

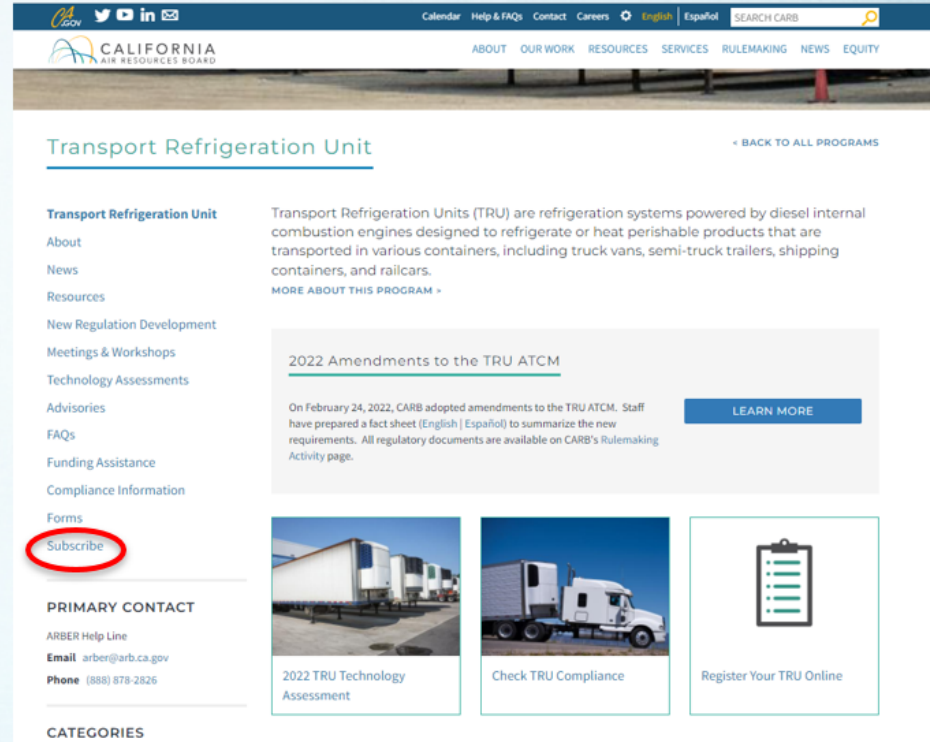






# **Draft Technology Assessment: Non-Truck Transport Refrigeration Units (TRU) Workshop**

May 17, 2022

# Workshop and Program Materials

- Workshop is *NOT* recorded
- Slides available at:  
<https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit/tru-technology-assessments>
- Subscribe to the TRU email list



**CARB**     [Calendar](#) [Help & FAQs](#) [Contact](#) [Careers](#) [English](#) [Español](#)

**CALIFORNIA**  
AIR RESOURCES BOARD

[ABOUT](#) [OUR WORK](#) [RESOURCES](#) [SERVICES](#) [RULEMAKING](#) [NEWS](#) [EQUITY](#)

## Transport Refrigeration Unit

[← BACK TO ALL PROGRAMS](#)

**Transport Refrigeration Unit**

[About](#)  
[News](#)  
[Resources](#)  
[New Regulation Development](#)  
[Meetings & Workshops](#)  
[Technology Assessments](#)  
[Advisories](#)  
[FAQs](#)  
[Funding Assistance](#)  
[Compliance Information](#)  
[Forms](#)  
[Subscribe](#)


Transport Refrigeration Units (TRU) are refrigeration systems powered by diesel internal combustion engines designed to refrigerate or heat perishable products that are transported in various containers, including truck vans, semi-truck trailers, shipping containers, and railcars.

[MORE ABOUT THIS PROGRAM >](#)


### 2022 Amendments to the TRU ATCM

On February 24, 2022, CARB adopted amendments to the TRU ATCM. Staff have prepared a fact sheet (English | Español) to summarize the new requirements. All regulatory documents are available on CARB's Rulemaking Activity page.


[LEARN MORE](#)



2022 TRU Technology Assessment



Check TRU Compliance



Register Your TRU Online

**PRIMARY CONTACT**

ARB Help Line  
**Email** [arber@arb.ca.gov](mailto:arber@arb.ca.gov)  
**Phone** (888) 878-2826

