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Waste-to-Energy Potential in Guam

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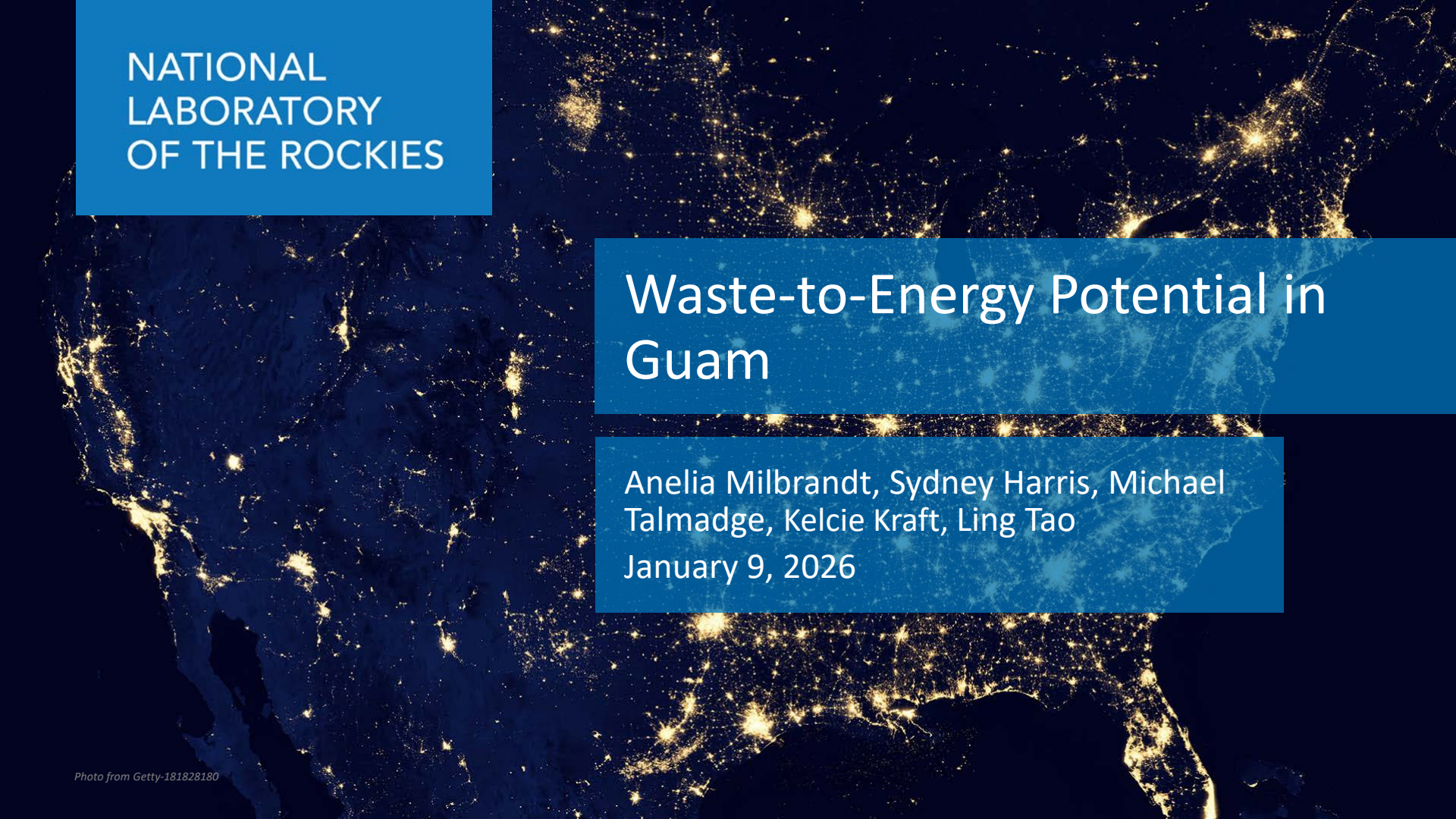
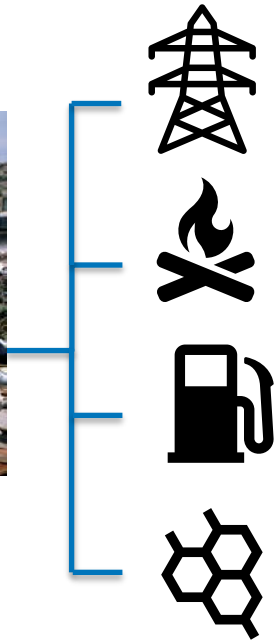


Photo from Getty-181828180

Waste-to-Energy

Waste-to-Energy (WTE) is conversion of waste materials into electricity, heat, transportation fuels, chemicals, and other products using a variety of processes as outlined below.

Photo by David Parsons, NLR 05289



Commercial Applications

- Combustion
- Gasification
- Pyrolysis
- Anaerobic digestion (AD)/landfill gas recovery
- Transesterification of fats, oils, and greases to biodiesel
- Hydroprocessing of fats, oils, and greases to alternative fuels (e.g., diesel, jet fuel, heating oil)

Advanced Applications

- Hydrothermal liquefaction (HTL) of organic waste to alternative fuels
- Hydrothermal carbonization (HTC) of organic waste to hydrochar used as solid fuel, soil amendment, and adsorbent
- Advanced AD (e.g., arrested methanogenesis, anaerobic membrane reactors, and various pre- and post-treatment strategies) to alternative fuels and chemicals.

Background

- Pacific island territory of the United States
- Land area ~210 sq. mi. with limited landfill space
- Population and municipal solid waste (MSW) disposal are projected to grow.
- Average annual MSW disposal from 2013–2021 was **1,147 lbs. per capita**.

Population and MSW Projections through 2040

Year	Population	Total MSW Disposal (tons)
2020	153,863	98,000*
2025	173,034	100,600
2030	179,932	103,600
2035	182,022	104,800
2040	183,580	105,700

Source: Guam EPA Integrated Solid Waste Management Plan 2023
**Represents 2019 disposal*

Image from https://www.uog.edu/_resources/files/wptrc/2024-wptrc-magic-lab-guam-forest-action-plan-reduced.pdf

Background (cont.)

Current MSW Management (2017)

- 44% landfilled
- 30% recycled
- 14% composted
- 12% hardfill – inert materials disposed separately

System Infrastructure and Policies

- **Disposal system:** Waste consolidated at three transfer stations and hauled to Layon Landfill (the island's only lined MSW landfill)
- **Recycling:** On-island material recovery facility sorts single-stream recyclables
- **Organics management:** Dedicated facilities for composting and wood processing
- **Landfill bans (since 2008):** Yard and vegetative waste, untreated wood, inert materials, metals, household hazardous waste, and corrugated cardboard.

