THE MARITIME ADMINISTRATION'S ENERGY AND EMISSIONS PROGRAM

An Industry/Government Cooperative

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Office of Shipbuilding and Marine Technology
Maritime Administration

Presented to DEER Workshop August 26, 2002

The Partners

U.S. DEPARTMENT OF TRANSPORTATION
Center for Climate Change and Environmental Forecasting

ABS

U.S. COAST GUARD

ROSEMOUNT ANALYTICAL

NETL

RSPA research and special programs administration

BROOKHAVEN NATIONAL LABORATORY

UNIVERSITY OF DELAWARE

CASRM Center for Advanced Ship Repair and Maintenance

bp marine

AQMD

Region 9

PRIME, Inc.

THE PORT OF LONG BEACH

MIDAS

BLUE & GOLD FLEET

NAVSEA PHILADELPHIA Ships Systems Engineering Station

California Air Resources Board

Seaworthy

gti

West Virginia University

Red and White Fleet SINCE 1892 – THE SAN FRANCISCO SIGHTSEEING TRADITION

Matson

U.S. Department of Transportation Federal Highway Administration

Port of Houston Authority

SUREPOWER™ CORPORATION

Santa Barbara County Air Pollution Control District

EPA United States Environmental Protection Agency

WATER TRANSIT AUTHORITY

HRT Hampton Roads Transit

Federal Transit Administration

Contents

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- Program Objective
- Program Plan and Status of Projects
  - Baseline Emission Monitoring
  - Diesel Retrofits
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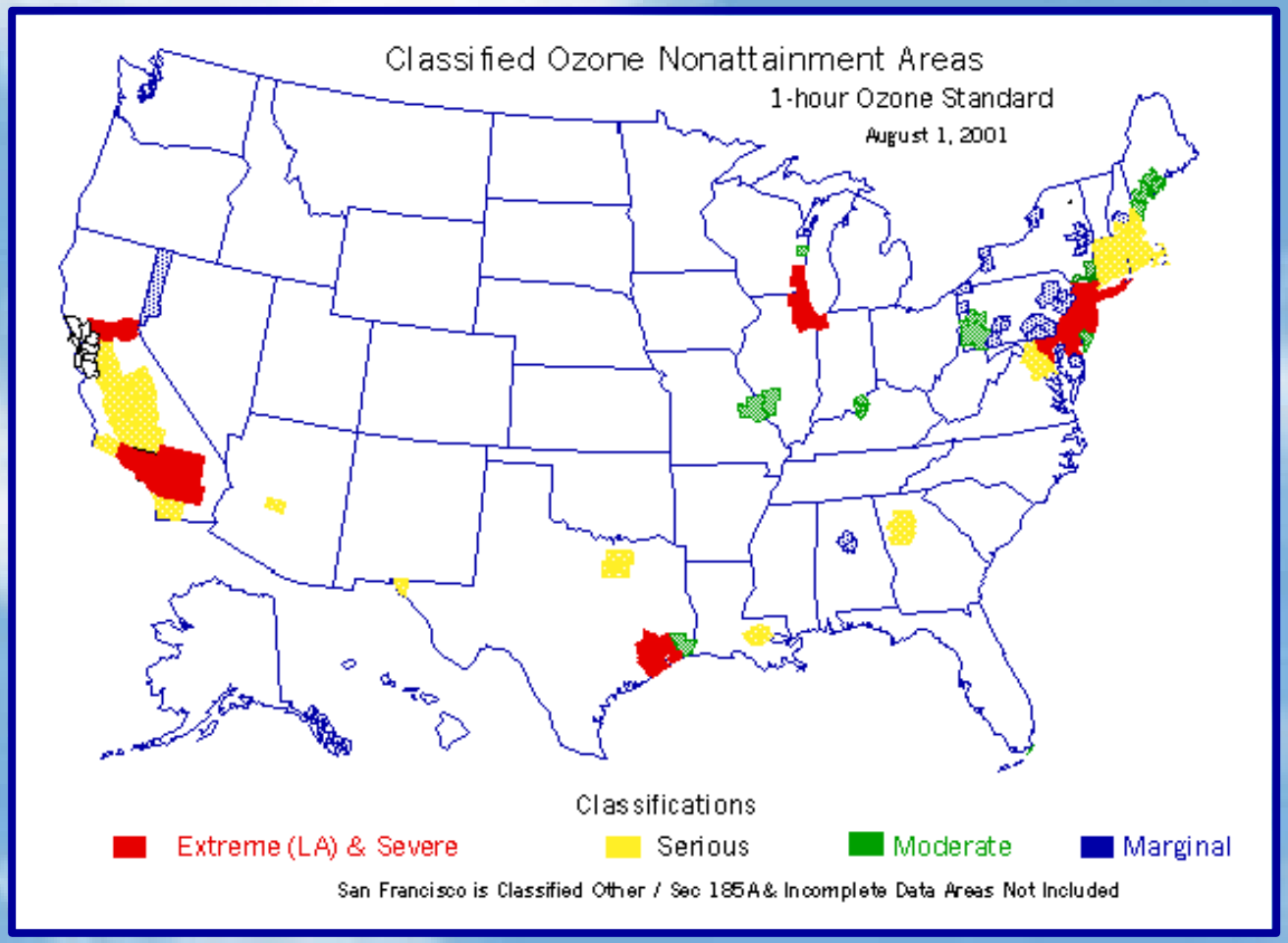
- Conclusion

