Air Quality Impacts of Using Fuel Cell Technologies to Power Vehicles and Equipment at Major Ports

ADVANCED POWER & ENERGY PROGRAM
UNIVERSITY of CALIFORNIA • IRVINE

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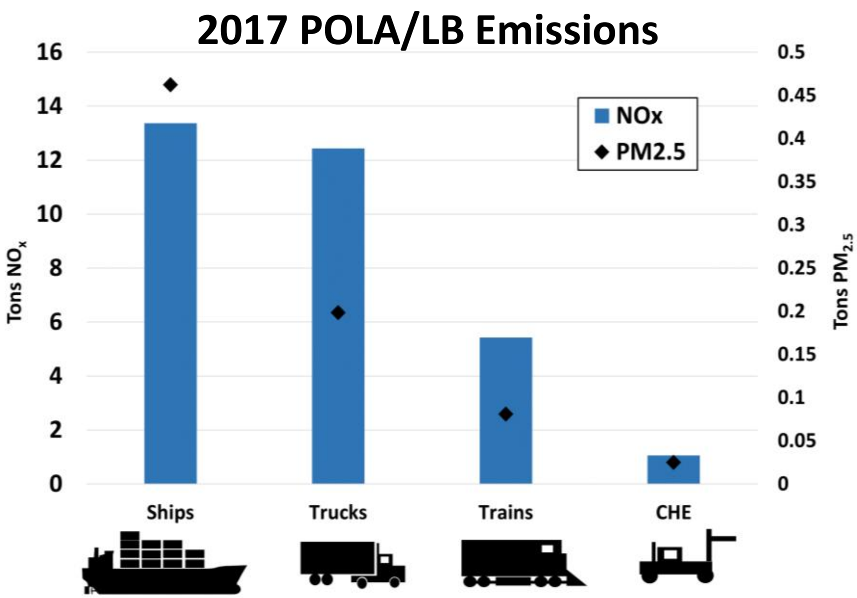
Introduction and Motivation

Ports of L.A. and Long Beach (POLA/LB) represent one of the largest and busiest port complexes in the world

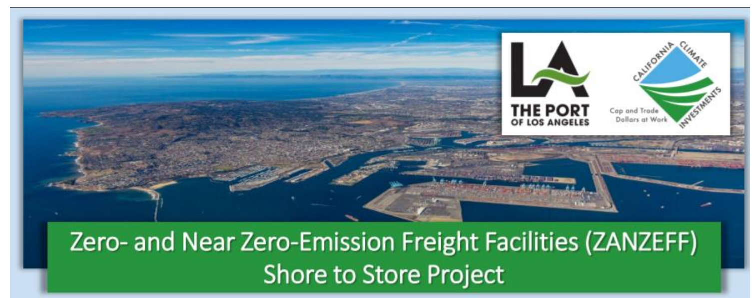
- Located in Southern California which is plagued by poor air quality and contains a dense urban populations including impacted disadvantaged communities
- Emissions from diesel equipment and vehicles a major contributor to AQ challenges



Introduction and Motivation

Transition to zero-emission equipment and on-road trucks at POLA/LB a major strategy to achieve emission reductions

- Fuel cell electric technologies (FCET) are a key technology to reduce impacts of goods movement activity on air quality
- Wide range of uses within goods movement vehicles and equipment
  - ✓ Propulsive power for drayage trucks, cargo handling equipment (CHE), rail, and auxiliary power for ships

