Renewable Energy Resource Assessment

Village Strategic Energy Planning

Develop a community energy baseline

Develop a common Village energy vision

Identify and support a Village champion

Identify culture and environmental constraints

Identify and evaluate resource options

Demand-Side Options

Supply-Side Options

Integrate supply and demand alternatives

Establish organizational and human resource needs

Strategic Plan

Programs & Projects

Village Objectives

- Energy Reliability & Security
- Off-Grid Electrification
- Minimize Environmental Impacts
- Supply Diversification
- Use of Local Resources
- Economic Development
- Jobs
- Build technical expertise
- Respect for Mother Earth
- Others??

Supply-Side Options

- Conventional Technologies
- Cogeneration
- Renewable Technologies
- Attributes to Consider
  - Plant Capacity
  - Fuel Type
  - Efficiency
  - Reliability
  - Capital, Operating & Lifecycles Costs
  - Lifetime & Decommissioning
  - Environmental Impacts

What is Resource Assessment?

Understanding the **spatial** and **temporal** variations of renewable energy resources:

» Solar Radiation
» Wind Power
» Bioenergy
» Geothermal
» Hydrological

For supporting:

- Production of electricity, heat, fuels and other products generally derived from non-renewable sources
- Energy efficiency opportunities (e.g., buildings, transportation, etc.)

Resource Assessment

Resource *DATA* → Technology *INFORMATION*

Maps

Databases

Models

Climate Summaries

Real-Time Data

Sources of Resource Data

- National and International Government Sources

  Provide access to long-term and experimental measurements

  - ✓ Weather & Climate Records
    - World Meteorological Organization (WMO)
    - Country-specific weather services
    - National Oceanic & Atmospheric Administration (NOAA)
    - US Department of Energy (DOE)
    - US Department of Defense
  - ✓ Environmental Monitoring
    - US Environmental Protection Agency (EPA)
    - Bureau of Land Management (BLM)
    - Nuclear Regulatory Commission (NRC)
    - State EPA, Health Departments, etc.
  - ✓ Agricultural Interests
    - US Dept of Agriculture
    - US Forest Service
  - ✓ Other Related Data
    - US Geological Survey (USGS)

Elements of Resource Assessment

- High resolution **spatial** data for site selection
- Historical **time-series** data for system design
- Specific data **elements** for technology options

  For example, Solar Utilization needs “Watts per square meter”:

  - Direct normal for concentrating solar power (10-sec)
  - Global for flat-plate collectors (daily)
  - Diffuse irradiance & illuminance for daylighting (monthly)
- Specified **confidence limits** of all information products

Consequences of Poor Resource Information

- At-risk Project definition and **approval**
- Unrealistic project **goals**
- Less than optimal **technology selection**
- Conservative design, driving up initial **costs**
- Project delays to conduct resource assessment (**additional** monitoring & analyses)

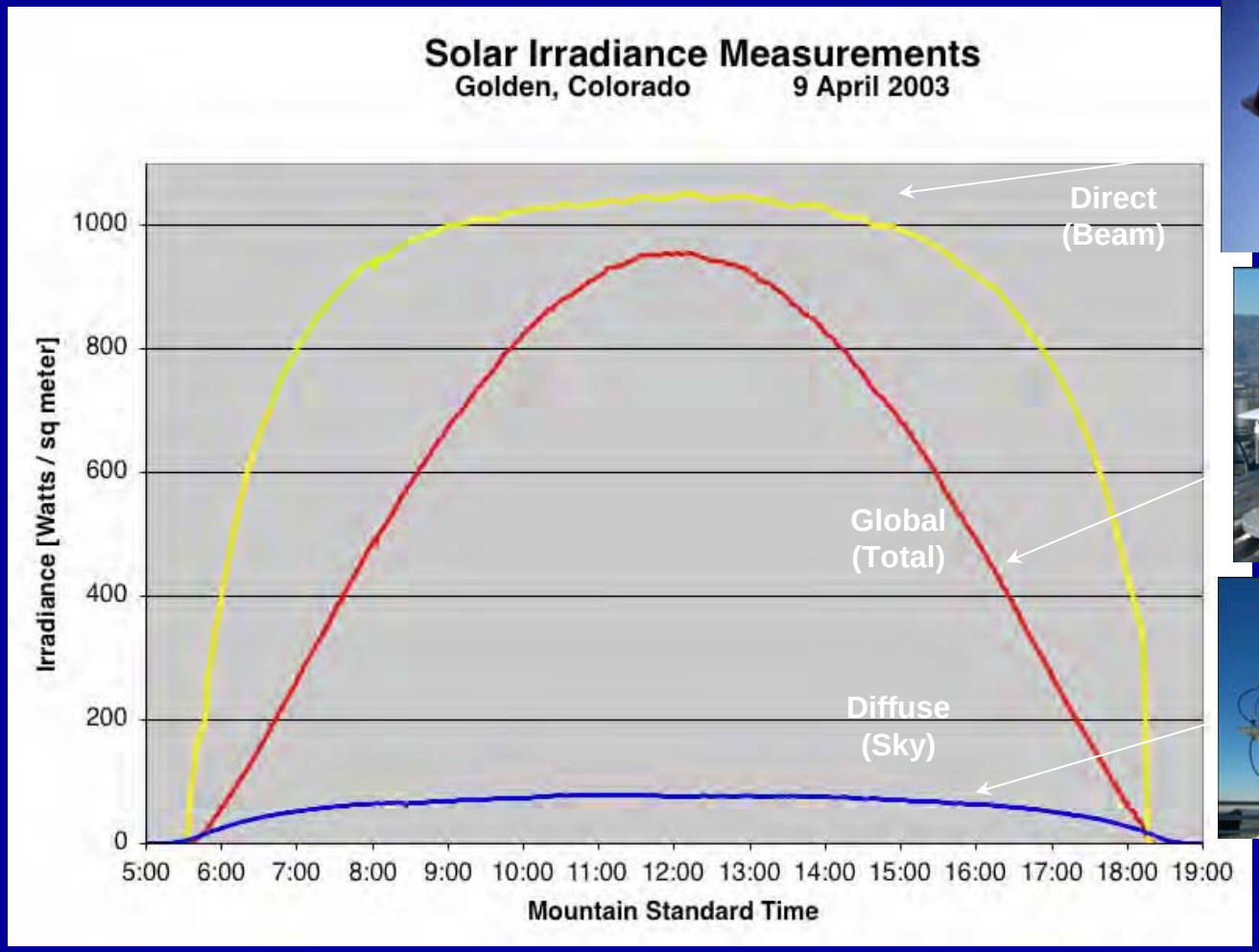
Measurements & Instrumentation

Solar Radiation Research Laboratory

- Instrument Calibrations
- Solar & Wind Resource Climatology
- Network Operations
- Training

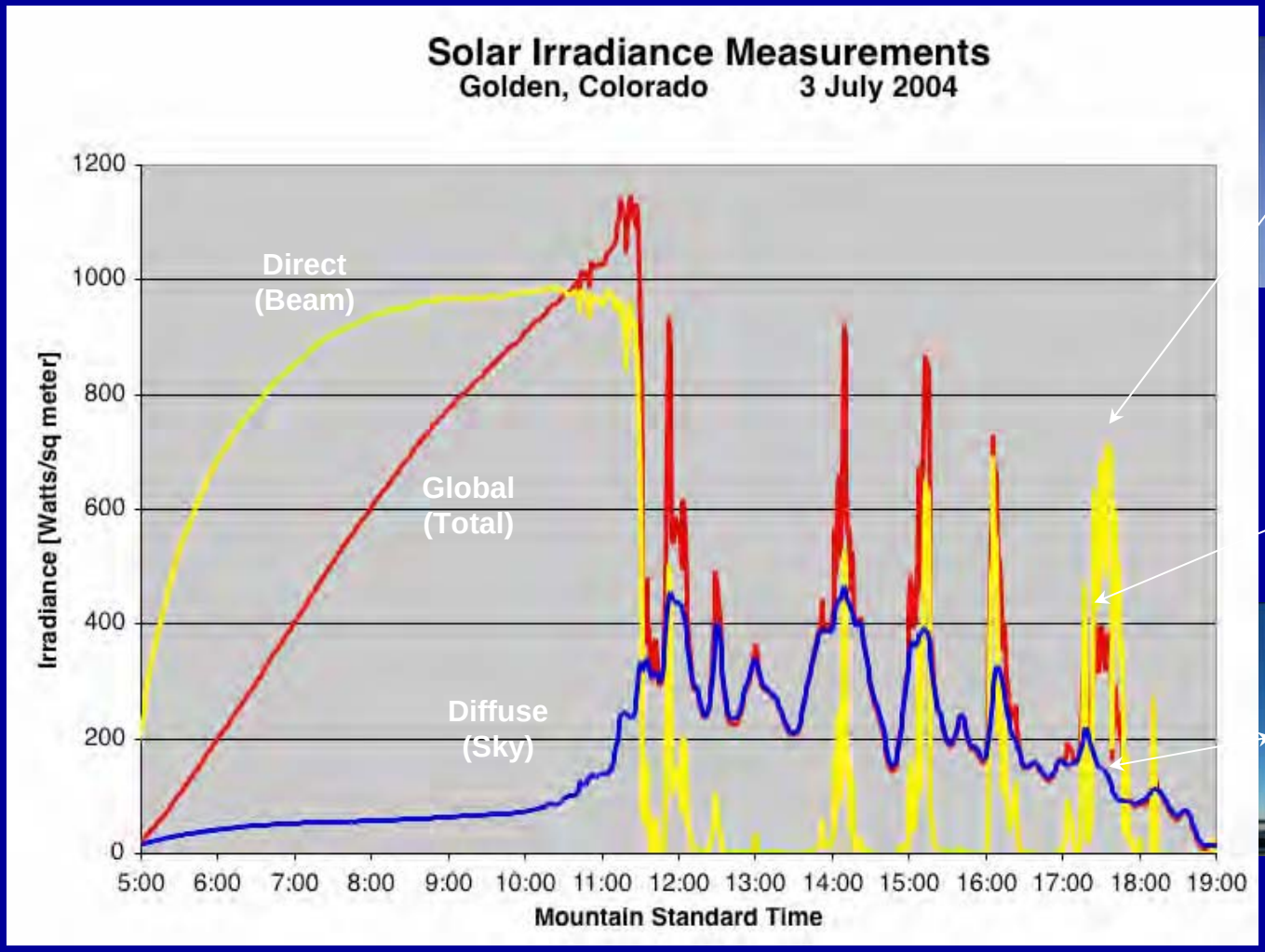
http://www.nrel.gov/srrl

Clear Sky



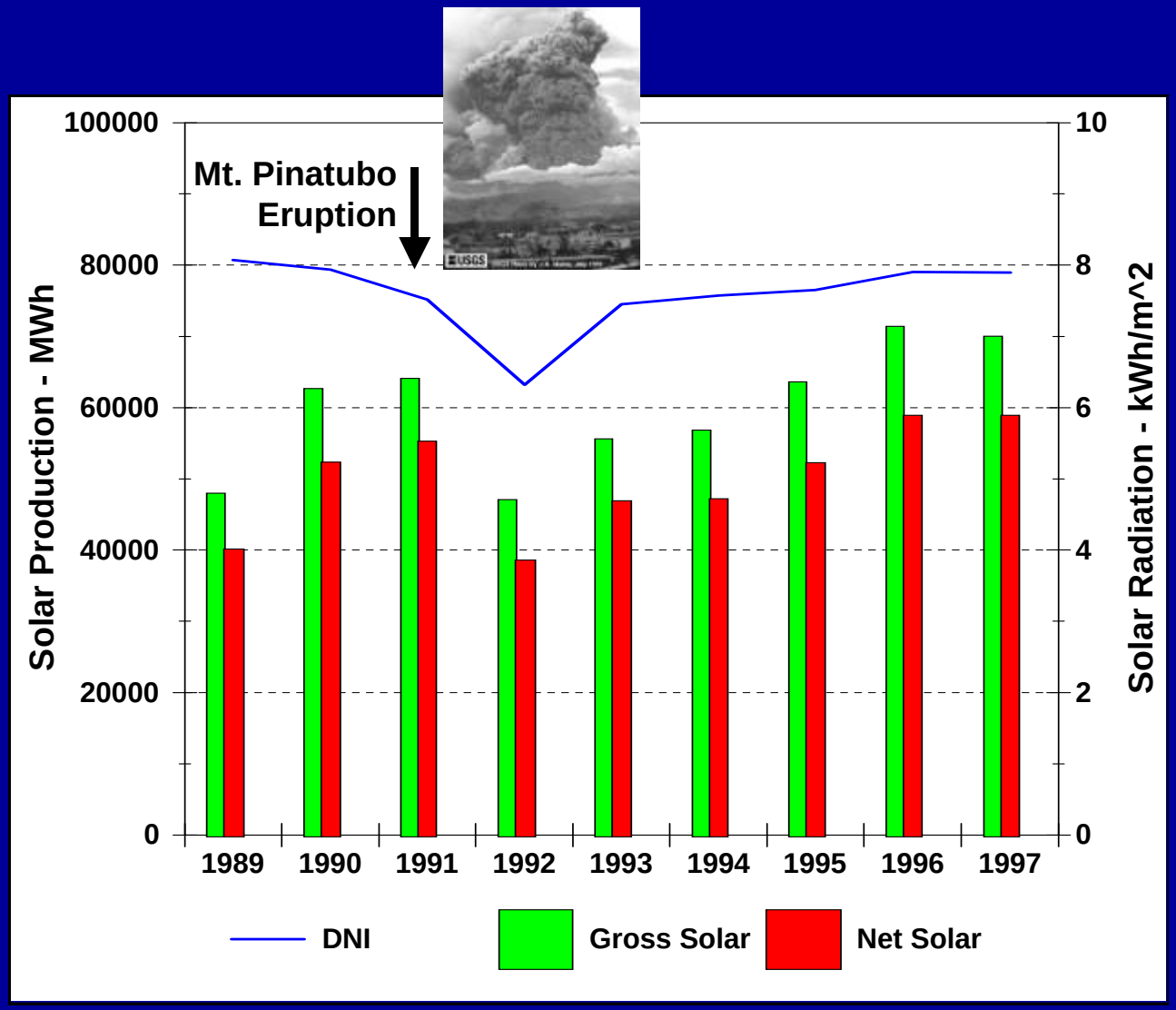
http://www.nrel.gov/srrl

Partly Cloudy Sky



http://www.nrel.gov/srrl

SEGS VI Historical Performance



Combined Outreach Tools

Resource Integration Group

GIS Map Server www.nrel.gov/maps

- Resource Maps & Summary Data

Renewable Resource Data Center rredc.nrel.gov

- Historical Data
- Publications (PDF)
- Tutorials
- Links

Measurement & Instrumentation Data Center

- Current Data (SRRL, HBCU, etc.) www.nrel.gov/midc

Technical Request Database

- Off-line PC

http://rredc.nrel.gov

RReDC
Renewable Resource Data Center

General Information

- News
- Links

Special Features

GLOSSARY

PV Watts

Kidz Links

ENERGY TIDBITS

Unit Conversions

Introduction

Welcome to the Renewable Resource Data Center (RReDC). The RReDC is supported by the National Center for Photovoltaics (NCPV) and managed by the Department of Energy's Office of Energy Efficiency and Renewable Energy. The RReDC is maintained by the Electric and Hydrogen Systems Center at the National Renewable Energy Laboratory.

The RReDC provides information on several types of renewable energy resources in the United States, in the form of publications, data, and maps. An extensive dictionary of renewable energy related terms is also provided. The News section announces new products on the RReDC.

