Air Emission Mitigation Opportunities for shipping and ports

Environment Performance Metrics Workshop
Norfolk, VA

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Outline

- Background
  - The impact of shipping on urban air pollution
- Technical and operational measures
  - Opportunities for ocean-going vessels
    - Ranking by cost effectiveness
  - Opportunities for ports
    - Air quality toolbox update
    - Incentive schemes
  - Other existing and proposed technical and operational metrics
Background

- Shipping is the most energy efficient mode in the transportation sector.
- It is a major contributor to air pollutants near ports.

Shares of air pollutants by sources in Hong Kong in 2007

Calculated from: Hong Kong EPD http://www.epd.gov.hk/epd/english/environmentinhk/air/data/emission_inve.html
Energy efficiency ranking: Summary

- **Study:**
  - Marginal abatement cost and cost effectiveness of energy-efficiency measures (MEPC 62 INF 7)

- **Key parameters**
  - Fuel price in 2020: $700 per ton
  - Internal Rate of Return: 10%
  - 318 ship type, size, and age combination
  - 22 technologies and operational options
  - 15 technology/operational groups

- **Key Findings**
  - Many opportunities to increase energy efficiency and reduce CO₂
  - Many opportunities with fuel saving benefits that outweigh technology costs
  - Market barriers forbid many cost effective measures from being used
Potential for OGVs

- Measures for 450 million metric tons (mmt) of CO$_2$ emission reduction were identified.
- Slow steaming posted the biggest reduction potential from any single measure.
- About 280 mmt of CO$_2$ can be reduced with net benefits.

### Air quality toolbox update

#### General Emissions Control Technologies

<table>
<thead>
<tr>
<th>Technology Name</th>
<th>Application</th>
<th>Targeted Air Pollutant</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Oxidative Catalysts (DOC)</td>
<td>Trucks CHE (&gt;750hp) Marine &amp; CHE (&lt;750hp) Locomotives</td>
<td>PM 20-30% HC 50-90% CO 70-90%</td>
<td>$1,000-4,000 ($48-50 filter replacement)</td>
</tr>
<tr>
<td>Closed Crankcase Ventilation (CCV)</td>
<td>Truck CHE (&gt;750hp) Marine Locomotive</td>
<td>PM 15-20% HC, CO 60-90%</td>
<td>$700</td>
</tr>
<tr>
<td>Diesel Particulate Filters (DPF)</td>
<td>Truck CHE (&gt;750hp) Marine Locomotive</td>
<td>NOx 70-90%</td>
<td>$6-18K (Truck) up to $40K (Marine)</td>
</tr>
<tr>
<td>Selective Catalytic Reduction (SCR)</td>
<td>Truck CHE (&gt;750hp) Marine Locomotive</td>
<td>Moderate NOx Reductions</td>
<td>$36K (Truck &amp; CHE) $60K-120K (Marine)</td>
</tr>
<tr>
<td>Lean NOx Catalyst (LNC)</td>
<td>Truck Marine</td>
<td>SOx 90-99% PM 60-80%</td>
<td>$14K (On-road) $40K (Off-road (application limited))</td>
</tr>
<tr>
<td>Exhaust Gas Scrubbers</td>
<td>CHE Marine Locomotive</td>
<td>100% emission reduction at berth</td>
<td>$5M (Marine)</td>
</tr>
<tr>
<td>Cold Ironing</td>
<td>Marine</td>
<td></td>
<td>$1-15M</td>
</tr>
</tbody>
</table>

Starcrest (2012) “Developing Port Clean Air Programs” prepared for the ICCT
<table>
<thead>
<tr>
<th>Technology Name</th>
<th>On-Engine Modification</th>
<th>Diesel Fuel Alternatives</th>
<th>Operational Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Gas Recirculation (EGR)</td>
<td>Engine Replacement, Repower, Rebuild, Refuel</td>
<td>Ultra Low Sulfur Diesel (ULSD)</td>
<td>Vessel Speed Reduction (VSR)</td>
</tr>
<tr>
<td>Diesel Fuel Alternatives</td>
<td></td>
<td>Biodiesel Fuel (BXX)</td>
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<tr>
<td></td>
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<td>Emulsified Diesel Fuel (EDF)</td>
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<tr>
<td>Operational Strategies</td>
<td></td>
<td></td>
<td>Landside Operational Improvements</td>
</tr>
</tbody>
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<tr>
<td>Targeted Air Pollutant</td>
<td>NOx 40-50% PM 70% (with DPF)</td>
<td>NOx up to 90% PM 10-50% NOx 10-25%</td>
<td>PM 5-15% SOx 99% PM 15-70% HC 10-40% CO 10-50% CO2 70%</td>
<td>NOx 10-20% PM 15-60%</td>
</tr>
<tr>
<td></td>
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<td>net reductions in NOx, PM, and other air pollutants</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Net emissions reductions</td>
</tr>
<tr>
<td>Cost</td>
<td>$12K (Truck) $10M (Marine)</td>
<td>$0.5-1.5M</td>
<td>$1.5-16K (Marine)</td>
<td>Surcharge: $0.05-0.15/gal Surcharge: $0.25-0.40/gal</td>
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<tr>
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<td>net negative cost over time (balance fuel savings and travel time increase)</td>
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<td>Multi-million/billion dollar improvements</td>
</tr>
</tbody>
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Voluntary approach: Inventive tool

