Carbon Neutral Electrical Generation from Human Solid Waste

Developing the Energy Balance and Identifying Suitable Electrical Generation Solutions Capable of Harnessing the Thermal Energy

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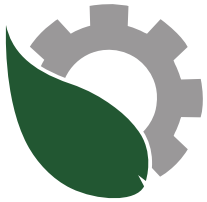

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Outline

- Our First Pyrolysis Unit
- The Energy Balance
- Electrical Generation Solutions
- Next Generation Units
- Lessons Learned
- Next Steps

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The First Unit

THE GOAL

- Off-grid pyrolysis unit
- Economically viable
- Treat faecal sludge from 500-10,000 individuals
- No harmful pollutants, no safety hazards
- Carbon neutral or negative

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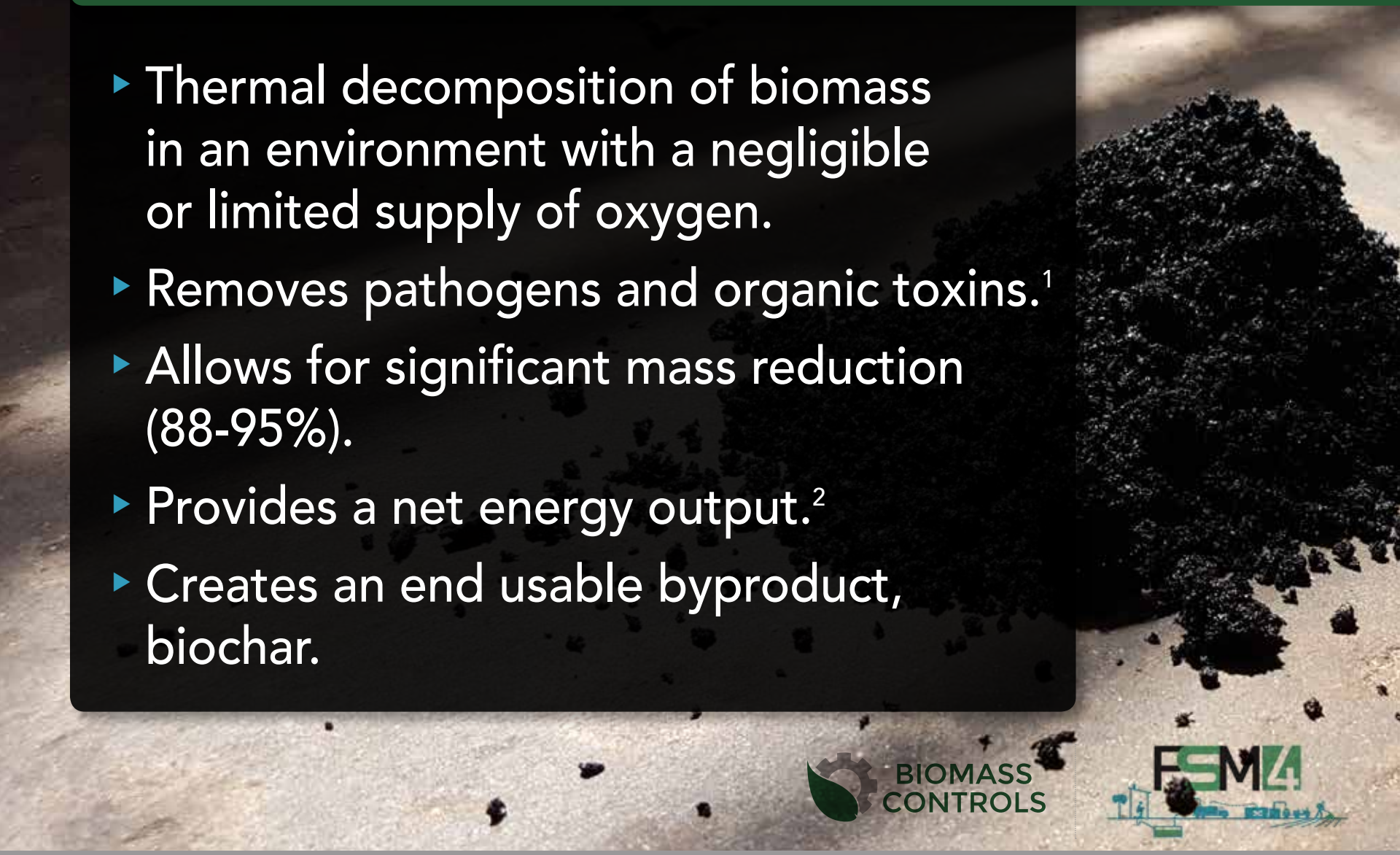
Pyrolysis

