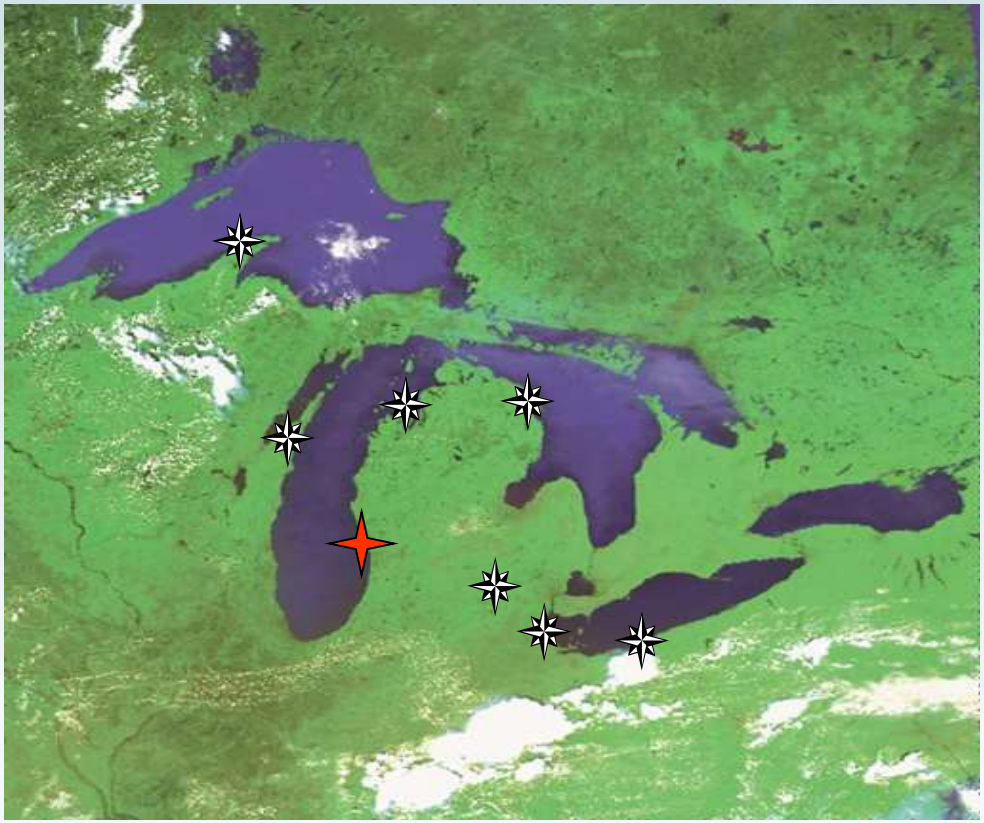
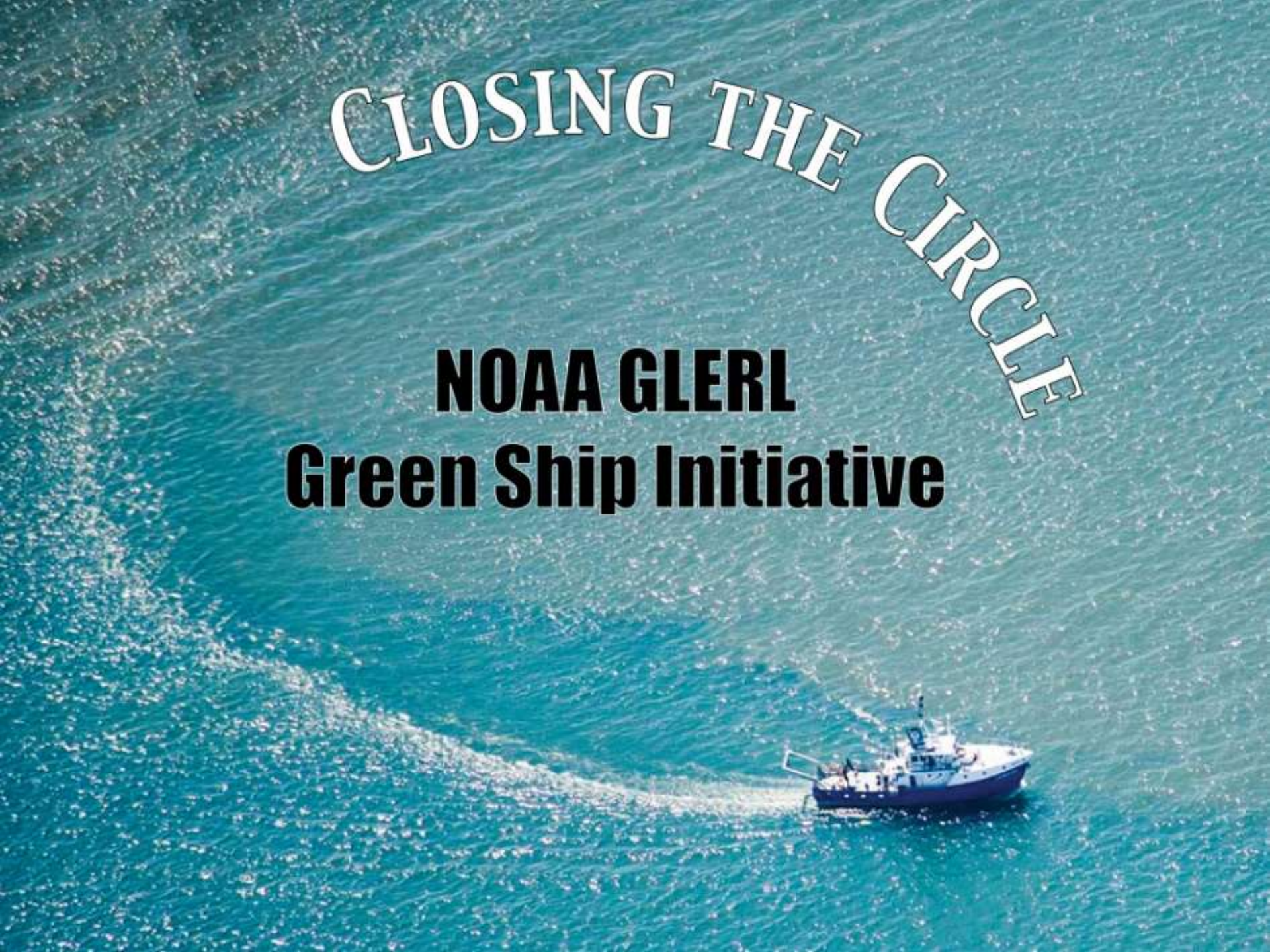
Developments in Marine Alternative Fuels



