Michigan Energy Use, Biomass Resources & Tech
OU Clean Energy Research Center

Presentation:

- Overview of Michigan energy use
- Overview of Michigan biomass resources
- Brief introduction to bioenergy technologies

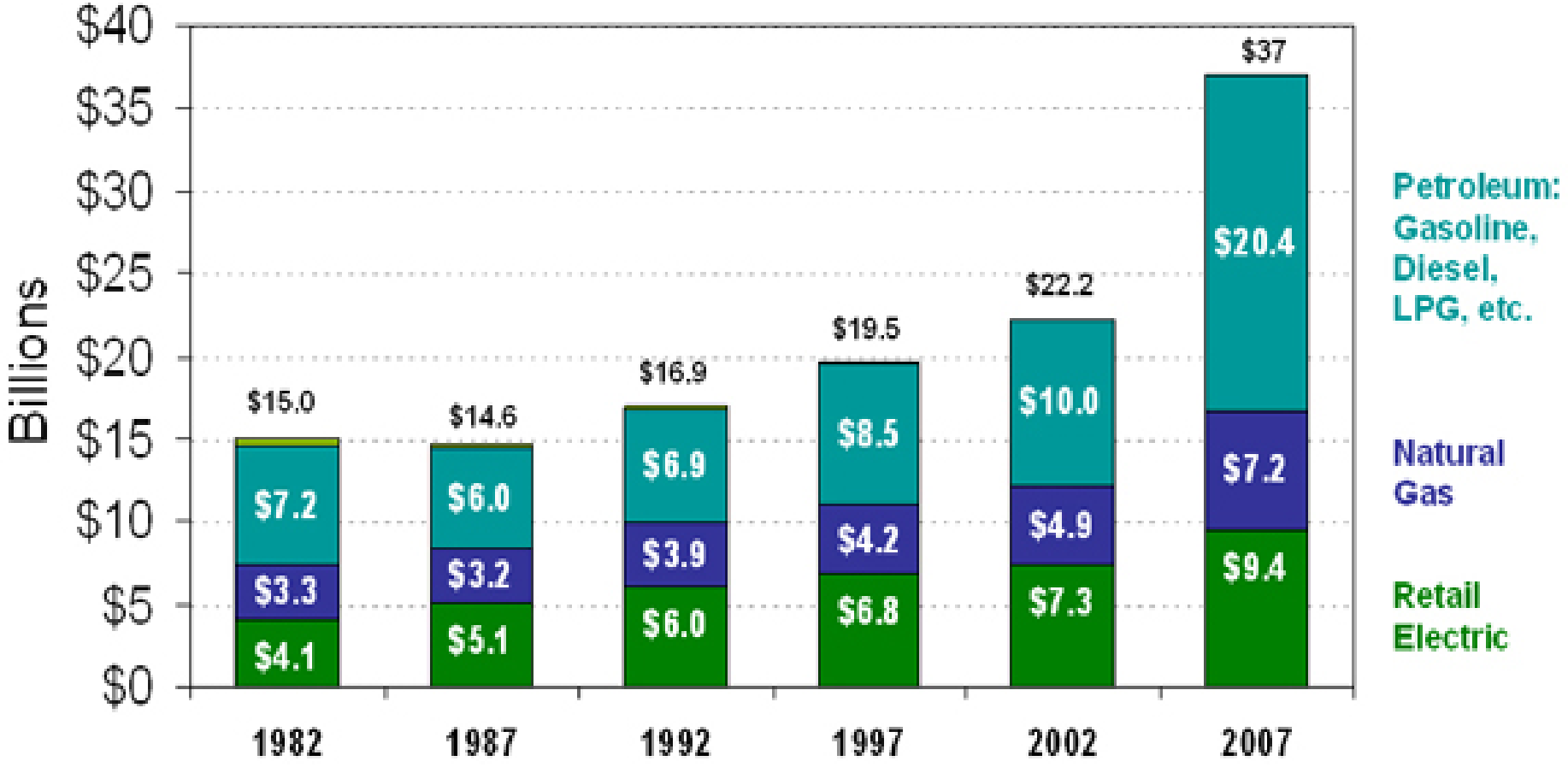
Presenter

Jim Leidel
Energy Manager

GOAL:

Let's produce 10% of Michigan's energy from local bioenergy for non-transportation needs by 2030

Michigan Total Energy Expenditures



Source:
www.dleg.state.mi.us/mpsc/reports/energy/energyoverview

Department of Energy, Labor & Economic Growth
DELEG
Working to Create Michigan's Future Today

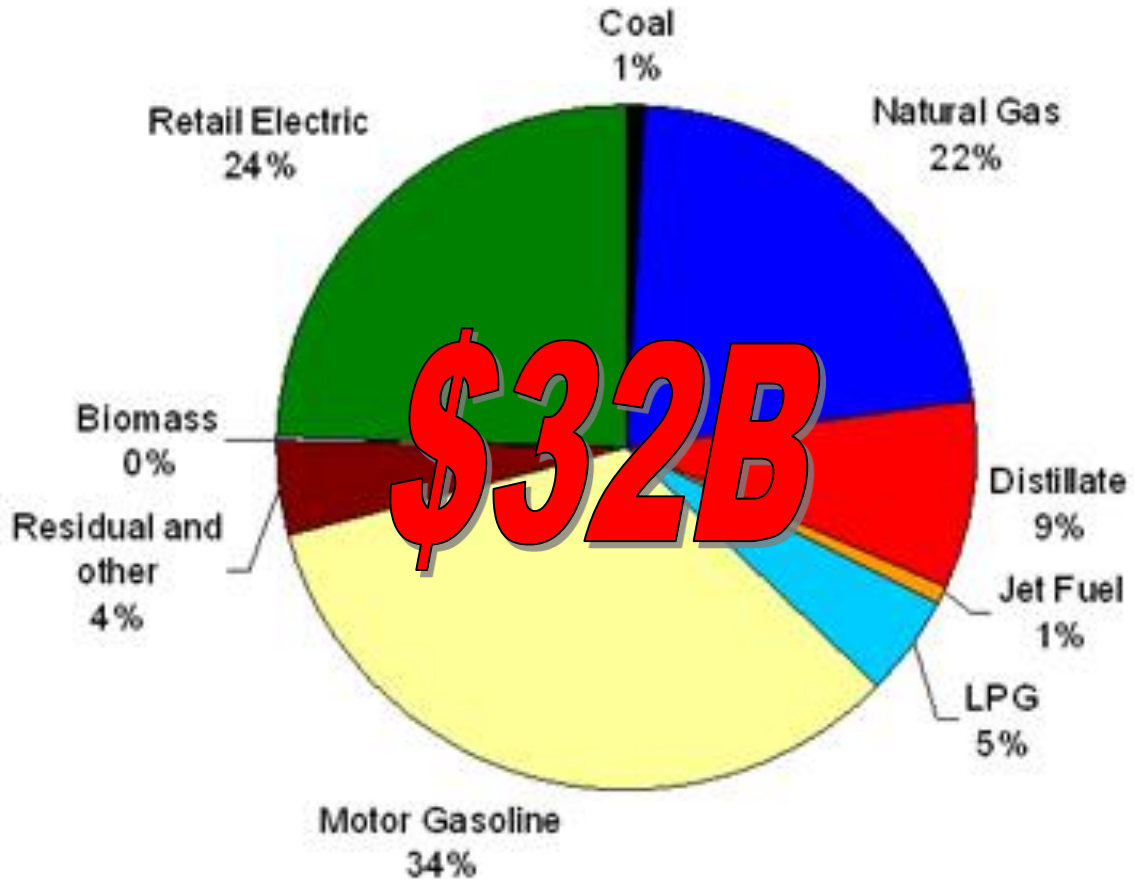
Michigan imports 97 percent of its petroleum needs, 80 percent of its natural gas and 100 percent of coal and nuclear fuel from other states and nations. These imports account for about 70 cents of every dollar spent for energy by Michigan's citizens and businesses.

