SCAQMD Air Quality Challenges and Critical Role of OGV Incentive Programs

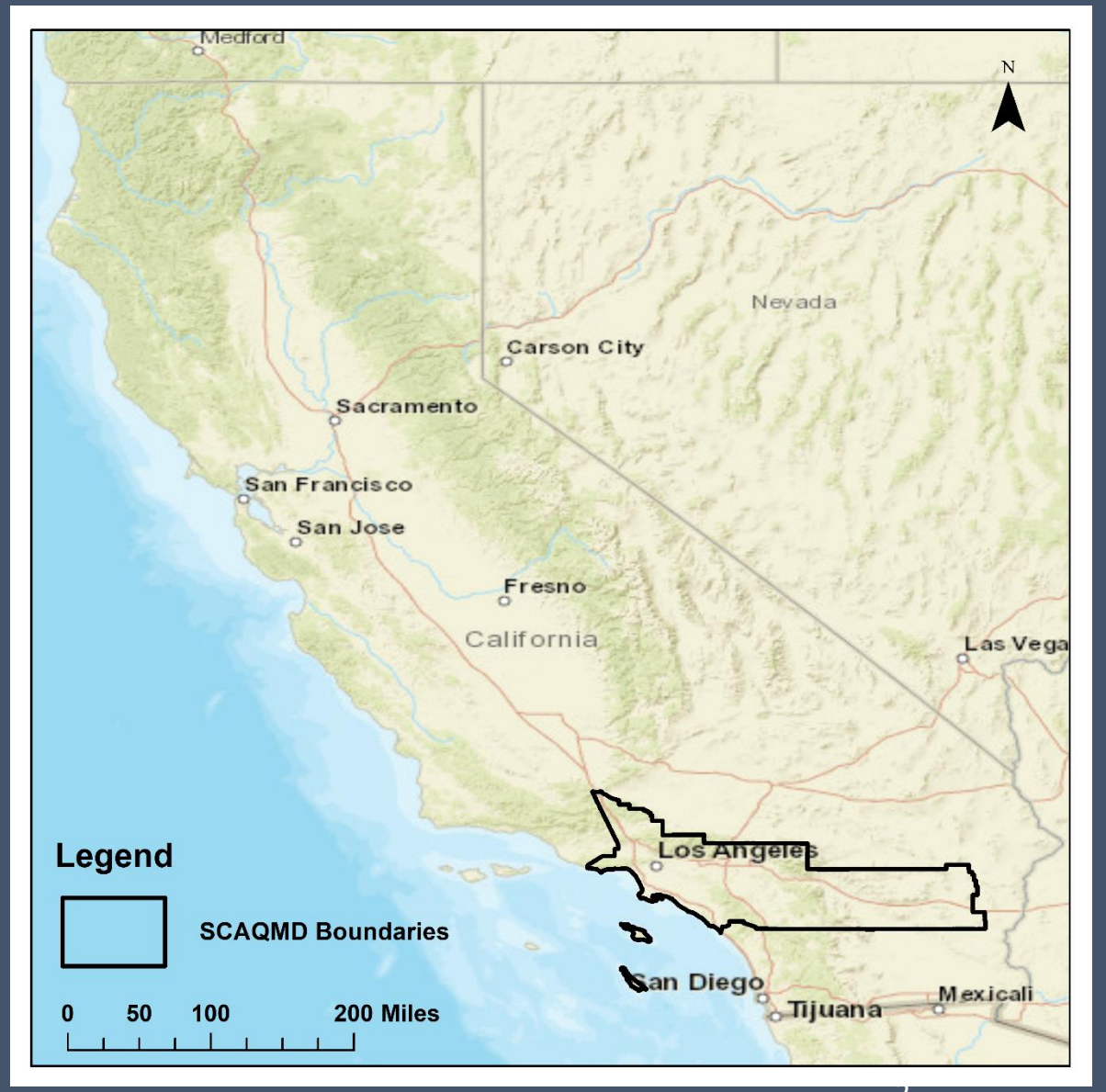
Philip Fine, Deputy Executive Officer

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 km^2
  - 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

Los Angeles c. 1950

Los Angeles 2017

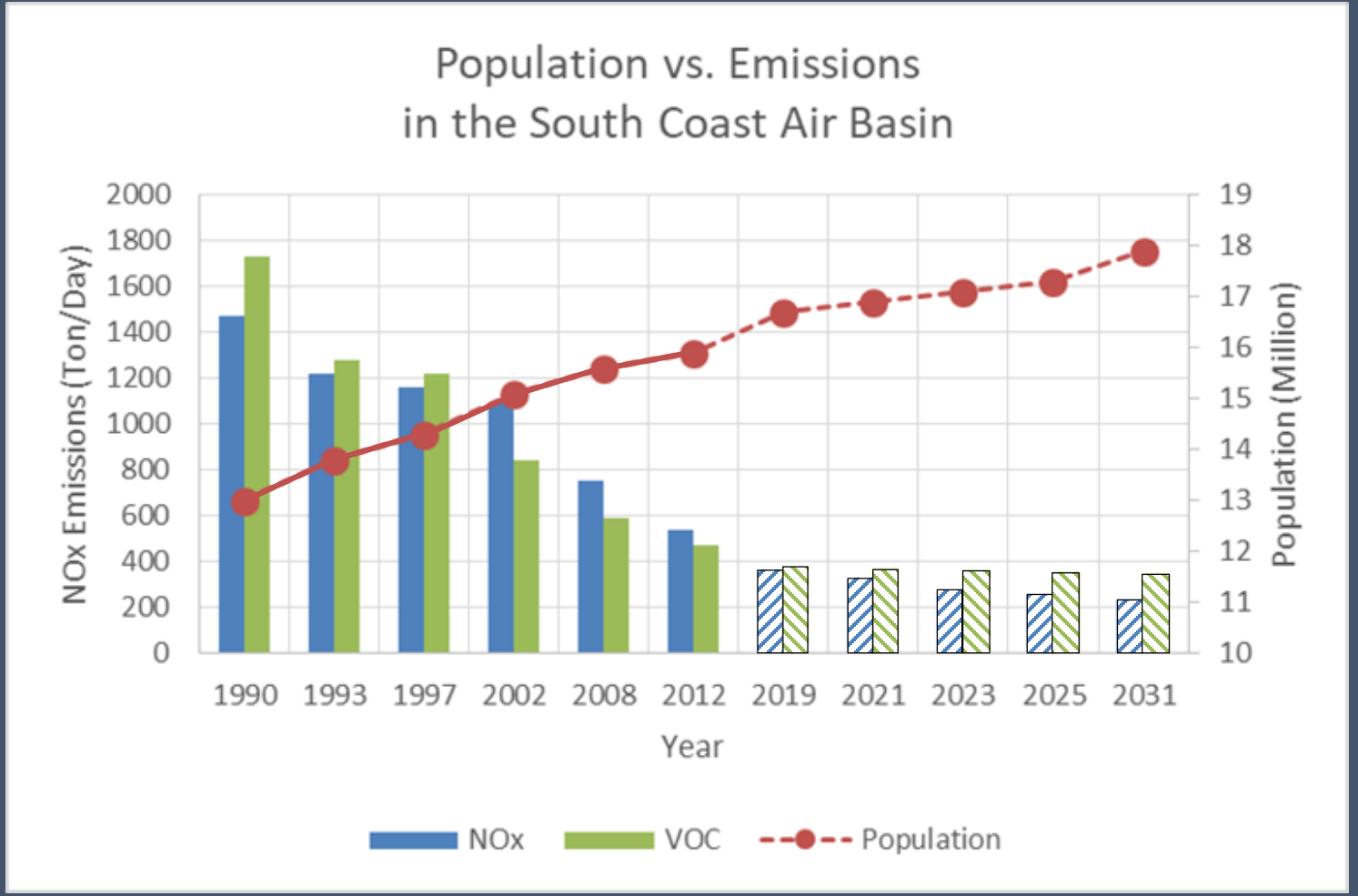
We've made significant progress, but still suffer from poor air quality

- 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

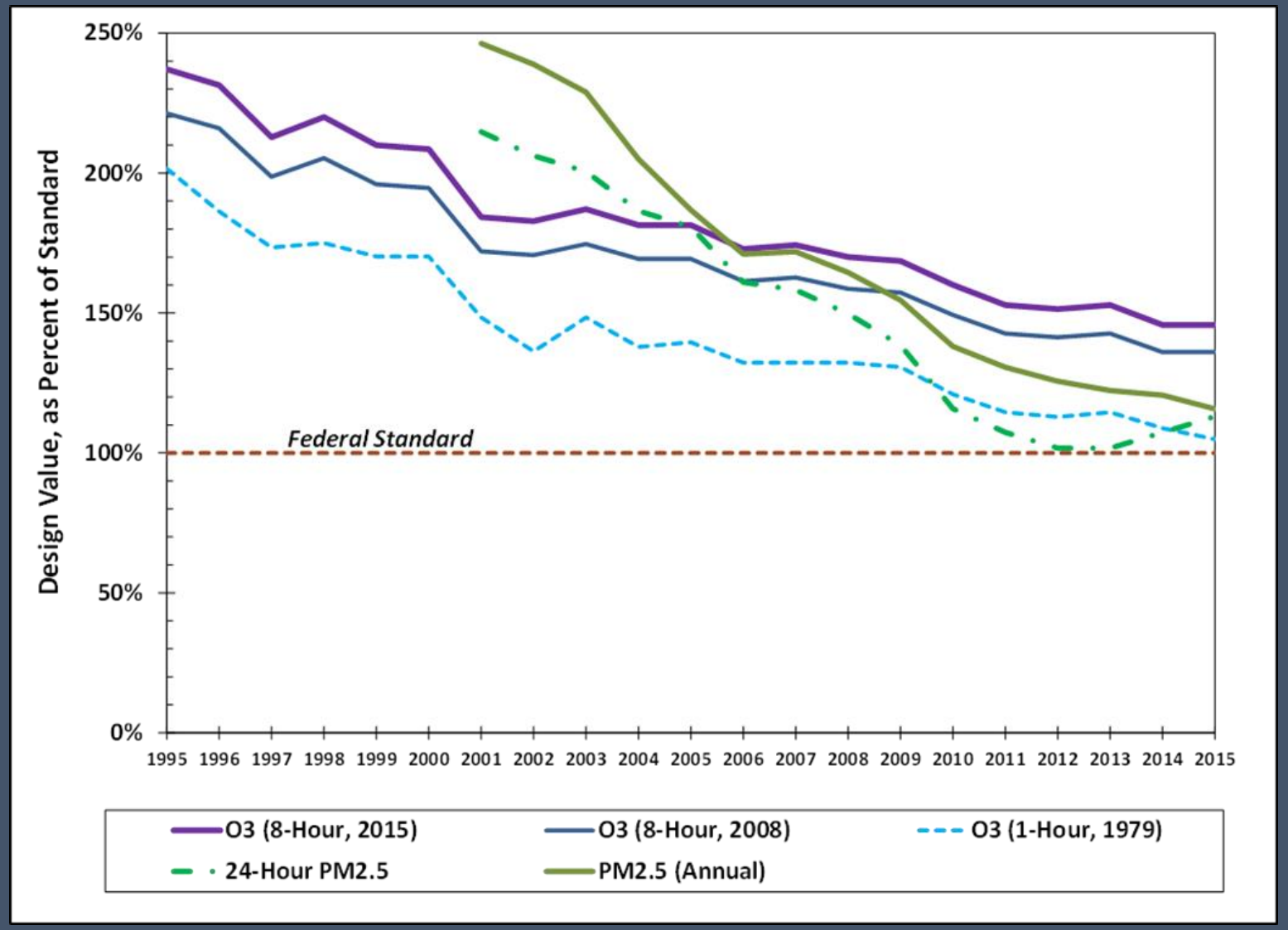
Significant Emissions Reductions Achieved Despite Population Growth



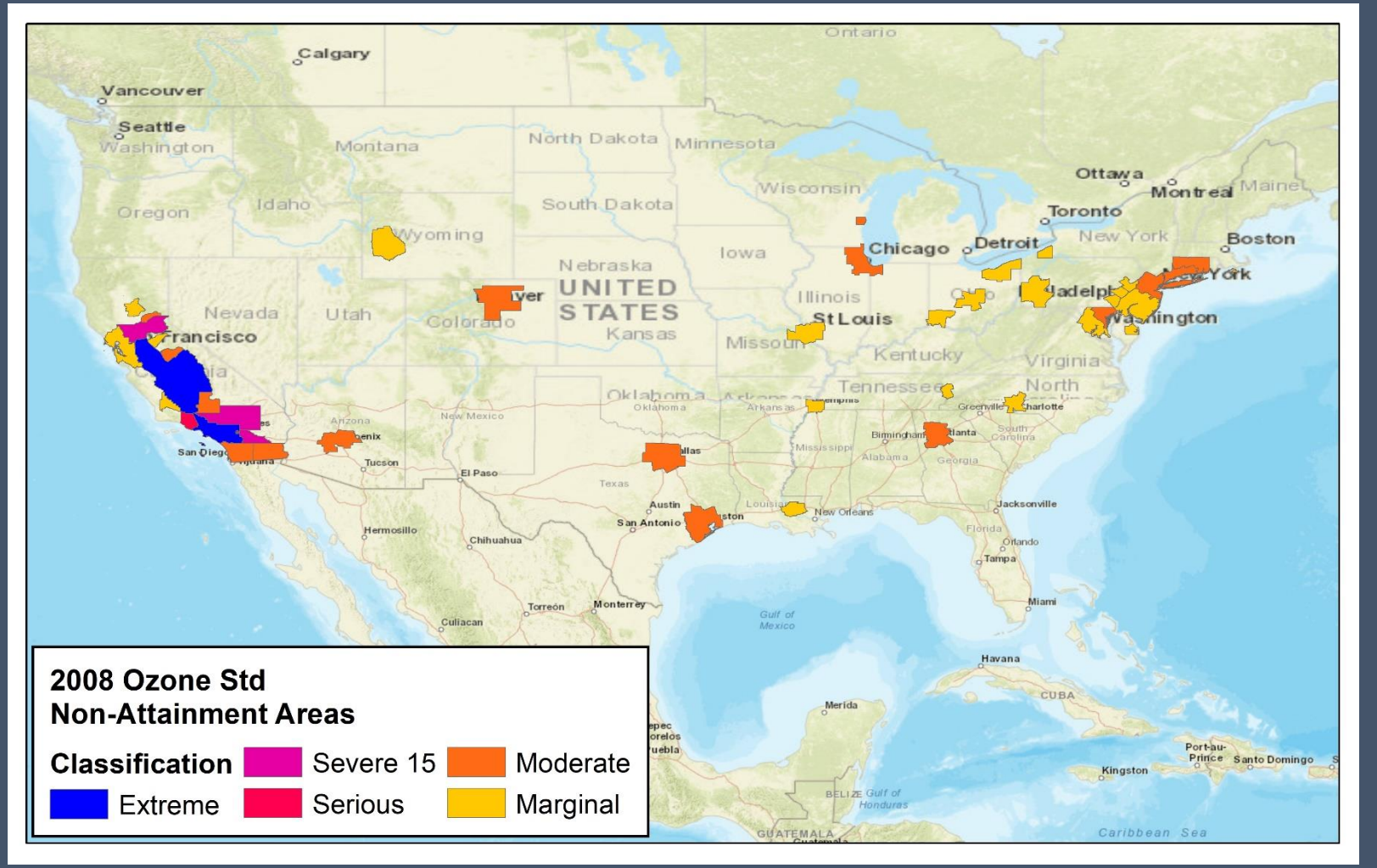
Upcoming Deadlines to Attain National Standards

Standard	Concentration	Classification	Attainment Year
2008 8-hour Ozone	75 ppb	Extreme	2031
2012 Annual PM2.5	12 ug/m3	Moderate/Serious	2021/2025
2006 24-hour PM2.5	35 ug/m3	Serious	2019
1997 8-hour Ozone	80 ppb	Extreme	2023
1979 1-hour Ozone	120 ppb	Extreme	2022

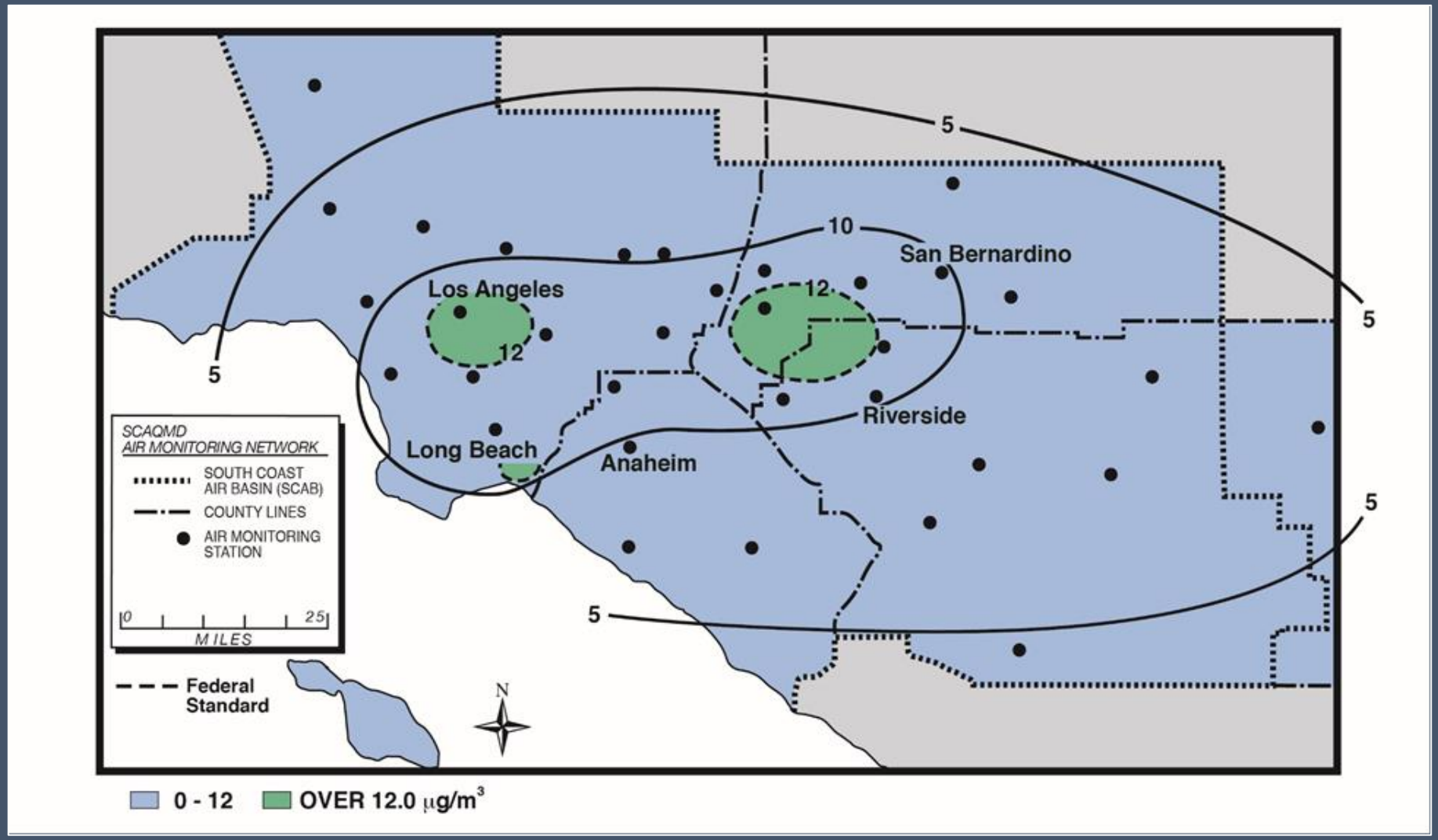
Ozone and $PM_{2.5}$ Air Quality Trends in the South Coast Air Basin



