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

De-Carbonizing Transportation With Sustainable Aviation and Marine Fuels

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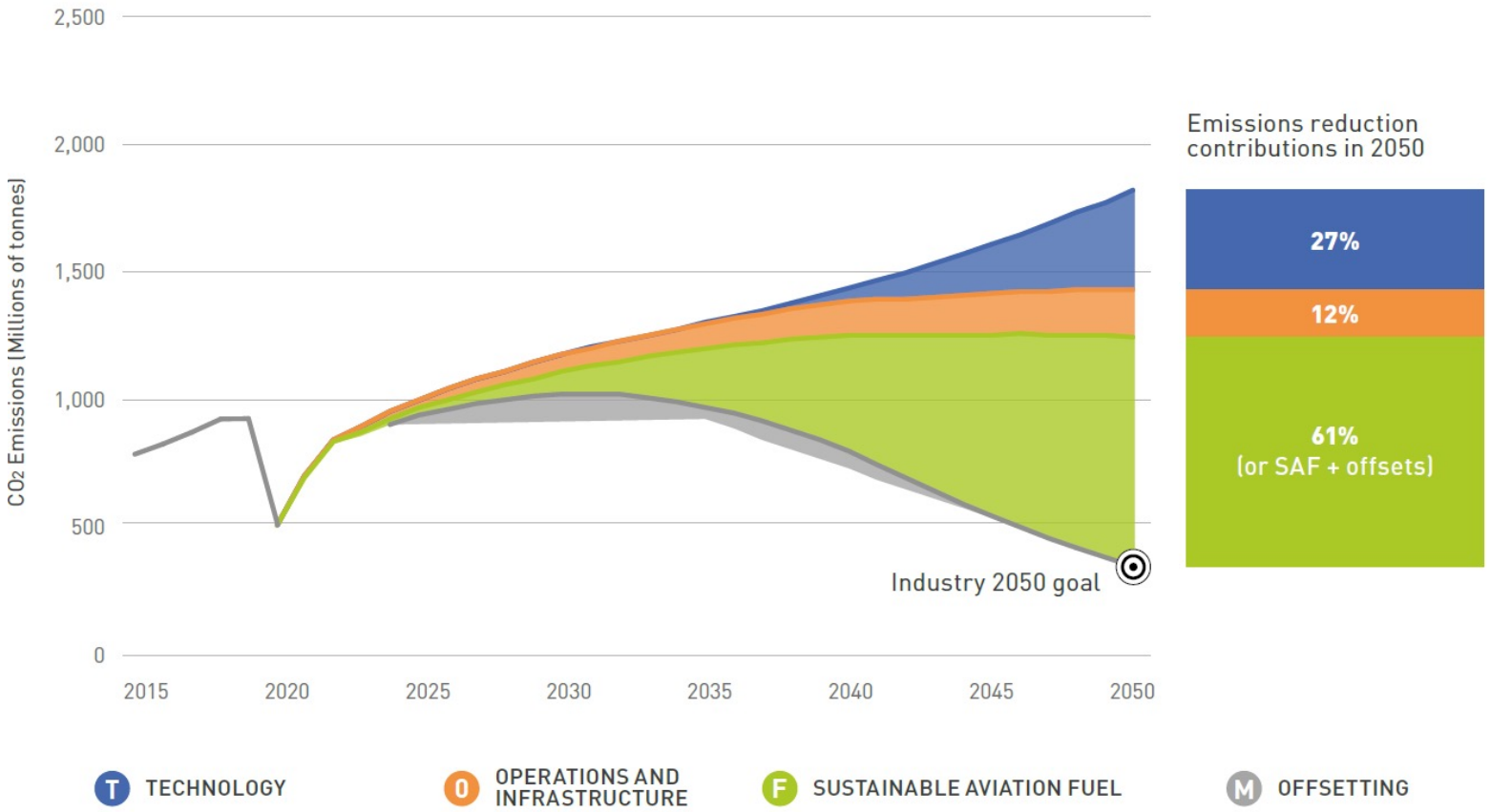
SAF and De-carbonization

- Aviation a difficult to decarbonize sector
- Reliant on liquid transportation fuels for the foreseeable future
- International commitments for GHG reductions
- SAF reduces GHG and other emissions – reduction in aromatics, contrail, synergistic benefits
- Viable SAF technologies exist - seven fuels currently approved for use, more under evaluation for approval
- Wastes, residues, biomass, sugars and energy crops can supply feedstocks
- Support among federal agencies for meeting critical goals - climate, energy security, rural economic development