- Thermal decomposition of biomass in an environment with a negligible or limited supply of oxygen.
- Removes pathogens and organic toxins.[1]
- Allows for significant mass reduction (88-95%).
- Provides a net energy output.[2]
- Creates an end usable byproduct, biochar.



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India Fair 2014

- Treat faecal sludge from 2,000 individuals
- 85% moisture
- Limited use of supplemental fuel

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Energy Balance Assumption

FAECAL SLUDGE

Moisture Content	85%
Energy Content	17.2 MJ/kg
Biochar Output	25.8 MJ/kg

BIOGENIC SUPPLEMENTAL FUEL

Energy Content	16.9 MJ/kg
Moisture Content	5%

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Energy Demand

THEORETICAL ENERGY DEMAND

Start-up	3.5 kWe/hr
Steady-state	18 kWe/hr
Shutdown	0.5 kWe/hr

- **Most electrical components were oversized**
- **Observational data** 3.8 kWe/hr

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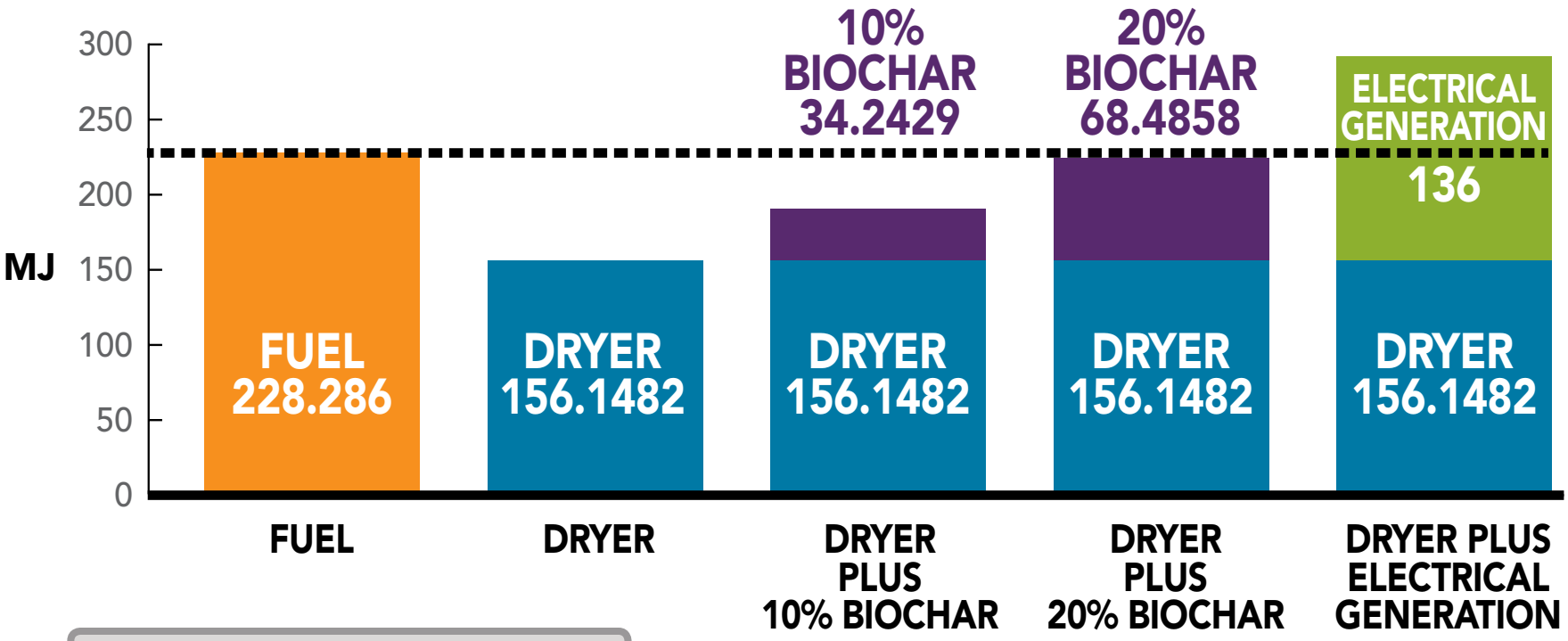
100% Efficiency, 0% Supplemental Fuel



