SCAQMD Air Quality Challenges and Critical Role of OGV Incentive Programs

Philip Fine, Deputy Executive Officer
OGV Retrofit Technology Forum
December 5, 2018
South Coast Air Quality Management District

- Local air pollution control agency for the greater Los Angeles area (South Coast Air Basin)
  - Largest of the 35 local air agencies in CA and in the U.S.
  - Covers 27,800 km²
  - 17 million residents
  - Over 10 million gasoline vehicles; 300,000 on-road diesel vehicles

- Responsibilities
  - Regulate emissions from stationary sources
  - Develop and implement plans to meet national air quality standards
  - Permit and inspect 28,400 affected businesses
  - Administer over $100 million of incentive funding annually
Our Challenge

The Los Angeles area has historically suffered from some of the worst air quality in the country.

We’ve made significant progress, but still suffer from poor air quality:
- Worst ozone in the country
- Second-worse fine particulate matter (PM$_{2.5}$)
History of Successful Air Quality Programs

• Mobile Sources (U.S. EPA, CARB)
  • Emission standards for new vehicles/equipment
  • Clean fuels
  • In-use programs for existing vehicles/equipment
  • Incentive programs

• Stationary Sources (SCAQMD)
  • Source-specific regulations
    • Combustion sources (NOx, SOx)
    • Zero and low-VOC coatings and solvents/Consumer products
    • Fugitive emissions (VOC, PM)
    • Air toxics
  • Incentive programs
Significant Emissions Reductions Achieved Despite Population Growth
## Upcoming Deadlines to Attain National Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Concentration</th>
<th>Classification</th>
<th>Attainment Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 8-hour Ozone</td>
<td>75 ppb</td>
<td>Extreme</td>
<td>2031</td>
</tr>
<tr>
<td>2012 Annual PM2.5</td>
<td>12 ug/m3</td>
<td>Moderate/Serious</td>
<td>2021/2025</td>
</tr>
<tr>
<td>2006 24-hour PM2.5</td>
<td>35 ug/m3</td>
<td>Serious</td>
<td>2019</td>
</tr>
<tr>
<td>1997 8-hour Ozone</td>
<td>80 ppb</td>
<td>Extreme</td>
<td>2023</td>
</tr>
<tr>
<td>1979 1-hour Ozone</td>
<td>120 ppb</td>
<td>Extreme</td>
<td>2022</td>
</tr>
</tbody>
</table>
Ozone and PM$_{2.5}$ Air Quality Trends in the South Coast Air Basin
2008 Ozone Standard Non-Attainment Areas

2008 Ozone Std
Non-Attainment Areas

Classification

- Extreme
- Severe 15
- Moderate
- Serious
- Marginal

Map showing non-attainment areas across the United States.
Annual Average PM2.5 in South Coast Air Basin

(2015 Data)
2016 Air Quality Management Plan

- Blueprint for how to meet and maintain air quality standards
- The 2016 Plan is the SCAQMD’s 11th plan
- Implementing the 2016 Plan will result in:
  - An average of 1,600 premature deaths avoided per year
  - ~2,500 fewer asthma-related emergency room visits per year
  - ~700 fewer hospital admissions related to asthma, cardiovascular, or respiratory conditions per year
  - >200,000 fewer person-days of work and school absences/year

Public health benefits estimated to be $173 billion cumulatively (2017-2031)
Significant Additional NOx Reductions Are Still Needed to Meet Air Quality Standards
NOx Also Contributes to PM2.5

Annual PM2.5 Speciation (%)

- **Sulfate**: 33.0%
- **Nitrate**: 23.7%
- **Ammonia**: 10.3%
- **Organic Carbon**: 8.9%
- **Elemental Carbon**: 7.7%
- **Crustal**: 5.2%
- **Salt**: 2.1%
- **Particle Bound Water**: 9.1%
Reducing NOx Emissions is the Key to Attaining Air Quality Standards

• Forms ozone; contributes to PM$_{2.5}$
• Over 80% of the basin’s NOx emissions from mobile sources
• SCAQMD has limited authority to regulate mobile sources
  • Need for New Incentive Programs

2023 NOx = 271 tons/day
Successful History of Mobile Source Incentive Programs

• Technology Demonstration and Commercialization
• Incentives to date (since 1998)
  • $1.5 Billion
  • 22,000 Vehicles/Equipment Replaced/repowered/retrofitted
  • 17,000 tons of NOx reduced
  • 500 tons of PM reduced
• Significant levels of incentive funding needed to achieve 2016 AQMP reduction targets
Importance of Ship Emissions

- Ships and commercial boats were the 3\textsuperscript{rd} largest contributor to NOx in 2012, and will be the top contributor in 2023.

- Over 50\% of NOx emissions from the ports are from ocean going vessels.

Shipping is the only category with a projected increase in NOx emissions.
Existing Control Programs for Ship Emissions

• IMO/U.S. EPA
  • NOx Engine Standards; Fuel Requirements
    • Tier 3 engines for new vessels at ECAs
• California Air Resources Board
  • At-Berth Regulation
  • Low-Sulfur Fuel Regulation
• Ports of Los Angeles and Long Beach
  • CAAP, Incentive Programs
• Other Programs
  • Ports - Local Programs (e.g., VSR)
  • Shipping Lines
Challenge of Controlling Ship NOx Emissions

- Ships represent a significant source of NOx emissions
  - Substantial NOx reductions needed beyond existing regulations and programs
- Existing IMO regulations will not provide short-term benefits
  - Near-term deployment of Tier 3 vessels at local ports not expected
  - Substantial ship orders made prior to 1/1/2016 keel laid date
- Existing Programs are not adequate to address our air quality needs

*New and Innovative Voluntary Incentive Programs Are Needed for Reducing Ship Emissions*
New OGV Incentive Programs

• Incentives Considered in Three Areas
  • Deployment (re-routing) of existing and future Tier 3 vessels
  • Construction of Tier 3 vessels on pre-2016 keels
  • Retrofits of existing main/auxiliary engines to be cleaner than Tier 2

• Critical elements for successful new OGV incentive programs
  • Availability of adequate incentive funding (agencies, ports)
    • Multiple ports participation will make program more cost-effective
  • Participation of shipping lines (frequent callers)
    • Commit vessels to ports on same strings for several years (e.g., 5 years)
  • Development of viable retrofit technologies by engine manufacturers
    • Technology demonstration and verification
INTERNATIONAL CLEAN VESSELS

Incentives and Collaboration
OUTLINE

- Industry-Initiated Green Shipping Incentive Schemes
- Examples of Country-Specific Green Shipping Incentive Schemes
- Examples of Port-specific Clean Vessel Incentive Programs
- Other clean vessel and port collaborative efforts
### INDUSTRY-INITIATED/THIRD-PARTY GREEN SHIPPING INCENTIVE/RATING SCHEMES