Issues Impacting Commercial Marine Industry

Issues Impacting Marine Industry

- Marine Vessels Pollute the Air
  - For Twenty-Five Years - Attention Paid to Land Transportation
  - Now Maritime in the Spotlight
- International Maritime Organization (IMO) - Seeking to Ratify Annex 6 - Retroactively Influencing New Marine Engines
- CY 99 & 02 - Environmental Protection Agency (EPA) Marine Engine Regulations
- State Air Quality Plans
  - So. Cal. Voluntary Vessel Slow Down (NOx), Port Vol. to Increase 3X by ’20
  - Alaska Cruise Ships (Visible Smoke), Cruise Vessels on Shore Power
  - Port of Houston & State Implementation Plan (NOx)
  - Port of New York Dredging Issues (NOx), Fed Project Must Conform with SIP
- Highway Congestion and Fast Ferries (Effects on Air Quality)

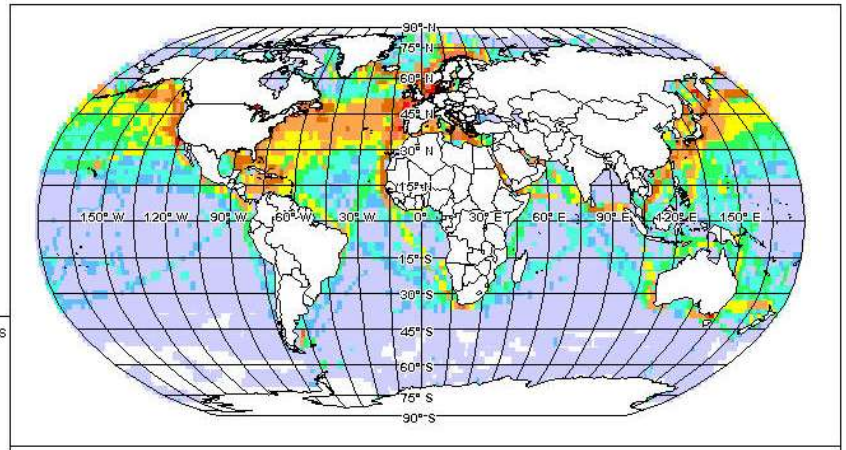
Ozone Nonattainment Areas

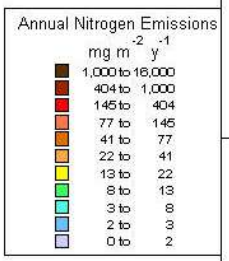


Source: EPA Office of Air & Radiation, AIR Database

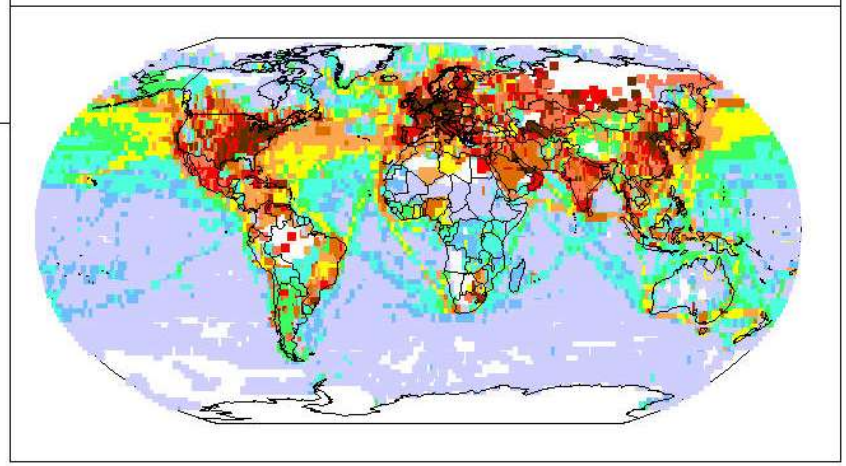
Geographic Distribution of Global Nitrogen Emissions

SEA nitrogen data only





SEA nitrogen data with GEIA data



Scale is defined to increase resolution for ocean regions; see Corbett, J. J. and P. S. Fischbeck (1997). .Emissions From Ships.. Science **278**(5339): 823–824; and Corbett, J. J., P. S. Fischbeck, et al. (1999). .Global Nitrogen and Sulfur Emissions Inventories for Oceangoing Ships.. Journal of Geophysical Research **104**(D3): 3457–3470

Program Objective

Program Objective

- Promote the application of energy efficient, low emission technologies to marine power plants

- **Outcomes**

- Protect Human and Natural Environment;
- Reducing Dependence on Foreign Oil and;
- Improving Competitiveness of Marine Transportation

