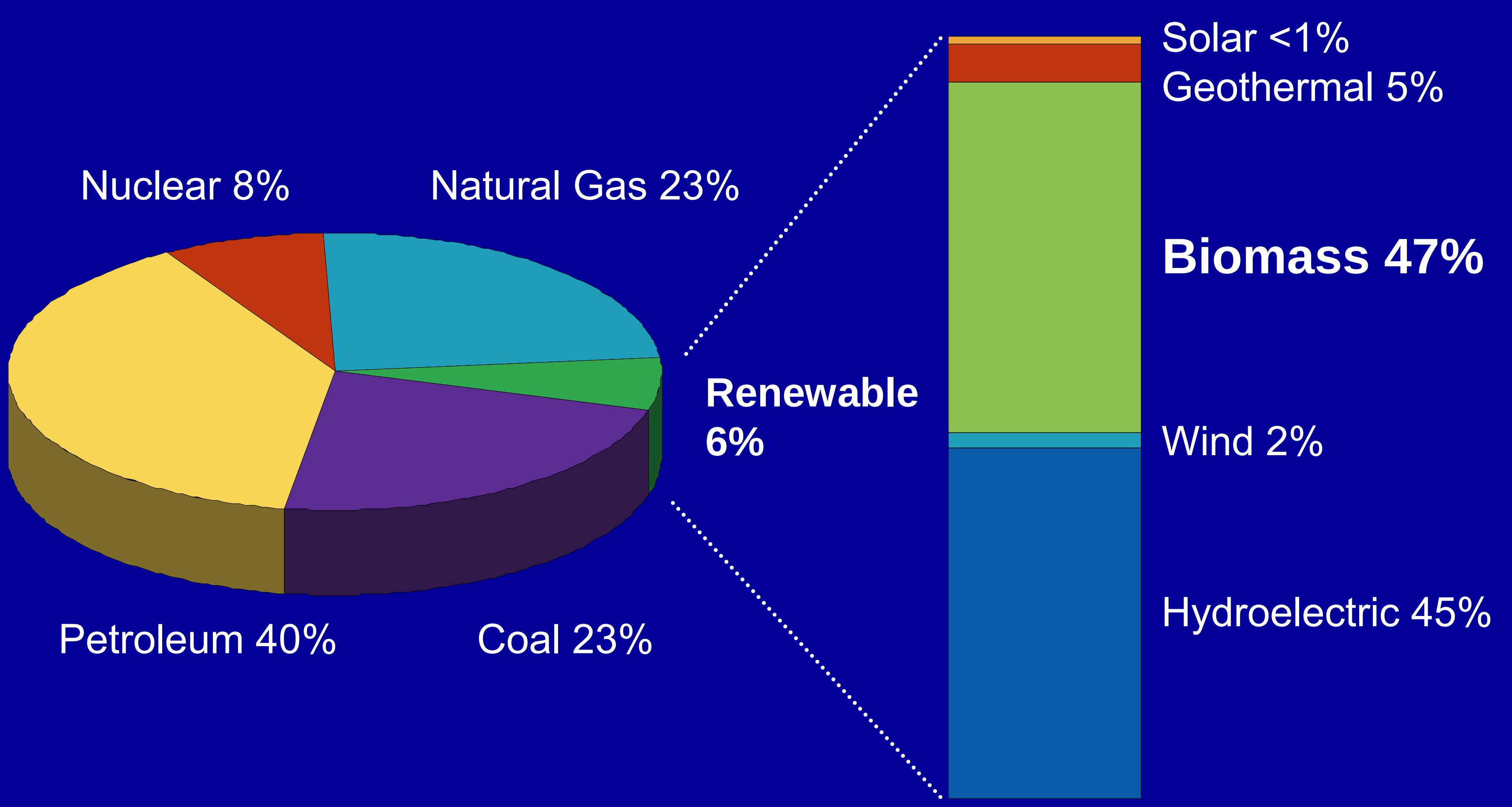
Biomass for Community Energy

Biomass Share of U.S. Energy Supply (2004 data)



Source: Renewable Energy Trends 2004; Energy Information Administration, August 2005.
Note: Total U.S. Energy Supply is 100.278 QBtu; Energy Information Administration, August 2005.

U.S. Biomass Resource Potentials

- Corn (largest volume grain and source of EtOH in U.S.)
  - Potential to displace 10-20% of our gasoline

Soybeans, fats & greases (largest sources of biodiesel)

  - Potential to displace 5-10% of our diesel

Food Supplies

Over 1 billion tons/year of lignocellulosic biomass (trees, grasses, etc.) could be available in the U.S.

  - Potential to displace 50-70% of our gasoline

Not a Food Supply

Short-term: improve cost and efficiency of corn ethanol & biodiesel
Mid to Long-term: focus on lignocellulose (trees, grasses, & residues)

Biomass Feedstocks

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

Renewable Energy Use Matrix

Energy End-Use Needs

Renewable Energy Technology Options

	Heat	Electricity	Fuel Gas	Fuel Liquids
Solar	✓	✓		
Wind		✓		
Geothermal	✓	✓		
Hydro		✓		
Biomass	✓	✓	✓	✓

Renewable Energy Use Matrix

Energy End-Use Needs

Renewable Energy Technology Options

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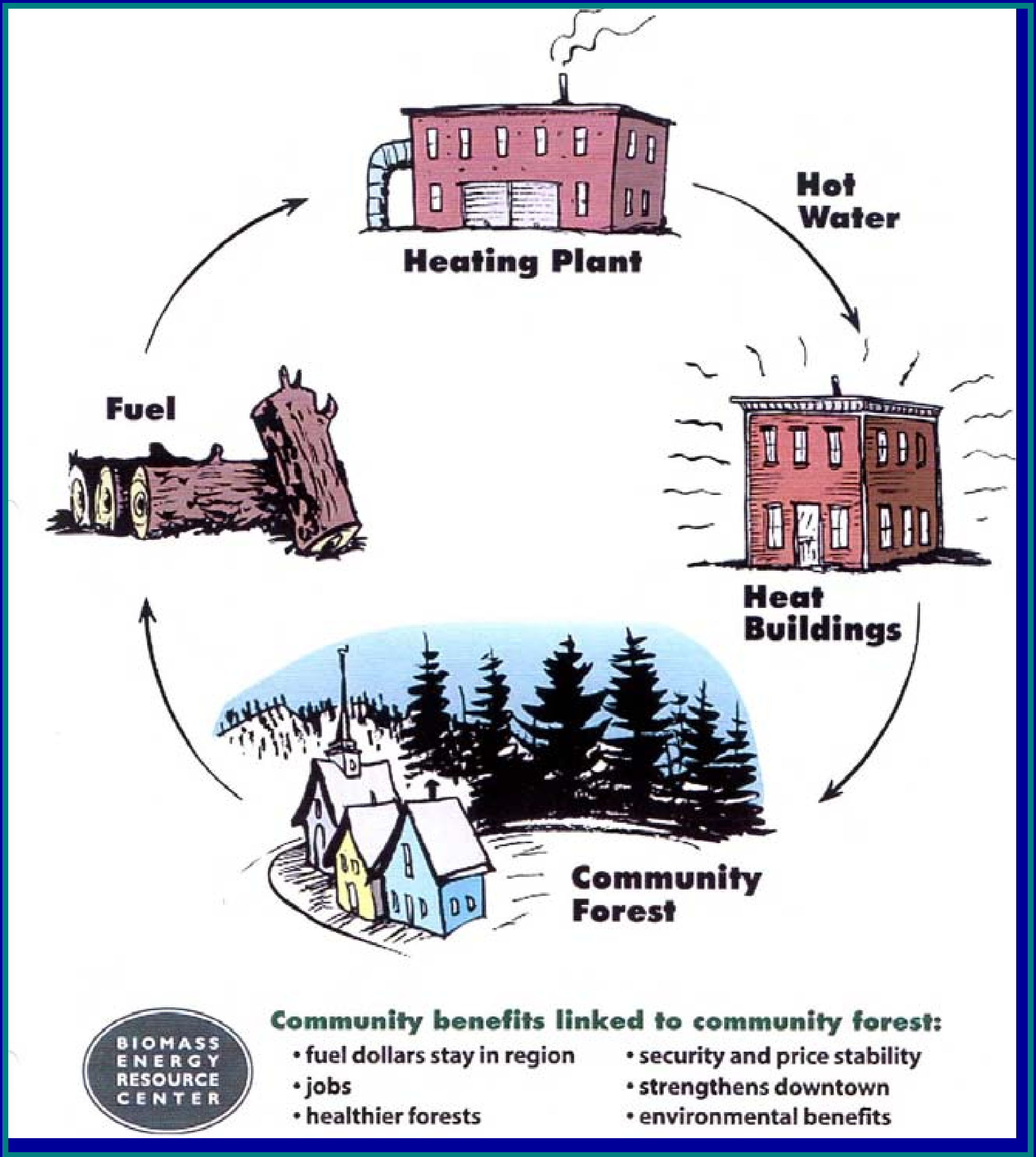
Biomass	✓	✓	✓	✓

Benefits of Using Forest Biomass



- Sustainable renewable fuel source
- Local and regional economic development
- Positive action on climate change
- Low cost fuel
- Restoring forest health

Fuel Energy Value Comparison

Fuel	Unit	Cost/unit	Average Efficiency	$/MMBtu Delivered
#2 Oil	gallons	$2.20	75%	$21.26
Propane	gallons	$1.80	80%	$21.74
Natural gas	therms	$1.00	80%	$13.13
Wood chips	**tons**	**$45.00**	**65%**	**$6.87**
Wood pellets	tons	$175.00	80%	$14.10

Wood Energy Applications

- Space heat, cooling, domestic hot water, and power generation
- Wide range of building sizes (23,000 – 750,000 square feet)
- Wide range of building types
- Multiple buildings using central heating plant
- In regions with over 8,000 HDD and under 4,500 HDD

Wood Chip Heating Applications

- Schools
- Office Complexes
- College and University Campuses
- Maintenance Facilities
- Hospitals
- Correctional Facilities
- Farms and Greenhouses
- Other Commercial Facilities

Wood Chip Heating in Vermont

- 26 public schools currently heating with woodchips
- 2 major state office complexes heating with chips
- 8 other state facilities heating with chips (including correctional facilities, court houses, etc.)
- 1 hospital using wood for CHP
- 1 college campus system – under development
- Numerous commercial systems

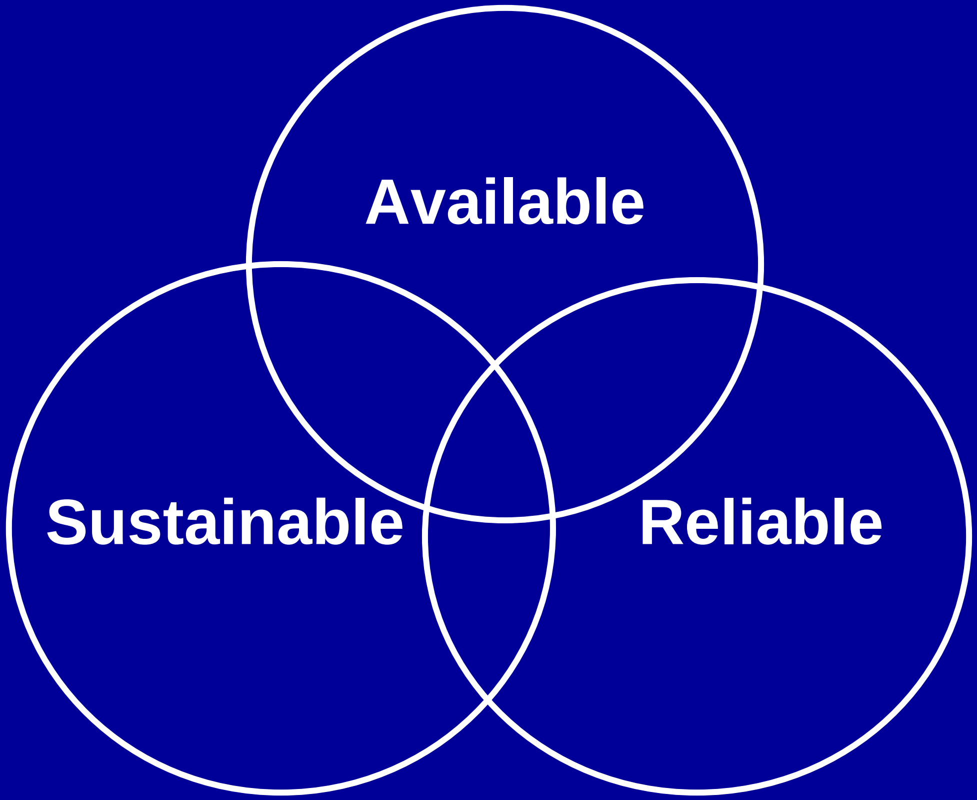
Institutional Wood Energy - Schools

Vermont's School Experience

- 26 Schools over 20 years
- 12% of student population
- Schools range in size between 23,000 ft^2 and 270,000 ft^2, average is 110,000 ft^2
- 16,000 tons of wood chips per year total
- Average annual fuel cost is \$0. 24/ ft^2

How Woodchip Systems Work

Fuel supply needs to be…



Wood Fuel Types

- Cord wood
- **Wood chips**
- Wood pellets
- Other (sawdust, bark, etc.)

