

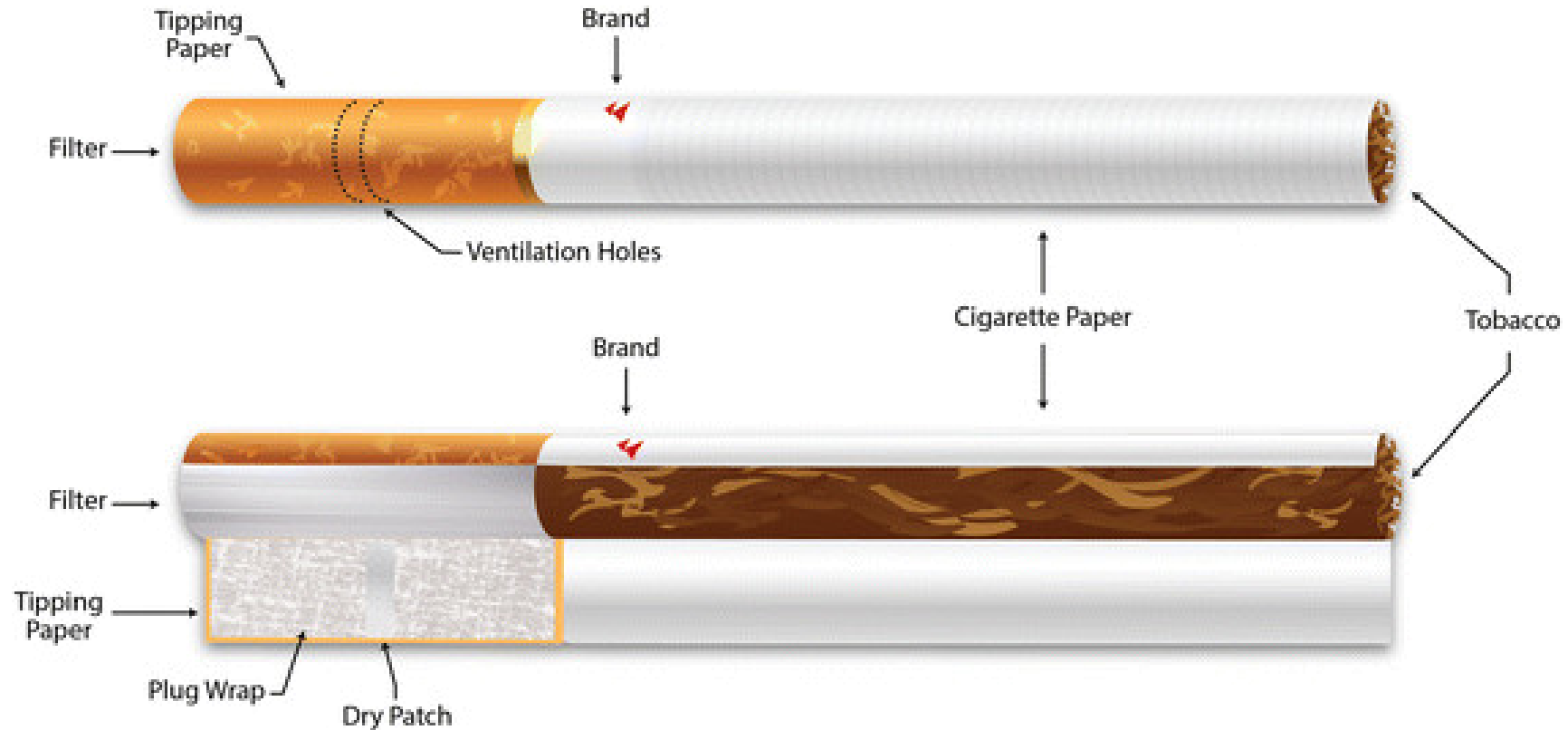


The Story Behind TarFreeGas®

tcbiomass

August 25, 2026

Consider a cigarette...



Tar filter is ~ 40% of the size of the bed of biomass (tobacco)!

Stratton, Julie & Shiplo, Samantha & Ward, Megan & Babayan, Alexey & Stevens, Adam & Edwards, Sarah. (2016). Assessing contraband tobacco in two jurisdictions: A direct collection of cigarette butts. BMC Public Health. 16. 10.1186/s12889-016-3229-0.

