Biofuels Technology Options for Waste to Energy

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RTI International

Turning Knowledge Into Practice

One of the world's leading research organizations

3,700 staff
Work in 75 countries

1,800+
Active RTI projects

scientific staff
Highly qualified with tremendous breadth

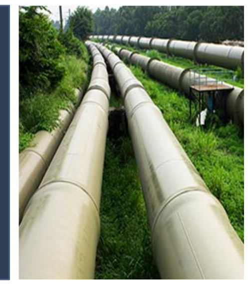
$780 million
Research budget

Energy Technologies

Developing advanced process technologies for energy applications by partnering with industry leaders

Biomass and Biofuels

Natural Gas



Carbon Capture

Industrial Water

Syngas

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Waste-to-Energy

<u>Characteristics of Waste Streams</u>

- Quantity (scale)
- Cost
- Composition
- Water content
- Density

<u>Technology Considerations</u>

- Anaerobic Digestion - Biogas
- Hydrothermal Liquefaction – Bio-oil intermediate

Wet

- Pyrolysis – Bio-oil Intermediate
- Gasification – Syngas Intermediate

Dry

Waste feedstocks:

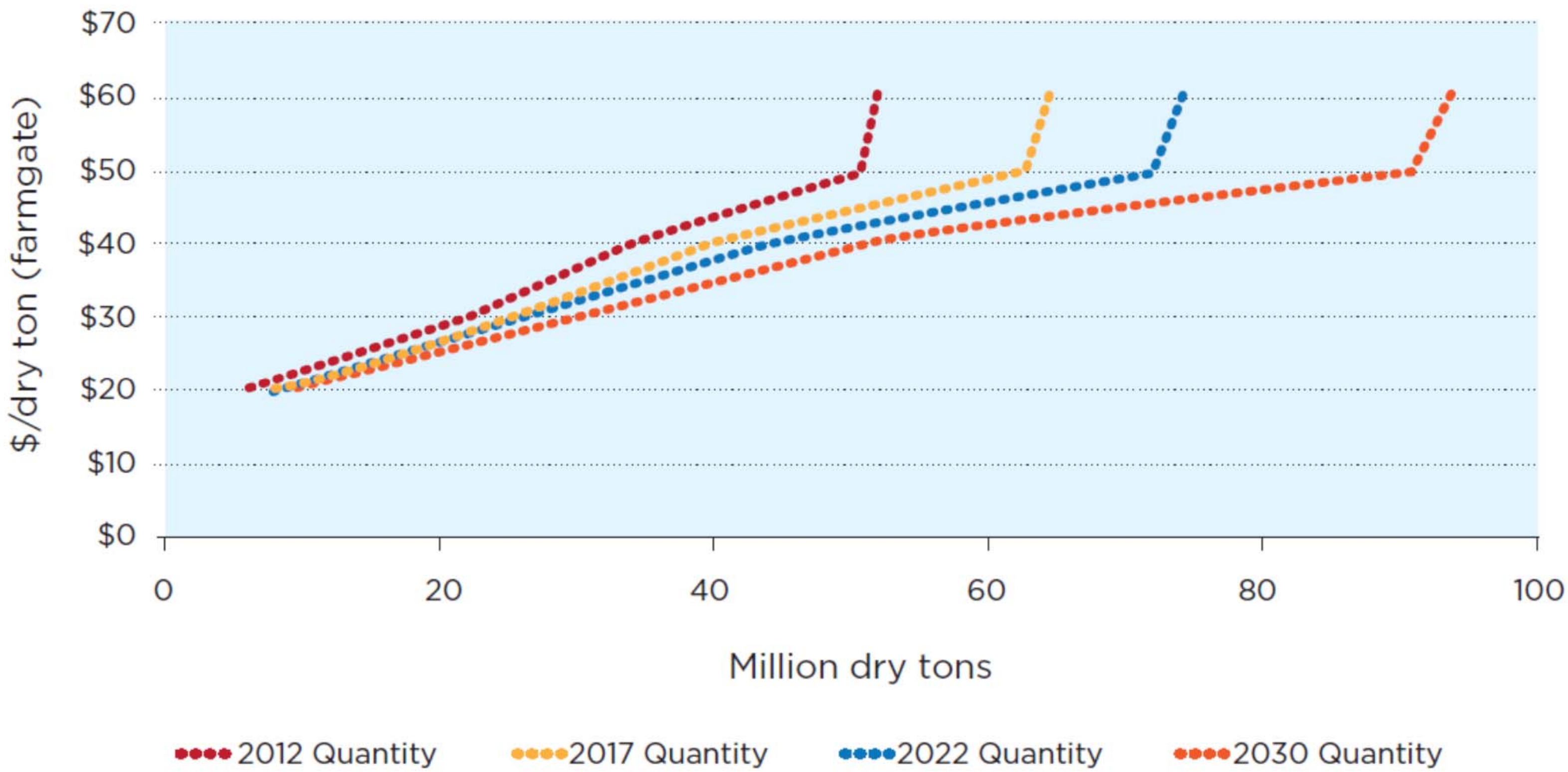
- *Typically less expensive than other biomass feedstocks*
- *More established supply chains; continuous availability*
- *Significantly greater variability*