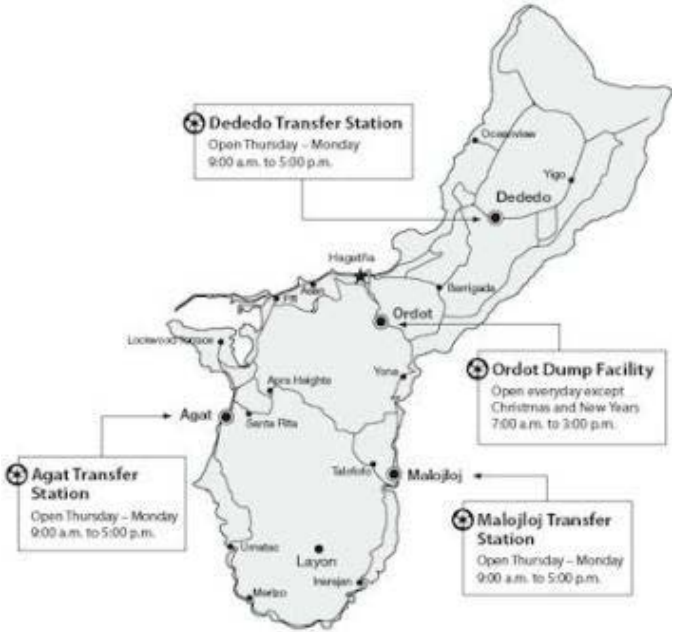


Image from https://uscdiving.wordpress.com/2012/05/18/the-ordot-dump-and-layon-landfill/

Waste to Energy Resources in Guam

Municipal Solid Waste (MSW):

- Food waste
- Paper and cardboard
- Plastics
- Waste tires
- Textiles
- Wood
- Yard waste

Agricultural waste:

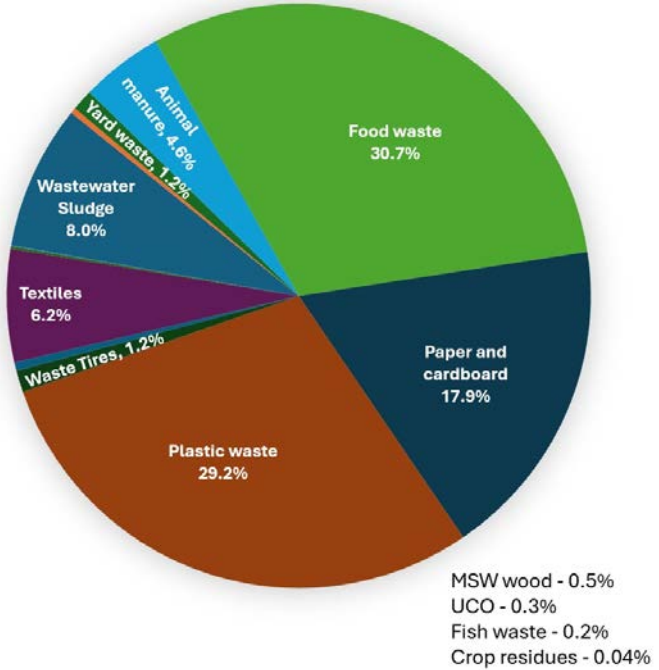
- Crop residues (corn stover and coconut husks)
- Animal manure

Industrial/commercial waste:

- Fish waste
- Wastewater sludge
- Used cooking oil (UCO)

Breakdown of Waste Resource Availability

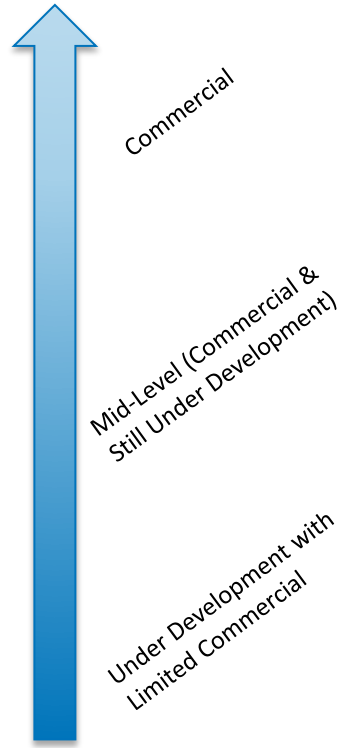
Estimated total waste resources **~124,000 wet tons per year**



Source: Various data providers; data generation and analysis by NLR

Waste to Energy Potential in Guam

Feedstock	Technology	Biofuel/ Biopower	Bioenergy Potential (Gigawatt-hours (GWh) for power and thousand diesel gallon equivalent/yr for fuels)*
Food waste, manure, sludge, fish waste, UCO, crop residues	AD	Power	10.4 GWh
UCO	Transesterification	Biodiesel	88.2
UCO	Hydrotreating	Renewable diesel, Sustainable Aviation Fuel (SAF)	84.7
MSW (paper, plastic, waste tires, wood, food waste, yard waste, textiles)	Gasification	Power	61.6 GWh
Food waste, manure, sludge, fish waste, UCO, crop residues	AD	Bio-LNG (Liquified Natural Gas)	889
Food waste, manure, sludge, fish waste, UCO, crop residues	Steam Methane Reforming of Renewable Natural Gas via AD	Bio-methanol	774
Crop residues	Fermentation to ethanol + catalytic upgrading	SAF	0.39
MSW (paper, plastic, waste tires, wood, food waste, yard waste, textiles)	Ex-situ Catalytic Fast Pyrolysis	Bio-oil (could be upgraded to renewable diesel and SAF)	3,348
MSW (paper, plastic, waste tires, wood, food waste, yard waste, textiles)	Gasification	Bio-methanol (SAF also possible)	4,664
Food waste, manure, sludge	Hydrothermal Liquefaction + Mild Hydroprocessing	Bio-crude (could be upgraded to renewable diesel and SAF)	1,219



*WTE potential values for each feedstock are exclusive of each other; not additive

Market Overview: Power and Heat

Current Electric System, Demand, and Prices

- Peak demand in 2022 was 260 megawatts (MW) and total electric sales were 1,540 GWh.
- There are 464 MW of installed capacity, of which 85 MW are renewable (solar), remaining capacity is mainly diesel-fired units.
- Guam Power Authority (GPA) recently commissioned a new 198 MW power plant that can be run on LNG, although current fuel is diesel.
- Prices: Average retail rate including fuel surcharges was around $0.268/kWh in 2025.

Waste to Energy Opportunities

- **Biogas/Landfill Gas (LFG):** Can be used for heating and power generation
  - Ordot landfill has a gas collection system installed; the gas is flared, not utilized.
- **On-site and district combined heat and power (CHP):** Facilities with steady thermal demand (wastewater treatment plants, hospitals, industry, schools, large hotels) could use WTE heat and power.
- **Microgrids:** WTE co-located at critical facilities could support microgrids, improving energy security and system resilience.
- **Grid electricity:** Power via WTE could be sold to GPA via power-purchase agreement or utility ownership, displacing high-cost diesel generation.

Photo by Dennis Schroeder, NLR 62203

Market Overview: Fuels

Fuel Dependence

- Guam has no domestic oil or gas production and relies entirely on imported foreign petroleum products (primarily from Asia).
- Diesel fuel (mainly for power generation) accounts for 53% of petroleum sales—motor gasoline is 26%, jet fuel is 19%, and propane is most of the remainder.