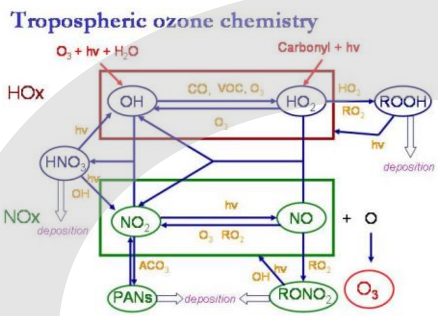


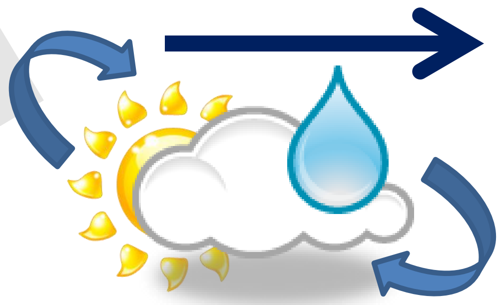
Vehicles & Equipment Funded

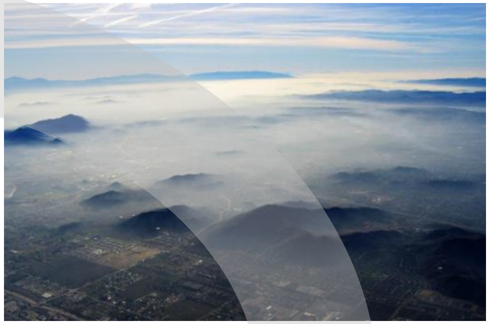
- 10 Class 8 hydrogen fuel cell electric trucks
- 2 hydrogen fueling stations
- 2 zero-emission yard tractors
- 2 zero-emission forklifts
- Infrastructure development

Project Methodology

Atmospheric Chemistry + **Transport** = **Air Quality**







Ozone

PM

\+

Emissions

PM

NO_x

VOC

SO_2

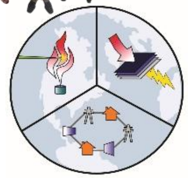
CO

Project Approach

- Develop FCET scenarios
- Quantify/resolve emission reductions (SMOKE)
- Simulate AQ changes via atmospheric model (CMAQ)
- Conduct health benefits assessment (BenMAP)

Health Impacts

Morbidity & Mortality

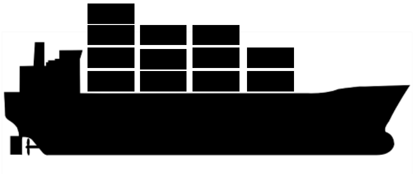


Fuel Cell Deployment Scenarios

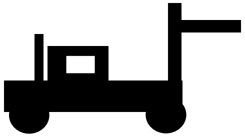
Scenarios developed and evaluated both individually and collectively

- Range of penetration assumed to account for uncertainties associated with technoeconomic factors

Fuel cell drayage trucks → Cases assume penetrations of 45% to 79% of the total drayage fleet



Fuel cells in place of auxiliary engines and boilers → Cases assume penetrations of 25% to 75% of auxiliary engine/boiler emissions



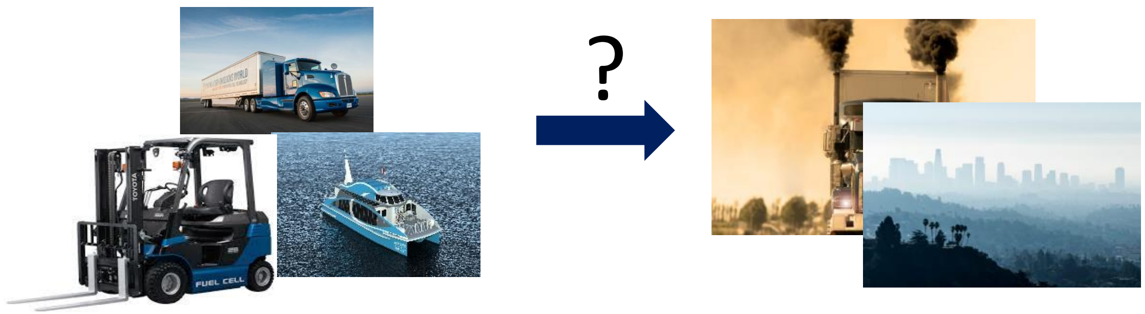
Fuel cell CHE → Cases assume penetrations of 25% to 75% of all CHE equipment

Fuel cell locomotives → Cases assume penetrations of 25% to 75% of freight locomotives

Project Goals

Project Goals

1. **Assess the emissions and AQ impacts of fuel cell technologies at the POLA/LB**