Strategies for Achieving Objective

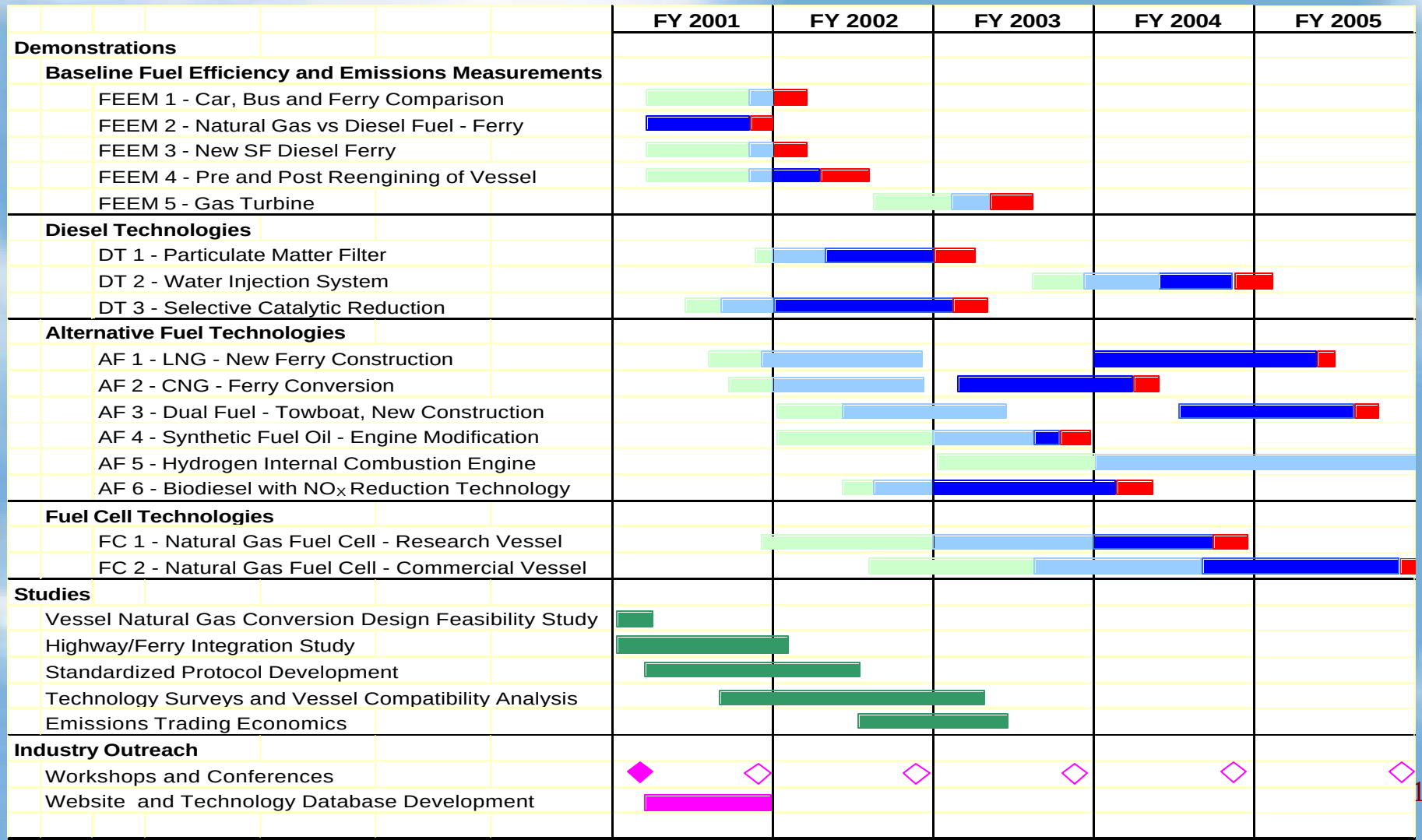
- Identify and study technologies to determine their applicability to marine applications
- Demonstrate energy and emission technologies on marine platforms
- Become the US repository of national and international maritime related energy and emission information
- Publicize and support useful energy and emissions findings via outreach programs

Program Plan and Status of Projects

Five Year Program Plan Overview

- Baseline Performance and Emission Testing
  - Existing Vessel Data and Measurement Techniques
- Diesel Retrofits
  - Emulsified Fuel, Water Injection, SCR, Particulate Traps
- Alternative Fuels
  - Natural Gas, Biodiesel, Hydrogen, Synthetic Diesel
- Advanced Technologies
  - Fuel Cells, High Efficiency Gas Turbines
- Supporting Studies
  - Technology Evaluations, Incentives and Emission Trading
- Industry Outreach
  - Newsletter, Conferences, Website, and Presentations

Five Year Program Plan



Diesel Engine Baseline Emission Measurements (Completed)

