Next Generation Marine Vessels
Fuel Cells and Gas Turbines

Presented at

Workshop on

Maritime Energy and Clean Emissions

Washington, DC

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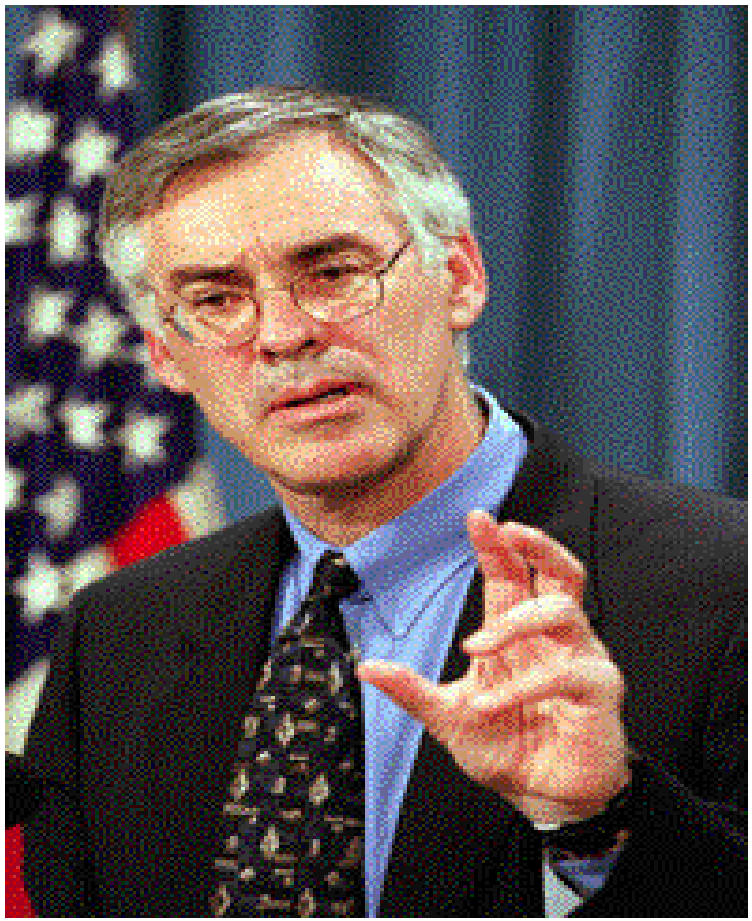
Diane Hooie, Senior Advisor

Strategic Center for Natural Gas

Navy Recognizes Benefit of Electric Drive

"The key design element of integrated power and electric drive is a single source generator for the requirements of all ship's power needs, including propulsion."



Roadmapping Participants

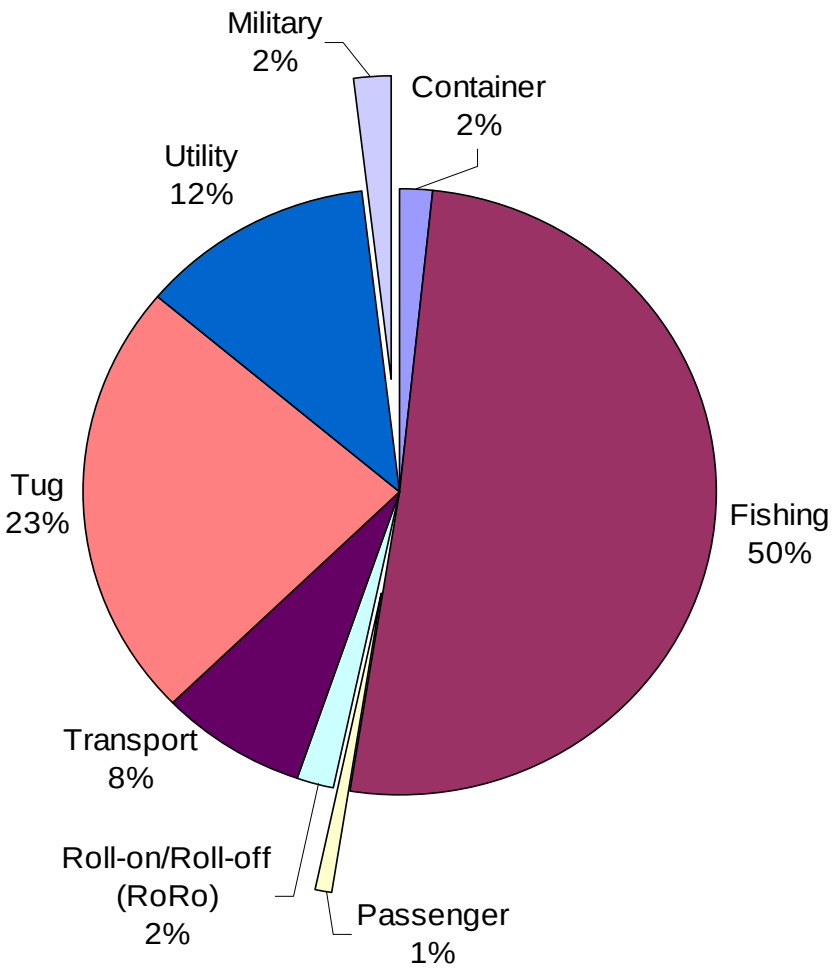
- **Government**
  - DOE/NETL
  - ONR
  - NAVSEA
  - NAVAIR
  - TACOM
  - USCG