Where does the fuel come from?

- Directly from forest harvesting
- Sawmills or other generators of by-product

Fuel Sources

Sawmill Residues

Fuel Sources

Low-grade & small diameter wood & harvesting residues

What makes quality wood chips?

- Uniform shape and size
- Moisture content
- Absence of dirt and bark
- Tree species

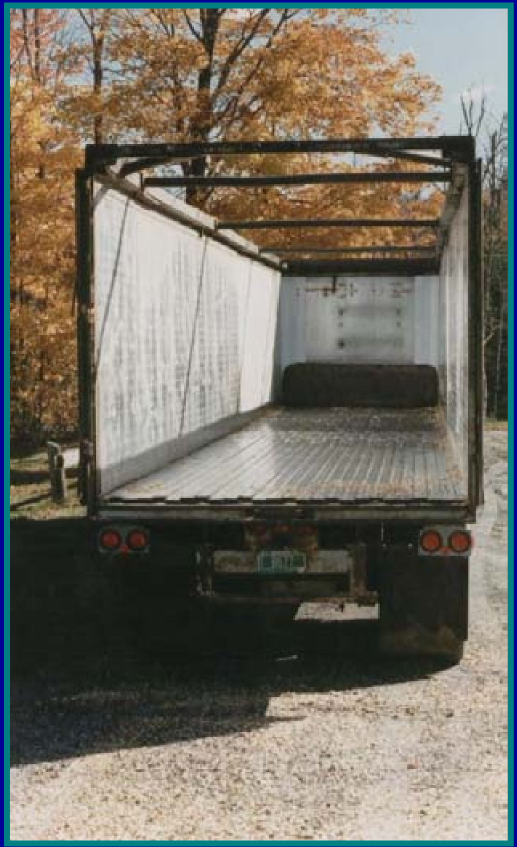
Wood Fuel Properties

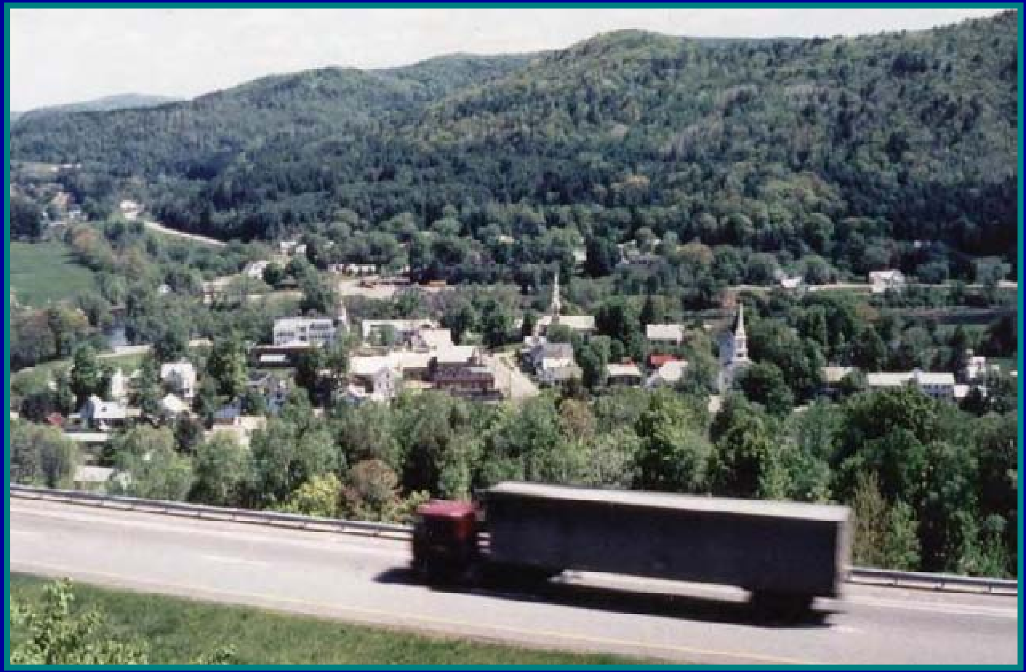
- Dry basis 16.8 MMBtu/ ton
- Average moisture content 35-45%
- Wet basis 10.1 MMBtu/ ton

Wood Fuel Properties

- Ash content
- Silica
- Alkali

Fuel Transport and Delivery





Fuel Transport and Delivery

"Walking floor" trailer

Dump truck

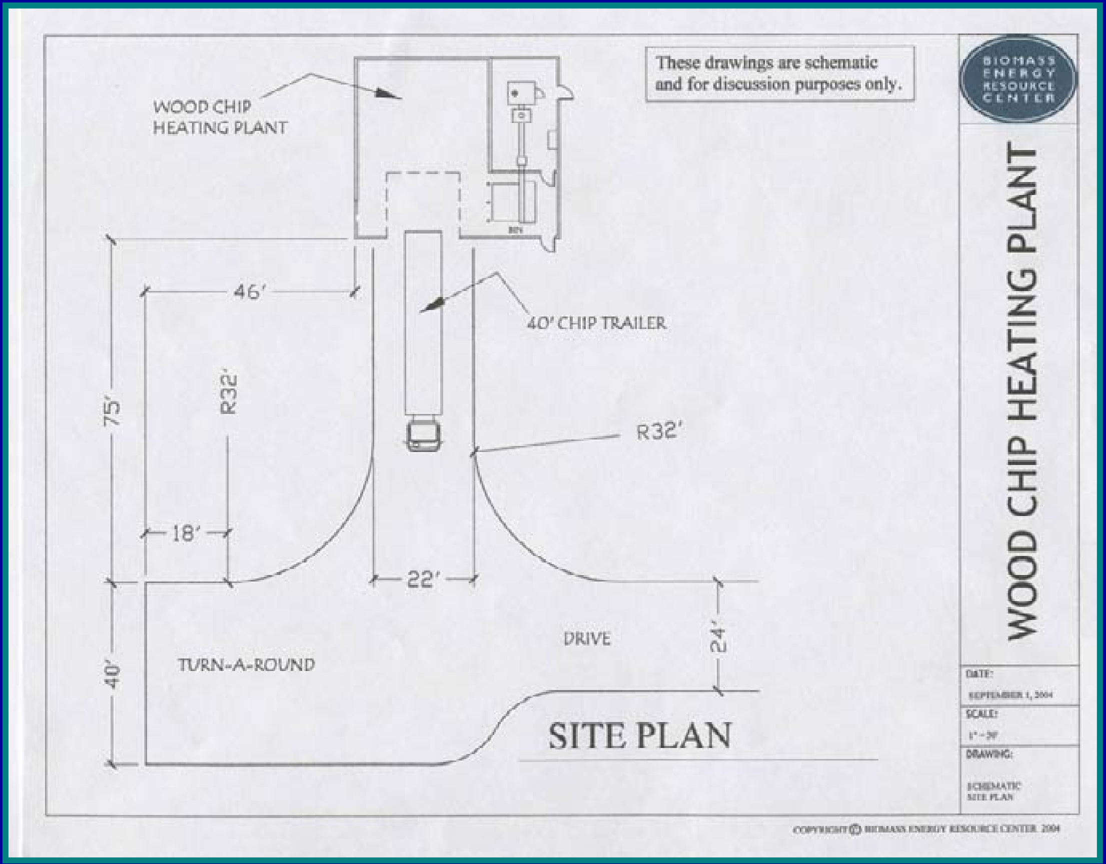
Fuel Storage

Emory Hebard State Office Building
Newport, Vermont

Mt. Mansfield Union HS
Jericho, Vermont

Automated Fuel Handling

Semi-Automated Fuel Handling



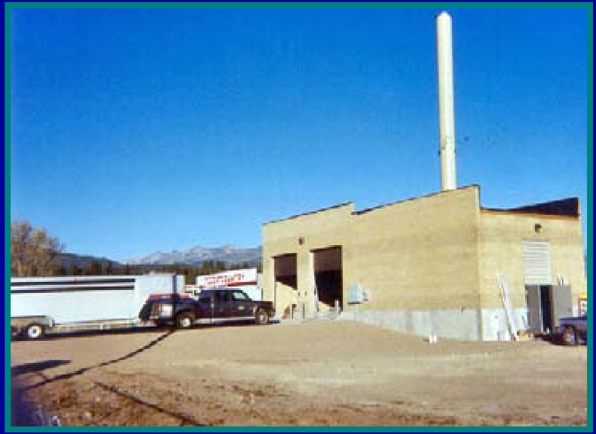
(Conceptual Drawings)

Boiler Configuration

Schools

U-32 High School, Montpelier, VT

Schools



Darby School District Montana

Office Complexes

State Office Complex, Waterbury, VT

Office Complexes

State Capital Complex, Montpelier, VT

College & University Campuses

Middlebury College, Middlebury, VT

Maintenance Facilities

Town Garage, Lyme, NH

Hospitals

South Shore Regional Hospital, Bridgewater, Nova Scotia

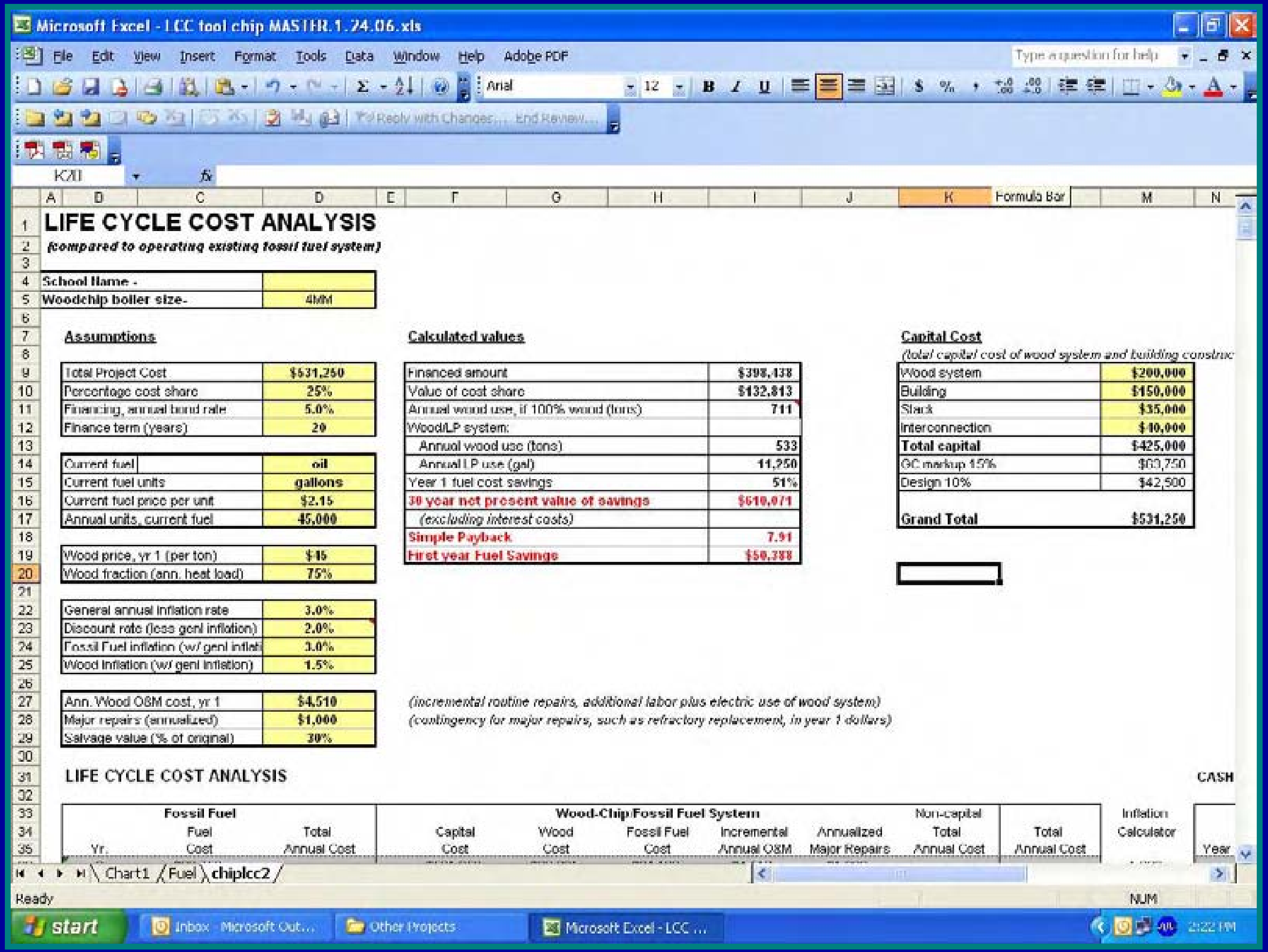
Businesses

Wood products business

Farm – slab floor heating

Commercial greenhouse

Life Cycle Cost Analysis



Microsoft Excel - LCC tool chip MASTER.1.24.06.xls

LIFE CYCLE COST ANALYSIS

(compared to operating existing fossil fuel system)

