Laboratory for Aviation and the Environment

Massachusetts Institute of Technology

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

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Background

Approach & methods

Results

Summary

Background (1 of 2)

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

However, ICAO's "carbon-neutral growth" goal states that CO_2 emissions shall not grow from 2020 onward

Carbon-neutral growth not achievable with aircraft and infrastructure efficiency improvements alone

Background (2 of 2)

ICAO-CAEP created the Alternative Fuels Task Force (AFTF) to answer the question:

What is alternative jet fuels' potential contribution to closing the "**GHG emissions gap**" in the **near-term** and in the **long-term**?

<u>Scope</u>

Temporal:	Near-term: 2020 Long-term: 2050
Geographical:	Global
Emissions:	Lifecycle GHG emissions

Acknowledgements (1 of 2)

Contributions from > 80 technical experts from 23 different countries

Significant input from, e.g.:

- Volpe National Transportation Systems Center
- Argonne National Laboratory
- Purdue University
- EU Joint Research Center

Acknowledgements (2 of 2)

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ASCENT AVIATION SUSTAINABILITY CENTER

PARTNER

The work presented may not necessarily represent the views of the FAA.

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Approach

Created and used modelling capabilities:

- for quantification of **global alternative jet fuel** (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

Feedstock scope

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

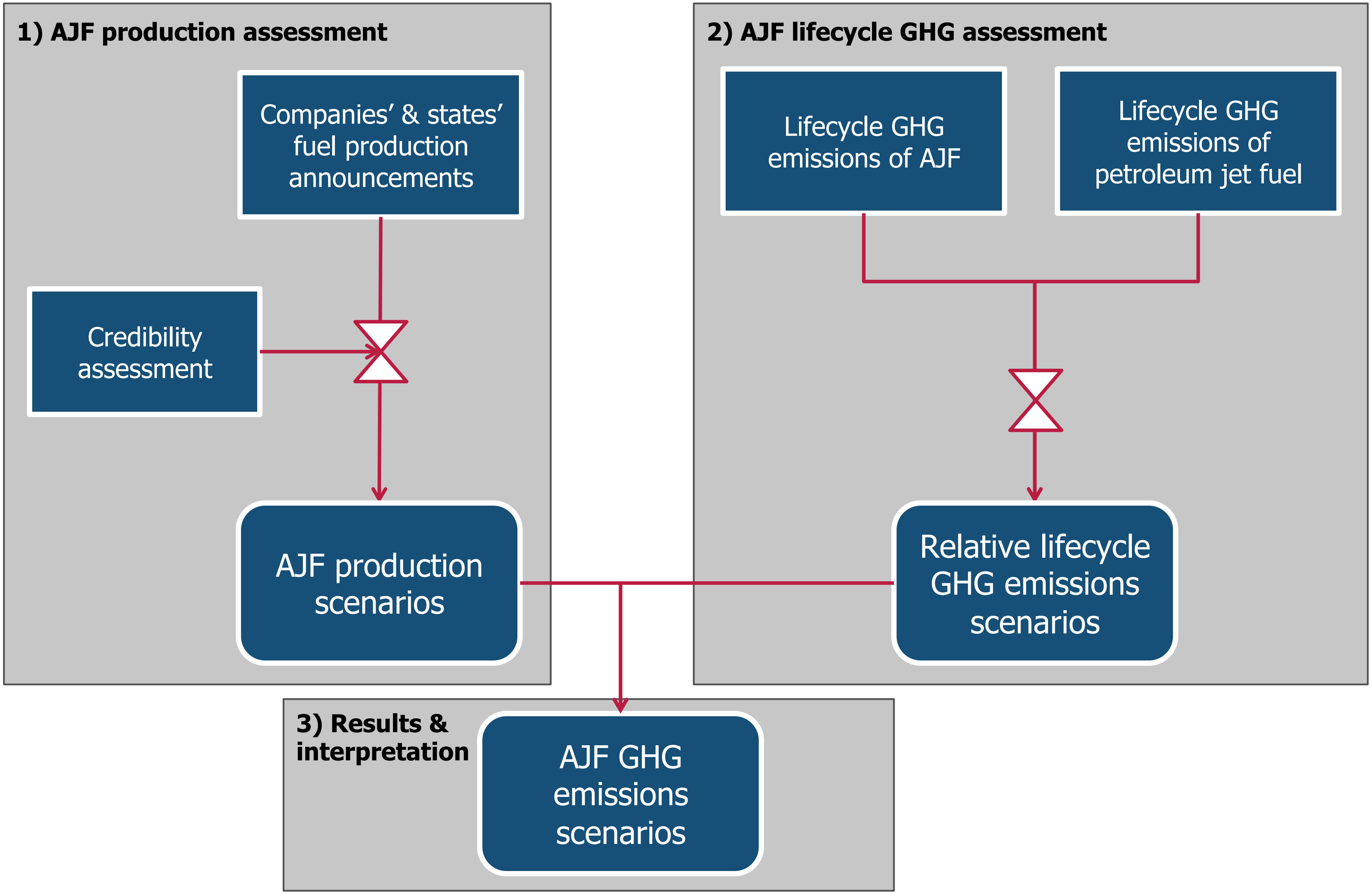
Technology scope

Conversion technologies are modelled in terms of conversion efficiency parameters and product slate assumptions