WTE Opportunities

- **Biogas/biomethane:** Can be used as vehicle fuel; potential to supplement LNG at Ukudu if it operates on gas
- **Liquid fuels (e.g., biodiesel, renewable diesel):** Potential supplemental fuel for GPA, industry, or maritime sector
  - The Guam Solid Waste Authority (GSWA) has procured biodiesel production equipment capable of converting up to 12,000 gallons of UCO per month into ASTM D6751-compliant biodiesel.
- **Solid fuels (pellets/refuse-derived fuel [RDF]):** Possible on-island thermal use in boilers, but limited solid-fuel infrastructure (cement, steel) may constrain market viability.

U.S. Department of Energy flickr 530 002 001

Market Overview: Products

Compost

- Residential backyard composting and five privately operated commercial facilities are active on the island.
- In addition to traditional composting (windrow and aerated static pile), in-vessel composting could be explored due to superior odor, vermin, and process control, particularly in sensitive or space-constrained areas.

Biochar (via pyrolysis)

- Organic waste: Soil amendment for agriculture, landscaping, golf courses; stormwater and wastewater filtration media; additive in construction materials
  - Pyrolysis of wastewater sludge can achieve high PFAS destruction efficiencies, and the resulting biochar may be suitable for land application.
- MSW: Building material, for road surfacing, or potential solid fuel source in industrial applications
- Waste tires: Recovered carbon black (rCB) can be reused in various rubber applications.

Photo by Dennis Schroeder, NLR 47115

Market Overview: Products (cont.)

Digestate (coproduct of AD)

- Potential uses: Fertilizer or soil conditioner for local agriculture, municipal grounds, and landscaping, partially offsetting imported fertilizer costs; solids could be used as animal bedding
- Quality control (pathogens, contaminants, salinity) and a clear product standard are often critical to acceptance.

Pellets (densification)

- Organic waste: Industrial applications, soil amendment
  - Paper pellets can be used as fuel, animal bedding, cat litter
- MSW (refused-derived fuel): Industrial application (e.g., cement kilns, power plants).

Photo by Dennis Schroeder, NLR 30633

Key Takeaways

- Local waste feedstocks provide **limited energy displacement** (**<1% of grid demand and fuel consumption**).
  - Cost data review (see backup slides):
    - **Electricity:** AD of food waste and gasification of MSW-derived waste could be promising pathways for electricity production; gasification's higher conversion efficiency results in more competitive costs per unit of power than combustion.
    - **Liquid Fuels:** Biodiesel from UCO and HTL of wet wastes represent the lower-cost liquid fuel options. Pyrolysis to bio-oil and gasification to Fischer–Tropsch liquids from MSW are higher-cost pathways but could enable larger fuel volumes if markets and economics support deployment.
- **Small-scale, distributed WTE systems** at facilities with steady energy demand (e.g., wastewater treatment plants, hospitals, schools, large hotels) may be more feasible than centralized options, offering enhanced resilience.
- The primary value of waste utilization lies in **waste minimization**, **meeting diversion targets**, and **producing locally usable products**, rather than bulk energy generation.

Considerations for Strategic Focus Areas

- Preserve **high-value recyclables** (e.g., metals, clean aluminum, corrugated cardboard) for existing markets.
- Expand reuse and recycling of **specialty waste streams** such as:
  - **Textiles:** Resale, donation, upcycling or recycling (e.g., industrial rags, insulation and sound-dampening materials, or regenerated fibers for new textile products)
  - **Waste tires:** Reuse in rubberized asphalt and road surfacing, playground and athletic surfaces, and tire-derived aggregate; recycling via pyrolysis into fuel oil or rCB
- Prioritize **low-value, hard-to-recycle materials** (e.g., mixed plastics, contaminated paper) for WTE/Waste-to-Products applications.
- Focus on **niche, high-value applications** (e.g., CHP, microgrids, critical facilities) rather than bulk energy production.
- Emphasize **locally usable products** (e.g., compost/biochar as soil amendment or building material, digestate as fertilizer, etc.).

Key Challenges

1. Limited land and long-term capacity
2. High system costs and affordability
3. Participation and contamination
4. Market dependence and exports
5. Meeting diversion targets (50% diversion by 2035; 75% waste reduction by 2040)

Potential Next Steps

- Engage relevant stakeholders to clarify goals, priorities, and decision criteria for waste diversion, product and energy recovery.
- Identify near-term opportunities (such as expanding reuse and recycling markets for high- and specialty-value materials) and assess associated logistics and implementation needs.
- Evaluate market readiness, policy considerations, and deployment requirements to inform phased or pilot-scale implementation of WTE/waste-to-product applications (e.g., AD, in-vessel composting, biochar).

Case Studies

Commercial Anaerobic Digestion on the Canary Islands

- Canary Islands face high waste management costs, tourism-driven organics, and full dependence on imported fossil fuels – similar context to Guam.
- ATH Bioenergy is building a semi-dry AD project across four islands to process organic waste (hotel food waste, supermarket, pruning and banana residues, food-industry waste).
- Anticipated to produce >133 GWh/yr of biomethane and roughly 6,700 tons/yr of organic fertilizer.

Island	Plant Capacity (ton/yr)
Gran Canaria	~31,000
Tenerife	~35,000
Fuerteventura	~32,000
Lanzarote	~30,000
Total	**~130,000**

Commercial Anaerobic Digestion on the Canary Islands (cont.)

- The biomethane will be used to displace imported liquefied petroleum gas and other fuels for heat and hot water at hotels/industry.
- The project represents a roughly €100 million (~118 million USD) investment from private developers with InvestEU support.
- Construction began in 2024 and completion is anticipated in 2026.
- Policy drivers include:
  - Spain's Waste Law requiring 55% organic recycling by 2025.
  - Building codes requiring >70% renewable energy for domestic hot water.
- Represents private IPP development – plants will be financed, built, and operated privately without the need for the utility to own generation.

American Samoa WTE – Gasification Plant

- Feedstock: MSW (e.g., green waste, plastics, tires, wood, paper)
- Constructed on a three-acre lot by a landfill
- Foundation construction underway; expected to be in operation by the end of 2026
- Received U.S. EPA permit; received local land use permit for construction
- Capacity: >70 tons of MSW/day
- Generation: 1 MW per month
- Main benefit: extends the life of the landfill
- Biochar is used for landfill cover

Photos provided by American Samoa Power Authority

Source: Tuato'o, Ryan, 2025. "American Samoa Power Authority Waste to Energy Project." Presented at Office of Insular Affairs Territory Energy Coordination Meeting, Sept. 4, 2025, Washington, D.C.

Waste-to-Energy Combustion on Oahu (H-POWER Hawaii)

- Oahu generates ~1.8 million tons/year of solid waste; with limited landfill capacity, Honolulu relies on WTE as its cornerstone disposal strategy.
- Honolulu Program of Waste Energy Recovery (H-POWER) is operated by Covanta under contract with Honolulu.

