Sustainable Energy Project Development Workshop for Public Institutions

May 22, 2008
Oakland University
Jim Leidel
Energy Manager

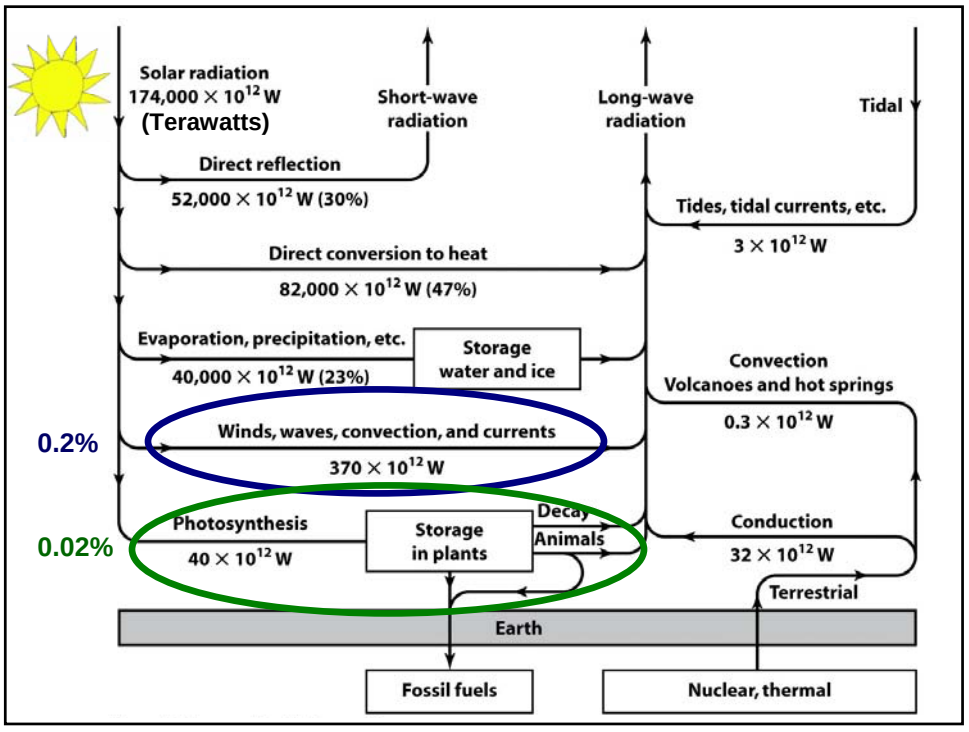
Thank you to our sponsors:

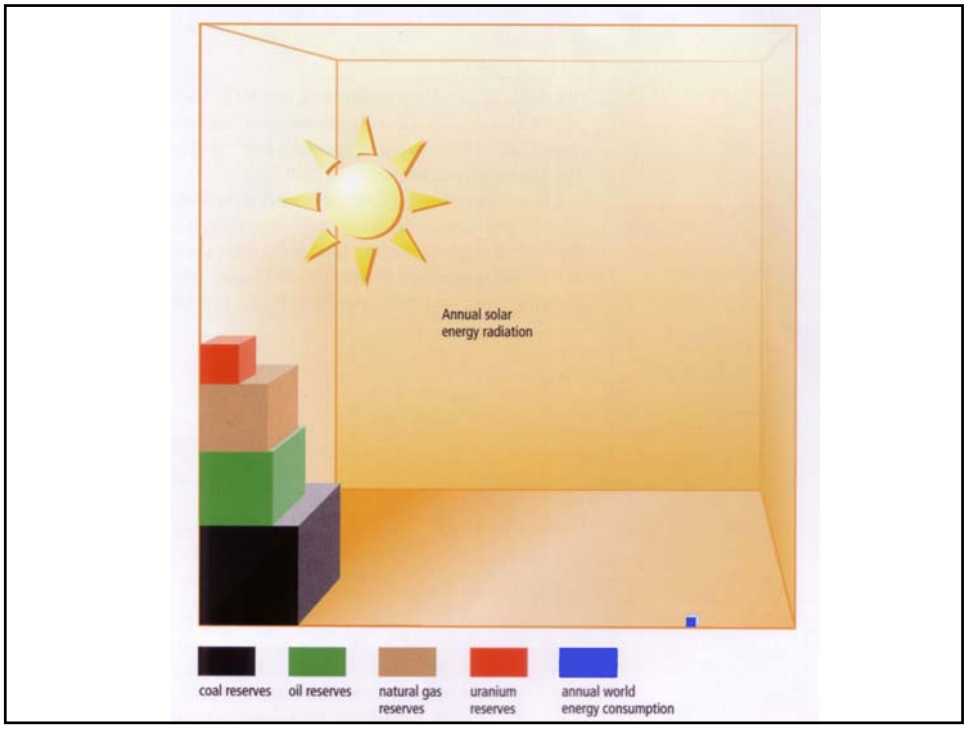
- Oakland University Facilities Management
- SE Michigan Resource Development Council
- Entegrity Wind Systems
- State of Michigan Energy Office
- Chevron Energy Solutions
- Thermo Energy Systems

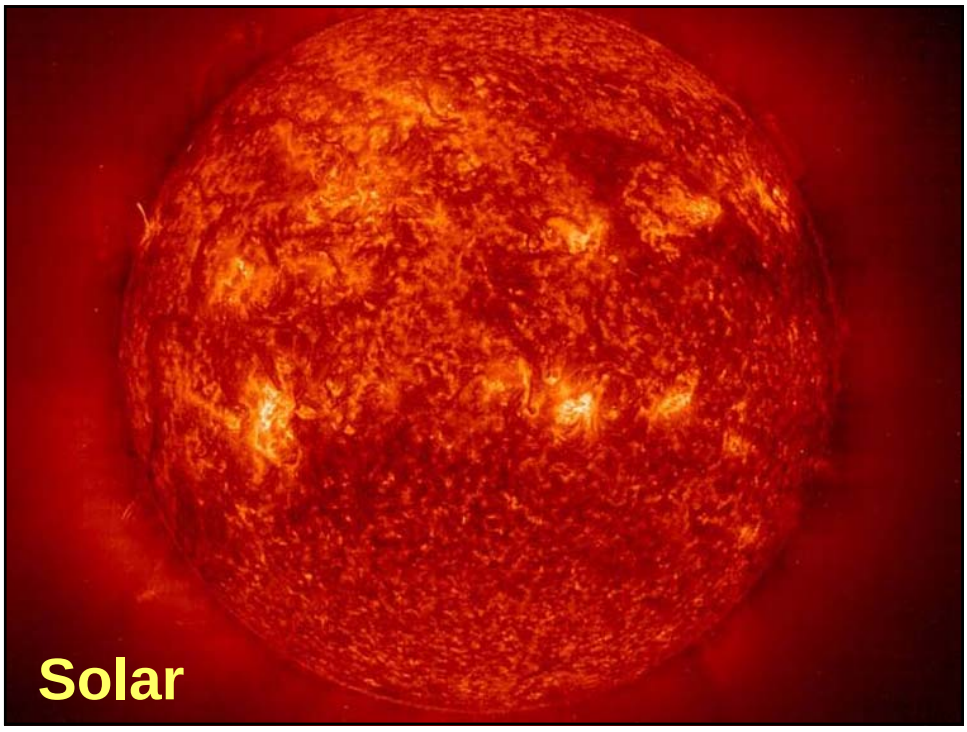
Introduction to Renewable Energy Resources

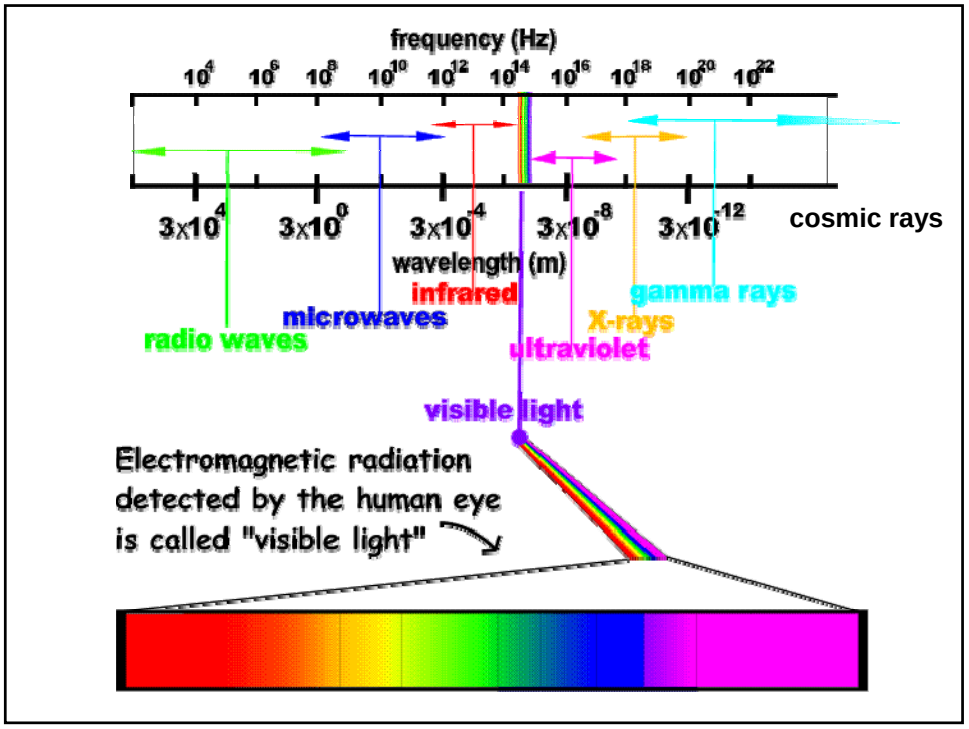
- *Solar*
- *Wind*
- *Biomass*
- *Others*

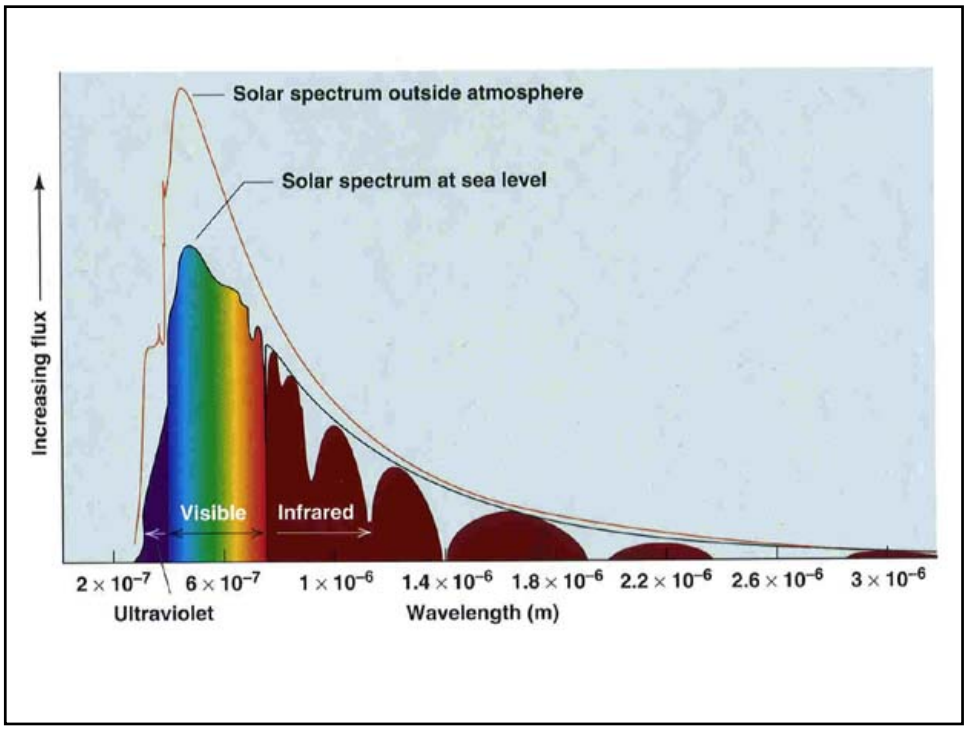
Brief Review of Oakland University Feasibility Studies

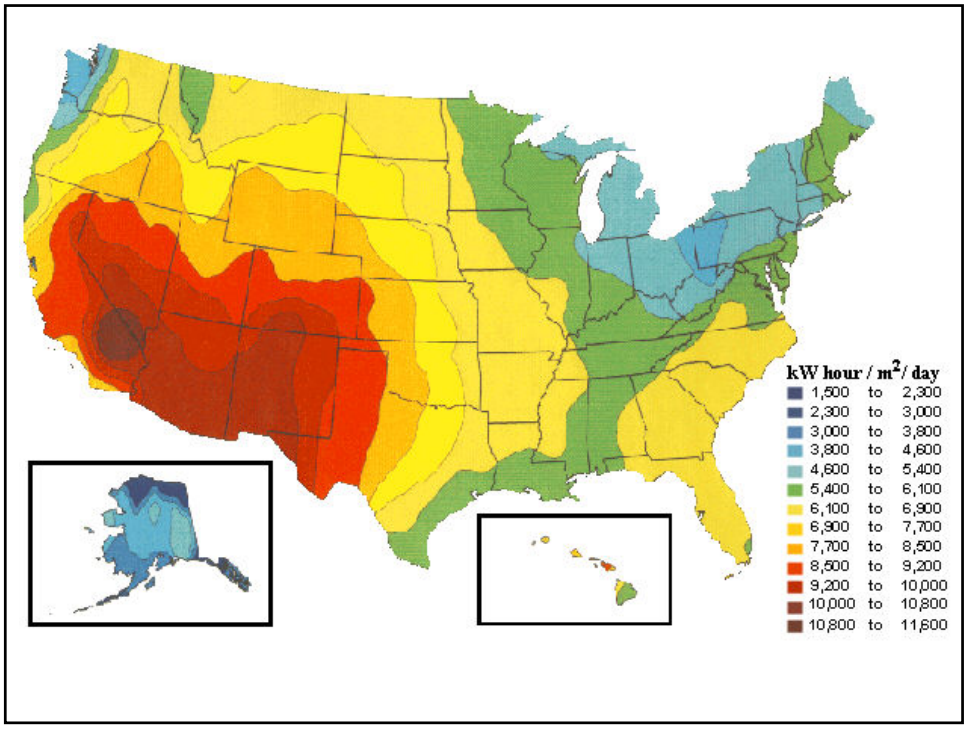


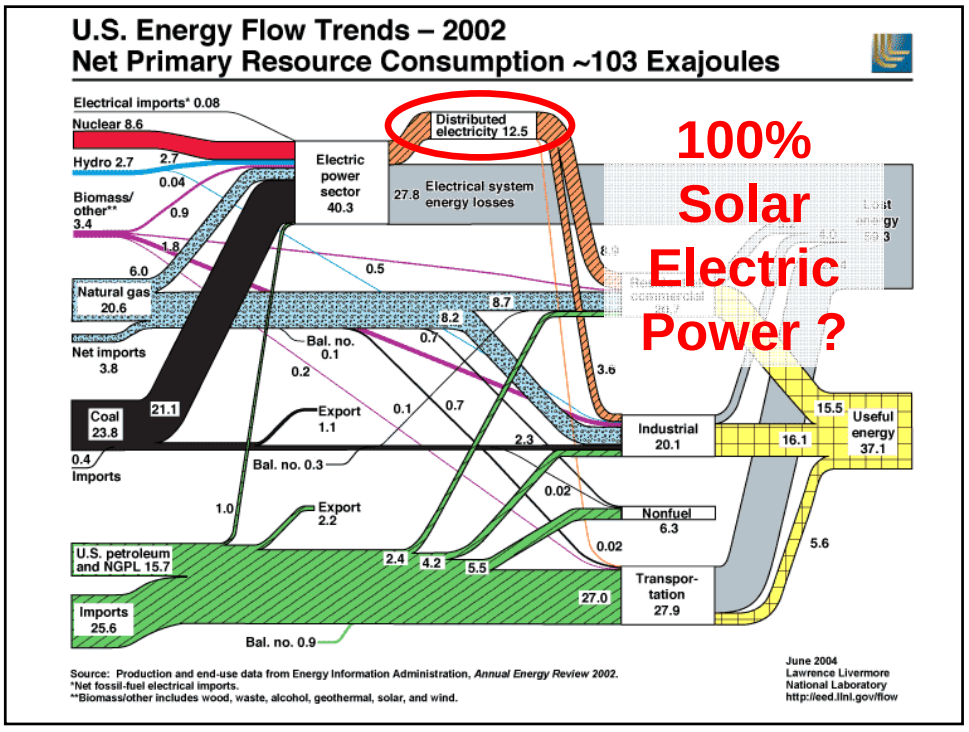

Annual solar
energy radiation
coal reserves
oil reserves
natural gas
reserves
uranium
reserves
annual world
energy consumption


