHE

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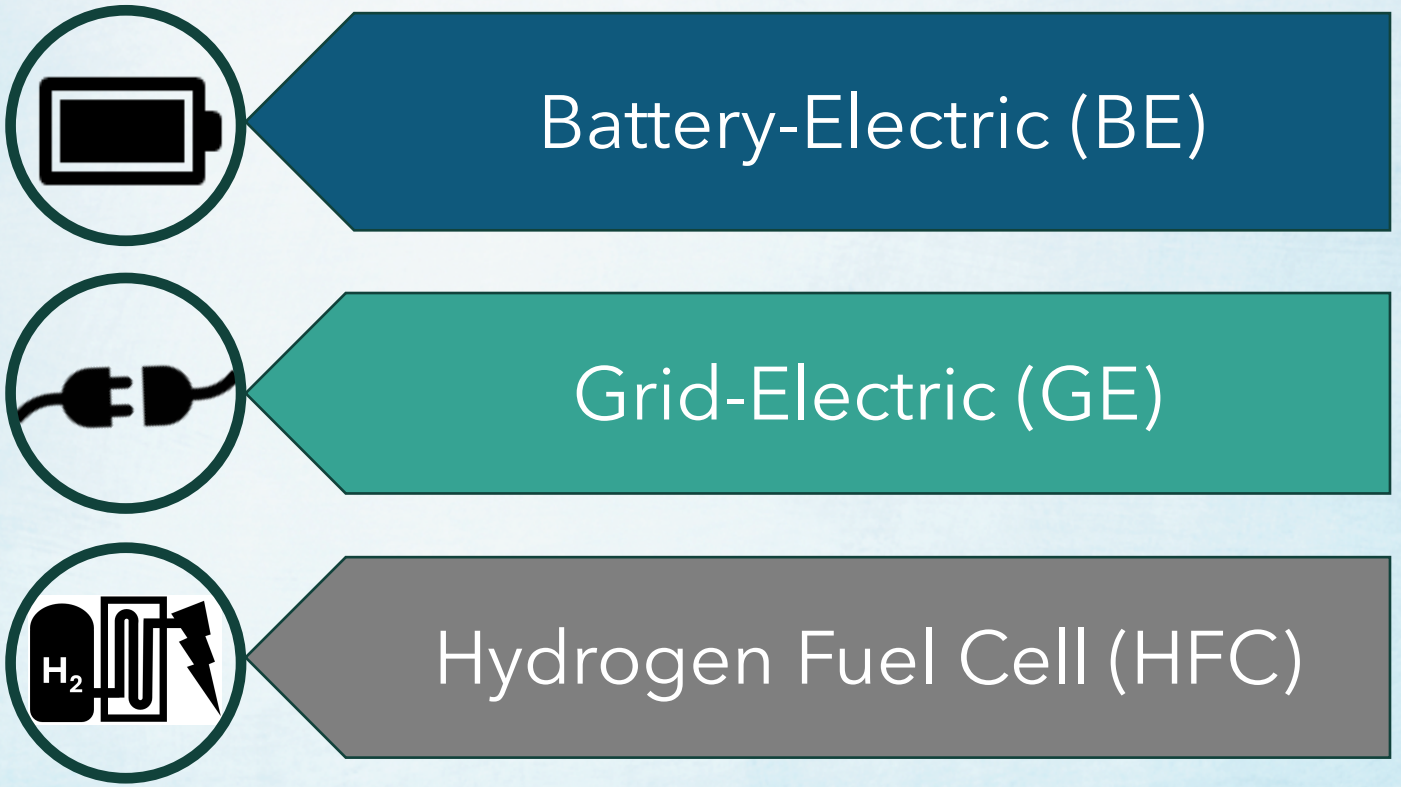
