Renewable Energy and Energy Efficiency for Tribal Community and Project Development

Overview of Biomass Energy and Biomass Heating Case Study

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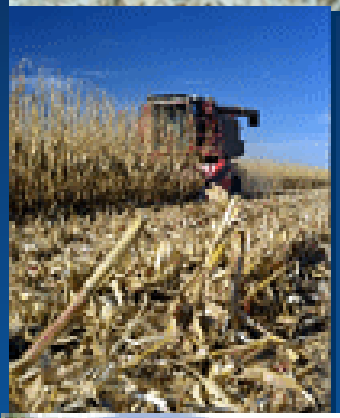
Biomass Resources

- The term "biomass" means any plant derived organic matter available on a renewable basis
- States have various definitions of eligible biomass resources for state portfolio standards
  - Colorado has the term “slash and brush” for forest biomass
  - Arizona puts a diameter limit on forest biomass
- FERC definition - “any organic material not derived from fossil fuels” is better

Biomass Resources and Issues

Wood Residues
- Sawdust
- Wood waste
- Forest thinnings



Agricultural Residues
- Corn stover
- Wheat straw
- Rice hulls
- Sugarcane bagasse
- Animal waste

Energy Crops
- Switchgrass
- Hybrid poplar
- Willow

Landfill gas, manure

- **Cost**
  - Production
  - Collection and Transportation
  - Quantity Available
  - Integrated Supply System
- **Sustainability**
  - Land, Air and Water Resources
- **Quality**
  - Composition
  - Ease of Conversion

Forest Biomass: Sample Combustion Properties and Estimated Ethanol Yield

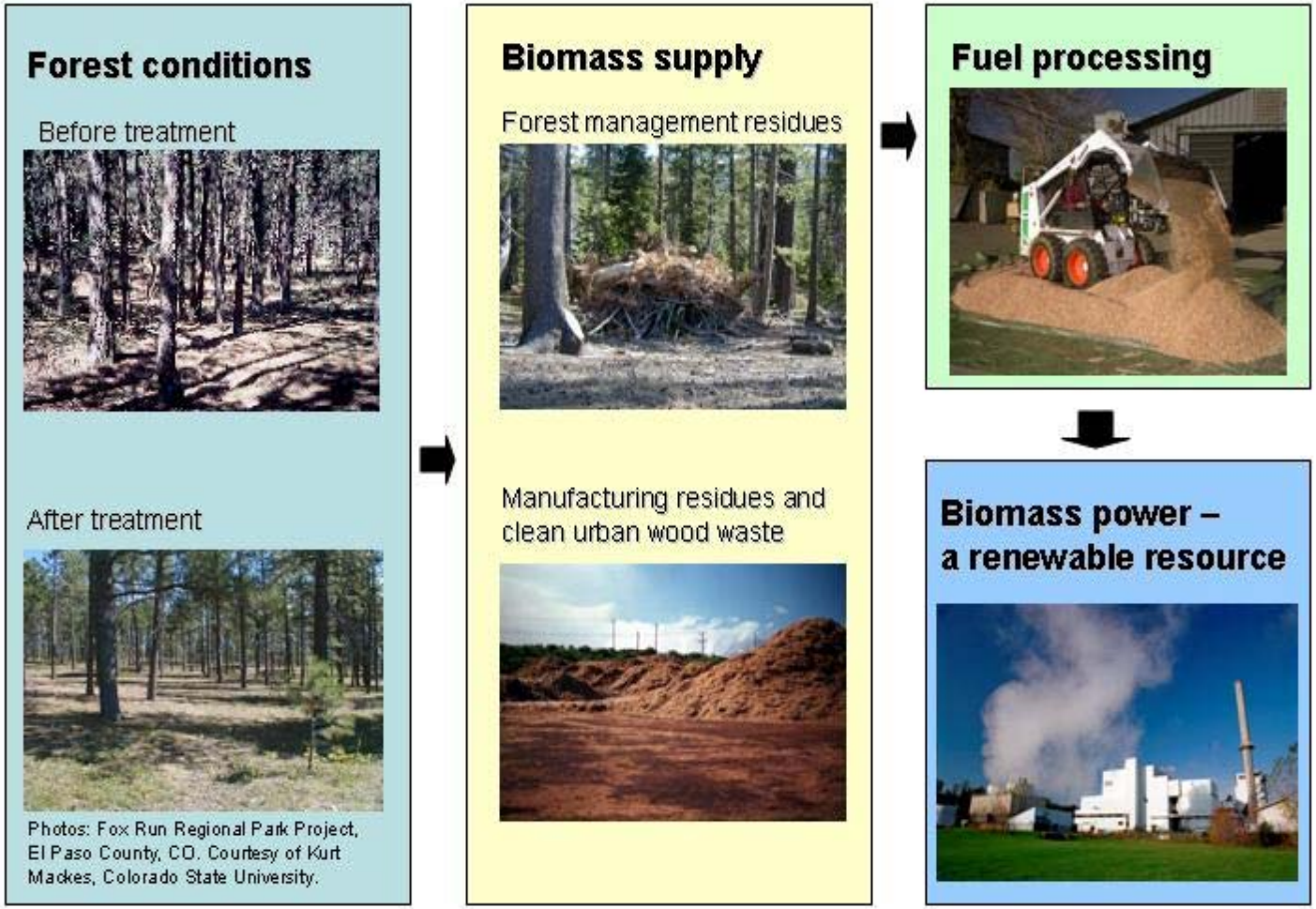
	Gross heat of combustion[1]		Estimated Ethanol Yield for Woody Biomass) (Gallons per bone dry ton)
	Btu/lb	J/g	
Ponderosa pine	8,613	20,020	60 -70
White fir	8,583	19,950	60 -70
Western hemlock	8,626	20,050	60 -70
Douglas-fir	8,710	20,250	60 - 70
Aspen	8,782	20,414	60 - 70

Source: [1] Thermodynamic Data for Biomass Conversion and Waste Incineration. (September 1986). Domalski, Eugene S., Jobe, Jr., Thomas L., (Nat'l B Standards); & Milne, Thomas A., (SERI). SERI/SP-271-2839); [2] Multiple published reports and personal communications from NREL

Biomass fuels database, online at: http://www1.eere.energy.gov/biomass/feedstock_databases.html

Notes: Btu/lb = British thermal units per pound; J/g = Joules per gram; Ethanol yield is influenced by conversion process used and percentage of bark in feedstock