Information by Resource

Biomass Resource Information

Geothermal Resource Information

Solar Resource Information

Wind Resource Information

Dynamic Maps and GIS Data

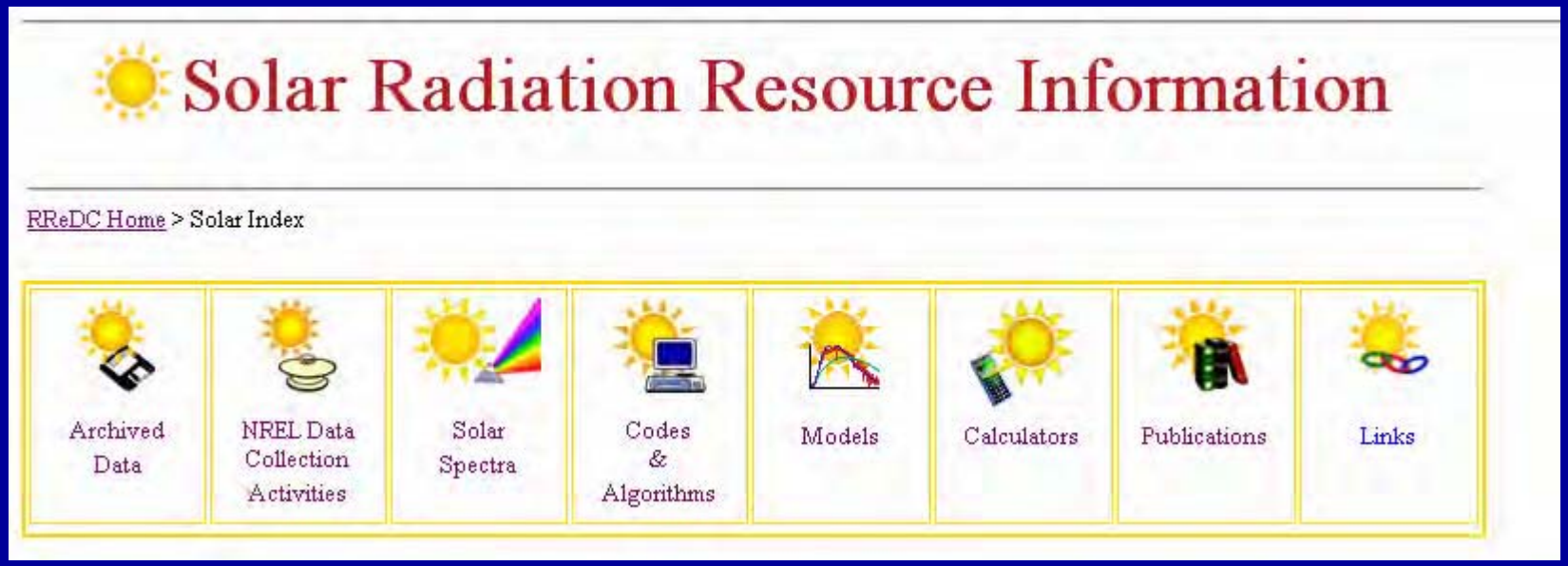
Related Information

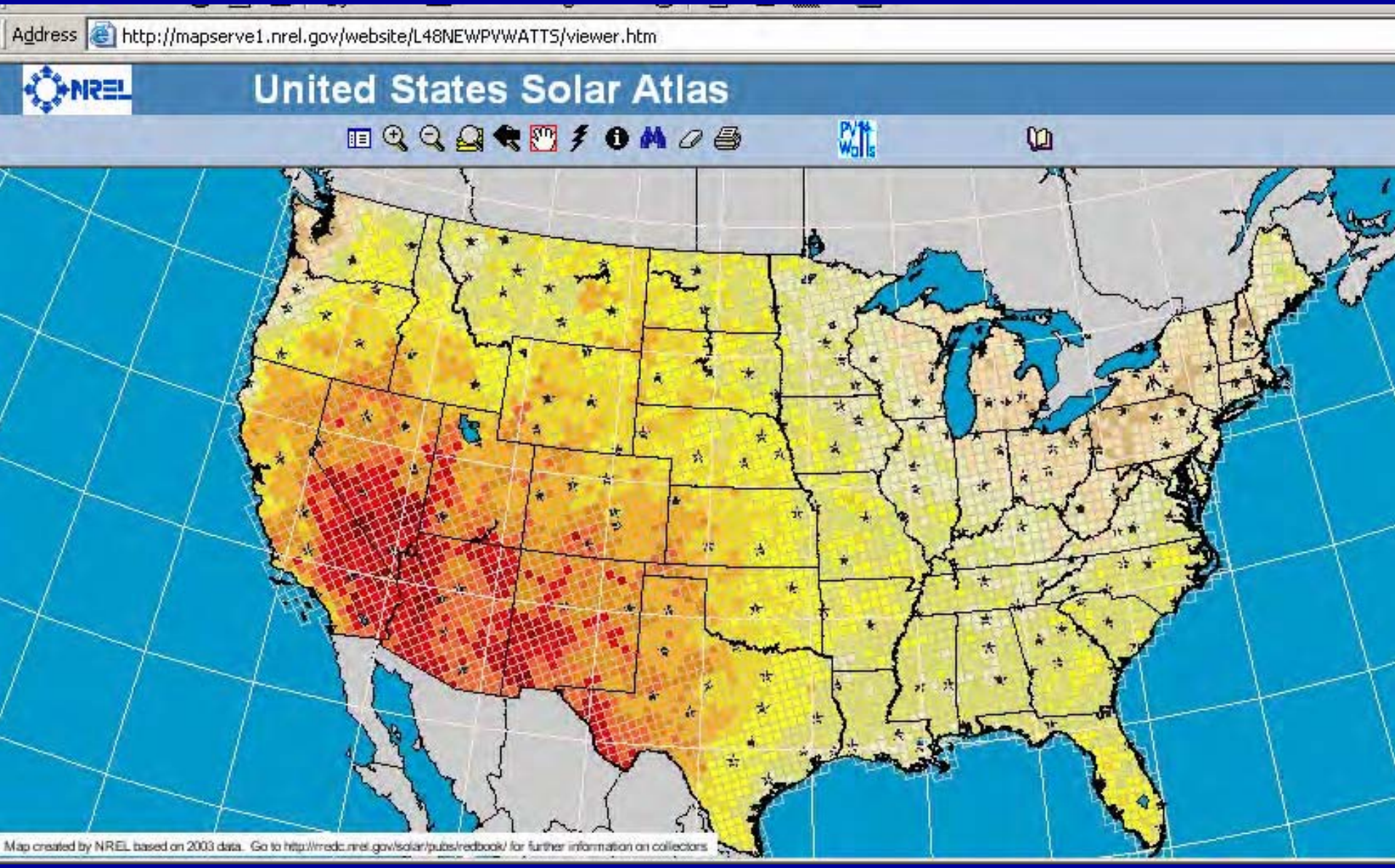
National Center for Photovoltaics

EERE
Office of Energy Efficiency and Renewable Energy

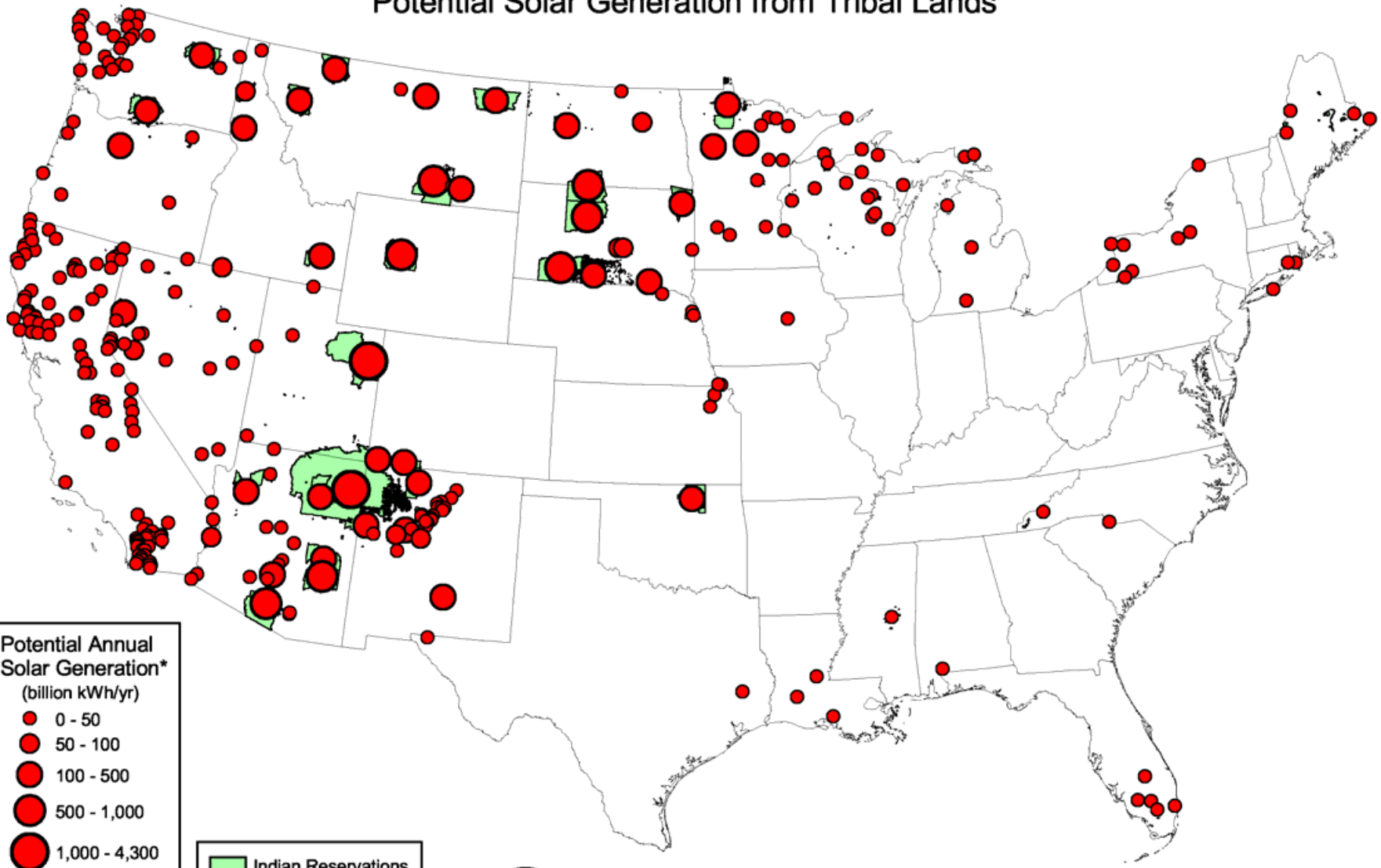
NREL
National Renewable Energy Laboratory

http://rredc.nrel.gov/solar/




Address
http://mapserve1.nrel.gov/website/L48NEWPVWATTS/viewer.htm
NREL
United States Solar Atlas
PV Watts
Map created by NREL based on 2003 data. Go to http://rredc.nrel.gov/solar/pubs/redbook/ for further information on collectors

Potential Solar Generation from Tribal Lands



Potential Annual Solar Generation*
(billion kWh/yr)

- 0 - 50
- 50 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 4,300

Indian Reservations

Total Tribal Solar Generation Potential: 17,606 Billion kWh/yr

U.S. Total Electric Generation (2004 Est.): 3,853 Billion kWh/yr (EIA)

* Generation estimated using annual average solar resource from a tilt = latitude collector. The formula is: Resource (kWh/m^2/day) * 365 * Area (m^2) * 0.03, where 0.03 represents solar panels covering 30% of the total reservation area with a panel efficiency of 10%.

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DHJul3004solgen

Where to Find Resource Maps and Data

- NREL's Renewable Resource Data Center: http://rredc.nrel.gov
  - Includes data, models (PVWATTS), and related links
- Geographic Information System: http://www.nrel.gov/GIS
  - Contains on-line map tools
- Measurement & Instrumentation Data Center: http://www.nrel.gov/midc
  - Provides access to real-time and historical solar and wind data

Contacts

Dave Renné: david_renne@nrel.gov

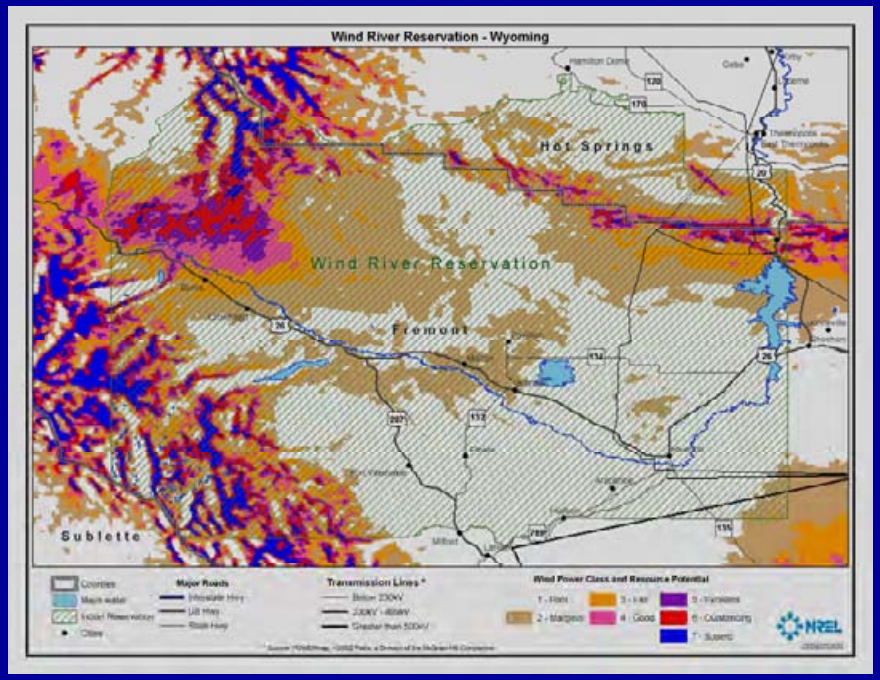
Tom Stoffel: thomas_stoffel@nrel.gov

Geographic Information System

Computer-based Information System that Links Descriptive and Geographic Data:

What Things are like ⟷ ***Where*** Things are

- Political Boundaries
- Land Use
- Highways
- Major Water
- Resource Data



WIND POWER RELATIONSHIPS

$$P = \frac{1}{2} \rho A V^3$$

- P → AVAILABLE POWER
- ρ → AIR DENSITY
- A → SWEPT AREA
- V^3 → WIND VELOCITY CUBED

EXAMPLE: SAME TURBINE, SEA LEVEL, DIFFERENT SITE

$$P = KV^3$$

WIND VELOCITY = v $\quad P_1 = Kv^3$

WIND VELOCITY = $2v$ $\quad P_2 = 8Kv^3$

$$P_2 = 8P_1$$

EXAMPLE: DIFFERENT TURBINE, SEA LEVEL, SAME SITE

$$P = CD^2$$

ROTOR DIAMETER = d $\quad P_1 = Cd^2$

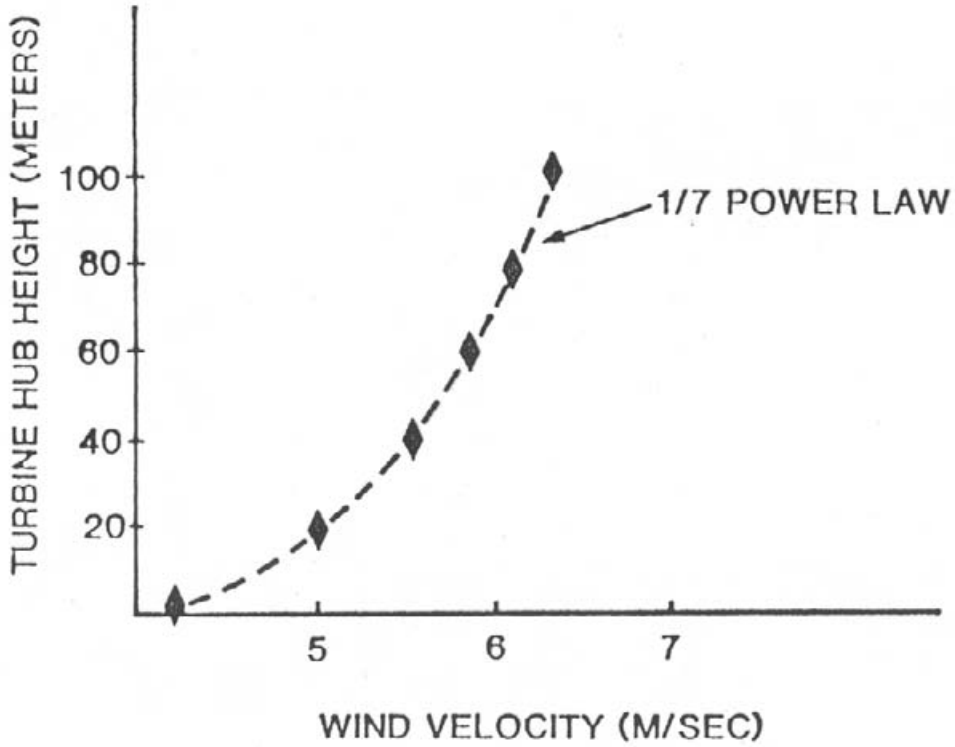
ROTOR DIAMETER = $2d$ $\quad P_2 = 4Cd^2$

$$P_2 = 4P_1$$

WIND VELOCITY VERSUS ALTITUDE

$$\frac{V}{V_o} = \left(\frac{H}{H_o}\right)^n$$

WHERE: V_o = REFERENCE WIND VELOCITY
H_o = REFERENCE HEIGHT
n = DEPENDENT EXPONENT



Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
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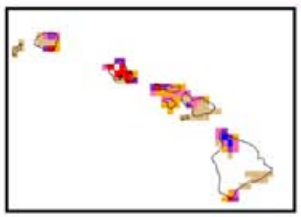
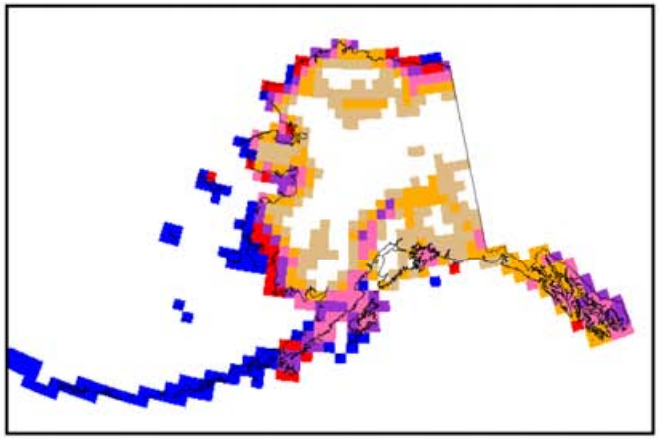
7	Superb	800 - 1600	8.8 - 11.1	19.7 - 24.8

[a] Wind speeds are based on a Weibull k value of 2.0

United States - Wind Resource Map





Source: "Wind Energy Resource Atlas of the United States", 1987

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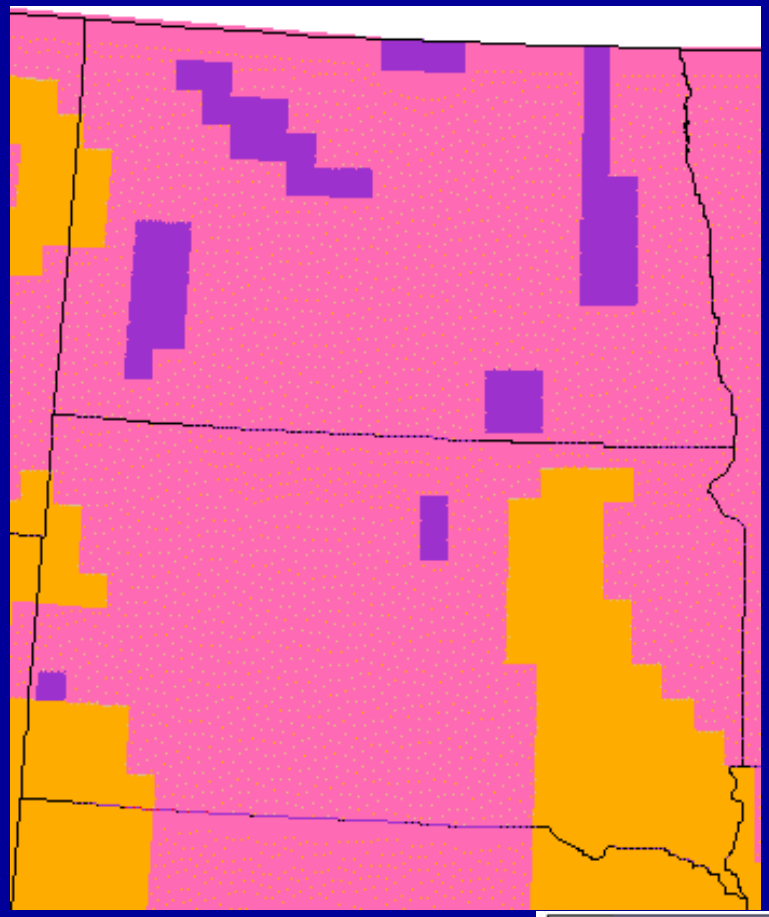
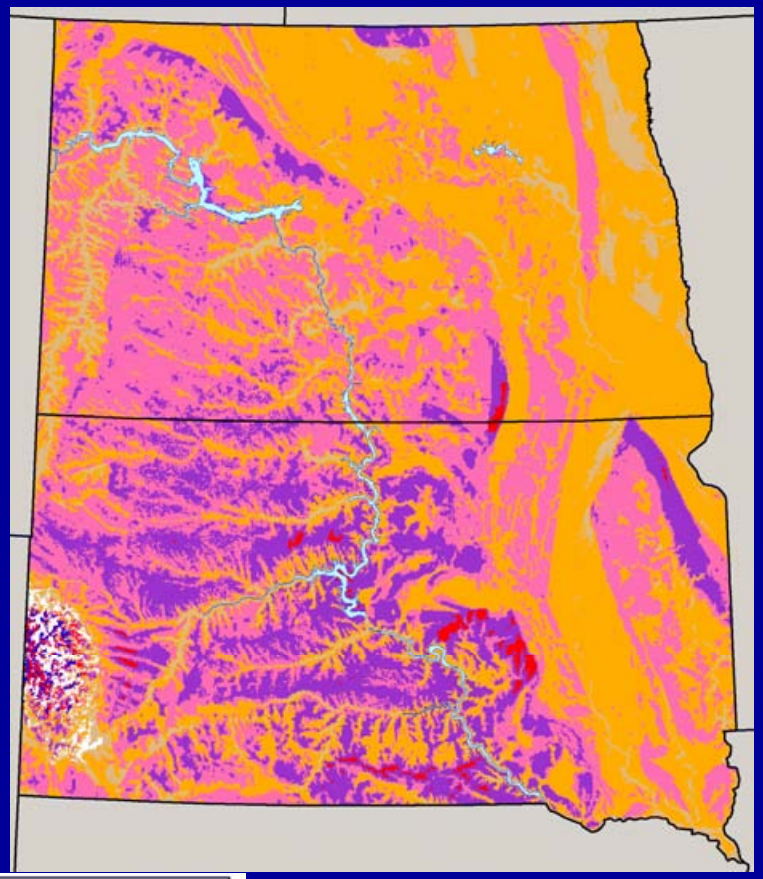
20-MAR-2000 1.1.5

Comparison of Digital Wind Map from 1987 U.S. Wind Atlas and New (2000) High-Resolution (1-km^2) Wind Map North and South Dakota



1987



2000

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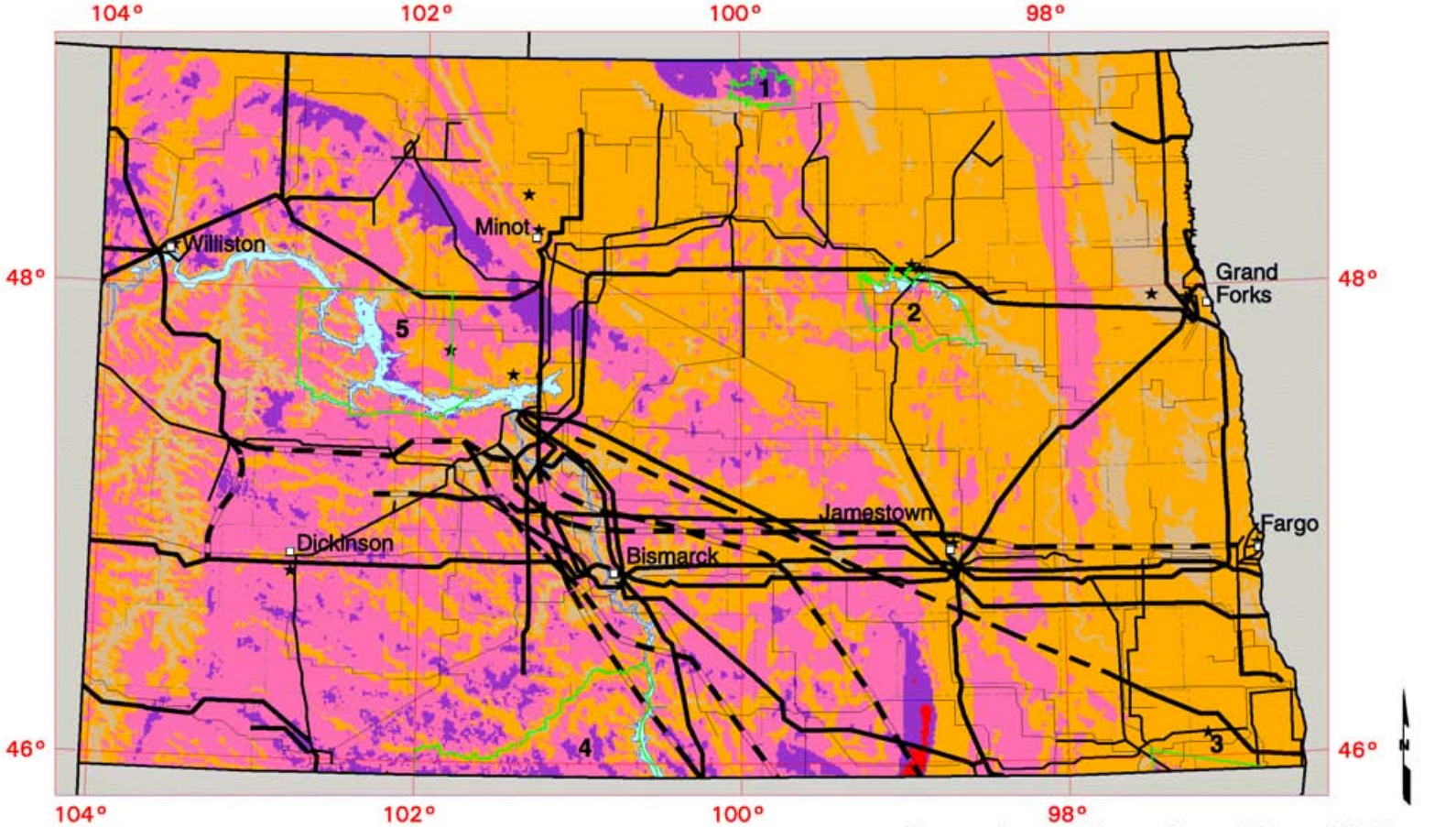
North Dakota - Wind Resource Map



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[a]Wind speeds are based on a Weibull k value of 2.0

★ Meteorological Station with Wind Data
□ City or Town

Transmission Line Voltage

- 69 Kilovolts
- 115 Kilovolts
- 230 Kilovolts
- 345 Kilovolts
- Under Construction