2008 Ozone Standard Non-Attainment Areas



Annual Average PM2.5 in South Coast Air Basin



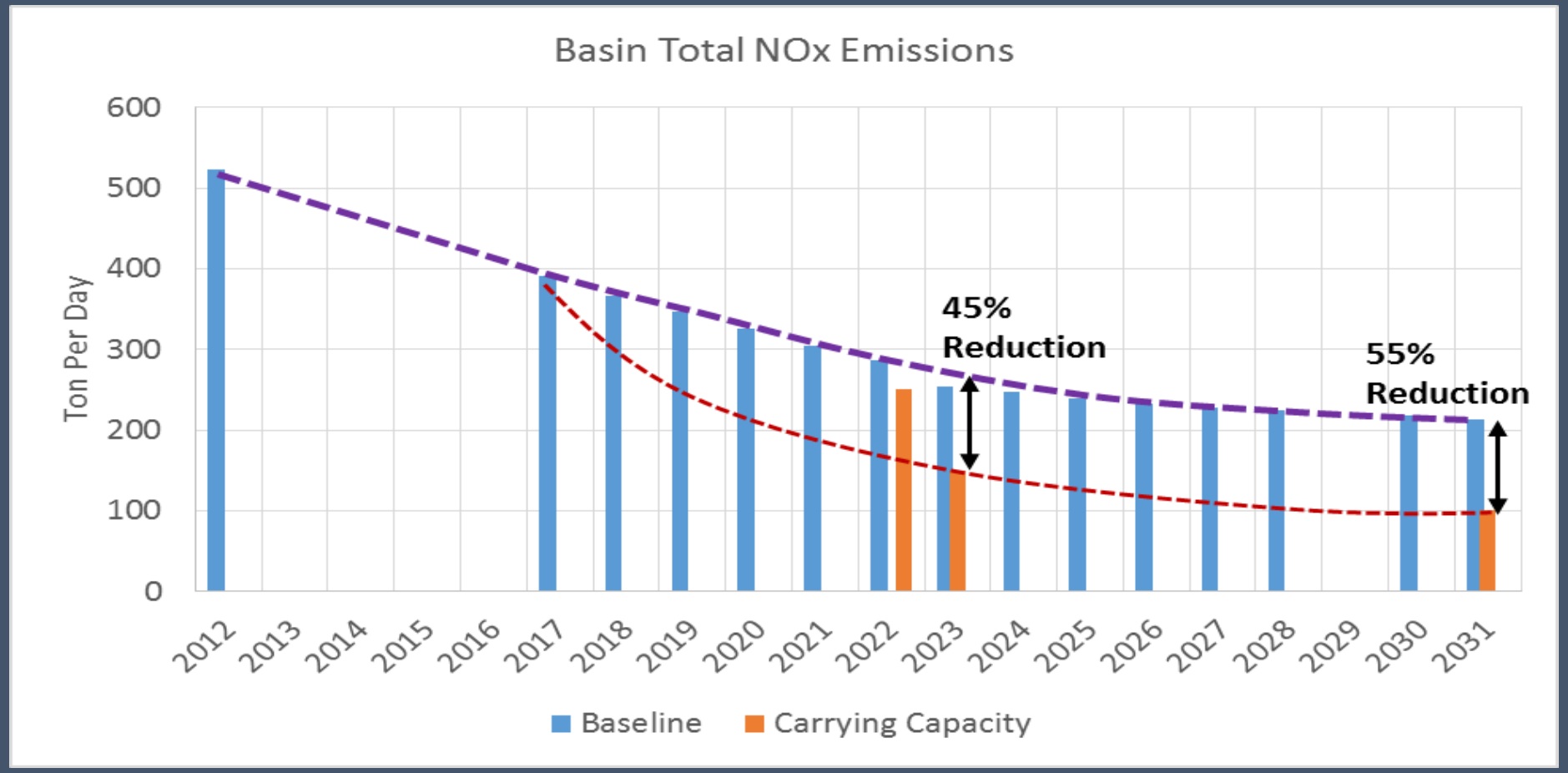
(2015 Data)

2016 Air Quality Management Plan

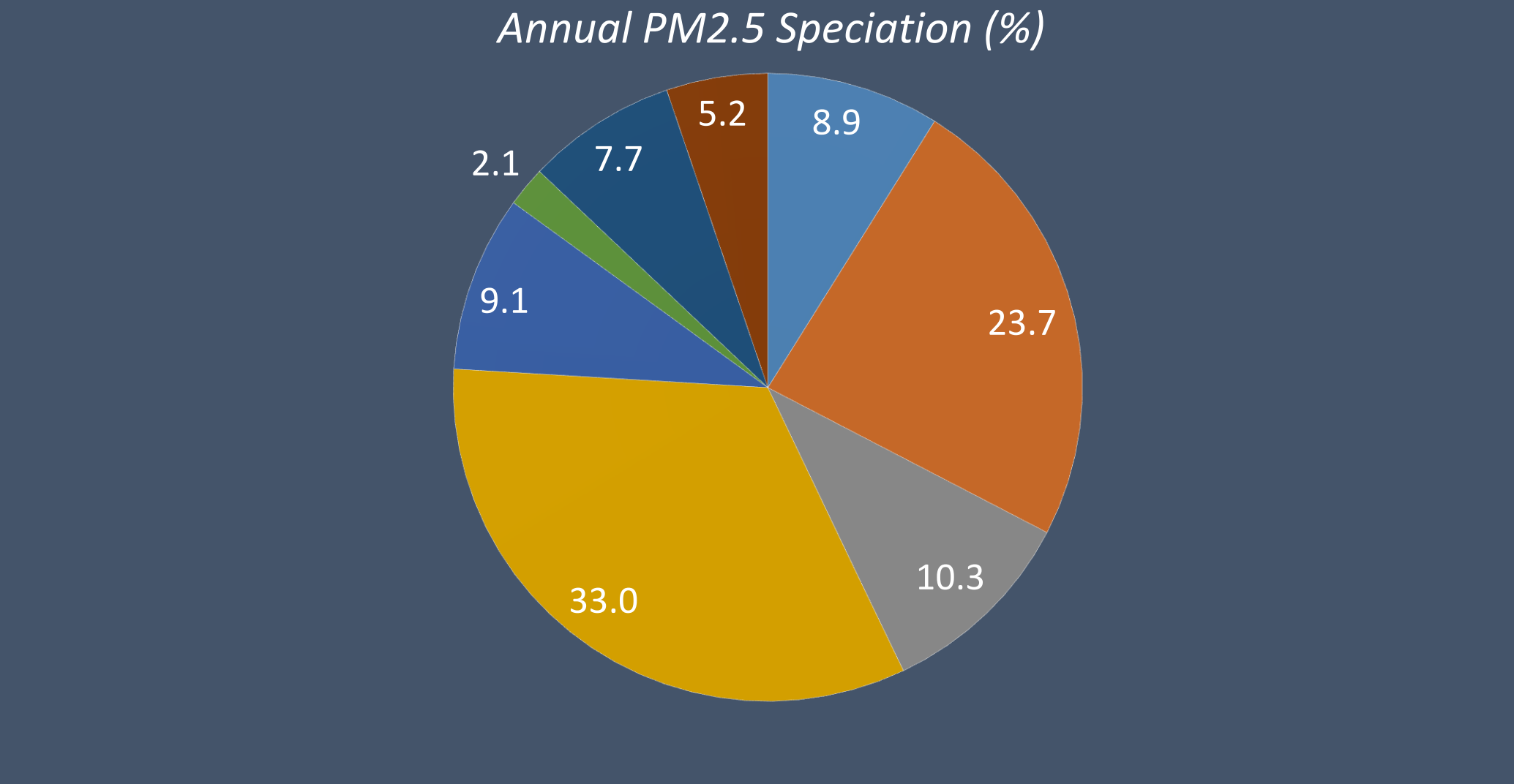
- Blueprint for how to meet and maintain air quality standards
- The 2016 Plan is the SCAQMD's 11th plan
- Implementing the 2016 Plan will result in:
  - An average of 1,600 premature deaths avoided per year
  - ~2,500 fewer asthma-related emergency room visits per year
  - ~700 fewer hospital admissions 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

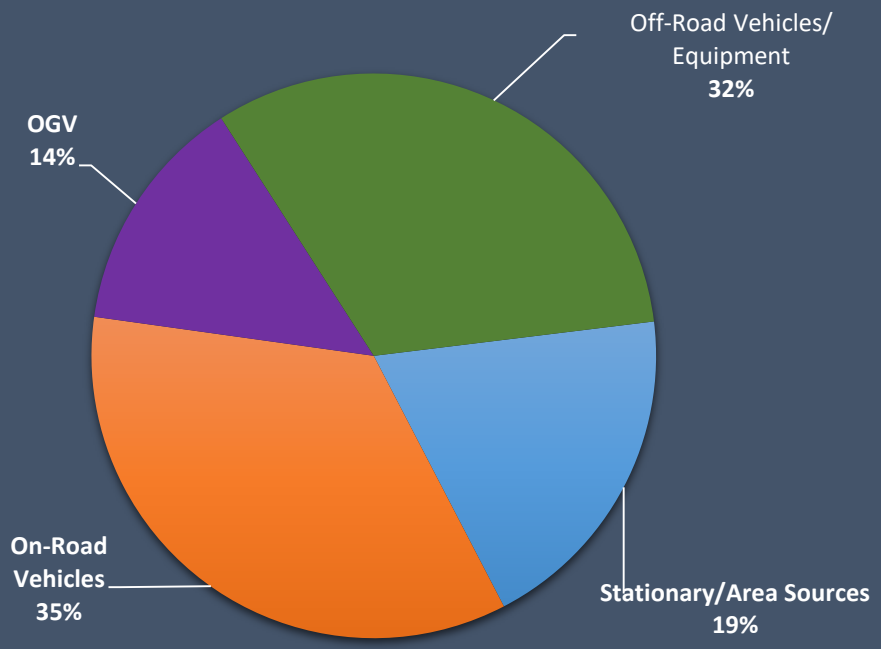


NOx Also Contributes to PM2.5



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

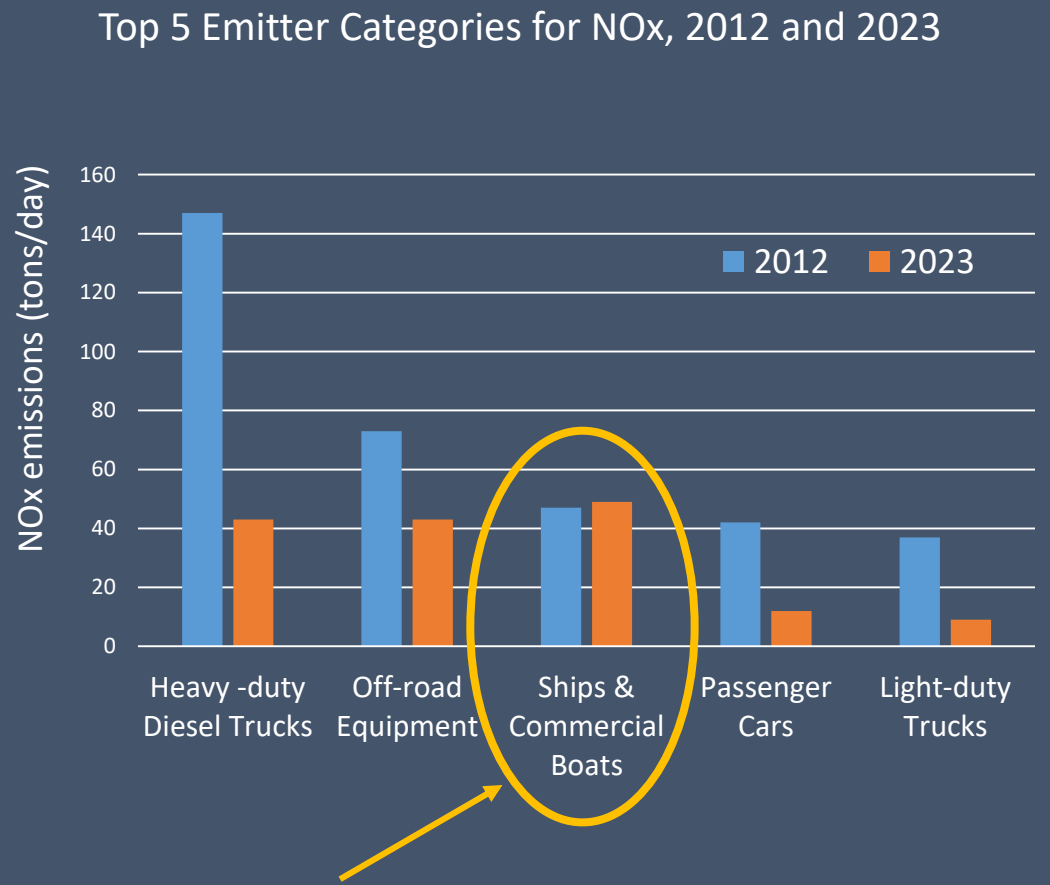
Successful History of Mobile Source Incentive Programs

- 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 3rd 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

Rating system	Categories	Stakeholders/Users
Environmental Ship Index (ESI)	NOx, SOx, PM, GHG	The ESI provides a reduction in port dues or tonnage charges for registered ocean-going vessels (OGVs) with below-average SOx, NOx, and/or CO_2 emissions, compared to the current emission standards of the IMO. http://www.environmentalshipindex.org Registered OGVs can received 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: http://www.environmentalshipindex.org/Public/PortIPs
Clean Shipping Index (CSI)	NOx, SOx, PM, GHG, chemicals, water/waste	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. https://cleanshippingindex.com
Green Award	NOx, SOX, PM, VOC, GHG, water ballast, anti-fouling, ship breaking, navigation in sensitive areas, waste, safety	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. http://www.greenaward.org/greenaward/22-list-of-incentive-providers.html#agreena48 Green Award certification is open to oil and chemical tankers, dry bulk, LNG, LPG, and container carriers, and most inland navigation vessels. https://www.greenaward.org
RightShip	GHG	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. www.shippingefficiency.org
Clean Cargo Working Group (CCWG)	GHG	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. https://www.clean-cargo.org
Green Marine (North America only)	NOx, SOx, PM, GHG, aquatic invasive species, oily water, waste, underwater noise	Green Marine is an environmental certification program for the North American marine industry. Participants include ship owners, ports, Seaway corporations, terminals and shipyards. https://www.green-marine.org

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
  - 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 AIR RESOURCES BOARD

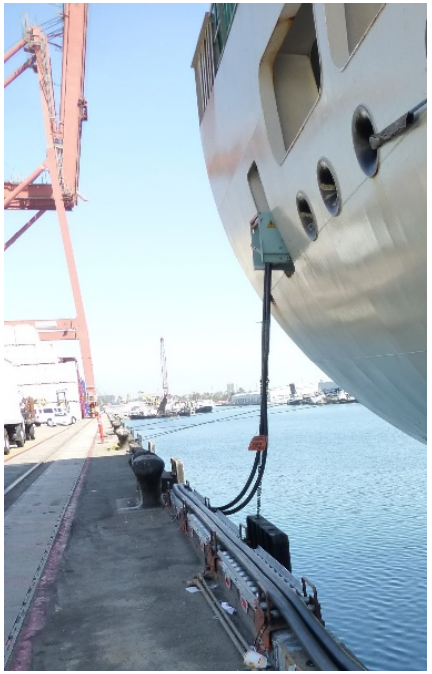
California OGV Regulations & Incentive Programs

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

Trucks	Ships	Locomotives	Equipment	Harbor Craft
• Idling and smoke limits • International trucks • Drayage trucks • All on-road trucks • GHG limits for tractor-trailers	• Fuel standards • At-berth reductions • Ship incineration ban	• Fuel standards • Fleet emission limits for South Coast • Diesel soot reduction at rail yards	• Fuel standards • Port & rail equipment • Transport refrigerators	• Fuel standards • Aftertreat-ment Controls • Repower

----------Incentives for cleaner equipment----------

CA Freight Strategies Are Effective

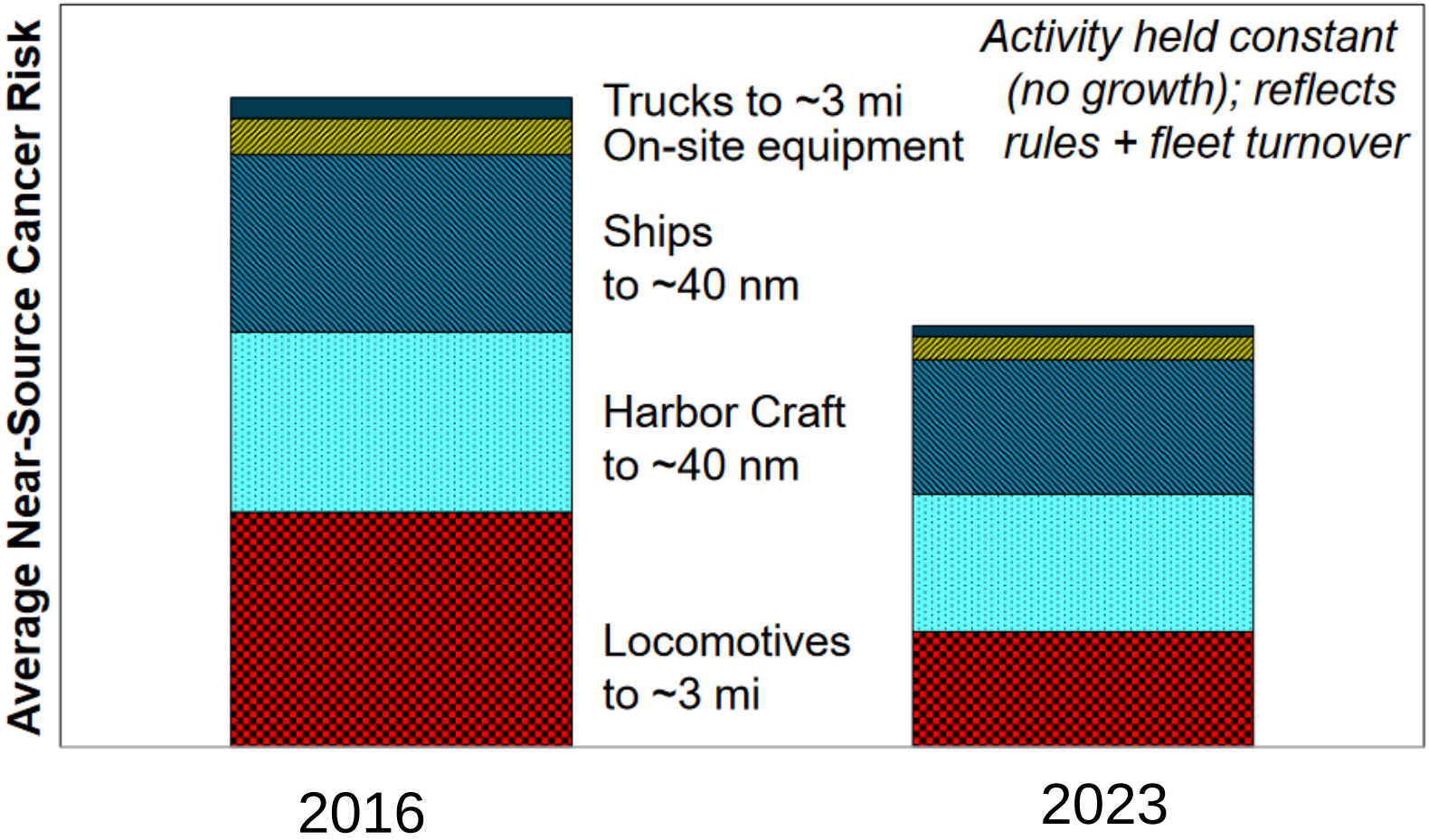
Change in cancer risk since 2005:

80 to 85% reduction
at largest seaports





Seaport-Contribution to Near-Source Cancer Risk



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
- Step down in sulfur levels: 2009, 2012, 2014
- 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