Overview of Biomass Energy Conversion Process

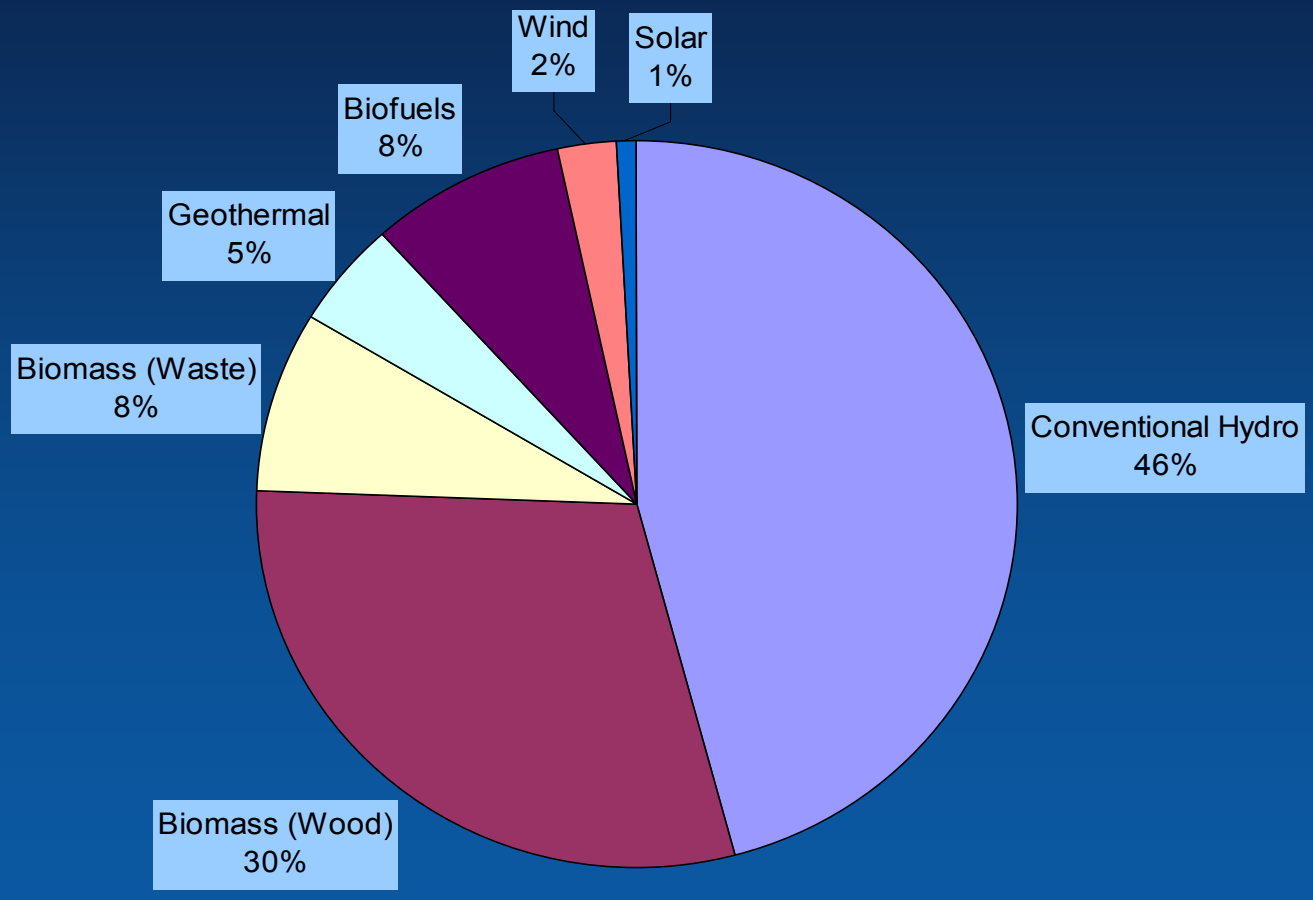


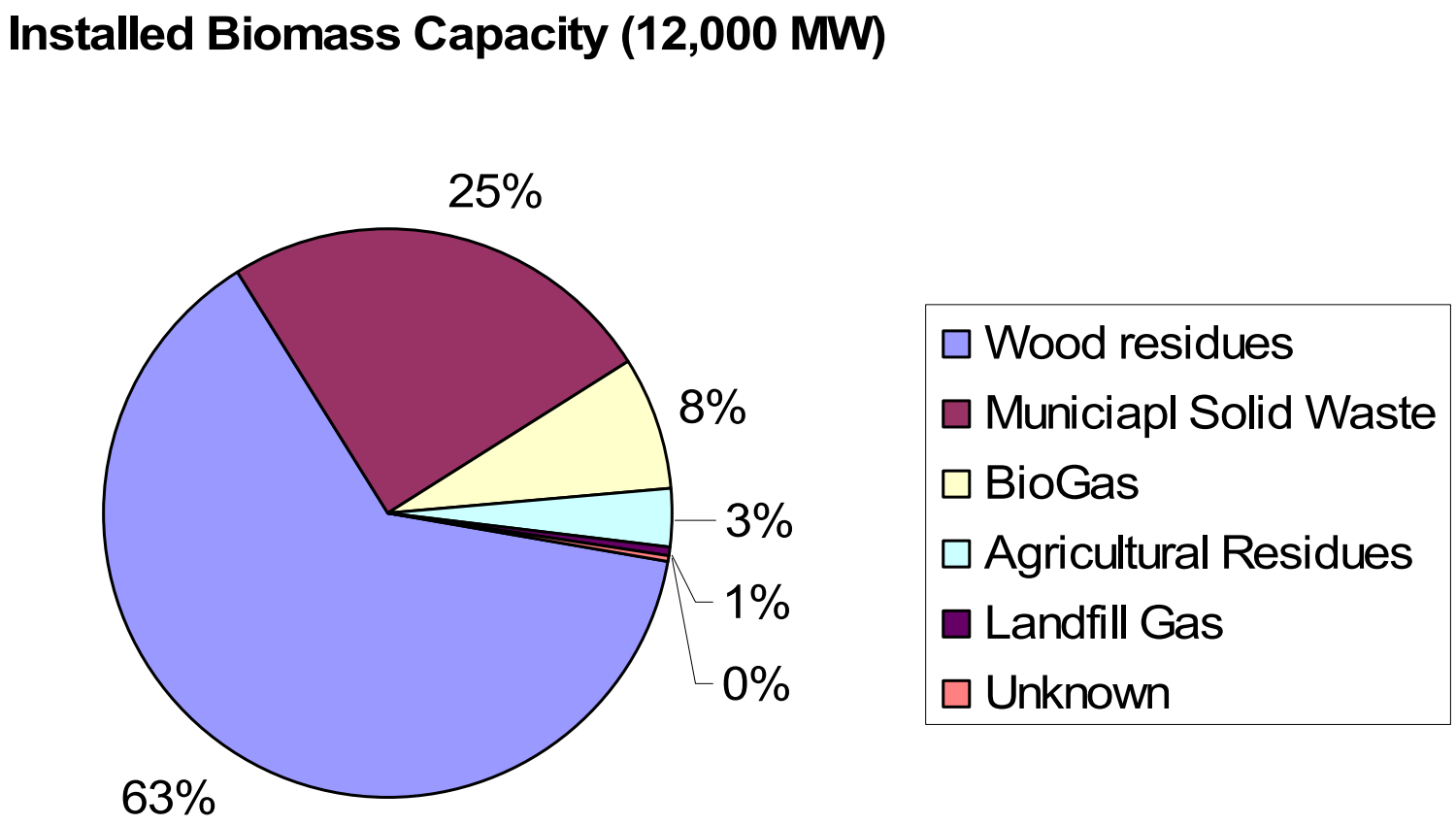
BioMax 15-35
BioMax 15-35
GENERAC
POWER SYSTEMS

SOYBEAN POWERED
This Bus Runs On Soybean Bio-Diesel
This Bus Gets 250
Miles Per Acre.
'94 1 24