**CATEGORIES**



# Before We Get Started

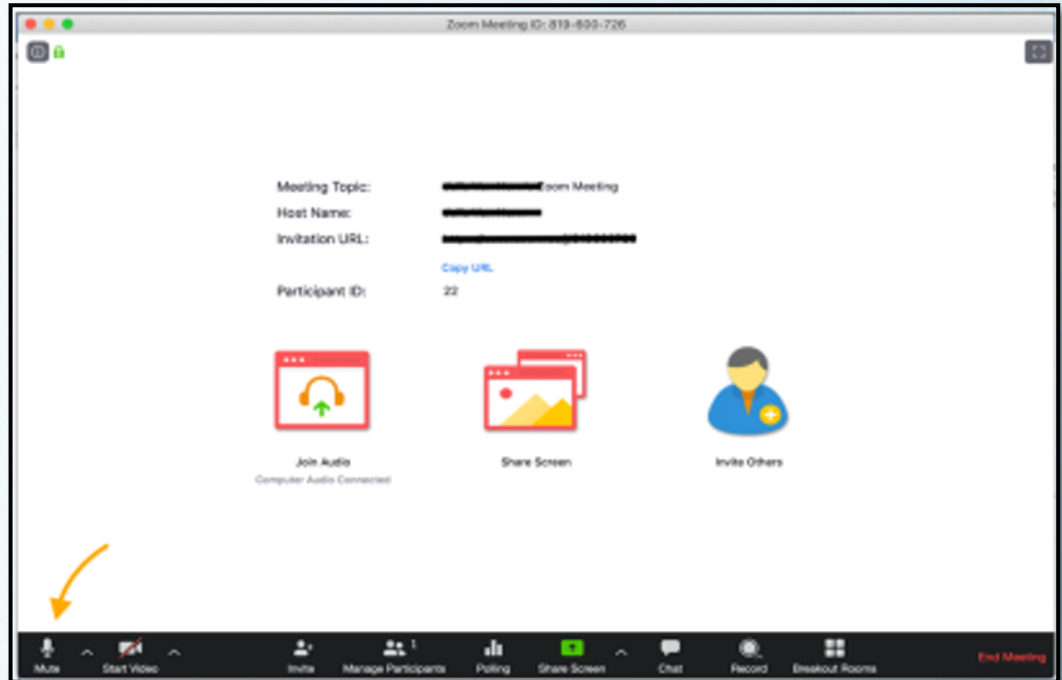
- Please **mute yourself** and make sure your name is showing as your screen name
- To **rename**, click on the top right side of your picture/video
- Use this naming convention, **First Last - Affiliation** (e.g. Jane Doe - CARB)
  - **Community Organization / Company / Air District / Agency / etc.**
- **Need help?** Use the Chat function to request assistance

# Zoom Orientation

## Mute/Unmute

Please remain on mute unless your name has come up in the speaking queue

- Zoom: **Mute/Unmute** button at the bottom left
- Phone: Dial \*6 to mute/unmute





# Raise Hand

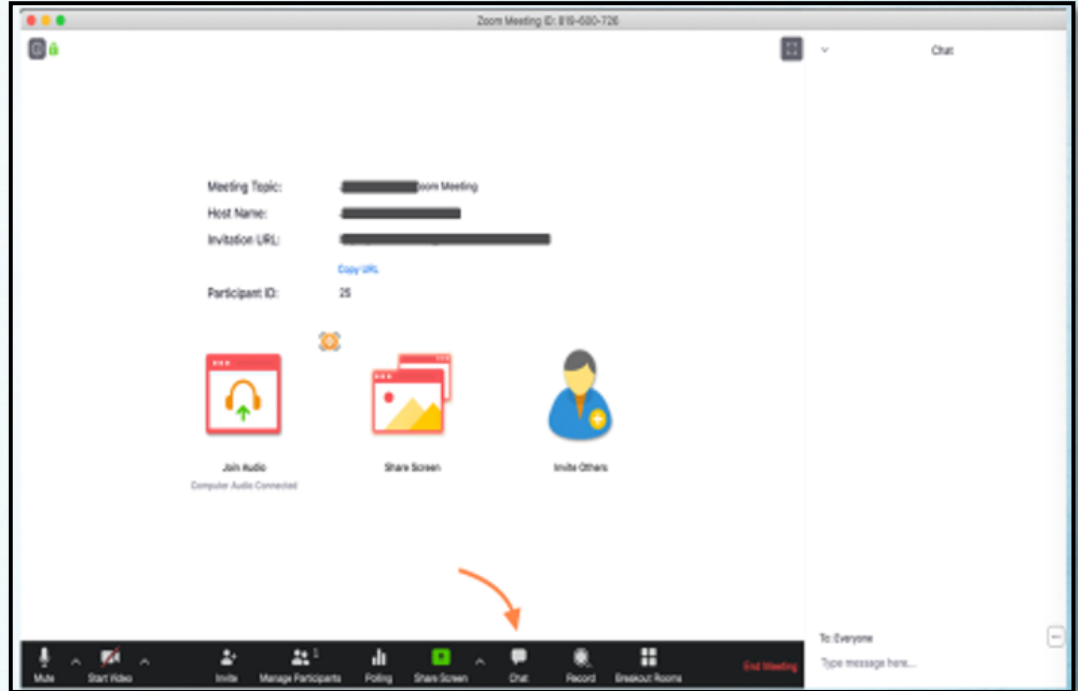
To be added to the speaking queue, please use the **Raise Hand** option.

- Zoom: Click **Participants**, then **Raise Hand**
- Phone: dial \*9  
We'll check in with the phone line periodically



# Chat

- Click on the **chat** icon near the center bottom of your screen
- Choose “private” chat to chat with the Host or Co-host
- Private chats are archived





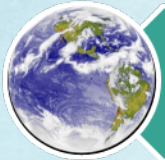
# Need for Zero-Emission TRUs



Cut community health risk  
(support Assembly Bill 617 emission reductions)



Help attain regional air standards  
(support State Implementation Plan)



Mitigate climate change (support Scoping Plan and  
Short-Lived Climate Pollutant Reduction Strategy)



Governor's Executive Order N-79-20

# Workshop Agenda

- TRU and Document Overview
- eTRUs
- Battery-electric TRUs
- Hydrogen Fuel Cell TRUs
- Cryogenic TRU Systems
- Range Extending Technologies
- Cold Plates
- Zero-emission Infrastructure
- Next Steps and Conclusion



*Discussion/Q&A planned for **bolded** topics*





# **Overview:**

## **Transport Refrigeration Units and Draft Document**

# Non-Truck TRU Classes

Domestic  
Shipping  
Container TRU

What is a  
transport  
refrigeration  
unit (TRU)?

Refrigeration system that  
controls the environment  
of temperature-sensitive  
products during  
transport.



Trailer  
TRU



Railcar TRU





# TRU Generator Sets

What are  
TRU  
Generator  
Sets?

