Thermochemical Technology Overview

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Biorefinery Analysis
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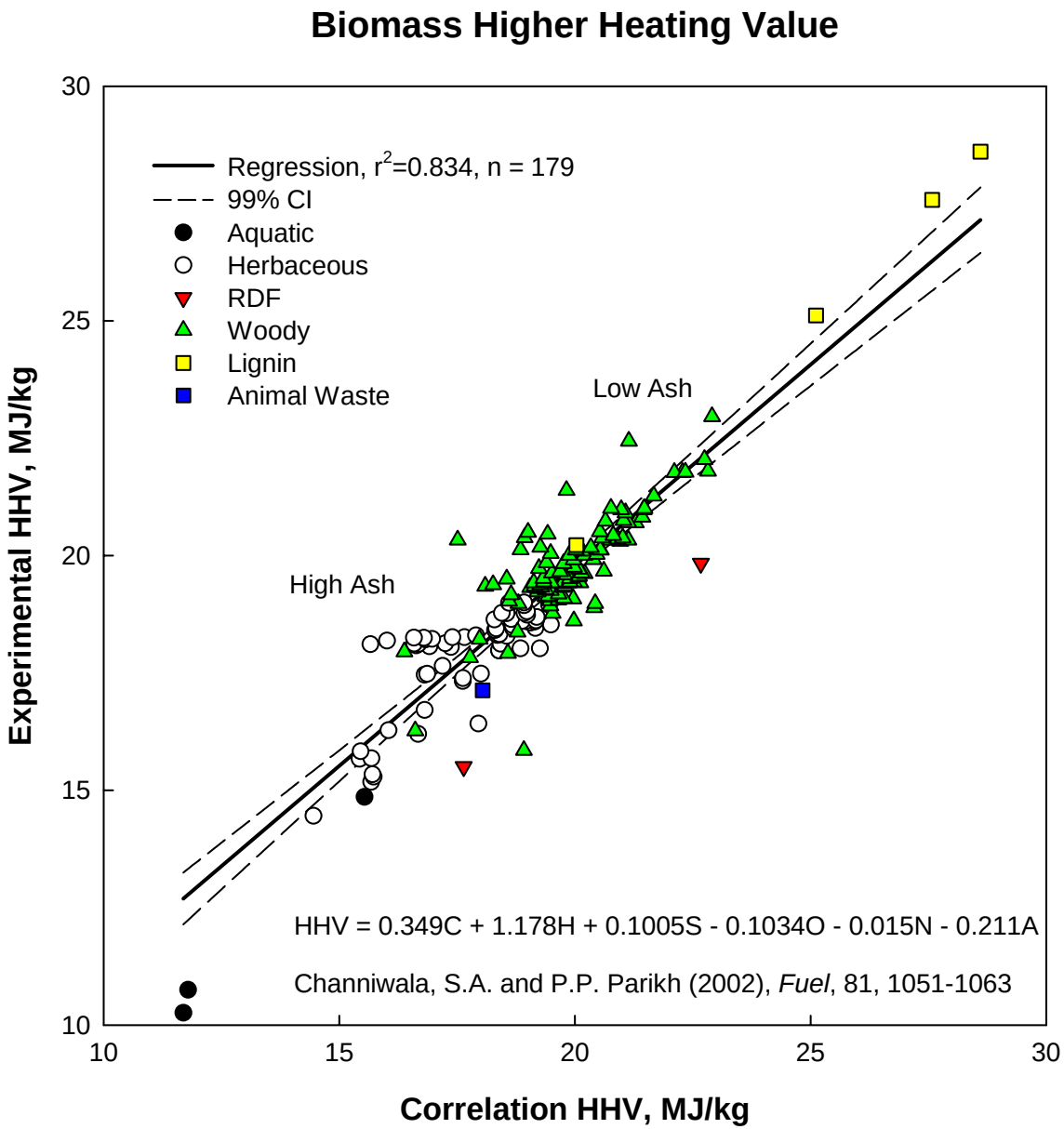
Presentation Outline

- Biomass Properties
- Combustion
- Gasification
- Pyrolysis

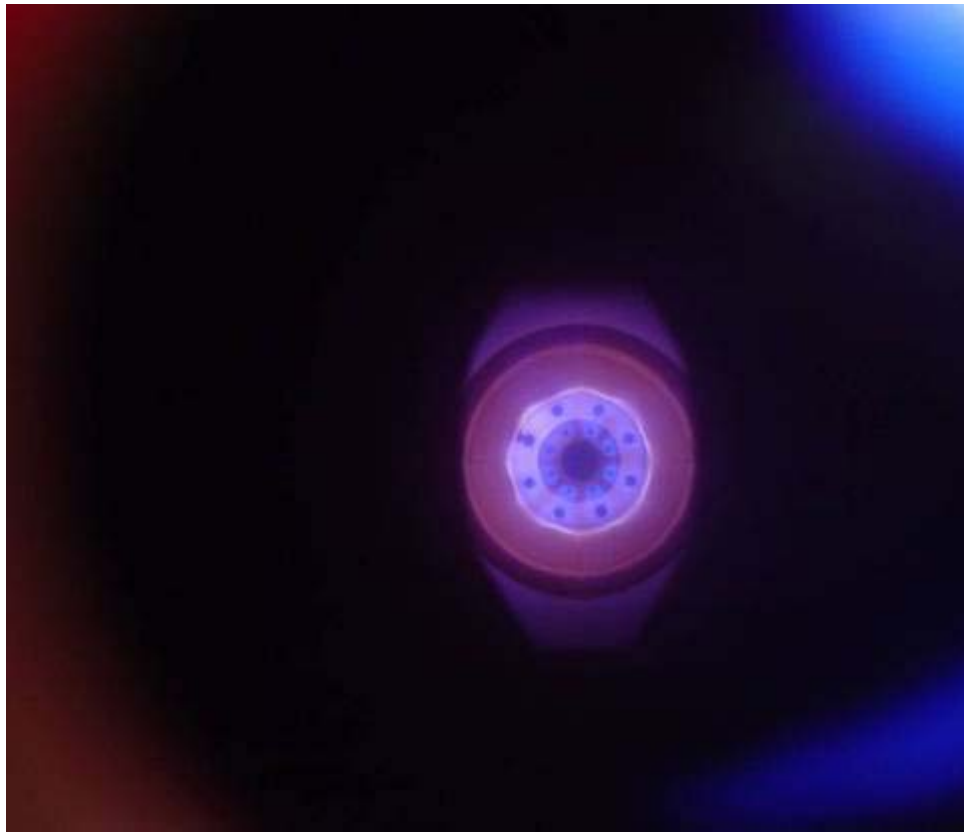
The basic properties for the comparison of thermal behavior are proximate and ultimate analyses

