Diversity of Biofuels

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Biofuels

Fuels Made from Biomass Resources

- Ethanol, Methanol, Butanol
- Biogas (Methane)
- Biodiesel
- Pyrolysis oil (Bio-oil)
- Synthesis gas (Syngas)

Converting Biomass to Biofuels

Three Conversion Processes:

- Biochemical
- Chemical
- Thermochemical

Biochemical Conversion

Biochemical - Fermentation

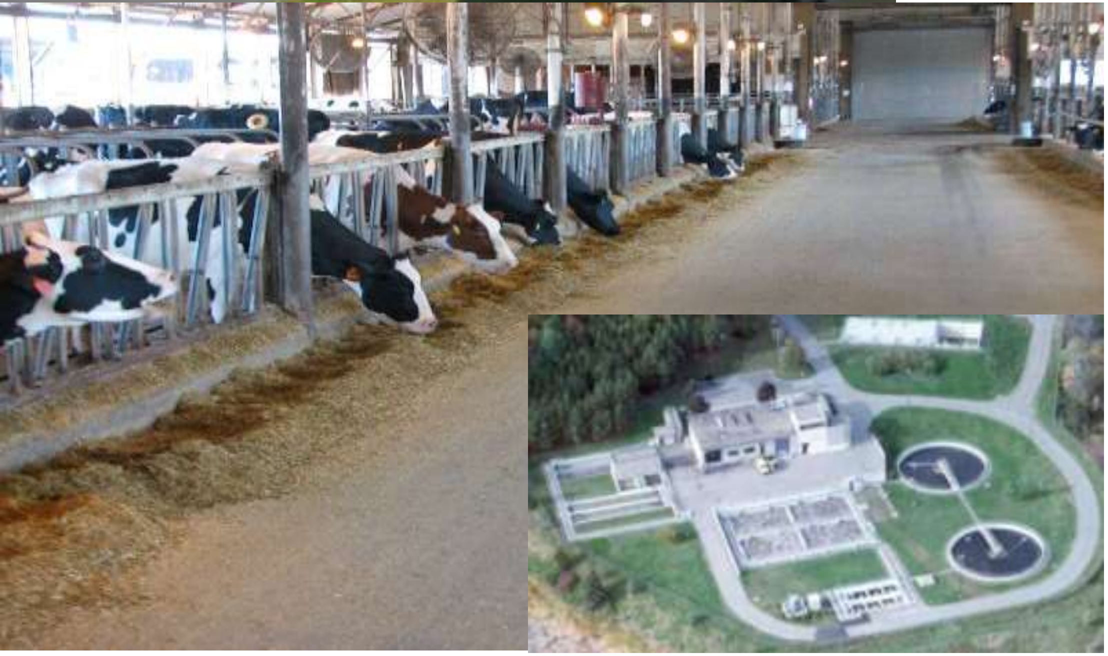
Aerobic Fermentation

- Common Feedstocks:
  - Starches, Sugars
- Coming Feedstocks:
  - Cellulose

VERY Familiar Product: Ethanol

Biochemical - Fermentation

Anaerobic Fermentation



Common Feedstocks:

- Animal Manures
- Municipal WTP Biosolids
- Industrial WW
- MSW Landfills

Not So-Familiar Product: Biogas (methane)

Anaerobic Fermentation

- Already Applicable at Farm-Scale
- Best Suited to Liquid Wastes
- Biogas Composition
  - Methane, CO_2
- Biogas Uses
  - Heat, Hot Water, Electricity
- Benefits
  - Odor Control
  - Energy
  - Conserves Nutrients
  - Reduces Greenhouse Gas Emissions