Dryer 96.6 kg/hr
at 85% moisture

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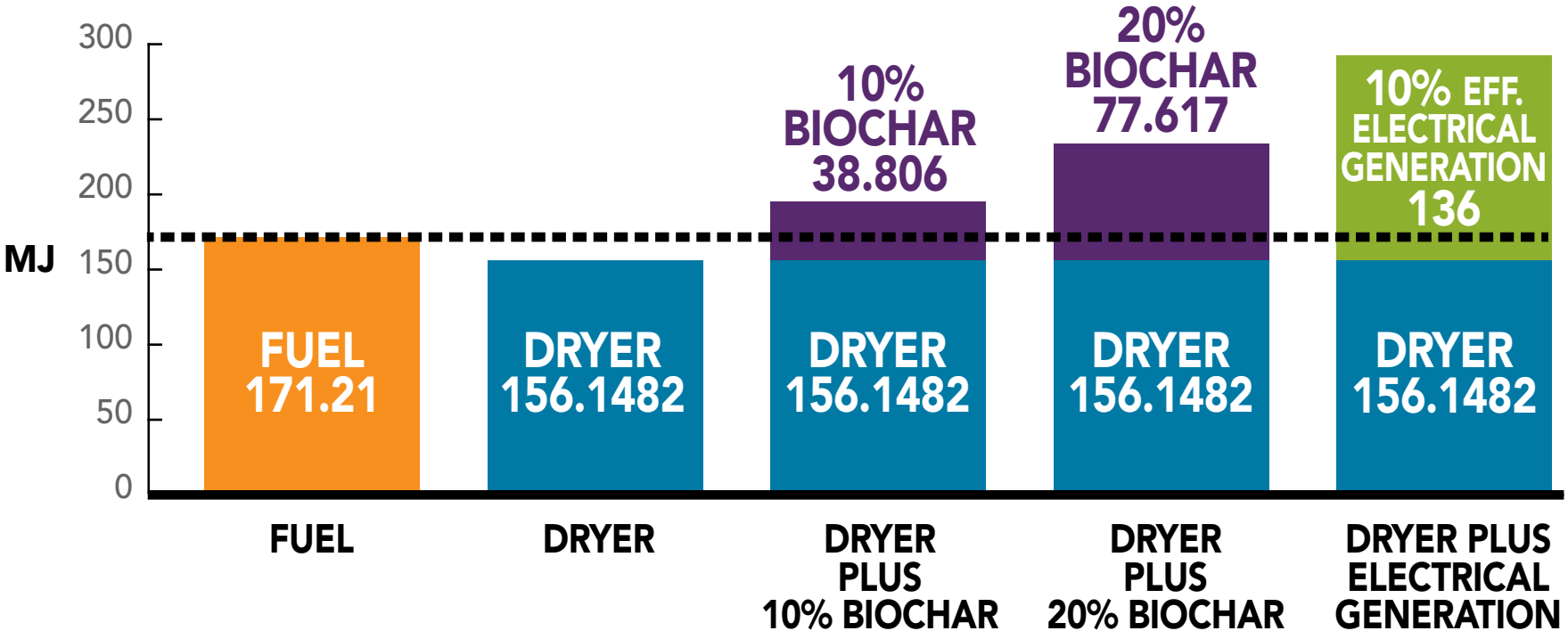
75% Efficiency, 0% Supplemental Fuel