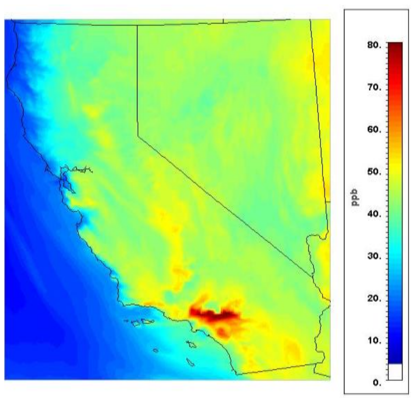


Air Quality Model

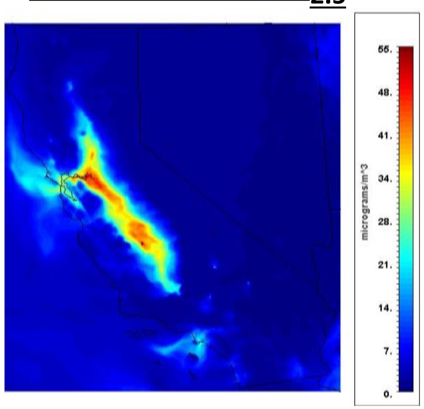
Simulations of atmospheric chemistry and transport via CMAQ to resolve impact on primary and secondary pollutants including ozone and $PM_{2.5}$

- **Seasonal two-week episodes of high pollutant formation in 2035 to account for differences in meteorology, energy demands, etc.**

Summer MD8H Ozone



Winter 24-h $PM_{2.5}$



	Model or Data Source
Base Year Inventory	2012 CARB
Projection Year	2035
Projection Method	CEPAM: 2016 SIP - Standard Emission Tool
Emissions Processing	SMOKE version 4.0
Air Quality Model	CMAQ version 5.2
Chemical Mechanism	SAPRC-07
Biogenic Emissions	MEGAN v2.1
Meteorological Files	WRF-ARW
Boundary Conditions	MOZART-4

FCET Impacts on Ozone

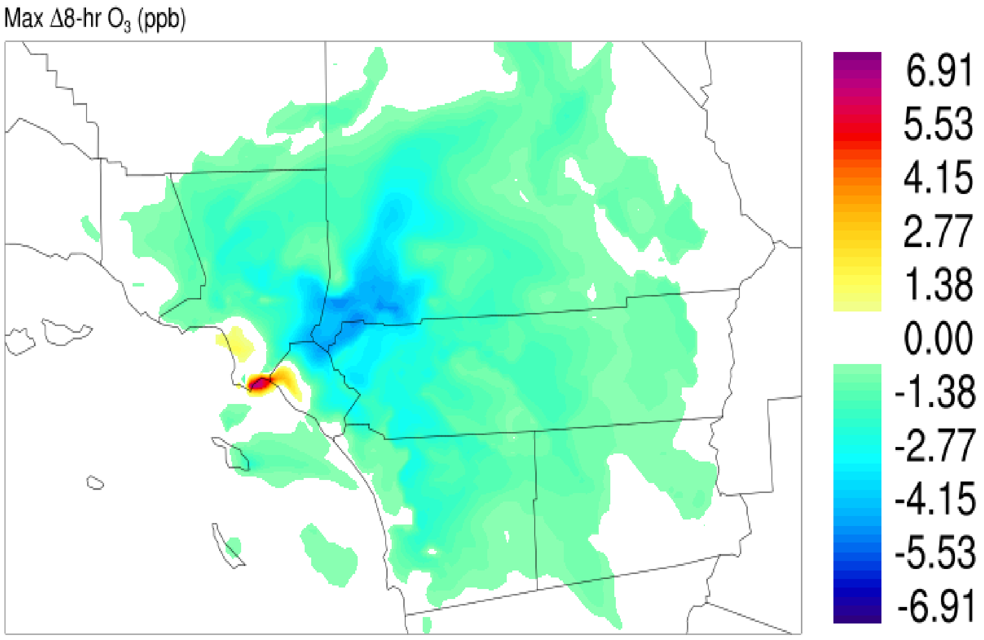
Reductions exceed 7 ppb for the most aggressive case

