Alternative Jet Fuel Production from Tropical Biomass Resources

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Background

- The objectives of HNEI's part of the study:

  1) Evaluate the potential of tropical crops for AJF production.

  2) Provide baseline information relevant to developing production scenarios for regional supply chains in Hawaii and tropical regions.

  3) Investigate some key implications (e.g. growing conditions, invasiveness, energy balance, sustainability) related to the use of these alternative biofuels.

  4) Review available information on AJF production, summarizing technological aspects, feedstock properties, conversion yields, co-products and cost estimates where possible.

Tropical Crops

17 tropical plants that produce oil, fiber, or sugar were identified.

No	Crop Common Name	Scientific / Latin Name	Family	Feedstock type
1	Banagrass	*Pennisetum purpureum* Schumach	Poaceae	Fiber
2	Energycane	(*Saccharum officinarum* X *S. rubustum)*	Poaceae	Fiber
	Eucalyptus:			
3	-Bluegum Eucalyptus	*Eucalyptus globulus* Labill	Myrtaceae	Fiber
4	-Rainbow Eucalyptus	*Eucalyptus deglupta* Blume	Myrtaceae	Fiber
5	-Robusta Eucalyptus	*Eucalyptus robusta* Sm.	Myrtaceae	Fiber
6	-Rose gum Eucalyptus	*Eucalyptus grandis* W. Hill ex Maiden	Myrtaceae	Fiber
7	-Saligna Eucalyptus	*Eucalyptus saligna* Sm.	Myrtaceae	Fiber
8	Gliricidia	*Gliricidia sepium* (Jacq.) Kunth ex Walp.	Fabaceae	Fiber
9	Leucaena hybrid	*Leucaena*-KX_4	Fabacaea	Fiber
10	Rice (husks &staw)	*Oryzae sativa* L.	Poaceae	Fiber
11	Sorghum	*Sorghum bicolor* L.	Poaceae	Fiber
12	Sesbania (Ohai)	*Sesbania grandiflora* (L.) Poir	Fabaceae	Fiber
13	Sugarcane	*Saccharum officinarum* L.	Poaceae	Sugar & Fiber
14	Jatropha	*Jatropha curcas* L.	Euphorbiaceae	Oil
15	Kamani	*Calophyllum inophyllum* L.	Clusiaceae	Oil
16	Pongamia	*Pongamia pinnata* (L.) Pierre	Fabaceae	Oil
17	Croton (Musine)	*Croton megalocarpus* Hutch.	Euphorbiaceae	Oil

Tropical Crops - Oil

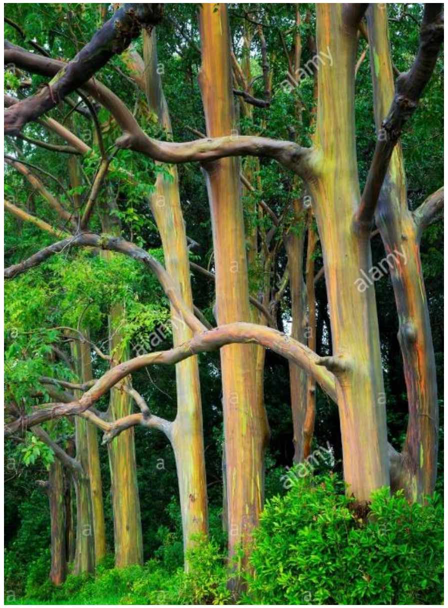
Jatropha curcas L. tree and seeds

Kamani trees and Kamani fruit

Pongamia tree, flowers, and seed pod

Croton tree and fruits

Tropical Crops - Fiber



Eucalyptus grandis

Six months old *Luecaena*-KX4

Gliricidia sepium

Sesbania grandiflora

Tropical Crops - Grasses

Three months old
fiber sorghum
(hybrid SS506)

