NREL
National Renewable Energy Laboratory

Biomass Resources and Technology Options

2003 Tribal Energy Program

Project Review Meeting

Golden, CO

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Operated for the U.S. Department of Energy by Midwest Research Institute • Battelle • Bechtel

Outline

Biomass

Technologies and Products

Economics

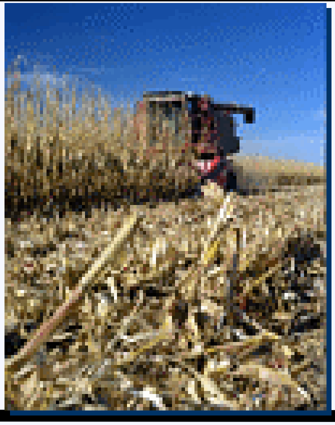
Future Trends

Biomass is the only renewable resource that causes problems when it is NOT used!

Hog farm lagoon

Biomass Feedstocks

Wood Residues



Agricultural Residues

Energy Crops

Sawdust
Wood chips
Wood waste
- pallets
- crate discards
- wood yard trimmings

Corn stover
Rice hulls
Sugarcane bagasse
Animal biosolids

Hybrid poplar
Switchgrass
Willow

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Biomass Properties

Source	Sawdust	Poultry Litter	Willow	Switchgrass
Carbon, % AR	24.17	27.22	44.07	44.70
Hydrogen	2.75	3.72	5.29	5.57
Oxygen (diff)	18.25	23.10	39.21	36.98
Nitrogen	0.22	2.69	0.32	0.29
Sulfur	0.02	0.33	0.03	0.05
Chlorine	--	0.71	--	0.08
Ash	1.96	15.70	0.85	4.53
Selected Ash Components				
SiO_2, % of ash	35.6	8.10	8.08	68.18
Na_2O	1.71	9.20	2.47	0.20
K_2O	5.75	16.30	13.20	8.38
P_2O_5	1.90	24.40	10.04	5.30
SO_3	0.78	6.70	1.15	1.81
CaO	24.90	17.30	45.62	6.51
Moisture, %	52.63	27.4	10.23	7.88
HHV A.R., Btu/lb	4,150	4,637	7,478	7,370
HHV Dry	8,760	6,394	8,330	8,000

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Biomass Constituents

Lignin: 15-25%

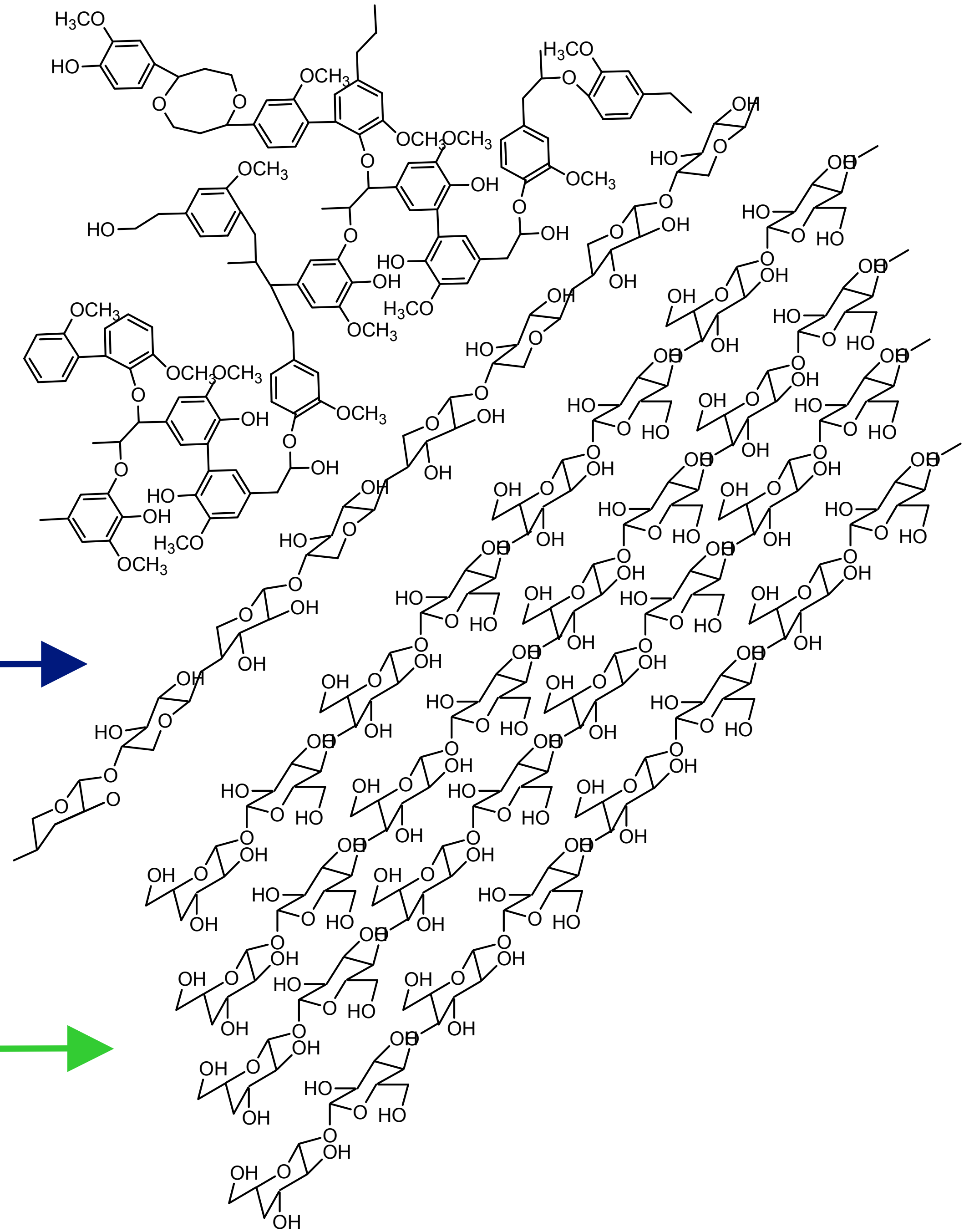
- Complex aromatic structure
- Very high energy content