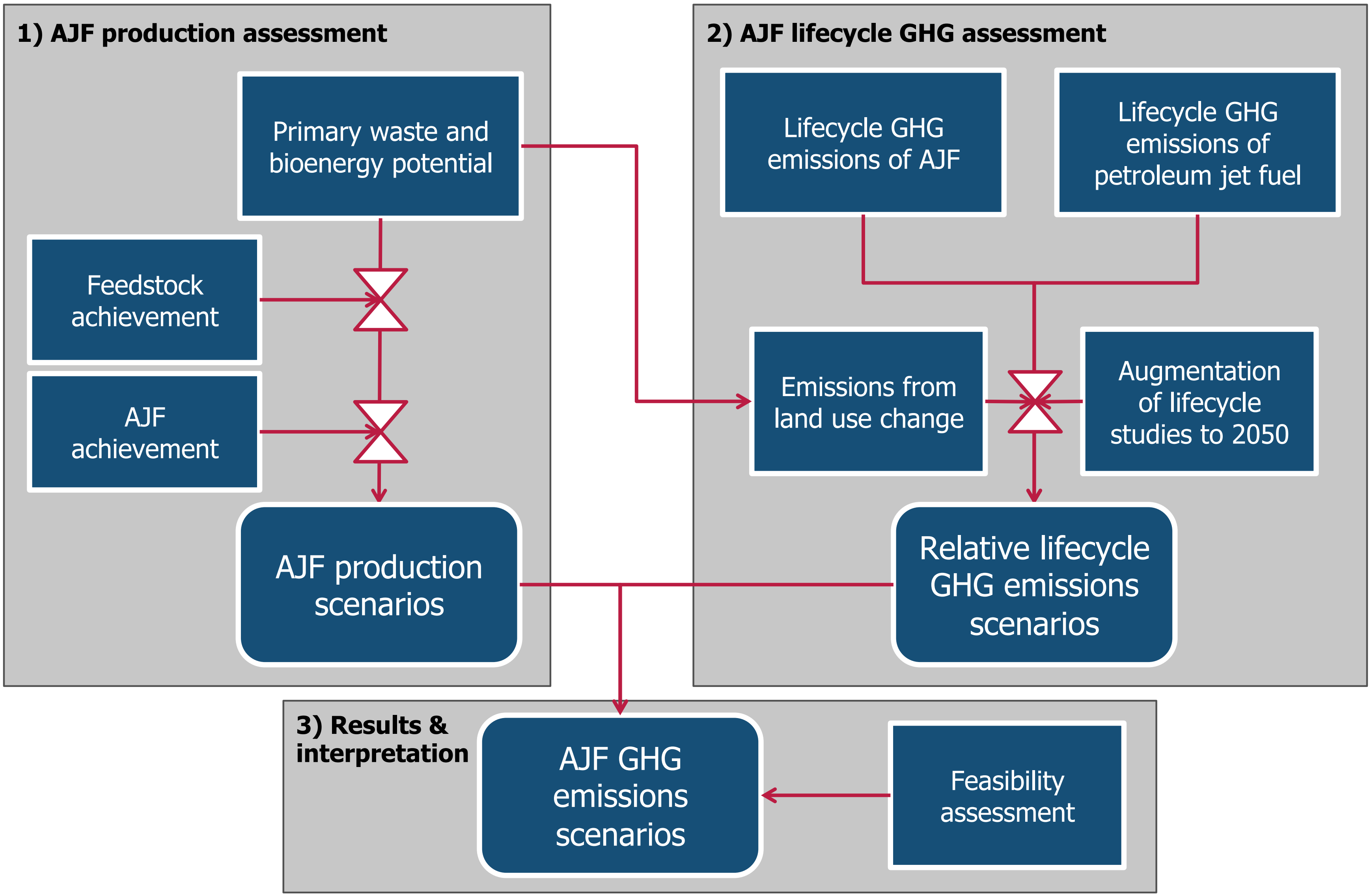
Scope includes fuel production technologies already approved, or under consideration, for use in jet engines (e.g. HEFA, FT, SIP, ATJ)