- Two Vessels
  - San Francisco and Norfolk
- Both 2 Stroke Detroits
- One Bench Grade Equip.
- One Handheld Equipment
- Measured at 4 Speeds
  - NOx 12 - 30 g/bhp-hr range
- WTA Tested 4 Stroke Eng
  - NOx Lower than Expected

Diesel Retrofit Technology Effectiveness (From Completed Literature Search)

Control Technology	% NO_X Reduction	Fixed Costs – Hardware, Installation, Design	Annual Costs – Maintenance, Operating, Fuel	NPV Costs (15% over 23 years)	Cost-effectiveness ($/ton NO_X)
Selective catalytic reduction	81	$285,000	$30,000	$477,000	$5,889
Water/fuel emulsion	42	$119,000	$32,000	$324,000	$7,714
Injector upgrade	16	$41,000	$24,000	$195,000	$12,188
Water in combustion air	28	$134,000	$36,000	$364,000	$13,000
Fuel pressure increase	14	$36,000	$29,000	$222,000	$15,857
Aftercooler upgrade	10	$12,000	$27,000	$185,000	$18,500
Injection timing retard	19	$250	$57,000	$365,000	$19,211
Engine derating	14	$34,000	$55,000	$386,000	$27,571
Exhaust gas recirculation	34	$3,500	$2,640,000	$16,896,000	$496,941

