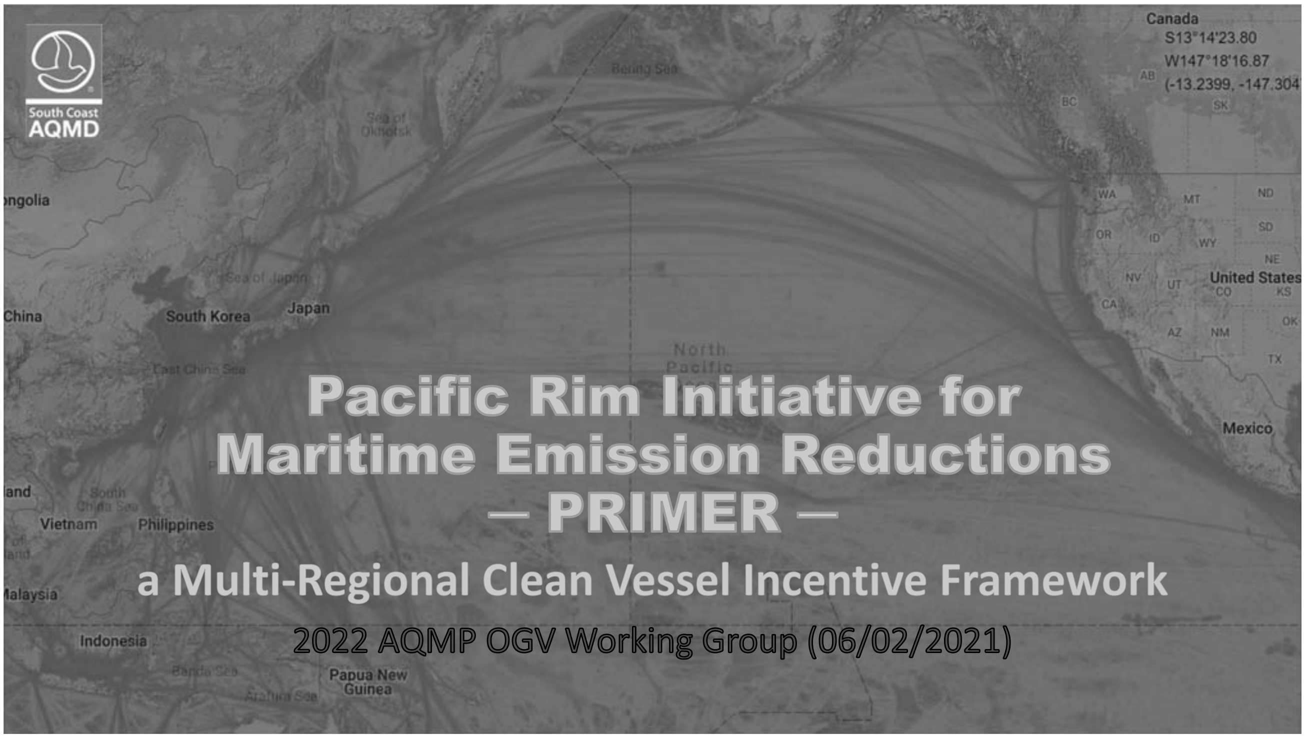



# Pacific Rim Initiative for Maritime Emission Reductions – PRIMER –

## a Multi-Regional Clean Vessel Incentive Framework

2022 AQMP OGV Working Group (06/02/2021)

## PRIMER Concept

- Trans-Pacific partnerships of multiple port regions around the Pacific Rim
- Coordinated efforts to incentivize cleaner ocean-going vessels (OGV) on shared routes

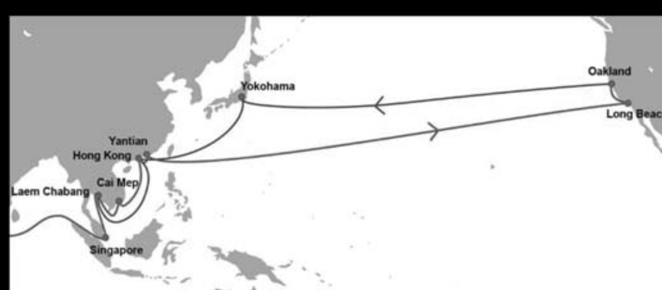



Image Source: Ocean Network Express Service FP2 (https://www.one-line.com/en/routes/current-services).