Metric	Value
Technology	Mass-burn WTE + front-end recycling and metals recovery
Feedstock	MSW + commercial waste
Throughput	~700,000 tons/yr
Electric output	~90 MW gross; ~60 MW delivered to Hawaiian Electric; covers 8–10% of Oahu's electricity
Landfill Diversion	~70% of Oahu's MSW diverted
Commissioned	Units one and two in 1990; third unit added in 2012

Waste-to-Energy Combustion on Oahu (H-POWER Hawai'i)(cont.)

Key Successes

- H-POWER displaces imported oil on a historically fossil-fuel dominated grid and provides stable dispatchable power to complement Hawaii's increasing solar/wind energy.
- Long-term public-private partnership enabled capital investment and professional operations without requiring utility ownership and has kept pricing predictable.
- Island geography makes landfill alternatives essential – the WTE facility extends landfill life and stabilizes waste-disposal costs.

Photo by David Humber, NLR 01371

Textile Recycling Pilot: Fairfax County, Virginia

- Launched in early 2025 in partnership with Helpsy to make it easier for residents to recycle clothing, footwear, linens, and other household textiles
- Collection containers placed at local transfer station and landfill
- By October 2025, nearly **49 tons** of textiles had been collected, far exceeding early expectations and prompting operational adjustments.
- Collected items are sorted for the highest and best use — including resale, donation, upcycling, or recycling — with most materials reused rather than landfilled.
- Based on early success, the county plans to expand textile collection to additional facilities as the program continues.

Photo by Warren Gretz, NLR 06482

In-Vessel Composting: Nederland Transfer Station, Colorado

Operator: Boulder County
Feedstock: Food waste and wood chips
Capacity: 360 tons/year
Year Installed: 2024

- **Objectives:** Reduce landfill waste and transportation costs, improve composting efficiency with minimal labor, and produce high-value compost for community use
- **Local participation:** Residents actively participate by dropping off their recyclables and food waste.
- **Product utilization:** The finished compost will be utilized for local projects within the county and is planned for distribution to local gardeners.

Image from Green Mountain Technologies, Earth Flow™

Pyrolysis of Wastewater Sludge to Biochar: Silicon Valley Clean Water, Redwood City, California

- **Year Installed:** 2017
- **Feedstock:** 7,000 tons of biosolids
- **Equipment:** Six BioDryers and one Pyrolysis system supplied by Bioforcetech
- The self-sustained and automated process ensures high-quality biochar output without the need for fossil fuels:
  - The BioDryers only require 220 kWh/ton of energy to remove all moisture from biosolids, and the pyrolysis system produces 150 kW of energy 24/7, which is used to run the facility.
- Biosolids reduction up to 90% by weight
- Bioforcetech Sigma Pyrolysis system achieves **99.98% PFAS removal** across all output streams, including biochar, discharge water and exhaust gases (confirmed by independent testing).

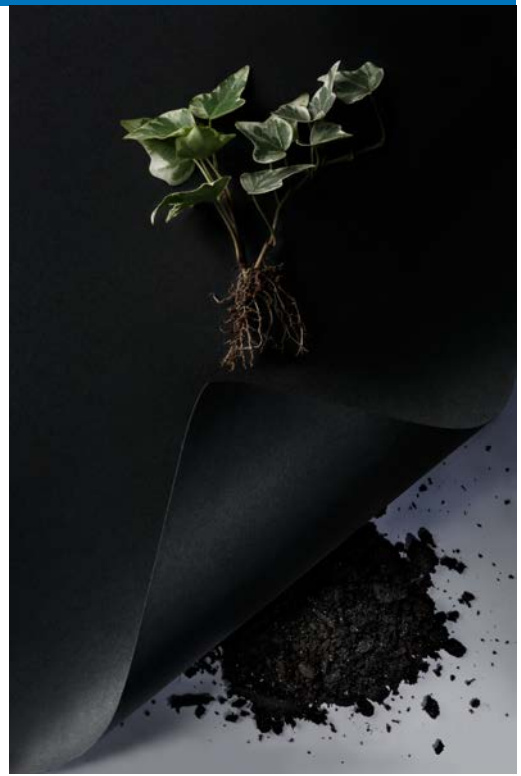


Image from Microsoft Stock

Pyrolysis of Waste Tires in Nigeria

- A Nigerian company specializing in waste recycling is facing a growing pressure to manage the increasing volume of end-of-life tires.
- Beston Group was selected as the technology provider.
- The project has successfully completed installation and commissioning and is now operating steadily.
- Processing capacity: 10–12 tons of waste tires per batch, with an annual processing volume of up to 4,000 tons
- Products: rCB and pyrolysis oil (oil yield about 40%)
- Expansion plan: The company is currently gaining operational experience to support the future integration of plastic and oil sludge pyrolysis.

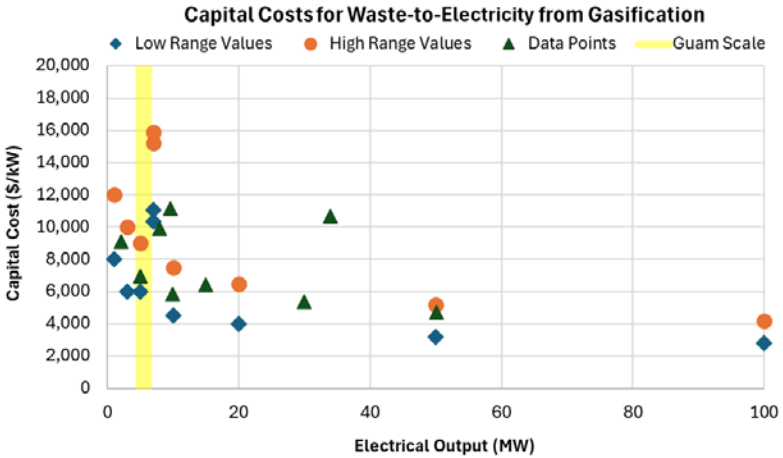
Image from Microsoft Stock

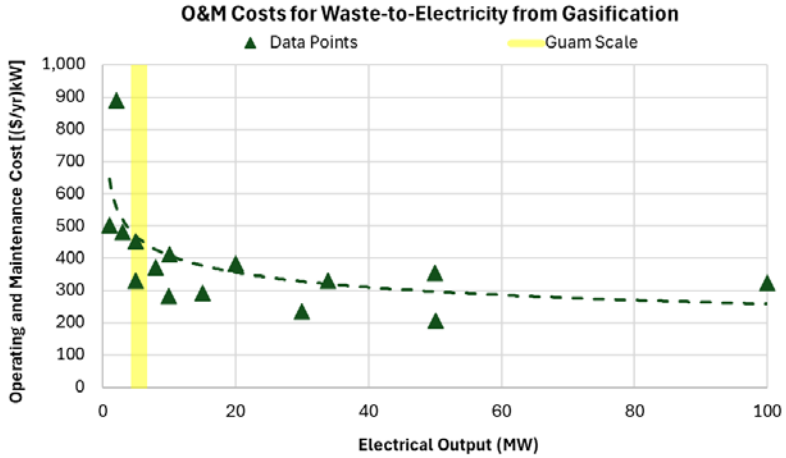
Capital and Operating Cost Ranges for Waste-to-Energy Pathways