Corbett and Fischbeck study for large vessels

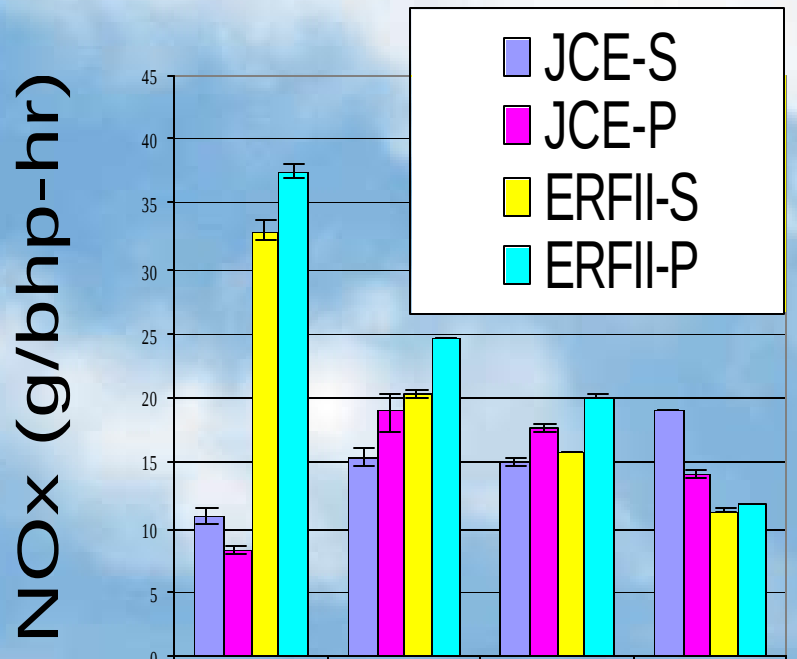
Diesel Retrofit Technologies Installed (Completed)

- Water in Air System
  - 24% NOx Reduction
  - No PM Reduction
  - No Fuel Penalty
- Emulsified Fuel (WTA)
  - 37% NOx Reduction
  - 42% PM Reduction
  - ----------
  - (Port of Houston)
  - 24 – 33% Nox Reduction
  - 25% Fuel Penalty ?
  - ----------
  - (CARB Certified)
  - 14% Nox, 63% PM

Alternative Fuels - Natural Gas
(Two Projects Completed)

- Regulatory Approved Conversion Design
  - KINGS POINTER - USMMA
  - ABS and USCG Review
  - CAT Diesel Conversion Needs Inlet Gas Valves
- Comparative Emission Tests
  - Diesel vs Natural Gas
  - Norfolk Sister Ferries

Natural Gas vs Diesel Comparative Test Results



		40% Spd	60% Spd	80% Spd	100% Spd
Natural Gas	JCE-S	10.8194333	15.37897239	15.0910283	19.13024704
	JCE-P	8.174634023	18.89920492	17.7258142	14.10820107
Diesel	ERFII-S	32.98840739	20.28816307	15.85482951	11.31313954
	ERFII-P	37.57725264	24.53683537	20.14538061	11.93625683