Two year old
sugarcane

Six months old
banagrass

One year
(2nd Ratoon)
energycane

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Tropical Crops – Yields

Candidate Crop	Yield Mg ha^{-1} yr^{-1}	Location	Latitude	Longitude	Rain fall (mm)	Temp (°C)	Growing period (d)
Croton	10	Kagera-Tanzania	-5.51	32.71	705	23	180-209
Jatropha	5	Managua-Nicaragua	11.83	-85.75	1400	26.6	220-239
Kamani	4.8	Java-Indonesia	-7.14	108.69	2311	24	300-329
Pongamia	4.9	Baramati Maharata -India	18.65	-73.5	2656	24.2	150-179
Banagrass	40	Waimanalo-Hawaii	21.39	-157.78	1298	24.1	282
Bluegum Eucalyptus	35* 13-44*	Tasmania-Australia Santiago-Chile	-41.09 -32.31	145.32 -71.53	1415 372	11.6 15.1	264 187
Energycane	26.9-31.3	Florida-USA	25.82	80.49	1258	24.1	282
Gliricidia	5.3	Morogoro, Tanzania	-8.94	36.82	1598	25.1	210-239
Leucaena hybrid	15	Waimanalo-Hawaii	21.39	-157.78	1298	24.1	282
Rainbow Eucalyptus	24.4 39*	Misamis- Philippines Huetarnorte Costa Rica	7.69 10.85	124.78 -48.65	2003 1700	24.2 26.5	365 240-269
Rice	22.4	Lalanda-Bihar-India	26.34	85.62	1149	24.9	180-209
Robusta Eucalyptus	10-35*	Madagascar	-15.78	48.27	2057	23.7	300-329
Rose gum Eucalyptus	22*	Dehra Dun-India	31.83	75.72	1425	22.6	210-239
Saligna Eucalyptus	20.6	Hilo-Big Island, Hawaii	19.54	-154.98	3040	22.5	
Sorgham	20	Northern Territ -Australia	-15.6	132.99	741	26.6	120-149
Sesbania	20-25*	Java-Indonesia	-7.01	108.96	2401	25.48	300-329
Sugarcane	40-80	Maui- Hawaii	20.57	-156.69	1305	22.1	

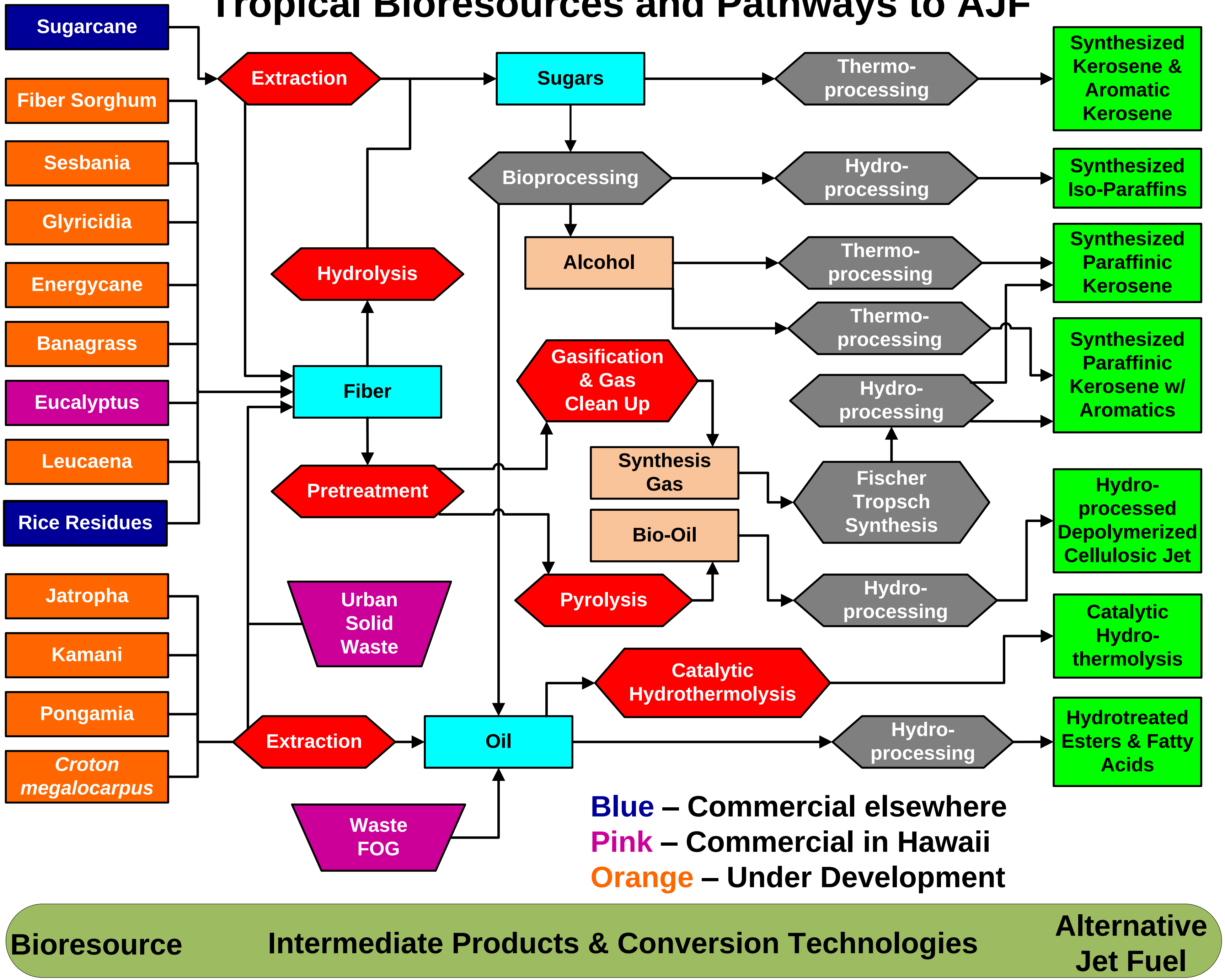
* Yield estimated as m^3 ha^{-1} yr^{-1} (mass yield data not available), the others are estimated as Mg ha^{-1} yr^{-1}