Container

Refrigerated cargo

Cruise

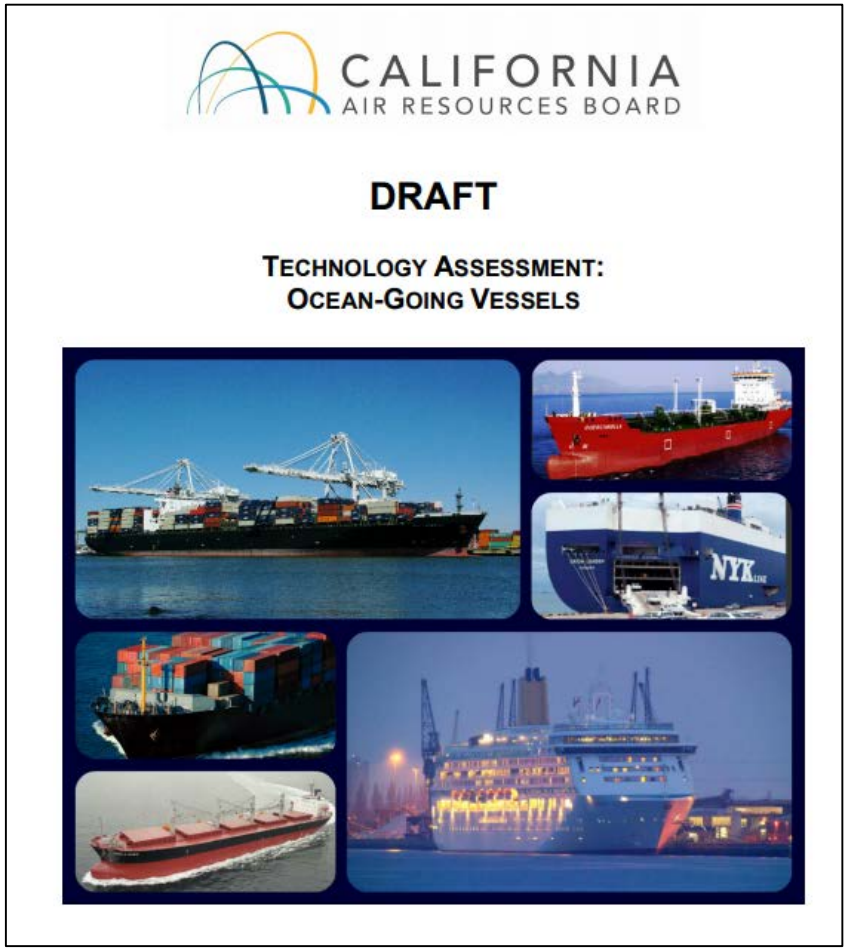
At-Berth Regulation Achievements

- 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



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

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

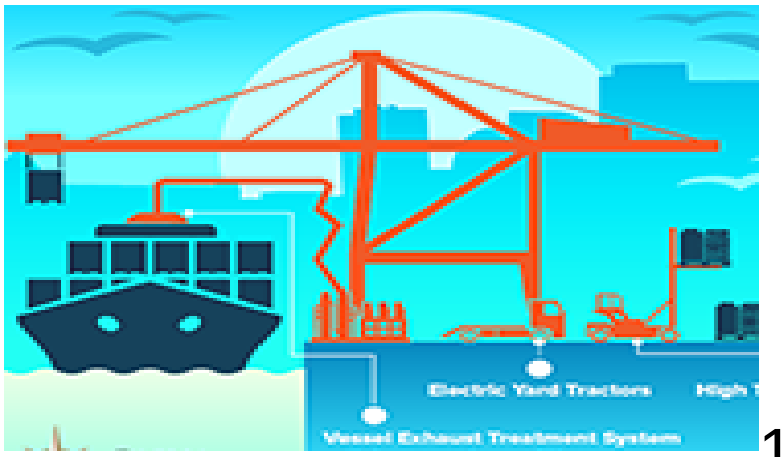
https://www.arb.ca.gov/ports/marinevess/ogv/ogvreports.htm

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

2017 Air Emissions Reductions

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

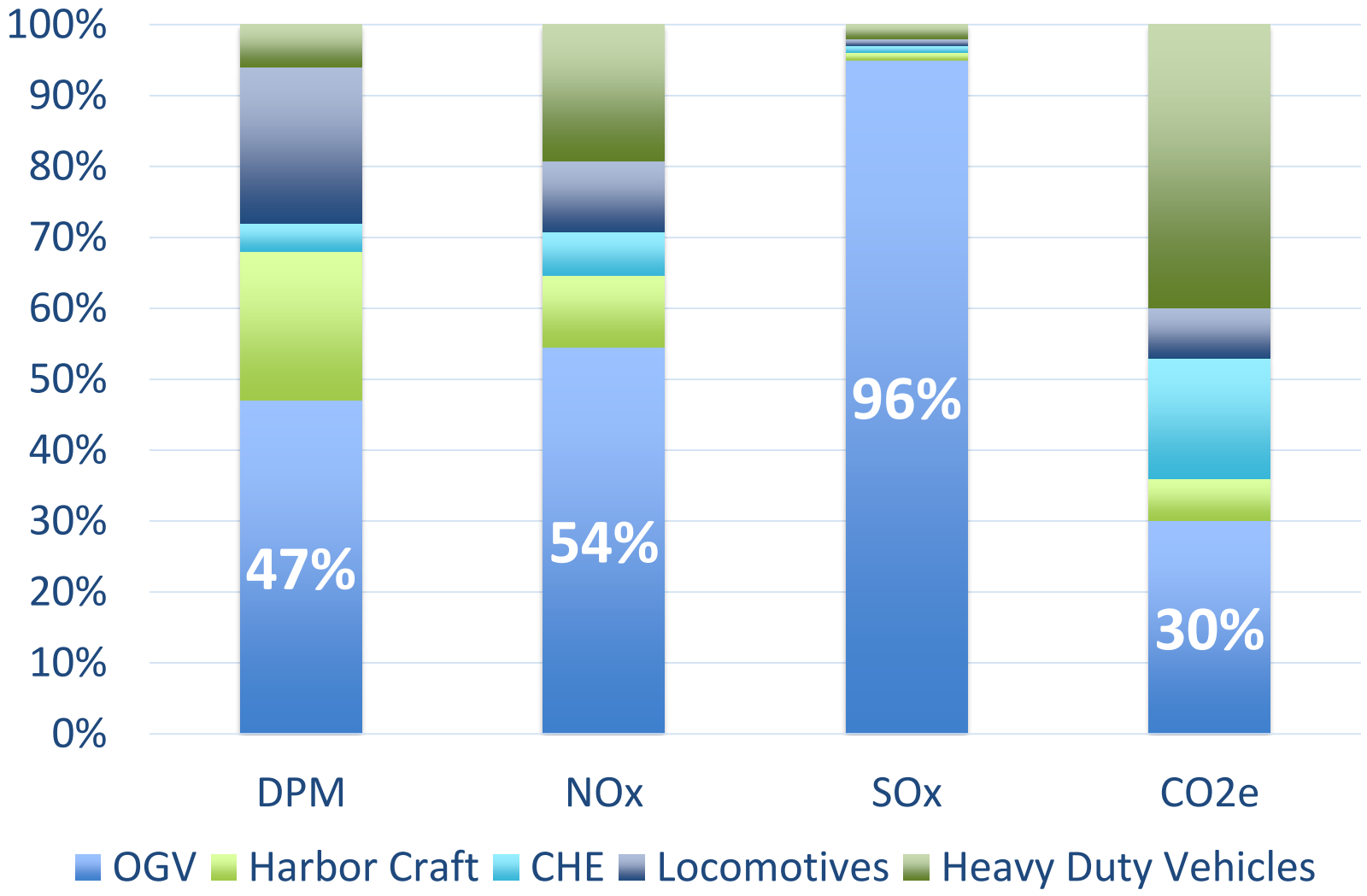
15%

Up **19%**

TEUs

*Compared to 2005 Levels
**GHG emissions (CO_2e) are reported in metric tons (MT) per year; all other pollutants are shown in tons per year.

Emissions Today

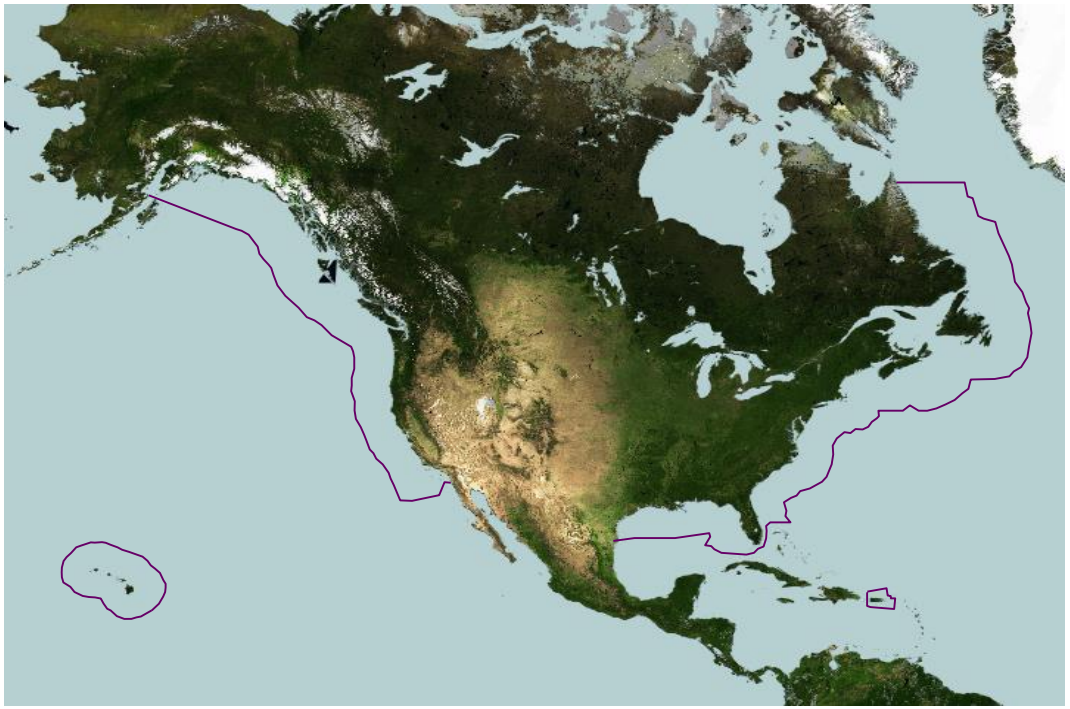


Strategies for Ships

- 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

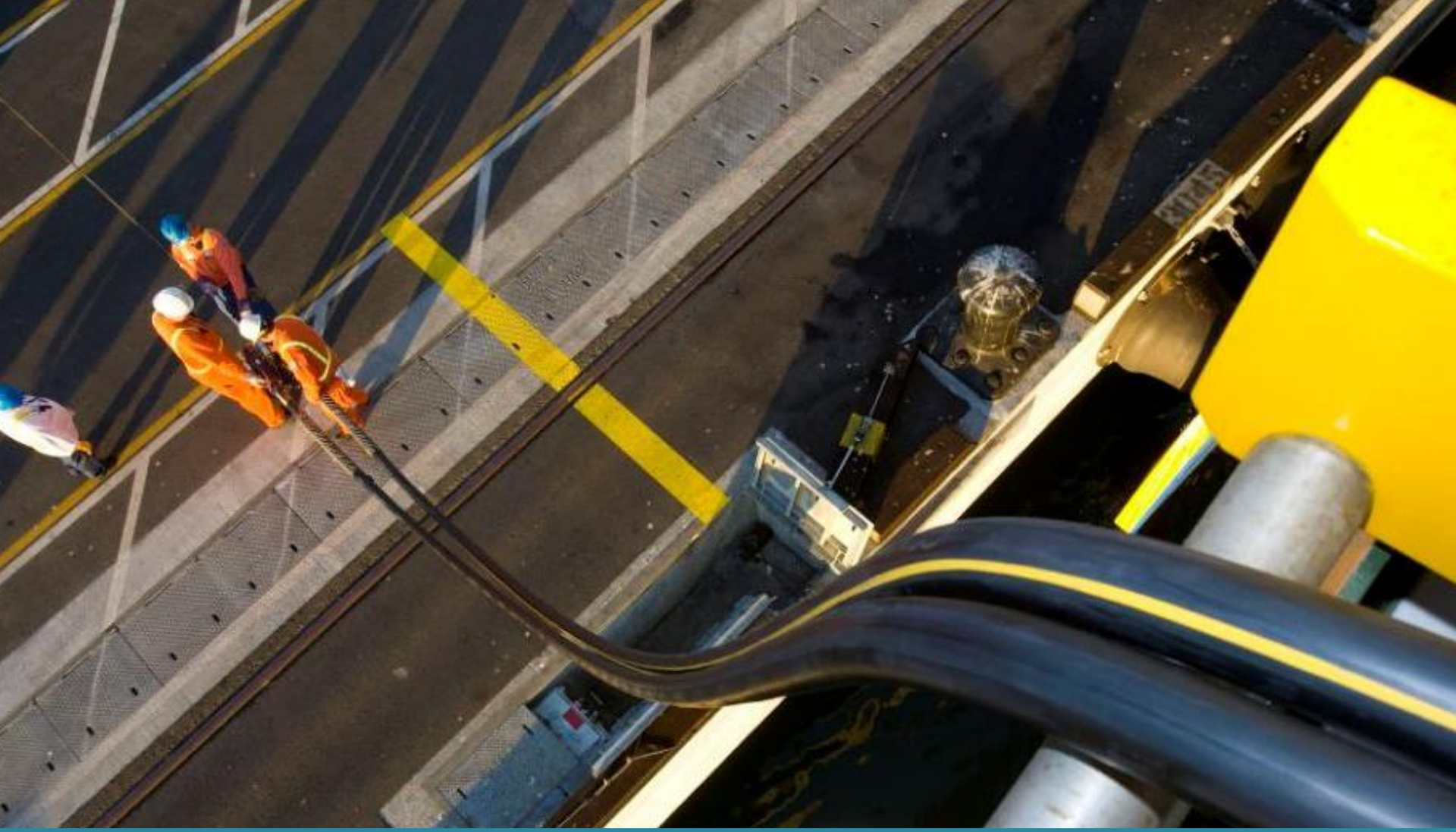


Vessel Speed Reduction

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

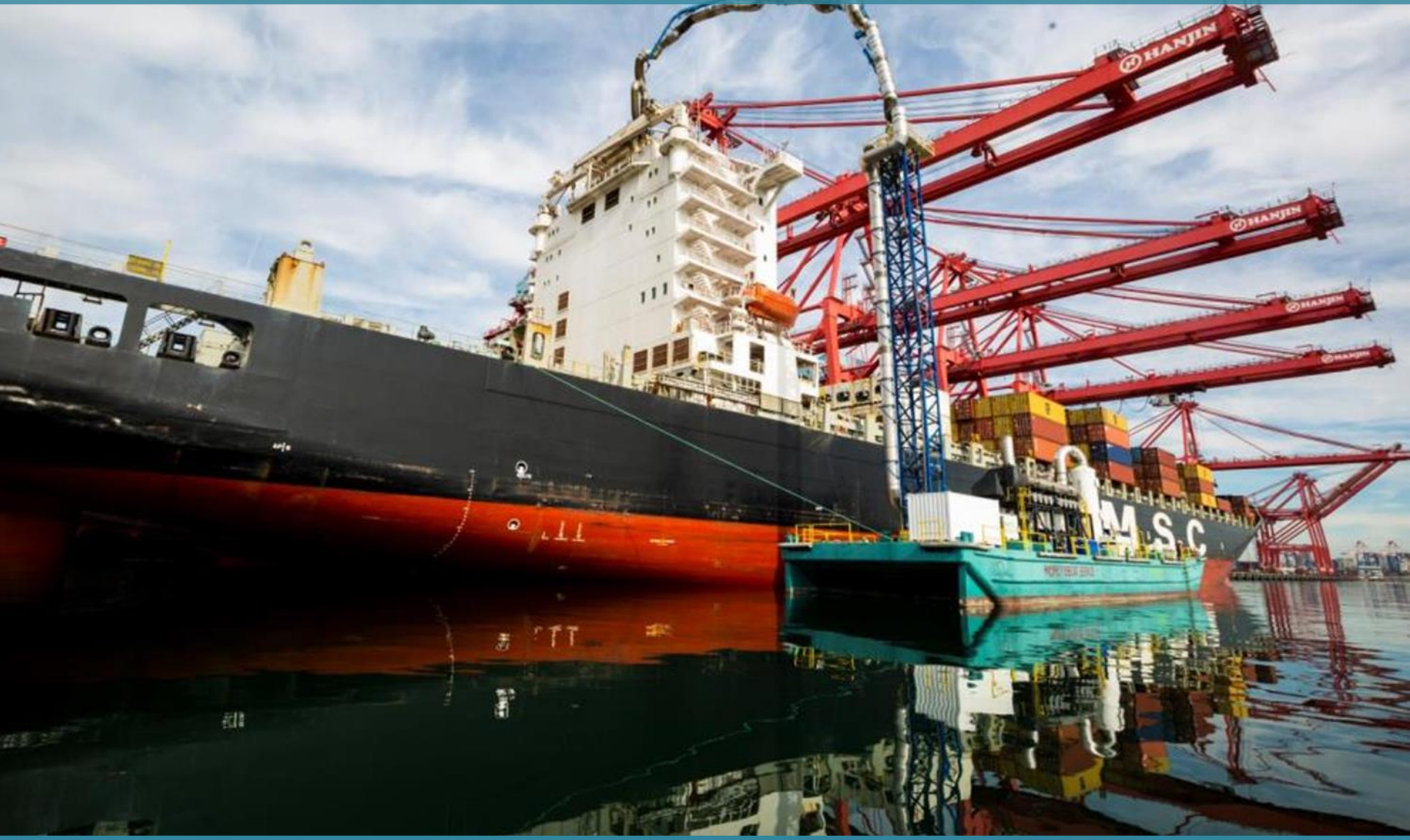


Shore Power

Ships have been plugging in since 2008

Equivalent of taking 42,000 cars off the road each day

Shore Power Alternatives

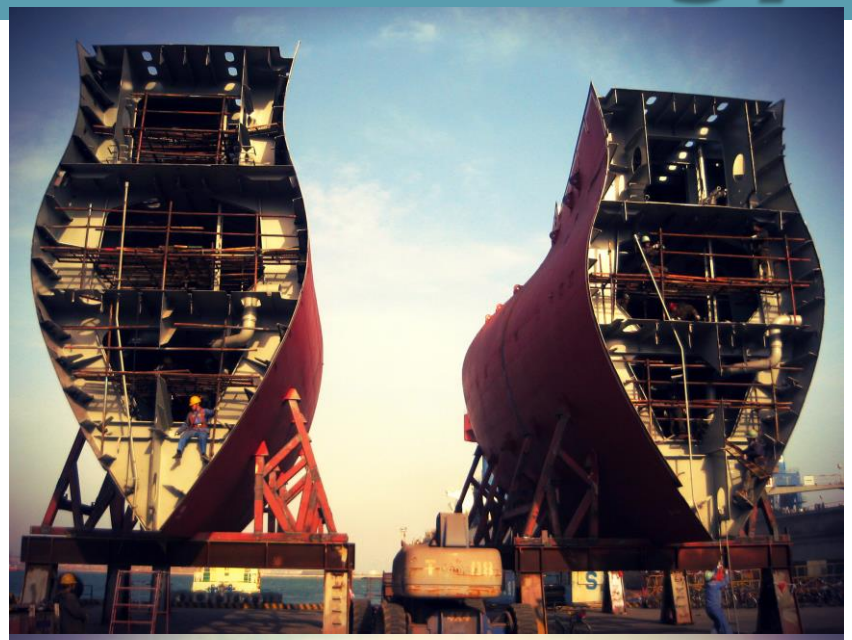


Technology Advancement

Technology Advancement

- Maersk Vessel Efficiency Improvements
  - Modify Bulbous Bows
  - Improve Efficiency Propellers
  - Raise Bridge to Increase Capacity
  - De-rate Propulsion Engines
  - High Fidelity Data Collection
- Maersk Investing Over $125 Million
- Ports Investing $1 Million ($500K per Port)
  - TAP assisted in purchasing fuel flow meters, data acquisition and transmission, and data analysis