Match technology options with resource availability and composition

Waste-to-Energy Resources

Categorized in the Billion Ton Update (USDOE & USDA) Secondary Cropland Residues and Waste Resources

- Currently about 50 million dry tons available annually (2012)
- Projected to be 90 million dry tons by 2030



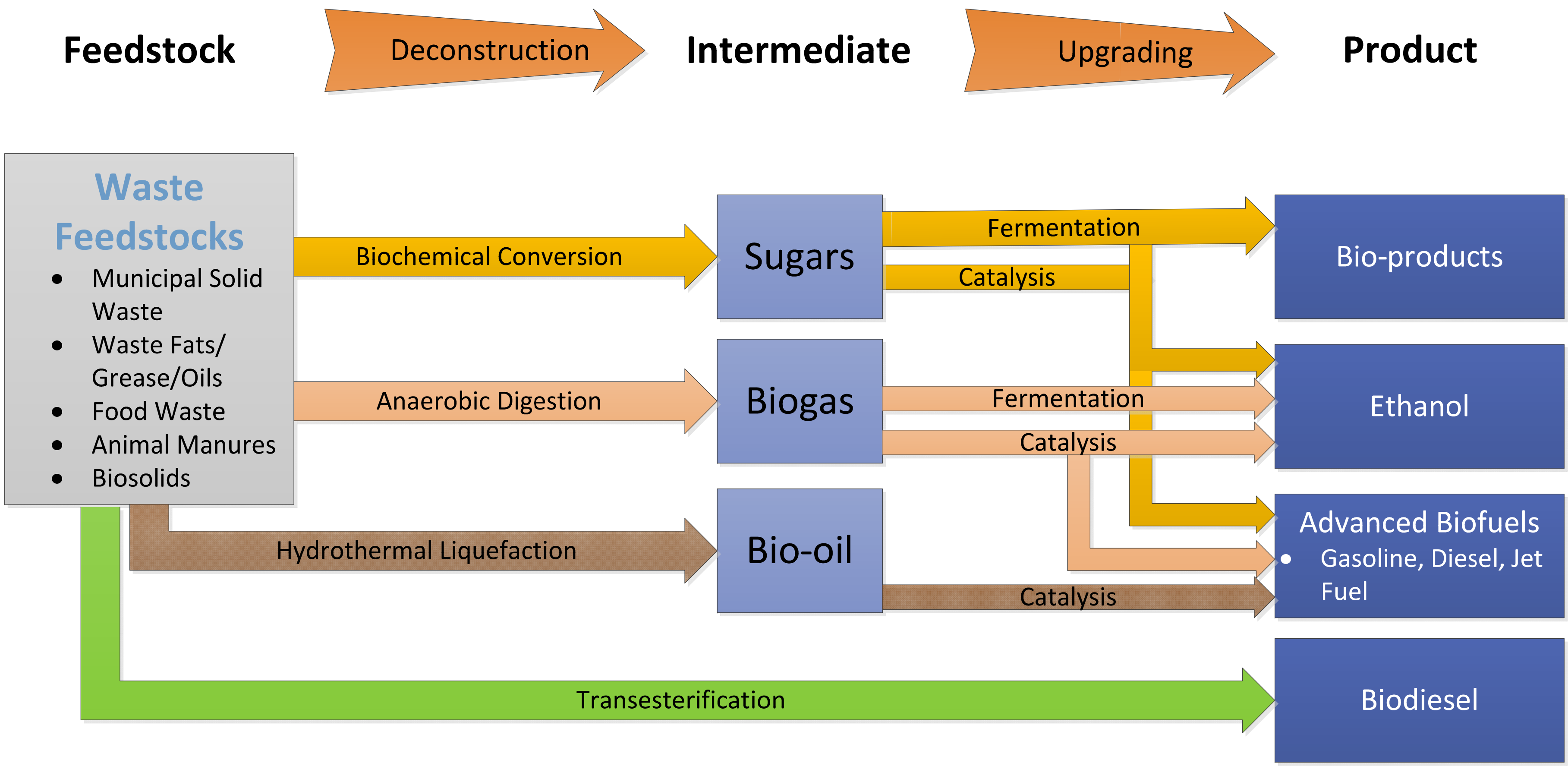
http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf - p. 77

