U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Biofuels in Defense, Aviation, and Marine

Bioenergy Technologies Office Peer Review

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U.S. Department of Energy

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DPA Initiative Goals

- In June 2011, Secretaries of Agriculture, Energy, and Navy signed MOU to commit $510M (up to $170M from each agency) to produce hydrocarbon jet and diesel biofuels in the near-term. This initiative sought to achieve:
  - Multiple, commercial scale integrated biorefineries
  - Cost-competitive biofuel with conventional petroleum (w/o subsidies)
  - Domestically produced fuels from non-food feedstocks
  - Drop-in, fully compatible, MILSPEC fuels (F-76, JP-5, JP-8)

- DoD uses approximately 5 billion gallons of fuel annually and represents a key market adopter for advanced biofuels technologies

- Navy solicitations via Defense Logistics Agency to purchase biofuel blends through regular procurement contracts as long as they meet cost and performance criteria

Fuels for Distillate and Jet Market

US Liquid Fuels and Products Market Size (billion gallons/year)

	2012	2040	Growth Rate 2012 – 2040 (%/year)
Gasoline	134	105	-0.9%
Diesel	57	71	0.8%
Liquefied Petroleum Gas[1]	36	42	0.6%
Other[2]	30	39	0.9%
Jet Fuel	21	24	0.5%
Residual fuel oil	5	6	0.6%
Total	**283**	**287**	

1. Includes ethane, natural gasoline, and refinery olefins.
2. Includes kerosene, petrochemical feedstocks, lubricants, waxes, asphalt, and others commodities.
Source: Energy Information Administration, "Annual Energy Outlook 2014", Reference Case.

- Defense – Facilitating commercial scale production capacity
- Aviation – Testing and certification of alternative fuels
- Marine – Meeting environmental regulations

DPA Initiative – Accomplishments/Milestones

- In May 2013, four projects were selected for Phase I awards with $30M from DoD funds - Phase I was an 18 month effort to accomplish front end engineering design, site selection, and permitting tasks

- Successful projects have been selected to go on to Phase II (construction, equipment purchases, and commissioning) if funds are available. A down-select from four to three projects was announced September 2014:

  - **Emerald Biofuels** - hydro-treating and upgrading of fats, oils and greases
  - **Fulcrum Brighton Biofuels** – municipal solid waste gasification followed by Fischer-Tropsch conversion to jet fuel
  - **Red Rocks Biofuels** – forest biomass and wood wastes gasification followed by Fischer-Tropsch conversion to diesel and jet

Down-Select for Phase 2

Project	Location	Feedstock	Capacity (million gallons/year)
Fulcrum	McCarran, NV	Municipal solid waste	10
Emerald	Gulf Coast	Fats, oils, and greases	82
Red Rock	Lakeview, OR	Woody biomass	12

- Production anticipated to begin in 2016/2017.
- Fuels are approved for use as jet fuel by ASTM at up to 50/50 blends.
- Fuels successfully demonstrated during Rim of the Pacific (RIMPAC) demonstration in 2012 for ships and planes.
- Fuels can be utilized in Navy's warfighting platforms with no degradation to performance or mission.

Fulcrum Bioenergy

Pilot Plant Test of Fulcrum Process

Technology Guaranteed Performance

- 120-Day Continuous Integrated MSW-to-Fuels Test Required by Project Lender
- Test Confirmed the Performance and Reliability of Fulcrum's Process
- Fuel ASTM Certified
- Completed Full FEED for Sierra
- Secured Fixed-Price, Performance Guaranteed EPC Contract

Fulcrum BIOENERGY

6

Red Rock Biofuels

RRB Improved Conventional Tech to Use Biomass, Enabling "Carbon Reuse" as Liquid Fuels

RED ROCK BIOFUEL

1

Gasification
England, early 1800's
(Baltimore Gas Works, 1816)

Fischer-Tropsch
Germany, 1930's

Hydroprocessing
Russia, 1930's

2

Sasol, Shell & Others
Coal or natural gas feed only;
no ability to scale down

3

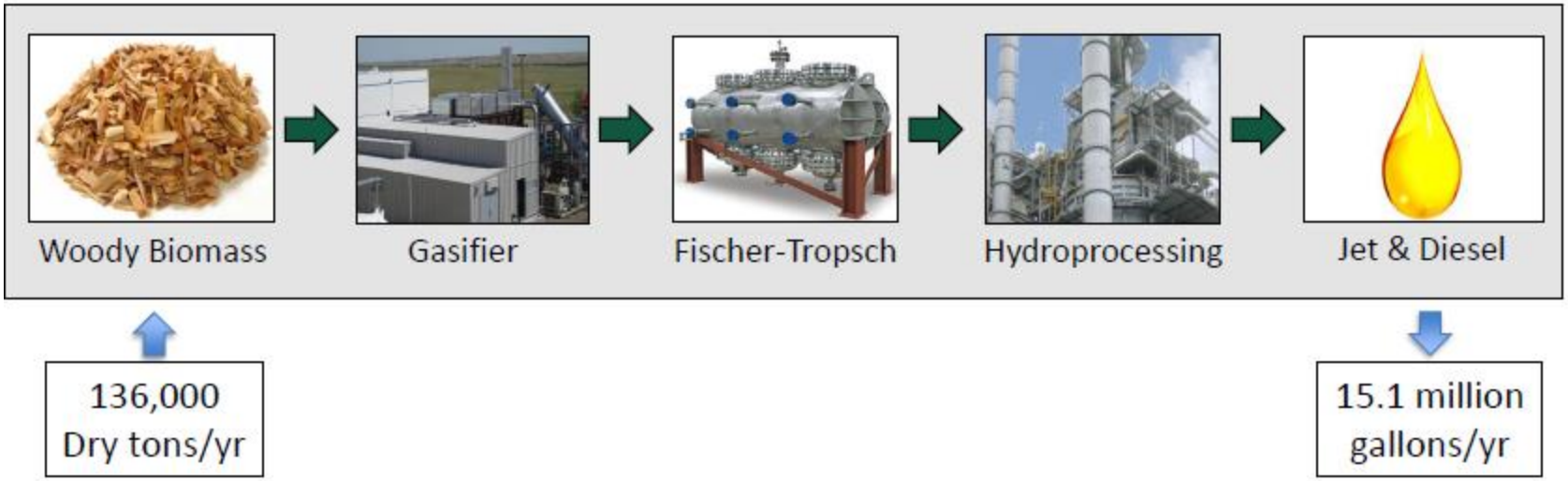
Red Rock Biofuels
Modular and Scalable;
Biomass/NatGas flexible

