A MODELING CASE STUDY: SAF SUPPLY CHAINS IN VIRGINIA

Coalition Working Towards SAF for IAD

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UNIVERSITY of VIRGINIA

Contents

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CCALS is Virginia's logistics and supply chain hub, offering a multi-university, multi-disciplinary ecosystem that not only provides an opportunity for faculty and students to collaborate with private, public, and non-profit sector professionals to proactively engage logistics and supply-chain challenges through project and research experiences but also supports the transformation of Virginia's linear supply chain into tomorrow's "Next Generation Supply Networks" through public-private research and analytic efforts.

CHRONOLOGY

PHASE I – FEEDSTOCK ASSESSMENT

- 2014
- Motivation = Dulles (IAD)
- Outcomes

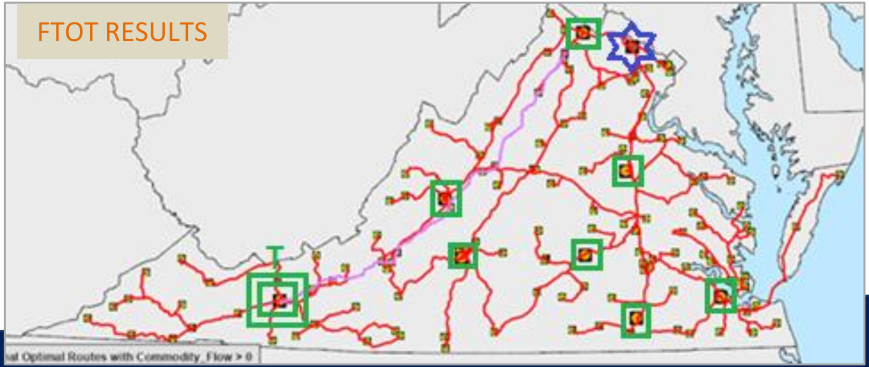
PHASE II – SUPPLY CHAIN MODELING ANALYSIS

- 2020
- Motivation: HOW, WHEN, WHERE, HOW MUCH? – in VIRGINIA
- Outcomes

2021 GC, 2022 RM

OVERARCHING VISION FOR SAF IN VIRGINIA

- WOODY WASTE FEEDSTOCK from Central Appalachian Region (e.g., Tazewell vicinity)
- Conversion to SAF via GFT or PYROLYSIS
- TRANSPORT via existing ROADWAY, RAIL, or PIPELINE network
- Use at DULLES (IAD)



KEY MOTIVATING QUESTIONS

HOW, WHERE, WHEN?

- Which conversion platforms and feedstocks should be used?
- Where should production facilities be located within the state, to minimize production cost and/or maximize CO_2 reductions compared to fossil jet fuel?
- What is anticipated performance in near-term ("pilot") and longer-term ("mature") future?

HOW MUCH?

- How much SAF can be produced via each pathway?
- How do economic cost ($/gallon) and environmental performance (CO_2e/gallon) compare?
- What amount and type of state incentives make VA SAF cost-competitive with fossil jet fuel?

METHODOLOGY

MODELING OVERVIEW

HOW?

- ASTM, ICAO CORSIA pathways
- Local feedstocks = woody waste (WW), MSW

WHERE? [BY COUNTY]

- Freight & Fuel Transport. Optimization Tool, FTOT
- KNOWN locations for biomass availability, demand node (IAD), pipeline.
- WHERE, HOW MANY conversion nodes?

WHEN? HOW MUCH? [FUEL VOLUME & COST]

- ASCENT TEAs compute conversion cost
  - Pilot vs. mature facilities
  - Varying facility size
- Add in feedstock, transport, capital cost
- Account for incentives
  - Current FEDERAL (RFS, IRA BTC)
  - HYPOTHETICAL state
- Benchmarking – fuel vol (50:50 blend), $/gal fossil
- Excel

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ICAO ENVIRONMENT

Approved Conversion Processes

ASTM reference	Conversion process	Abbreviation	Possible Feedstocks	Maximum Blend Ratio
ASTM D7566 Annex A1	Fischer-Tropsch hydroprocessed synthesized paraffinic kerosene	FT	Coal, natural gas, biomass	50%
ASTM D7566 Annex A2	Synthesized paraffinic kerosene from hydroprocessed esters and fatty acids	HEFA	Vegetable oils, animal fats, used cooking oils	50%
ASTM D7566 Annex A3	Synthesized iso-paraffins from hydroprocessed fermented sugars	SIP	Biomass used for sugar production	10%
ASTM D7566 Annex A4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	FT-SKA	Coal, natural gas, biomass	50%
ASTM D7566 Annex A5	Alcohol to jet synthetic paraffinic kerosene	ATJ-SPK	Ethanol, isobutanol and isobutene from biomass	50%
ASTM D7566 Annex A6	Catalytic hydrothermolysis jet fuel	CHJ	Vegetable oils, animal fats, used cooking oils	50%
ASTM D7566 Annex A7	Synthesized paraffinic kerosene from hydrocarbon - hydroprocessed esters and fatty acids	HC-HEFA-SPK	Algae	10%
ASTM D7566 Annex A8	Synthetic Paraffinic Kerosene with Aromatics	ATJ-SKA	C2-C5 alcohols from biomass'	
ASTM D1655 Annex A1	co-hydroprocessing of esters and fatty acids in a conventional petroleum refinery		Vegetable oils, animal fats, used cooking oils from biomass processed with petroleum'	5%
ASTM D1655 Annex A1	co-hydroprocessing of Fischer-Tropsch hydrocarbons in a conventional petroleum refinery		Fischer-Tropsch hydrocarbons co-processed with petroleum	5%
ASTM D1655 Annex A1	Co-Processing of HEFA	Hydroprocessed esters/fatty acids from biomass'		10%