- **Industry**
  - NNS
  - Bath Iron Works
  - Ingalls

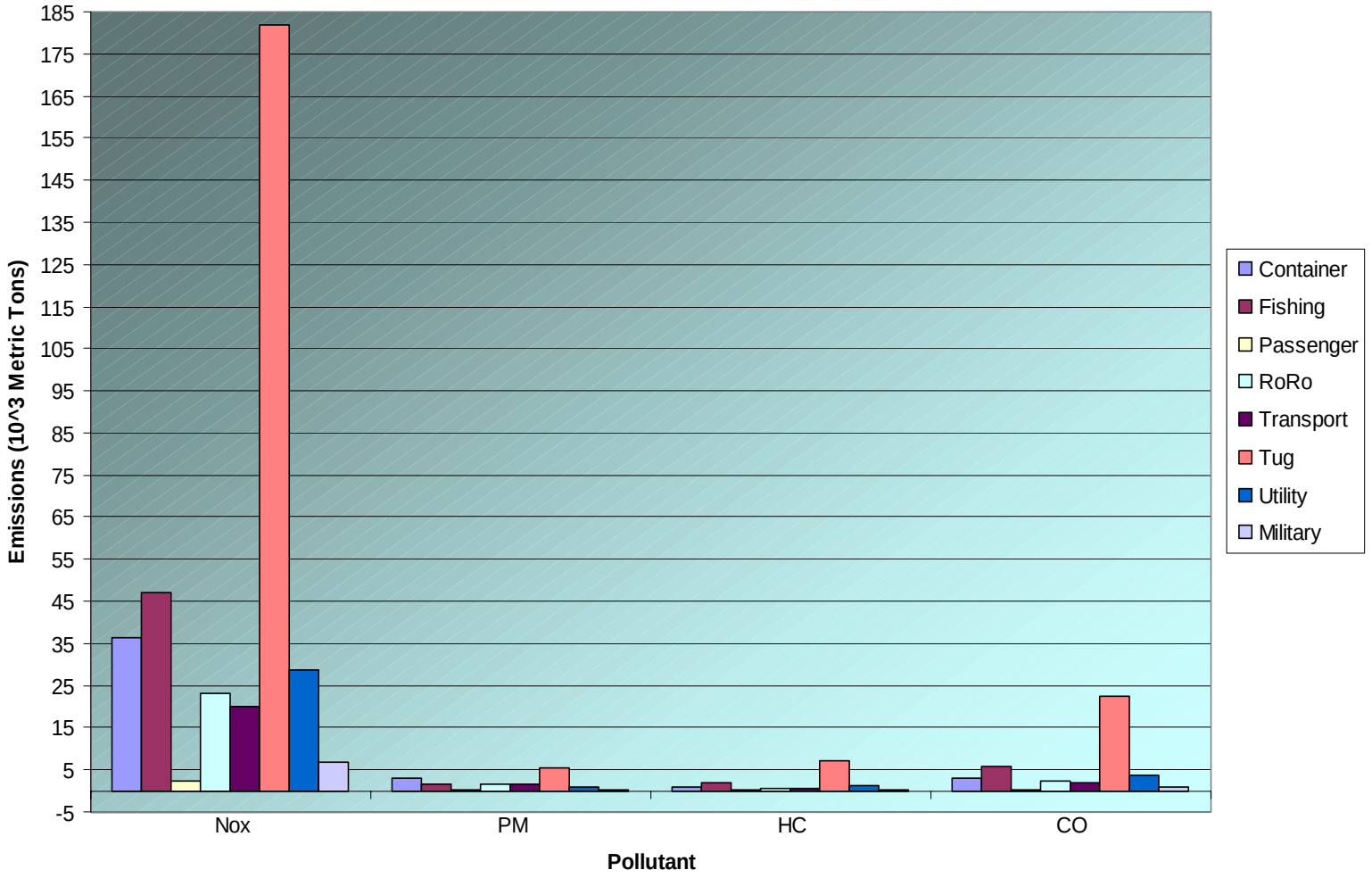
Goals

- Optimize programs
- Leverage research dollars
- Identify role of each agency and participant.