NREL National Renewable Energy Laboratory

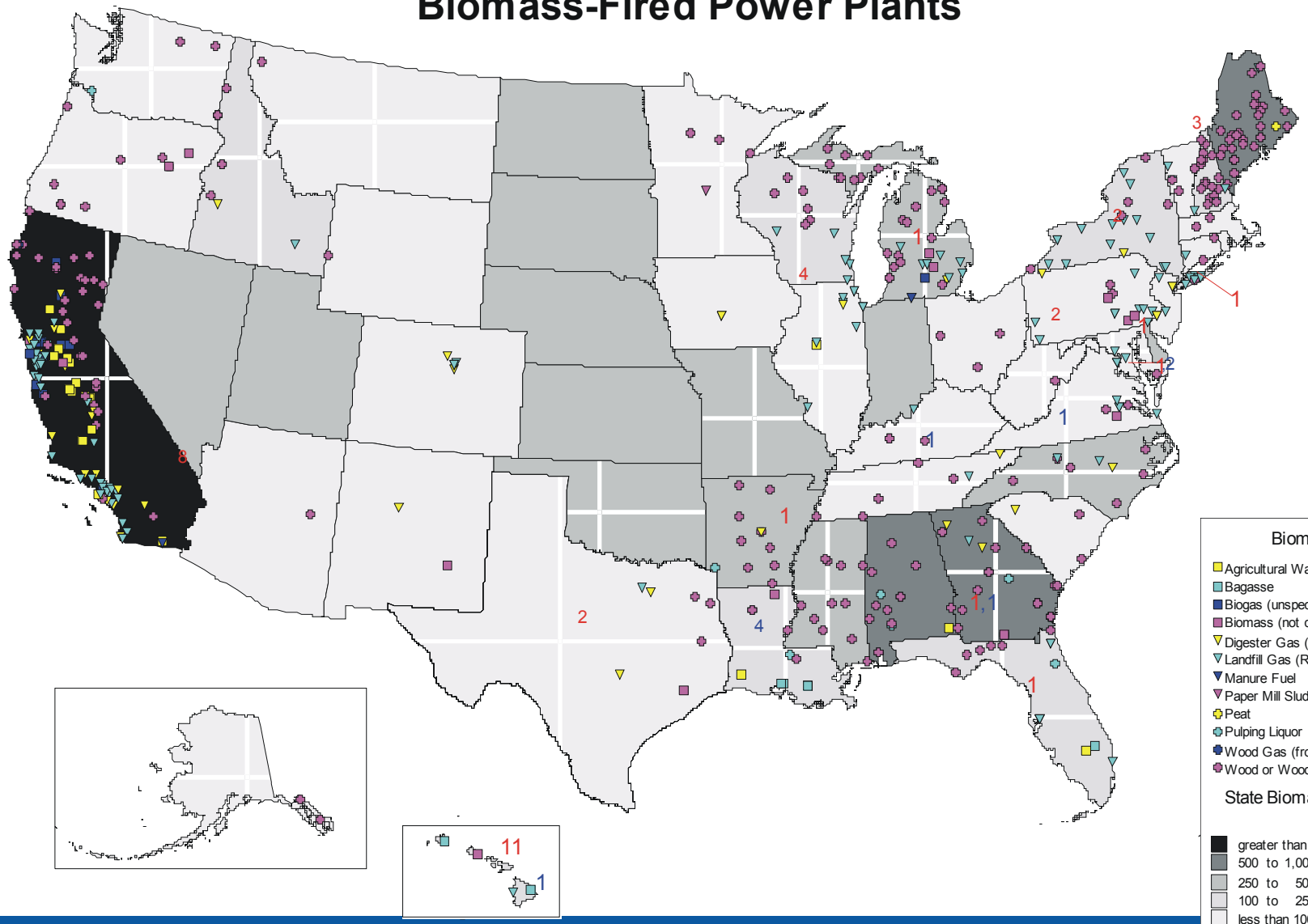
U.S. Renewable Energy Consumption (2005)
Total = 6.5 Quads/year (6.5% of US Total)



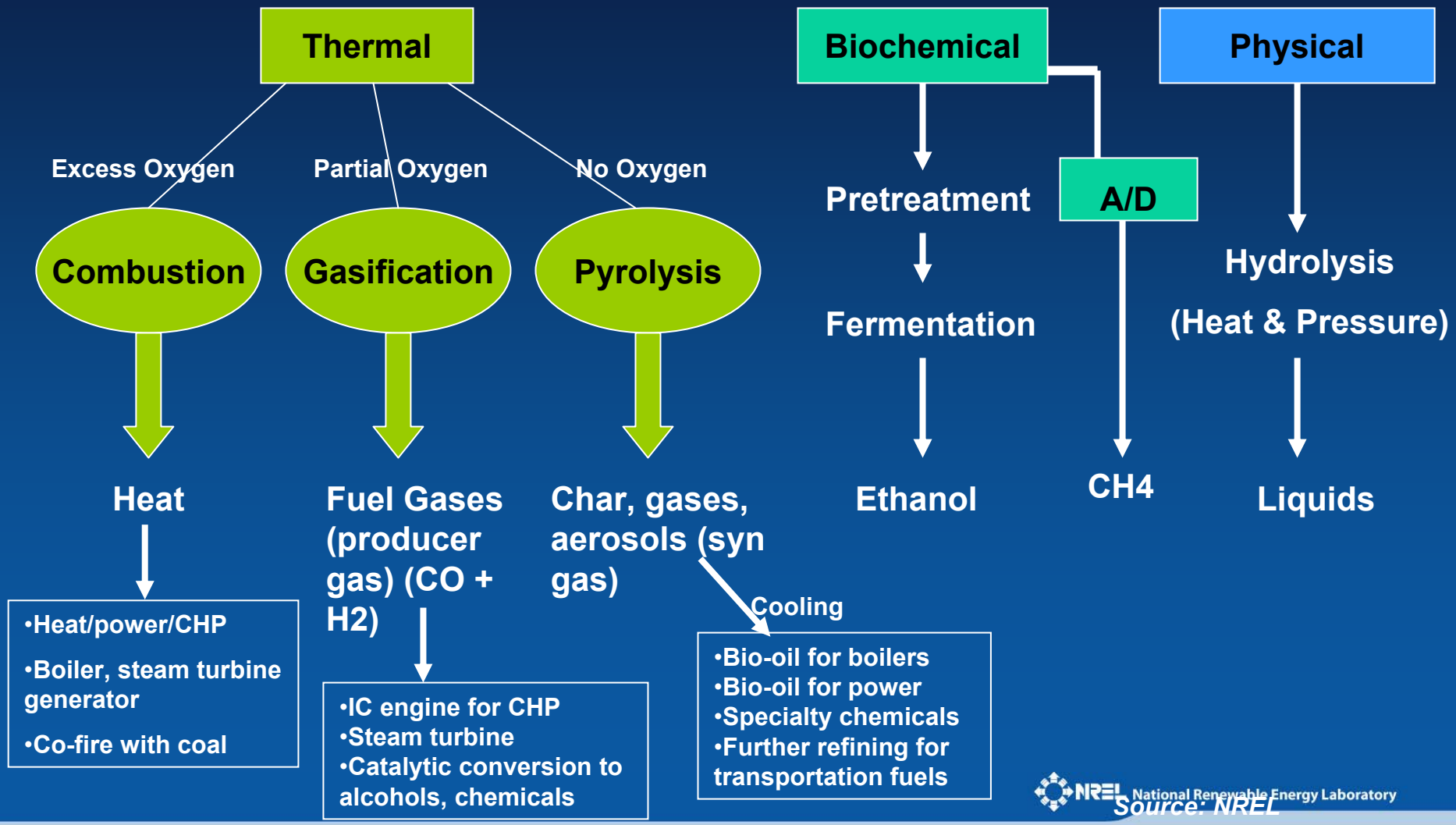


Source: NREL, REPIS (2002)

Biomass-Fired Power Plants



Biomass Energy Pathways



NREL National Renewable Energy Laboratory

Source: NREL

Commercial Technologies

- Almost all commercial systems are combustion/steam turbine
- Most are grate stokers, but some fluidized bed combustion
- 1-110 MW (average is ~20)
- 500+ facilities in U.S
- Installed costs $1,700 - $3,500/kW
- Smaller systems (< 5 MW still have poor economics)
- Gasification/pyrolysis emerging
  - Use of pyrolysis oils in diesel generators being done in Canada (Dynamotive)