Dennis Donahue
NOAA-GLERL
Marine Superintendent


CLOSING THE CIRCLE
NOAA GLERL
Green Ship Initiative

Marine Environmental Stewardship

Compliance | **Energy** | Platforms | Operations

Management | **Emissions** | **Sustainability**

ULSD | Bio Diesel | Blends | Hybrids | CNG LNG | Bio Methane | Fuel Cells | ?

Technical Uncertainties | Mission Conflicts | Infrastructure

Capital Investment | Speculative Business Model | End User Economics

Green Ship Initiative
Guiding Principles

1. Use Scale to an Advantage
2. Find Enhancements to Mission
3. Find Added Operational Value
4. Engage Allied Industries
5. Refine Standard Operations
6. Create Flexible Systems
7. Anticipate Emerging Technologies
8. Address Regional Players and Perspectives

GLERL B100 Fleet

Successful Strategy

- **Conventional Test Methodology**
  - **Stabilize** the process
  - **Maintain** process parameters
  - Introduce one variable (Fuel)
  - Measure process response
- **"Measure of Equivalency"**

- **LMFS Test Methodology**
  - ***Optimize*** the process
  - ***Adjust*** Process variables to reflect what is known about the test material
  - ***Monitor*** process controls that could be impacted by unknown attributes
  - ***Measure*** changes to output, process and effort
  - ***Readjust*** based upon experience
- **"Measure of Effort for Optimum Results"**

Technology Transfer

Federal Green Fleet Working Group - 2010-14

- Multi- agency
- Shared interest in alternative fuels
- Consolidate experience / resources
- Establish cooperative projects
- Establish protocols
- Advance renewable technologies

Army Corps of Engineers – 2011-14

- B100 Feasibility Study
- Package NOAA experience
- Emphasis on engine loading

MARAD – 2011-13

- 2nd Generation Biodiesel
- T-AGOS platform trials
- Emphasis on protocols

CMTS

U.S. Committee on the Marine Transportation System

Cabinet Level Focus - 2013

- Coordination of all Federal Interests

Technology Transfer

Green Ship Working Group

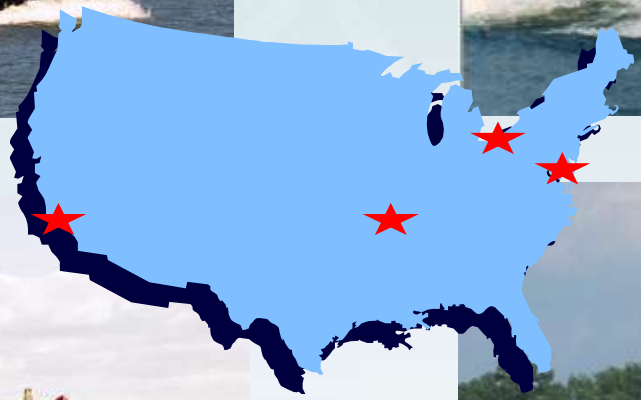
- 150 + Vessels
- 1M+ gallons annually
- Equipment development
- Shared expertise
- Logistic support

- Broad spectrum of vessels
  - Government
  - Research
  - Passenger
  - Fishing
  - Tug / Transport
  - Utility / dredge

USACE – B100 Test Vessels -2011-2014

Grizzly

Mike Donlon



DB-5

Pathfinder

Conclusions

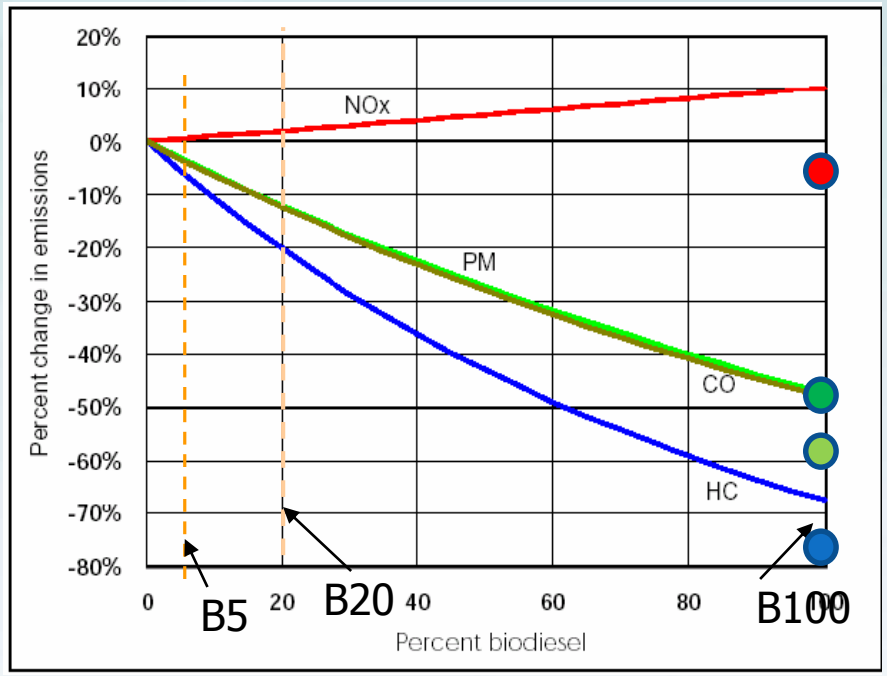
Operations

- No adverse impacts
- Availability and quality of fuel confirmed
- Operators and crew prefer B100
- No cold flow issues to date
- Material compatibility issue on 1 vessel (hoses)
- No observed microbial growth, lube oil dilution, water separation, and storage stability
- No filter plugging
- No issue with switch fueling (biodiesel to diesel)

