FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Short- and long-term global alternative jet fuel production and associated GHG emissions benefits

Project 1

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AVIATION SUSTAINABILITY CENTER

Motivation

- Global air traffic is projected to grow substantially in the next decades (btw. 3-4% p.a.)

- ICAO has an aspirational goal of "carbon-neutral growth" from 2020 onward

- In order to achieve this goal, ICAO and ICAO member states are working on a "basket of measures" to address CO_2 emissions

- One element of that basket is alternative jet fuels (AJF)

Research objectives

ICAO-CAEP created the Alternative Fuels Task Force (AFTF) for two purposes:

1. To determine the potential contribution of AJF towards achieving the goal of carbon neutral growth in the near- and long-term
2. Develop a methodology for how to appropriately credit the use of AJF under a global market-based measure (GMBM) to mitigate aviation CO_2 emissions

This work was carried out primarily by researchers at MIT, but reflects the contributions of >80 technical experts

- Significant input from Volpe, Argonne National Lab, Purdue U, EU Joint Research Council

AJF production potential analysis scope

Temporal: Near-term - 2020
Long-term - 2050

Geographical: Global

Emissions: Lifecycle GHG emissions

Feedstocks:

Feedstock group	Feedstock sub-group
Crops	Vegetable oil crops Starchy crops Sugary crops Lignocellulosic energy crops
Wood	Wood fuel & roundwood
Residues	Agricultural residues Forestry residues
Wastes	Waste fats, oils and greases (FOG) Municipal solid waste (MSW) Waste gases
Algae	Microalgae

AJF production technologies: Approved or under consideration for ASTM certification (HEFA, FT, SIP, ATJ)

GHG emissions reductions from AJF

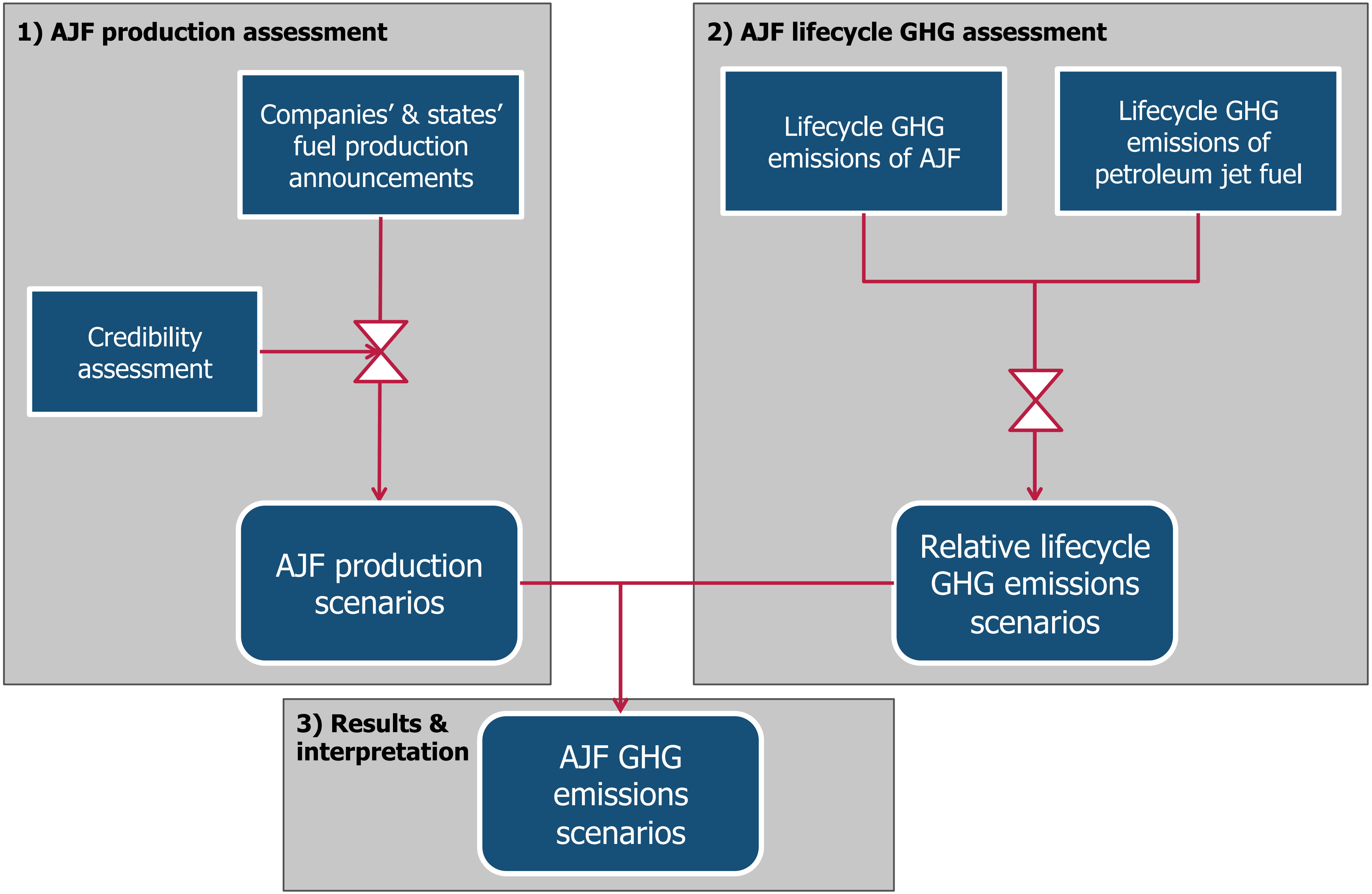
Created and used modelling capabilities:

- for quantification of **global AJF production scenarios** in 2020 and 2050, broken out by feedstock-group, feedstock location, and land types used

- for estimation of **AJF lifecycle GHG intensity**, broken out by feedstock-group and conversion technology, relative to petroleum-derived jet fuel

- for estimation of **global scenarios of aviation GHG emissions reductions** through the use of AJF, including emissions from direct land-use change

2020 analysis components



1) AJF production assessment

Companies' & states' fuel production announcements

Credibility assessment

AJF production scenarios

2) AJF lifecycle GHG assessment

Lifecycle GHG emissions of AJF

Lifecycle GHG emissions of petroleum jet fuel

Relative lifecycle GHG emissions scenarios

3) Results & interpretation

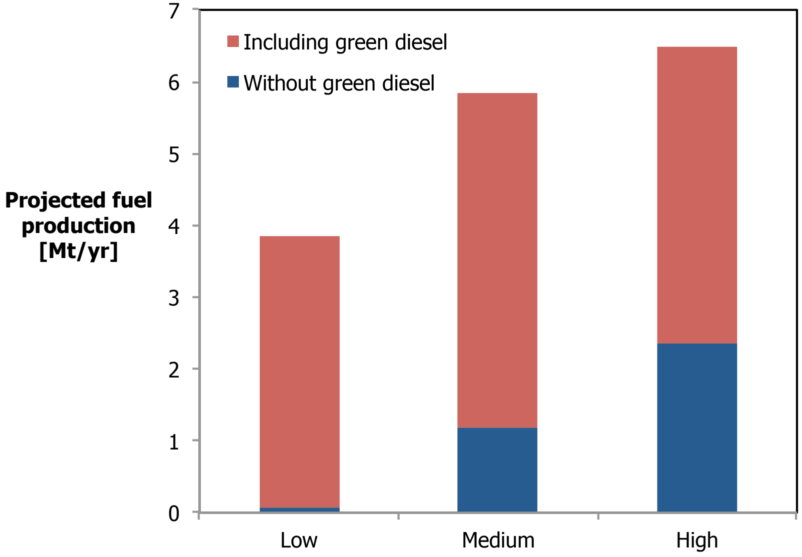
AJF GHG emissions scenarios

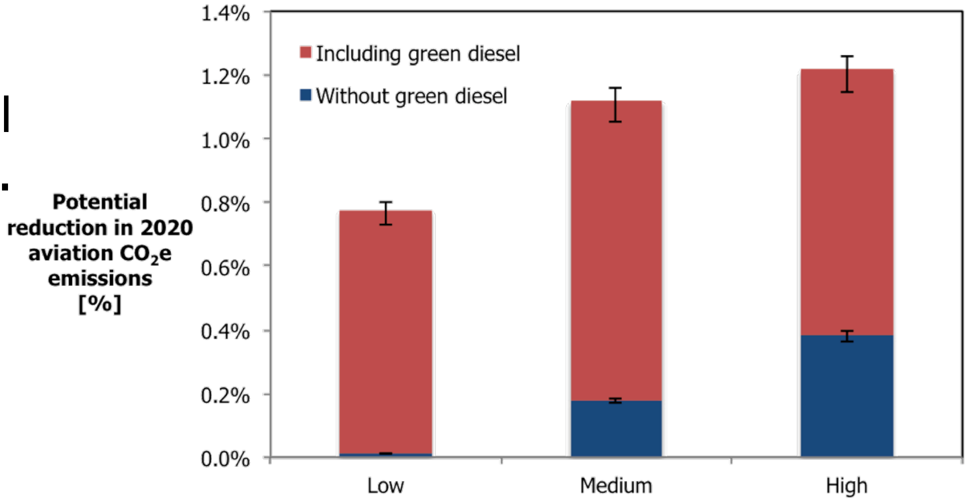
Results: 2020 AJF production scenarios

AJF production scenarios range from **0-2% (0-150,000 bpd)** of projected global jet fuel demand in 2020

This results in a lifecycle GHG emissons reduction of **0-1.3%** GHG emissions reduction compared to petroleum-derived jet fuel use, only