Ships by Type

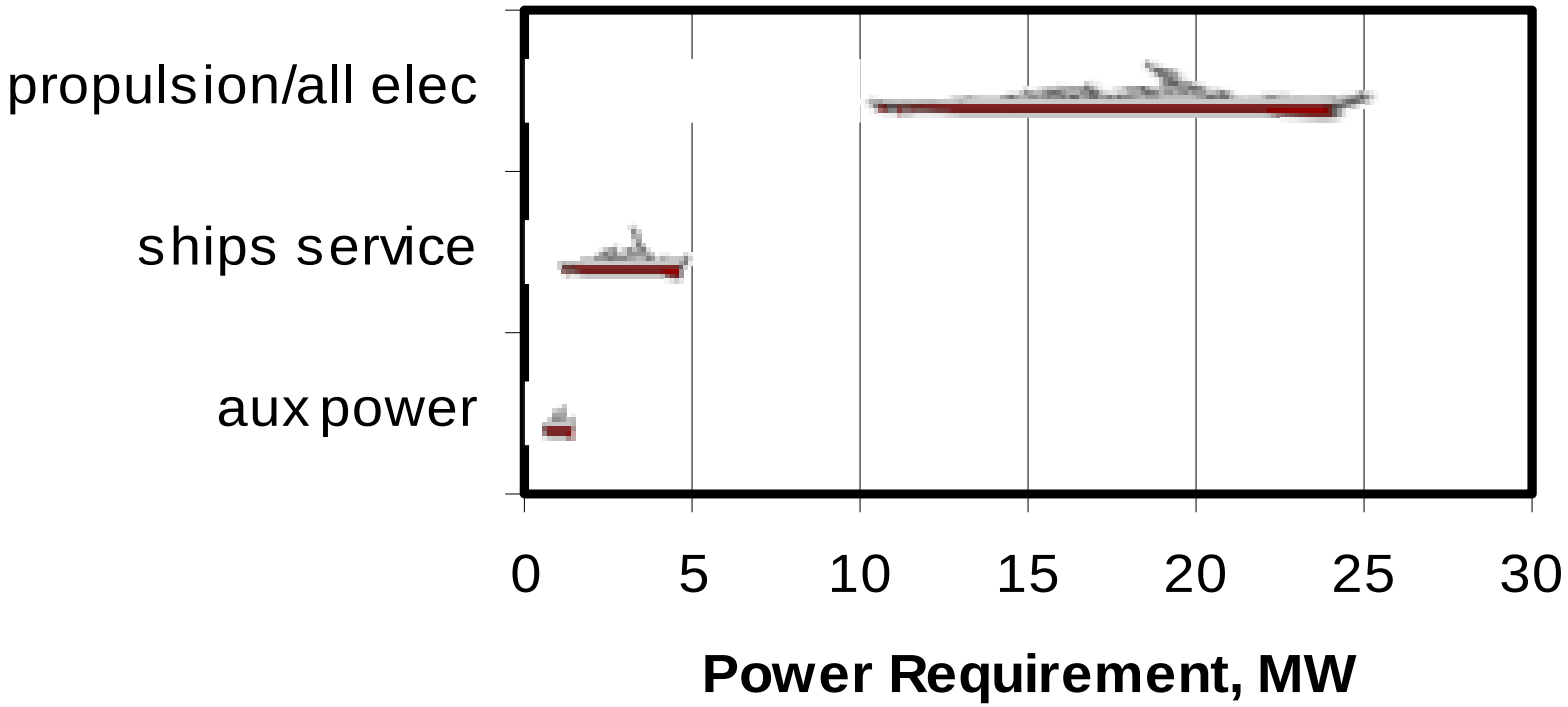


Emissions by Type

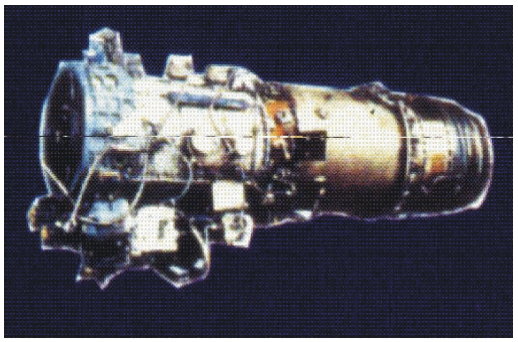


Source: EPA

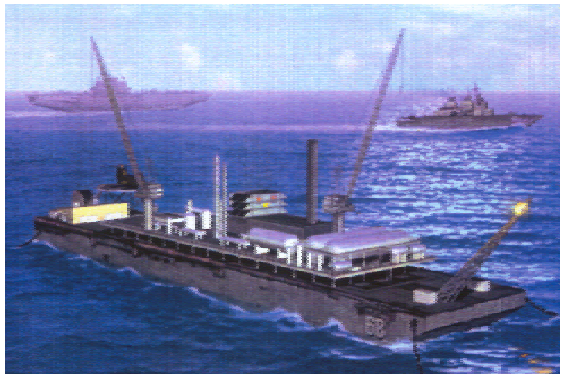
Key Power Plant Sizes Identified



Technologies of the Future

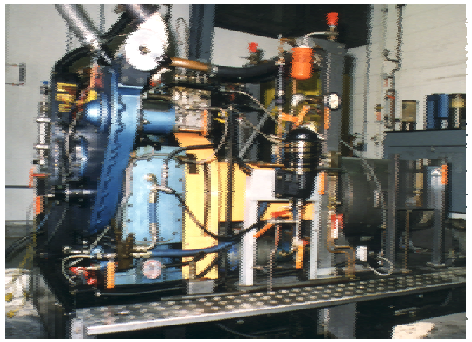


Turbines



Fuels

Fuel Cells

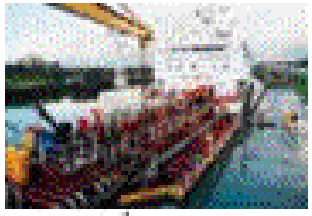


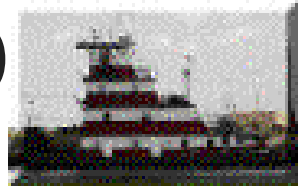
Engines

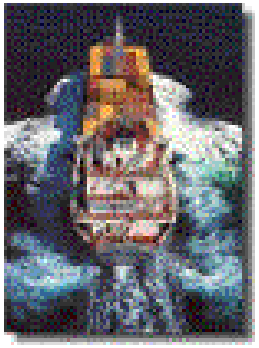
Hybrids

Turbines for Marine Applications

- **Inland Waterways(600-3760kW)**
  - Microturbines, IC Engines, Hybrids
- **Inland and Coastal(2255-9022kW)**
  - Industrial GT, Engines, Hybrids
- **Ocean Going Ships(6015-67,669kW)**
  - Aeroderivatives, Industrial GT, Hybrids
- **Fast Container Ship(150,000-375,000kW)**
  - Large Aeroderivatives