School Name -	
Woodchip boiler size-	4MM

Assumptions

Total Project Cost	$531,250
Percentage cost share	25%
Financing, annual bond rate	5.0%
Finance term (years)	20
Current fuel	oil
Current fuel units	gallons
Current fuel price per unit	$2.15
Annual units, current fuel	45,000
Wood price, yr 1 (per ton)	$45
Wood fraction (ann. heat load)	75%
General annual inflation rate	3.0%
Discount rate (less genl inflation)	2.0%
Fossil Fuel inflation (w/ genl inflati	3.0%
Wood inflation (w/ genl inflation)	1.5%
Ann. Wood O&M cost, yr 1	$4,510
Major repairs (annualized)	$1,000
Salvage value (% of original)	30%

(incremental routine repairs, additional labor plus electric use of wood system)
(contingency for major repairs, such as refractory replacement, in year 1 dollars)

Calculated values

Financed amount	$398,438
Value of cost share	$132,813
Annual wood use, if 100% wood (tons)	711
Wood/LP system:	
Annual wood use (tons)	533
Annual LP use (gal)	11,250
Year 1 fuel cost savings	51%
30 year net present value of savings	**$610,071**
(excluding interest costs)	
Simple Payback	**7.91**
First year Fuel Savings	**$50,388**

Capital Cost

(total capital cost of wood system and building construc

Wood system	$200,000
Building	$150,000
Stack	$35,000
Interconnection	$40,000
Total capital	**$425,000**
GC markup 15%	$63,750
Design 10%	$42,500
Grand Total	**$531,250**

LIFE CYCLE COST ANALYSIS

CASH

Fossil Fuel			Wood-Chip/Fossil Fuel System							Inflation	
Yr.	Fuel Cost	Total Annual Cost	Capital Cost	Wood Cost	Fossil Fuel Cost	Incremental Annual O&M	Annualized Major Repairs	Non-capital Total Annual Cost	Total Annual Cost	Calculator	Year

Chart1 / Fuel / chiplcc2

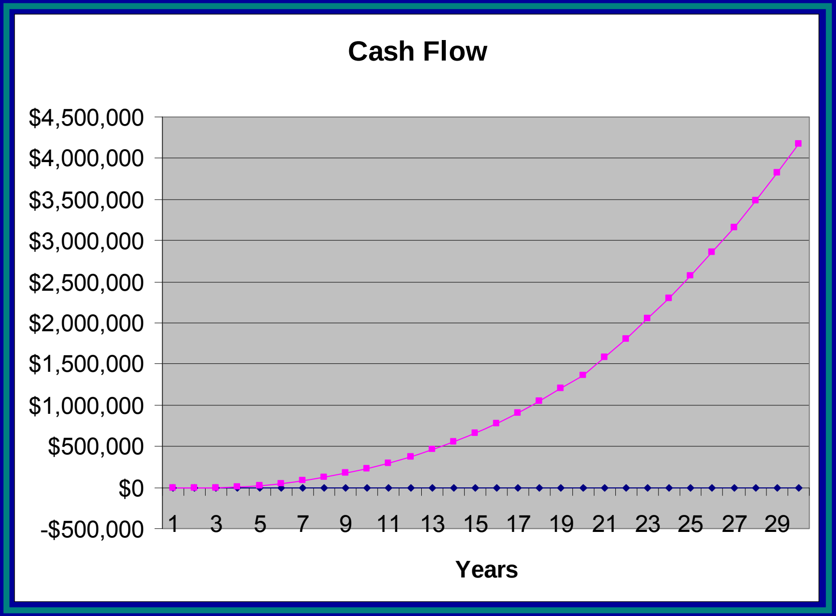
LCC Analysis Tool developed by BERC

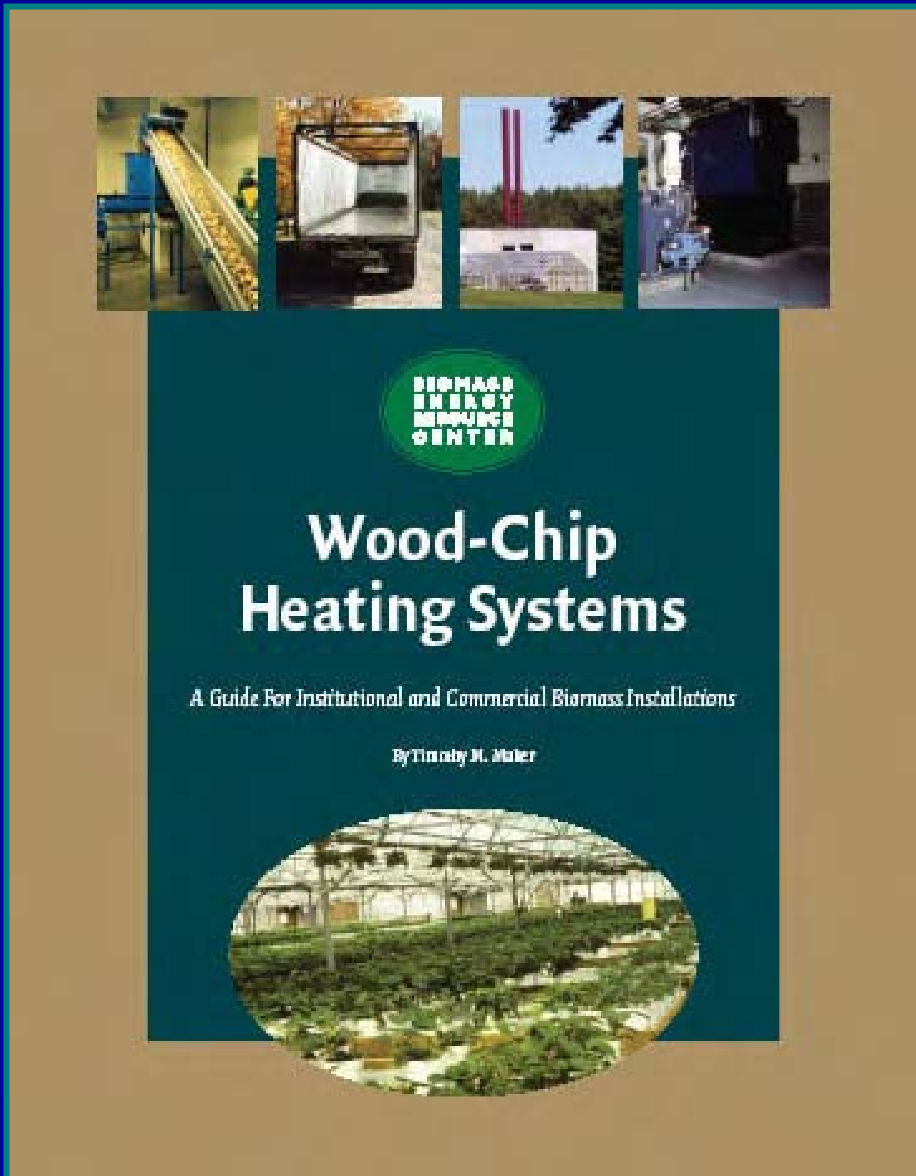
Life Cycle Cost Analysis - (Example)

Key Assumptions

- 200,000 square feet
- 120,000 therms natural gas @ $1.10/therm
- Wood cost = $35/ton
- $850,000 financed over 20 years @ 5.5%
- Offsetting 85% natural gas
- 20% cost share

First Year Fuel Savings	$72,096
Positive Cash Flow	Year 3
Simple Payback	9.4 years
30 Year Net Present Value of Savings	$1,434,476





BIOMASS ENERGY RESOURCE CENTER

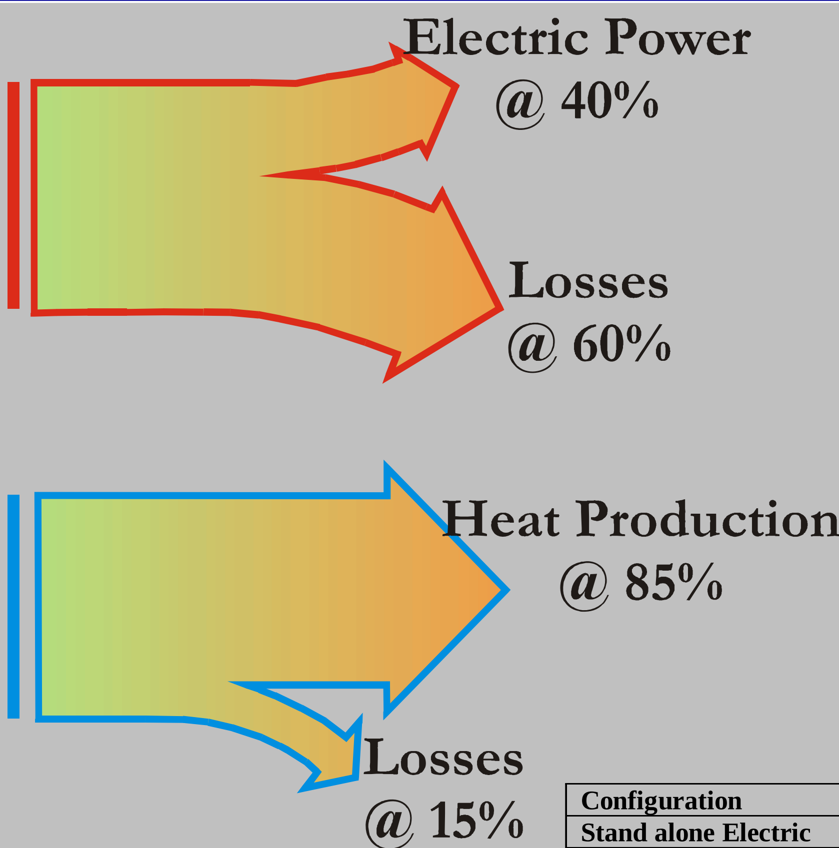
Wood Stove Heating

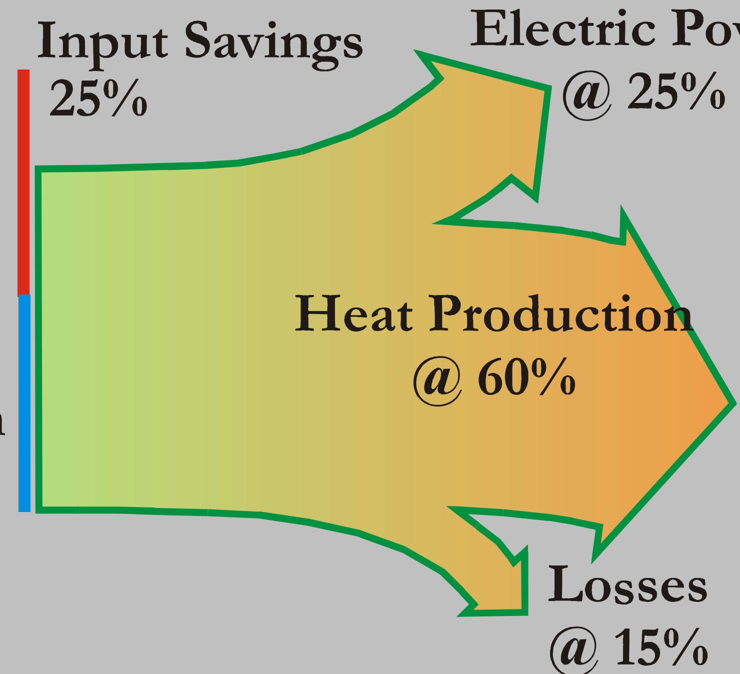
Seasoned firewood (20% moisture) @ $200/cord (~$100/ton)

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

= $13/MBTU delivered to home

Energy Efficiency is the Argument for CHP





Configuration	Input	Heat	Electricity	Losses
Stand alone Electric	88.5	0	35.4	53.1
Stand alone Heat	100	85	0	15
Stand alone total	188.5	85	35.4	68.1
CHP to provide same heat and e	142	85	35.4	21.25
Input Energy Saved	46.9			
Perecntage of Stand Alone	25			

Community CHP

- Community - CHP is mainly being considered for Northern Communities Alaska and Canada's Northern Territories
- Studies underway in Alaska for CHP
- Canada has a number of installations in British Columbia
- In Quebec a novel restructuring of a Cree village Ouje-Bougoumou
- Uses wood residues from sawmill 26 km distant
- District heating system hot water based