Tropical Crops – Yields

Candidate resources	Feedstock type	Yield	AJF yield	Oil content	Invasive status	Mechaniz.
		$Mg\ ha^{-1}\ yr^{-1}$	$L\ ha^{-1}$	%		
Croton (Musine)	oil	10	2400	30-32	Yes[1]	No
Jatropha	oil	5	2000	30-35	Yes[3]	Yes
Kamani	oil	4.8	1440	30	No[2]	No
Pongamia	oil	4.9	1238	25	Yes[3] & No[4]	No
Banagrass	fiber	40-49			Yes[3]	Yes
Blue gum eucalyptus	fiber	5-7			Yes[3]	Yes
Energycane	fiber	26.9-31.3			No	Yes
Gliricidia	fiber	5-6			No[3]	No
Leucaena hybrid	fiber	15			No[5]	Yes
Rainbow eucalyptus	fiber	24.4			No[3]	Yes
Rice (Husks)	fiber	2.4-4.2			No	Yes
Rice (Straw)	fiber	2.7-4.8			No	Yes
Robusta eucalyptus	fiber	13			No[3]	Yes
Rose gum eucalyptus	fiber	22			Yes[3]	Yes
Saligna eucalyptus	fiber	20.6			Yes[3]	Yes
Sorgham	fiber	20			No[3]	Yes
Sesbania (Ohai)	fiber	4-12			No[3]	No
Sugarcane (bagasse)	fiber	10			No[3]	Yes
Sugarcane	sugar	40-80			No[3]	Yes

[1] Croton is invasive according to Maroyi, [220].
[2] Kamani is not invasive according to Friday and Okano [54].
[3] The Hawaii-Pacific Weed Risk Assessment [71] List.
[4] Pongamia is not considered an immediate problem [72].
[5] Hybrid Leucaena-KX4 is low risk invasiveness according to Brewbaker [110].

Tropical Bioresources and Pathways to AJF



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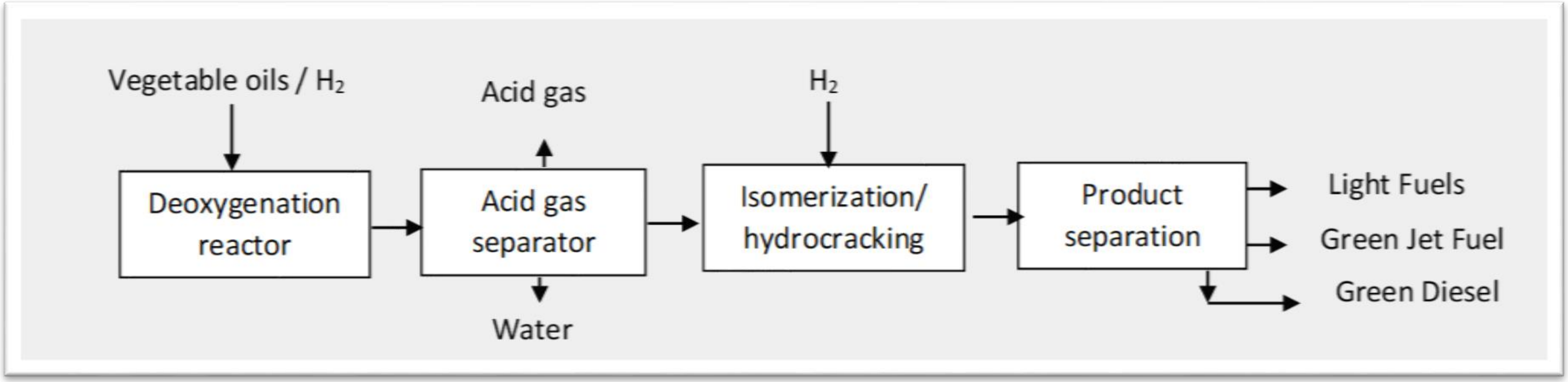
Scope of HNEI's Review