Gasification, Combustion/Thermal Incineration, Pyrolysis, Hydrothermal Liquefaction, Biodiesel via Transesterification, Anaerobic Digestion, Landfilling with Gas Recovery

Gasification to Electricity
(By Electrical Output)

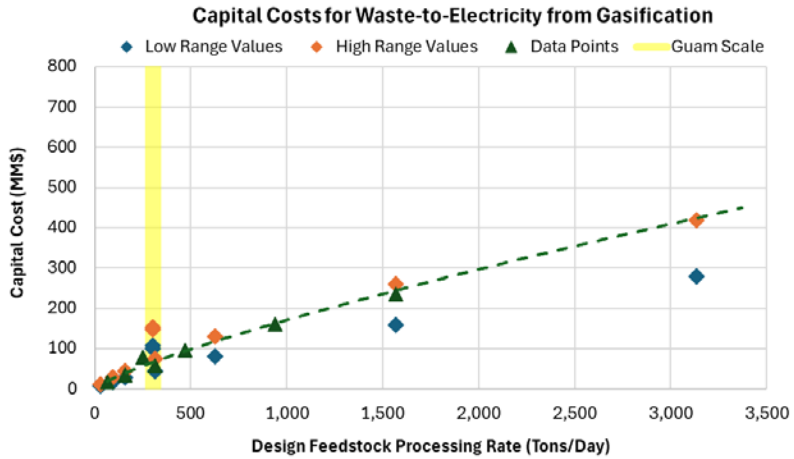
- **Products:** Electricity, thermal energy, synthesis gas or syngas (CO and H_2), solid residues (ash)
- **Yield:** 800 – 1,000 kWh per ton (varies with feedstock quality and technology)
- **Capital Costs:** $6,000 – 12,000 /kW
- **Annual Operations and Maintenance (O&M) Costs:** $300 – 500 /kW
- **Technology Maturity:** Commercial gasification facilities are well-established in Europe. Several facilities (mainly coal) in operation in the U.S.
- **Advantages:** Higher overall efficiency and lower emissions than combustion.

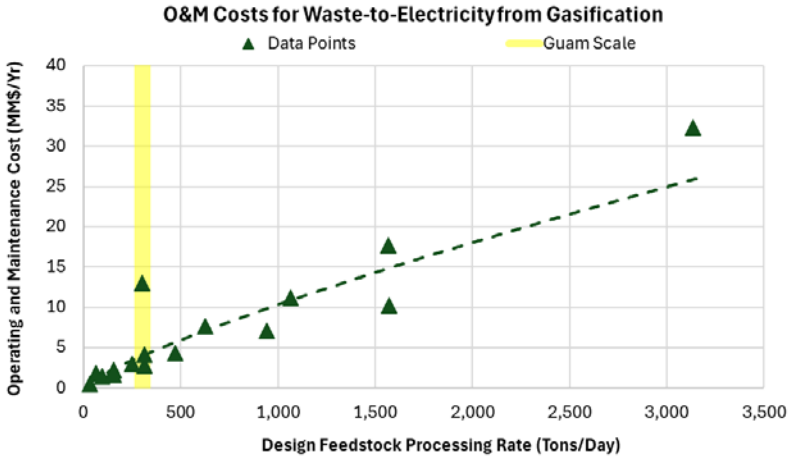




Gasification to Electricity
(By Feedstock Throughput)

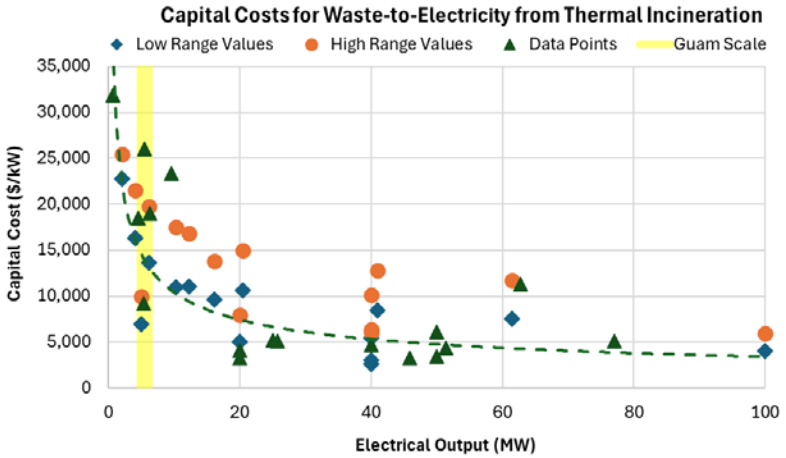
- **Products:** Electricity, thermal energy, synthesis gas or syngas (CO and H_2), solid residues (ash)
- **Yield:** 800 – 1,000 kWh per ton (varies with feedstock quality and technology)
- **Capital Costs:** $50 – 150 Million
- **Annual O&M Costs:** $3 – 5 M
- **Technology Maturity:** Commercial gasification facilities are well-established in Europe. Several facilities (mainly coal) in operation in the United States.
- **Advantages:** Higher overall efficiency and lower emissions than combustion.

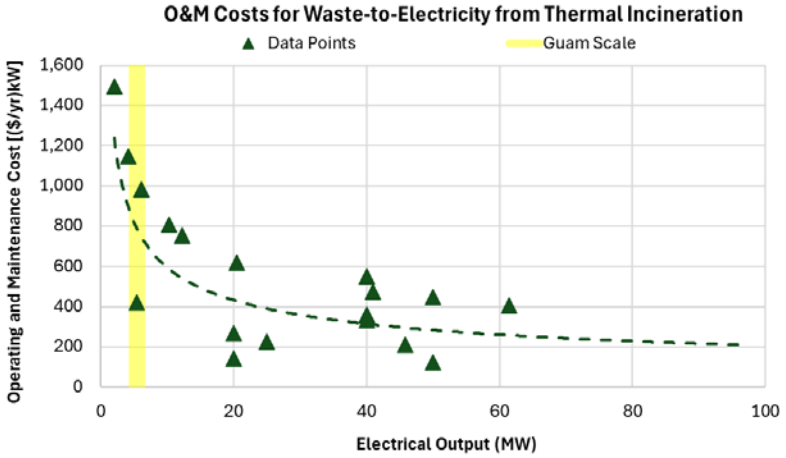




Combustion to Electricity
(By Electrical Output)