<table>
<thead>
<tr>
<th>Rating system</th>
<th>Categories</th>
<th>Stakeholders/Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Ship Index (ESI)</td>
<td>NOx, SOx, PM, GHG</td>
<td>The ESI provides a reduction in port dues or tonnage charges for registered ocean-going vessels (OGVs) with below-average SOx, NOx, and/or CO₂ emissions, compared to the current emission standards of the IMO. <a href="http://www.environmentalshipindex.org">http://www.environmentalshipindex.org</a> Registered OGVs can receive incentives from participating ports. 35 in Europe; 4 in Asia; 4 in U.S. and Canada; 2 Middle East; 1 Latin America; 1 Oceania Full list of ESI incentive providers: <a href="http://www.environmentalshipindex.org/Public/PortIPs">http://www.environmentalshipindex.org/Public/PortIPs</a></td>
</tr>
<tr>
<td>Clean Shipping Index (CSI)</td>
<td>NOx, SOx, PM, GHG, chemicals, water/waste</td>
<td>Vessel scoring system with CSI score between 1 – 5. Vessel choose to register. On-line tool for shippers/cargo owners and forwarders seeking to purchase capacity on a CSI-participating vessel. Can be used by Ports as part of their incentive programs. <a href="https://cleanshippingindex.com">https://cleanshippingindex.com</a></td>
</tr>
<tr>
<td>Green Award</td>
<td>NOx, SOX, PM, VOC, GHG, water ballast, anti-fouling, ship breaking, navigation in sensitive areas, waste, safety</td>
<td>Designed as an incentive to encourage large vessels to improve safety and environmental protection by certifying ships that are particularly clean and safe. Ships with a Green Award certificate can qualify for financial and non-financial benefits, including receiving a discount of port dues at major ports in 12 countries and recognized by 34 ports. <a href="http://www.greenaward.org/greenaward/22-list-of-incentive-providers.html#agreena48">http://www.greenaward.org/greenaward/22-list-of-incentive-providers.html#agreena48</a> Green Award certification is open to oil and chemical tankers, dry bulk, LNG, LPG, and container carriers, and most inland navigation vessels. <a href="https://www.greenaward.org">https://www.greenaward.org</a></td>
</tr>
<tr>
<td>RightShip</td>
<td>GHG</td>
<td>Provides ratings for commercial vessels, focused on GHG Emissions Rating to rate the design energy efficiency of ocean going vessels. Incentive providers are given access to the RightShip database at no cost. <a href="http://www.shippingefficiency.org">www.shippingefficiency.org</a></td>
</tr>
<tr>
<td>Clean Cargo Working Group (CCWG)</td>
<td>GHG</td>
<td>Clean Cargo is a business-to-business leadership initiative that involves major brands, cargo carriers, and freight forwarders dedicated to reducing the environmental impacts of global goods transportation and promoting responsible shipping. <a href="https://www.clean-cargo.org">https://www.clean-cargo.org</a></td>
</tr>
<tr>
<td>Green Marine (North America only)</td>
<td>NOx, SOx, PM, GHG, aquatic invasive species, oily water, waste, underwater noise</td>
<td>Green Marine is an environmental certification program for the North American marine industry. Participants include ship owners, ports, Seaway corporations, terminals and shipyards. <a href="https://www.green-marine.org">https://www.green-marine.org</a></td>
</tr>
</tbody>
</table>
COUNTRY-SPECIFIC CLEAN SHIPPING INCENTIVE SCHEMES

• Norway – NOx Fund
  • NOx emission reduction fund, paid for with a tax or fee on all sectors emitting NOx.

• Sweden – Environmentally Differentiated Fairway Dues
  • Fairway dues assessed to vessels entering Swedish ports based on NOx emission levels (gNOx/kWh)

• Singapore – Maritime Green Initiative
  • Three programs:
    • Green Ship Program (GSP)
      • Reduction in initial registration fees, rebates on annual tonnage tax
    • Green Port Program (GPP)
      • Reduction in port dues
    • Green Technology Program (GTP)
      • Grants to Singapore-registered companies to develop and adopt green maritime technologies
PORT-SPECIFIC CLEAN VESSEL INCENTIVE PROGRAMS

• Examples
  • Port of Los Angeles – Environmental Shipping Index (ESI)
  • Port of Long Beach – Green Vessel Incentive Program
  • Port of New York and New Jersey – Clean Vessel Incentive Program / ESI
  • Port of Vancouver – EcoAction / ESI
  • Port of Rotterdam – Green Award / ESI
  • Port of Gothenburg – ESI / CSI
OTHER CLEAN PORT AND VESSEL COLLABORATIVE EFFORTS

• U.S.-China Green Ports and Vessels Initiative (GPVI)
• International Collaboration on Ship Emission Reductions (ICSER)
• Clean Vessel Incentive Program (CVIP) / Pacific Rim Initiative for Maritime Emissions Reductions (PRIMER)
INTERNATIONAL COLLABORATION ON SHIP EMISSION REDUCTIONS (ICSER)

- Many clean vessel and port incentives globally
- Various clean vessel rating schemes available
- Many ports around the world also offer environmental infrastructure such as shore power, ship emissions capture technologies or LNG bunkering
- Working together to coordinate better access to information about available incentives
  - Port/vessel incentives
  - Rating schemes
  - Port environmental infrastructure
- Better access to information can result in:
  - Greater uptake of clean vessel incentives
  - More participation in rating schemes
  - More ports offering incentives
  - Cleaner vessels
  - Vessel emission reductions and fewer environmental impacts from international shipping

Working together, our incentive programs and environmental infrastructure can more efficiently and effectively reduce emissions and other impacts from international shipping.
# INTERNATIONAL COLLABORATION ON SHIP EMISSION REDUCTIONS

## Discussion Platform
- Quarterly teleconferences
- Share information on common issues
- Further conversation on international collaboration

## Project Team
- Port of Gothenburg
- Port of Long Beach
- Port of Los Angeles
- Port of Vancouver
- China Waterborne Transport Research Institute
- Natural Resources Defense Council (Hong Kong)
- Transport Canada
- U.S. Environmental Protection Agency

## Phase 1 Activities
- Advisory Group
- Stakeholder mapping and prioritization
- Surveys, interviews, presentations, landing page
- Review with stakeholders
- Final proposal
MORE INFORMATION & JOIN OUR ICSER COLLABORATION EFFORT

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Thank you!

