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Aviation Biofuels – Critical to Aviation's Attainment of Environmental Sustainability

Port of Seattle Commission Meeting
June 28, 2016

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Director, Aviation Sustainability Center (ASCENT) – the FAA Center of Excellence for Alternative Jet Fuels and Environment
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Washington State University

ASCENT
AVIATION SUSTAINABILITY CENTER

FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

The FAA Center of Excellence for Alternative Jet Fuels and Environment (Aviation Sustainability Center – ASCENT) is funded by the US Federal Aviation Administration (FAA) Office of Environment and Energy under FAA Award Number 13-C-AJFE.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the FAA or other ASCENT Sponsors.

ASCENT - FAA Center of Excellence for Alternative Jet Fuels and Environment

Ralph Cavalieri, Director
Washington State University

R. John Hansman, Co-Director
Massachusetts Institute of Technology

James Hileman, FAA Program Manager

Research Focus Areas

Alternative Jet Fuels

3.1.1. Feedstock Development, Processing and Conversion

3.1.2. Regional Supply and Refining Infrastructure

3.1.3. Environmental Benefits Analysis

3.1.4. Aircraft Component Deterioration and Wear

3.1.5. Fuel Performance Testing

Environmental

3.1.6. Aircraft Noise and Impacts

3.1.7. Aviation Emissions and Impacts

3.1.8. Aircraft Technology Assessment

3.1.9. Energy Efficient Gate-to-Gate Aircraft Operations

3.1.10. Aviation Modeling and Analysis

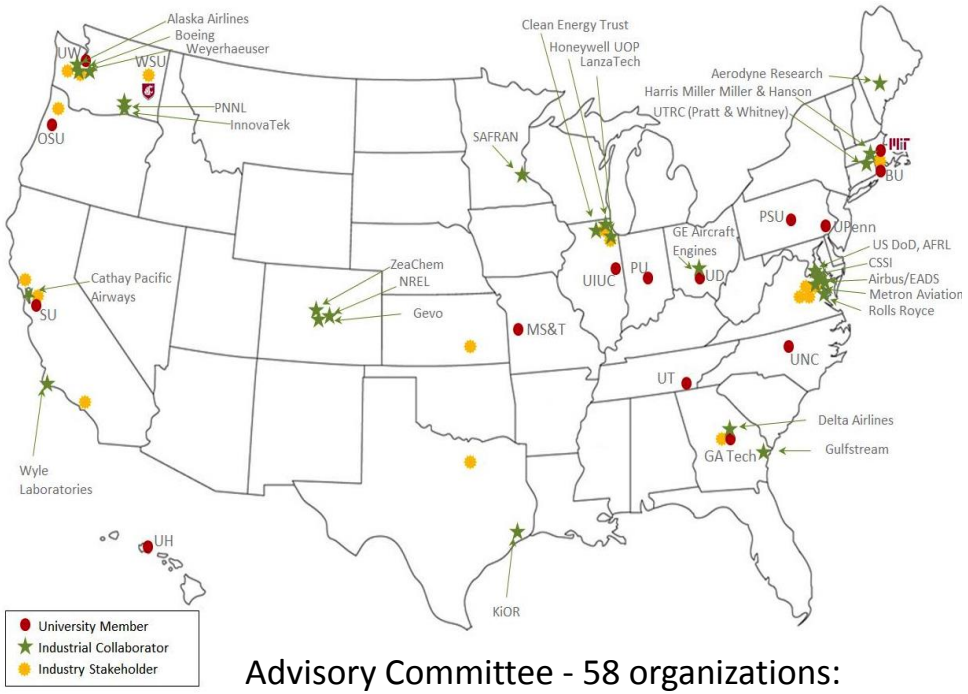
ASCENT Team

Lead Universities:

- Washington State University (WSU)*
- Massachusetts Institute of Technology (MIT)

Core Universities:

- Boston University (BU)
- Georgia Institute of Technology (Ga Tech)
- Missouri University of Science and Technology (MS&T)
- Oregon State University (OSU)*
- Pennsylvania State University (PSU)*
- Purdue University (PU)*
- Stanford University (SU)
- University of Dayton (UD)
- University of Hawaii (UH)*
- University of Illinois at Urbana-Champaign (UIUC)*
- University of North Carolina at Chapel Hill (UNC)
- University of Pennsylvania (UPenn)
- University of Tennessee (UT)*
- University of Washington (UW)*