Representative Biomass & Black Liquor Compositions				
	Poplar	Corn Stover	Chicken Litter	Black Liquor
Proximate (wt% as received)				
Ash	1.16	4.75	18.65	52.01
Volatile Matter	81.99	75.96	58.21	35.26
Fixed Carbon	13.05	13.23	11.53	6.11
Moisture	4.80	6.06	11.61	9.61
HHV, Dry (Btu/lb)	8382	7782	6310	4971
Ultimate, wt% as received				
Carbon	47.05	43.98	32.00	32.12
Hydrogen	5.71	5.39	5.48	2.85
Nitrogen	0.22	0.62	6.64	0.24
Sulfur	0.05	0.10	0.96	4.79
Oxygen (by diff)	41.01	39.10	34.45	0.71
Chlorine	<0.01	0.25	1.14	0.07
Ash	1.16	4.75	19.33	51.91
Elemental Ash Analysis, wt% of fuel as received				
Si	0.05	1.20	0.82	<0.01
Fe	---	---	0.25	0.05
Al	0.02	0.05	0.14	<0.01
Na	0.02	0.01	0.77	8.65
K	0.04	1.08	2.72	0.82
Ca	0.39	0.29	2.79	0.05
Mg	0.08	0.18	0.87	<0.01
P	0.08	0.18	1.59	<0.01
As (ppm)			14	

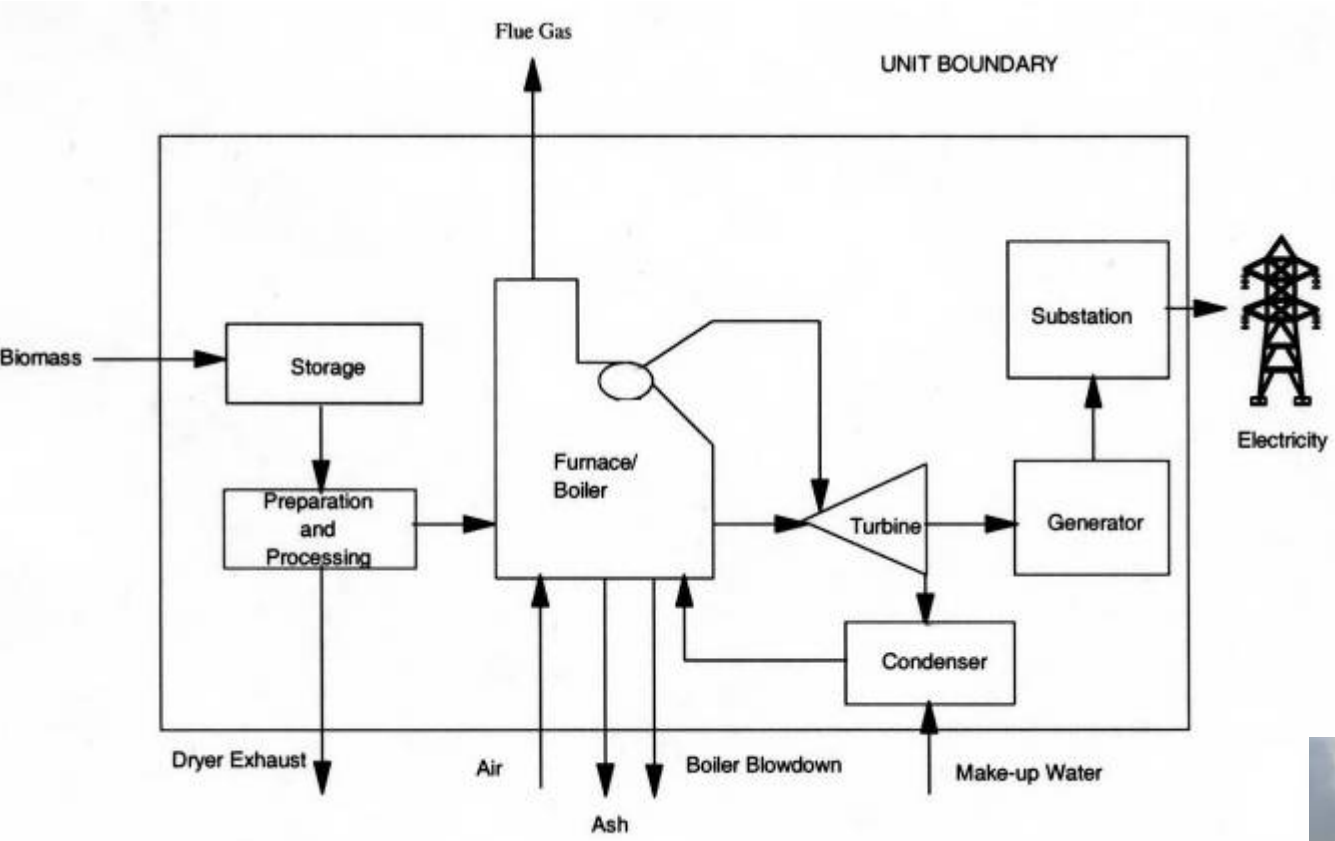
The heating value is important in estimating process efficiency