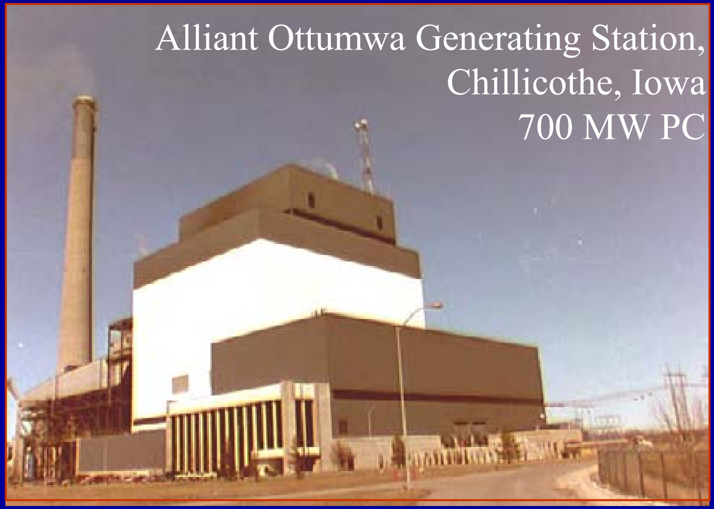
Renewable Energy Use Matrix

Energy End-Use Needs

Renewable Energy Technology Options

	Heat	Electricity	Fuel Gas	Fuel Liquids
Solar	✓	✓		
Wind		✓		
Geothermal	✓	✓		
Hydro		✓		
Biomass	✓	✓	✓	✓

Electricity from Biomass



- **Existing Industry (~7,000 MW in U.S.)**
  - **Direct combustion, residues, ~20% efficiency.**
- **Near Term**
  - **Co-firing with coal, ~35% efficiency**
  - **Several successful demonstrations**
  - **SOx and some NOx reductions**
  - **Encourages feedstock supply/infrastructure**

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

Technical Issues
Combustion

- Conversion efficiency - 20-25% to power
- Mineral management
- Emissions NO_x, SO_x, CO, particulate
- Mature technology (low risk)

Renewable Energy Use Matrix

Energy End-Use Needs

Renewable Energy Technology Options

	Heat	Electricity	Fuel Gas	Fuel Liquids
Solar	✓	✓		
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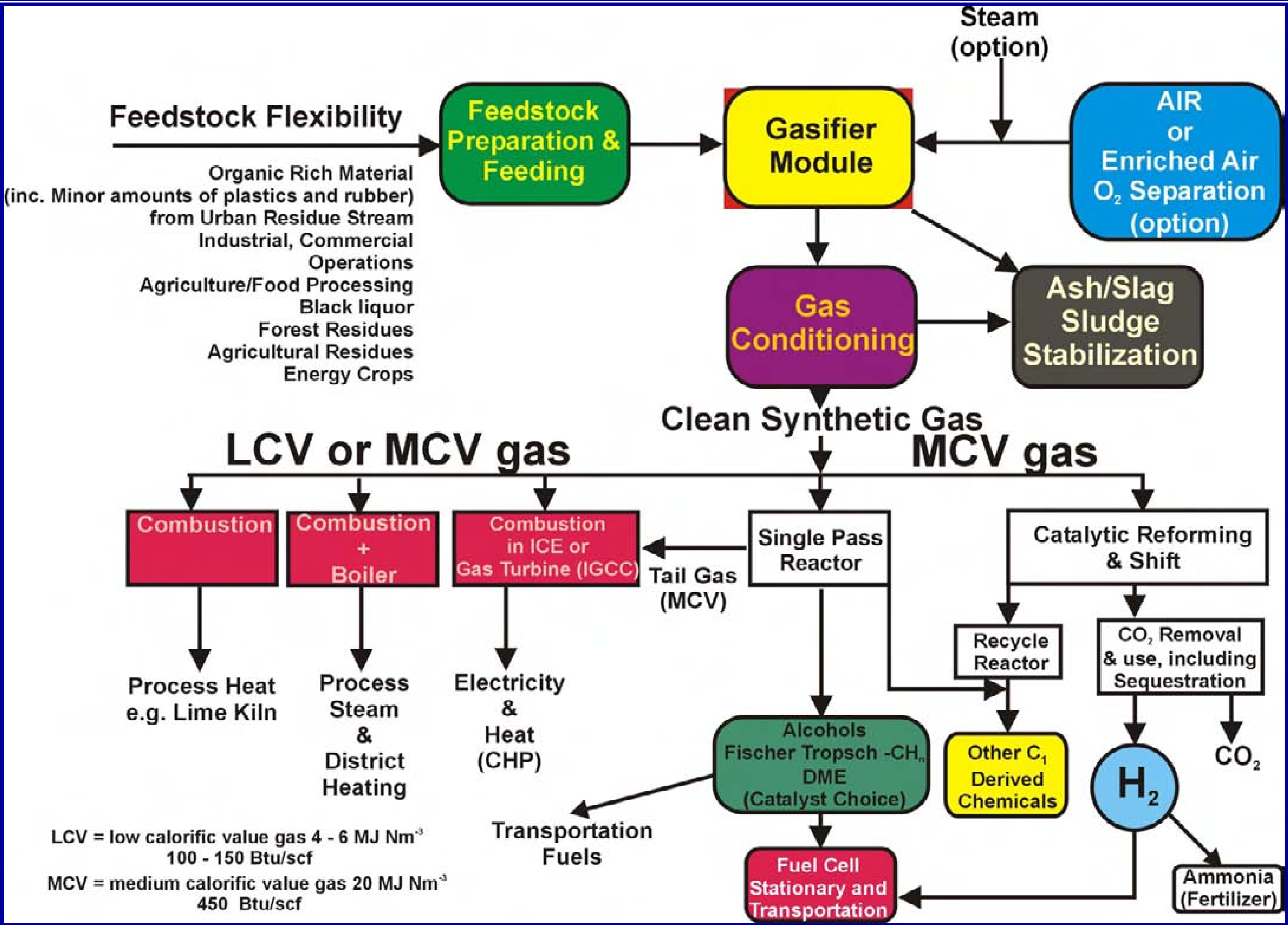
Biomass	✓	✓	✓	✓