Advisory Committee - 58 organizations:

- 5 airports
- 4 airlines
- 7 NGO/advocacy
- 9 aviation manufacturers
- 11 feedstock/fuel manufacturers
- 22 R&D, service to aviation sector

* Denotes USDA NIFA AFRI-CAP Leads and Participants & Sun Grant Schools

Economic and Social Benefits of Aviation

5.4% of U.S. GDP

11.8 Million
U.S. jobs

1.5 Trillion
in U.S. economic activity annually

27% of U.S. exports
$430.9 billion

22% of U.S. imports
$509.4 billion

SOURCE: FAA Air Traffic Organization; US Census Bureau

Environmental Protection to Enable Increased Mobility

NOISE

Reduce the number of people exposed to significant noise around U.S. airports

AIR QUALITY

Reduce significant air quality impacts attributable to aviation

CLIMATE

Achieve carbon neutral growth by 2020 relative to a 2005 baseline

ENERGY

Develop and deploy sustainable alternative aviation fuels

ENVIRONMENT AND ENERGY GOALS

The Five Pillar Approach

Science and Tools

PILLAR 1: Improved Scientific Knowledge and Integrated Modeling

- Decision-making based on solid scientific understanding
- Work with research community through the **Aviation Sustainability Center (ASCENT)**
- Understand public health and welfare impacts
- Incorporate this knowledge within the Aviation Environmental Tool Suite

Technology

PILLAR 2: New Aircraft Technologies

- Offer the greatest opportunity to reduce environmental impacts
- Partner with industry, research community, NASA, and Department of Defense
- Mature new engine and airframe technologies through the **Continuous Lower Energy, Emissions and Noise (CLEEN) Program**

Alternative Fuels

PILLAR 3: Sustainable Alternative Aviation Fuels

- Reduce environmental impacts, enhance energy security, and provide economic benefits
- Collaborate with stakeholders through the **Commercial Aviation Alternative Fuels Initiative (CAAFI)**
- Test alternative jet fuels to ensure they are safe for use through **ASCENT** and **CLEEN**
- Analyze their potential for reducing the environmental impacts of aviation

Operations

PILLAR 4: Air Traffic Management Modernization and Operational Improvements

- Increase efficiency of aircraft operations through the **Next Generation Air Transportation System (NextGen)**
- Engage with industry, research community, NASA, and Department of Defense
- Develop advanced operational procedures to optimize gate-to-gate operations
- Integrate infrastructure enhancements to the National Airspace System (NAS), improving environmental performance

Policy

PILLAR 5: Policies, Environmental Standards, and Market Based Measures

- Implement domestic policies, programs, and mechanisms to support technology and operational innovation
- Develop and implement aircraft emissions and noise standards
- Work within the International Civil Aviation Organization (ICAO) to pursue a basket of measures to address emissions that affect climate, including a global market based measure as a gap filler
- Seek international partners to further our environmental and energy strategy

NextGEN
http://www.faa.gov/nextgen

CAAFI
http://www.caafi.org

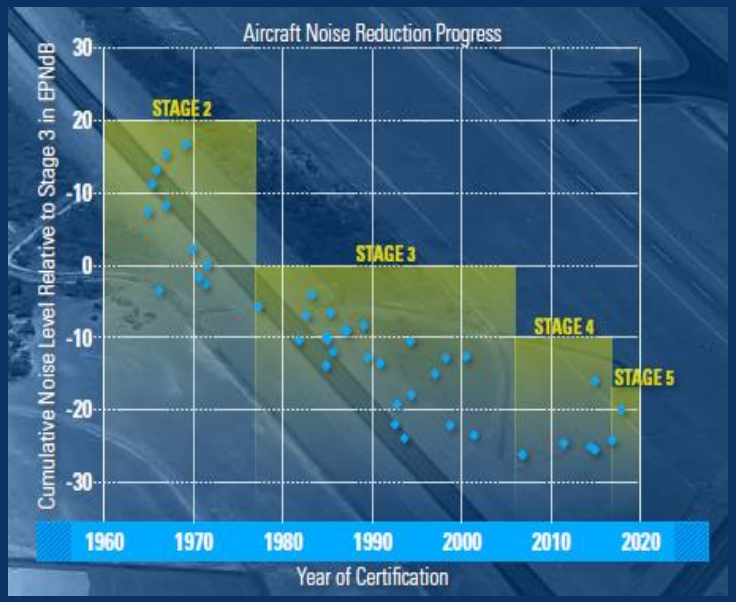
CLEEN
NextGEN
http://www.faa.gov/go/cleen