Technology Advancement



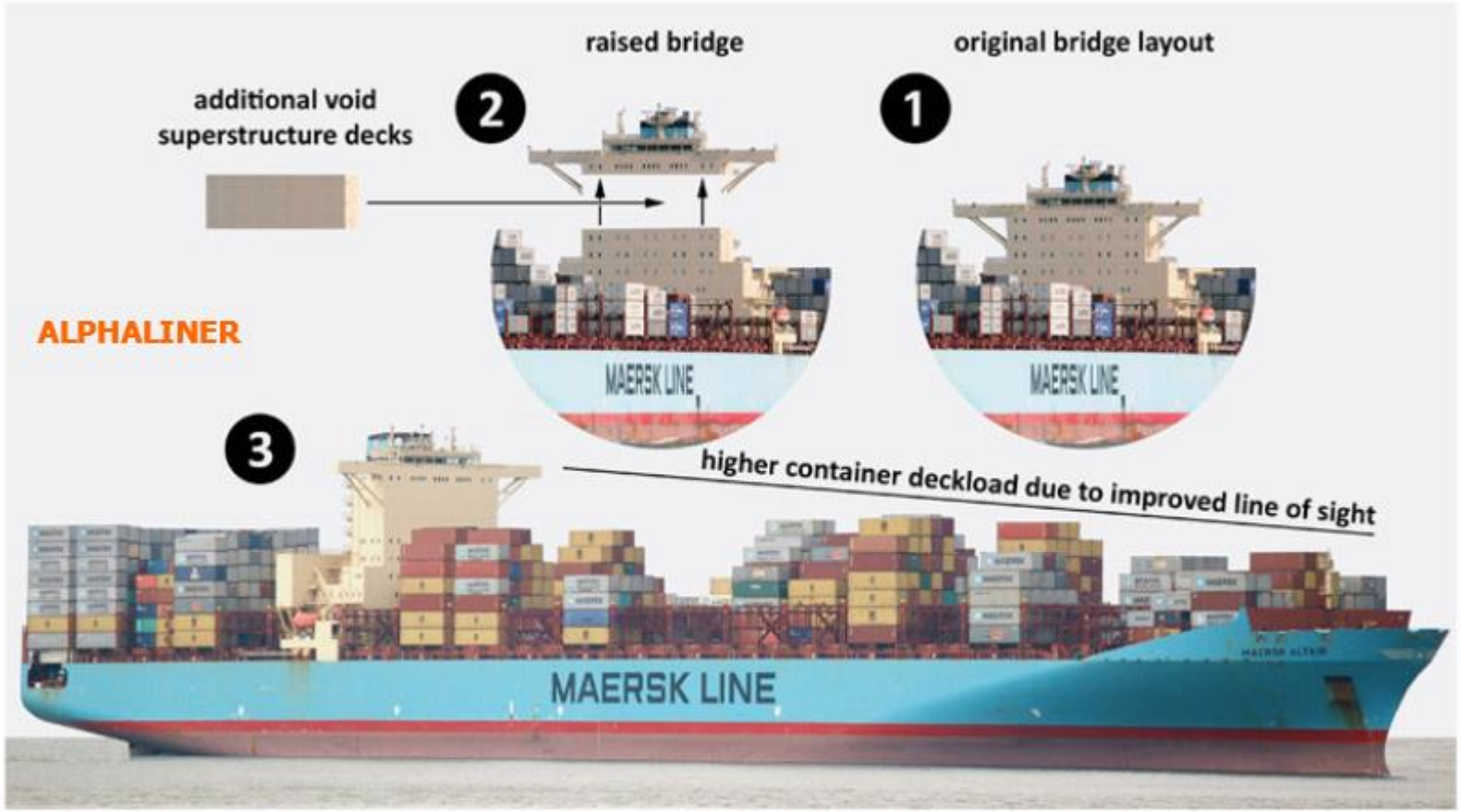
Bulbous Bow Modification

Technology Advancement

Propeller Replacement

Technology Advancement

Raise Bridge



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:
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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

Year Built	Engine Tier	NOx (g/kWh)*
Pre-2000	Tier 0	18+
2000	Tier 1	17
2011	Tier 2	14.4
2016	Tier 3	3.4

*<130 rpm

Emission Control Area (ECA) only

Current Emission Control Areas

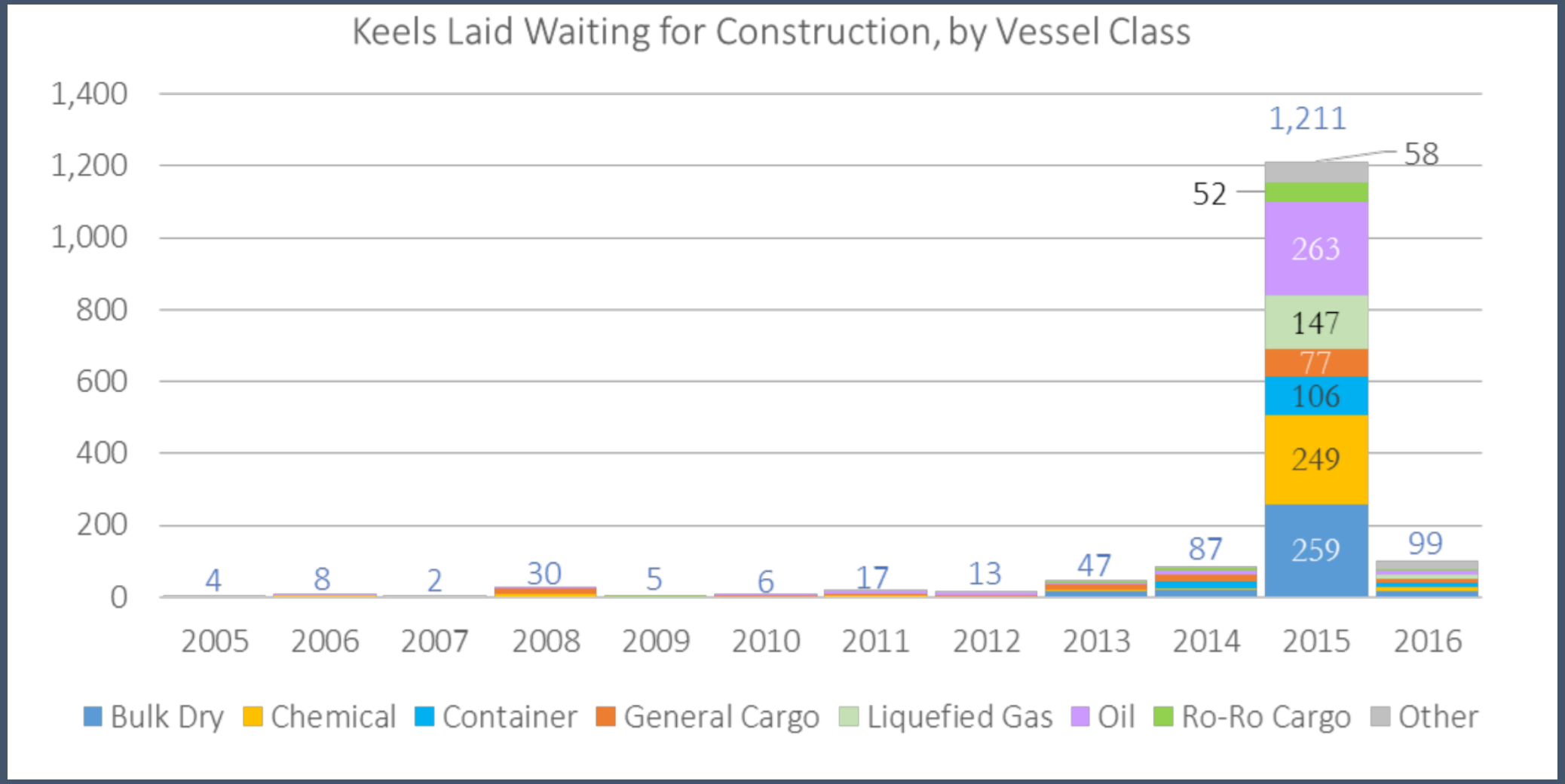
Chinese emission control zones for SOx; recently added NOx

- 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

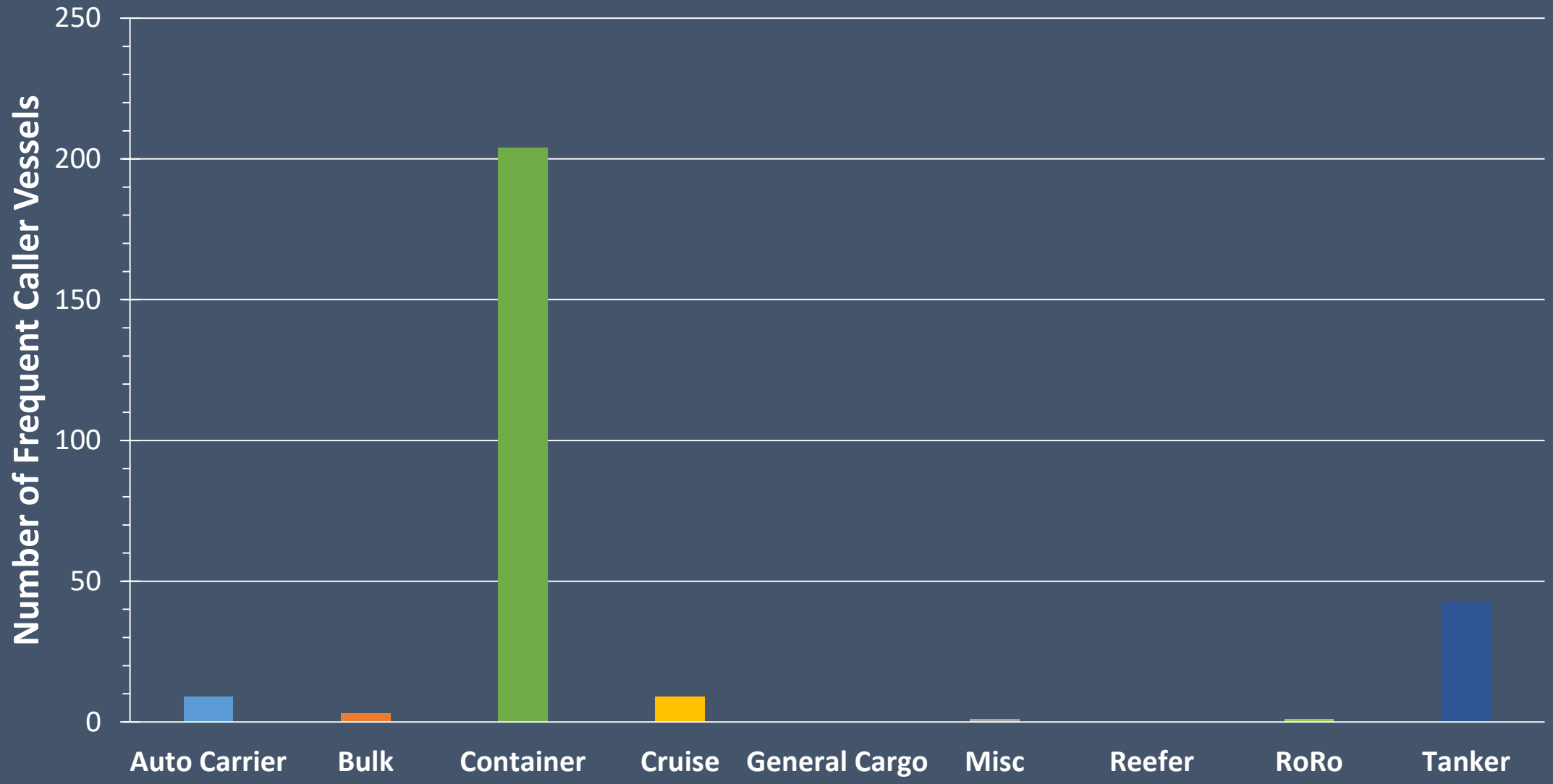
Considerations for OGV Engine NOx Retrofits

- 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

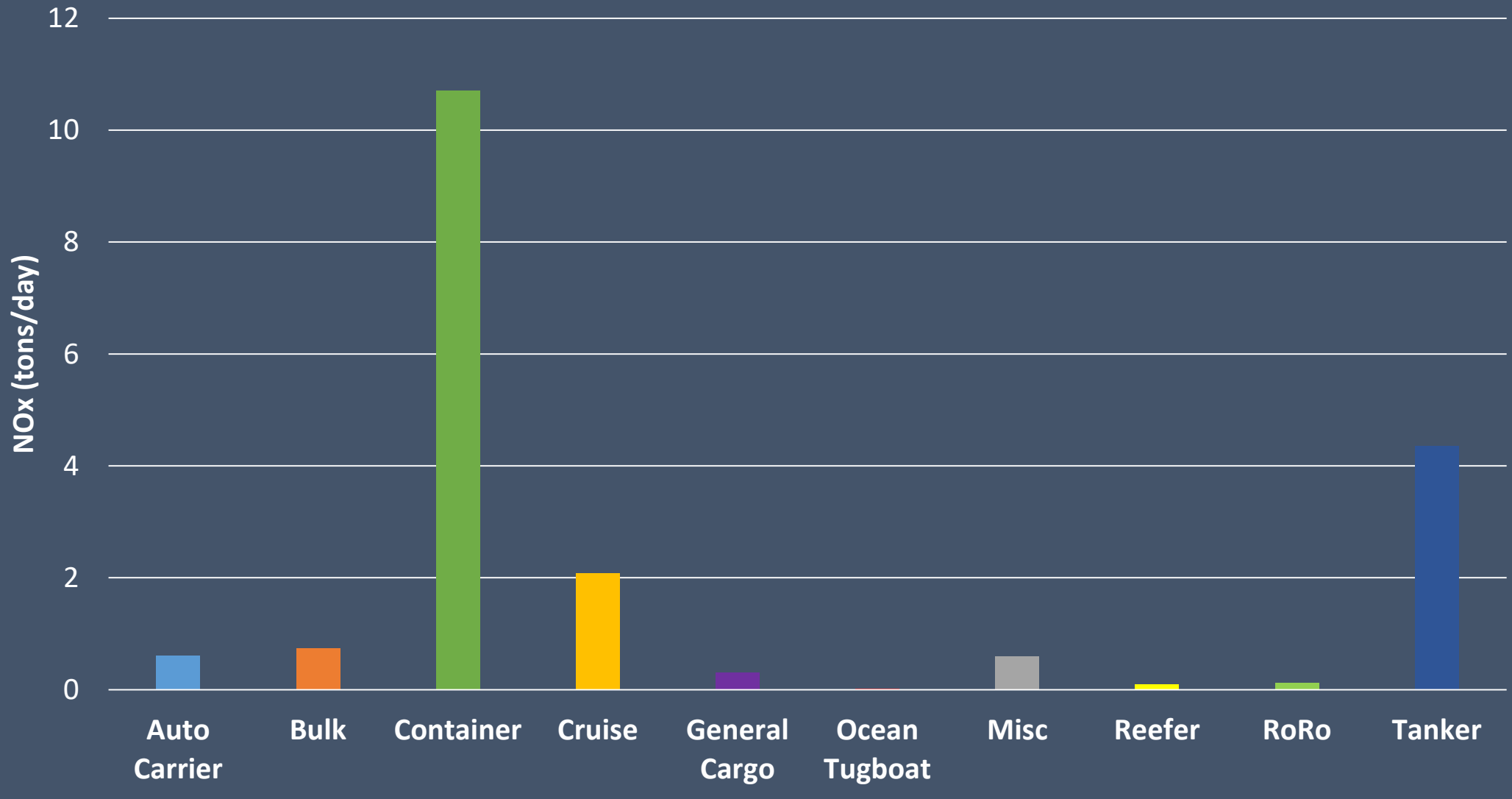
- Applicability
  - Main and Auxiliary Tier 0, 1, and 2 Diesel Engines
  - Transit, Maneuvering, Hoteling, Anchoring Modes (within 100 nm)
- Promising retrofit technologies available today and emerging
  - Retrofit packages expected to be offered/supported by engine manufacturers
  - NOx benefits to 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

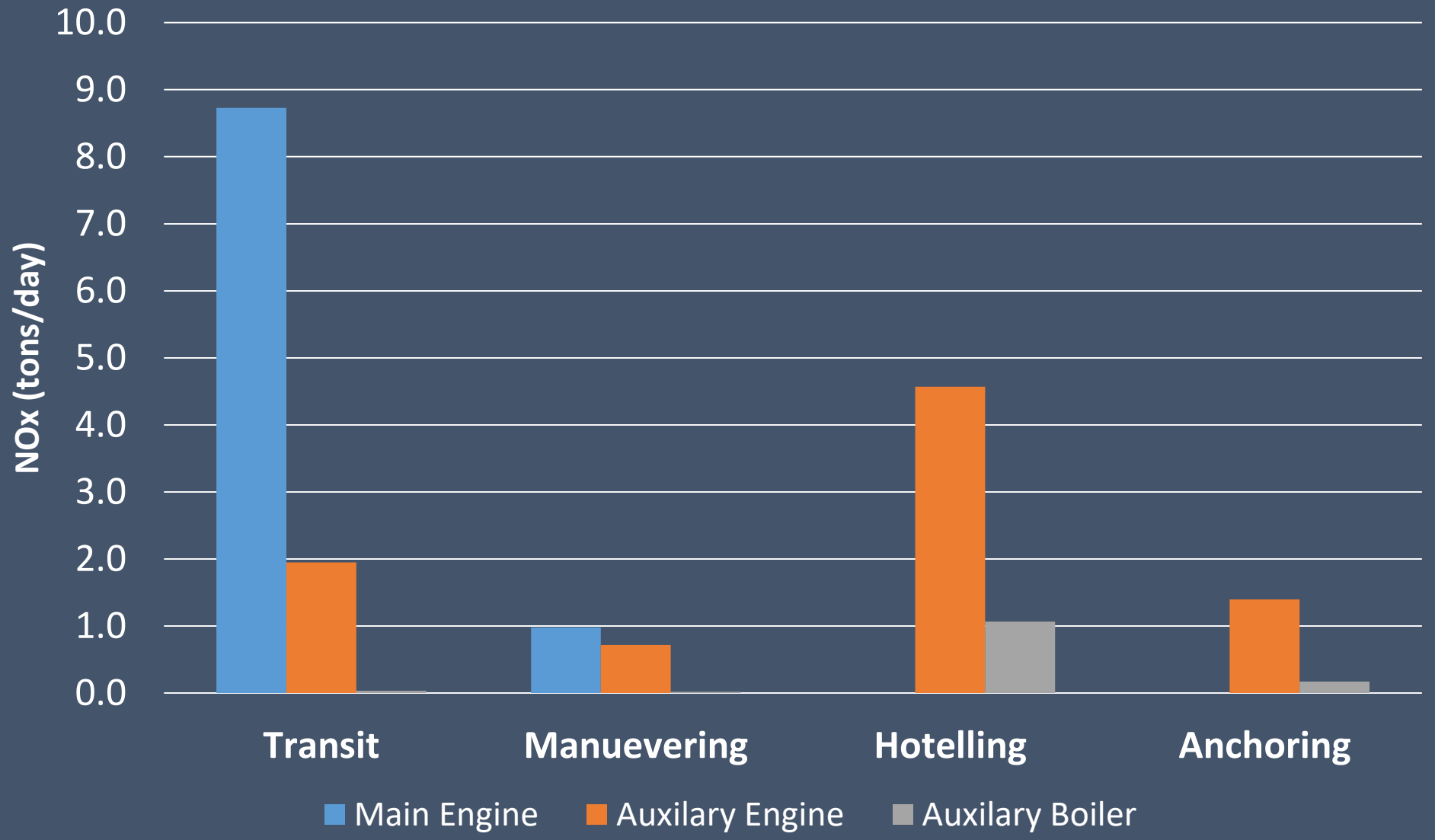


Frequent Caller (≥5) Container Vessels at Ports of LA/LB and Key Asian Ports in 2016