Combustion



Biomass combustion systems use combustion to generate steam that is used for heat and for electricity in a steam turbine (Rankine cycle)



Most commercial combustion boilers are traditional stoker grates, with some larger CFB systems in use

Biomass Systems Can Meet Regulatory Standards

	Units	Colorado Regulations	California	Typical AP-42 Emission Factors	ChipTec
Opacity	%	20			
PM	lb/MMBtu feed	0.275*		0.22 - 0.3	0.1-0.2
NOx	lb/MMBtu	NA	0.35	0.49	0.3
	ppmv@12% CO2		115 or 50% reduction		
SO2	lb/MMBtu feed	1.2		0.6	0.025
CO	ln/MMBtu feed	NA		0.06	0.3
Total Organic Compounds	lb/MMBtu	NA		0.025	0.06
Fugitive Dust					

* for 10 MMBtu/hr fuel

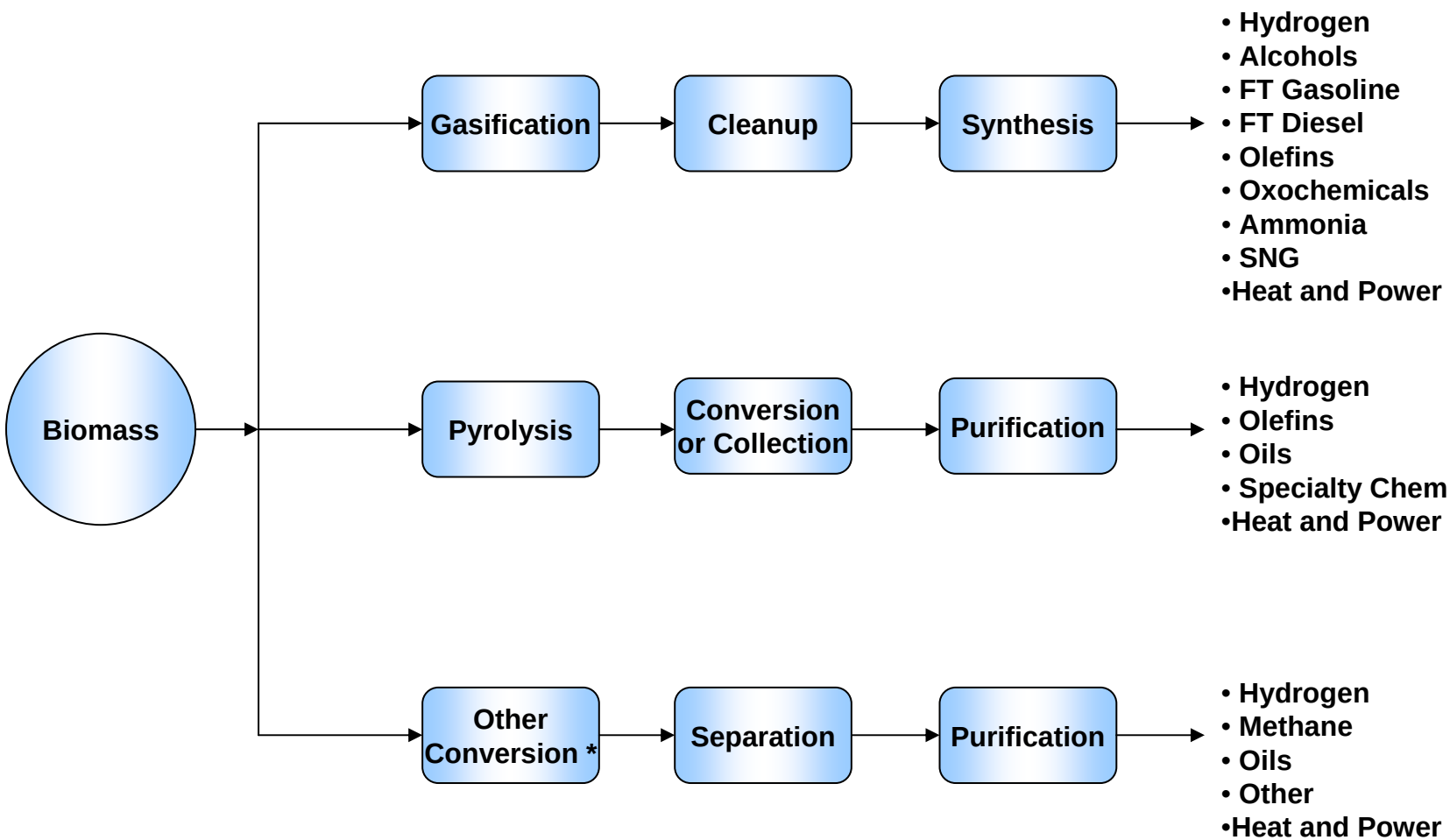
On site heating is a good application of biomass combustion

School heating system

Biomass Cost of Electricity

Year --- >	1990	2000	2010	2020
		(cents/kWh)		
Utility Scale and Large Distributed Power				
Cofiring (incremental)	NA	2 - 4	1 - 3	1 - 2
Direct-Fired Biomass	10 - 15	8 - 12	7 - 8	6 - 7
Gasification	NA	6 - 8	5 - 7	4 - 6
Small Modular - Distributed Generation				
Solid Biomass	NA	15 - 20	8 - 12	6 - 10
Biogas	NA	8 - 12	5 - 8	2 - 8

Fungible fuels & chemicals are major products, along with heat and power. New classes of products (e.g., oxygenated oils) require market development