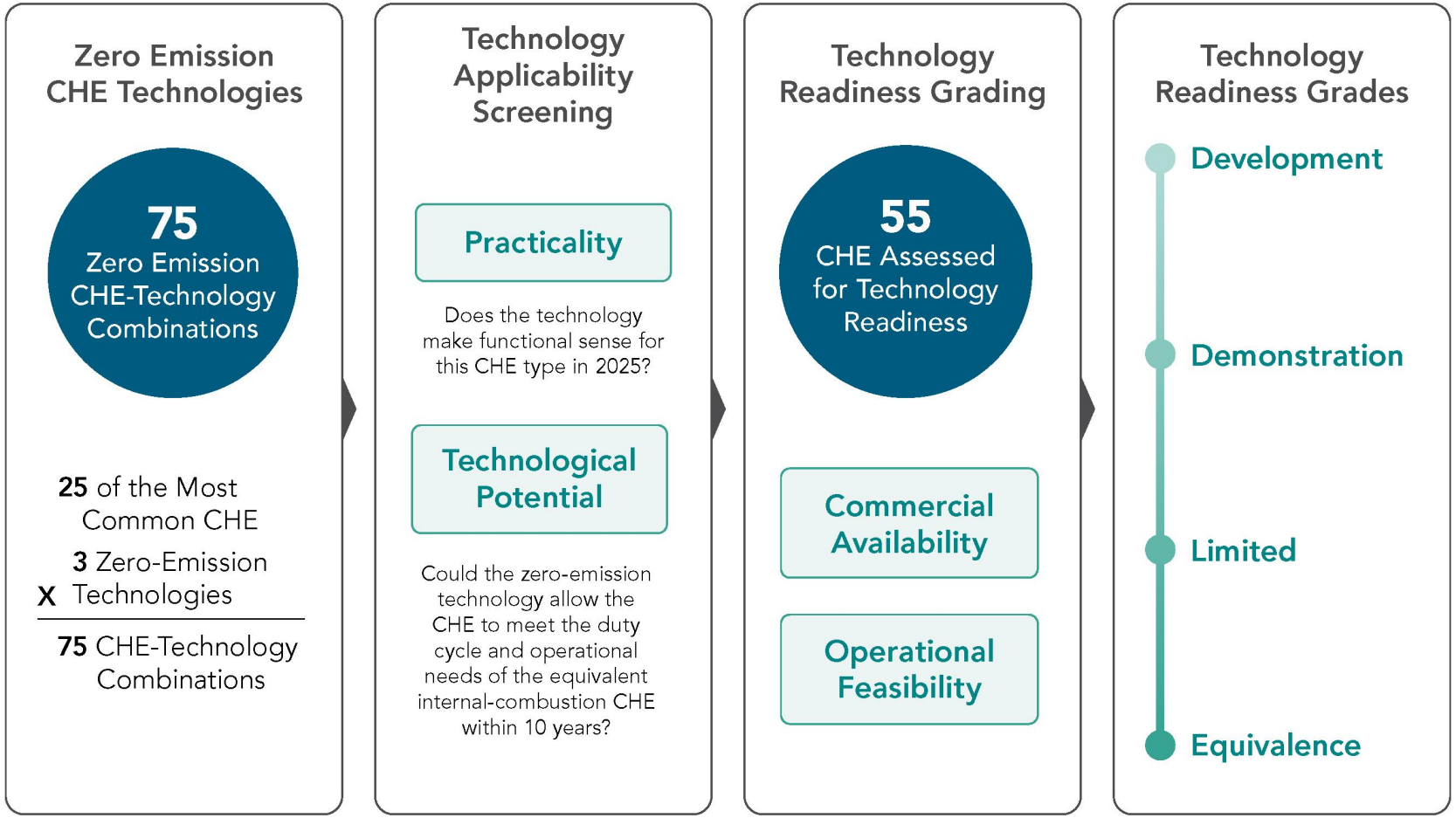
Zero-Emission (ZE) CHE Technologies