DER "Prime Movers"

Examples

Advanced Turbines

Reciprocating Engines

Photovoltaics

Fuel Cells

Wind

Microturbines

Advanced Microturbines

2000

17-30% Efficiency*

2007

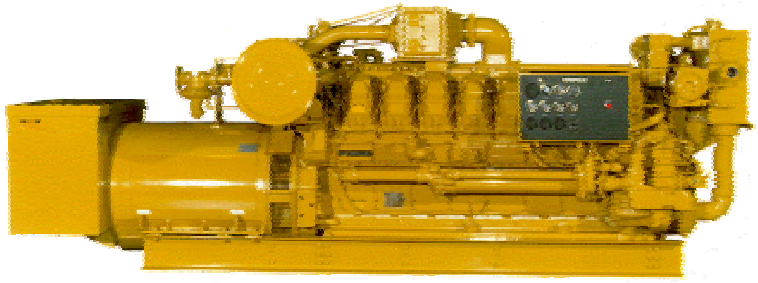
40% Efficiency*

* Lower Heating Value

Reciprocating Engines

2000

25 - 40% Efficiency



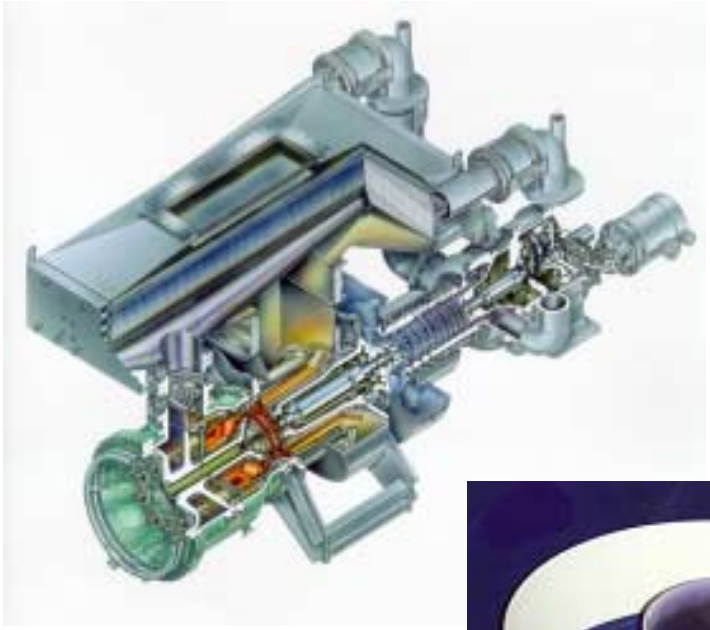
2007

50% Efficiency

Industrial Gas Turbines

1992

Double digit ppm NOx



2010

<5 ppm NO_x

DOE/NETL Products Availability

Turbine Technologies

Year	Merc 50	Aero-gas	Aero-gas	Micro-turbine	Ram-jet
2000 *now*	$400, 4 MW 41%, Demo test	$500, 25 MW 42%, Commercial	$500, 42 MW 42%, Commercial	$700, <100 kW 30%, Commercial	$250, 5 MW 50%, Tested
2001	Commercial				
2002					
2003					15 MW, 50% Prototype
2004		30+ MW, 50% Demo/Test			
2005				100 kW to 1 MW 40%, Demo/Test	15 MW Commercial
2006					
2007				Commercial	5–15 MW 60%, Test
2008					