Michigan spent a total of $37 billion on all forms of energy in 2007 and of that amount $26 billion was for the energy resources imported from other states and nations.

2005

Michigan Energy Expenditures by Source

Spending as a percentage of the total for calendar year 2005



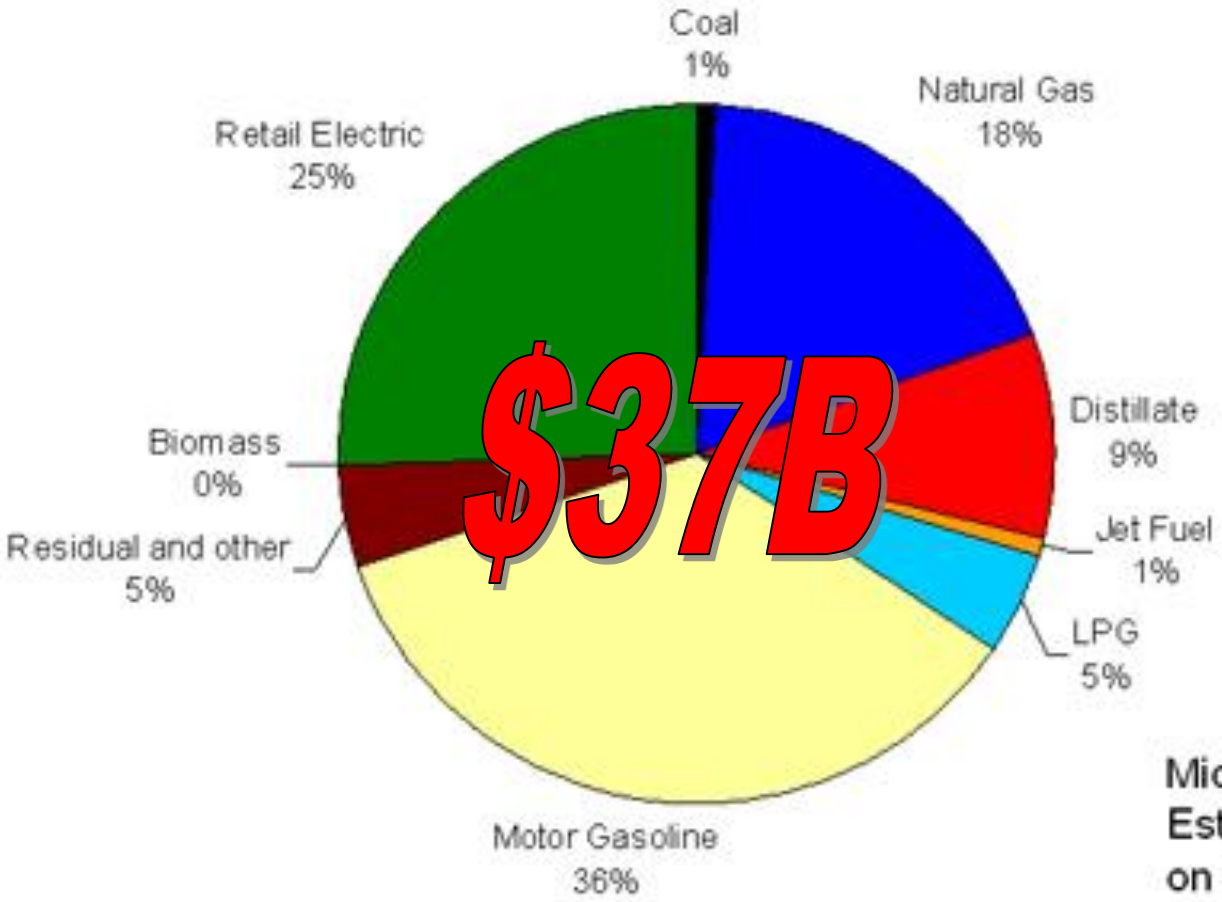
Michigan Spent
$32.4 Billion on
Energy in 2005