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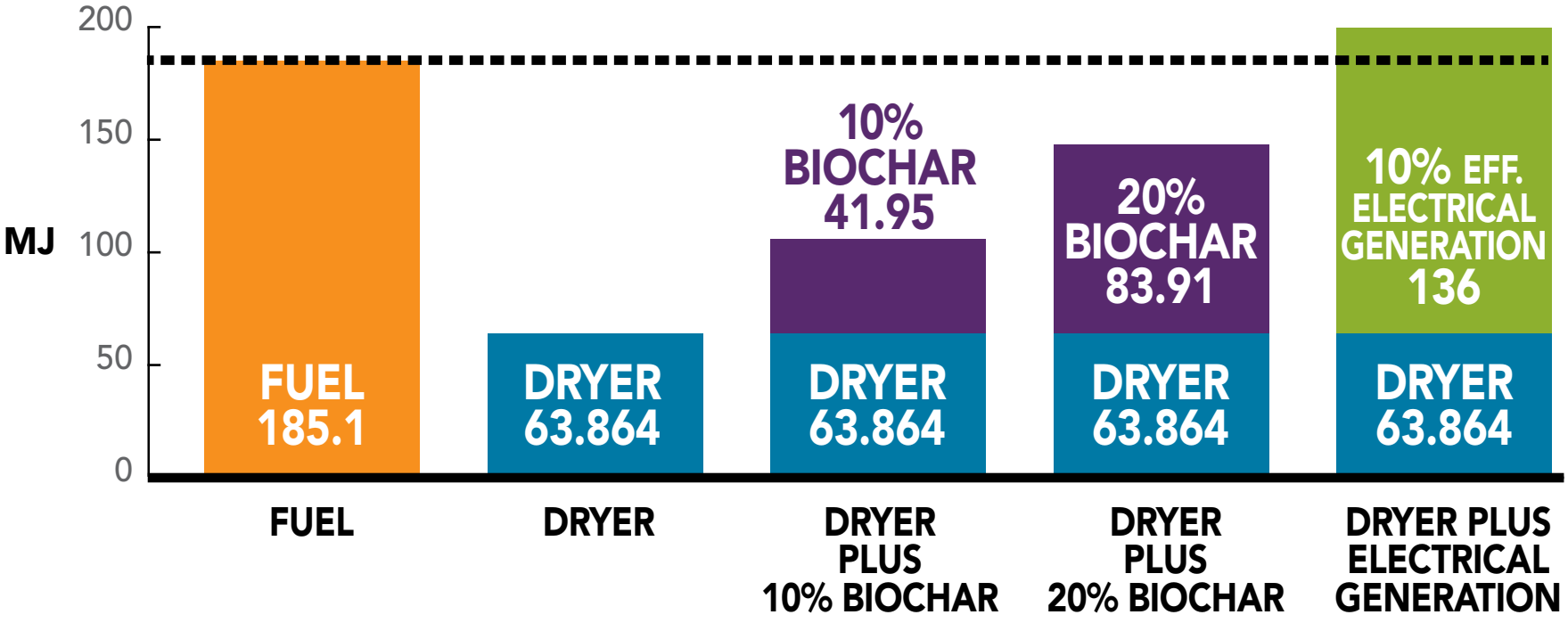
75% Efficiency, 15% Supplemental Fuel



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Identifying Technology Options

GOAL: IDENTIFY A THERMAL ENGINE THAT COULD GENERATE 3-5 KWE/HR

- Most thermal generators produce >1 MW/hr.
- January-March 2016
  - Commercially available
  - Harness waste heat
  - Produce <1MW/hr