Questions?
California OGV Regulations & Incentive Programs

Bonnie Soriano, Chief
Freight Activity Branch
Diamond Bar, CA, December 5, 2018
Ocean Going Vessels Retrofit Technology Forum
Discussion Items

I. CARB’s Freight Strategies
II. Existing Programs for Ocean-Going Vessels
III. Vessel Control Technology
IV. Incentive Programs and Projects
V. How Can We Collaborate
I. CARB’S FREIGHT STRATEGIES
## Existing CARB Strategies Cut Freight Emissions and Health Risk

<table>
<thead>
<tr>
<th>Trucks</th>
<th>Ships</th>
<th>Locomotives</th>
<th>Equipment</th>
<th>Harbor Craft</th>
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</thead>
<tbody>
<tr>
<td>• Idling and smoke limits</td>
<td>• Fuel standards</td>
<td>• Fuel standards</td>
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<td>• Fuel standards</td>
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<tr>
<td>• International trucks</td>
<td>• At-berth reductions</td>
<td>• Fleet emission limits for South Coast</td>
<td>• Port &amp; rail equipment</td>
<td>• Aftertreatment Controls</td>
</tr>
<tr>
<td>• Drayage trucks</td>
<td>• Ship incineration ban</td>
<td>• Diesel soot reduction at rail yards</td>
<td>• Transport refrigerators</td>
<td>• Repower</td>
</tr>
<tr>
<td>• All on-road trucks</td>
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<tr>
<td>• GHG limits for tractor-trailers</td>
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Incentives for cleaner equipment
CA Freight Strategies Are Effective

Change in cancer risk since 2005:

80 to 85% reduction at largest seaports
Seaport- Contribution to Near-Source Cancer Risk

Activity held constant (no growth); reflects rules + fleet turnover

Average Near-Source Cancer Risk

- Trucks to ~3 mi
- On-site equipment
- Ships to ~40 nm
- Harbor Craft to ~40 nm
- Locomotives to ~3 mi

2016

2023
CARB Advocates for a Suite of Approaches

- Reduce NOx, PM\(_{2.5}\), diesel PM, SOx and GHGs
- More shore power (State, national and international) and standardized connections
- Tighter IMO emissions standards, establish PM limits and more efficiency measures
- Cleaner vessels to California
- On-board engine technologies and control strategies
- Strategies with demonstrated emissions reductions using uniform test protocols
II. EXISTING PROGRAMS FOR OCEAN-GOING VESSELS

Cleaner Fuels

At-Berth
CA Vessel Fuel Regulation - Overview

- Reduces diesel PM, PM$_{2.5}$, SOx, and NOx
- 2008 CA rule for cleaner fuels within 24 nm zone
- U.S. and foreign-flagged ocean-going vessels
- Main & auxiliary engines, auxiliary boilers
- Now: 0.1% sulfur distillate
- Practical experience supported North American ECA
CA Vessel Fuel Regulation - Achievements

♦ Based on inspections in 2017, 97% compliance rate with clean fuel requirements
♦ CARB enforcement adds to success
♦ By 2015, emissions from the clean fuel rule decreased by:
  – 16 tpd diesel PM
  – 12 tpd NOx
  – 148 tpd SOx
Existing At-Berth Regulation

- Vessels must connect to shore power or use an approved alternative
- Ports of Los Angeles, Long Beach, Oakland, San Diego, Hueneme, and San Francisco
- Visit and power reduction:
  - 50% in 2014, 70% in 2017 and 80% in 2020
- Requires reduction in NOx and diesel PM, reduced GHGs due to clean electricity grid
At-Berth Regulation Achievements

- Between 2014-2017, ~10,000 shore power visits in California
- Shore power ready: 23 terminals, 63 berths, >200 vessels
- Two alternatives in commercial operation
- In 2016, fleets reduced emissions from OGVs at-berth by:
  - 3.5 tpd NOx
  - 21.5 tpy diesel PM
At-Berth Updates Needed to Achieve Added Health Benefits

- Additional vessel categories and boilers (for certain tankers)
- Controls at more ports and marine terminals
- Use an approved compliance strategy for each visit
  - Shore power or technologies with a CARB Executive Order
- Draft implementation schedule
  - Containers/Reefers/Cruise in 2021
  - Ro-Ro/Auto carriers in 2025
  - Tankers in 2025 and 2031
- Future strategies might also include onboard controls and cleaner vessels
- Opacity standards at-berth and at-anchor
III. VESSEL CONTROL TECHNOLOGY

DRAFT

TECHNOLOGY ASSESSMENT: OCEAN-GOING VESSELS
Technology Challenges

- Technologies require significant investment
- Vessel visiting California represent a small portion of the global fleet
- Ocean-going vessels have:
  - Long lifespan/low turnover
  - High energy requirements
  - Complex equipment, standards and requirements
  - Operate in marine environment
CARB OGV Technology Assessment Findings

- Published Draft OGV Technology Assessment-May 2018
- Findings include:
  - Added At-berth reductions needed
    - Technologies are available to meet zero and near-zero control at-berth
  - Stricter IMO standards are essential to achieve goals
  - Significant reductions possible as engine and control technologies advance
  - Research and demonstrations needed to identify and develop most promising strategies
  - Incentives and other funding will accelerate adoption

[Source](https://www.arb.ca.gov/msprog/tech/techreport/ogv_tech_report.pdf)
Vessel and Technology Testing and Evaluation

- Uniform evaluation methods provide opportunity to coordinate strategies between measures
- Reductions demonstrated using robust testing protocols such as: *Recommended Emissions Testing Guidelines for Ocean-going Vessels (CARB/UCR/Ports)*
- Emission testing programs to demonstrate baselines and reductions:
  - Engines, fuels and aftertreatment strategies
  - Cleaner vessels: Tier II or III engines
  - Boilers

https://www.arb.ca.gov/ports/marinevess/ogv/ogvreports.htm
IV. INCENTIVE PROGRAMS AND PROJECTS
OGV Incentive Projects

✦ Incentives are:
  – Critical to achieve additional reductions beyond regulatory requirements
  – Provide investments for new and developing technologies

✦ California Low Carbon Transportation Funding
  – Shore side control system for vessels while at-berth (ShoreKat system)
  – Technology development project for vessel retrofits to reach IMO Tier III standard
OGV Incentive Projects

- **Goods Movement (Prop 1B) Funding**
  - 37 shorepower berths at California ports, vital to the success of the At-Berth Regulation
  - BAAQMD project for a barge-based capture and control system for auto carrier/roll on-roll off vessels
CARB Incentive Programs Funding Port/Marine/Freight Projects

- Low Carbon Transportation Investments and AQIP Funding Plans
  https://www.arb.ca.gov/msprog/aqip/fundplan/fundplan.htm

- Carl Moyer Program – ongoing funding source
  https://www.arb.ca.gov/msprog/moyer/guidelines/current.htm

- AB 617 Community Air Protection Program
  https://www.arb.ca.gov/msprog/cap/capfunds.htm

- Volkswagen Environmental Mitigation Trust
  https://www.arb.ca.gov/msprog/vw_info/vsi/vw-mititrust/vw-mititrust.htm
How Can We Collaborate?