Diesel-powered  
generators that power  
electrically driven  
refrigeration units,  
mainly refrigerated  
ocean containers.



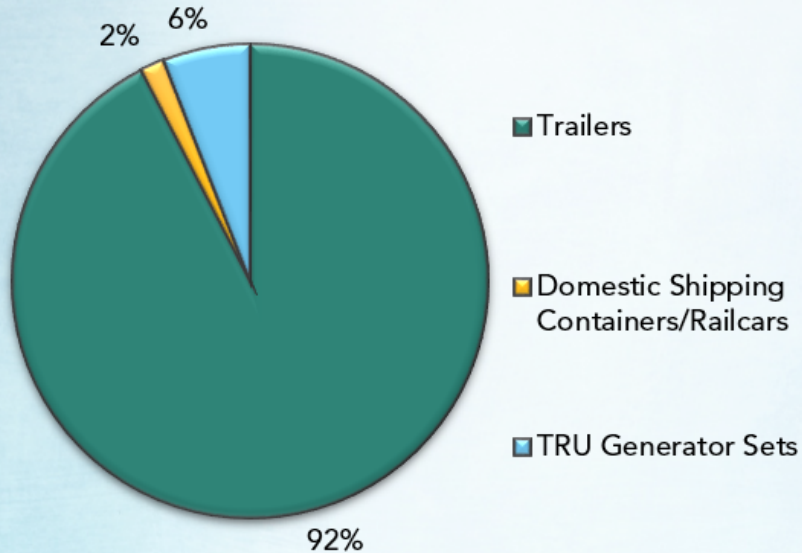
# Non-Truck TRU and TRU Generator Set Population in CA (2021)

|   | # TRUs that Operate in CA | TRUs Operating in CA Per Day |
|---|---------------------------|------------------------------|
| Trailer TRU                                     | 158,403                   | 42,004                       |
| Domestic Shipping Container TRU and Railcar TRU | 4,081                     | 774                          |
| TRU Generator Set                               | 30,255                    | 7,031                        |
| <b>Total</b>                                    | <b>192,709</b>            | <b>49,809</b>                |

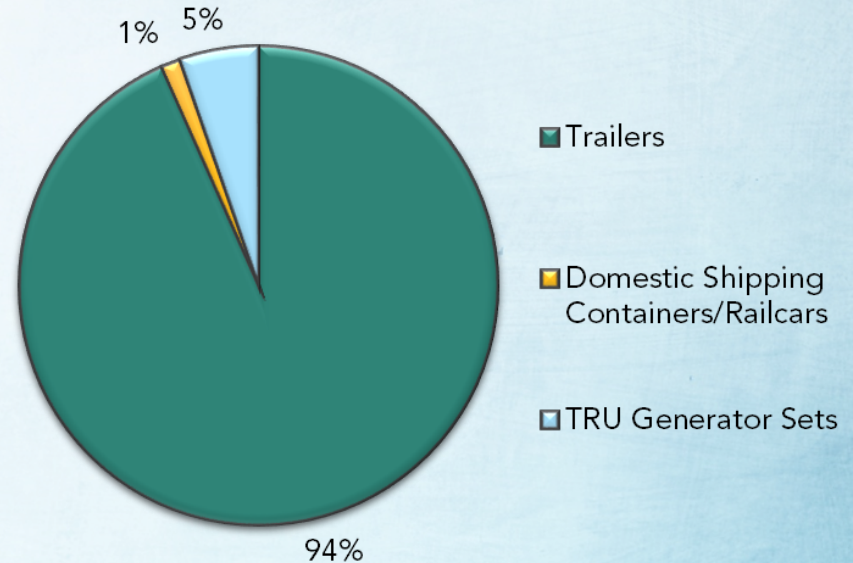


# 2021 Emissions Inventory

Annual PM2.5 Emissions (percent by class)



Annual NOx Emissions (percent by class)



# Workshop Purpose

1. Document  
Framework

2. Zero-Emission  
Technologies

3. Solicit  
Input



# Technology Assessment Framework

Introduction

Non-Truck  
TRU Overview

Zero-Emission  
Technologies

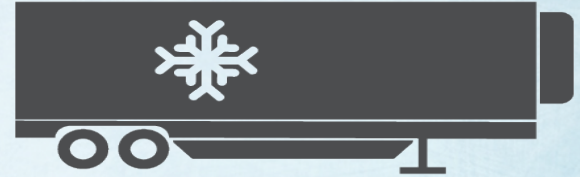
Conclusion

Appendices

|                                       |    |
|---------------------------------------|----|
| III. ZERO-EMISSION TECHNOLOGIES ..... | 17 |
| eTRUs .....                           | 17 |
| Technology Description .....          | 17 |
| Technology Readiness .....            | 22 |
| Emissions Benefits .....              | 23 |
| Infrastructure Requirements .....     | 23 |
| Economics .....                       | 24 |
| Technology Outlook.....               | 27 |

# Appendix Items

- **Appendix A:** Zero-Emission Demonstration Projects (2015-2021)
- **Appendix B:** 2021-2022 Federal, State, and Local Funding Opportunities
- **Appendix C:** List of Reviewed Studies



*More info on other State funding programs:*

- <https://business.ca.gov/industries/zero-emission-vehicles/zev-funding-resources/>
- <https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program>



# Call Out Boxes

Example:

*CARB staff seeking information on the demonstration projects in this table.*

*CARB staff also seeking information on any other demonstration projects for zero-emission technologies for non-truck TRUs which are not listed in this table.*