- Trucks & ships highest individual impact

Peak changes occur in eastern regions of SoCAB

- Large populations and pre-existing degraded air quality

Difference in MD8H Ozone (ppb): All High



FCET Impacts on $PM_{2.5}$

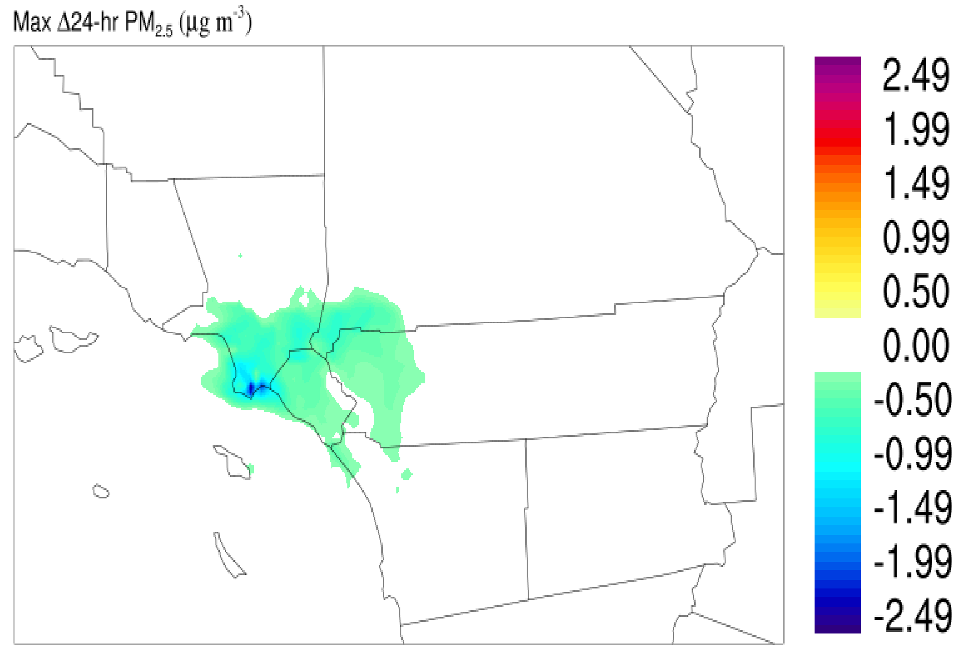
Impacts beneficial in both summer and winter

- Peak reduction exceeds 2 ug/m^3

Peak changes localized to areas adjacent to POLA/LB

- Large populations and pre-existing degraded air quality

Difference in Summer 24-h $PM_{2.5}$ (ug/m^3): All High

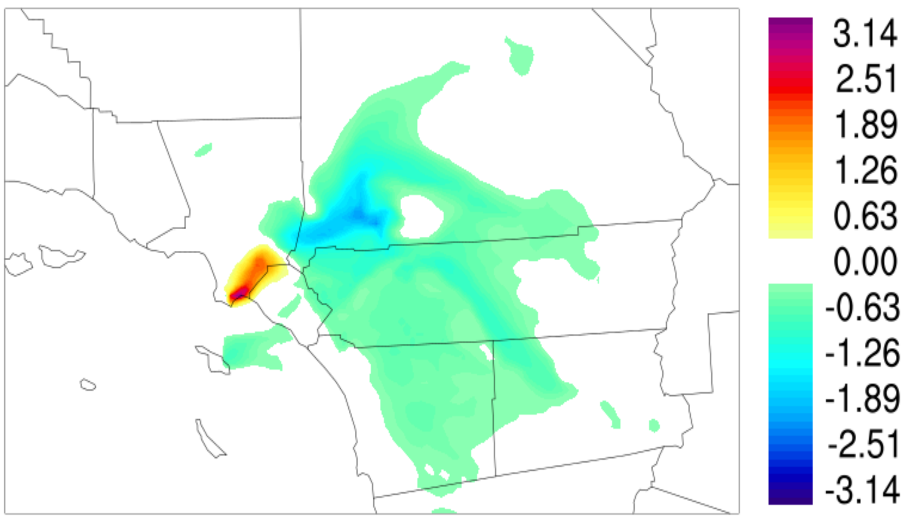


Ships vs. Trucks – Ozone

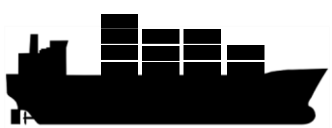
Highest individual impacts from ships and drayage trucks