No disruptive conversion technologies considered

Analysis components - 2020

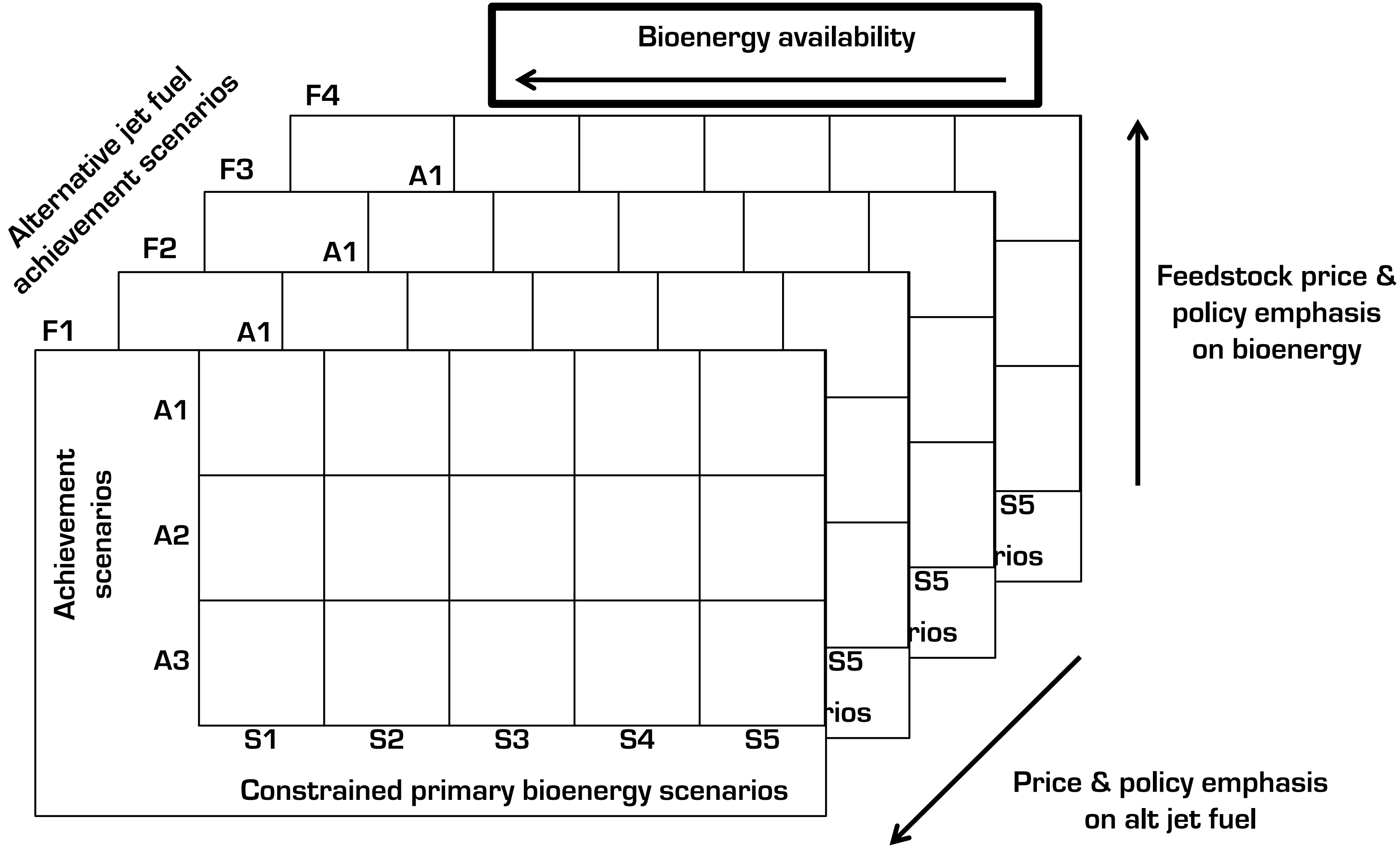


Analysis components - 2050



AJF fuel production scenarios - 2050

Scenario approach in each of the three analysis steps to capture wide range of potential outcomes