Conversion processes under evaluation

Various conversion processes are currently under evaluation by ASTM. More information is availa the article "New Sustainable Aviation Fuels (SAF) technology pathways under development", publ the ICAO Environmental Report 2022. Work is also ongoing to allow the use of 100% SAF in aircr to increase the maximum blending for co-processing (from 5% to 30%).

Conversion process under evaluation	Abbreviation	Lead developers
synthesized aromatic kerosene	SAK	Virent
Integrated hydropyrolysis and hydroconversion	IH2	Shell
Single Reactor HEFA (Drop-in Liquid Sustainable Aviation and Automotive Fuel)	DILSAAF	Indian CSIR-IIP
Pyrolysis of non-recyclable plastics	ReOIL	OMV
Co-processing of pyrolysis oil from used tires	TPO	Philips 66
Methanol to jet	MTJ	ExxonMobil
Increase in fatty acid/ester co-processing from 5% to 30%		
HEFA with higher cycloparaffins'		Revo
Biomass pyrolysys		Alder
Biomass/Waste pyrolysis		Green Lizard
Cycloalkanes from Ethanol		Vertimass

SAF Conversion processes (icao.int) | July 2023

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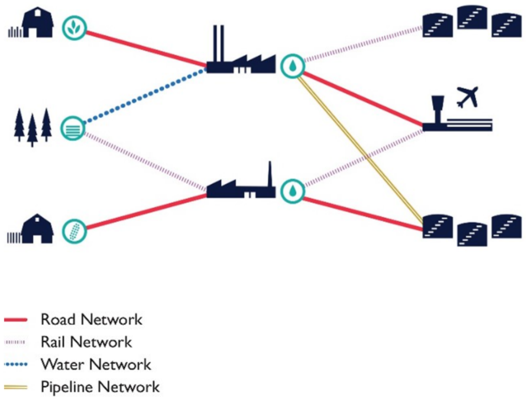
The Freight and Fuel Transportation Optimization Tool

Explore Optimal Transportation Solutions for Freight and Supply Chain Scenarios



Related Links

- Download FTOT on GitHub Today

Related Documents

- Learn More about the Freight and Fuel Transportation Optimization Tool

Tags

- energy

Rationale

Freight and fuel supply chains provide access to essential goods and services and are dependent on transportation infrastructure. Supply chain planners want to identify transportation solutions that maximize supply chain delivery and minimize costs and/or CO2 emissions. In addition, they want to understand how those solutions change under different supply chain and network conditions.

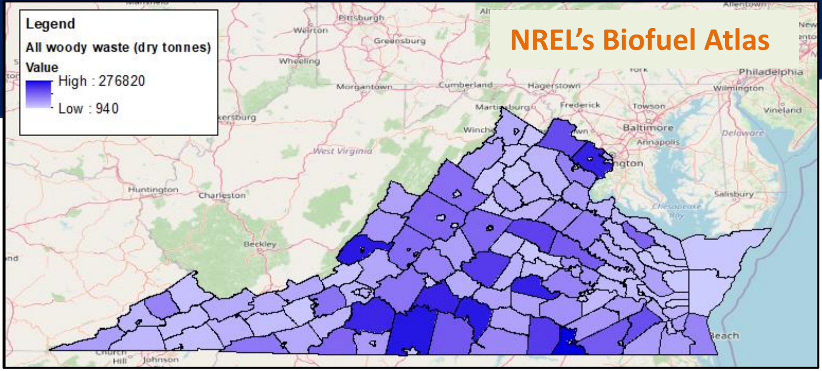
The U.S. DOT Volpe Center developed the Freight and Fuel Transportation Optimization Tool (FTOT) as a flexible scenario-testing tool that optimizes the transportation of materials for energy and freight scenarios. The tool is designed to analyze the transportation needs and constraints associated with material collection, processing, and distribution to provide an optimal solution to supply chain routing and flows. FTOT can analyze a variety of commodities, datasets, and assumptions, and is customizable to each user's particular needs and questions.