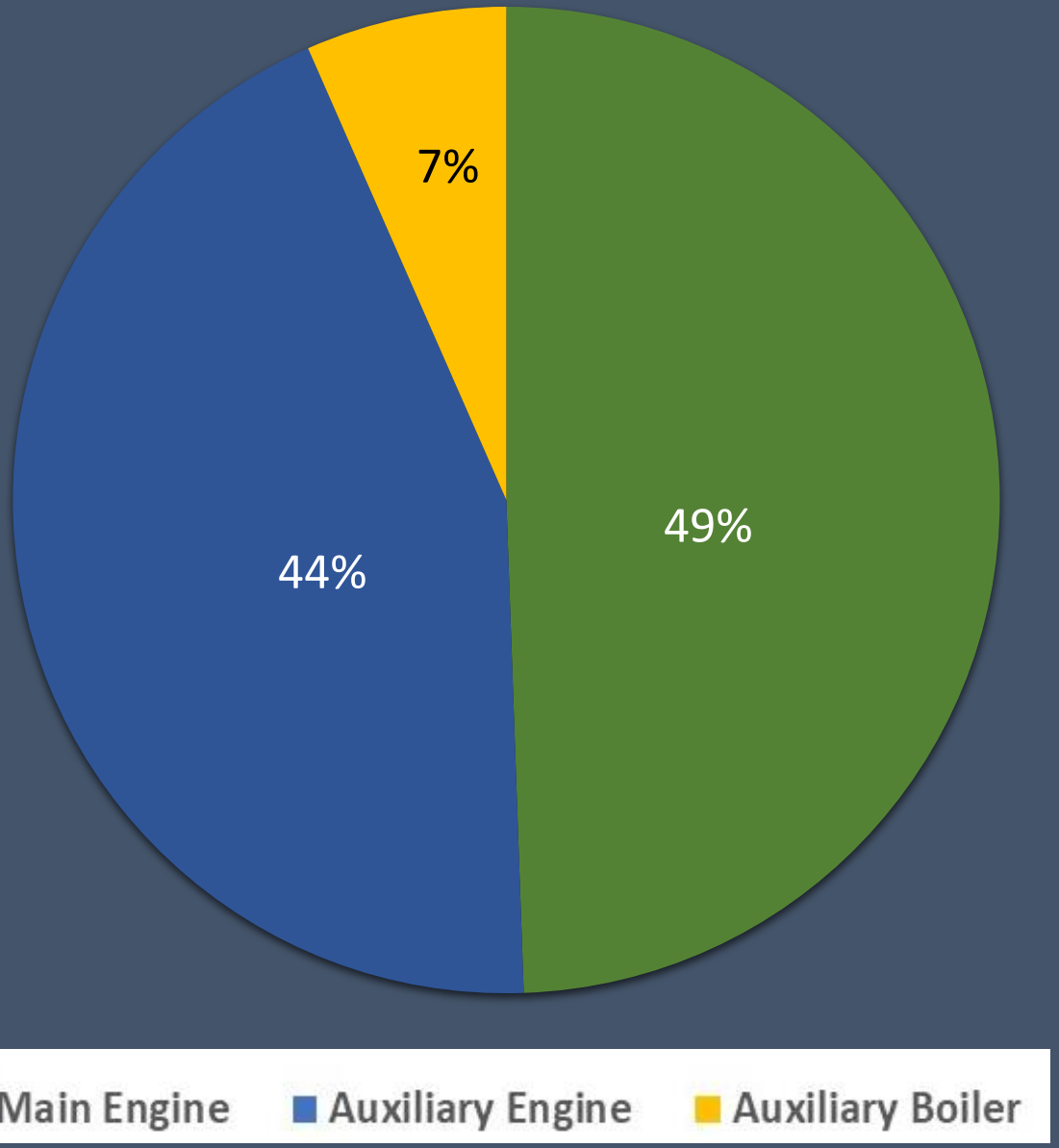
OGV Emissions by Vessel Type at Ports of LA/LB (2016)



OGV Emissions by Operational Mode at Ports of LA/LB (2016)

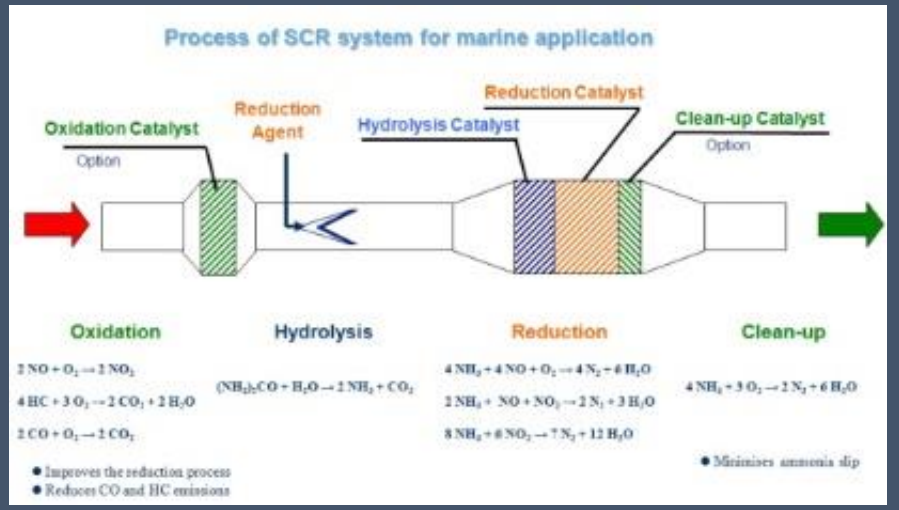


OGV Emissions by Engine Type at Ports of LA/LB (2016)



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

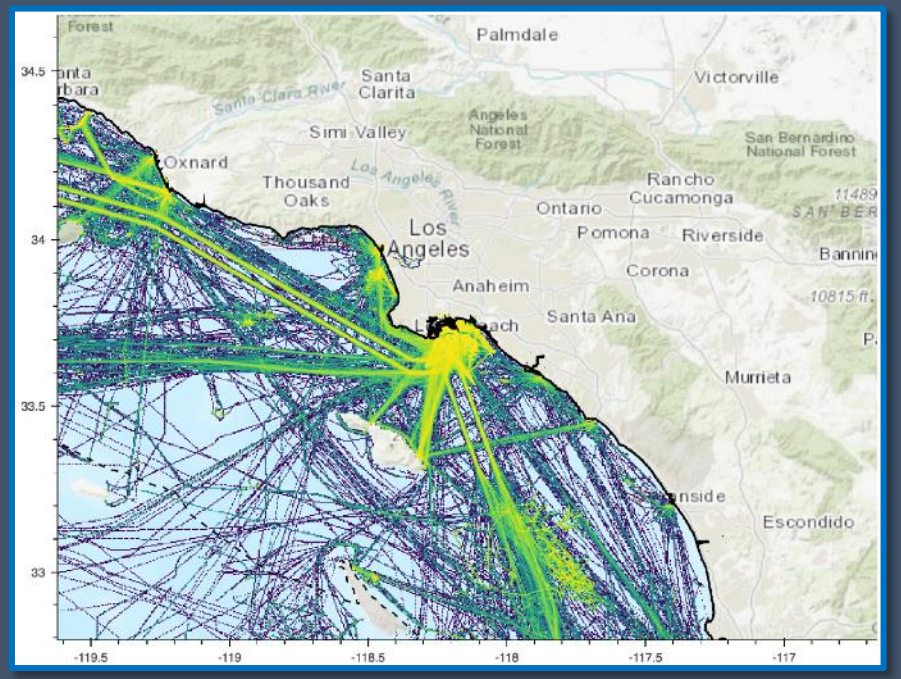


Estimated NOx Reduction Efficiency for Potential Retrofit Technologies

Retrofit Control Technology	NOx Reduction Efficiency
Selective Catalytic Reduction	80% - 90%
Exhaust Gas Recirculation	50% - 80%
Air Humidification	Up to 70%
Direct Water Injection	Up to 50%
Water Fuel Emulsion	20% - 40%
Engine De-Rating	Up to 10%

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 Energy Solutions
Future in the making

MAN B&W 2-stroke Engines
Ocean Going Vessels Retrofit Technology

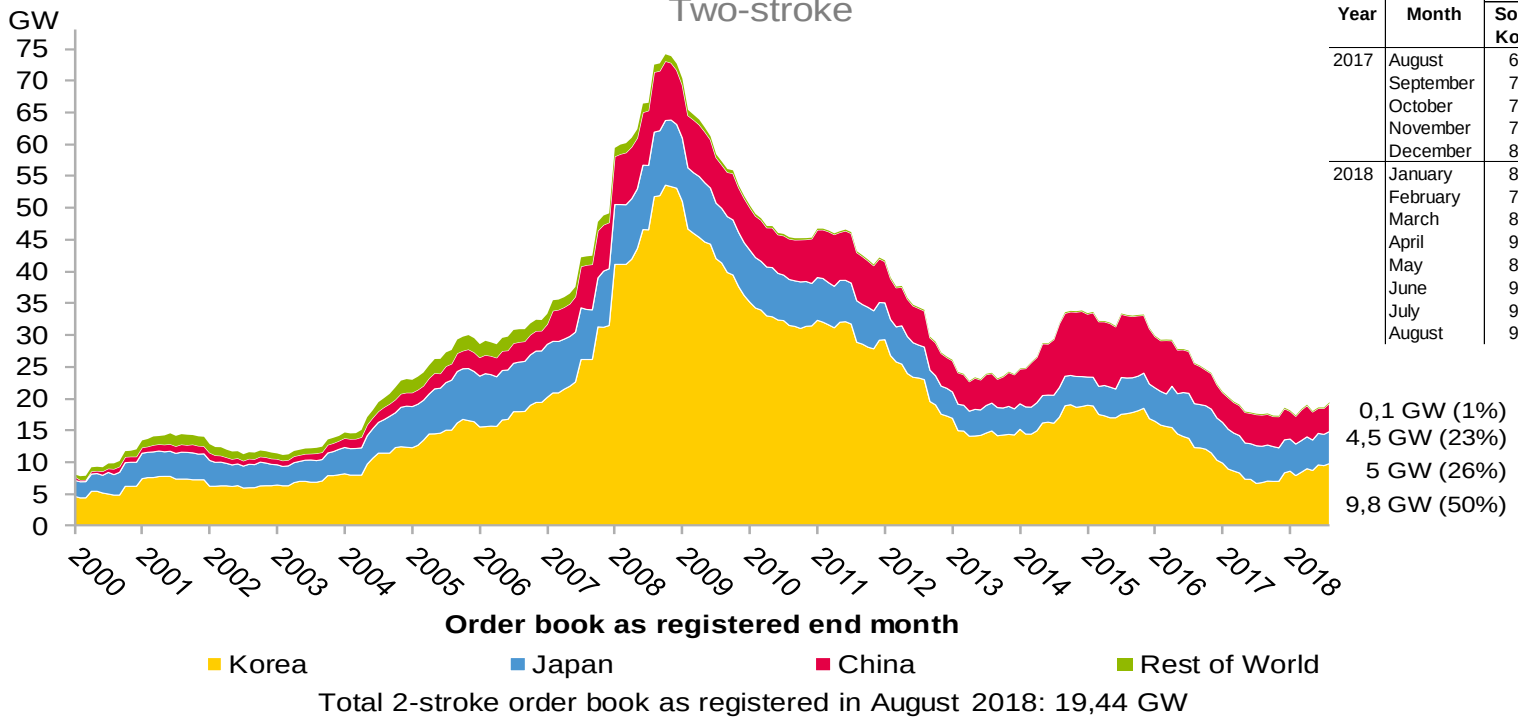
Technology Forum at SCAQMD Headquarters,
December 5th, 2018

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



GW on order end month

Two-stroke

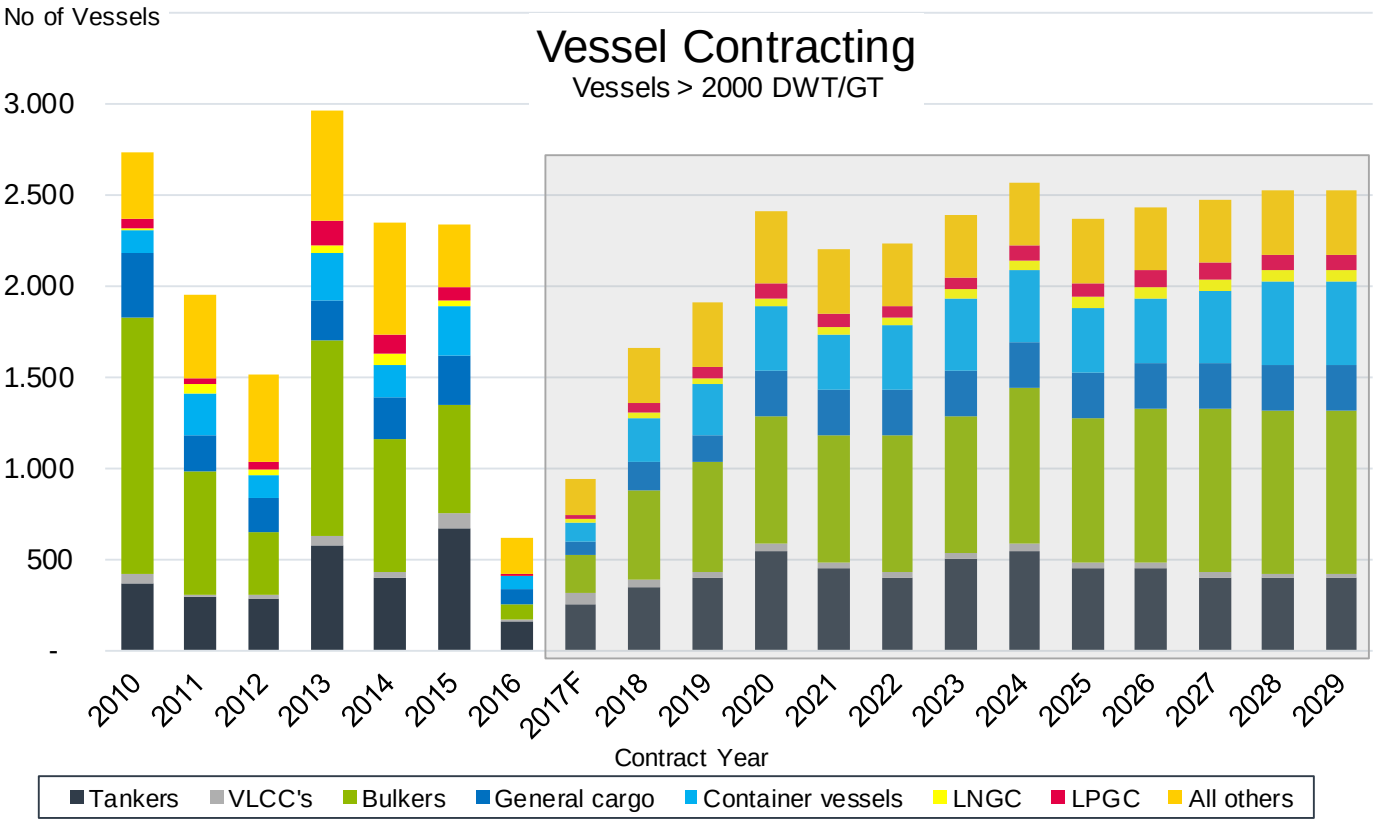
Year	Month	Licensee country				
		South Korea	Japan	China	Rest of World	Total
2017	August	6,8	5,7	4,9	0,1	17,6
	September	7,0	5,7	4,8	0,1	17,7
	October	7,0	5,5	4,7	0,1	17,3
	November	7,0	5,3	4,9	0,1	17,3
	December	8,3	5,2	4,9	0,1	18,6
2018	January	8,6	5,0	4,4	0,1	18,1
	February	7,9	5,0	4,4	0,1	17,4
	March	8,4	5,0	4,8	0,1	18,3
	April	9,0	5,0	4,9	0,1	19,1
	May	8,7	4,8	4,4	0,1	18,0
	June	9,6	5,0	3,9	0,1	18,6
	July	9,5	4,9	4,1	0,1	18,6
	August	9,8	5,0	4,5	0,1	19,4

Status Reported end August 2018

Source: Licensees order book

Vessel Contracting, No of Vessels >2000 DWT/GT

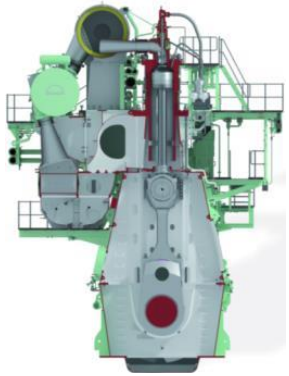
Total Shipbuilding Forecast



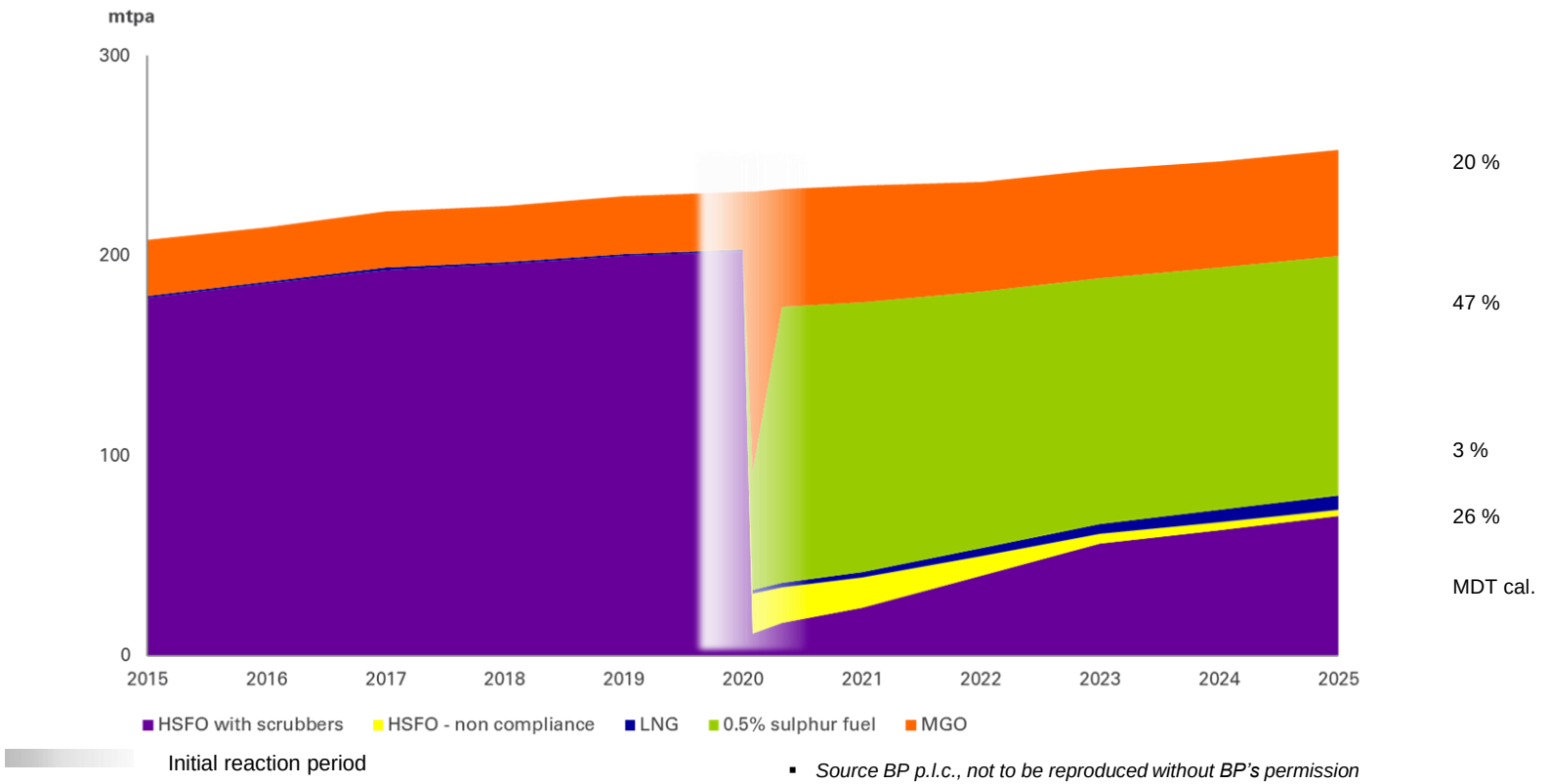
Source: IHS Ltd & MDT

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

Compliant fuel		High sulphur fuel
MC/ME/-C engine Single Fuel: 0.1%S fuel, 0.5%S fuel	ME-GI / ME-LGI engine Dual Fuel: LNG, Ethane, LPG, MeOH ……..	MC/ME/-C engine 0-5%S fuels: HFO/MDO + Scrubber
		