* Examples: Hydrothermal Processing, Liquefaction, Wet Gasification

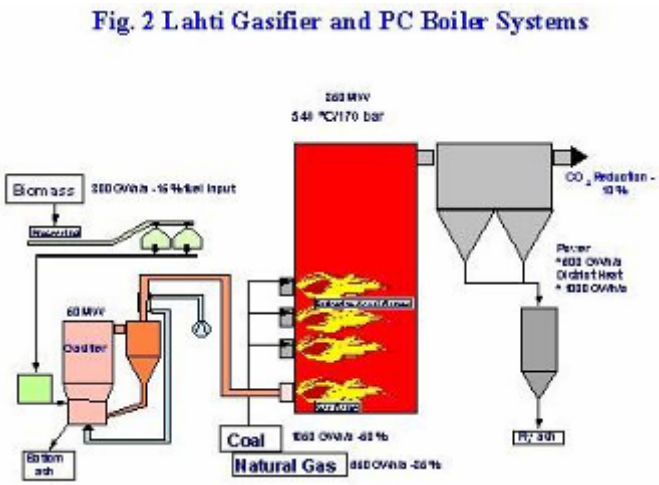
Primary thermochemical product distributions depend on processing conditions

	Liquid	Char	Gas
•FAST PYROLYSIS	75%	12%	13%
	•moderate temperature		
	•short residence time		
•CARBONIZATION	30%	35%	35%
	•low temperature		
	•long residence time		
•GASIFICATION	5%	10%	85%
	•high temperature		
	•long residence time		

There are a number of commercialization projects for biomass gasification

Commercial Biomass-to-Liquids Plant, Choren Industries, Freiberg Germany, 2007: 200 mt/d biomass, 2010: 2,000 mt/d biomass

300 ton/day gasifier Burlington Electric, VT

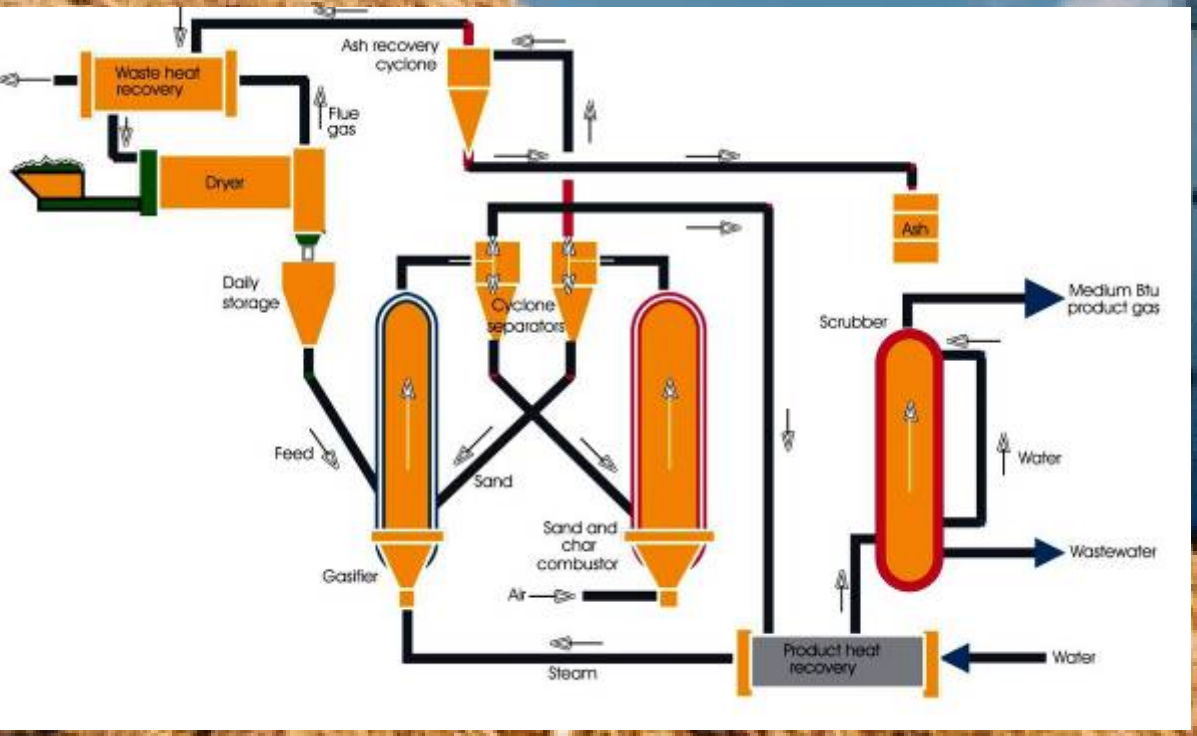


Foster Wheeler CFB Gasifier, Lahti Finland, 300 mt/d; 30,000 hours of operation at >95% availability