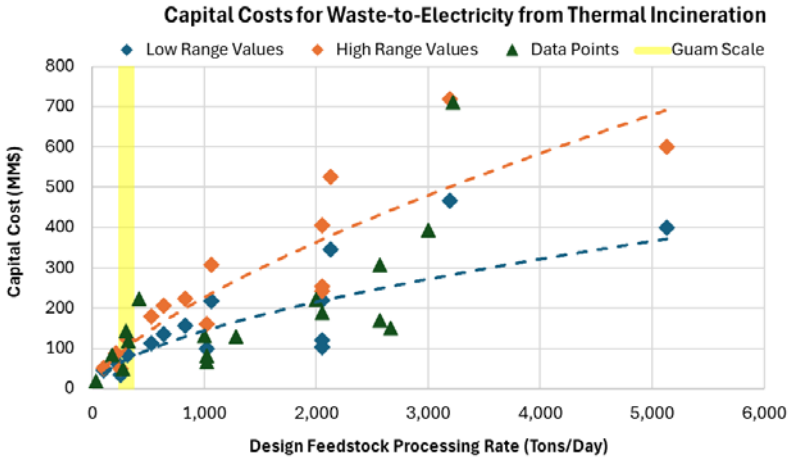
- **Products:** Electricity, thermal energy, flue gas (CO_2, water), solid residues (ash)
- **Yield:** 500 – 600 kWh per ton (varies with feedstock quality and technology)
- **Capital Costs:** $10,000 – 20,000 /kW
- **Annual O&M Costs:** $400 – 1,000 /kW
- **Technology Maturity:** Commercial applications around the world. Emissions control is important element of process designs.
- **Advantages:** Mature technology. Lower overall capital costs than alternatives.

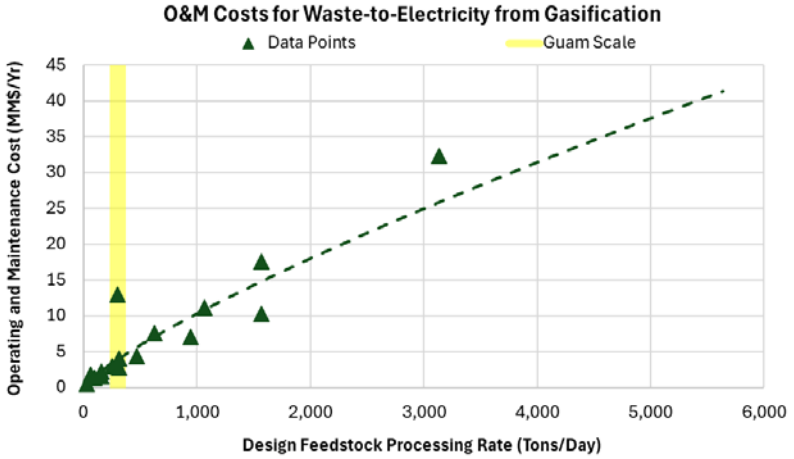




Combustion to Electricity
(By Feedstock Throughput)

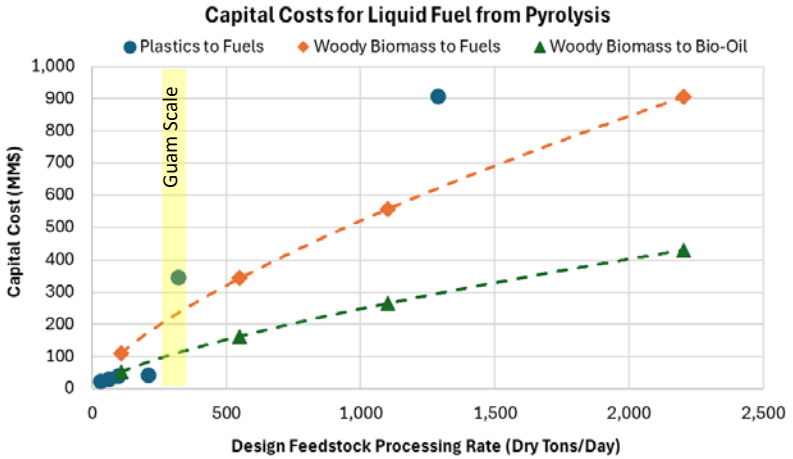
- **Products:** Electricity, thermal energy, flue gas (CO_2, water), solid residues (ash)
- **Yield:** 500 – 600 kWh per ton (varies with feedstock quality and technology)
- **Capital Costs:** $30 – 130 M
- **Annual O&M Costs:** $3 – 5 M
- **Technology Maturity:** Commercial applications around the world. Emissions control is important element of process designs.
- **Advantages:** Mature technology. Lower overall capital costs than alternatives.

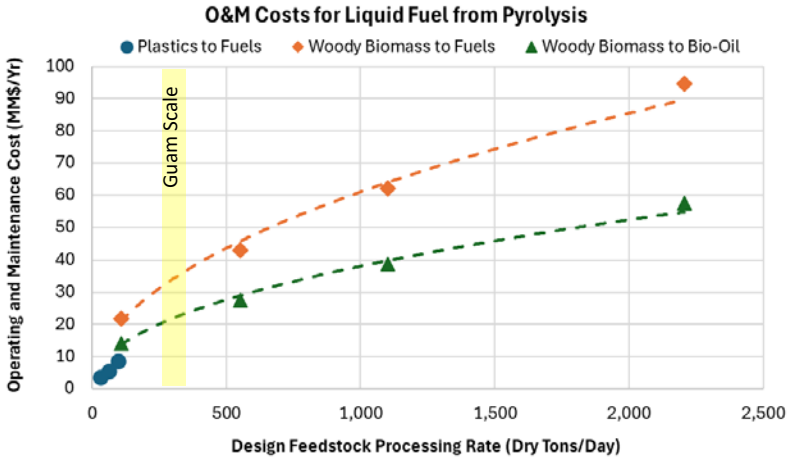




Pyrolysis

- **Products:** Bio-oil, fuel gas, biochar
- **Yield:** Up to 120 gasoline gallon equivalent (GGE)/ton (bio-oil)
- **Capital Costs:** $100 – 120 M (bio-oil)
- **Annual O&M Costs:** $20 – 25 M (bio-oil)
- **Technology Maturity:** Commercial applications from Ensyn (Canada) and BTG (Europe).
- **Advantages:** Bio-oil blending with diesel/marine fuel, asphalt. Fuel gas for electricity or thermal energy. Biochar as soil amendment, construction additive, rCB.