Technology Assessment Approach



Details on the Technology Applicability screening and Technology Readiness Grades can be found in Appendix C and Appendix D, respectively.

Technology Assessment Approach (continued)

Technology Readiness Grades

Grade	Description	Deployment Assessment
Development	• Early product development to pre-production	Not ready for deployment
Demonstration	• Early/limited commercial availability • Not fully demonstrated or reliable	Further demonstrations are required
Limited	• Commercially available • Minor reliability issues • Likely first-generation equipment	Can be deployed on a limited basis
Equivalence	• Full commercial availability • Achieves operational and functional equivalency to diesel counterparts	Ready for full scale adoption at most facilities

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Details on Technology Readiness Grades can be found in Appendix D.

Questions/Comments

Any questions or comments on what we presented?

- CHE Definition
- Current CHE Regulation
- CHE Population and Emissions Inventory
- CHE Types and Categories
- The 3 ZE technologies
- Technology Assessment

Draft CHE Technology Assessment Results

- Technology Description and Readiness
- **Emissions Benefits and Considerations**
- Infrastructure
- **Economics**
- Technology Outlook

Discussion/Q & A after bolded topics

Battery-Electric CHE
Technology Description

- Uses rechargeable batteries to power both movement and cargo handling
- Two primary battery chemistries: lead-acid and lithium-ion
  - Lithium-ion lasts longer, weighs less, but costs more
- Matching diesel-powered CHE runtime with batteries is challenging
  - Facilities want at least one – ideally two – shifts before recharging
  - Charging can happen strategically between shifts, known as "opportunity charging"

Battery-Electric CHE
Technology Description (continued)

Benefits	Potential Challenges

• Increased mobility compared to GE CHE, which often require cables or busbars for power
• Several types of this CHE are commercially available
• Battery technology is continually improving:
  ○ Increased capacity
  ○ Faster charge times
  ○ Lower cost
	• More expensive than diesel
	• Batteries are heavy
	• Requires frequent recharging
	• Takes longer to charge than refueling equivalent diesel-powered CHE
	• Charging infrastructure occupies facility real estate

BE Bulk Material CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
Crane, Material Handling	4	3	0	Demonstration
Crane, Mobile	8	0	1	Demonstration
Crane, Off-Road	5	0	0	Demonstration
Dozer	0	2	0	Demonstration
Excavator	7	7	0	Demonstration
Forklift, Heavy Lift	39	6	2	Demonstration
Forklift, Telehandler	8	3	1	Demonstration
Haul Truck	1	2	5	Limited
Loader or Loader-Excavator	21	7	3	Demonstration
Log Stacker	0	0	0	Development

BE Container CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
AGV	3	1	0	Equivalence
Rail-Mounted Gantry Crane	0	0	0	Development
Reach Stacker	8	1	1	Demonstration
Rubber-Tired Gantry Crane	2	1	0	Demonstration
Shuttle and Straddle Carriers	2	1	0	Demonstration
Side Handler	9	1	1	Demonstration
Top Handler	3	0	0	Limited
Yard Truck	20	0	2	Limited

BE Facility Support CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
Aerial Lift	16	1	0	Demonstration
Cone Vehicle	4	0	0	Demonstration
Railcar Mover	21	1	0	Demonstration
Utility Truck, Other	20	1	1	Demonstration
Utility Truck, Sweeper	4	11	0	Demonstration

Grid-Electric CHE
Technology Description

- Powered by a continuous grid connection using cables, busbars, or pantographs
- Best for CHE that is mostly stationary or follows predictable paths
- Most still require batteries, but not as much as BE CHE
- Providing a grid connection for mobile equipment often requires infrastructure changes and a lot of planning
- Dynamic charging is being explored for cars and delivery vehicles but is not yet used for CHE

Grid-Electric CHE
Technology Description (continued)

Benefits	Potential Challenges
• Reduces or eliminates the need for batteries • Reduces or eliminates long charge times • Several types of this CHE are industry standard and commercially available	• Grid connections (e.g., cables, busbars, etc.) can limit mobility • Infrastructure is expensive, disrupts operations during construction, uses valuable real estate

GE Bulk Material CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
Crane, Material Handling	14	1	0	Demonstration
Crane, Mobile Harbor	2	0	2	Demonstration
Crane, Off-Road	4	0	0	Demonstration
Excavator	2	0	0	Demonstration

GE Container CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
Rail-Mounted Gantry Crane	9	0	0	Equivalence
Rubber-Tired Gantry Crane	9[1]	3[2]	0	Demonstration
Ship-to-Shore Crane	8	0	0	Equivalence
Yard Truck	0	0	0	Development

1. Includes 4 new GE RTGs and 5 conversions from diesel to GE.
2. Includes 1 new GE RTG and 2 conversions from diesel to GE.