Indian Reservations

1. Turtle Mountain
2. Devil's Lake Sioux
3. Lake Traverse
4. Standing Rock
5. Fort Berthold

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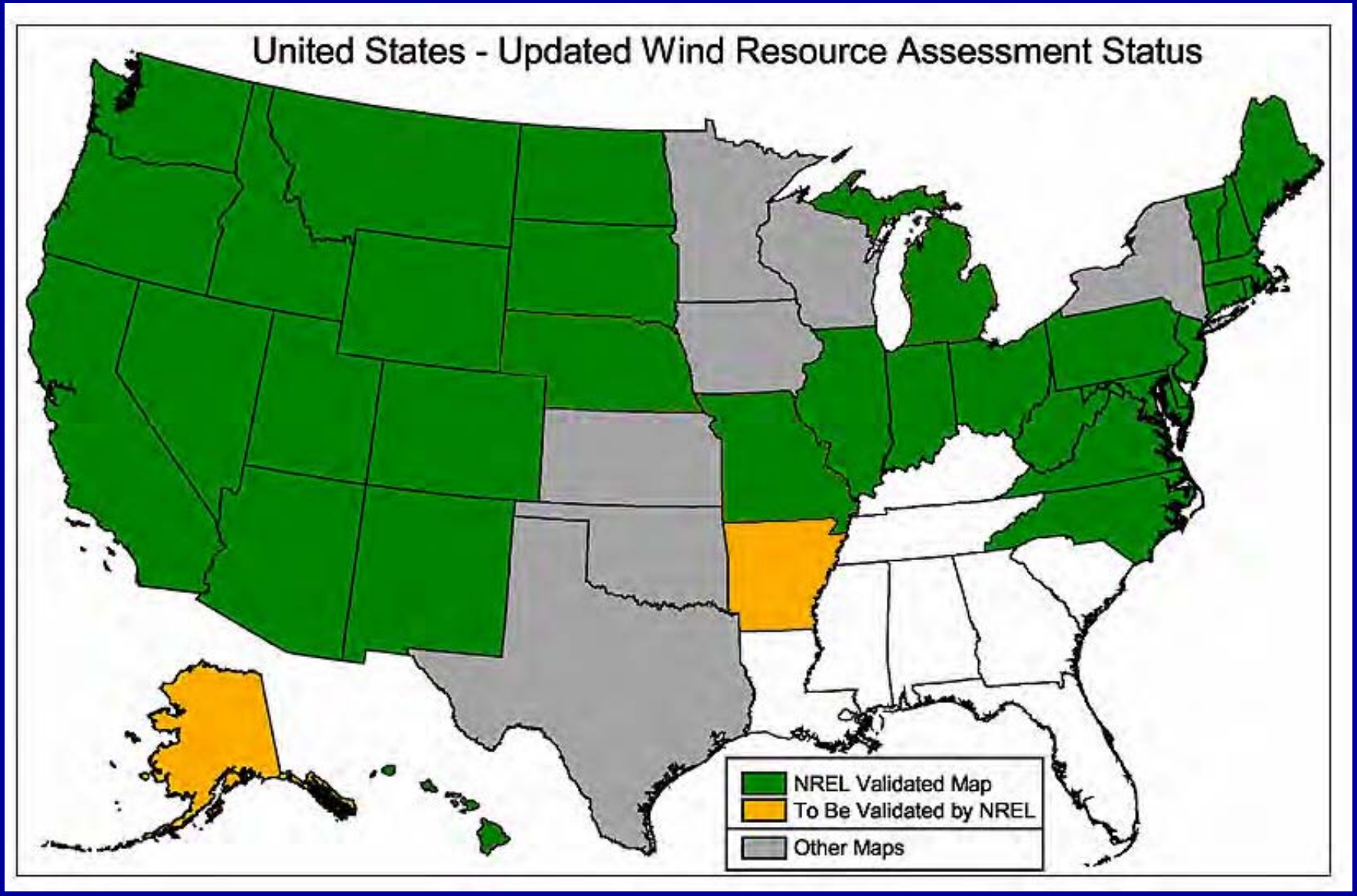
Wind Mapping Approach

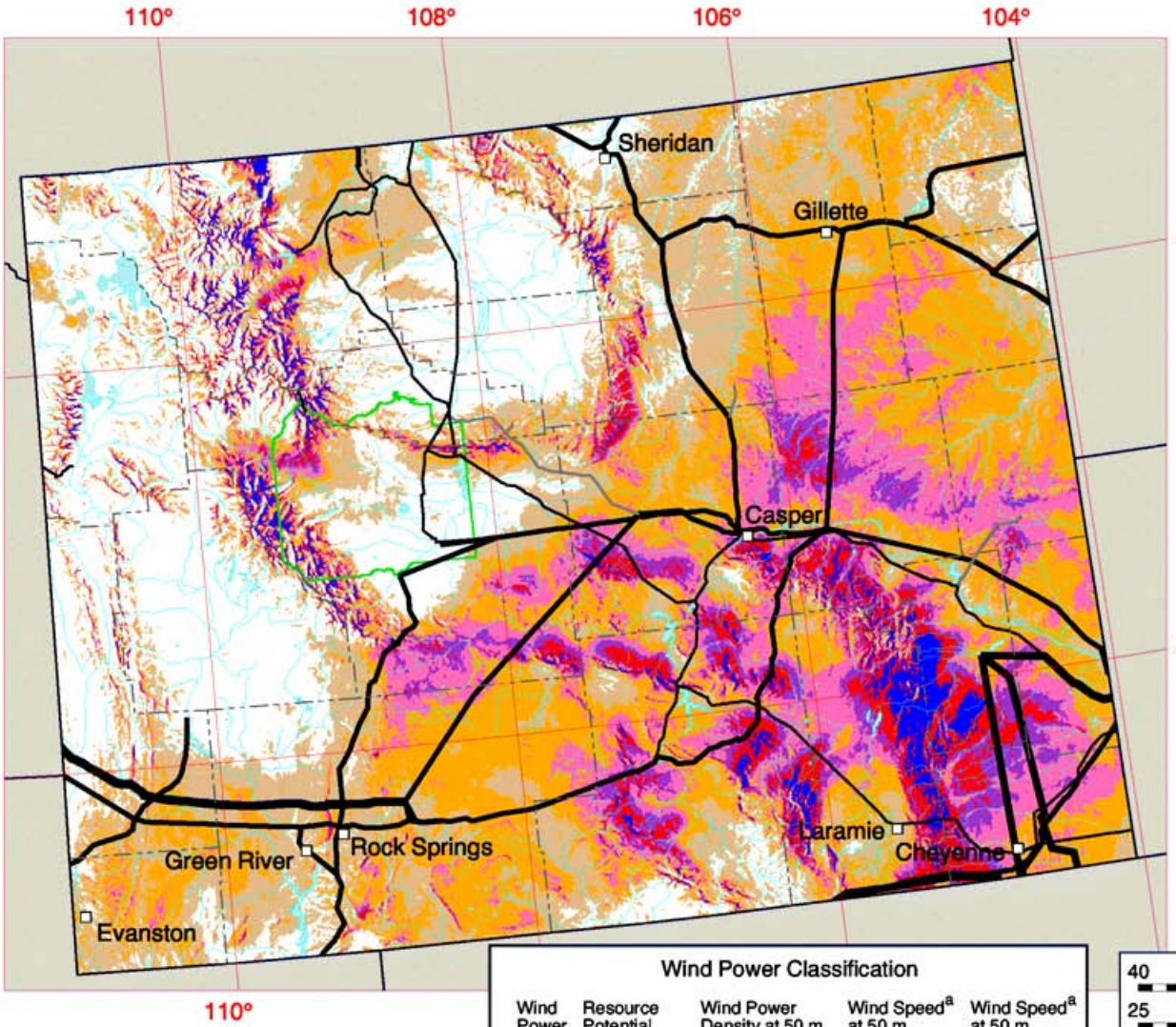
- Computerized mapping approach using Geographical Information System (GIS) software (ArcInfo® and ArcView®)
- Designed for regional wind mapping (not micrositing)
- Combination of analytical, numerical, and empirical methods
- Does not depend on high-quality surface wind observations (but it helps)
- Produces high resolution (1 km^2 or finer) wind power maps



http://www.windpoweringamerica.gov/where_is_wind.html

Wyoming

Wind Power Resource Estimates



Wind River Indian Reservation

Transmission Line*
Voltage (kV)
- 69
- 115
- 230
- 345

* Source: POWERmap,©2002 Platts, A Division of the McGraw-Hill Companies

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[a]Wind speeds are based on a Weibull k value of 2.0

40 0 40 80 120 160 Kilometers
25 0 25 50 75 100 Miles

The wind power resource data for this map was produced by TrueWind Solutions using the Mesomap system and historical weather data. It has been validated with available surface data by the National Renewable Energy Laboratory and wind energy meteorological consultants.

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National Renewable Energy Laboratory

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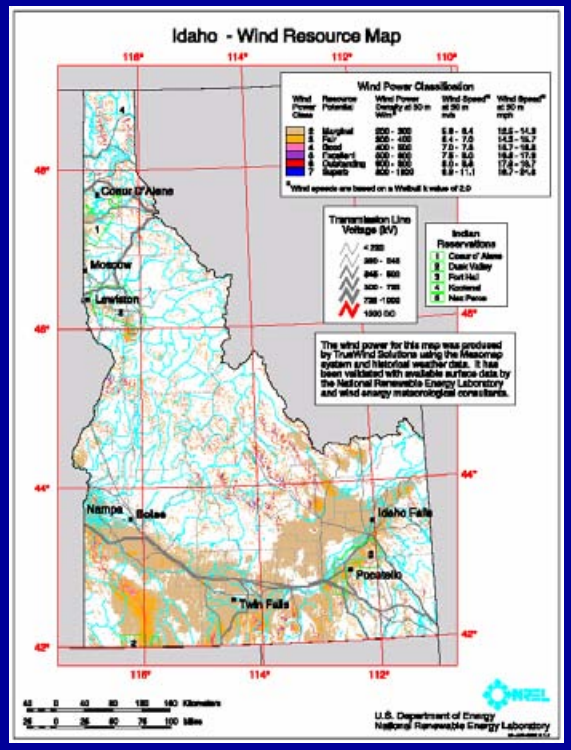
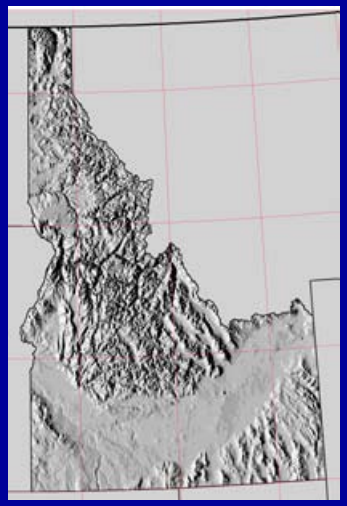
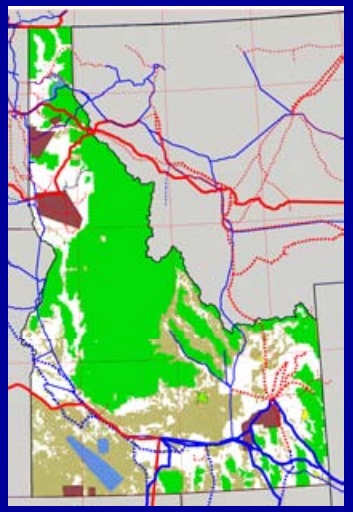
06-JUN-2002 2.1.2

Integration of GIS Data Sets

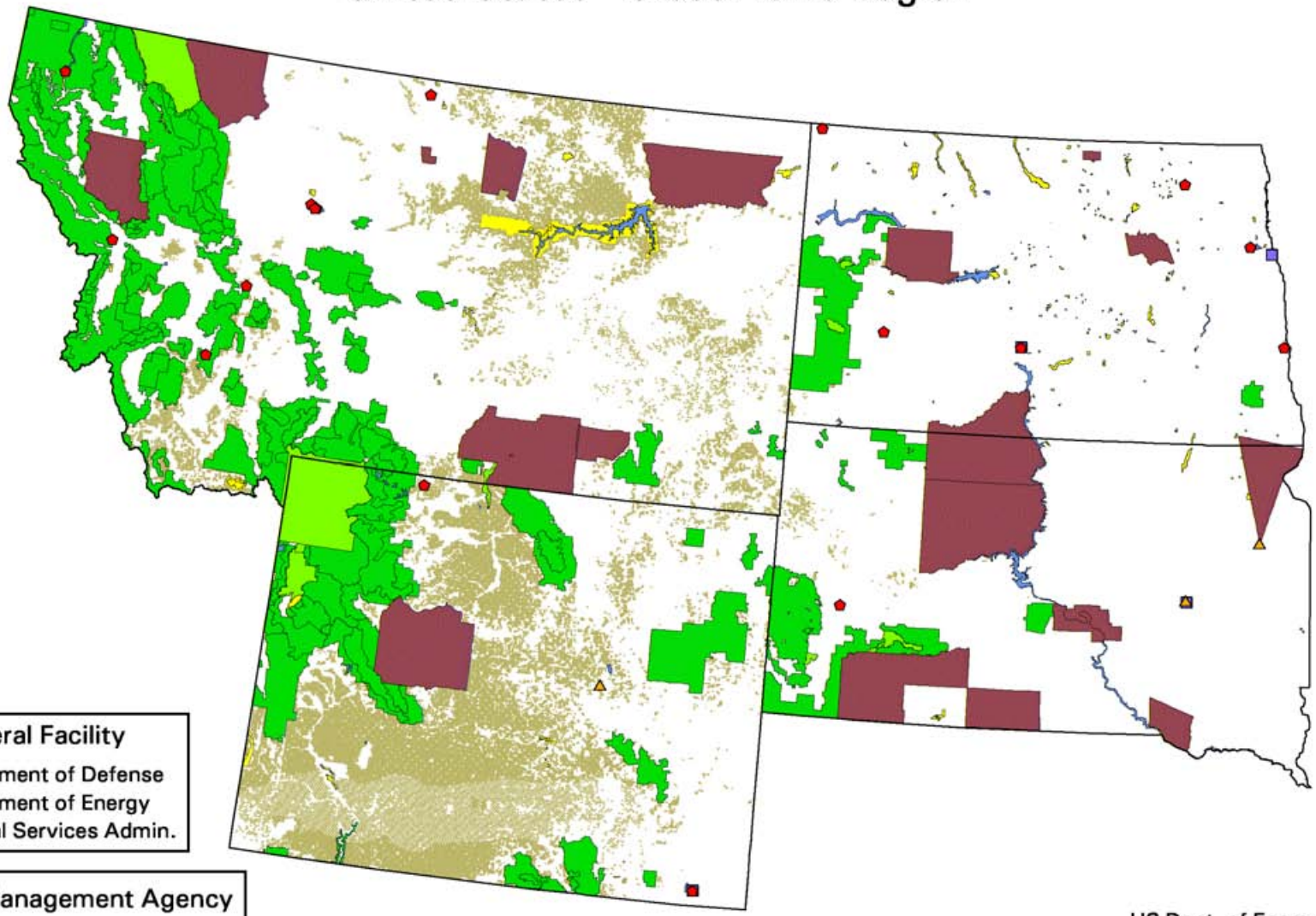
- Topography (1-km^2)
  - Slope
  - Relative elevation
  - Aspect
- Transmission lines
- Meteorological Stations
- Federal lands and facilities
- Native American lands







United States - Great Plains Region



Federal Facility

- Department of Defense
- Department of Energy
- General Services Admin.

Land Management Agency

- Indian Reservation or Alaska Native Village Area
- Department of Defense
- Forest Service
- National Park Service
- Bureau of Land Management
- Fish and Wildlife Service

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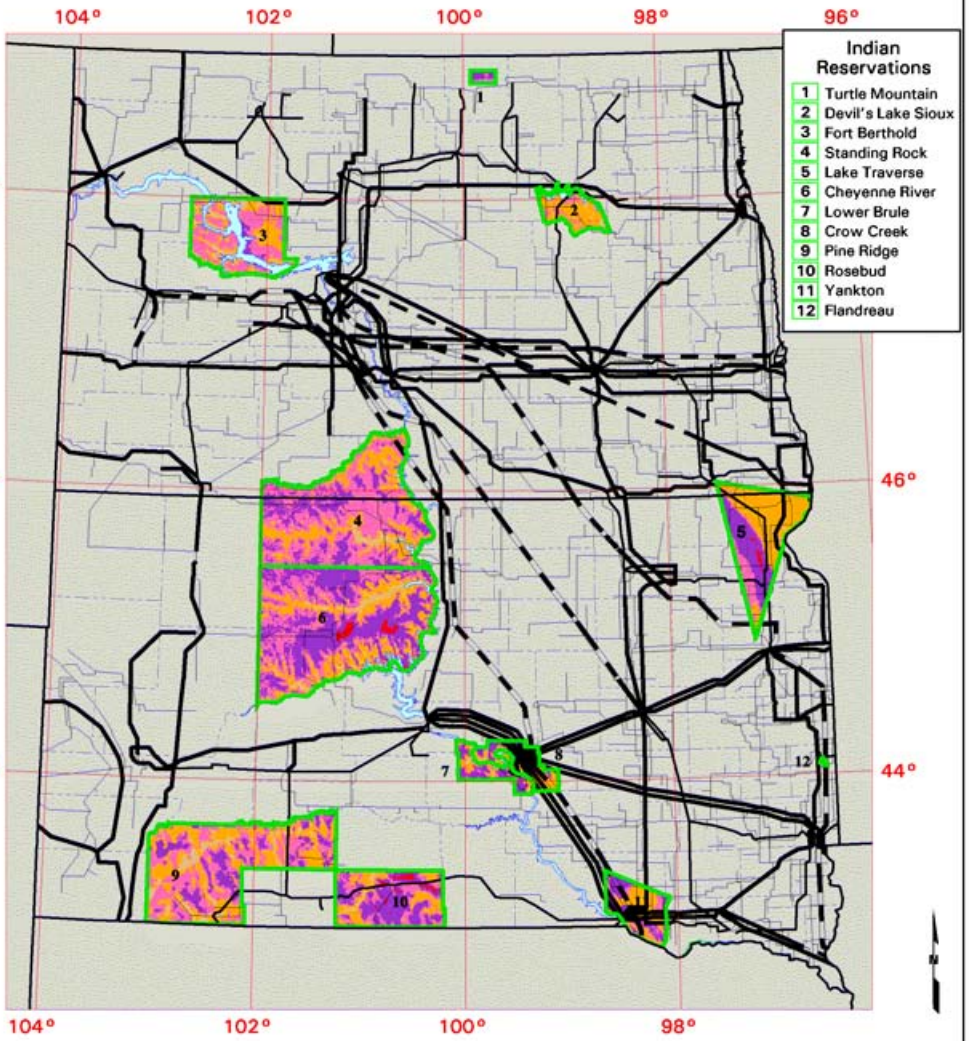
North and South Dakota - Wind Resource Map



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Transmission Line Voltage

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40 0 40 80 Kilometers

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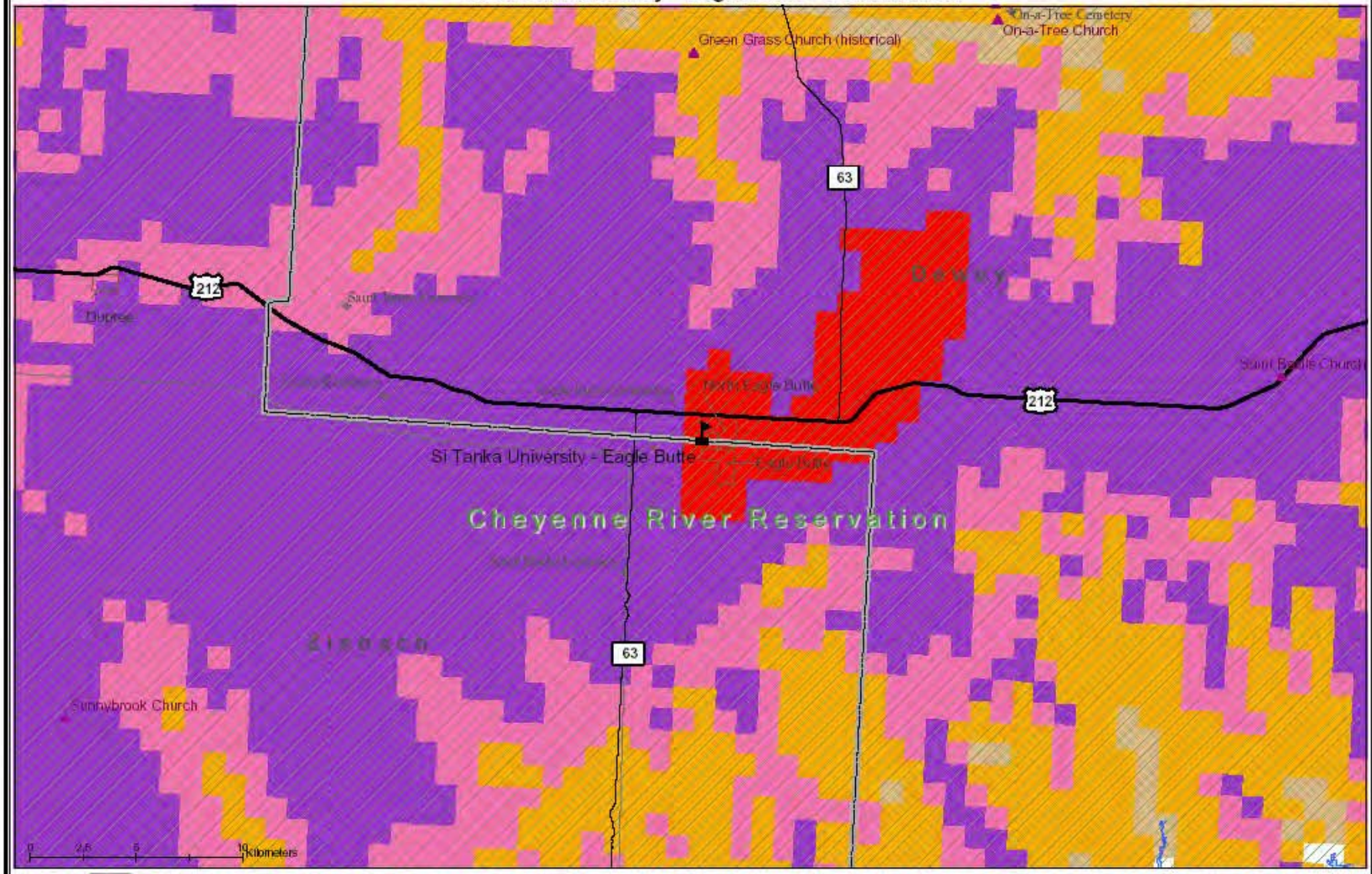
Si Tanka University - Eagle Butte - South Dakota



Counties
Urban areas
Major water
Indian Reservation
Parks

Major roads
Interstate Hwy
US Hwy
State Hwy

Transmission Lines *
Below 230kV
230kV - 344kV
345kV - 499kV
Greater than 500kV

Wind Power Class and Resource Potential
1 - Poor
2 - Marginal
3 - Fair
4 - Good
5 - Excellent
6 - Outstanding
7 - Superb