Hemicellulose: 23-32%

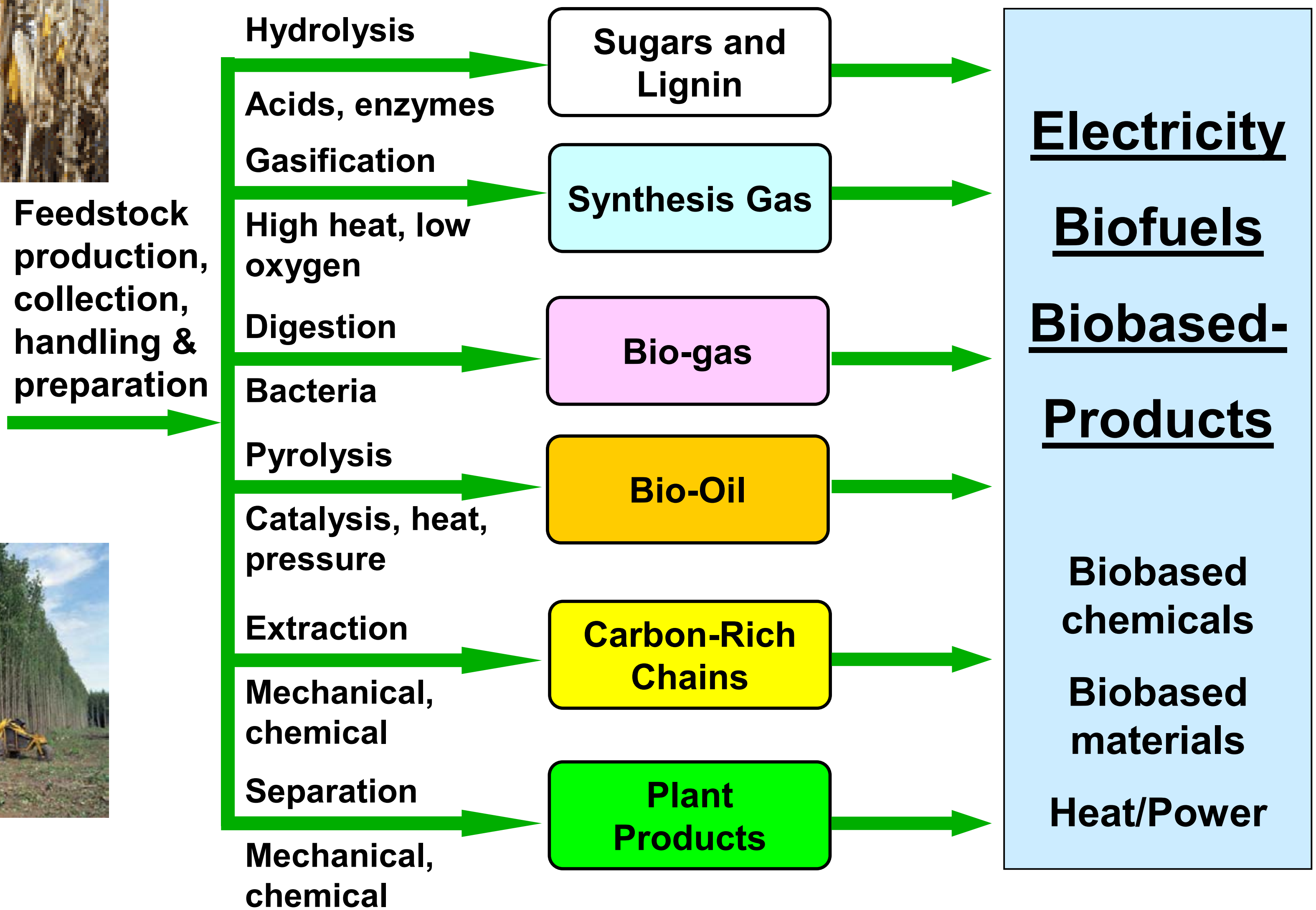
- Polymer of 5 & 6 carbon sugar

Cellulose: 38-50%

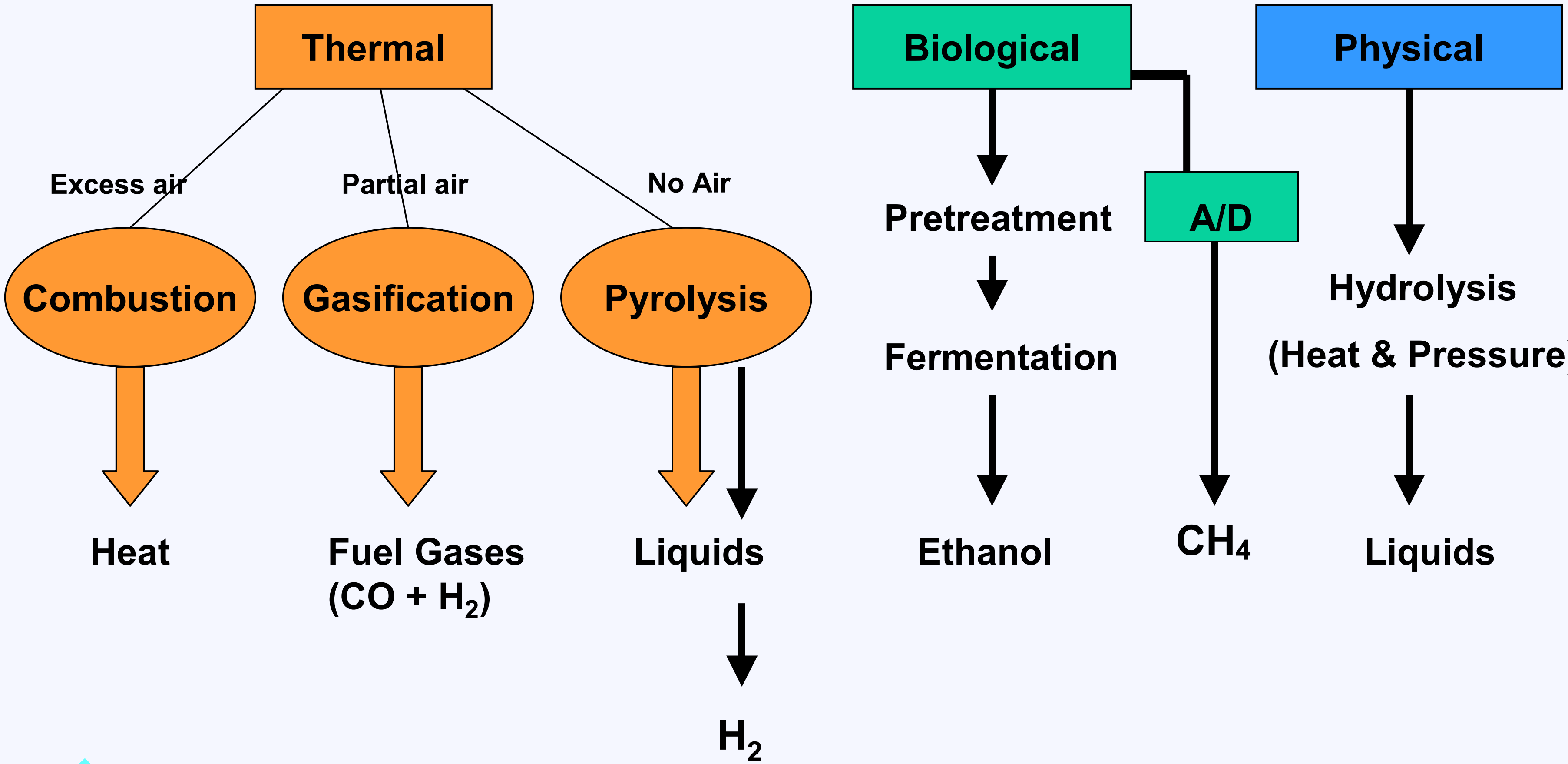
- Polymer of glucose, very good biochemical feedstock



Integrated Biomass Options



Biomass Energy Pathways



Ethanol from Biomass

Existing Industry:

- ~2 Billion gallons/year from starch containing grains

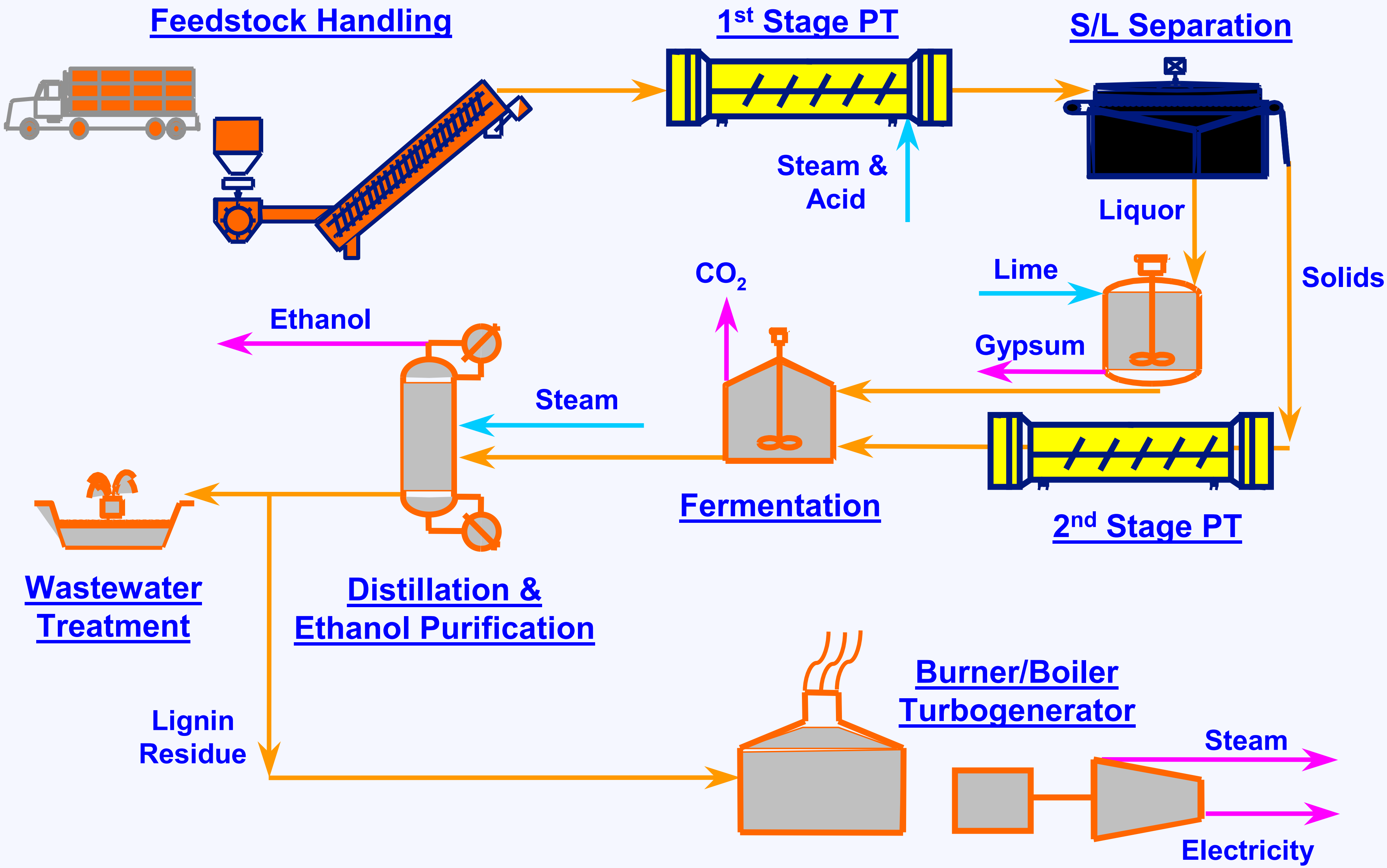
Future Industry:

Ethanol from Lignocellulosics

- Agricultural residues
- Woody biomass

Biological or thermochemical conversion paths

Conceptual Process Design

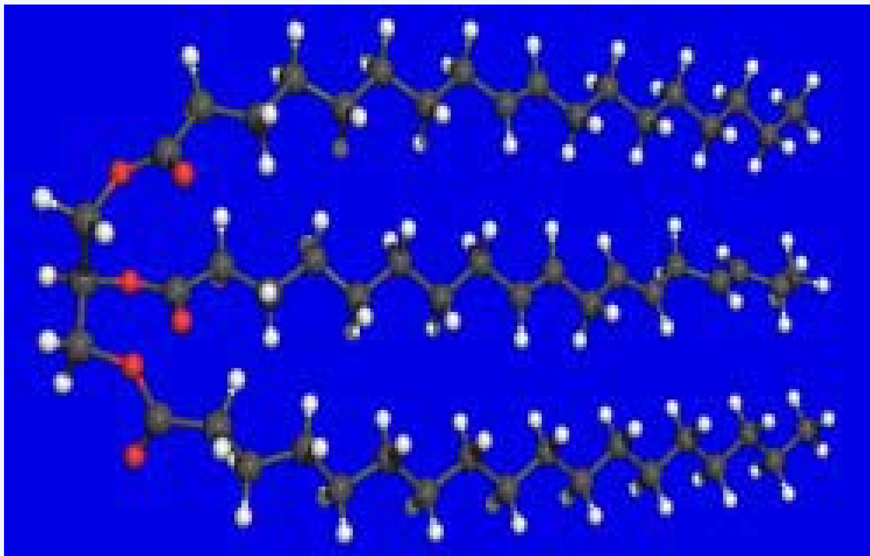


For more information, see Wooley, et. al *"Lignocellulosic Biomass to Ethanol Process Design and Economics…"* NREL/TP-580-2615 July, 1999

Biodiesel

Griffin Industries, USA and
Bruck Industries, Austria

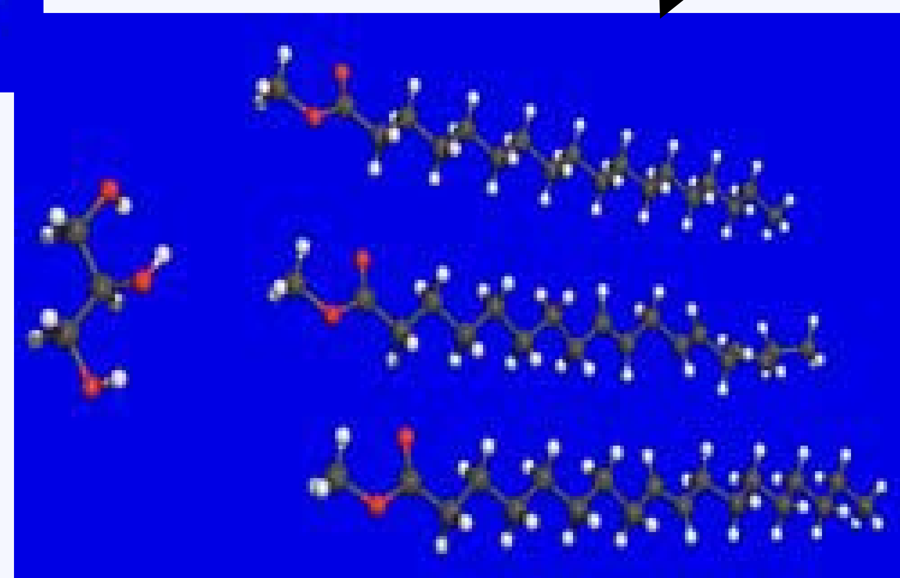
Biodiesel Chemistry



Fat or Oil molecule

Biodiesel molecules

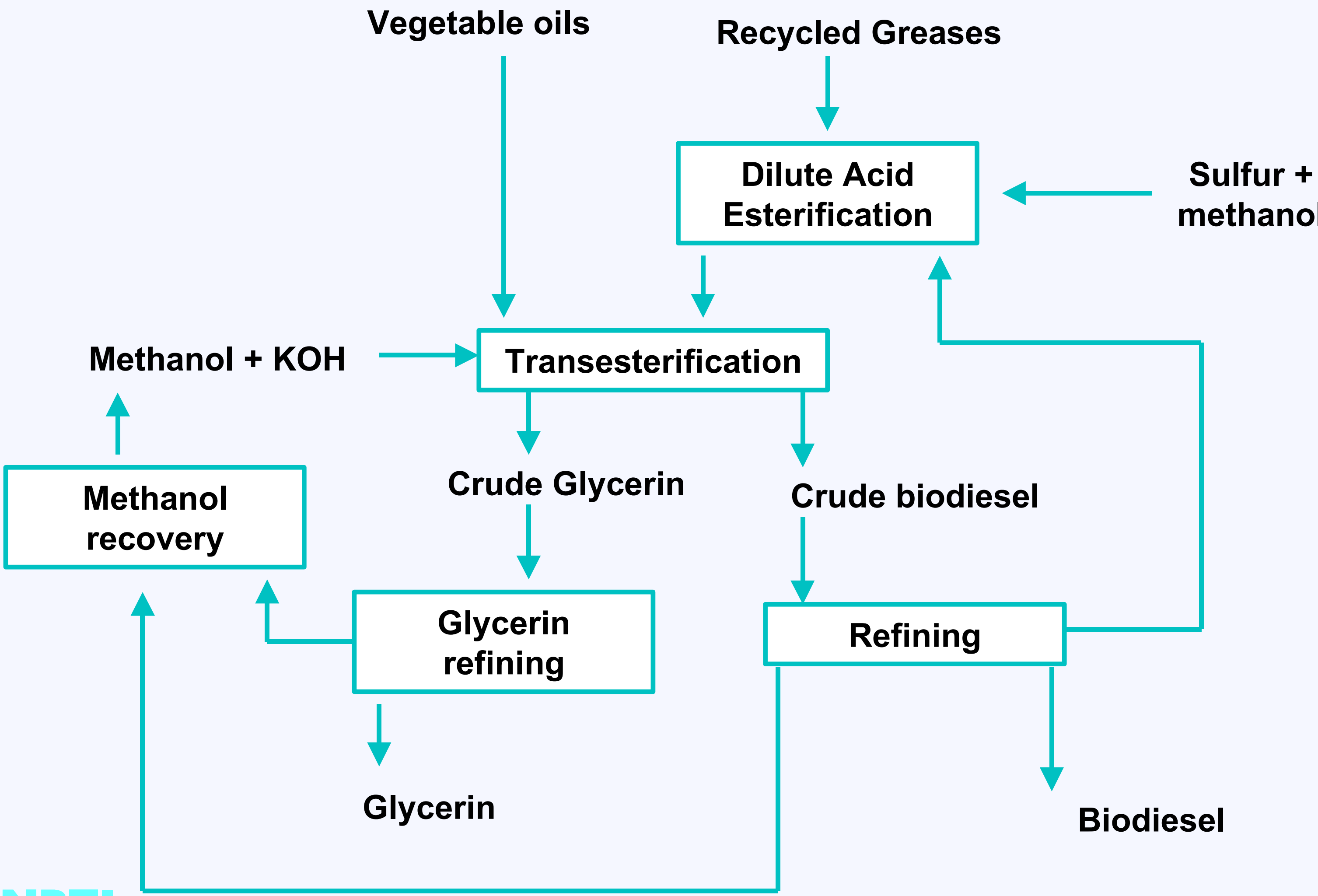
Glycerin molecule



Pictures provided by

Campa® als Kraftstoff

Basic Technology



Domestic Resources

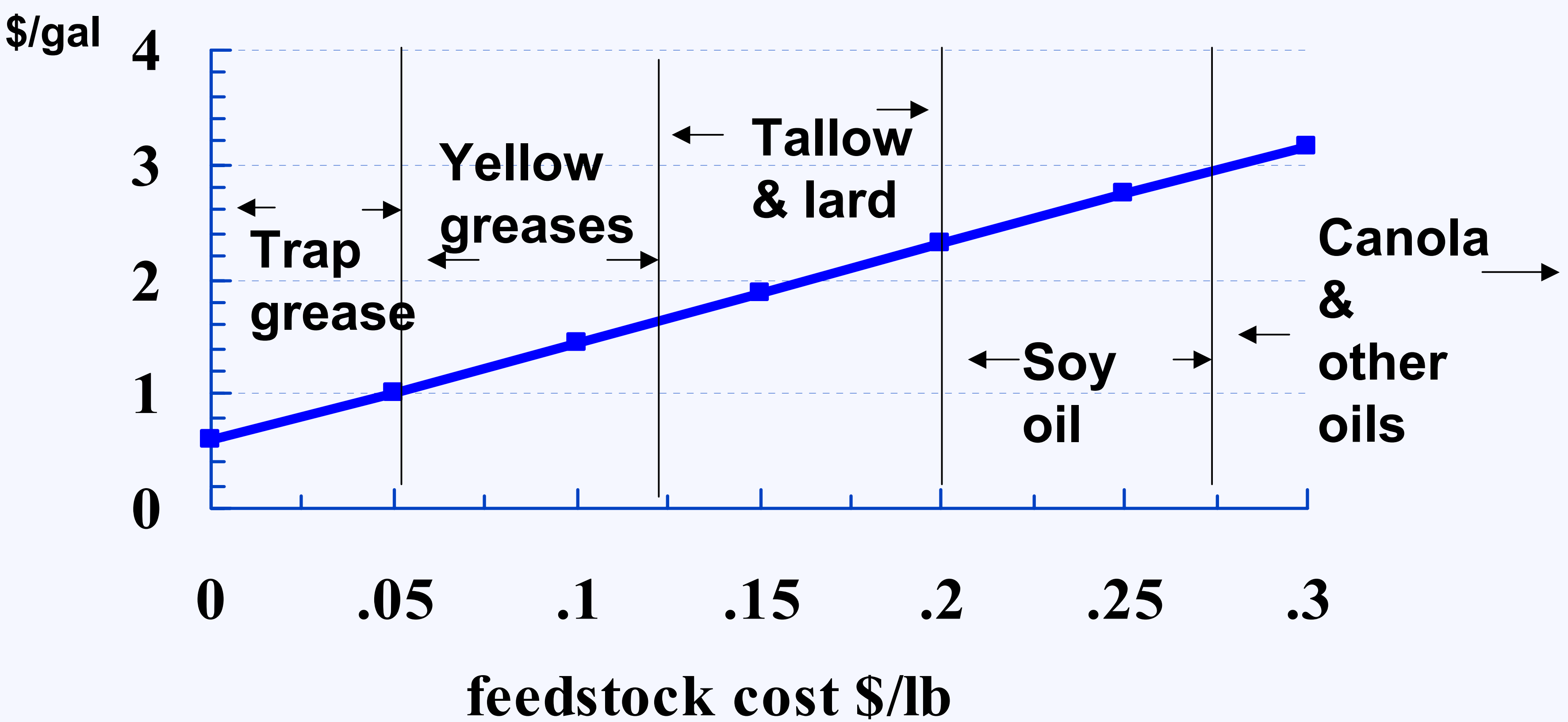
- Food Grade Cooking oils
  - soy, rape, canola, palm, peanut, olive, sunflower, ….

$$$$

- Off quality and rancid vegetable oils
- Animal fats
  - Lard, tallow, chicken fat, fish oils, ……
- Used cooking oils from restaurants
- Waste oils
  - trap and sewage greases

$

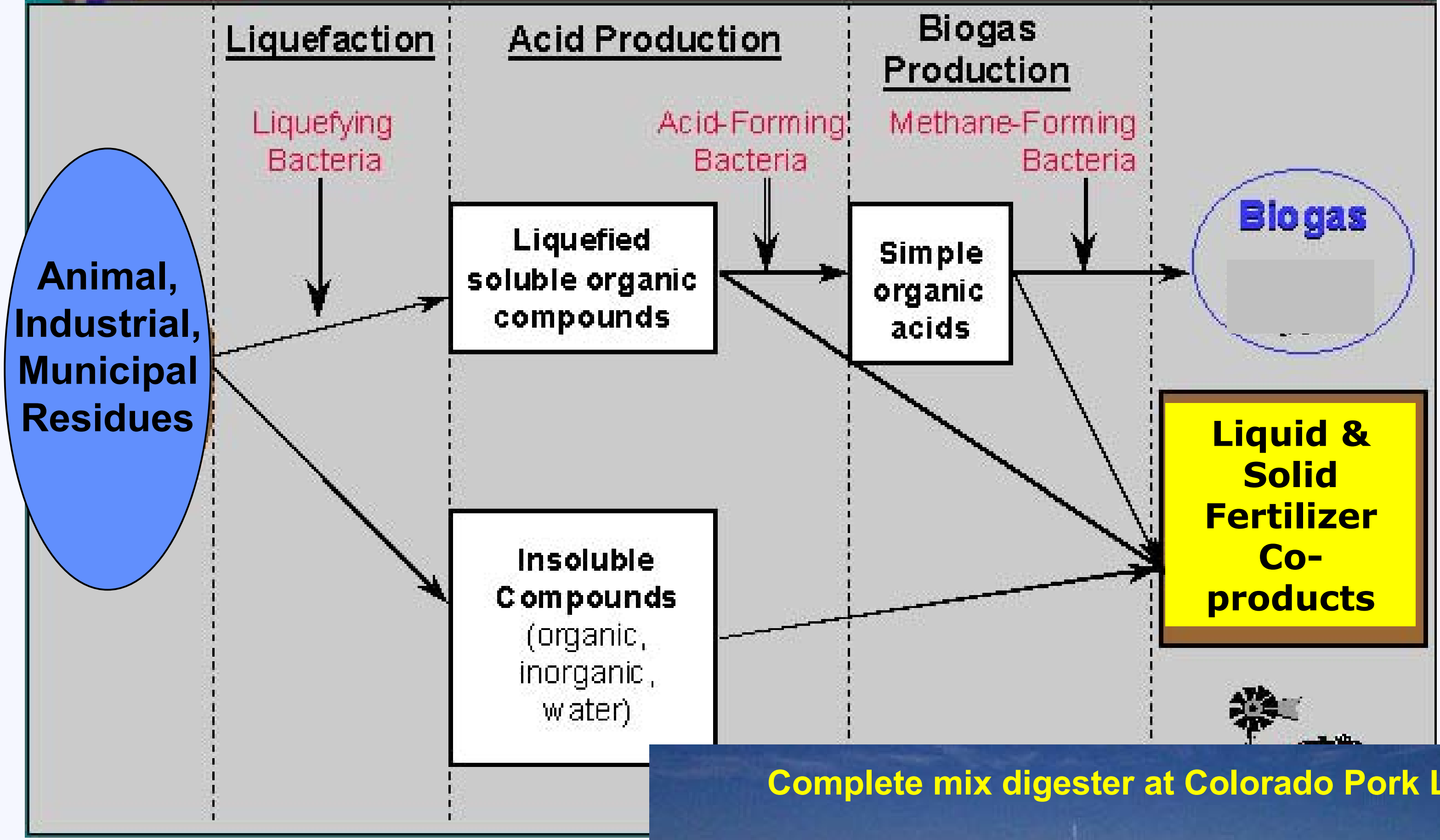
Production Cost per Gallon Biodiesel



3 mil gal/yr plant, 80% glycerin. Total cost at plant gate.

Does not include transportation and handling.

Anaerobic Digestion Process



Status of Anaerobic Digestion (AD) implementation

"Commercial – water treatment "

Food Processing Industry
Pharmaceutical
Brewery
Distillery
Amino Acid Production
Municipal Sewage

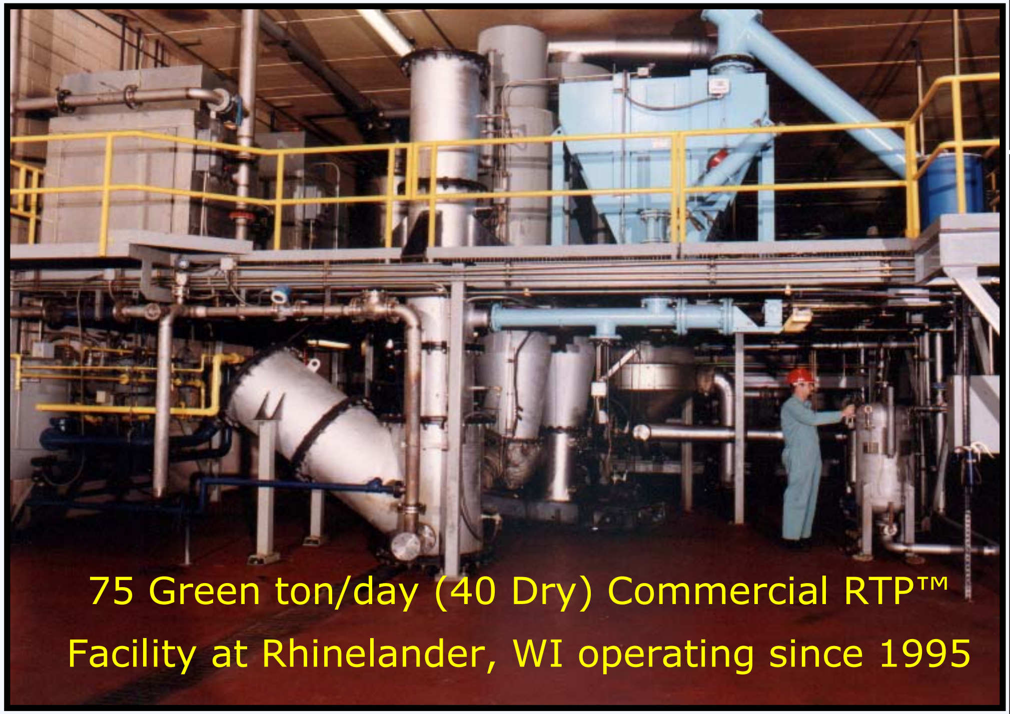
Denmark –Integrated Urban Residue and Concentrated Animal Feeding Operations (CAFO) 19 plants

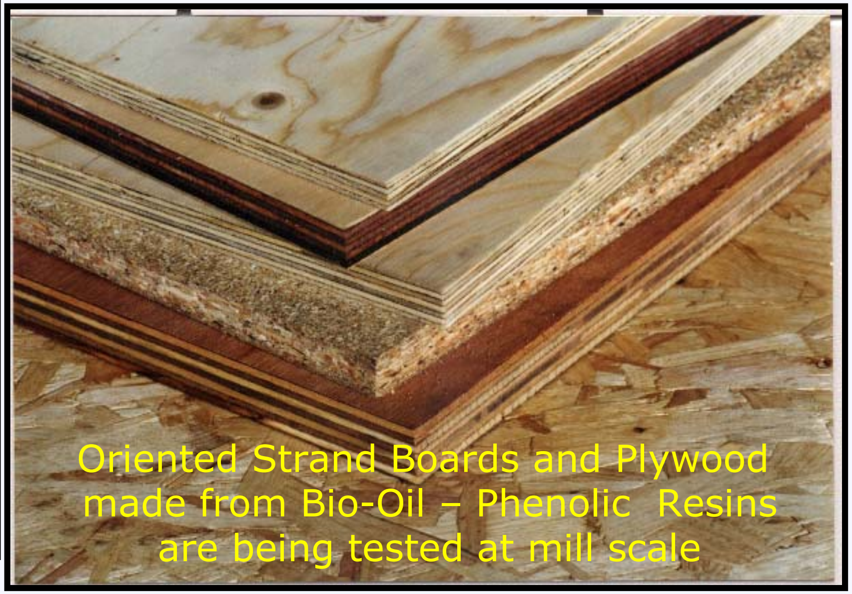
Environmental Regulations

Increasing in EU and USA

Germany: Subsidy program for farms

Bio-Oil From Pyrolysis





Biomass Power
Current Commercial Technology

Itasca Power 20 MW Plant
Prince Edward Island, Nova Scotia

- Almost all systems are combustion / steam turbine
- Most are grate stokers but FBC increasingly used
- 1-110 MW (avg. 20 MW)
- Heat rate 11,000-20,000 BTU/kWh
- Installed cost $1700-$3500 kW

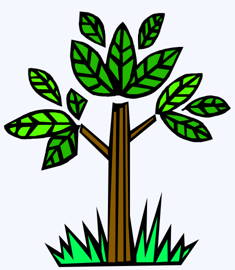
Biomass Power

Combustion Technology

- 500 Facilities use wood to generate power in U.S. < 20 owned by utility
- CA plants peaked early 90's declined 1/3 by 2000
- 34 still in operation (685 MW)
- Future uncertain

Gasification

Air (0.3)
O_2 (0.3)
Steam



Heat

Producer Gas (mol%)

CO	24
H_2	13
CH_4	3
CO_2	8
N_2	52

(tars & particulate)

Fuel Gases

Synthesis Gas (mol%)

CO	39
H_2	20
CH_4	17
C_2H_2	6
CO_2	18
N_2	0

(tars & particulate)

Gasifier Types

Design Basis: Fuel Properties, End Use, Scale, Cost

1. Updraft
2. Downdraft
3. Fluidized Bed
   – Bubbling
   – Circulating Flow
4. Entrained Flow

Technical Issues
Combustion

- Conversion efficiency - 20-25% to power
- Mineral management
- Emissions NOx, CO, particulate
- Mature technology

Gasification

- More efficient than combustion, 30%- 40%
- Effectively manages mineral matter
- Fuel gas ($CO + H_2 + CH_4$) can be used in prime movers
- Installed Cost $1800 - $2000 / kW

Updraft Gasifier

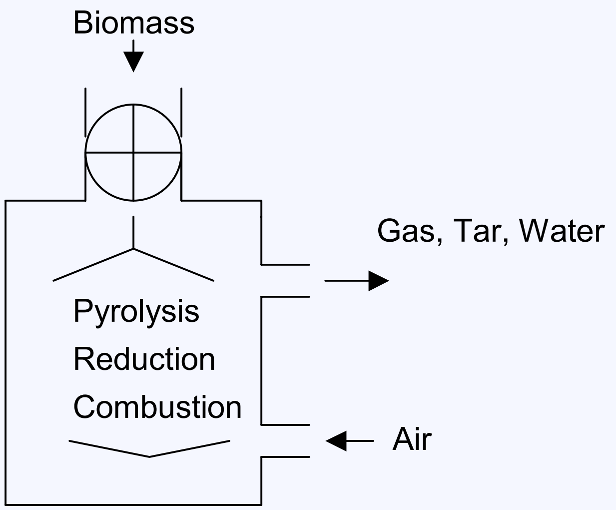
- **Simple, reliable**
- **Commercial history**
- **High tars**
- **Close coupled combustion**

$C + CO_2 = 2CO$

$C + H_2O = CO + H_2$

$C + O_2 = CO_2$

$4H + O_2 = 2\ H_2O$



Source: Renewable Energy Corp. Ltd (Waterwide Technology)

Downdraft Gasifier

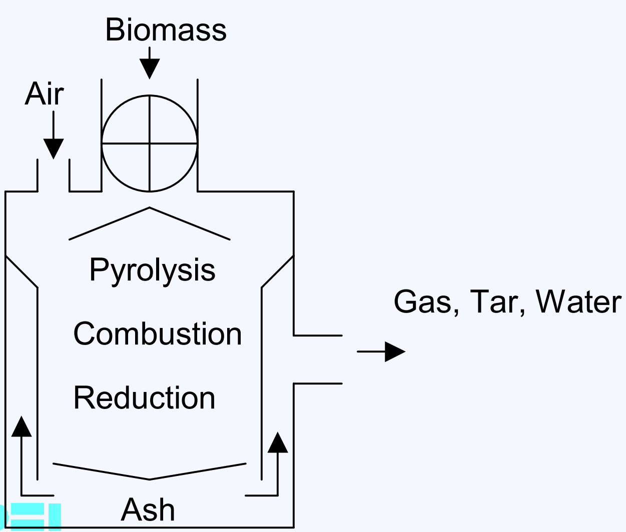
- **Requires low moisture (<20%)**
- **Lowest Tar**
- **Can use gas in engines (after conditioning)**

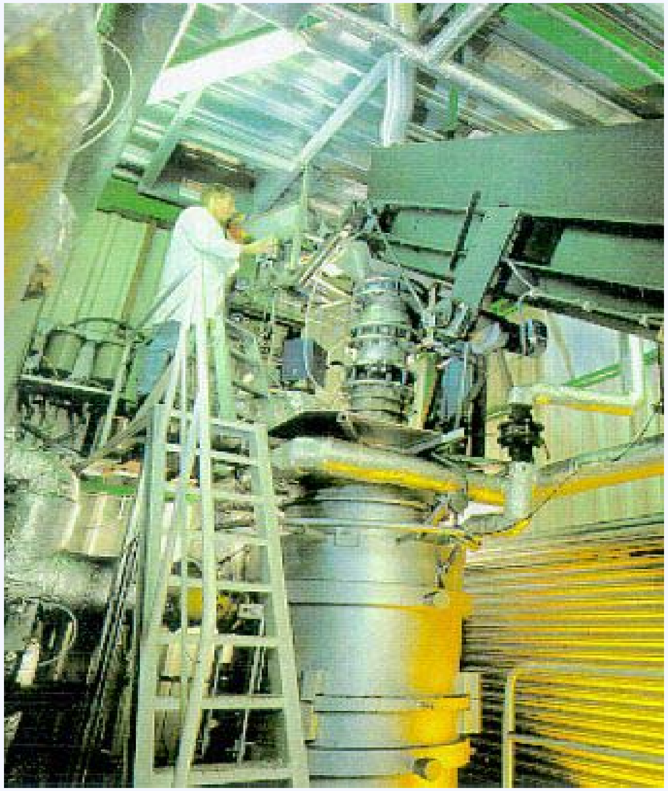
$C + O_2 = CO_2$

$4H + O_2 = 2H_2O$

$C + CO_2 = 2CO$

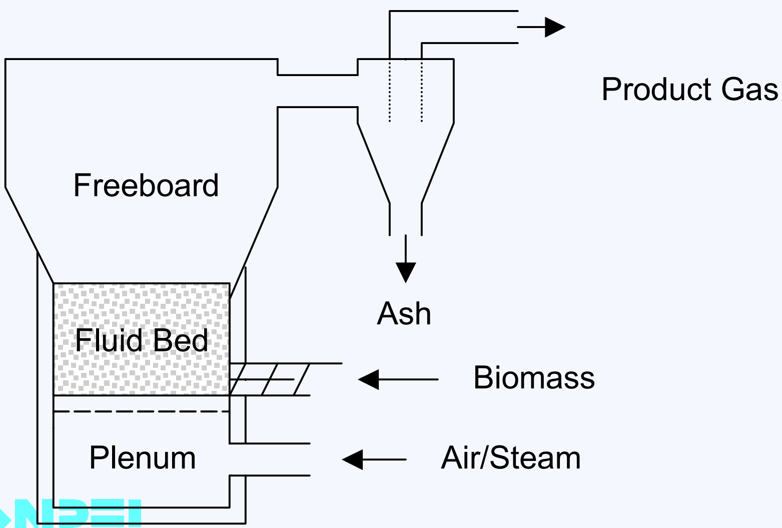
$C + H_2O = CO + H_2$





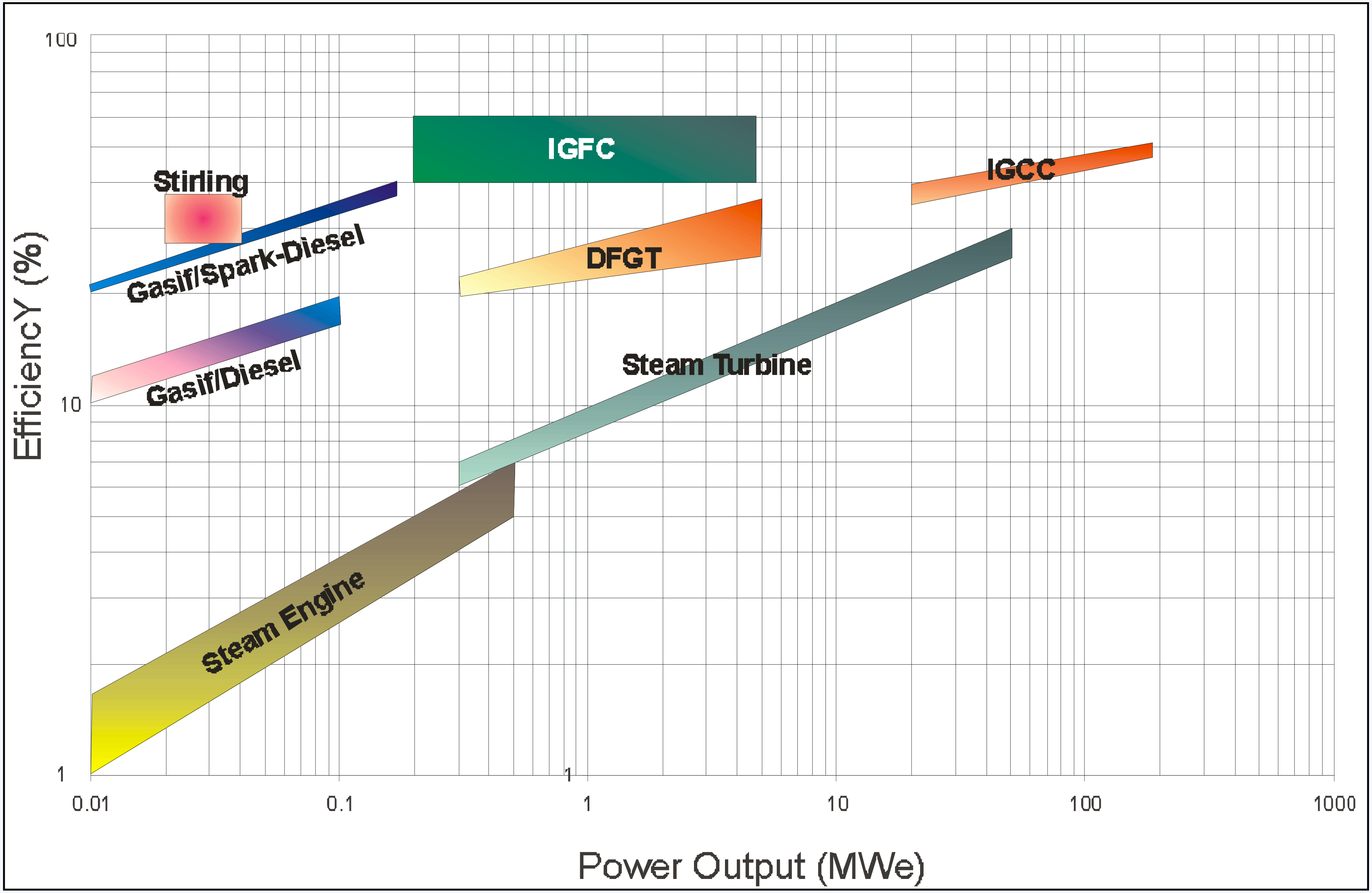
Fluidized Bed Gasifier

- Highest throughput
- Fuel flexible
- Tolerates moisture
- Complex operation



Gasification Technical Issues

- Emissions (NOx) at small scale
- Gas Conditioning
  - Tars
  - Particulates (< 2 micron in size)
  - Acid gases (H_2S, NH_3, HCN, HCl)



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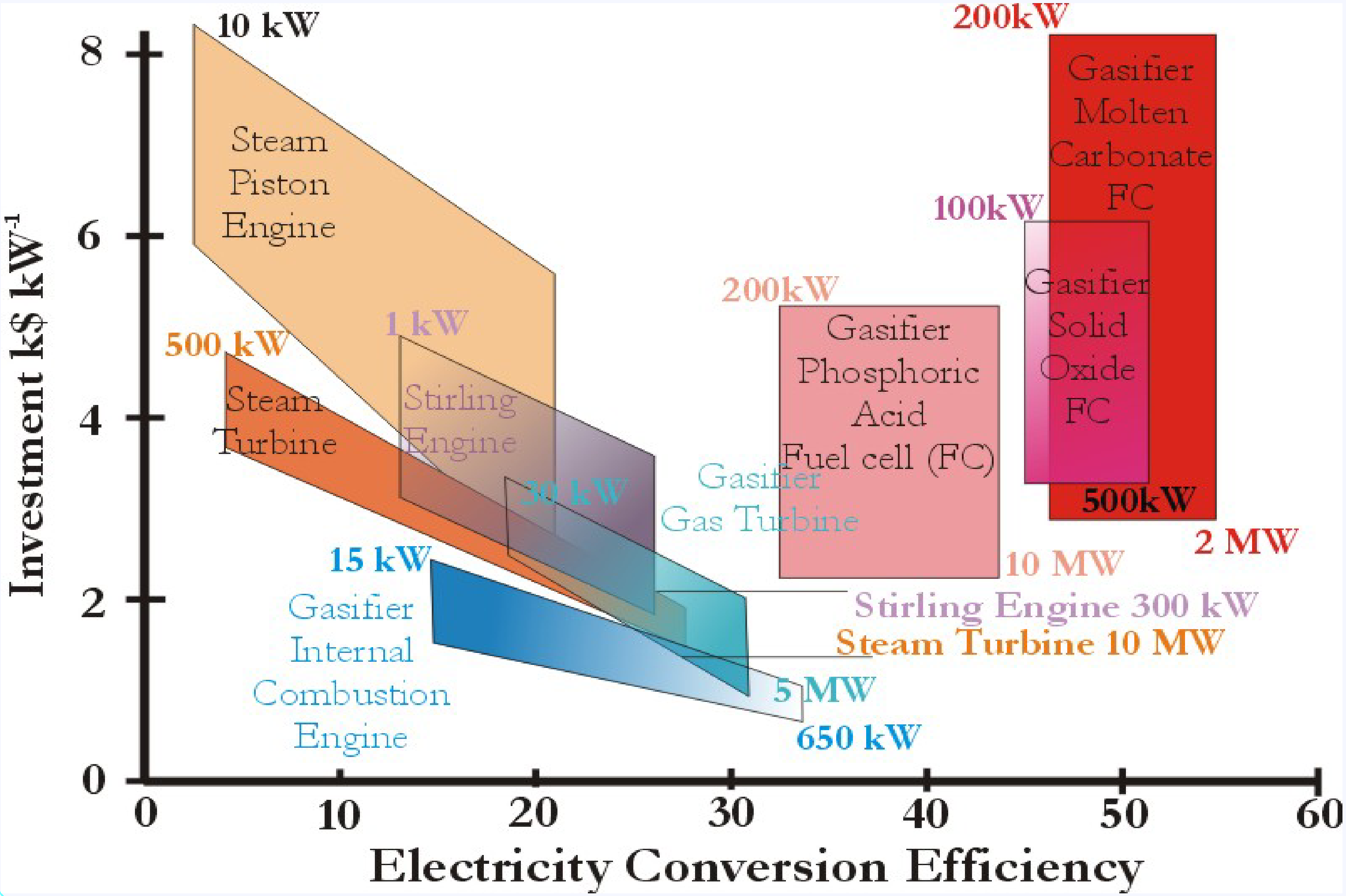
Comparative Process Efficiency

Technology Performance



SMALL MODULAR BIOMASS

Combined Heat and Power at Small Scale
Economic, Clean, Easy to Operate
Use Local Resources - Forest Thinnings and Agricultural Residues
Provide Local Employment

Community Power Corporation
Littleton, Colorado

5 – 25 kW

External Power, LLC
Athens, Ohio

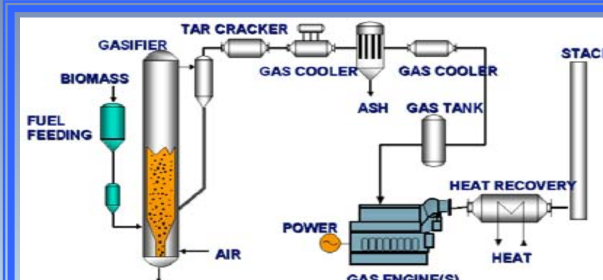
3 – 18 kW

Residences
Remote Communities
Native American Communities
Farms, Ranches, Co-ops
Small Industrial Sites
Urban Mini-Grids

Flex Energy
Mission Viejo, California

30 – 60 kW

Carbona Corporation
Orinda, California



2 – 5 MW

Small Modular Biomass Systems

- Factory assembled units to convert
  - Solid biomass resources
    - Fuel wood
    - Straws and Stalks
  - Biofuels
    - Biogas (biological and thermal)
    - Liquid fuels (ethanol, biodiesel, bio-oils)
- For electricity and heat in local applications and markets
  - Grid connected distributed energy resources
  - Stand-alone “Village Power” systems

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SMBS criteria

- Modular and mass production for:
  - Quality
  - Efficiency
  - Low cost
- High degree of automation:
  - Simple operator interface
  - Reliability and maintenance reduced
  - Health, safety and environmental performance
- Size Range
  - 1-2 kWe for household(s) up to
  - 5 MW for communities and small industries

SMBS – Simple criteria and rules

- Electricity generation (today) < 20% efficient
- CHP (combined heat and power) range of heat:power
  - Steam 3 – 4:1, low grade heat (hot water), 1.5:1, low pressure steam (medium grade heat)
  - ICE 2:1 medium grade heat from exhaust gas
  - Gas Turbine 2:1 medium grade heat from exhaust gas
- 1 MWh requires the following quantities of fuel per hour
  - 1 tonne of dry fuel wood
  - 1200 m^3 of biogas from anaerobic digestion (1250 cows)
  - 4000 m^3 of thermal biogas from 2 tonne of straw

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Community Power Corp SMBS
Zuni Furniture Enterprises

Zuni Workshop

Zuni Furniture Company

SMBS at Zuni

- Application:Power & Heat Furniture making shop
- Fuel: Wood scraps and forest thinning residues
- Operation: Daily
- Wood Consumption: 3 lbs/kWh
- Daily Load: 8 to 12 kW, 60-80 kWh
- Maintenance: 30 minutes per week
- Installation: October 2003
- Advantage: Disposes of on-site wood wastes and reduces costs of electricity and propane for heat