Waste Resources – Cost and Availability

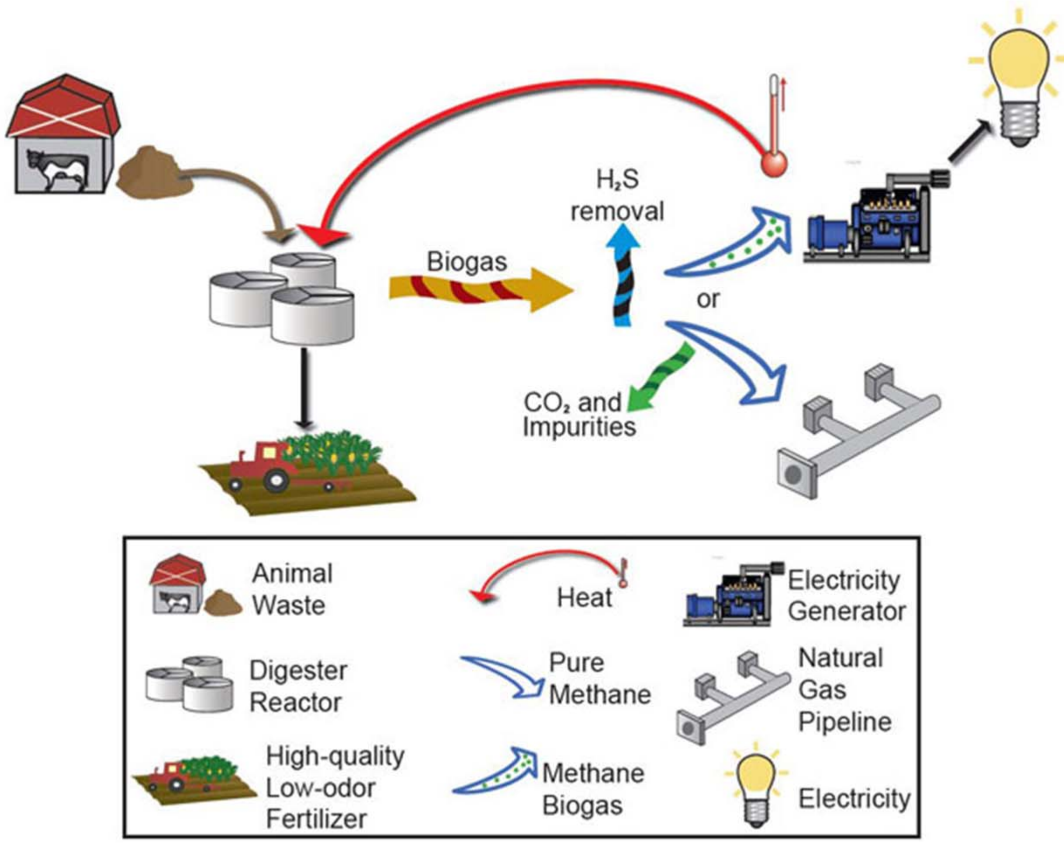
Feedstock	<$20 per dry ton 2012	2017	2022	2030	<$30 per dry ton 2012	2017	2022	2030	<$40 per dry ton 2012	2017	2022	2030
	Million dry tons											
Rice field residue	0.0	0.0	0.0	0.0	6.3	6.9	7.4	8.0	6.5	6.9	7.4	8.0
Rice hulls	0.8	0.8	0.8	0.9	1.5	1.6	1.7	1.7	1.5	1.6	1.7	1.7
Cotton field residue	1.2	2.1	2.3	3.3	4.1	5.3	5.9	6.7	4.2	5.3	5.9	6.7
Cotton gin trash	0.7	0.8	0.8	0.9	1.4	1.6	1.7	1.8	1.4	1.6	1.7	1.8
Wheat dust	0.3	0.3	0.3	0.3	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Sugarcane residues	0.1	0.1	0.1	0.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Orchard and vineyard prunings	2.9	2.8	2.8	2.8	5.7	5.6	5.5	5.5	5.7	5.6	5.5	5.5
Animal manures	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12	13	16	20
Animal fats	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total secondary residues & wastes	**5.8**	**6.9**	**7.1**	**8.2**	**21**	**23**	**24**	**25**	**33**	**36**	**40**	**46**

