Breaking the Barriers with Breakthrough Jet Fuel Solutions

TOTAL | AMYRIS®

4th ICBS Biofuels Conference

NIST Campus, Gaithersburg, MD, USA

14 November 2012

Total – Amyris: A Partnership Leveraging Expertise

- **Leading international oil & gas company and jet-fuel supplier to the aviation sector**
- **Technical knowledge of the target drop-in molecules**
- **Technical expertise in industrialization and DSP:**
  - Finding synergies with existing plants and optimized refining technologies for the final Downstream Processing (DSP) steps

- **Industry-leading renewable fuel development expertise and capabilities**
- **Technology converting plant sugars into hydrocarbon fuels and chemicals**
- **Access to low cost feedstock (e.g. Brazilian sugarcane)**

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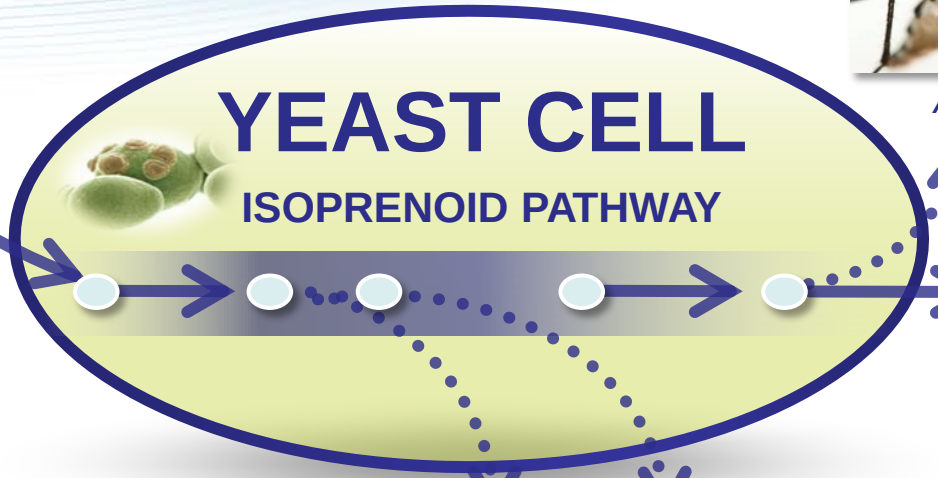
Direct Sugar to Hydrocarbon (DSHC) Technology

SUGAR SOURCES



ANTI-MALARIAL DRUG

C15: FARNESENE/FARNESANE

Jet A/A1 Fuel

C10 MOLECULE

ISOPRENE

INDUSTRIAL SYNTHETIC BIOLOGY PLATFORM

Amyris-Total DSHC Production Process

FERMENTATION

DOWNSTREAM PROCESSING

BIOMASS SUGARS

HYDROCARBONS

JET A/A1 FUEL

Fermentation of sugars directly into a hydrocarbon, followed by DSP finishing into an ASTM compliant Jet A/A1 Fuel

Bio-sourced Farnesane

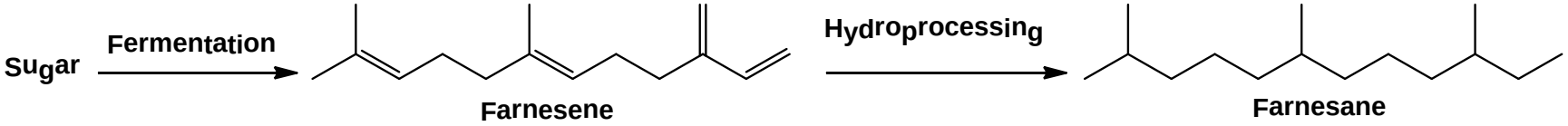
Farnesane (C15): 2,6,10-trimethyldodecane
CAS: 3891-98-3
C15 iso-paraffin molecule

Production of >30,000 liters of bio-jet to date

Fermentation Precursor: trans-β-Farnesene
CAS: 18794-84-8
Terpene hydrocarbon

Amyris has produced well over a million liters of farnesene to date and is completing construction of the purpose-designed farnesene plant in Paraiso, Brazil with up to 50 million liters per year at target efficiency.