Red Rock Biofuels

FEED/FEL3 Design & Engineering by FLUOR

RED ROCK BIOFUELS

VELOCYS



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Additional Supporting Activities

- As fuels become available Navy will make advanced drop-in biofuels a regular part of its bulk fuel procurement.

- USDA has awarded Fulcrum a $105 million Biorefinery Assistance Program loan guarantee through Bank of America for construction of their facility. The total project cost is $266 million. 147,000 tons/year of MSW will be gasified to synthesis gas followed by Fischer-Tropsch conversion to jet fuel.

- Cathay Pacific Airways has become an investor in Fulcrum and has negotiated a 10 year supply agreement for jet fuel.

- Southwest Airlines has signed a fuel purchase agreement with Red Rock for 3 million gallons/year of jet fuel. Blended product will be used at Southwest's Bay Area operations. 140,000 dry tons/year of woody biomass feedstock will be converted into renewable jet, diesel, and naphtha.

Relevance of DPA to DOE - Commercialization Pipeline

- DOE involvement is essential in both the DPA and internal demonstration and deployment activities
- DPA strength is commercialization (each facility producing 10 million gallons/year or more, capital cost $200 - $400 million each, selling fuels to the market) – requires leveraging of funds among multiple agencies due to cost
- DOE strength is pilot and demonstration of innovative technologies (facilities producing fuels in batch or campaign mode, capital cost $25 - $150 million each, using fuels for testing/certification purposes)
- DOE investment in demonstration and deployment activities places conversion technologies at the beginning of the pipeline that subsequently becomes eligible for DPA funding

DOE Joins Farm to Fly 2.0

- We appreciate the hard work in approving alternative fuels and commitment to sustainable growth made by the aviation industry.
- DOE is actively committed to accelerating the adoption of alternative fuels by this market.
- In 2013, USDA and FAA made a commitment to the aviation industry to help meet their goals with the Farm to Fly 2.0 agreement. This effort seeks to enable the use of commercially viable and sustainable renewable jet fuel in the United States.
- In July 2014, Secretary Moniz signed an amendment officially making DOE the newest partner agency in this significant initiative.
- Welcome input on specific areas of collaboration for DOE via F2F2

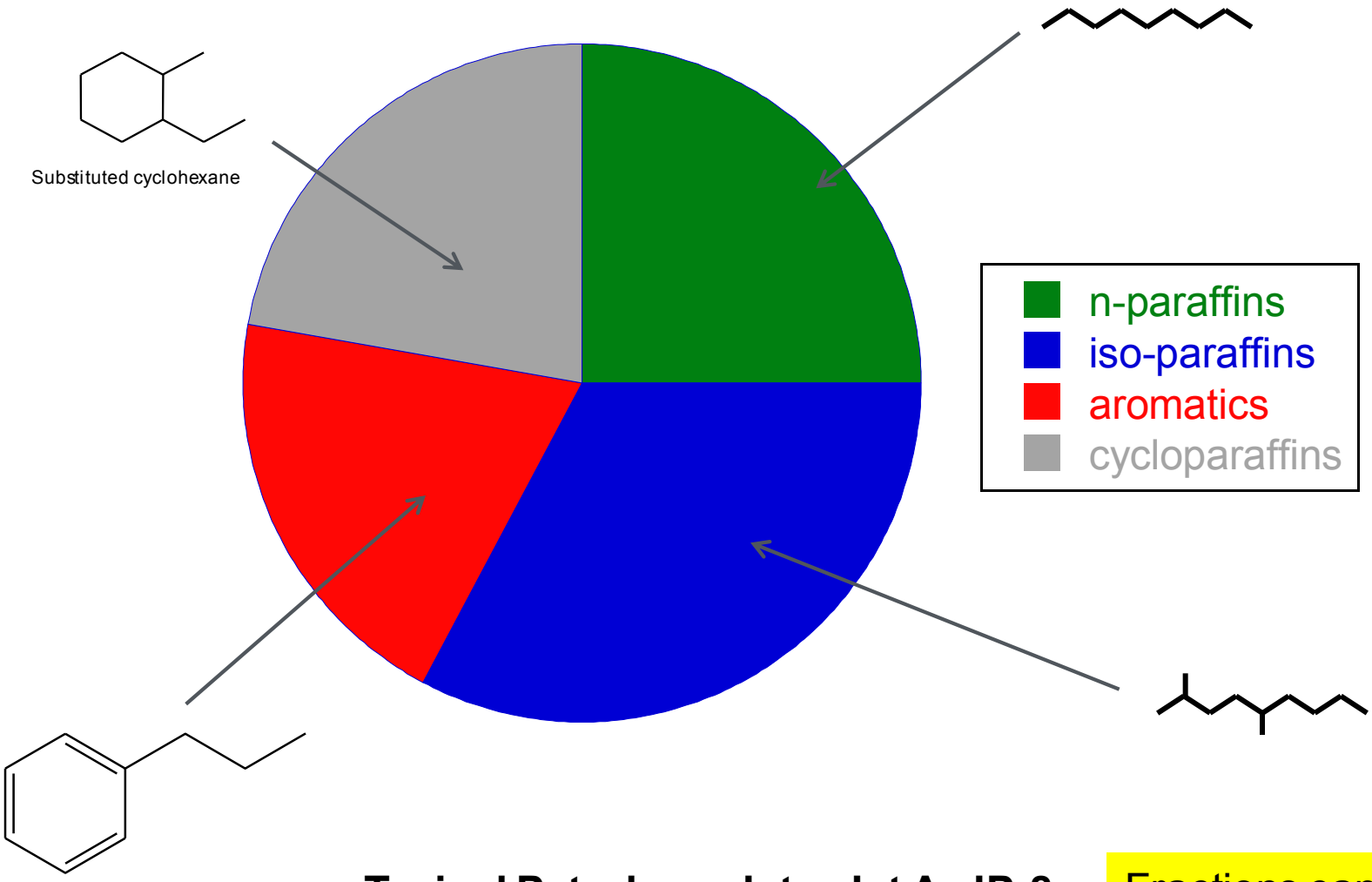
Criteria for Alternative Fuels in Aviation

