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National Renewable Energy Laboratory

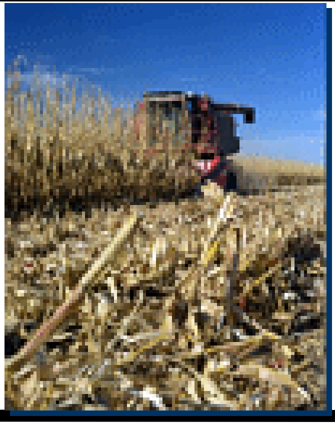
Biomass to Energy:Present Commercial Strategies and Future Options

Healthy Landscapes, Thriving Communities: Bioenergy and Wood Products Conference
January 21, 2003

John Scahill
National Bioenergy Center

Biomass Feedstocks

Forest Wood Residues



Agricultural Residues

Energy Crops

Forest Wood Residues

- Thinning Residues
- Wood chips
- Urban Wood waste
  - pallets
  - crate discards
  - wood yard trimmings

Agricultural Residues

- Corn stover
- Rice hulls
- Sugarcane bagasse
- Animal biosolids

Energy Crops

- Hybrid poplar
- Switchgrass
- Willow

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Biomass Constituents

Lignin: 15-25%

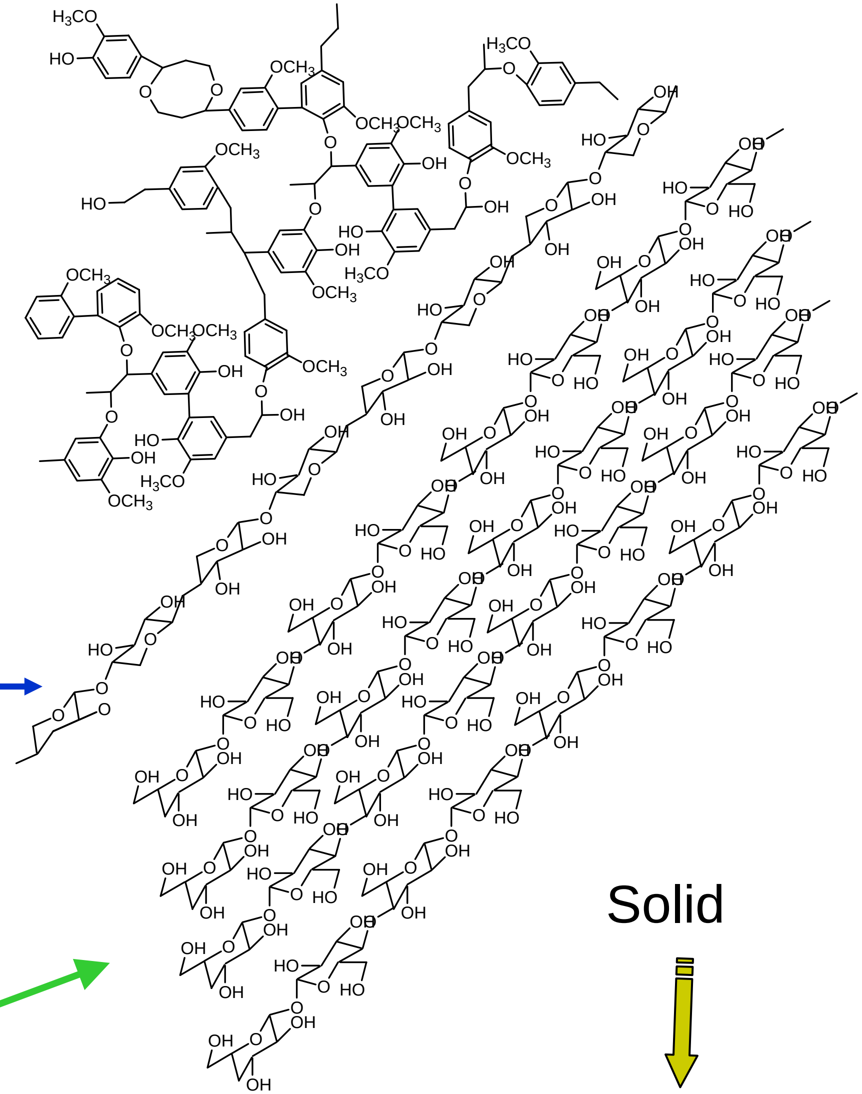
- Complex aromatic structure
- Very high energy content