- Shore power + standardized connections
- On-board vessel emission controls + testing
- Tighter IMO standards (NOx, PM, GHG)
- Incentives for cleaner vessels on trans-Pacific routes
- Funding for technology development and demonstrations
- Engagement with engine makers for advanced engine technologies
CARB Contacts

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Commercial Marine Vessels:
https://www.arb.ca.gov/ports/marinevess/marinevess.htm
Overview of POLB and POLA Vessel Emission Reduction Strategies

Heather Tomley
Acting Managing Director of Planning and Environmental Affairs
Port of Long Beach
2005 vs. 2017

- Container throughput up 19%
- Containers (TEUs) per call up 58%
- Containership calls down 25%

2017 Air Emissions Reductions
Diesel Particulate Matter Down 87%
Nitrogen Oxides Down 58%
Sulfur Oxides Down 97%
Greenhouse Gases Down 15%

*Compared to 2005 Levels
**GHG emissions (CO$_2$e) are reported in metric tons (MT) per year; all other pollutants are shown in tons per year.
Emissions Today

- DPM: 47%
- NOx: 54%
- SOx: 96%
- CO2e: 30%

Legend:
- OGV
- Harbor Craft
- CHE
- Locomotives
- Heavy Duty Vehicles
Strategies for Ships

• Incentive Programs (Past & Present)
• Technology Solutions
• Regulatory & Funding Advocacy
Low Sulfur Fuel

- Initiated as a port funded incentive to encourage voluntarily switching to low sulfur fuels in main engines
- Incentive sunset when state regulation came into effect
- Now a requirement under North American ECA
Vessel Speed Reduction

Program in place since 2001. Ports provide incentives for ships that slow down to 12 knots within 40 nm.
Green Ships/Environmental Ship Index
The Ports give financial incentives for ships with the cleanest engines
Shore Power

Ships have been plugging in since 2008
Equivalent of taking 42,000 cars off the road each day
Shore Power Alternatives
Technology Advancement

• Maersk Vessel Efficiency Improvements
  o Modify Bulbous Bows
  o Improve Efficiency Propellers
  o Raise Bridge to Increase Capacity
  o De-rate Propulsion Engines
  o High Fidelity Data Collection

• Maersk Investing Over $125 Million

• Ports Investing $1 Million ($500K per Port)
  o TAP assisted in purchasing fuel flow meters, data acquisition and transmission, and data analysis
Technology Advancement

Bulbous Bow Modification
Technology Advancement

Propeller Replacement
Technology Advancement

Raise Bridge

- Additional void superstructure decks
- Raised bridge
- Original bridge layout

ALPHALINER

- Higher container deck load due to improved line of sight

MAERSK LINE

MAERSK ALKIR
Technology Advancement

De-Rating Propulsion Engine

- Reduce engine output for lower maximum vessel speed
  - Utilize latest engine tuning methods
  - Estimated 10-12% fuel savings based new optimized speed
Technology Advancement

Previous Vessel Projects

- Tri-Mer Mobile Emissions Treatment System (METS-1)
- ACTI Advanced Maritime Emission Control System
- APL Singapore Slide Valve & Water-In-Fuel Emulsion
- Alternative Petroleum Technologies
- Bluefield Holdings/Krystallon Ocean Going Vessel Scrubber
- OGV Slide Valve Low-Load Emissions Evaluation
Strategies in the CAAP

• Participation in the State Amendment of Vessel At-Berth Regulation
• RFP for Emissions Capture & Treatment Systems
• 2019 - Ship Incentive Program Modification
• 2023 - Economic Assessment for Clean Ship Rate
• 2025 - Clean Ship Differential Rate Program
• Ongoing - West Coast Ship Incentive Collaboration
• At-Berth Infrastructure Assessments
• VSR Program Modification
Send comments to:
caap@cleanairactionplan.org
Development of New Incentive Programs for Ocean-Going Vessels

Sarah Rees, Assistant Deputy Executive Officer
OGV Retrofit Technology Forum
December 5, 2018
New OGV Incentive Programs

• New OGV Incentives Considered in Three Areas
  • Deployment (Re-routing) of existing and future Tier 3 vessels
  • Construction of Tier 3 vessels on pre-2016 keels
  • Retrofits of existing main/auxiliary engines to be cleaner than Tier 2

• Benefits to Participating Ports/Regions
  • Local/regional air quality benefits (NOx, PM2.5)

• Benefits to shipping lines
  • Financial (after ROI period)
  • Environmental recognition, non-monetary benefits
General Principles for New OGV Incentive Programs

• Voluntary incentive programs based on achieving NOx reductions beyond existing regulations
• Incentives offered by local/state/federal authorities and participating ports
• Incentives offered to shipping lines committing frequent callers to ports for a minimum number of years
• Incentives adequate to encourage participation by shipping lines and proportional to cost and level of NOx reductions
• Return on Investment (e.g., less than 2 years)
### Current IMO Regulations for NOx

- Established classification of engines required for vessels based on year built

<table>
<thead>
<tr>
<th>Year Built</th>
<th>Engine Tier</th>
<th>NOx (g/kWh)*</th>
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</thead>
<tbody>
<tr>
<td>Pre-2000</td>
<td>Tier 0</td>
<td>18+</td>
</tr>
<tr>
<td>2000</td>
<td>Tier 1</td>
<td>17</td>
</tr>
<tr>
<td>2011</td>
<td>Tier 2</td>
<td>14.4</td>
</tr>
<tr>
<td>2016</td>
<td>Tier 3</td>
<td>3.4</td>
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</tbody>
</table>

*<130 rpm

**Emission Control Area (ECA) only**
Current Emission Control Areas

- Imposes requirements within 200 nautical miles of an ECA
  - SOx: requires low sulfur fuel
  - NOx: requires vessels built after 2016 to meet Tier 3 engine standards
- North Sea and Baltic ECA will add NOx requirements in 2021
Tier 3 Vessels Availability/Forecast

• Tier 3 vessels only required in North America Emission Control Area (ECA) after 2016 (keel laid date after 1/1/2016)
• Limited number of Tier 3 vessels built thus far and on order
• Pre-2016 Tier 0-2 vessels are not restricted from entering ECAs
• There is a surplus of pre-2016 keels; new vessels are mostly being constructed on these keels
• San Pedro Bay Ports forecast Tier 3 vessels mostly in 2030s and 2040s
  • No Tier 3 vessel visits so far based on existing incentive programs
  • Limited number of Tier 3 vessels expected in next few years
Number of Keels Laid Through 2016

(Figure is from San Pedro Bay Ports 2017 CLEAN AIR ACTION PLAN)
Potential Opportunities for Deployment of New Tier 3 Vessels

• New non-ECA Tier 3 vessels currently not targeted for deployment to Ports of LA/LB and Transpacific trade routes in the near term
  • Opportunity to offer incentives for deployment of these vessels

• New vessel build orders on pre-2016 keels are primarily based on Tier 2 engines
  • Small window of opportunity to offer incentives for building these new vessels with Tier 3 engines and deployment

• Adequate incentive funding needed to offset increased cost of Tier 3 vessel deployments
Considerations for OGV Engine NOx Retrofits

- Technology needs to be feasible, practical and economically viable
- Technology demonstration and verification required
- Achieve Tier 2+ NOx level targets
  - 25% - 80%+ (beyond Tier 1)
- Avoid or minimize fuel penalty (GHG impact)
- Retrofit technology customized for applicable vessel/engine types
- Minimize impact on vessels (installation and operation)
- Lead time for ordering and installing retrofit technologies
- Operation of retrofit technologies limited to within 100 nm of ports
Potential Opportunities for OGV Retrofits

• Applicability
  • Main and Auxiliary Tier 0, 1, and 2 Diesel Engines
  • Transit, Maneuvering, Hoteling, Anchoring Modes (within 100 nm)

• Promising retrofit technologies available today and emerging
  • Retrofit packages expected to be offered/supported by engine manufacturers
  • NOx benefits to be verified/optimized through technology demonstration