- Engine re-light at altitude, polar climate, in winter - transport properties of alternative fuels and/or blends have to be within acceptable limits (viscosity, freeze point, fluid flow at low temperatures)
- Flame stability – compounds in alternative fuels should not adversely impact flame stability
- Energy content – should be as high as fossil derived jet fuel or higher
- Emissions
  - Aromatics – too much can cause soot, too little can cause seal swell problems which becomes a maintenance issue
  - Greenhouse gas emissions should be lower than fossil derived jet fuel on a life cycle basis

Status of ASTM Certification of Alternative Jet Fuel

- ASTM Certification in process with task forces
  - Alcohol to jet – synthetic paraffinic kerosene (bio/thermochemical butanol) with annex for ethanol – Gevo, Lanzatech, Cobalt, Swedish Biofuels, Byogy
  - Synthetic kerosene/synthetic aromatic kerosene – catalytic conversion of sugars and aqueous phase reforming to jet fuel – Shell/Virent
  - Catalytic hydro-thermolysis of lipids to jet fuel – ARA
  - Hydro-treated esters and fatty acids+ (HEFA)+ - wider cut HEFA with renewable diesel – Boeing
  - Pyrolysis from lignocellulosic feedstocks – UOP, Kior
  - Fischer-Tropsch synthetic kerosene with aromatics – Sasol, Rentech
  - Co-processing – multiple approaches – Chevron, BP, Phillips 66
- Pathways in future that could enter pipeline
  - Vertimass – catalytic conversion of alcohols
  - Global Bioenergies – biochemical production of isobutene
  - Algenol – hydrothermal liquefaction of algae
  - Kiverdi – biochemical conversion of wastes