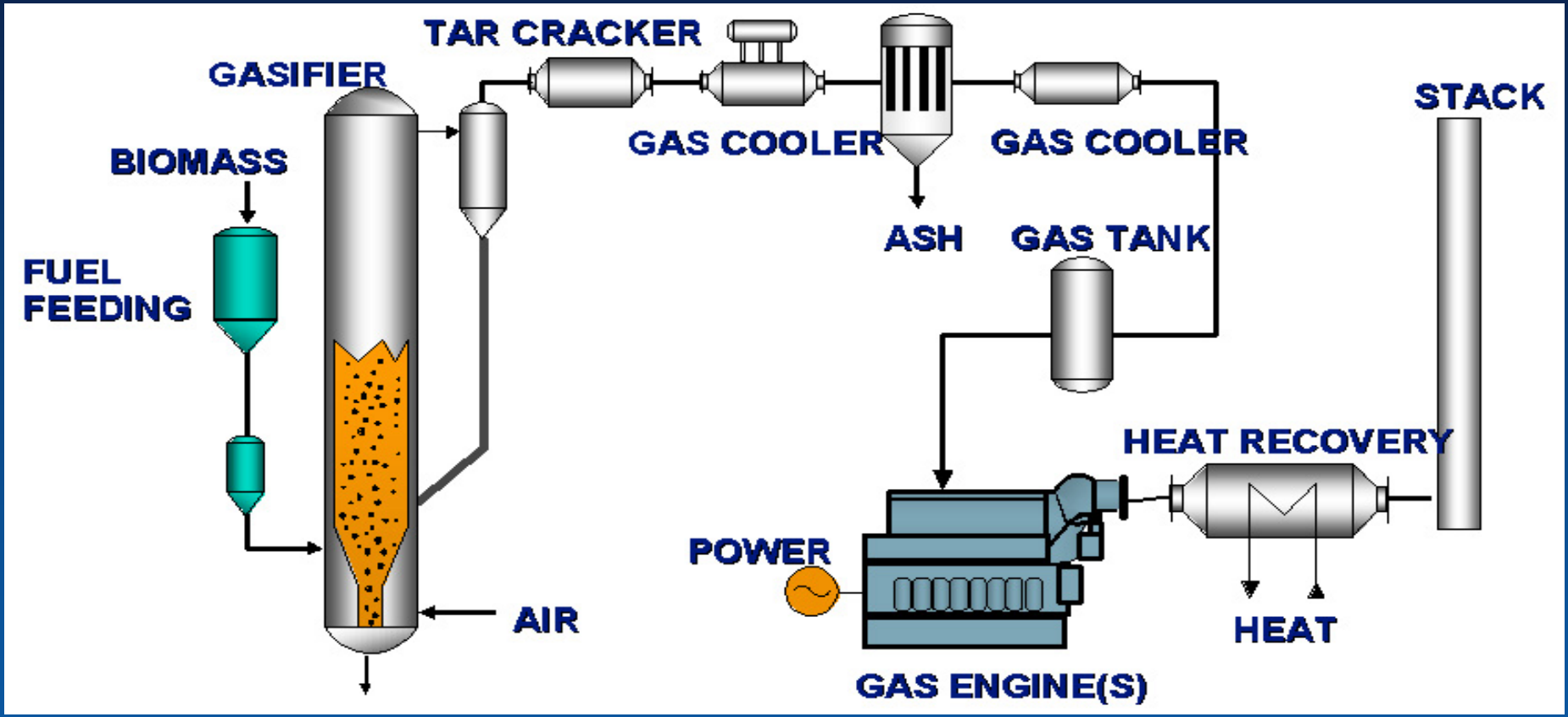
Technical Issues - Combustion

- Poor conversion efficiency: 20-25% of fuel input converted to power
- Mineral management issues (slagging and fouling of the boiler)
- Emissions: NOx, CO, particulate
- Wide range of fuel types
- Multiple vendors
- Equipment warranties
- Tried and true

Biomass Gasification

- More efficient than combustion, 30%- 40%
- Manages mineral matter
- Fuel gas (CO + H2 + CH4) can be used in engines, gas turbines, steam turbines
- Pre-commercial, early demo
- Installed Cost $2,500 and up per kW

Sample Application for Gasification



Comparison

Gasification

- Next generation, near commercial
- Higher efficiency
- Clean burning, versatile uses for gas
- Fuel specifications more stringent
- Reduced water requirements

Combustion

- Commercial technology
- Inefficient but reliable
- Emissions are a concern
- Large water requirements

Emissions

- Modern biomass technologies are automated, efficient and clean burning
- Emissions from plants can be controlled through scrubbers, precipitators, baghouse
- Biomass has almost no sulfur
- Considered CO_2 neutral by the Intergovernmental Panel on Climate Change (IPCC)
  - Considered CO_2 negative by California Public Utilities Commission

Bioenergy Power Plant Overview

1. Fuel Handling
    1. Storage, sizing, movement
    2. Drying
2. Conversion technology
    1. Combustion, gasification, biochemical, pyrolysis, physical
        1. Boiler/steam
        2. Gasifier – producer gas or syn gas
3. Prime mover
    1. Steam turbine/generator
    2. Internal combustion engine, gas turbine
4. Controls
5. Emissions control
6. Ash removal
7. Water treatment and cooling
8. Product delivery (pipes for hot water, power lines)

Prominent Firms
(last 10 - 15 years)

EPI

Babcock & Wilcox
world leader in power generation
equipment design, supply and service

FOSTER WHEELER

ALSTOM

SIEMENS

Wheelabrator Technologies Inc.

BLACK & VEATCH

WELLONS

Contact Us
Detroit Stoker Company
"The World's Largest Manufacturer of Industrial Stokers"

Four Classes of Biomass Power

- "Large" industrial (> 10 MW)
- Commercial (1 MW – 10 MW)
- Small (250 kW – 1 MW)
- Micro (< 250 kW)

Large-scale biopower (20 MW)

Coronado Generating Station
Large Coal Plant (700 MW)

Medium Gasifier (Emerging Technology)

- Bioconversion Technologies (BCT)
  - Range Fuels
- Pyrolysis/gasification with steam reformation
- High conversion efficiency
- Needs ~40% moisture fuel
- Produces clean gas, used in engine
- Can produce heat, electricity, or ethanol and other chemicals
- Minimal water requirements
- Semi-mobile
- Many other companies are out there in various phases of development