http://www1.eere.energy.gov/bioenergy/pdfs/billion_ton_update.pdf - p. 80

Technology Options for Wet Feedstocks



Anaerobic Digestion



Prepared by Sarah G. Lupis, Institute for Livestock and the Environment (www.ile.colostate.edu), Colorado State University.
Symbols courtesy of the Integration and Application Network (ian.umces.edu/symbols/), University of Maryland Center for Environmental Science.

Challenges:

Gas Purification and use beyond CHP

Biogas typically contains between 60-70% methane. Other constituents include carbon dioxide, hydrogen sulfide, ammonia, and other trace organics.

Feedstock variability/blending

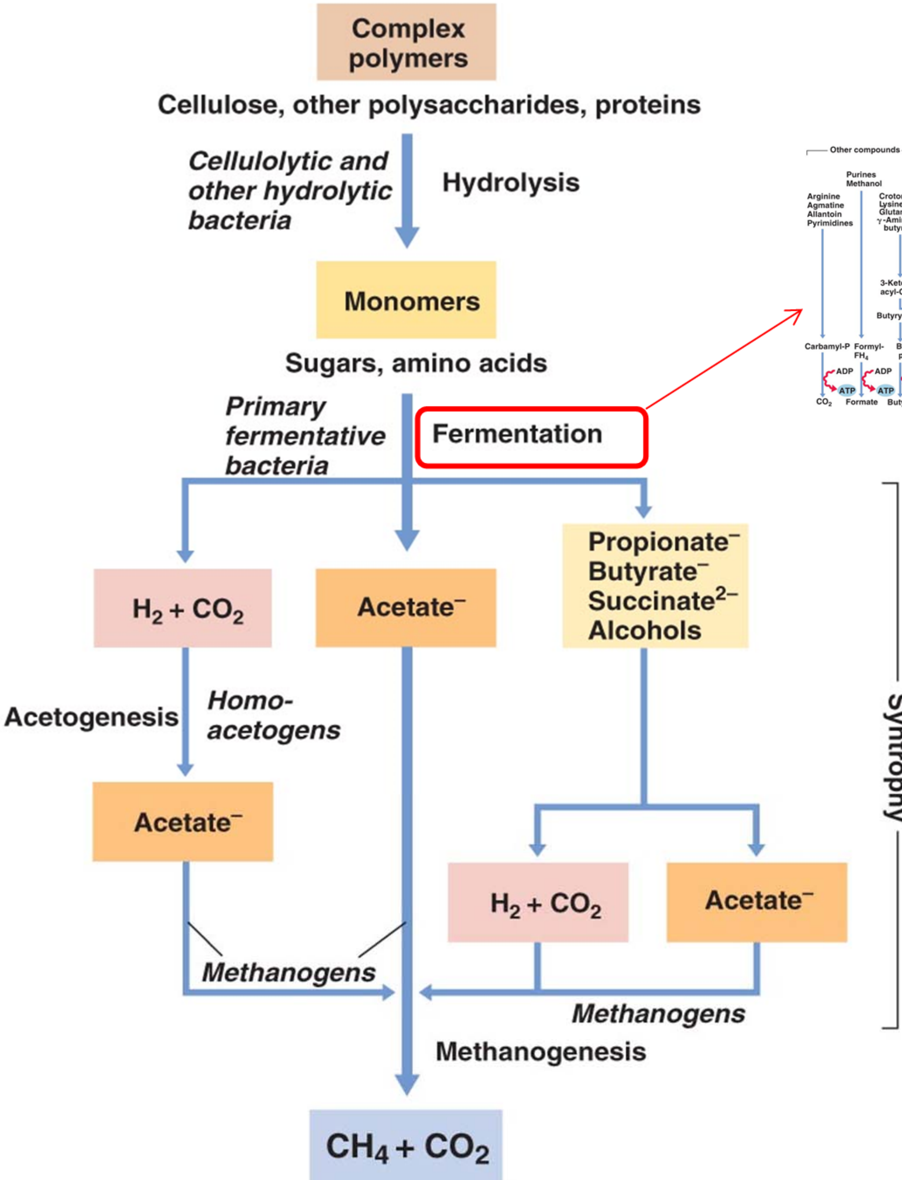
- Livestock manure (dairy, swine, poultry, and beef)
- MSW
- Wastewater bio-solids and primary sludge
- Food waste
- Food production residues