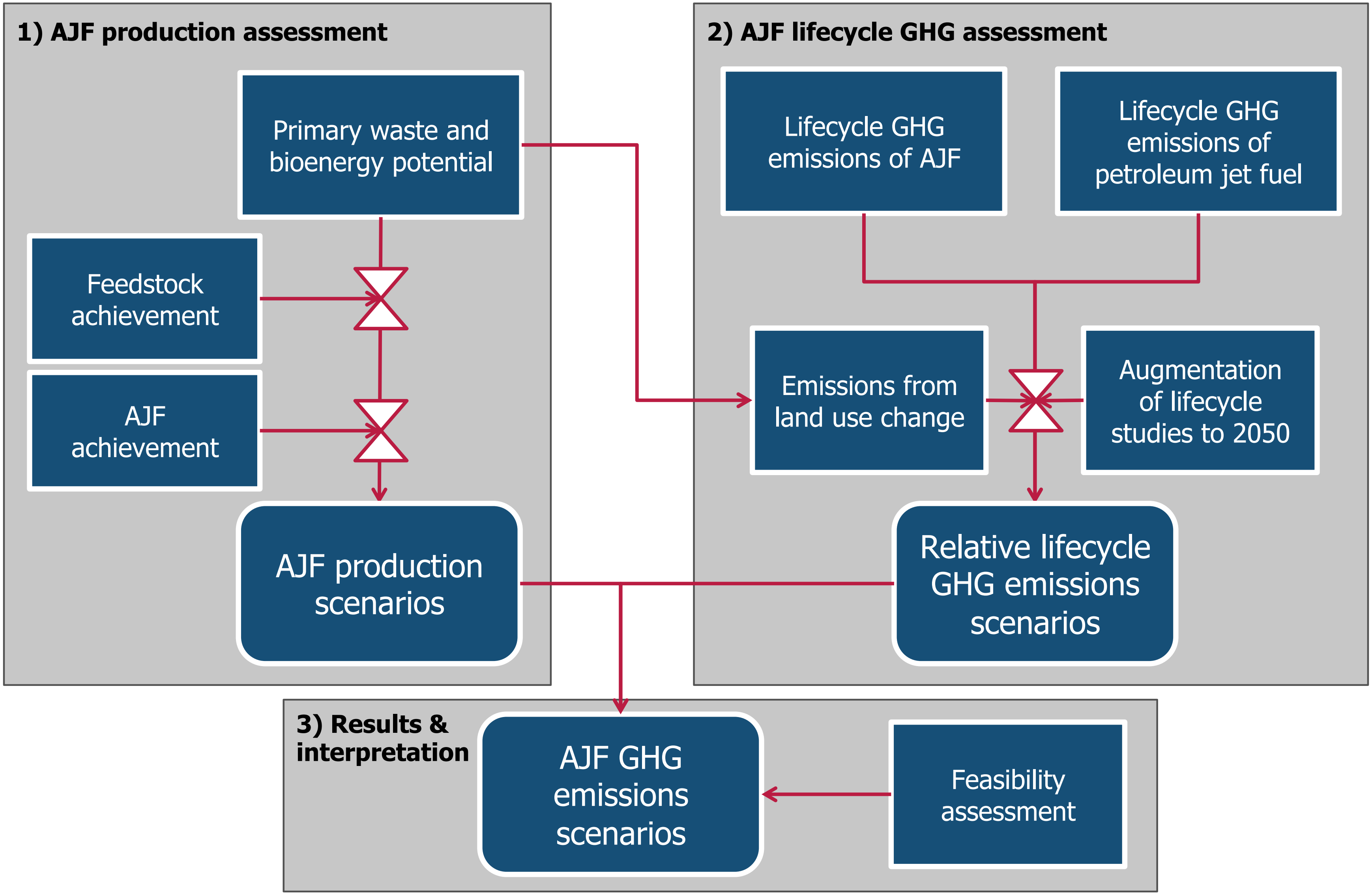
High-end only achievable if green diesel blends are approved for jet engines. Without green diesel max. GHG emissions' reductions are approx. **0.4%**





Preliminary results - do not cite or quote.