Bioenergy availability - 2050

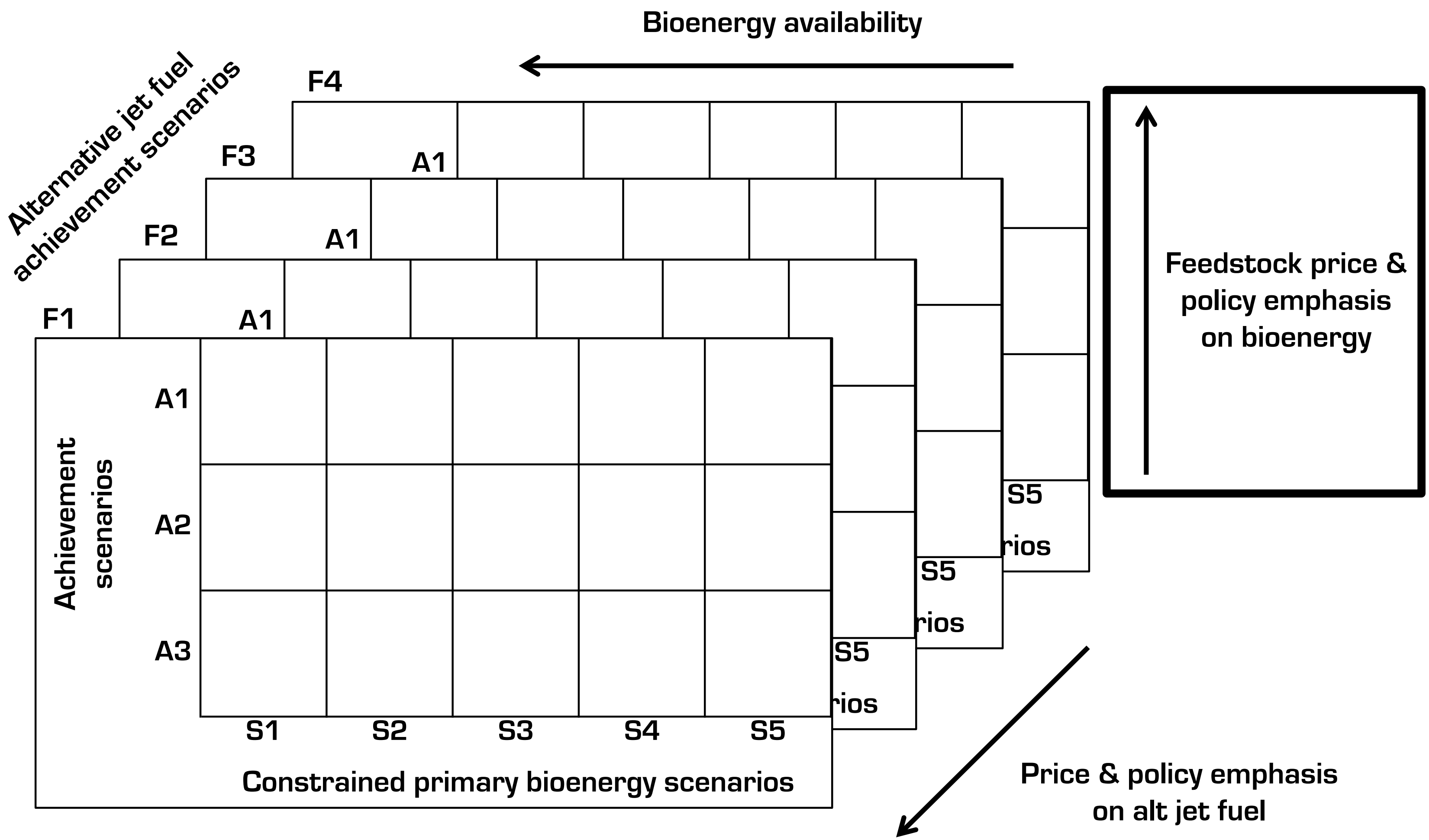
Scenarios reflect bioenergy availability, limited by:

- Arable land & agricultural yields
- Sustainability constraints
- Socio-economic conditions (eg. world population, GDP)
- Future environmental policies

Five scenarios (S1 to S5) are defined to capture the effect of variability in these parameters on the size of the global primary bioenergy resource

AJF fuel production scenarios - 2050

Scenario approach in each of the three analysis steps to capture wide range of potential outcomes