- Review information on pretreatment requirements and conversion processes for the 17 feedstocks:
  - mass and energy balances,
  - product and byproduct yield and quality,
  - scale requirements/unit sizes.

- Six biomass to jet fuel conversion processes were considered:
  - gasification-FT (FT),
  - fast pyrolysis (PY),
  - hydrothermal liquefaction (HTL),
  - direct sugars to hydrocarbons (DSCH),
  - alcohol to jet (ATJ),
  - hydrotreated esters and fatty acids (HEFA).

Oil Crop Conversion (HEFA)

- Hydrotreated esters and fatty acids (HEFA) are produced from fatty acid triglycerides from oil feedstocks (vegetable oils, waste cooking oils, seed oils, tallow, etc.). Also known as Hydro-treated renewable jet fuel (HRJ).



Simplified schematic of UOP's Renewable Jet Fuel process

HEFA Mass Balances

- There is limited information on HEFA mass balances for tropical biomass.

- Wang & Tao [221] summarized the production yields of intermediates and HEFA for eight (*non-tropical*) feedstocks normalized to GGE product per dry Mg of feedstock, as of 2016.

  – In terms of **HEFA yields** the **range is 34 to 85 GGE/dry Mg** (30 to 75 gal./dry Mg).

- For Jatropha seed with 35% oil content, the jet fuel yield is **~68 GGE HEFA/dry Mg** (~60 gal./dry Mg) [221].

221. Wang, W.C. and L. Tao, *Bio-jet fuel conversion technologies.* Renewable and Sustainable Energy Reviews, 2016. 53: p. 801-822.

Production costs HEFA

- There is limited information in the open literature for production, capital and operating costs of HRJ/HEFA processes, especially for tropical feedstocks.
- Cost estimates from a 2016 review article on non-tropical feedstocks [221].
  - Based on a range of different feedstocks, HEFA production cost ranges **from 4.1 to 9.2 $/gal** where soybean and algae represent the lowest and highest production costs.
  - Maximizing jet fuel yield would require additional hydrogen that would add an extra ~$0.30/gal to the MSP.
  - **Pongamia oil derived HRJ has been estimated to cost $8.9/gal (2011 US$) [221, 237].**
- Wang & Tao [221] estimated that HEFA capital costs are ~20% greater than bio-diesel production (FAME) due to the hydro-treating required by the HEFA process.
- Feedstock cost is the greatest contributor to MSP, accounting for 70-80% of costs.

221. Wang, W.C. and L. Tao, *Bio-jet fuel conversion technologies.* Renewable and Sustainable Energy Reviews, 2016. 53: p. 801-822.

HRJ Strengths & Weaknesses

Summary of the strengths and weaknesses of HRJ/HEFA processes.

Strengths	Weaknesses
• Mature technology. • Uses exiting refinery practices. • High energy density product. • The product is free from the 'blend wall' limitations imposed on bio-ethanol and bio-diesel (FAME).	• Cost of the feedstock. • Limited availability of feedstocks. • Aromatics are not produced.

- Jatropha & Pongamia (karanja oil): There are a large numbers of publications, however most are related to the production of bio-diesel or direct combustion of the oil.
- Kamani & Croton (Musine): no publications.

Fiber Crop Conversion

- Tropical fiber crops include soft and hard woods, grasses (herbaceous biomass) and agricultural residues
  - Grasses & Ag. Residues: banagrass, sorghum, sugarcane (bagasse), energycane, and rice (husks and straw).
  - Trees: eucalyptus, hybrid leucaena, gliricidia, and sesbania.
- Thermochemical processes (FT, PY or HTL) are well suited to the production of jet fuel from these feedstocks.
- An alternative pathway to jet fuel from fiber crops is through the production of sugars and/or alcohol intermediates.