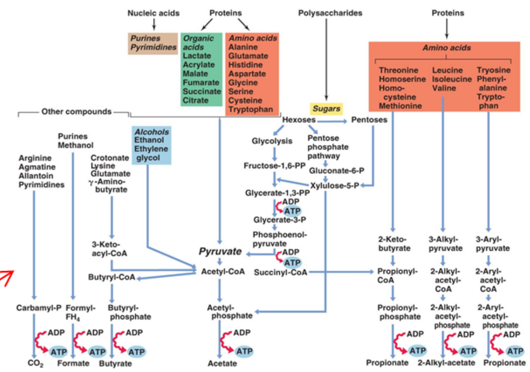
Permitting and Regulatory Issues

Scale and CAPEX

Waste-to-energy is dominated by anaerobic digestion for Biogas production

Anaerobic MBR (RTI wastewater treatment technology)





- **Absence of specific microbial populations results in unbalanced anaerobic food web.**
- **Unbalanced anaerobic food web leads to metabolic imbalance.**
- **Metabolic imbalance leads to process failure.**
- **Balanced anaerobic food web requires the right microbes with the right quantity for each target substrate and intermediate.**

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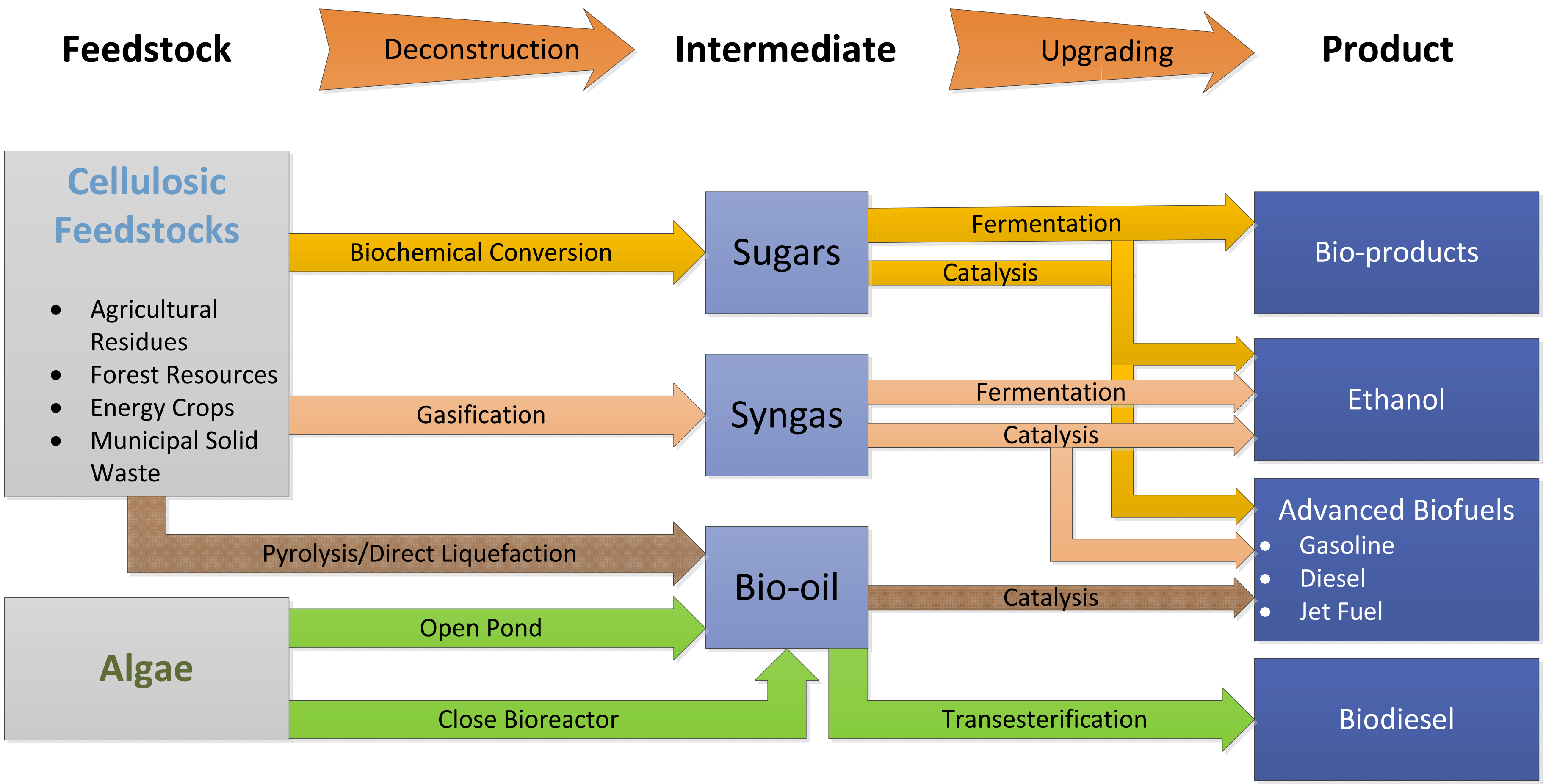
Biofuels Technology Options for Dry Feedstocks



Source: Bioenergy Technologies Office Replacing the Whole Barrell, DOE/EE-0920 • July 2013

Catalytic Biomass Pyrolysis at RTI

Feedstocks
Woody biomass
Switchgrass
Corn Stover

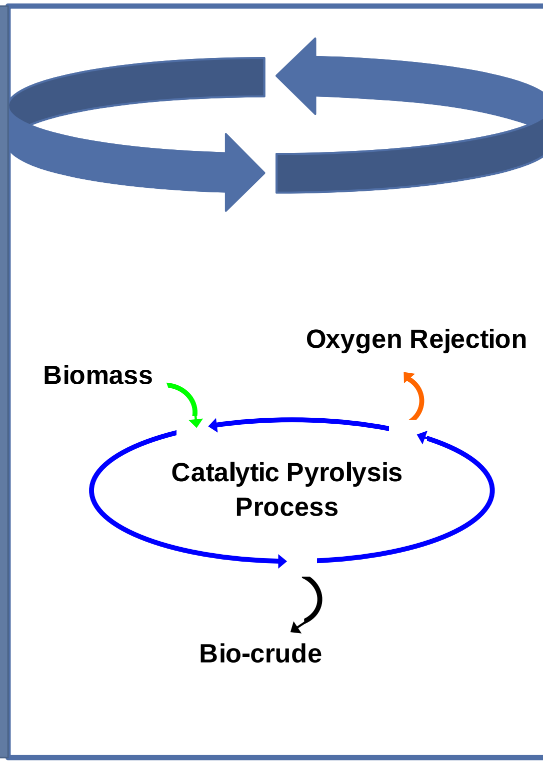
Conversion Technology
Catalytic Biomass Pyrolysis