GE Facility Support CHE
Technology Readiness

- There are no commercially available models of GE facility support CHE
- All GE facility support CHE score 0 for Technology Applicability
  - Mainly due to availability of battery-electric versions
- BE and HFC technology provide ZE solutions for this category of CHE

Hydrogen Fuel Cell CHE
Technology Description

- Uses a fuel cell instead of a battery or a connection to the grid
  - Similar to a battery but uses hydrogen as a fuel instead of needing to be recharged
- Most common type for CHE: polymer electrolyte membrane (PEM) fuel cells using hydrogen as the fuel
- Hydrogen fuel cells are a mature technology but not widely used for CHE

Hydrogen Fuel Cell CHE
Technology Description (continued)

Benefits	Potential Challenges
• Same mobility as batteries • Refueling times for hydrogen fuel cell CHE are like those of diesel-powered CHE • Reduces battery-dependency	• Limited commercial availability • More expensive than diesel • Hydrogen supply and support infrastructure are not readily available • Hydrogen is more expensive than diesel

HFC Bulk Material CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
Crane, Material Handling	0	0	0	Development
Crane, Mobile	0	0	0	Development
Crane, Mobile Harbor	0	0	1	Development
Crane, Off-Road	0	0	1	Development
Dozer	0	0	0	Development
Excavator	0	0	6	Development
Forklift, Heavy Lift	9	9	0	Demonstration
Forklift, Telehandler	0	0	1	Development
Haul Truck	0	0	4	Development
Loader or Loader-Excavator	0	1	2	Development
Log Stacker	0	0	0	Development

HFC Container CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
AGV	0	0	0	Development
Rail-Mounted Gantry Crane	0	0	0	Development
Reach Stacker	0	0	1	Development
Rubber-Tired Gantry Crane	0	0	4	Demonstration
Shuttle and Straddle Carriers	0	0	0	Development
Side Handler	0	0	1	Development
Top Handler	0	0	2	Development
Yard Truck	0	0	4	Demonstration

HFC Facility Support CHE
Technology Readiness

Equipment Type	Commercially Available in the U.S.	Commercially Available Outside the U.S.	Non-Commercial Units	Technology Readiness Grade
Aerial Lift	2	0	0	Demonstration
Cone Vehicle	0	0	0	Development
Railcar Mover	0	0	0	Development
Utility Truck, Other	0	0	4	Development
Utility Truck, Sweeper	1	1	0	Limited

Emissions Benefits and Considerations

Benefits and Considerations	Technology
No exhaust emissions of criteria pollutants, toxic pollutants, or GHGs	BE, GE, HFC
California's grid is very clean* and getting cleaner – powering BE and GE CHE	BE, GE
Reduces e-waste from spent batteries	GE, HFC
Helps avoid charger congestion and unmanaged charging, reduces grid stress and reliance on less clean power sources (peaker plants)	GE, HFC
Hydrogen can be renewably produced, offering the fewest life-cycle emissions	HFC
Hydrogen leakage may have indirect GHG impacts	HFC

*In 2024, nearly 60% of California's in-state electricity generation came from renewable sources.

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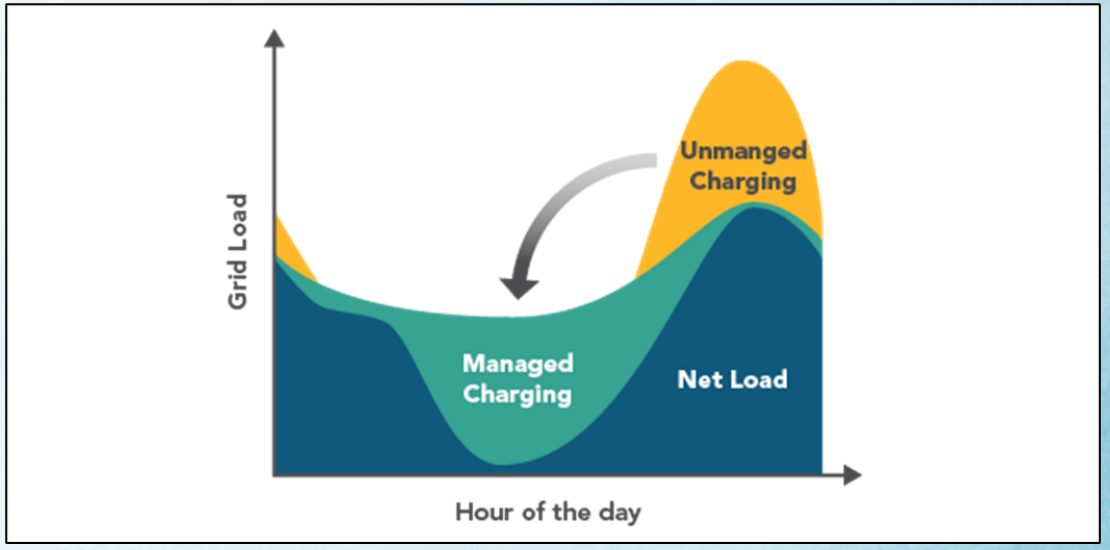
Questions/Comments

Any questions or comments on what we presented?