- Differences from (1) spatial distribution of emissions and (2) fuel displacement
- Ozone impacts similar but ships achieve higher PM benefits

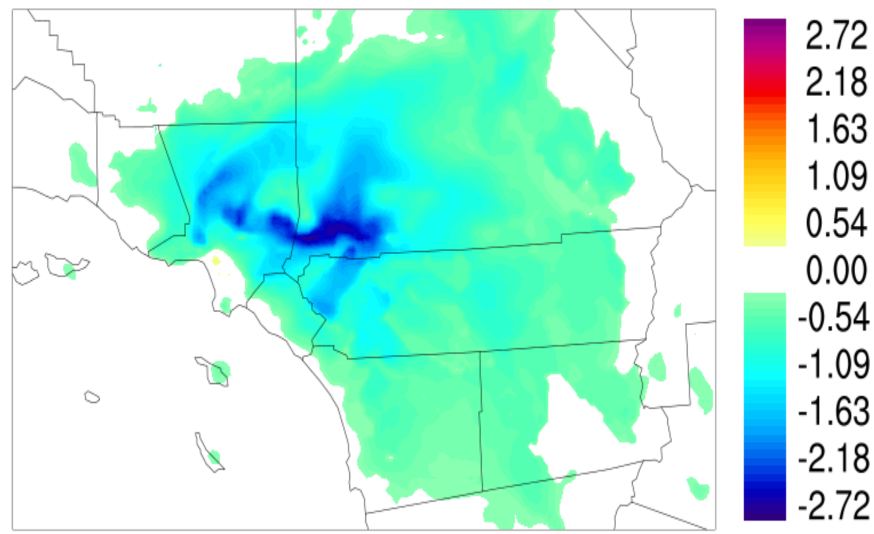
Δ Summer Ozone: Ships High



Maximum Change: -2.96 ppb



Δ Summer Ozone: Trucks High



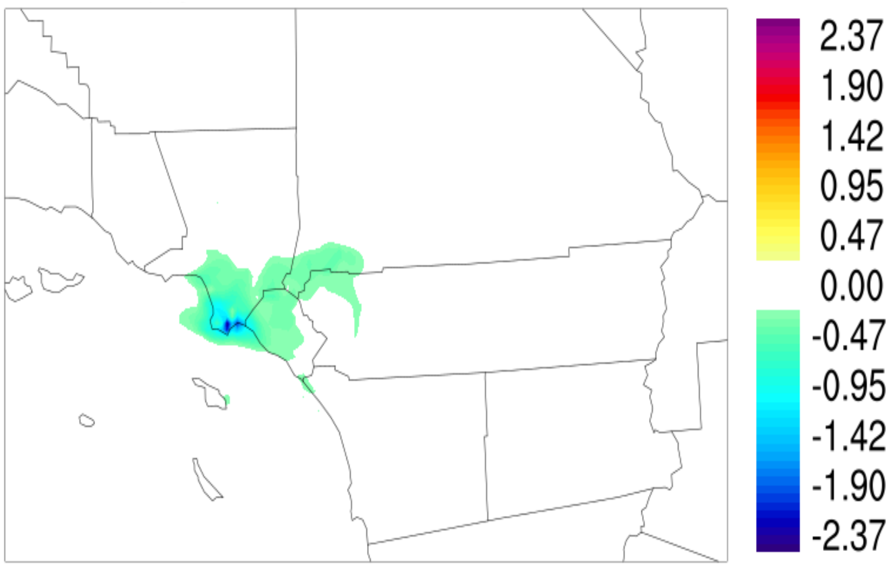
Maximum change: -2.81 ppb

Ships vs. Trucks – $PM_{2.5}$

Highest individual impacts from ships and drayage trucks

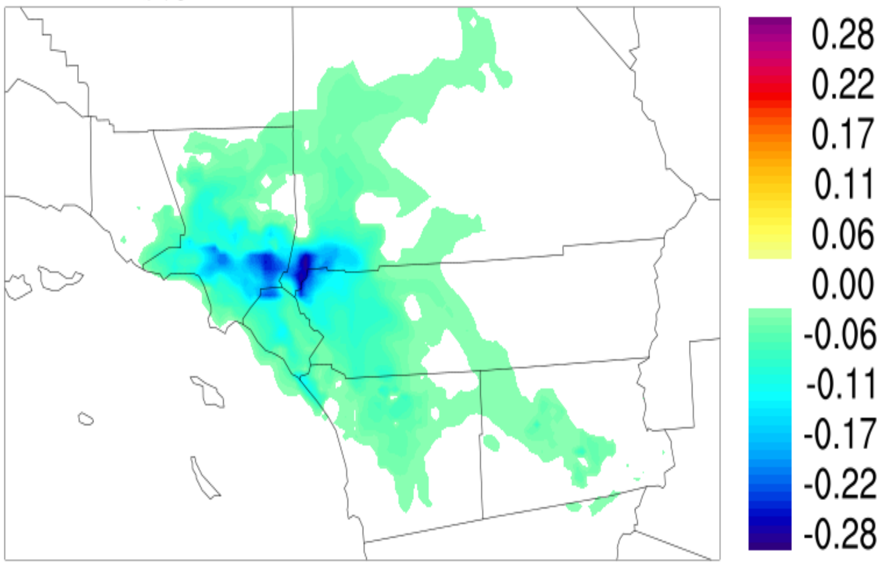
- Differences from (1) spatial distribution of emissions and (2) fuel displacement