R&D Activities: First Generation Fuel Cell – Turbine Hybrids

2000

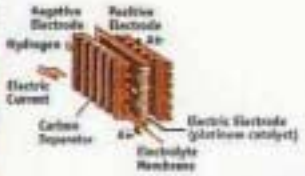
- 60% Efficiency (LHV)
- <1 ppm NOx

- Advanced systems integration
-Improved control systems

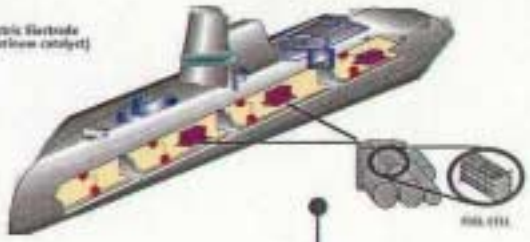
2007

- >70% Efficiency (LHV)
- <<1 ppm NOx

Fuel Cell Power Ranges



SSFC



UUV/MCM

10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^7

Power (Watts)

MEMS

"BA5590"

Home Electricity

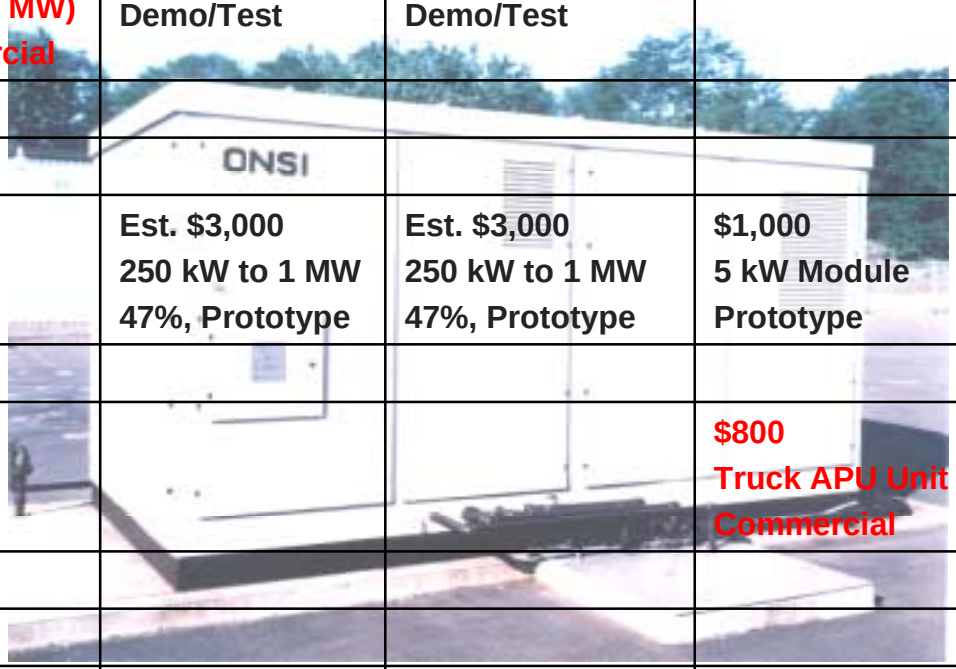
UAV

SSN Emergency Power

DOE/NETL Products Availability

Fuel Cells and Hybrids

Year	PAFC	MCFC	SOFC	SSFC	Hybrids
2000 *now*	$4,250 200 kW (modular to approx. 1.2 MW) 40%, Commercial	R&D Prototype 250 kW, 47% Demo/Test	R&D Prototype 100 kW, 45% Demo/Test		R&D Prototype 25 kW, 57% Demo/Test
2001					
2002					
2003		Est. $3,000 250 kW to 1 MW 47%, Prototype	Est. $3,000 250 kW to 1 MW 47%, Prototype	$1,000 5 kW Module Prototype	$3,000 250 kW to 1 MW, 60% Demo/Test
2004					
2005				$800 Truck APU Unit Commercial	
2006					
2007					
2008		Est. $1,500 ≤ 3 MW Commercial	Est. $1,500 ≤ 3 MW Commercial	$400 Lux. Vehicle APU, Commercial	$1,300 3 MW, 74% Commercial