ASCENT
http://ascent.aero

Noise

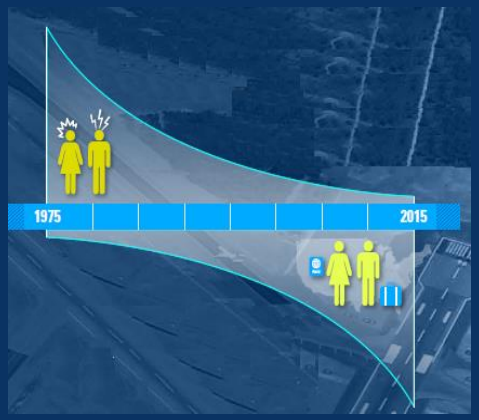
GOAL: Reduce population exposure to significant noise around U.S. airports

What we have ACHIEVED



SOURCE: FAA Office of Environment and Energy

95% reduction
in the number of people exposed to significant noise in proximity to U.S. airports



260% increase in passengers travelling in the U.S. from **200 million** to **720 million**

9 Billion provided by FAA
since 1982 for sound insulation of homes and schools around U.S. airports

Developed a **Balanced Approach** using Source Reduction, Land Use Planning, and Operational Procedures and Restrictions

Noise: What we are DOING NOW

SCIENCE & INTEGRATED MODELING

ANNOYANCE
Nationwide survey to understand community reaction to aircraft noise

CHILDREN'S LEARNING
Case Studies through the National Academy of Science

HUMAN HEALTH
Explore the incremental effects of aviation noise on human health

SLEEP DISTURBANCE
Field studies to determine physiological impacts of aviation noise

MODELING
Improve modeling of noise effects and impacts

MITIGATION

NEW TECHNOLOGY
Mature new aircraft and engine technologies to reduce aircraft source noise through FAA's CLEEN Program

OPERATIONS
Develop and implement procedures to reduce noise exposure

SOUND INSULATION
Continue the long-established Sound Insulation Program and improve eligibility criteria

LAND USE PLANNING
Examine land use compatibility older jet aircraft so Stage guidelines

POLICY
Promulgate Stage 5 noise standard and phase out 3 and quieter are flying after end of 2015

Air Quality

GOAL: Reduce significant air quality impacts attributable to aviation

What we have ACHIEVED

Eliminated smoke emissions

DC-8, 1958

Boeing 787, 2012

50% reduction in CAEP Nitrogen Oxides (NO_x) emissions standard since 1995

18% reduction in fuel burned over the last 7 years, yielding lower pollutant emissions despite growth in civil aviation

Characterized gaseous and Particulate Matter (PM) emissions from aircraft engines burning jet fuel

Measured 50% reduction in PM emissions from the use of alternative jet fuels in full scale jet engines

SOURCE: EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012, EPA 430-R-14-003, April 15, 2014

Air Quality: What we are DOING NOW

SCIENCE & INTEGRATED MODELING

HUMAN HEALTH
Explore the incremental effects of aviation emissions on human health

ENGINE CERTIFICATION
Use the latest measurement technology to certify engine emissions

EMISSION MEASUREMENTS
Develop gaseous and PM emissions measurement systems for jet engine exhaust

MODELING
Improve modeling of aviation emissions consequences and impacts

MITIGATION

NEW TECHNOLOGY
Mature new aircraft and engine technologies to reduce emissions through FAA's CLEEN Program