Chemical Conversion

Chemical - Biodiesel

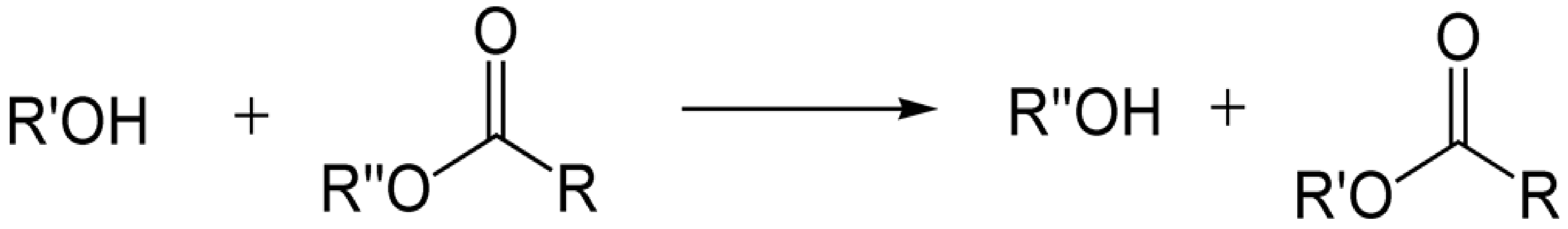
- **Biodiesel**: Fuel derived from vegetable oils or animal fats.
- Compatible with petroleum-based diesel
- Virtually every diesel engine can use biodiesel fuel mixes
- Reduced emissions

Chemical - Biodiesel

- Plant sources
  - Soybean, palm, olive, rape, sunflower, etc.
  - Algae
- Animal sources
  - Tallow, lard, poultry fat, etc.
- Mixed sources
  - Recycled from food processing, restaurants, wastewater and sludges, grease traps

Chemical - Biodiesel

- Produced by a chemical process called *transesterification* where the glycerin is separated from the fat or vegetable oil.
- The process leaves behind two products
  - methyl esters (the chemical name for biodiesel)
  - glycerin (a valuable byproduct usually sold to be used in soaps and other products).



Thermochemical Conversion

Possible Benefits of Thermochemical Conversion

- Significantly lower energy input requirements [net energy production]
- May be commercially viable (at current petroleum prices) w/o subsidies
- Can produce high-energy density fuels
- Can utilize existing fuel-refining and fuel-distribution infrastructure

Possible Benefits of Thermochemical Conversion

- May convert low-energy-density [Btu/ft^3] biomass to high-energy-density pyrolysis oil at or near the farm
  - reducing collection/transportation costs
  - strengthening the rural economy

- Can use a variety of feedstocks, including agricultural residues, dedicated energy crops, woody material, mixed biomass streams, municipal solid waste