Gasification

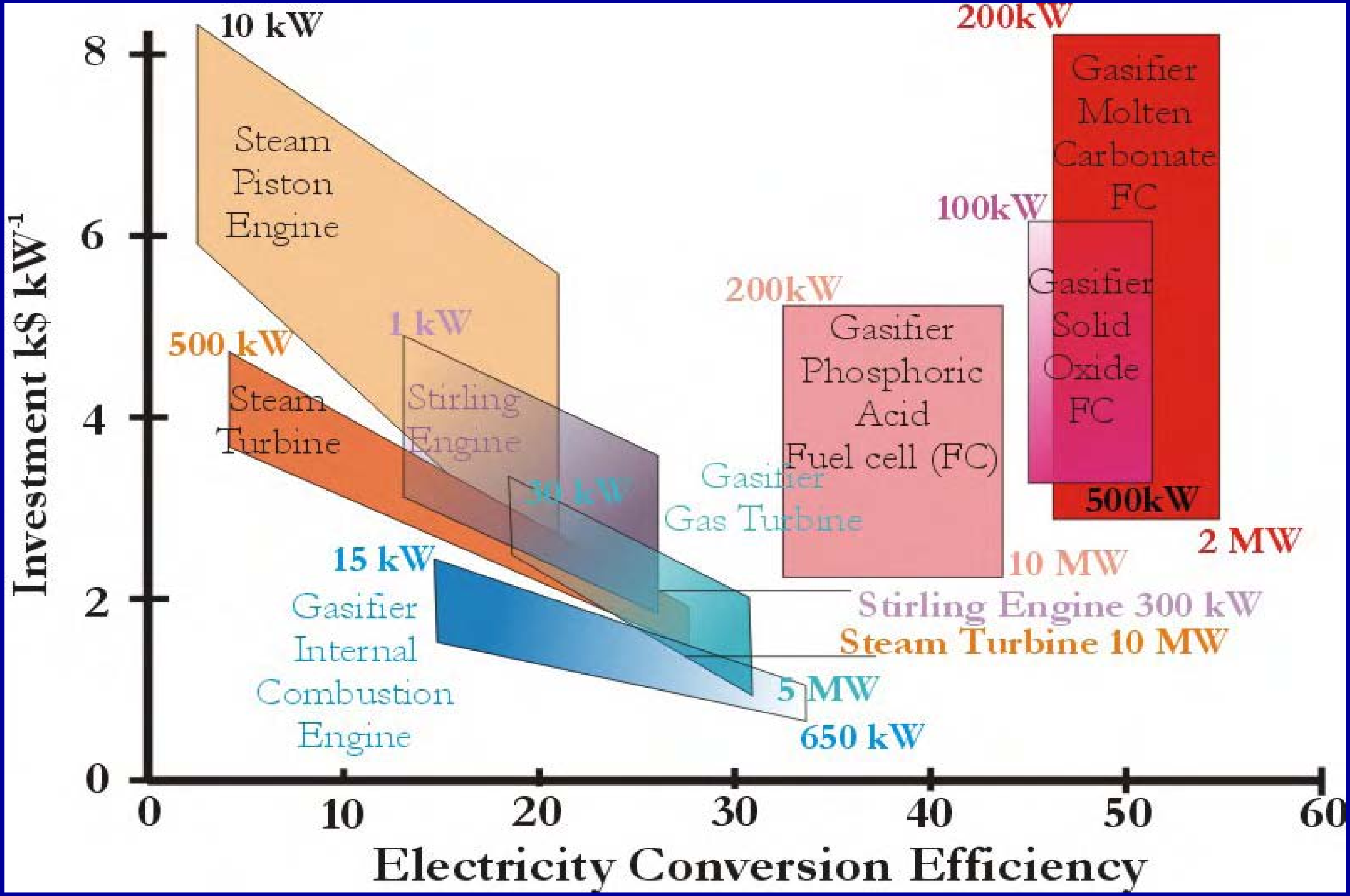


Community Power Corp SMBS
Zuni Furniture Enterprises

- **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**

Power Generation Technologies

Technology Performance



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

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

Renewable Energy Use Matrix

Energy End-Use Needs

Renewable Energy Technology Options

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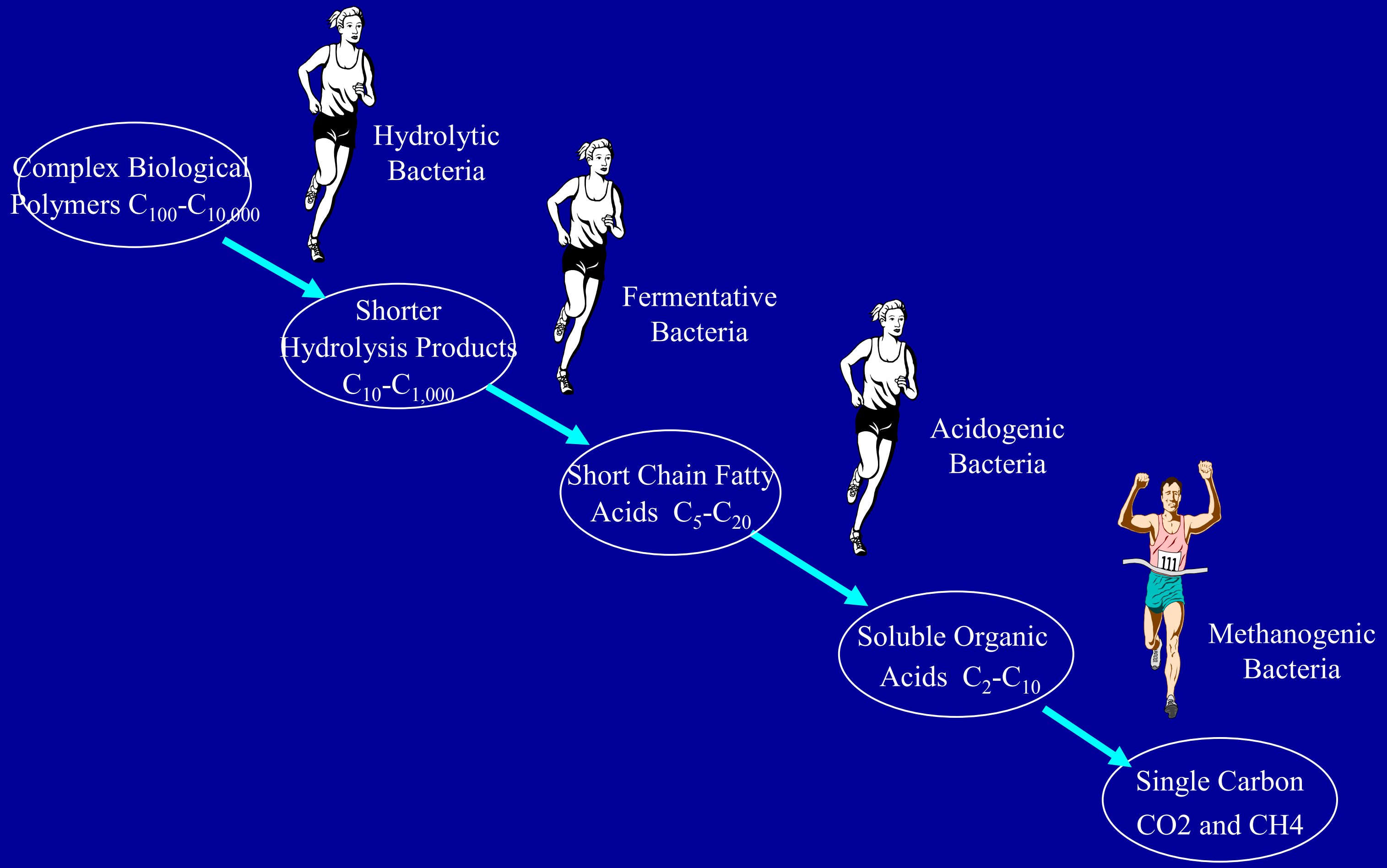
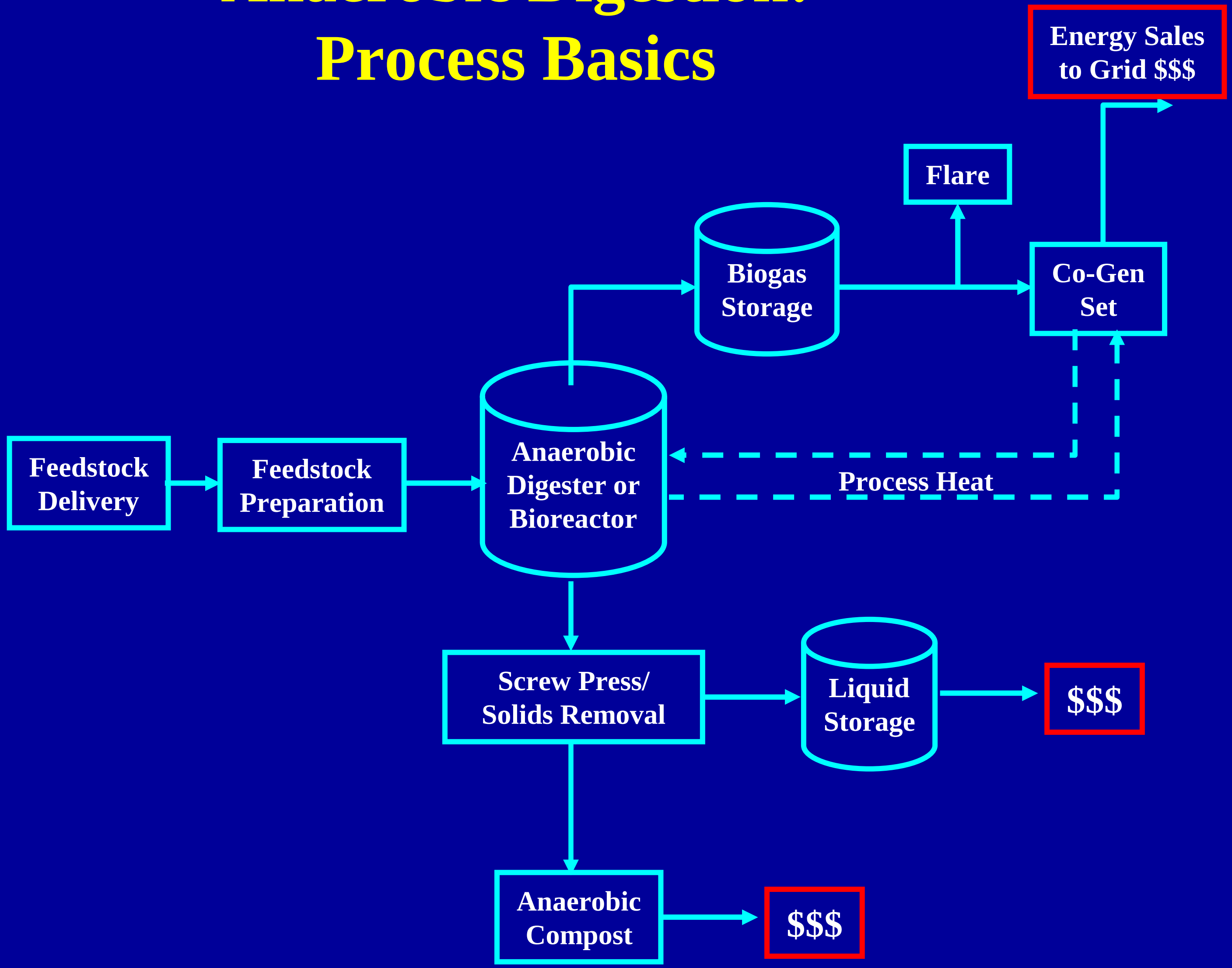
Solar	✓	✓		
Wind		✓		
Geothermal	✓	✓		
Hydro		✓		
Biomass	✓	✓	✓	✓

"The Anaerobic Digestion Relay Race: Passing the Carbon Baton"



Anaerobic Digestion: Process Basics



Anaerobic Digestion:
Key Process Control Parameters

- Feedstock Composition
- Feedstock Concentration
- Temperature
- pH and Alkalinity
- Presence of toxic compounds
- Residence Time
- Organic Loading Rate
- Ratio of feedstock to microbial populations

Anaerobic Digestion:
Feedstock Resource Drives Process Design

- Low Solids Feedstocks
  - <3% total solids by weight
  - little or no suspended solids
  - single phase liquid system, readily mixed
- Medium Solids Feedstocks
  - 3% to 12% total solids by weight
  - contains suspended solids
  - slurry system, can still be mixed
- High Solids Feedstocks
  - up to 25% total solids by weight
  - “solids-processing” system
  - requires non-traditional mixing

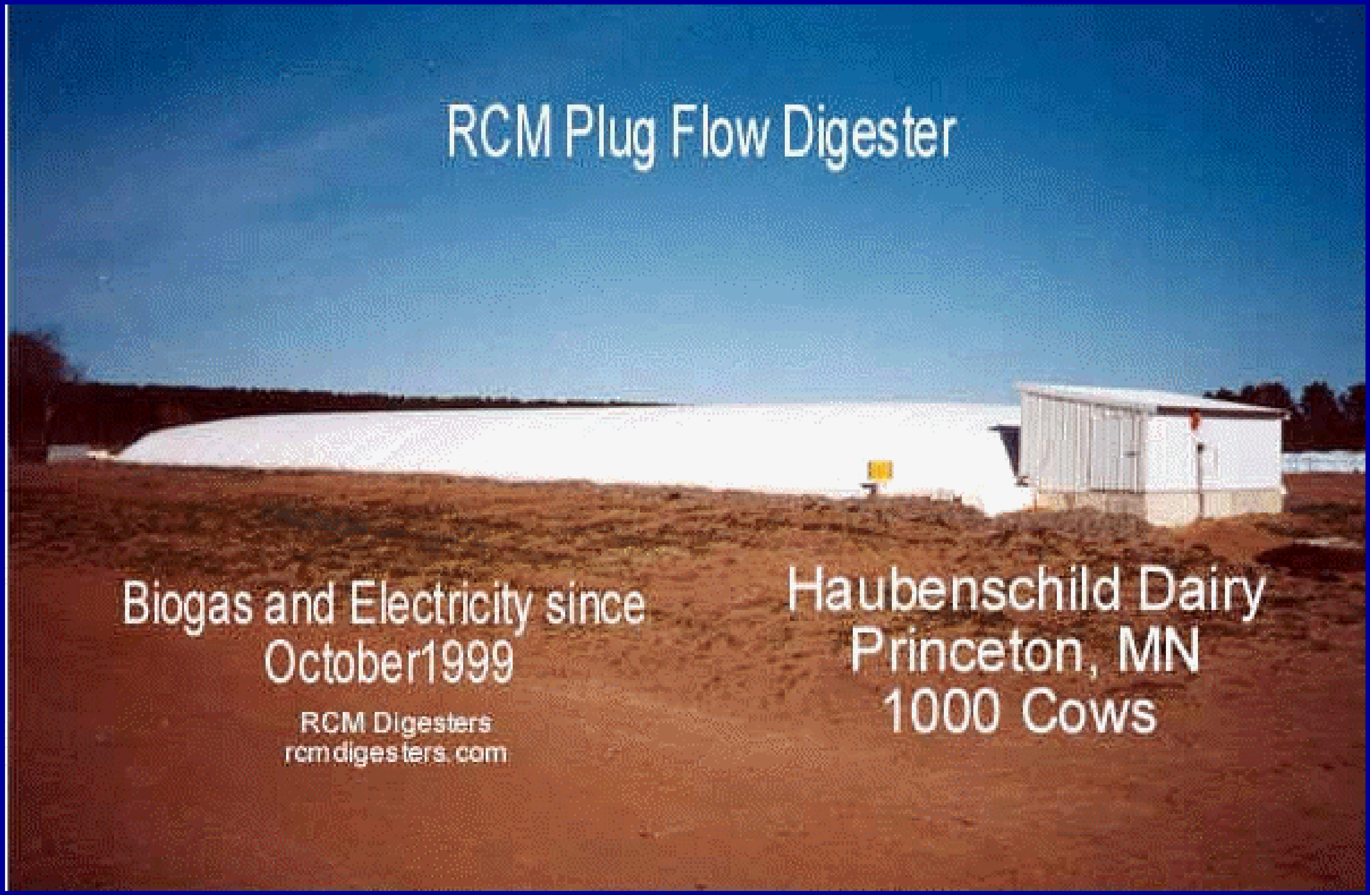
Anaerobic Digestion:
Low Solids Covered Lagoon

(Photo of Courtesy of RCM Digesters)

Anaerobic Digestion: Medium Solids Applications: Complete Mix Slurry Digesters

(Photo Courtesy of the Danish Biogas Program)

Anaerobic Digestion:
Medium Solids Applications:
Plug Flow Digester



(Photo of Courtesy of RCM Digesters)

Anaerobic Digestion:
High Solids Applications:
Plug Flow Digester

(Photo of Plug Flow MSW Digester Courtesy of Pinnacle Biotechnologies)

Anaerobic Digestion:
High Solids Applications: Plug Flow Digester

(Photo Courtesy of www.kompogas.ch)

The Benefits of Anaerobic Digestion: Environmental

- Closed Systems Eliminate Odors
- Residence time reduces Pathogens, Weed Seeds; Produces Sanitized Compost
- Reduces CH4 and CO2 GHG Emissions; Ammonia Emissions
- Captures Nutrients for Reuse & Reduces Use of Inorganic Fertilizers
- Promotes Carbon Sequestration
- Increases Beneficial Reuse of Recycled Water
- Protects Groundwater and Surface Water Resources

The Benefits of Anaerobic Digestion: Energy

- Net Energy-Producing Process
- Generates High-Quality Renewable Fuel
- Produces Surplus Energy as Electricity and Heat
- Reduces Reliance on Energy Imports
- Contributes to Decentralized, Distributed Power Systems
- Proven Source of Electricity, Heat, and Transportation Fuel

The Benefits of Anaerobic Digestion: Economic

- Turns Waste Liabilities Into New Profit Centers
- Adds Value to Negative Value Feedstocks
- Reduces Operating / Energy Costs
- Reduces Water Consumption
- Reduces Reliance on Energy Imports
- Increases Self-Sufficiency

Summary of Anaerobic Digester Systems Operating in the US and Europe

Country	Biosolids	Biowaste/Solid Industrial	Agricultural	Industrial Wastewater
Austria	100	3	100	25
Canada	50			13
Czech Republic			10	4
Denmark	64		21	5
Finland		1		3
Germany		49	1500	91
Greece	2		1	2
Italy		4	50	38
Netherlands		2	0	84
Norway	17		2	5
Portugal			94	3
Spain		1	6	27
Sweden	134	4	3	8
Switzerland	70	11	69	20
UK	200	1	25	26
USA	1600		28	92

(Table from www.iea.org/)

Working Examples of Anaerobic Digestion Technology: Blaabjerg, DK

Blaabjerg Plant Equipment:

1. Blending Tank
2. Industrial Sludge Holding Tank
3. Manure Hold Tank
4. Digester
5. Gas holder
6. Effluent Sludge Tank
7. CO-GEN Building
8. Office & Laboratory Bldg.

