DYNAMIC SUSTAINABILITY LAB™
AT SYRACUSE UNIVERSITY

SUSTAINABLE FUELS & THE AVIATION SECTOR

www.DynamicsLab.org
Researching the Risks and Opportunities of the Global Sustainability Transition

Bulletin No. 20220101

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INTRODUCTION

The transition to Sustainable Aviation Fuels (SAF) has the potential to significantly benefit both the domestic economy and environment. SAF can reduce the risks of the Electric Vehicle Transition which is expected to have significant implications for the production and demand of sustainable/renewable fuels such as Ethanol of renewable diesel.

NET-ZERO CARBON EMISSIONS

On March 30, 2021, Airlines for America (A4A) the trade industry that represents major U.S. Airlines as well as other global commercial and business aviation industry associations announced commitments to achieve net-zero carbon emissions by 2050.

WHY NET-ZERO CARBON EMISSIONS

The aviation sector around the globe contributed approximately 915 million tonnes of CO2 in 2019. Around 2% of anthropogenic CO2 emissions. According to the World Wildlife Federation (WWF) Air travel is currently the most carbon intensive activity an individual can make. A passenger taking flight from New York to London and back emits more emissions than an average person in Paraguay over the course of an entire year.

US AIRLINE SIGNATORIES OF NET-ZERO CARBON COMMITMENTS

Alaska Airlines, American Airlines, Atlas Air Worldwide, Delta, FedEx, Hawaiian, jetBlue, Southwest, United, UPS.

FAST FACTS

The Dynamic Sustainability Lab™

80%

Sustainable Aviation Fuels reduce up to 80% in carbon emissions over the lifecycle of the fuel compared to traditional jet fuel depending on the feedstock, production methods and the supply chain.

4.5 BILLION

Number of passengers worldwide in 2019 up from 100 million in 1960.

915 M TONNES

Worldwide, flights produced **915 million tonnes of CO_2** in 2019. This amounts to around 2% of anthropogenic CO_2 emissions.

2050

The year which the global aviation sector has committed to **Net-Zero Carbon Emissions.**

45 BILLION

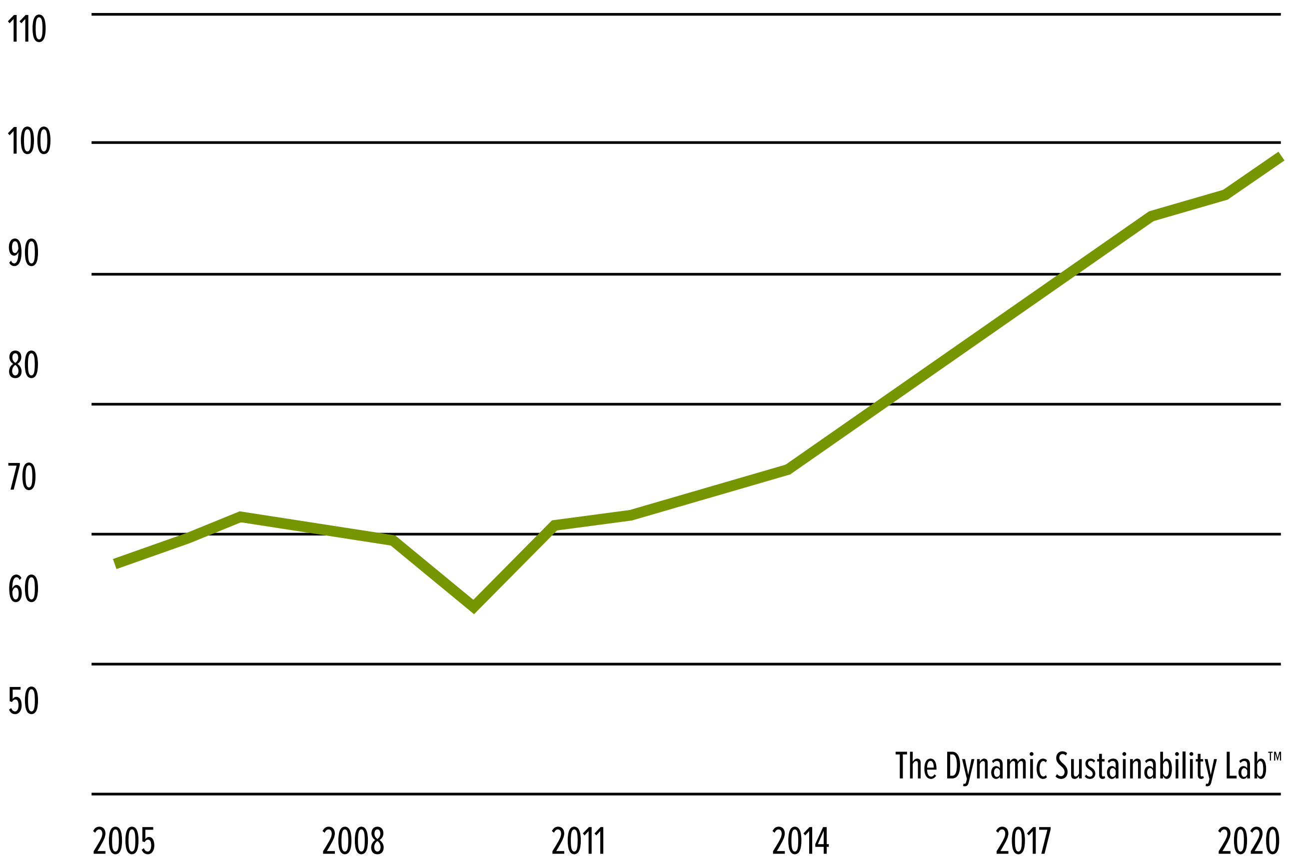
The U.S. and European Union goals together would support almost 4 billion gallons of annual sustainable aviation fuel production in 2030, and more than 45 billion by 2050.