• Significant number of OGV calls made by frequent callers (making 5 or more visits per year)
  • Container ships, cruise vessels, tankers

• Dedicated vessels on common strings serving Ports of LA/LB and other ports participating in the Incentive Program
Frequent Callers (>5/year) by Vessel Type at Ports of LA/LB in 2016

Number of Frequent Caller Vessels

- Container
- Tanker
- Auto Carrier
- Bulk
- Cruise
- General Cargo
- Misc
- Reefer
- RoRo

Port of LA/LB in 2016
Frequent Caller (>5) Container Vessels at Ports of LA/LB and Key Asian Ports in 2016
OGV Emissions by Vessel Type at Ports of LA/LB (2016)

The chart shows the emissions of NOx (tons/day) for different vessel types at ports of LA/LB in 2016. The vessel types include:

- Auto Carrier
- Bulk
- Container
- Cruise
- General Cargo
- Ocean Tugboat
- Misc
- Reefer
- RoRo
- Tanker

The emissions vary significantly across these types, with Container vessels emitting the highest amount of NOx, followed by RoRo and Tanker vessels. The emissions for other vessel types are much lower.
OGV Emissions by Operational Mode at Ports of LA/LB (2016)

- **NOx (tons/day)**
  - **Transit**: Main Engine (9.0), Auxiliary Engine (2.0), Auxiliary Boiler (0.0)
  - **Maneuvering**: Main Engine (0.0), Auxiliary Engine (1.0), Auxiliary Boiler (0.0)
  - **Hotelling**: Main Engine (0.0), Auxiliary Engine (4.0), Auxiliary Boiler (1.0)
  - **Anchoring**: Main Engine (0.0), Auxiliary Engine (1.0), Auxiliary Boiler (0.0)
OGV Emissions by Engine Type at Ports of LA/LB (2016)

- Main Engine: 49%
- Auxiliary Engine: 44%
- Auxiliary Boiler: 7%
Potential OGV Retrofit Technologies

- Selective Catalytic Reduction
  - Urea solution used as reducing agent
- Exhaust Gas Recirculation
  - Recirculated exhaust air lowering peak combustion temperature
- Fuel/Water Emulsification
  - Water mixed into the fuel
- Humid Air Motor
  - Heated intake air saturated with water vapor
- Direct Water Injection
  - Water directly injected into the combustion cylinder
- Battery/Hybrid
## Estimated NOx Reduction Efficiency for Potential Retrofit Technologies

<table>
<thead>
<tr>
<th>Retrofit Control Technology</th>
<th>NOx Reduction Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selective Catalytic Reduction</td>
<td>80% - 90%</td>
</tr>
<tr>
<td>Exhaust Gas Recirculation</td>
<td>50% - 80%</td>
</tr>
<tr>
<td>Air Humidification</td>
<td>Up to 70%</td>
</tr>
<tr>
<td>Direct Water Injection</td>
<td>Up to 50%</td>
</tr>
<tr>
<td>Water Fuel Emulsion</td>
<td>20% - 40%</td>
</tr>
<tr>
<td>Engine De-Rating</td>
<td>Up to 10%</td>
</tr>
</tbody>
</table>
Analysis Underway on OGV Incentive Concept

• SCAQMD is working with a consultant to estimate the potential emissions reductions from a cleaner vessel incentive program

• Analysis will build an emissions model of ports of LA/LB using detailed vessel activity data

• Using this model, different control scenarios will be analyzed

• Goal is to identify optimal incentive levels to promote specific emission reduction technologies
Proposed Next Steps

• Establish Two OGV Incentive Working Groups (Jan/Feb 2019)
  • OGV Tier 3 Vessel Deployments
  • OGV Retrofits

• Continue Analysis on Scenario Modeling (2018-2019)

• Initiate 1st Retrofit Technology Demonstration on a Main Engine in 2019
  and conduct other demonstration projects in 2019-2021 timeframe

• Development of New OGV Incentive Programs through working groups
  (2019-2021)

• Launch of New OGV Incentive Programs
  • Tier 3 vessels - 2020+
  • Retrofits - 2021+
Tier 3 Vessel Deployment Working Group

• Identify potential participation level by shipping lines and ports
  • Existing and future Tier 3 deployments
  • New vessel builds upgraded with Tier 3 engines

• Understand economic and business drivers for shipping lines and potential barriers and issues

• Determine total cost

• Evaluate types of incentives
  • Monetary award per ship call or discount on port fees
  • Non-monetary (Preferential berthing, environmental awards/recognitions)

• Determine appropriate levels of incentive funding

• Develop model(s) for implementation at participating ports
OGV Retrofit Working Group

• Conduct 1st retrofit technology demonstration on main engines
  • Water/Fuel Injection; 40% NOx reduction target
• Identify and conduct other feasible demonstration projects for main and auxiliary engines
• Identify potential participation level by shipping lines and ports
• Determine total retrofit costs for feasible technologies
• Evaluate potential barriers and issues for implementation
• Evaluate types of incentives (monetary and non-monetary)
• Determine appropriate levels of incentive funding
• Develop model(s) for implementation at participating ports
Example for OGV Incentive Program

• Frequent caller vessel on a common string identified by shipping line for participating in the incentive program
  • Tier 3 vessel or retrofit technology
• Commitment/agreement by shipping line to operate at Ports of LA/LB for a min number of years or calls
• Funding offered per vessel visit through Ports of LA/LB and other participating ports for agreed period
• Vessel operator to comply with program requirements (e.g., reporting, record keeping)
Collaboration is the key to success
MAN B&W 2-stroke Engines
Ocean Going Vessels Retrofit Technology

Technology Forum at SCAQMD Headquarters,
December 5th, 2018

Kjeld Aabo
Director New Technologies
MAN ES 2-stroke engines Copenhagen

Michael Witt
Head of Retrofit Development
MAN ES 2-stroke engines Copenhagen
The Licensees Reported Order Book
Two-Stroke Low Speed. Highlights from latest New Building / Engine Program

The licensees’ order books by licensee area since 2000

GW on order end month

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Licensee country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>South Korea</td>
</tr>
<tr>
<td>2017</td>
<td>August</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>October</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>November</td>
<td>7.0</td>
</tr>
<tr>
<td></td>
<td>December</td>
<td>8.3</td>
</tr>
<tr>
<td>2018</td>
<td>January</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>February</td>
<td>7.9</td>
</tr>
<tr>
<td></td>
<td>March</td>
<td>8.4</td>
</tr>
<tr>
<td></td>
<td>April</td>
<td>9.0</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>June</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td>July</td>
<td>9.5</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>9.8</td>
</tr>
</tbody>
</table>

0.1 GW (1%)
4.5 GW (23%)
5 GW (26%)
9.8 GW (50%)

Status Reported end August 2018

Source: Licensees order book
Vessel Contracting, No of Vessels >2000 DWT/GT

Total Shipbuilding Forecast

Vessel Contracting
Vessels > 2000 DWT/GT

Source: IHS Ltd & MDT
**Fuel 2020 and DSO choices**

- **HFO standard engine shall always be followed by a scrubber** – this will be part of a new CEAS update.
- **ME-GI is as standard a LS design** – all fuels, also pilot fuel need individually to be compliant.