GCxGC - Dividing Up The Hydrocarbon Pie

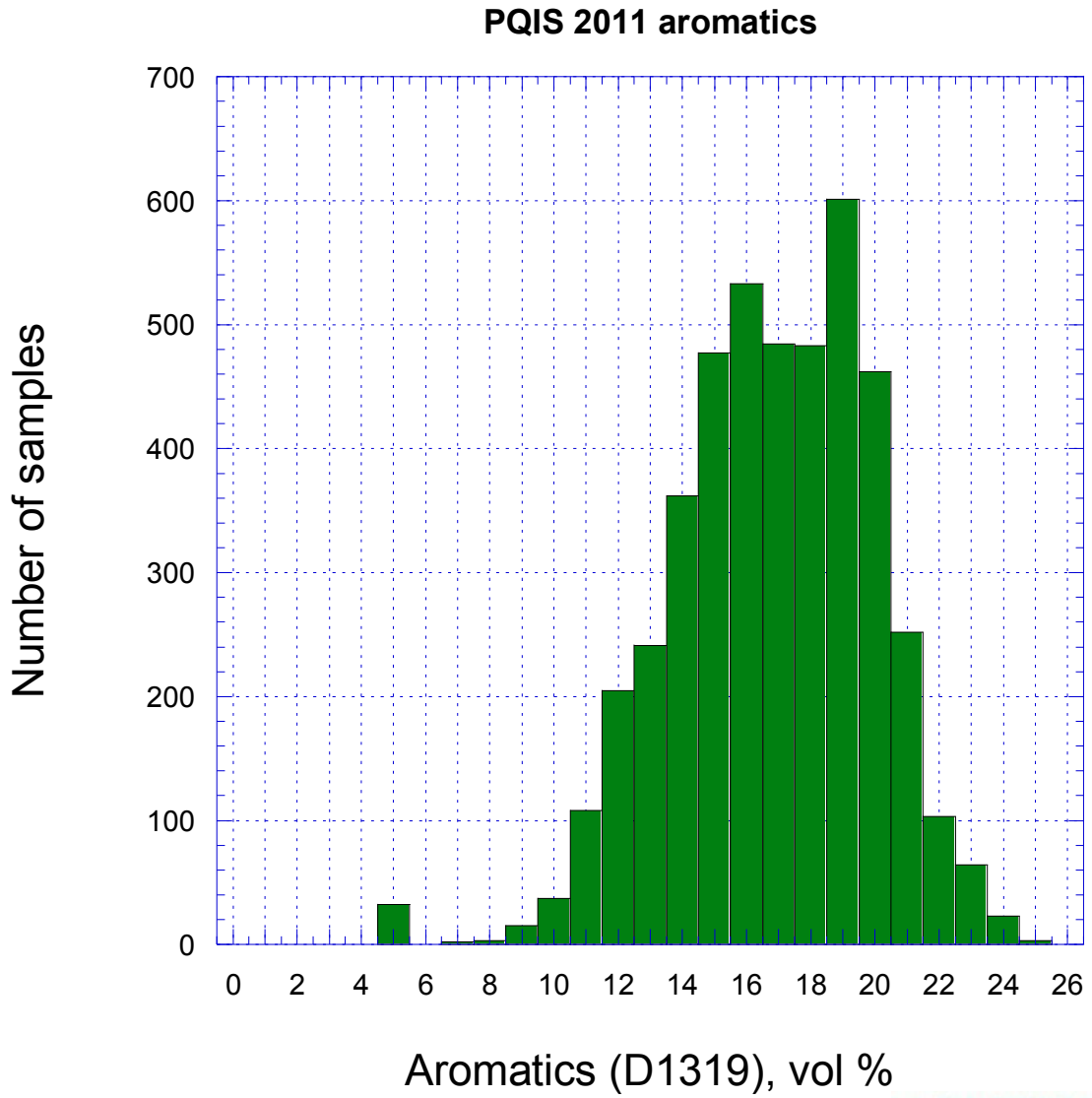


Typical Petroleum Jet – Jet A, JP-8

Fractions can vary!

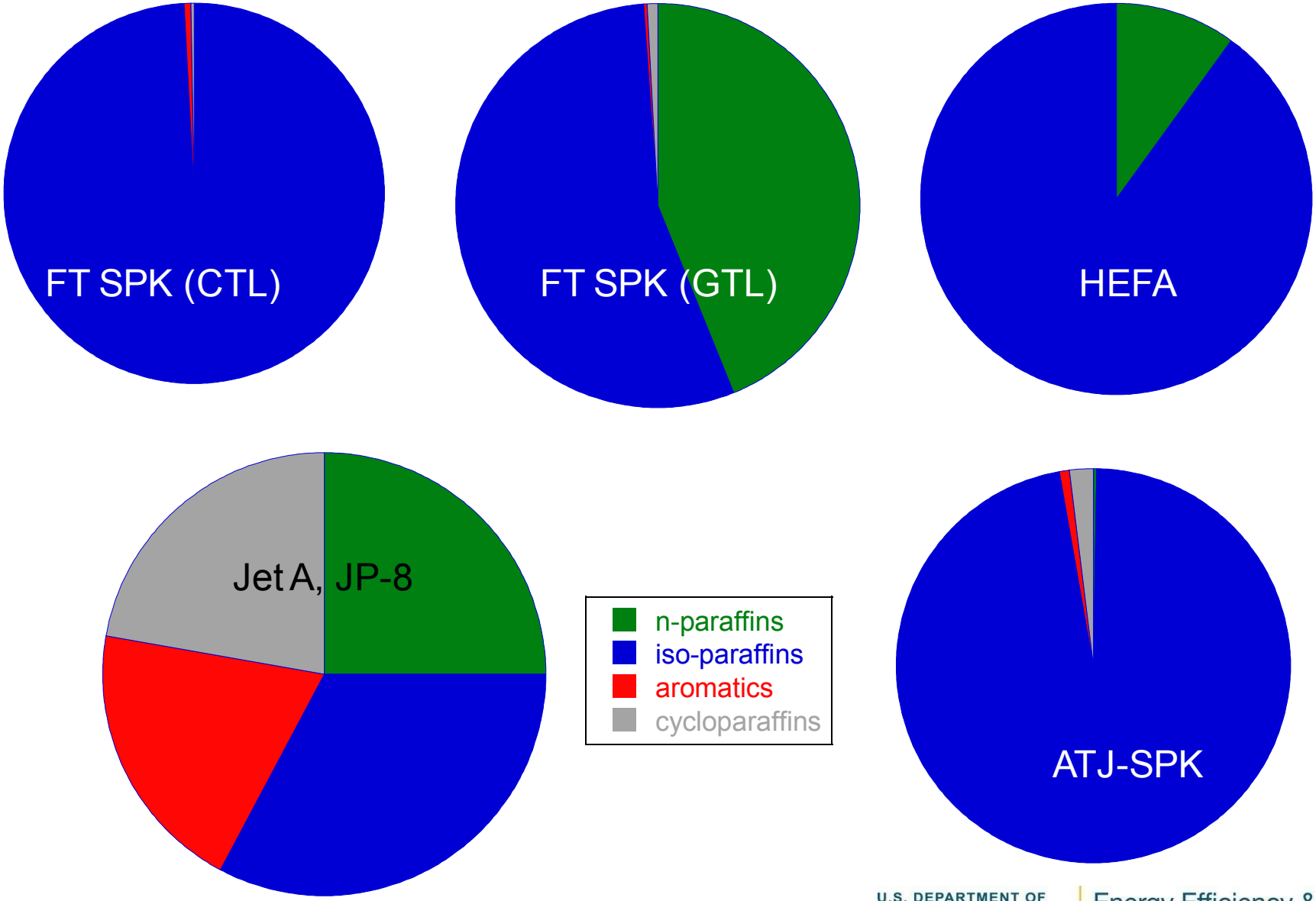
Source: Dr. Timothy Edwards, Air Force Research Laboratory