# Incentive Study to Inform PRIMER Design

Cumulative incentives awarded for all PRIMER port calls over Years 1-3 $\geq$ Technology investment at Year 0 + O&M costs over Years 1-3

Focuses on NOx abatement marine technologies: Tier II+ or Tier III



# Sources of Data and Key Assumptions

***PER-PORT-CALL INCENTIVES***

- Costs of technology: literature + industry experts
- Payback period: 2-3 years per industry
- Port calls: based on historical IHS-Seaweb (formerly Lloyds Fairplay) data*
- Uniform incentive amount: all partnering ports assumed to offer the same amount of per-port-call incentive for the sake of analytical simplicity, but not necessary for actual program implementation

(* Using 2017-19 data and excluding "shifts" between terminals or subports within the same port group)

# Sources of Data and Key Assumptions (Cont.)

***NOX EMISSIONS***

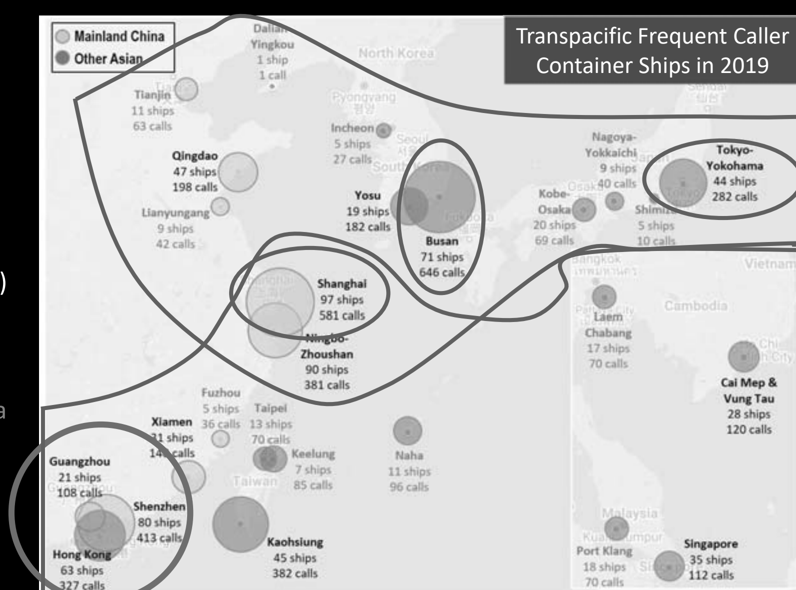
- Geographical domain:
  - Vessel activities within 100 nautical miles radius
- Emission reduction rates:
  - **Tier III:** single parameter of 80% reduction from Tier I & 76% from Tier II based on IMO limits
  - **Tier II+:** assuming a distribution/range of reduction rates to account for uncertainties
  - No surplus emission reductions at berth for California ports due to shore power requirements
- Operational threshold for Tier III technologies:
  - 25% propulsion engine load: benchmark assumption based on the lowest certification test cycle load point
  - 10% & 0%: sensitivity tests
- Engine loads: based on historical AIS data



# Five Scenarios of Transpacific Partnerships

California ports:
- Port of Oakland
- San Pedro Bay Ports (POLA/LB)

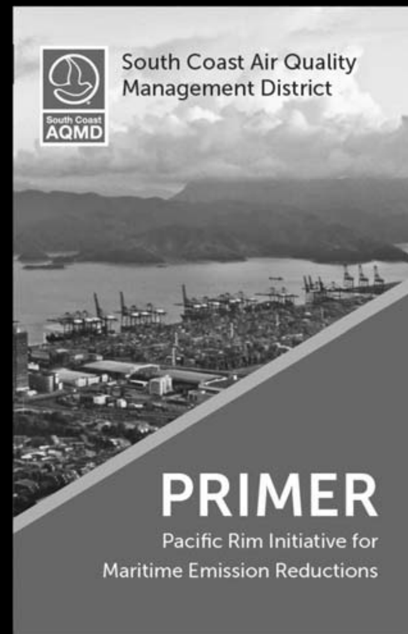
1. Greater Bay Area & California
2. Top National Ports & California
3. Northern Transpacific Routes
4. Southern Transpacific Routes
5. All Transpacific Routes




Note: Frequent callers are defined for analytical purposes as ocean-going vessels making 5 or more calls per year at POLA/LB, and 5 or more calls in the same year at one or more of the large-scale East and Southeast Asian ports.
Source: South Coast AQMD staff analysis of the IHS-Seaweb data.