- Ozone impacts similar but ships achieve higher PM benefits

Δ Summer $PM_{2.5}$: Ships



Maximum Change: -2.96 ug/m^3

Δ Summer $PM_{2.5}$: Trucks



Maximum change: -0.29 ug/m^3

Project Goals

Project Goals

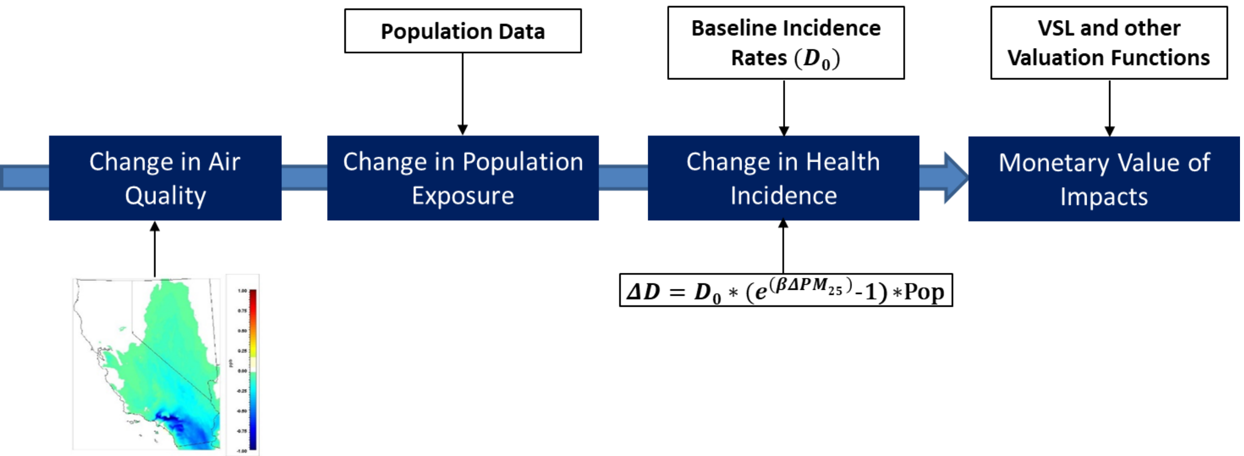
2. **Quantify and value the corresponding impacts on human health from improvements in AQ**

Health Impact Assessment

Environmental Benefits Mapping and Analysis Program Community Edition (BenMAP-CE) used to determine health benefits

- Selection of health impact and valuation functions from thorough review to support the SCAQMD 2016 AQMP Socioeconomic Report