Note: the cost of fuels used to generate electricity are included in the retail electric costs. Coal use is non-utility industrial costs
Source: State Energy Expenditures Report Energy Information Administration,
Graph prepared by: Energy Data and Security, Michigan Public Service Commission

2007

Michigan Energy Expenditures by Source

Spending as a percentage of the total for calendar year 2007

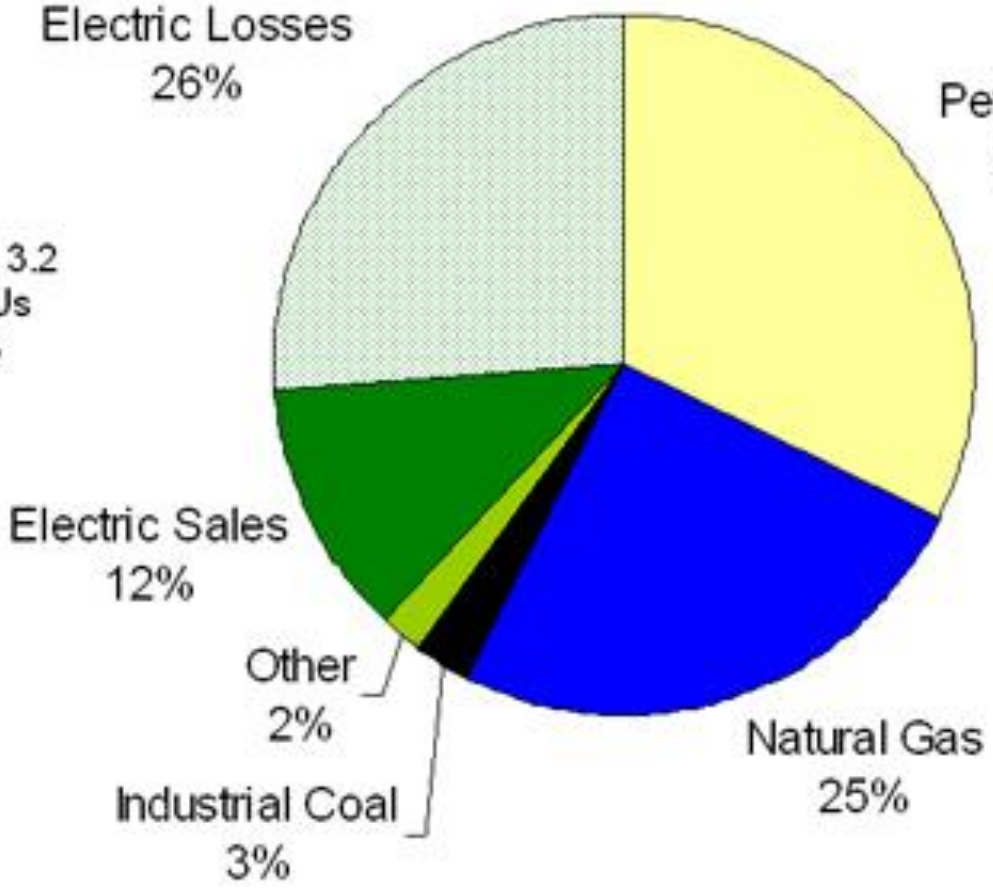


Michigan Spent an Estimated $37 Billion on Energy in 2007

Note: the cost of fuels used to generate electricity are included in the retail electric costs. Coal use is non-utility industrial costs
Source: Base data, State Energy Expenditures Report Energy Information Administration
2007 Estimates and graph prepared by: Energy Data and Security, Michigan Public Service Commission

Michigan Energy Use by Source

Total use 3,166.5 Trillion British Thermal Units (BTUs)