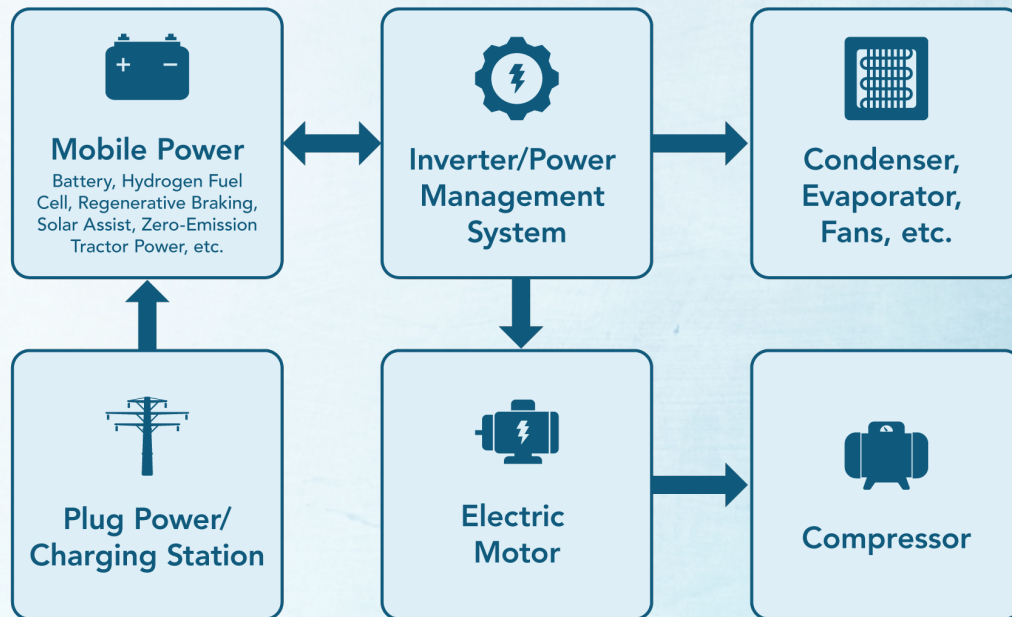


# Zero-Emission Technologies



# eTRUs Overview

- A TRU electrically driven at least part of the time
- 3 Categories:
  - All-electric
  - Hybrid-electric
  - Standby-electric



# eTRU Readiness

## Advantages

- Can use several power sources
- Readily Available
- Competitive pricing

## Challenges

- Compatibility



# Estimated Costs

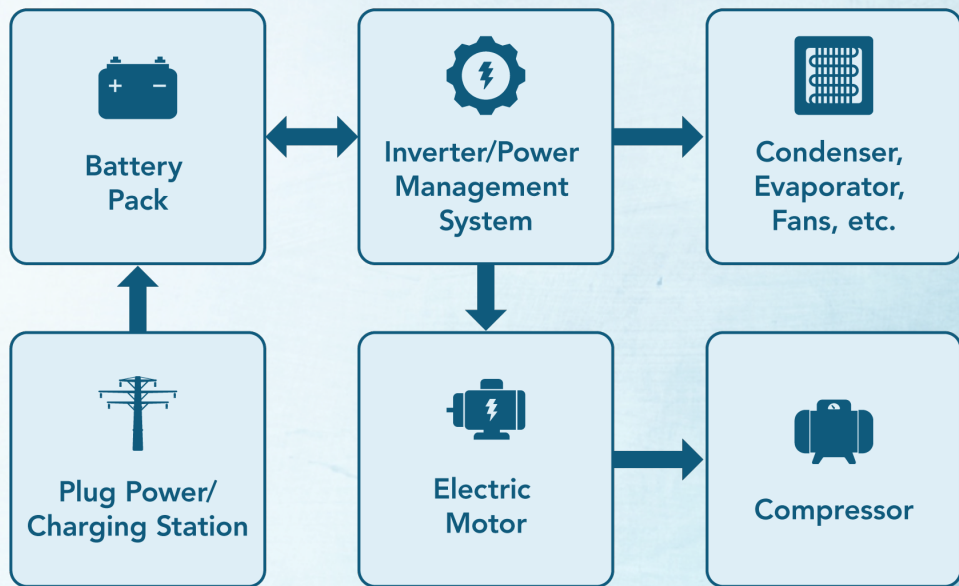
| Cost Component  | All-electric eTRU  | Hybrid-electric/stationary eTRU Using Plug-In when Stationary Costs  | Hybrid-electric eTRU when Mobile Costs   | Mobile Diesel-Powered TRU Costs     |
|---|--|--|--|-------------------------------------|
| Capital Cost of Equipment (manufacturer's suggested retail price) | [CARB Staff Seeking Info]                                      | \$33,500 to \$36,000 (<25 hp with new standards)   | \$33,500 to \$36,000 (<25 hp with new standards)   | \$24,400 to \$28,500 (<25 hp)       |
| Annual Fuel Costs   | \$1.52 per hour on electricity<br>\$3,040 per year electricity | \$1.52 per hour on electricity<br>\$760 per year electricity<br>\$4,780 per year total (diesel and electric) | \$2.68 per hour on diesel<br>\$4,020 per year diesel<br>\$4,780 per year total (diesel and electric) | \$2.68 per hour<br>\$5,360 per year |
| Operation and Maintenance – Maintenance                           | \$0.50 per hour<br>\$1,000 per year                            | \$0.50 per hour<br>\$1,000 per year  | \$0.50 per hour<br>\$1,000 per year  | \$0.95 per hour<br>\$1,900 per year |
| Infrastructure  | \$8,900 (one-time)   | \$8,900 (one-time)   | No additional cost   | No additional cost                  |

