Agriculture Residues

Flared Gas

Food Processing Waste

Municipal Solid Waste

Pulp Waste

Wet Sludges

ENERGY EVERYWHERE

Modular chemical conversions delivering clean energy

Tom Brouns, tom.brouns@pnnl.gov, (509) 372-6265

John Holladay, john.holladay@pnnl.gov, (509) 375-2025
Cynthia Jenks, cjenks@ameslab.gov, (515) 294-8486

PNNL-SA-119178

The Big Idea

Locally transform

the nation's stranded, underutilized, and distributed waste into fuels and chemicals

Impact

Fuel for 240 million cars

Waste – National Impact

Waste Sources	Total Resource (barrel of oil/year)
Agricultural and forest waste	600 – 800 million barrels
Animal waste (manures)	350 – 700 million barrels
Food processing	100 – 270 million
Waste water sludge	30 million barrels
Flared gas	50 million barrels
CO_2 (ethanol prod)	Tbd
Municipal and industrial solid waste	400 – 700 million barrels

Impact

1.5-2.5 billion barrels of oil

(2015 imports = 1.7 billion barrels)

Solves waste disposal challenges

New domestic industry

GHG reduction (exceeding 60-80%)

Waste – National Impact, Locally Distributed

Waste Sources	Total Resource (barrel of oil/year)	Local Size
Agricultural and forest waste	600 – 800 million barrels	2-200 BOE/D
Animal waste (manures)	350 – 700 million barrels	4-150 BOE/D
Food processing	100 – 270 million	2-50 BOE/D
Waste water sludge	30 million barrels	30 BOE/D
Flared gas	50 million barrels	20-200 BOE/D
CO_2 (ethanol prod)	Tbd	10-300 BOE/D
Municipal and industrial solid waste	400 – 700 million barrels	70-1500 BOE/D

Individual unit is small

20-200 barrels per day production

RIGHT SIZED

US petroleum refinery
125,000 bpd

Gas to liquids*
30,000 bpd

US ethanol†
2,000 bpd

Energy Everywhere
200 bpd

Compact, local systems
Huge national impact

* Typical GTL plant planned for China
† either corn dry mill or BETO 2,000 tonne/day plant

GOAL

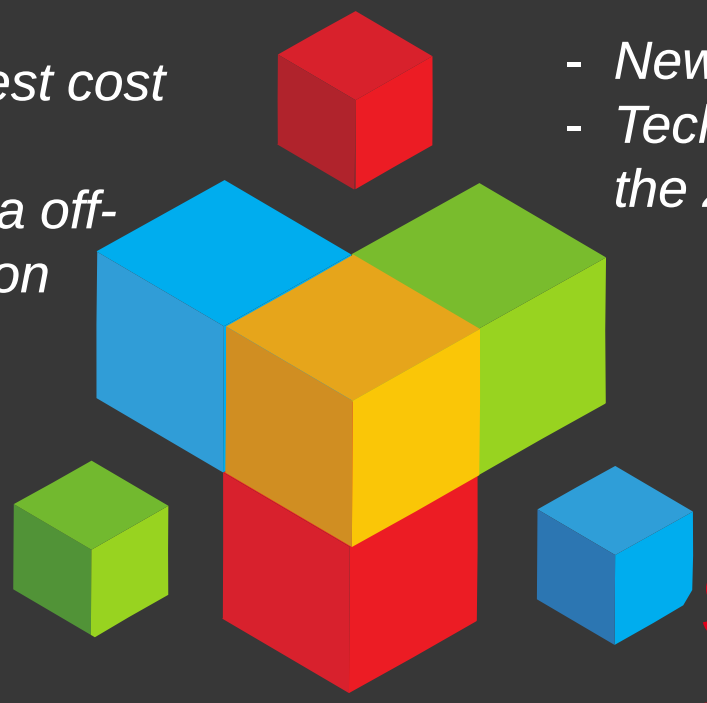
Economic Enablers

Small scale

- *Reduces risk*
- *Enables use of lowest cost feedstock*
- *Provides benefits via off-site plant construction*

New technologies

- *New scientific advances*
- *Technologies that avoid the 2/3 power scaling law*



Mass production

- *Modular design flexibility*
- *Flexible product production*
- *Learning curve 3x greater*