Solar


frequency (Hz)
10^4 10^6 10^8 10^{10} 10^{12} 10^{14} 10^{16} 10^{18} 10^{20} 10^{22}
$3x10^4$ $3x10^0$ $3x10^{-4}$ $3x10^{-8}$ $3x10^{-12}$
cosmic rays
wavelength (m)
infrared
gamma rays
microwaves
X-rays
radio waves
ultraviolet
visible light
Electromagnetic radiation detected by the human eye is called "visible light"


Solar spectrum outside atmosphere
Solar spectrum at sea level
Increasing flux
Visible
Infrared
2×10^{-7} 6×10^{-7} 1×10^{-6} 1.4×10^{-6} 1.8×10^{-6} 2.2×10^{-6} 2.6×10^{-6} 3×10^{-6}
Ultraviolet
Wavelength (m)

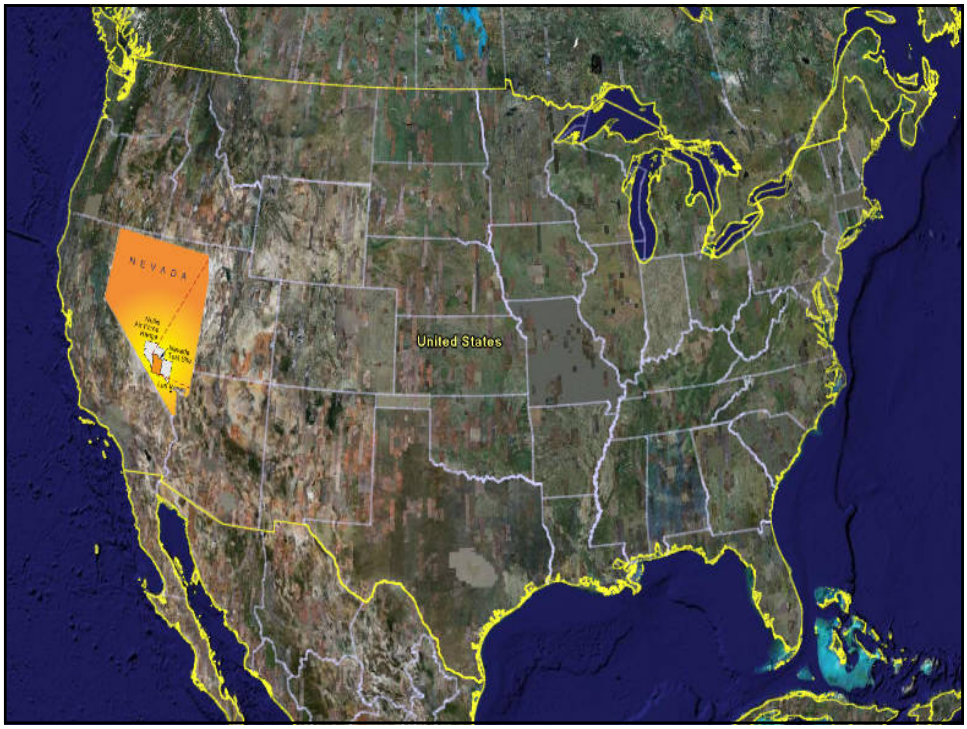

kW hour / m² / day
1,500 to 2,300
2,300 to 3,000
3,000 to 3,800
3,800 to 4,600
4,600 to 5,400
5,400 to 6,100
6,100 to 6,900
6,900 to 7,700
7,700 to 8,500
8,500 to 9,200
9,200 to 10,000
10,000 to 10,800
10,800 to 11,600

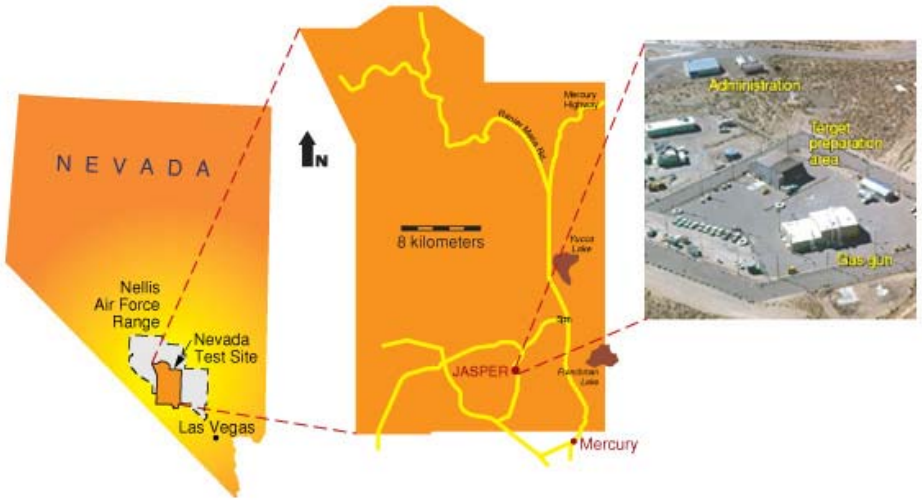

U.S. Energy Flow Trends – 2002
Net Primary Resource Consumption ~103 Exajoules
Electrical imports* 0.08
Nuclear 8.6
Hydro 2.7
Biomass/ other** 3.4
Natural gas 20.6
Net imports 3.8
Coal 23.8
0.4 Imports
U.S. petroleum and NGPL 15.7
Imports 25.6
Electric power sector 40.3
Distributed electricity 12.5
27.8 Electrical system energy losses
Industrial 20.1
Nonfuel 6.3
Transpor-tation 27.9
Useful energy 37.1
Export 1.1
Export 2.2
Bal. no. 0.1
Bal. no. 0.3
Bal. no. 0.9
100% Solar Electric Power ?
Source: Production and end-use data from Energy Information Administration, Annual Energy Review 2002.
*Net fossil-fuel electrical imports.
**Biomass/other includes wood, waste, alcohol, geothermal, solar, and wind.
June 2004
Lawrence Livermore National Laboratory
http://eed.llnl.gov/flow

Calculation of Solar Panle Area Required to Meet 2002 US Electrical Energy Consumption

Annual electrical energy required =	1.25E+19	Joules / yr
=	3.47E+12	kW hr / yr
Average POWER of full sun at solar panel =	1,000	W / m^2
=	1.0	kW / m^2
Average capacity factor	20%	
Hours per year	8,760	hours / yr
Average solar ENERGY available to solar panel =	1752	kW hr / m^2 / yr
=	4.8	kW hr / m^2 / day
Estimated average PV total system efficiency =	10%	
Estimated average system losses =	15%	
Estimated electrical energy output =	148.92	kW hr / m^2 / yr
=	0.408	kW hr / m^2 / day
Area required	2.33E+10	m^2
Area required	2.51E+11	ft^2
Area required	5,761,310	acres
Area required	**9,002**	**$miles^2$**
	~ Vermont	

Link to Spreadsheet

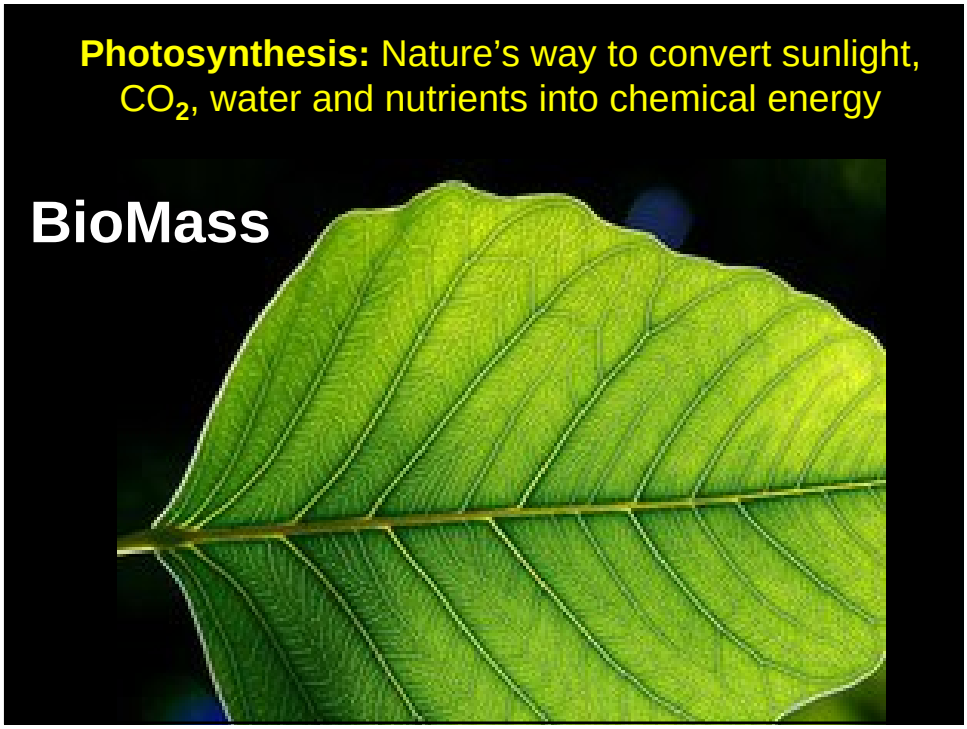




Nellis Air Force Range & the Nevada Test Site

= 16,000 square miles

Photosynthesis: Nature's way to convert sunlight, CO_2, water and nutrients into chemical energy



Photosynthesis:

$CO_2 + H_2O$ + solar energy ⇨ O_2 + glucose

… nature's battery stores solar energy in chemical bonds of glucose.

Reverse of photosynthesis:

$CO_2 + H_2O$ + heat energy ⇦ O_2 + glucose

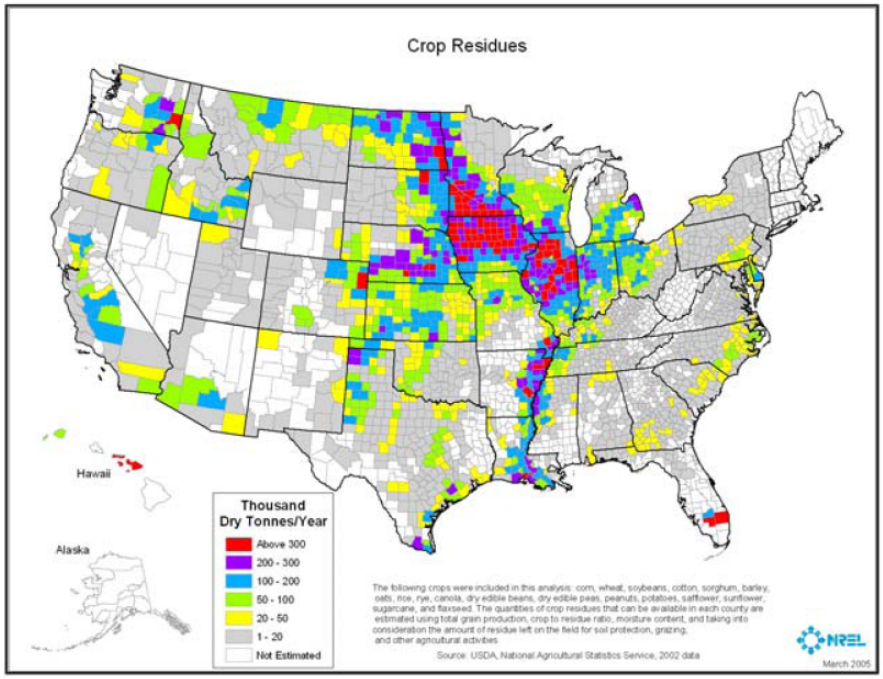
… also called combustion, oxidation, biodegradation
…chemical bonds in glucose are broken

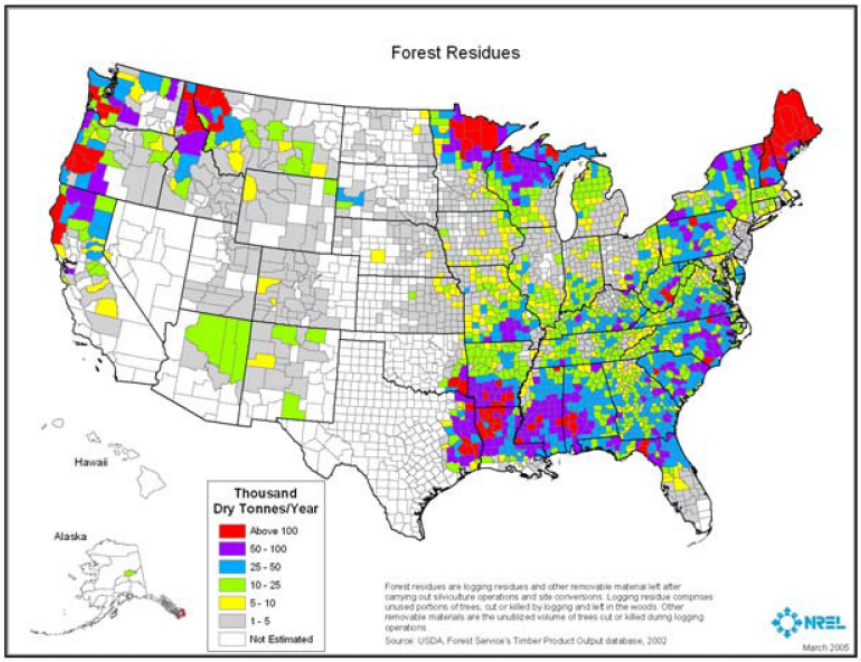
Prospecting for Biomass ?

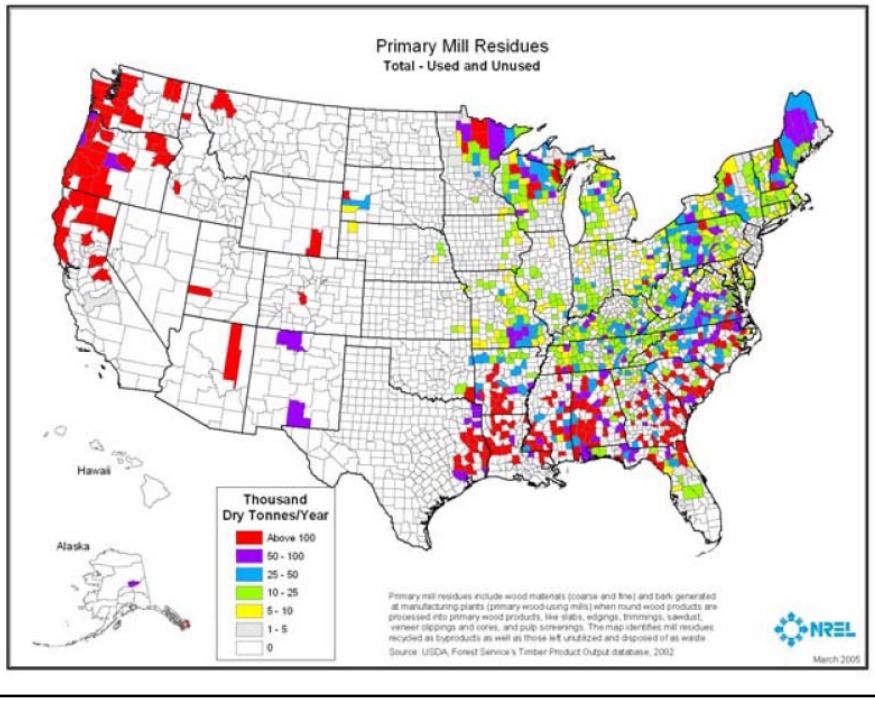
A Geographic Perspective on the Current Biomass Resource Availability in the United States