# Incentive Model Design

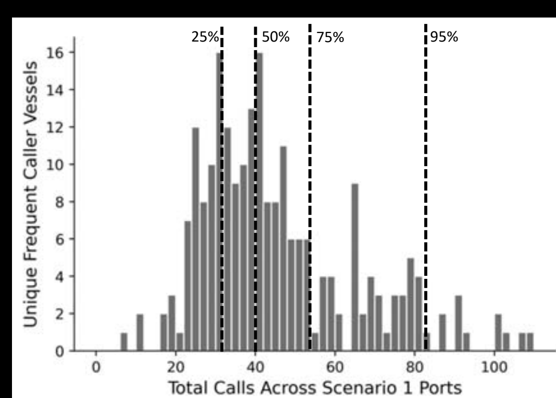
- Port-specific network geometries and bottom-up activity profiles
- RATES model emission estimation methodology aligned with IMO GHG4 Study, U.S. EPA OGV Emissions Inventory, and the San Pedro Bay Ports Emissions Inventory
- Cost, per call, for NOx control technology
  - Selective Catalytic Reduction (SCR) – Tier III
  - Exhaust Gas Recirculation (EGR) – Tier III
  - Water in Fuel (WiF) – 20 – 40% NOx reduction





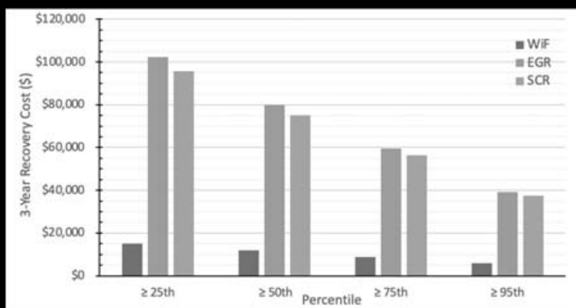

# Scenario 1 – China GBA + San Pedro + Oakland

- 6 Ports: Port of Los Angeles, Long Beach, Oakland, Shenzhen, Hong Kong, and Guangzhou
- 3-year period of analysis
  - 224 frequent caller container ships
  - 10,101 total calls across all ports
- 4 vessel groups by call percentile
  - ≥ 95%; ≥ 75%; ≥ 50%; ≥ 25%
- Technology operational thresholds
  - 25% main engine load
  - 10% main engine load
  - No threshold

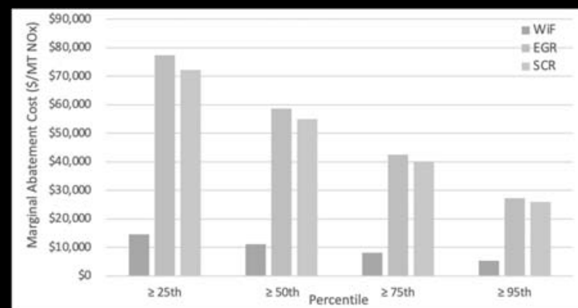


# Scenario 1 – Incentive and Abatement Costs

## Per-Call Incentive




## Cost per MT NOx Abated

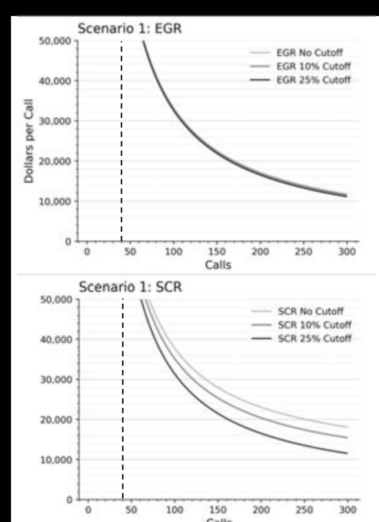



*Assuming an operational threshold of 25% main engine load for EGR & SCR.



# Scenario 1 – Total Costs and Abatement

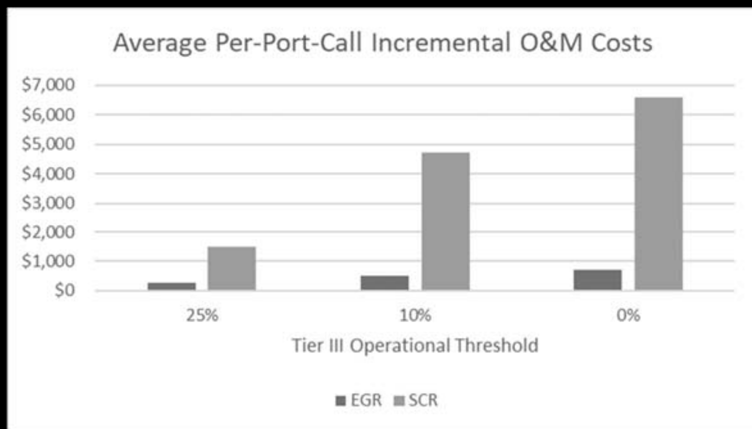

San Pedro Bay Ports would see NOx reductions of ~200 MT from most frequent flyers, assuming the benchmark operational threshold for EGR & SCR