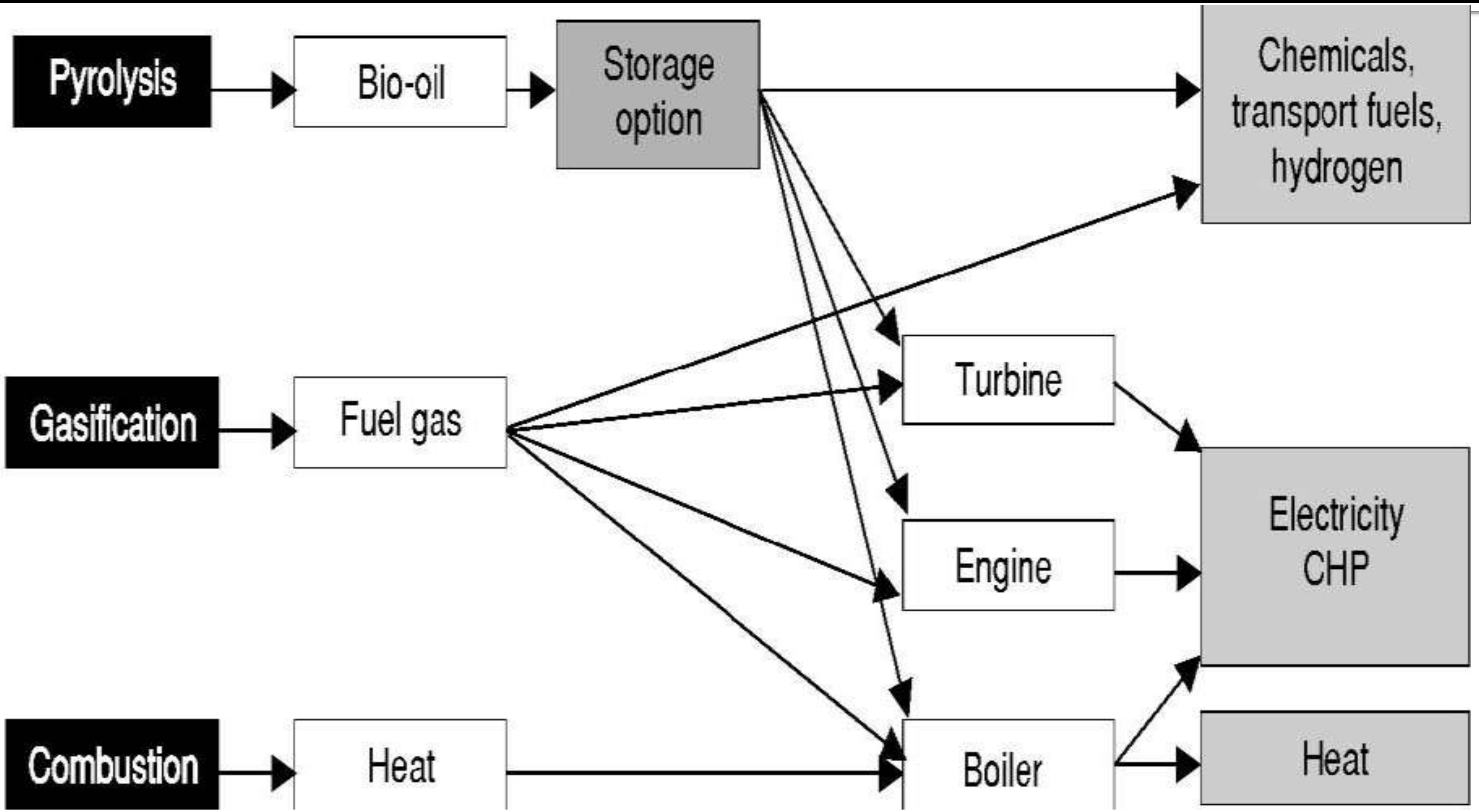
Thermochemical Processes

- **Combustion**
  - Burning by direct heat
  - Stoichiometric to excess oxygen
  - Products are hot gases, CO_2 and H_2O
- **Gasification**
  - Thermal degradation by heat
  - Limited oxygen
  - Products are predominantly H_2 and CO

Thermochemical Processes

- **Pyrolysis**
  - Thermal degradation by heat
  - No oxygen
  - Three products: permanent gases, BioOil, Char
- **Hydrothermal Liquefaction**

Pathways of thermal conversion



Bridgewater, A.V. 2004. Thermal Science, 8(2):21-49

Gasification

History of Gasification

Town Gas

Town gas is a gaseous product manufactured from coal.

- First practical use of town gas in modern times was for street lighting
- The first public street lighting with gas took place in Pall Mall, London on January 28, 1807

- **Baltimore, Maryland began the first commercial gas lighting of residences, streets, and businesses in 1816**

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Gasification Chemistry

Gasification with Oxygen

$$C + {}^{1}/_{2}\, O_2 \longleftrightarrow CO$$

Combustion with Oxygen

$$C + O_2 \longleftrightarrow CO_2$$

Gasification with Carbon Dioxide

$$C + CO_2 \longleftrightarrow 2CO$$

Gasification with Steam

$$C + H_2O \longleftrightarrow CO + H_2$$

Gasification with Hydrogen

$$C + 2H_2 \longleftrightarrow CH_4$$

Water-Gas Shift

$$CO + H_2O \longleftrightarrow H_2 + CO_2$$

Methanation

$$CO + 3H_2 \longleftrightarrow CH_4 + H_2O$$

Gasifier Gas Composition (Vol %)