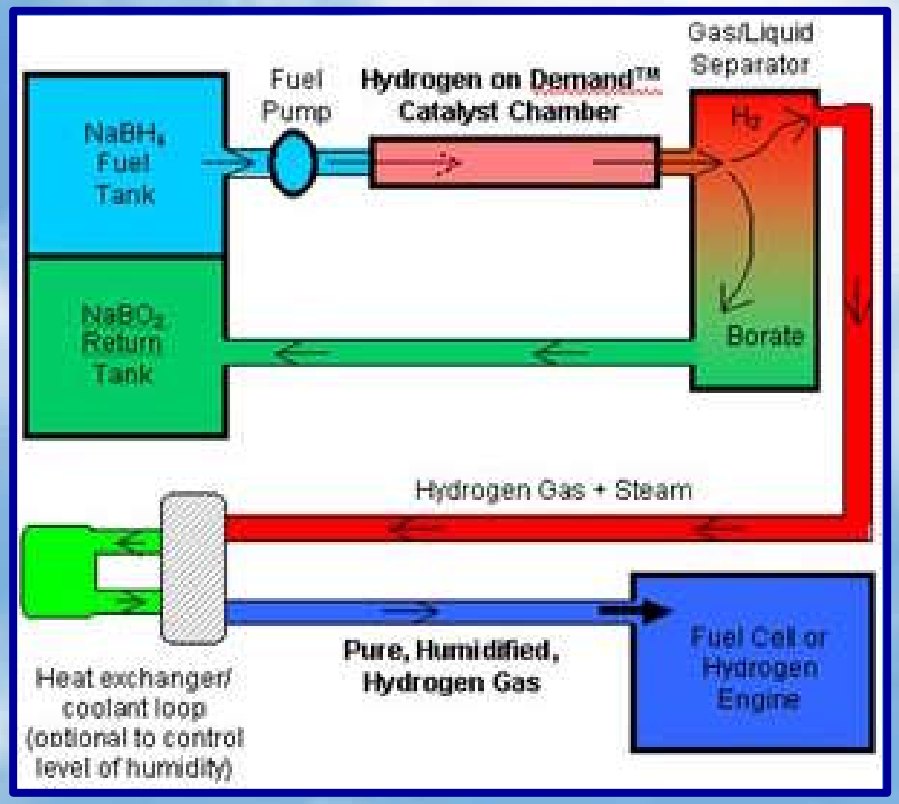
ERF II - Diesel, JCE - Natural Gas

- No NOx Reduction for Natural Gas
  - Except at slow speed
  - FYI - Studies project 1.3 g/hp-hr
- HCs High for Natural Gas
  - Methane up the stack
- PM Low for Natural Gas
- Fuel Penalties for Natural Gas
  - Added vessel weight
  - Higher fuel costs
  - Lesser efficiency
- High Conversion Capital Costs
- Right Engine for Application?

Alternative Fuel - Biodiesel
(Completed)

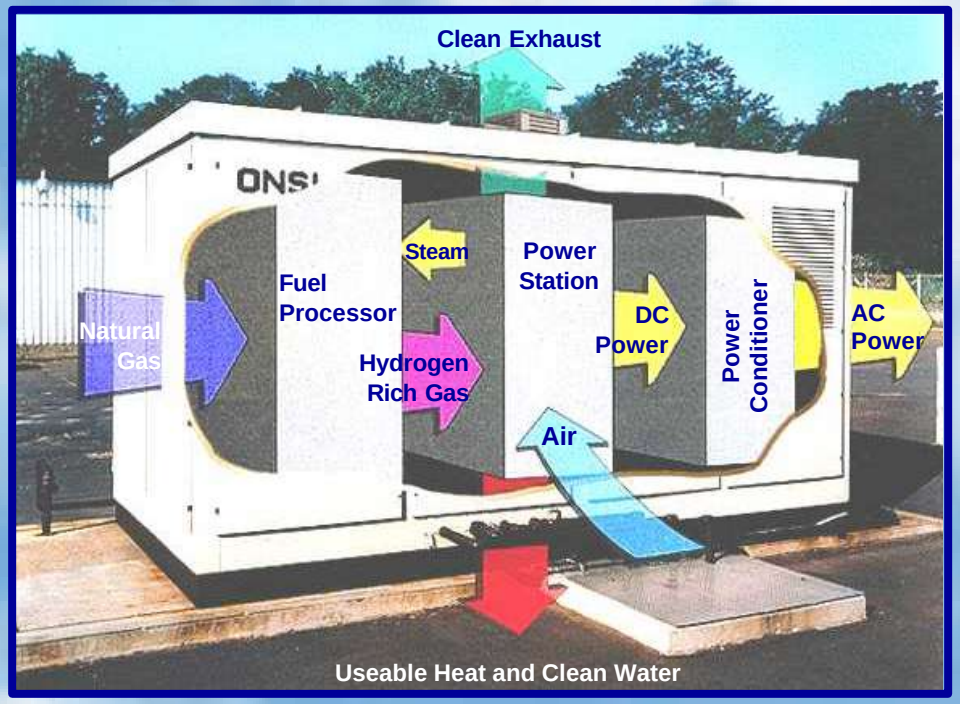
- San Francisco Bay Ferry
- Soy Based Biodiesel
- Renewable, SO_2 & $C0_2$ Friendly
- 20% Biodiesel
  - Nox Increase 10%
- 100% Biodiesel
  - NOx increase 24%
  - PM reduction 50%
  - Other Pollutants = Diesel Fuel
  - Combined w/Air Humidification - NOx reduced 12%
  - Fuel Penalty $.40/gallon