- Thermoacoustic, Thermoelectric, Stirling, Steam, and Organic Rankine Cycle

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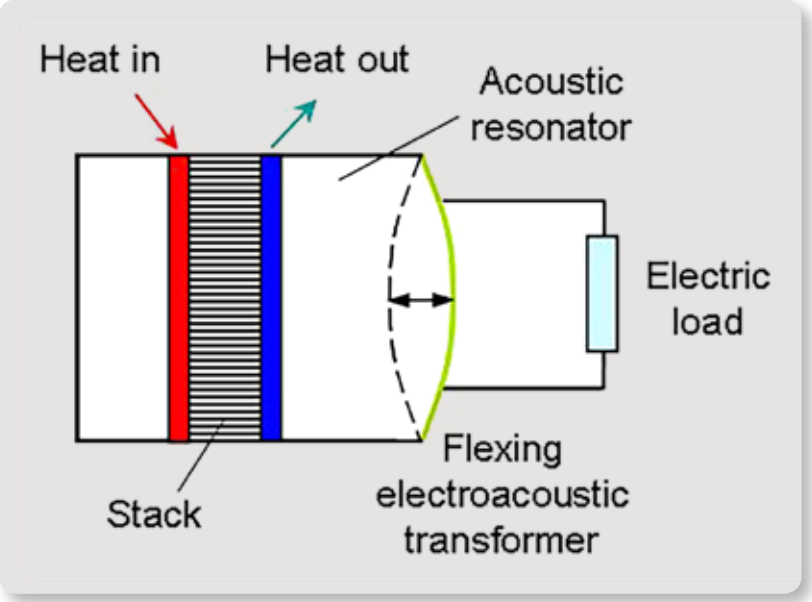
Thermoacoustic Engines

- No moving parts
- No annual maintenance
- High life expectancies
- Capable of generating 1-5 kWe
- Three identified manufacturers
- No products commercially available



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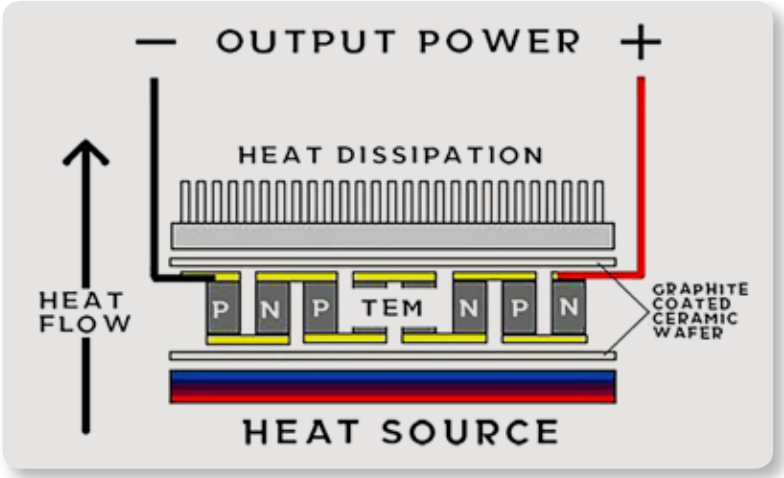
Thermoelectric Generators

- No moving parts or maintenance
- Destroyed when overheated (400-450°C)
- Output: 5-100W
- Three manufacturers identified
- Electrical Efficiency: 0.5-5%
- Price per watt: 7.25-26.00 USD
- Cannot generate sufficient power



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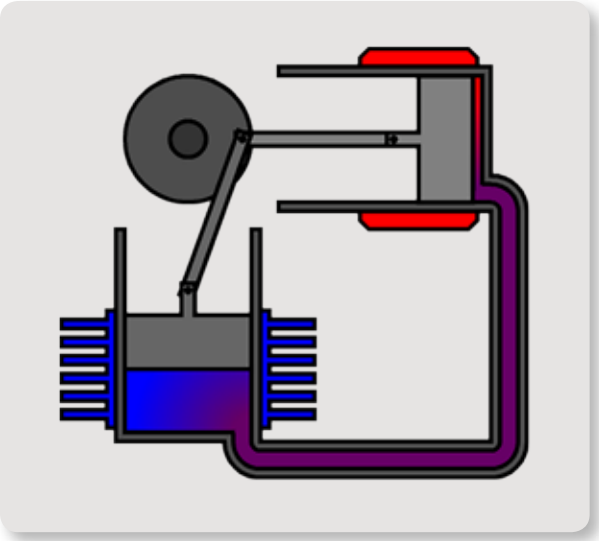
Stirling Engines