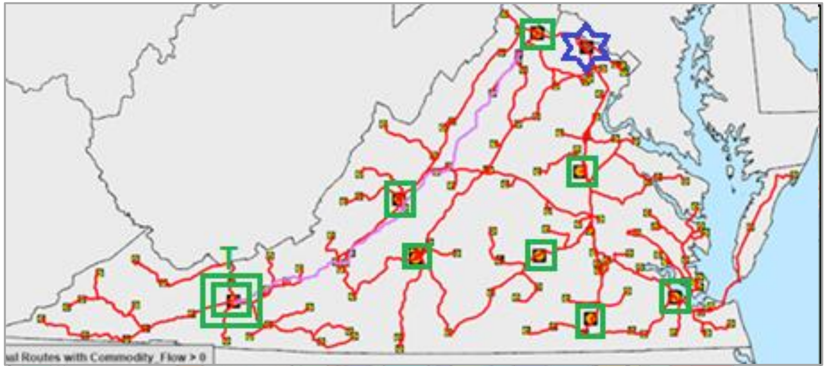
Kristin Lewis
[Kevin Zhang]

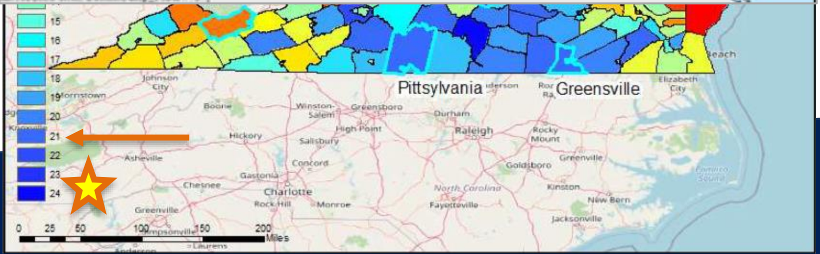
https://www.volpe.dot.gov/our-work/policy-planning-and-environment/volpe-tool-evaluates-freight-and-fuel-transport-options

BACK

NREL's Biofuel Atlas







ASCENT – THE AVIATION SUSTAINABILITY CENTER

ASCENT – the Aviation Sustainability Center – is a cooperative aviation research organization co-led by Washington State University and the Massachusetts Institute of Technology. Also known as the Center of Excellence for Alternative Jet Fuels and Environment, ASCENT is funded by the FAA, NASA, the Department of Defense, Transport Canada, and the Environmental Protection Agency. ASCENT works to create science-based solutions for the aviation industry's biggest challenges. A coalition of 16 leading US research universities and over 60 private sector stakeholders committed to reducing the environmental impact of aviation, ASCENT also works in partnership with international research programs, federal agencies and national laboratories to create an all-inclusive research capability for whatever environmental impact obstacle the aviation industry faces.

Our Mission

The Aviation Sustainability Center is

- Focusing on meeting the environmental and energy goals of the Next Generation Air Transportation system, including reducing noise, improving air quality, reducing climate impacts, and energy efficiency.
- Exploring ways to produce sustainable aviation fuels at commercial scale, creating an industry with the potential for large-scale economic development and job creation.
- Discovering science-based solutions will benefit the aviation industry and improve the health and quality of life of those living and working around airports.

NEWS

Impact of Proposed Sustainable Skies Act on Sustainable Aviation Fuel Minimum Selling Price

ASCENT project 1 has built a set of decision support tools to inform development of the SAF production to reach national and international greenhouse gas reduction goals. One of these tools is a set of harmonized techno-economic analyses (TEAs) for the certified SAF pathways. Recently, these TEA tools were used to assess possible scenarios for the Sustainable Skies Act to be enacted and its impact on potential SAF fuel prices.

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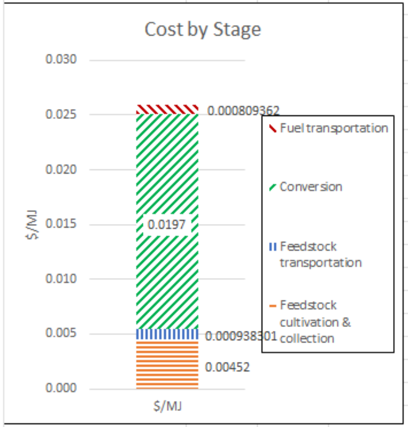
Civil, Supersonic Over Flight, Sonic Boom (Noise) Standards Development