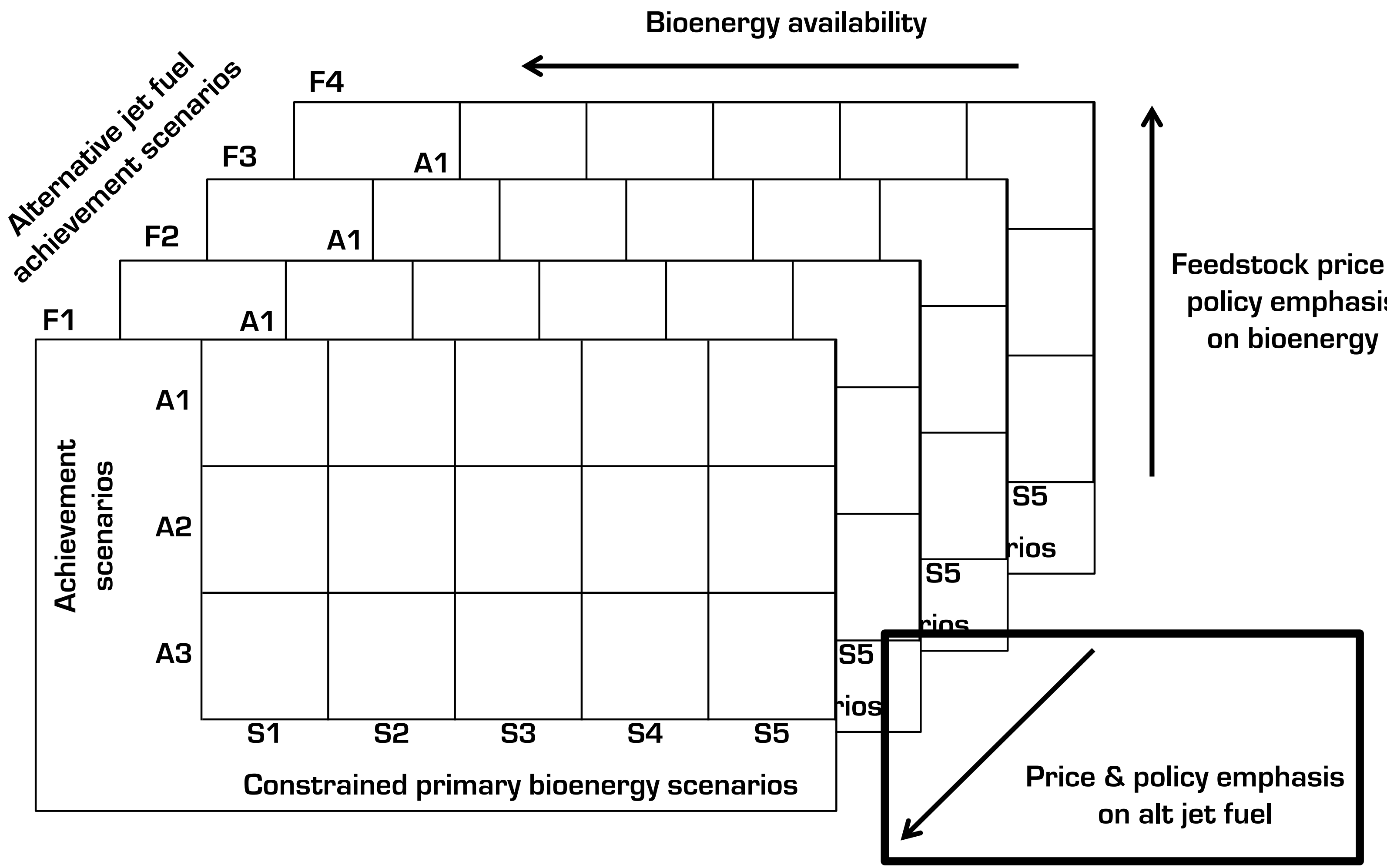
Bioenergy achievement - 2050

Bioenergy achievement scenarios are a function of **bioenergy supply costs** and **achievable market prices**, driven by economics of primary energy production and energy/environmental policies

Existing studies on achievement rates leveraged and translated into **3 achievement scenarios** (A1 to A3), with A1 being the highest achievement, and A3 the lowest.

AJF fuel production scenarios - 2050

Scenario approach in each of the three analysis steps to capture wide range of potential outcomes



AJF achievement - 2050

AJF achievement scenarios **capture the degree of priority** given to **bioenergy usage for AJF**, as opposed to other potential end uses (eg. road transportation fuels, electricity and heat)

Four scenarios range from:

Bioenergy used for AJF **only once demand for all other usages** in 2050 is **satisfied** (F4)

to

Highest technically possible bioenergy share used for AJF (F1)

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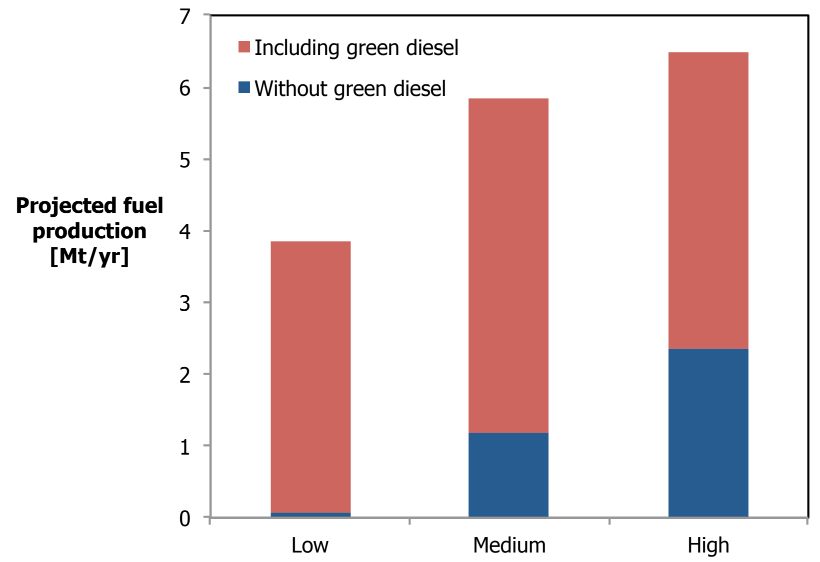
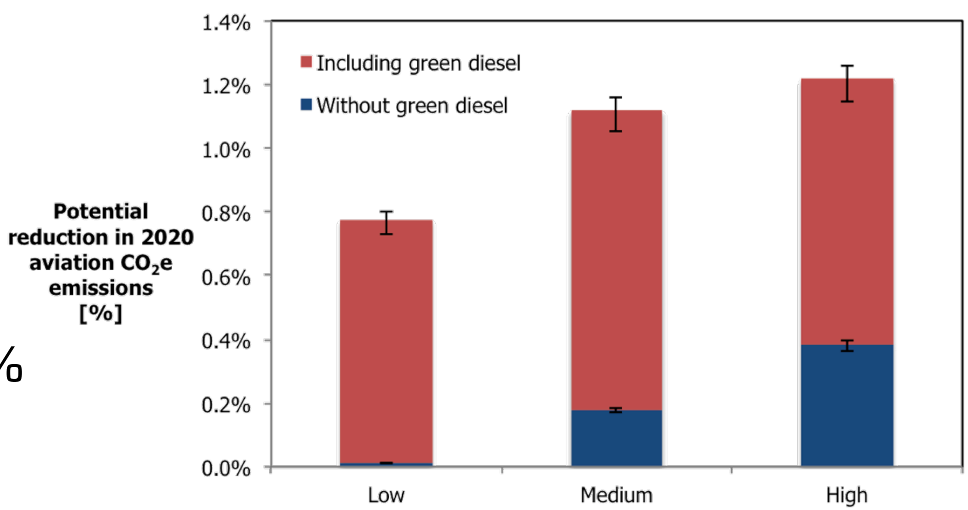
2020 results