Chemical Transformation:



Key Molecule Neat Properties

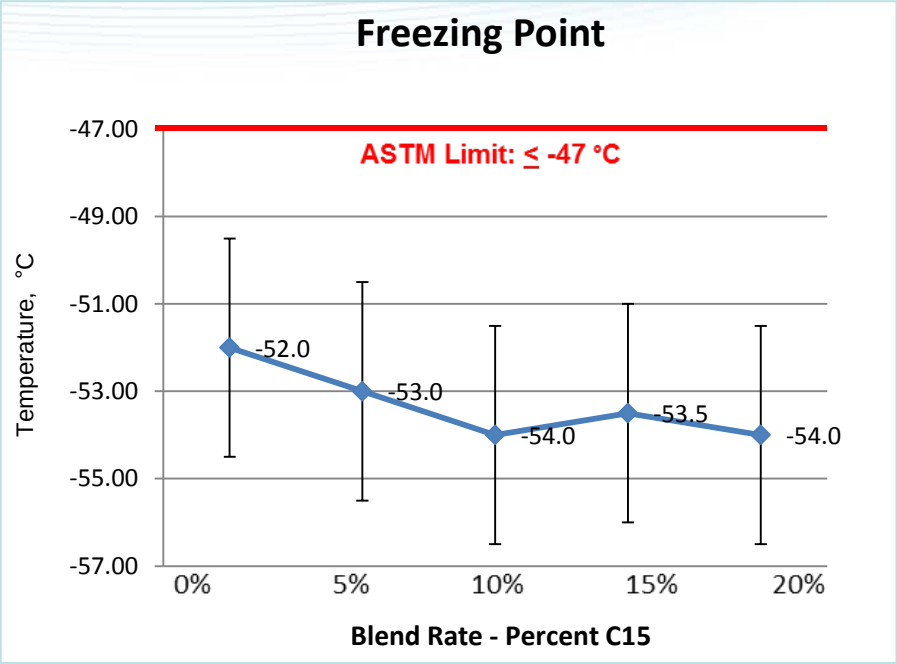
Farnesane (C15)

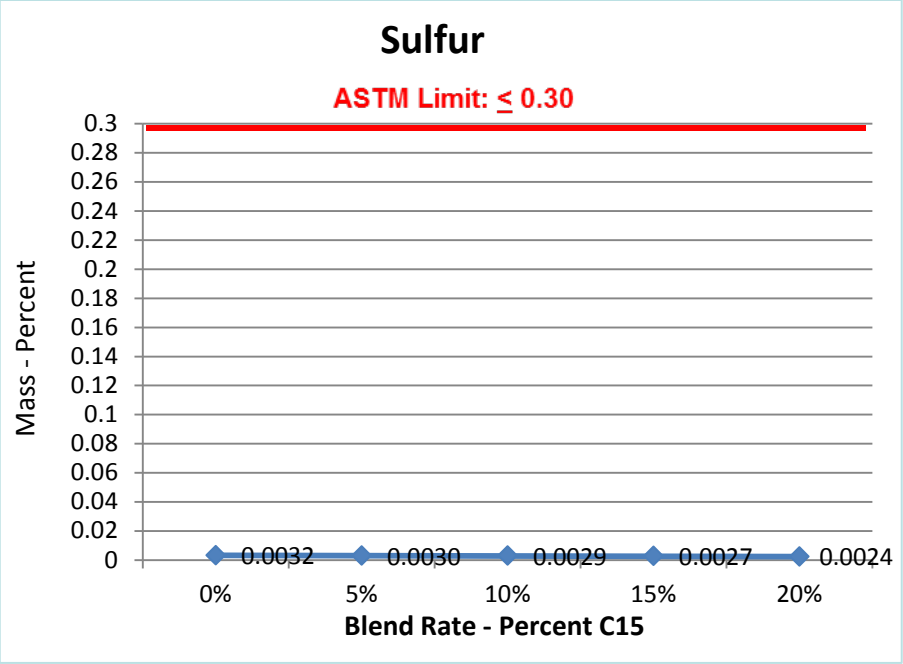
Property	C15 Results	ASTM D7566 Annexes A1.1 & A2.1
Acidity Total mg KOH/g	< 0.002 (w/o BHT)	0.015
Physical Distillation (°C)	10%: 244.6 50%: 245.0 90%: 245.7 FBP: 251.0 Residue: 1.2 Loss: 0.2	10% <205 (SPK) FBP <300 (SPK) Residue <1.5 (jet spec) Loss <1.5 (jet spec)
Flash Point	108 °C	38 °C min
Density at 15°C	773 kg/m^3	775 to 840 kg/m^3 (jet spec)
Freezing Point	< -100 °C	-40 °C max
Lubricity	0.643 mm	<0.85 (jet containing more than 95% of hydroprocessed compounds)
Existent Gum, mg/100 mL	4 and 3 (w/o BHT)	<7 (HEFA)
FAME, ppm	<4.5 mg/kg	<5 (HEFA)
MSEP	87 (95 w/o BHT)	>85 (jet w/o antistatic)
Thermal Stability - 2.5 h at 380°C	1	<3
Net Heat of Combustion, MJ/kg	44.0 MJ/kg	>42.80 (jet spec)