- High efficiency
- 11 manufacturers identified
- Output: 0.60-25 kWe
- Price per watt: 7-30 USD
- No products commercially available capable of harnessing waste heat



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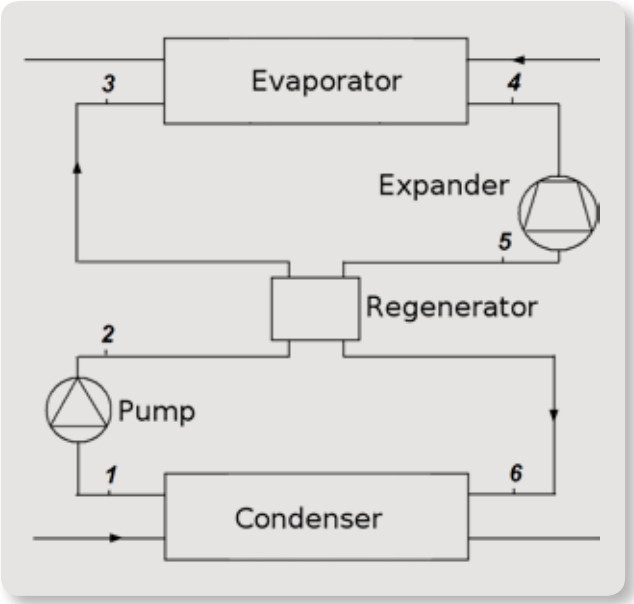
Steam Engines

- Powered with any heat source
- 11 manufacturers, 16 products
- Output: 1.5-18.6 kWe
- 10-20% efficiency
- Price per watt: 1-6 USD
- Multiple products identified



Cyclone Power Technologies

Pearl Steam Engine Company

VP Village Industrial Power

Steam Engine Works™

Quasiturbine.com

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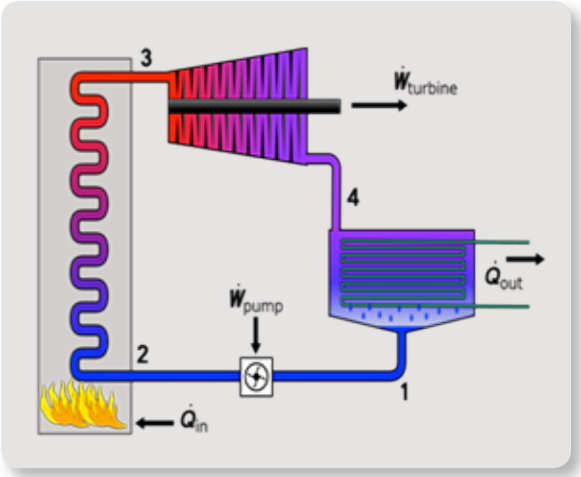
Organic Rankine Cycle

- Capture low temperature heat
- Long life expectancies
- Eight manufacturers
- 9-17% efficiency
- Less corrosion and mechanical stress
- Output: 2-800 kWe
- Price per watt: 4-8 USD
- Multiple products identified



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Thermal Power Generation Summary

Thermoacoustic	Not commercially available
Thermoelectric	Limited generation potential
Stirling	Not commercially available
Steam	**Viable option**
Organic Rankine Cycle	**Viable option**

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Improving the Energy Balance

- Improved combustion efficiency (95%)
- Decreased electrical needs
- Data, Data, Data