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Fiber Crop Conversion - FT

- **Gasification-FT:** There are a great number of possible reactor configurations and operating conditions that could be used.
- Five modes of gasification were examined, fixed bed down draft, fixed bed updraft, fluidized bed, dual fluidized bed and entrained flow.
- There are numerous other important variables to consider such as: gasifiying medium (air, steam, oxygen or their combinations), operating pressure, heating (direct or indirect), etc.
- There are two general modes of gasification that are suited to the production of jet fuel from biomass:

  i. **Steam blown**, low to medium temperature, atmospheric pressure fluidized bed designs.

  ii. **Oxygen blown**, medium to high temperature, elevated pressure fluidized bed or entrained flow designs.

  iii. An emerging approach is the use of mixtures of steam and oxygen to reduce the amount of oxygen and related costs.

Summary of the strengths and weakness of different modes of gasification.

Gasifier Type	Strengths	Weaknesses
Fluidized-bed	• Can accept a wide variety of feedstocks. • Feasible at medium to large scale (5 to ~400 MW_{th}). • Proven at commercial scale.	• Requires feedstock particle size <10 cm. • Medium amount of tar in product gas (~10 g/Nm^3). • Bed agglomeration can be an issue.
Dual Fluidized-bed	• Nitrogen free product gas. • Can accept a wide variety of feedstocks. • Feasible at medium to large scale (5 to ~400 MW_{th}). • Proven at commercial scale. • Producer gas has medium calorific value (~17-18 MJ/Nm^3) • High energy conversion efficiency. • Good quality producer gas when steam blown (does not require pure oxygen)	• Requires feedstock particle size <10 cm. • Medium amount of tar in product gas (~10 g/Nm^3). • Bed agglomeration can be an issue. • More complex to build than traditional fluidized bed and greater capital cost.
Entrained Flow	• Can accept liquid-solid feedstocks slurries. • Complete conversion of the feedstocks within a few seconds. • Very low levels of tar and methane in the producer gas. • Good quality producer gas which requires minimal gas cleaning. • Increased efficiency when used for synthesis. • Can accept feedstocks with ash that melts at low temperatures. • Proven at commercial scale (coal).	• Requires feedstock particle size ~1 mm. • Requires pure oxygen. • Operates at high pressure (up to 100 bar). • Operates at high temperature (~1200 °C). • Greater capital costs than other gasifiers. • Requires large scale (~1000 MW_{th}) to be economically viable. • Limited experience with biomass feedstocks.

Fiber Crop Conversion - FT

- NREL concluded that the most promising route for biomass processing is steam blown, low pressure (33 psi), indirect dual-bed gasification (circulating entrained flow design).
- There is limited information available on yields and costs related to gasification, especially with regard to tropical feedstocks.
- **In summary:** the most widely studied tropical crops are sugarcane bagasse, rice straw and husks, and eucalyptus.
- There is limited information on banagrass and leucaena.
- There is virtual no information on sorghum, energycane, sesbania, and glyricidia.

Fiber Crop Conversion - PY

- **Pyrolysis:** similar to gasification, there are a number of reactor designs and operating conditions that could be employed for AJF production.

- Fast-pyrolysis and catalytic fast-pyrolysis for producing liquid fuels from biomass are still under development, and are yet to be proven at commercial scale.

- A number of companies are offering 'Off The-Shelf' fast-pyrolysis units at scales up to 400 Mg/d dry input (~80 MW_{th}).
  - However, due to a lack of operational commercial facilities and the proprietary nature of cost and efficiency data, limited information is available.

Fiber Crop Conversion - PY

- When ‘drop in’ transportation fuels are considered as the final product from bio-oil, cost estimates range from:

  ~$2/gal in 2006 using hydro-treatment (including all costs)

  ~$2/gal in 2008 using EFG-FT (feedstock and capital costs for EFG-FT plant were not accounted for)

  ~$3/gal in 2009 using hydro-treatment (not accounting for capital costs)

  ~$4.6/gal in 2012 using hydro-reforming from a company website (no information regarding capital cost)

Fiber Crop Conversion - PY

- Based on the review of various technological and economic studies, the production of bio-oil from biomass fast pyrolysis is technically feasible.