SAF

Sustainable Aviation Fuel (SAF) is a **biofuel** that is derived from over 1 billion dry tons of biomass which can be **sustainably collected every year in the United States.** This is enough to produce 50-60 billion gallons of low-carbon sustainable biofuels.

Various agricultural resources can be used including corn grain; oil seeds; algae; forest harvesting residues; oils and greases; municipal solid waste streams; other wet wastes like sludges and dedicated energy crops.

COMMERCIAL AVIATION ANNUAL FUEL CONSUMPTION WORLDWIDE



Note: 2020 Numbers Pre Pandemic [1].

FUEL CONSUMPTION TRENDS

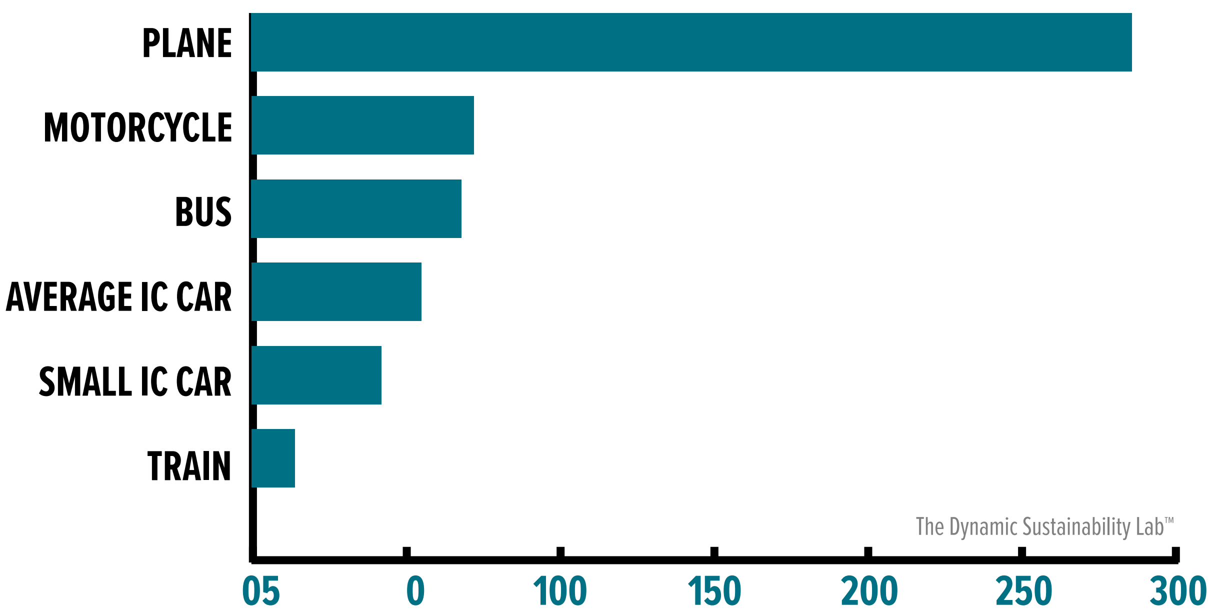
Aviation fuels currently used today are dominated by **petroleum-based fuels**.