Blaabjerg Main Operating Data:

Animal manure.......................... 222 tons/day
Alternative biomass.................... 87 tons/day
Biogas production...................... 3,1 mill m³/year
Digester capacity (2 x 2500 m³).. 5000 m³
Process temperature.................. 53,5°C
Utilisation of biogas................... CHP-plant
Average transport distance......... 5,0 km

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Solar	✓	✓		
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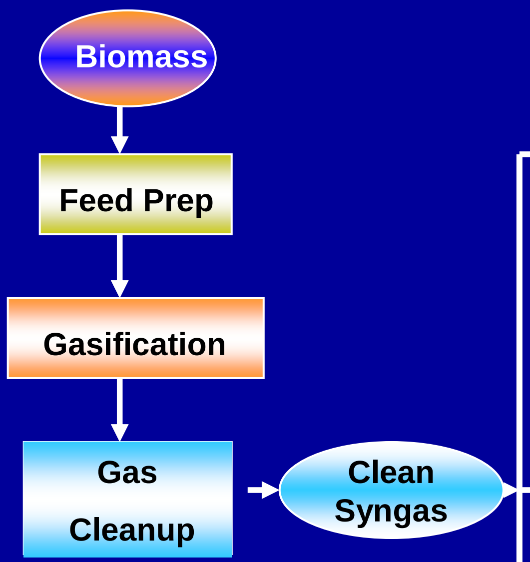
Biomass	✓	✓	✓	✓

Syngas to Liquid Fuel Options



H2/CO	Catalyst	Temp °C	PSI
1.0-1.4	Cu-Zn Cu-Co Others	200-420	750-3800

→ Ethanol

Mixed Alcohols

H2/CO	Catalyst	Temp °C	PSI
2.3	Cu-ZnO	< 250	1450

→ Methanol / DME → Zeolite Cat. → Gasoline

H2/CO	Catalyst	Temp °C	PSI
2.0	Fe	340	340
2.0	Co-K	240	370

F-T Liquids

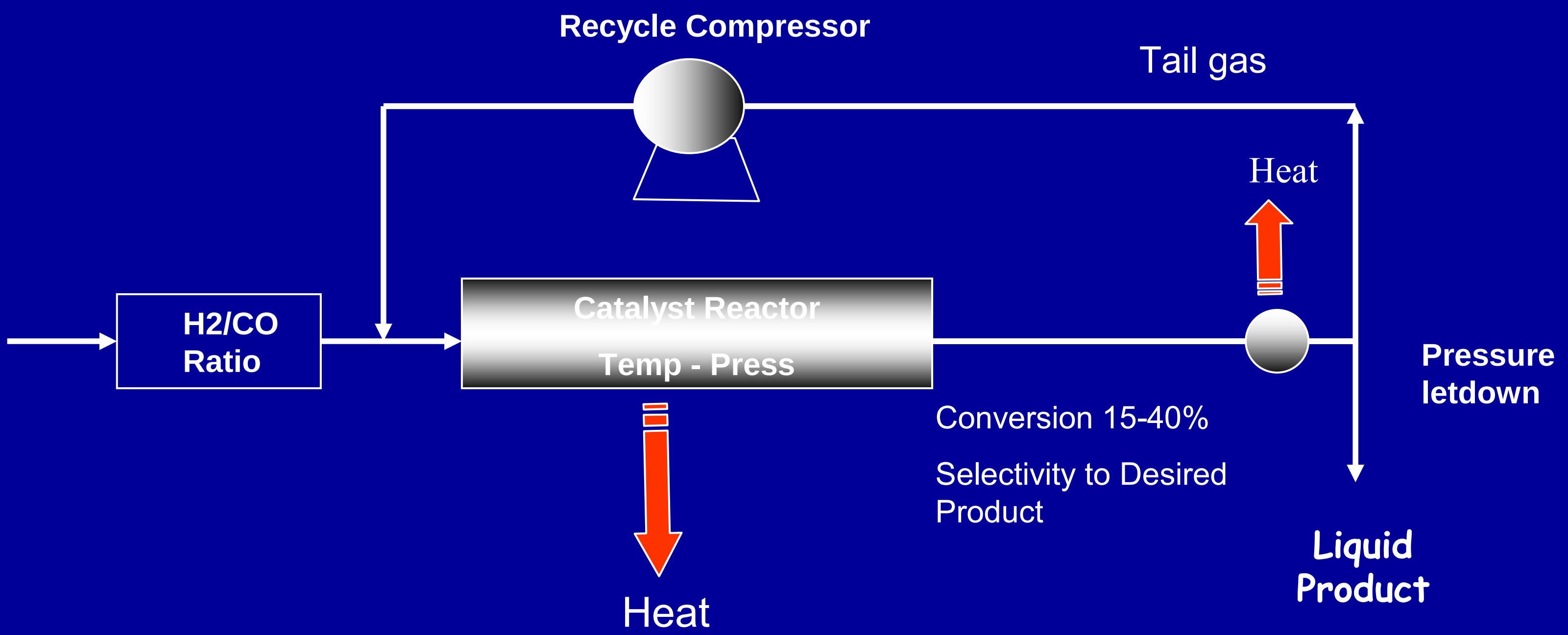
Gasoline -Wax

Diesel -Wax

→ Hydrocracking → Gasoline/diesel

Source: NREL/TP 510-34929

Gas to Liquids Process Issues



- Syngas Conditioning (cleanup)
- Gas recycle costs
- Heat removal (highly exothermic)

Renewable Energy Use Matrix

Energy End-Use Needs

Renewable Energy Technology Options

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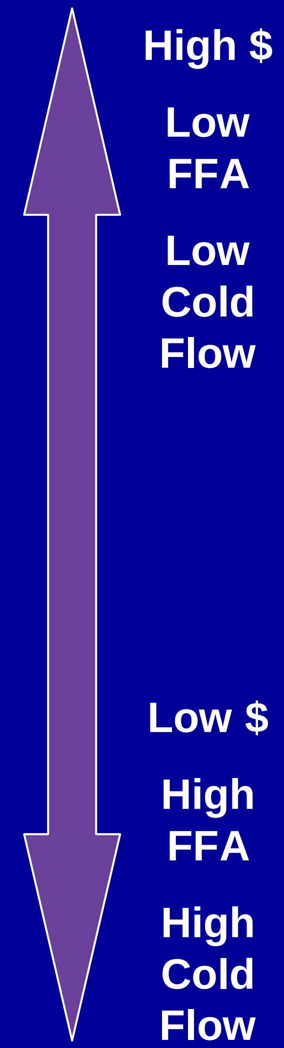
Geothermal	✓	✓		
Hydro		✓		
Biomass	✓	✓	✓	✓

Biodiesel

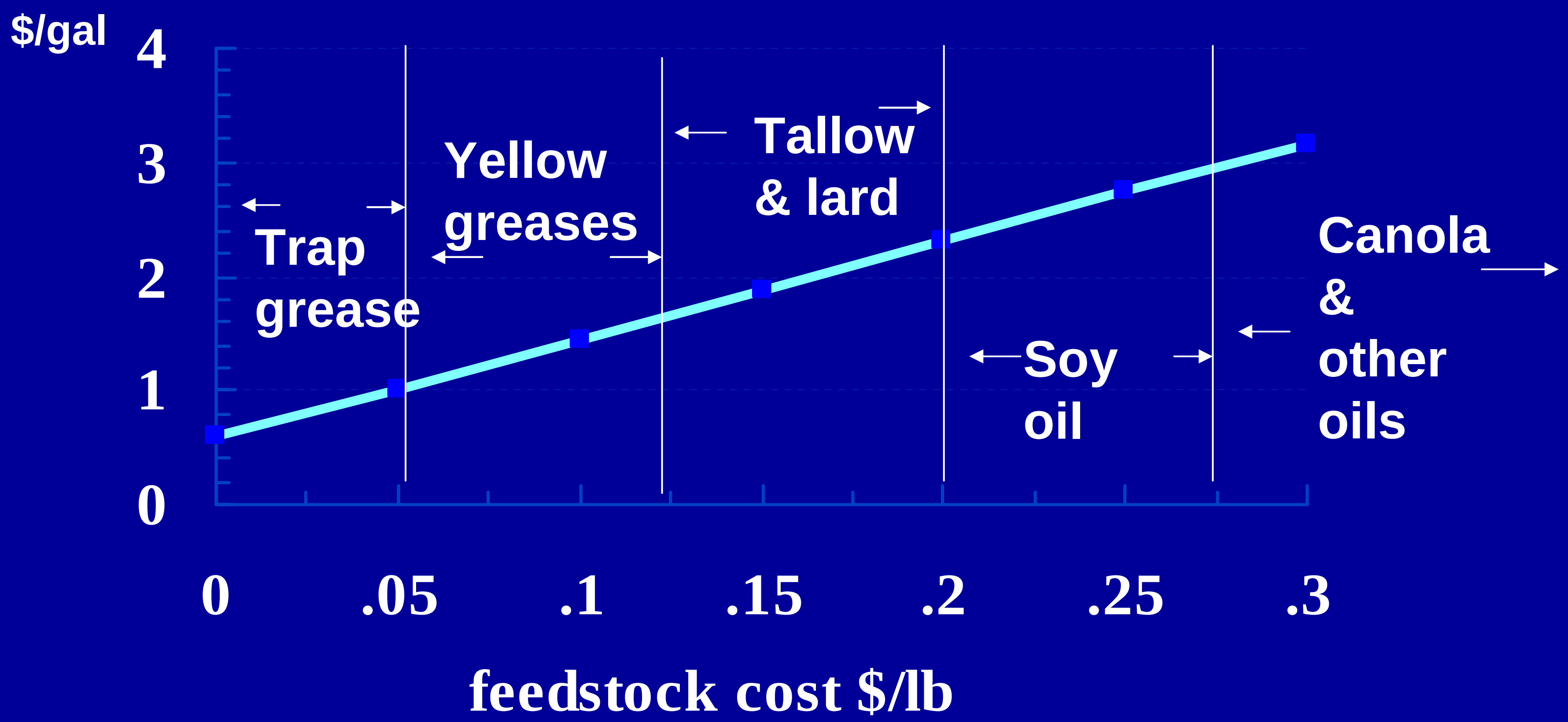
- A clean burning renewable fuel made from agricultural products
- Blends with petroleum diesel up to 20%
  - B100 is pure fuel
  - BXX is blend

Feedstocks

- **“Virgin” vegetable oils**
  - Soy, Canola, Corn, Mustard, Palm, Refined tall oil
  - Peanuts, Olive, Sesame, Hemp, etc.
- **Animal Fats**
  - Poultry (chicken, turkey, geese, ducks, etc.)
  - Fish oil
  - Lard and pork grease (pigs)
  - Tallow (beef, sheep, goat, camel, llama, etc.)
- **Recycled Grease**
  - Used cooking oils
  - Trap Grease



Production Cost per Gallon Biodiesel



3 million gal/yr plant.   Total cost at plant gate.

Does not include transportation and handling.

Biodiesel Benefits

- Reduces air pollution
- Reduces air toxics
- Non toxic, biodegradable, safe
- Reduces CO_2
- Displaces fossil petroleum and foreign oil
- Produced in US by farmers and recyclers
- Blends in any fraction
- No changes to vehicles or infrastructure

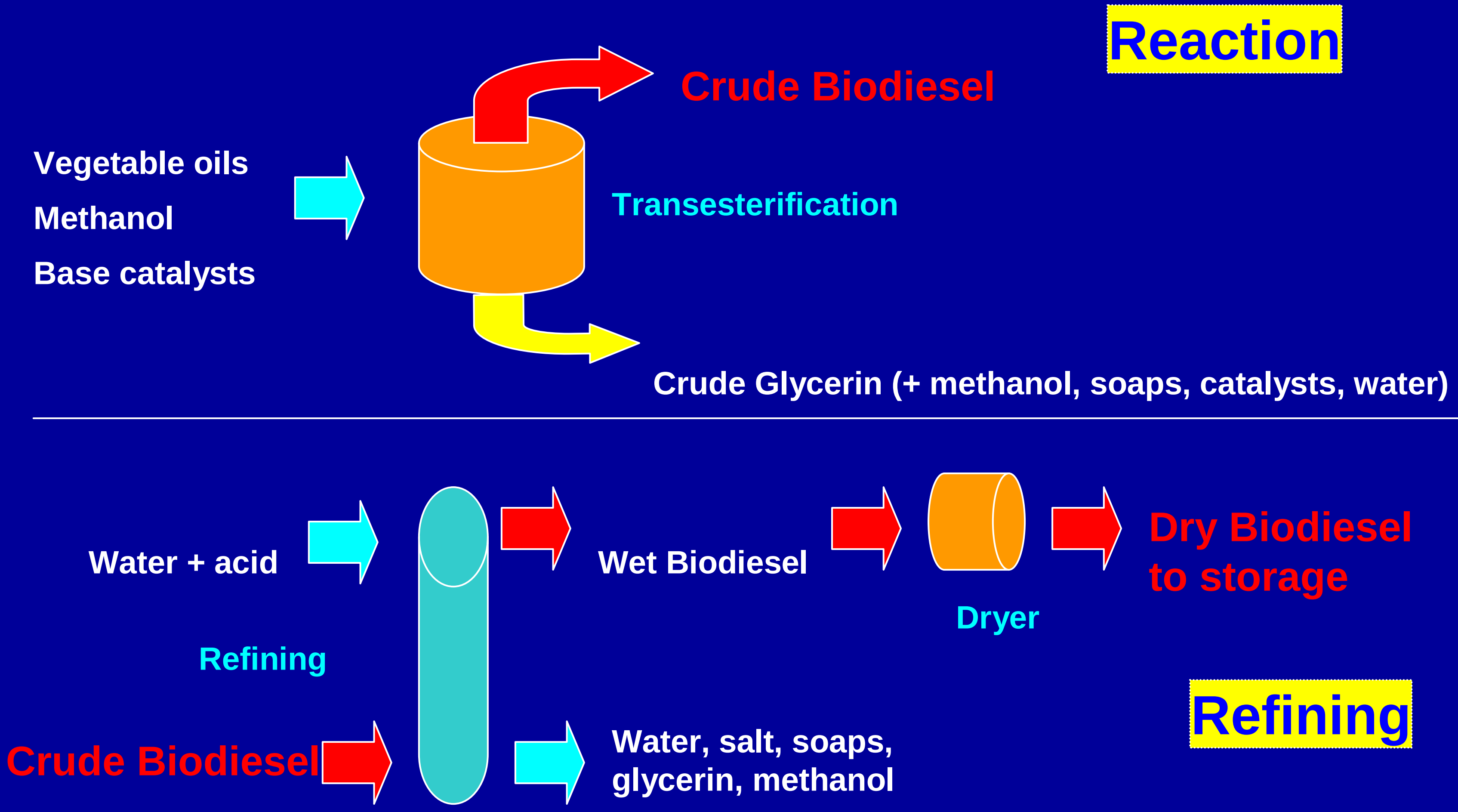
Biodiesel Markets

- **B100 - pure biodiesel**
  - Expensive, technical limitations,
  - Not recommended for use
- **B20 - 20% biodiesel, 80% petroleum diesel**
  - Bulk fuel fleets, primarily government, some retail
  - High cost offset by emission benefits
- **B5-B10 Heating oil, Boil Fuels**
  - Emission benefits
- **B2 - 2% biodiesel, 98% petroleum diesel**
  - Commercial as premium diesel
  - Lubricity value, fuel diversity