OPERATIONS
Develop and implement procedures to reduce emissions

ALTERNATIVE FUELS
Deploy alternative fuels to reduce PM emissions

POLICY
Promulgate engine PM emissions standard

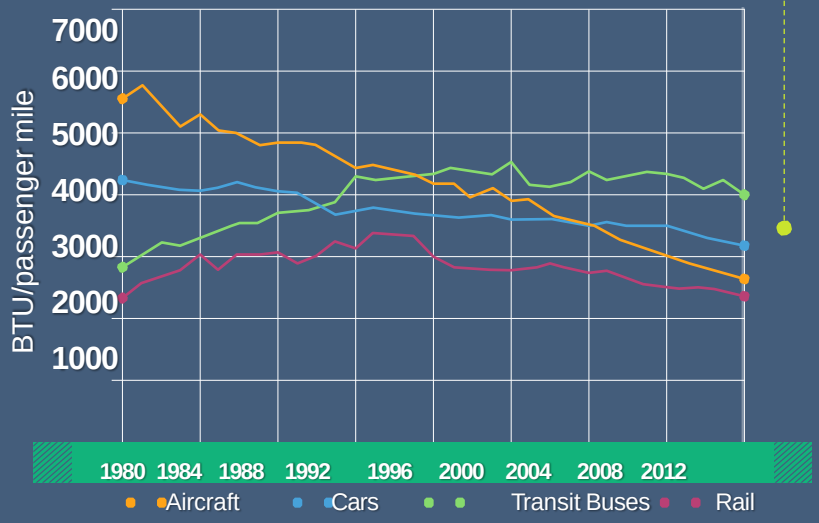
Climate

GOAL: Achieve carbon neutral growth by 2020 relative to a 2005 baseline

What we have ACHIEVED

Three decades of aviation energy efficiency improvement

SOURCE: FAA Office of Environment and Energy, Transportation Energy Data Book, 2014



Climate Action Plan
for U.S. Aviation

Estimated that **global aviation Carbon Dioxide (CO_2) emissions** could grow to **5%** by 2050 from current 2% level

80% reduction in lifecycle greenhouse gas emissions compared to conventional fuels achievable via certified alternative jet fuels

Quantified aviation greenhouse gas emissions and **reduced uncertainties on contrail effects**

Climate: What we are DOING NOW

SCIENCE & INTEGRATED MODELING

CLIMATE METRICS
Explore the incremental effects of aviation emissions on climate change

CONTRAILS
Understand condensation trails formation and their effects

CRUISE EMISSIONS
Study impacts from aircraft emissions at altitude

MODELING
Improve fuel use calculations and climate impacts modeling

MITIGATION

NEW TECHNOLOGY
Mature new aircraft and engine technologies to reduce CO_2 emissions through FAA's CLEEN Program

OPERATIONS
Develop and implement procedures to reduce fuel use

ALTERNATIVE FUELS
Advance certification of drop-in alternative jet fuels, and calculate well-to-wake climate benefits