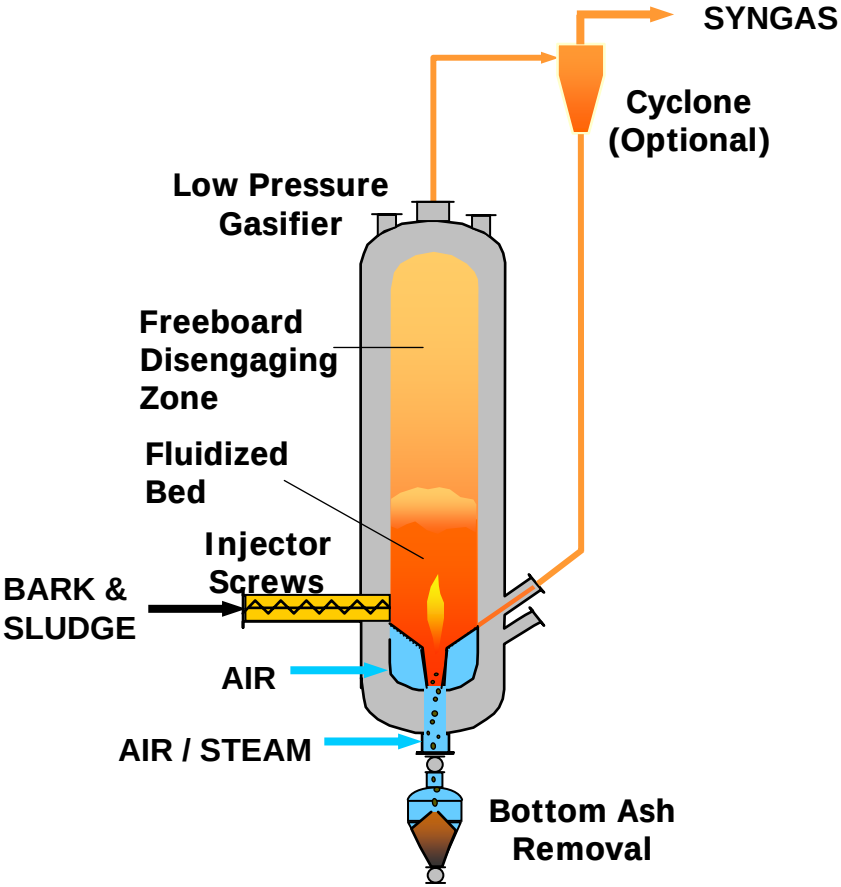
Varnamo Sweden, 100 mt/day, 6 MWe + 9 MWth demo run for 5 years, now being retrofitted for BTL

FERCO GASIFIER- BURLINGTON, VT

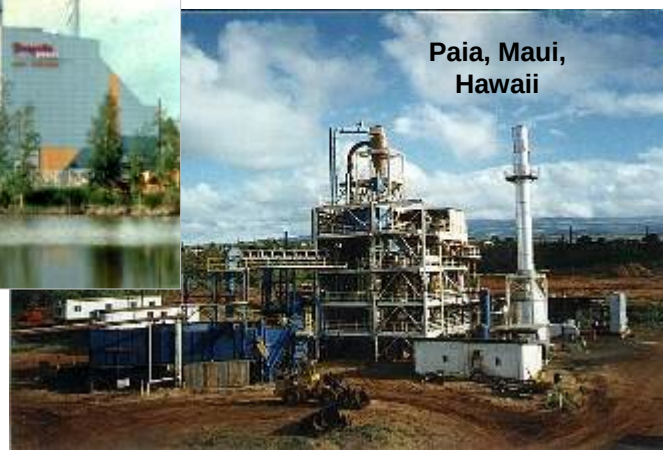
350 TPD



GTI RENUGAS Directly-Heated Single-Stage Pressurized, Steam-O_2 Fluid-Bed Gasifier

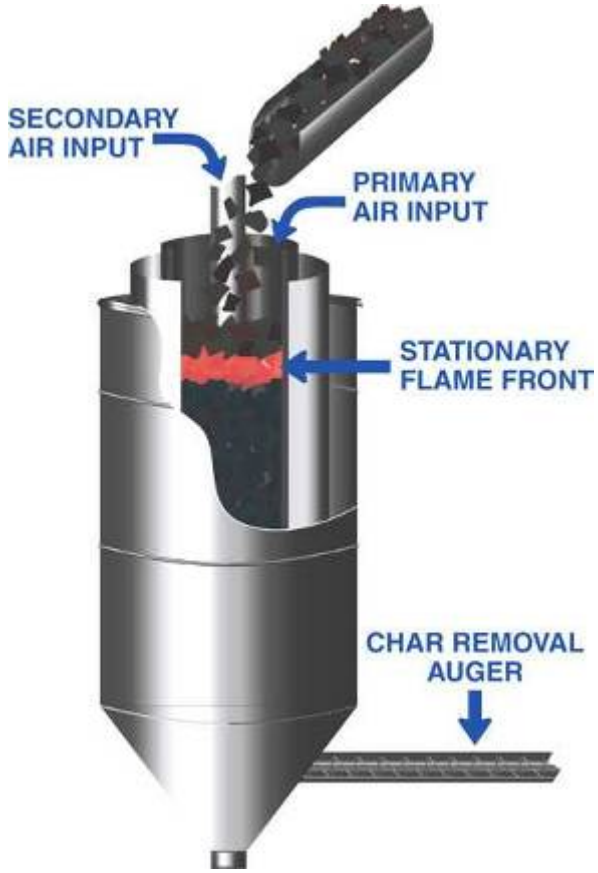


- Converts fossil, biomass and waste fuels to syngas
- Operates at Low or Elevated Pressures
- 95%$^+$ Carbon Conversion
- 75%$^+$ Cold Gas Thermal Efficiency



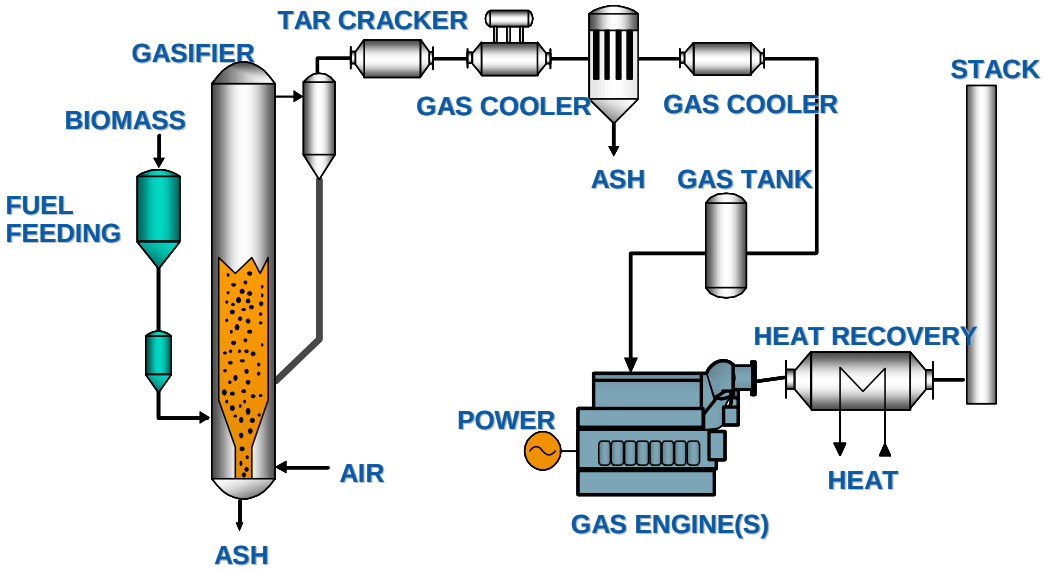
DOE and the USDA Forest Service have supported development Community Power Corporation's BioMax Modular Biopower System