Theoretical Inputs and Outputs

- **Inputs**
  - 100 lbs refined vegetable oil
  - 10 lbs anhydrous methanol (or ethanol)
    - (practical usage is 30-60 lbs methanol)
  - 1-3 lbs catalyst
- **Outputs**
  - 100 lbs biodiesel
  - 10 lbs crude glycerin
  - 1-3 lbs spent catalyst
  - Recovered excess alcohol, original use minus10 lbs

Basic Transesterification



Biodiesel

Griffin Industries, USA and
Bruck Industries, Austria

Ethanol

- **Established Ethanol Industry**
  - Industrial interest increasing (oil companies)
  - Biotechnology improvements will continue to reduce costs
  - Supporting industrial enzyme business well established
- **Environmental Benefits**
  - Oxygenates critical to attainment of CAA CO objectives
    - 39 regions in non-compliance
  - Biomass ethanol decreases CO by 90% and SO_2 by 70% compared to RFG
  - Ethanol is a “clean” biotechnology-based technology

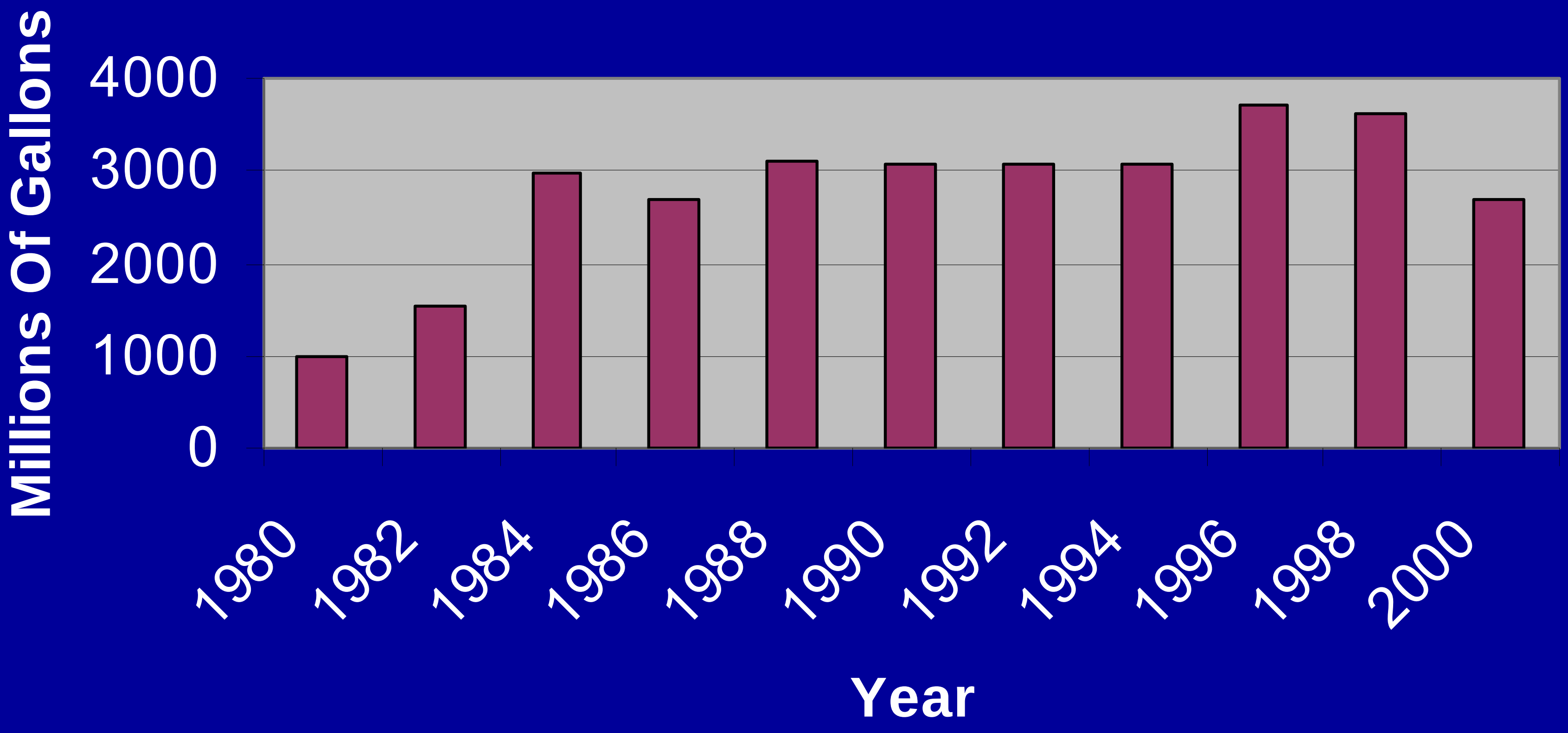
Properties of Ethanol, ETBE, and Gasoline

	Ethanol	ETBE	Unleaded Gasoline
Lower heating value (kJ/kg)	26,860	36280	41,800 - 44,000
Energy content (MJ/kg)	26.68	36.29	42 - 44
Research octane number (RON)	106	118	91 - 93
Solubility in water, percent (fuel in water)	100	2	Negligible
Boiling temperature	78	70	27 - 225
Reid Vapor Pressure* (kPa)	83 - 186	21 - 34	55 - 103

* 10 percent blends

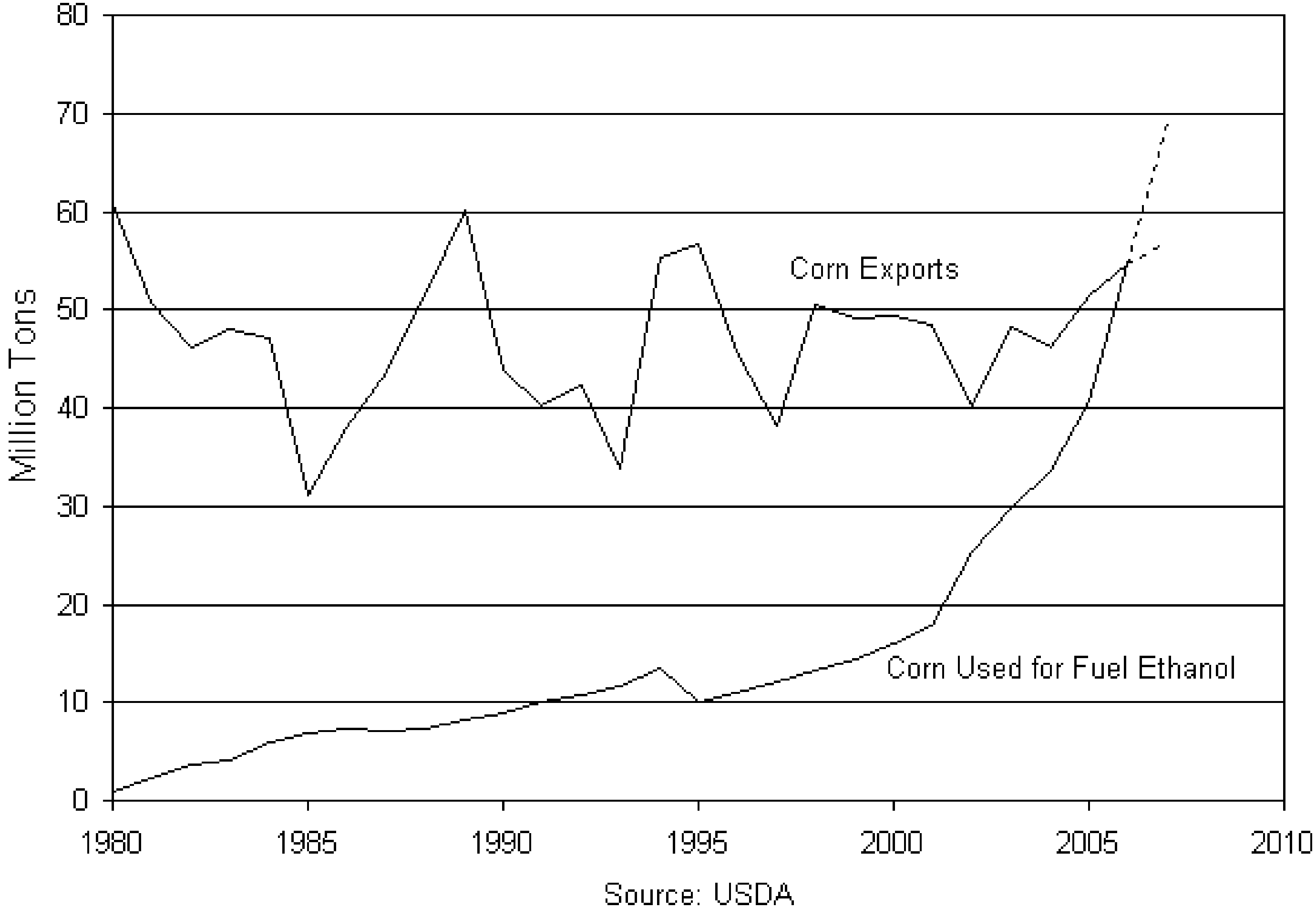
ETBE = ethyl tertiary butyl ether

Historical Ethanol Production - Brazil

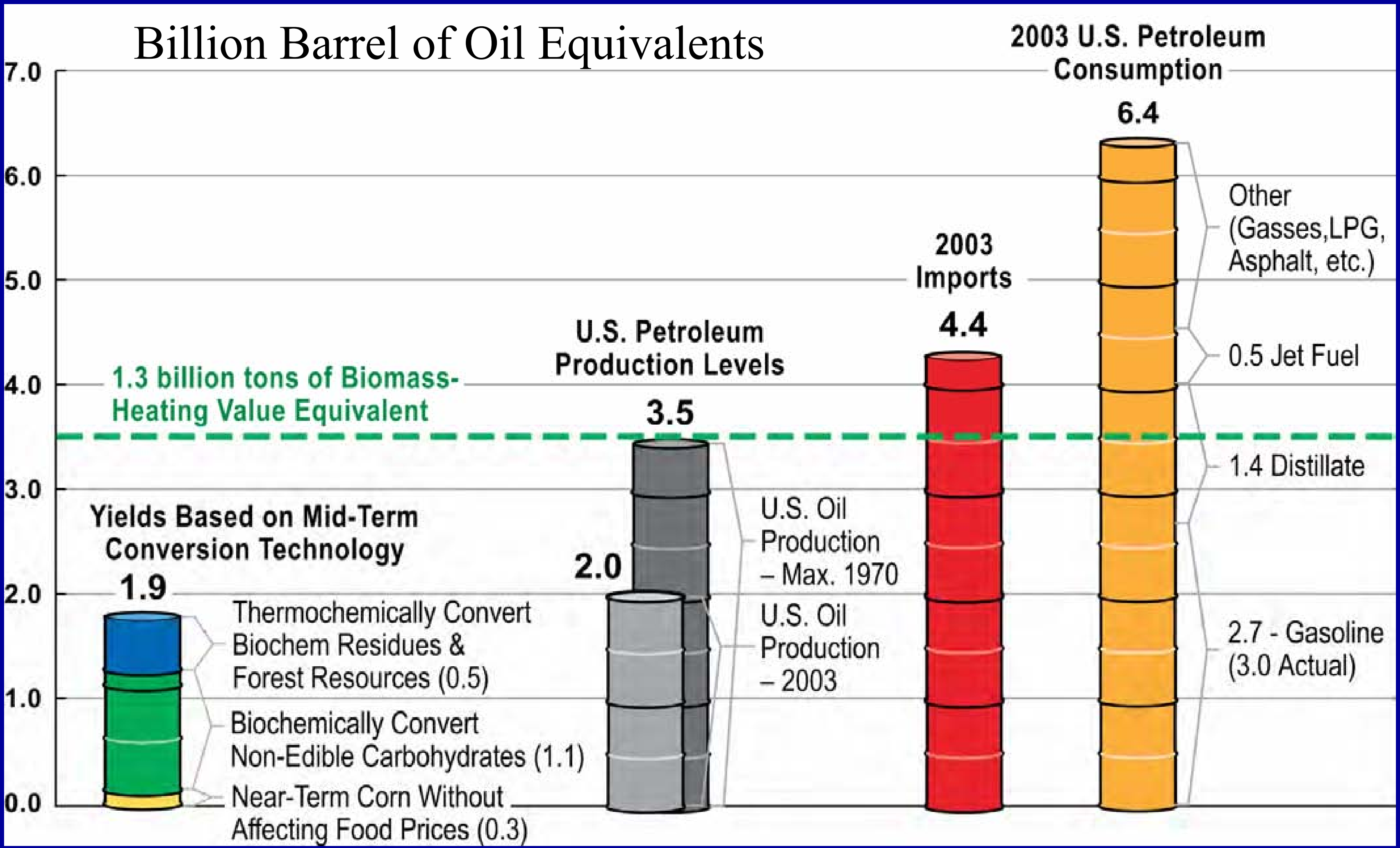


U.S. production about 1800 MM gallons

U.S. Corn Use for Fuel Ethanol and for Export, 1980-2006, with Projection to 2007