Upgrading Technology
Hydroprocessing

Advanced Biofuels
Diesel (F-76)
Jet Fuel (JP-5, JP-8)

RTI Catalytic Biomass Pyrolysis Process based on a Multi-functional Catalyst ……

- Multi-functional catalyst to maximize carbon efficiency, remove oxygen, and control bio-crude properties
- High attrition resistance

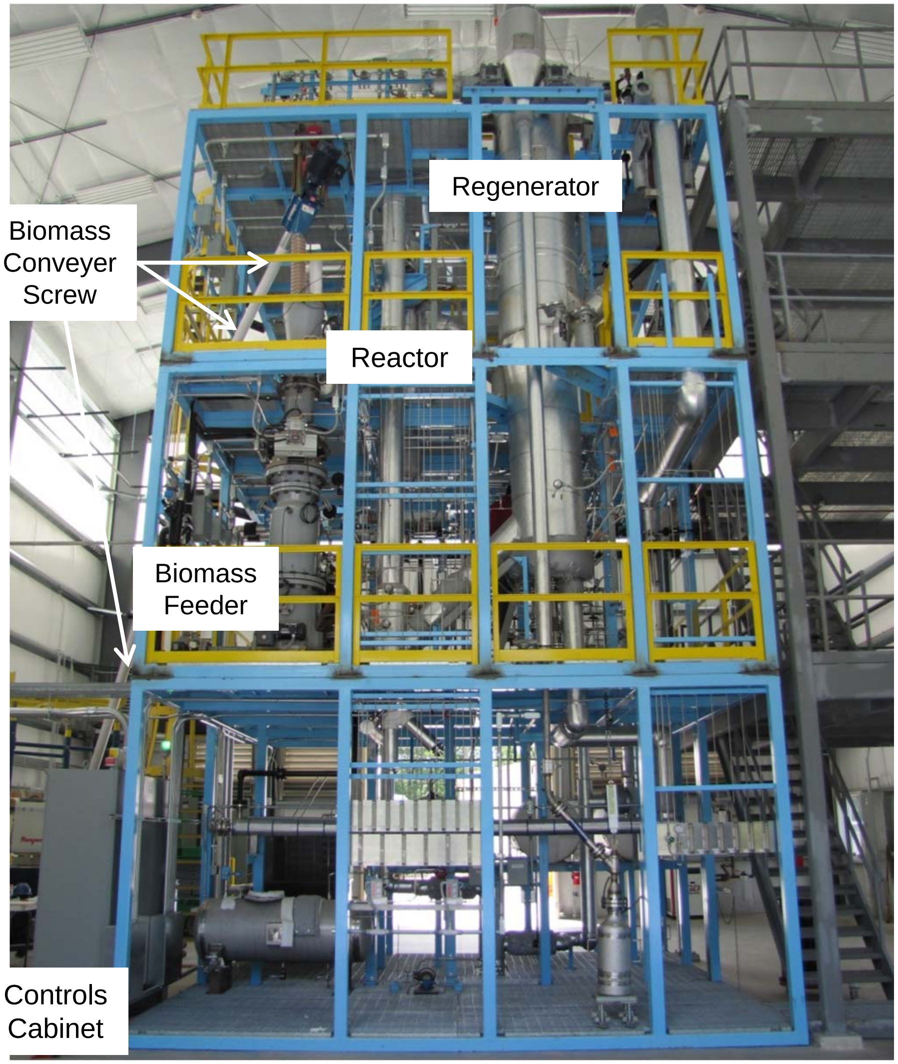


…..in a Fluidizable form for use in a single loop Transport Reactor

- "Bio-crude" intermediate that can be processed with existing refining technology
- Continuous catalyst reaction and regeneration
- System can be operated auto-thermally with heat of regeneration