# Requested Info: eTRUs

- Zero-emission tractor power demonstrations
- Additional implementation challenges or technologies (Chapter III)
- Population of TRUs operating as eTRUs
- Cost Info:
  - Capital – units
  - Operation – fuel
  - Maintenance
  - Zero-emission infrastructure, maintenance (charging and plug), and installation

# Battery-Electric TRU Overview

- An eTRU powered by rechargeable battery packs
- Rely on a power management system
- Plug into grid power or electric vehicle supply equipment (EVSE)





# Battery-Electric TRU Readiness

## Advantages

- Commercially available
- Quiet operations
- Reduced maintenance

## Challenges

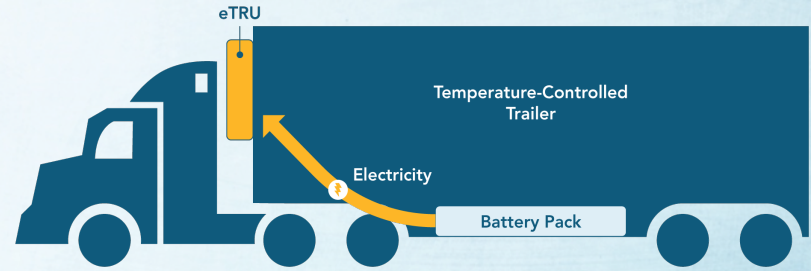
- Cost
- Limited operating range
- Longer refuel times

# Estimated Costs

| Cost Component                    | Battery-Electric             | Diesel-Cost     |
|-----------------------------------|------------------------------|-----------------|
| Capital                           | \$80,000                     | \$36,000        |
| Lithium-Battery Pack              | \$450 to \$500 per kWh       | Not Applicable  |
| Battery/Diesel Engine Replacement | \$9,000 to \$50,000          | \$7,295         |
| Annual-Fuel                       | \$3,950                      | \$4,150         |
| TRU Maintenance                   | \$0.50 per hour of operation | \$0.95 per hour |
| Infrastructure Capital            | \$4,300 to \$5,700           | \$0             |

# Requested Info: Battery-Electric TRUs

- Additional implementation challenges
- Battery Info
  - Average power draw
  - Door opening impacts
  - Required battery capacity
- Cost Info:
  - Capital – units
  - Operation – fuel
  - Maintenance
    - Zero-emission infrastructure, maintenance, and installation
- Any additional manufacturers (Chapter III)
- Additional demonstration projects (Appendix A)



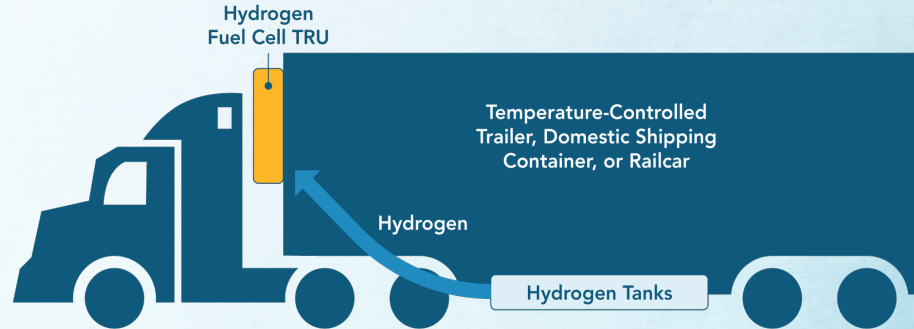
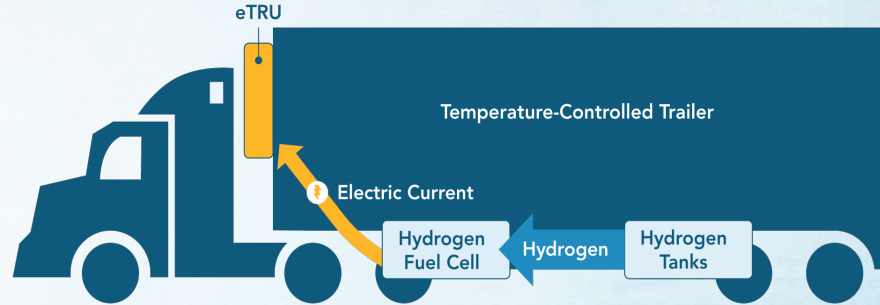


# Workshop Questions & Discussion

- Please use the **raise hand** function (\*9 if calling on the phone) to speak or use the chat function
- Please include slide numbers
- Please state your name and affiliation before asking a question or making a comment

# Hydrogen Fuel Cells Overview

- eTRU that uses hydrogen fuel cells as its power source
- Three potential configurations
  - Integrated fuel cell engine
  - Mounted fuel cell
  - Fuel cell housed with tanks