Jet engines use an unleaded kerosene-based fuel such as Jet A-1 or a naphtha-kerosene blend (Jet-B) while piston-engine aircraft use gasoline also known as Avgas.

AVIATION & CLIMATE CHANGE

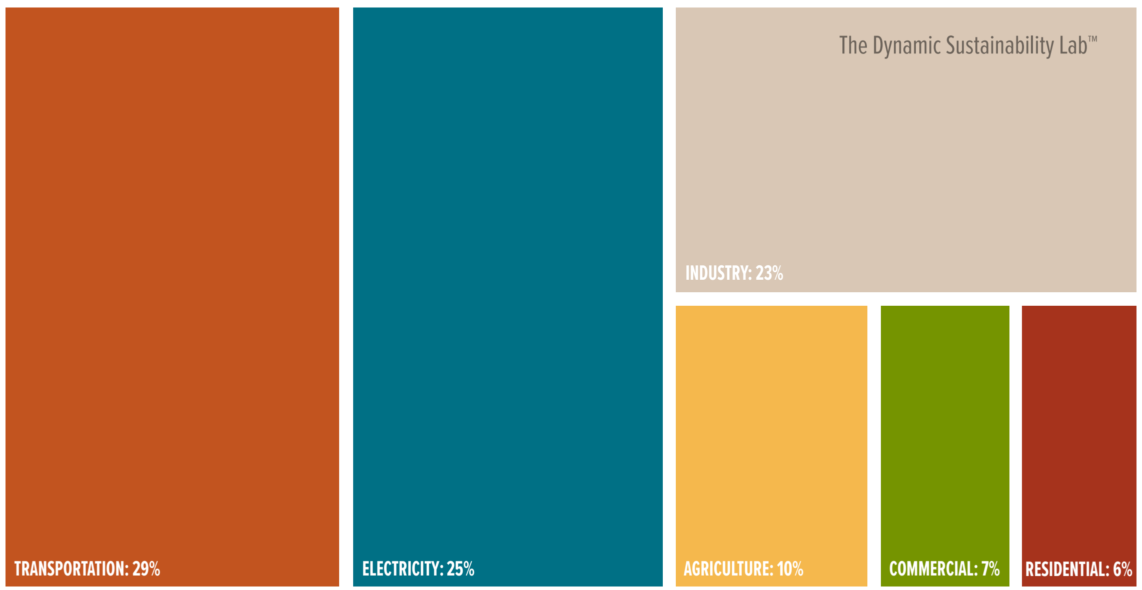
Transportation plays a significant role in greenhouse gas emissions. In fact, in the United States the transportation sector was the largest emitter of GHG in pre-pandemic 2019. By mile / kilometer, aviation is the most carbon intensive form of transportation which is driving the industry to advance sustainable aviation fuels.

GRAMS OF CO2/PASSENGER/KM



Source: European Environment Agency (2021)

US GREENHOUSE GAS EMISSIONS BY SECTOR, 2019



Source: US EPA (2019)

RENEWABLE FUELS

CAN SAF FILL THE EV GAP?

In 2020, more than 62,000 jobs were directly associated with the ethanol industry in the United States which supported an additional 242,600 indirect and induced jobs across.