Biomass Gasification Challenges

1. Tars

Condensable and polymerizable hydrocarbons in the syngas

2. Material handling issues

Feeding biomass into a pressurized gasifier is difficult

3. Sulfur and other contaminants in the syngas

Can poison catalysts or corrode equipment

4. Integration with other process units

Variability in biomass feedstock causes variability in syngas composition and make rate, which can be problematic

5. Other, more subtle issues

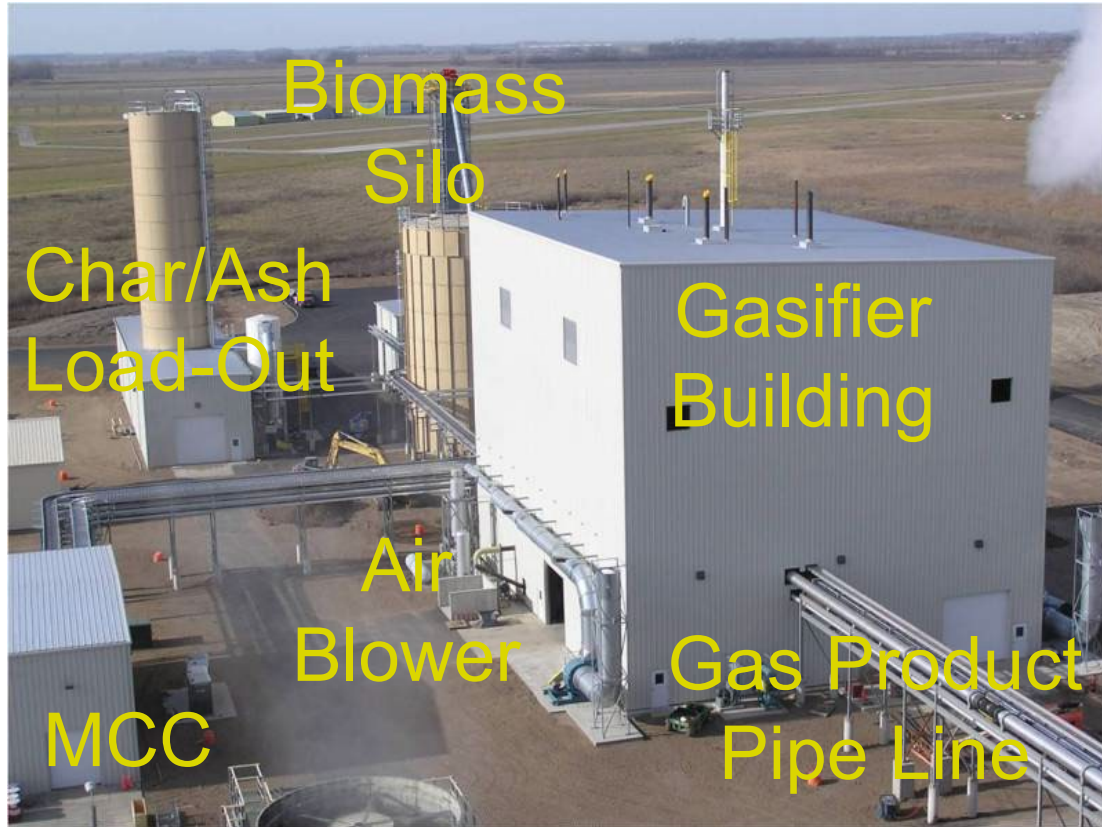
Experience is needed to know what you didn't know

Frontline Commercial Gasifier (2005-2010)

- Application: boiler fuel production to replace fossil natural gas
- Designed, built, and operated from 2005-2010
- Conventional, air-blown BFB gasifier
 - Nominal capacity: Phase 1 up to 110 tpd
- Gas clean-up
 - Gas cooler and PMFreeGas[®] high-efficiency filtration for particulate free producer gas
 - Producer gas for boiler fuel



Frontline Gasifier using PMFreeGas®



Located at Chippewa Valley Ethanol Company in Benson, MN

What are Biomass Gasifier Tars?



Tars from a conventional biomass gasifier

What makes tars from biomass gasification so difficult to deal with?