Standardized platforms

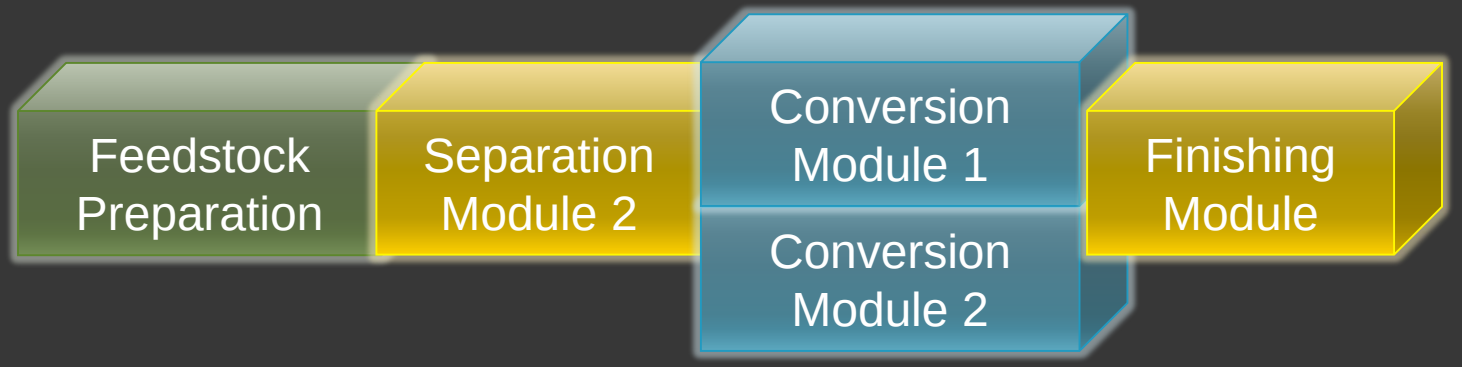
- *Reduce operating cost with sensor and controls*
- *Support innovation with plug and play approach*

CHALLENGES

How to handle feedstock variability?

Feed forward controls

Redirect feeds to alternate conversion modules



How to handle intermittent feedstocks?

Small, modular systems enable rapid redeployment

Mixed waste opportunities

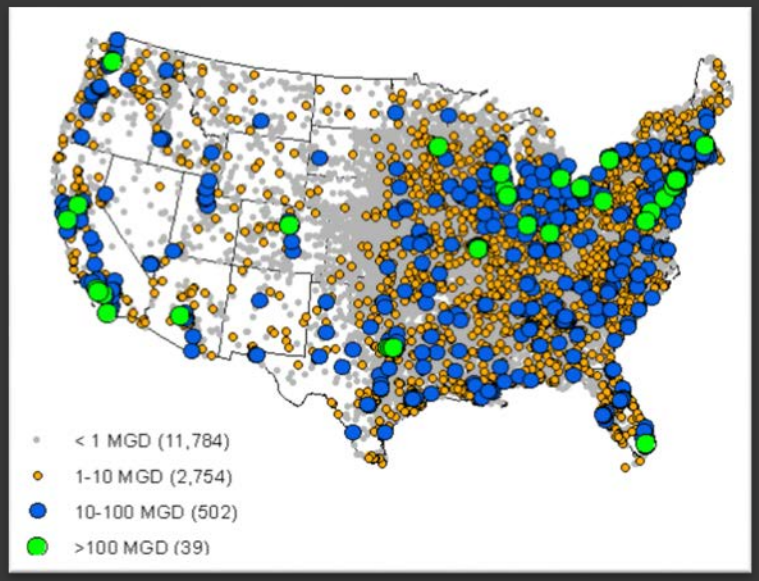
Early targets and adopters?