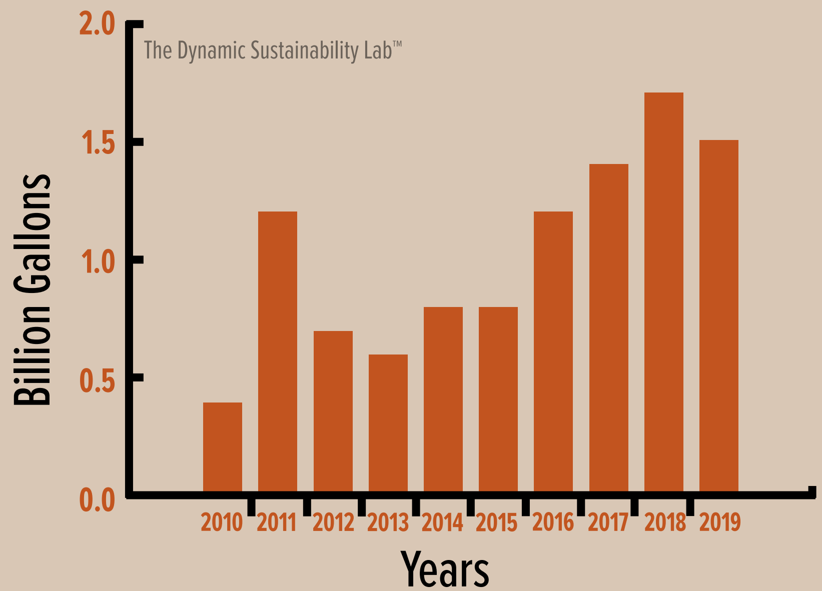
The industry created $18.6 billion in household income and contributed $34.7 billion to the national Gross Domestic Product while spending $21.4 billion on raw materials, inputs, and other goods and services (RFA, 2021).

Much of this economic and job creation supports Rural America and the domestic agriculture sector.

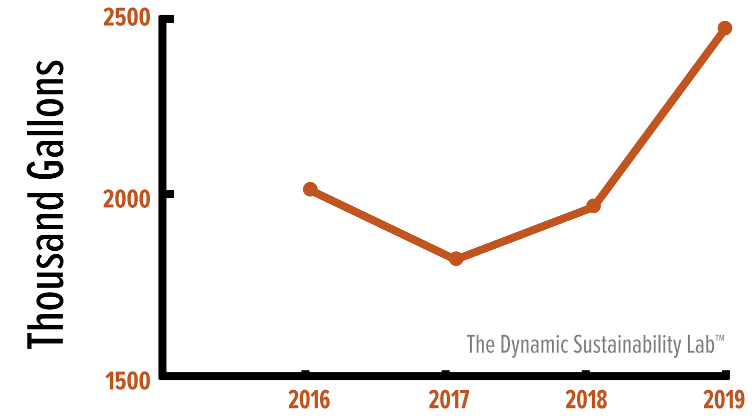
Fuel ethanol production capacity in the United States totaled 17.3 billion gallons per year (gal/y), or 1.1 million barrels per day (b/d), as of January 2020, according to the U.S. Energy Information Administration's (EIA) 2020.

Nameplate capacity of operable ethanol plants increased by 3% — 470 million gal/y — between January 2019 and January 2020.

US Ethanol Production for Vehicles



US Renewable Jet Fuel Production



Renewable aviation fuel production in the United States was 2.4 M gallons while ethanol production reached 16 B gallons. Renewable aviation fuels will play a pivotal role in the domestic economy and jobs as ethanol demand will substantially decrease due to electric vehicles.