BP prediction of fuel in the future



- *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

Residual
ME / MC

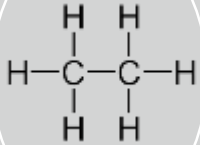
Distillates
ME / MC

ULSFO
ME / MC

Methane
ME-GI

Methanol
ME-LGIM

LPG
ME-LGIP



Ethane
ME-GIE

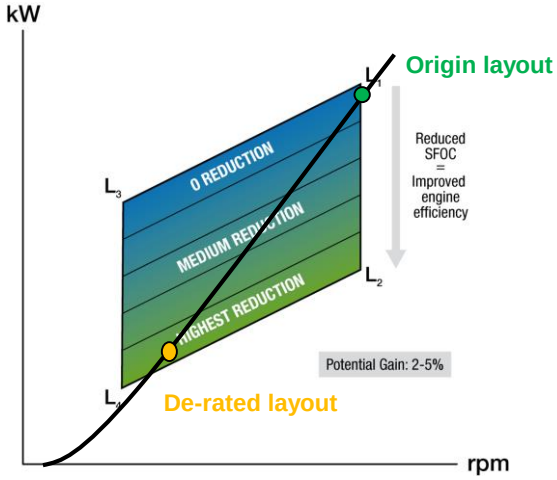
Biofuel
(2nd+3rd gen.)
ME / MC

MAN Diesel & Turbo supports all

MAN B&W 2-stroke Engines Retrofitting

Retrofit Experience

Engine De-Rating

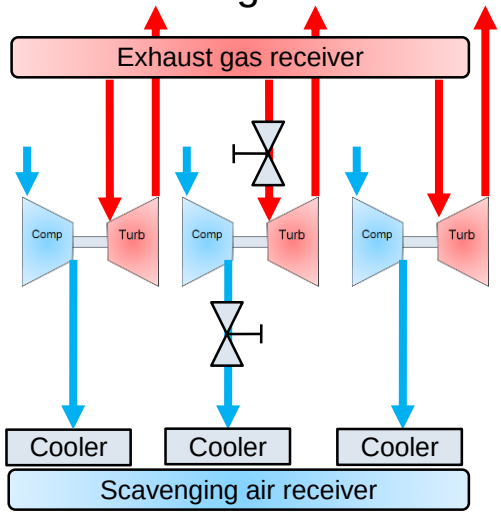


Features:

- 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)

Turbo Charger Cut Out

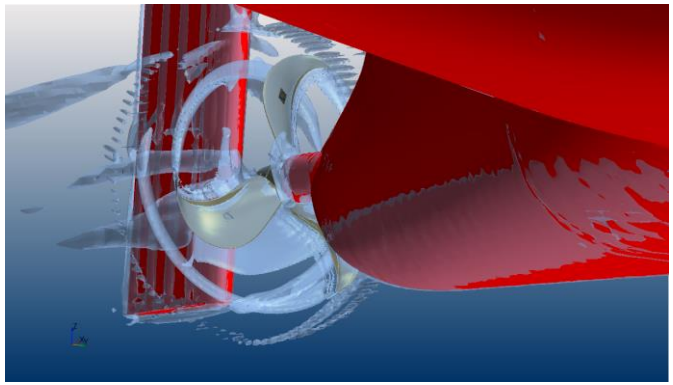


Features:

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

Fuel-gain: 2-4%

Propeller Retrofitting



Features:

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

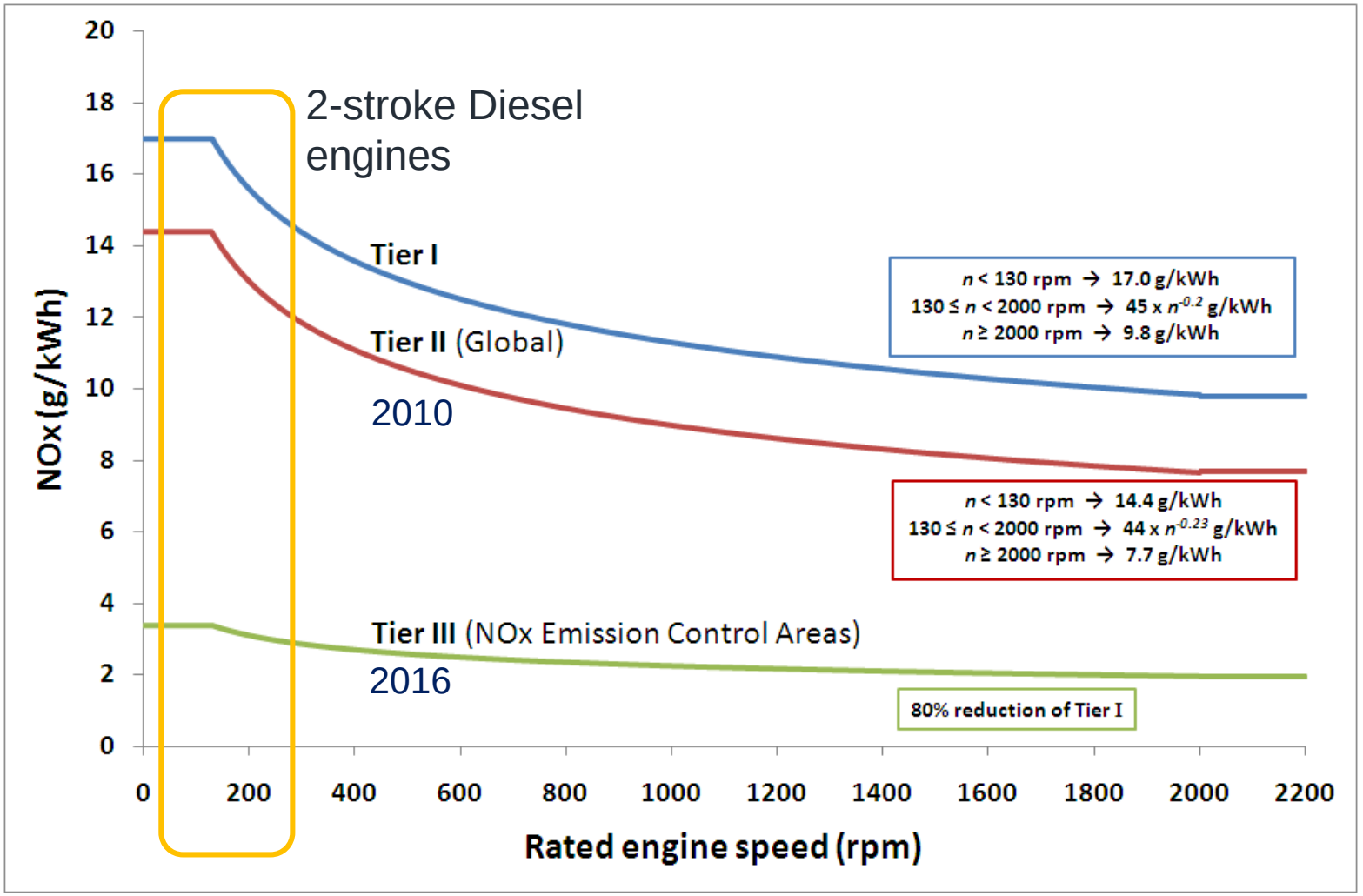
Fuel-gain: 4-8%

Motivation/Business Case: **Fuel consumption optimization, Economy**

NOx level according regulatory limits remained unchanged

MAN B&W 2-stroke Engines Retrofitting

Development of NOx regulatory levels

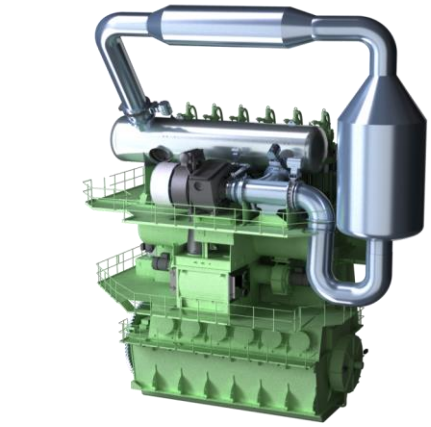


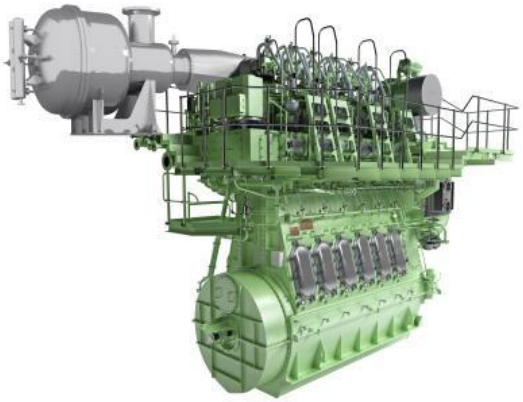
MAN B&W 2-stroke Engines Retrofitting

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

EGR

HP SCR



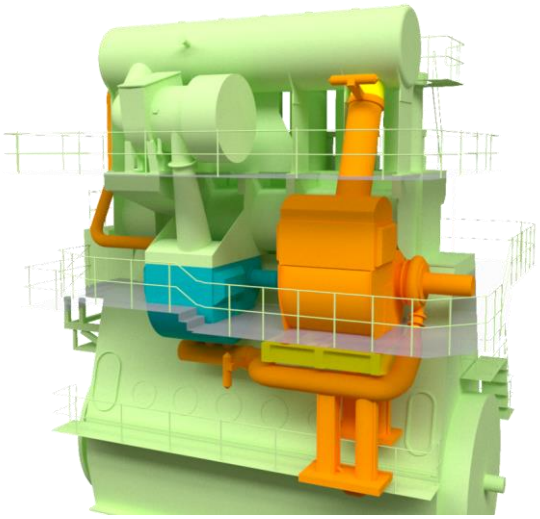


LP SCR

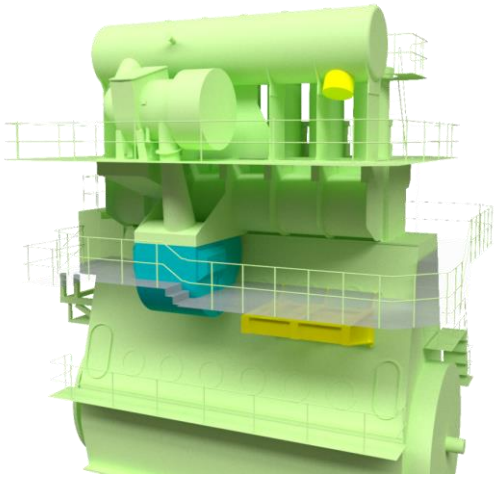
MAN B&W 2-stroke Engines Retrofitting

Tier III retrofitting solution

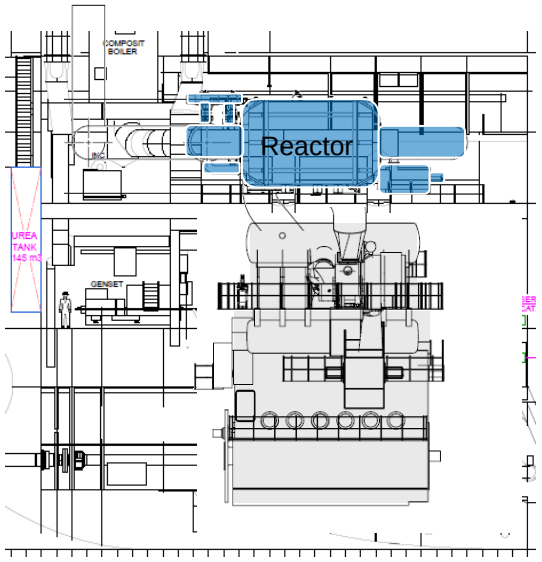
EGR Tier III engine



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 ?

Fuel	NOx reduction	CO2 (carbon content only) reduction
LNG*	-25%	-25%
LPG (propane)*	0%	-13%
Methanol*	-30%	-7%
Ethane*	0%	-18%

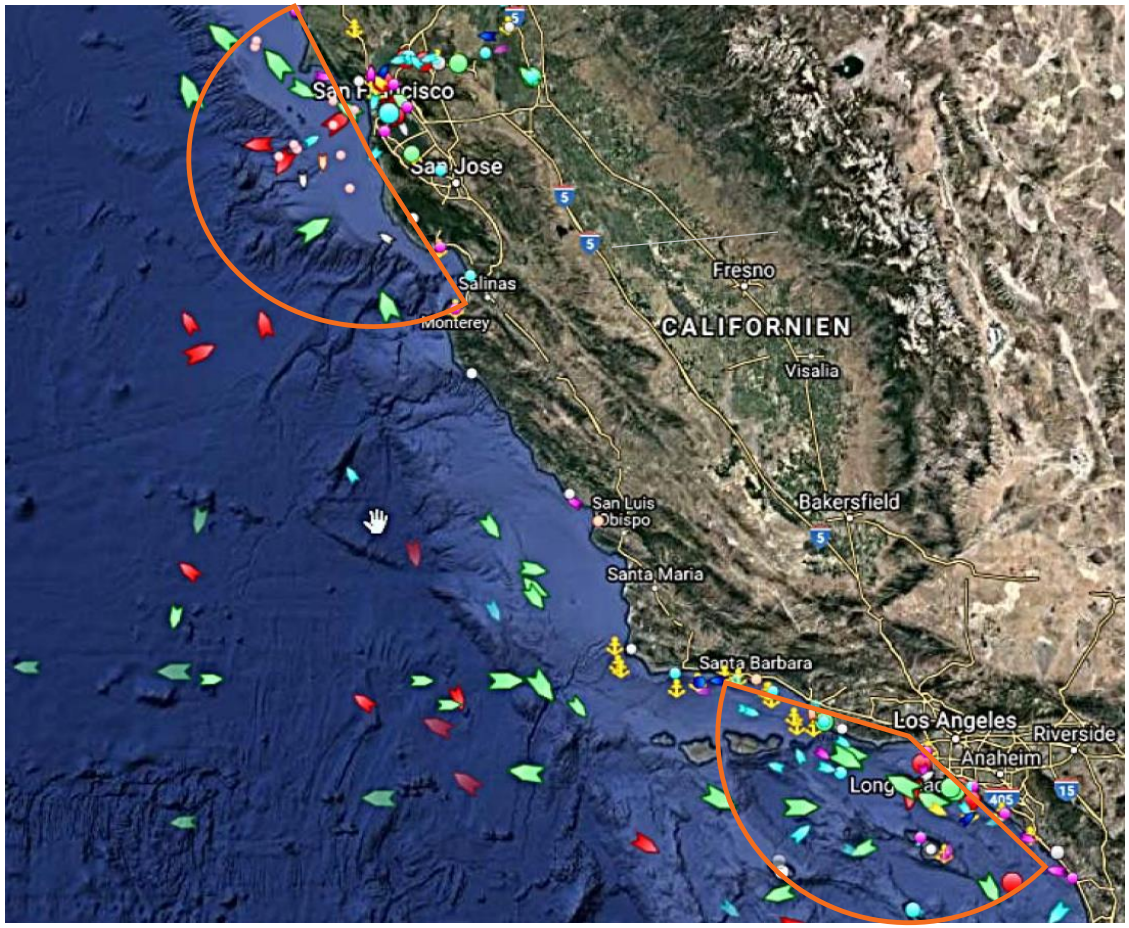
Comparison based on 2-stroke engine operation Tier II mode with HFO at same engine performance, * pilot fuel (3% of MCR fuel flow) not considered

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 require 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

MAN B&W 2-stroke Engines Retrofitting

Voluntary NOx reduction in coastal operation areas

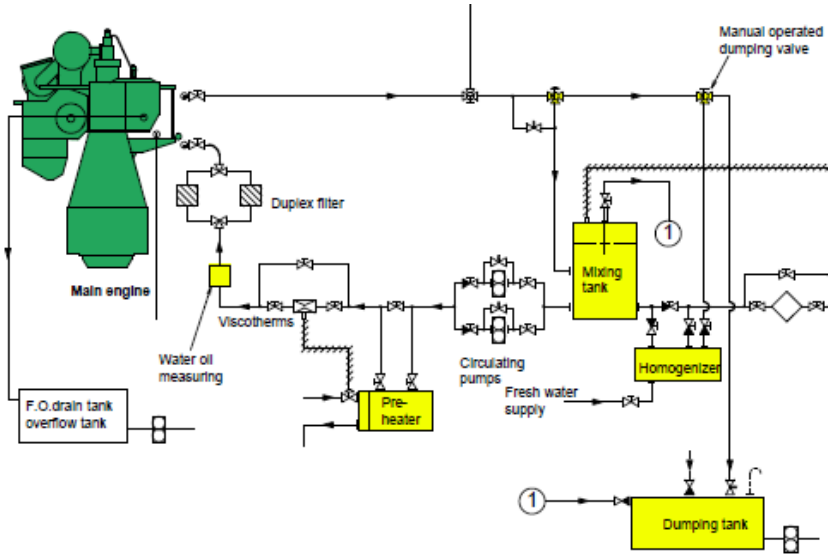
A possible technical solution for this task:

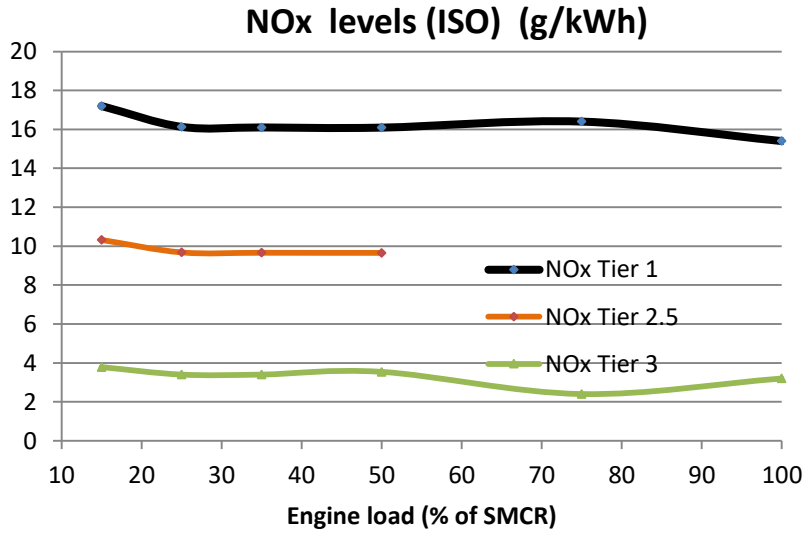
Retrofitting in service OGV with “Water in Fuel” (WIF) technology.