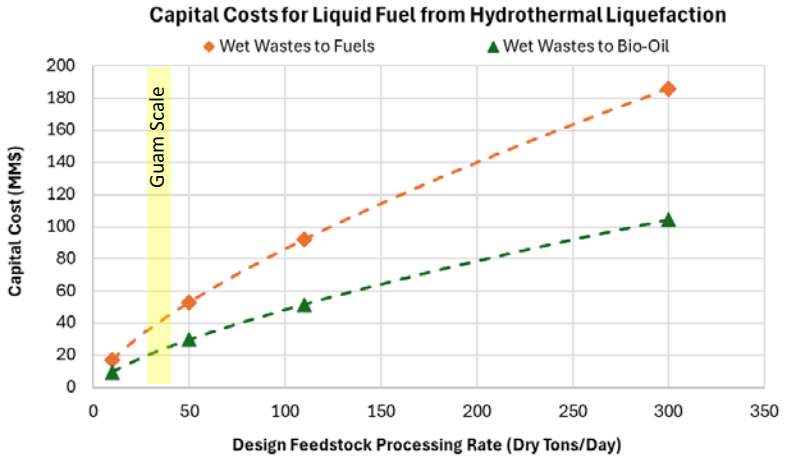


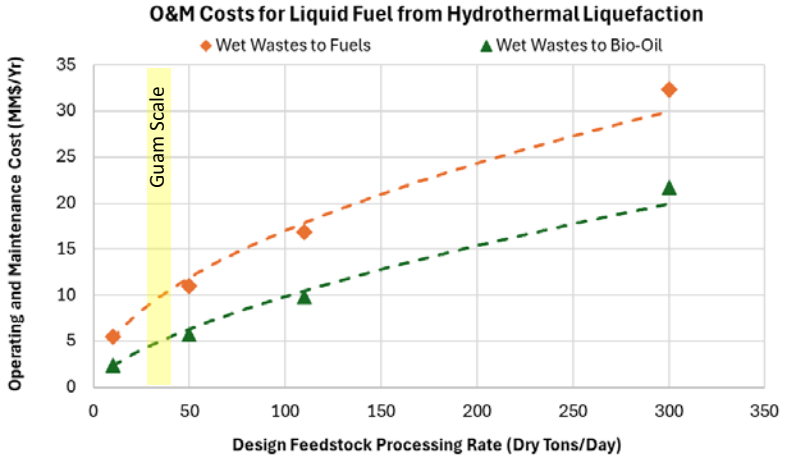


Gallons of gasoline equivalent on energy content basis.

Hydrothermal Liquefaction

- **Products:** Bio-oil, fuel gas, biochar, wastewater
- **Yield:** Up to 100 GGE/ton (bio-oil)
- **Capital Costs:** $20 – 30 M (bio-oil)
- **Annual O&M Costs:** 4 – 6 M (bio-oil)
- **Technology Maturity:** Emerging technology at demonstration scale.
- **Advantages:** Bio-oil blending with diesel/marine fuel, asphalt. Fuel gas for electricity or thermal energy. Biochar as soil amendment or construction additive. Process is tolerant of high ash and moisture feedstocks.

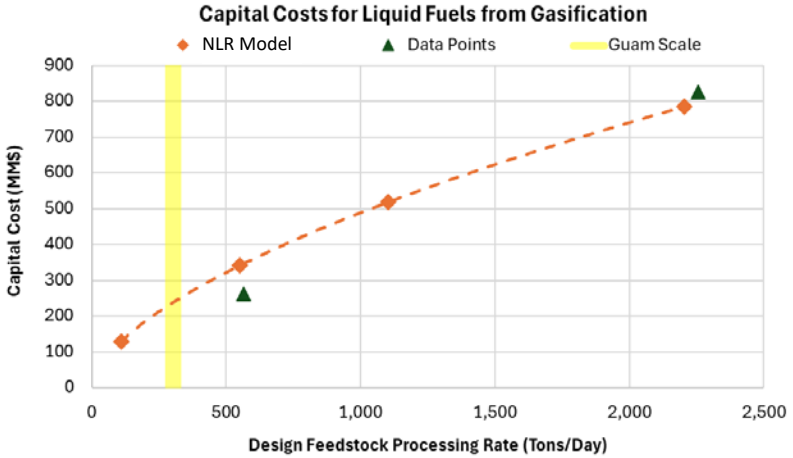


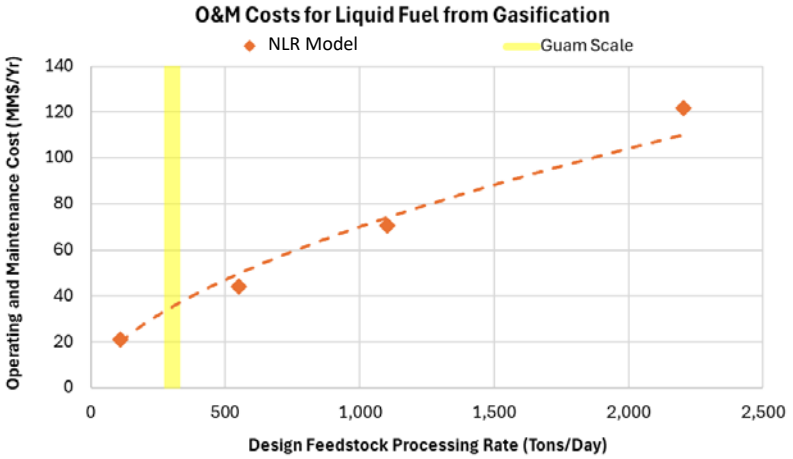


GGE = gallons of gasoline equivalent on energy content basis.

Gasification to Fuels

- **Products:** Fischer-Tropsch liquids, fuel gas, ash
- **Yield:** 65 GGE/ton total fuel products
- **Capital Costs:** $200 – 300 M
- **Annual O&M Costs:** $30 – 40 M
- **Technology Maturity:** Commercial technology for natural gas-derived syngas. Demonstration scale for biomass and MSW. Multiple technologies and designs (e.g., plasma).
- **Advantages:** High quality gasoline, diesel/marine blendstocks. Fuel gas for electricity or thermal energy. Ash/solids as soil amendment (source-dependent) or construction additive.

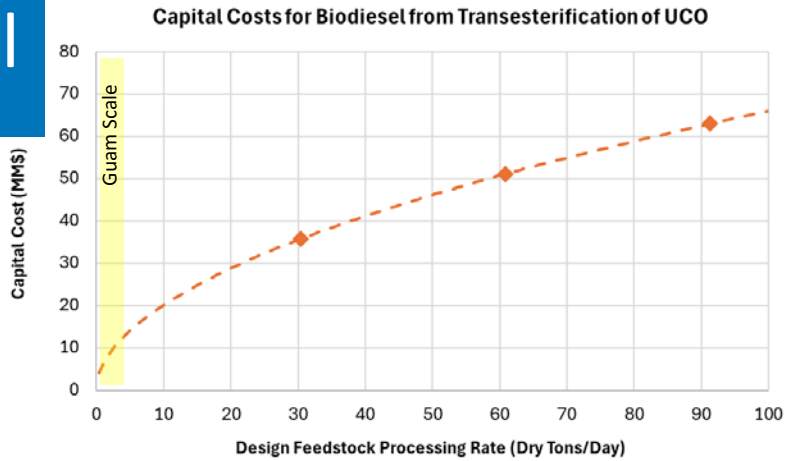


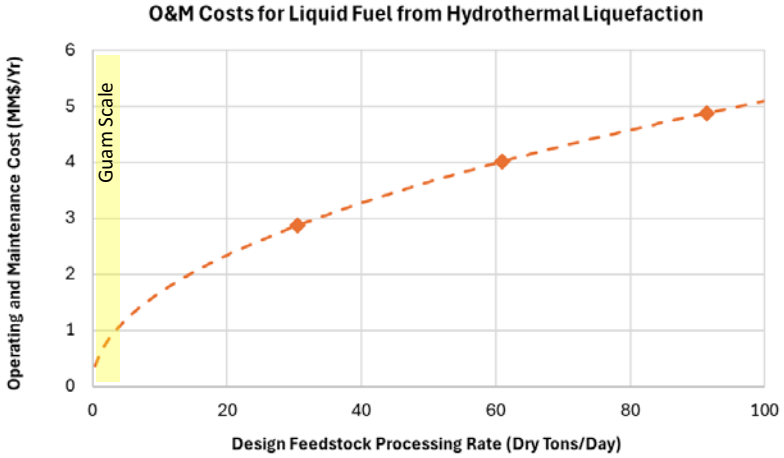


GGE = gallons of gasoline equivalent on energy content basis.