US Army Corps of Engineers

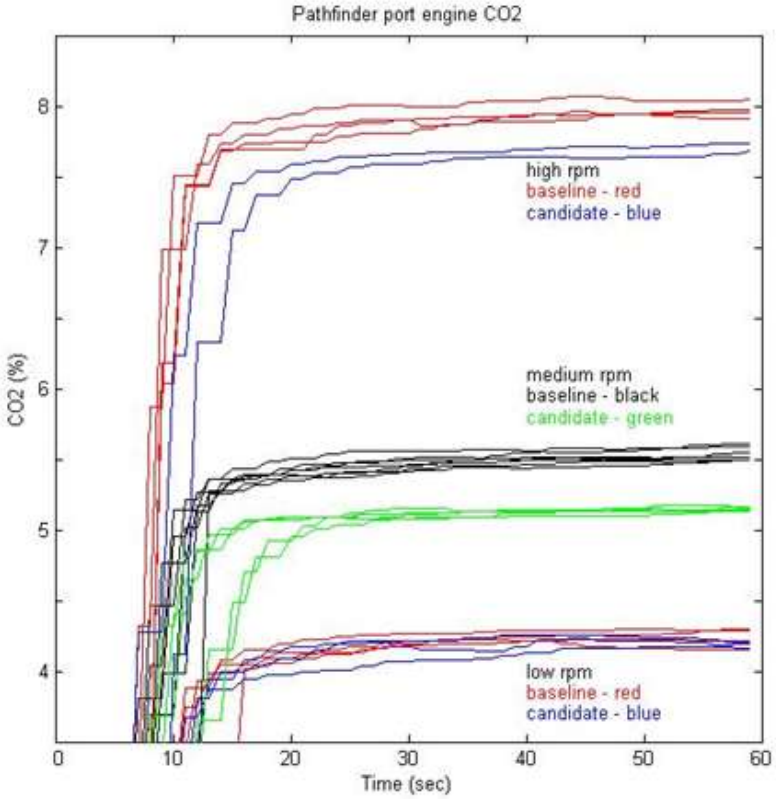
B100 Real World Value

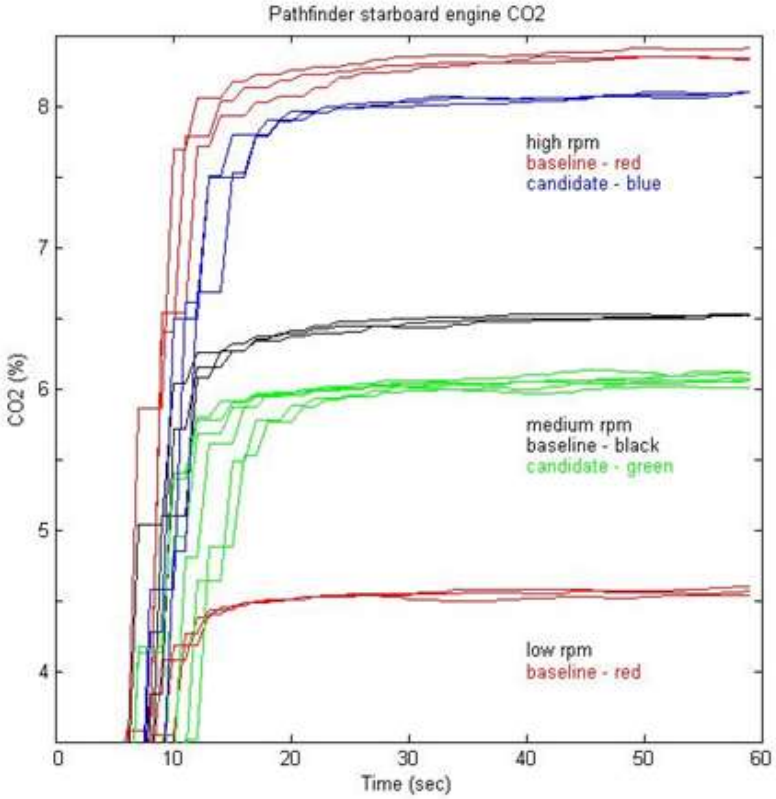
- "Legacy" Engine Performance
- No Blending Cost or Issues
- Lubricity
- Emissions
- Detergency
- Health and Safety
- Cost Savings
- Quality Control
- Local Feed Stocks



NOAA – Army Corp of Engineers - CO_2

- Higher or equal for biodiesel at low RPM
- Lower for biodiesel at mid RPM
- Lower for biodiesel at high RPM