- Technology Description
- Technology Readiness
  - Commercial Availability
  - Technology Readiness
- Emissions Benefits and Considerations

BE and GE Infrastructure
Requirements and Considerations

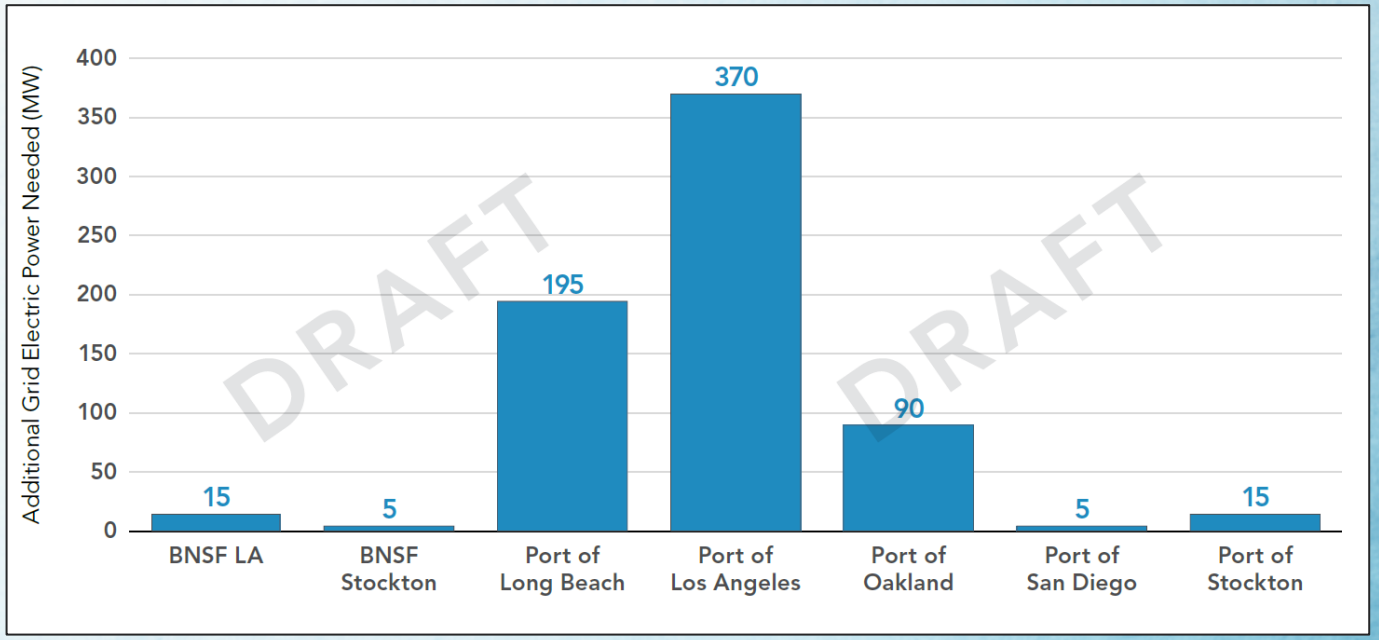
- Electricity source
  - Statewide grid analysis
  - Utility grid infrastructure upgrades
  - Microgrids
- Charging equipment
  - Space and permitting
  - Certification (BE only)
  - Charging station (BE only)



- Logistics
  - Charging interfaces: manual conductive, hands-free conductive, and inductive charging (BE only)
  - Charging practices: managed charging and unmanaged charging (BE only)
  - Obstructions and mobility limits (GE only)

BE and GE Infrastructure (continued)
Statewide Grid Analysis

- Additional ~ 695 MW needed for full ZE CHE fleet at California facilities
- 21 of the 28 CHE facilities analyzed have sufficient utility-provided load capacity
- Greatest shortfalls at Ports of Long Beach, Los Angeles, and Oakland
- Methodology and assumptions can be found in Appendix F



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BE and GE Infrastructure (continued)
Challenges

- Costs
- Long deployment timelines
  - Permitting processes
  - Certification processes (BE only)
- Space constraints
- Charging equipment (BE only)
  - Availability, reliability, and compatibility
- Utility grid reliability