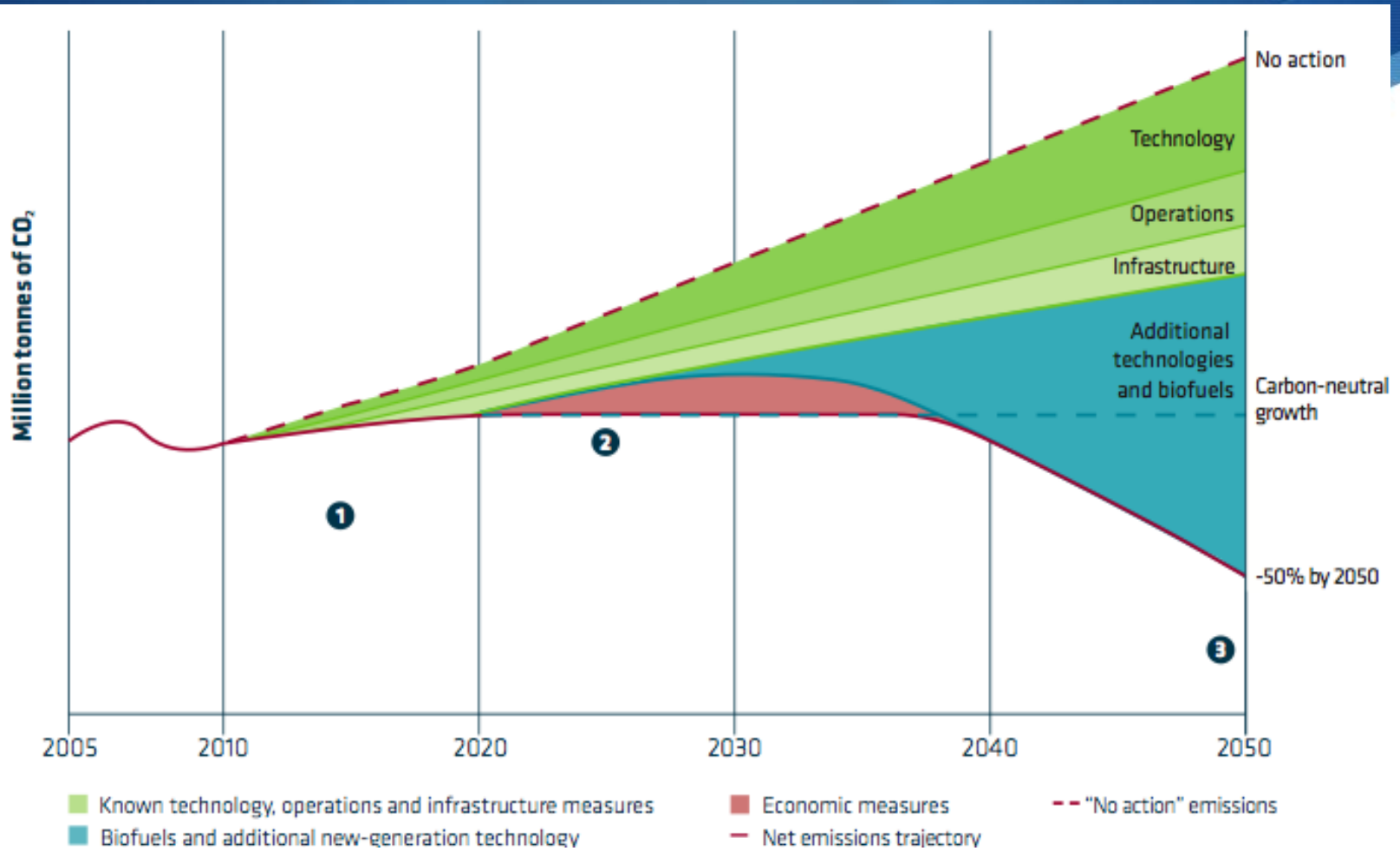
POLICY
Develop global market based measure for international aviation and promulgate aircraft CO_2 standard

Climate: What we are DOING NOW

The FAA's CLEEN Program is developing aircraft technologies that **reduce fuel use and CO_2 emissions**, including Boeing's adaptive trailing edge and ceramic matrix composite exhaust nozzle technologies which were flight tested on the Boeing ecoDemonstrator aircraft

NASA and FAA are working with international partners from Canada and Germany to **characterize alternative fuel emissions in flight and to understand contrail formation**

Carbon Mitigation Strategy



Source: Air Transport Action Group (ATAG) (2010), —The right flight path to reduce aviation emissions, ATAG. Geneva.

ASCENT Alternative Jet Fuel Projects

Project #	Title
01	Alternative Jet Fuel Supply Chain Analysis
21	Improving Climate Policy Analysis Tools
24	Emissions Data Analysis for CLEEN, ACCESS, and Other Recent Tests
25	National Jet Fuels Combustion Program – Area #1: Chemical Kinetics Combustion Experiments
26	National Jet Fuels Combustion Program – Area #2: Chemical Kinetics Model Development and Evaluation
27	National Jet Fuels Combustion Program – Area #3: Advanced Combustion Tests
28	National Jet Fuels Combustion Program – Area #4: Combustion Model Development and Evaluation
29	National Jet Fuels Combustion Program – Area #5: Atomization Tests and Models
30	National Jet Fuels Combustion Program – Area #6: Referee Swirl-Stabilized Combustor Evaluation/Support
31	Alternative Jet Fuels Test and Evaluation
32	Worldwide LCA of GHG Emissions from Petroleum Jet Fuel
33	Alternative Fuels Test Database Library
34	National Jet Fuels Combustion Program – Area #7: Overall Program Integration and Analysis