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)



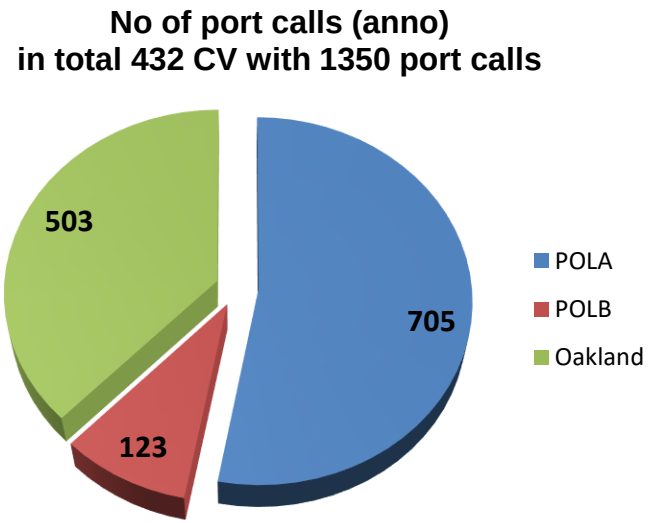


MAN B&W 2-stroke Engines Retrofitting

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

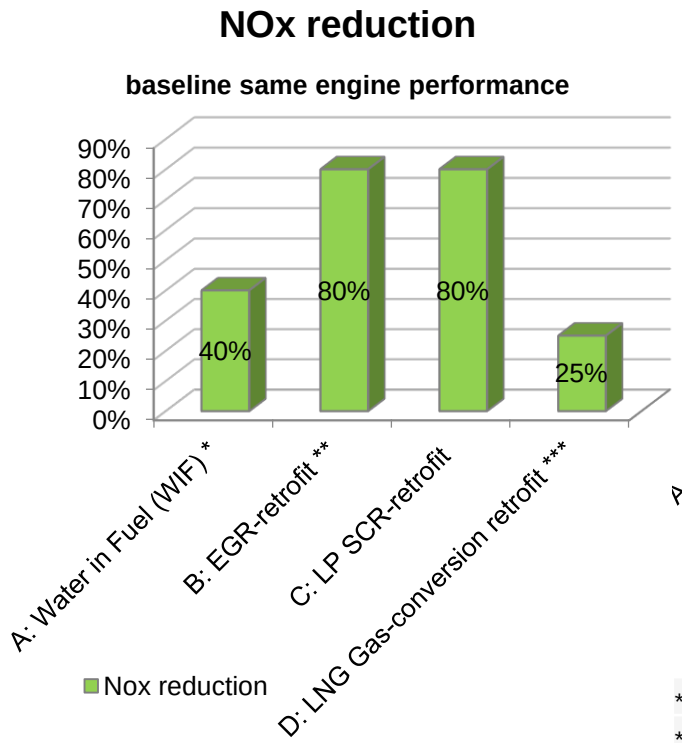


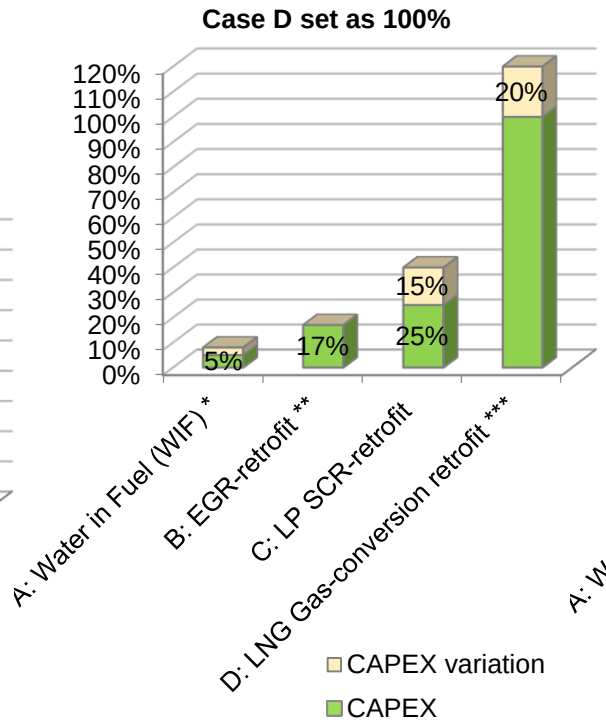
Large potential for NOx emission savings

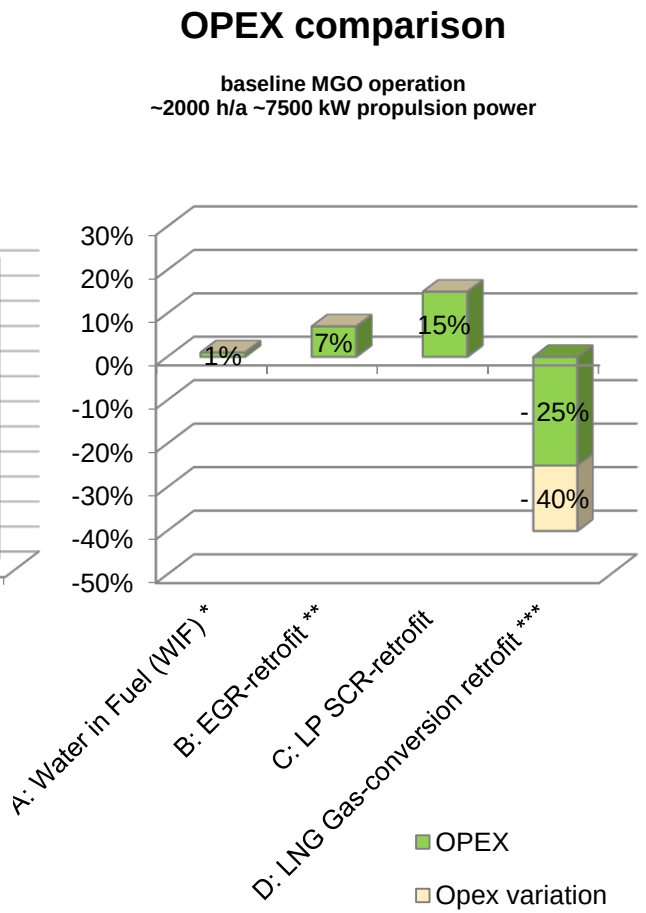
It require a close cooperation of SCAQMD, owners and engine designer

NO_x-Reduction Technologies 2-Stroke

Comparison of Reduction Potentials vs. Invest Cost vs. Operational cost





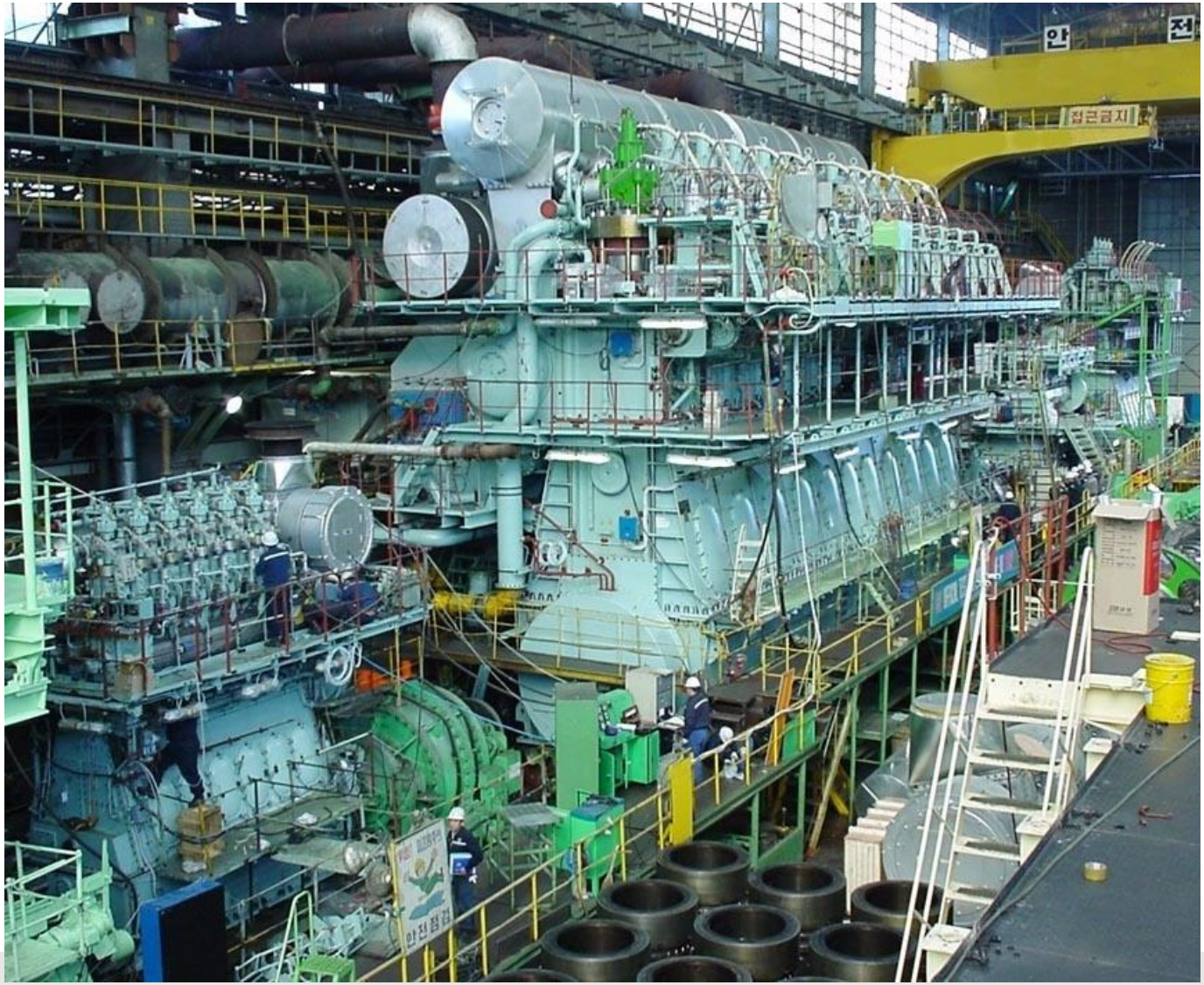


* up to 50%SMCR

** if ME-engine is prepared for EGR

*** ME engine types Tier II

MAN B&W 6S35MC and MAN B&W 10K98MC-C on Testbed



MAN Energy Solutions
Future in the making

PrimeServ Augsburg

NOx reduction opportunities for four-stroke engines Augsburg

MAN Energy Solutions SE
Augsburg, Germany, SEAA
2018

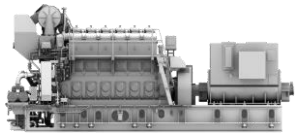
MAN PrimeServ

NO_x-Reduction Technologies 4-Stroke

Engine-internal Potentials Base TIER I

Tier I to Tier II (Performance & Emission Upgrade):

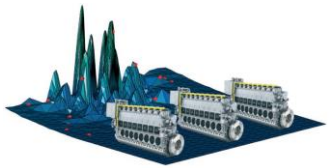
Modification of Valve opening strategy, Combustion chamber design, Injection System, Turbocharger



NOx	SFOC	Invest
~ 20%	→	medium

Power Management (MAN EcoLoad-System):

Example: 1 engine @75% load instead of 3 engines @25% load



NOx	SFOC	Invest
< 30%	→	low

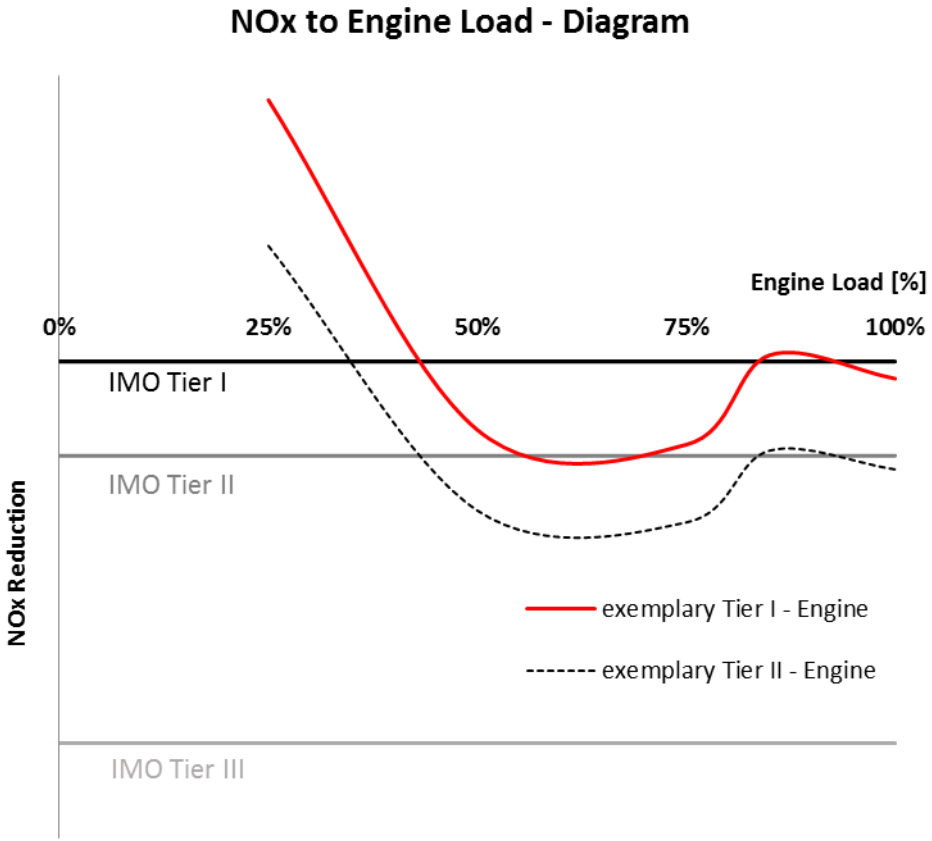
Water in Fuel Emulsion:

NOx	SFOC	Invest
~ 20%	→	low

Variable Injection Timing:

Nox Reduction by individual injection timing depending on engine load and environmental conditions

NOx	SFOC	Invest
< 20%	→	low



Efficiency & Environment

SCR Upgrade

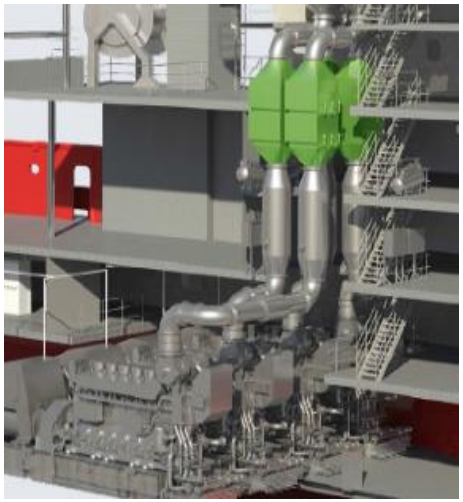
Selective Catalytic Reduction - Compliance with lowest NOx Limits

Description:

- SCR catalysts technology is an exhaust gas after treatment for NO_x emission reduction
- SCR technology achieves NO_x reduction rates of up to 90%
- SCR involves urea injection as reducing agent
- Chemical reaction of NO_x in SCR to N_2 and H_2O
- 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_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

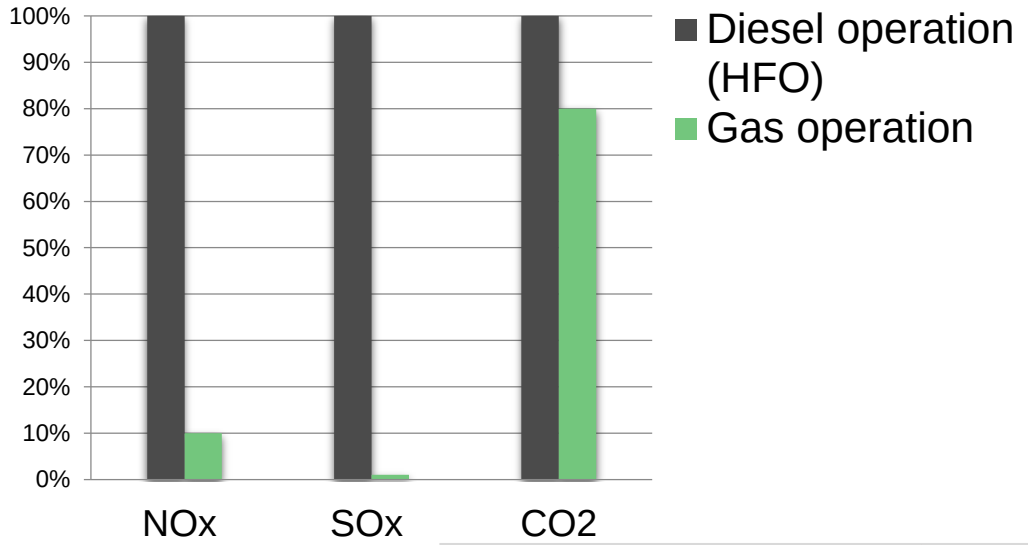
Efficiency & Environment

Dual-Fuel / Gas Upgrade

Converting Diesel engines to run on gaseous fuels

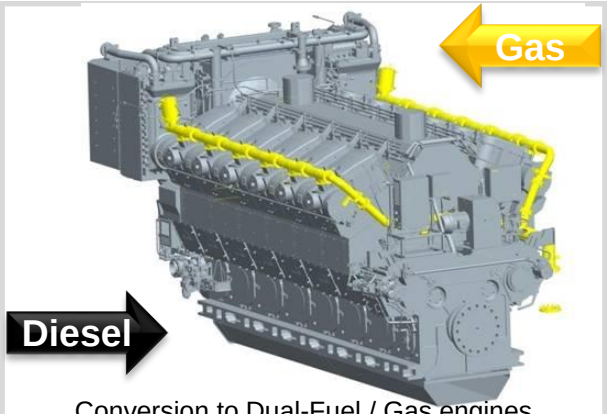
Description:

- 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_x and 20% less CO_2 emissions
- Dual-Fuel engines offer the ability to run either on gaseous or liquid fuels: Switching between fuels for full flexibility

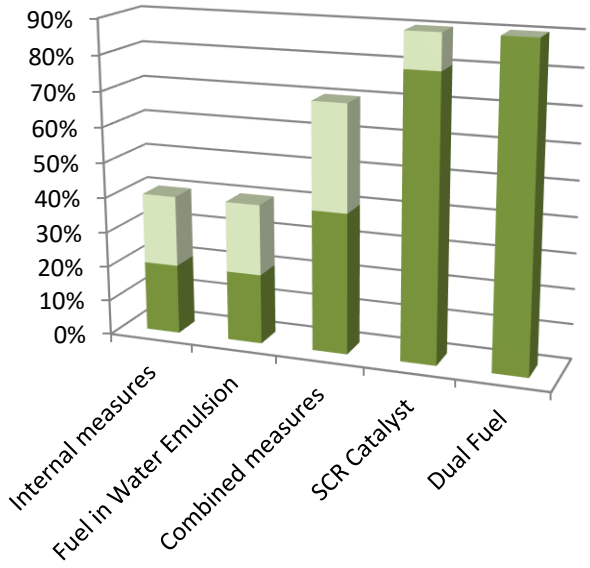


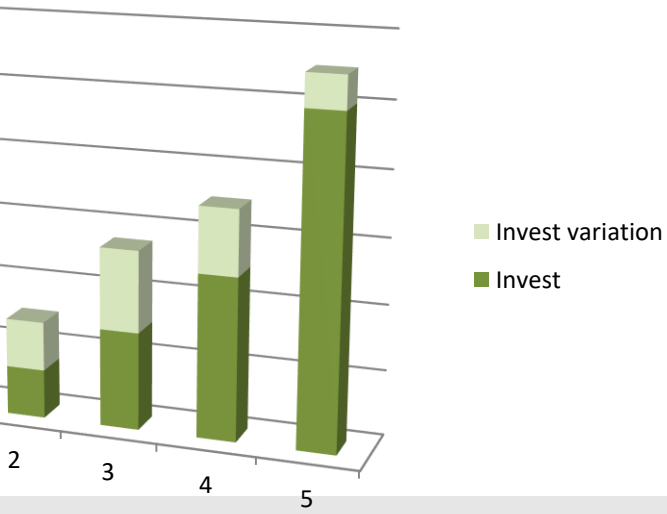
Conversion to Dual-Fuel / Gas engines

Efficiency & Environment

NO_x-Reduction Technologies 4-Stroke

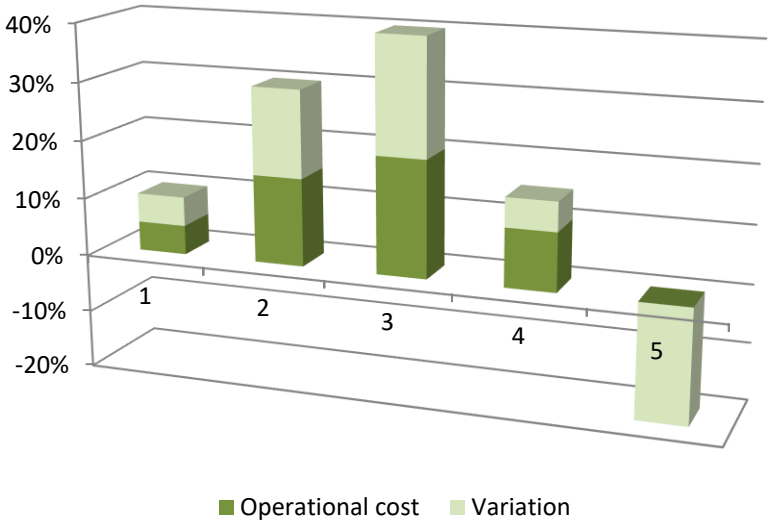
Comparison of Reduction Potentials vs. Invest Cost vs. Operational cost