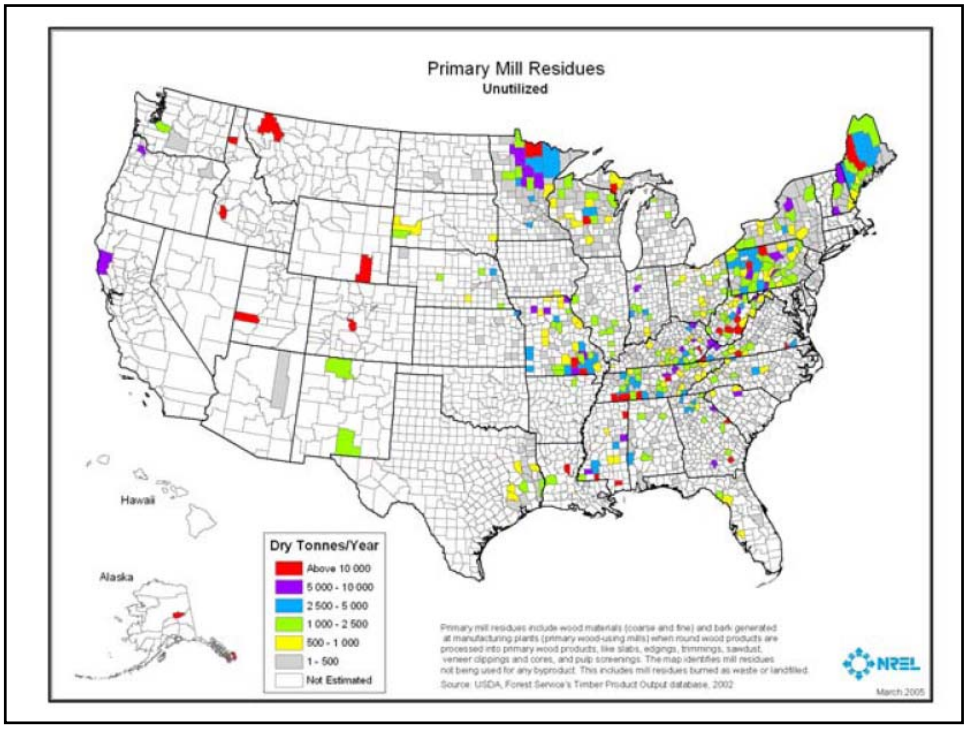
A. Milbrandt **2005**

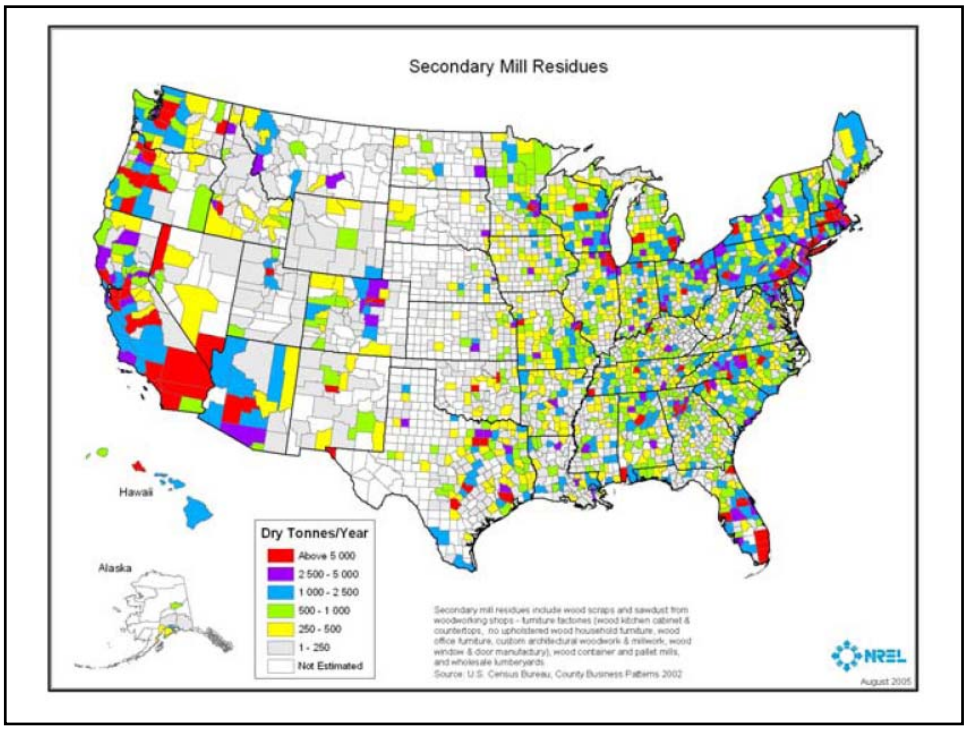
NREL National Renewable Energy Laboratory

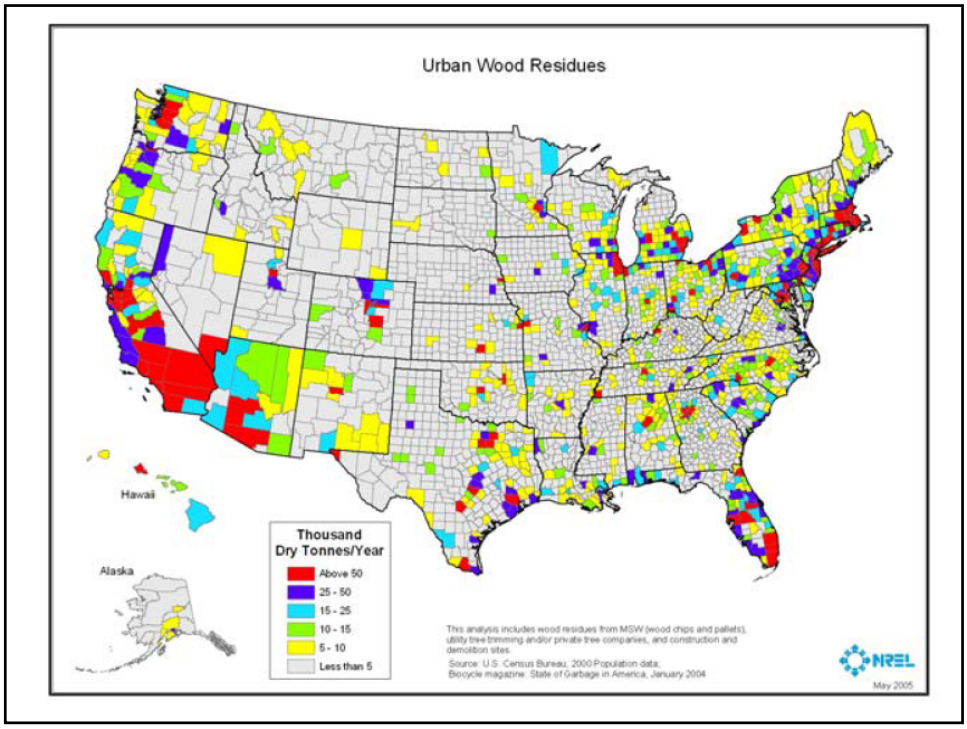


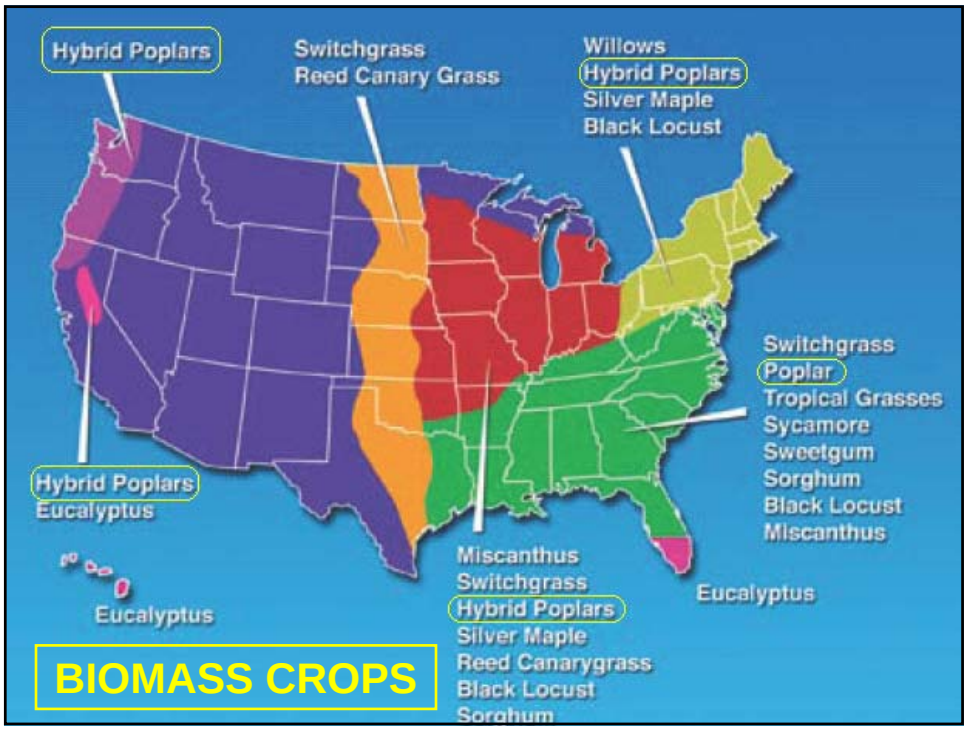

Forest Residues
Hawaii
Alaska
Thousand
Dry Tonnes/Year
Above 100
50 - 100
25 - 50
10 - 25
5 - 10
1 - 5
Not Estimated
Forest residues are logging residues and other removable material left after carrying out silviculture operations and site conversions. Logging residue comprises unused portions of trees, cut or killed by logging and left in the woods. Other removable materials are the unutilized volume of trees cut or killed during logging operations.
Source: USDA, Forest Service's Timber Product Output database, 2002
NREL
March 2005

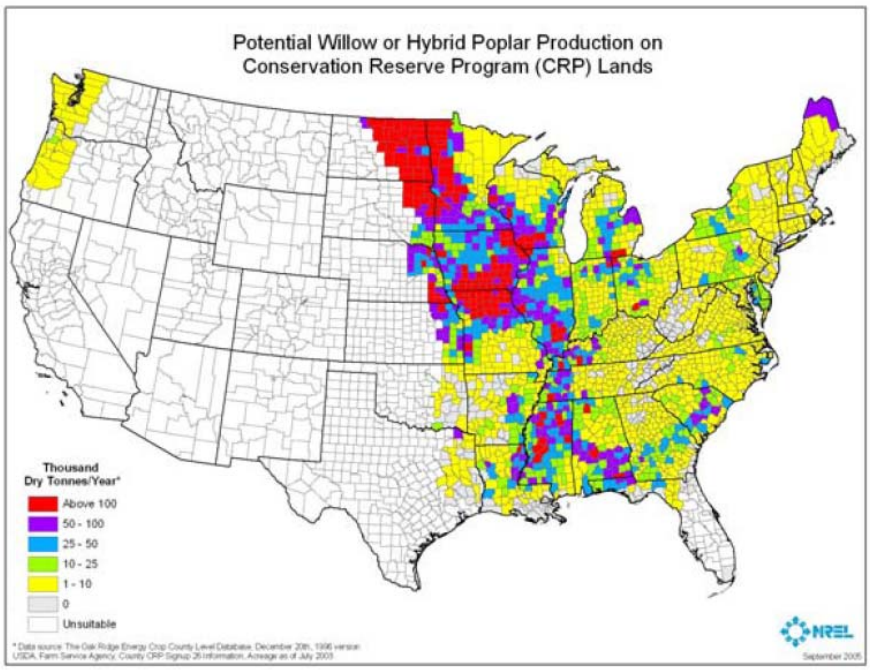

Primary Mill Residues
Total - Used and Unused
Hawaii
Alaska
Thousand
Dry Tonnes/Year
Above 100
50 - 100
25 - 50
10 - 25
5 - 10
1 - 5
0
Primary mill residues include wood materials (coarse and fine) and bark generated at manufacturing plants (primary wood-using mills) when round wood products are processed into primary wood products, like slabs, edgings, trimmings, sawdust, veneer clippings and cores, and pulp screenings. The map identifies mill residues recycled as byproducts as well as those left unutilized and disposed of as waste.
Source: USDA, Forest Service's Timber Product Output database, 2002
NREL
March 2005

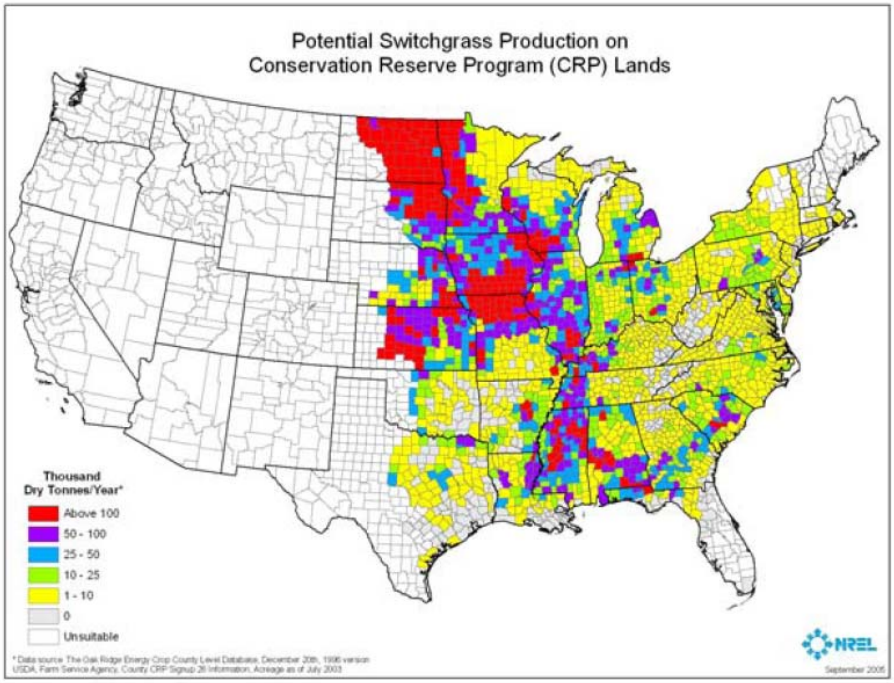

Primary Mill Residues
Unutilized
Hawaii
Alaska
Dry Tonnes/Year
Above 10 000
5 000 - 10 000
2 500 - 5 000
1 000 - 2 500
500 - 1 000
1 - 500
Not Estimated
Primary mill residues include wood materials (coarse and fine) and bark generated at manufacturing plants (primary wood-using mills) when round wood products are processed into primary wood products, like slabs, edgings, trimmings, sawdust, veneer clippings and cores, and pulp screenings. The map identifies mill residues not being used for any byproduct. This includes mill residues burned as waste or landfilled.
Source: USDA, Forest Service's Timber Product Output database, 2002
NREL
March 2005


Secondary Mill Residues
Hawaii
Alaska
Dry Tonnes/Year
Above 5 000
2 500 - 5 000
1 000 - 2 500
500 - 1 000
250 - 500
1 - 250
Not Estimated
Secondary mill residues include wood scraps and sawdust from woodworking shops - furniture factories (wood kitchen cabinet & countertops, no upholstered wood household furniture, wood office furniture, custom architectural woodwork & millwork, wood window & door manufactury), wood container and pallet mills, and wholesale lumberyards.
Source: U.S. Census Bureau, County Business Patterns 2002
NREL
August 2005

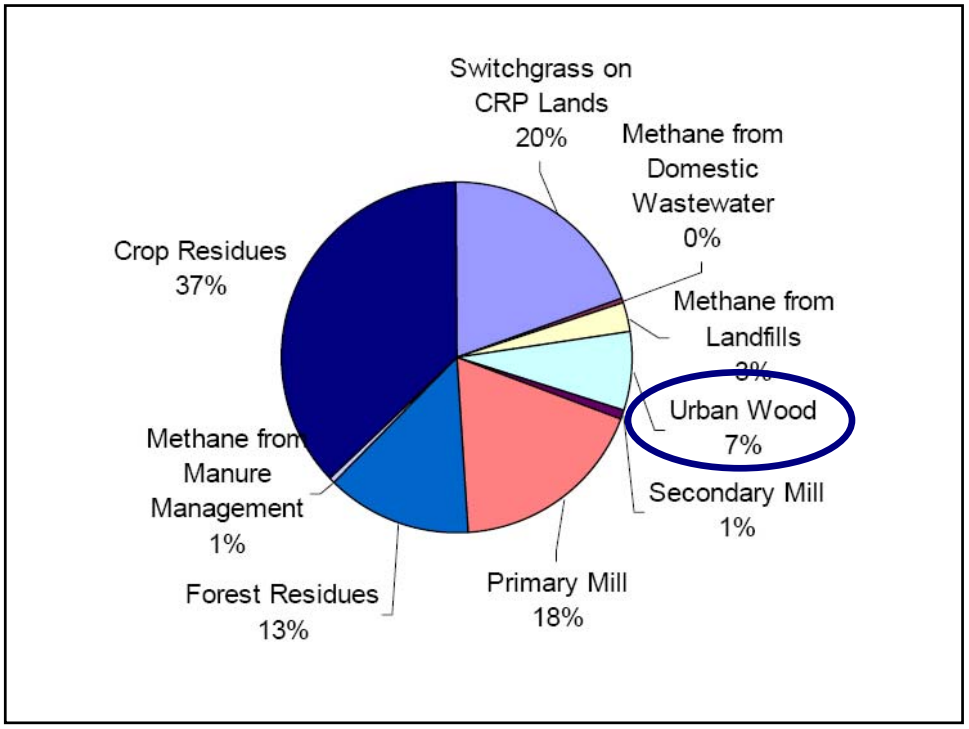

Urban Wood Residues
Hawaii
Alaska
Thousand
Dry Tonnes/Year
Above 50
25 - 50
15 - 25
10 - 15
5 - 10
Less than 5
This analysis includes wood residues from MSW (wood chips and pallets), utility tree trimming and/or private tree companies, and construction and demolition sites.
Source: U.S. Census Bureau, 2000 Population data; Biocycle magazine: State of Garbage in America, January 2004
NREL
May 2005