1. Carbon rings are present in high abundance
 - Cellulose (C_6), hemicellulose (C_5), lignin (aromatics)
2. Biomass is 30-40% oxygen by mass
 - Oxygen in hydrocarbons is always a reactive center

These structures result in easily polymerizable species and the polymers produced are refractory

What if there were a biomass gasifier that would not produce these?

Approaches to solving the biomass gasifier tar problem

- High temperature conversion via POX or other thermal reforming
 - Penalties are lower syngas yield, high CAPEX, level of difficulty in operations (soot, alkali, etc.)
- Removal via scrubbing or adsorption processes
 - Penalty in treating the reject stream - managing toxic waste
- Catalytic conversion as achieved in Frontline's low temperature conversion (TarFreeGas®)
 - This purely catalytic approach requires very low tar production in the gasifier to avoid catalyst deactivation
 - Benefits are higher yield, lower CAPEX, easier operations

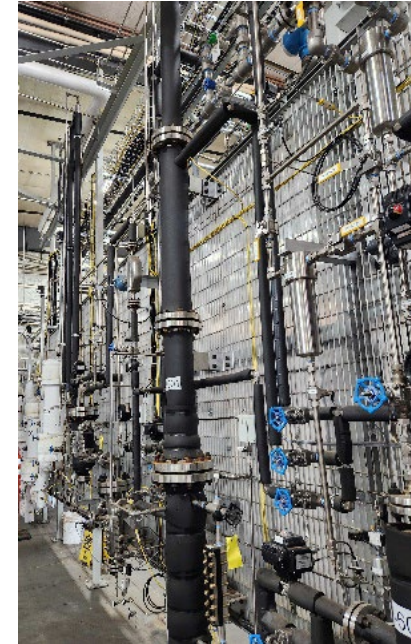
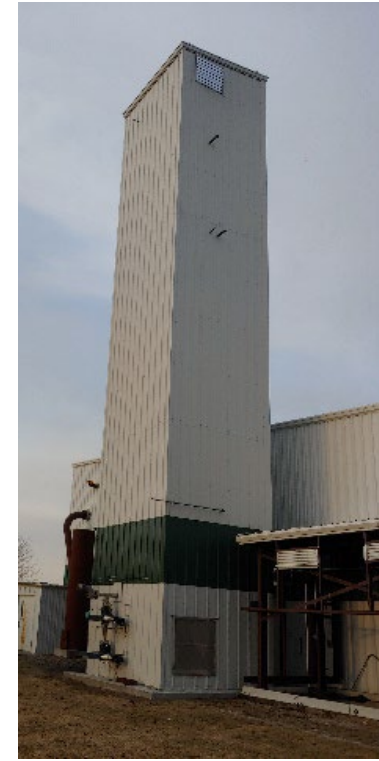
Low-P TarFreeGas® Gasifier Build & Operation (2012-2020)

- Design incorporated lessons learned from other technologies
 - Tar reforming predicated on catalytic activity of biochar
- 7 years of design, testing, rework, repeat resulted in a successful (low-tar) gasifier
 - Low pressure operation: up to 10 psig
 - Oxygen + steam blast
 - Very low tar (< 1000 mg/Nm³) concentration achieved
 - Residual tars were primarily BTX
- Successful full process integration to produce MeOH