NARA

Northwest Advanced Renewables Alliance

A new vista for Green Fuels, Chemicals, & Environmentally Preferred Products

Ralph Cavalieri

Associate Vice-President for Alternative Energy

Project Director

Michael Wolcott

Regents Professor

Project Co-Director

Washington State University

USDA

NARA Team

Alaska Airlines
ANDRITZ
Biomass ad Infinitum LLC
Catchlight Energy
CLH
Cosmo Specialty Fibers Inc.
Facing the Future
Forest Business Network LLC
Gevan Marrs LLC
Gevo, Inc.
ICM
Montana State University
National Center for Genome Research
National Renewable Energy Laboratory
Oregon State University
Penn State University
Salish Kootenai College
South Hampton Resources Inc.
Steadfast Management Inc.
Thomas Spink Inc.
University of Idaho
University of Minnesota
University of Montana
University of Utah
University of Washington
University of Wisconsin-Extension
USDA Forest Products Laboratory
USDA Forest Service
Washington State University
Western Washington University
Greenwood Resources
Weyerhaeuser

USDA

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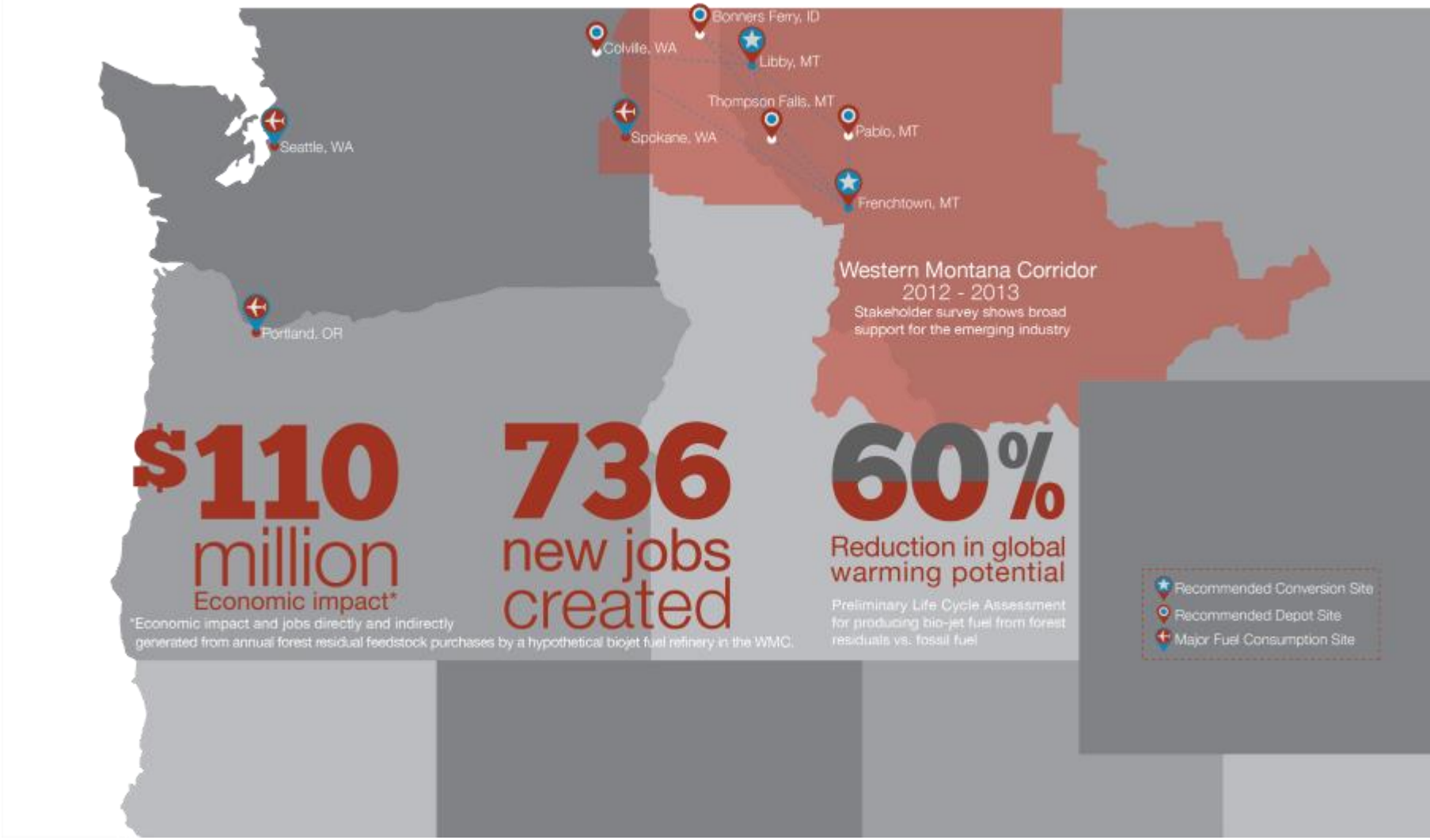
Economic Impact