AGRICULTURE & FUELS

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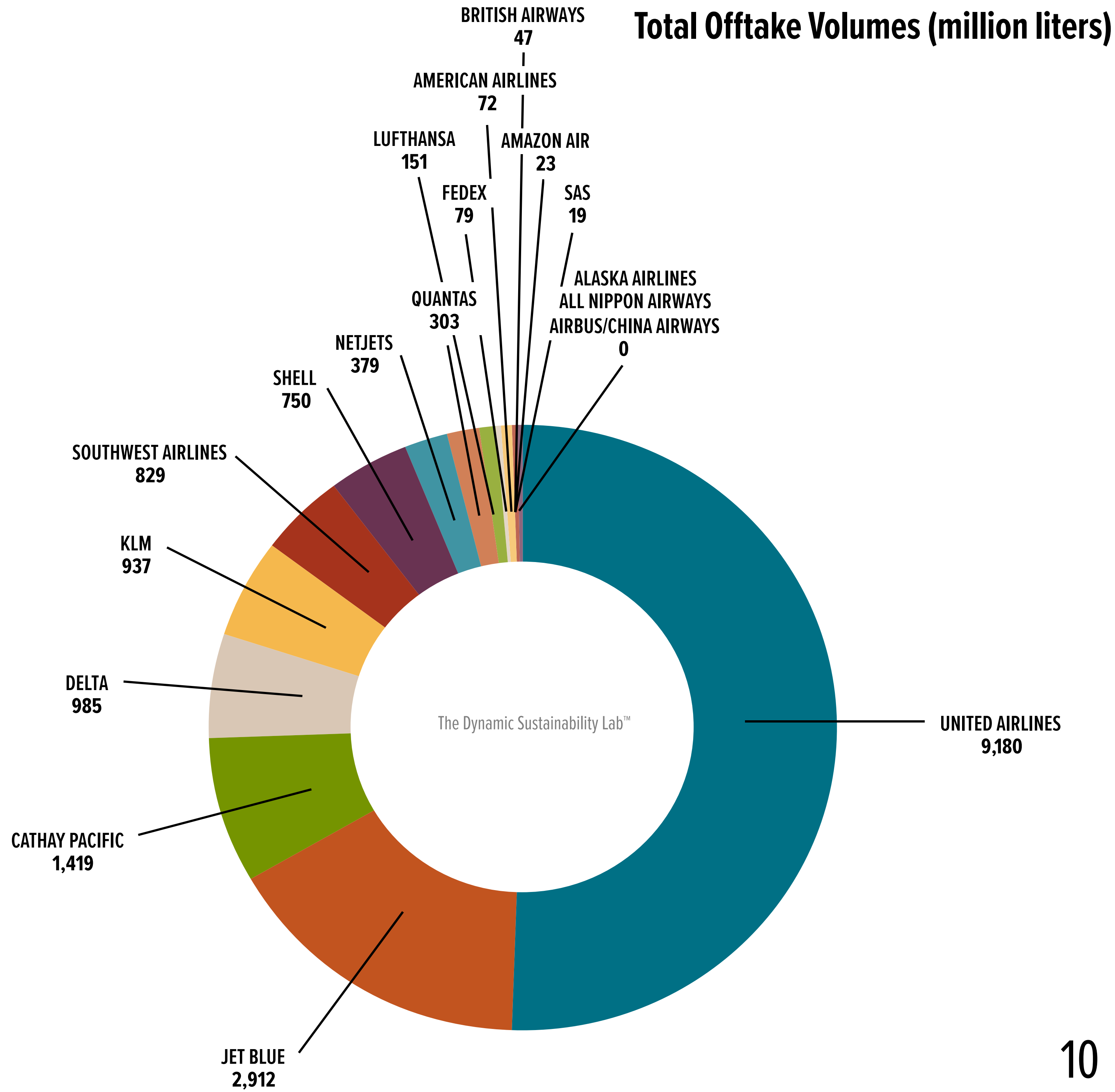
AIRLINE SAF PURCHASES

The International Civil Aviation Organization (ICAO) which is funded and directed by 193 national governments tracks offtake agreements. These are agreements to purchase all or a substantial part of the manufacturer's upcoming SAF production.

The most recent data is presented by listing each major airline and their current offtake agreements for SAF by volume.



SIX PATHWAYS TO CREATE SUSTAINABLE AVIATION FUELS

FT – SPK

PROCESS NAME
Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene

FEEDSTOCK/WASTE
solid biomass resources such as wood residues, municipal solid waste

BLENDING LIMIT
up to 50%

HEFA – SPK

PROCESS NAME
Synthesized paraffinic kerosene produced from hydroprocessed esters and fatty acids

FEEDSTOCK/WASTE
cooking oils, animal fat, algae and vegetable oil (e.g. camelina)

BLENDING LIMIT
up to 50%

SIP – HFS

PROCESS NAME
Synthesized iso-paraffins produced from hydroprocessed fermented sugars

FEEDSTOCK/WASTE
microbial conversion of hydro carbon from sugars

BLENDING LIMIT
up to 10%

FT – SPK/A

PROCESS NAME
Synthesized kerosene with aromatics derived by alkylation of light aromatics from nonpetroleum sources