Operational threshold has minimal effect on EGR costs, but a large effect on SCR costs due to changes in catalyst (urea) consumption

Important to understand operational parameters of the systems for comparing costs

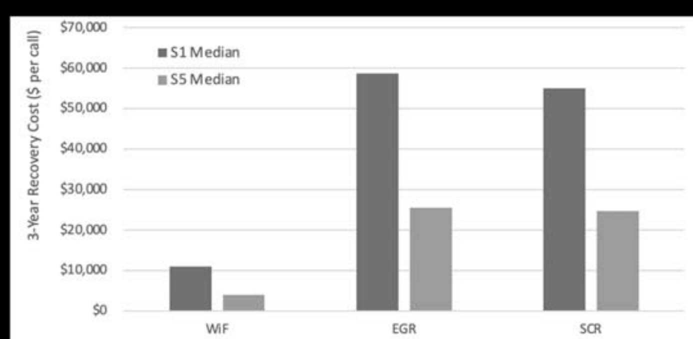
# Scenario 1 – Incremental O&M Costs for Tier III Technologies



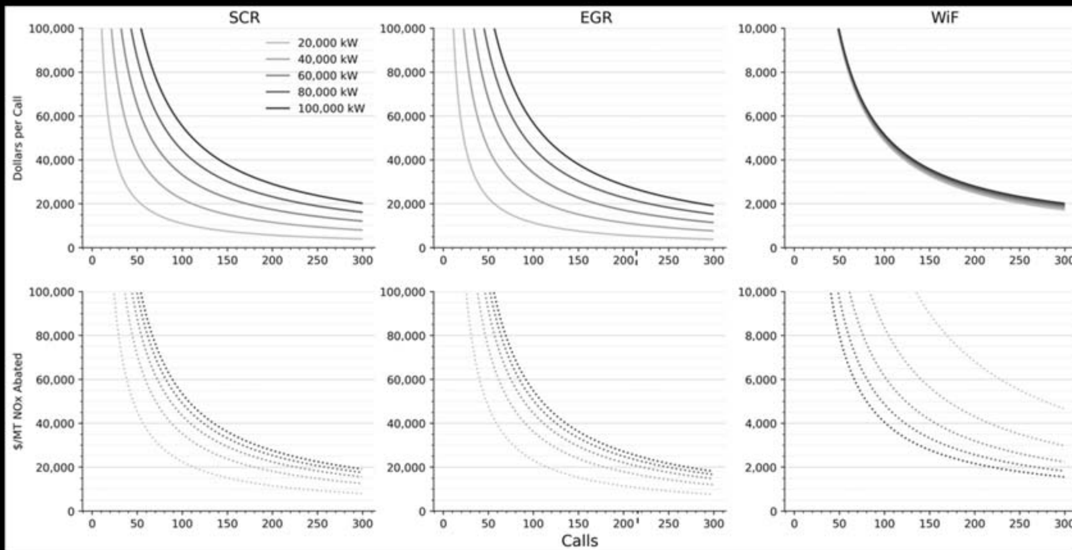



# Scenario 1 vs Scenario 5

- 6 Ports vs 26 Ports
- 36% - 45% reduction in costs per call
- Same per-call NOx abatement
- Greater overall NOx abatement for lower marginal costs



# Engine Power





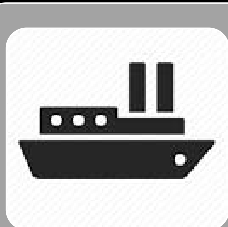

# Conclusions

- WiF, EGR, and SCR each offer significant NOx abatement
- WiF offers the least cost option, Tier III costs are 6-7x WiF
- Targeting most frequently calling OGVs (e.g., ≥ $95^{th}$ percentile) results in the lowest per-call and overall program costs, but also lowers overall NOx abatement when compared to targeting a larger group of frequent callers
- Engaging more ports lowers per-call costs while per call NOx abatement remains consistent
- Vessel/engine size has a large effect on Tier III capital expenditures and associated per-call costs
- Understanding operational thresholds is imperative for fine tuning Tier III cost and abatement estimates

# PRIMER Status Updates Since OGV Meeting #1

## Engagement with Asia

- Virtual meeting with the Tokyo Metropolitan Government on regional air quality management and shipping emissions control programs and policy
- Joint presentation with the Hong Kong Department of Environmental Protection at the 3rd Conference on Ozone Pollution Control in China, organized by the Chinese Society for Environmental Sciences



