Economic and environmental performance perspectives of alternative aviation fuels

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IEA Bioenergy Workshop "Drop-in biofuels for international marine and aviation markets"

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Laboratory for Aviation and the Environment
Massachusetts Institute of Technology

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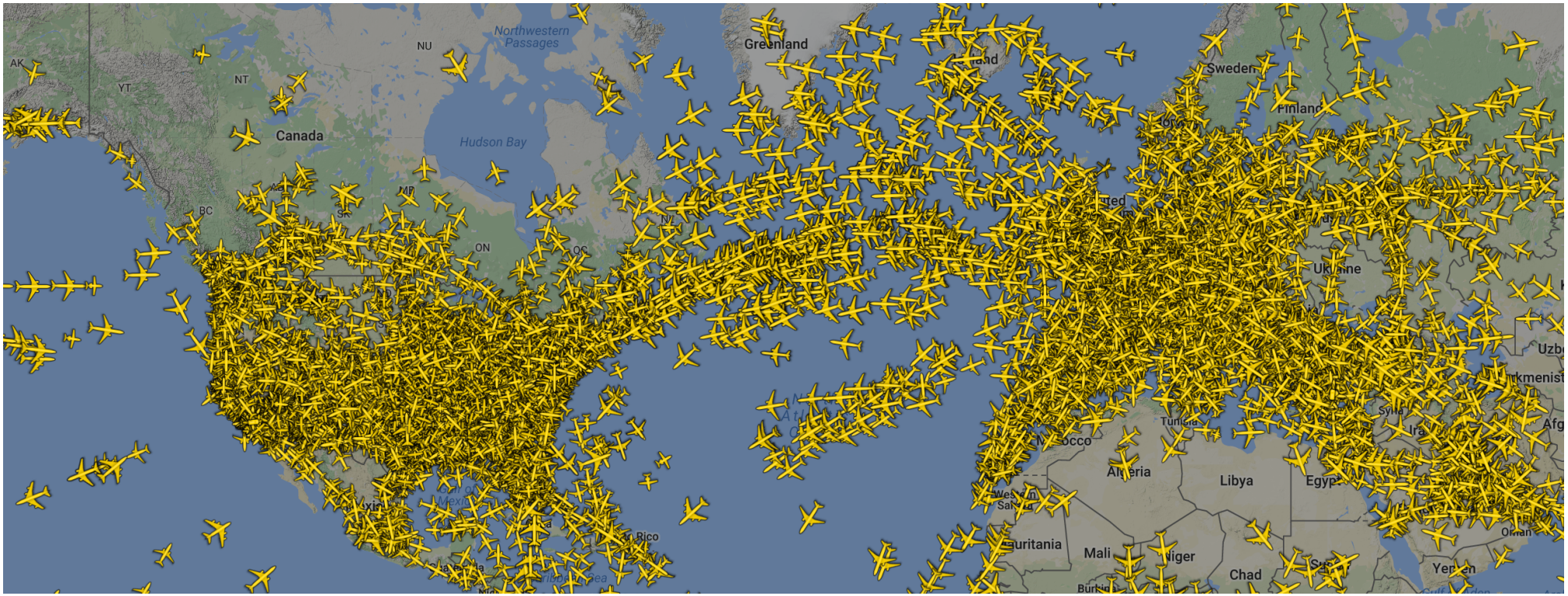
Reminder: Infant industry



Friday, October 21 2016, 10.25 am EDT
Data from Planefinder

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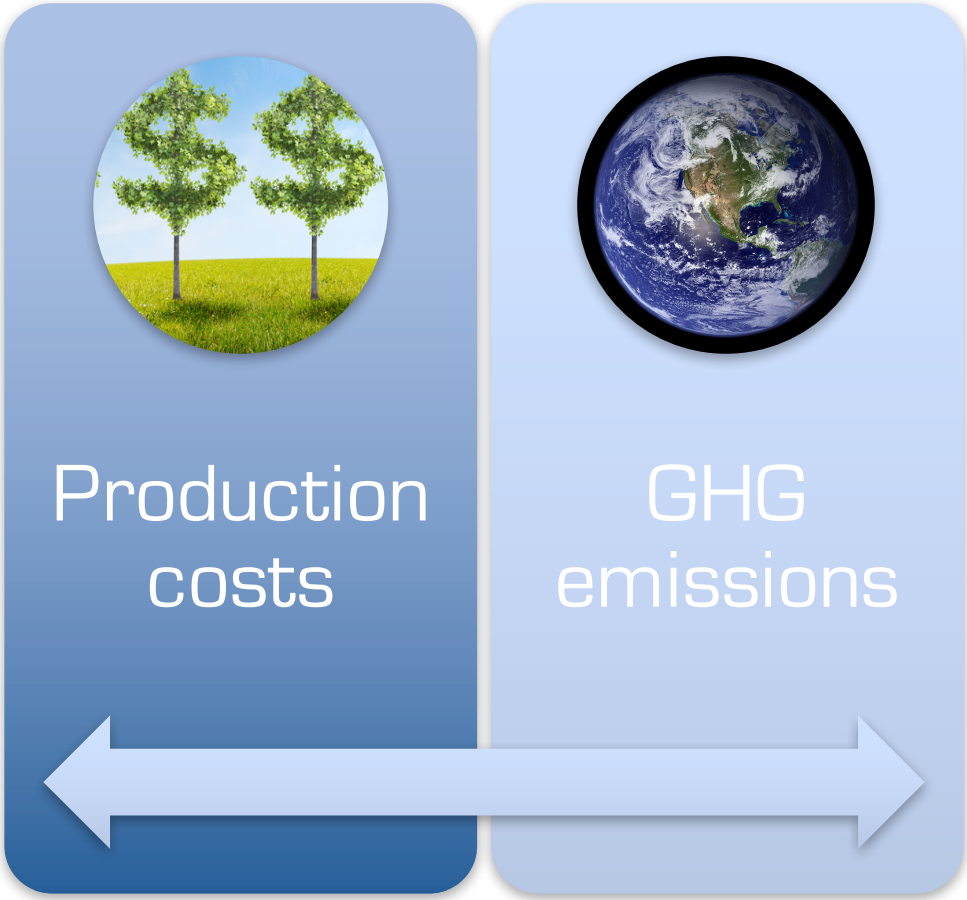
Reminder: Infant industry

Friday, October 21 2016, 10.25 am EDT
Data from ICAO Alternative Fuels Planefinder

Traditional view on Alternative Jet Fuel "Viability"



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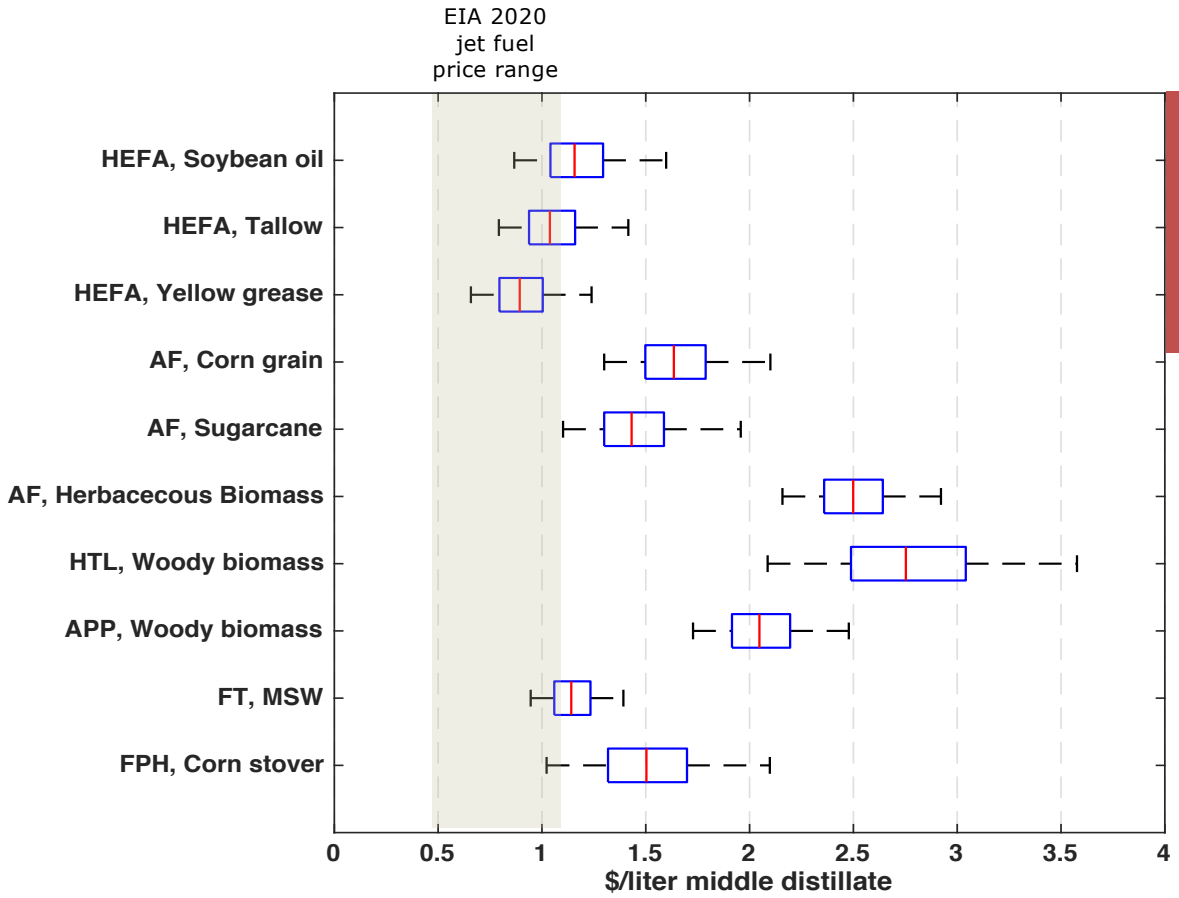
Static costing perspective (1 of 3)



AJF currently, and in the medium term, more costly to produce than conventional jet fuel

No RIN credits or other subsidies included.

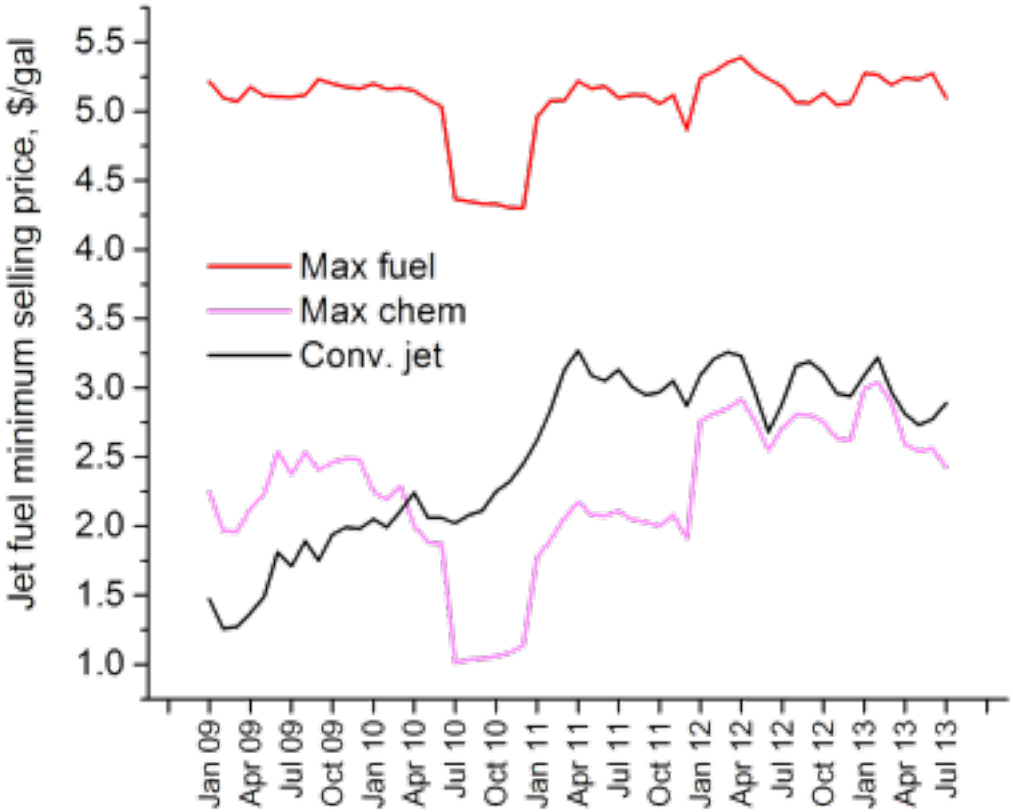
Results from harmonized TEA assessment

Do not cite, as currently under peer-review.

Static costing perspective (2 of 3)

Commercial opportunities from value-added bio-renewables

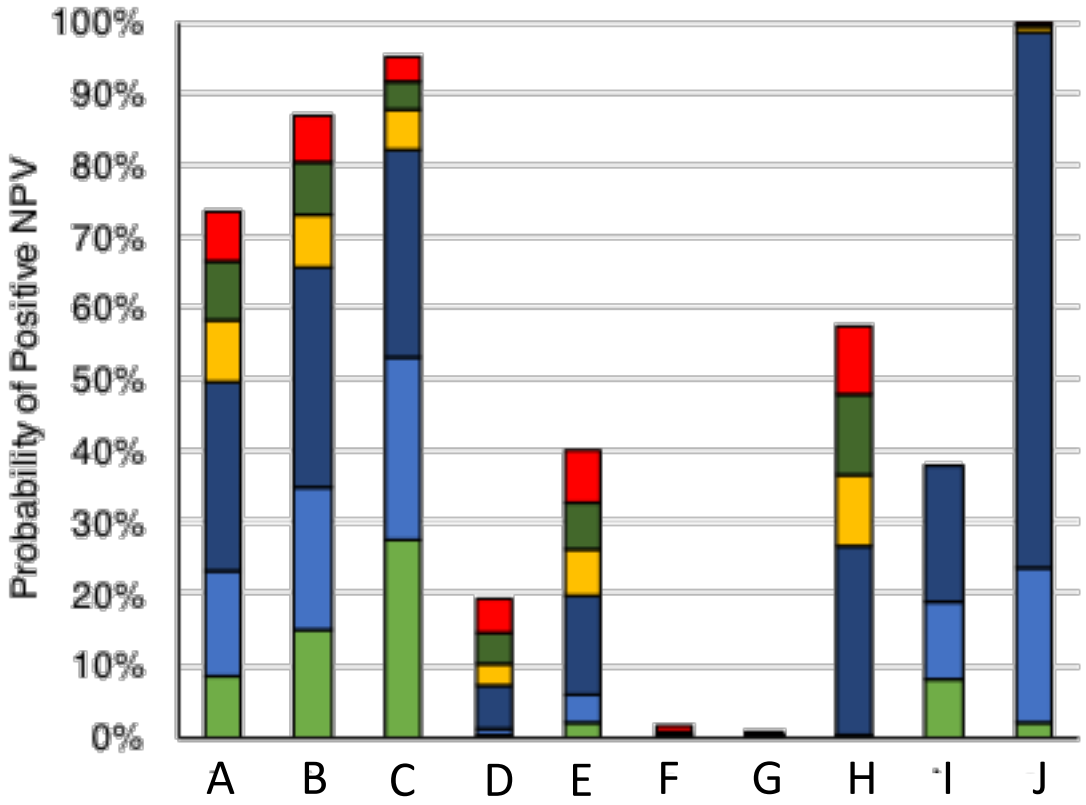
Example for aqueous phase reforming-derived jet fuel:



Large discrepancy in economic viability between product-slate choices.

Optimizing product-slate for biochemical production provides commercial opportunity for biojet as a co-product

Static costing perspective (3 of 3)

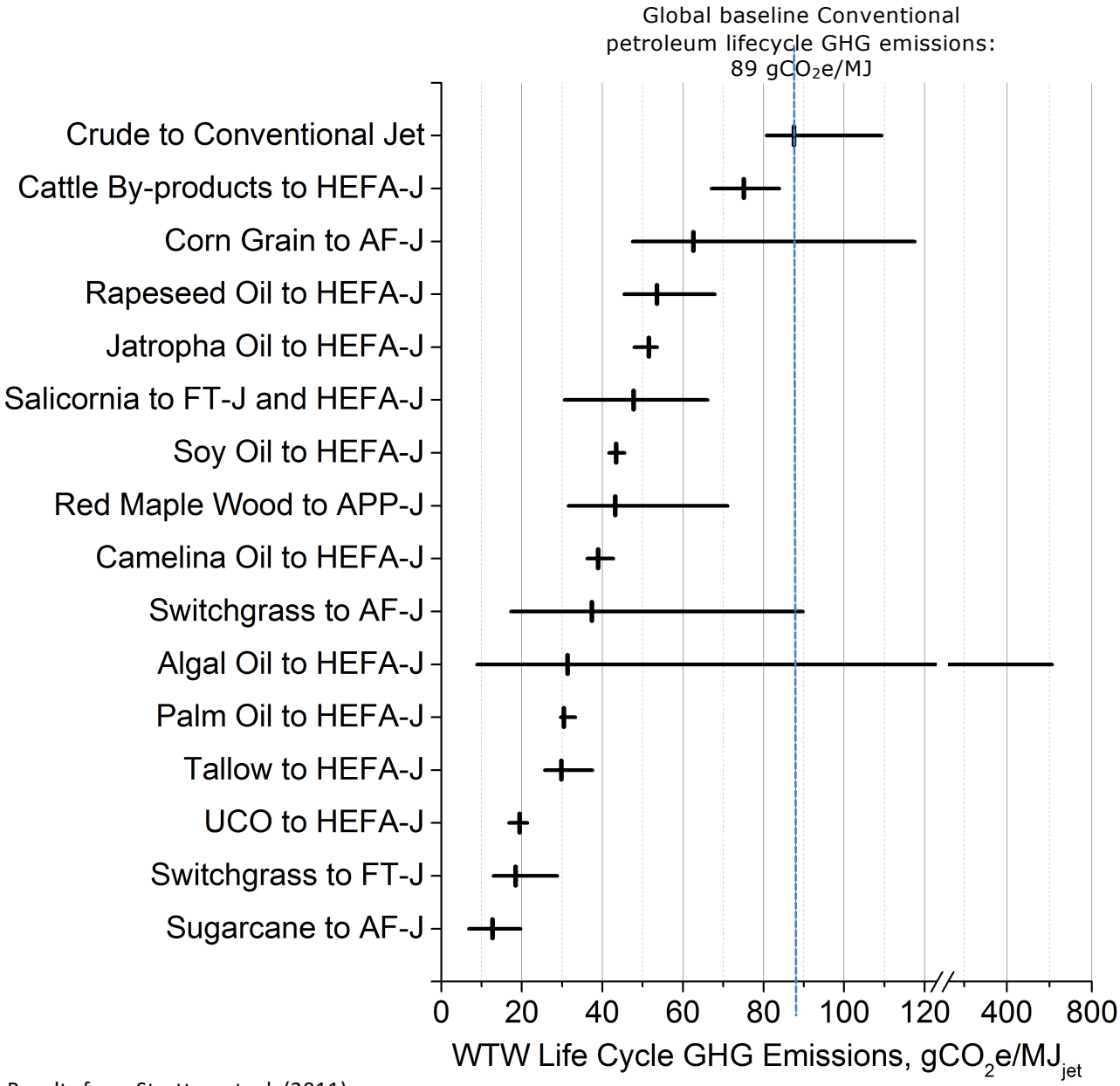


AJF economic viability highly dependent on biofuel policies

- 100% credit share + RIN market
- 75% credit share + RIN market
- 50% credit share + RIN market
- 25% credit share + RIN market
- Blender's credit expiry + no RIN market
- No Policy

Pathway results anonymized. Analysis based on TEA for US

Static GHG emissions perspective

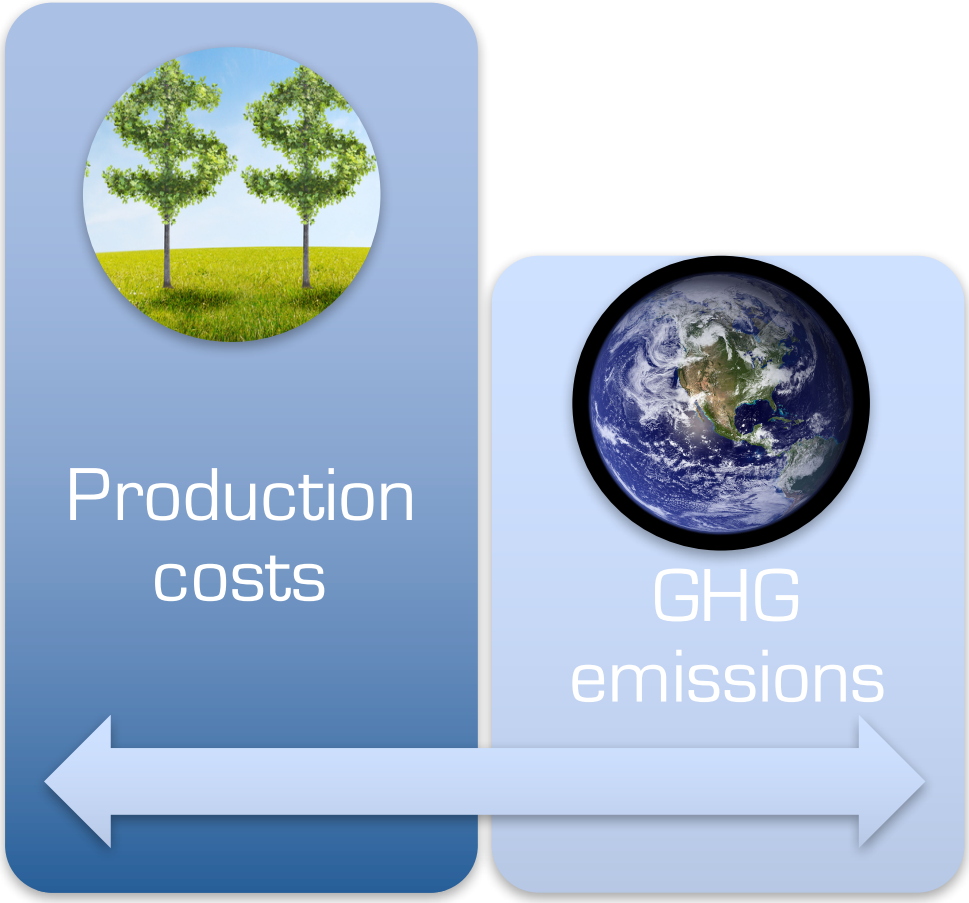


Significant potential for GHG emissions reduction compared to conventional jet fuel, if emissions from land-use change can be avoided.

Results from Stratton et. al. (2011), Carter (2012), Staples et al. (2014), Seber et al. (2014), Bond et al. (2014) and on-going work. All data peer-reviewed with exception of APP results. Results shown for production scenarios without land-use change

Missing facets

1. Weighing up of costs and emissions



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Missing facets

2. Inclusion of fuel availability

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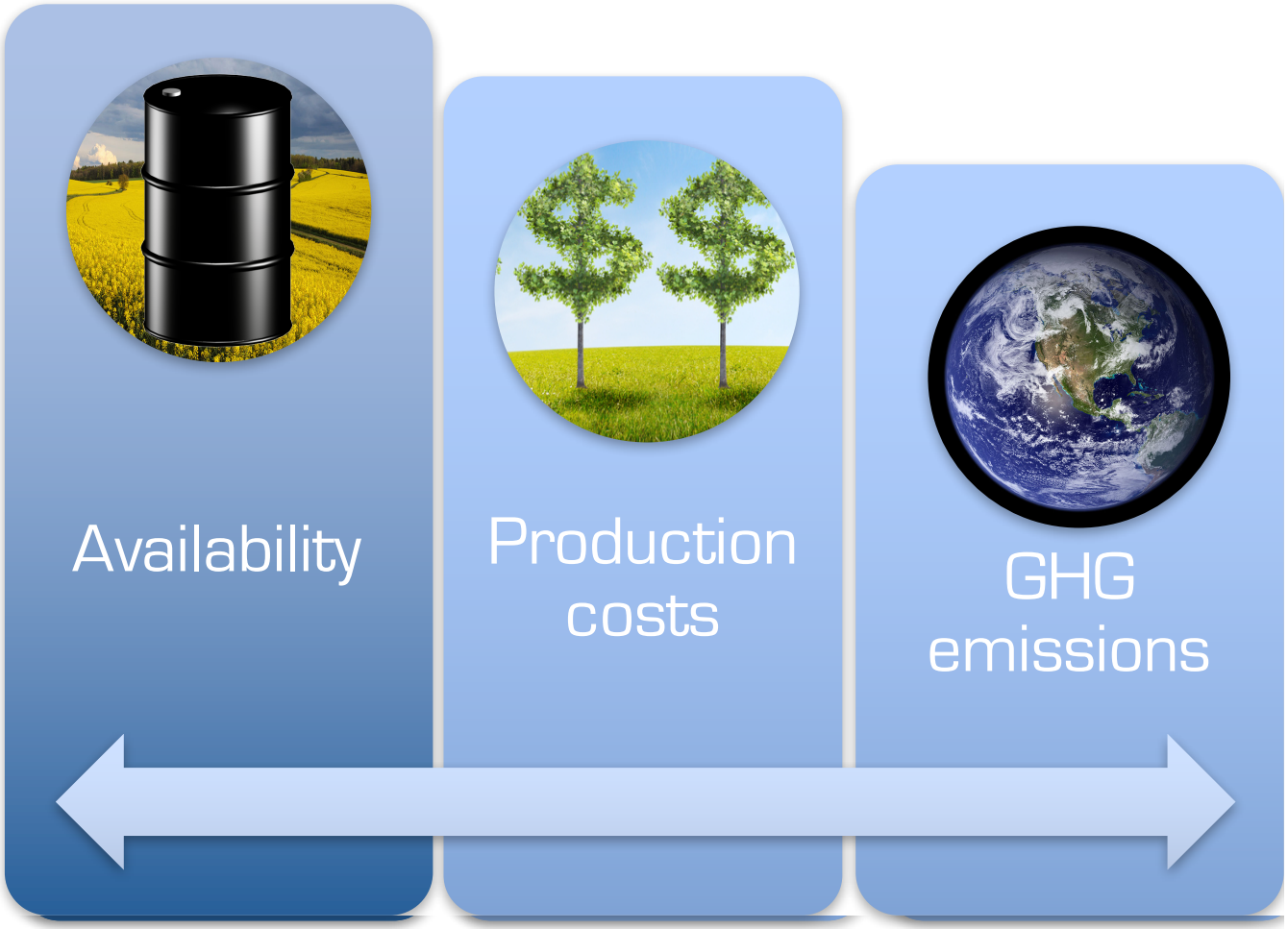
Missing facets

3. Changes of viability over time



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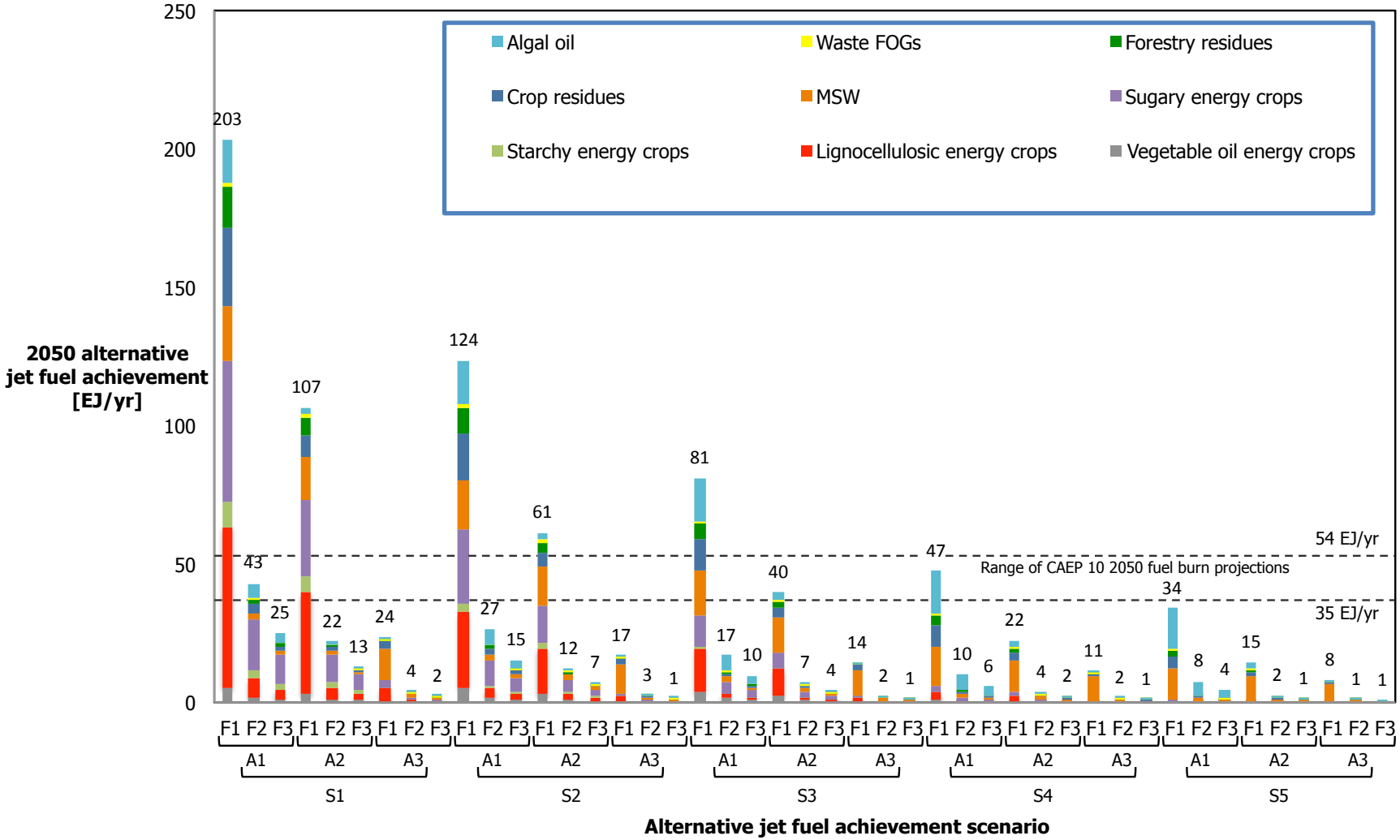
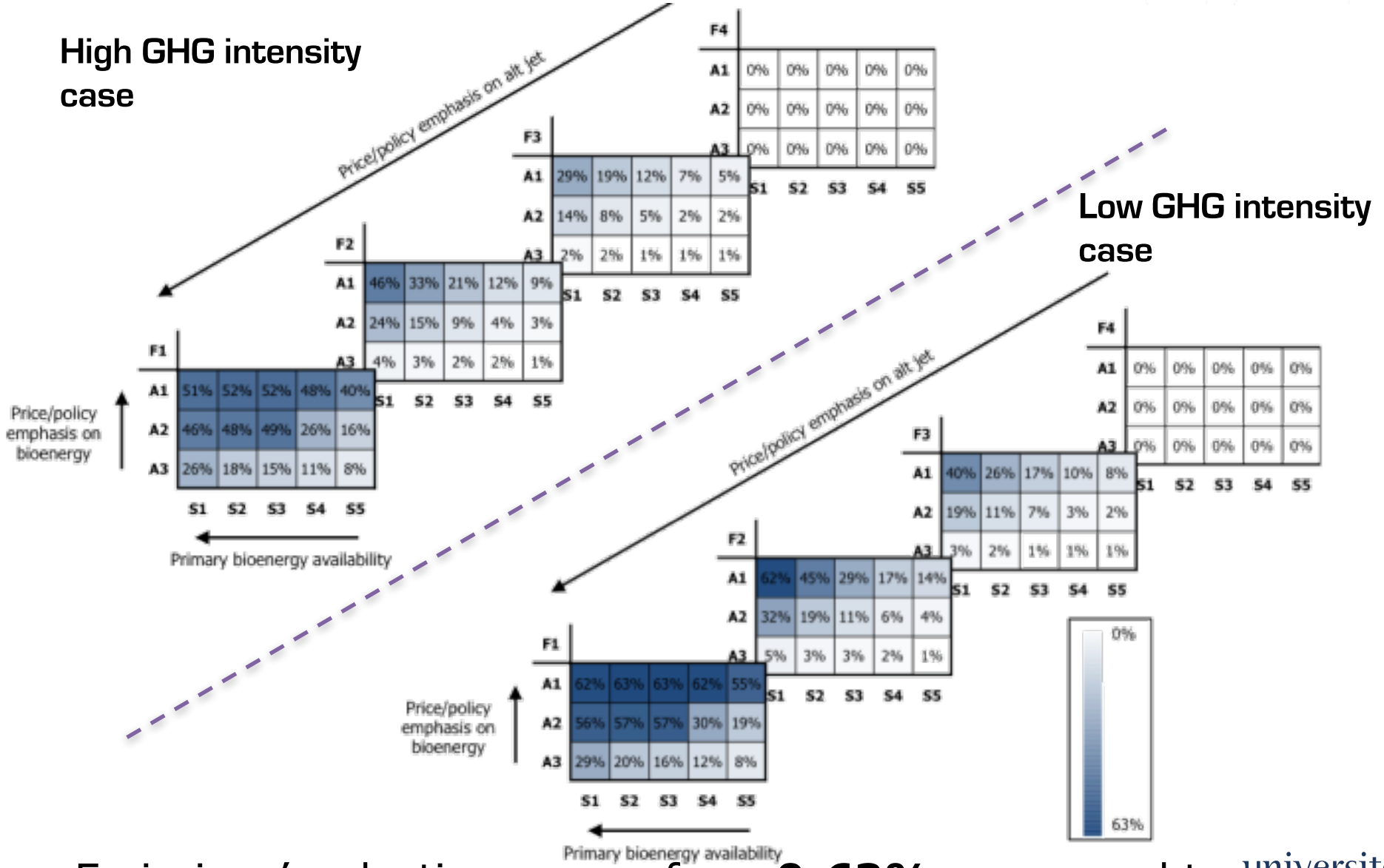
Future availability of alternative jet fuel and production ramp-up over time

2050 global AJF production scenario results



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

2050 global AJF GHG emissions reduction



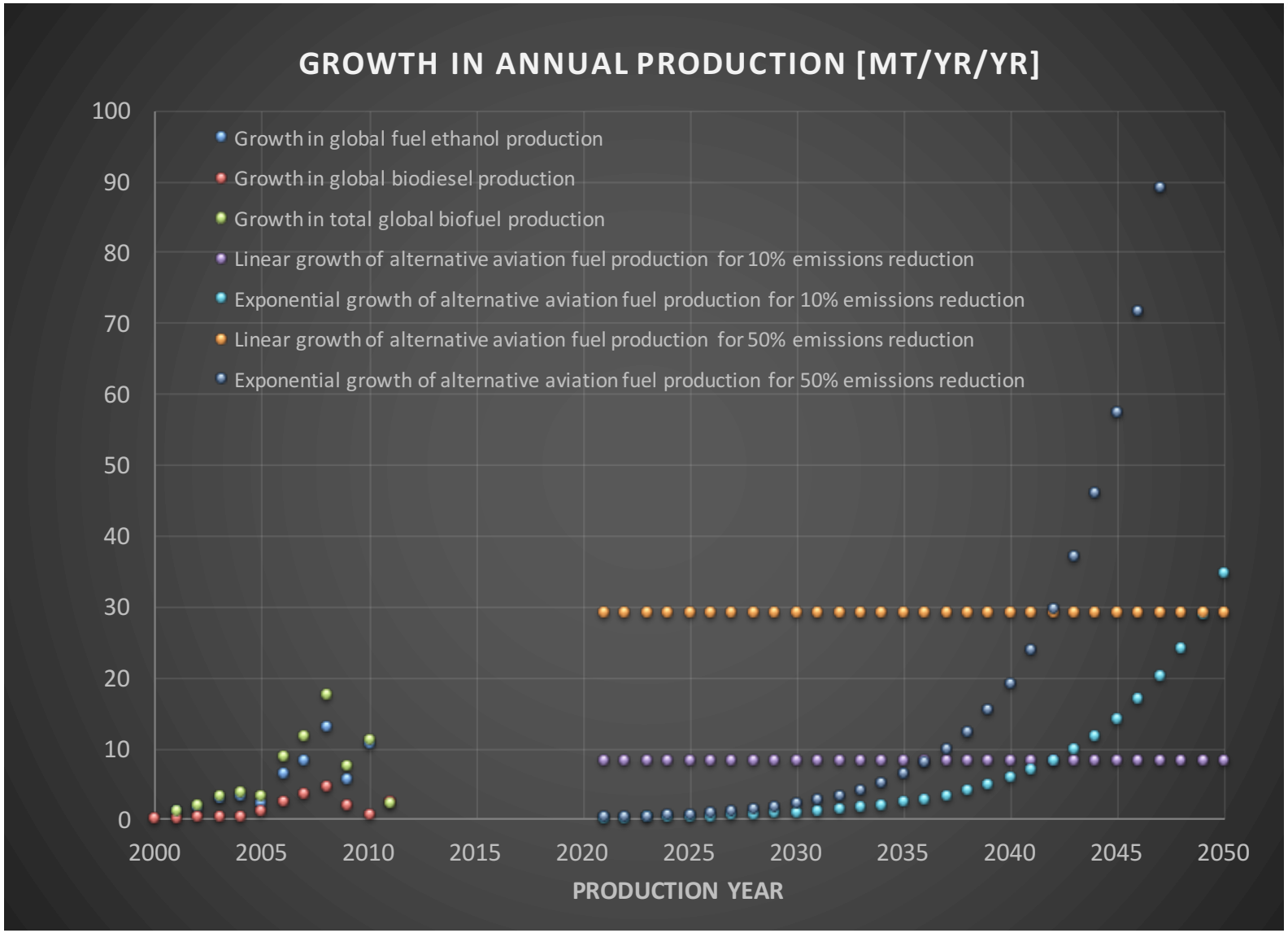
- Emissions' reduction ranges from **0-63%**, compared to petroleum-derived jet fuel usage only.

Production-ramp up assessment (1 of 3)

Aviation GHG emissions reduction	Required AJF production volume in 2050 (Mt/yr)	Number of "additional" biorefineries/yr	Capital investment/yr
2%	30	10	$2B - $12B
10%	130	40	$6B - $28B
17%	220	70	$12B - $50B
40%	570	170	$30B - $120B
63%	870	260	$40B - $180B

Assumptions: 5,000 bpd biorefinery with 50% jet fuel output share, capex range $35,000-140,000/bpd. Capex values are provided based on total biorefinery investment, not just jet-fuel portion. Fuel demand projections based on ICAO forecasts.

Production-ramp up assessment (2 of 3)



Source: Historical data from Brown (2012) , other values own calculations.

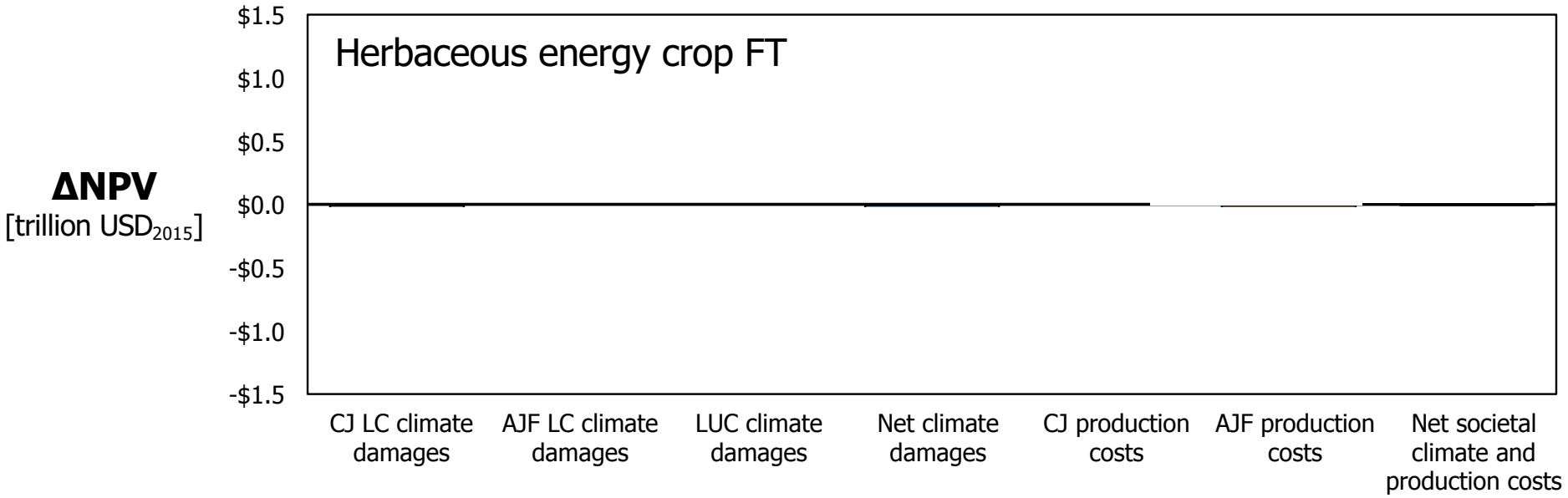
Production-ramp up assessment (3 of 3)

Annual **growth in AJF production** out to 2050 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%.**

Weighing up additional production costs and GHG emission benefits

Herbaceous FT jet fuel example



Do not cite, as preliminary.
Results are specific to the assumptions below and cannot be generalized

CJ: Conventional jet fuel from petroleum
AJF: Alternative jet fuel
LC: Lifecycle
LUC: Land-use change

Assumptions used:

- 150 Mt/yr. AJF mandate for 2035 (~30% global jet fuel burn)
- Learning curve effects for alternative jet fuels as production increases
- Increases in agricultural productivity
- Changes in carbon intensity of conventional jet fuel

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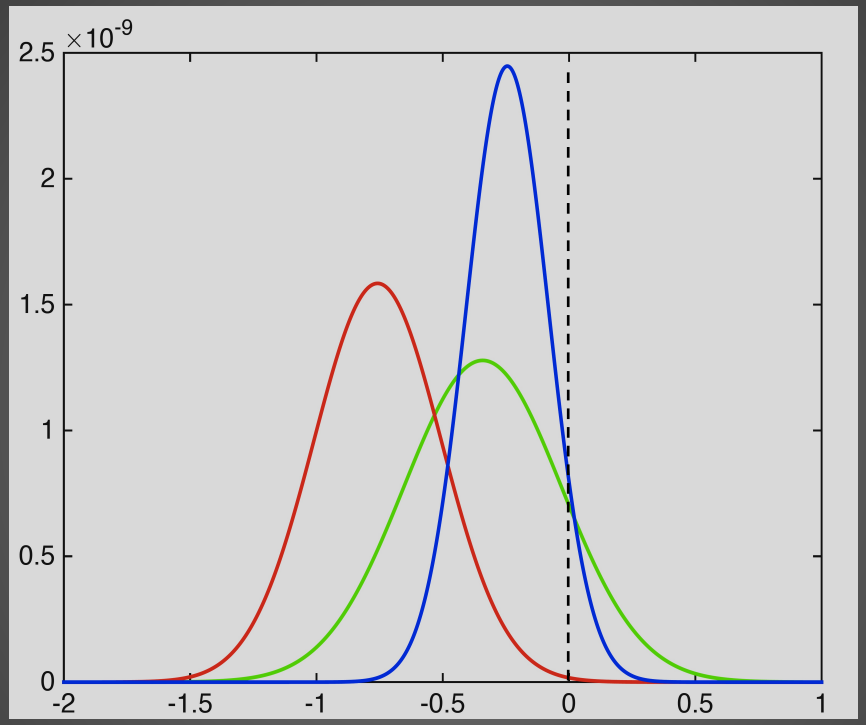
MSW to jet fuel example

Investor perspective:

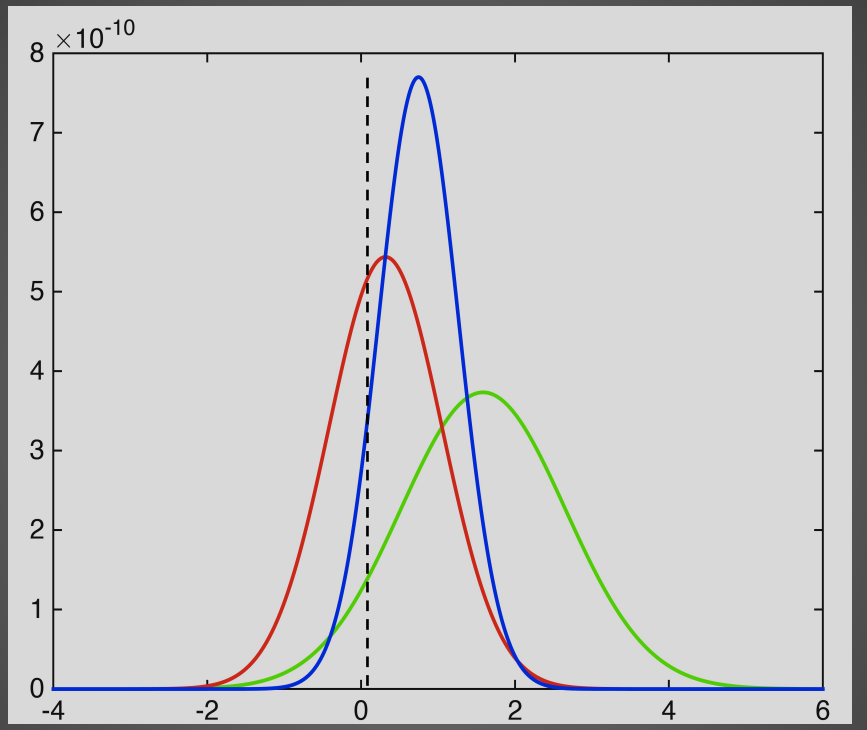


Net present value ($B)*

Probability of NPV>0:

14%, 0.1%, 7%

"Societal" perspective:



Net present value ($B)

Probability of NPV>0:

93%, 67%, 92.5%

FT MD
Plasma FT MD
ATJ MD

*No RIN credits included

Results are specific to the assumptions below and cannot be generalized

Assumptions used for societal case

- Costs of carbon based on US EPA social costs of carbon
- Societal costs of capital of 3.2%
- Taxes and subsidies excluded as they constitute transfers

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Summary statement

- The potential magnitude of aviation GHG emissions reductions from the use of alternative fuels **is limited by their environmental benefits**, and the **availability of the fuels**.
- However, significant reductions are possible by 2050 with an alternative aviation fuel industry **many times larger** than the **existing capacity for total biofuel production**.
- The development of such an industry would require **immediate** and **sustained investment** in alternative aviation fuel production infrastructure, which will only take place if enabled by the **right policies**.
- Alternative aviation fuels will remain **more expensive** to produce **than conventional jet fuel** in the short- and medium term. Those higher costs are **justifiable** from a societal perspective as long as the **environmental benefits compensate** for the **additional costs**. In order to achieve this, significant **cost savings** will need to be realized for many pathways.

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Work presented here may not represent the views of the FAA.

Thank you for your attention!

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