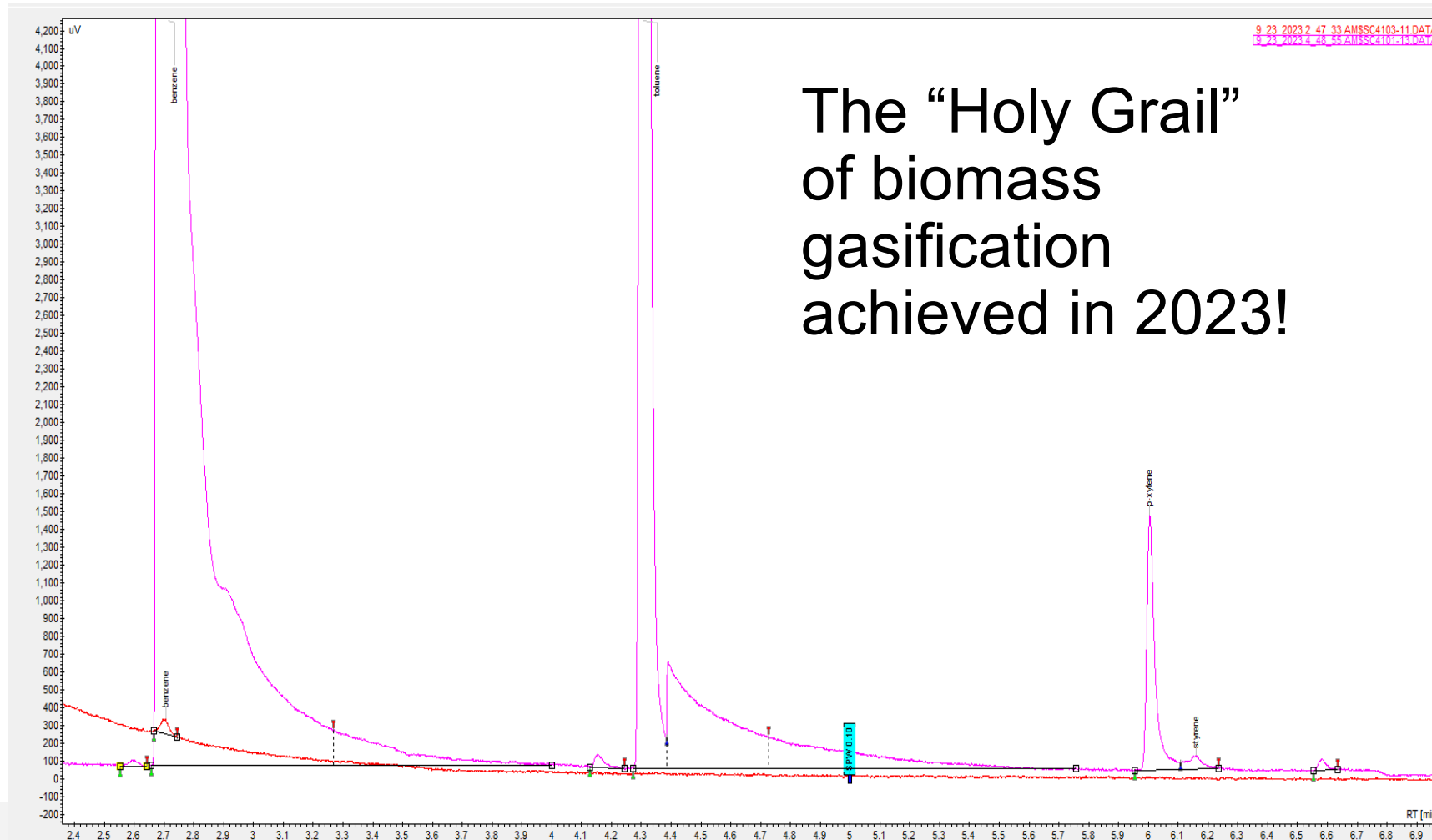


High-P TarFreeGas® Gasifier Build & Operation (2021-2025)

- Process intensification through increased gasifier pressure operation
 - Successful operation at > 300 psig (21.7 barg)
 - Nominal capacity of 1000 lb/day (450 kg/day)
- Full integration: feedstock input to product output
 - Includes catalytic syngas clean-up and conditioning unit operations
 - RNG with cold gas efficiencies approaching 60%
- Methanol & gasoline full integration coming in 2027
 - Expected yield ~0.48 tonne MeOH/tonne biomass
 - 33% higher compared to POX yield at 0.36



Is It Possible to Achieve Absolute Zero Tars Using Only Catalysts?



Tar Wars: FrontLine BioEnergy's tar-free gasification force awakens

October 10, 2023 | [Jim Lane](#)

What happens in Vegas, stays in Vegas, but what happens in Nevada occasionally rocks the world. Nevada, Iowa, that is. Sure enough, news arrives from Nevada that Frontline BioEnergy announced has achieved a breakthrough in syngas quality for biomass gasification at its new pilot facility located in Nevada, Iowa. Nevada is, if you will, to the [...]



The Effort Was Worth It!