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

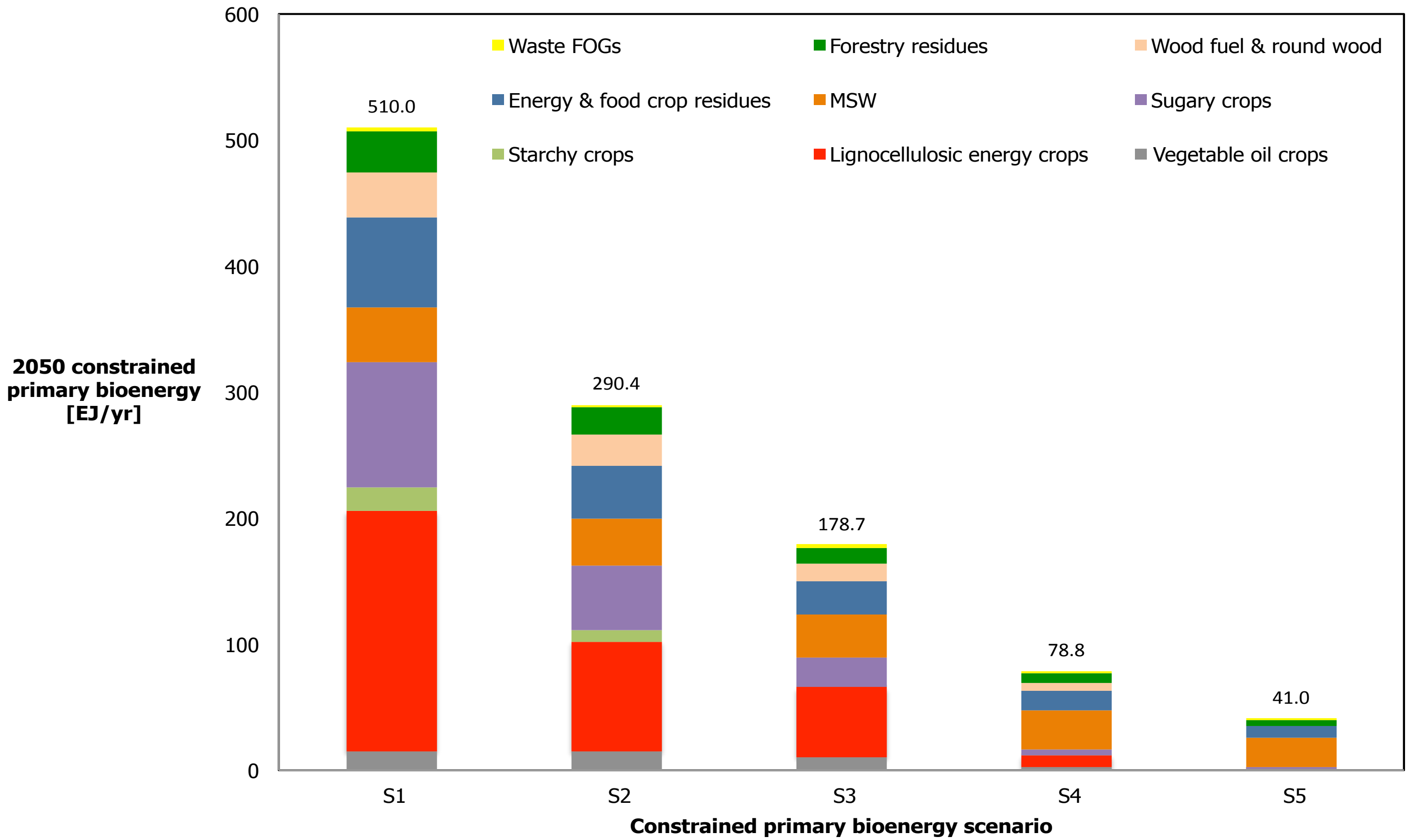


This results in a lifecycle GHG emissons reduction of **0-1.3%** GHG emissions reduction compared to petroleum-derived jet fuel use, only