<table>
<thead>
<tr>
<th>Compliant fuel</th>
<th>High sulphur fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MC/ME/-C engine</strong></td>
<td></td>
</tr>
<tr>
<td>Single Fuel:</td>
<td></td>
</tr>
<tr>
<td>0.1%S fuel, 0.5%S fuel</td>
<td></td>
</tr>
<tr>
<td><strong>ME-GI / ME-LGI engine</strong></td>
<td></td>
</tr>
<tr>
<td>Dual Fuel:</td>
<td></td>
</tr>
<tr>
<td>LNG, Ethane, LPG, MeOH ..........</td>
<td></td>
</tr>
<tr>
<td><strong>MC/ME/-C engine</strong></td>
<td></td>
</tr>
<tr>
<td>0-5%S fuels:</td>
<td></td>
</tr>
<tr>
<td>HFO/MDO + Scrubber</td>
<td></td>
</tr>
</tbody>
</table>

**MAN B&W 2-stroke Engines**
BP prediction of fuel in the future

![Graph showing fuel predictions from 2015 to 2026 with categories such as HSFO with scrubbers, HSFO - non compliance, LNG, 0.5% sulphur fuel, and MGO.]

- Source BP p.l.c., not to be reproduced without BP’s permission
MAN B&W 2-stroke Engines
Multi fuel: New Technologies Information update

MAN Diesel & Turbo supports all

Residual ME / MC
Distillates ME / MC
ULSFO ME / MC
Methane ME-GI
Methanol ME-LGIM
LPG ME-LGIP
Ethane ME-GIE
Biofuel (2\textsuperscript{nd}+3\textsuperscript{rd} gen.) ME / MC
MAN B&W 2-stroke Engines Retrofitting

Retrofit Experience

Engine De-Rating

- Reduction of cylinder compression volume
- Modification of T/C process
- Enhancing max. cylinder pressure in Part-load
- Implementation of advanced fuel-injection
- Optional: Optimization of propeller for:
  - new rated power
  - new rated engine speed
  - new expected vessel speed

Fuel-gain: 2-5%, 13% (combined with propeller)

Motivation/Business Case:
Fuel consumption optimization, Economy
NOx level according regulatory limits remained unchanged

Turbo Charger Cut Out

- 1 of 3 T/C, 66% power limit
- 1 of 4 T/C, 75% power limit
- Enhancing max. cylinder pressure in Part-load

Propeller Retrofitting

- Optimized propeller for lower speed
- Propeller hull interaction optimized
- Propeller geometry optimized

Fuel-gain: 2-4%
Fuel-gain: 4-8%
MAN B&W 2-stroke Engines Retrofitting

Development of NOx regulatory levels

2-stroke Diesel engines

Tier I

Tier II (Global)

Tier III (NOx Emission Control Areas)

NOx (g/kWh)

18
16
14
12
10
8
6
4
2
0

Rated engine speed (rpm)

0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200

2010

2016

$n < 130 \text{ rpm } \rightarrow 17.0 \text{ g/kWh}$

$130 \leq n < 2000 \text{ rpm } \rightarrow 45 \times n^{-0.2} \text{ g/kWh}$

$n \geq 2000 \text{ rpm } \rightarrow 9.8 \text{ g/kWh}$

$n < 130 \text{ rpm } \rightarrow 14.4 \text{ g/kWh}$

$130 \leq n < 2000 \text{ rpm } \rightarrow 44 \times n^{-0.23} \text{ g/kWh}$

$n \geq 2000 \text{ rpm } \rightarrow 7.7 \text{ g/kWh}$

80% reduction of Tier I
MAN B&W 2-stroke Engines Retrofitting

NOx Reduction Technologies (Tier III) for our 2-stroke engine

- EGR
- HP SCR
- LP SCR
MAN B&W 2-stroke Engines Retrofitting

Tier III retrofitting solution

EGR Tier III engine       Engine Tier III EGR “prepared”       LP SCR Tier III retrofit

HP SCR retrofit on “in service” engine does not work, due to:
- space requirements
- vessel structure / engine room requirements

Tier III retrofit on a prepared 2-stroke engine for EGR is possible (operation on: HSF, LSF)
Tier III retrofit by added LP SCR is in some cases possible (operation on ULSF)

Business case related to regulatory demands and number of operating hours in Tier III
MAN B&W 2-stroke Engines Retrofitting

2020 fuel related retrofitting solution

Global sulphur cap on fuels (0.5%) enforced by 1.1.2020 is a game changer in maritime industry
- price level predictions of HFO, LSF, ULSF, LNG, LPG, Ethane, Methanol…. is very volatile

A number of gas-conversion retrofit projects are already completed successfully
Further retrofit project development for gas conversion is under construction

Why can “multi-fuel” engine operation on OGV help both the targets, environmental improvements and improved vessel economy?

<table>
<thead>
<tr>
<th>Fuel</th>
<th>NOx reduction</th>
<th>CO2 (carbon content only) reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG*</td>
<td>-25%</td>
<td>-25%</td>
</tr>
<tr>
<td>LPG (propane)*</td>
<td>0%</td>
<td>-13%</td>
</tr>
<tr>
<td>Methanol*</td>
<td>-30%</td>
<td>-7%</td>
</tr>
<tr>
<td>Ethane*</td>
<td>0%</td>
<td>-18%</td>
</tr>
</tbody>
</table>

Comparison based on 2-stroke engine operation Tier II mode with HFO at same engine performance, * pilot fuel (3% of MCR fuel flow) not considered

Business case decision for gas conversion projects are depending on:
- Type of vessel (e.g. gas or product tanker, container vessel)
- Level of independence need/ wish from fuel-oil prize development
- Operation pattern of OGV, e.g. short sea voyages
Man B&W 2-stroke Engines Retrofitting

Voluntary NOx reduction in 100 nautical miles coastal operation areas

In opposite to mandatory NOx Tier III technology (in ECA only) such voluntary NOx reduction efforts are subject to time limited use in 100 nm area.

For an existing OGV fleet it requires an evaluation of feasibility of integration on the vessel, as well as a reasonable level of CAPEX.

Everyone would agree that “going greener” is the right direction to go, however, someone has to pay for, as all the players in the maritime transport segment need to compete on a global level plain field.
Voluntary NOx reduction in coastal operation areas

A possible technical solution for this task:

Retrofitting in service OGV with “Water in Fuel” (WIF) technology. WIF technology has the potential to reduce up to approx. 40% of NOx emission in low-load fuel-oil based operation.