- However the upgrading of bio-oil to jet fuel is yet to be demonstrated at a significant scale.

- It is not straight forward to compare the production costs of bio-oils from different studies as the assumptions and/or bases are not the same.

- Production costs often do not account for capital investment costs and therefore should only be considered as preliminary estimates.

- Only a limited number of studies have been reported for the fast pyrolysis of tropical biomass species other than rice husks, rice straw and bagasse.

- To our knowledge there are no publications that provide complete mass balances, energy balances or techno-economic analyses for any tropical biomass feedstock.

Summary of the strengths and weakness of different modes of fast pyrolysis.

Pyrolyzer Type	Strengths	Weaknesses
Bubbling Fluidized bed	• Mature technology. • Relatively easy to construct and operate. • Scaling is well understood. • Produces a relatively stable, single-phase bio-oil. • Char separation is easier than from circulating FB designs.	• At scales >40 MW_{th} input heat transfer may be an issue. • Requires particle size of < 3 mm. • Requires high flow rate of inert gas. • Requires larger processing equipment than Rotating cone design which increases cost and reduces efficiency. • Limited peer-reviewed information on mass and energy balances for larger reactors.
Dual fluidized bed	• Mature technology. • Relatively easy to construct and operate. • Scaling is well understood. • Potential for greater through-put than BFB. • Produces a relatively stable, single-phase bio-oil.	• Requires particle size of 2-6 mm. • Char separation is more difficult than from BFB. • Requires high flow rate of inert gas. • Requires larger processing equipment than Rotating cone design which increases cost and reduces efficiency. • Limited peer-reviewed information on mass and energy balances for larger reactors.
Rotating Cone	• Requires less inert gas than FB designs, and unit operations are smaller which reduces costs and increases efficiency. • Bio-oil recovery is easier than from FB designs.	• Requires particle size of ~0.2 mm. • Less mature technology than FB designs. • More difficult to integrate with other unit operations in the process which makes construction more complex than FB designs. • Scaling may be an issue at sizes >25 MW_{th} input.

Fiber Crop Conversion - HTL

- **Hydro Thermal Liquefaction** (HTL) of woody biomass to liquid fuels (gasoline to diesel range) is technically feasible but production costs are high in comparison to petroleum based fuels or biomass fast pyrolysis or gasification.
- The key aspect to reducing costs of the HTL route is to improve the recovery of products from the aqueous phase.
- Liquid fuels produced from HTL of woody biomass is not economically competitive with petroleum derived fuels, based on current data.
- In addition, costs are higher and the technology readiness is lower than alternative woody biomass to liquid fuels process routes such as fast pyrolysis or gasification-FT.

Fiber Crop Conversion - HTL

- Due to the lack of information on continuous-flow processes for biomass HTL or for processes operating at meaningful scales, it is not possible to identify a reactor type best suited to the production of jet fuel.

- Recent HTL research has focused on developing scalable plug-flow reactors instead of continuous stirred-tank reactors with an aim of reducing capital costs.

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Fiber Crop Conversion - HTL

Summary of the strengths and weakness of biomass hydrothermal liquefaction for the production of jet fuel.

Strengths	Weaknesses
• Processing of wet biomass or waste (eliminates need for drying). • Minimal feedstock preparation (often only size reduction is required). • Potential for high throughputs. • Potential for high energy efficiency. • Potential for high separation efficiency. • Ability to use mixed feedstocks like wastes and lignocellulose. • Production of direct replacements for existing fuels. • No need to maintain specialized microbial cultures or enzymes.	• Unknown or largely uncharacterized reaction pathways and kinetics. • Inadequate catalysts which do not withstand hydrothermal conditions. • Inadequate solid management practices. • Fouling and plugging issues. • Bio-crude phase separation. • No demonstrated use for the aqueous phase. • Specialized materials required to withstand high temperature, high-pressure, and often corrosive environments. • No experience at commercial scale. • Low yields. • High costs.

There is a lack of information on mass and energy balances for biomass HTL processes operating at meaningful scales and virtually no information for tropical biomass feedstocks.

Fiber Crop Conversion - DSHC

- Biomass with high sugar or starch contents, or sugars generated from cellulose and hemicellulose via hydrolysis, can be converted to jet fuel using processes known as Direct Sugars to Hydrocarbons (DSHC) or Alcohol to Jet (ATJ).

- In our review the focus was placed on:

  i. the production of sugars via hydrolysis of lignocellulosic biomass,

  ii. the production of alcohols via methods other than fermentation of sugars.