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



2050 bioenergy potential results (1 of 2)



Bioenergy potential results range from **41.0 EJ** per year in S5, up to **510.0 EJ** per year in S1. As a point of reference, total global primary energy demand was approximately 549.1 EJ in 2011

2050 bioenergy potential results (2 of 2)

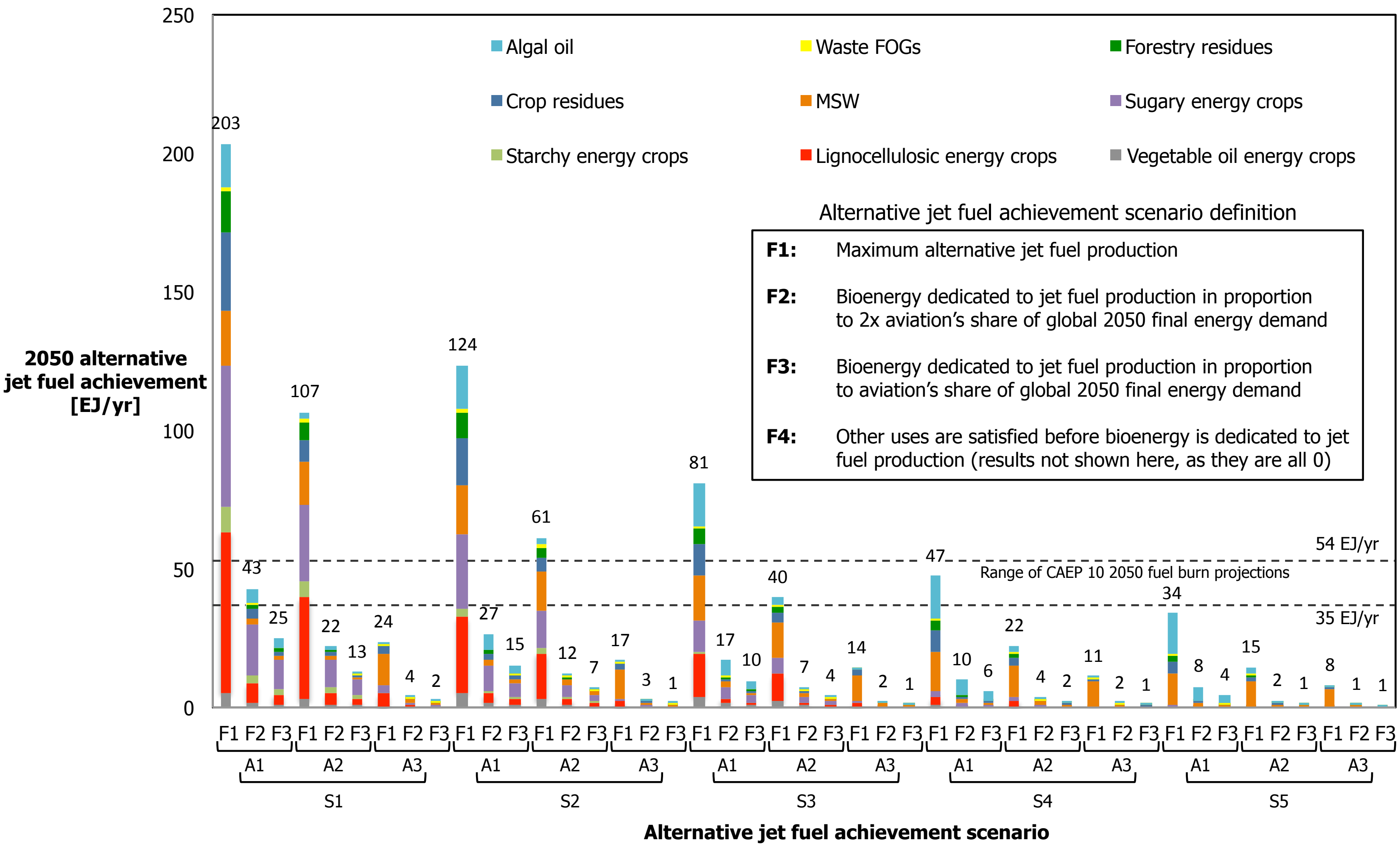
Bioenergy potential results can also be broken out by:

- Aggregate feedstock types
- World region (or higher geo-spatial resolution) of origin
- Types of land use conversion for energy crop cultivation