Hemicellulose: 23-32%

- Polymer of 5 & 6 carbon sugar

Cellulose: 38-50%

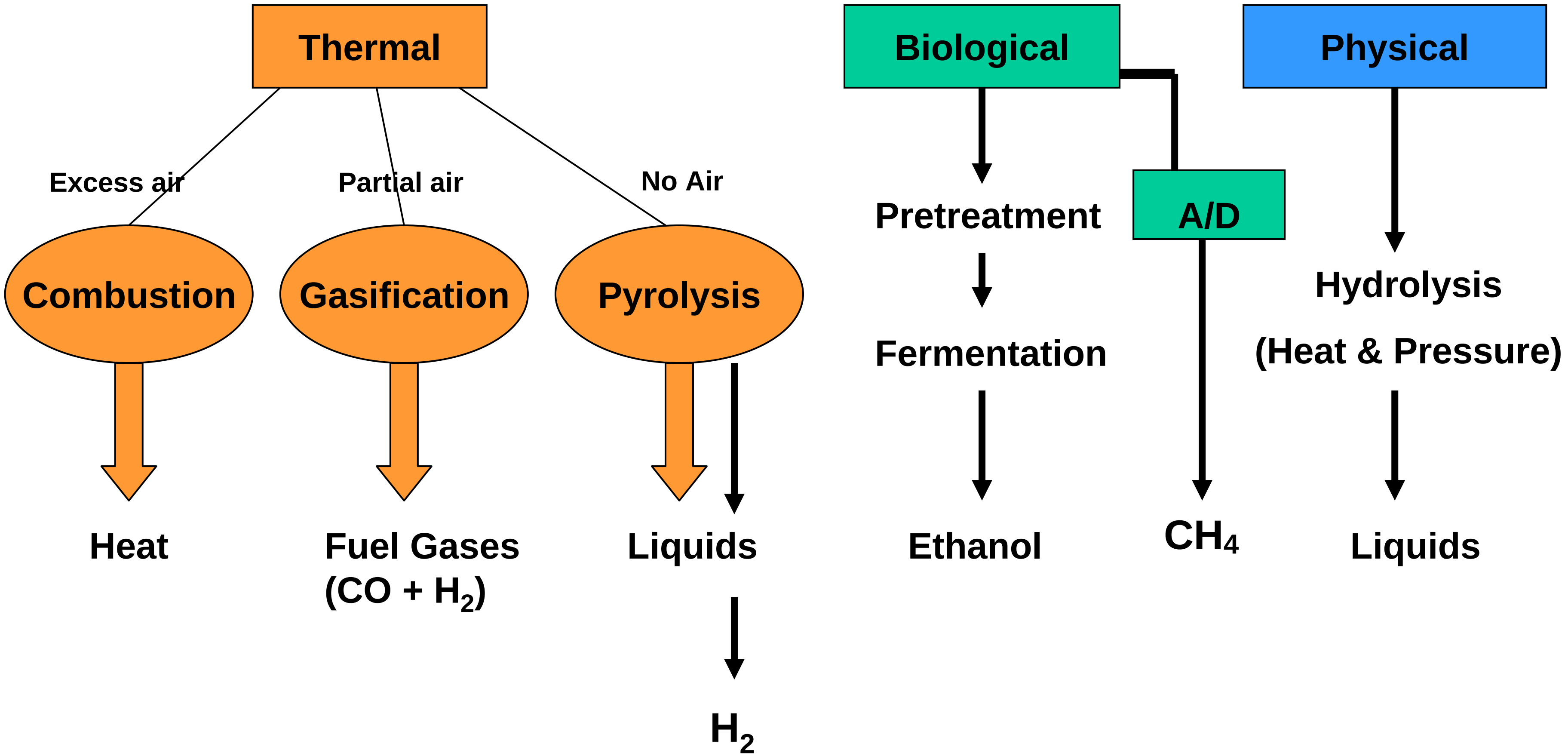
- Polymer of glucose, very good biochemical feedstock