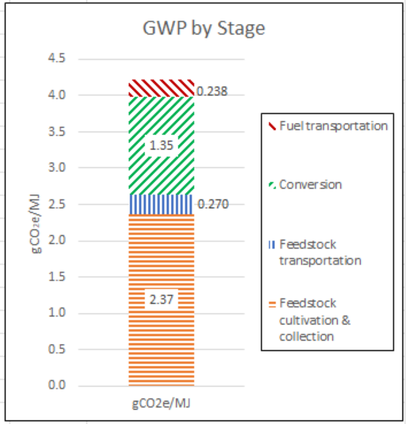
Kristin Brandt

https://ascent.aero/

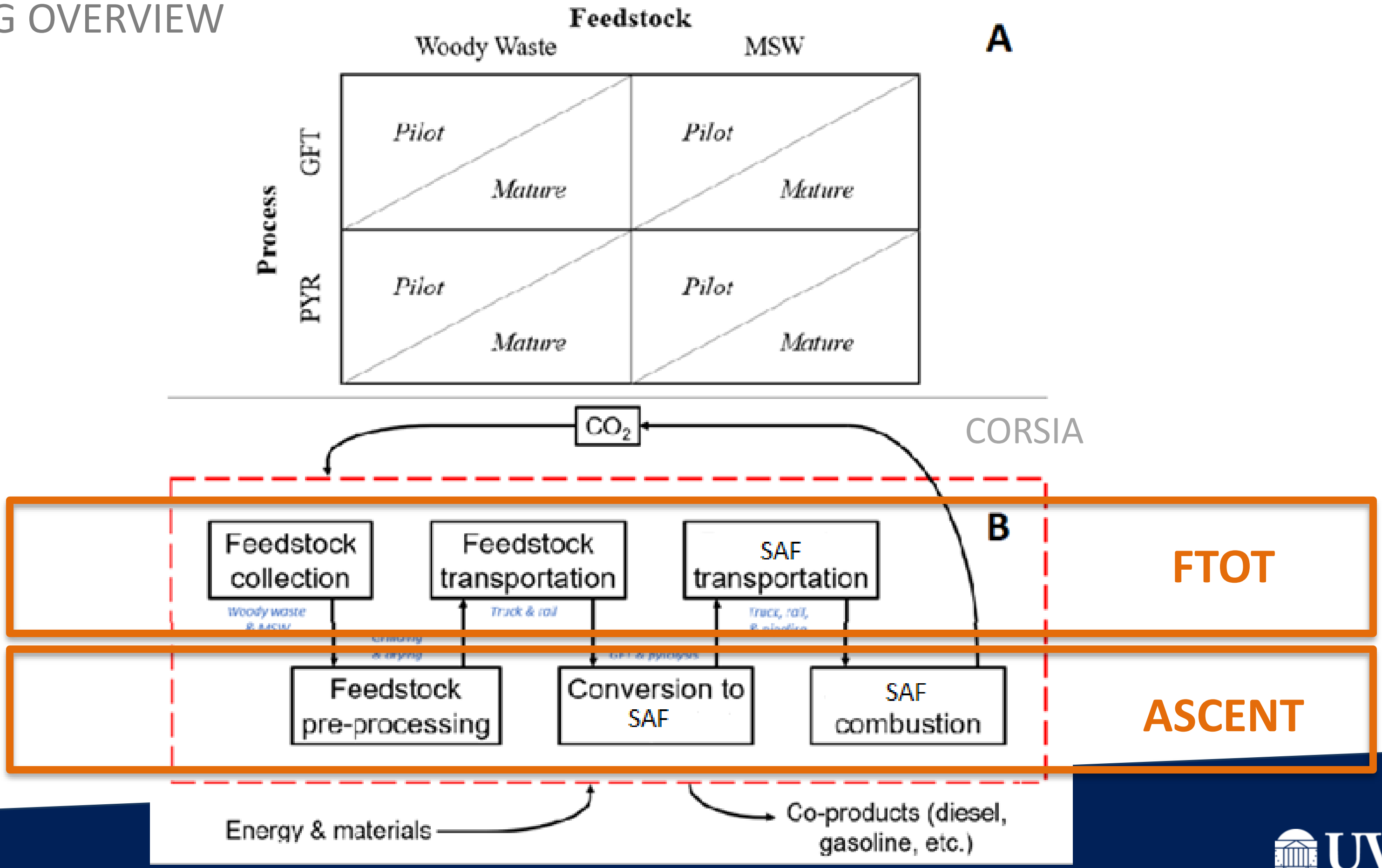
SAF	$/MJ	Range	gCO2e/MJ	Range	Notes
Feedstock cultivation & collection	0.00452	0.00452	2.37	2.37	Nationwide average assumption from USDA Woody Biomass Briefing Paper; CORSIA
Feedstock transportation	0.000938	0.00099	0.270	0.285	USDOT AFTOT model
Conversion	0.0197	0.0197	1.35	1.35	Veipa et al., 2020: Operating costs; CORSIA, CORSIA
Fuel transportation	0.000809	0.000854	0.238	0.251	USDOT AFTOT model
Total	**0.0259**	**0.0260**	**4.23**	**4.26**	

SAF	$/gal	Range	gCO2e/gal	Range	Notes
Feedstock cultivation & collection	0.500	0.527	261.6	275.9	Nationwide average assumption from USDA Woody Biomass Briefing Paper; CORSIA
Feedstock transportation	0.1094	0.1094	31.53	31.53	USDOT AFTOT model
Conversion	2.17	2.29	149.6	157.8	CAPEX = Veipa et al., 2020: OPEX = ASCENT; CORSIA
Fuel transportation	0.0944	0.0944	27.69	27.69	USDOT AFTOT model
Total	**2.88**	**3.02**	**470.4**	**492.9**	





MODELING OVERVIEW



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KEY RESULTS

WHERE, HOW, WHEN, HOW MUCH?