H_2	25 - 30
CO	30 - 60
CO_2	5 - 15
H_2O	2 - 30
CH_4	0 - 5
H_2S	0.2 - 1
COS	0 - 0.1
N_2	0.5 - 4
Ar	0.2 - 1
NH_3 + HCN	0 -0.3

Ash/Slag/PM

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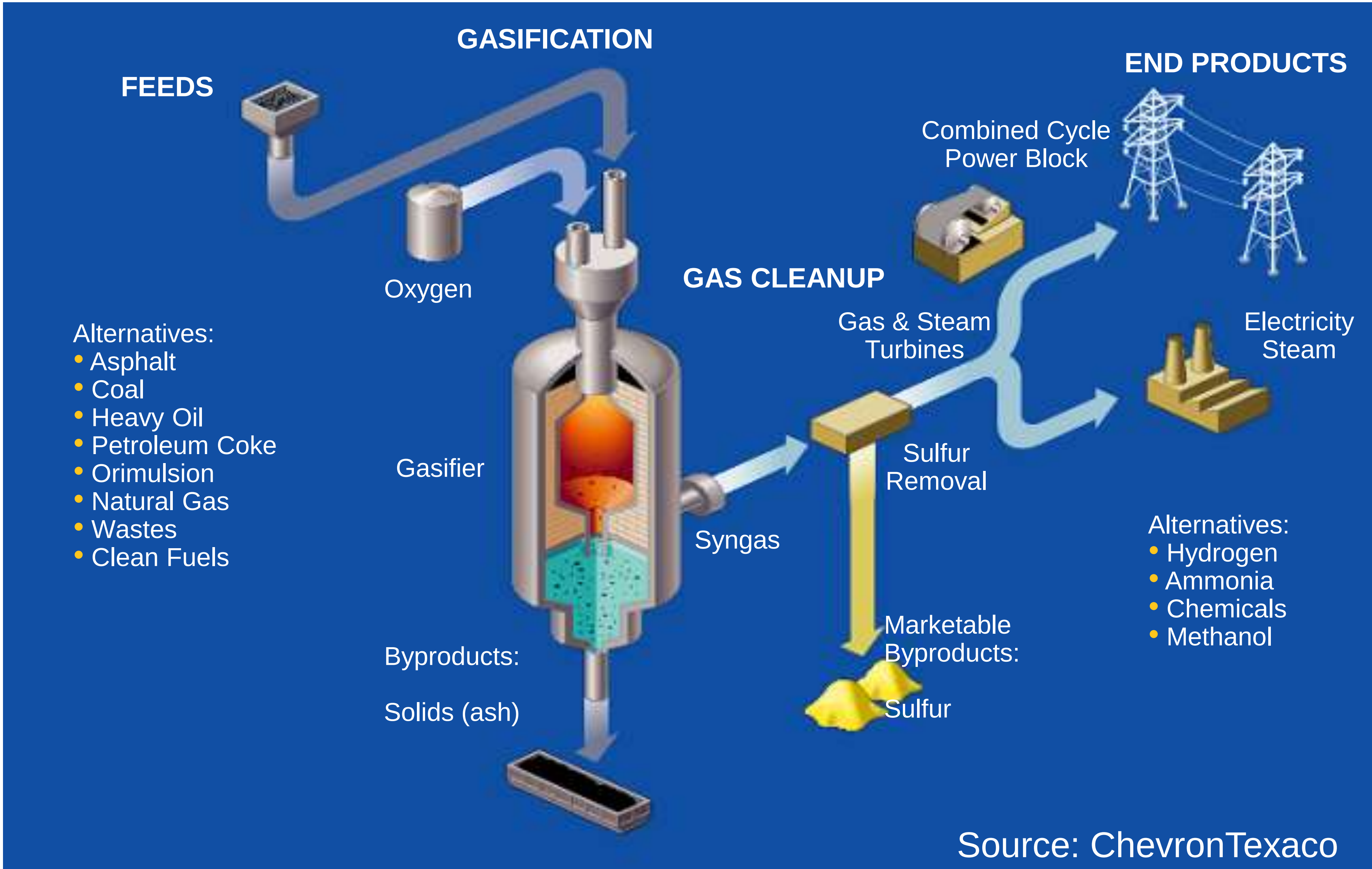
Characteristics of a Gasification Process