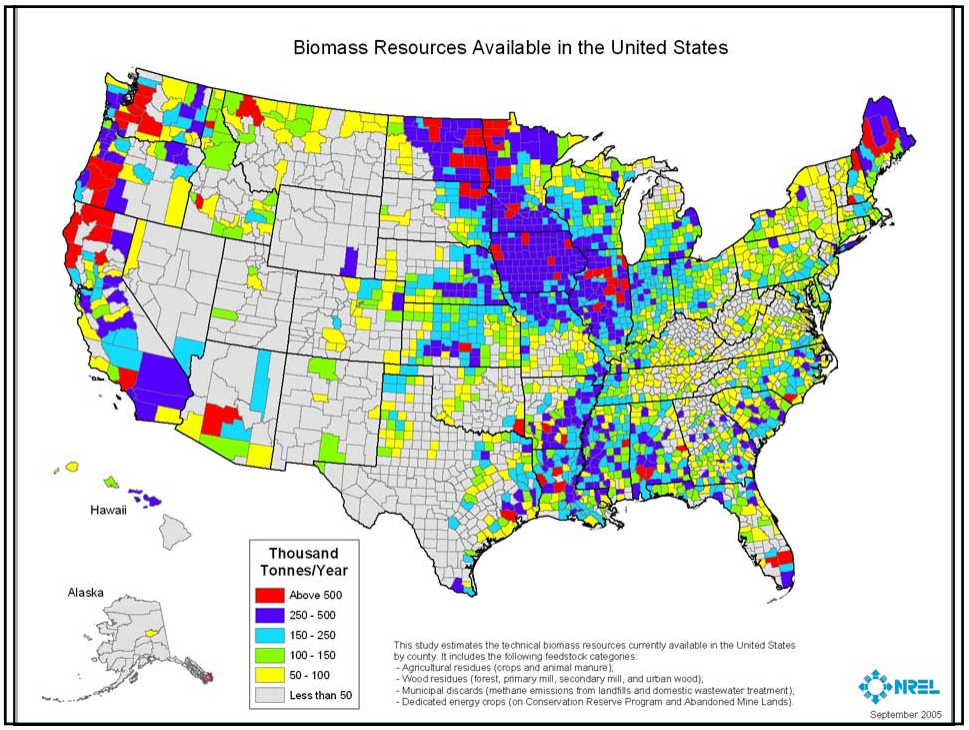

Hybrid Poplars
Switchgrass
Reed Canary Grass
Willows
Hybrid Poplars
Silver Maple
Black Locust
Switchgrass
Poplar
Tropical Grasses
Sycamore
Sweetgum
Sorghum
Black Locust
Miscanthus
Hybrid Poplars
Eucalyptus
Eucalyptus
Miscanthus
Switchgrass
Hybrid Poplars
Silver Maple
Reed Canarygrass
Black Locust
Sorghum
Eucalyptus
BIOMASS CROPS


Potential Willow or Hybrid Poplar Production on
Conservation Reserve Program (CRP) Lands
Thousand
Dry Tonnes/Year*
Above 100
50 - 100
25 - 50
10 - 25
1 - 10
0
Unsuitable
NREL
September 2005

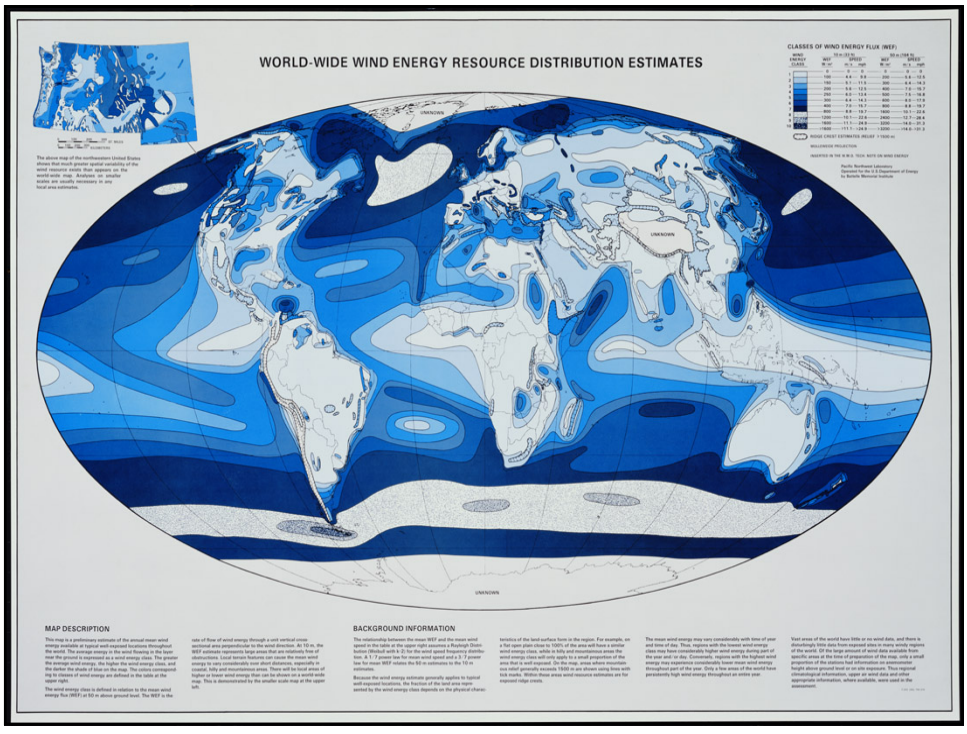


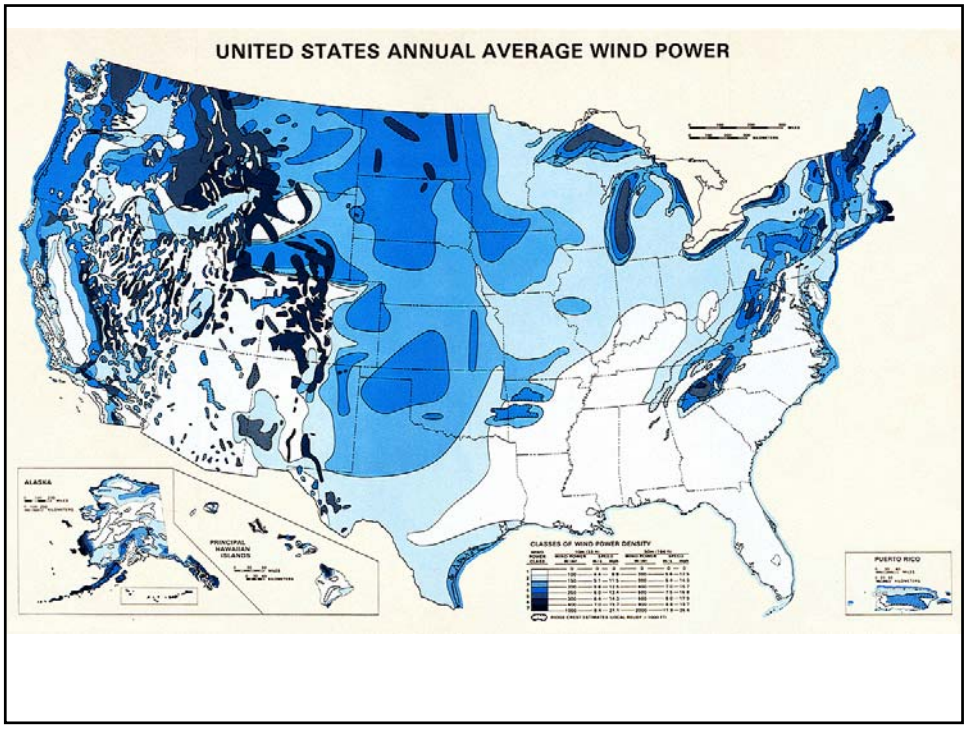
Switchgrass

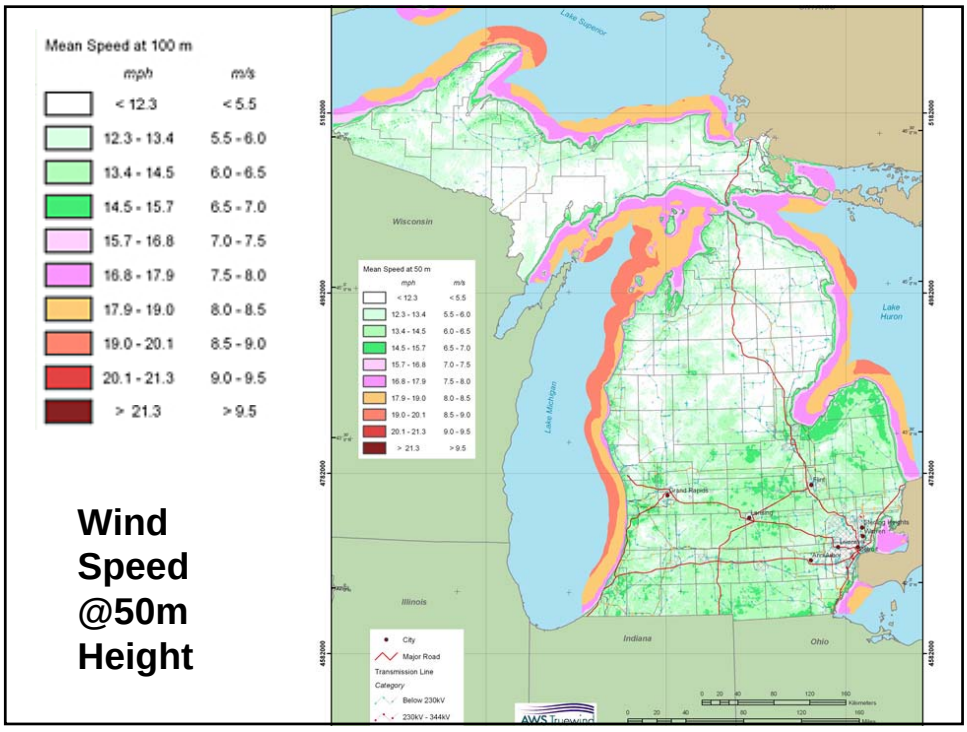

Switchgrass on CRP Lands 20%
Methane from Domestic Wastewater 0%
Methane from Landfills 3%
Urban Wood 7%
Secondary Mill 1%
Primary Mill 18%
Forest Residues 13%
Methane from Manure Management 1%
Crop Residues 37%

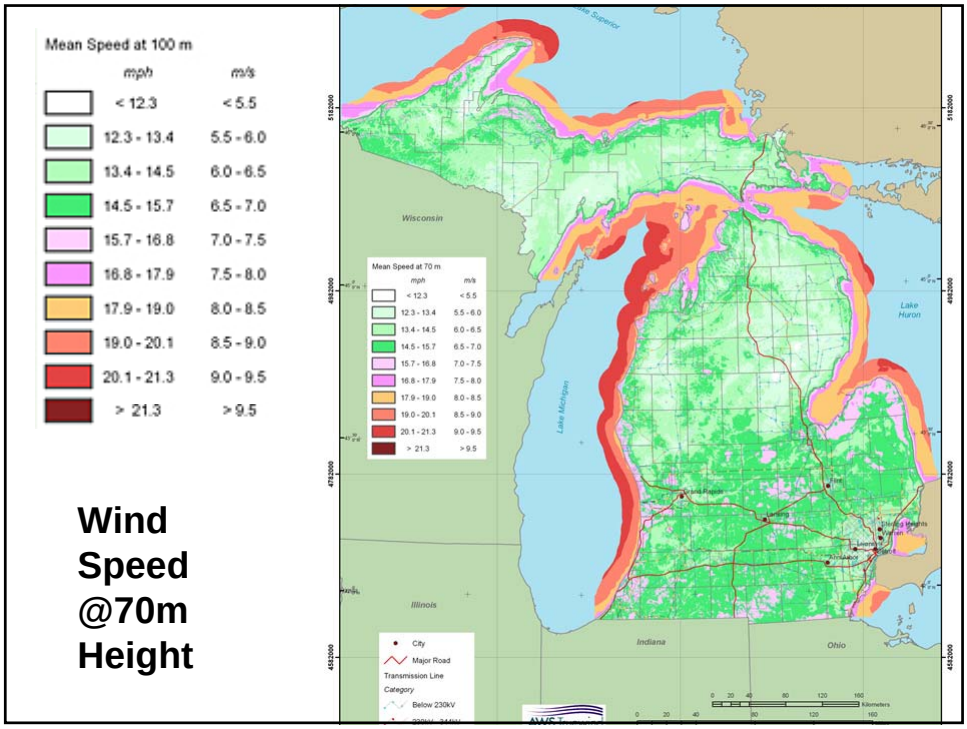

Biomass Resources Available in the United States
Hawaii
Alaska
Thousand Tonnes/Year
Above 500
250 - 500
150 - 250
100 - 150
50 - 100
Less than 50
This study estimates the technical biomass resources currently available in the United States by county. It includes the following feedstock categories:
- Agricultural residues (crops and animal manure);
- Wood residues (forest, primary mill, secondary mill, and urban wood);
- Municipal discards (methane emissions from landfills and domestic wastewater treatment);
- Dedicated energy crops (on Conservation Reserve Program and Abandoned Mine Lands).
NREL
September 2005

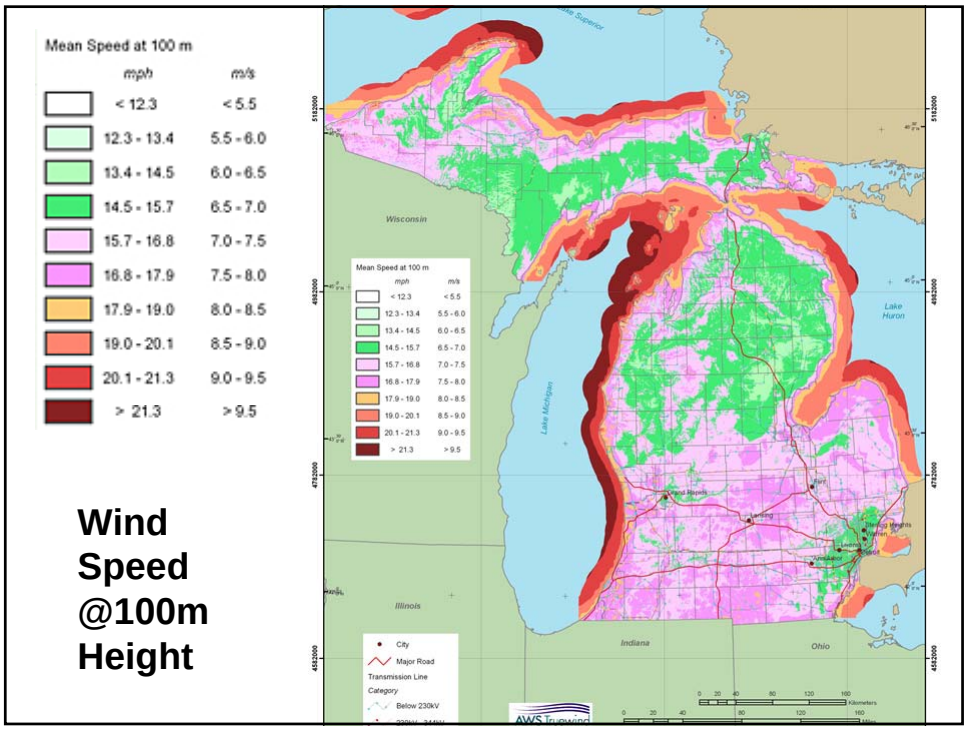
The Wind


WORLD-WIDE WIND ENERGY RESOURCE DISTRIBUTION ESTIMATES
CLASSES OF WIND ENERGY FLUX (WEF)
UNKNOWN
UNKNOWN
UNKNOWN
MAP DESCRIPTION
BACKGROUND INFORMATION