# Hydrogen Fuel Cell Readiness

## Advantages

- Commercially available
- Quiet operations
- Reduced maintenance

## Challenges

- Cost
- Limited operating range
- Tank weight
- Safety



# Estimated Costs

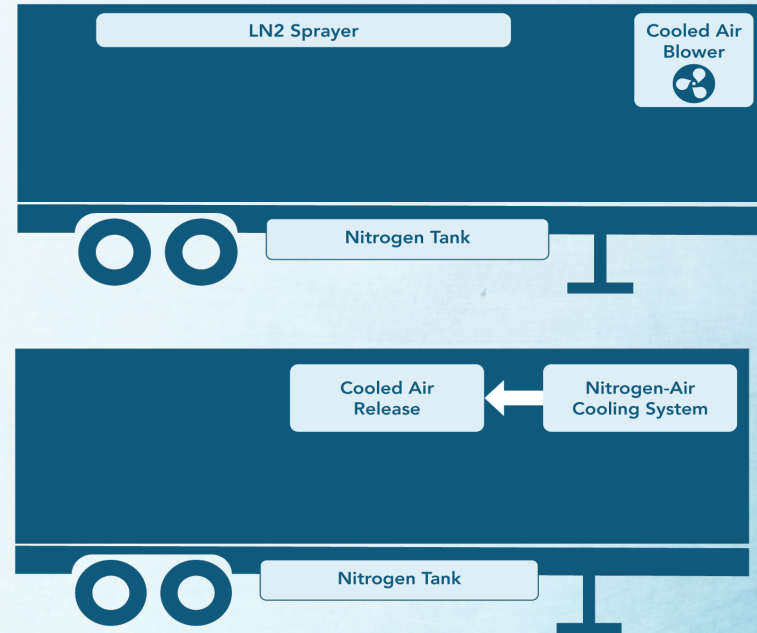
| Cost Component  | Hydrogen Fuel Cell Costs         | Diesel Costs                     |
|---|----------------------------------|----------------------------------|
| Hydrogen Fuel Cell TRU                                    |                                  |                                  |
| Capital: Fuel Cell TRU<br>(TRU with integrated fuel cell) | [CARB staff seeking information] | \$29,400                         |
| Capital: Tanks  | [CARB staff seeking information] | [CARB staff seeking information] |
| Annual Fuel   |                                  |                                  |
| Maintenance   |                                  |                                  |
| Hydrogen Fuel Cell-Powered eTRU                           |                                  |                                  |
| Capital: eTRU   | [CARB staff seeking information] | \$29,400                         |
| Capital: Fuel Cell  |                                  | Not applicable                   |
| Capital: Tanks  |                                  | [CARB staff seeking information] |
| Annual Fuel   |                                  |                                  |
| Maintenance   |                                  |                                  |
| Hydrogen Fuel Cell TRU Generator Set: Pin-On Class        |                                  |                                  |
| Capital   | [CARB staff seeking information] | \$17,940                         |
| Annual Fuel   |                                  | [CARB staff seeking information] |
| Maintenance   |                                  |                                  |
| Hydrogen Fuel Cell TRU Generator Set: Underslung Class    |                                  |                                  |
| Capital   | [CARB staff seeking information] | \$17,250                         |
| Annual Fuel   |                                  | [CARB staff seeking information] |
| Maintenance   |                                  |                                  |
| Hydrogen Fuel Cell TRU Generator Set: Powerpack           |                                  |                                  |
| Capital   | [CARB staff seeking information] | [CARB staff seeking information] |
| Annual Fuel   |                                  |                                  |
| Maintenance   |                                  |                                  |

# Requested Info: Hydrogen Fuel Cells

- Additional demonstration projects (Appendix A)
- Cost Info
  - Capital – units
  - Operation – fuel
  - Maintenance
  - Zero-emission infrastructure, maintenance, and installation
- Refueling
  - How operators will refill hydrogen tanks
  - Fill rate standard preferences
  - Connection standard preferences

# Cryogenic TRU System Overview

- A cooling system that uses
  - Liquid nitrogen
  - Oxygen
  - Carbon dioxide
- Two systems
  - Standard v. Dearman
- Two Methods
  - Direct injection v. indirect-injection





# Cryogenic TRU System Readiness

## Advantages

- Quiet operations
- Reduced maintenance
- Faster cooling times

## Challenges

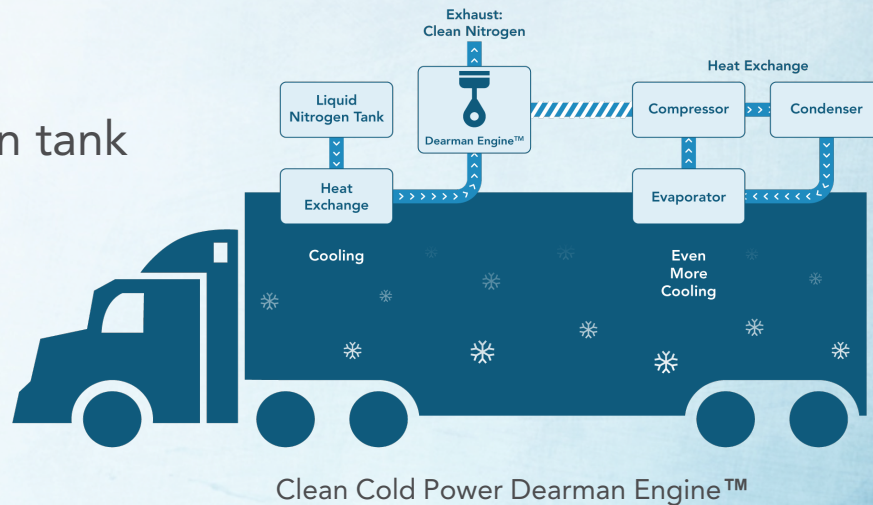
- Cost
- Limited operating range

# Estimated Costs

| Frequency       | Cost Component          | Cryogenic TRU System Costs | Diesel Costs     |
|-----------------|-------------------------|----------------------------|------------------|
| One-Time Costs  | Capital                 | \$35,000-\$50,000          | \$29,400         |
|                 | Dispensing System       | \$10,000                   | Not applicable   |
| Recurring Costs | LN2 Gravity Feed System | \$1,500 per month          | Not applicable   |
|                 | LN2 Quick Fill System   | \$3,000 per month          | Not applicable   |
|                 | Tank Lease              | \$270 per month (13-ton)   | Not applicable   |
|                 | Operation               | Cost varies                | Cost varies      |
|                 | Maintenance             | \$100 per year             | \$1,900 per year |