5, 15, 50, 100 kW systems



Credit: Community Power Corp

DOE, the European Union, the Danish government, Skive Fjernvarme, and Carbona are cooperating in the 5MWe Carbona Project in Skive, Denmark

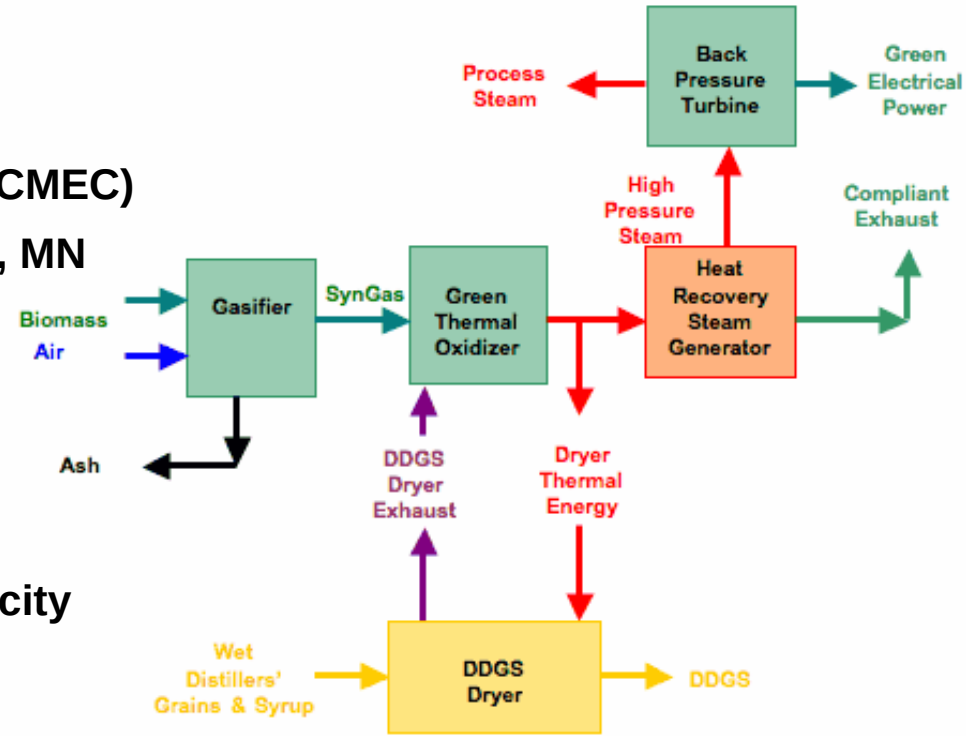


- 110 tpd wood pellets
- 5.4 MW electric power
- 11.5 MW thermal
- 30% elec LHV eff, 90% overall

Credit: Carbona Corp.

Producers are starting to use biomass gasifiers for CHP in corn ethanol facilities

- Central Minnesota Ethanol Cooperative (CMEC)
- 15million gpy ethanol plant in Little Falls, MN
- Funding – USDA, XCEL Energy, Private
- E&C – Sebesta Blomberg
- Gasifier – Primenergy
- 280 tpd wood
- 50 k-lb/hr high pressure steam for electricity
- 35 MMBtu/hr thermal energy



http://www.primenergy.com/Projects_detail_LittleFalls.htm 8/28/06

Pyrolysis is:

- thermal decomposition occurring in the absence of oxygen
- always the first step in combustion and gasification processes
- known as a technology for producing charcoal and chemicals for thousands years