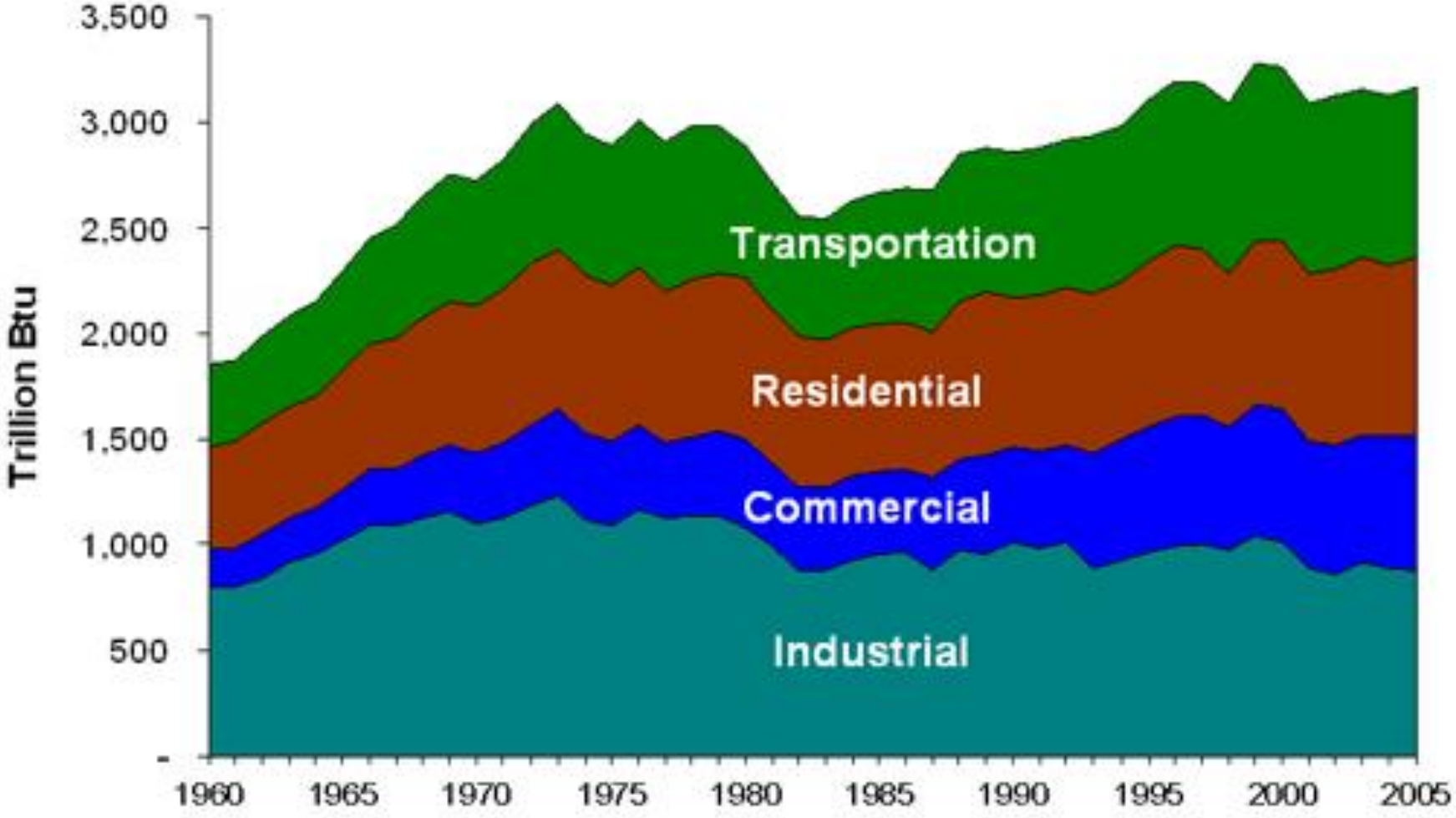
Michigan Used 3.2 Quadrillion BTUs of Energy 2005

A BTU is about the same amount of energy as contained in a match. It's the amount of energy needed to raise the temperature of 1 pound of water 1 degree F.