Feedstocks



Biomass



Waste



Wood Waste

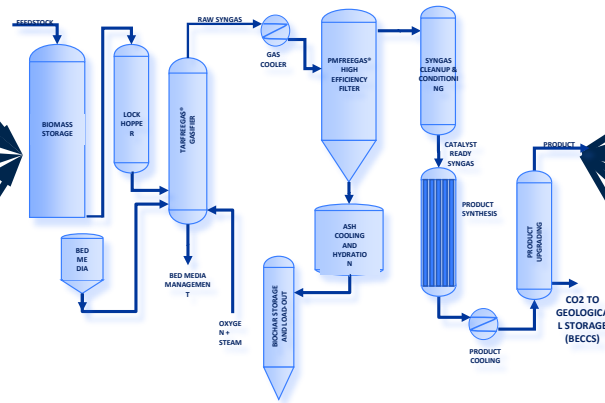


RDF Pellets



Agri-Waste

Frontline TarFreeGas® Gasification

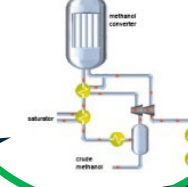


Products

Hydrogen &
derivatives like
ammonia



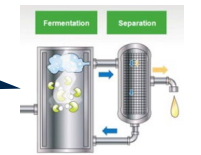
Methanol &
derivatives like
gasoline and SAF



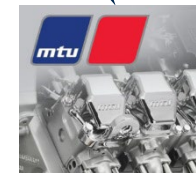
Pipeline quality
synthetic natural gas



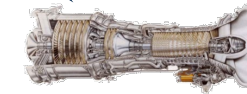
Drop-in fuels
via FT



Syngas Fermentation
to EtOH & derivatives
like ethylene or SAF



Reciprocating
Engine, IGCC

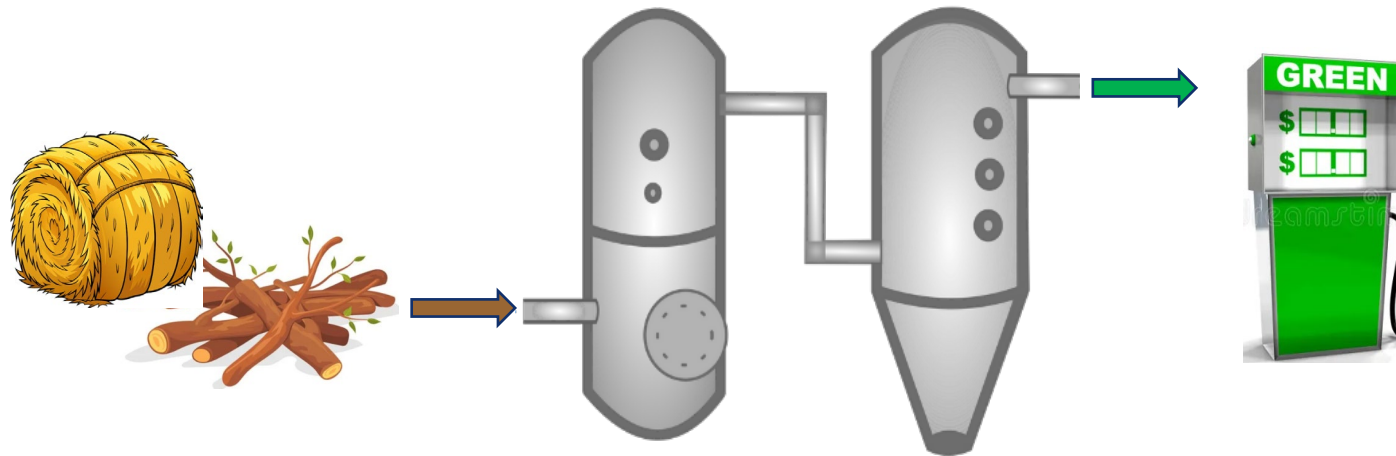


Combustion Turbine,
IGCC



Boilers

Frontline Synfuels LLC



1.5 Million Gallons Per Year of Renewable Gasoline from Biomass

Transforming Biomass into Renewable Gasoline



~ 30,000 dry-basis tons per year (90 tpd) of **urban wood** and/or **corn seed/cobs**



Generates 2 million kg per year of clean **H₂ intermediate**



Resulting in 1.5 million gallons per year (4,500 gpd) of **renewable gasoline** (drop-in; equivalent to gasoline)



Thank you!

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