Farnesane properties make it a good candidate for blend in jet

Jet Fuel Properties: Freezing Point & Sulfur Content

Farnesane blended with petro Jet A1

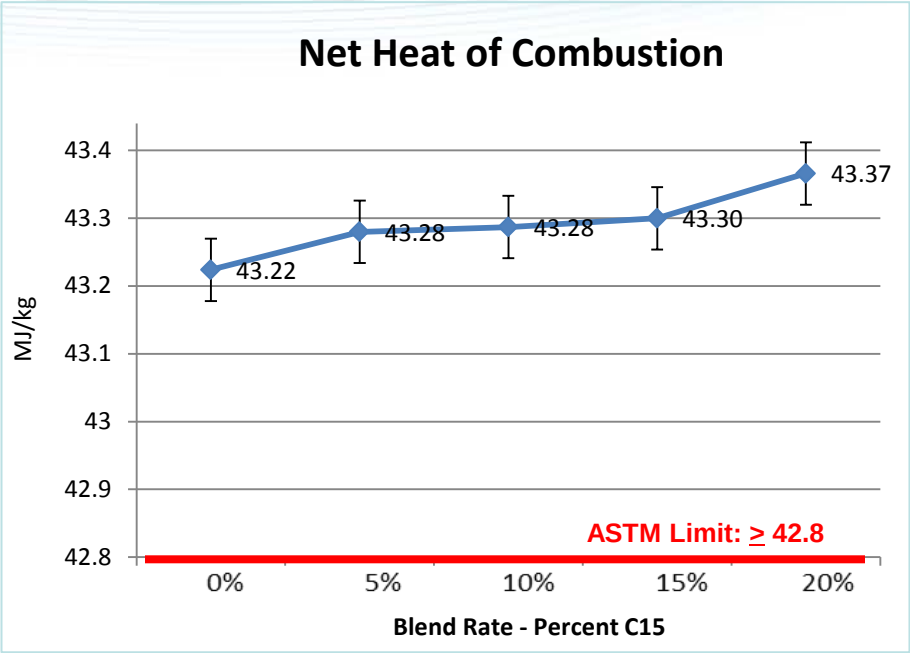


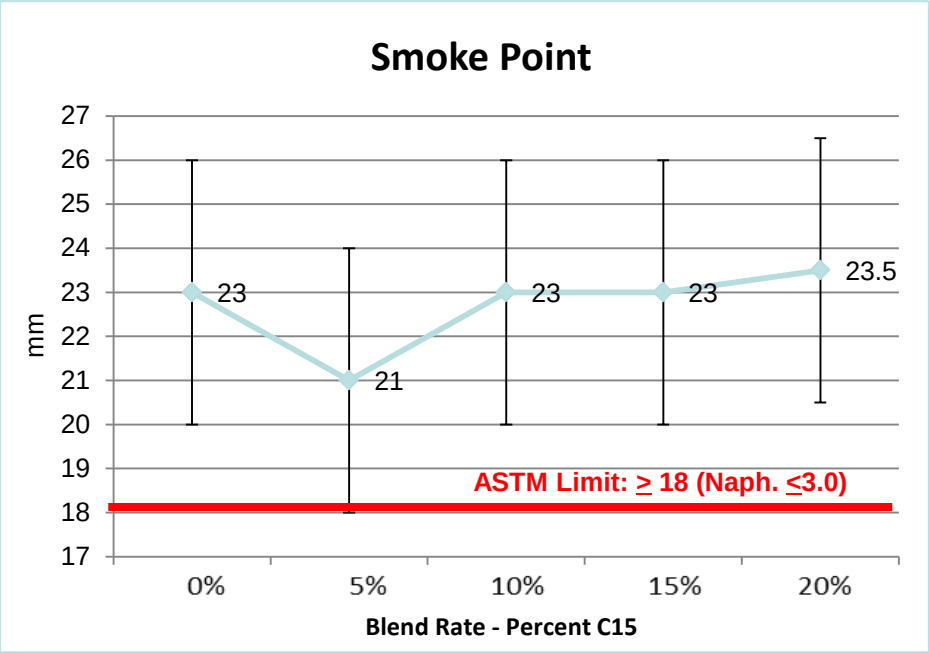


Good Freezing Point & Decreased Sulfur

Jet A/A1 Fuel Properties HoC & Smoke Point

Farnesane blended with petro Jet A1

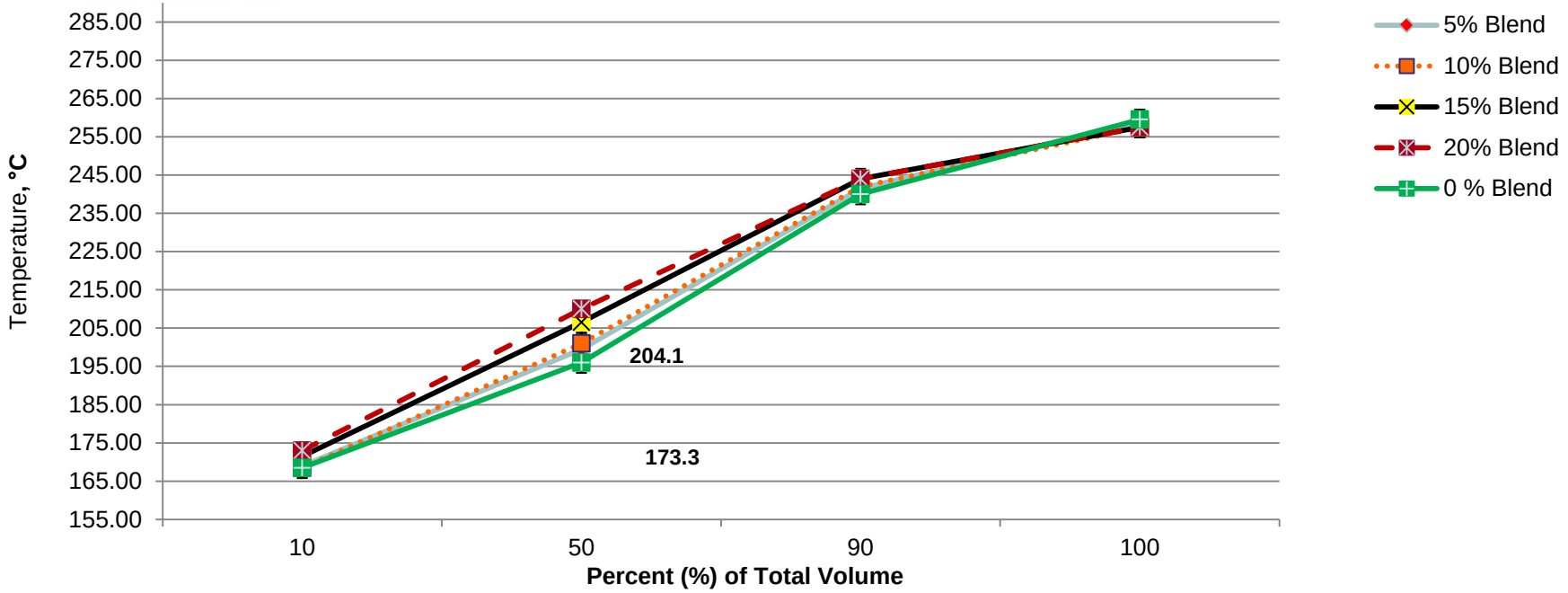