* Source: POWERmap, ©2002 Platts, a Division of the McGraw-Hill Companies

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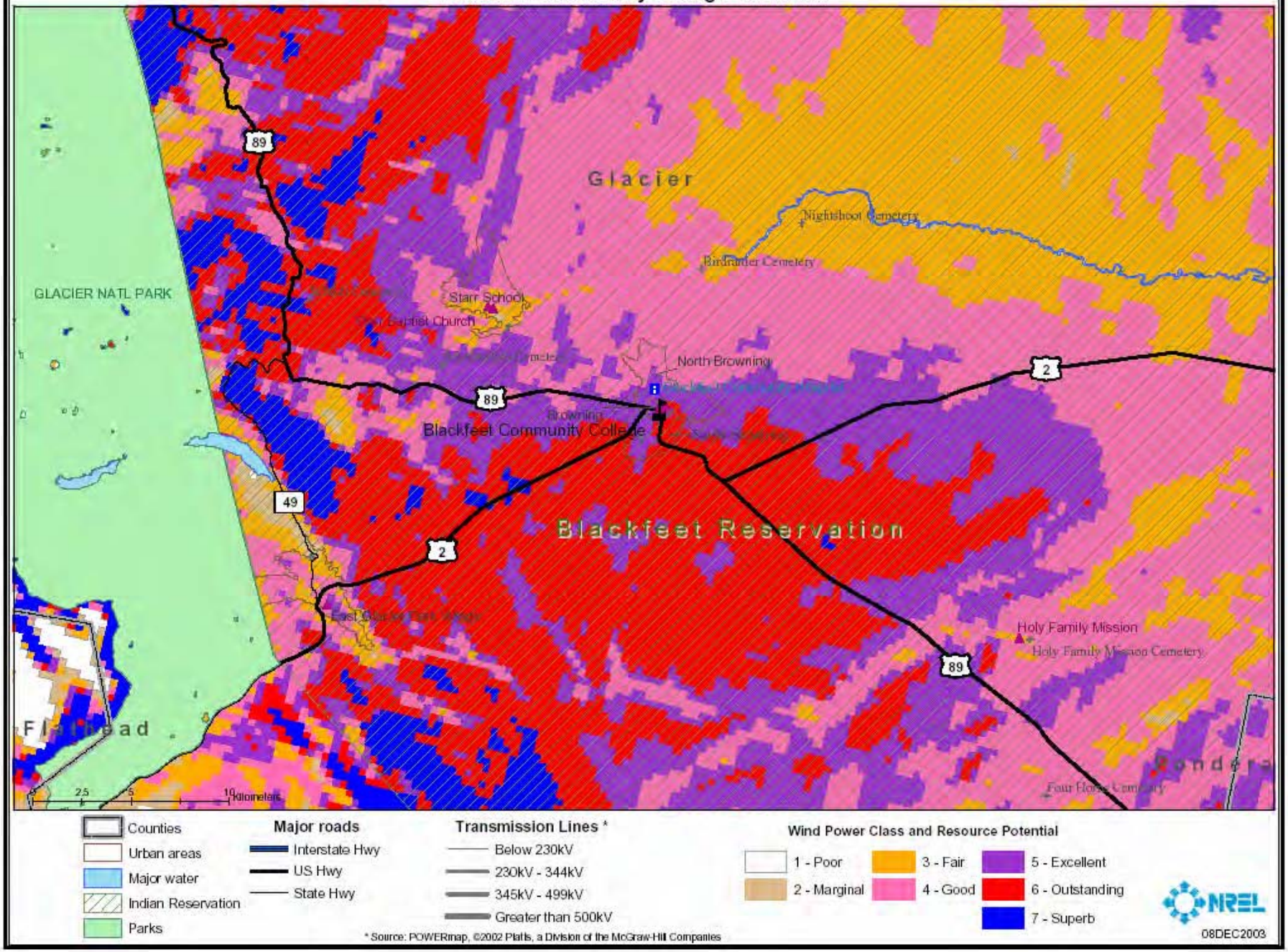
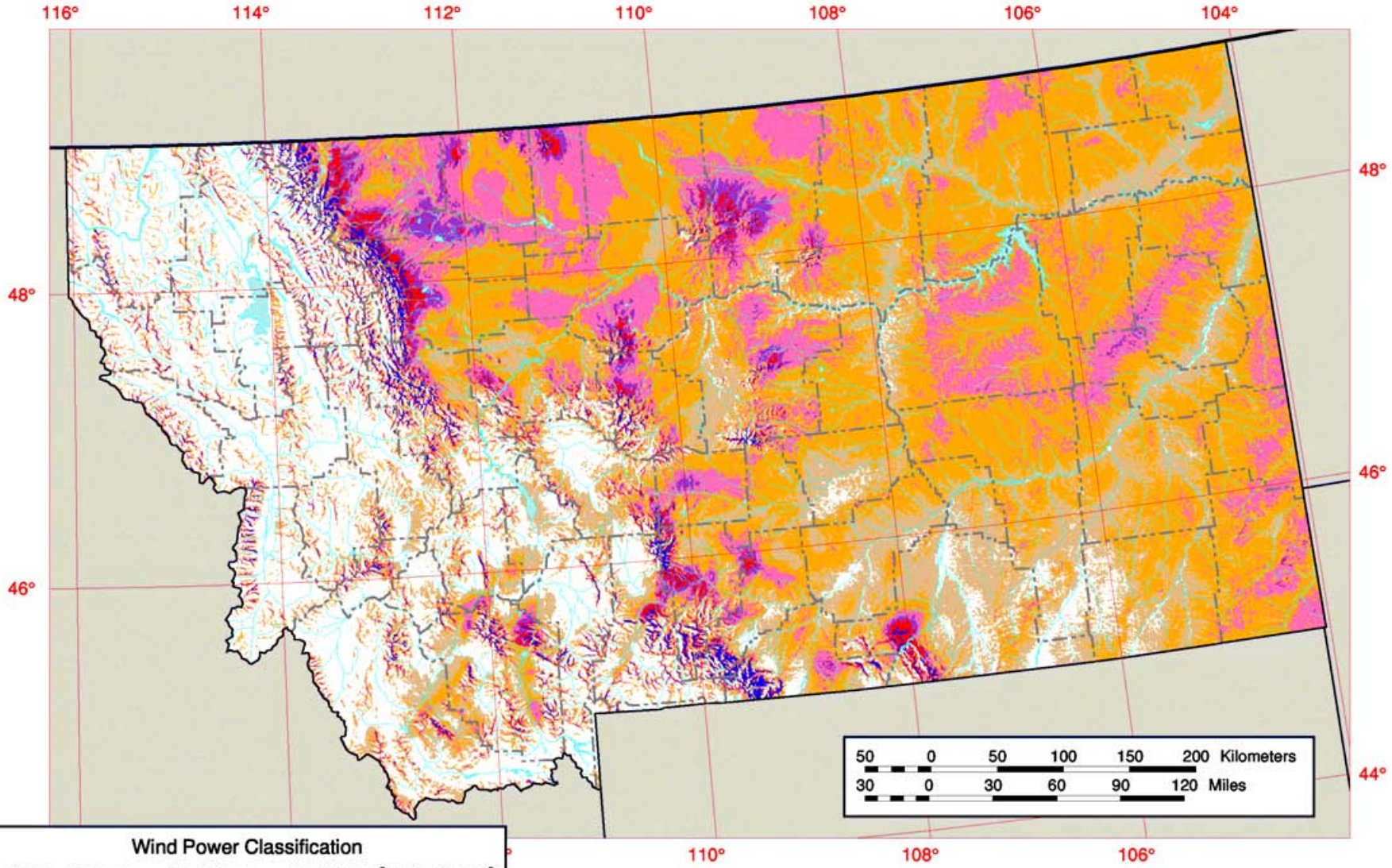
08DEC2003

Blackfeet Community College - Montana





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[a]Wind speeds are approximate and based on a Weibull k value of 2.0

Montana
Wind Power Resource Estimates

The wind power resource estimates were produced by TrueWind Solutions using their Mesomap system and historical weather data. This map has been validated with available surface data by the National Renewable Energy Laboratory and wind energy meteorological consultants.

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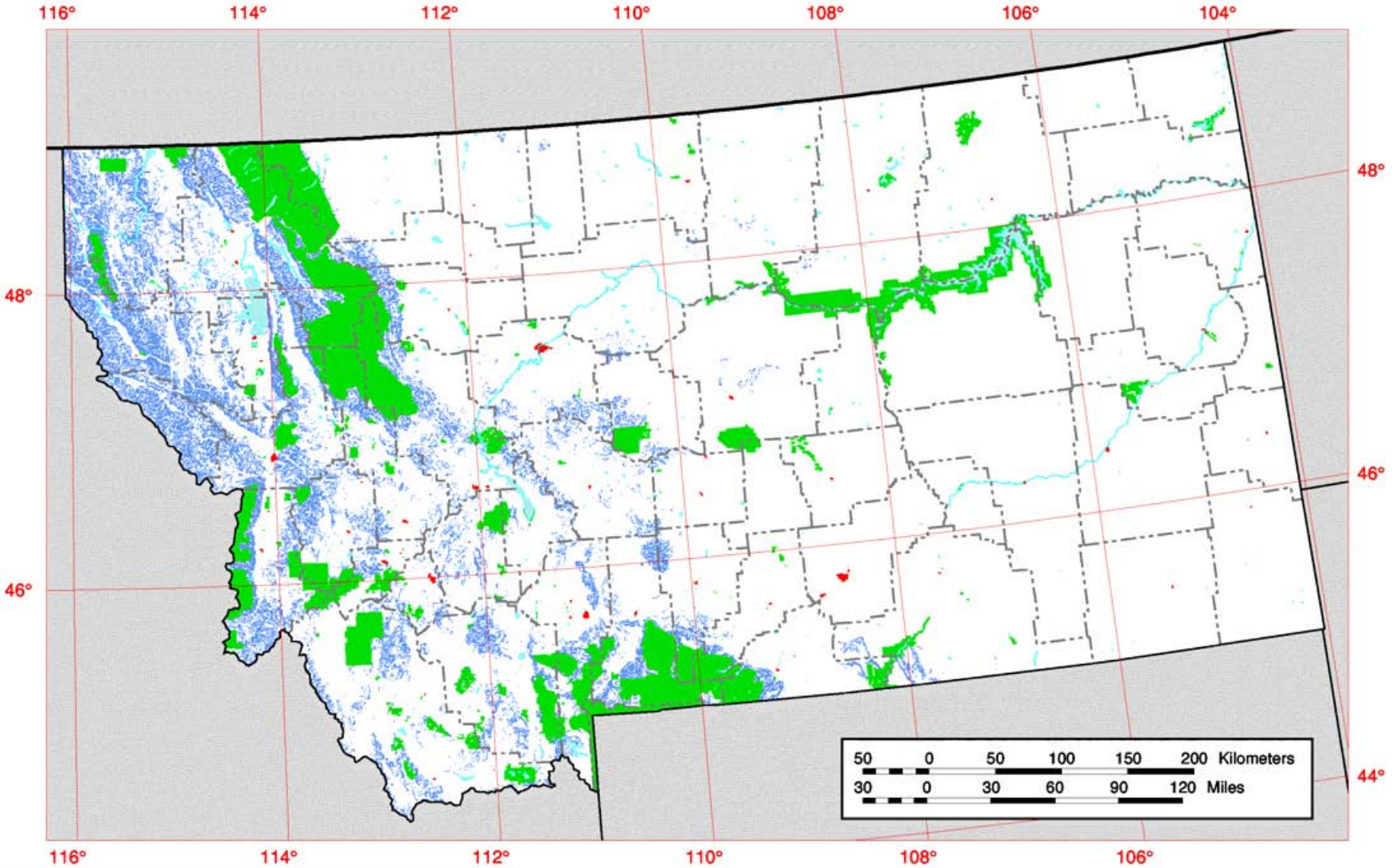
12-MAR-2002 1.1.2

Areas are excluded from the developable wind potential in the following categories:

1) Potentially sensitive environmental lands:
   - National Park Service and Fish and Wildlife Service are completely excluded
   - Wildlife, wilderness, recreation areas, and other specially designated areas on federal land are completely excluded (predominantly Forest Service and BLM lands)
   - Some state and private environmental lands where data was available
   - Half of the remaining U.S. Forest Service and Department of Defense lands were excluded to represent current dedicated use of land
2) Potentially incompatible land use:
   - Urban areas, airports, wetlands and water bodies were completely excluded
   - Half of non-ridge crest forested areas were excluded
3) Other factors:
   - Slopes greater than 20% were completely excluded
   - A 3 kilometer area surrounding environmental and land use categories that were completely excluded (except water bodies) was also eliminated
   - Small, isolated class 3 and greater resource areas were eliminated using a minimum density criteria



Excluded Areas*

- Water Bodies (i.e. lakes, reservoirs, wide rivers)
- Environmentally Sensitive State and Federal Lands (i.e. wildlife refuges, parks, wilderness areas)
- Major Urban Areas
- Slope > 20%

* Data shows no wetlands for Montana

Montana Exclusions Used in Windy Lands Analysis

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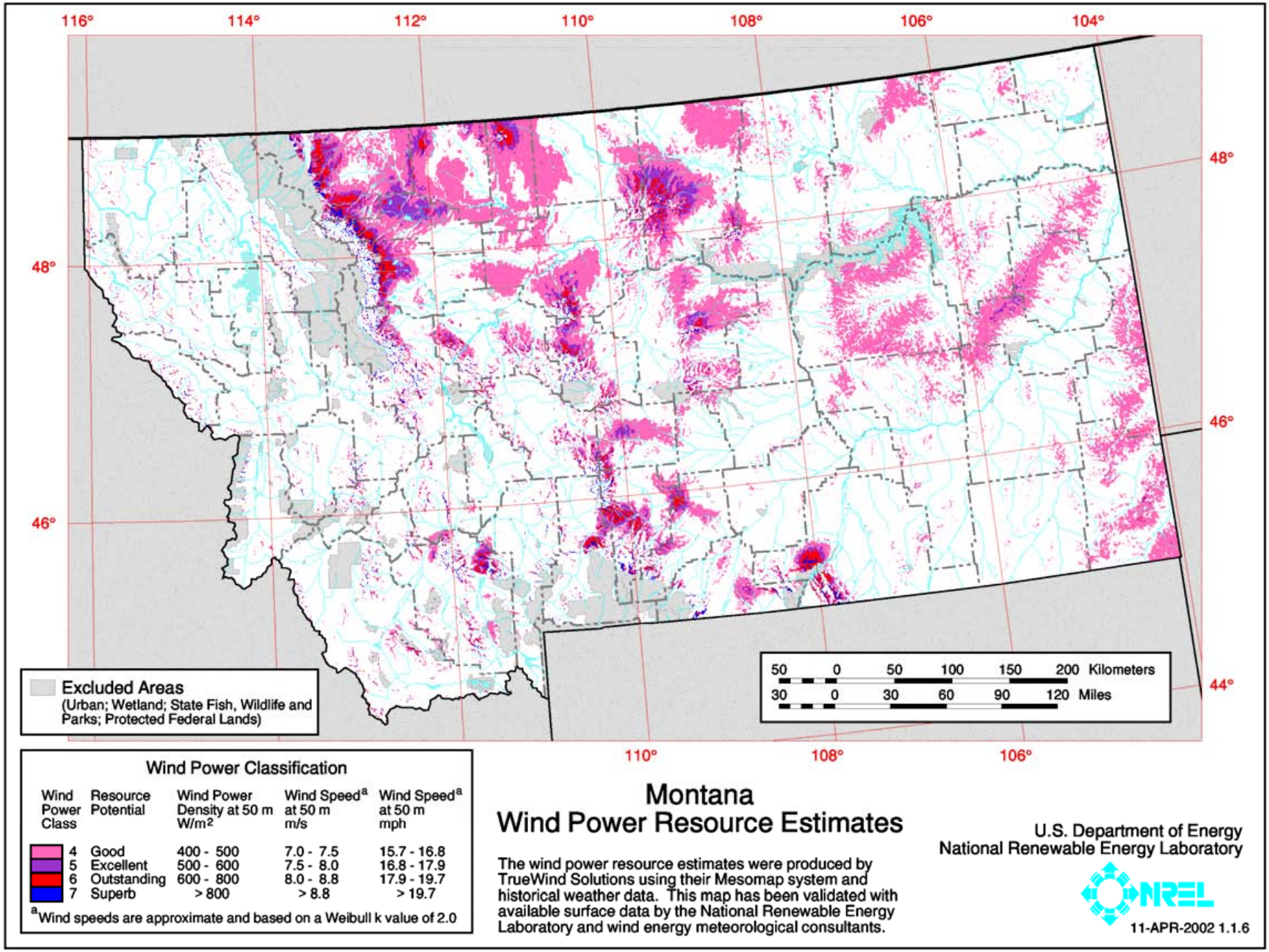
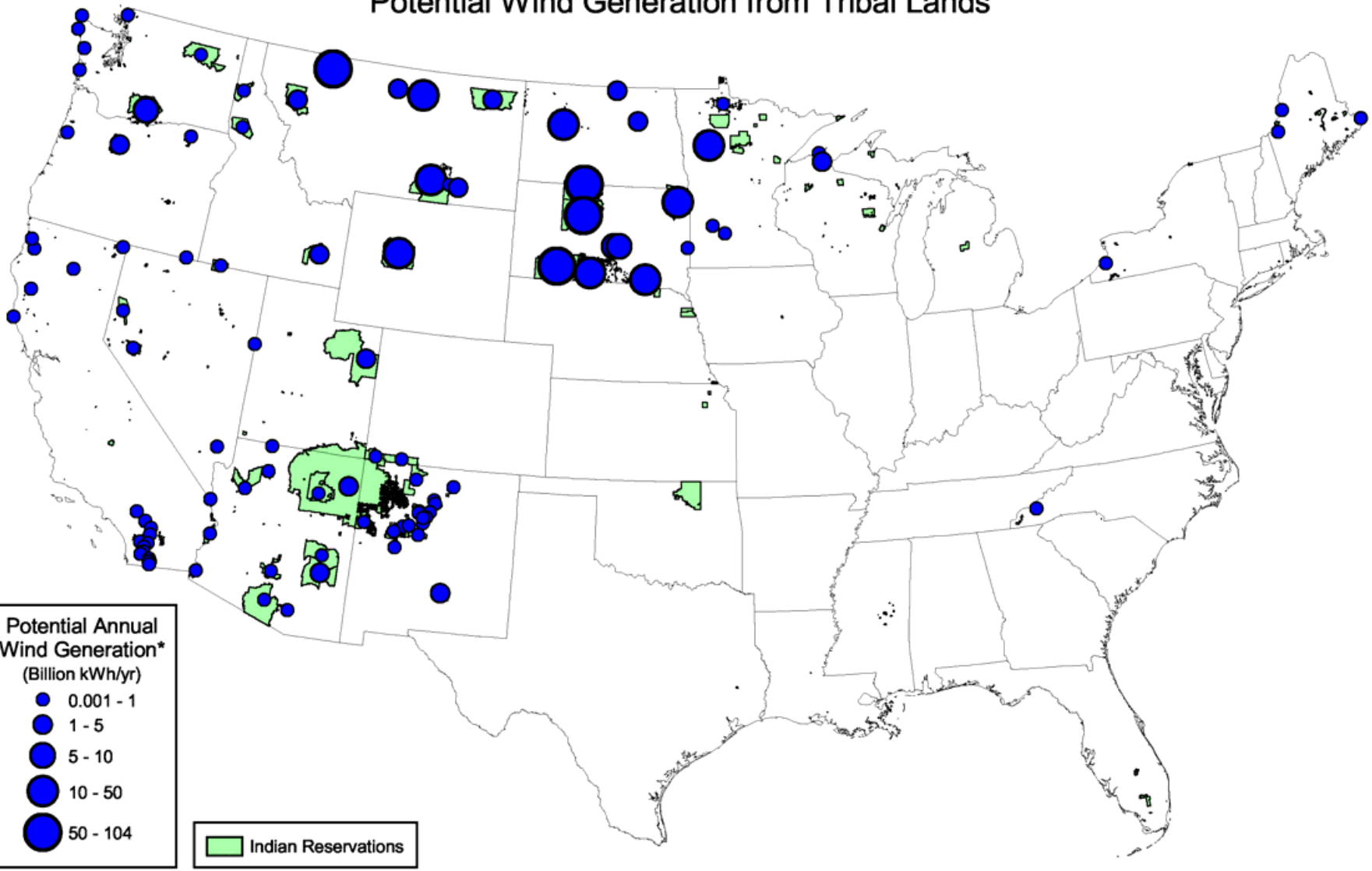
11-APR-2002 1.1.8


116°
114°
112°
110°
108°
106°
104°
48°
46°
44°
Excluded Areas
(Urban; Wetland; State Fish, Wildlife and Parks; Protected Federal Lands)
50 0 50 100 150 200 Kilometers
30 0 30 60 90 120 Miles
Wind Power Classification
Wind Power Class | Resource Potential | Wind Power Density at 50 m W/m2 | Wind Speed[a] at 50 m m/s | Wind Speed[a] at 50 m mph
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb > 800 > 8.8 > 19.7
[a]Wind speeds are approximate and based on a Weibull k value of 2.0
Montana
Wind Power Resource Estimates
The wind power resource estimates were produced by TrueWind Solutions using their Mesomap system and historical weather data. This map has been validated with available surface data by the National Renewable Energy Laboratory and wind energy meteorological consultants.
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
11-APR-2002 1.1.6

Potential Wind Generation from Tribal Lands



* Generation estimated for areas of class >= 4 annual average wind resource, assuming 5 MW/km^2 of installed capacity, and capacity factors ranging from 25.1% (class 4) to 41.4% (class 7).

Aggregate technical estimate of 209 GW does not account for sacred sites, transmission access, water bodies, or other factors that will significantly impact development potential.

