U.S.-Mexico Fuel Switching Demonstration on Ocean Going Vessels in the Gulf of Mexico

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Background

Contribution of shipping to PM2.5 concentrations (in $\mu g/m^3$)

Project Partners

- Port of Houston Authority
- U.S. Maritime Administration
- Mexican Ministry of Environment/PEMEX
- Maersk Line/Hamburg Süd
- ICF and University of California at Riverside
Project Goals

- Demonstrate Switching to Low Sulfur Distillate Fuels in Gulf of Mexico
- Measure Emission Reductions
- Estimate Emission Reductions at Mexican Ports from Fuel Switching
- Estimate Health and Environmental Benefits from Fuel Switching
- Raise Awareness of upcoming Emission Control Area
MARPOL Annex VI Emission Control Area

- **ECA NOx Controls**
  - Tier 3 NOx 80% reduction new vessels (2016)

- **ECA PM and SOx Controls**
  - 1.00% Fuel Sulfur (2010-2014)
    - By 2012 in NA ECA
  - 0.10% Fuel Sulfur 2015+
    - Up to 96% reduction in SOx
    - ~85% reduction in PM

Only US/Canada and Baltic States (Europe) have successfully applied for an ECA so far
North American Emission Control Area
2020 Potential ECA PM$_{2.5}$ Reductions
2020 Potential Sulfur Deposition Reductions

Improvements in deposition for marine and terrestrial ecosystems
Project Design

- Demonstration of fuel switching on two ocean going vessels of Maersk and Hamburg Süd
  - Fuel switched from high sulfur heavy fuel oil (>3.0% sulfur) to marine gas oil (< 0.1% sulfur)

- Stack emission monitoring

- Modeling – Port emission inventories, air quality, loadings
Maersk Demonstration

- **Maersk Roubaix**
  - Container Ship – 1118 TEUs
  - 9.7 MW Propulsion Engine
  - Medium Speed Engine

- Switched from Bunker Fuel (3.3% Sulfur) to Distillate Fuel (0.14% Sulfur) 24 nm from shore at Port of Houston and Port of Progreso, Mexico

- Calculated Emission Reductions per call at Progreso
  - 27 kg NOx (7%)
  - 47 kg PM$_{2.5}$ (81%)
  - 479 kg SOx (88%)
  - 2% increase in operating costs
Hamburg Süd Demonstration

- **Cap San Lorenzo**
  - Container Ship – 3,739 TEUs
  - 28.8 MW Propulsion Engine
  - Slow Speed Engine

- Represents 40% of container ships and 20% of all ships calling on Veracruz and Altamira

- Stack emissions measured in port and at sea at Altamira, Veracruz and Houston
Observed Operational Findings

- No significant issues encountered
- No additional training needed for crew involved in this demonstration
- Cost and Availability of Low Sulfur Fuel
  - Additional cost for fuel switch represents less than 2% of voyage costs
  - Demonstration fuel available in U.S.
- Tank Size
  - Sufficient capacity to carry MGO for demonstration
- Fuel Switching Procedure
  - Boilers must be slowly turned down
  - Switch over took about an hour
Emission Sampling

- Measurements of in-use stack emissions and their reduction from fuel switching
  - MARPOL NOx Technical Code (NTC) and other protocols
  - Specific engine loads and transient operations, main and auxiliary engines

Pollutants measured
- NOx, CO, CO$_2$ continuously
- PM continuously and speciated PM (EC, OC) with discrete filter samples
- Measure SO$_2$ and calculate SOx from fuel measurements
Propulsion Engine Results – SO2

![Graph showing emission factor (g/kWh) for HFO (3.79% S) and MGO (0.01% S) at different speeds: Dead Slow, Half, Full, and Top Speed. The graph indicates significantly higher emission for HFO at all speeds, with MGO showing minimal emission.]
Propulsion Engine Results – $PM_{2.5}$

Emission Factor (g/kWh)

- HFO (3.79% S)
- MGO (0.01% S)

<table>
<thead>
<tr>
<th>Speed</th>
<th>HFO 3.79% S</th>
<th>MGO 0.01% S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead Slow</td>
<td>3.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Half</td>
<td>2.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Full</td>
<td>2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Top Speed</td>
<td>3.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Comparison to other ships

Half Speed

PM$_{2.5}$ Emission Factor (g/kWh)

Cap San Lorenzo

West Coast Ships

HFO
MGO

OC

EC
Fuel Switching Emissions
HFO -> MGO

HFO to MGO Fuel Switch (CASLO, 4/20/10 0540-0710)
Reductions from Fuel Switching in the Port of Veracruz
With 24 nm Boundary

Emission Inventory based on 2005 activity data
Effect of Fuel Switching Zone Size for Port of Veracruz

![Graph showing emission reductions for NOx, PM2.5, and SOx with different fuel switching zones.]

- NOx: 4.8x
- PM2.5: 4.4x
- SOx: 4.3x

The graph compares emission reductions for different fuel switching zones (24 nm and 200 nm) for NOx, PM2.5, and SOx.
Dispersion Modeling
Modeling Domain: Sources and Receptors

Sources:
• Activity in shipping lanes
• Hotelling/Maneuvering within the harbor

Receptors:
• Deposition monitors in island/reef network
• Concentration monitors throughout domain (50 km from port in all directions)
24 Hour Concentrations – PM$_{2.5}$
24 Hour Concentrations – SO₂
Dispersion Modeling
Results: Annual Total Deposition

- Sulfur deposition (from dry and wet settling of SO$_2$ from ship exhaust) at two sensitive reef areas near the port is dramatically reduced from fuel switching.

<table>
<thead>
<tr>
<th>Reef</th>
<th>Total Annual SO$_2$ Flux</th>
<th>Units</th>
<th>HFO</th>
<th>MGO</th>
<th>Difference</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reef Area 1</td>
<td></td>
<td>g/m$^2$</td>
<td>0.19</td>
<td>0.01</td>
<td>0.18</td>
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<tr>
<td></td>
<td>Total Annual Deposition</td>
<td>kg</td>
<td>53,000</td>
<td>1,900</td>
<td>52,000</td>
<td>96%</td>
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<tr>
<td>Reef Area 2</td>
<td>Total Annual SO$_2$ Flux</td>
<td>g/m$^2$</td>
<td>0.0093</td>
<td>0.00081</td>
<td>0.008</td>
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<tr>
<td></td>
<td>Total Annual Deposition</td>
<td>kg</td>
<td>540</td>
<td>47</td>
<td>490</td>
<td>91%</td>
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<tr>
<td>Total</td>
<td>Total Annual SO$_2$ Deposition</td>
<td>kg</td>
<td>54,000</td>
<td>2,000</td>
<td>52,000</td>
<td>96%</td>
</tr>
</tbody>
</table>
Summary

- Fuel Switching reduces PM emissions by up to 80 percent and SOx emissions by up to 97 percent.
- Fuel switching within 24 nm reduces annual emissions of PM by 78% and SOx by 87% at the Port of Veracruz.
- Concentrations of PM and SOx emissions around Veracruz reduced by 7x and 24x respectively.
- Deposition of SOx on sensitive reefs around Veracruz reduced by 52 Metric Tonnes per year (96%).