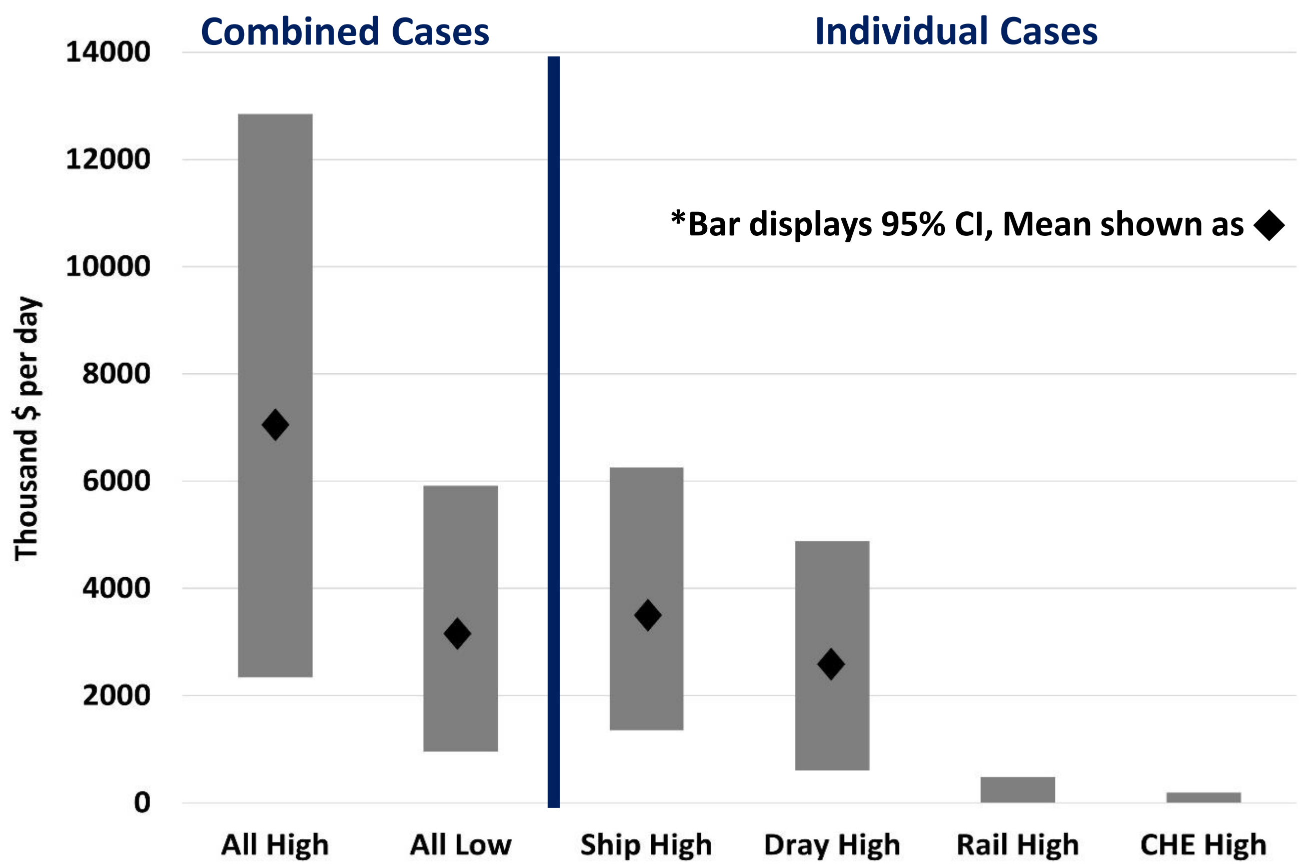
BenMAP
COMMUNITY EDITION



Health Benefits

AQ improvements provide notable value in avoided health costs

- Total mean value exceeding $3 to $7 million per day
- Difference between ships and drayage trucks is ~$1 million



Conclusions

- **Displacing petroleum fuel equipment with FCET at POLA/LB is an effective strategy to improve regional air quality in Southern California**
  - **Results support the continued funding of zero emission projects at the POLA/LB**
- **The use of FCET to replace auxiliary ship engines provides the most important individual $PM_{2.5}$ benefits and attains the highest health savings**
- **Fuel cell powered drayage trucks provides the largest ozone benefits to the region and achieves important health benefits**
- **FCET face important challenges that must be overcome to achieve widespread deployment**
  - **Technology development and commercialization**
  - **Hydrogen fuel and infrastructure development**