Total Tribal Wind Generation Potential: 535 Billion kWh/yr

U.S. Total Electric Generation (2004 Est.): 3,853 Billion kWh/yr (EIA)

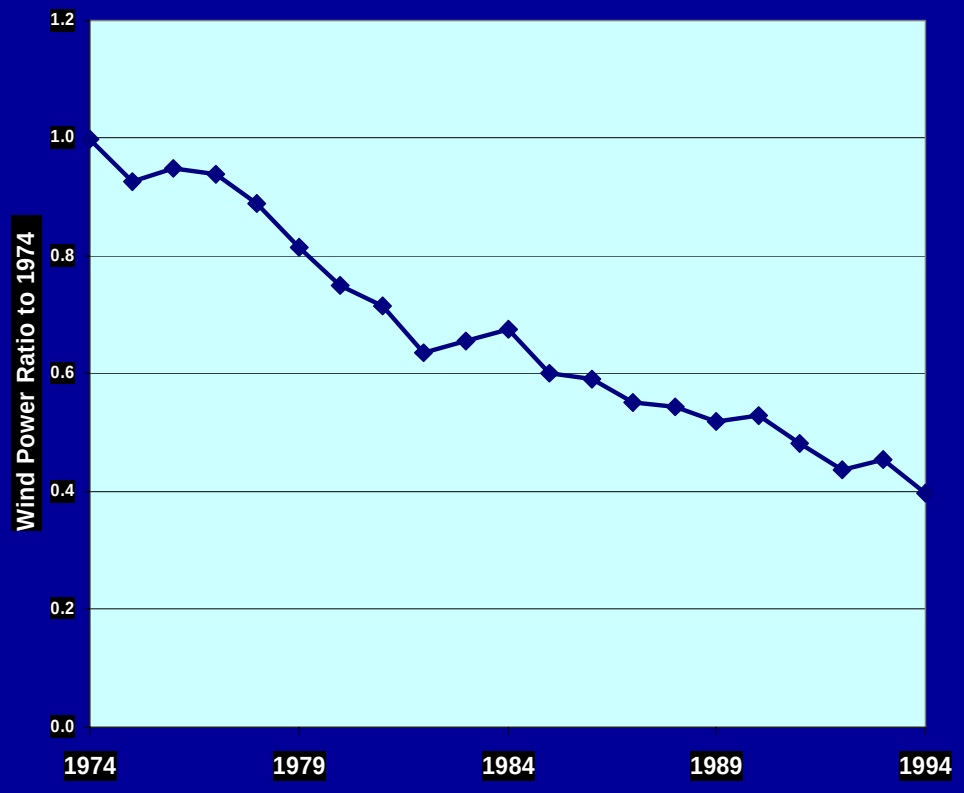
U.S. Department of Energy
National Renewable Energy Laboratory

NREL

DHJul3004wingen

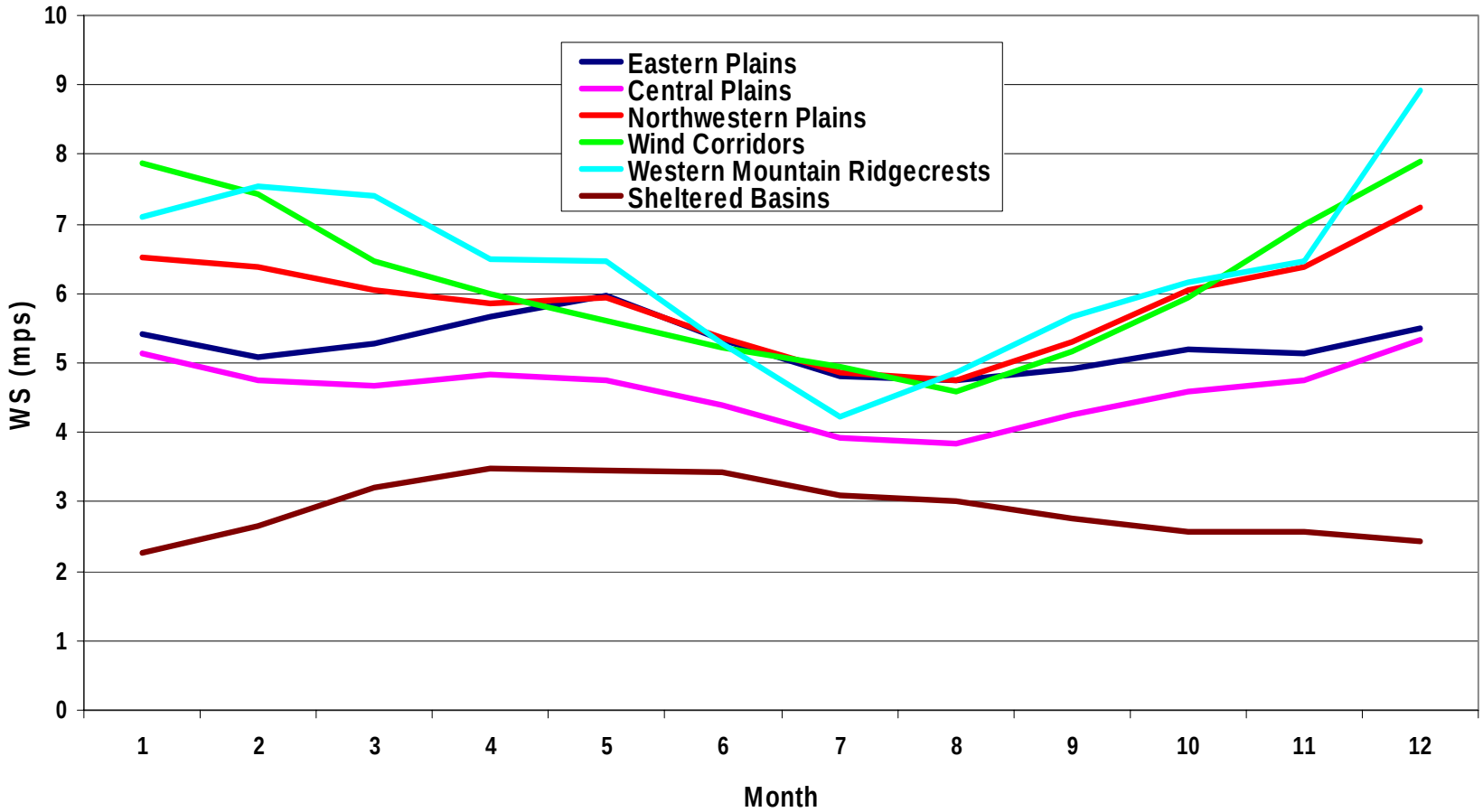
“Disappearing Wind” Syndrome

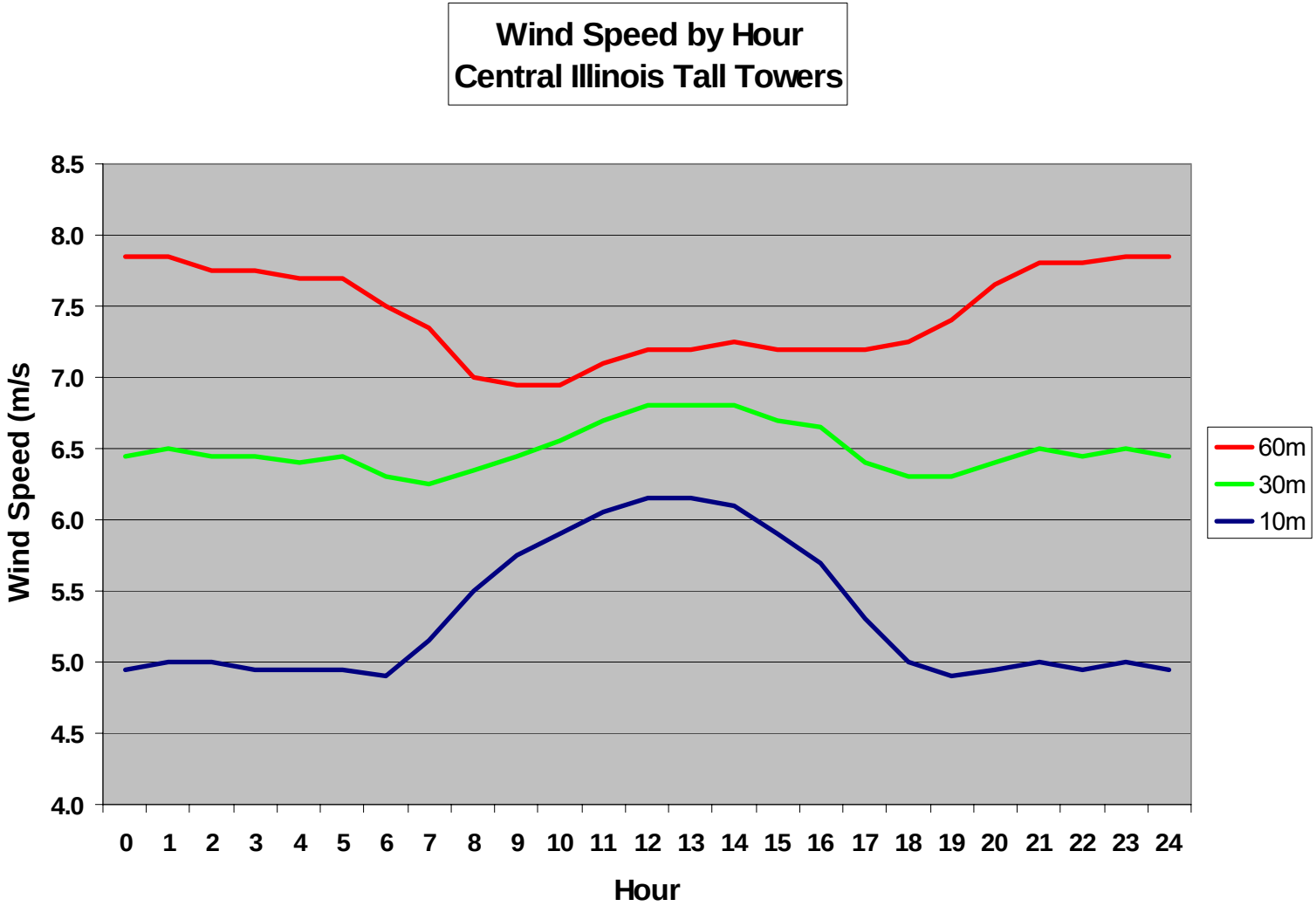
- >90% of meteorological stations in southeast China indicate “disappearing wind”



- Data from 1974 to 1994 for 79 meteorological stations
- Apparent wind power decreases by 60% over 20 years
- Decrease caused by new construction around meteorological stations, which reduces the measured wind speeds

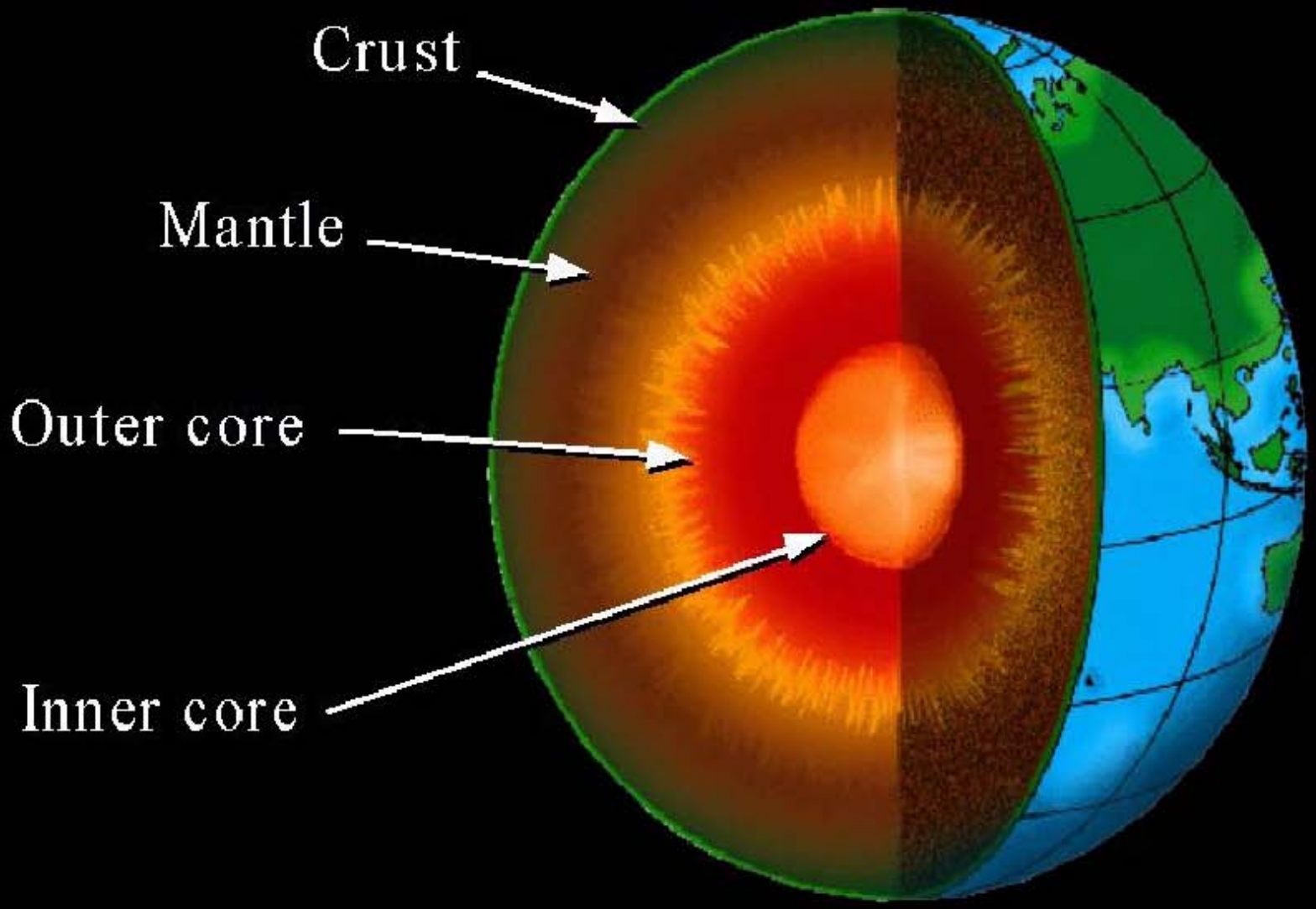
Montana Annual Wind Speed Pattern by Region



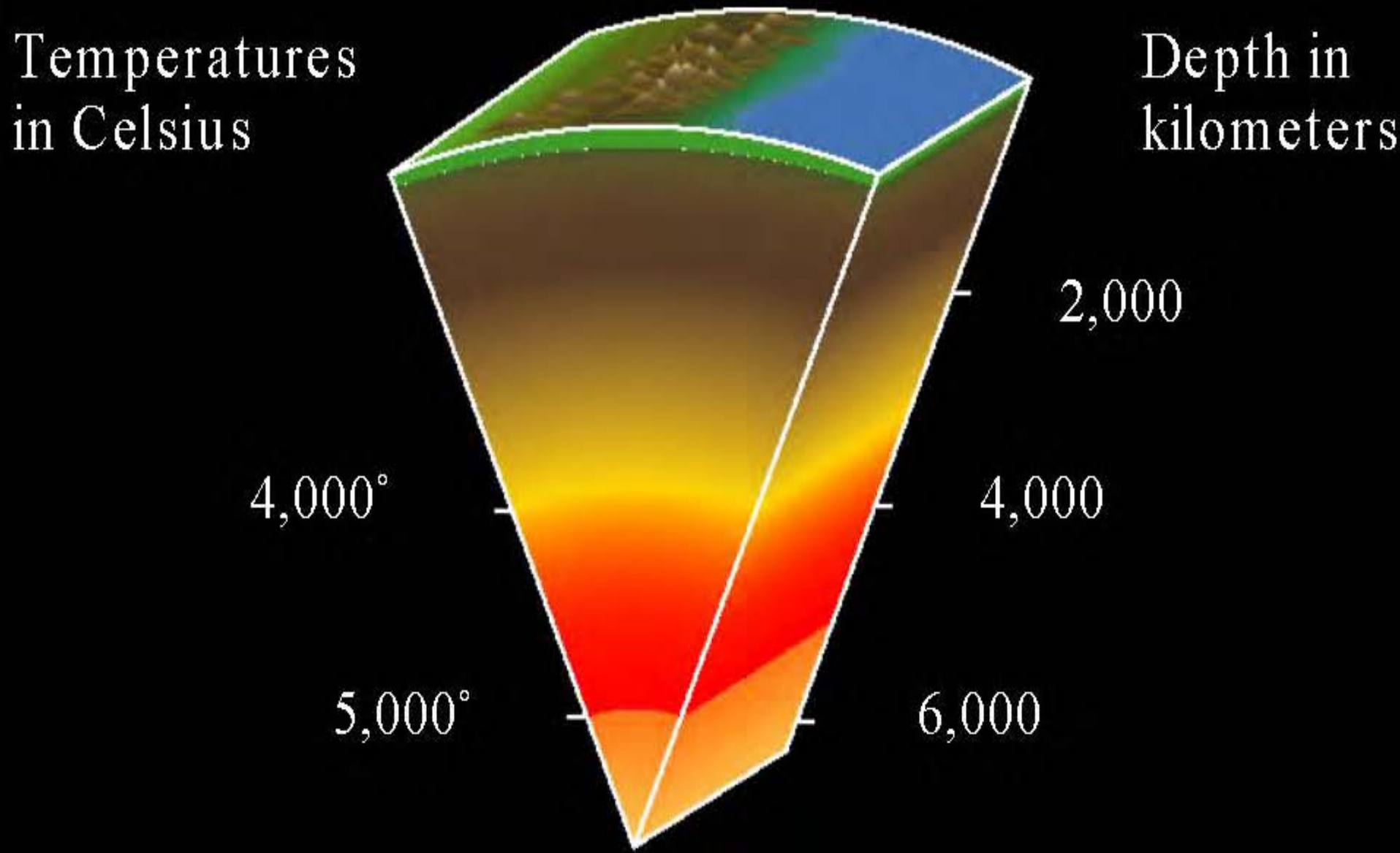


- Wind speed increases dramatically with height above ground
- Diurnal profile of wind changes with height above ground

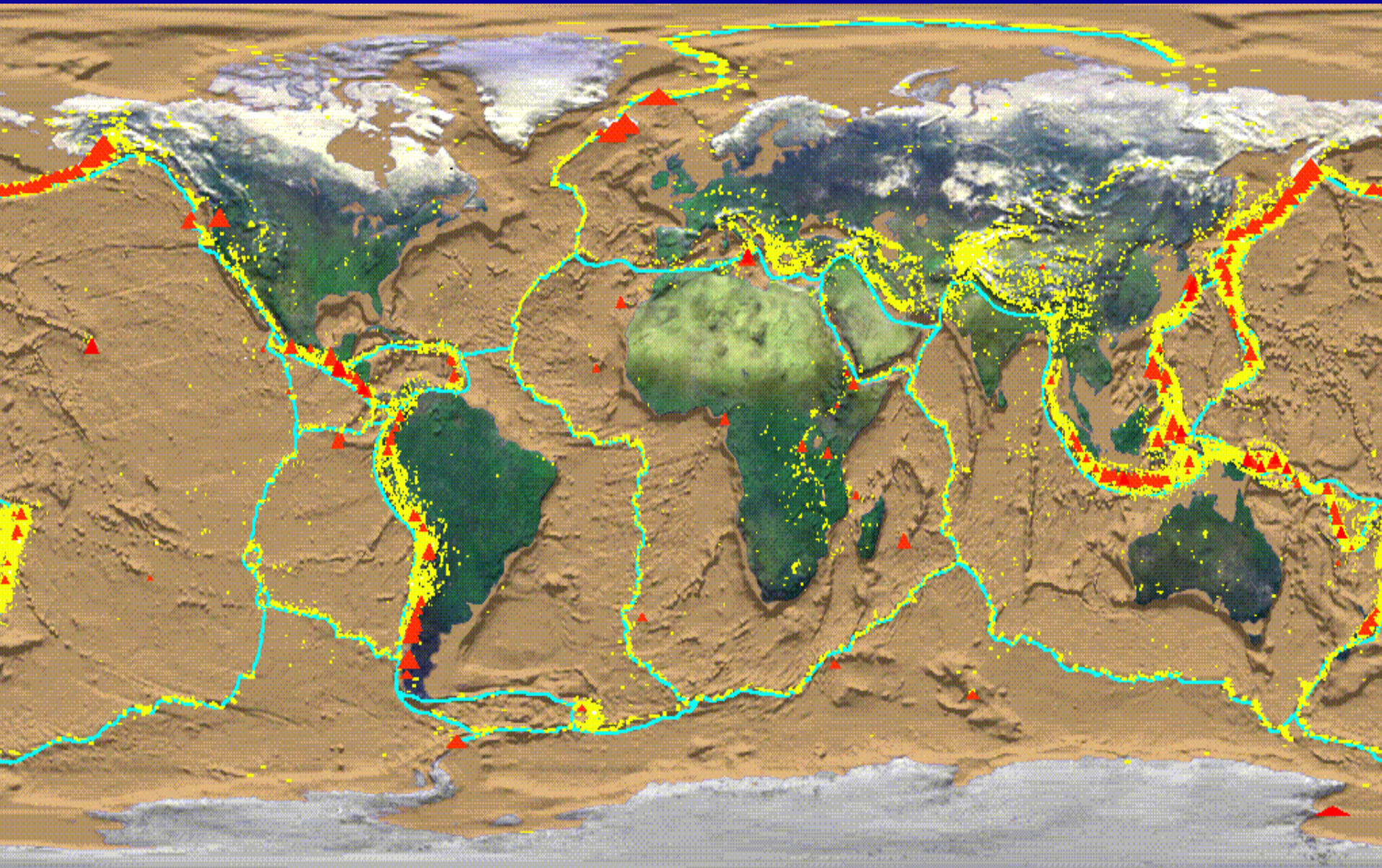
The Earth

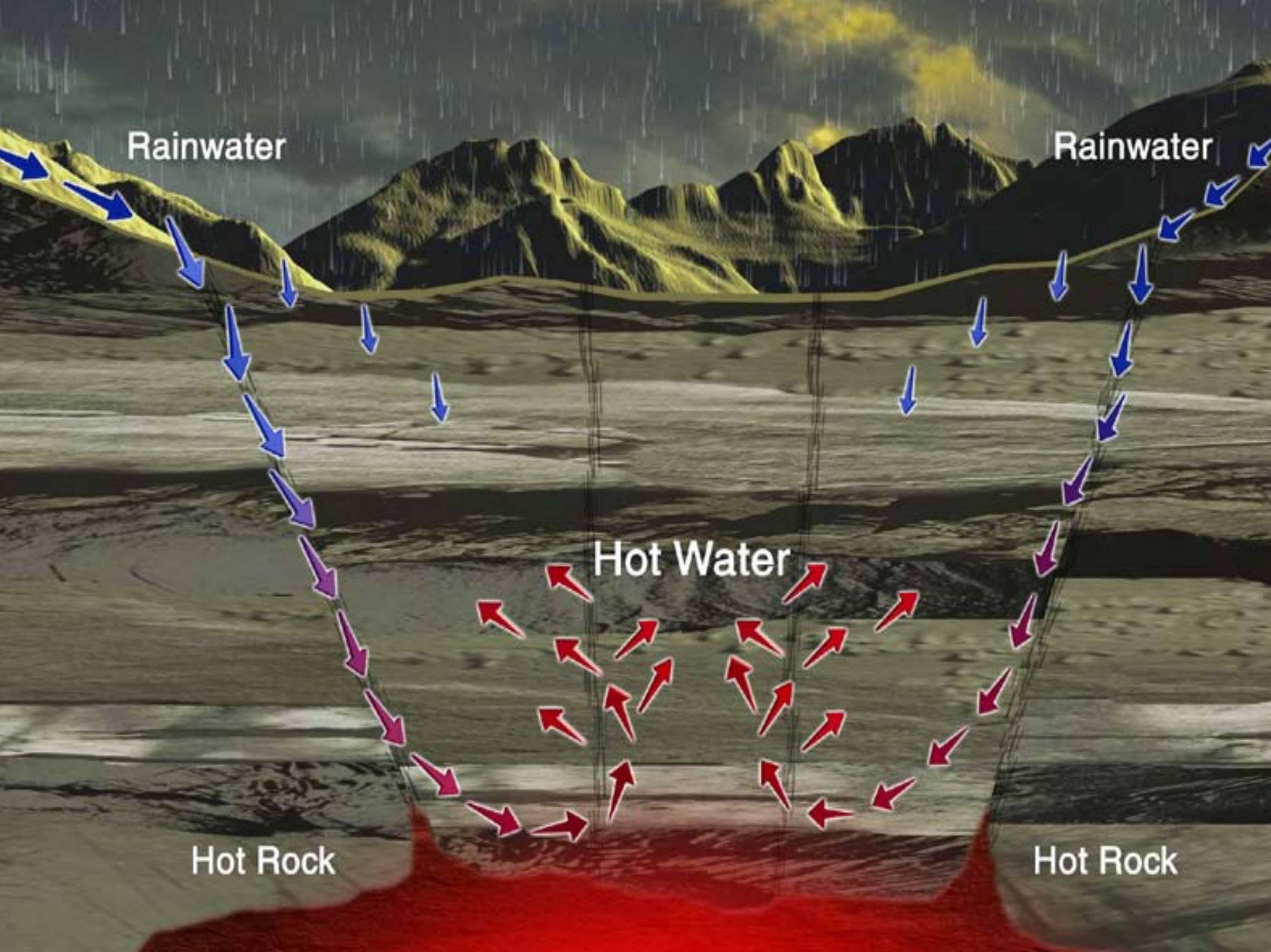


Temperatures in the Earth



Tectonic Plate Boundaries




Rainwater
Rainwater
Hot Water
Hot Rock
Hot Rock

Plant Type vs. Temperature

175°C (350°F)