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Pathway to Commercial Reality

Current Process Design

- Current Status is FEL-1 (Preliminary Process Design) to FEL-2 (Detailed Process Design)
- Needs Optimization of Value Chain
- Refinement of Market and Equipment Costs

Consideration for Comparison to Petroleum

- Petroleum fuel production does not account for green house gas production, only costs
- Petroleum fuel allowed to fully depreciate capital including drilling assets
- Petroleum fuels are lowest in value chain that includes petrochemicals

Regional Supply Chain Analyses

Pacific Northwest (PNW)
Supply Chain Analysis

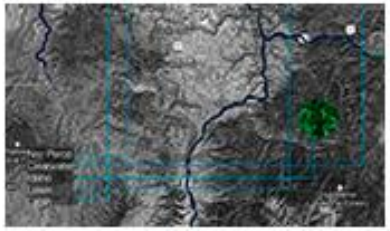
This site provides supply chain data and analysis generated by NARA research for the region identified as the Pacific Northwest, which includes Montana, Idaho, Washington, and Oregon.

Mid-Cascades to Pacific (MC2P)
Supply Chain Analysis

This site provides supply chain data and analysis generated by NARA research for the region identified as Mid-Cascades to Pacific, which includes the western sections of Washington and Oregon.

Western Montana Corridor (WMC)
Supply Chain Analysis

This site provides supply chain data and analysis generated by NARA research for the region identified as the Western Montana Corridor, which includes the western section of Montana, Northern Idaho and northeast Washington.



Clearwater Basin
Supply Chain Analysis

This site provides supply chain data and analysis generated by NARA research for the region identified as the Clearwater Basin, located in central Idaho.

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Making Alternative Jet Fuel is Complicated

And It's Even More Complicated to Make Money!

But it's Good for the Environment

And Good For Local Economies

Continue on the Pathway to Commercial Reality

Continue to Focus on Supply Chains

TAKE HOME LESSONS FROM NARA

1K-IPK – Fuel Distribution and Demonstration

Fuel Certification

Alternative Jet - ASTM D7566
Blending
Conventional Jet – ASTM D1655
Distribution to Wing
Commercial Demonstration
Flight

Processing Partners

Gevo Corp
South Hampton Refining
Blending Partner
Alaska Airlines

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Moving from Invention to Commercial Reality

- Forest Residue Collection and Preparation
- Envisioning Integrated Facilities and Siting
- SPORL / MBS Pretreatment
- Alcohol to Jet
- Demonstrating Feasibility with Supply Chain Implementation Partners
- Educating Citizens, Industry, Policy Makers

Advancing Supply Chain Development

THE ROLE OF NARA

LEARN MORE ON THE WEB AT NARARENEWABLES.ORG

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Creating a Market

Port of Seattle's visible and tangible leadership sends clear message to potential alternative jet fuel producers and their financial backers that Sea-Tac is planning for the day that biojet will be available through the hydrant system for the aircraft that use the airport

THE ROLE OF THE PORT OF SEATTLE