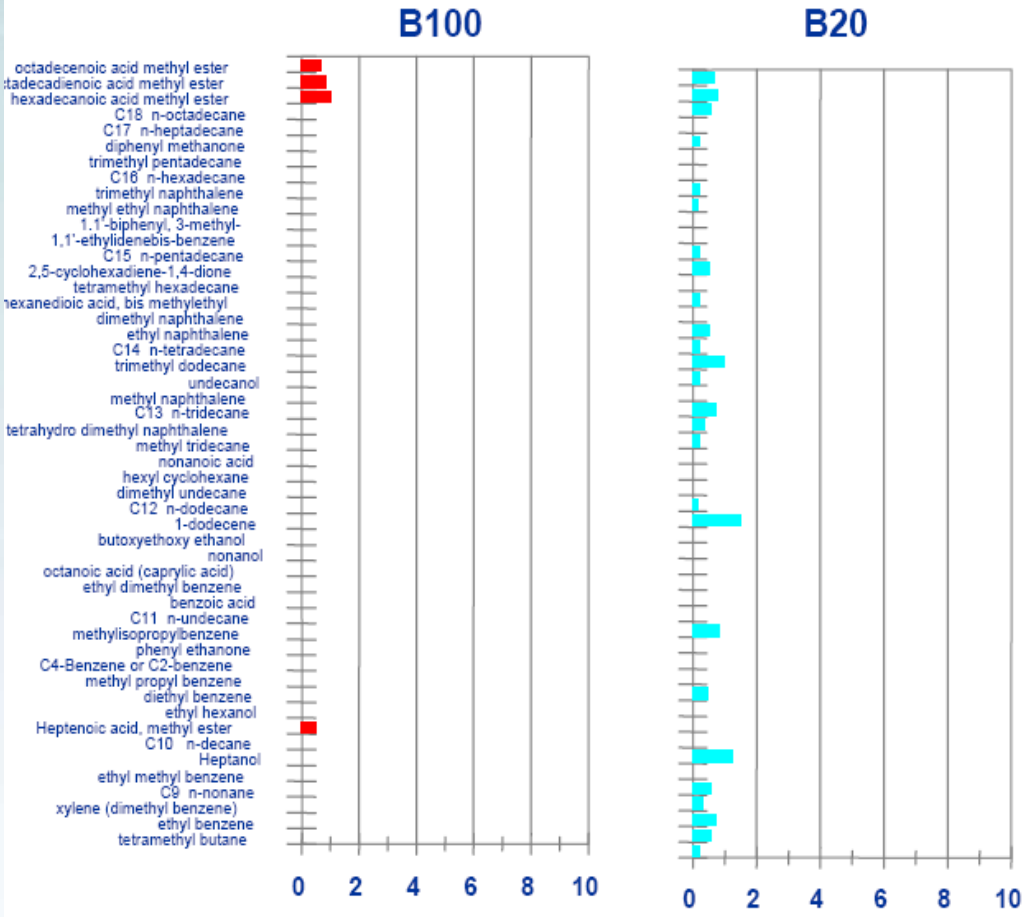




Added Value - Crew Health

Reduced carcinogens Less offensive odor Reduce seasickness

Tier 1 Health Effect Data

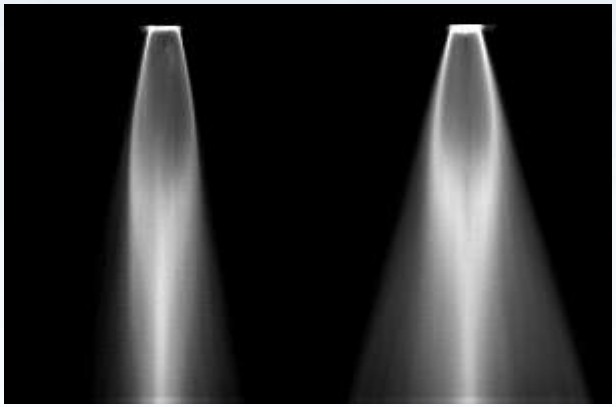


Tier I Health Effects Data supplied by SWRI, 1997-8

Added Value – B100 Detergency

#2 Diesel 4 Years	B100 1 Tank Turn	B100 3 Tank Turns	B100 One year

Tank Bottom Samples



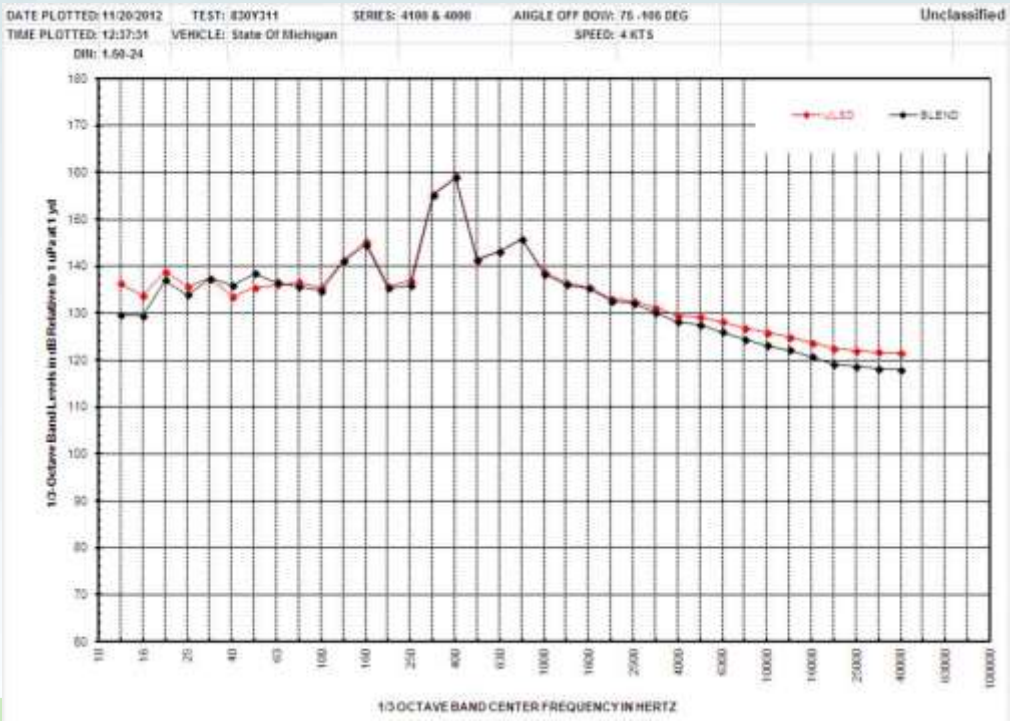
Improved Injector Performance

Lubricity

Fuel Property	Diesel	Biodiesel	Units
Fuel Standard	ASTM D975	ASTM D6751	
Lower Heating Value	~129,050	~118,170	Btu/gal
Kinematic Viscosity @ 40o C	1.3 - 4.1	1.9 - 6.0	mm2/s
Specific Gravity @ 60o C	0.85	0.88	kg/l
Density	7.079	7.328	lb/gal
Water and Sediment	0.05 max	0.05 max	% volume
Carbon	87	77	wt. %
Hydrogen	13	12	wt. %
Oxygen	0	11	wt. %
Sulfur	0.0015	0.0 to 0.0024	wt. %
Boiling Point	180 to 340	315 to 350	o C
Flash Point	60 to 80	130 to 170	o C
Cloud Point	-15 to 5	-3 to 12	o C
Pour Point	-35 to -15	-15 to 10	o C
Cetane Number	40 to 55	47 to 65	
Lubricity SLBOCLE	2,000 to 5,000	>7,000	grams
Lubricity HFRR	300 to 600	<300	microns