Alternative Fuel - Sodium Borohydride System (Regulatory Analysis Completed)



- Liquid Hydride
- High Energy Storage
- Benign Liquid Borax w/ H
- Separate Hydrogen via Catalyst Chamber
- Feasible for Fuel Cell and I.C. Engines
- Technically Viable but
  - How High ?? X Diesel Cost
  - Recycling Issues
  - Expensive/Rare Catalyst

Advanced Technology - Fuel Cell Marine Electrical Load Testing (Completed)



- 400 kW Plants (2 - 200s)
- Phosphoric Acid Fuel Cells
- Flywheel for Load Changes
- ABS, USCG, IEEE Gen Tests
  - Voltage Regulation
  - Frequency Regulation
  - Over-current
- Test Successful
- Flywheel and Power Conditioning Incur Efficiency Penalty

Supporting Studies - Car and Ferry Emission Comparisons (Completed)

- Study @ www.calstart.org, San Fran
- Cars getting cleaner for 30 yrs
- Use of ferries with technologies can improve area air quality
- Esp. lower speed ferries with treatmen
- High speed ferries NOx/PM challenged
  - Very high horsepower required
  - People drive cars to terminal
  - Often at 50% passenger capacity
- In California – Many new designs will be looking to new techs. or alternative fuels

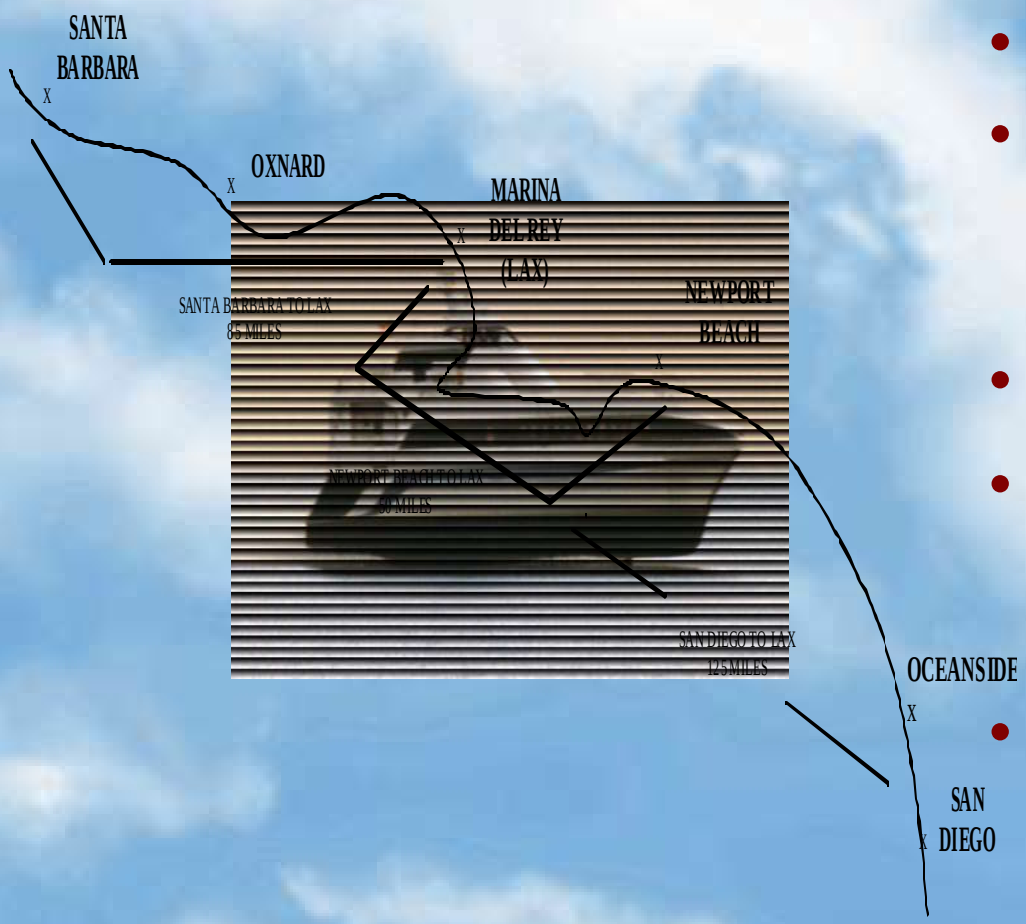
Supporting Studies - Emissions Measurement Protocol (In Progress)