90°C (195°F)

0°C 32°F)

Flash steam

Binary cycle

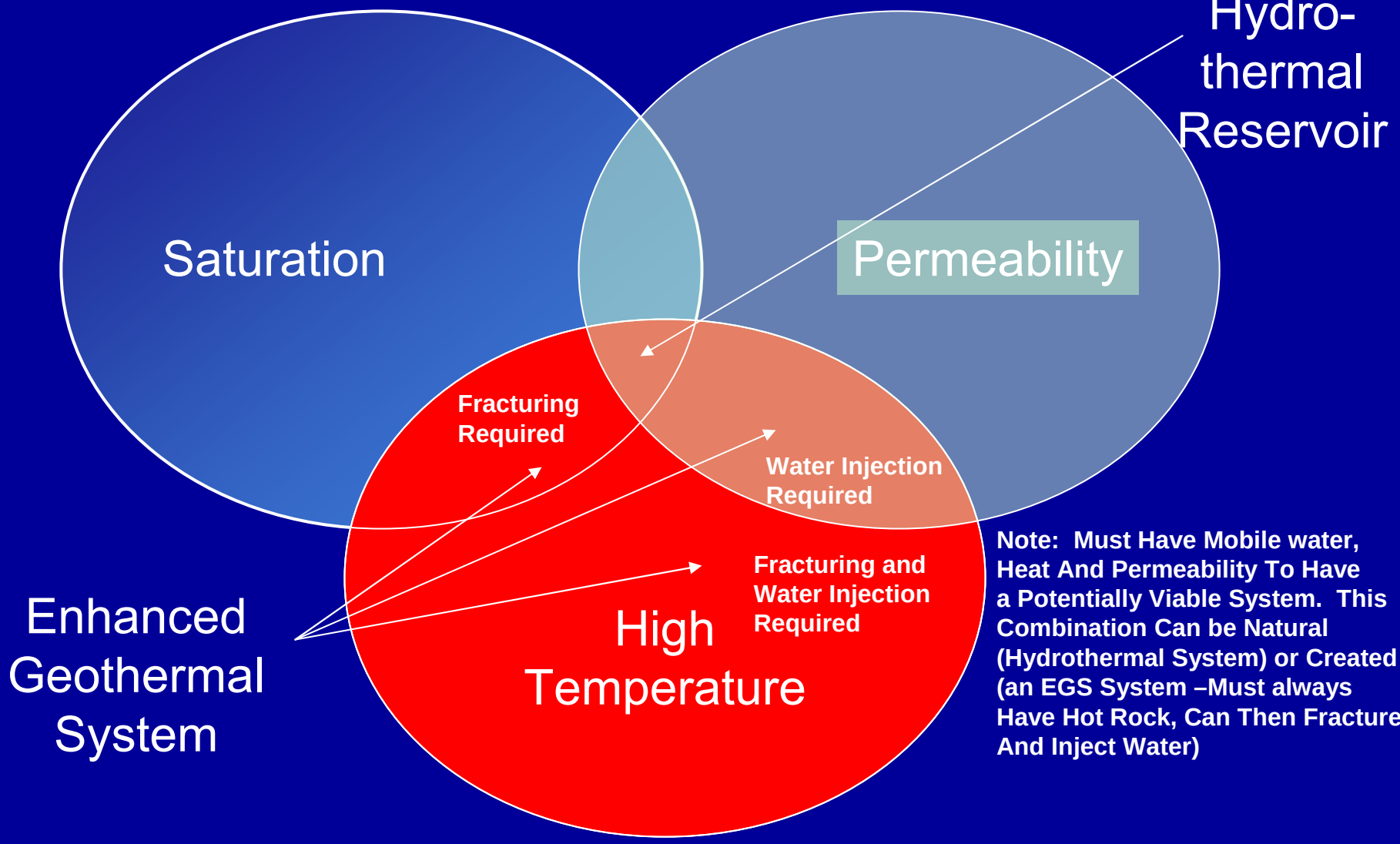
Direct Use

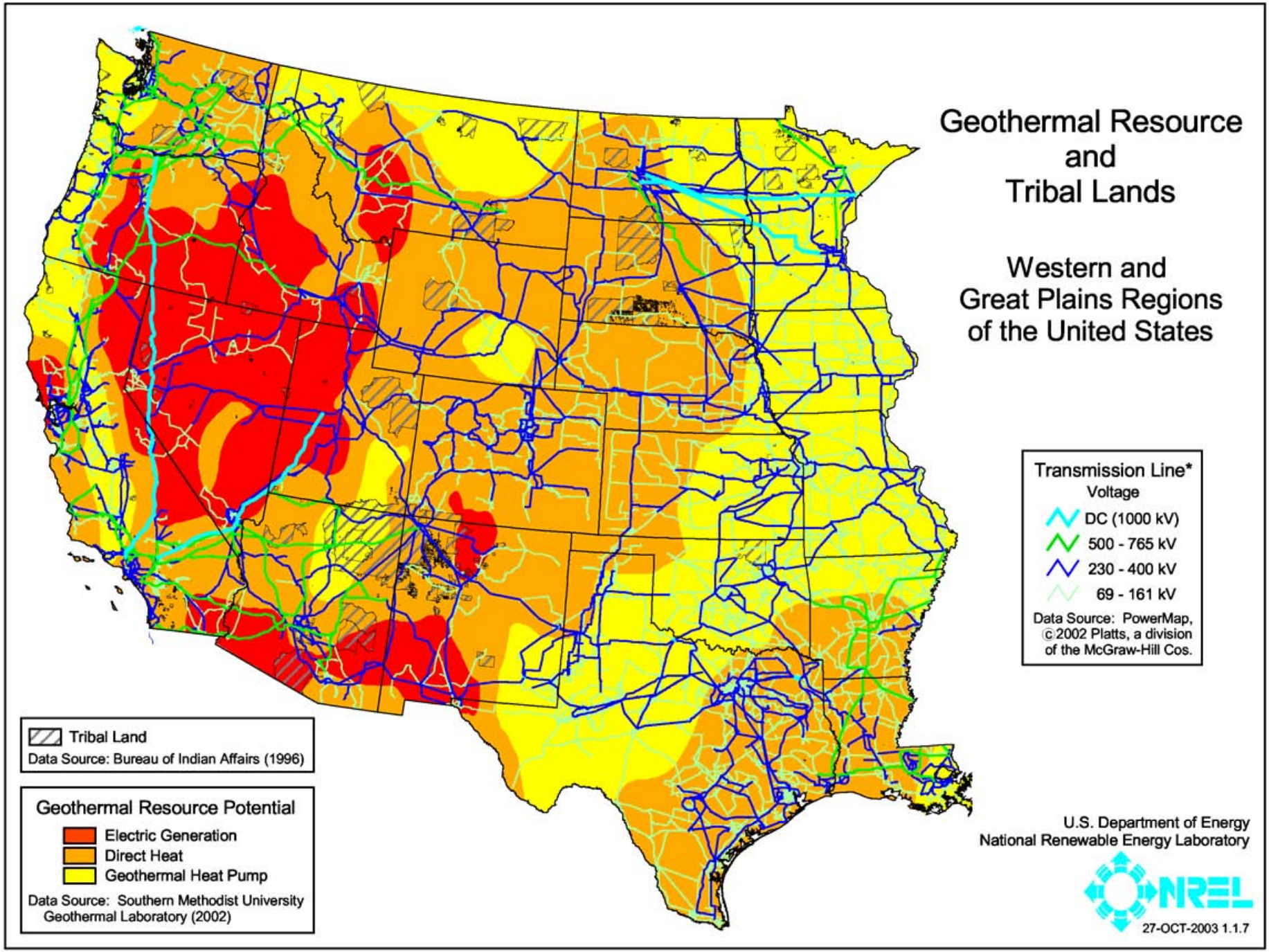
Carnot Efficiency
Eff = 1-Tamb/Tsource

400C Tsource	**53%**
300C	**45%**
200C	**34%**
150C	**26%**
125C	**21%**
100C	**16%**

For Tamb=40C (104F)

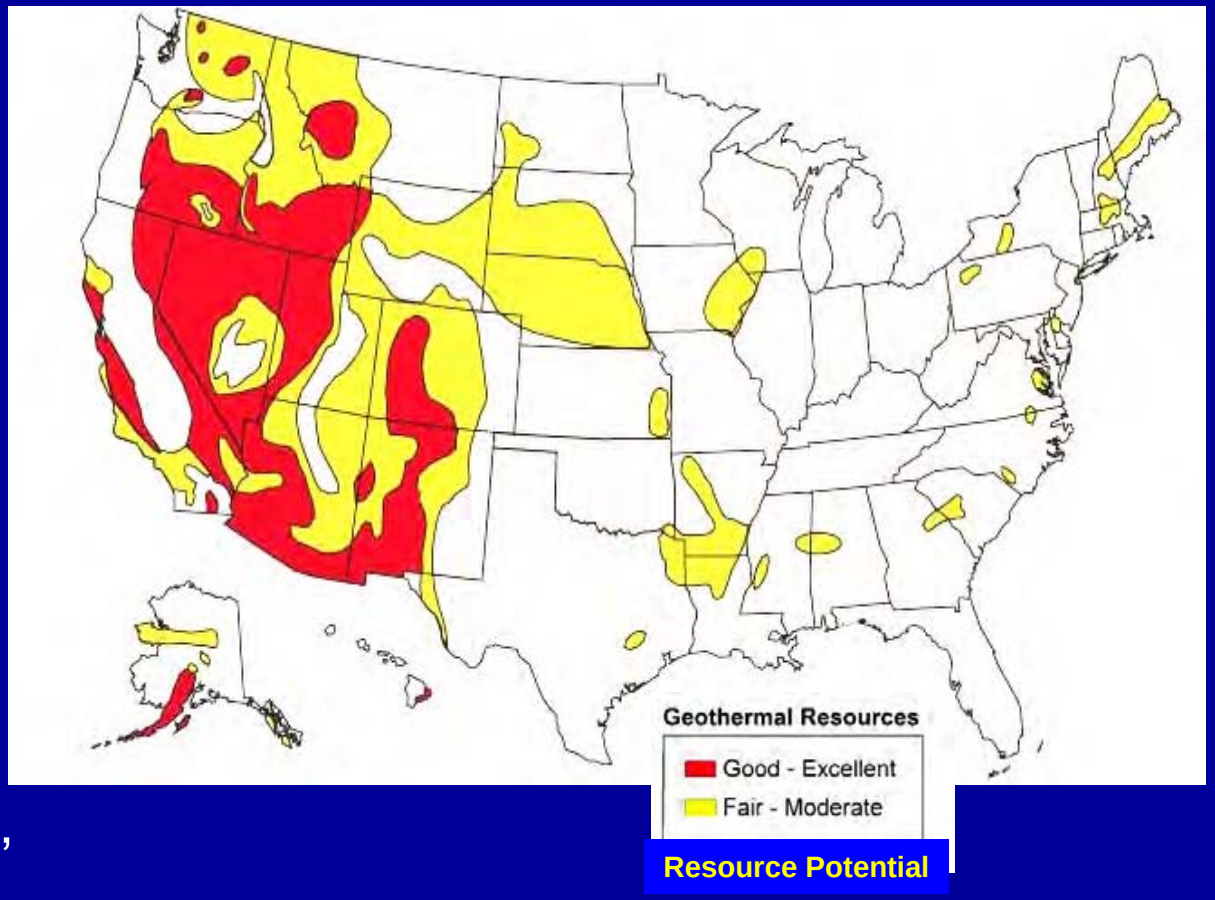
Geothermal Domains



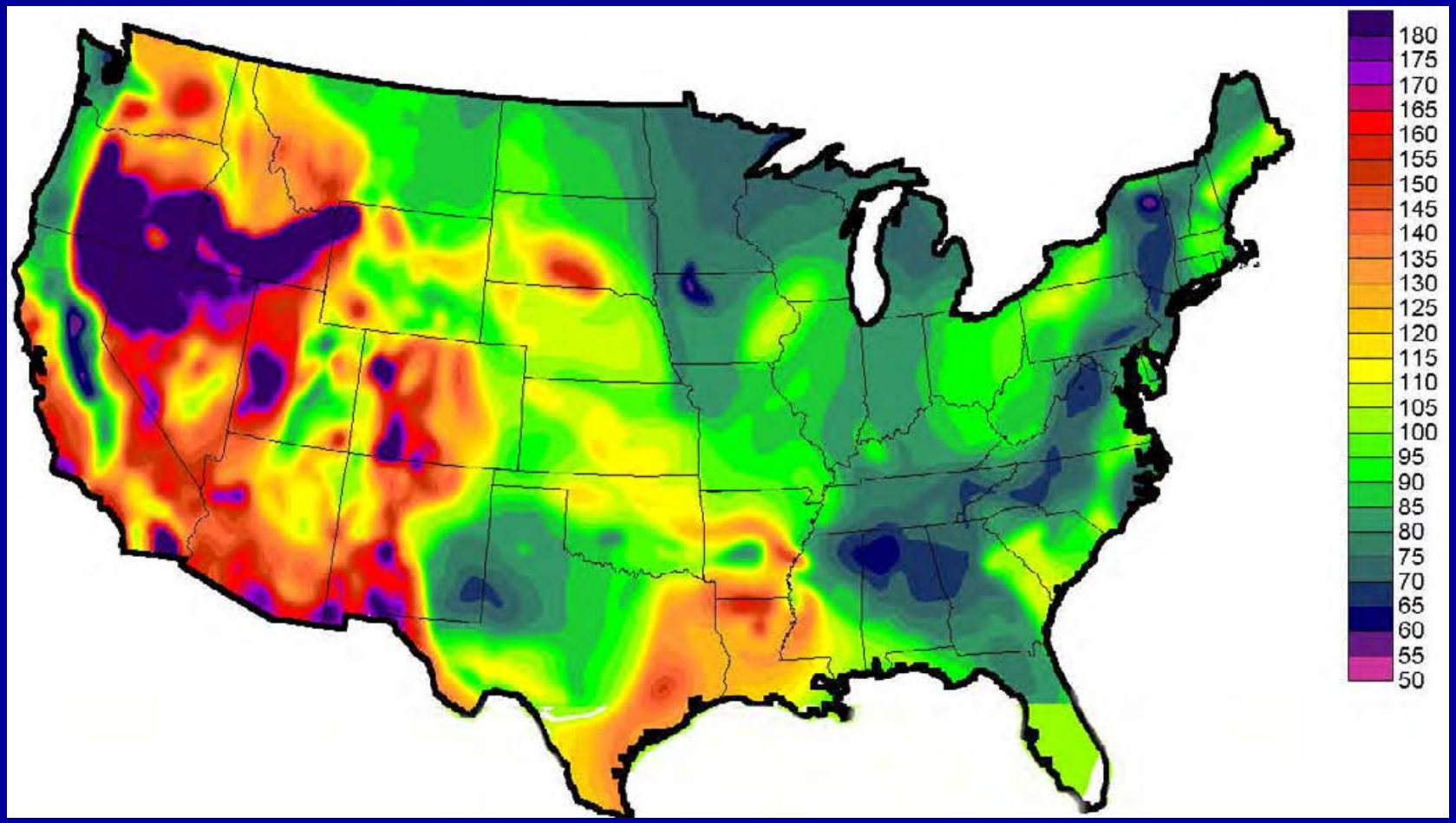

Geothermal Resource
and
Tribal Lands
Western and
Great Plains Regions
of the United States
Transmission Line*
Voltage
DC (1000 kV)
500 - 765 kV
230 - 400 kV
69 - 161 kV
Data Source: PowerMap,
©2002 Platts, a division
of the McGraw-Hill Cos.
Tribal Land
Data Source: Bureau of Indian Affairs (1996)
Geothermal Resource Potential
Electric Generation
Direct Heat
Geothermal Heat Pump
Data Source: Southern Methodist University
Geothermal Laboratory (2002)
U.S. Department of Energy
National Renewable Energy Laboratory
NREL
27-OCT-2003 1.1.7

Geothermal Resource Potential
Hydrothermal Resources

- Top Three States:
  - Nevada
  - California
  - Utah
- Other High Potential States:
  - Alaska, Arizona, Colorado, Idaho, Hawaii, New Mexico, and Oregon



Projected Temperatures at a Depth of 4 Km
(Source - SMU)