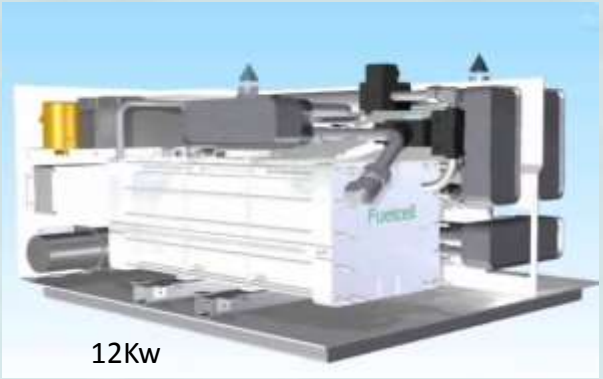
MARAD – 2nd Generation Biodiesel

- Navy/EPA/MARAD test protocols
- Large scale trial of HR-D (50% petroleum/50% algae)
- Blended Sugar based bio / #2 Diesel (30%/70%)
- Trial translates to large Research Vessels
  - 4 Caterpillar D398 engines
  - 450 Hours
  - 10,000 gallons
- 2012 Under-water sound transmission
- 2014 Scripps Research Institute
  - Higher Bio blends
  - Full operational conditions



Bio Diesel - Near Term

- Apply Biodiesel to fuel cell technology
- Explore Biodiesel from catalytic reactors
- Develop regional partnerships
- Develop supply of alternate feed stocks
  - Animal fat
  - Bio waste
  - Cellulose byproducts