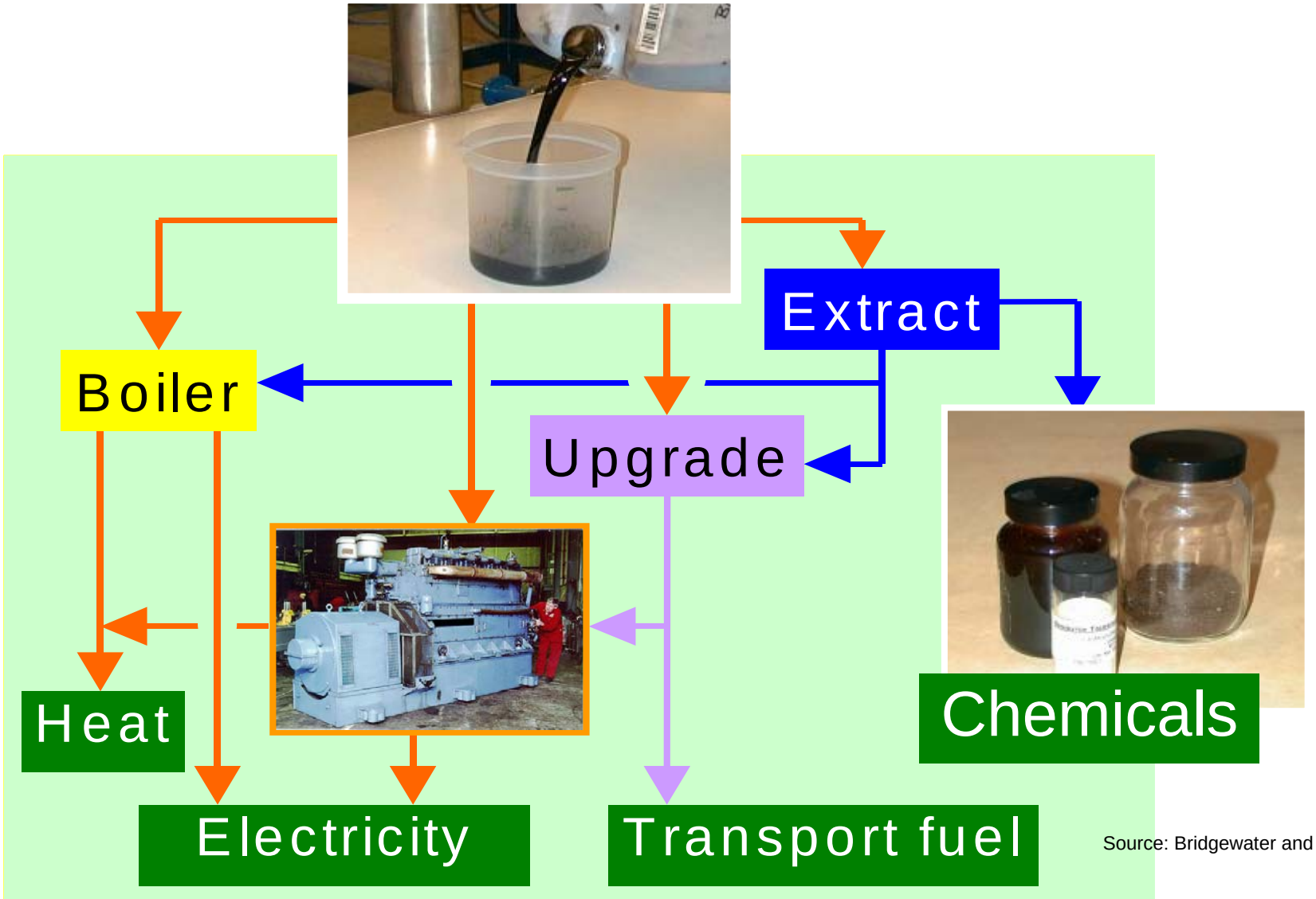
Biomass fast pyrolysis involves rapid heating and rapid cooling

- Fast pyrolysis is a process of rapid heating biomass (>1000°C/s) to a desired temperature (450-550°C) followed by rapid cooling of the volatile products that form in the reactor.

- Offers the advantage of producing a liquid that can be stored and transported for use as fuel or as a source of chemicals.

- At present is at early stage of commercialization (DynaMotive 50 t/day fuel bio-oil plant).

There are a number of applications for biocrudes



Source: Bridgewater and Czernik

There are a number of operating systems in North America and Europe

- Fluid beds 400 kg/h at DynaMotive
- 20 kg/h at RTI
- Many research units
- CFBs 1000 kg/h at Red Arrow (Ensyn)
- 20 kg/h at VTT (Ensyn)
- 350 kg/h (Fortum, Finland)
- Rotating cone 200 kg/h at BTG (Netherlands)
- Vacuum 3500 kg/h at Pyrovac
- Auger 200 kg/h at ROI

Source: Bridgewater and Czernik

Fast pyrolysis is being commercialized by a number of firms – including ENSYN and Dynamotive

Dynamotive Energy Systems Corp.