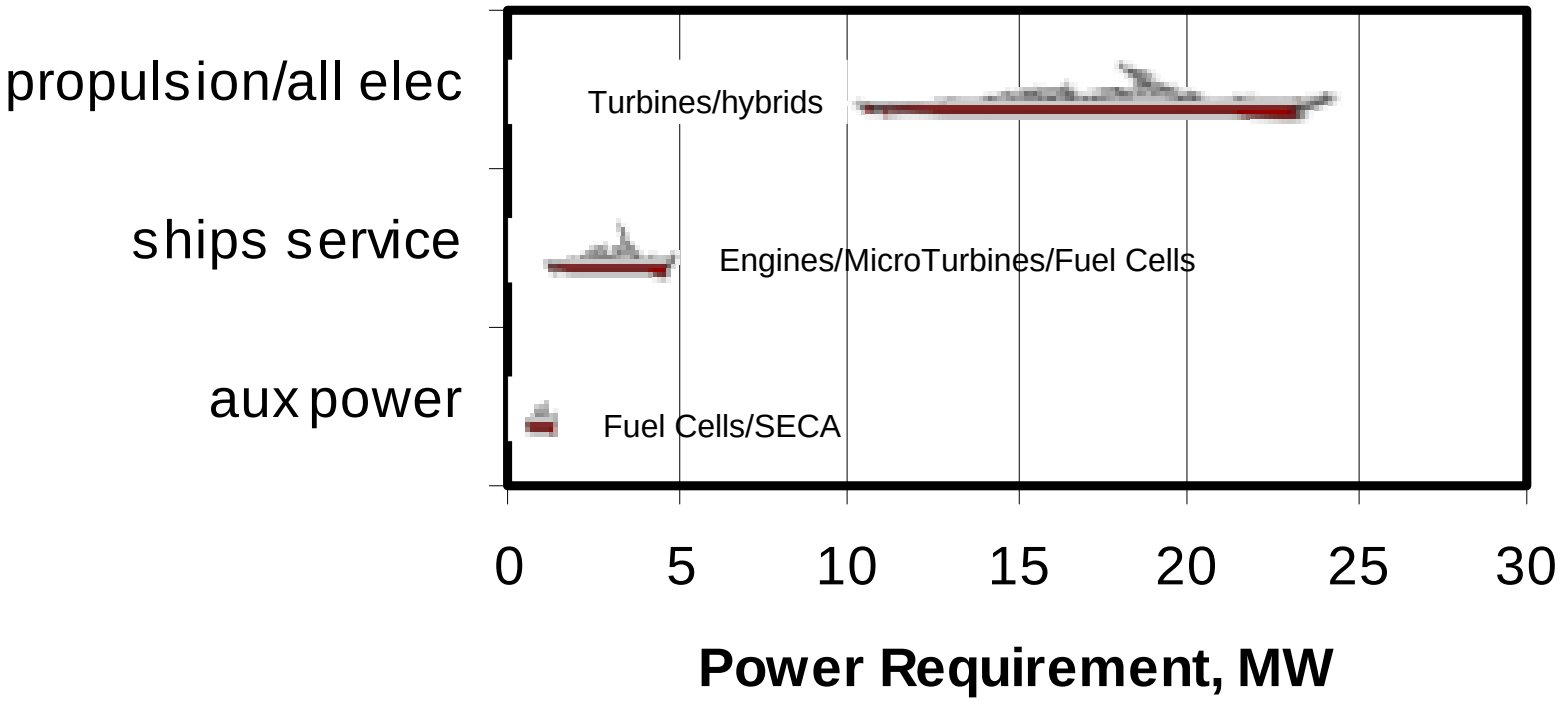
Emission Reduction Key

(emission goals)	Fuel Cells (45-55%)	Gas Turbines (45-55%)	Hybrids (50-85%)*	2007 Regulations (2030)
NOx, ppm	Negligible	<5 ppm	Negligible-< 5 ppm	<11 g/kW-hr (-24%)
SOx, ppm	Negligible	Negligible	Negligible	(<15 ppm)
Particulates	Negligible	Negligible	Negligible	<0.5 g/kW-hr (-12%)
CO	<5 ppm	<10 ppm	Negligible to < 10 ppm	5 g/kW-hr