Biomass

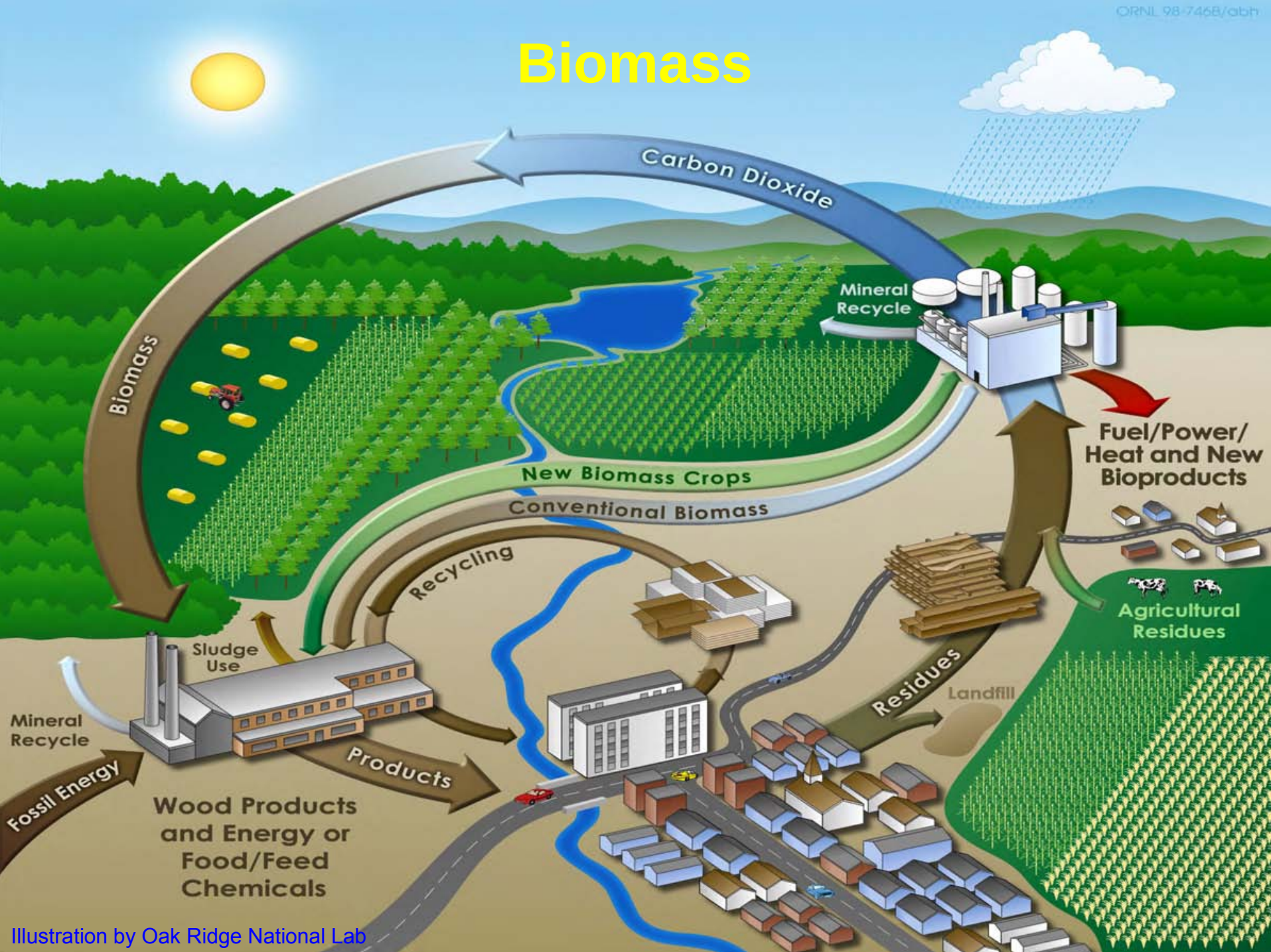
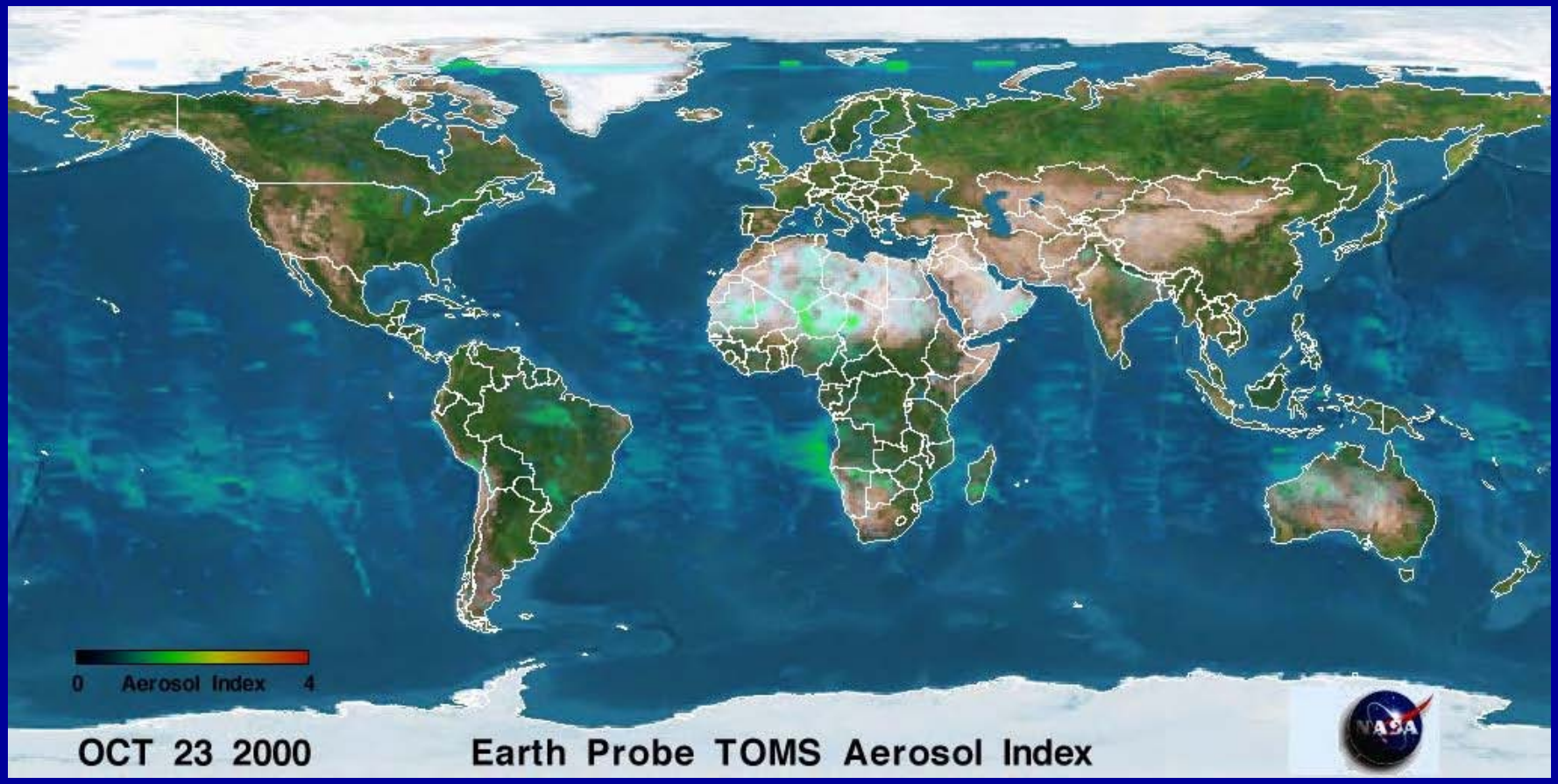
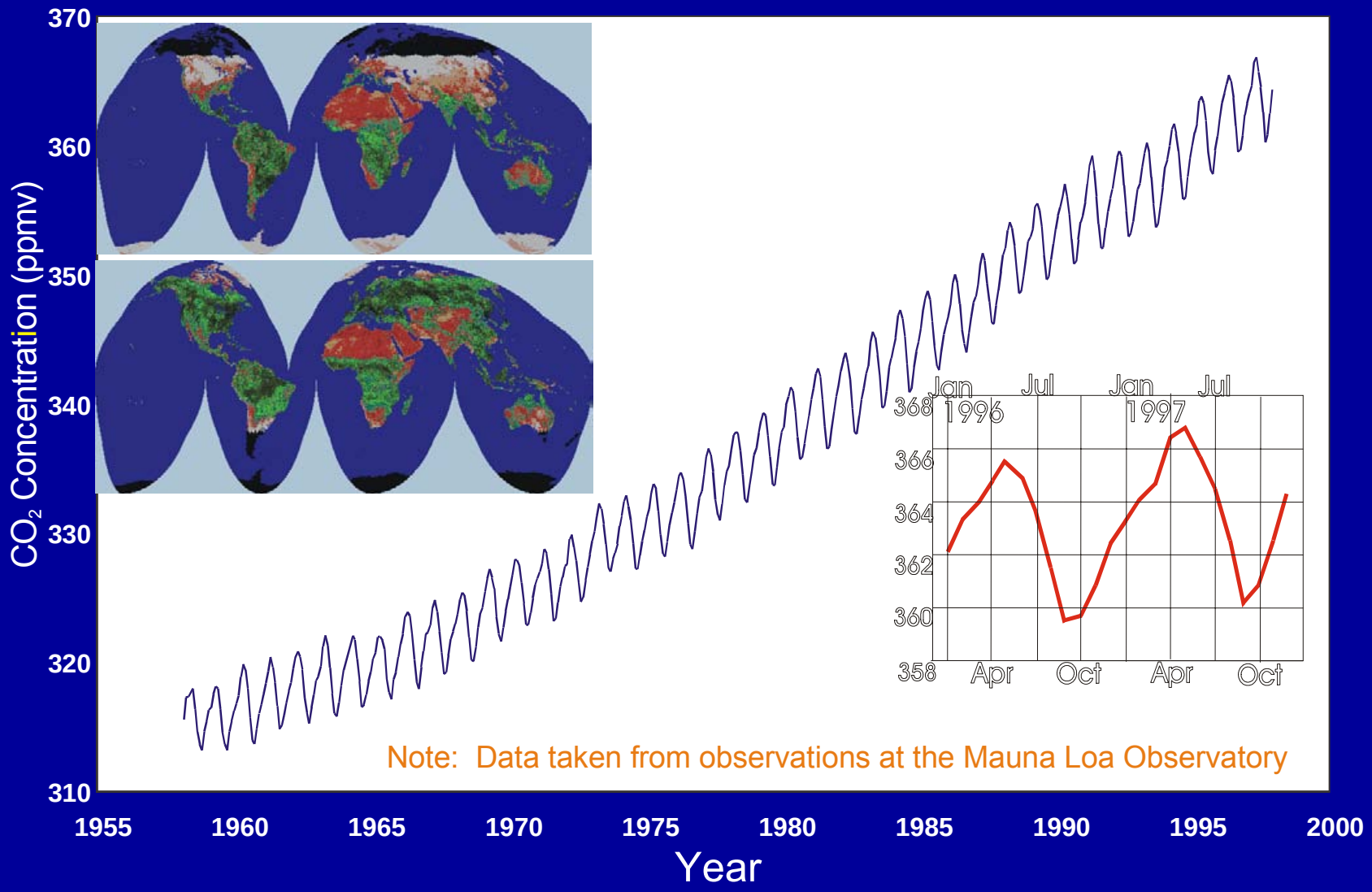


Illustration by Oak Ridge National Lab

Biomass Distribution



Carbon Dioxide - The Biosphere and the Earth's Atmosphere



The Unique Role of Biomass

While the growing need for sustainable electric power can be met by other renewables…

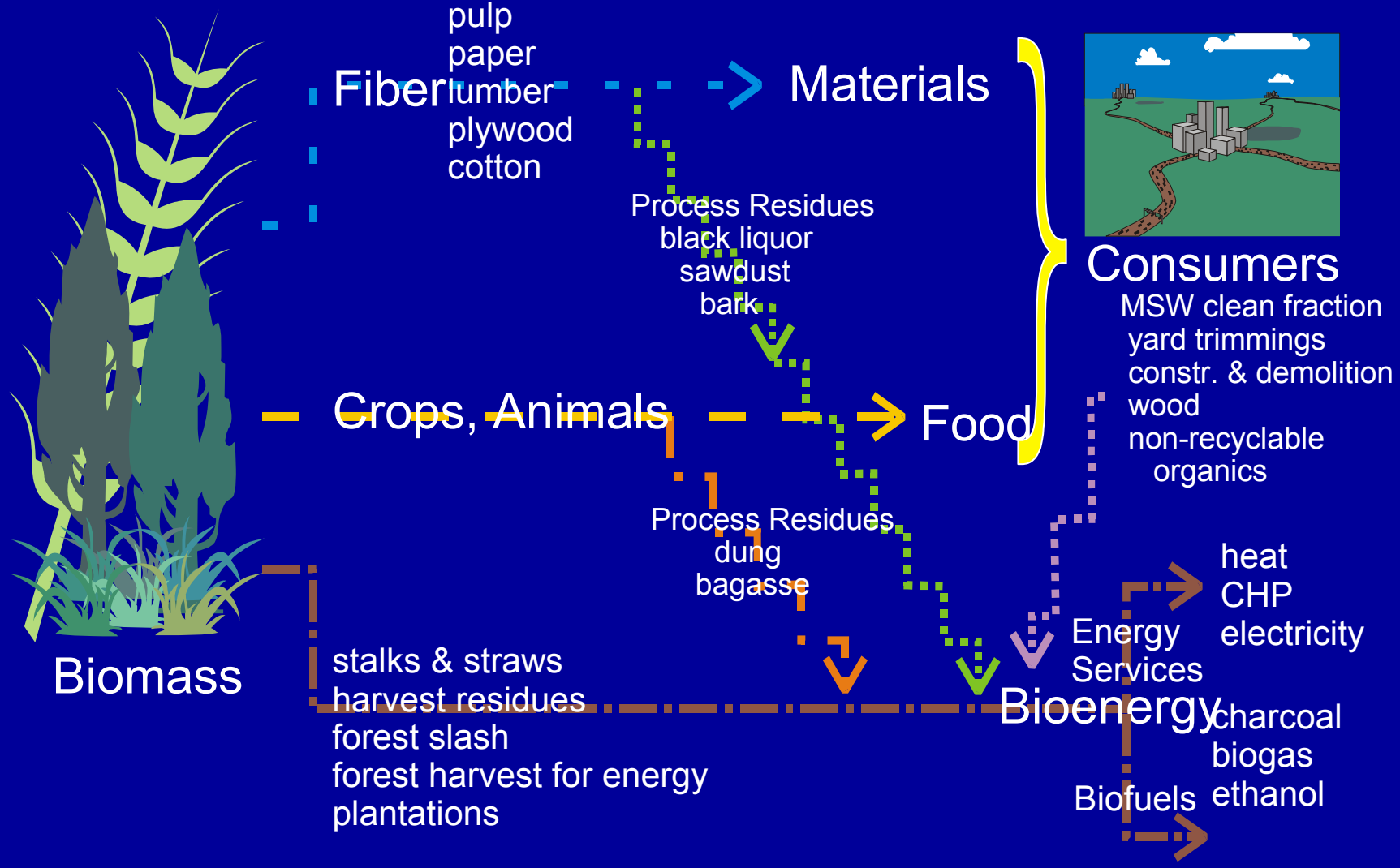
Biomass is the only renewable that can meet our demand for carbon-based liquid fuels and chemicals

Biomass Resources are Diverse

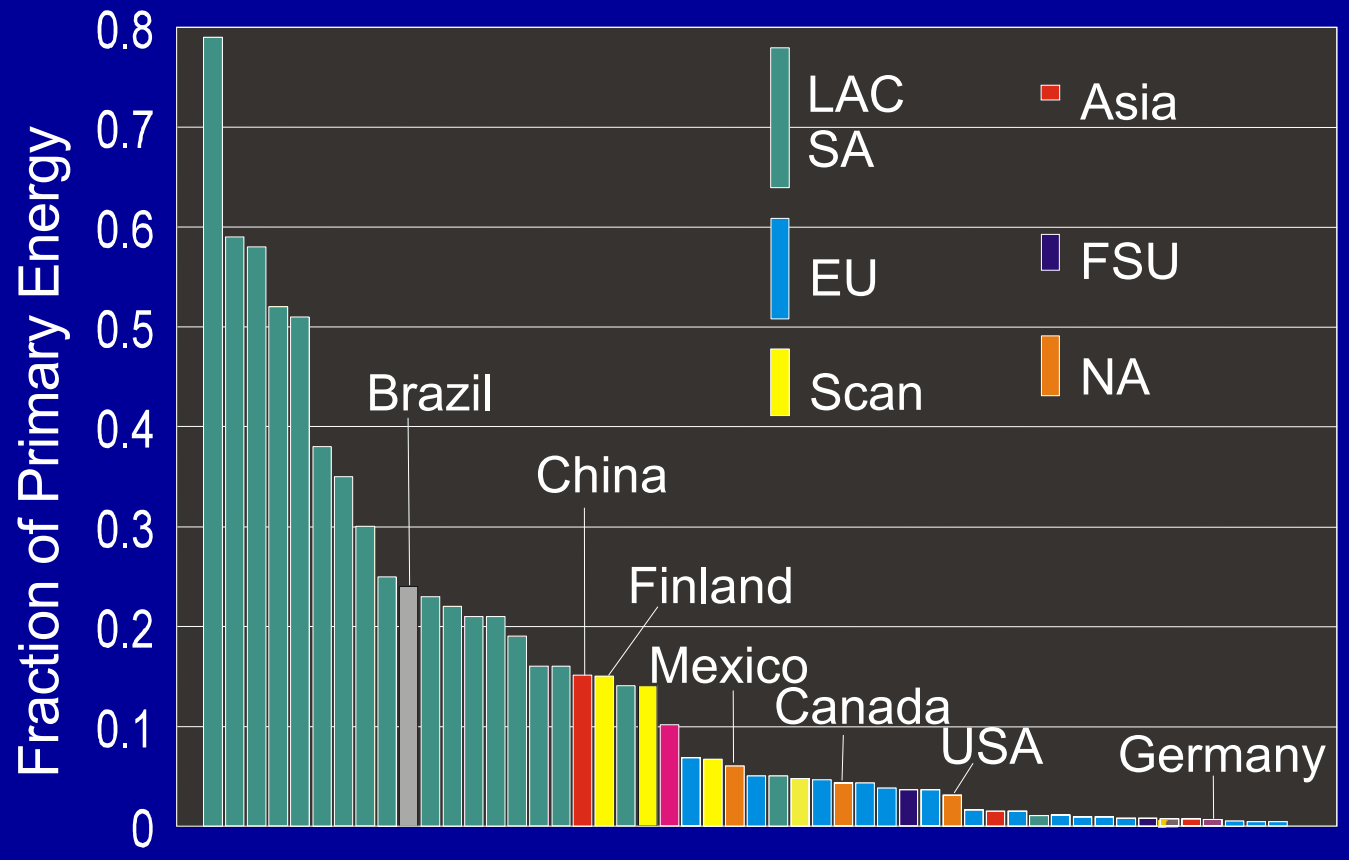
- Solid Fuels for direct use or production of biofuels
  - Urban/Rural household and garden residues
  - Fuel wood
  - Straws and Stalks (Maize, Wheat, mixed grains)
  - Forest industry residues (sawdust, bark, shavings etc)
  - Food process residues (bagasse)
  - Energy Crops

- Biofuel resources
  - Biogas from landfills, sewage works, brewery-distillery, CAFO (concentrated animal feed operations – poultry, swine, cattle)
  - Ethanol from sugar cane, beet, corn, starch crops via fermentation
  - Oil bearing crops – sunflower, soya, rape, palm etc