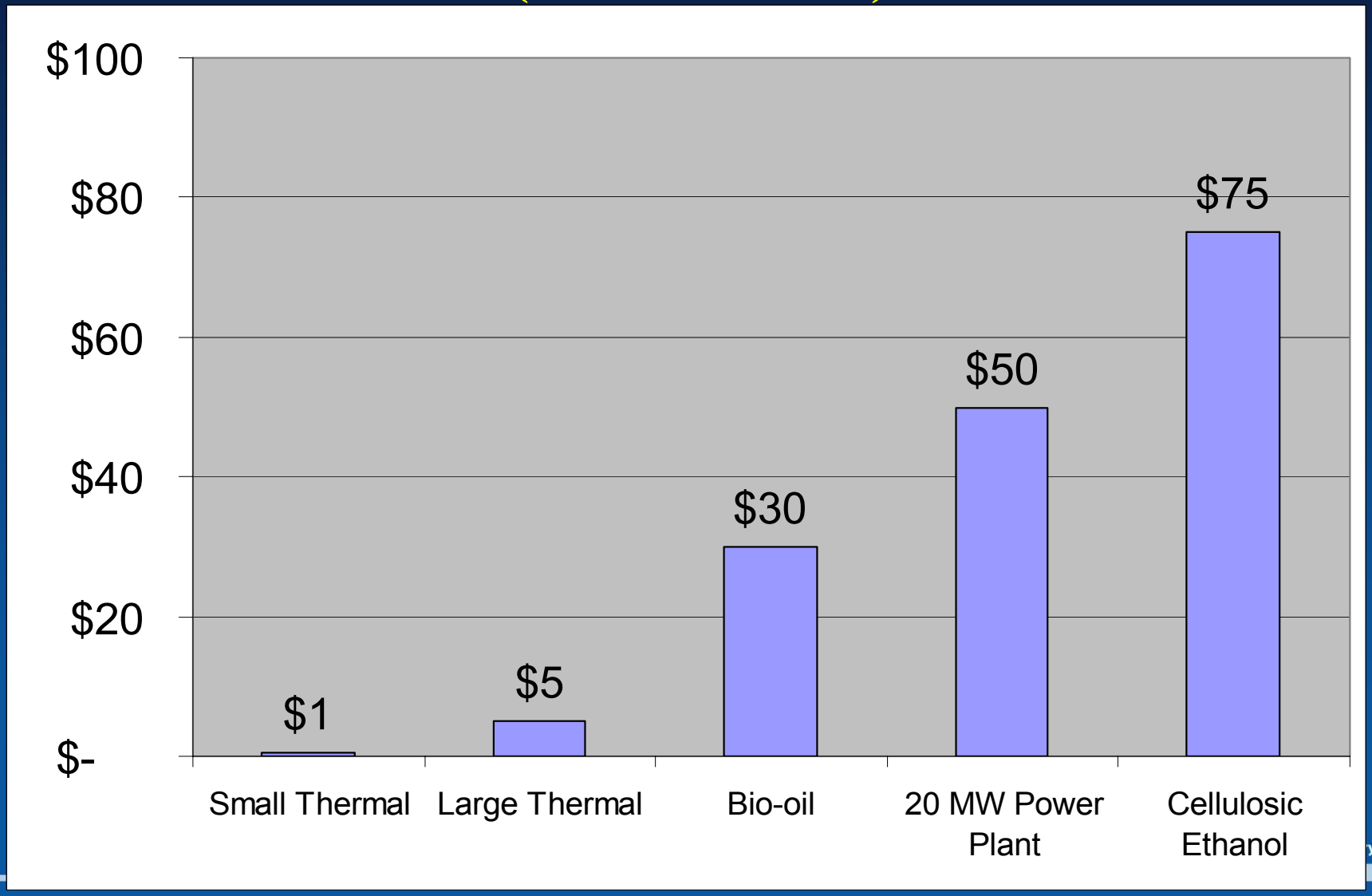
Small to Medium Scale

- Chiptec
- Close-coupled gasification
  - (gas is ignited right away to produce steam for traditional steam turbine
- Hundreds of thermal only systems
- A few power generation systems
- Simple technology

EERC-Gasifier

Micro Scale (Community Power Corp 15 kW – 100 kW)

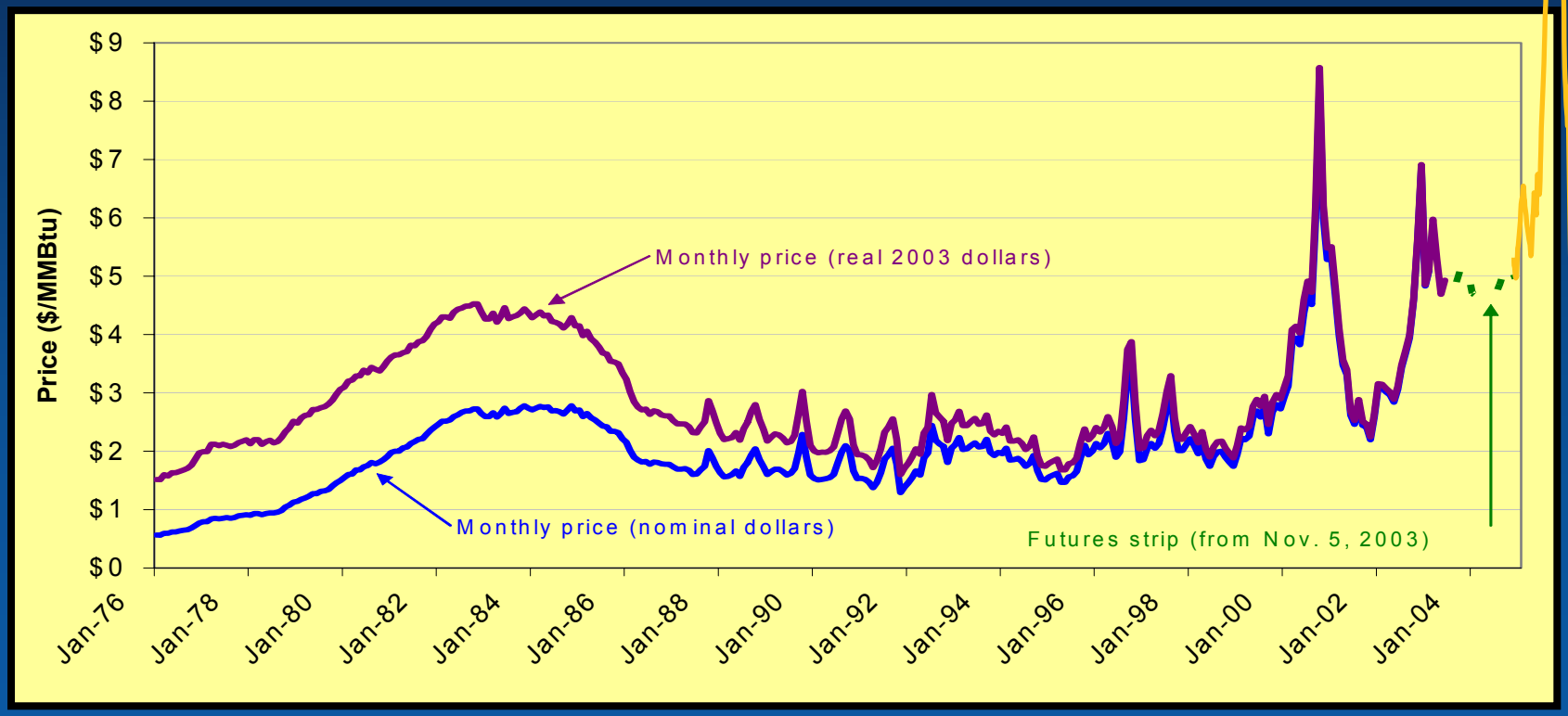
Capital costs of bioenergy applications (million $)



Biopower Success Factors

- Supply
  - Low cost resource
  - Flexible contracts from multiple sources
  - Permit plant for multiple fuels
  - Develop the business models to deliver fuel
- Power
  - "Fair" power purchase contract
- Location
  - Proximity to supply, T&D infrastructure
  - Strategic value, strategic facility
- Technology
  - Reliable, efficient, fuel flexible

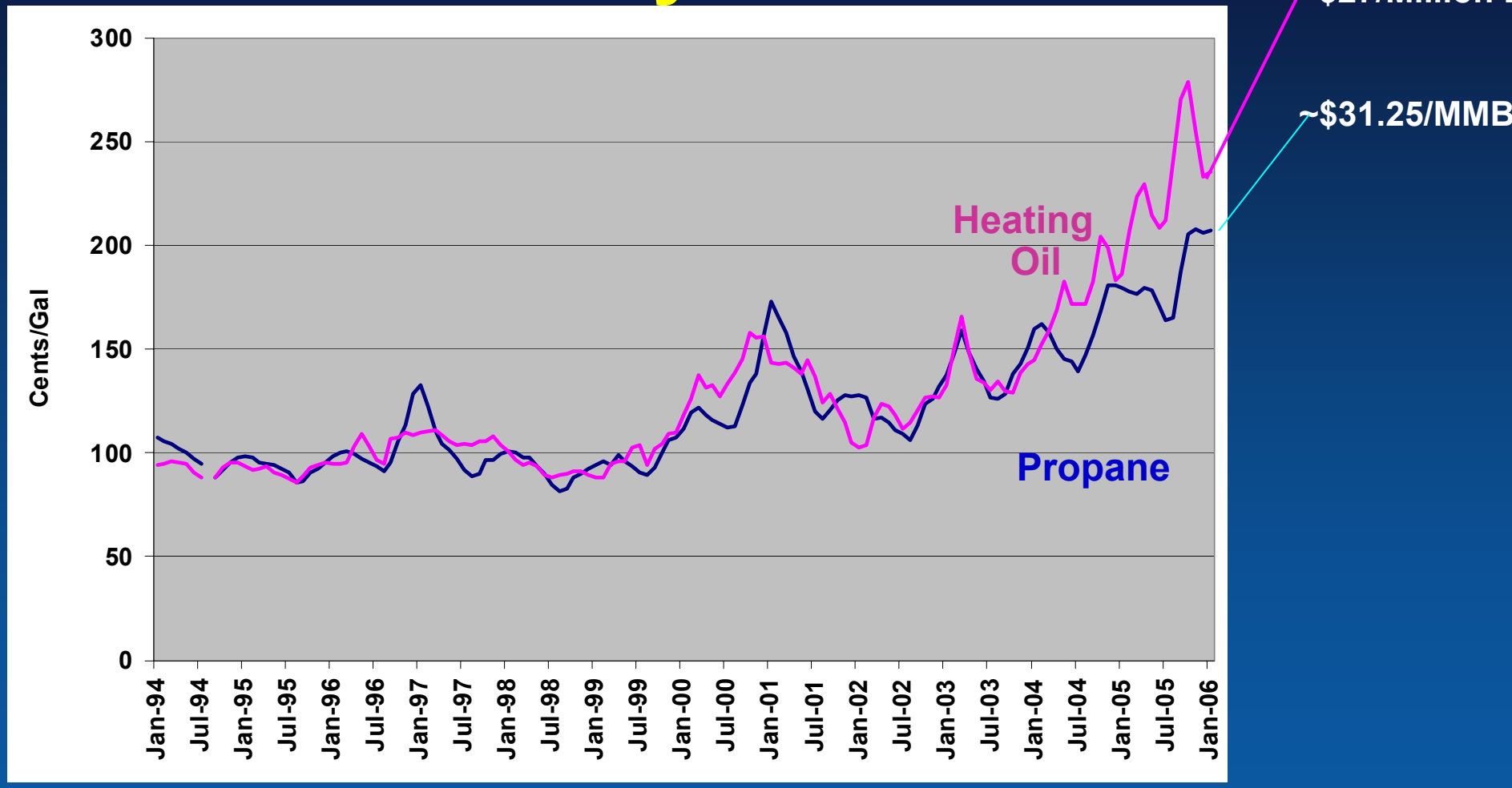
After a decade of low prices, natural gas prices are now more volatile at a higher level