WHERE, HOW, WHEN?

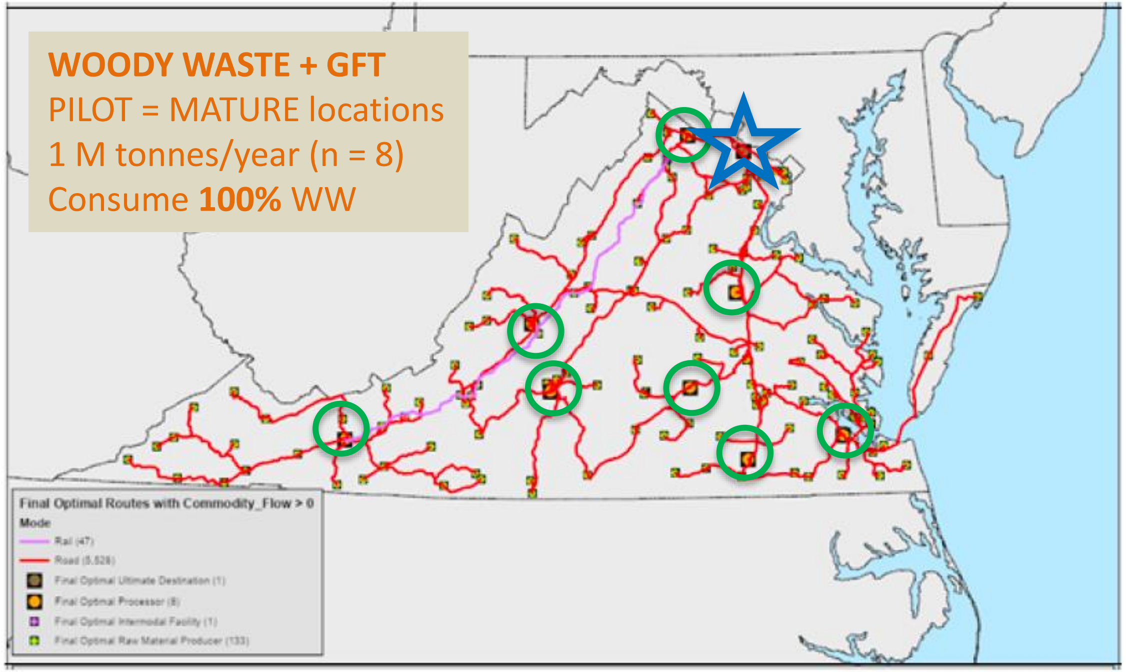

Figure 11. *The proposed network of mature SAF production facilities via GFT conversion of woody waste feedstock at 1.0M tonnes/yr. This network captures all woody waste in Virginia. Selection county locations include Amelia, Campbell, Caroline, Clarke, Greensville, Isle of Wight, Rockbridge, and Wythe Counties. Pink links correspond to railways; red links correspond to roadways (trucking).*

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WHERE, HOW, WHEN?