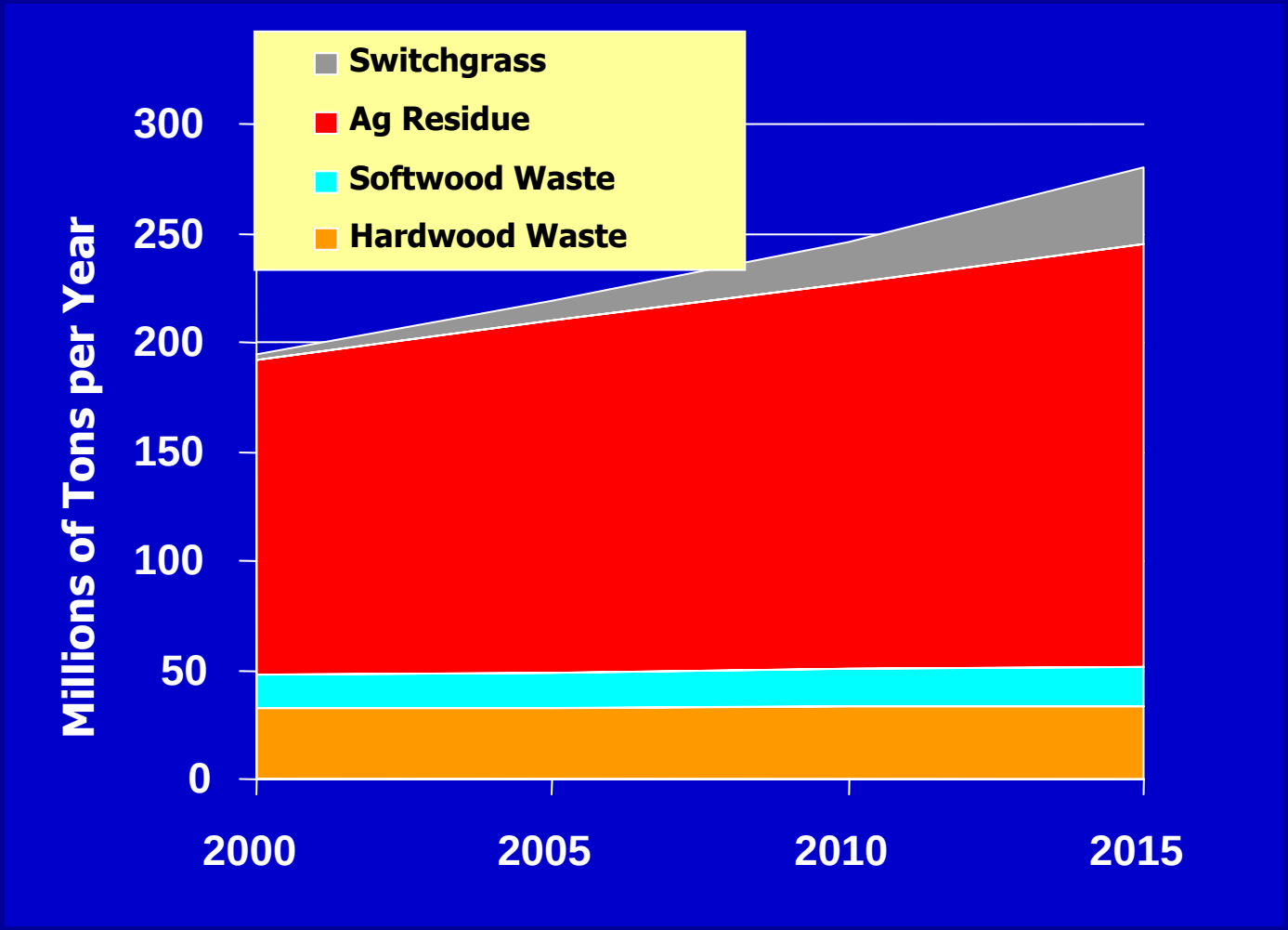
Biomass & Bioenergy Flows



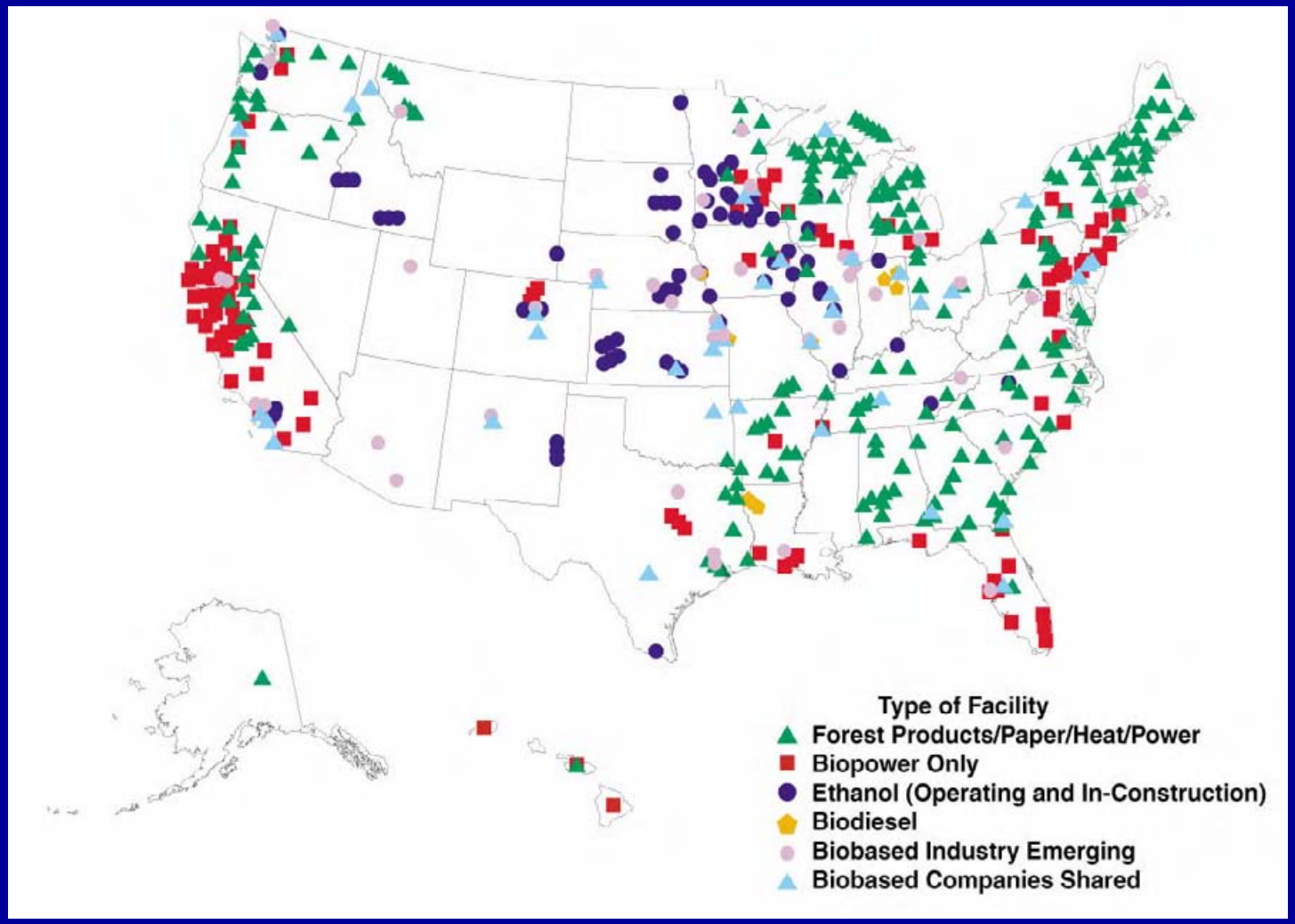
Biomass Contribution to Primary Energy



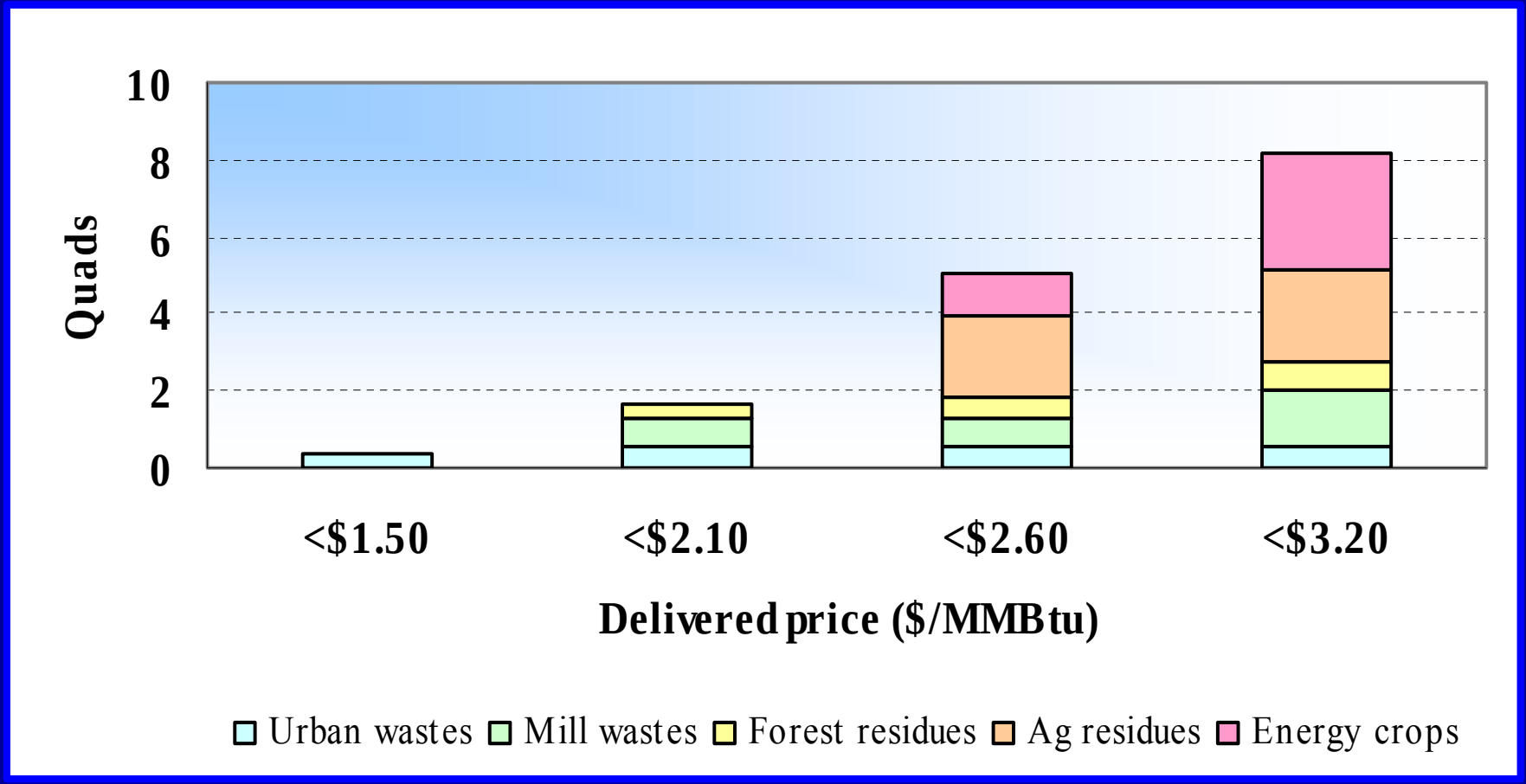
Biomass Feedstocks



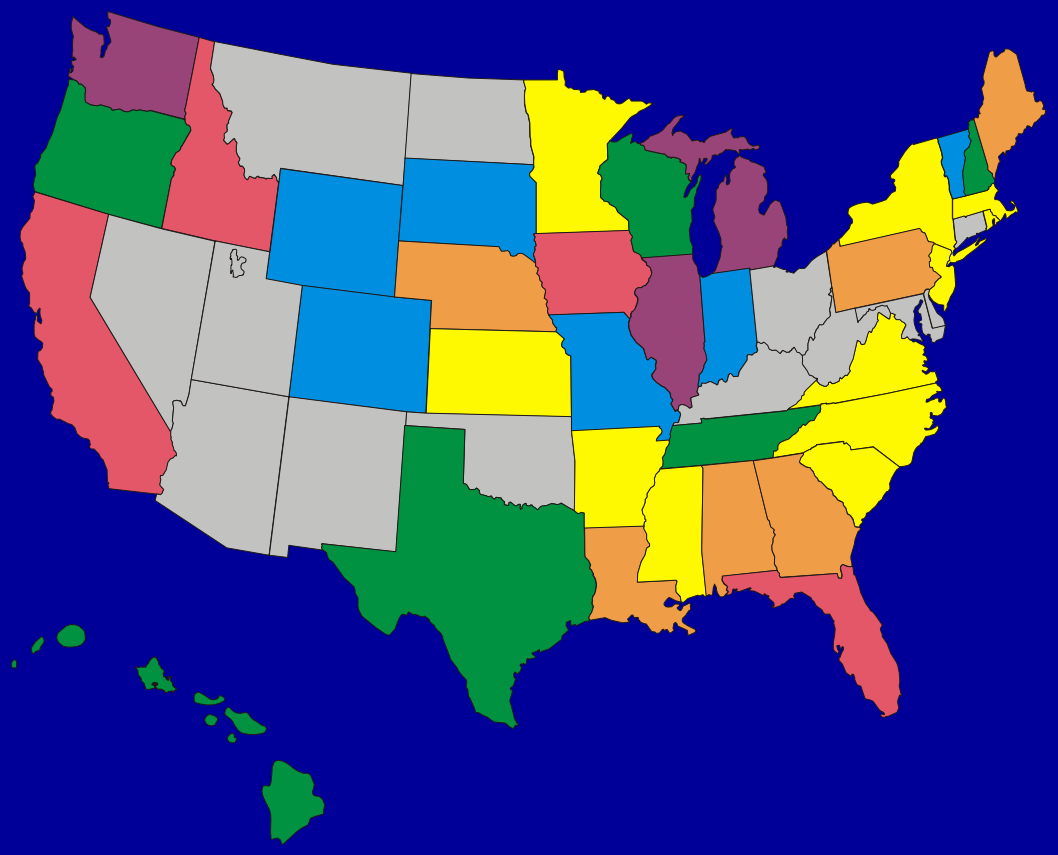
Biomass-Bioenergy-Biobased Industry



Potential Midterm U.S. Biomass Supply



Biomass Electricity Production
Wood Residues, Landfill Gas, MSW



Total = 61 TWh/a

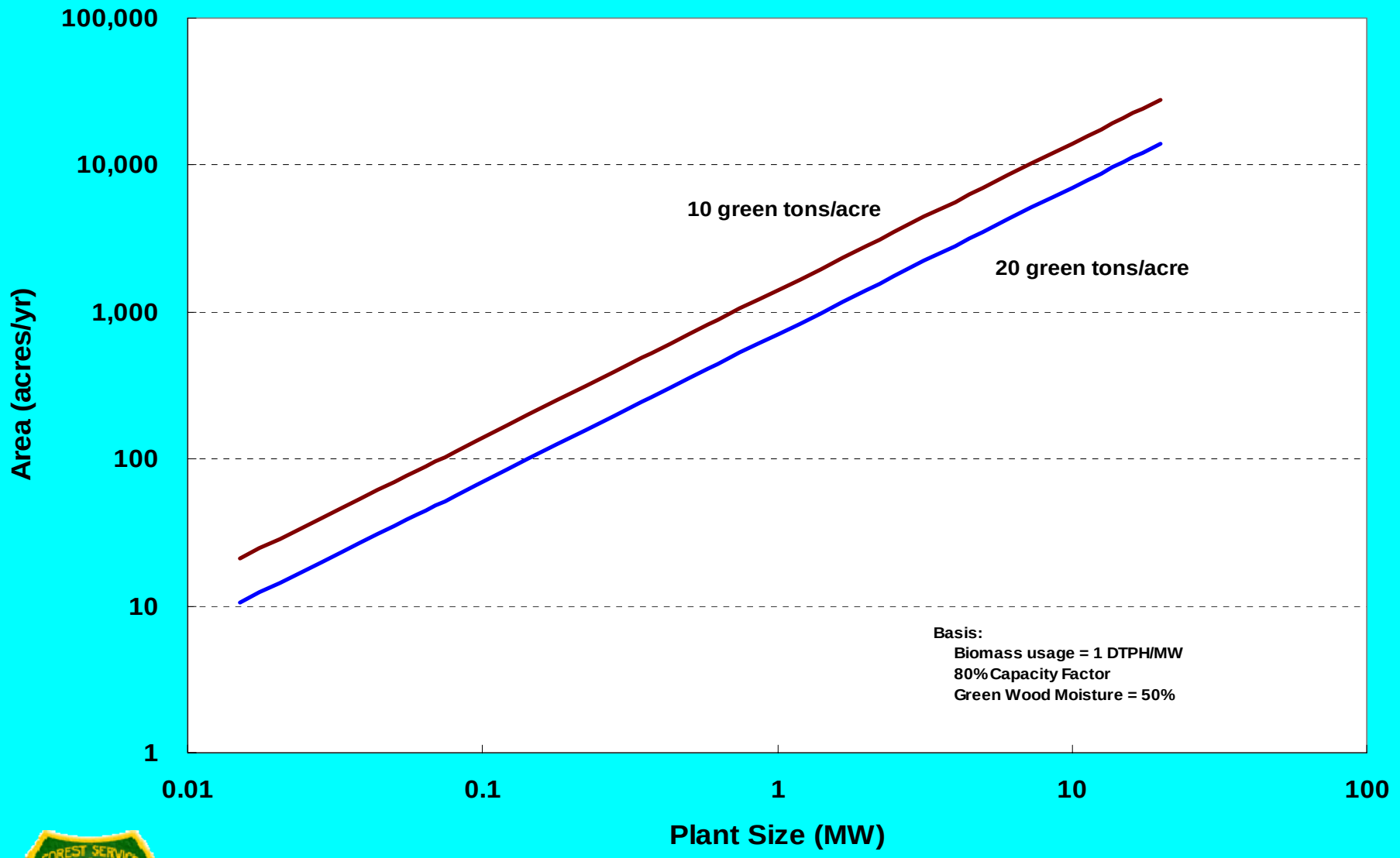
- > 5TWh/a
- > 2.5 TWh/a
- >1.25 TWh/a
- >625 GWh/a
- > 325 GWh/a
- < 130 GWh/a

Icepag

National Fire Plan
Thinning Residues

- 28 MM acres in need of treatment
- Opportunity via stewardship contracts
  - www.blm.gov
  - www.fs.fed.us

Sustainable Forest Thinning Acreage Versus Power Plant Size



Industry Captive Use

- Largest Single Sector for Biomass Use
  - Bio-processing industries
    - Sugar cane processing (Mexico and the USA)
    - Wood processing - lumber, OSB, Plywood
    - Pulp and Paper Sector

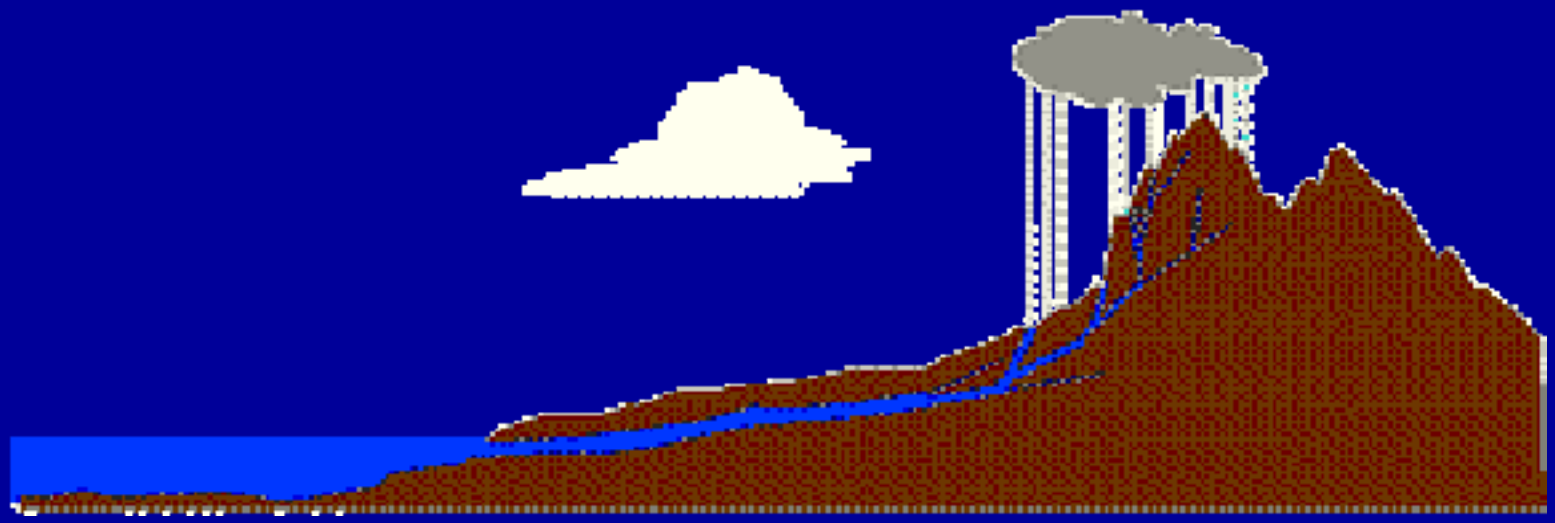
- Residues usage
  - Process heat and drying
  - Electricity generation (CHP)

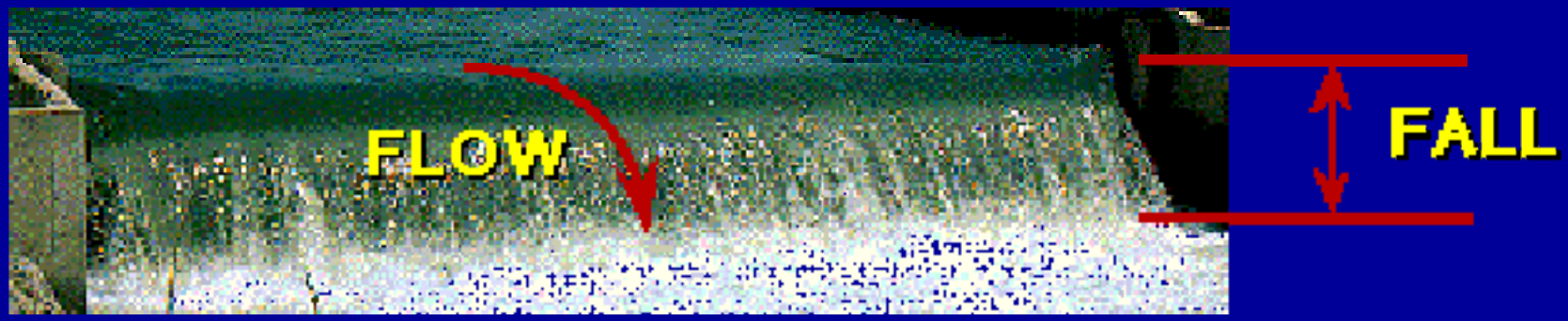
US Pulp and Paper sector is currently 57% self sufficient.

New market uses for waste residues will influence cost

Status of U.S. Forest Products Industry
Pulp, Paper & Paperboard Mills
Employees Laid Off
Closed Saw Mills & Paper Mills, 1989-2003
PPRC
Pulp & Paperworkers' Resource Council

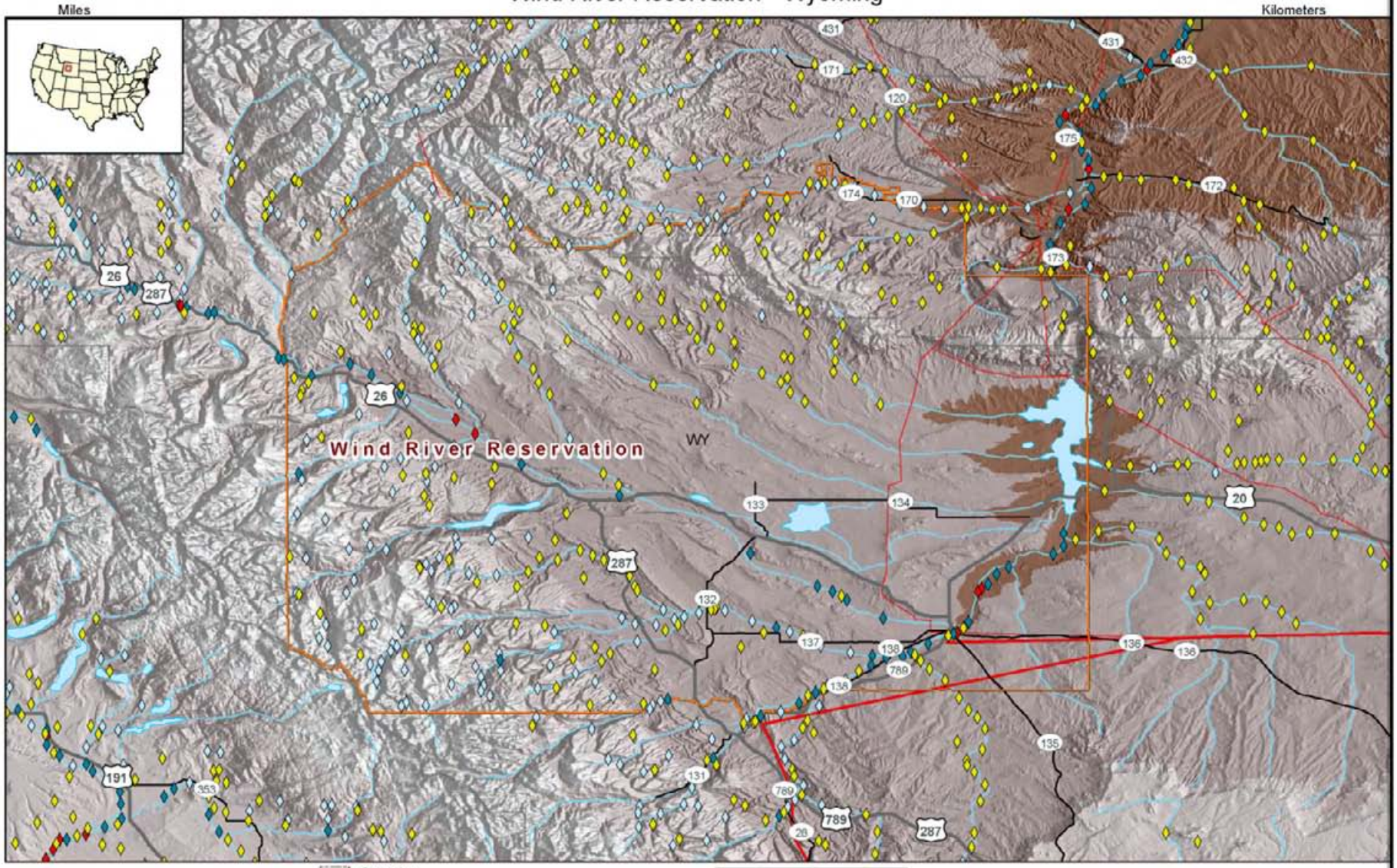
Hydro Power Resource Assessment





Power (kW) = 10 x flow (m^3/s) x fall (m) x η

Wind River Reservation - Wyoming



High Head >10m - Low Power <1MW

Low Head <10m - Low Power <1MW

- Conventional Turbines
- Unconventional Systems
- Microhydro <100kW

- Counties
- Lakes and Rivers
- Indian Reservation
- Cities

Major Roads

- Interstate Hwy
- US Hwy
- Other Roads

Transmission Lines *

- <230kV
- 230kV - 499kV
- >500kV

* Source: POWERmap, ©2002 Platts, a Division of the McGraw-Hill Companies

Legend (meters)

3000 - 4418	600 - 700
2000 - 3000	500 - 600
1500 - 2000	400 - 500
1250 - 1500	300 - 400
1000 - 1250	200 - 300
800 - 1000	100 - 200
700 - 800	0 - 100

Note: This computer-generated map shows potential small hydroelectric plant sites. The low power sites (< 1 MW) shown are color coded by the class of technology that might be installed. Power potential is based on mean annual flow rate over a 30 year period and varies from year to year. Flow rate and therefore potential power are also likely to exhibit seasonal variations. A lower limit of 10kW has been used to remove microhydro sites suspected of having very short flow durations. Actual on-site measurements and evaluations must be undertaken during the feasibility assessment of any proposed project. Sites are not shown in protected and biologically sensitive areas.

The hydro data was produced by the Idaho National Laboratory for the DOE Wind and Hydropower Technologies Program

NREL

July 5, 2005

Questions on Renewable Energy Resource Assessment ?