~$15 MMBTU Henry Hub

~$8.00 MMBTU

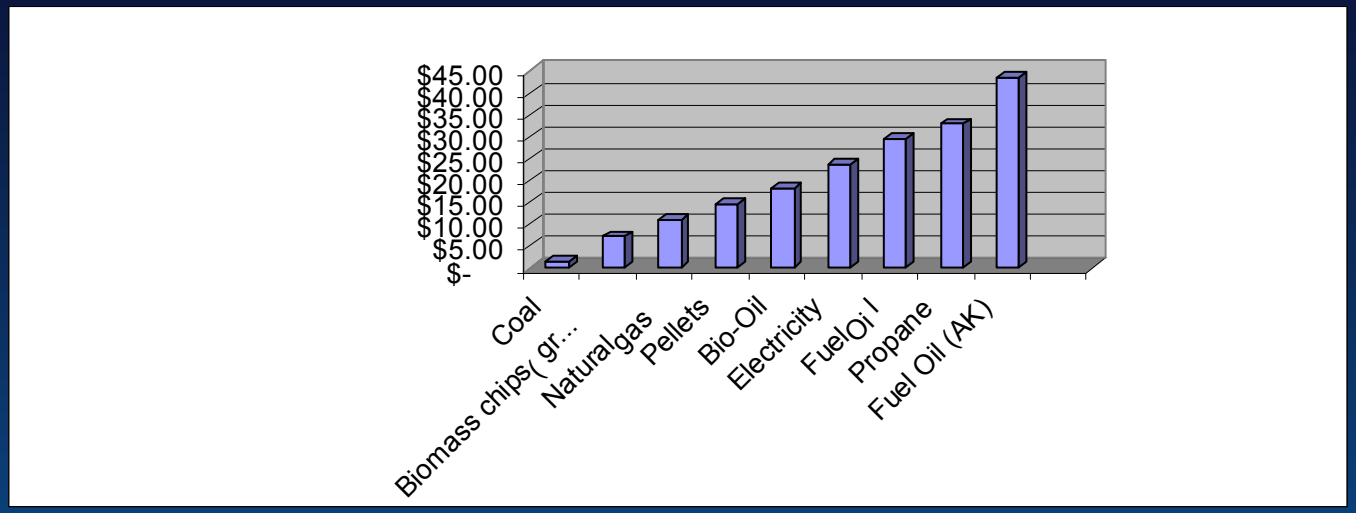
Propane and heating oil over the years



1/7/08 - residential heating oil price = 339 cents/gal

propane = 256 cents/gal

Fuel cost comparisons ($/MMBtu delivered)



Source	Units	Value	Efficiency	Btu/unit	$/MMBtu
Coal	$/ton	$ 25.00	70%	21,000,000	$ 1.70
Biomass chips (green)	$/green ton	$ 40.00	70%	8,000,000	$ 7.14
Natural gas	$/therm	$ 0.98	90%	100,000	$ 10.89
Pellets	$/ton	$ 200.00	85%	16,000,000	$ 14.71
Bio-Oil	$/gallon	$ 1.25	85%	80,000	$ 18.38
Electricity	$/kWh	$ 0.08	100%	3,413	$ 23.44
Fuel Oil	$/gallon	$ 3.39	85%	135,000	$ 29.54
Propane	$/gallon	$ 2.56	85%	91,600	$ 32.88
Fuel Oil (AK)	$/gallon	$ 5.00	85%	135,001	$ 43.57

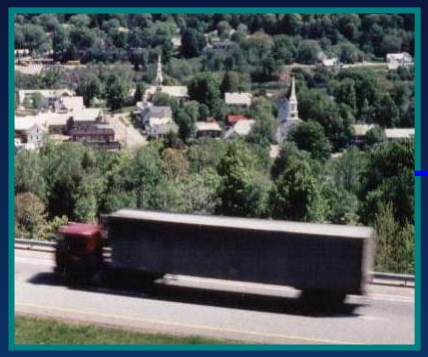
Wood stove heating

Seasoned firewood (20% moisture) @ $300/cord (~$150/ton)

~20 MBTU/cord → high efficiency wood stove @ 77% efficiency

~ $20/MBTU delivered to home
~$2.50/gal heating oil

Commercial-Scale Wood Heating



Green wood chips (50% moisture) @ $50/ton
~8.6 MBTU/ton in a
high efficiency wood boiler @ 85% efficiency

~ $7.00/MBTU delivered to building

Existing Systems

Wood Products Industry

Darby, MT

Four Main Sizes of Commercial Biomass Heating Systems

- Large, automated wood chip
  - Typically buildings over 100,000 square feet
  - Smaller buildings if they have year round need for hot water (prison, hospital
  - Must have large heating bills to justify investment
- Semi-automated surge bin
  - 10,000 – 100,000 square feet
  - Bucket loader
- Pellet-fired
  - 5,000 square feet and up
  - Systems less expensive, less storage
- Cord wood
  - 5,000 – 50,000 square feet
  - Manual loading of fire wood 1-3 times/day

Automated chip heating systems

- High capital costs,
- Storage needs,
- Fuel must be consistent, no sticks
- Minimal labor

- 4 acres under glass
- Biomass system saves $400/day in propane costs
- Without biomass, would need to close down due to high propane costs