Fiber Crop Conversion - DSHC

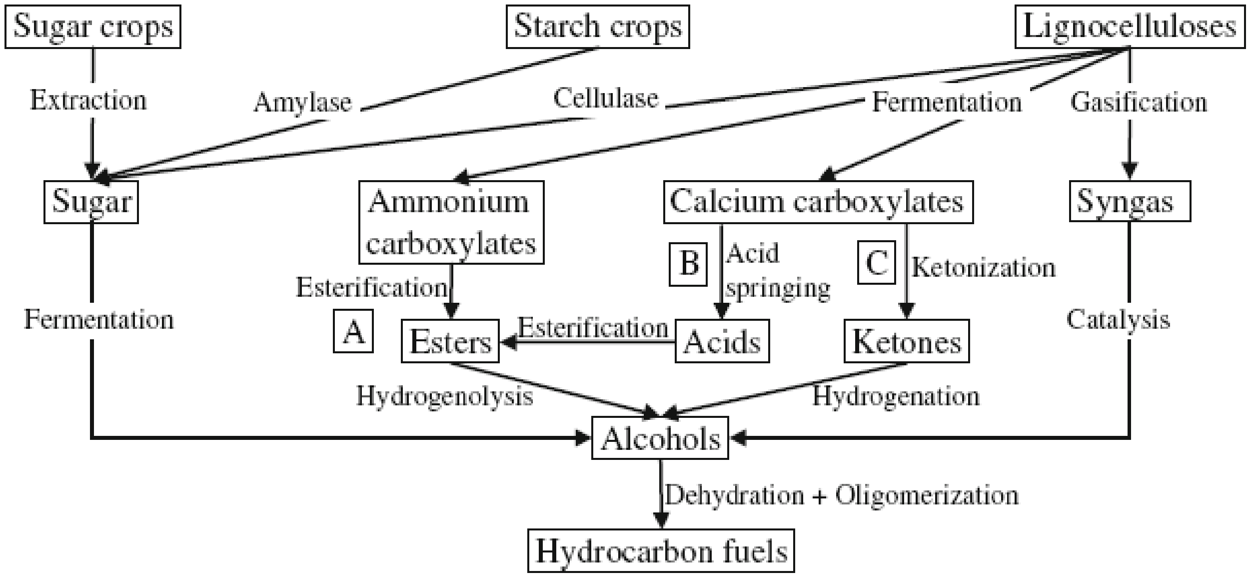
Summary of the strengths and weakness of sugar to hydrocarbon processes.

Strengths	Weaknesses
• Feedstock flexibility. • High specificity for jet fuel range compounds. • Potential for high energy efficiency.	• Limited information for reaction pathways and kinetics for the entire process. • Catalysts are under development (for catalytic pathways). • Need to maintain specialized microbial cultures (for biochemical pathways). • No experience at commercial scale. • Yields are not available from the open literature. • Energy efficiency of the entire process is not available from the open literature. • Costs are largely unknown. • More feedstocks need to be studied.

There is a general lack of information for DSCH processing of tropical biomass species apart from sugarcane bagasse and rice straw.

Fiber Crop Conversion - Alcohol

- The alcohol to jet fuel process (ATJ) relies on a ready supply of alcohols as feedstock.
- Alcohols can be produced from sugar and starch crops, or lignocellulosic biomass including manure, sewage sludge, and MSW via numerous thermo- and biochemical process routes.



Overview of pathways being considered for producing alcohols from various feedstocks for use in alcohol to jet processes [451].

451. Pham, V., M. Holtzapple, and M. El-Halwagi, *Techno-economic analysis of biomass to fuel conversion via the MixAlco process.* J. Ind. Microbio. & Biotech., 2010. 37(11): p. 1157-1168.

Fiber Crop Conversion - Alcohol

- All the steps required to convert alcohols to jet fuel are mature technologies widely used in existing refinery operations.

Alcohol → Dehydration → Olefins → Oligomerization → Distillation → Hydrogenation → Jet

Main steps of the ATJ process.

- Nonetheless, there are continued research efforts to develop more efficient catalysts for the production of alcohols and their conversion to jet fuel.

- The main issues to be solved are related to the production of the sugars used to produce alcohol.