WIF concept is known as an emulsion of fuel-oil with added up to 40% of distillate-water. WIF implementation has the potential for an artificial Tier 2.5 level (up to < 50% SMCR)
MAN B&W 2-stroke Engines Retrofitting

Voluntary NOx reduction in coastal operation areas

Typical OGV emission pattern reduction potential in area of 100 nautical miles to / from port
- approx. 10 hours of operation on each port approach
- low load engine operation, typically at approx. 12-15% SMCR
- Analysis made for large Container Vessel called US California ports in 2018

Large potential for NOx emission savings
It require a close cooperation of SCAQMD, owners and engine designer
NO\textsubscript{x}-Reduction Technologies 2-Stroke
Comparison of Reduction Potentials vs. Invest Cost vs. Operational cost

**NO\textsubscript{x} reduction**
Baseline same engine performance

- A: Water in Fuel (WF) \* 40%
- B: EGR-retrofit ** 80%
- C: LP SCR-retrofit 80%
- D: LNG Gas-conversion retrofit *** 25%

**CAPEX comparison**
Case D set as 100%

- A: Water in Fuel (WF) \*
- B: EGR-retrofit **
- C: LP SCR-retrofit
- D: LNG Gas-conversion retrofit *** 20%

**OPEX comparison**
Baseline MGO operation
~2000 h/a ~7500 kW propulsion power

- A: Water in Fuel (WF) \*
- B: EGR-retrofit **
- C: LP SCR-retrofit
- D: LNG Gas-conversion retrofit ***

* CAPEX variation
** OPEX

* up to 50\%SMCR
** if ME-engine is prepared for EGR
*** ME engine types Tier II
MAN B&W 6S35MC and MAN B&W 10K98MC-C on Testbed
PrimeServ Augsburg

NOx reduction opportunities for four-stroke engines
Augsburg

MAN Energy Solutions SE
Augsburg, Germany, SEAA
2018
NO$_x$-Reduction Technologies 4-Stroke

Engine-internal Potentials Base TIER I

**Tier I to Tier II (Performance & Emission Upgrade):**
Modification of Valve opening strategy, Combustion chamber design, Injection System, Turbocharger

<table>
<thead>
<tr>
<th>NO$_x$</th>
<th>SFOC</th>
<th>Invest</th>
</tr>
</thead>
<tbody>
<tr>
<td>~ 20%</td>
<td></td>
<td>medium</td>
</tr>
</tbody>
</table>

**Power Management (MAN EcoLoad-System):**
Example: 1 engine @75% load instead of 3 engines @25% load

<table>
<thead>
<tr>
<th>NO$_x$</th>
<th>SFOC</th>
<th>Invest</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 30%</td>
<td></td>
<td>low</td>
</tr>
</tbody>
</table>

**Water in Fuel Emulsion:**

<table>
<thead>
<tr>
<th>NO$_x$</th>
<th>SFOC</th>
<th>Invest</th>
</tr>
</thead>
<tbody>
<tr>
<td>~ 20%</td>
<td></td>
<td>low</td>
</tr>
</tbody>
</table>

**Variable Injection Timing:**
Nox Reduction by individual injection timing depending on engine load and environmental conditions

<table>
<thead>
<tr>
<th>NO$_x$</th>
<th>SFOC</th>
<th>Invest</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20%</td>
<td></td>
<td>low</td>
</tr>
</tbody>
</table>
SCR Upgrade
Selective Catalytic Reduction - Compliance with lowest NOx Limits

Description:

- SCR catalysts technology is an exhaust gas after treatment for NO\textsubscript{x} emission reduction
- SCR technology achieves NO\textsubscript{x} reduction rates of up to 90%
- SCR involves urea injection as reducing agent
- Chemical reaction of NO\textsubscript{x} in SCR to N\textsubscript{2} and H\textsubscript{2}O
- MAN SCR technology is specifically developed for MAN engines
- MAN PrimeServ offers to upgrade MAN engines with SCR

Benefits / Targets:

- MAN SCRs are adapted to our medium speed engine portfolio
- Integration of SCR control system into engine control
- Exhaust gas temperature control for optimum fuel consumption
- Closed loop NO\textsubscript{x} control for lowest urea consumption
- MAN SCR technology offers significantly better performance and longer life cycle compared to third party supplies
- MAN SCR system portfolio is available in fourteen different sizes

SCR system
Dual-Fuel / Gas Upgrade
Converting Diesel engines to run on gaseous fuels

**Description:**
- Natural gas becomes more and more attractive as an alternative fuel
- MAN PrimeServ offers to convert several MAN engine types to dual-fuel or gas engines
- Conversion project covers
  - Engine conversion
  - Plant systems conversion
  - Commissioning procedures

**Benefits / Targets:**
- Economical advantages: Reduction of operation costs
- Environmental advantages: Improvement of emission profile
- Gas fueled engines have no sulfur, up to 90% less NO\textsubscript{x} and 20% less CO\textsubscript{2} emissions
- Dual-Fuel engines offer the ability to run either on gaseous or liquid fuels: Switching between fuels for full flexibility

![Chart showing NO\textsubscript{x}, SO\textsubscript{x}, and CO\textsubscript{2} emissions comparison between Diesel (HFO) and Gas operation]

Conversion to Dual-Fuel / Gas engines

Efficiency & Environment
NO\textsubscript{x}-Reduction Technologies 4-Stroke

Comparison of Reduction Potentials vs. Invest Cost vs. Operational cost
All data provided in this document is non-binding. This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.
Application of LNG Fueled Ship in China: Current State, Challenges and Prospect

Speaker: Prof. Peng Chuansheng

China Waterborne Transport Research Institute
Implementation Plan of Energy Conservation and Emissions Reduction in Waterborne Transport Industry During the National 12th 5-Year Plan set up a pilot project for LNG fueled inland river ships.

① Shale gas mining technology progress will result that more and more natural gas available in the market

② As a clean energy, natural gas share of total energy consumption in China will be increased with Chinese energy structure adjustment
<table>
<thead>
<tr>
<th>Normative document</th>
<th>Standard</th>
<th>Regulation</th>
<th>Law</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Work program</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Action plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pilot project</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Guiding opinion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Development plan</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Administrative Enforcement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Economic incentive</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All red font mark methods can often be used by MOT to guide industry development.
Set goals for application of LNG fueled ship in China:

① LNG share of total inland river ship energy consumption is 2% in 2015

② LNG share of total inland river ship energy consumption is 10%, and ocean going vessels begin to use LNG as fuel in 2020
1 Background

2 Current state

3 Challenges

3 Prospect
Natural Gas Share of Total Energy Consumption in China (2017: 7.2%)
<table>
<thead>
<tr>
<th>LNG Fueled or Bi-Fuel Ships</th>
<th>LNG Fueled</th>
<th>Bi-Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>175</td>
<td></td>
</tr>
<tr>
<td>285</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Except 2 tugs, all are inland river ships.

<table>
<thead>
<tr>
<th>LNG Fueled or Bi-Fuel Ships</th>
<th>Retrofit</th>
<th>New building</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original Engine</td>
<td>Update Engine</td>
</tr>
<tr>
<td></td>
<td>46</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Retrofit ships use original oil engine to use LNG.
LNG Fueled or Bi-Fuel Ships in China by October 2018
In fact, about 120 ships use LNG as fuel currently.

According to goals set by MOT, more than 3000 ships should use LNG as fuel in 2015, and more than 15000 ships will use LNG as fuel in 2020.