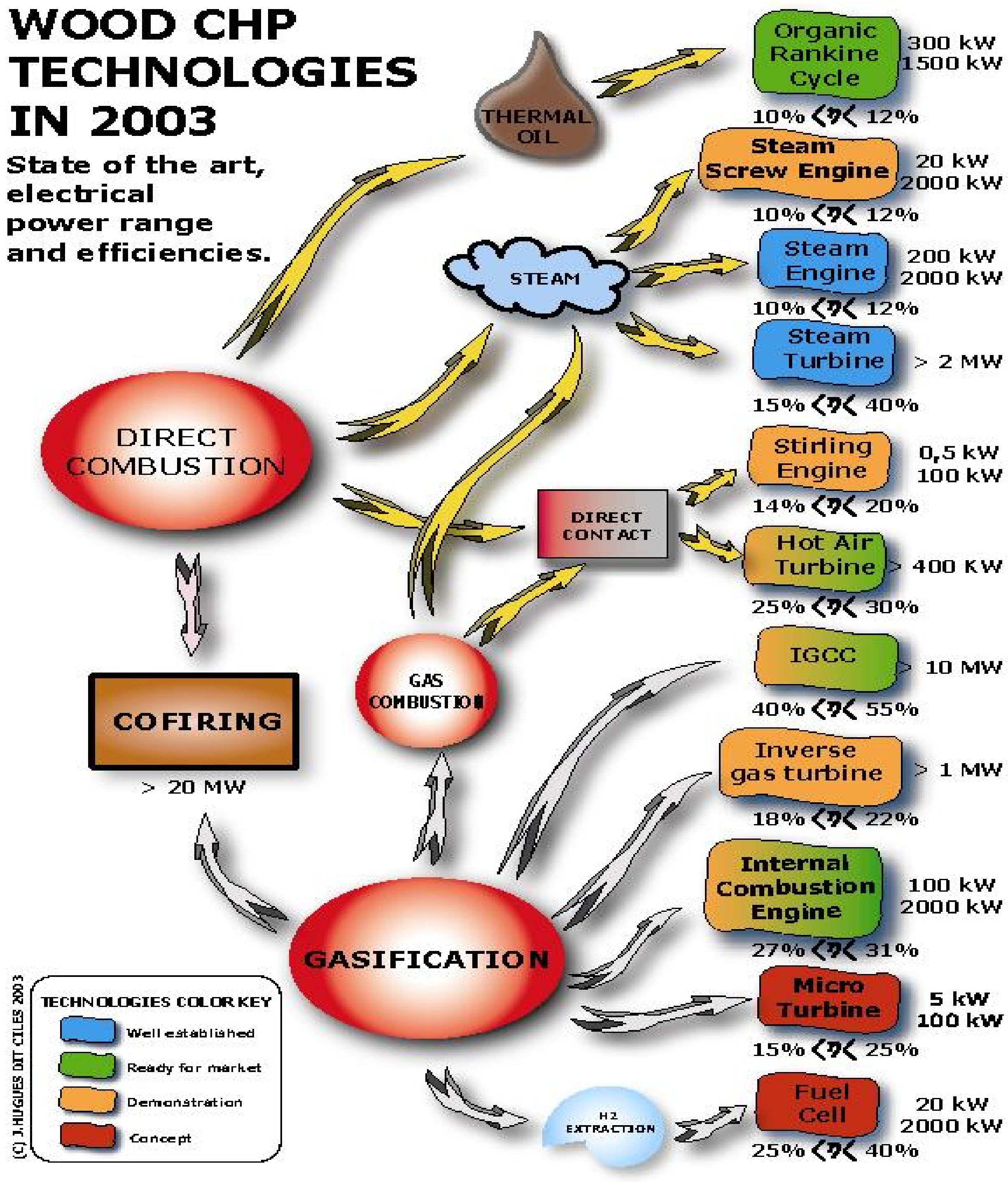


Solid

Gas or Liquid

Biomass Conversion Pathways





Source: Cogeneration and On-site Power Production July 2003

Jeremy Hugues

Commercial Viability Issues for Biomass CHP Technologies

- Difficult to exploit economies of scale (< 20 MW)
- Fuel costs are major cost driver (add $.01kW/$10 BDT) *
- Water requirements
  - Combustion steam turbine (high)
  - Gasification gas turbine (low)

* Source: TSS Consultants

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)**
- **Installed cost $980-$2500 kW ($1700- $2500 typical)**

Combustion for Heat

- Can be cost effective if loads > 1MMBtu/hr
  - District heating a plus
- Need wood fuel cost < $20/ton
- Heat and power applications > 10 MMBtu/hr
- Generally easy to permit at small scale
  - No demolition or treated wood

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Combustion Systems

Automated bin feeding system

Wood heated greenhouse

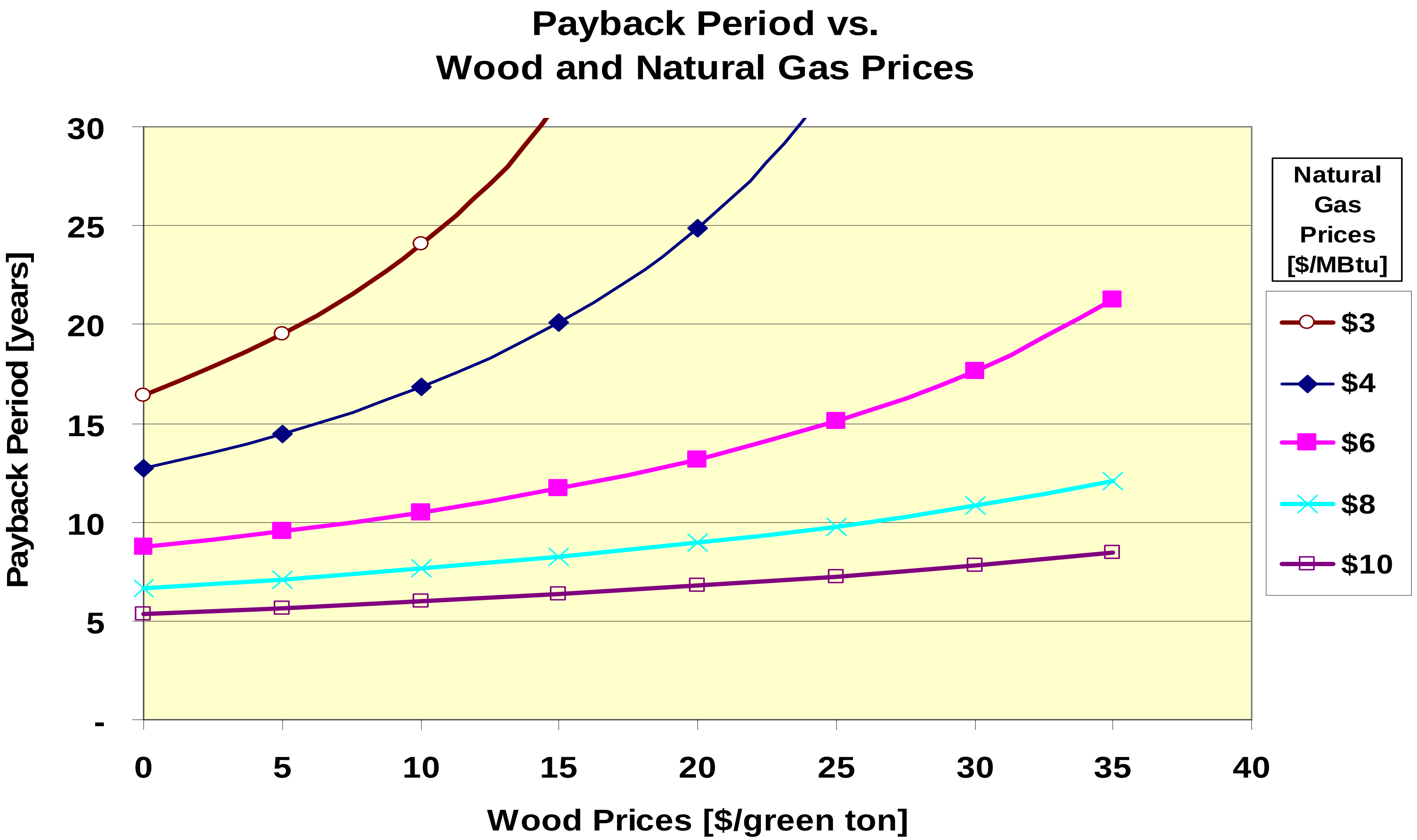
Source: Tim Maker – Biomass Energy Resource Center

Wood Heating in Vermont

- 20 public and 3 private schools heat with wood chips
- Average cost $28.80/ton
- Use ~ 8000 tons/yr
- $220,000 savings over fuel oil

Source: Vermont Superintendents Association, 2000-2001 season

Small Scale (100 kWe) Biomass CHP Economics



Source: McNeil Technologies June 2003

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

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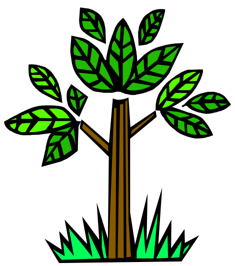
Gasification

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 (CO, H_2, CH_4)

Synthesis Gas (mol%)

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

(tars & particulate)

Gasification

Thermochemical Reactions

$$C + CO_2 \longrightarrow 2\,CO$$ **(Boudouard)**

800° - 850° C

$$C + H_2O \longrightarrow CO + H_2$$ **(Water gas shift)**

Biomass = $CH_{1.4}\,O_{0.6}$

Gasifier Types

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

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

Updraft Gasifier

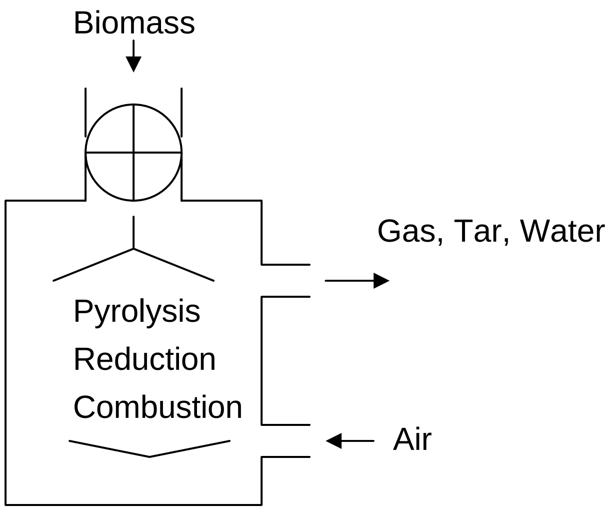
- **Simple, reliable**
- **Commercial history**
- **High tars**
- **Close coupled combustion**

$C + CO_2 = 2CO$

$C + H_2O = CO + H_2$

$C + O_2 = CO_2$

$4H + O_2 = 2 H_2O$



Source: Renewable Energy Corp. Ltd (Waterwide Technology)

Downdraft Gasifier

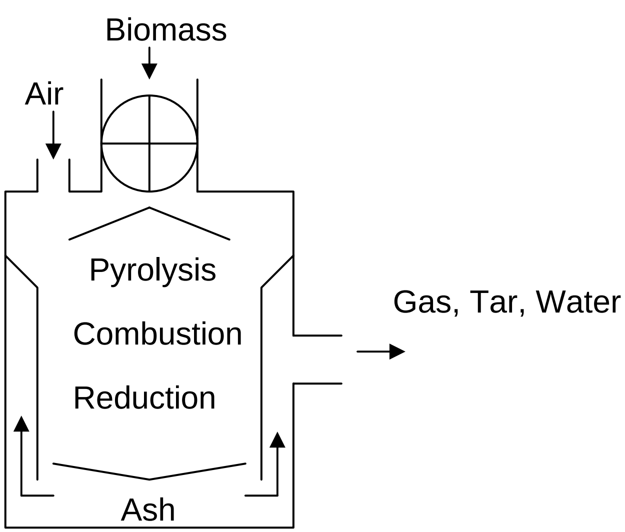
- **Requires low moisture (<20%)**
- **Lowest Tar**
- **Can use gas in engines (after conditioning)**

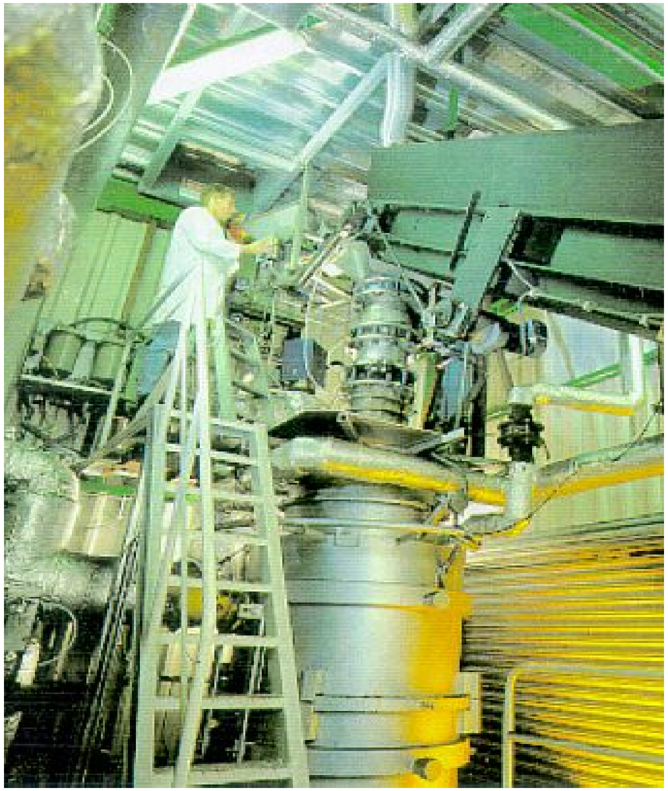
$C + O_2 = CO_2$

$4H + O_2 = 2H_2O$

$C + CO_2 = 2CO$

$C + H_2O = CO + H_2$





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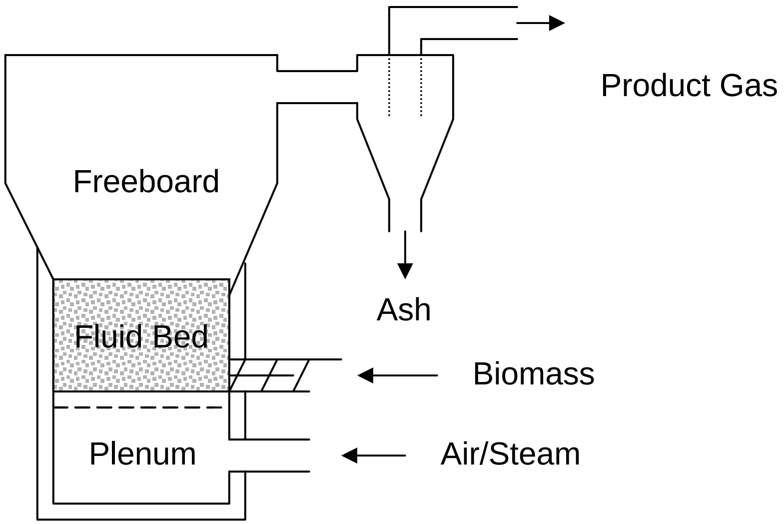
Fluidized Bed Gasifier

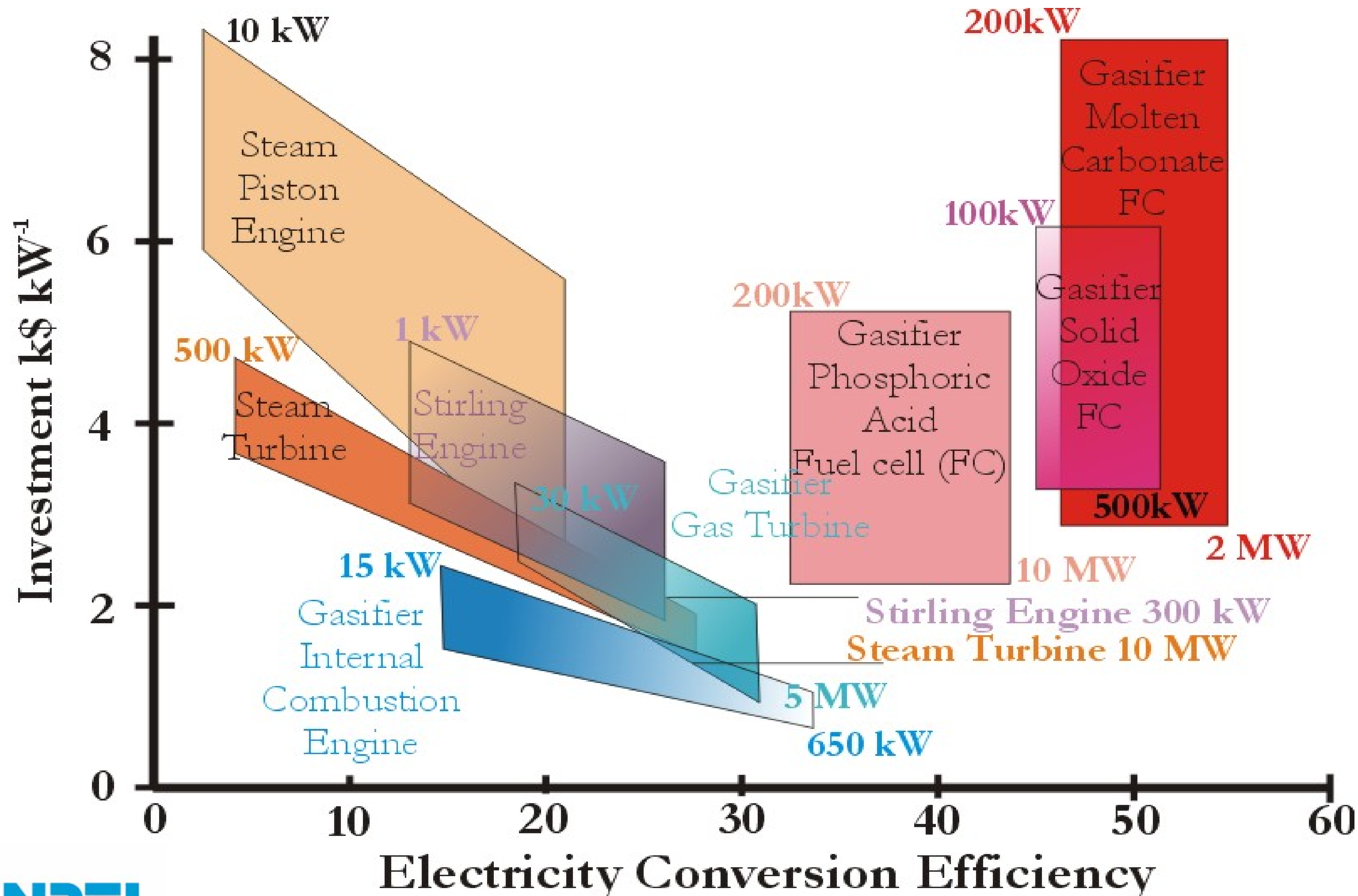
- Highest throughput
- Fuel flexible
- Tolerates moisture
- Complex operation



Gasification Technical Issues

- **Gas Conditioning**
  - **Tars**
  - **Particulates (< 2 micron in size)**
  - **Acid gases (H_2S, NH_3, HCN, HCl)**

Power Generation Technologies



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

Biomass CHP Technology Risk

Commercial ← **Demonstration** ← **Prototype**

Stoker grate combustion

(small) …………… **Downdraft Gasification**

FB Gasification

FB Combustion

Small Modular Systems

Updraft Gasification

Synthesis Gas Production

(entrained and FB)

Low installed cost
Low Efficiency
Low Risk

→

High installed cost
High Efficiency
High Risk

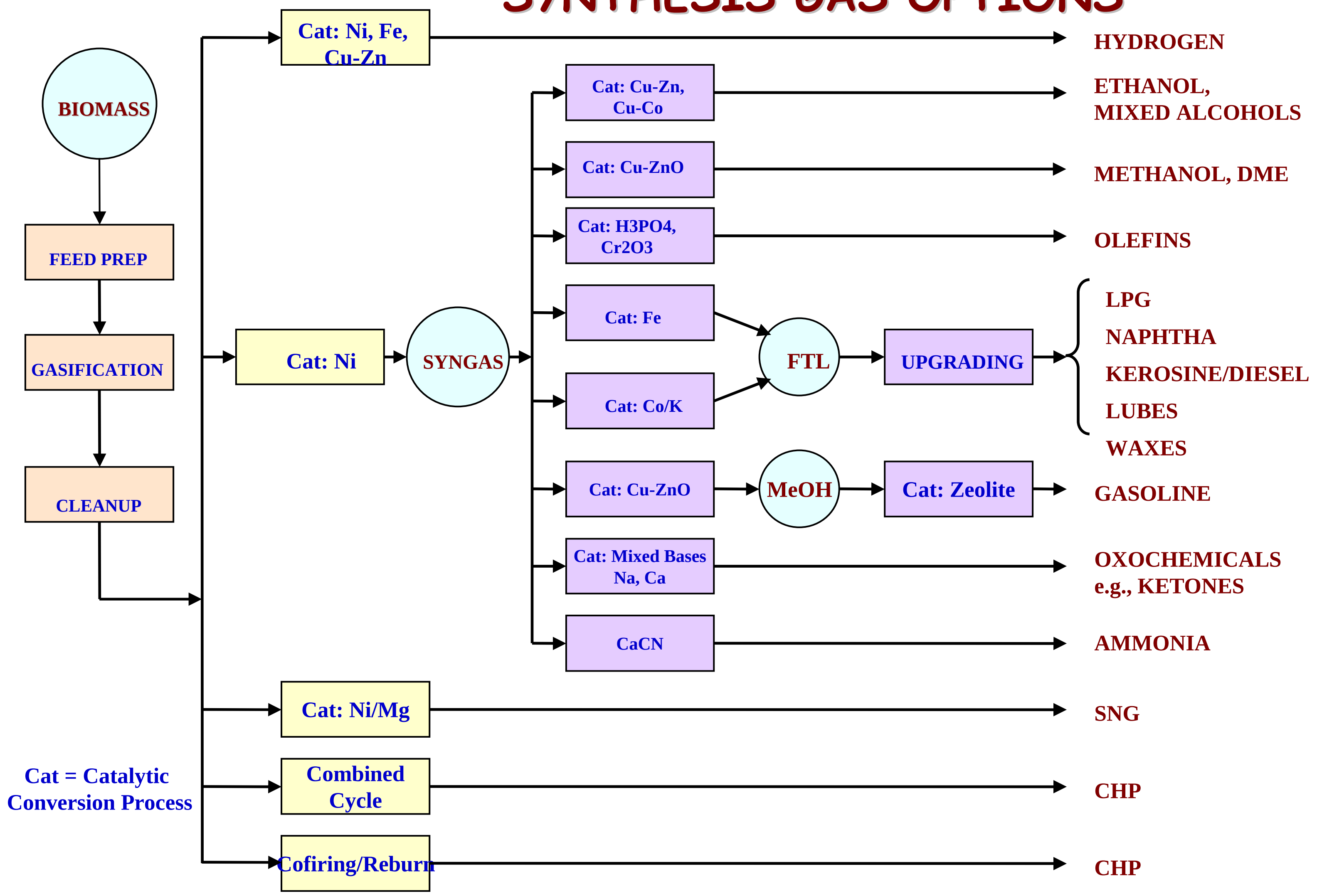
Requirements for Commercial Viability

Site Specific

- **Sustainable fuel supply (long term contract)**
- **Fuel costs $10- $20/ BDT**
- **Capital costs $1000 - $1500 / kW**
- **Power purchase agreement $.10 - $.20/ kWhr**
- **Identify niche market for CHP**