RTI's 1 TPD Catalytic Biomass Pyrolysis Unit

Front View



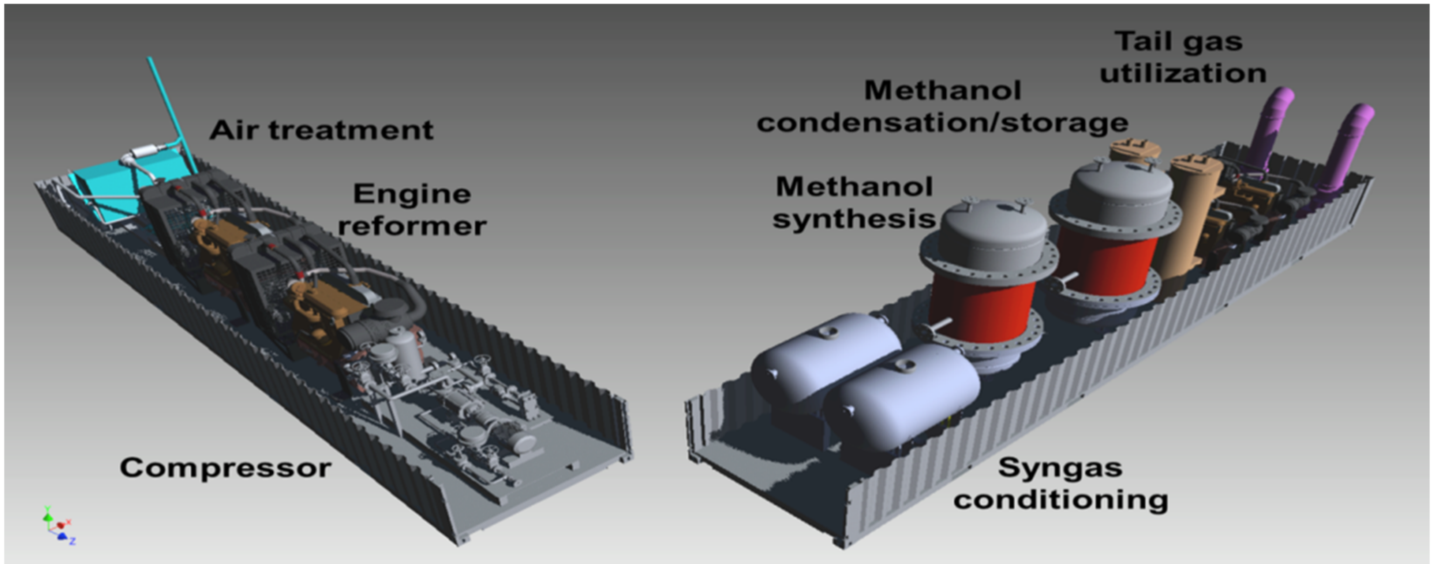
Back View

Summary of Technology Status

- Catalyst development included model compound screening and bench-top (~ 1 g/hr) biomass conversion
- Catalytic biomass pyrolysis in a 1”-dia fluidized bed reactor
- 20 wt% oxygen content with 42% energy recovery
- Preliminary techno-economic analysis complete
- Preliminary Bio-crude Upgrading complete
- Hydroprocessing unit installed
- 1 TPD unit operational for more than one year
  - 3 catalysts tested – FCC, RTI-A9, and RTI-A10A
  - 4 feedstocks attempted – loblolly pine, hybrid poplar, corn stover, hardwood pellets
  - Over 8000 lbs of biomass fed in the past 18 months
  - 24 hours of steady-state operation achieved without upset
  - 100-gal of loblolly pine bio-crude produced for upgrading
  - Yields in 1” FBR achieved in 1 TPD pilot plant

Mass Manufacturing for Distributed Fuel Production

- Compact, Inexpensive Micro-Reformers for Distributed GTL
- RTI and Columbia University have partnered with MIT to integrate engine reformer technology (proof-of-concept by MIT) with methanol synthesis. (Funding by U.S. DOE/ARPA-E)
  - Potential to demonstrate small footprint syngas production and utilization
  - Alternative paradigm to economy of scale
  - Demonstration with methanol but applicable to other liquid products
  - Modular unit design
  - Provides a rout to utilize small stranded natural gas or flared natural gas
  - Additional cleanup likely needed for biogas



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