Sensitivity of results to all major parameters have been calculated

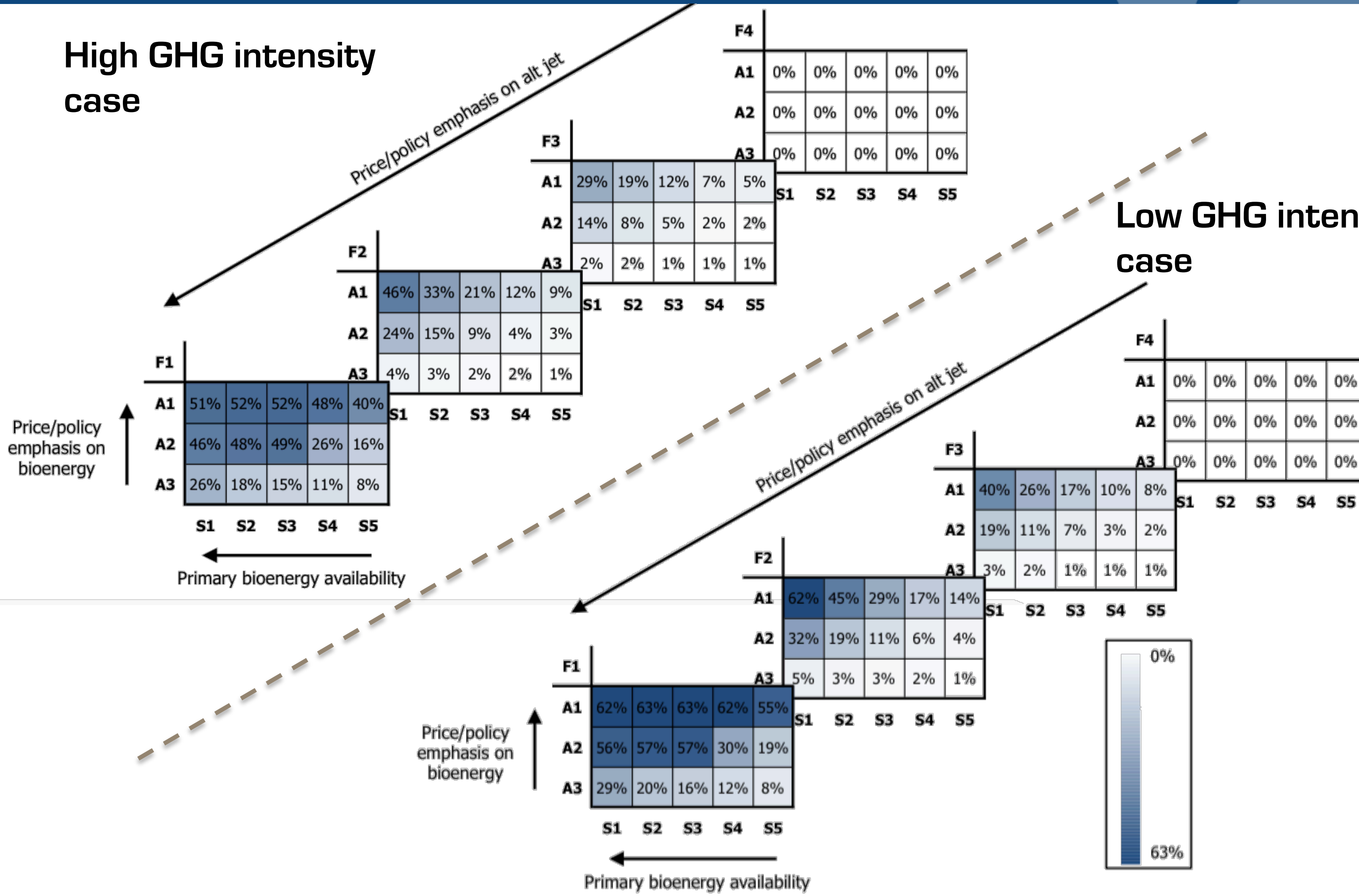
Not presented here for the sake of expediency

2050 AJF achievement results



AJF achievement range from **0-203 EJ (4,600 Mt)** in 2050, replacing **up to 100%** of 2050 jet fuel demand

2050 GHG emissions reduction from AJF by scenario



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

Feasibility assessment (1 of 2)

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

Feasibility assessment (2 of 2)

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%.**

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Summary of findings (1 of 4)

Created and employed modelling capability for developing and **assessing global short- and long-term global AJF production scenarios** and **associated GHG emission benefits**

For 2020, AJF production scenarios range from **0-2%** **(0-150,000 bpd)** of projected global fuel demand in 2020, leading to GHG emissions reductions of **0-1.3%** compared to petroleum-derived jet fuel use – high-end only achievable if green diesel blends are approved for jet engines

Summary of findings (2 of 4)

For 2050, **AJF production** could range from **0 to 4.600 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 is smaller than jet fuel replacement range, as the AJF mix in the different scenarios is associated with **lifecycle GHG emissions** of **31-64%** of those of petroleum-derived jet fuel, on average.

Summary of findings (3 of 4)

2050 (continued):

The highest modeled GHG emissions 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**.

Summary of findings (4 of 4)

2050 (continued):

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)

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