2050 analysis components



1) AJF production assessment

Primary waste and bioenergy potential

Feedstock achievement

AJF achievement

AJF production scenarios

2) AJF lifecycle GHG assessment

Lifecycle GHG emissions of AJF

Lifecycle GHG emissions of petroleum jet fuel

Emissions from land use change

Augmentation of lifecycle studies to 2050

Relative lifecycle GHG emissions scenarios

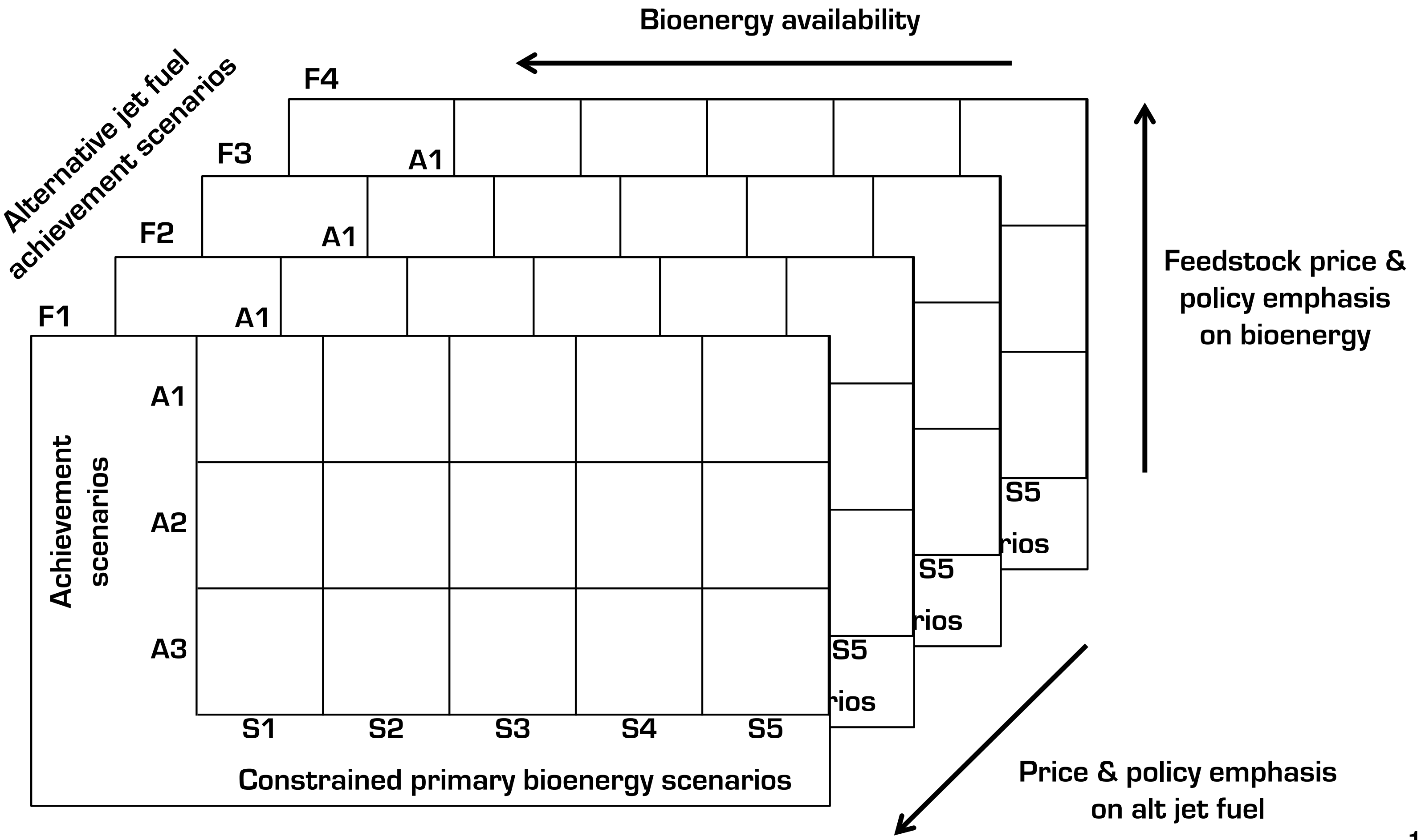
3) Results & interpretation

AJF GHG emissions scenarios