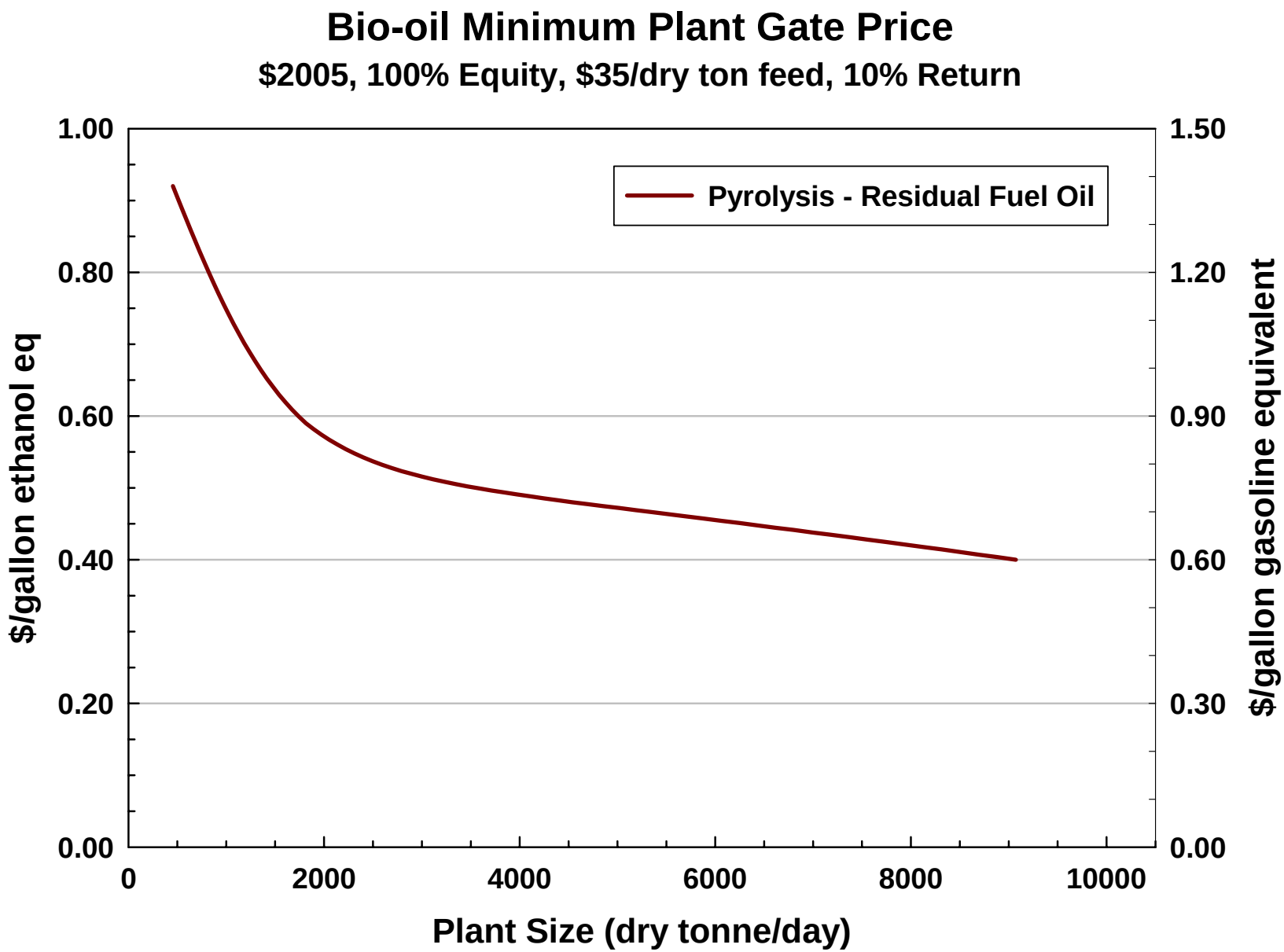
http://www.dynamotive.com

Fast Pyrolysis Process (Bubbling fluidized bed)

100 t/day plant in West Lorne, Ontario at Erie Flooring – operated for 267 days at up to 60% capacity; bio-oil was used to produce power using 2.5 MW Magellan turbine; currently being upgraded

200 t/day plant in Guelph, Ontario (commissioning)

The production of crude bio-oil is relatively inexpensive compared to processes making transportation fuels



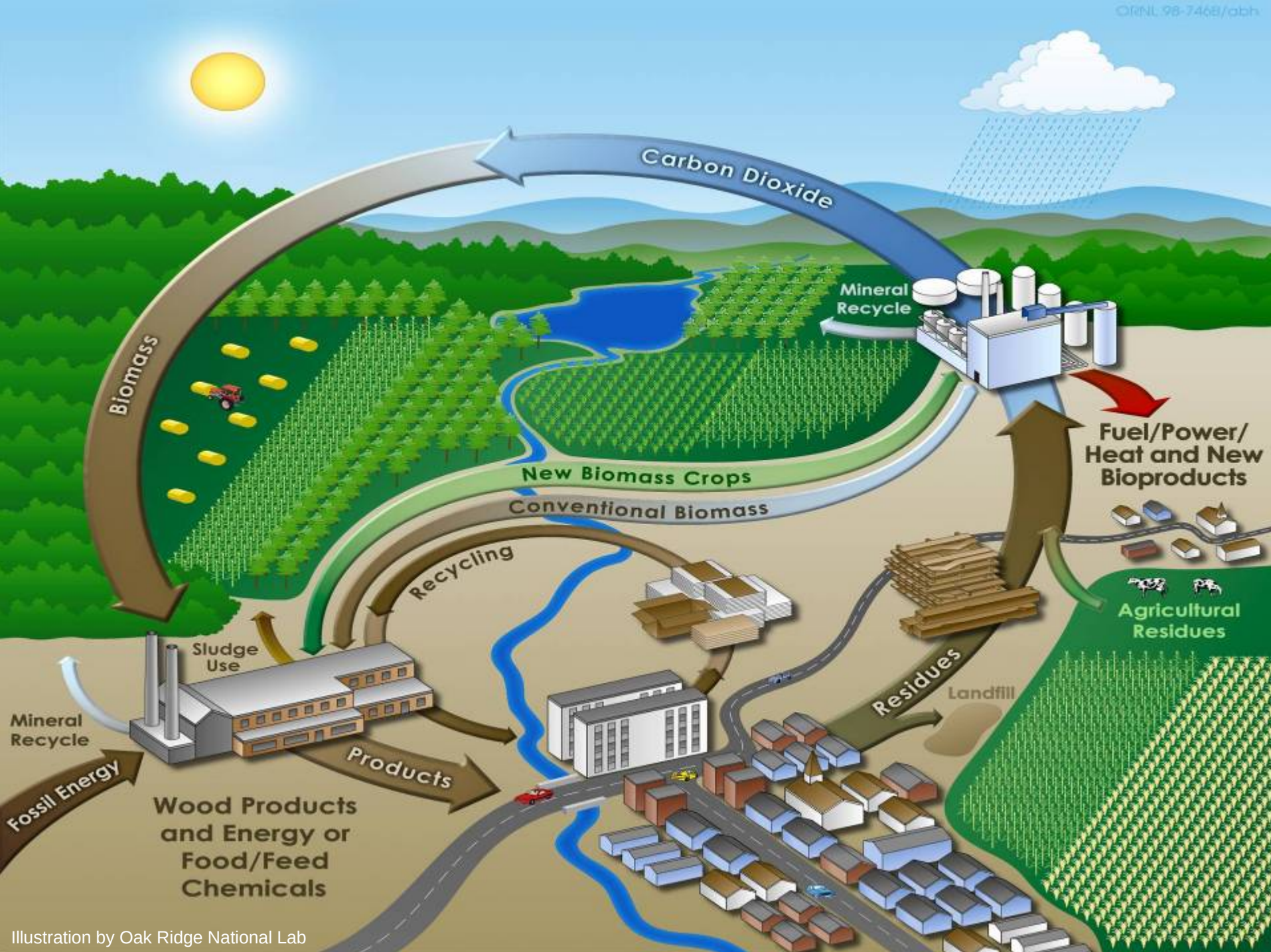


Illustration by Oak Ridge National Lab