FEEDSTOCK/WASTE
municipal solid waste, forestry residue

BLENDING LIMIT
up to 50%

ATJ – SPK

PROCESS NAME
Alcohol-to-jet synthetic paraffinic kerosene

FEEDSTOCK/WASTE
agricultural waste: crop straws, fine woody debris, stover

BLENDING LIMIT
up to 30%

CHJ

PROCESS NAME
Catalytic hydrothermolysis Jet Fuel

FEEDSTOCK/WASTE
plant oils, soybean oils, waste oil, algal oils, etc.

BLENDING LIMIT
up to 50%

SAF PATHWAYS

SAF is widely developed from biomass and feedstocks with a low carbon content to ensure that the carbon dioxide emissions produced during fuel burn are minimal. For a sustainable aviation to be used in aircraft, it must have "drop-in" characteristics i.e. automatically be used in existing aircraft technology and its performance must be comparable or exceed existing fossil fuels during the combustion process.

SAF PRODUCERS

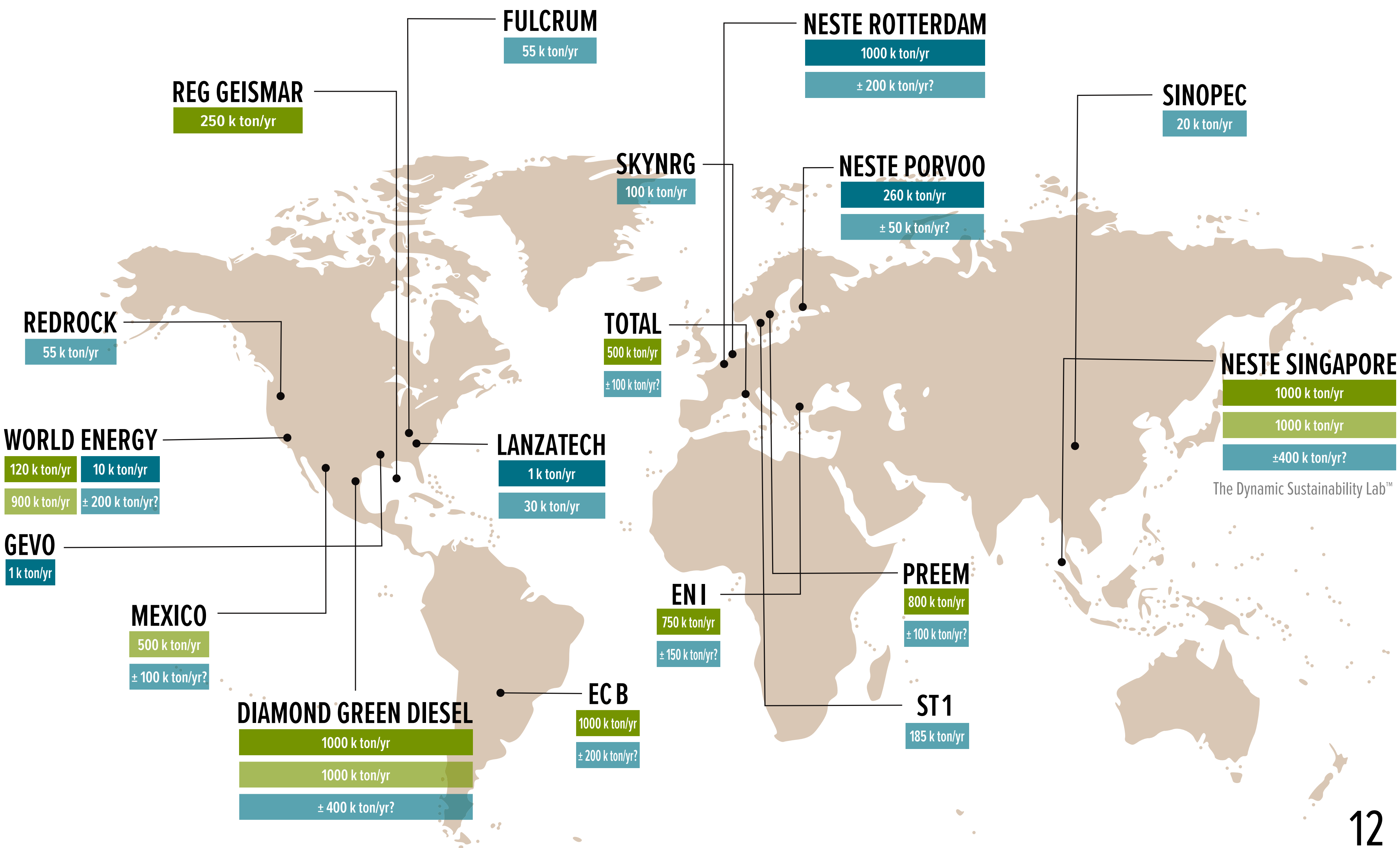
KEY

- Total Renewable Diesel
- Planned Diesel Expansion
- Total Renewable SAF
- Planned SAF Expansion

The legacy fossil fuel industry has taken notice of the aviation industry's net-zero carbon commitment as they think through the future phase out of internal combustion engines for vehicles.

For instance, in September of 2021 Shell announced it will convert one of its largest refineries located in the Netherlands to produce almost a half a million tons of SAF per year with production to start in 2024.

Delta airlines working with Chevron is testing SAF to replace 10% of the Delta's with SAF by 2030.



BATTERIES VERSUS SAF IN AVIATION

Energy Density is the Achilles heel of battery technology as a sustainable solution for aviation. Advanced batteries like those used in a Tesla Model 3 battery provides 207 Wh/kg. Current jet fuel has an energy density of 9.6 kWh/L.

This means that jet fuel, pound for pound, is nearly 50x more energy-dense than batteries but when adjusted for the inefficiency of internal combustion 1,000 pounds of jet fuel yields roughly 14x more power than 1,000 lbs of batteries.

Additionally, unlike battery technologies, aviation fuels are consumed during take-off and flight and thus reduce the weight of the aircraft and offering greater fuel efficiency. Additionally refueling a plane takes far less turnaround time than recharging current battery technologies.

