


Marine Port Emissions Inventory

An aerial photograph of a port area with a city skyline in the background. In the foreground, a large red U.S. Coast Guard cutter is docked at a pier. Several red gantry cranes are visible on the pier. The city skyline includes various skyscrapers and a prominent tower with a spire. The water is dark blue, and the sky is clear.

West Coast Region Conference on
Marine Port Air Quality Impacts
April 21 and 22, 2004

Chris Lindhjem
ENVIRON International Corporation

Purpose of Emission Inventory

- **International and Regional Haze**
- **State (State Implementation Plans, SIP)**
- **Metropolitan and regional (SIP and transportation conformity)**
- **Project level**
 - Regional impact (General Conformity and Neighborhood Hot Spots)
 - Specific studies (such as offsets)

Overview of Marine Ports Emissions

- Where to draw the boundaries?
- At the international boundary
- At the metropolitan boundary
- At the water edge
- At the fence line



Overview of Emissions Inventory

- **Stationary sources (large point sources)**
- **On-road (trucks, cars, buses)**
- **Area (anything not in the other two categories)**
 - Small point sources (includes diesel generators, pumps, etc.)
 - Off-road mobile sources
 - Shore-based equipment (forklifts, diesel-cranes, terminal tractors, other material handling)
 - Locomotive (switching and line-haul)
 - Ship operations (deep draft, tugs, push boats, ferries, dredges, supply vessels, excursion, commercial fishing, service, military)
 - Aircraft for airports (often operated by Port Authorities)



Overview of Transportation Operations

- **Trucks**
- **Rail**
- **Shore-based stevedoring**
- **Marine vessel**
 - Deep draft
 - Tug and Tow
 - Other vessels



On-Road Trucks

- **EPA - MOBILE6; California ARB – EMFAC**
- **Covered by U.S. and California emission stds.**
- **Inputs**
 - Speed by roadway links (small road sections)
 - Idle times (special consideration in South Coast)
 - Gross vehicle weight rating (GVWR)
 - Age distribution



Shore-Based Equipment

- **EPA-NONROAD; ARB-OFFROAD**
 - Provide default estimates and emission factors (per hp-hr)
 - Covered under U.S. EPA emission standards
 - Any thing that moves or can be moved not on water, locomotives, or registered for on-road use
- **Inputs (and alternatives to default estimates)**
 - Rated continuous power of engine and fuel type
 - Load factor (typically determined from fuel consumption rates)
 - Hours of use
 - Age distribution



Locomotives

- **EPA estimates from 1997 regulations background information**
- **Emissions (based on fuel consumption)**
 - Line-haul duty for long haul use
 - Switching (lower load factor and more idling)



Port Inventories

- **New area of study**
 - First EPA study, BAH 1991
 - EPA Revised; Arcadis 1999\ENVIRON 2002
 - Greater Vancouver; Levelton 2002
 - Starcrest detailed studies (Houston-Galveston, Los Angeles-Long Beach, New York-New Jersey)



Emission Approach

- **Approach, overall activity or per ship call**
 - Gallons (tonnes) of fuel consumed or ...
 - Engine load factor & time in mode
 - » Cruise
 - » Reduced-speed zone (possibly more than one)
 - » Maneuvering (typically minor)
 - » At dock (on-board generators)



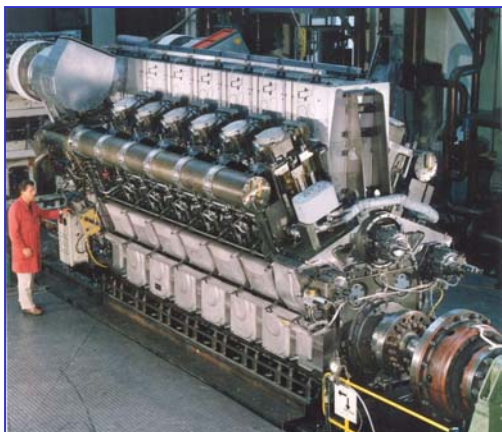
Marine Vessels Types

- **Deep draft ($\sim > 14$ ft) vessels**
- **Tow boats (barges)**
- **Tug (vessel assist and other general purpose)**
- **Other**
 - Ferries
 - Excursion, casinos, etc. (not registered as pleasure)
 - Supply\support vessels (off-shore oil, construction)
 - Service vessels (fire, police, other)
 - Commercial fishing



Marine Engine Types (EPA-Defined 3 types)