HFC Infrastructure
Requirements and Considerations

- Hydrogen supply
- Delivery methods
  - Gaseous (pipelines and high-pressure tube trailers), liquid transport, mobile refuelers, chemical carriers
- Storage method
  - Gaseous, liquid, material-based
- Safety standards
- Fueling stations
  - Design and components
  - Permitting
  - Operating requirements
  - Dispensing codes and standards

HFC Infrastructure (continued)
Challenges

- Costs
- Permitting
  - Lack of standardized industry protocols for hydrogen fueling
- Lengthy timelines for hydrogen infrastructure projects
- Technology maturity
  - Hydrogen loss during storage
  - Immature technology for material-based storage
- Safety concerns

BE and GE Economics

- Equipment capital costs
  - Electric CHE can cost over 1 to 2 times of diesel
  - Onboard batteries
  - Charging equipment (BE only)
- Operating costs
  - Electricity
  - Maintenance
  - Midlife battery replacement (BE only)
- Infrastructure costs
  - Utility grid infrastructure upgrades
  - Charging station installation (BE only)
  - Infrastructure maintenance

HFC Economics

- Equipment capital costs
  - Hydrogen fuel cell CHE can cost > 2 times diesel
  - Mobile refueler (optional)
- Operating costs
  - Hydrogen fuel
  - Maintenance
  - Midlife battery replacement
- Infrastructure costs
  - On-site production
  - Off-site production
    - Fueling station installation
    - Maintenance
    - Operation

Questions/Comments

Any questions or comments on what we presented?

- Infrastructure
- Economics

Technology Outlook

Outlook to Achieve a Technology Readiness Grade of Equivalence by 2035	Battery-Electric	Grid-Electric	Hydrogen Fuel Cell
CHE achieves Equivalence	1	2	0
Likely, given current regulations and incentive programs	2	0	0
Only with additional emission reduction strategies and incentive programs	13	5	6
Dependent on other CHE with similar ZE fuel	6	0	8
Not likely (assessed)	1	1	10
Not likely (not assessed, Technology Applicability=0)	2	17	1
Totals	**25**	**25**	**25**

Conclusion
ZE CHE Progress

Of the 25 types of CHE evaluated:

- 24 have commercially available ZE models
  - 23 are available in the U.S.
- 3 types achieve Equivalence
  - In California, 100% of these types are ZE – over 400 pieces of CHE
- 2 types are likely to achieve Equivalence with current regulations and incentives

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Conclusion (continued)
ZE CHE Challenges

- Most ZE CHE (80%) do not achieve Equivalence and likely will not within 10 years without market interventions
  - Based on Technology Readiness Grades, limited infrastructure, and cost of equipment
- ZE CHE is available, but infrastructure needs, high costs, and reliability must be addressed
- Additional emission reduction strategies, incentive programs, and other initiatives are needed

(Photo by Karl Nielsen, Autoweek.com)

Appendices

- Appendix A: List of CHE
- Appendix B: Commercially Available CHE
- Appendix C: Technology Applicability Scoring Methodology
- Appendix D: Technology Readiness Grading Methodology
- Appendix E: CHE Infrastructure Demonstrations, Pilots, Product Launches and Prototypes
- Appendix F: Grid Impact Analysis
- Appendix G: Electricity Cost Calculations
- Appendix H: 2024-2025 Funding Opportunities for ZE CHE and Infrastructure
- Appendix I: List of Individual Projects Boosting Hydrogen Supply in California

Wrap-Up

- Request for Information
- More Information
- Next Steps

Request for Information

- Callout boxes throughout the document requesting information on:
  - ZE CHE implementations and costs
  - ZE CHE infrastructure projects
  - Any ZE CHE or demonstration projects not on our lists
- Example:

> Staff is seeking information on hydrogen fuel cell CHE demonstration projects and development status.

Next Steps

We Want Your Input:
Submit written comments, feedback, and supporting data to cargohandling@arb.ca.gov
Deadline: December 12, 2025

Final Document
Expected: Mid-2026

More Information

- CHE Technology Assessment webpage:
  https://ww2.arb.ca.gov/our-work/programs/cargo-handling-equipment/che-technology-assessments

- Subscribe to the CHE email list:
  http://public.govdelivery.com/accounts/CARB/subscriber/new?topic_id=cargo

Questions/Comments