Transesterification to Biodiesel

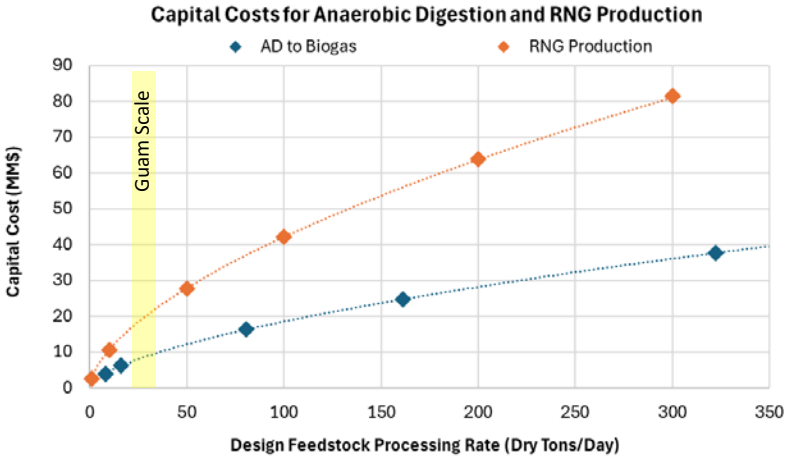
- **Products:** Biodiesel, glycerine
- **Yield:** Up to 270 gallons per ton
- **Capital Costs:** $5 – 10 M
- **Annual O&M Costs:** ≤ $1 M
- **Technology Maturity:** Mature, fully commercialized process
- **Advantages:** Product blending with diesel/marine fuel. No hydrogen required for fuel production like renewable diesel. Cost feasibility at small-scale.

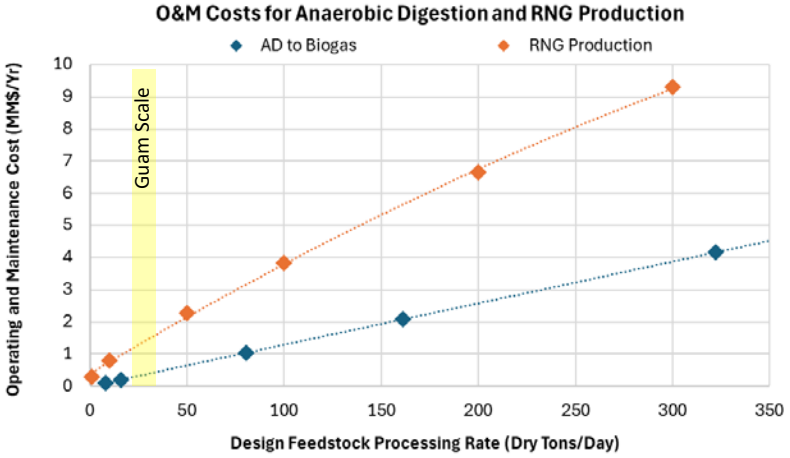




Anaerobic Digestion

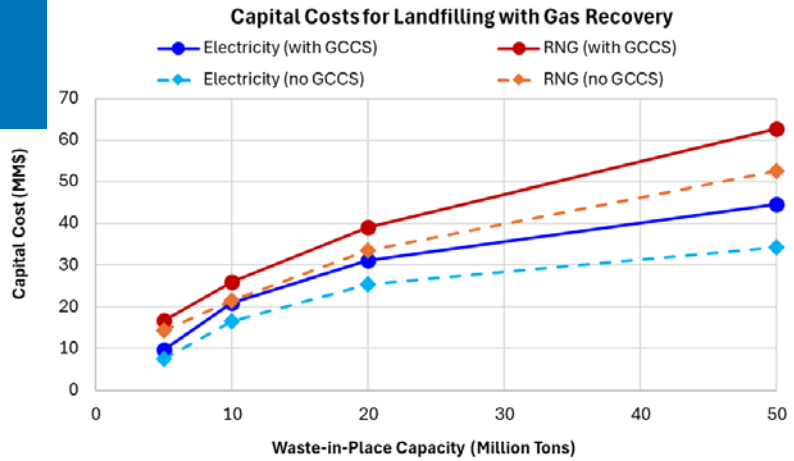
- **Products:** Biogas/renewable natural gas (RNG), CO_2, digestate
- **Yield:** 0.23 Ton RNG/ton for Guam wet waste
- **Capital Costs:** $17 – 23 M (RNG)
- **Annual O&M Costs:** $1.2 – 1.6 M (bio-oil)
- **Technology Maturity:** Mature, fully commercialized process
- **Advantages:** Biogas for electricity or thermal energy; RNG as transportation fuel. Digestate as fertilizer, soil amendment. Process is suitable for high moisture feedstocks.

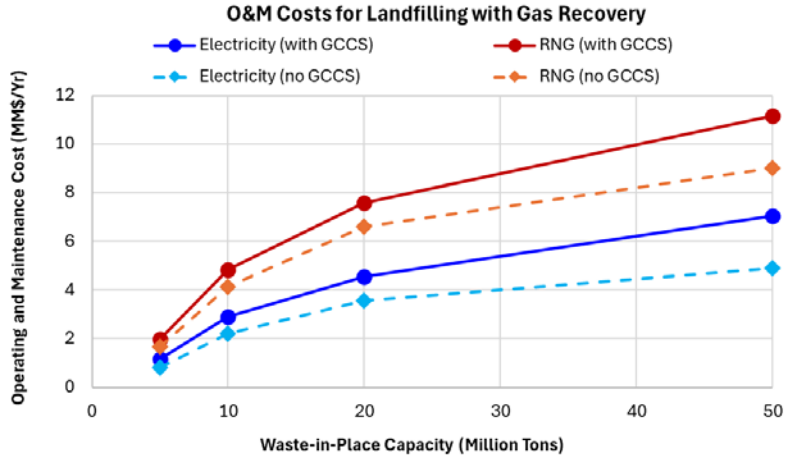




Landfill Gas Recovery

- **Products:** LFG/RNG, CO_2
- **Yield:** Lower expected yield than AD
- **Capital Costs:** Function of waste-in-place
- **Annual O&M Costs:** Function of waste-in-place
- **Technology Maturity:** Mature, fully commercialized process
- **Advantages:** LFG for electricity or thermal energy; RNG as transportation fuel. Builds on existing landfill infrastructure, reduces methane emissions, and provides a relatively low-cost WTE option where gas is already being captured or flared.





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Thank you!

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