The 1.3 Billion Ton Biomass Scenario



Based on ORNL & USDA Resource Assessment Study by Perlach et.al. (April 2005)
http://www.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

Biomass Project Development - Deal Killer Issues to Consider

- Community Support
- Fuel Supply
- Project Economics
- Appropriate Technology
- Siting/Infrastructure

Community Support

- Best to have grass roots support. Pride of ownership carries well.
- Poll key stakeholders:
  - Local peer groups
    - » Board of Supervisors
    - » Chamber of Commerce
    - » Green organizations
    - » Local, State and Federal agency representatives
    - » Private sector resource managers, landowners
    - » Tribal

Fuel Supply

- Sustainable long term supply located within close proximity (25 to 75 mile radius)
- Economically available
- Environmentally available
- Meets quality specifications
- Available in quantities and from diverse sources that support project financing:
  - » Minimum 10 year supply, 70% under contract
  - » Quantities that are 2 – 3 times minimum volume for plant operation

Project Economics

- Markets for heat and power
  - » Market support justifies capital investment
- Return on investment
  - » Minimum ROI of 17%
- Economies of scale
  - » Combustion efficiencies
  - » Labor and overhead

Appropriate Technology

- Search for most appropriate technology considering project location and fuel supply
  - » Ability to convert local fuel supply into heat/power
  - » Must meet local permitting specifications
- Technology must be proven:
  - » Commercially available
  - » Operates efficiently on available fuel supply
  - » Operates cleanly on available fuel supply
  - » Appropriate for site and local resources

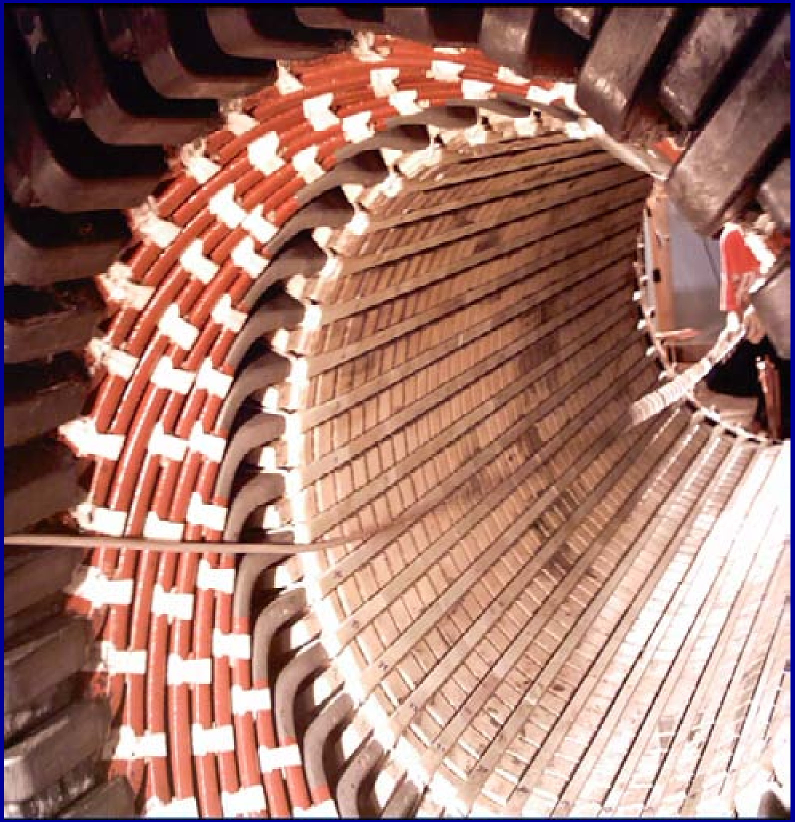
Observations On What Not to Do

- Do not oversell project.
- Do not set scale before assessing fuel resource.
- Expect less than 24 to 36 months for successful project development.

Project Development Steps Part I

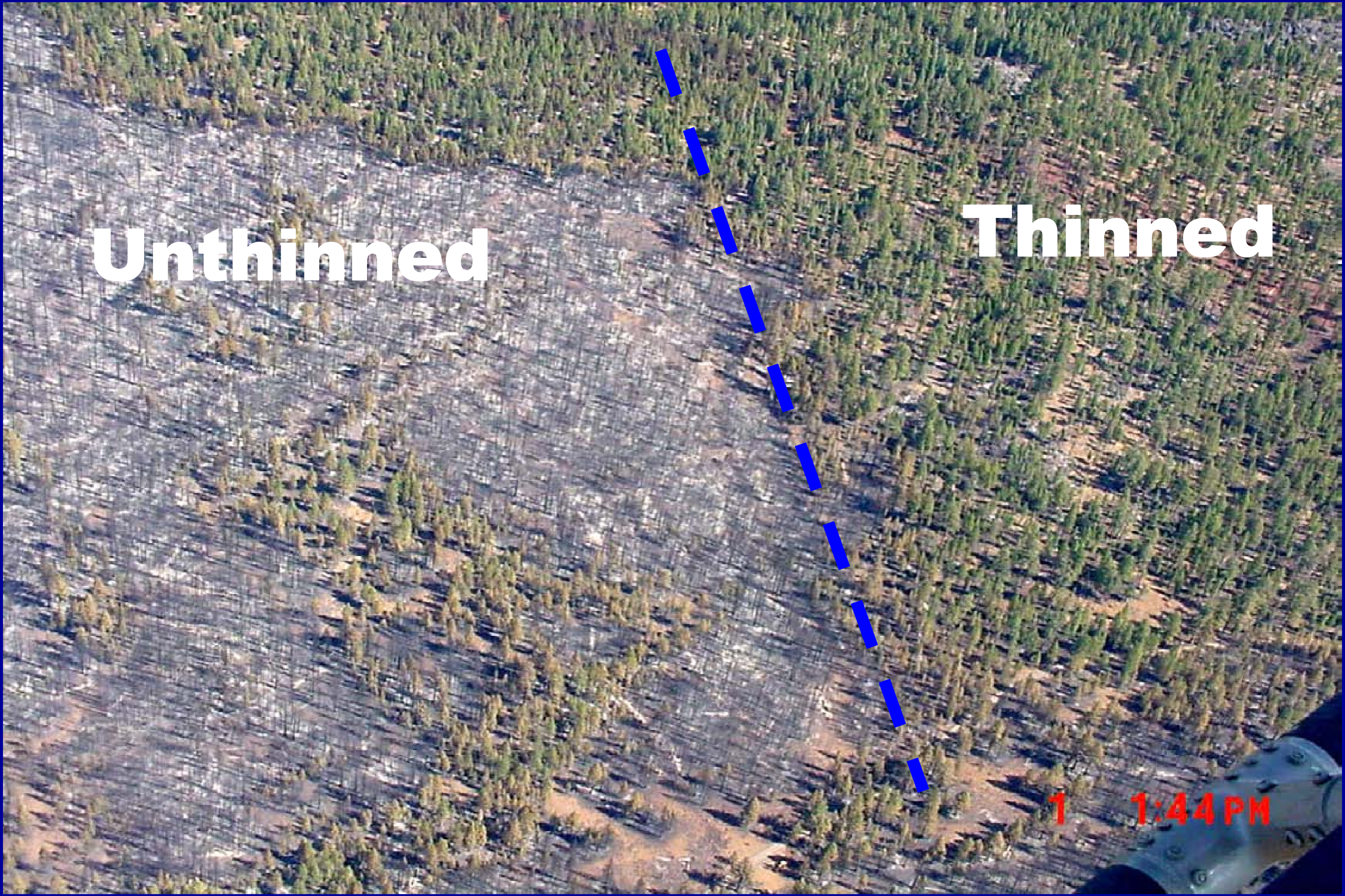
- 1.Conduct preliminary feasibility study
- 2. Confirm community support
- 3.Assess fuel resource availability
- 4.Consider siting and infrastructure issues
- 5. Complete due diligence Feasibility Study

Project Development Steps Part II

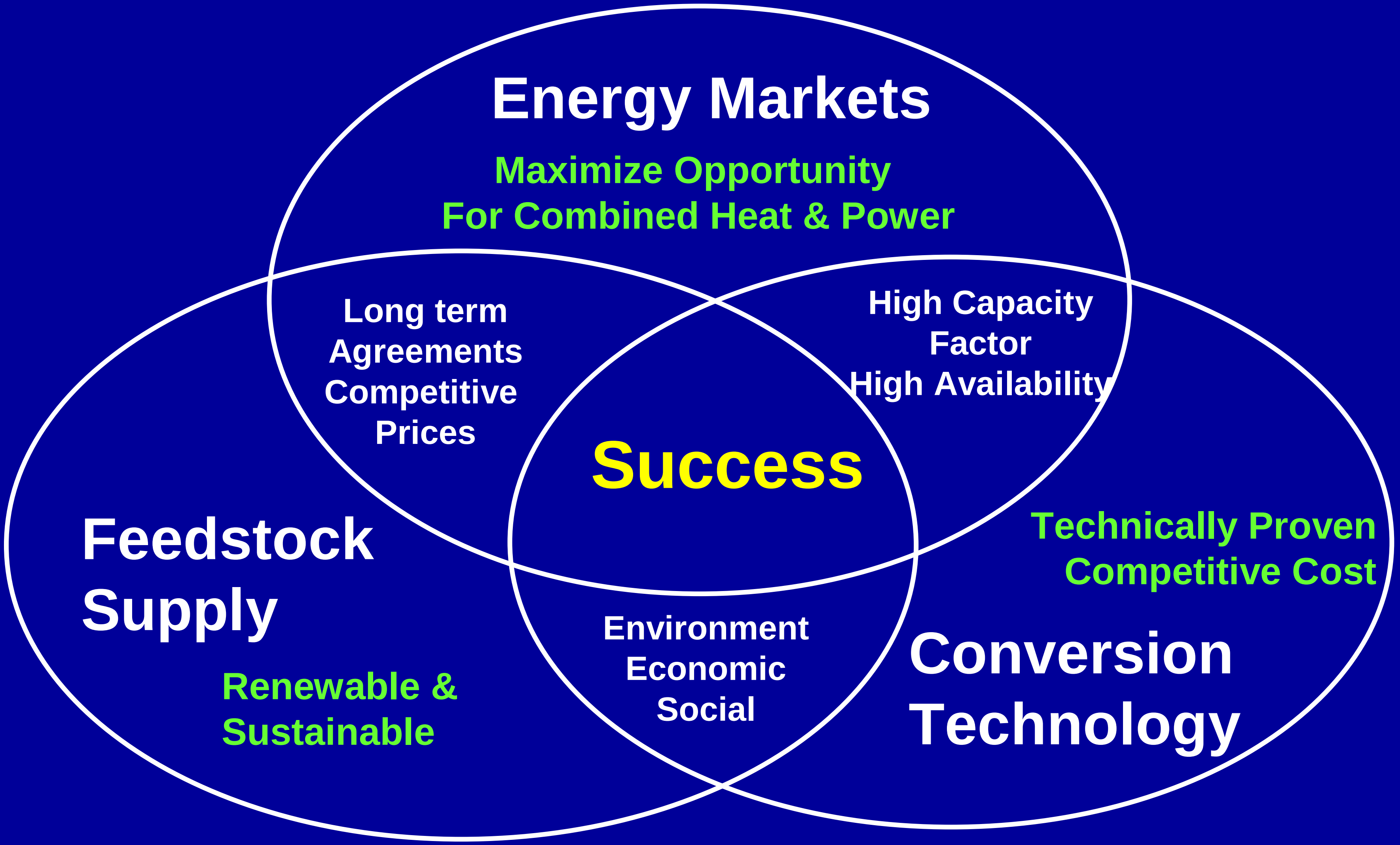


- 6. Secure developer and /or equity partners
- 7. Secure power purchase agreement/thermal delivery agreement
- 8. Secure financing
- 9. Engineer/construct project
- 10. Generate renewable energy

The real need



Bioenergy Criteria for Success



Making Biomass Disappear

Air curtain burner

400 tons / day

$0.00 Productivity

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