Jet A, JP-8 Composition Variations



Source: Dr. Timothy Edwards, Air Force Research Laboratory

GCxGC – Paraffinic Fuels



Source: Dr. Timothy Edwards, Air Force Research Laboratory

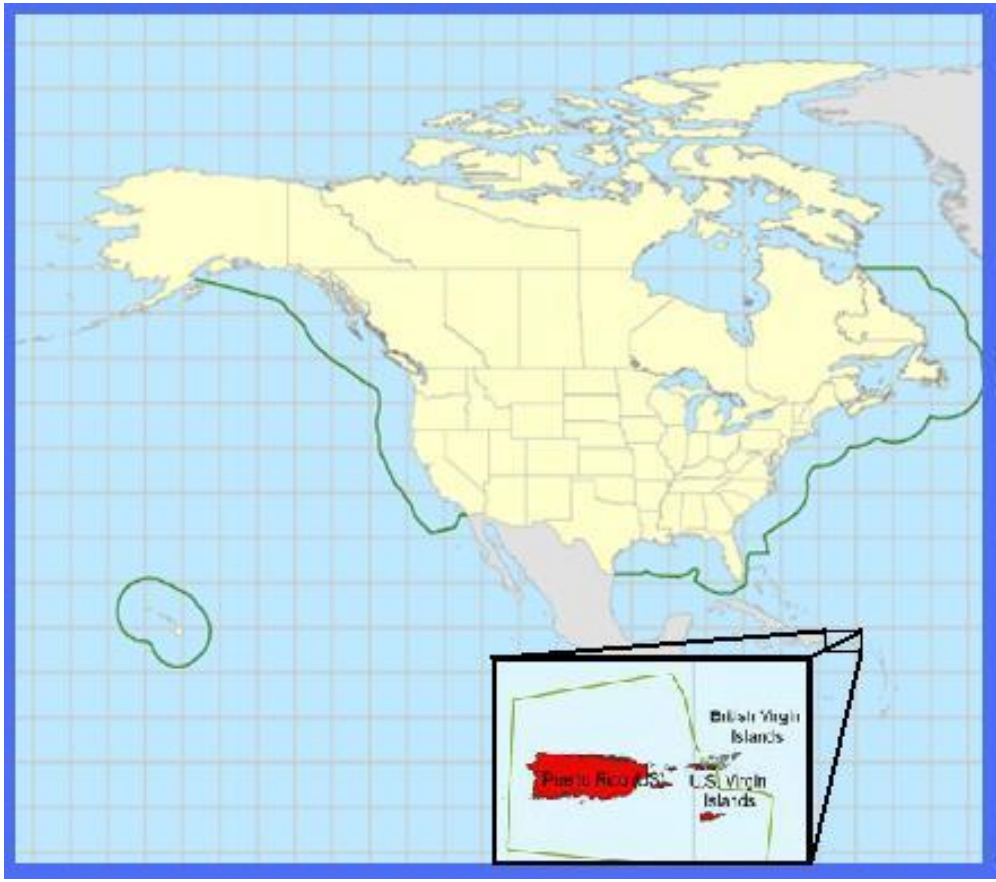
Airline Off-take Agreements – More in Process

Benefits of Aviation Biofuels

https://www.youtube.com/watch?v=_MCAgQLAvVI

Marine Emission Control Areas (ECA)

- **North American ECA**
  - Adopted by IMO: March 26, 2010
  - Entry-into-force: August 1, 2011
  - Enforcement: August 1, 2012 (Reg. 14.7)
- **U.S. Caribbean Sea ECA**
  - Adopted by IMO: July 15, 2011
  - Entry-into-force: January 1, 2013
  - Enforcement: January 1, 2014 (Reg. 14.7)



Marine Fuel Oil Requirements

MARPOL (International Convention for the Prevention of Pollution from Ships) Annex VI Regulation 14 and 18: SOx and PM emissions and fuel oil availability and quality

Shipboard Requirements

- Fuel Oil :
  - Sulfur Content Caps
  - Fuel Quality Standards
- Operations:
  - Bunker Delivery Notes & Samples
  - Fuel Oil Change-Over Procedures
  - Fuel Oil Change-Over Logbook Entries

Annex VI , Reg. 14 Fuel Oil Sulfur Content Limits	
ECA Sulfur Content Cap	
Effective Date	Sulfur Limit %m/m (ppm)
July 1, 2010	1.00% (10,000)
January 1, 2015	0.10% (1,000)
Global Sulfur Content Cap	
January 1, 2012	3.50% (35,000)
January 1, 2020	0.50% (5,000)

Engine NOx Requirements for January 1, 2016

- Tier III NOx-January 2016 applies to vessels with keels laid after 1/1/2016
- Will require after treatment - Selective catalytic reduction, exhaust gas recirculation, water injection strategies, dual fuel diesel/natural gas engines
- Applies in ECAs only (Tier II otherwise)
- U.S. domestic law implementing Annex VI– calls for joint enforcement by two separate U.S. government agencies.
- Coast Guard has the lead on vessel inspections.
- EPA has the lead on shoreside fuel supplier inspections, and on violations that are referred to EPA by the Coast Guard for enforcement.