UNITED STATES ANNUAL AVERAGE WIND POWER
ALASKA
PRINCIPAL HAWAIIAN ISLANDS
CLASSES OF WIND POWER DENSITY
PUERTO RICO


Mean Speed at 100 m
mph
m/s
< 12.3
< 5.5
12.3 - 13.4
5.5 - 6.0
13.4 - 14.5
6.0 - 6.5
14.5 - 15.7
6.5 - 7.0
15.7 - 16.8
7.0 - 7.5
16.8 - 17.9
7.5 - 8.0
17.9 - 19.0
8.0 - 8.5
19.0 - 20.1
8.5 - 9.0
20.1 - 21.3
9.0 - 9.5
> 21.3
> 9.5
Wind Speed @50m Height
Lake Superior
Wisconsin
Lake Huron
Lake Michigan
Illinois
Indiana
Ohio
City
Major Road
Transmission Line
Category
Below 230kV
230kV - 344kV
AWS Truewind


Mean Speed at 100 m
mph
m/s
< 12.3
< 5.5
12.3 - 13.4
5.5 - 6.0
13.4 - 14.5
6.0 - 6.5
14.5 - 15.7
6.5 - 7.0
15.7 - 16.8
7.0 - 7.5
16.8 - 17.9
7.5 - 8.0
17.9 - 19.0
8.0 - 8.5
19.0 - 20.1
8.5 - 9.0
20.1 - 21.3
9.0 - 9.5
> 21.3
> 9.5
Wind Speed @70m Height
Wisconsin
Lake Michigan
Lake Huron
Illinois
Indiana
Ohio
City
Major Road
Transmission Line
Category
Below 230kV


Mean Speed at 100 m
mph
m/s
< 12.3
< 5.5
12.3 - 13.4
5.5 - 6.0
13.4 - 14.5
6.0 - 6.5
14.5 - 15.7
6.5 - 7.0
15.7 - 16.8
7.0 - 7.5
16.8 - 17.9
7.5 - 8.0
17.9 - 19.0
8.0 - 8.5
19.0 - 20.1
8.5 - 9.0
20.1 - 21.3
9.0 - 9.5
> 21.3
> 9.5
Wind Speed @100m Height
Wisconsin
Lake Michigan
Lake Huron
Illinois
Indiana
Ohio
City
Major Road
Transmission Line
Category
Below 230kV

Other Sources:

Hydro Power

Geothermal Energy

Ocean Thermal

Ocean Currents

Tidal Energy

Wave Energy

Next,

A Brief Review of Oakland University Feasibility Studies

Wind Power Option

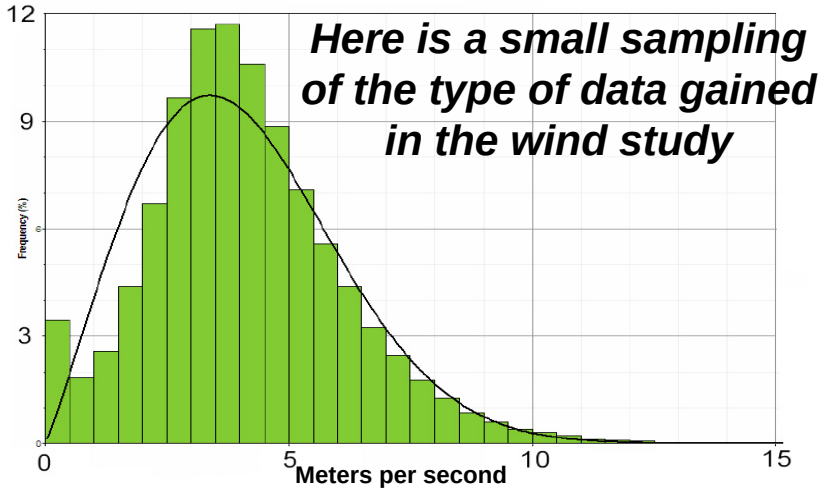
for Oakland University

There were two parts of the study

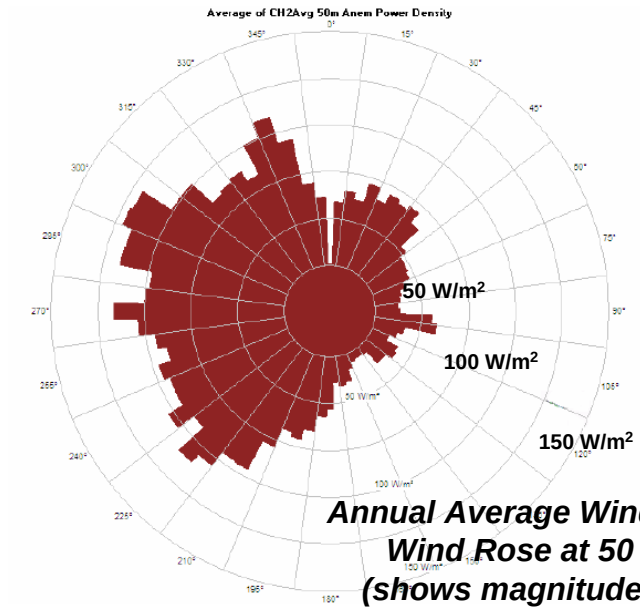
- **Wind Speed Study Results**
  - •Wind speed was recorded for two years at a 50 meter tall “met tower” located on the south side of the main campus
  - •Data collected for 2006 & 2007
- **Feasibility Study Results**
  - •This data was then used in a full engineering and cost analysis for one or more wind turbines for the Oakland campus

Average Wind Data Results

Height	Wind Speed	Method
30 m	3.0 m/s	measured
40 m	3.6 m/s	measured
50 m	4.1 m/s	measured
75 m	5.2 m/s	calculated
80 m	5.4 m/s	calculated
100 m	6.2 m/s	calculated

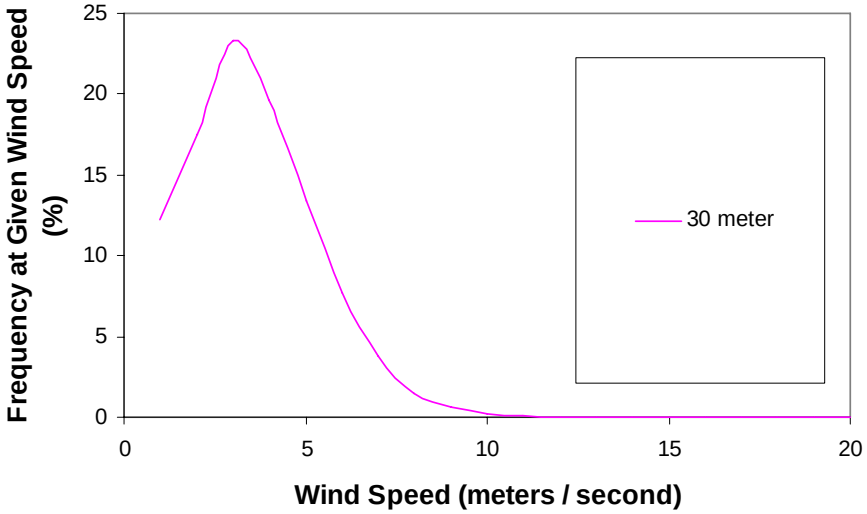


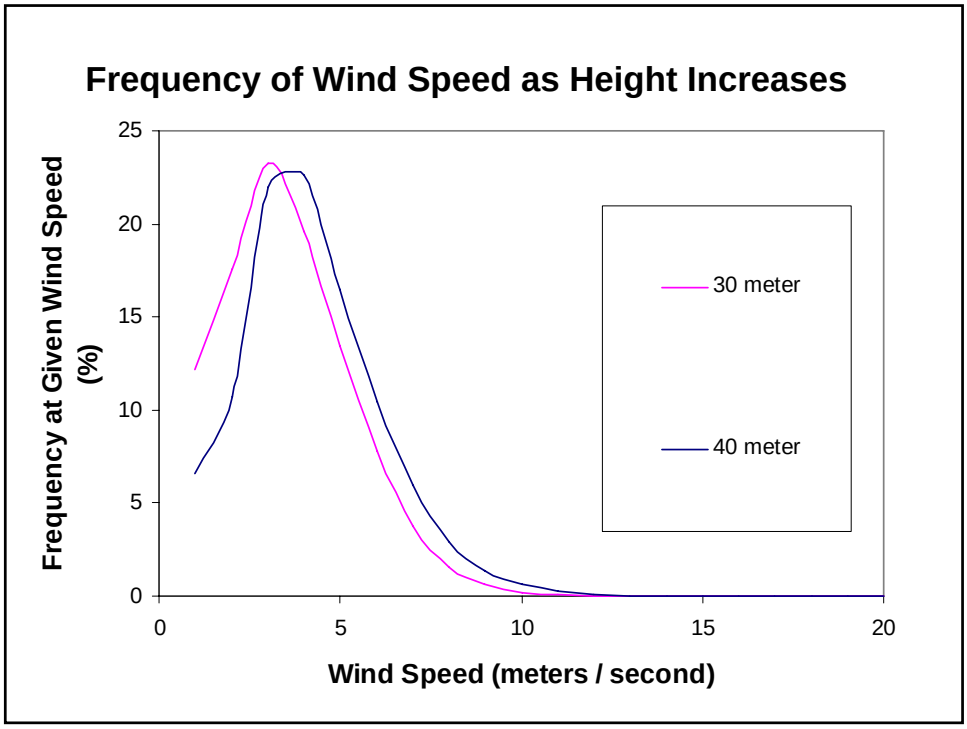
Wind Speed Frequency Distribution at 50 Meters (percent time for each wind speed)

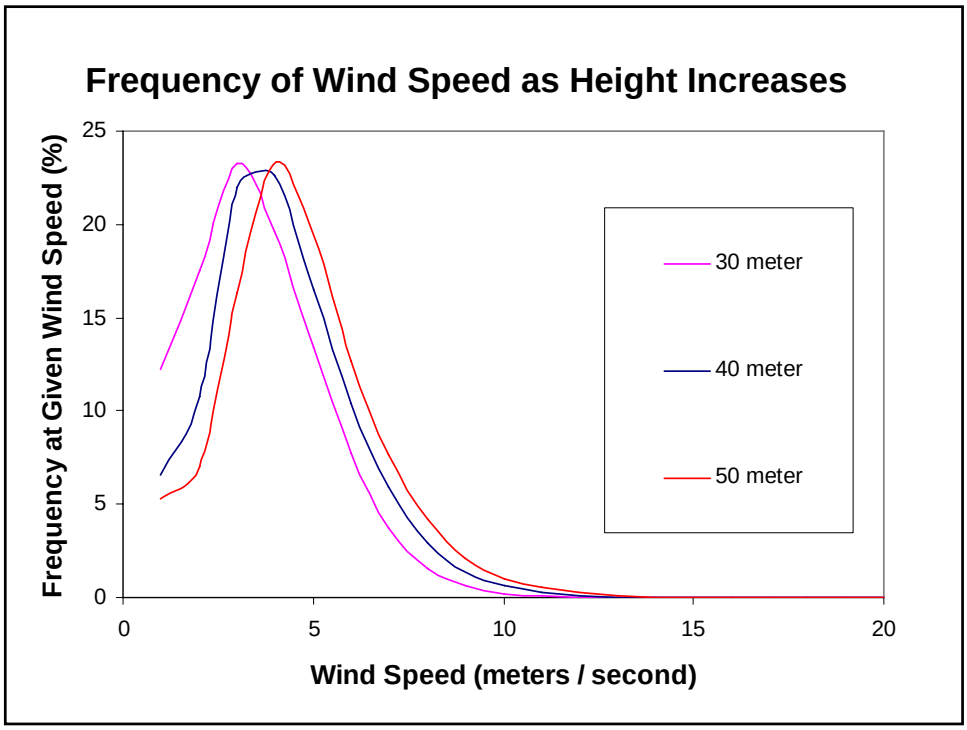


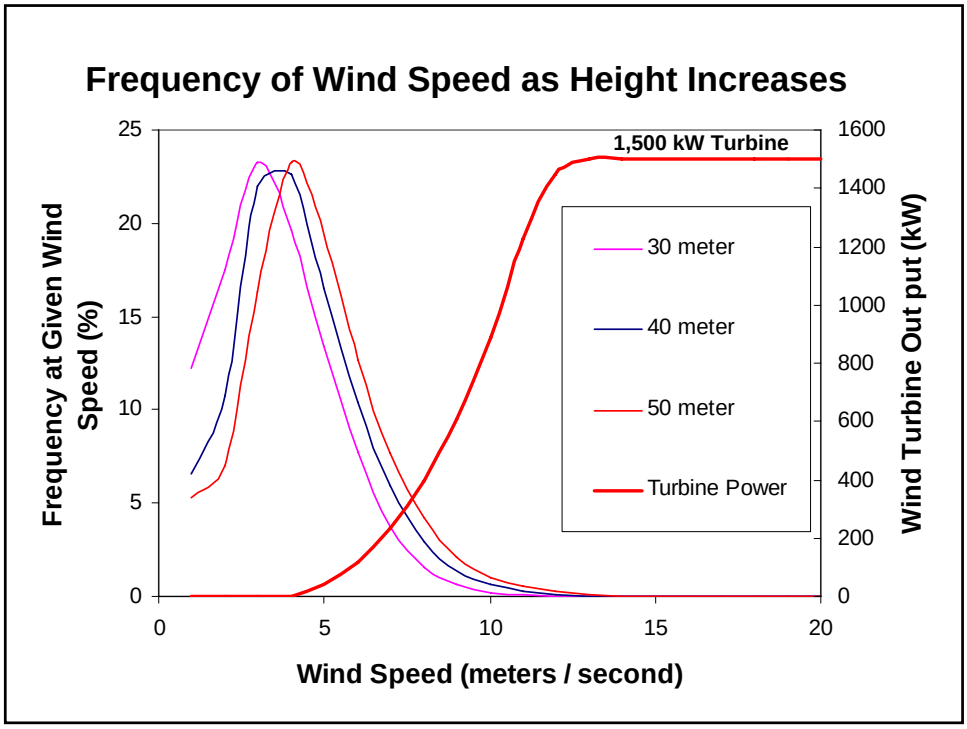
Annual Average Wind Power Density Wind Rose at 50 Meter Height (shows magnitude and direction of annual wind power potential)

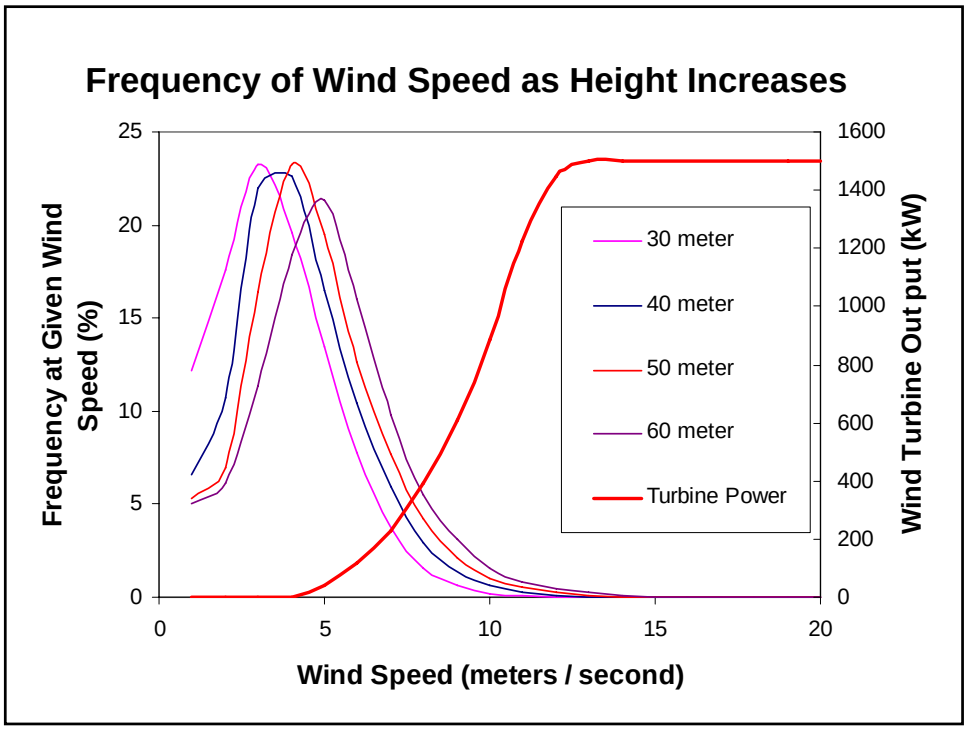
Frequency of Wind Speed as Height Increases