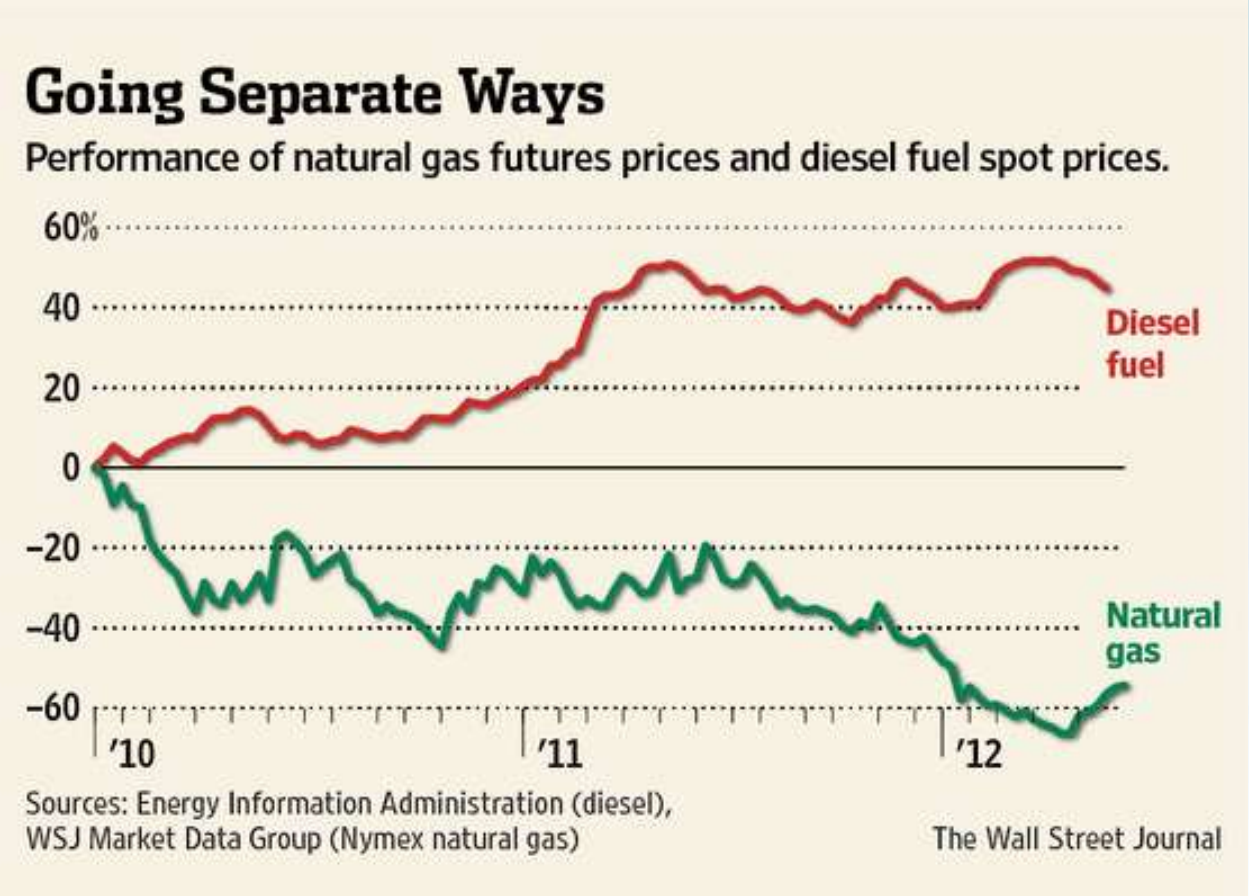

12Kw

Marine Alternative Fuels Initiative
Focus : Natural Gas

- **United States Department of Agriculture (USDA)**
- **United States Department of Commerce (DOC)**
  - Economic Development Administration (EDA)
  - International Trade Administration (ITA)
  - National Oceanic and Atmospheric Administration (NOAA)
- **United States Department of Defense (DOD)**
  - United States Army Corps of Engineers (USACE)
  - United States Navy (Navy)
  - United States Transportation Command (TRANSCOM)
- **United States Department of Energy (DOE)**
- **United States Department of the Interior (DOI)**
  - United States Fish and Wildlife Service (USFWS)
  - Bureau of Ocean and Energy Management (BOEM)
  - Bureau of Safety and Environmental Enforcement (BSEE)
  - United States Geologic Survey (USGS)
- **United States Department of Justice (DOJ)**
- **United States Department of Labor (DOL)**
  - Occupational Safety and Health Administration (OSHA)
- **United States Department of Homeland Security (DHS)**
  - Transportation Security Administration (TSA)
  - United States Coast Guard (USCG)
  - Federal Emergency Management Agency (FEMA)
- **United States Department of State (DOS)**
- **United States Department of Transportation (DOT)**
  - Office of the Secretary of Transportation (OST)
  - Research and Innovative Technology Administration (RITA)
  - Saint Lawrence Seaway Development Corporation (SLSDC)
  - Maritime Administration (MARAD)
  - Federal Railroad Administration (FRA)
- **Department of Treasury (Treasury)**
- **Federal Maritime Commission (FMC)**
- **National Transportation Safety Board (NTSB)**
- **Environmental Protection Agency (EPA)**

Natural Gas

- Cleaner Burning
- Cost Advantage



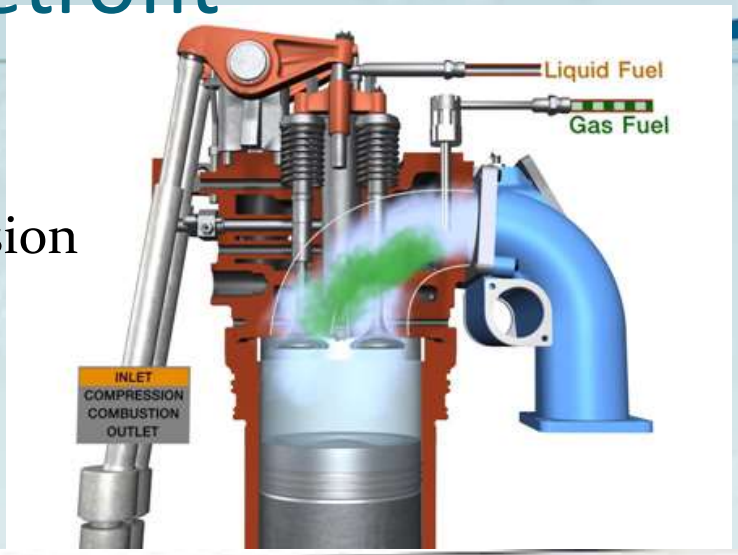
NG Marine Fuel – Scale Matters

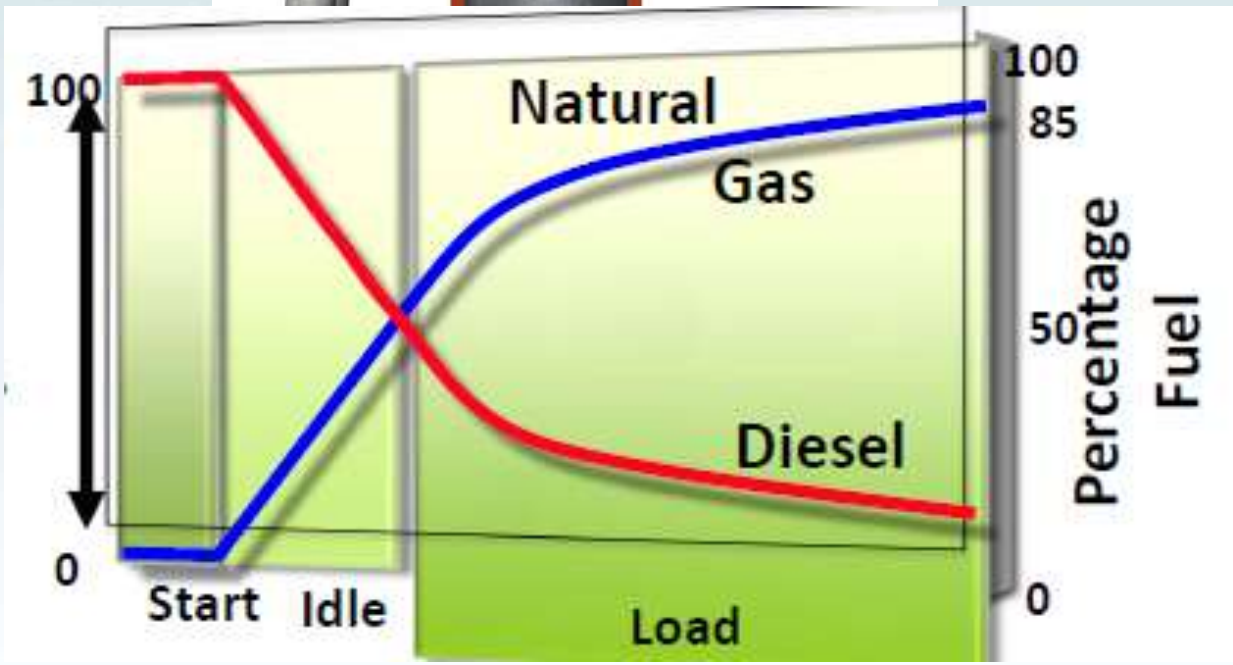
- New Build / Repower
  - LNG only
  - Dedicated NG engines
  - Infrastructure dependent
  - Significant capital
  - Large commercial platforms

- Retrofit Dual Fuel
  - CNG Centered / LNG option
  - Retain full diesel capability
  - Operator fueling stations
  - "Work boat" economics
  - Scaled to vessel architecture