# Requested Info: Cryogenic TRU Systems

- Additional demonstration projects (Appendix A)
- Refueling
  - How operators refill the cryogen tank
- Cost Info
  - Capital – units
  - Operation – fuel
  - Maintenance
  - Zero-emission infrastructure, maintenance, and installation
- How cryogenic systems perform in California
- Operating range capabilities



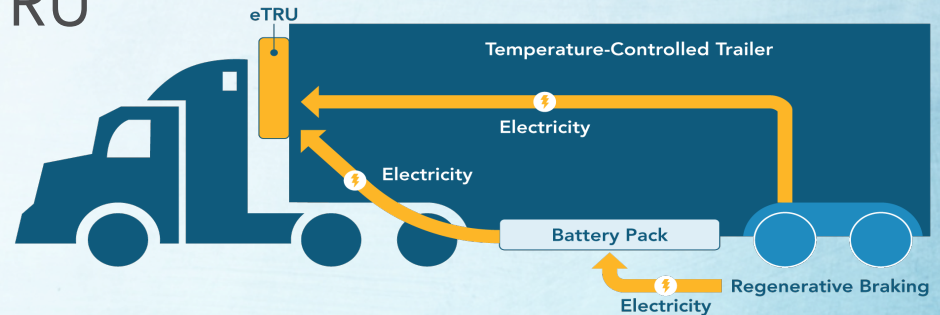


# Workshop Questions & Discussion

- Please use the **raise hand** function (\*9 if calling on the phone) to speak or use the chat function
- Please include slide numbers
- Please state your name and affiliation before asking a question or making a comment

# Range Extending Technologies Overview

- Regenerative braking systems
  - Installed on trailer axle or wheel hub
  - Generates electricity
- Solar assist
  - Provides power to eTRU
  - Charge batteries





# Regenerative Braking/Solar Assist Readiness

## Advantages

- Commercially available
- Extend operating range
- No infrastructure requirement

## Challenges

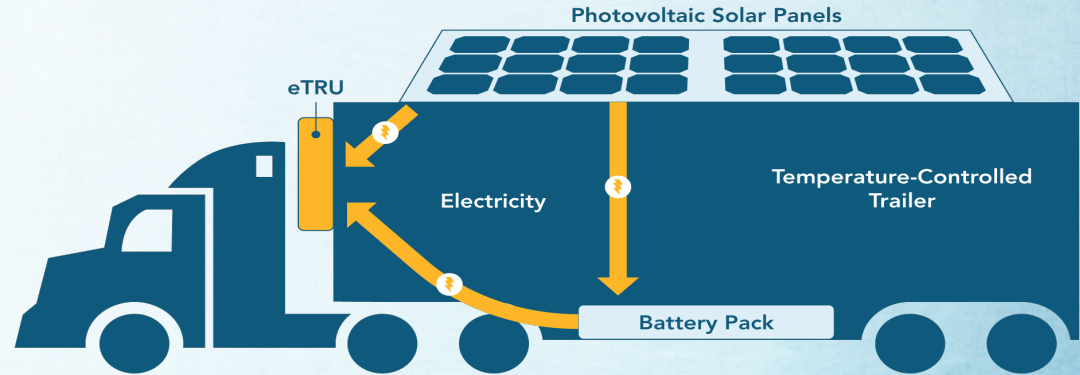
- Cost
- Additional weight (solar)



# Requested Info:

## Range Extending Technologies

- Data on range extension capabilities from both
- Data on energy generation from both systems
- Cost Info
  - Purchase of system
  - Installation



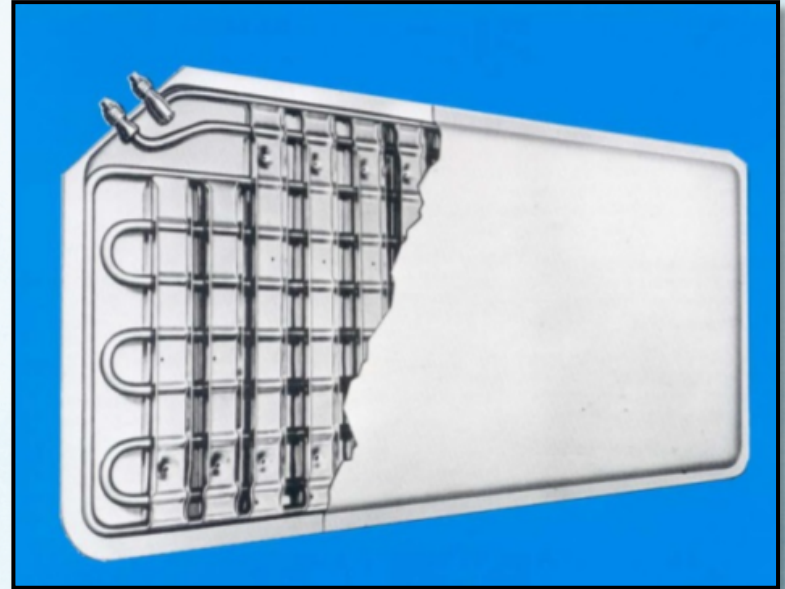
# Cold Plates

## Overview

- Sheet metal enclosures with internal evaporator coils surrounded by eutectic fluid.
- Absorb cargo space heat.

## Information Requested

- Development for non-truck transport.