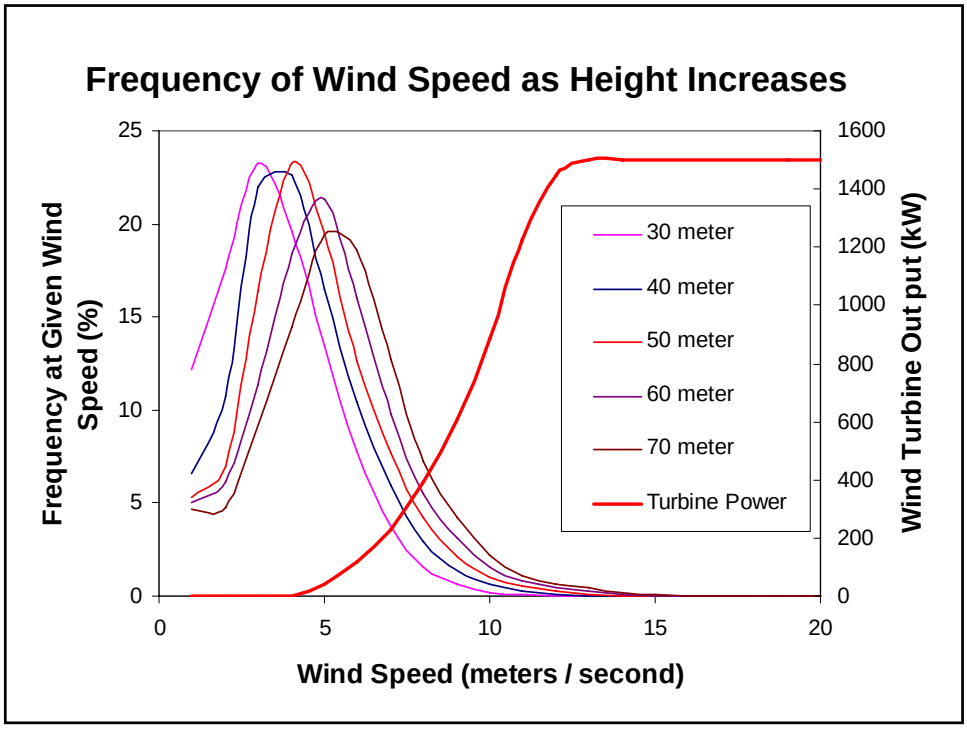


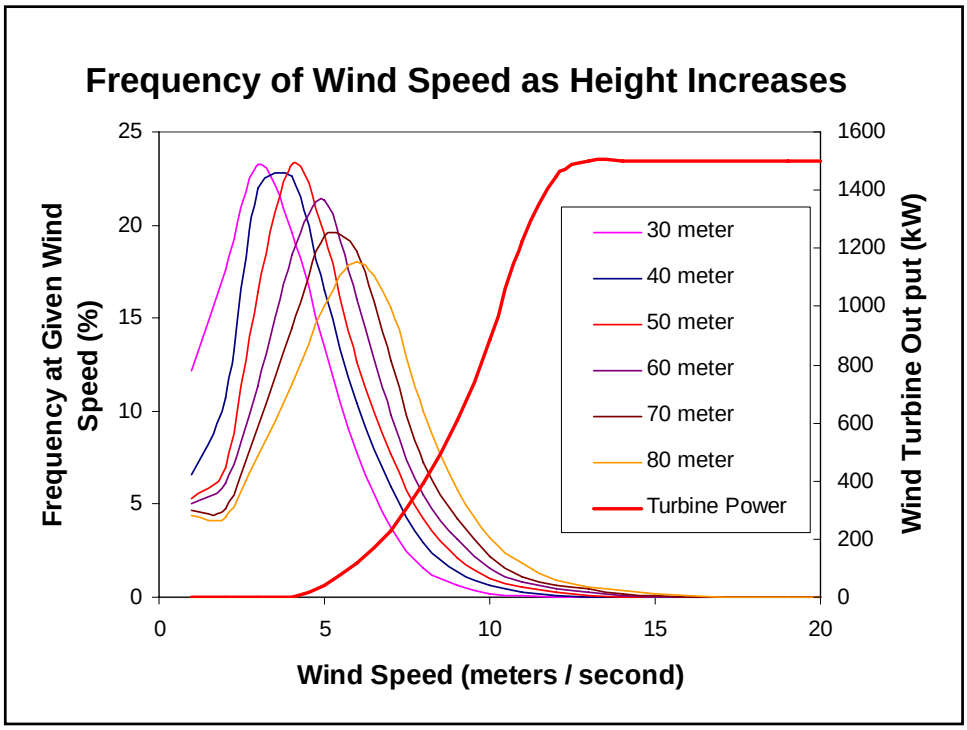

Frequency of Wind Speed as Height Increases
Frequency at Given Wind Speed (%)
25
20
15
10
5
0
0
5
10
15
20
Wind Speed (meters / second)
30 meter
40 meter

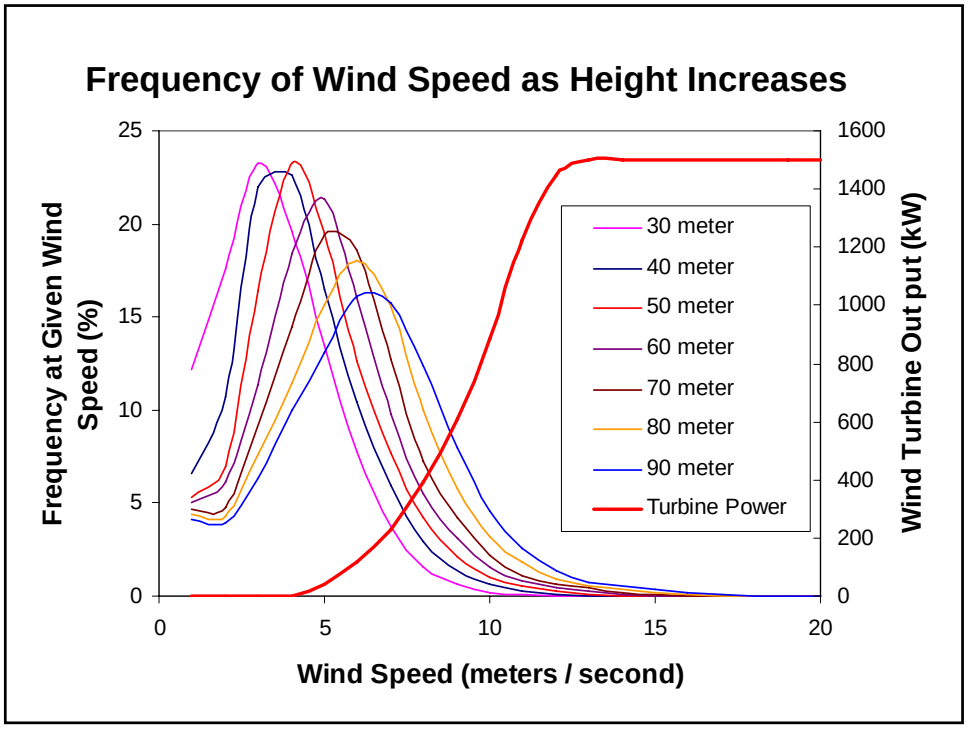

Frequency of Wind Speed as Height Increases
Frequency at Given Wind Speed (%)
25
20
15
10
5
0
0
5
10
15
20
Wind Speed (meters / second)
30 meter
40 meter
50 meter

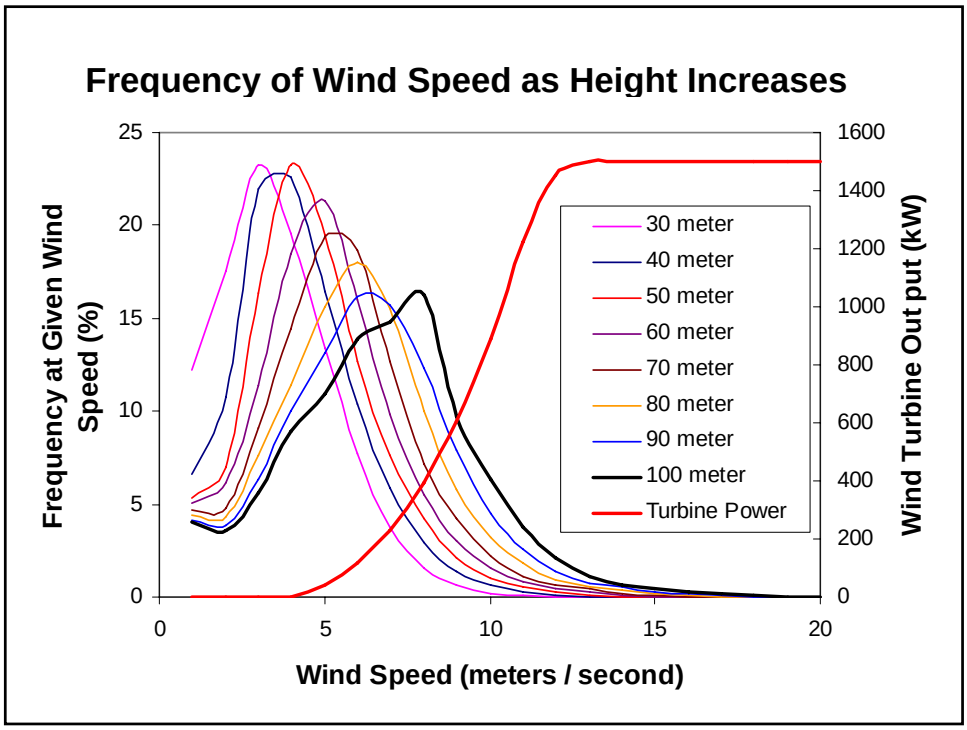

Frequency of Wind Speed as Height Increases
1,500 kW Turbine
Frequency at Given Wind Speed (%)
Wind Turbine Out put (kW)
Wind Speed (meters / second)
30 meter
40 meter
50 meter
Turbine Power
0
5
10
15
20
25
200
400
600
800
1000
1200
1400
1600

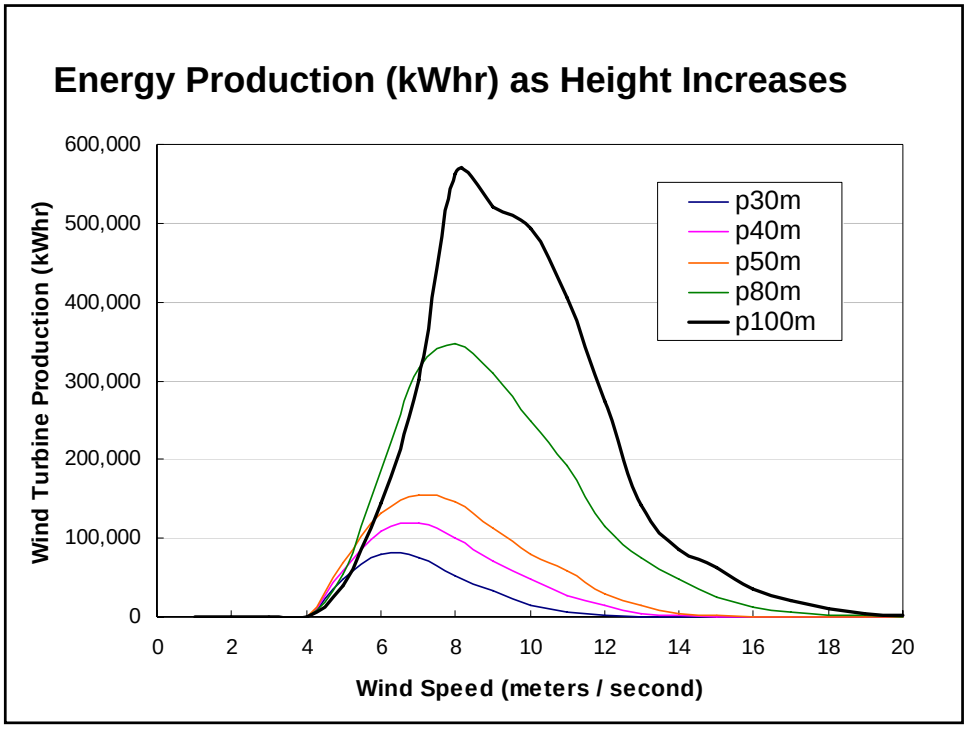

Frequency of Wind Speed as Height Increases
Frequency at Given Wind Speed (%)
Wind Turbine Out put (kW)
Wind Speed (meters / second)
30 meter
40 meter
50 meter
60 meter
Turbine Power
0
5
10
15
20
25
200
400
600
800
1000
1200
1400
1600

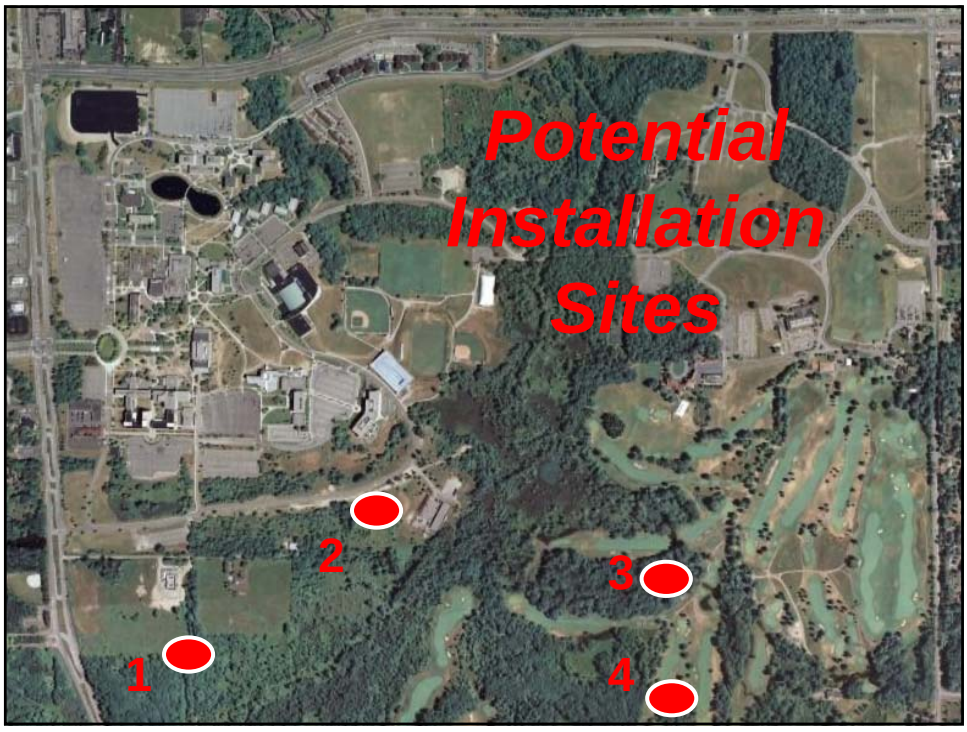

Frequency of Wind Speed as Height Increases
Frequency at Given Wind Speed (%)
Wind Turbine Out put (kW)
Wind Speed (meters / second)
30 meter
40 meter
50 meter
60 meter
70 meter
Turbine Power
0
5
10
15
20
25
200
400
600
800
1000
1200
1400
1600


Frequency of Wind Speed as Height Increases
Frequency at Given Wind Speed (%)
Wind Turbine Out put (kW)
Wind Speed (meters / second)
30 meter
40 meter
50 meter
60 meter
70 meter
80 meter
Turbine Power
0
5
10
15
20
25
200
400
600
800
1000
1200
1400
1600


Frequency of Wind Speed as Height Increases
Frequency at Given Wind Speed (%)
Wind Turbine Out put (kW)
Wind Speed (meters / second)
0
5
10
15
20
25
0
200
400
600
800
1000
1200
1400
1600
30 meter
40 meter
50 meter
60 meter
70 meter
80 meter
90 meter
Turbine Power