Cedar Mills Organic Greenhouse, Jackson, CA

Surge-bin system

Smaller,

Simpler,

Cheaper

Source: USFS Fuels for Schools Program

Pellet Systems

Source: USFS Fuels for Schools Program

- Fuel is twice as costly
- Storage smaller, cheaper
- Boiler smaller, cheaper

Pellet Storage

Source: USFS Fuels for Schools Program

Pellets vs. chips

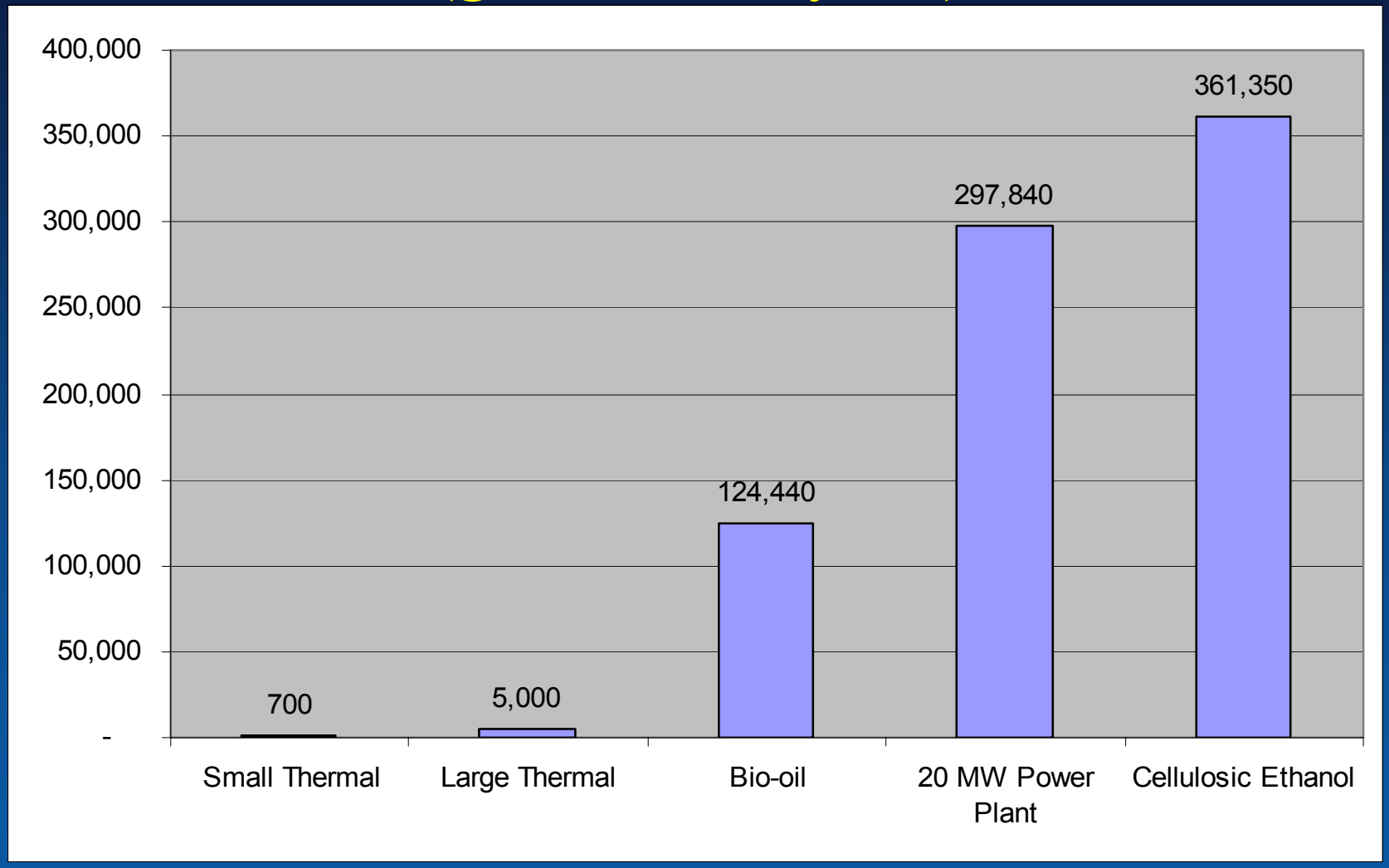
- Pellets
  - Consistent quality
  - Dry fuel
  - Lower capital costs
  - Smaller footprint
  - Storage in silos
  - Higher fuel costs
  - Need commercial pellet infrastructure for bulk fuel deliveries
  - Lower ash

- Chips
  - Lower fuel costs
  - Potential quality problems
  - Possible moisture issues
  - Larger footprint
  - Larger storage area
  - Higher equipment capital costs
  - Low ash

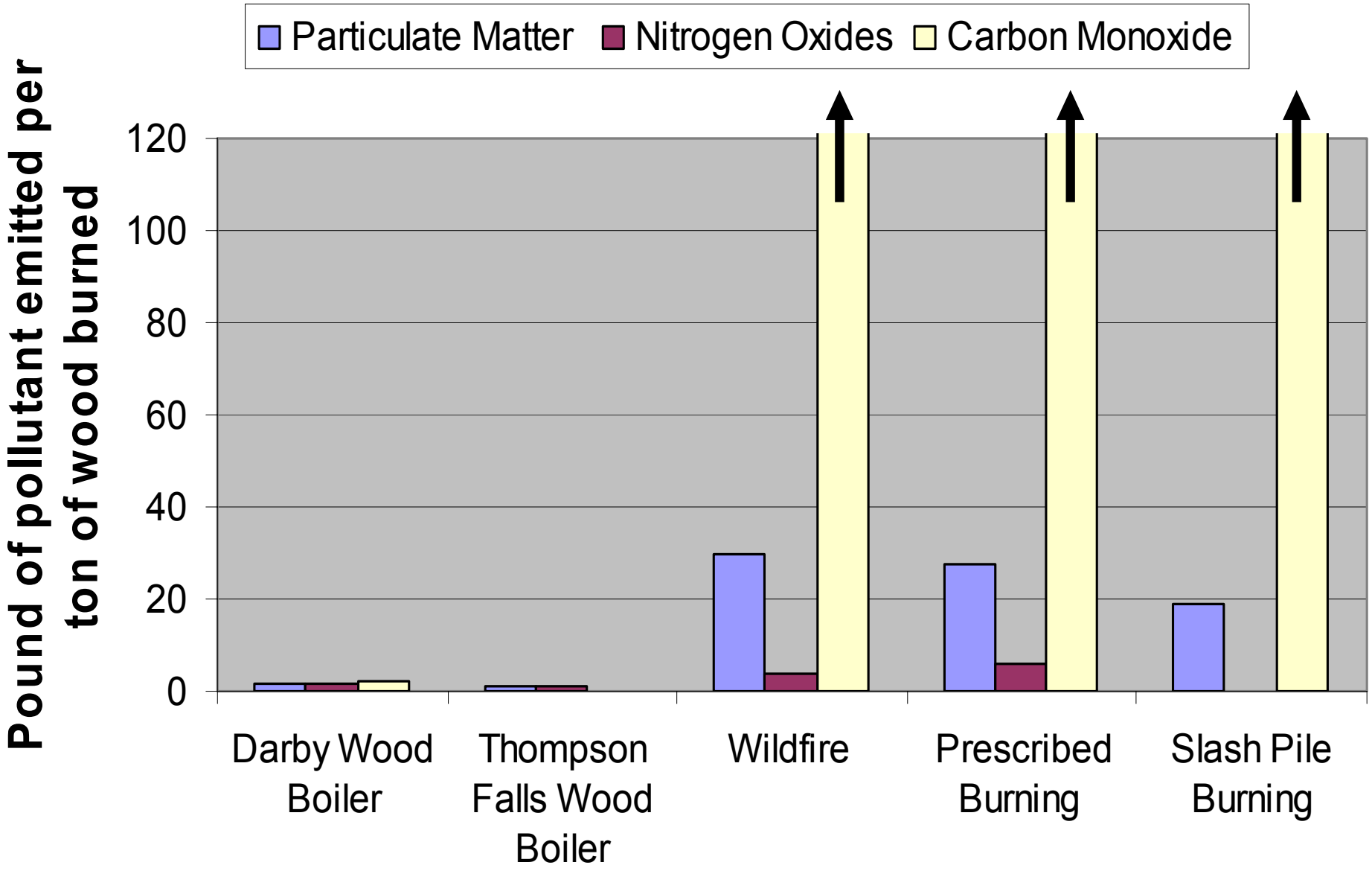
Garn – Cordwood

Source: USFS Fuels for Schools Program

Annual biomass fuel requirements (green tons/year)