The MOT did not realize the goal in 2015 and will not realize the goal in 2020.
## LNG Filling Stations for LNG Fueled Ship

<table>
<thead>
<tr>
<th></th>
<th>Planned</th>
<th>Constructed</th>
<th>Licensed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Many</td>
<td>18</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: It is very difficult to get a license from local governments, and it takes more than 100 approval formalities.
1 Background
2 Current state
3 Challenges
3 Prospect
The local governments are responsible for production safety, they are sensitive for dangerous cargo such as LNG, and have some unreasonable requirements for application of LNG fueled ships. For examples,

① LNG Filling Stations for LNG Fueled Ship

② Ships with LNG are banned to go through Three Gorge Shiplocks
Even for the clean energy, whether it is good for reducing air emission depends on how to use it.

Ship owner always worry about high price and lack of supply, they like to build bi-fueled ship and requires the engine can use LNG and oil independently. It is difficult to get good emission control performance for one engine and two different fuels.

The performance of current bi-fuel engine manufactured in China does not meet the requirements of clean way to use LNG.
The LNG-fueled ship need more space for storing fuel. If it still need to use SCR to reduce air emission, most of ship owners will think LNG is not a good option comparing with oil as fuel of cargo ship.
Lack of LNG supply infrastructures is one of worries of ship owner to build LNG-fueled ship potentially, otherwise, LNG storage in the ship will occupy too much space for cargo originally. For example,

CMA-CGM 9 22000TEU ships building in Chinese shipyards are diesel-LNG dual fuel type. LNG storage space is 18600 m³, because it must carry enough LNG used by the whole Asia-Europe return trip.
The price of LNG in China is seasonal change, it is often increased in the winter because some LNG must be used for residents’ heating.

LNG price is increased while oil price is decreased in China in present.

Comparing with oil, there is no stable price and supply system for LNG in China in present. It is another one of worries of ship owner to build LNG-fueled ship potentially. But for fuel price, any intervention measures are temporary and can not be sustainable.
Lack of training of crews for using LNG in ships safely.
For ship owner, the best option is “LNG-Ready” for new building ocean going vessels in present. For inland river or coastal ship, if all conditions concerned are OK, ship owner get more profit from LNG-fueled ships than oil fueled ships or bi-fuel ships, they will use LNG-fueled ships instead of them naturally.

For government, it is necessary to adjust policies, regulations and standards suitable for LNG-fueled ships, guarantee that LNG can be transport by inland waterway safety in China, and support good performance engine technology development. It is not necessary to set goal for application of LNG-fueled ships.
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Beijing, 100088
Tel: 86-10-65290315
Mobile: 13681524188
Email: pengcs@wti.ac.cn

THANKS
Fleet Modernization

Chevron Shipping Company
Mission
Chevron Shipping Company is the Marine Center of Expertise for Chevron. We provide safe, reliable and cost-competitive marine transportation, manage marine risk, and add value to the enterprise through our operations, technical, project, and commercial support to our customers.
Chevron Shipping Company Summary
by the numbers

- 1 billion barrels transported annually
- 123 years since first ship launched
- 14 years zero cargo spills
- $2 billion annual freight spend
- 2,000 employees from 20 countries
- 29 operated vessels

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Technical, construction, operational, commercial and legal support for:

- Ongoing Chevron operations (including joint ventures and affiliates)
- New major capital projects
- New business development
Chevron Shipping Company
Global tanker market background

Tanker industry
• Composed of many sectors, each with its own characteristics – Chevron is involved in almost all
• Fragmented group with hundreds of ship owners controlling assets worth ~$200B
• Financing provided by bank lending, private equity and some MLP; tax advantaged

~5,800 Ships
~700 Owners

Market characteristics
• Charterers include IOCs, NOCs, traders, refiners – Chevron is the 5th largest tanker charterer in the world
• Rates driven by supply / demand fundamentals, difficult to predict with long market cycles driven by major economic / geopolitical events
• Short-term market volatility driven by weather, price arbs, vessel positions, etc.

Long-term cycles driven by global events

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Chevron Shipping Company
Operated Fleet

Operated Fleet
9 Very Large Crude Carriers
3 Aframax Tankers
3 Lightering/Shuttle Ships
10 Liquefied Natural Gas Carriers
4 U.S. Flag Tankers

Operated Fleet provides
• A core component of Chevron’s marine transportation requirements
• World-class safety and environmental performance
• Transferable experience

Size and scale
Operated Fleet Upgrades Through Modernization

**VLCC**
- Scrubber (85% SOx reduction)
- Tier III engine (75% NOx reduction)
- Ballast water treatment system
- Fuel efficient design (20% lower fuel consumption)

**Aframax**
- Scrubber (85% SOx reduction)
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- Fuel efficient design (20% lower fuel consumption)

**Suezmax**
- Scrubber (85% SOx reduction)
- Tier III engine (75% NOx reduction)
- Ballast water treatment system (BWTS)
- Fuel efficient design (30% fuel savings)
Fleet Upgrade Highlights

New hull design
2%+ efficiency increase in calm water
10%+ efficiency increase in sea state 6
due to sharper bow with less resistance
from wave reflection

Propulsive Energy Saving Devices
Wake Equalizing duct combined with a
rudder bulb give ~4% efficiency increase

Main Engine Fuel Consumption
Current 12yrs old VLCC: 113 mt/day vs
New VLCCs: 82mt/day

Sulfur Scrubber
Meets or exceeds worldwide sulfur
emissions standards
NOx Reduction Technology
Main Engine: Exhaust Gas Recirculation
Auxiliary Generators: Selective Catalytic Reduction

SW Cooling System and E/R Ventilation System Energy Saving Device Variable
Frequency Drive controlled motors match motor speed with cooling and ventilation demands instead of running 100% power all the time

Variable Frequency Drives on Ballast Pump Motors
Allows for control of ballast rate by reducing pump output instead of throttling discharge valve on pump that is always running 100% power

Waste Heat Recovery Device on 2 Auxiliary generators
Our first ships to recover energy (in the form of steam) from generator exhaust. 600kg/hr of steam made for heating purposes with no additional fuel burned. (Always standard on main engines.)
Commercial Operations
Managing Chevron’s marine transportation requirements

One of the largest tanker charterers in the world

- Transports crude, products, LNG, LPG, and chemicals for Chevron operating companies and affiliates
- Charters quality third-party tonnage to supplement the operated fleet
- Worldwide commercial staff manages more than 2,000 voyages per year
- Handles voyage operations, demurrage and other claims management
- Co-located with key Chevron partners in five offices around the world

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• VLGC – 2 Ships, 5 year agreement

Scrubber (85% SOx reduction)
Tier III engine (75% NOx reduction)
Ballast water treatment system (BWTS)
“Green” fuel efficient design
At Berth
Cold Ironing, Capture and Control
GHG
IMO Strategy
40% reduction in carbon intensity by 2030, 70% by 2050
Short Term
Modifications, slower speeds/on time arrivals
Longer Term
Alternative Fuels
Biofuels, wind, battery, ammonia, hydrogen, nuclear

Today's vessels will reach 2030. It's time to design ships that meet post 2030 requirements ready for 2050.

Carbon neutral, Zero Carbon
Carbon trading, carbon tax