Potential NOx Reduction

NOx Reduction



Operational cost

Variation

Invest variation

Invest

Disclaimer

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

Contents

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

Administrative Legal and Institutional System

<table>
<tr><td colspan="3">Standard</td></tr>
<tr><td rowspan="5">Normative document</td><td>Work program</td><td rowspan="5">Administrative Enforcement

Economic incentive</td></tr>
<tr><td>Action plan</td></tr>
<tr><td>Pilot project</td></tr>
<tr><td>Guiding opinion</td></tr>
<tr><td>Development plan</td></tr>
<tr><td colspan="3">Regulation</td></tr>
<tr><td colspan="3">Law</td></tr>
<tr><td colspan="3">All red font mark methods can often be used by MOT to guide industry development.</td></tr>
</table>

2013: Guiding Opinion for LNG Application in Water Transport Industry

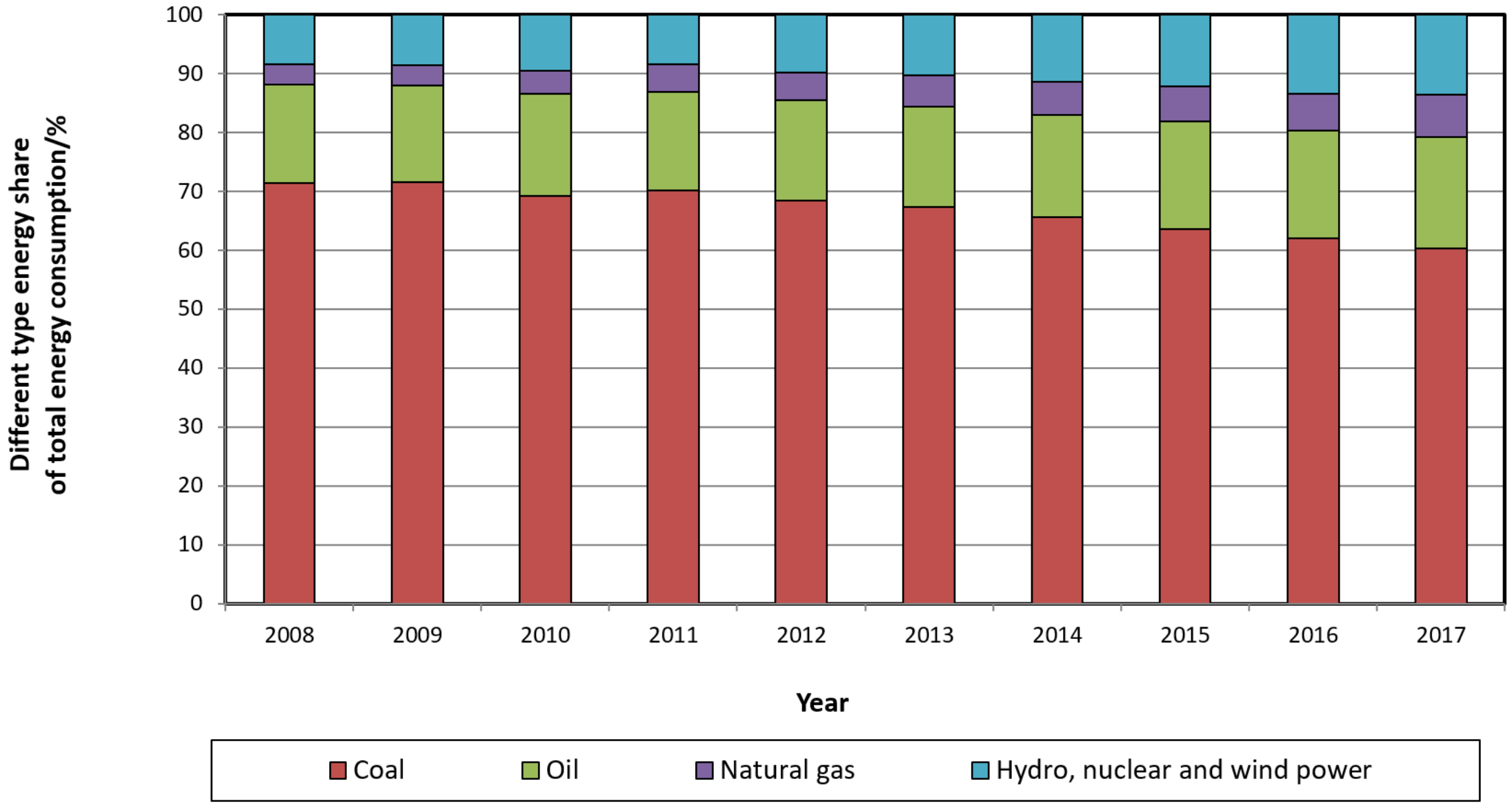
Set goals for application of LNG fueled ship in China:

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

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

Contents

Natural Gas Share of Total Energy Consumption in China (2017:7.2%)



LNG Fueled or Bi-Fuel Ships in China by October 2018

LNG Fueled or Bi-Fuel Ships	
LNG Fueled	Bi-Fuel
110	175
285	

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

LNG Fueled or Bi-Fuel Ships		
Retrofit		New building
Original Engine	Update Engine	
46	72	167
285		

Note: Retrofit ships use original oil engine to use LNG.

LNG Fueled or Bi-Fuel Ships in China by October 2018

Big Gap between Number of Ships Using LMG as Fuel and Goal

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	
Planned	Many
Constructed	18
Licensed	6

Note: It is very difficult to get a license from local governments, and It takes more than 100 approval formalities.

LNG Filling Stations for LNG Fueled Ship

Contents

Coordinated Policies, Regulations and Standards

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

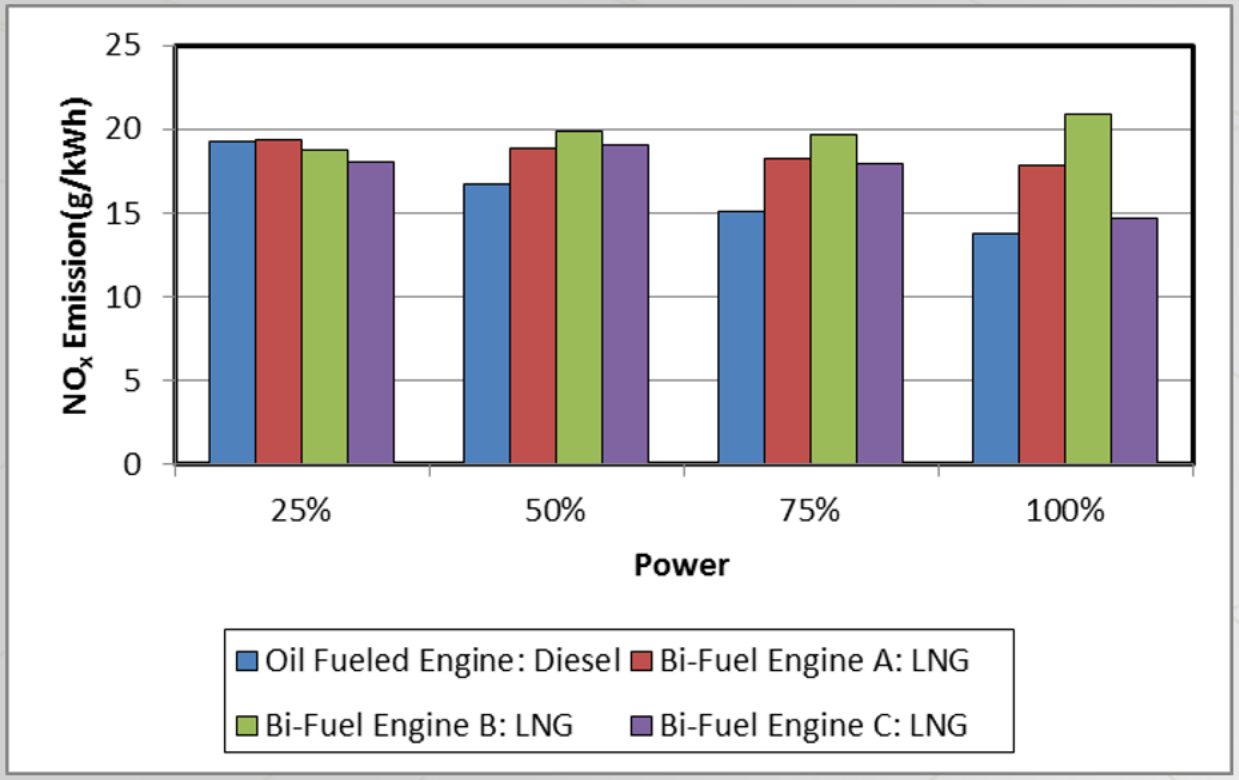
Specialized Engine

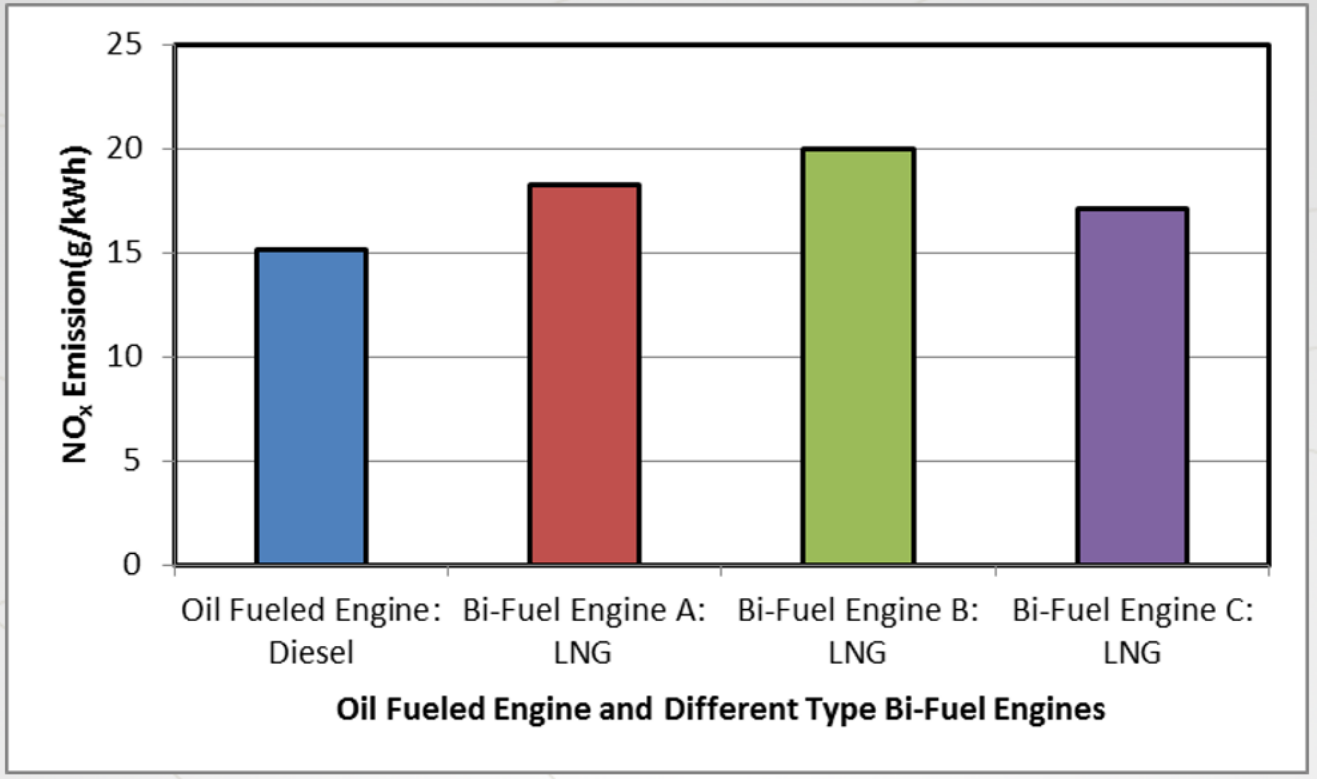
Even for the clean energy, whether it is good for reducing air emission depends on how to use it.

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.

Specialized Engine





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.

Supply Infrastructure

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 m^3, because it must carry enough LNG used by the whole Asia-Europe return trip.

Price

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.

Safety and Personnel Training

Lack of training of crews for using LNG in ships safely.

Contents

LNG: A Transitional Clean Fuel for Shipping in the Coming Decades

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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THANKS

Fleet Modernization

Chevron Shipping Company

Chevron Shipping Company
Mission

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

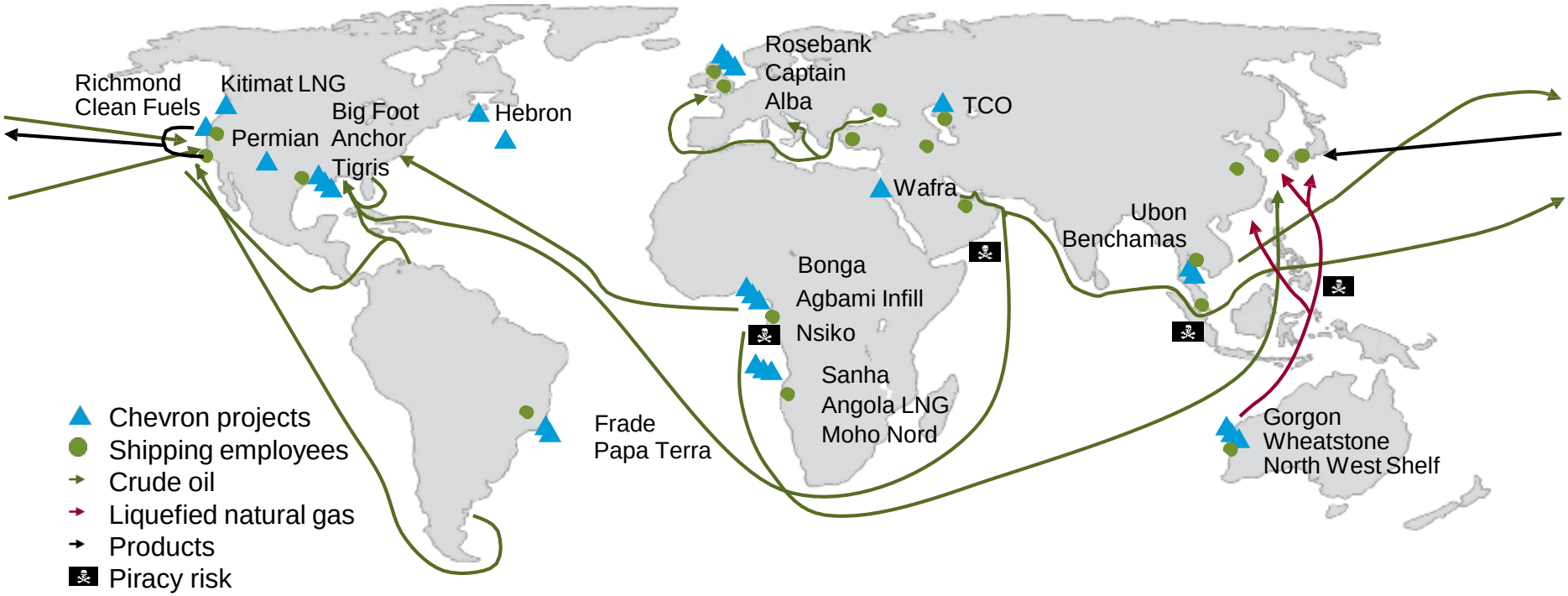
$2 billion annual freight spend

2,000 employees from 20 countries

29 operated vessels

Global Support of Chevron Operations

Enhancing value across the enterprise



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

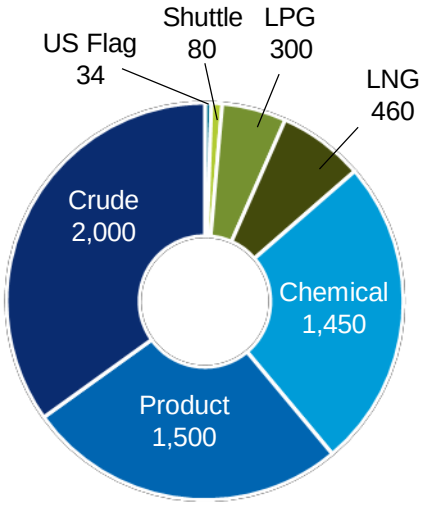
Tanker industry

- 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

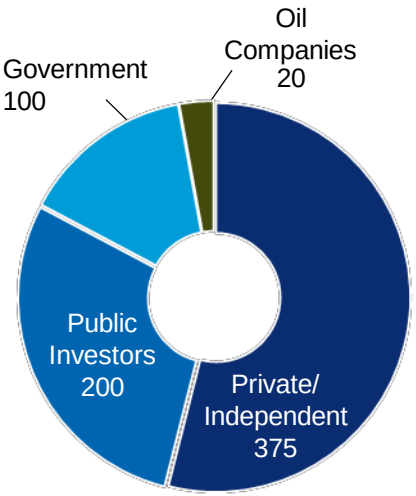
Market characteristics

- 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.

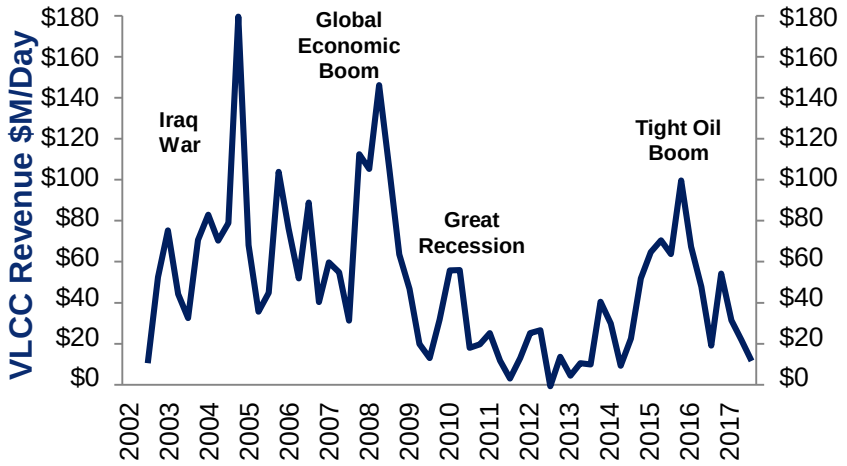
~5,800 Ships



~700 Owners



Long-term cycles driven by global events

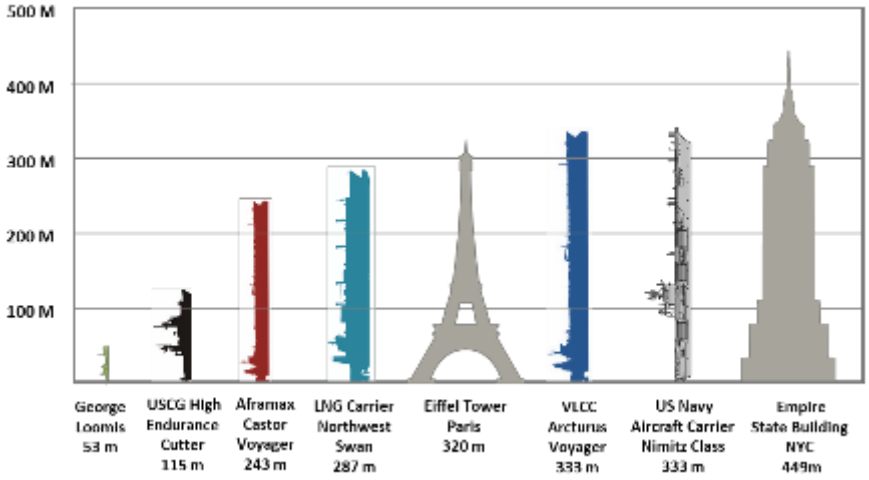


Chevron Shipping Company
Operated Fleet

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

Chevron

human energy

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)
- Tier III engine (75% NOx reduction)
- Ballast water treatment system
- 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

Chevron

human energy™

- **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

What's Next?

At Berth

Cold Ironing, Capture and Control

GHG

IMO Strategy

40% reduction in carbon intensity by 2030, 70% by 2050

Short Term

Modifcations, slower speeds/on time arrivals

Longer Term

Alternative Fuels

Biofuels, wind, battery, ammonia, hydrogen, nuclear

Todays 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