Fuel Oil Nonavailability

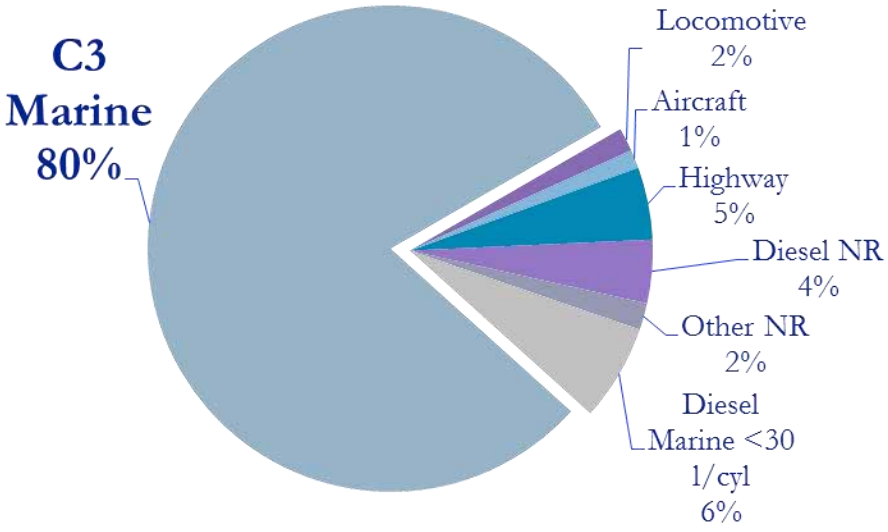
- A vessel is expected to use compliant fuel when operating in the ECAs.
- If a ship owner is not able to obtain compliant fuel because it is not available, a Fuel Oil Non-Availability Report (FONAR) must be submitted.
- A FONAR is not a waiver! It is a formal statement of noncompliance.
- If 0.10% (1,000 ppm) is not available, another ECA-compliant fuel must be used if it is available.
- ECA-compliant fuel will not be deemed "unavailable" for the purposes of a FONAR if another compliant fuel is available, for example a low sulfur marine distillate (MGO/MDO) below 1,000 ppm).

Maritime Fuel Issues Under Development

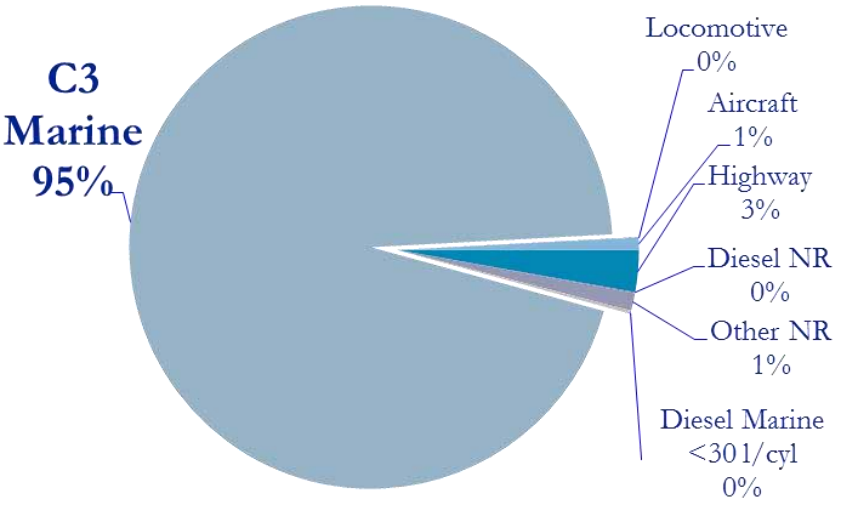
- Vessel fuel oil sampling program.
- Flyovers and other technology based targeting and compliance assurance efforts.
- Additional information at Coast Guard Homeport: www.Homeport.USCG.mil
  Select the following links: Missions > Domestic Vessels > Domestic Vessel General > MARPOL ANNEX VI
  - CG-543 Policy Letter 09-01 (Annex VI Implementation)
  - CG-CVC Policy Letter 12-04 (ECA Compliance)
  - CG-CVC Policy Letter 13-02 (IEE/SEEMP)
- EPA MARPOL Annex VI - http://www2.epa.gov/enforcement/marpol-annex-vi
- EPA Ocean Going Vessels Air Emissions Web Page: http://www.epa.gov/otaq/oceanvessels.htm

SOx Ship Emissions

2009 Mobile Source SOx Inventory



2030 Mobile Source SOx Inventory (without ECA controls)



Source: EPA Marine Diesel Notice of Proposed Rulemaking, 74 Fed. Reg. 44442 (August 28, 2009)