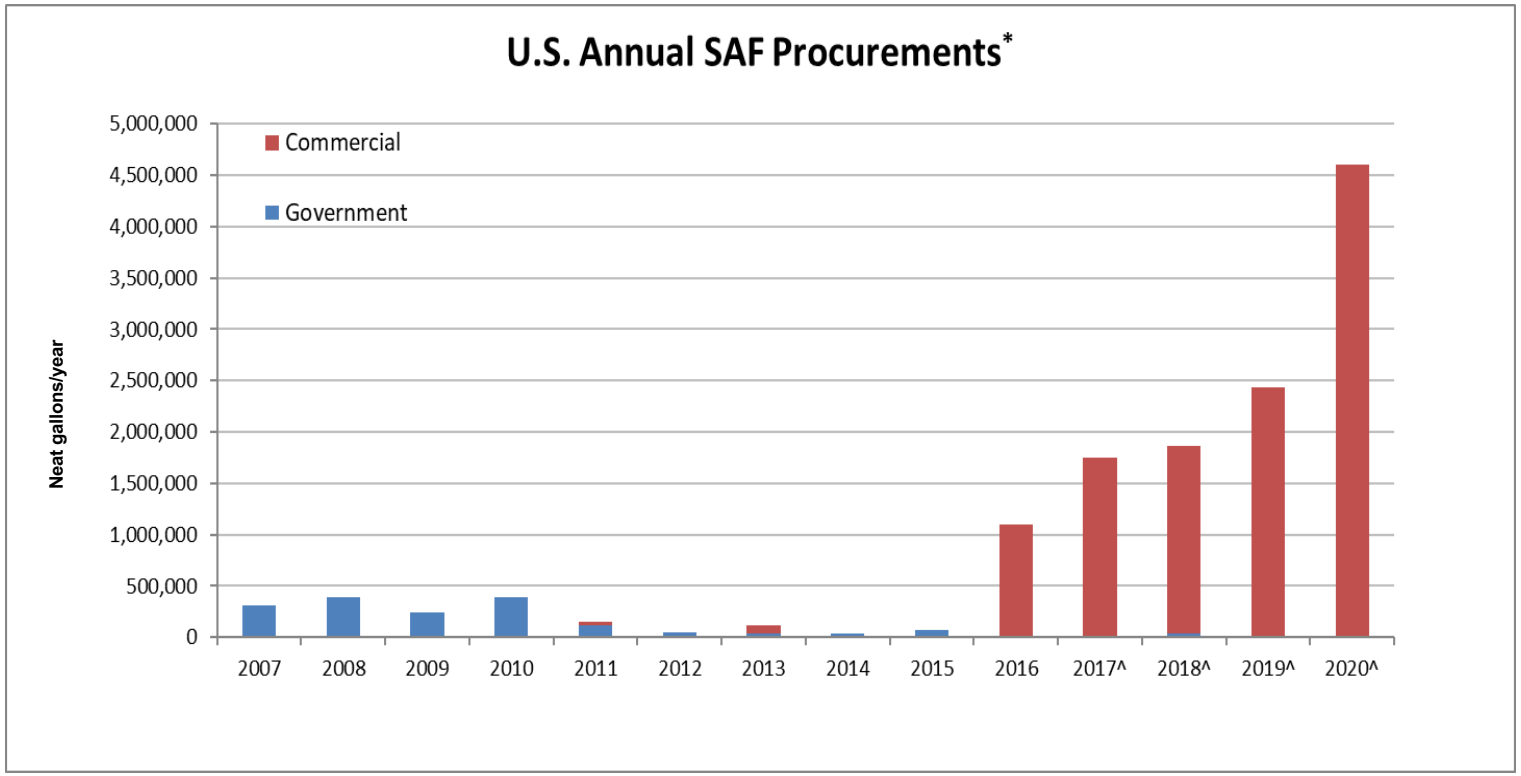
Aviation Industry Commitment to Action on International Aviation CO_2 Emissions



- SAF is a key enabling technology to meet goals
- Global CO2 reductions needed 900 million metric tonnes CO2e/year
- Global SAF volume of 95 to 130 billion gallons/year at 74 – 100% emission reduction needed to achieve this scenario
- Source: Air Transport Action Group, Waypoint 2050 Report, "Scenario 1: Pushing Technology and Operations", September 2020