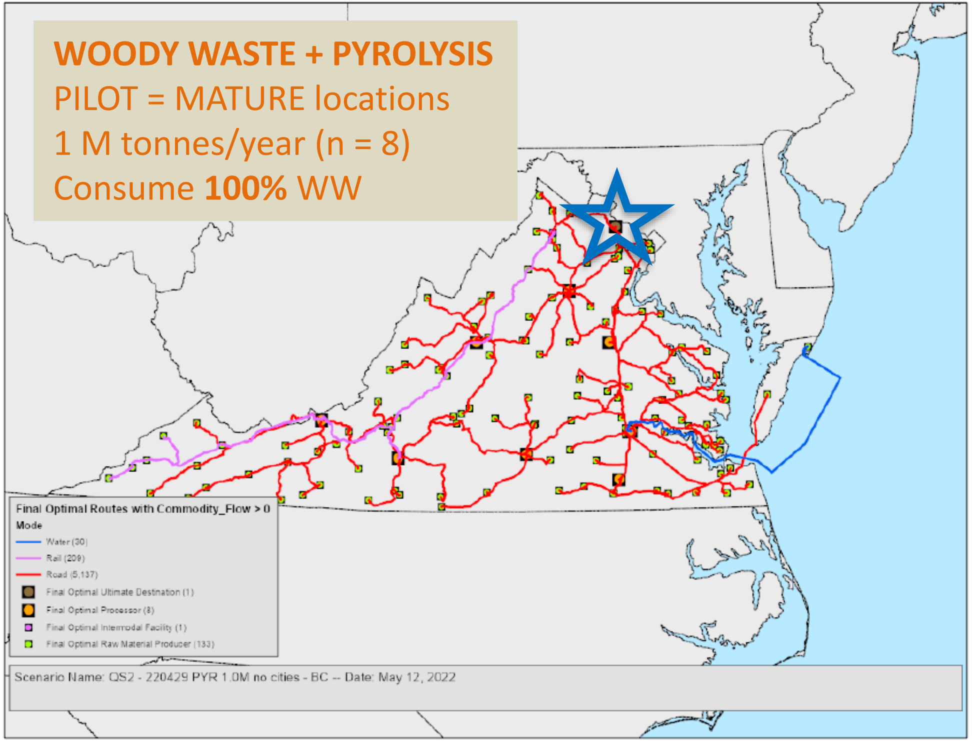

Figure 15. *The proposed network of mature SAF production facilities via pyrolysis conversion of woody waste feedstock at 1.0M tonnes/yr. This network captures all woody waste in Virginia. Selection county locations include Augusta, Caroline, Charlotte, Culpeper, Franklin, Giles, Greensville, and Prince George Counties. Pink links correspond to railways; red links correspond to roadways (trucking). The blue link corresponds to waterways (shipping); this is unique to this scenario because Prince George County was selected, which is accessible via the James River.*

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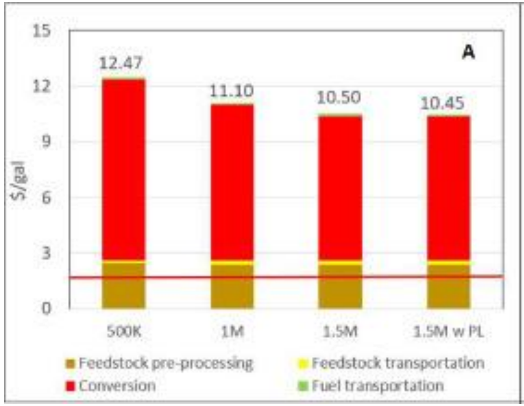
HOW MUCH? – PILOT

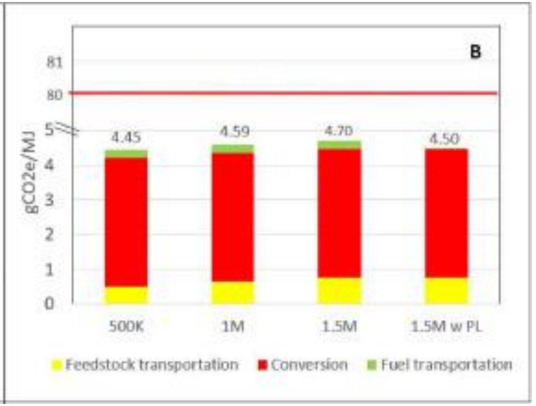
$/gallon**

GWP, g CO2e/MJ

GFT WW

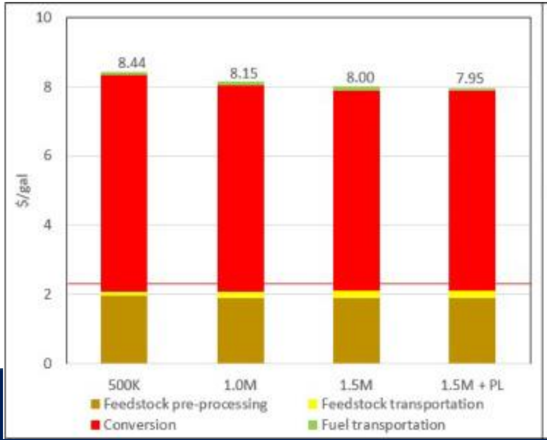
[7% IAD DEMAND*]

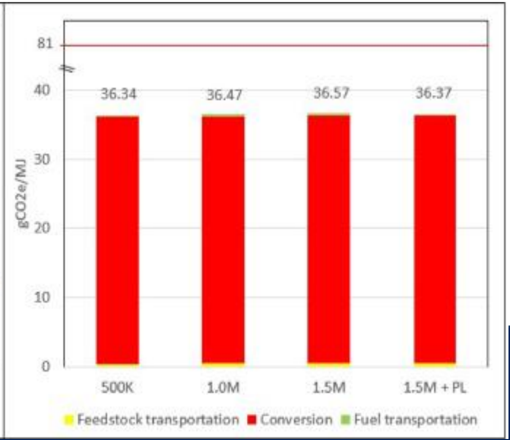




PYR WW

[8% IAD DEMAND*]





- MEDIAN county
- Influence of scale
- Impact by stage
- Benchmarks
- GFT vs. PYR

*Does not account for 50:50 blend.
**Does not include incentives.