Dual Fuel Engine Retrofit

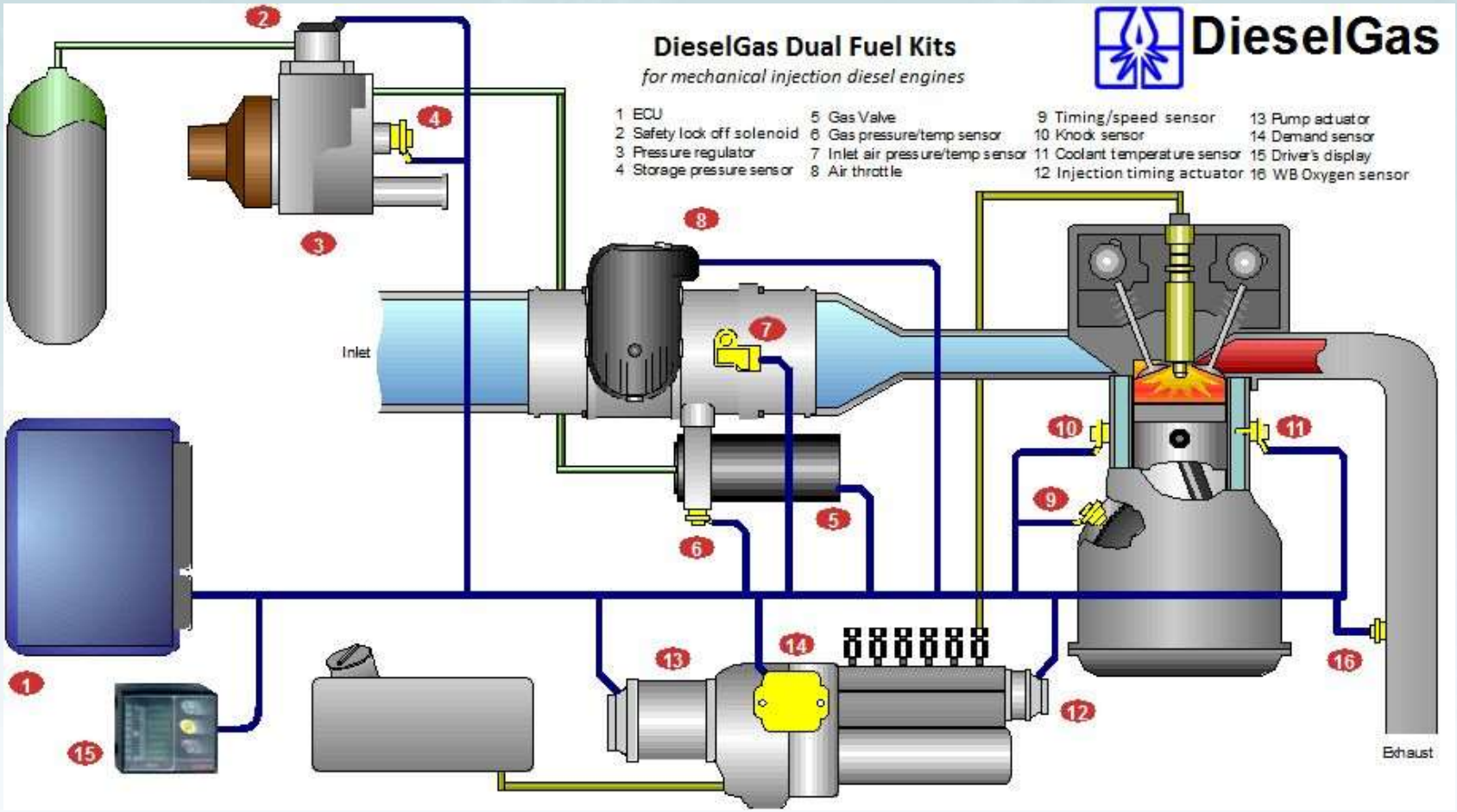
- Gas ignition by diesel compression
- No change to base engine
- Run on 85% CNG
- Run on 100% diesel fuel
- Fully automated





Mechanical and Electronic Controlled Engines

Legacy and Tier Engines



Dual Fuel Option

Benefits

- Significant Cost Savings - $1 / GDE
- Reduced Emissions
- Low Investment - 2yr payback
- Low Risk – Diesel system remains unchanged
- Increased Range
- Provides Dock Fueling Option
- Lower Radiated Noise
- Allows for emerging gas technologies