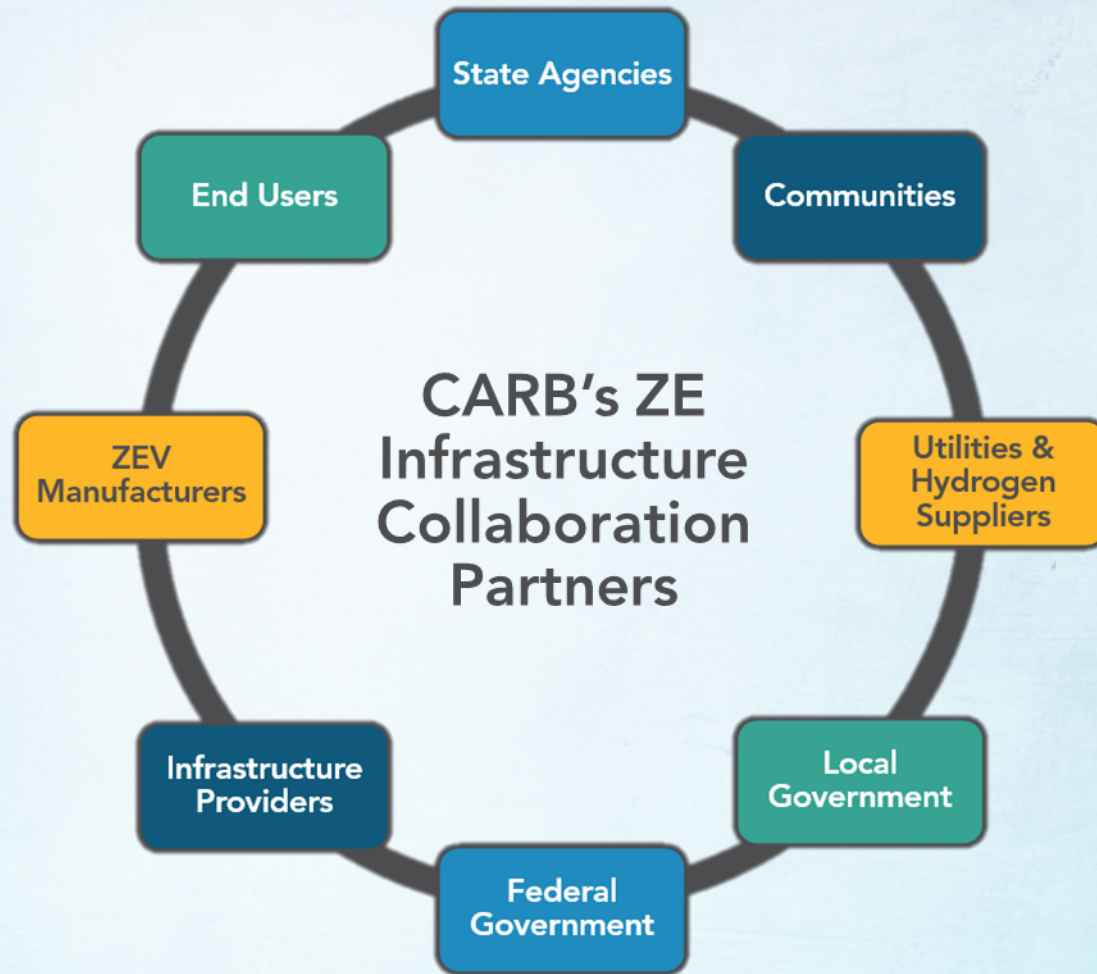
# Workshop Questions & Discussion

- Please use the **raise hand** function (\*9 if calling on the phone) to speak or use the chat function
- Please include slide numbers
- Please state your name and affiliation before asking a question or making a comment



# Zero-Emission Infrastructure







# CARB Shares Information

- Providing off-road equipment & emission impacts of technology shifts
- Coordinating with CA Energy Commission (CEC) on the development of ZE infrastructure
- Provide information to energy agencies
- Provide expertise to support development of new building codes for ZE infrastructure



# Infrastructure Deployment

- Determine which ZE technology best suits your operational needs with the lowest capital & operational costs
- Installation takes time, start early
- Coordinate early & often with fuel provider
- Consider ways to reduce costs

# Next Steps

- Submit comments and information by June 3, 2022
  - [freight@arb.ca.gov](mailto:freight@arb.ca.gov)
- Final draft release anticipated:
  - 2022



**DRAFT TECHNOLOGY ASSESSMENT:  
NON-TRUCK TRANSPORT  
REFRIGERATION UNITS (TRU)**

**Trailer TRUs, Domestic Shipping Container  
TRUs, Railcar TRUs, and TRU Generator Sets**

**May 2022**



# Please Submit Data for the Technology Assessment

- *Cost info (including infrastructure)*
  - *Operating info*
  - *Projects info*
- *Manufacturer and product info*
  - *Food safety considerations*



# Fleet Survey for Non-Truck TRUs



- California Air Resources Board is working with Foundation for California Community Colleges
- Survey will be administered online and by phone
- Survey anticipated to close **Late-2022**



# **We are looking for your input for the fleet survey:**

1. What is your fleet fuel use per day on average?
2. How many hours does your fleet spend at a given facility on average?
3. When considering transitioning your fleet to zero-emission, what factors go into your decision-making?

**Your input will help us transition to zero-emission TRUs**



# Thank You for Attending!

---

Please send written comments, feedback, and supporting data by **June 3, 2022**, to [freight@arb.ca.gov](mailto:freight@arb.ca.gov)

For more information on TRUs, please visit our webpage at:  
<https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit>