Nairobi, Kenya | Sept 11, 2023

HEFA costing study for Kenya

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During 2nd workshop and high-level meeting on development and deployment of sustainable aviation fuel (SAF) in Kenya on Monday, 11th September 2023 at Nairobi Serena Hotel

Introduction

- The HEFA costing study was done with financial support from the **World Bank**. All statements/views in this talk are our own, only.

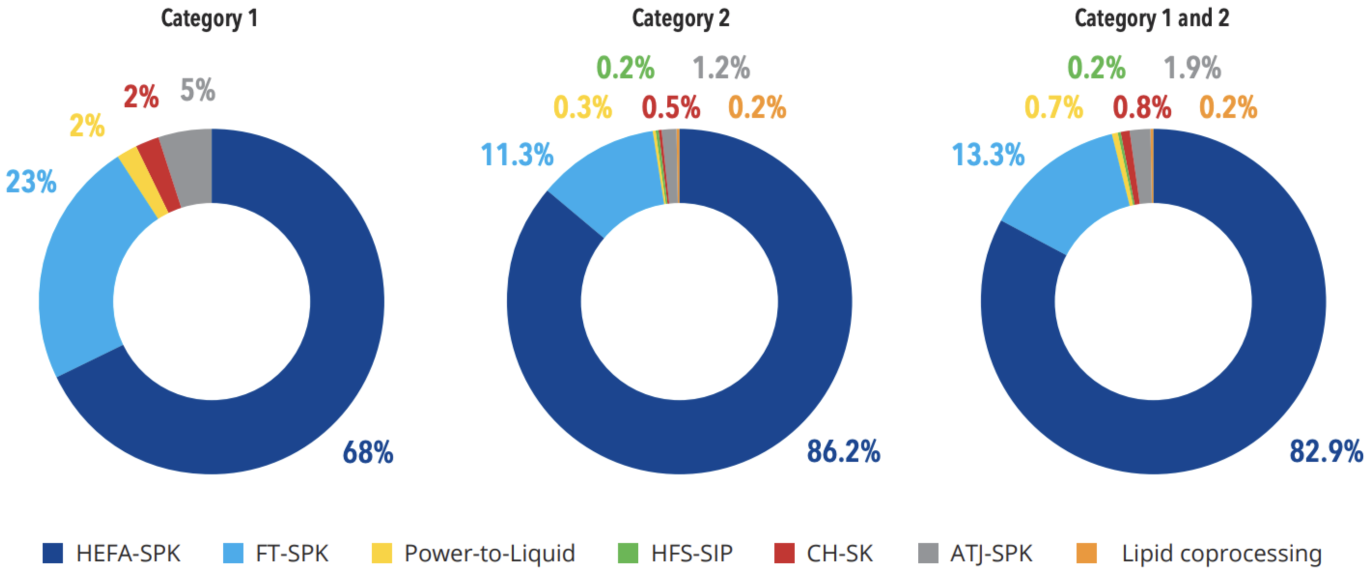
- We also draw upon work funded by the **US Federal Aviation Administration** on the economics of sustainable aviation fuels. Also here, all statements/views are our own, only.

Why a HEFA costing study for Kenya?

Why HEFA?

Most mature SAF technology with the highest share in expected SAF production capacity, at least in the short to medium term

Figure 3.1. Announced SAF Production in 2025, by Conversion Technology



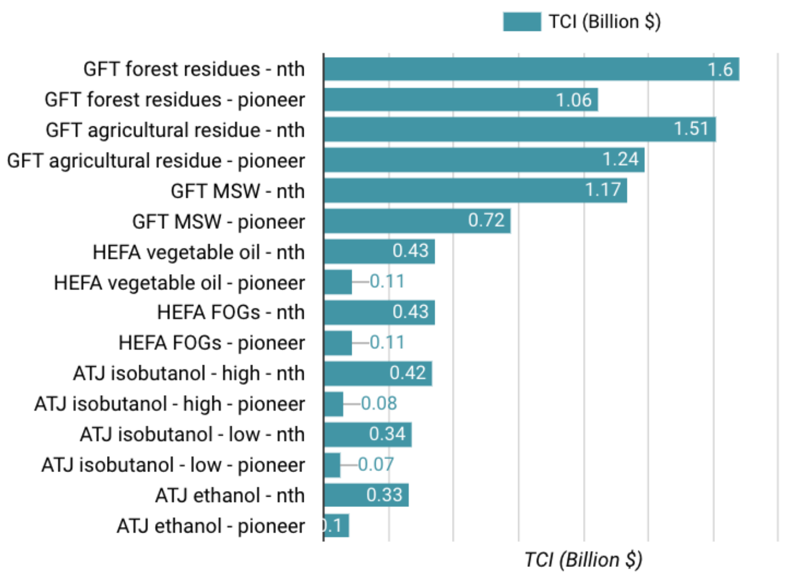
Source: World Bank (2022)

Why HEFA?

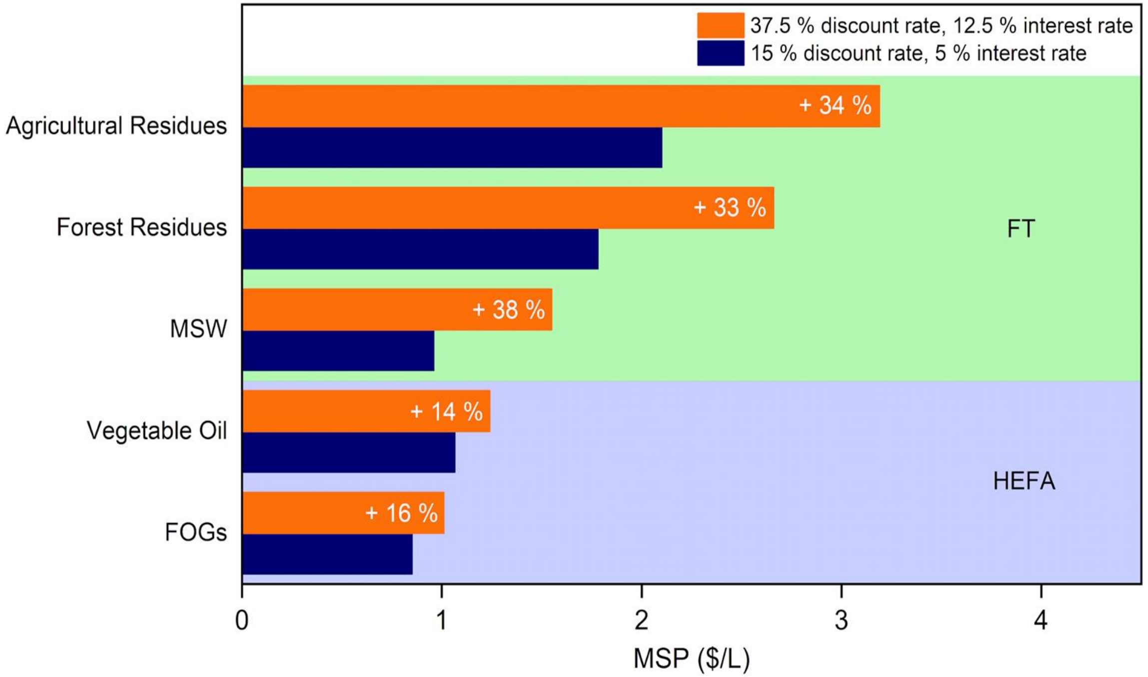
ii

Relatively low capex compared to other SAF pathways – makes risk premiums less severe (but still relevant, of course)

Total Capital Investment (TCI) for production facility (billion USD)



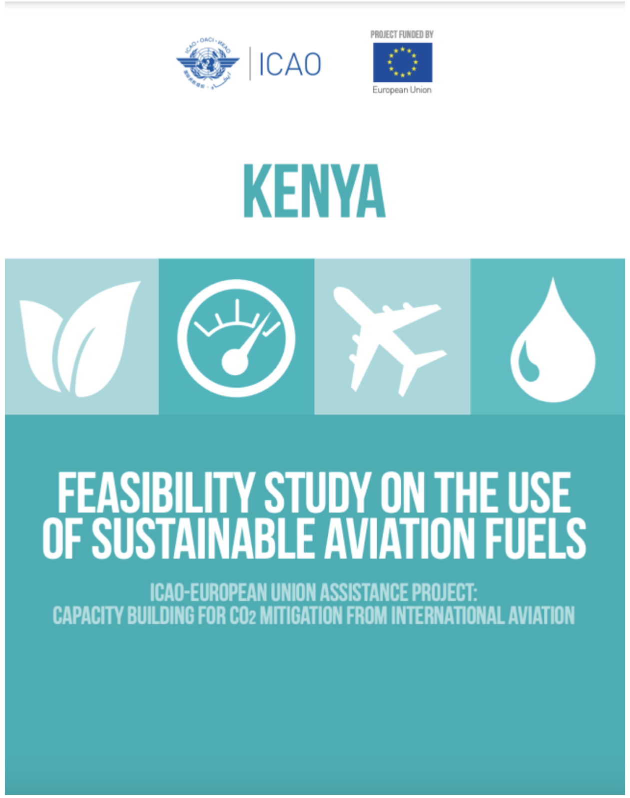
Note: Facility sizes vary between n-th and pioneer plant and between pathways.
Source: ICAO rules of Thumb.



Source: Own calculations based on publicly available DCFROR models for SAF (Hydroprocessed esters and fatty acids TEA V2.2 developed by Kristin Brandt et al. 2022, Fischer Tropsch TEA V2.2 developed by Kristin Brandt et al. 2022) . These are n-th plant estimates.Key Assumptions: Equity/loan split: 70/30, Duration 20 years, inflation: 2%. Discount rate and loan interest asssumed as mentioned above. No monetary incentives included. FOG: Fats, Waste Oils and Greases MSW: Municipal solid waste

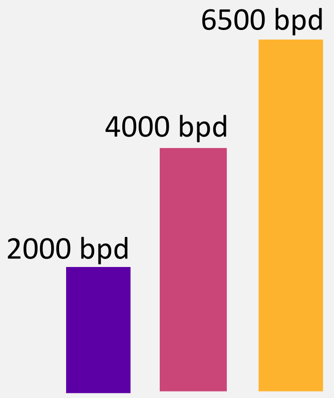
Why HEFA?

iii **Target technology** in Kenya **feasibility study & large feedstock potential** .

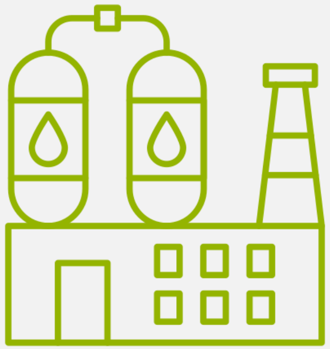


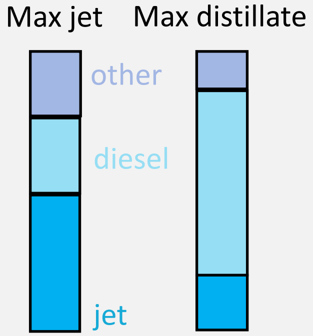
Scope and approach

Scope



3 factory sizes





2 product slates

Used cooking oil

Waste product, therefore low-cost

Limited sustainability issues

High GHG emissions benefit

Scalability questionable

Castor oil

Higher feedstock costs

Sustainability has to be safeguarded

Lower GHG emission benefit

Scalability high

2 feedstocks

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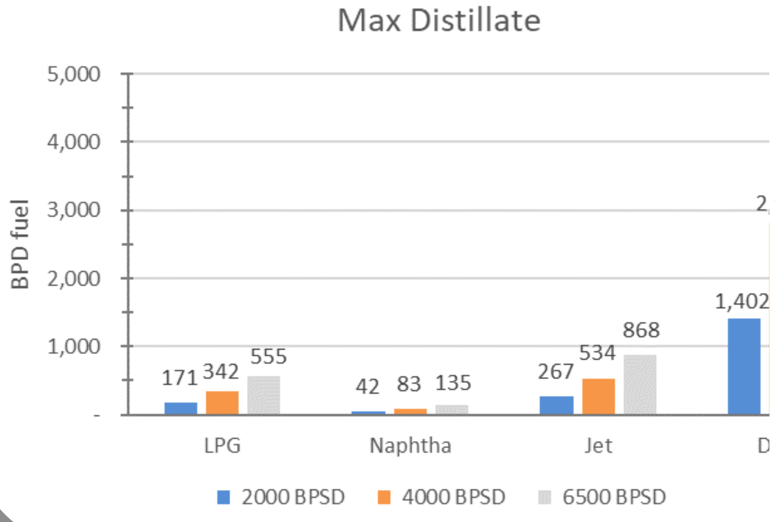
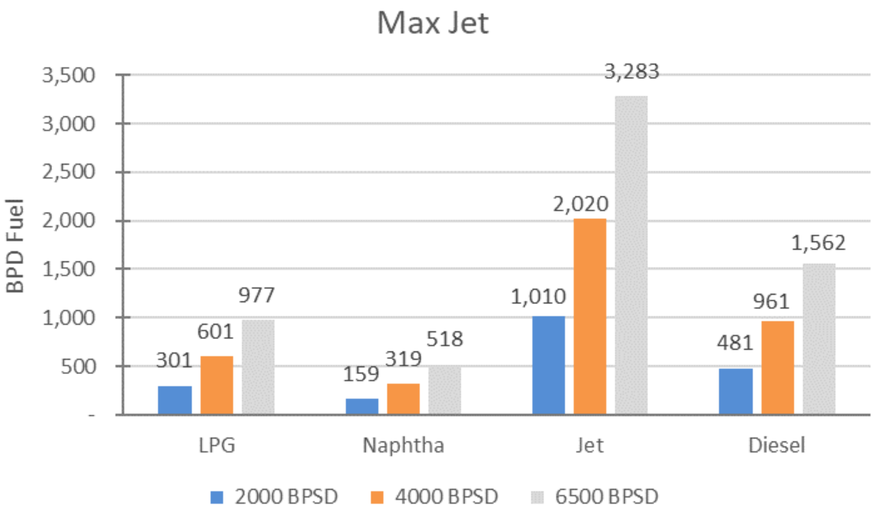
Scope

A commercial-scale facility aiming to maximize jet fuel production satisfies between **8%** and **26%** of the total year 2019 jet fuel demand in Kenya.

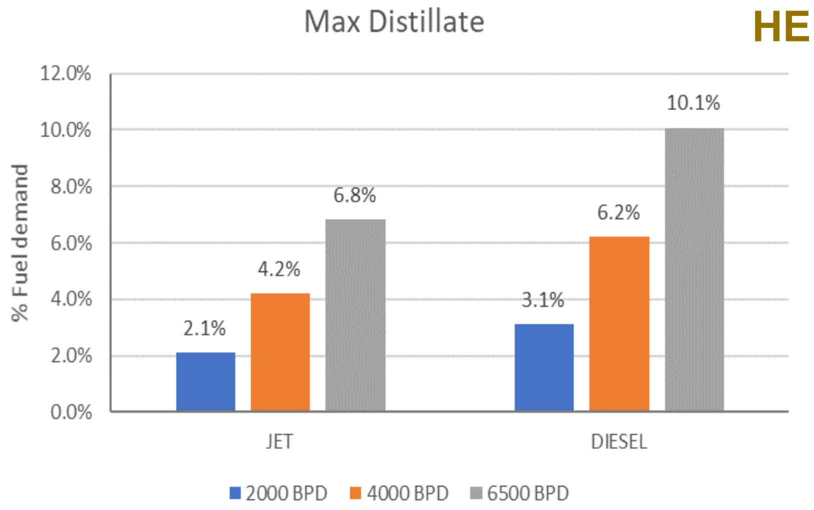
Feedstock and total Capex considerations imply that the **high-end** of the commercial-scale facilities **sizes** will be **difficult** to **built/operate**.

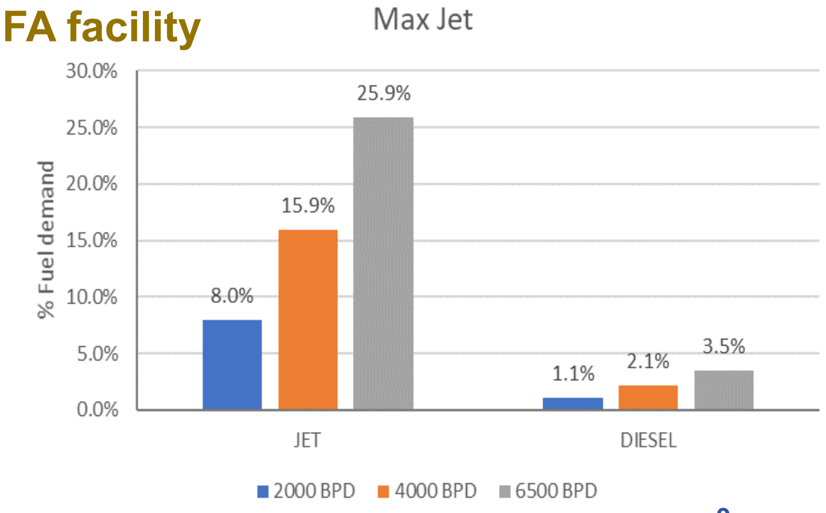
Fuel products that could be produced from maximum distillate and jet scenarios in barrels per day (BPD)





Share of daily jet and diesel fuel demand that could be met by the HEFA facility





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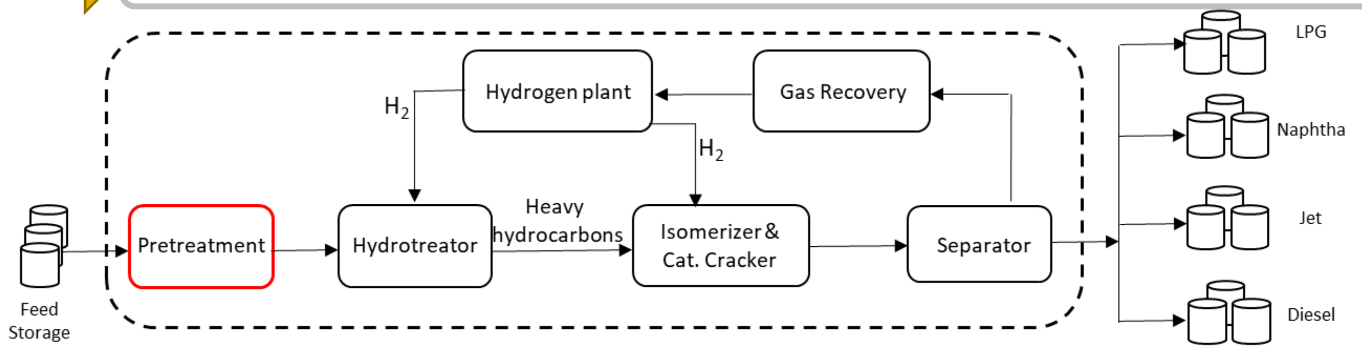
Approach

An existing **techno-economic model** for HEFA from soybean oil in the US is **augmented** to HEFA from **UCO** and **castor oil** in **Kenya** (Pearlson et al., 2012)

- A pretreatment unit is added
- Hydrogen requirements are adjusted according to the fatty acid profiles of the feedstocks
- Financial assumptions are adjusted (debt-equity ratios, loan rates, discount rates)
- Capex is adjusted according to location factors
- OPEX is adjusted according to Kenya-specific costs for feedstock, staff and utilities



Approach

ii Financial assumptions

Item	Value
Facility Size (BPD)	2000/4000/6500
Equity	30%
Loan Interest	15%
Loan Term, years	10
Working Capital (% of FCI)	5%
Type of Depreciation	VDB
Depreciation Period (Years)	10
Construction Period (Years)	3
% Spent in Year -3	8%
% Spent in Year -2	60%
% Spent in Year -1	32%
Discount Rate	35%
Income Tax Rate	30%
Operating Hours per Year	7878
Inflation [%/yr]	7.7%

Equity loan split: 30/70

Cost of debt: 15%

Cost of equity: 35%

Approach

iii Risk premium for debt and equity

- A minimum acceptable rate of return of **15%** is expected for a relatively new/risky operation in countries like **USA** and **Canada** (Chu et al. Applied Energy 198 (2017) 401–409).

- A report by the Independent High-Level Expert Group on Climate Finance shows (table to the right) the required return from solar projects by country. This information can be used to derive a relevant **risk adjustment factor (~2.5)**

- Based on this information, the baseline **rate of return** was set to **35%** for Kenya, and the baseline **loan rate** to **15%**.

Table 7.2. Return expectation from solar projects in EMDCs

Country	S&P Rating	Required return from solar project (%)
Germany	AAA	7%
USA	AA+	9%
UAE	AA	10%
Saudi Arabia	A-	12%
Chile	A	12%
Morocco	BBB-	15%
India	BBB-	17%
Algeria	B	18%
Oman	BB-	18%
Peru	BBB	20%
Costa Rica	B	21%
Namibia	BB-	21%
Ghana	B-	22%
Brazil	BB-	22%
Nigeria	B+	22%
Bolivia	B+	24%
Tanzania	B	24%
Egypt	B	28%
Zambia	CCC-	38 %
Argentina	CCC+	52%

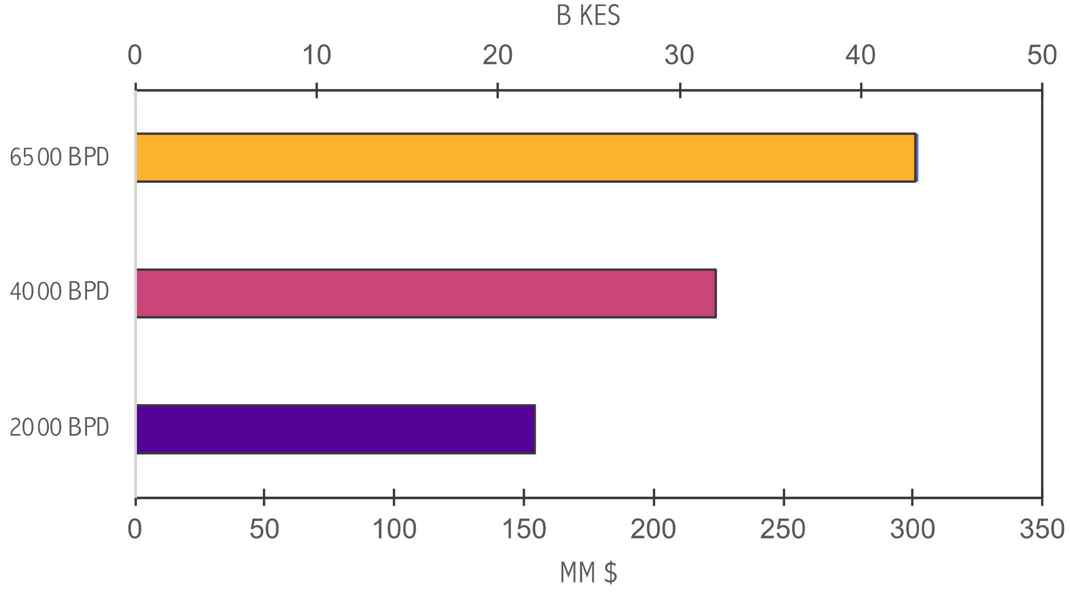
Songwe, V. et al. 2022 Finance for climate action: scaling up investment for climate and development Report by Independent High-Level Expert Group on Climate Finance

Key results

CAPEX required

Fixed Capital Investment (FCI)

- **Direct Costs (DC)**
  - Inside battery limits (ISBL)
    - Purchased equipment cost (PEC)
    - Installation
    - Instrumentation/controls
  - Other direct costs
    - Storage: feed./products
    - Buildings (45% PEC)
    - Service facilities (40 % PEC)
    - Yard improv. (15 % PEC)
- **Indirect Costs (IC)**
  - Engineering & supervision (30 % DC)
  - Construction & fees (30 % DC)
  - Contingency (20 % DC)



Capex requirements vary between **B. 22 KES (MM 154 $)** and **B. 43 KES (MM 154 $).**

CAPEX shows **significant economies of scale**, with per unit output CAPEX decreasing by 27% for a 4000 BPD facility and 40% for a 6500 BPD facility, compared to a 2000 BPD facility.

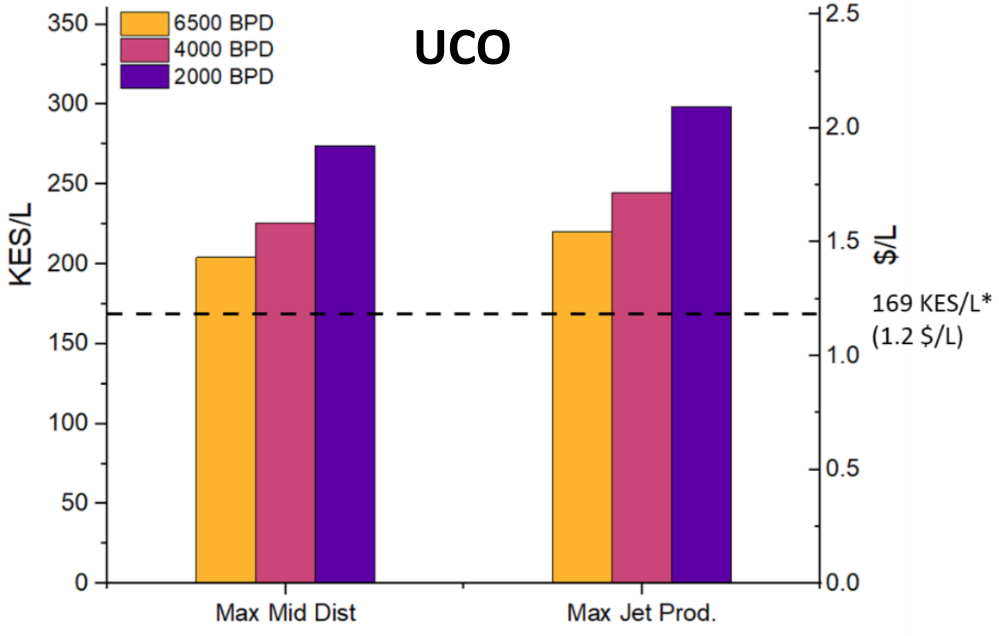
Minimum fuel selling price (MSP)

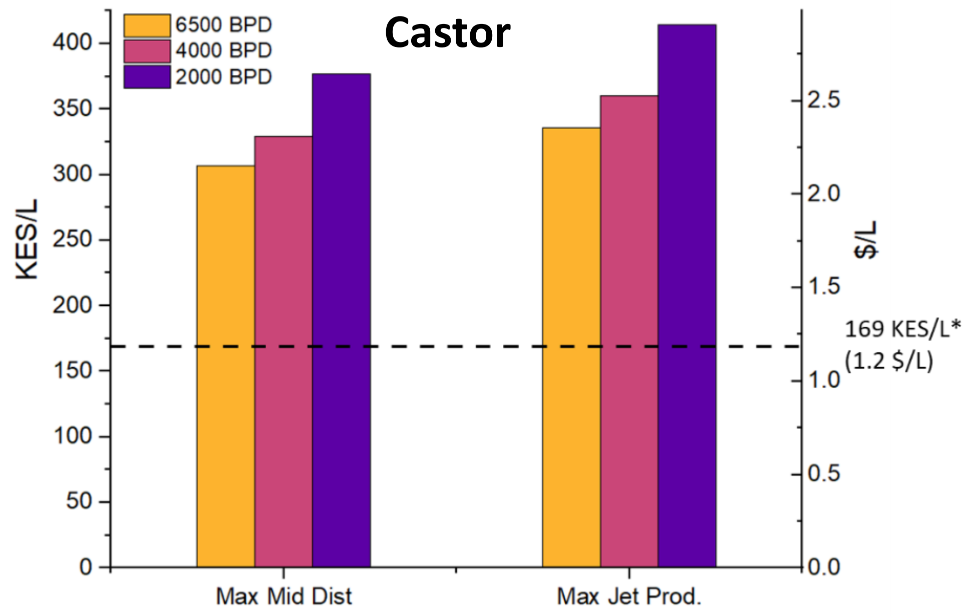
Minimum fuel selling price

The MSP is the price that the SAF needs to be sold for an investor to meeting the expected rate of return. This is the SAF price at which the net present value of the refinery project equals zero.

Under our baseline assumptions, depending on facility size and product slate assumptions, depending on facility size, the MSP for **UCO HEFA** is between **20%** and **76% higher than the conventional jet fuel** price in **Kenya**.

Under our baseline assumptions, depending on facility size and product slate assumptions, depending on facility size, the MSP for **Castor HEFA** is between **80%** and **140% higher than the conventional jet fuel** price in **Kenya**.

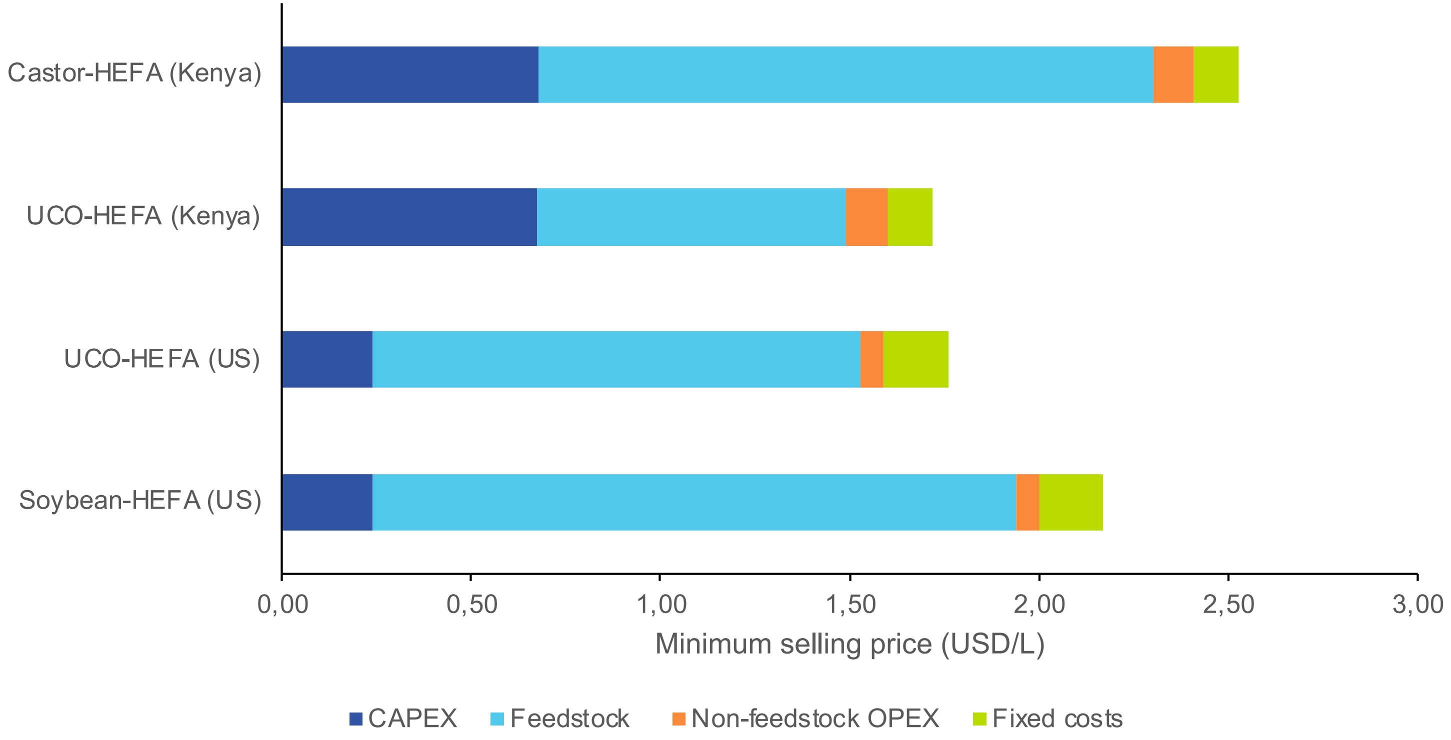




MSP comparison

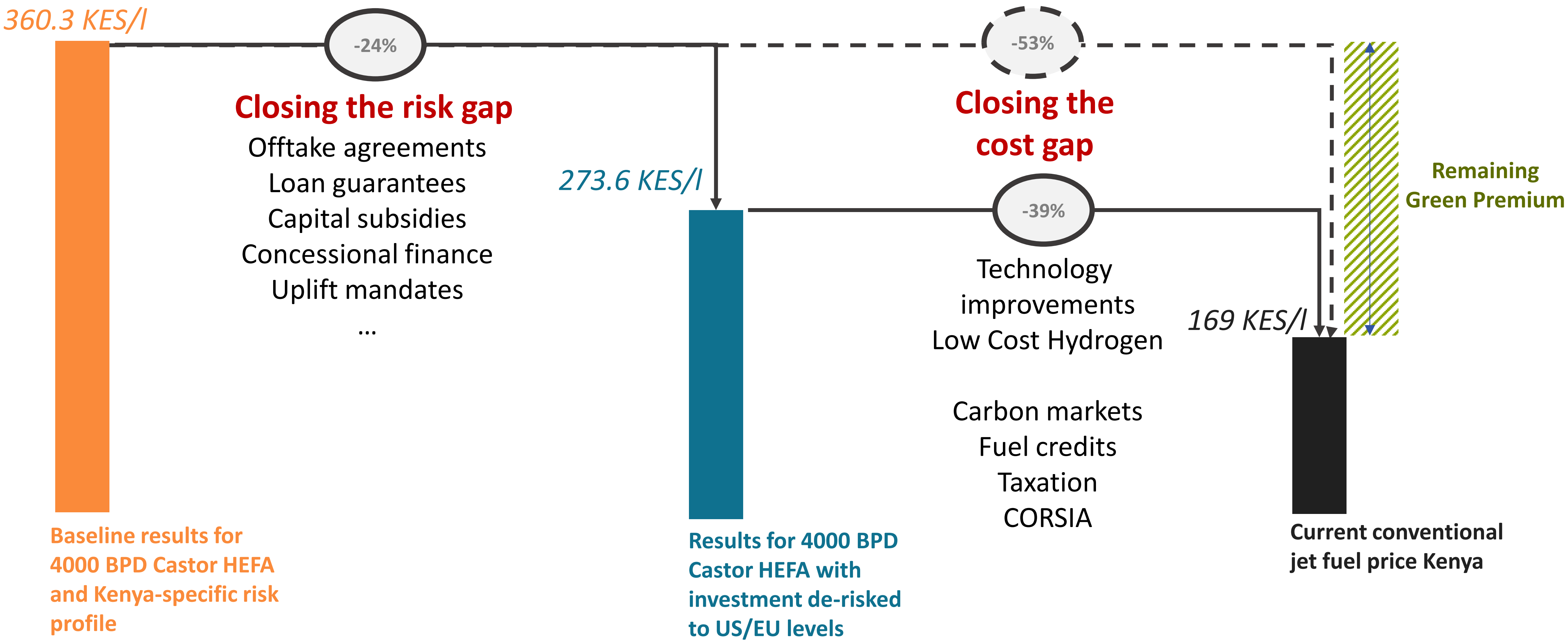
3 Takeaways:

- **Effect of risk markup clearly visible** in different importance of capital costs in Kenya and US.
- Costs of capital differences drive **Castor HEFA in Kenya costs above US soybean HEFA costs.**
- UCO HEFA Kenya in our modeling cheaper than UCO-HEFA US: Might be driven by **high feedstock demand in the US** + underestimating **UCO feedstock costs** in Kenya.



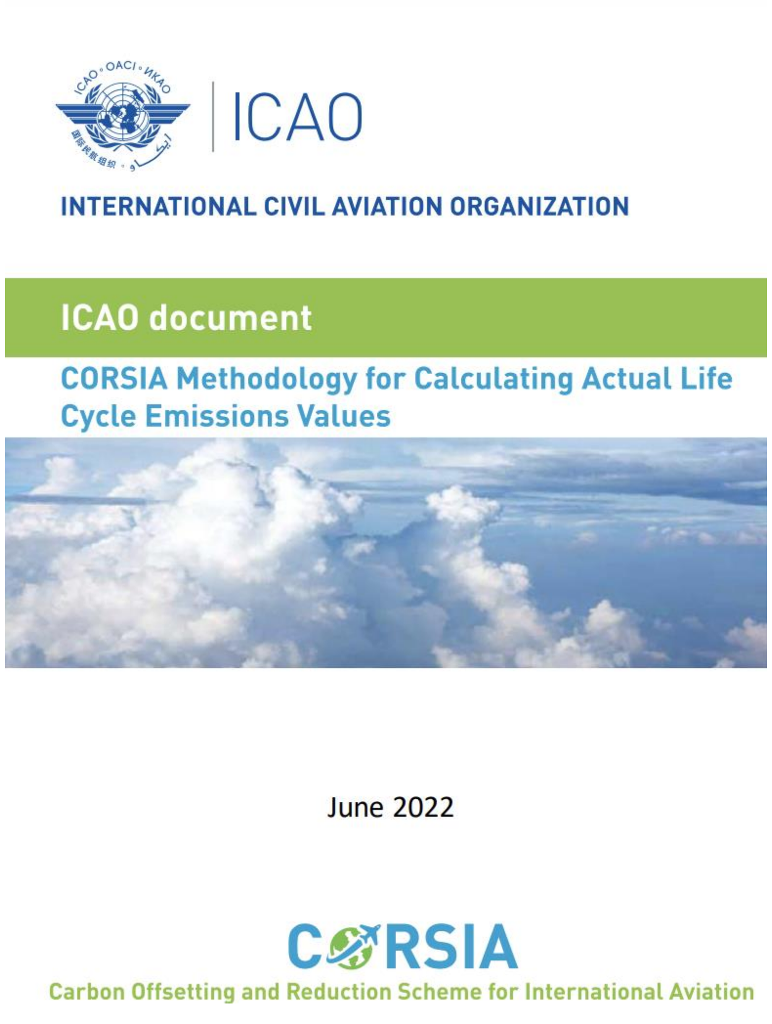
MSP estimates without inclusion of policy incentives such, as for example US IRA, LCFS, CORSIA

Closing of risk and cost gaps



Lifecycle GHG emissions

- We calculate lifecycle GHG emissions in alignment with the **CORSIA method** for both **UCO** and **Castor HEFA**.
- CORSIA mandates for vegetable oils the use of emission values from **induced land-use change**. Default values for Castor Oil are not available within CORSIA. Developing these requires the calibration and use of equilibrium models of the energy/agriculture system that were beyond of the scope of the current study.
- The **necessary data** comes from the **TEA analysis** and a recent journal paper on HEFA fuels from emerging vegetable oils - Seber et al. (2022).


ICAO

INTERNATIONAL CIVIL AVIATION ORGANIZATION

ICAO document

CORSIA Methodology for Calculating Actual Life Cycle Emissions Values

June 2022

CORSIA

Carbon Offsetting and Reduction Scheme for International Aviation

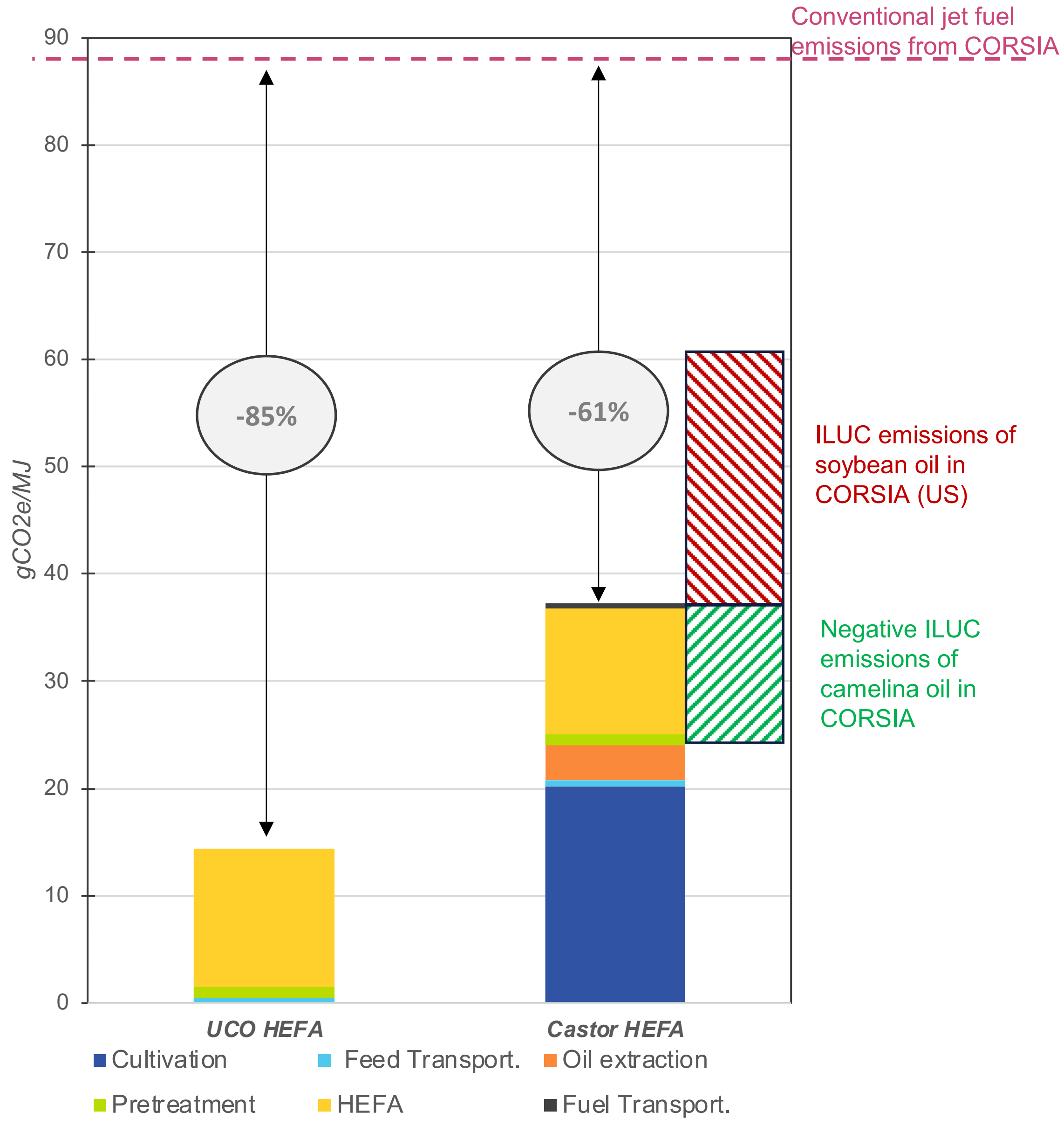
Lifecycle GHG emissions

Core results

Under baseline assumptions and using the max jet product slate, lifecycle GHG emissions of **UCO HEFA produced in Kenya** are approx. **85% lower** than those of **conventional jet fuel**.

For **Castor HEFA,** not including emissions from land use change, **baseline emission reductions** amount to approx. **61%.**

The Castor HEFA emissions **can change substantially** (positive or negative) if **emissions from land-use change** are included.



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