Frequency of Wind Speed as Height Increases
Frequency at Given Wind Speed (%)
Wind Turbine Out put (kW)
Wind Speed (meters / second)
0
5
10
15
20
25
0
200
400
600
800
1000
1200
1400
1600
30 meter
40 meter
50 meter
60 meter
70 meter
80 meter
90 meter
100 meter
Turbine Power


Energy Production (kWhr) as Height Increases
Wind Turbine Production (kWhr)
600,000
500,000
400,000
300,000
200,000
100,000
0
0
2
4
6
8
10
12
14
16
18
20
Wind Speed (meters / second)
p30m
p40m
p50m
p80m
p100m


Potential Installation Sites
1
2
3
4

Here is a typical wind turbine under consideration

1,500 kW each

77 meter blade diameter

100 meter tower

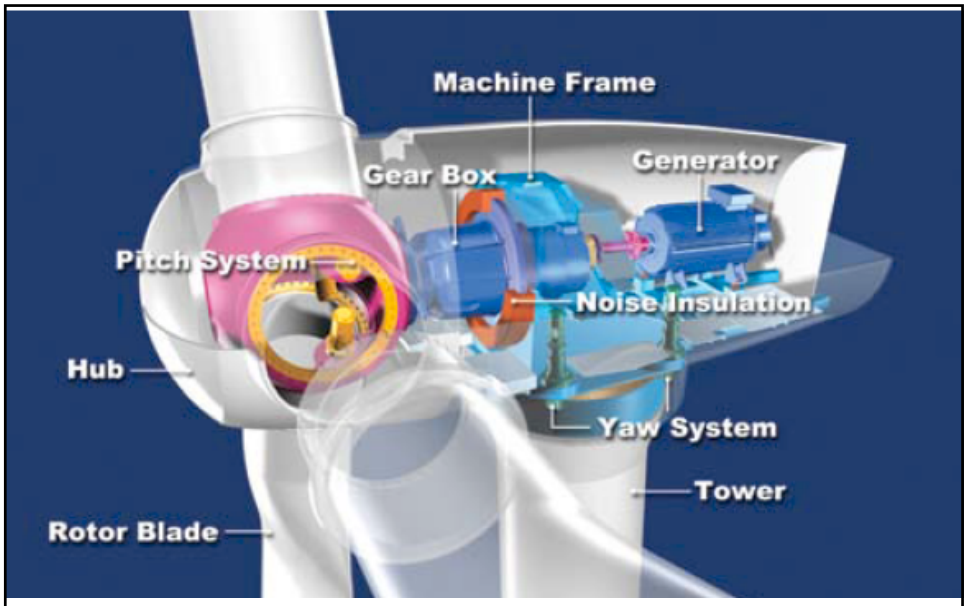
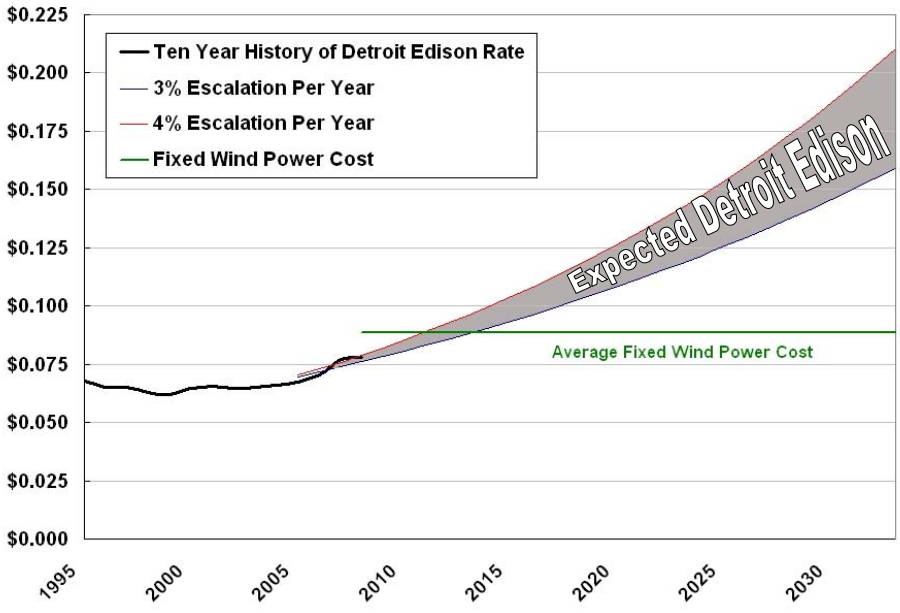
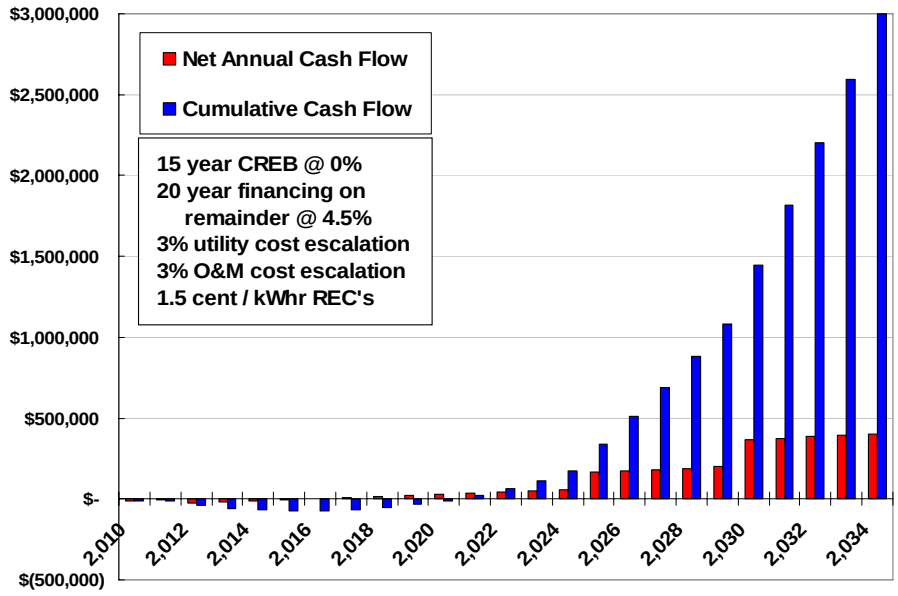


Illustration of turbine components



Projected Cost per kW-hr Electricity Over 25 Year Project



Net Annual and Cumulative Cash Flow Over 25 Year Project

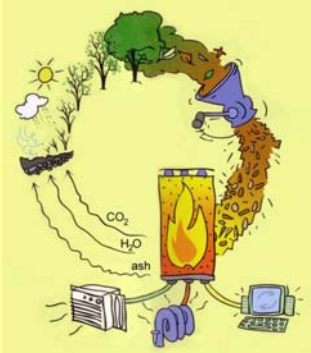
(construction in 2009, beginning operation in 2010)

Biomass Power Option

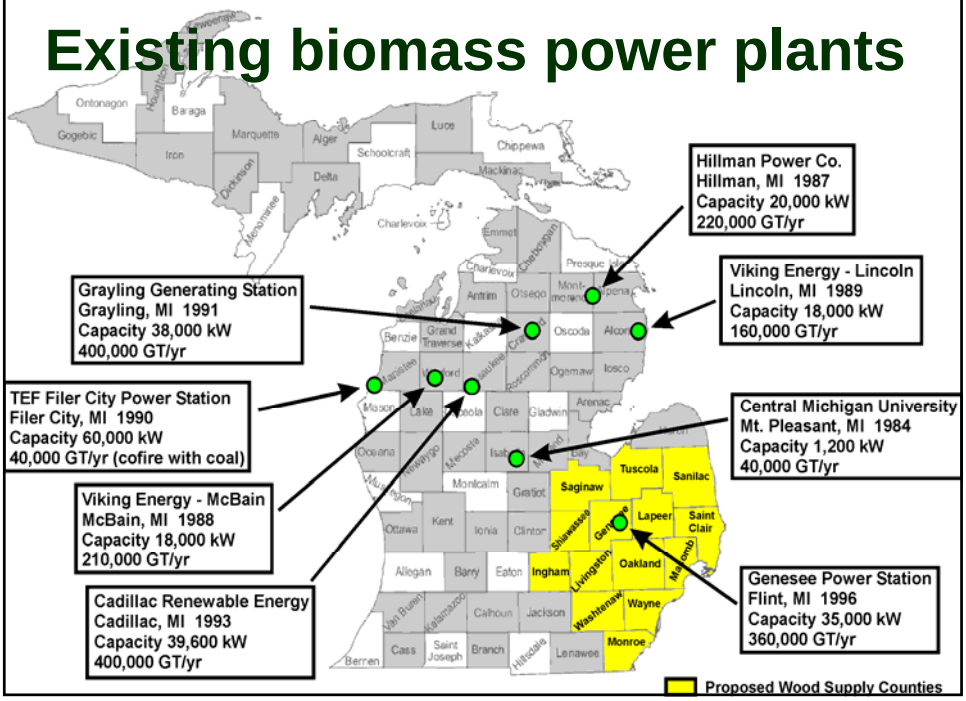
for Oakland University

- Wood supply
- Campus growth & future needs
- Wood boilers
- Proposed sites
- Costs & savings

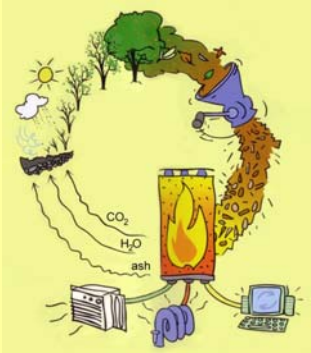
We looked at 14 counties in SE Michigan & found 1.7 million tons of urban waste wood per year



Existing biomass power plants



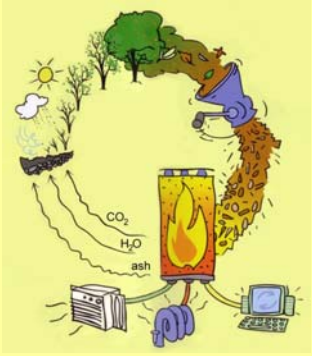
Nearby wood recyclers could easily serve the new system



J.h.Hart urban FORESTRY

Other campuses heat with wood

- Central Michigan University
- Northern Michigan University is developing a plant



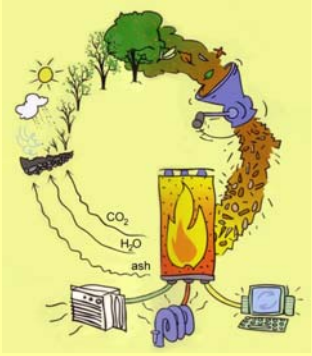
CMU Wood Boiler Plant

(heats most of campus)

(note: only water vapor is coming from stack)
photo - Jim Leidel 2005

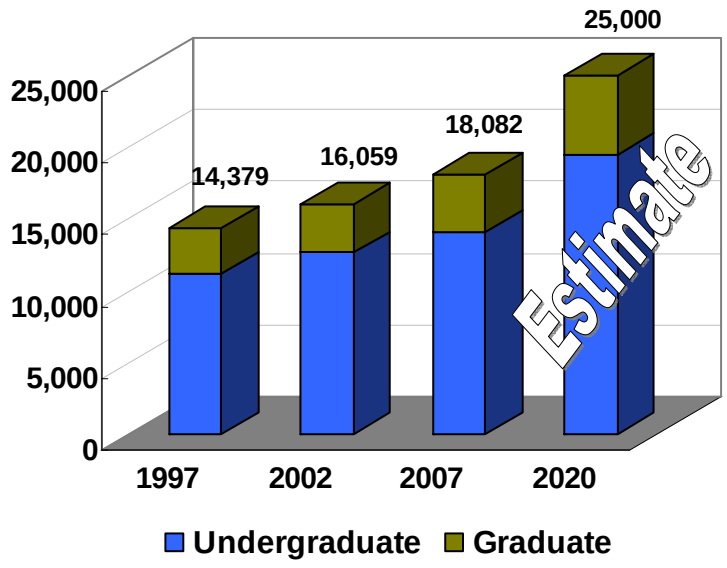
Next we look at the future needs for campus:

1. **Replace aging boilers**
2. **More capacity for future growth**

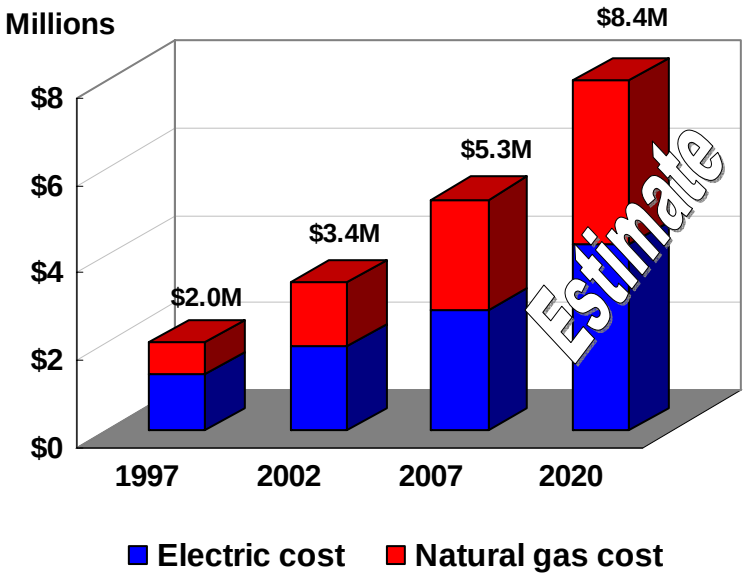


Existing Central Heating Plant

Unit	Capacity (MMBTU/hr)	Year Installed	Age in years / Condition
B-1	100	1969	39 / good
B-2	100	1969	39 / good
B-3	34	1959	49 / fair
B-4	32	1957	51 / marginal
Total	**265**		



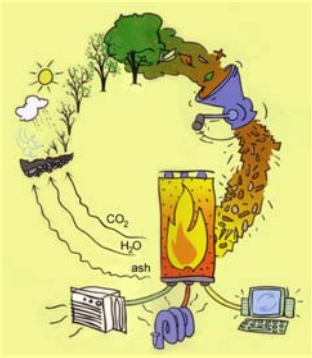
Oakland University Ten Year Fall Enrollment Growth with 2020 Vision

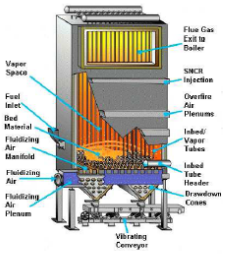


Oakland University Ten Year Energy Growth with 2020 Vision

2020 Projection based on $0.085/kWhr electricity and $11/MMBTU gas

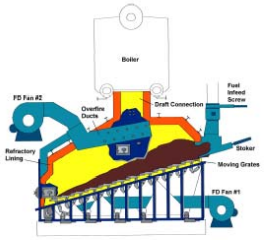
We then looked at various wood boiler systems





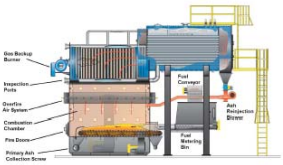
EPI Fluid Bed

(Steam & HW)