In the future could witness hybrid designs where sustainable aviation fuel is utilized during take-off and next generation of batteries that have much greater energy density can be used during normal flight. Current estimates put the timing at least 30 years in the future.

POLICIES IN PLAY

A number of policies have recently been enacted at the national and regional level.

REFEUL EU AVIATION

The European Commission published a number of legislative proposals including the ReFuelEU focused on increasing SAF production and use.
This includes a blending mandate for airlines flying out of EU airports starting in 2025 at 2% and increasing to a minimum volume of 63% in 2050 of which 28%, would be synthetic SAF.

THE U.S. SUSTAINABLE SKIES ACT

Introduced by Congress in May of 2021, the Act seeks to boost use of SAF by providing a $1.50 credit per gallon for blenders that supply SAF with a demonstrated 50% or greater GHG savings.
There is currently a proposal to allocate $1B in grants over 5 years to expand the number of SAF production facilities in the U.S.
President Biden in September of 2021 announced a goal to increase U.S. production of SAF to at least 3 billion gallons per year by 2030.

CALIFORNIA LOW CARBON FUEL STANDARD

The CA-LCFS that has a goal to reduce GHG emissions in the transportation sector.
The policy uses a carbon intensity reduction to put a value on carbon reduction generated from renewable fuels. The regulation was updated in 2019 to recognize SAF as an eligible fuel to generate credits.

POLICY NEEDS

The domestic aviation sector is dependent on the rapid scale up of affordable SAF. As such, a number of domestic policies are being sought after by businesses representing a number of sectors in the value chain.

TAX CREDIT FOR BLENDERS

Federal approval of a 10-year performance-based SAF blender's tax credit, at $1.50/gallon for SAF that achieves a 50% lifecycle GHG emissions benefit and additional credit up to $2/gallon for SAF with GHG emissions savings above 50%.

GRANTS AND LOAN GUARANTEES FOR SAF PRODUCTION

Enable SAF producers to construct facilities and establish or scale up operations by creating a new Department of Transportation (DOT)/FAA competitive grant program and a new loan guarantee program specific to SAF producers.