Hybrids are dependent upon configuration

Negligible = < 1 ppm

Technologies Match Needs

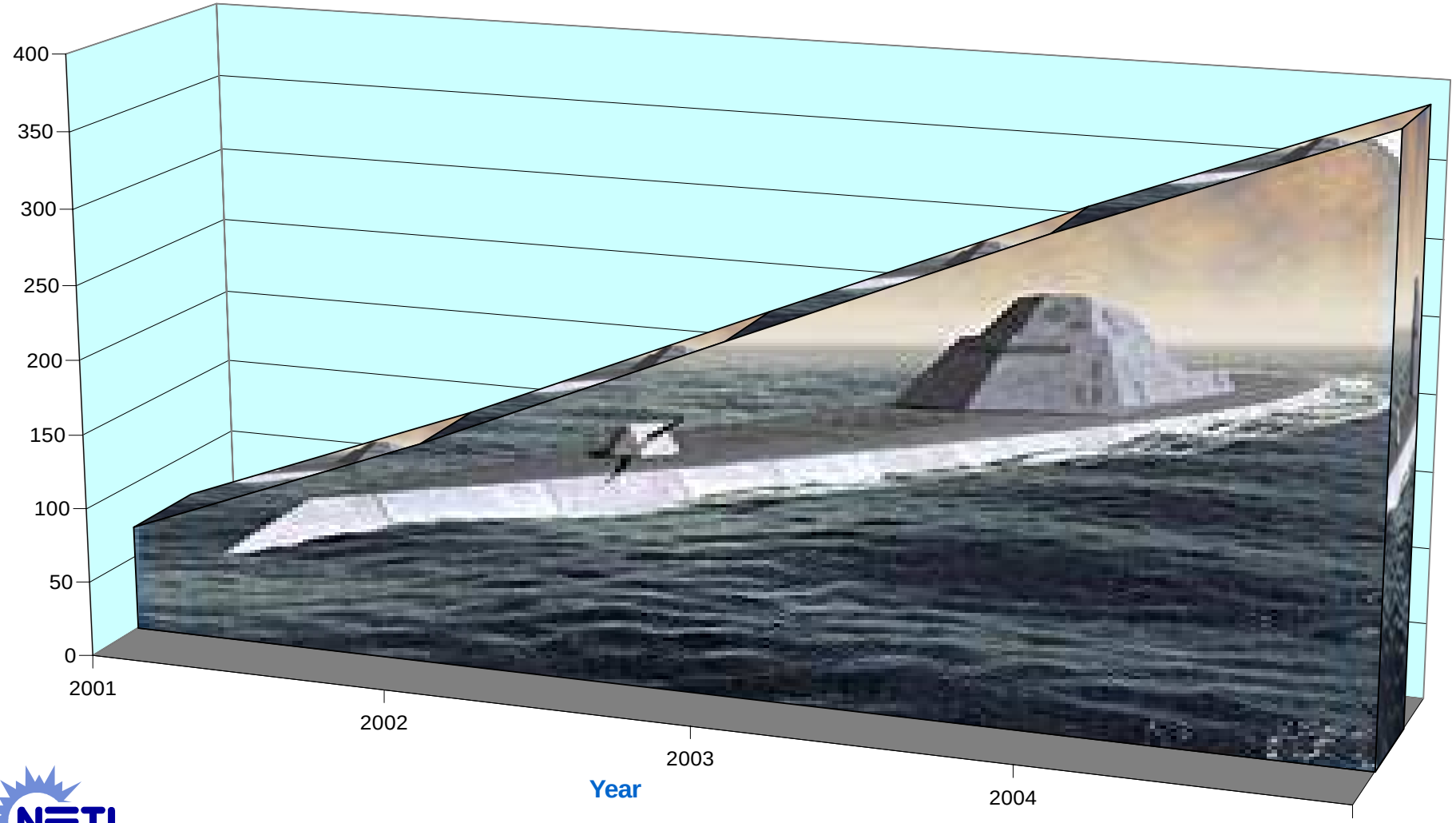


Panamax: First Fuel Cell Powered Ship?

Cruising Italian-American Style

Marine Vessel Initiative Budget Estimate

Cumulative Budget Needs, $Millions



DOE: Opening New Frontiers in Propulsion and Ships Service Power