Source: TSS Consultants & McNeil Technologies

SYNTHESIS GAS OPTIONS



Gas Cleanup Requirements

For Fischer-Tropsch gas-to-liquids

Impurity	Removal level
H2S, NH3, HCN	< 1 ppmv
HCl	< 10 ppbv
Soot, dust, ash	Essentially completely
Tars	Below dew point < 1 ppmv

Source: H. Boerrigter et al, October 2002

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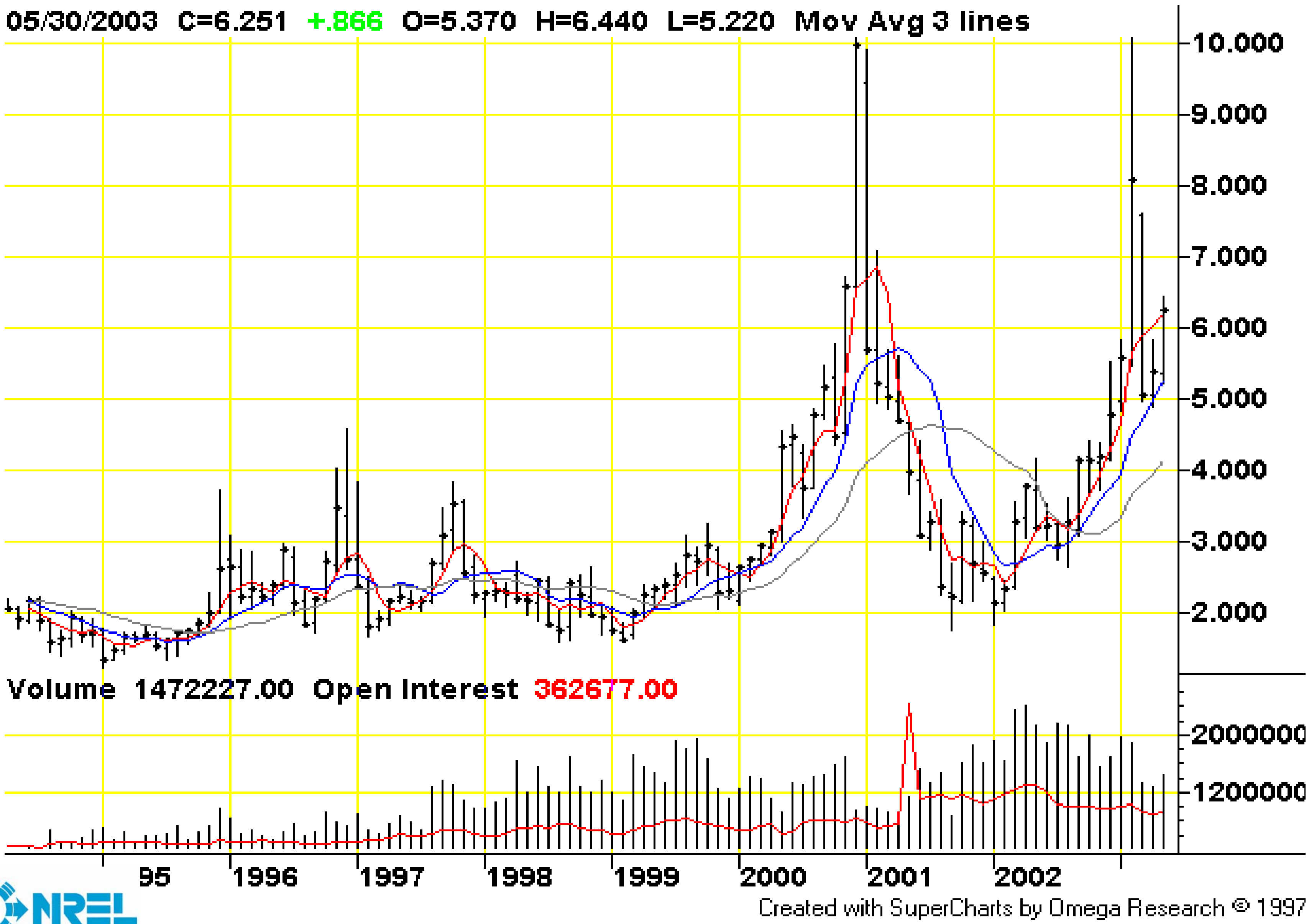
Historical Natural Gas Costs



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Making Biomass Disappear

Air curtain burner

400 tons / day

$0.00 Productivity