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NOx Ship Emissions

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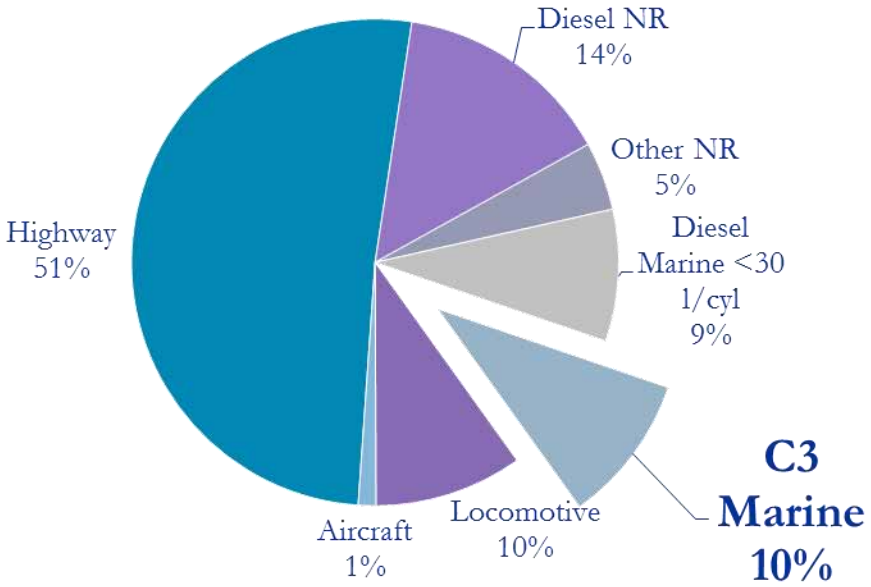

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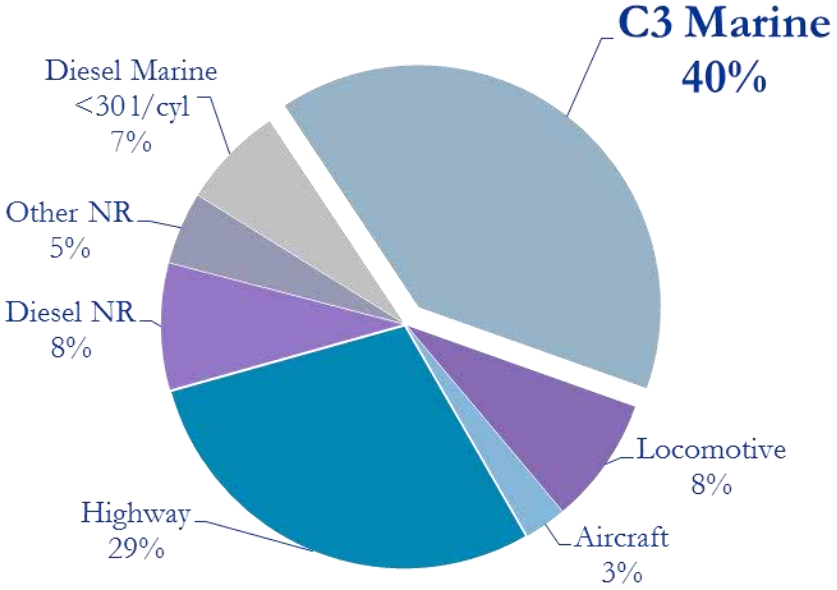

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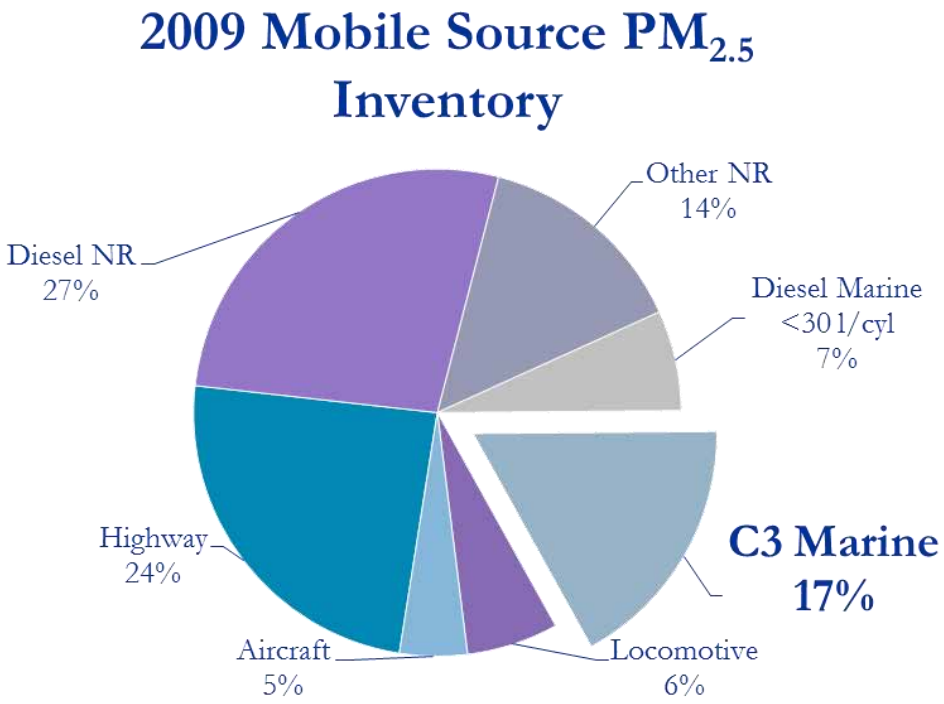
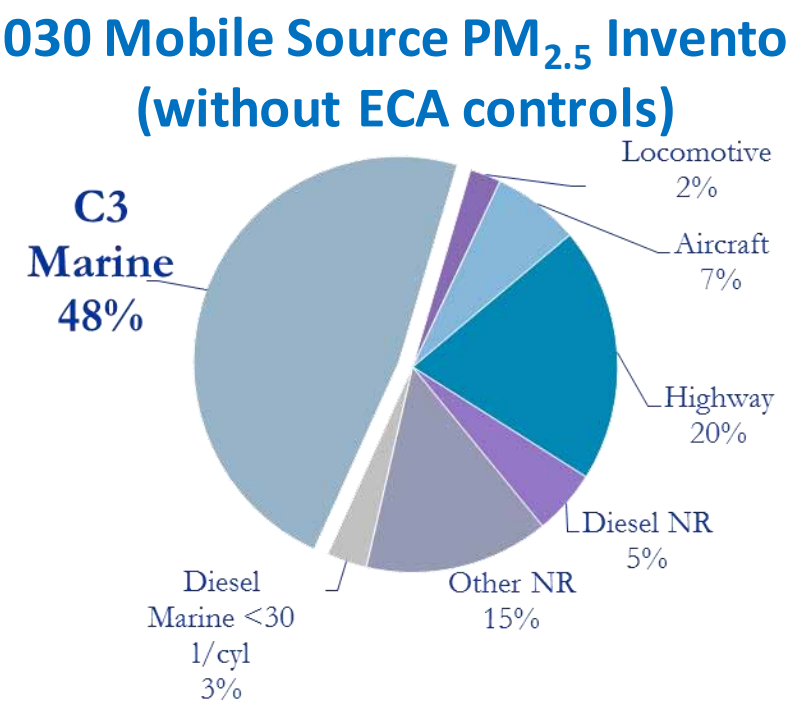
$PM_{2.5}$ Ship Emissions