SAF-SPECIFIC PRODUCTION TAX CREDIT

Establish a tax credit for the annual production of SAF, in addition to a SAF blender's tax credit, akin to the credit in Internal Revenue Code Section 40(b)(6) for the production of second-generation biofuels, or the credit in Section 40A(b)(4) for the production of small agri-biodiesel quantities, or the credit in Section 45H for the production by small business refiners of low sulfur diesel fuel.

GREATER R&D FUNDING

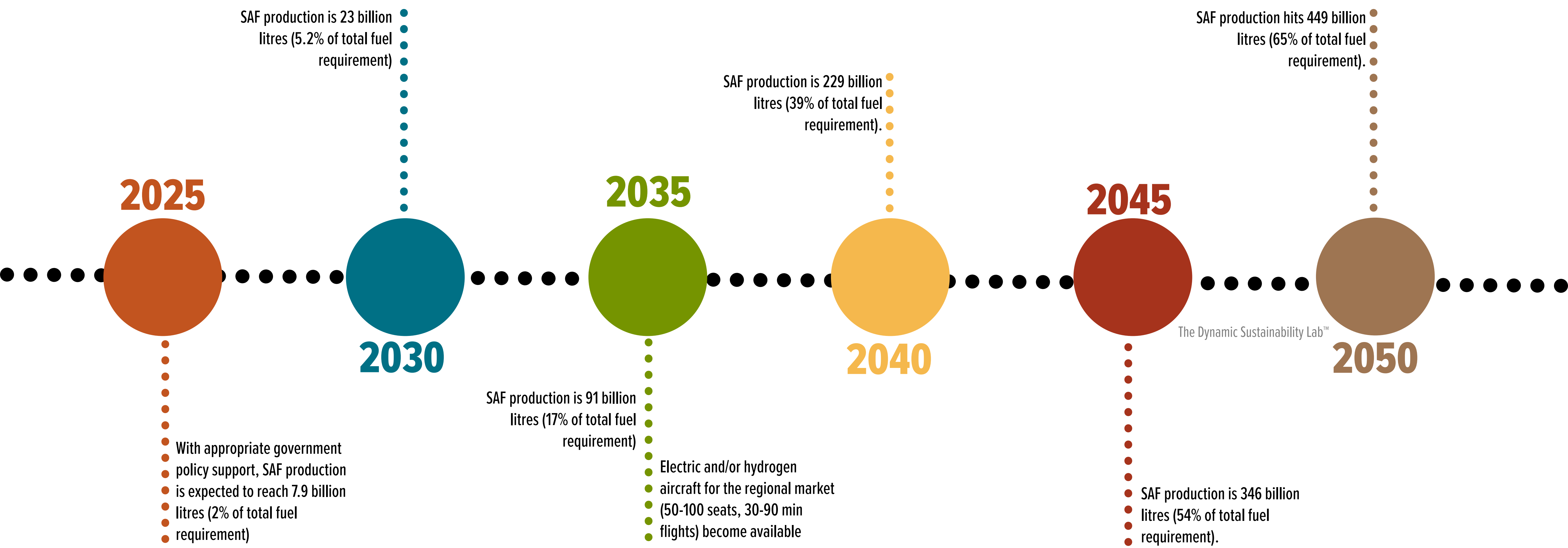
Update of the 2016 Federal Alternative Jet Fuels Research and Development Strategy to prioritize and accelerate federal funding for SAF research and development.

ASTM PROCESS

Direct funding assistance for the FAA-established ASTM D4054 Clearinghouse, which seeks to increase the efficiency of the SAF qualification process.

TIMEFRAMES & BENCHMARKS

The combination of measures needed to achieve net zero emissions for aviation by 2050 will evolve over the course of the commitment based on the most cost-efficient technology available at any particular point in time. A base case scenario as follows is the current focus:



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MISSION STATEMENT

Provide support to public and private organizations on the risks, unintended consequences, and opportunities of the global sustainability transition

PRIMARY TRANSITION AREAS OF FOCUS

Technology Transitions – Energy Transitions – Biobased Transitions Economy

COMPONENTS OF THE TRANSITION

Supply Chains – Green Finance – Critical Minerals – ESG – National Security

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