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Gasifier Characteristic Comparison

	Moving Bed		Fluidized Bed		Entrained Flow	Transport Flow
Ash Cond.	Dry	Slagging	Dry	Agglomerate	Slagging	Dry
Coal Feed	~2in	~2in	~1/4 in	~1/4 in	~ 100 Mesh	~1/16in
Fines	Limited	Better than dry ash	Good	Better	Unlimited	Better
Rank	Low	High	Low	Any	Any	Any
Gas Temp. (°F)	800-1,200	800-1,200	1,700-1,900	1,700-1,900	>2,300	1,500-1,900
Oxidant Req.	Low	Low	Moderate	Moderate	Low	Moderate
Steam Req.	High	Low	Moderate	Moderate	Low	Moderate
Issues	Fines and Hydrocarbon liquids		Carbon Conversion		Raw gas cooling	Control carbon inventory and carryover

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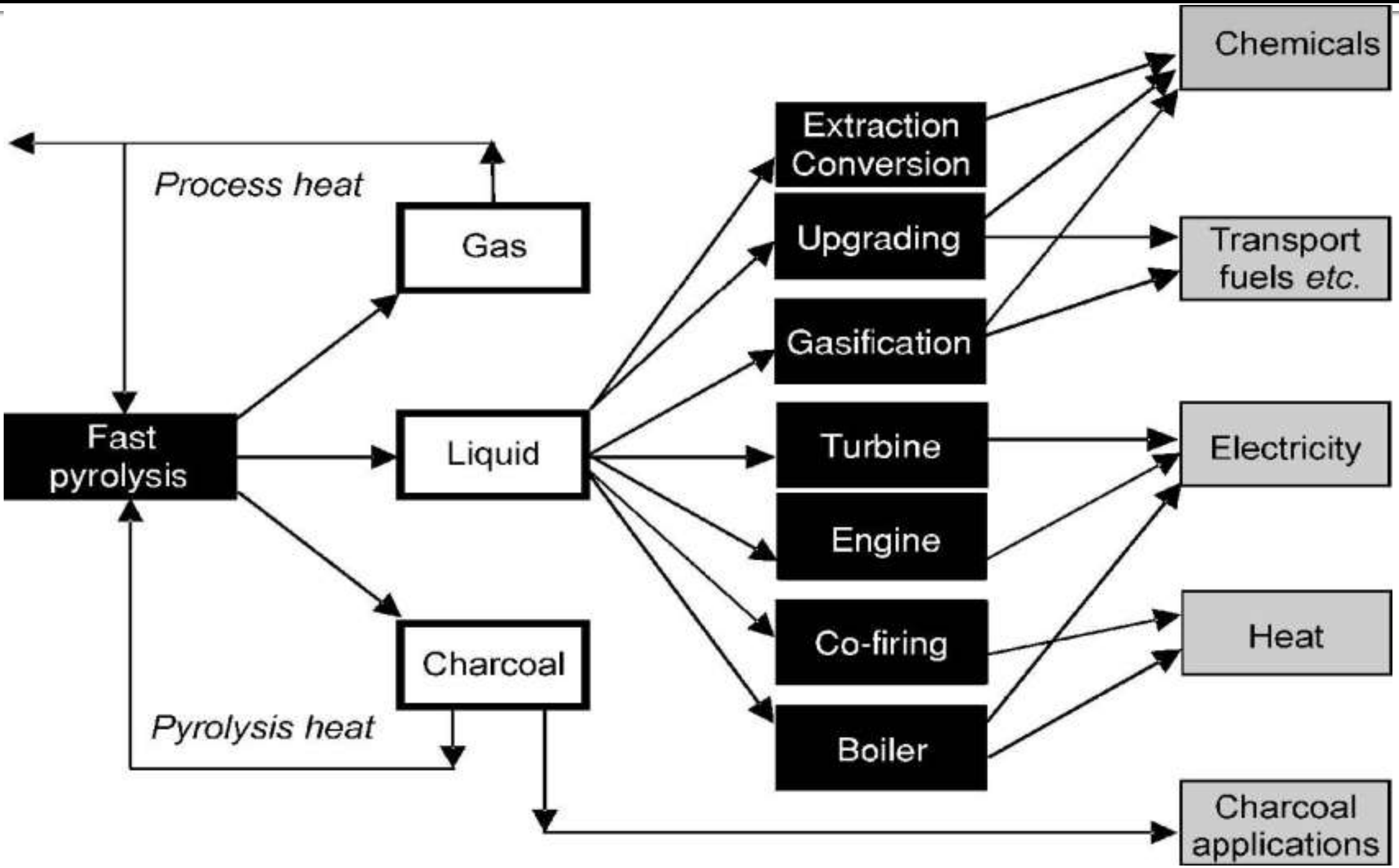
Pyrolysis