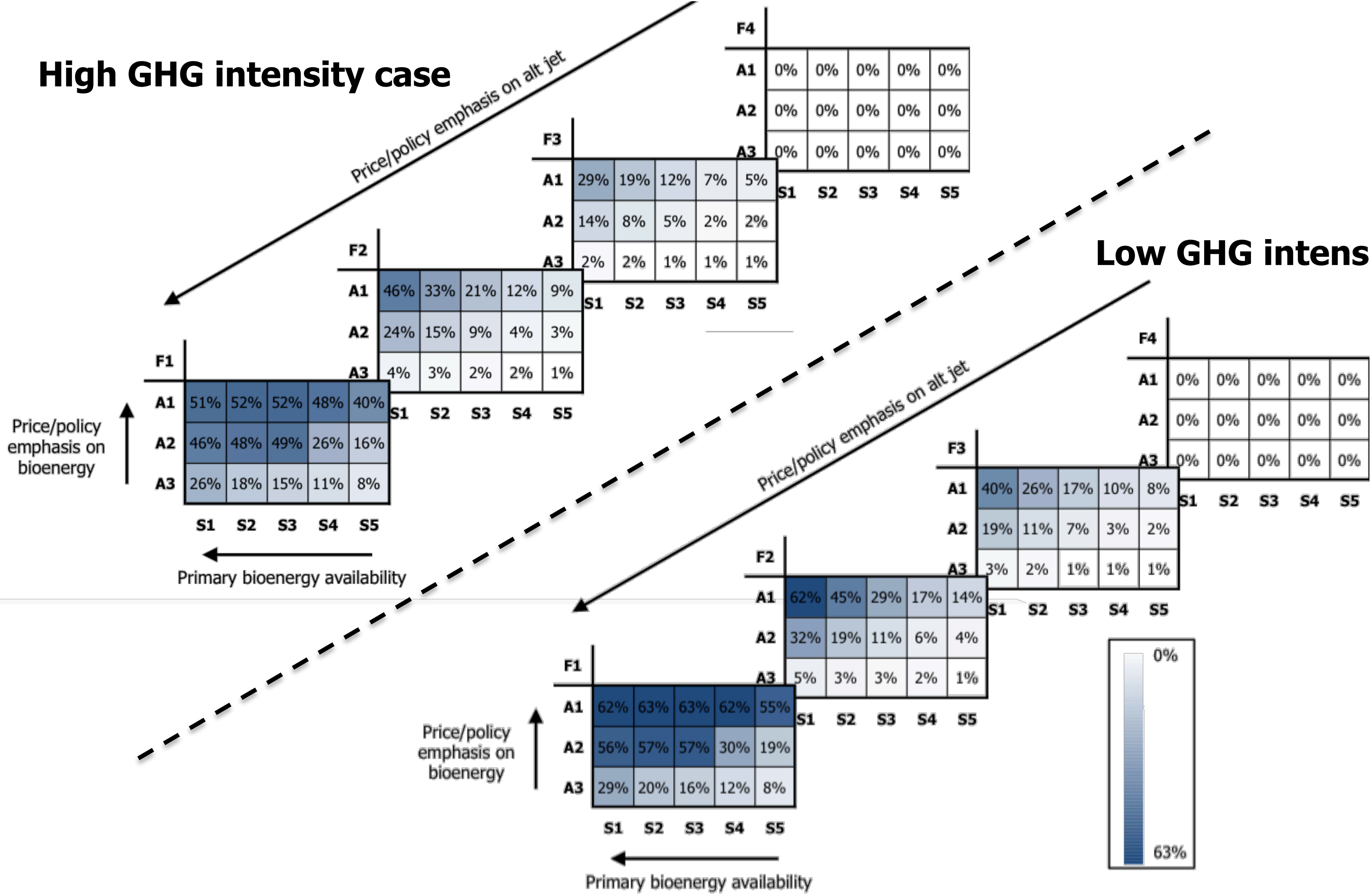
Feasibility assessment

2050 AJF production scenario definition

Scenarios defined at each step of the analysis to capture a wide range of potential outcomes



Results: 2050 GHG emissions reduction from AJF scenarios



High GHG intensity case

F4	S1	S2	S3	S4	S5
A1	0%	0%	0%	0%	0%
A2	0%	0%	0%	0%	0%
A3	0%	0%	0%	0%	0%

F3	S1	S2	S3	S4	S5
A1	29%	19%	12%	7%	5%
A2	14%	8%	5%	2%	2%
A3	2%	2%	1%	1%	1%

F2	S1	S2	S3	S4	S5
A1	46%	33%	21%	12%	9%
A2	24%	15%	9%	4%	3%
A3	4%	3%	2%	2%	1%

F1	S1	S2	S3	S4	S5
A1	51%	52%	52%	48%	40%
A2	46%	48%	49%	26%	16%
A3	26%	18%	15%	11%	8%

Low GHG intensity case

F4	S1	S2	S3	S4	S5
A1	0%	0%	0%	0%	0%
A2	0%	0%	0%	0%	0%
A3	0%	0%	0%	0%	0%

F3	S1	S2	S3	S4	S5
A1	40%	26%	17%	10%	8%
A2	19%	11%	7%	3%	2%
A3	3%	2%	1%	1%	1%

F2	S1	S2	S3	S4	S5
A1	62%	45%	29%	17%	14%
A2	32%	19%	11%	6%	4%
A3	5%	3%	3%	2%	1%

F1	S1	S2	S3	S4	S5
A1	62%	63%	63%	62%	55%
A2	56%	57%	57%	30%	19%
A3	29%	20%	16%	12%	8%

Emissions reduction ranges from **0-63%**, compared to petroleum-derived jet fuel usage only.