Waste – National Impact, Locally Distributed

Waste Sources	Total Resource (barrel of oil/year)	Local Size	
Agricultural and forest waste	600 – 800 million barrels	2-200 BOE/D	
Animal waste (manures)	350 – 700 million barrels	4-150 BOE/D	Focus: Wet waste (high moisture)
Food processing	100 – 270 million	2-50 BOE/D	
Waste water sludge	30 million barrels	30 BOE/D	
Flared gas	50 million barrels	20-200 BOE/D	Focus: Gas waste
CO_2 (ethanol prod)	Tbd	10-300 BOE/D	
Municipal and industrial solid waste	400 – 700 million barrels	70-1500 BOE/D	

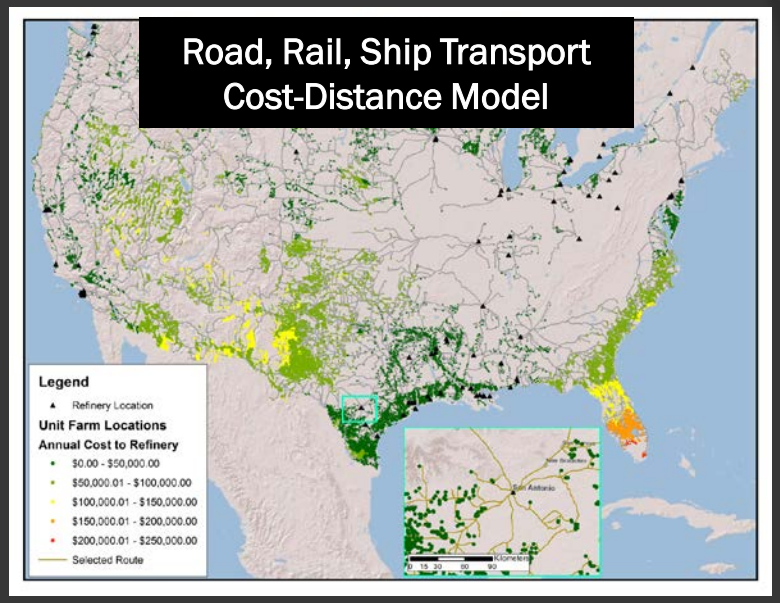
Analysis
Feedstock and Infrastructure

Resource Assessments



- Understand true availability
- Harness industry partners

National Infrastructure



- Place in context of current infrastructure

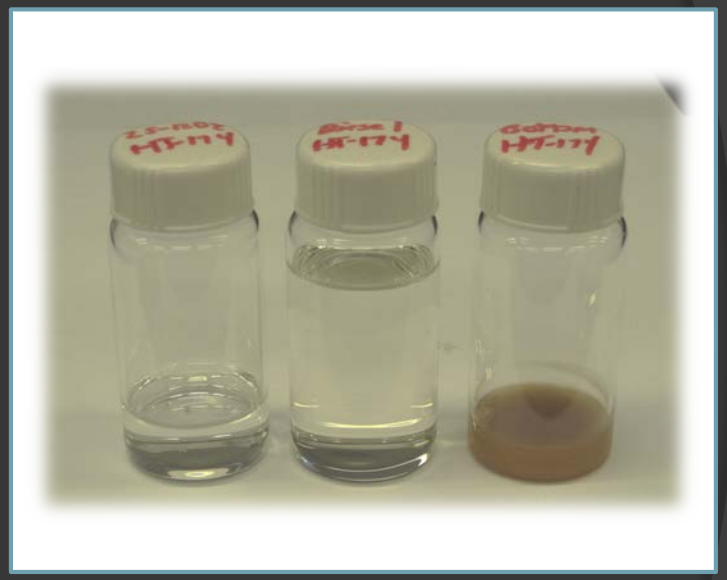
  (electrical transmission lines, gas pipelines, roads, rail, ports, refineries, renewable electrons)

S&T
Converted Sludge to Diesel Fuel

Liquefaction technology

- Waste water sludge
- Grape pomace
- Food processing waste
- Algal bodies
- Mixed waste

Fuel product



- 80% of carbon into useable fuel products
- 65% of energy in feed in fuel
- 60-80% GHG reduction

WORKSHOPS

- Chemical Conversions via Modular Manufacturing
- Fundamental Science Needs for Waste to Chemical Conversion
- DOE workshops
  - Dialogue on Modular Energy Systems (FE)
  - AMO workshops

Waste owners, Technology providers, Financers, Manufacturers

Conversions in condensed phase (catalysis, biological), separation science, instrumentation, and theory and modeling

Five Integrated Focus Areas

1. robust, flexible chemical conversion processes
2. low-energy separations
3. standardized “plug and play” modules
4. integrated sensors, and controls
5. local codes, resource logistics, and market analyses

Locally Transform Waste

Energy Everywhere

Clean Energy Mission Innovation