Where We Stand on U.S. SAF Commercialization

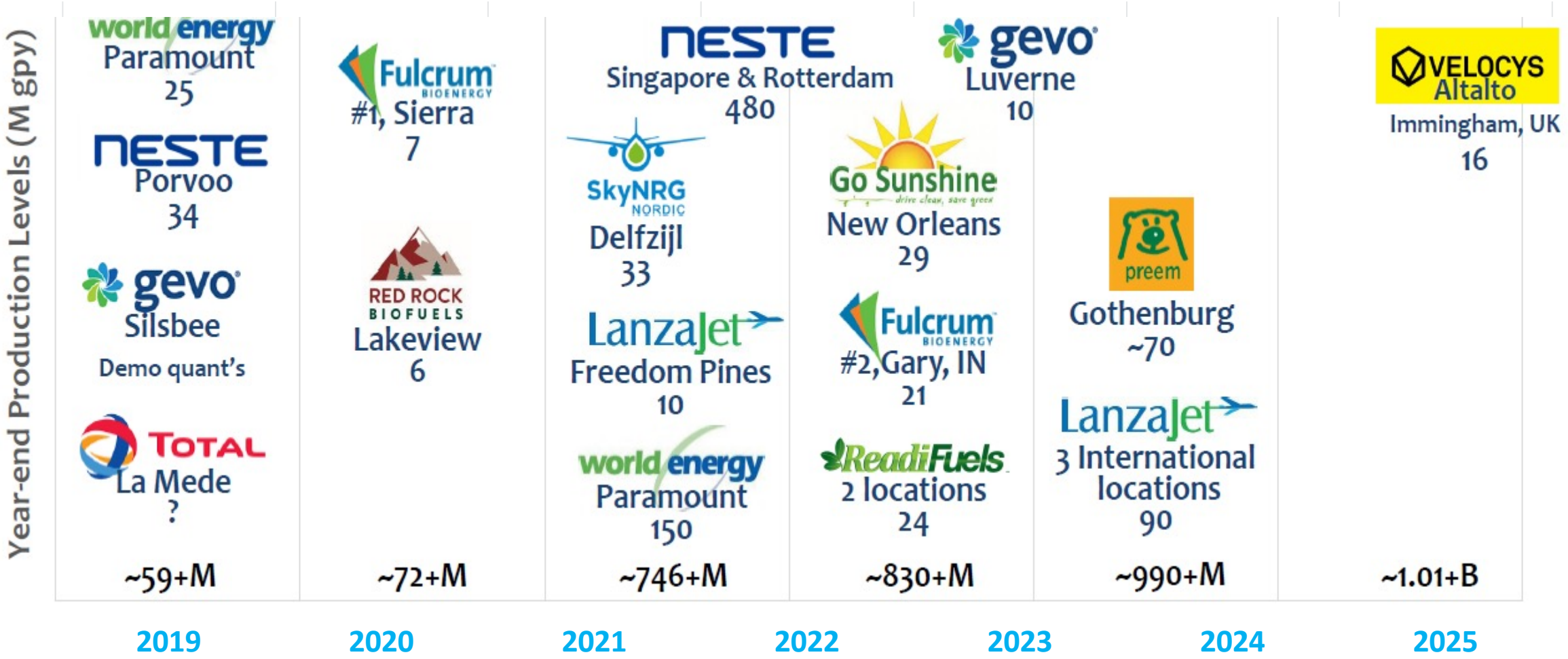
- Five years of sustained & increasing commercial use
- 4.6M gallons in 2020 – 190% increase over 2019
- Commercial & General Aviation engaged
- Two facilities in operation
- Two facilities under construction, others in development
- Cost delta still a challenge, and renewable diesel favored
- Coordinated support from federal agencies



*Reflects voluntarily reported data on use by U.S. airlines, U.S. government, manufacturers, other fuel users, and foreign carriers uplifting at U.S. airports.
^ 2017-2020 calculation incorporates data reported by EPA for RFS2 RINs for renewable jet fuel.