English Stoker

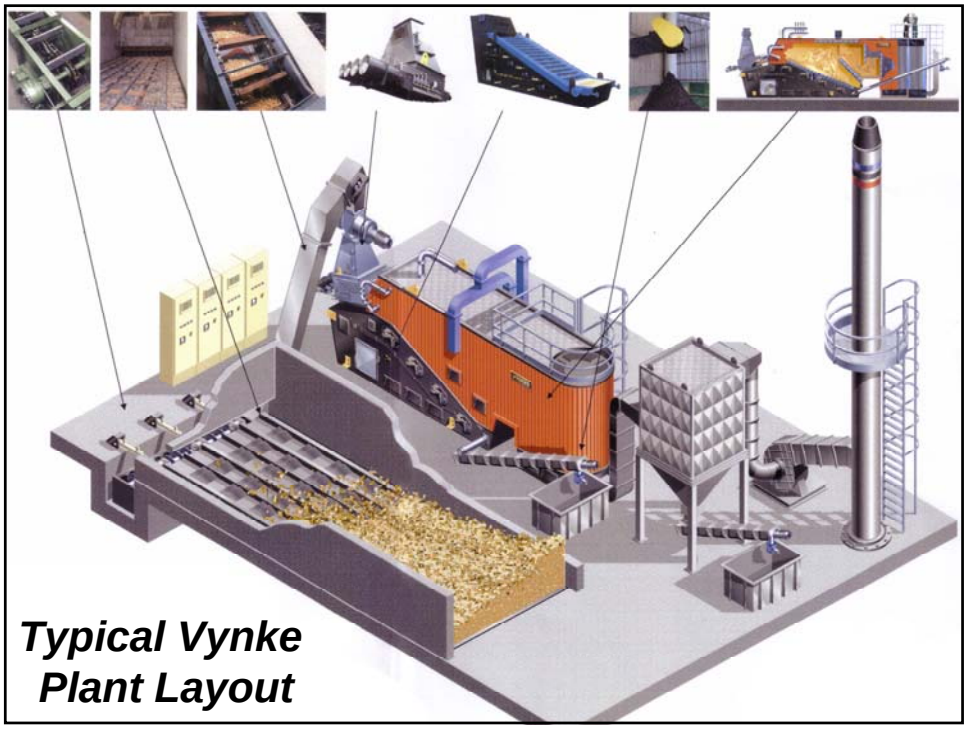
(Steam & HW)



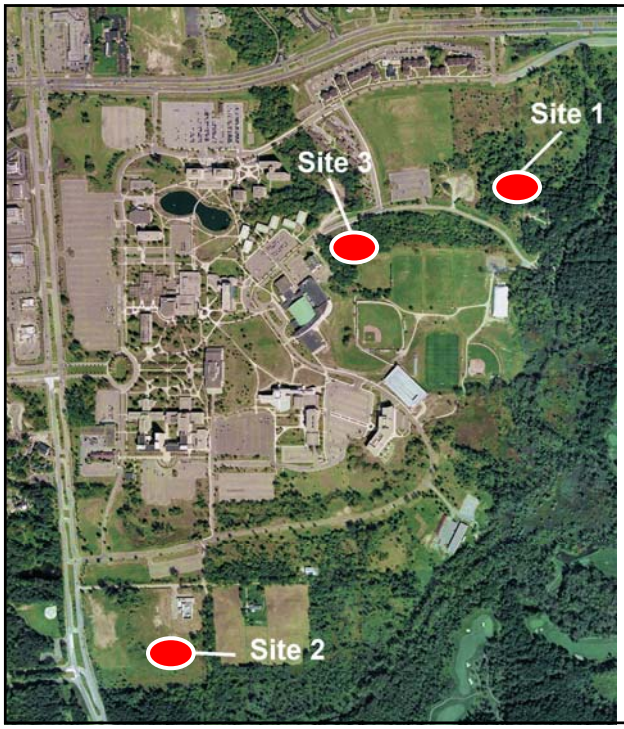
Hurst Stoker

(HW Only)

Vynke Stoker
(Steam & HW)



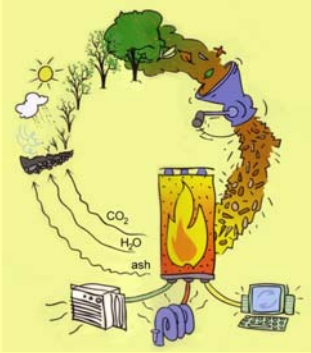
Typical Vynke Plant Layout



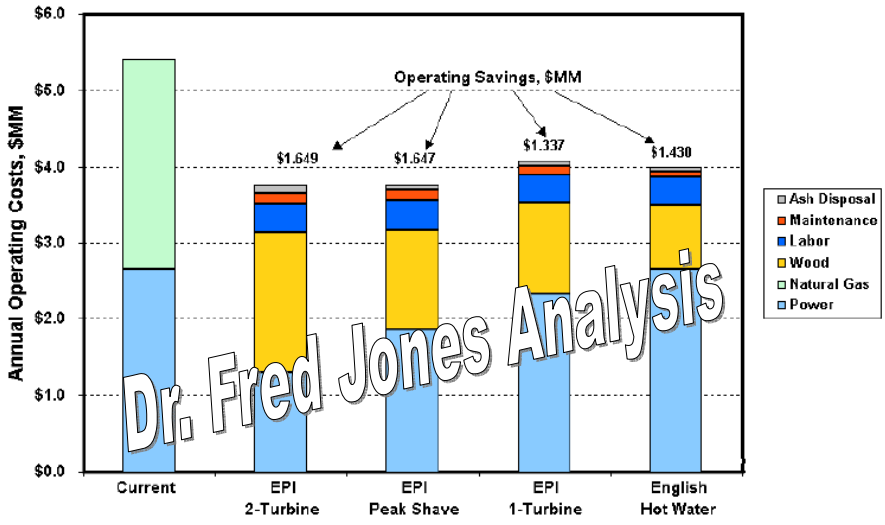
Three Proposed Site Locations

A new wood storage building
(in Kingsville, Ontario) ***80 MMBTU/hr***

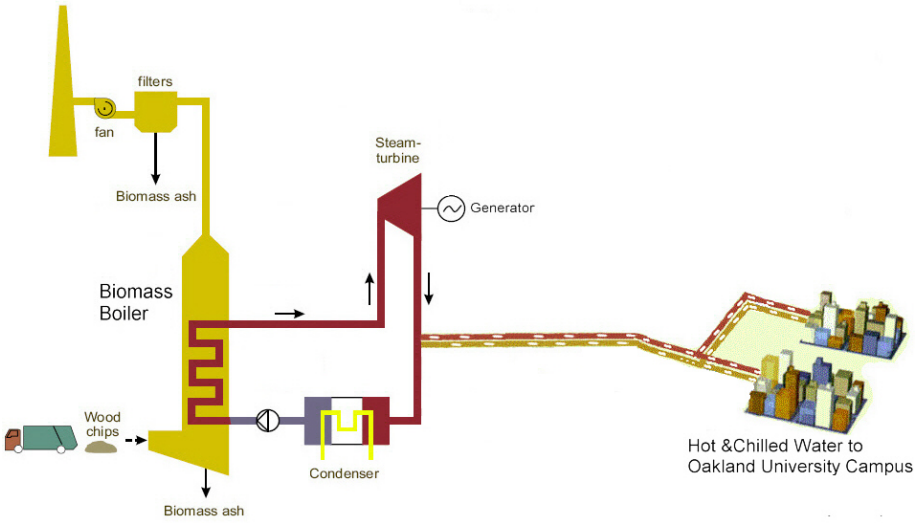
Annual operating savings are in the range of $1.5 million



Operating Cost Estimates



Overview of an Integrated, Renewable Energy Supply Infrastructure



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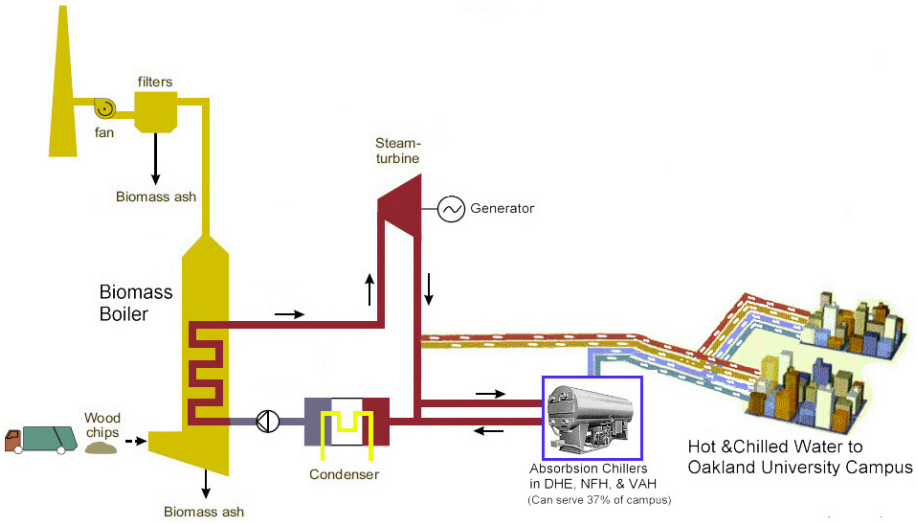

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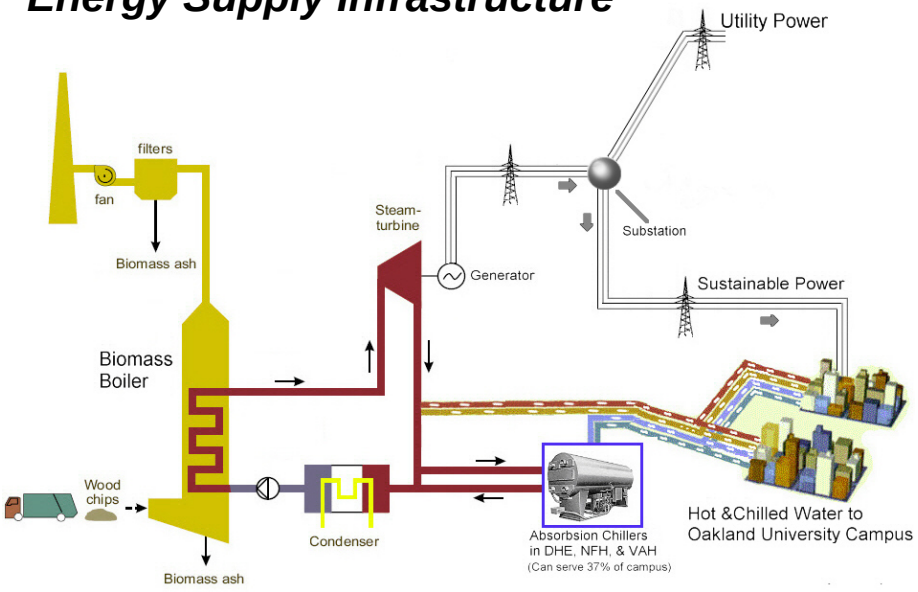

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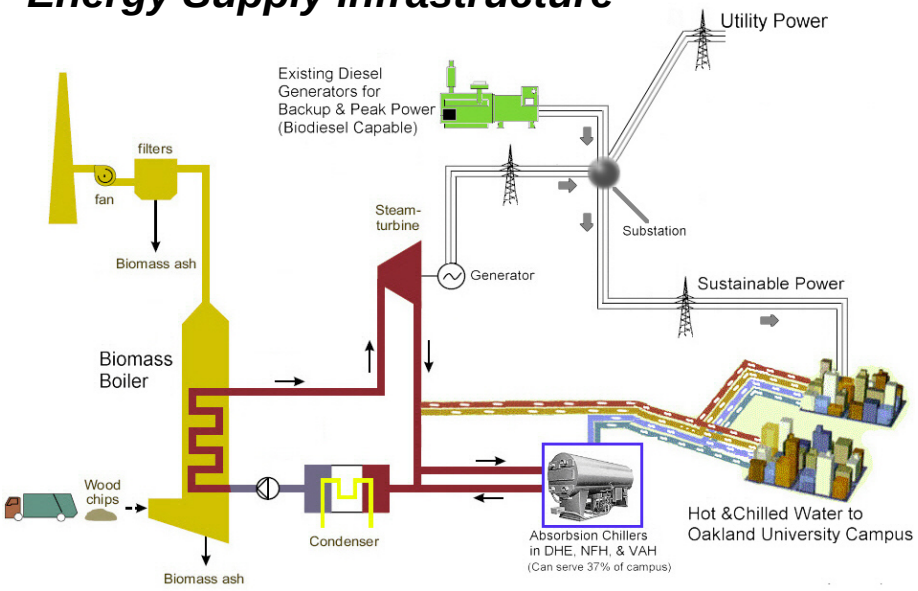

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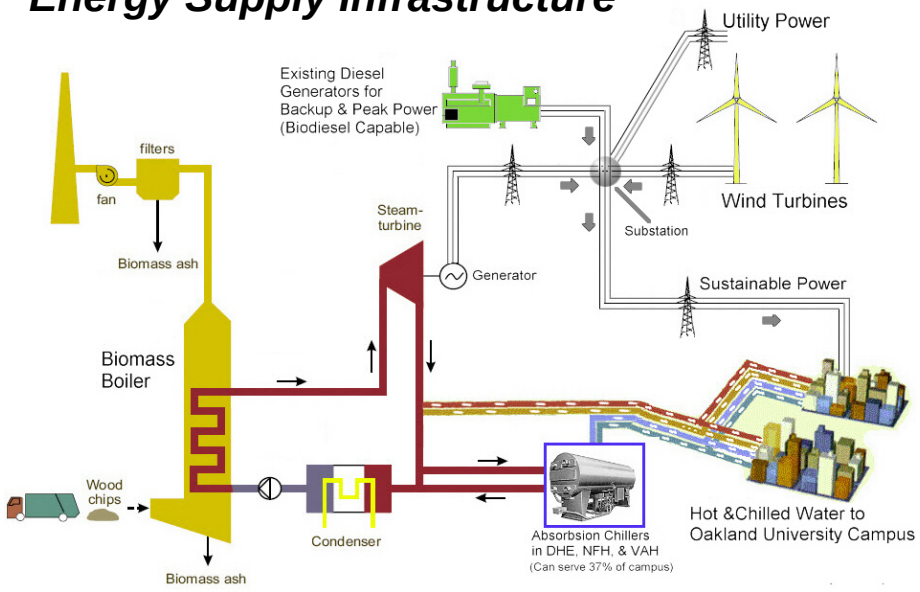
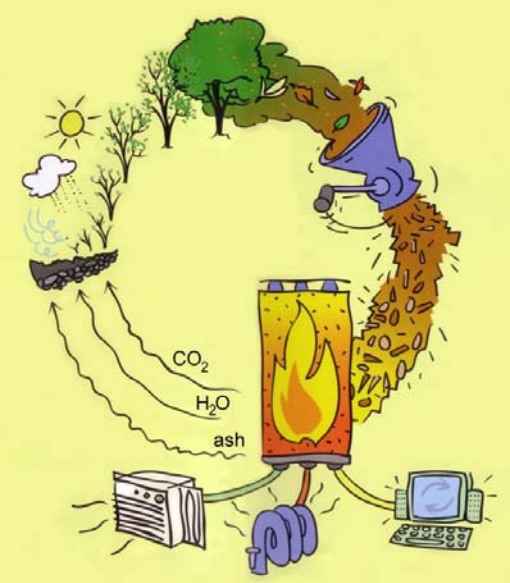
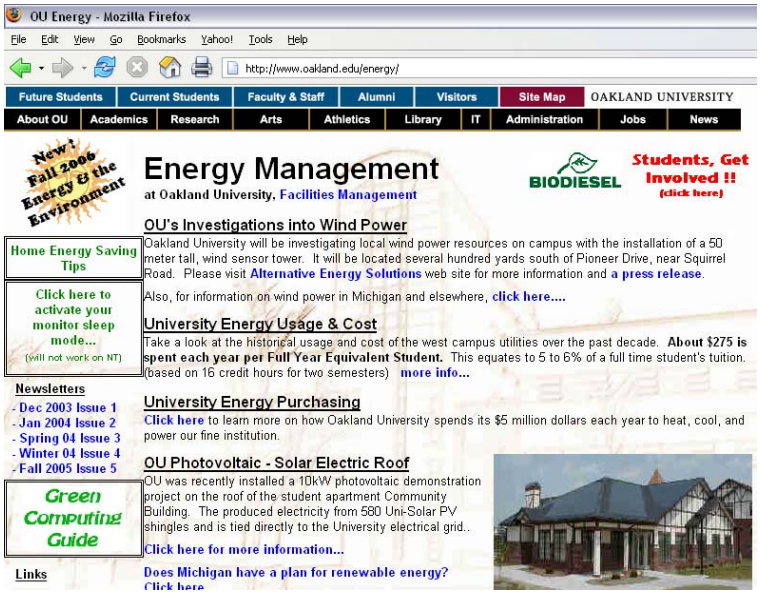


Overview of an Integrated Renewable Energy Supply Infrastructure

	Existing Fossil Fuel Mix		Proposed Renewable Energy	
	Thermal (Heating)	**Electrical**	**Thermal (Heating)**	**Electrical**
Central Heating Plant (natural gas)	100%		20%	
Detroit Edison		95%		20%
Diesel Generators		5%		10%
Biomass Boiler Plant			80%	50%
Wind Power				20%
Totals	100%	100%	100%	100%

Biomass & Wind Power

Sustainable Energy Options for the Future of Oakland University



For more info visit www.oakland.edu/energy