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

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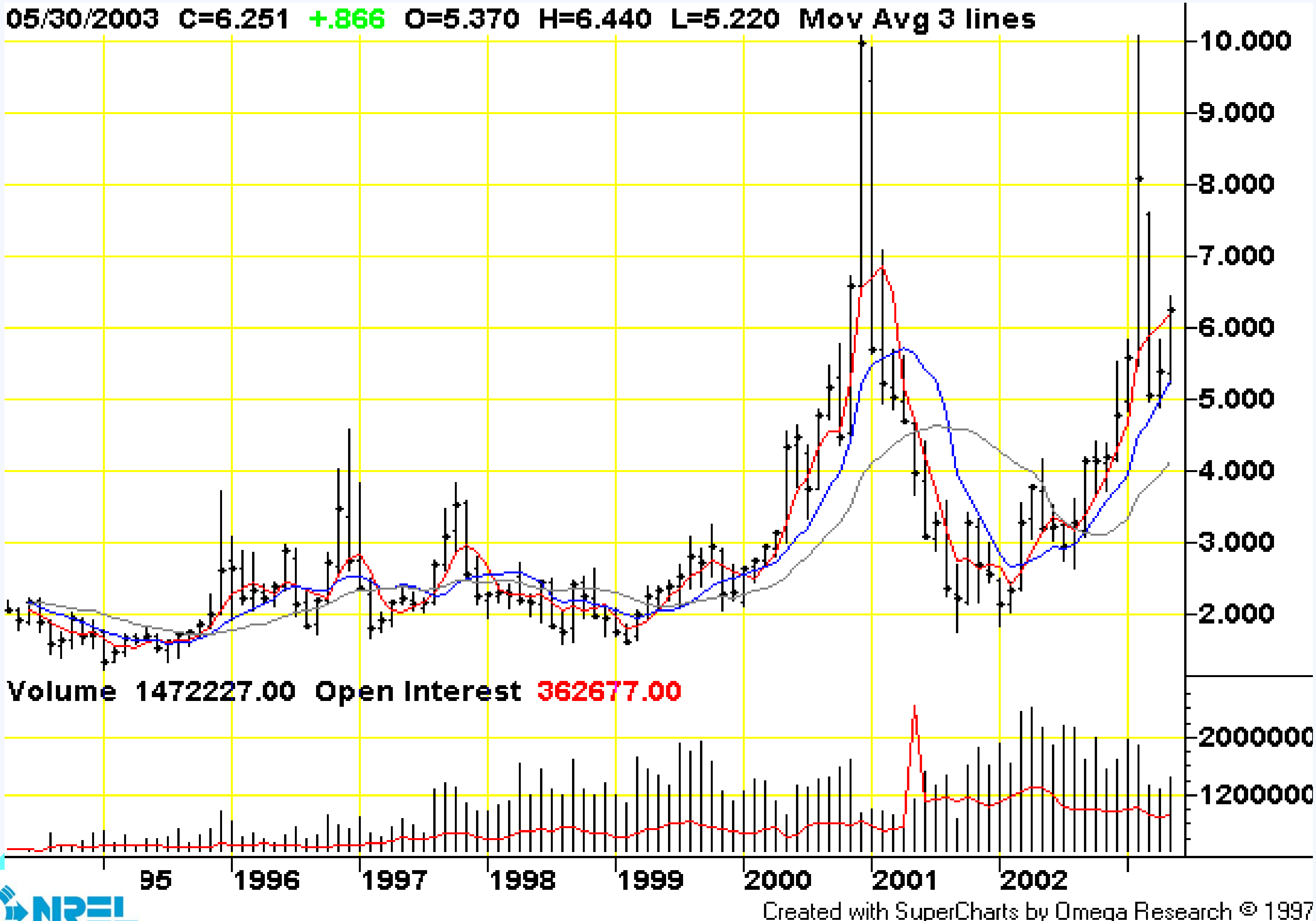
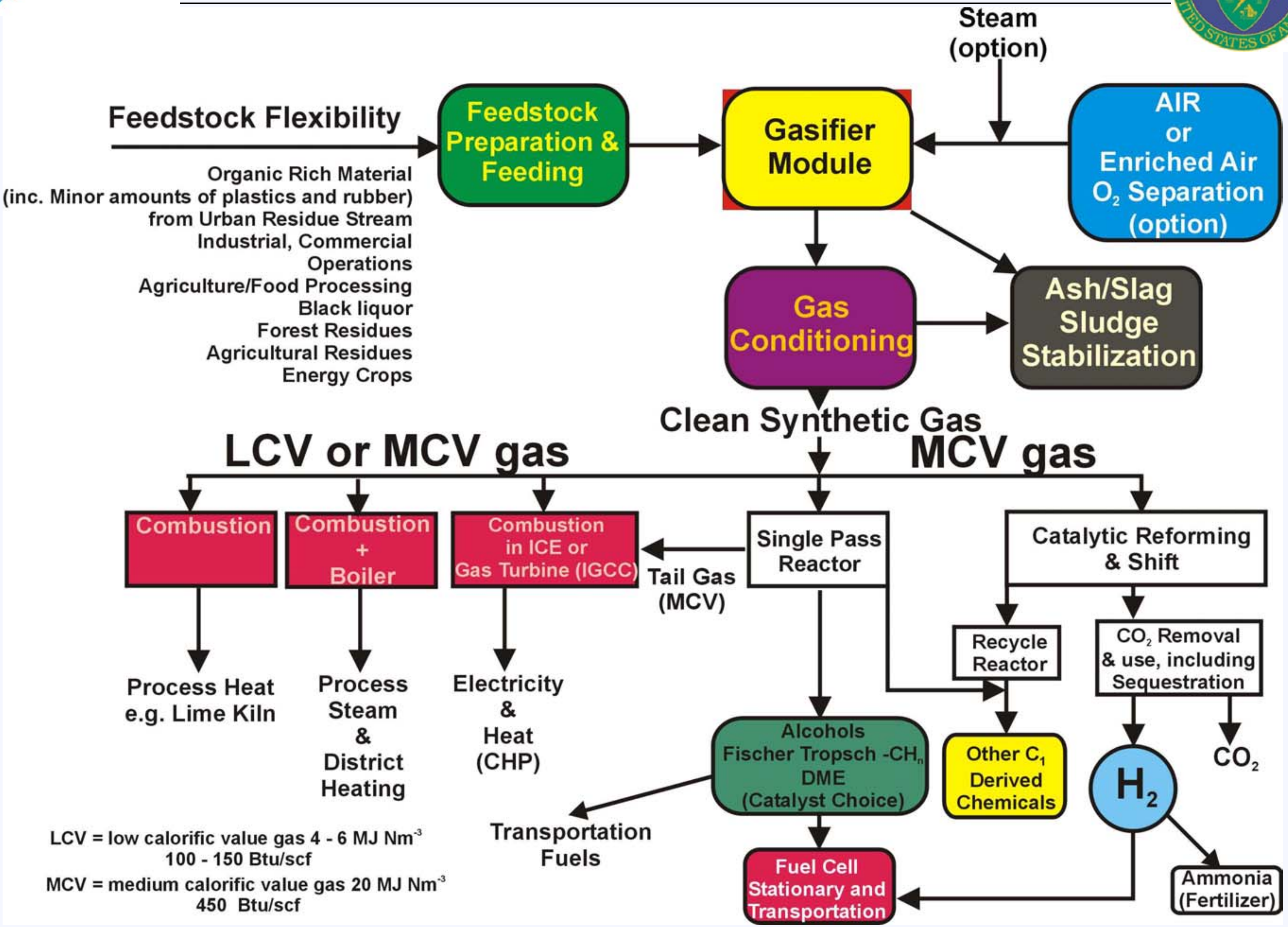
Source: Biopower Technical Assessment: State of the Industry and Technology, March 2003

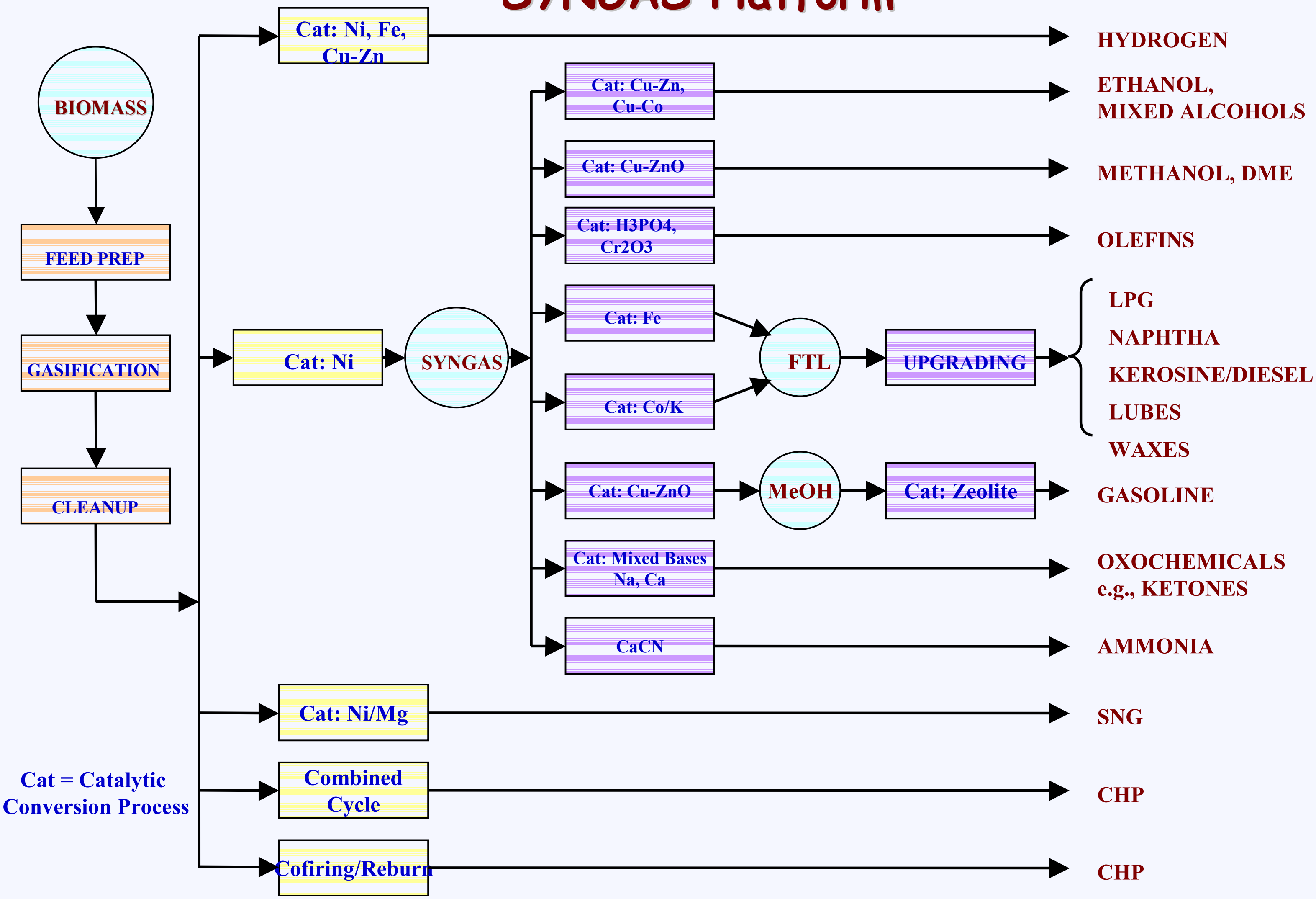
Historical Natural Gas Costs



Gasification



SYNGAS Platform



Energy Policy Act of 2003

Section 206

Improved biomass use grant program

- $20/ton to 25,000 ton/yr ($500,000)
- $50,000,000/yr for 10 years

100 projects @ 70 tons/day

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Energy Policy Act of 2003

Section 1513

Grants to merchant producers of cellulosic & waste derived ethanol

- Feedstocks
  - Cellulosic biomass
  - Agricultural residues
  - Municipal solid waste

- Funding Levels
  - $100,000,000 FY 04
  - $250,000,000 FY 05
  - $400,000,000 FY 06

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