Preliminary results - do not cite or quote.

Results: 2050 feasibility assessment

Aviation GHG emissions reduction	Required alternative jet fuel production volume in 2050 (Mt/yr)	Number of new biorefineries/yr	Capital investment/yr
2%	30	10	\$1B - \$3B
10%	130	40	\$3B - \$14B
17%	220	70	\$6B - \$25B
40%	570	170	\$15B - \$60B
63%	870	260	\$20B - \$90B

Average historical global ethanol and biodiesel production	**Total annual volumes (Mt/yr)**	10 (years 1975 - 2000) to 45 (2001 - 2011)
	Number of new biorefineries/yr	5 (years 1975 - 2000) to 60 (2001 - 2011)
Projection for average annual investment in petroleum refining in 2035		\$55B

Preliminary results - do not cite or quote.

Results: 2050 feasibility assessment

Growth in AJF production needs to be on the order of recently observed growth of 5-15 Mt/yr (**100k-300k bpd**) in global biofuel production capacity to **achieve between 10% and 20%** emissions reduction by 2050

Growth needs to **significantly exceed** historical global biofuel production growth rates for total GHG emission reductions **of greater than 20%.**

Preliminary results - do not cite or quote.

Summary of findings

For 2020: AJF production scenarios of **0-2% (0-0.15 Mbpd)** of projected global fuel demand in 2020, and GHG emissions reductions of **0-1.3%** compared to petroleum-derived jet fuel.

- High-end only achievable if green diesel blends are approved for jet engines

For 2050: AJF production could range from **0 to 4.6 Mt (0-100 Mbpd)**, offsetting between **0-100%** of the projected petroleum-derived jet fuel demand.

- Production range translates into a **reduction** of total lifecycle **GHG emissions** from aviation between **0-63%**
- GHG reductions < fuel replacement because AJF in the different scenarios is associated with **lifecycle GHG emissions** of **31-64%** of those of petroleum-derived jet fuel, on average

Preliminary results - do not cite or quote.

Summary of findings

For 2050 (cont'd): Highest modeled GHG emission reductions require:

- **Optimistic assumptions** on increases in agricultural productivity, land availability, sustainable residue removal rates, conversion efficiency improvements, reductions in GHG emissions of utilities
- construction of **>200 large biorefineries** per year, every year between 2020 and 2050, at an annual capital investment of **$20-$90 bn**.
- **strong** market or policy **emphasis** on AJF, which would entail **large shares** of the available bioenergy pool be **devoted to producing AFJ**.

Emission reductions on the order of **10-20%** (approx. **3-6 Mbpd**) in 2050 require annual growth in AJF production capacity to 2050 similar to growth in conventional biorefining capacity in the years 2000-2010 (**50-100** new large biorefineries per year).

Preliminary results - do not cite or quote.

On-going work with AFTF

This work is documented in Information Paper CAEP/2016-IP/01, and the final results were presented to CAEP in February 2016.

During CAEP/11 (beginning June 2016), AFTF scope of work is to enable inclusion of AJF under GMBM by:

- Calculating default LCA values for AJF that are feedstock, fuel conversion technology, and regionally specific, in accordance with the AFTF methodology
- Calculating ILUC factors for relevant AJF pathways
- Definition of non-GHG environmental feedstock sustainability criteria
- Exploration of policy options to enable AJF uptake under GMBM

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

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