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HOW MUCH?

PILOT

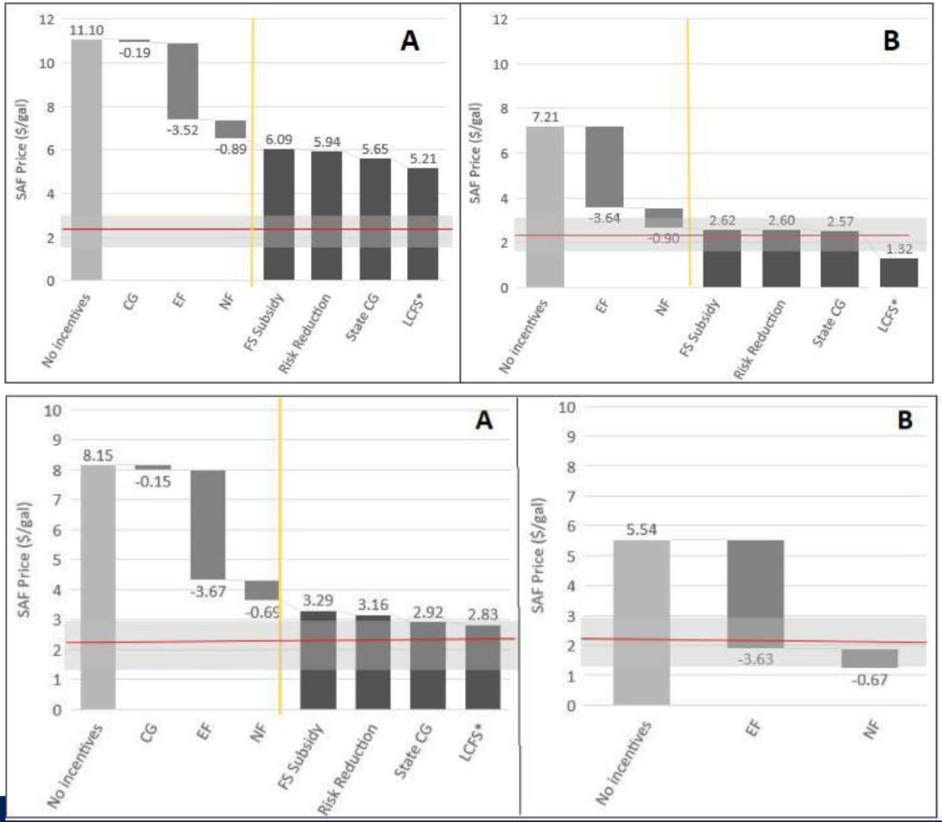
MATURE

GFT WW

[Mature = 55% IAD demand*]

PYR WW

[Mature = 63% IAD demand*]



*Does not account for 50:50 blend.

- MEDIAN county
- Benchmarks
- EXISTING federal
- HYPOTHETICAL state ($350M)
- GFT vs. PYR

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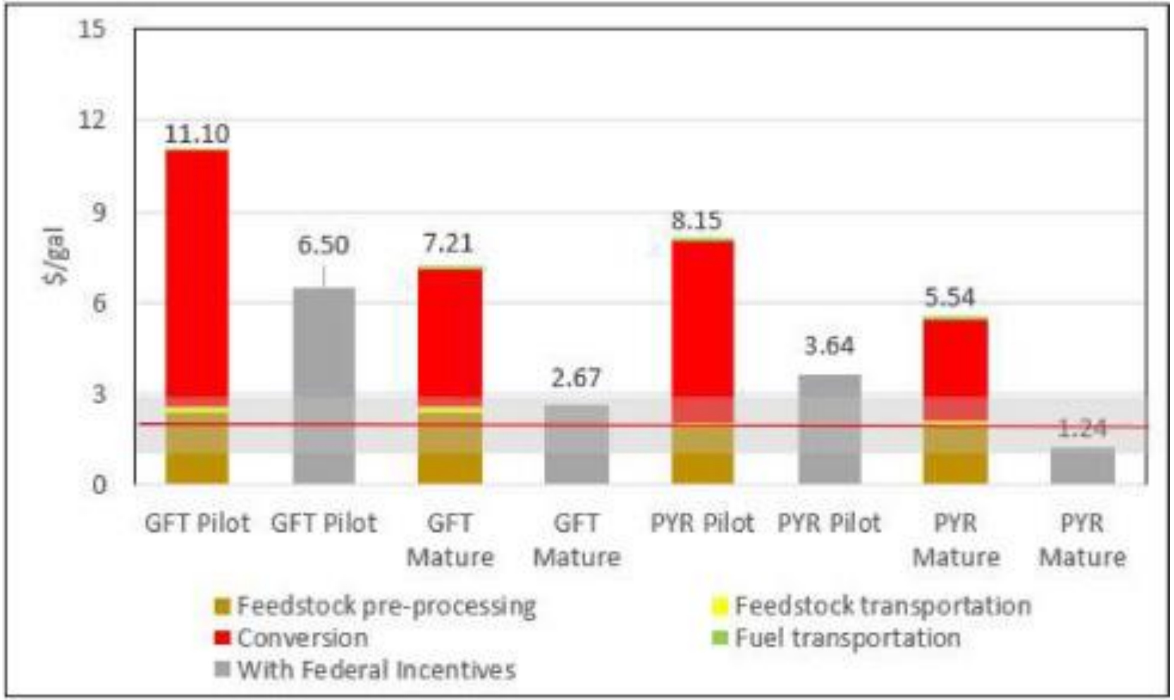
HOW MUCH? – SUMMARY