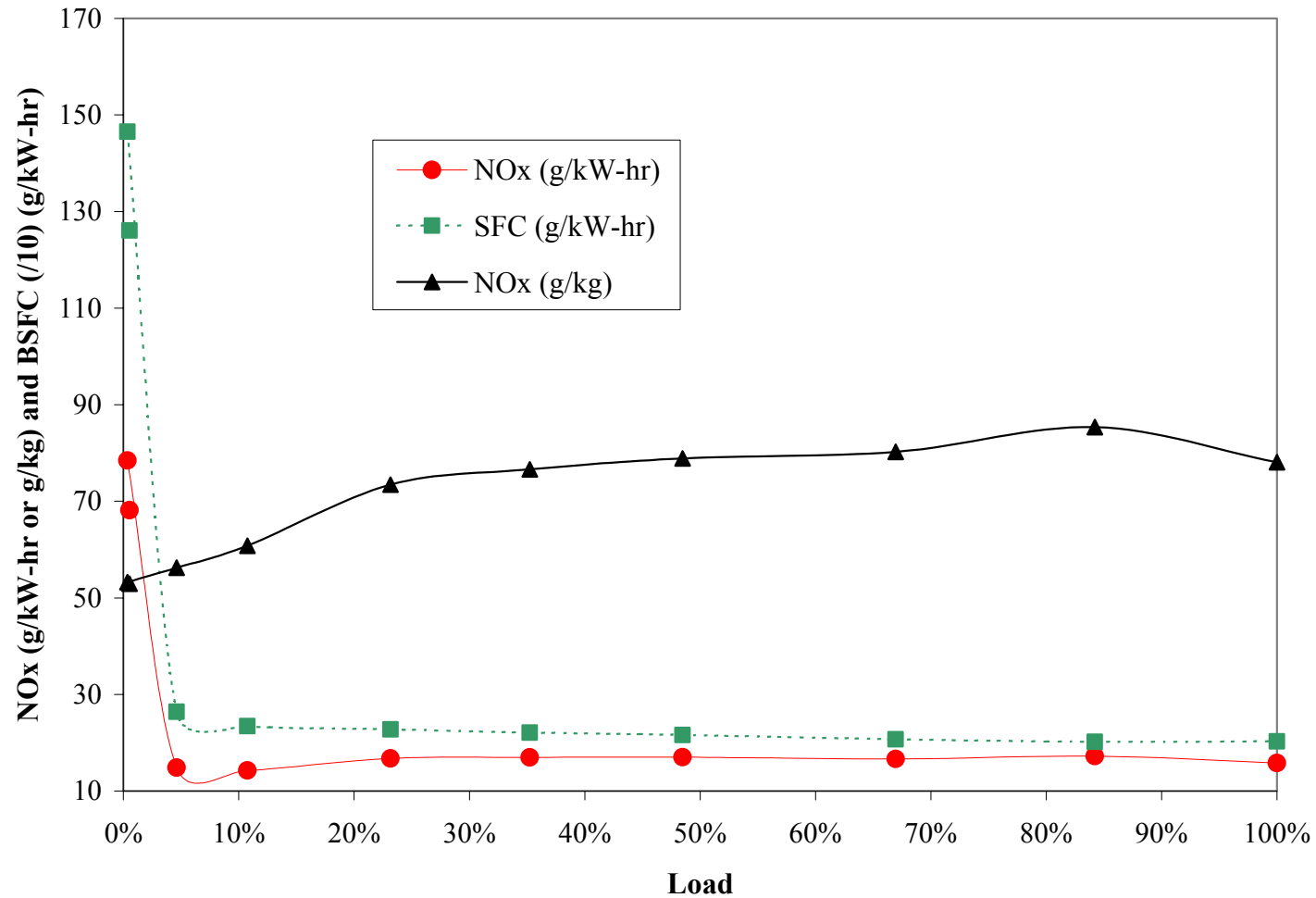
- **Category 3; cylinder displacement >30 l**
 - Deep draft propulsion power & rarely large auxiliary generators (cruise, reefers, new diesel-electric designs)
 - Slow speed, 2-stroke (rpm < ~250) {MAN, Sulzer, Mitsubishi}
 - 108 kg NO_x/tonne of fuel; 18 – 24 g/kW-hr (fuel efficiency?)
 - Medium speed, 4-stroke (250 to ~750 rpm) {Wartsila, MAN}
 - 75 kg NO_x/tonne; 13 –17 g/kW-hr (fuel efficiency?)
 - Particulate emissions – 90% of PM with high (3%) sulfur fuels
 - ~2% of fuel sulfur converts directly to sulfuric acid mist



Marine Engine Types (cont.)

- Category 2 (5 – 30 l/cylinder) {Wartsila, Caterpillar, MTU}
 - Used primarily for auxiliary generator engines for deep draft vessels
 - Or propulsion on larger tugs and ferries
 - Engine speed (750 – 1600 rpm); NO_x ~ 13 g/kW-hr
- Category 1 (<5 l/cylinder) {too many to name}
 - Most typical of off-road or truck engines
 - Propulsion on small vessels or auxiliary on larger vessels
 - Engine speed >1500 rpm; NO_x ~ 10 g/kW-hr

Effect of Engine Load





Regulations

- **IMO Standards (NOx only)**

- Need to be ratified (Minimal NOx reduction)

Engine Speed < 130 rpm; 17.0 g/kW-hr

*130 rpm # Engine Speed < 2,000 rpm; $45 * n^{-0.2}$ g/kW-hr*

Engine Speed \geq 2,000 rpm; 9.8 g/kW-hr

- **EPA standards**

- Category 3 must comply with IMO, regardless of ratification, for US vessels
- More stringent Category 1 and 2 engine (NOx and PM) standards on US vessels



Local Emission Reductions

- **State regulations and SIP goals**
 - Operating restrictions
 - Other emission reduction programs
- **Permit Requirements**
 - Ad hoc emission offsets
 - Good neighbor



Searching for Emissions Reductions?

- **Clean fuels (low sulfur and other)**
- **New\rebuild engines (marine and others)**
- **Aftertreatment retrofit (NOx and\or PM)**
- **Reduced idling (cold ironing, truck electrification\scheduling, and locomotive auto start\stop)**
- **Exotics; turbines, fuel cells, sails?**