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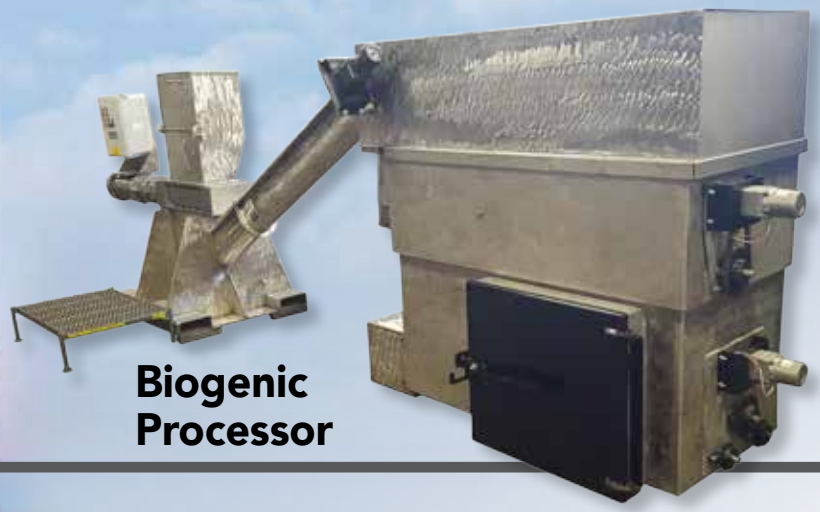
Thermal Power Generation Conclusion

- Eliminate Dryer
- Grinder for pre-processing supplemental fuel
- Smaller Footprint



Biogenic Processor

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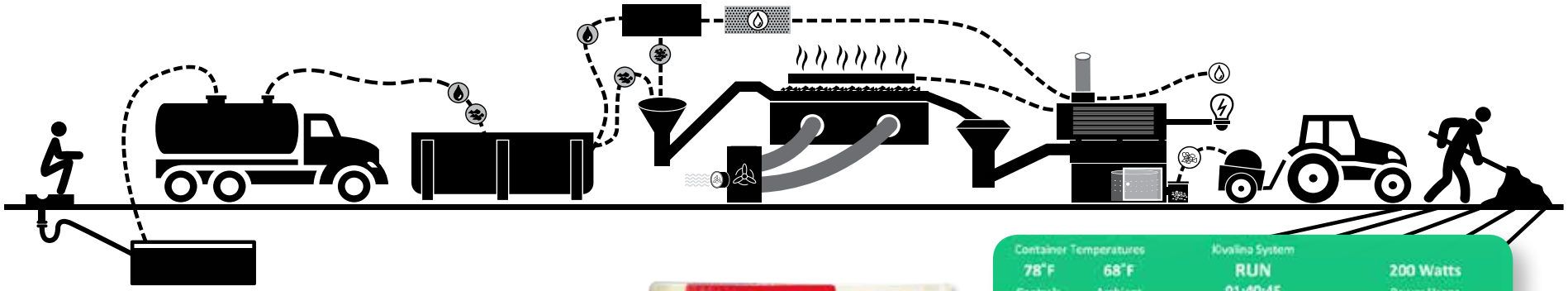
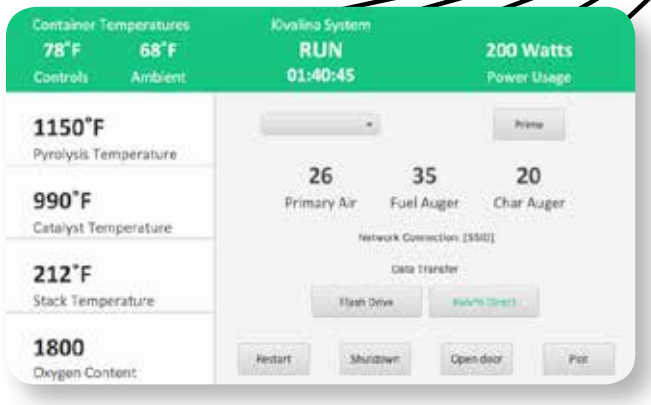
Lessons Learned

- Important to have variable controls
- The "one energy balance fits all" will not work