Worldwide SAF Production Projection

Announced intentions with specific commitments to SAF



Credit: CAAFI. Not; comprehensive CAAFI estimates (based on technology used) where production slates are not specified

Challenges to SAF Commercialization

- Timely certification for aviation use of SAF solutions
- Increasing blend limits to greater than 50%
- Reducing the costs of production
- Expanding scale of production
- Availability of conversion infrastructure
- Availability of feedstock supply

Fuel Type	ASTM Data Review	Final Phase II Report	ASTM Specification (D7566)	Estimated gallons of fuel produced for testing	Estimated time from first review to approval	Composition
FT-SPK	09/2007	09/2008	09/2009	710,000[1]	3 years	Mostly normal/ iso-paraffins
HEFA-SPK	06/2008	05/2010	07/2011	626,000[2]	3 years	
SIP*	06/2011	04/2013	06/2014	16,000	3 years	
Gevo ATJ-SPK (isobutanol)	12/2010	04/2015	06/2016	93,100[3]	5 $^{1}/_{2}$ years	
Lanzatech ATJ-SPK (ethanol)	09/2016	07/2017	04/2018	50[4]	1 $^{1}/_{3}$ years	
ARA CHJ	06/2012	10/2018	01/2020	79,000	7 years	Wider range of molecules
IHI HC-HEFA**	02/2019	06/2019	04/2020	50	~1 year	40% cycloparaffin

The Biomass Research and Development Board

Leads the Bioeconomy Initiative

- Co-Chaired by DOE and USDA; at least one Board Member from each of 8 agencies
- Coordinate federal R&D activities relating to biofuels & bio-based products & their commercialization with collaboration between agencies
- Commercialization includes production at competitive prices via collaborations to enhance efficiencies along the entire bioenergy supply chain
- Assesses & provide strategic guidance regarding energy & environmental impacts
- Directs Board Operations Committee and interagency working groups (IWG)
- SAF IWG established in July 2020 – co-chaired by FAA, DOE & USDA

Membership

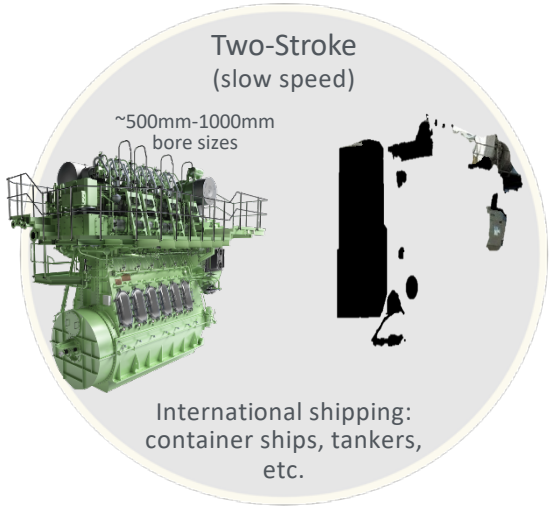
Senate-confirmed sub-cabinet officials from 8 executive branch agencies

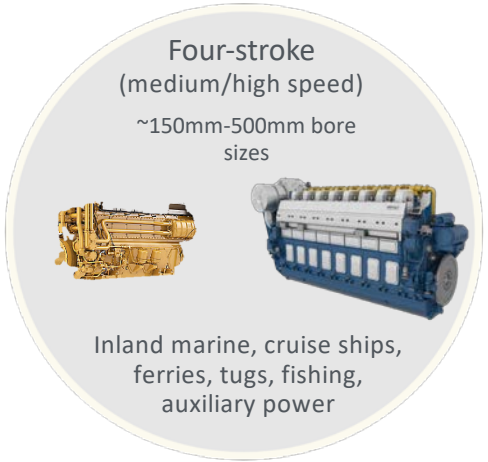
Co-chair

Co-chair

Rationale for Biofuels in Marine Freight Transportation

- Responsible for 90% of world trade
- Shipping consumes 80 billion gallons/year of fossil fuel
- International Maritime Organization (IMO) targeting a 50% reduction in CO2 emissions by 2050 compared to 2008
- Demand for marine fuels is expected to double by 2030
- Largest anthropogenic source of sulfur in the atmosphere and black carbon in the arctic – synergistic benefits of de-carbonization
- Biofuels can present short-term (straight vegetable oil, hydro-treated esters and fatty acids, biodiesel, renewable natural gas), mid-term (bio-oils, bio-crudes, lignin/alcohol mixtures), and long-term solutions (methanol)





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De-Carbonizing Marine Freight Transportation Using Biofuels

- Biofuel pathways (gasification, pyrolysis) will make renewable jet, diesel, and naphtha
- Marine sector is exploring low carbon fuel options
- Marine transportation (similar to jet) is sensitive to cost of fuel
- Biofuels along with fuel cells and efficiency improvements are among a suite of options being considered
- De-carbonizing marine has benefits beyond this sector – agriculture sector relies on global trade in commodities using vessels