Petro-like HoC & Smoke Point

Jet A1 Fuel Properties: Distillation

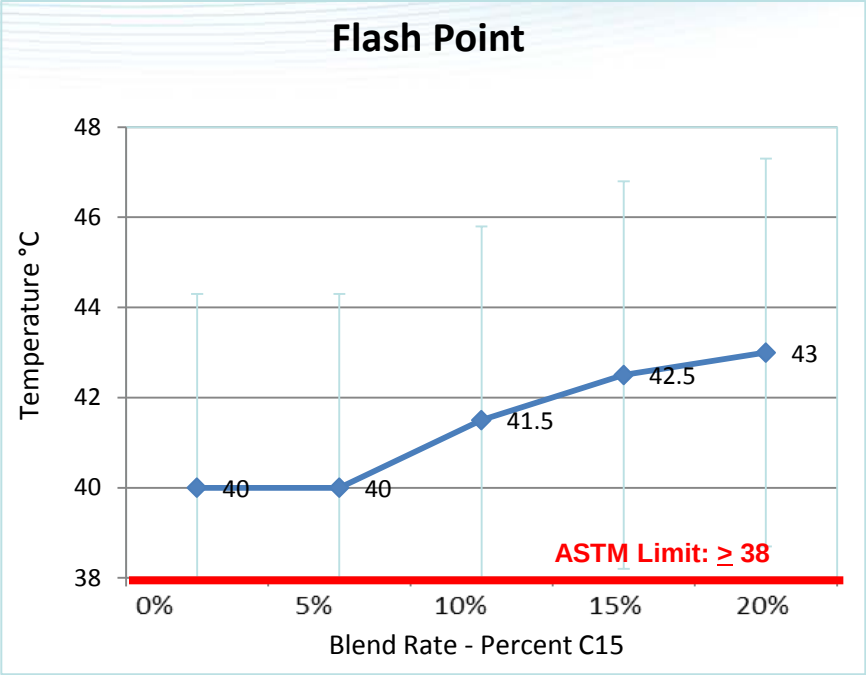
Farnesane blended with petro Jet A1

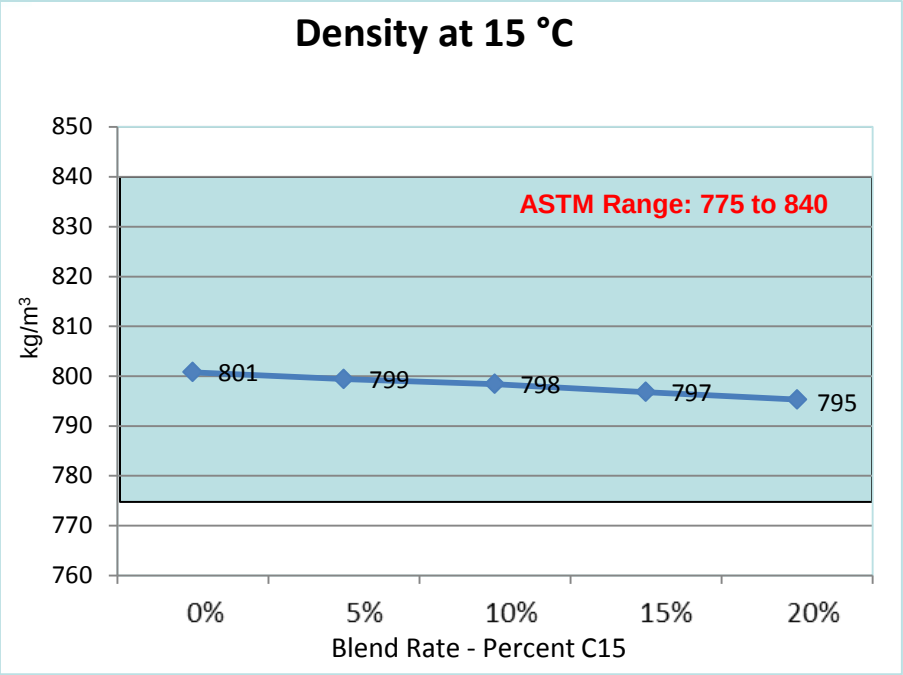


Petro-like Distillation Characteristics

Jet A1 Fuel Properties: Flash Point & Density

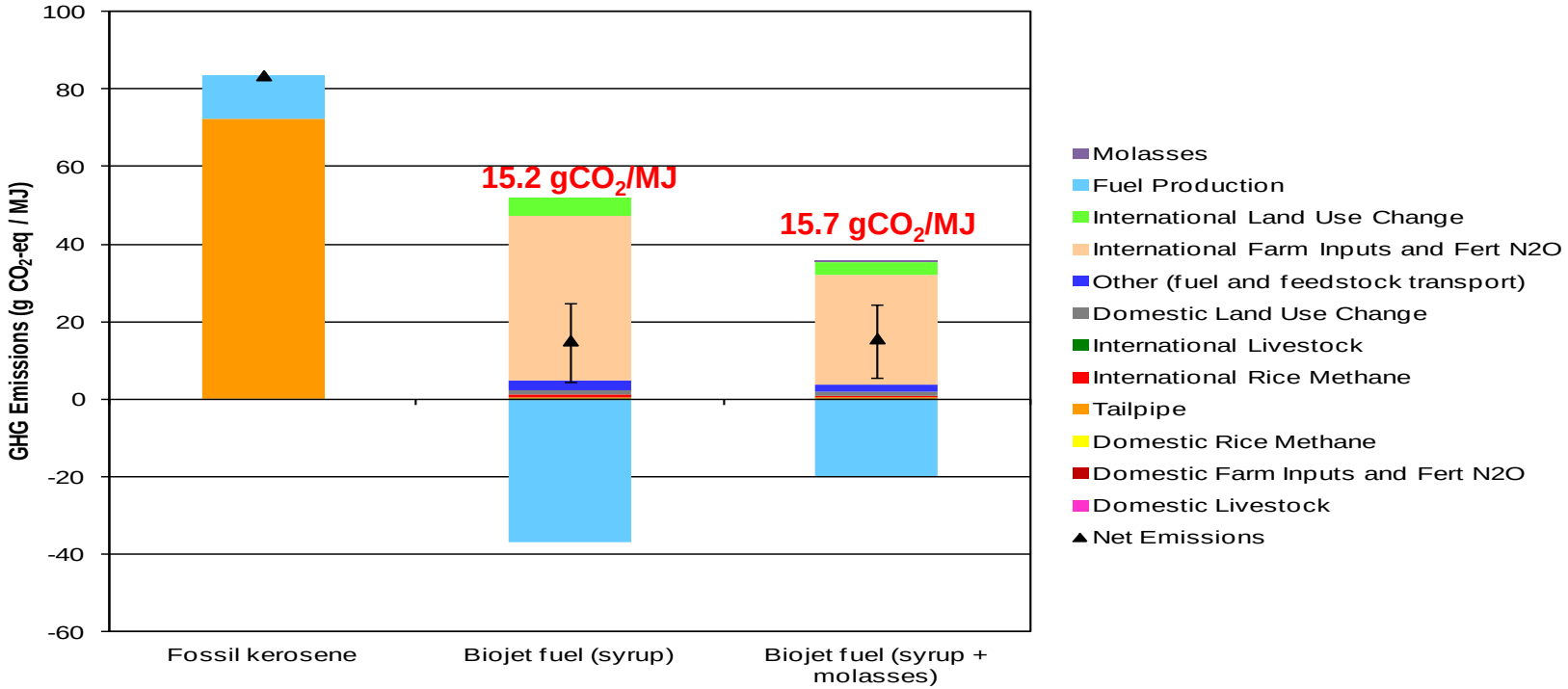
Farnesane blended with petro Jet A1





Higher Flash Point with Petro-like Density

ICONE results for the biojet fuel by life cycle

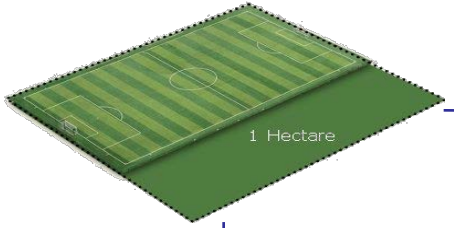


Based on US EPA Jet A Baseline = 83.8 gCO_2eq/MJ

Results revealed net life cycle emissions of around 15 g CO_2eq/MJ, which leads to mitigation around 82%* of the GHG emissions considering fossil fuel

Amyris - Total Renewable Jet Fuel

Land use efficiency in comparison to other alternatives in Brazil



2.839 liters/year

927 km

CAMELINA

3.246 liters/year

1060 km

JATROPHA

4.180 liters/year

1365 km

AMYRIS CANE-DERIVED JET FUEL

Source: UNICA, Jatropha Alliance, Wiley Online Library

Successful Demonstration Flight with Renewable Jet Fuel containing Farnesane, p-Menthane, p-Cymene

(at 20%, 20% and 10%, respectively)

São Paulo , Brazil, June 2012

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