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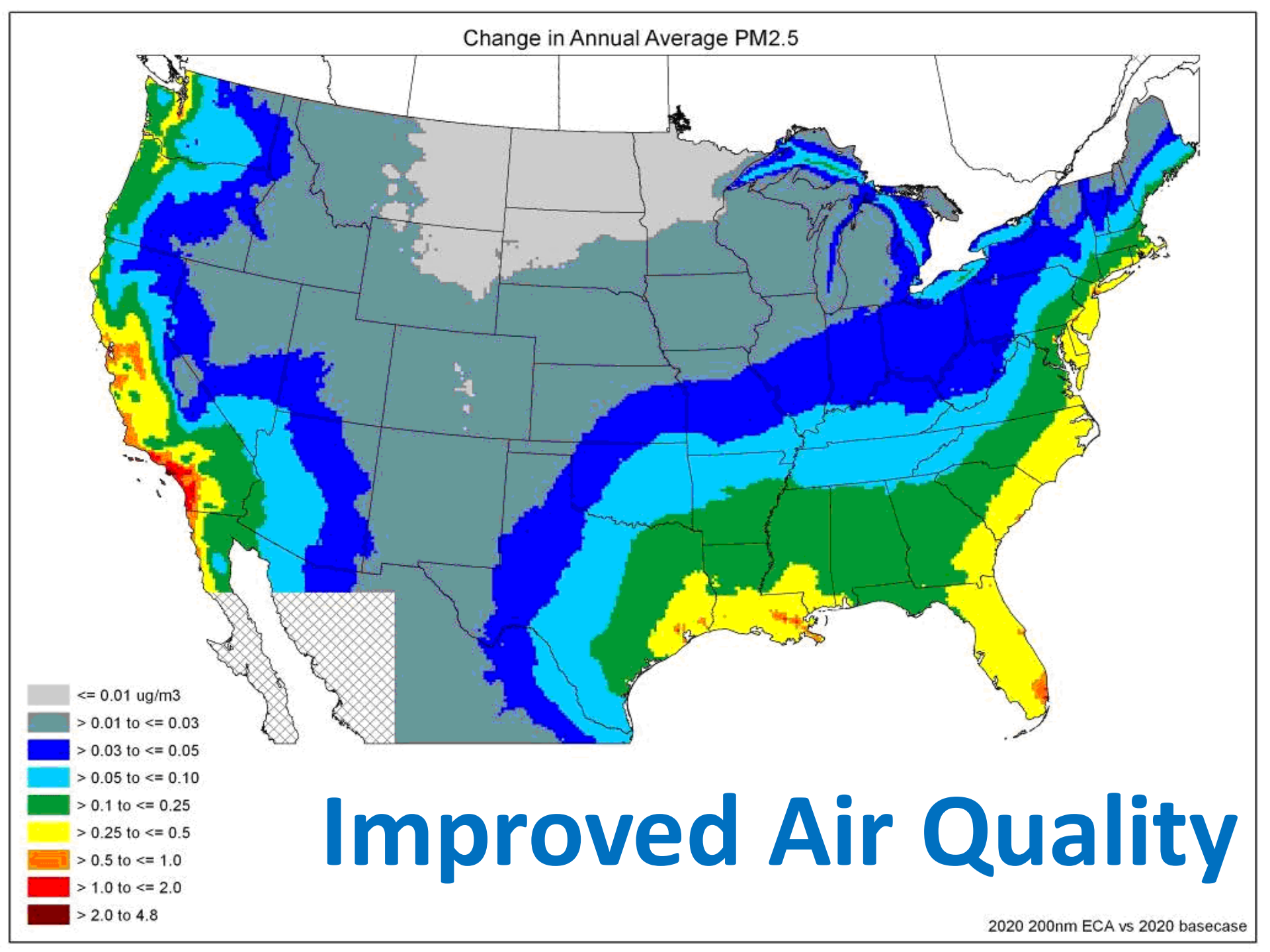
Change in Annual Average PM2.5
<= 0.01 ug/m3
> 0.01 to <= 0.03
> 0.03 to <= 0.05
> 0.05 to <= 0.10
> 0.1 to <= 0.25
> 0.25 to <= 0.5
> 0.5 to <= 1.0
> 1.0 to <= 2.0
> 2.0 to 4.8
Improved Air Quality
2020 200nm ECA vs 2020 basecase