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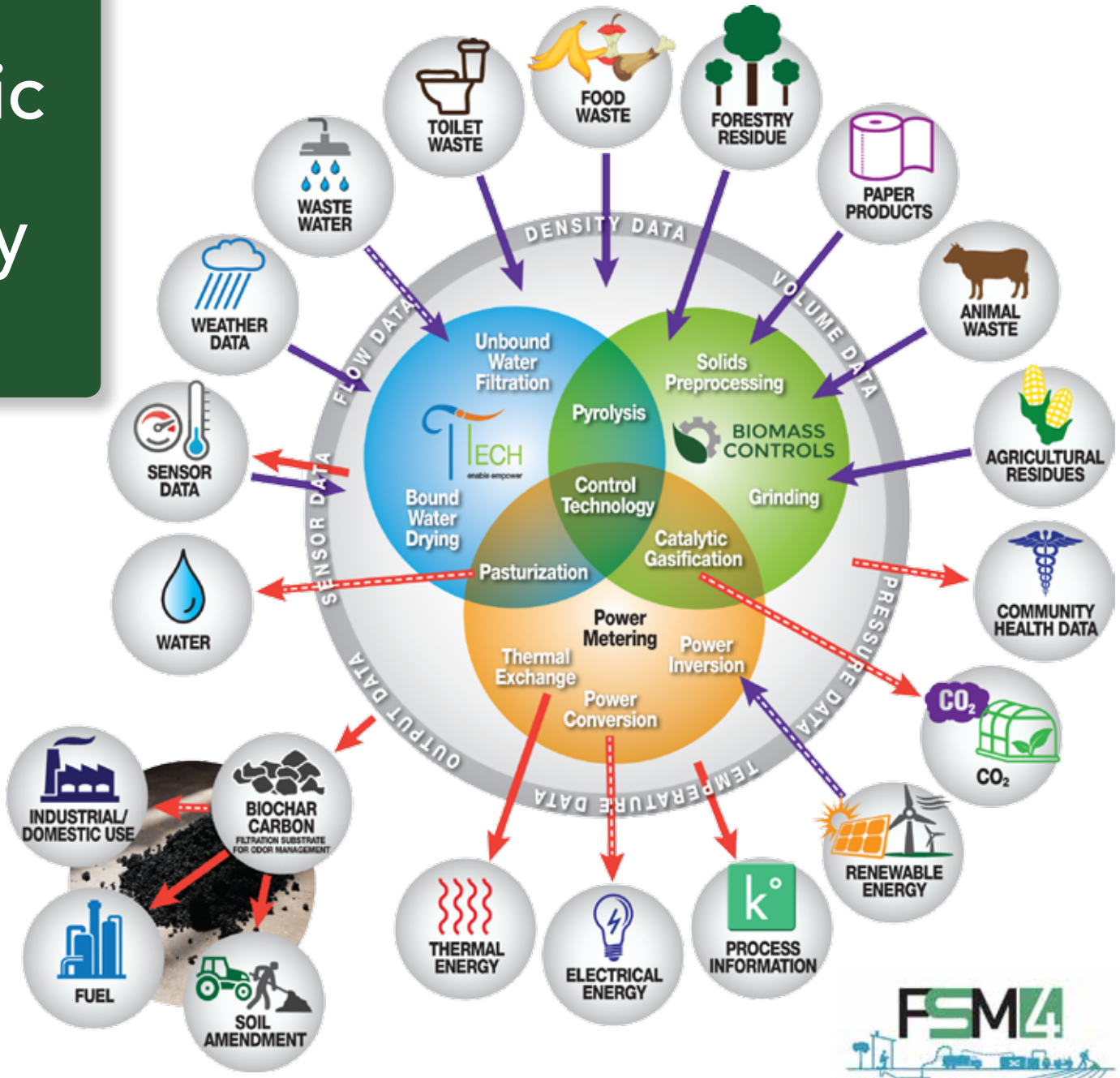
Biogenic Waste Refinery



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Next Steps

Energy, enthalpy, mass, and mass carbon balance

Product Integration

Exploring hybrid power options

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Funding

WE WOULD LIKE TO THANK OUR FUNDERS

- Bill & Melinda Gates Foundation
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- NANA (a Regional Native Corporation)
- Teck Resources Limited

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Contact Biomass Controls

Thank you for your time!

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Work Cited

1. Laird, D. A., Brown, R. C., Amonette, J. E., & Lehmann, J. (2009). Review of the pyrolysis platform for coproducing bio-oil and biochar. *Biofuels, Bioproducts and Biorefining, 3*(5), 547-562.

2. Liu, Xuan, et al. "Characterization of human manure-derived biochar and energy-balance analysis of slow pyrolysis process." *Waste Management* 34.9 (2014): 1619-1626.

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