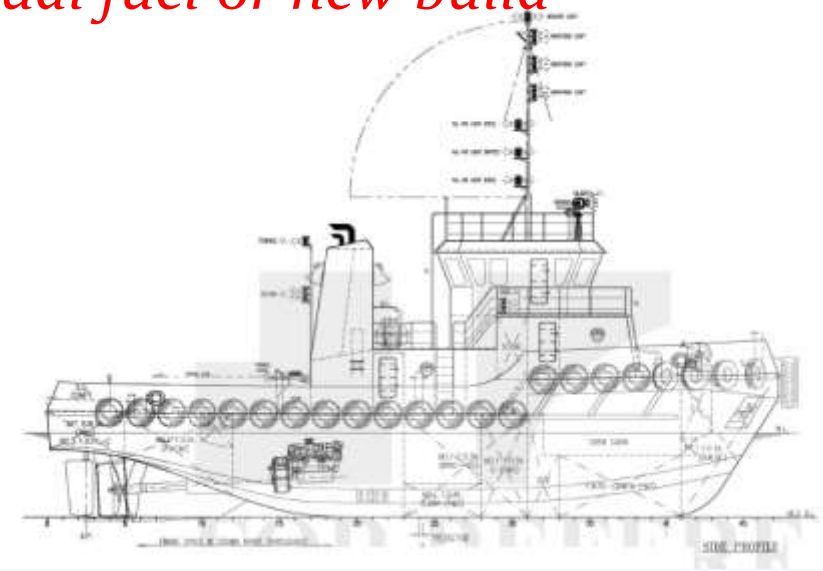
Challenges

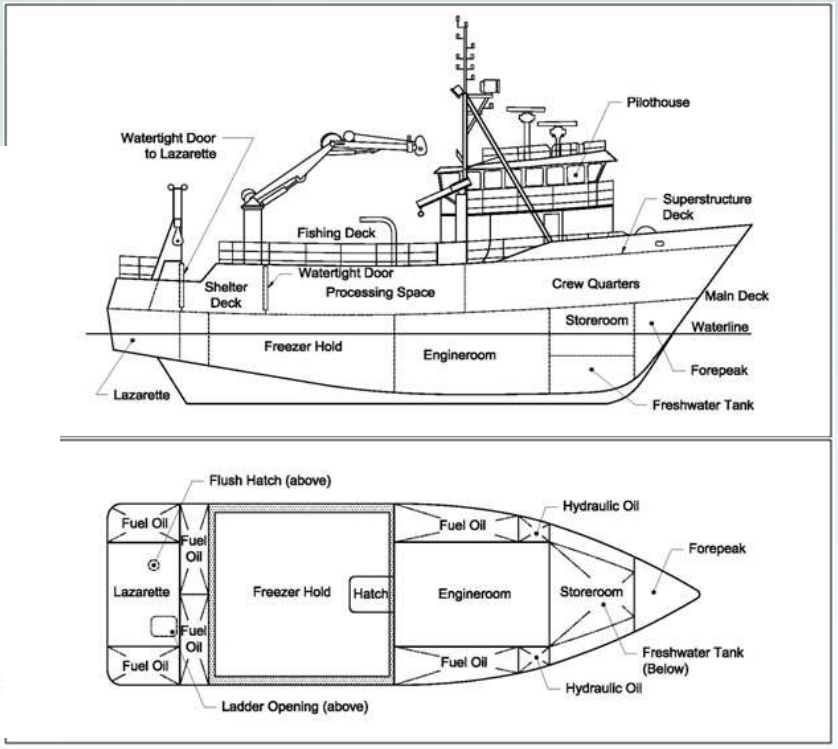
- Tank design and construction
- Location of tanks
- “Marine” control systems
- System integration
- Port fueling infrastructure

Work Boat Limitations

Naval Architecture Marine Engineering

- Fuel tanks significant impact on CG >20%
- Deck space premium
- NG Options
  - *Dual fuel or new build*

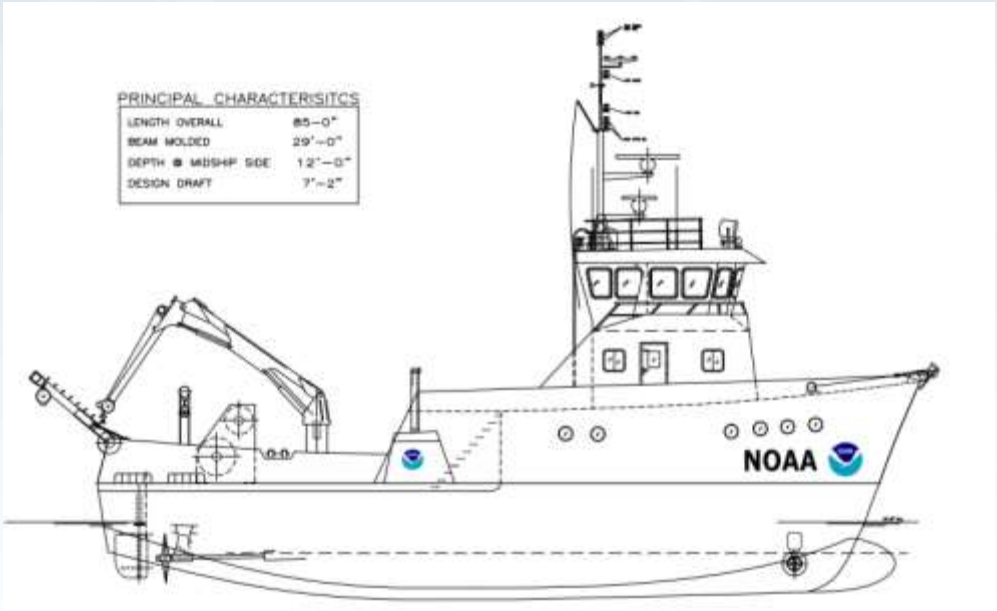




Dual Fuel - CNG/Diesel

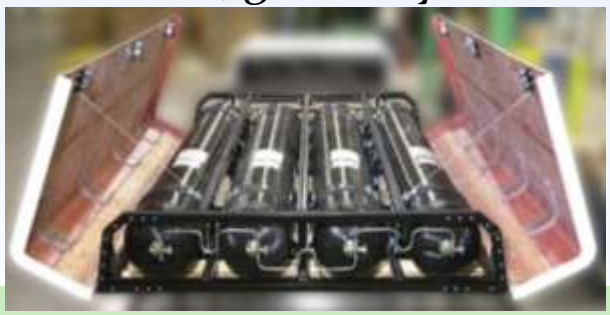
Market Potential Study

- "Work Boat" fleet
- Coastal and Waterways vessels
- Less than 150 feet, 200 gross tons
- Less than 1500 Hp
- Non cargo carrying
- Legacy Engines



Project Elements

- Engine retrofit
  - Electronic / Mechanical
  - Two and Four stoke
  - Tier / Legacy
- ECU / GCU controls
  - Sensors
  - Interfaces and logic
- Vessel systems integration
  - Fuel delivery
  - Monitoring
  - Fire suppression
- Tank engineering
  - Optimum unit / total volume
  - Material, geometry
- Shore fueling stations
- Safety, regulatory, compliance
- Human factors
  - Training
  - Operational impact
- Performance evaluation
  - Bio Diesel / Petro Diesel
  - Power / efficiency curves
  - Emissions



Dual Fuel Time Line

- Mile stones
  - July 2014 – 30’ Survey boat , Cummins QSD
    CNG fueling station at Muskegon, Mi
  - October 2014 – 50’ Research boat, Detroit 8V92 ’s
    CNG fueling station at Alpena, Mi
  - June 2015 – 80’ SRV, Cummins KTA
    - 55’ Buoy tender, Detroit 12V71’s
    - 41’ UTB, Cummins 903’s
    CNG fueling station at Monroe, Mi

End Game - Flexibility

Liquid Fuel

Bio Diesel
2nd Generation
GTL

Energy
Management
Systems

Vapor Fuel

CNG/LNG
Bio- methane

Hybrid

Electric
prolusion

Fuel Cell
Applications