- Tools with greater rigor, quantification allow for better decision-making at the port level
- Environmental Shipping Index (ESI)
  - An index that scores the environmental performance (air emissions) of seagoing ships relative to IMO Rules
  - Serves as a ranking tool for governments or ports to reward clean ships (NOx, SOx, and CO2) on a voluntary basis
- Goal: Allow regulators and port operators to analyze costs and benefits of incentive scenarios, voluntarily adopt new measures
<table>
<thead>
<tr>
<th>Technical/operational matrix</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>As-designed technical efficiency</td>
<td>The efficiency of a ship in its as-designed condition in ideal conditions.</td>
</tr>
<tr>
<td>Technical efficiency in real operating conditions</td>
<td>The efficiency of a ship in its as-designed condition in real conditions (wind and waves etc).</td>
</tr>
<tr>
<td>Technical efficiency at a point in time</td>
<td>The efficiency of a ship of a certain age, following wear, deterioration and fouling, benchmarked in ideal conditions.</td>
</tr>
<tr>
<td>Measured technical efficiency</td>
<td>The efficiency of a ship of any age and condition, measured from fuel consumption but assuming full capacity utilization.</td>
</tr>
<tr>
<td>Transport supply efficiency</td>
<td>This embodies the relationship between the transport demand (tonnes of a commodity to be moved from point A to B), with the actual capacity-distance (i.e. DWT ton-mile) supplied to satisfy the demand</td>
</tr>
<tr>
<td>Achieved operational efficiency</td>
<td>The energy consumed to satisfy a given transport demand.</td>
</tr>
</tbody>
</table>
An Anatomy of the Energy Efficiency Design Index (EEDI) Equation for Ships

\[
\begin{align*}
\text{Main Engines Emissions:} & \quad \left( \prod_{j=1}^{M} f_j \sum_{i=1}^{n_{\text{M}}} (P_{\text{M}} - C_{\text{M}} - S_{\text{FC}}) \right) \\
\text{Auxiliary Engines Emissions:} & \quad (B_{\text{A}} - C_{\text{A}} - S_{\text{FC}}^a) \\
\text{Shaft Generators/Motors Emissions:} & \quad \left( \prod_{j=1}^{M} f_j \sum_{i=1}^{n_{\text{M}}} (P_{\text{M}} - C_{\text{M}} - S_{\text{FC}}) \right) \\
\text{Efficiency Technologies:} & \quad \left( \sum_{i=1}^{n_{\text{eff}}} f_{\text{eff}} (B_{\text{A}} - C_{\text{A}} - S_{\text{FC}}) \right)
\end{align*}
\]

\[ f_{\text{Capacity}} V_{\text{ref}} f_{\text{u}} \]

**Transport Work**

**Engine Power (P):**
- \( P_{\text{M}} \): Main engine power rating due to individual technologies for mechanical energy efficiency
- \( P_{\text{A}} \): Auxiliary engine power rating due to individual technologies for electrical energy efficiency
- \( P_{\text{sys}} \): Power of individual shaft systems divided by the efficiency of shaft generators
- \( P_{\text{inst}} \): Combined installed power of auxiliary engines
- \( P_{\text{mot}} \): Individual power of main engines

**CO₂ Emissions (C):**
- \( C_{\text{M}} \): Main engine composite fuel factor
- \( C_{\text{A}} \): Auxiliary engine fuel factor
- \( C_{\text{MA}} \): Main engine individual fuel factors

**Specific Fuel Consumption (SFC):**
- \( S_{\text{FC}} \): Main engine composite SFC
- \( S_{\text{FC}}^a \): Auxiliary engine SFC
- \( S_{\text{FC}}^i \): Main engine individual SFC

**Correction and Adjustment Factors (f):**
- \( f_{\text{sys}} \): Availability factor of individual energy efficiency technologies 1:10 if needed available
- \( f_{\text{A}} \): Correction factor for ship specific design elements, e.g., transom ships which require more weight for smaller hulls
- \( f_{\text{ref}} \): Coefficient indicating the decrease in ship speed due to maritime and environmental conditions
- \( f_{\text{C}} \): Capacity adjustment factor for any technical/regulatory limitation on capacity (1:10 if normal)

**Ship Design Parameters:**
- \( V_{\text{ref}} \): Ship speed at minimum design load conditions
- \( \text{Capacity} \)
- \( \text{Draught} \): Draught Tonnes (DWT) rating for both ships and loads, a parameter of DWT for Container ships DWT deviation due to wind can be loaded onto a ship
Improved data: Operational efficiency

- Data: Utilize satellite AIS data to reveal the real-world, spatially-resolved shipping operation
- Methodology: Calculate the energy efficiency for existing ship and construct a new index
- Industry engagement: analyze and identify best practices for adoption
Conclusion

• Shipping and ports offer enormous potential to increase energy efficiency and reduce emissions cost effectively.
• There are direct economic benefits from fuel savings and air quality co-benefits.
• Improved data and long-term policies are critical to measure environmental performances of ports and ships.
Thank You

www.theicct.org/marine

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