Fiber Crop Conversion - Alcohol

- There is insufficient information available to make a detailed comparison of ATJ process routes, or for the production of alcohols in general.
- This includes a lack of mass and energy balances, as well as production, capital and operating costs.
- There is a need for studies on lower cost feedstocks such as agricultural residues and organic waste (manure, sludge, MSW, etc.), as well as algae and tropical biomass species.

Fiber Crop Conversion - Alcohol

- Diederichs et al. [462] reported on the minimum selling prices (MSP) for jet fuel produced by five processes – all of which are significantly greater than conventional jet fuel (2-4 times higher).

- The lowest MSP was for HEFA (2.22 $/kg jet fuel) followed by the gasification processes (2.44-2.49 $/kg), with the routes via ethanol having the greatest MSP.

- The main contributors to the ATJ costs were feedstock and fixed capital (and enzymes for the fermentation routes).

462. Diederichs, G.W., et al., *Techno-economic comparison of biojet fuel production from lignocellulose, vegetable oil and sugar cane juice.* Biores. Tech., 2016. 216: p. 331-339.

Fiber Crop Conversion - Alcohol

Summary of the strengths and weaknesses of alcohol to jet (ATJ) process routes.

Strengths	Weaknesses
• The main steps to convert alcohols to jet fuel are mature commercial scale technologies. • Feedstock flexible, sugar crops, starch crops, lignocellulosic biomass and MSW. • Some ATJ processes produce aromatics, meaning it is not necessary to blend with petroleum derived fuels – current blend requirement is up to 30%. • Relatively small hydrogen requirement (~1 kg/800 kg dry biomass input). • For fermentation routes, the alcohol to hydrocarbon reactions are highly selective producing high yields of the desired product.	• Alcohol production costs are high, especially for lignocellulosic biomass. • Limited experience with alcohols other than methanol/ethanol. • Process routes are not optimized. • Inherent challenges to working with living microorganisms. • Production rates when working with living microorganisms are low by chemical refinery standards. • Microorganisms are sensitive to impurities that inhibit their activity, including their own byproducts. • High enzyme cost.

Relatively few studies of tropical biomass species have been reported with the exception of sugarcane bagasse, rice husks and rice straw.

A number of thermo- and bio-chemical approaches (or in combination) are under investigation for the production of alcohols from 2nd generation feedstocks.

Conclusions

- Based on this review, croton, kamani, jatropha, and pongamia are promising candidates as oil producing crops.

- Banagrass, sorghum, sugarcane (bagasse), rice (husks and straw) and trees (eucalyptus, hybrid leucaena, gliricidia, and sesbania) have significant potential as fiber resources for energy application in general and for AJF production specifically.

- Sugarcane is a good feedstock for producing alternative jet fuel via the alcohols to hydrocarbon and/or direct sugars to hydrocarbon pathways in Hawaii and other tropics.

- In general, however, there is insufficient information in the open literature for most tropical crops in relation to mass and energy balances, or production and capital costs.

Summary of the state of development of feedstock-technology ombinations for the production of jet fuel from tropical biomass

	TC Pretreat	Gasification	Fast Pyrolysis	HTL	Hydrolysis Pretreat	Hydrolysis Sugars	Other Alcohol	HRJ/ HEFA
Eucalyptus	**na**	**2-3**	**2**	**1**	**1-2**	**1-2**	**0**	**-**
Leucaena	na	1	1	0	1	1	0	-
Rice Husks	2	2	2	1	1	1	0	-
Rice Straw	2	2	3	1	2	2	1	-
Bagasse	**na**	**3**	**2-3**	**1**	**2**	**2-3**	**1-2**	**-**
Energycane	1	1	1	0	0	0	0	-
Banagrass	2	1	1	1	1	1	0	-
Sorghum	0	0	0	1	0	0	0	-
Sesbania	0	0	0	0	0	0	0	-
Glyricidia	0	0	0	0	0	0	0	-
Sugarcane	-	-	-	-	-	3#	-	-
Jatropha	-	-	-	-	-	-	-	1
Pongamia	-	-	-	-	-	-	-	0*
Kamani	-	-	-	-	-	-	-	0
Croton	-	-	-	-	-	-	-	0

0 = no publications identified; 1 = preliminary research; 2 = extensive research; 3 = pilot or greater scale.

* Although no publication for production of hydrotreated pongamia oils were identified there are numerous reports for production of FAME.

The production of alcohol via fermentation of sugar from sugarcane is a commercial process .

Thank you for your attention

Questions ??

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