Potential from fast pyrolysis



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Pyrolysis products: BioOil and Char

Land Application of Char

K. C. Das, UGA BAE Dept.

BioOil

K. C. Das, UGA BAE Dept.

Pyrolysis Oil (BioOil) Properties

Property	Value
Water content	20 to 30 %
pH	2.5
Oxygen content	37 to 48 %
Specific gravity	1.2
HHV	22.5 MJ/kg

Bridgewater et al., 1999. Organic Geochemistry, 30, 1479-1493

Eprida-UGA Pilot Pyrolysis Unit with Steam Reforming
Feed Capacity = 50 kg/hr

K. C. Das, UGA BAE Dept.

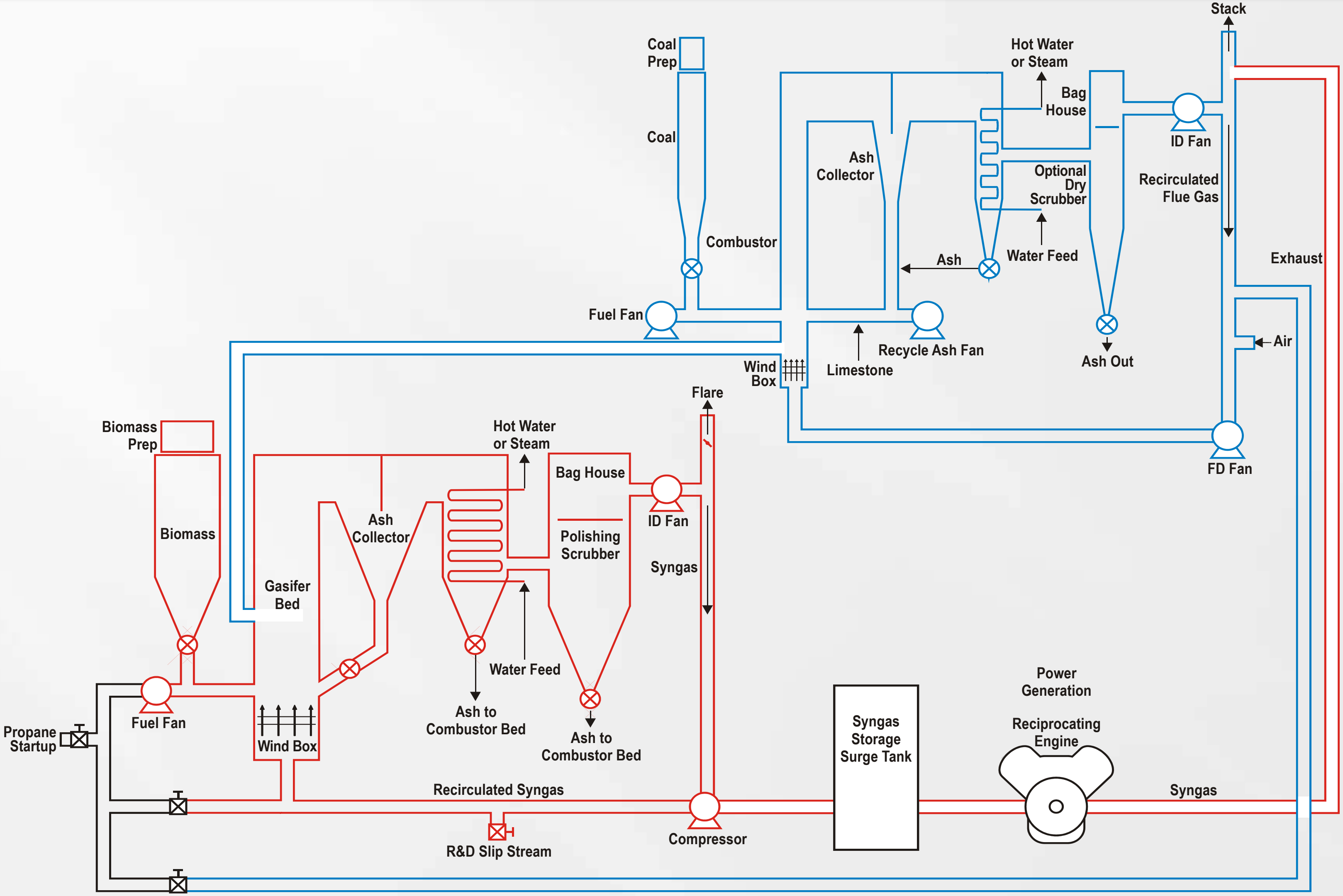
Beltsville Bioenergy Activities

Hybrid Gasifier

- Cooperative project between ARS-BARC and DOE-NETL
- Feasibility study in progress
- Original goal: supply up to 20% of BARC energy needs
  - 1-2 MW
  - Approximate scale for application at rural-urban interface
  - Utilize "Opportunity Fuels"

- Hybrid biomass and coal feed
  - Research: syngas composition, materials handling, pyrolysis, biomass drying and heat recycle, CO_2 capture and reuse for algal production, ash as soil amendment
  - May include pyrolysis unit

Hybrid Gasification Diagram



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Other Bioenergy Activities

- Biodiesel process QA/QC [Schmidt]
- Biodiesel from poultry fat [Schmidt]
- Bio-based substitutes for petroleum products [Schmidt]
- Heat and CO_2 recycle from composting [Milner]

- Development of new multi-use crops [Devine]
- Biomass crops: nutrient sinks, water quality protection, new sources of revenue [Smith, Codling, & UMD cooperators]
- Biogas production from dairy manure; co-digestion with food wastes and other biomass [Smith]

Bioenergy at other ARS Locations

See web site for ARS National Program 307: Bioenergy and Energy Alternatives

http://www.ars.usda.gov/research/programs/programs.htm?NP_CODE=307

~~Summary~~ Soapbox

- Replacing fossil fuels will require multiple alternative sources: bioenergy, solar, wind, geothermal, etc.
- Each should be used at appropriate locations and scales
- Our greatest source of “renewable” energy is reducing demand…

Thanks for Your Attention

Questions?

Easy ones preferred…