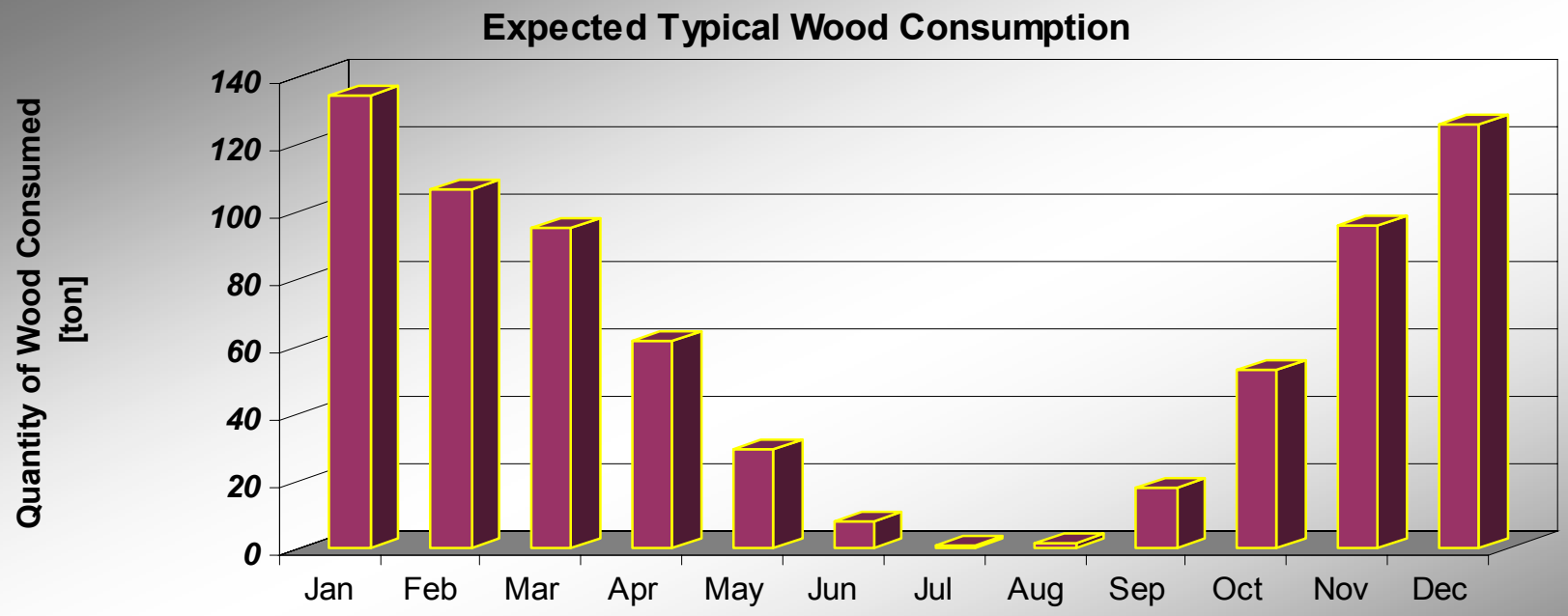
Pollutant Emission Rates for Wood Boilers and Fire Activities



Source: USFS Fuels for Schools

							Wood Properties	
		Btu/dd/ft2				ft2	40	% MC wb
	Office (avg)	10.2			Office Space	27535	8640	Btu/lb dry
	Garage (avg)	14.0			Garage Space	45151	5184	Btu/lb wet
Heated Storage (avg)		2.5			Heated Storage	53724	103.68	Therm/ton
					Total	126410	0.5	% ash
Analysis of Past Bills				**Biomass heating value 5184 Btu/green lb**				
		Office	Garage	Heated Storage	Input	Delivered to bldg	Needed from Biomass	Tons
Period	# days	Therms	Therms	Therms	Therms	90% eff	80% eff	
Jan	31	3311	7448	1588	12,347	11,112	13,890	134.0
Feb	28	2636	5929	1264	9,829	8,846	11,058	106.7
Mar	31	2353	5293	1128	8,774	7,897	9,871	95.2
Apr	30	1516	3409	727	5,651	5,086	6,357	61.3
May	31	731	1645	351	2,726	2,454	3,067	29.6
Jun	30	188	422	90	700	630	787	7.6
Jul	31	22	50	11	84	75	94	0.9
Aug	31	39	88	19	146	132	165	1.6
Sep	30	443	996	212	1,650	1,485	1,857	17.9
Oct	31	1314	2955	630	4,899	4,409	5,511	53.2
Nov	30	2362	5312	1132	8,806	7,925	9,906	95.5
Dec	31	3098	6969	1485	11,553	10,398	12,997	125.4
12-mont	365	18014	40516	8636	67,166	60,449	75,561	728.8

Total therms input are based on an efficient natural gas system



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wood	134	107	95	61	30	8	1	2	18	53	96	125

Delivered Energy Example

Energy Input (therms)	67,166
Natural Gas System efficiency (%)	90
Delivered Energy (therms)	60,449
Assume 10% will still come from gas (therms)	6,045
Delivered energy that needs to come from biomass (therms)	54,404
Biomass system efficiency (%)	80
Biomass Input energy needed to deliver biomass output (therms)	68,006
Heating content of fuel (Btu/lb)	5,184
Heating content of fuel (MMBtu/ton)	10.37
Actual biomass needed (tons)	655.92
Acres needed @ 10 tons/acre	65.59
Annual Ash Production (.5%) (tons)	3.28

Economics

- Estimate incremental capital cost when compared to fossil fuel system
- Estimate annual operations and maintenance costs of each system
- Estimate annual fuel costs
  - You will never replace 100% of wood
  - Size the system to replace 80-95% of gas, but let the natural gas back-up system meet peak requirements
- Simple payback is a quick measure

Economic Analysis

From previous example, assume we are replacing 90% of energy with wood

System Cost:	$ 300,000		
Biomass System	**Quantity**	**Cost**	Total
Biomass fuel use	656.00	$ 15.00	$ 9,840
Natural gas use	6,716	$ 1.02	$ 6,850
O&M			$ 2,200
Annual Cost			$ 18,890
Natural Gas System			
Natural gas use	67,166	$ 1.02	$ 68,509
O&M			$ 200
Annual cost			$ 68,709
Savings of biomass system			$ 49,819
Simple payback			**6.02**

Fuel supply and quality is the single most important factor in a successful project

Biomass Supply Questions

- How much do I need?
- Where is it going to come from?
- How reliable is the source?
- Who will bring it to me?
- What will it cost?
- What is the quality of the fuel?
- Sizing, storing?

Fuel handling issues

Poor quality wood

Poor quality fuel (90% needles)

Clinker, due to sand in fuel

Federal / State Tax Credits and Incentives for Biomass Power

- Production tax credit (PTC)
- Local property tax credits
- Accelerated depreciation (MACRS)
- Fuel production grant (authorized, not appropriated)
- Loan guarantees (DOE, USDA, BIA)
- Renewable portfolio standards
- Renewable energy certificates
- Carbon credits (mostly signatories to Kyoto)
- New Market Tax Credits
- CREBS (Clean Renewable Energy bonds)

Bioenergy Feasibility Studies: Steps

- Supply: resource assessment and costs
- Project type: "behind the meter", export to grid, or both
  - On-site demand: assess on-site loads, local market analysis for product if doing cogeneration at a host site (e,g. sawmill)
  - Talk to your utility early
- Technology characterization and sizing
- Environmental review
- Capital costs
- Economic analysis
- Community support
- Fatal flaw analysis
- Power purchase agreement
- Financing

Summary

- Reliability of biomass supply is critical
- Partnership between conservation community, industry and agencies
- Leverage economic incentives, green power

Additional Resources

- US EPA - Biomass Combined Heat and Power Catalog of Technologies (2007)
  - http://www.epa.gov/chp/documents/biomass_chp_catalog.pdf
- Western Governor's Association Biomass Energy Task Force Report (2006)
  - http://www.westgov.org/wga/initiatives/cdeac/biomass.htm
- Biopower Technical Assessment: State of the Industry and Technology (2003)
  - http://www.nrel.gov/docs/fy03osti/33123.pdf

Resources

- Wood Chip Heating Systems
  - http://www.biomasscenter.org/pdfs/Wood-Chip-Heating-Guide.pdf
- Boulder County Feasibility Study
  - http://www.co.boulder.co.us/openspace/resources/forestry/for_pdfs/BCPOS_Final_Biomas_Report_web.pdf
- US Forest Service Fuels for Schools
  - http://www.fuelsforschools.org/