## Technical analysis & industry outreach

- Active discussions with interested parties in the U.S. and Europe to identify ways to better understand OGV NOx emissions during low load operations, especially for Tier III
- Began working with Explicit ApS to analyze drone-based NOx measurements
- Outreach to the industry regarding a potential phase 1 incentive for existing Tier III ships and inquire willingness to collaborate on a low load study



# Contacts

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# OGV Working Group

June 2, 2021

Thomas Jelenić
Vice President

PMSA
PACIFIC MERCHANT SHIPPING ASSOCIATION

## Current Issues Facing Industry

Nationwide Supply Chain Disruptions
Pandemic-induced Cargo Surge
Global Fleet Management
  -including Regulatory Management

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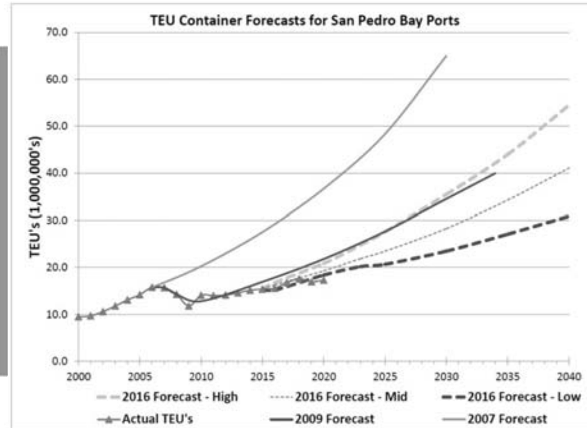
## Emissions Forecast

Growth forecast too high
2018 was peak year
10% below forecasts
CAGR: 0.65% from
pre-recession peak

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## Incentive Programs

Needs:
Proven Technology
Multi-Port Coordination
Speed of Implementation

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At Berth Rule

- Increased compliance requirements 2025
- With OGV Fuel Rule, risk creating de facto California fleet, potentially limiting slowing turnover


Global Focus: GHGs
Criteria pollutants don't appear to be IMO priority
No discussions for new criteria pollutant standards
CMA CGM A.LINCOLN
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Global Focus: GHGs
Regional Strategies Must Support Global Requirements
Potential Changes in Vessel Technology
Possible Delays to Vessel Replacement
EVERGREEN
PMSA
PACIFIC MERCHANT SHIPPING ASSOCIATION

# New Vessel Technologies

Table 1

| Energy storage type | Supply energy | Energy density | Required tank volume | Supply pressure | Injection pressure | Emission reduction compared to HFO Tier II | | | |
|---|---|---|---|---|---|---|---|---|---|
| | MJ/kg | MJ/L | $m^3$ *1 | bar | bar | % | % | % | % |
| HFO | 40.5 | 35 | 1,000 | 7-8 | 950 | $SO_x$ | $NO_x$ | $CO_2$ | PM |
| Liquefied natural gas (LNG -162°C) | 50 | 22 | 1,590 | 300 methane | 300 methane | 90-99 | 20-30 | 24 | 90 |
| | | | | 380 ethane | 380 ethane | 90-97 | 30-50 | 15 | 90 |
| LPG (including Propane / Butane) | 42 | 26 | 1,346 | 50 | 600-700 | 90-100 | 10-15 | 13-18 | 90 |
| Methanol | 19.9 | 15 | 2,333 | 10 | 500 | 90-95 | 30-50 | 5 | 90 |
| Ethanol | 26 | 21 | 1,750 | 10 | 500 | | | | |
| Ammonia* (liquid -33°C) | 18.6 | 12.7 | 2,755 | 70 | 600-700 | 90-95 | Tier | 95 | 90 |
| Hydrogen (liquid -253°C) | 120 | 8.5 | 4,117 | | | | | | |
| Marine battery market leader, Corvus, battery rack | 0.29 | 0.33 | 106,060 | | | | | | |
| Tesla model 3 battery Cell 2170 *2 | 0.8 | 2.5 | 14,000 | | | | | | |

Table 1: Physical and chemical fuel properties related to combustion in two-stroke engines, where *1 is based on a 1000 $m^3$ HFO tank, the additional space required for insulation is not included in the table. All pressure values are for high-pressure injection and *2 the values for the Tesla battery do not contain the energy/mass needed for cooling/safety/classification

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Source:
Engineering the future two-stroke green-ammonia engine
Man Energy Solutions
November 2019