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

Incentive Study to Inform PRIMER Design

Cumulative incentives awarded for all PRIMER port calls over Years 1-3 ≥ 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**
  - $\geq 95\%$; $\geq 75\%$; $\geq 50\%$; $\geq 25\%$

• **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

![Average Per-Port-Call Incremental O&M Costs](image.png)
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

SCR
- 20,000 kW
- 40,000 kW
- 60,000 kW
- 80,000 kW
- 100,000 kW

EGR

WiF

Dollars per Call

Calls

$MWT NOx Abated
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., ≥ 95th 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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Current Issues Facing Industry

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

PACIFIC MERCHANT SHIPPING ASSOCIATION
Emissions Forecast

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

Needs:
Proven Technology
Multi-Port Coordination
Speed of Implementation
Incentive Programs

Challenges:
Global Fleet Management
All Ports Want Clean Ships
Port Coordination Likely Difficult
Emissions at Anchorage

Pandemic-induced Technology/Safety Questions
Normal operations later this year?
Maneuvering/Transiting Emissions

VSR Highly Effective

POLA 2020 – 20nm: 96%, 40nm: 93%

POLB 2020 – 20nm: 96%, 40nm: 90%
Maneuvering/Transiting Emissions

Outstanding Question:
Do Tier III controls work at low loads?
Should Tier III OGVs have VSR pass?
At Berth Rule
Increased compliance requirements 2025
With OGV Fuel Rule, risk creating de facto California fleet, potentially limiting slowing turnover
Global Focus: GHGs

2030 Goal: 40% Carbon Intensity Reduction
2050 Goal: 50% Emission Reduction
Increased Requirements Expected
Global Focus: GHGs

Criteria pollutants don’t appear to be IMO priority

No discussions for new criteria pollutant standards
Regional Strategies Must Support Global Requirements
Potential Changes in Vessel Technology
Possible Delays to Vessel Replacement
## New Vessel Technologies

### Table 1

<table>
<thead>
<tr>
<th>Energy storage type</th>
<th>Supply energy (MJ/kg)</th>
<th>Energy density (MJ/L)</th>
<th>Required tank volume (m³)</th>
<th>Supply pressure (bar)</th>
<th>Injection pressure (bar)</th>
<th>Emission reduction compared to HFO Tier II (%)</th>
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<tbody>
<tr>
<td>HFO</td>
<td>40.5</td>
<td>35</td>
<td>1,000</td>
<td>7-8</td>
<td>950</td>
<td>SO₂: 90-99, NOₓ: 20-30, CO₂: 24, PM: 90</td>
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<tr>
<td>Liquefied natural gas (LNG -162°C)</td>
<td>50</td>
<td>22</td>
<td>1,590</td>
<td>300 methane (380 ethane)</td>
<td>90-99, 20-30, 24, 90</td>
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<tr>
<td>LPG (including Propane / Butane)</td>
<td>42</td>
<td>26</td>
<td>1,346</td>
<td>50</td>
<td>600-700</td>
<td>90-100, 10-15, 13-18, 90</td>
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<tr>
<td>Methanol</td>
<td>19.9</td>
<td>15</td>
<td>2,333</td>
<td>10</td>
<td>500</td>
<td>90-95, 30-50, 5, 90</td>
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<tr>
<td>Ethanol</td>
<td>26</td>
<td>21</td>
<td>1,750</td>
<td>10</td>
<td>500</td>
<td>90-95, 30-50, 5, 90</td>
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<tr>
<td>Ammonia* (liquid -33°C)</td>
<td>18.6</td>
<td>12.7</td>
<td>2,755</td>
<td>70</td>
<td>600-700</td>
<td>90-95, Tier 95, 90</td>
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<td>Hydrogen (liquid -253°C)</td>
<td>120</td>
<td>8.5</td>
<td>4,117</td>
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<td>Marine battery market leader, Corvus, battery rack</td>
<td>0.29</td>
<td>0.33</td>
<td>106,060</td>
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<tr>
<td>Tesla model 3 battery Cell 2170*</td>
<td>0.8</td>
<td>2.5</td>
<td>14,000</td>
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</table>

*1: based on a 1000 m³ 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.

Source:
[Engineering the future two-stroke green-ammonia engine](#)
Man Energy Solutions
November 2019
Strategy Challenge

Identify Next Generation Technology
Accelerate Implementation