- Which Protocol for Which Application
- International, Federal, State Agency
- Full Bench Test or Small Scale
- Transient vs Steady St
- University of Delaware
- Completion FY 03

Planned Studies & Demonstrations - Navy Engine Five Fuels & Technologies

- NAVSEA Philadelphia
- Commence FY 03
- Fuels - Nato F76, JP-5, Synthetic Diesel, Biodiesel, Special Blend
- Technologies - Air Humidification, Clean Cam, Small Sac Volume, Particulate Trap, Additive
- MARAD is One Co-Funder of Many

Planned Studies and Demonstrations - Hydrofoil Ferry Diesel Retrofit



- SCX Ferries San Diego
- Department of Energy and West Virginia University
  - Emission Testing
- One Year Demo
- Leased Hydrofoil
  - (4) Two-Stroke Detroit Diesels
  - Wet exhaust system
- Two Technologies?
  - Air Fumigation
  - Low Sulfur Diesel

Planned Studies and Demonstrations - Ultra-Low Emission Ferry Design

- Discussions with:
  - SCX, DOE, AQMD, GTI, etc
- High Speed / Hydrofoil
- Evaluate Best
  - Natural Gas, Diesel, Turbine, or Combined Plant
- Sponsoring a LNG Infrastructure Evaluation
- Results Applicable To all of CA

Planned Studies and Demonstrations - Large Vessel Diesel Retrofit

- Discussions with:
  - DOT, SCAQMD, Ports, CARB, SBCAPCD, Operators
- Category 3 Marine Engines
  - Primarily Slow Speed
- Technologies
  - Air Fumigation, Fuel Emulsion, Manufacturer Retrofits

Survey, Install, and Test Technologies in FY 03

Developing Project - Cargo Vessel Emission Trading

- Discussions with BP, WVU, and AQMD
- Coastal Cargo Vessel Operators Need Incentives to Retrofit
- Technology could reduce NOx by 33% or so
- NOx Credits Trade at $19,000/Ton
- If Vessel Generates 3 Tons / Visit:

  .33 x 3 x 20 (visits) x 19K = $380,000/yr
- Need to Evaluate Rules and Monitoring Requirements

Conclusions

- Foresee More Energy & Emission Pressures
- Technologies are Available at a Cost
- Incentives Needed to Drive Industry Implementation
- MARAD Program On Track
- Robust Outreach Effort is Underway
  - Conferences, Presentations, Newsletter
  - Web Site *www.marad.dot.gov/nmrec/energy&emissions*

F:\762\Energy and Emissions\Outreach\Presentations

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