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CONCLUSIONS

WHERE?

- Transportation matters less than facility size.
- VA has widely distributed feedstock resources.

WHEN?

- Counties picked for PILOT implementation remain good choices under MATURE scenario.
- Avoid stranded assets!

HOW MUCH? [FUEL VOLUME & COST]

- Pioneer facilities produce <10% IAD demand
- Mature facilities (n = 8) produce >50% demand
    - Consume 100% of WW (?)
- State incentives required for cost parity with fossil

HOW?

- PYR delivers lower cost, higher GWP than GFT.
- GFT is certified, PYR is not yet certified
- In near-term, PYR co-produces diesel, gasoline?

ONGOING & FUTURE WORK (FAST-SAF)

I. FEEDSTOCK and CONVERSION LOGISTICS
   - Finer-scale resources availability

II. SAF TRANSPORT LOGISTICS
   - Finer-scale transportation networking
   - Pipeline considerations

III. BLENDING and STORAGE LOGISTICS
   - Blend before store?
   - Influence of storage requirements on siting, transport

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ACKNOWLEDGEMENTS




Kristin Lewis, Kevin Zhang (Volpe FTOT)
Kristin Brandt (WSU, ASCENT)

"THE AVIATOR"

WHERE?

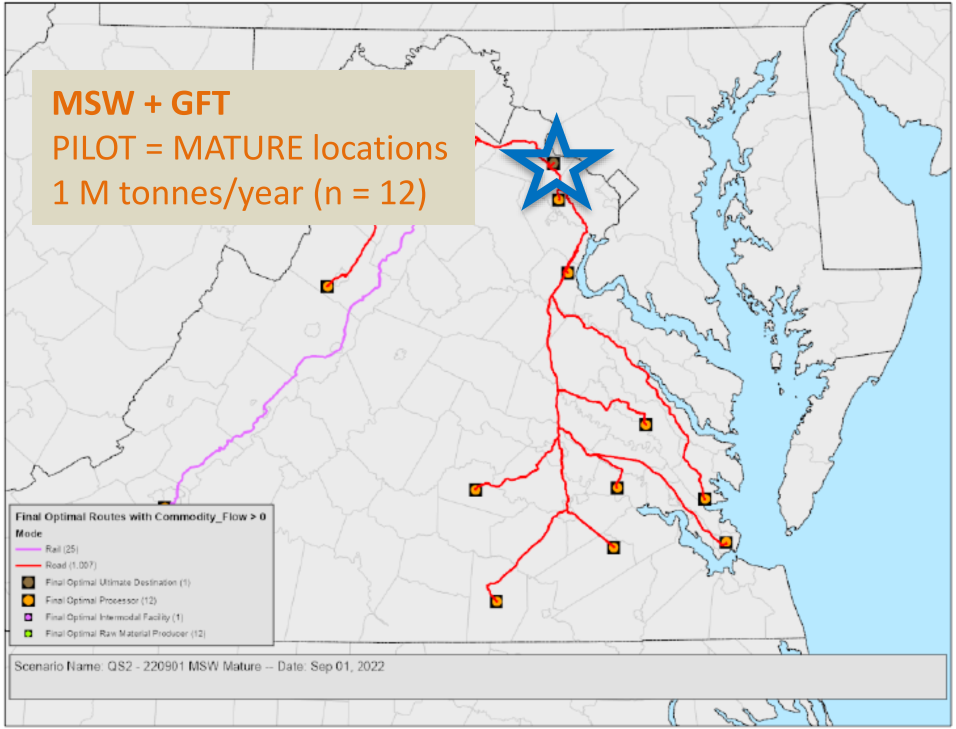

Figure 12. *The proposed network of mature SAF production facilities for GFT conversion of MSW feedstock. This network captures all MSW from twelve county/city landfills: Amelia, Brunswick, Charles City, Fairfax, Gloucester, King and Queen, Loudoun, Roanoke, Rockingham, Stafford, Sussex, and City of Hampton. Pink link corresponds to railways; red links correspond to roadways (trucking).*

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