Source: State Energy Data Report, Energy Information Administration.
Graph prepared by: Energy Data and Security, Michigan Public Service Commission

Energy Use By Sector in Michigan

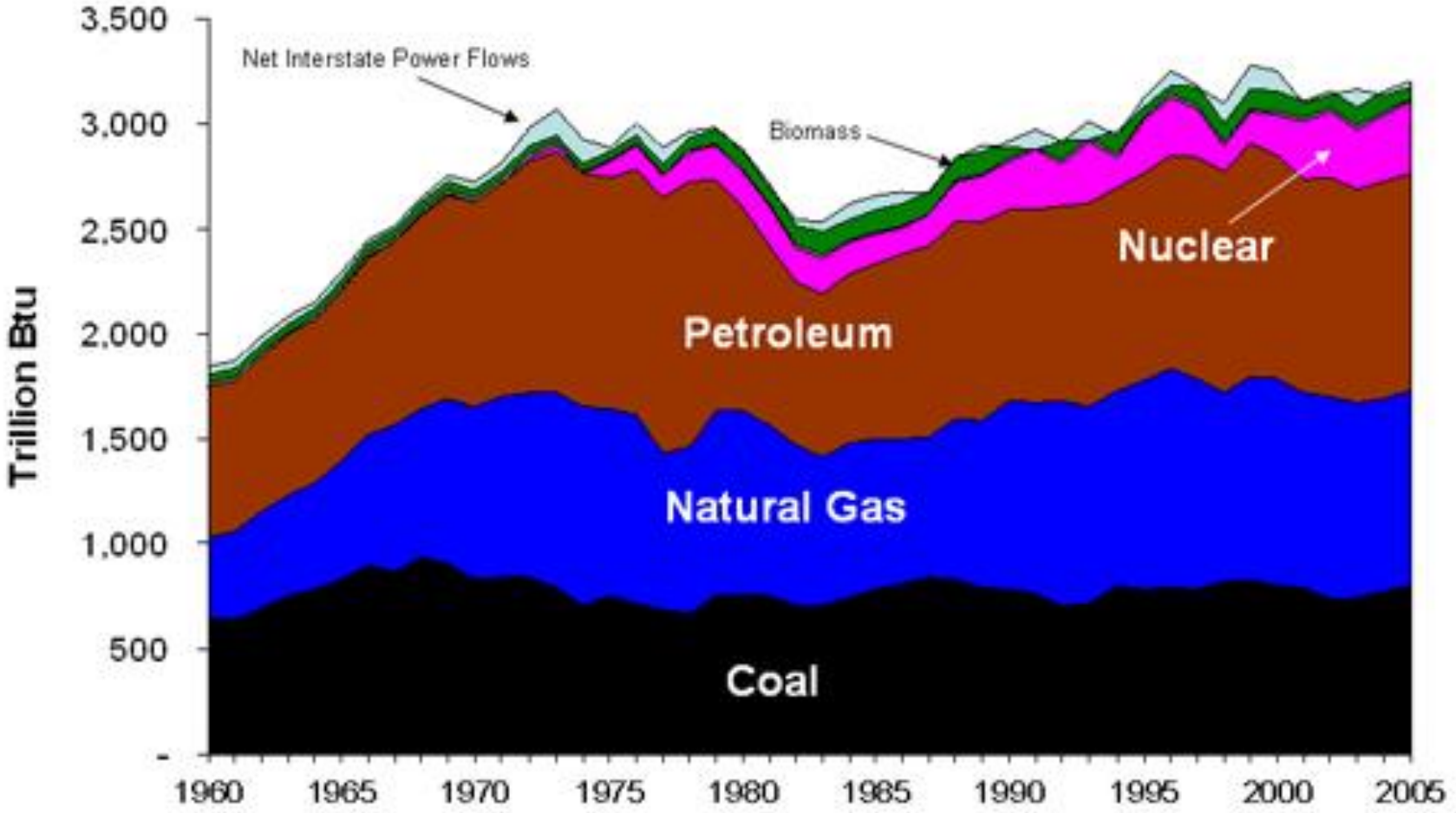
Electricity use and losses are included in each sector



Source: State Energy Data Report, Energy Information Administration,
Graph prepared by: Energy Data and Security, Michigan Public Service Commission

Total Energy Use in Michigan

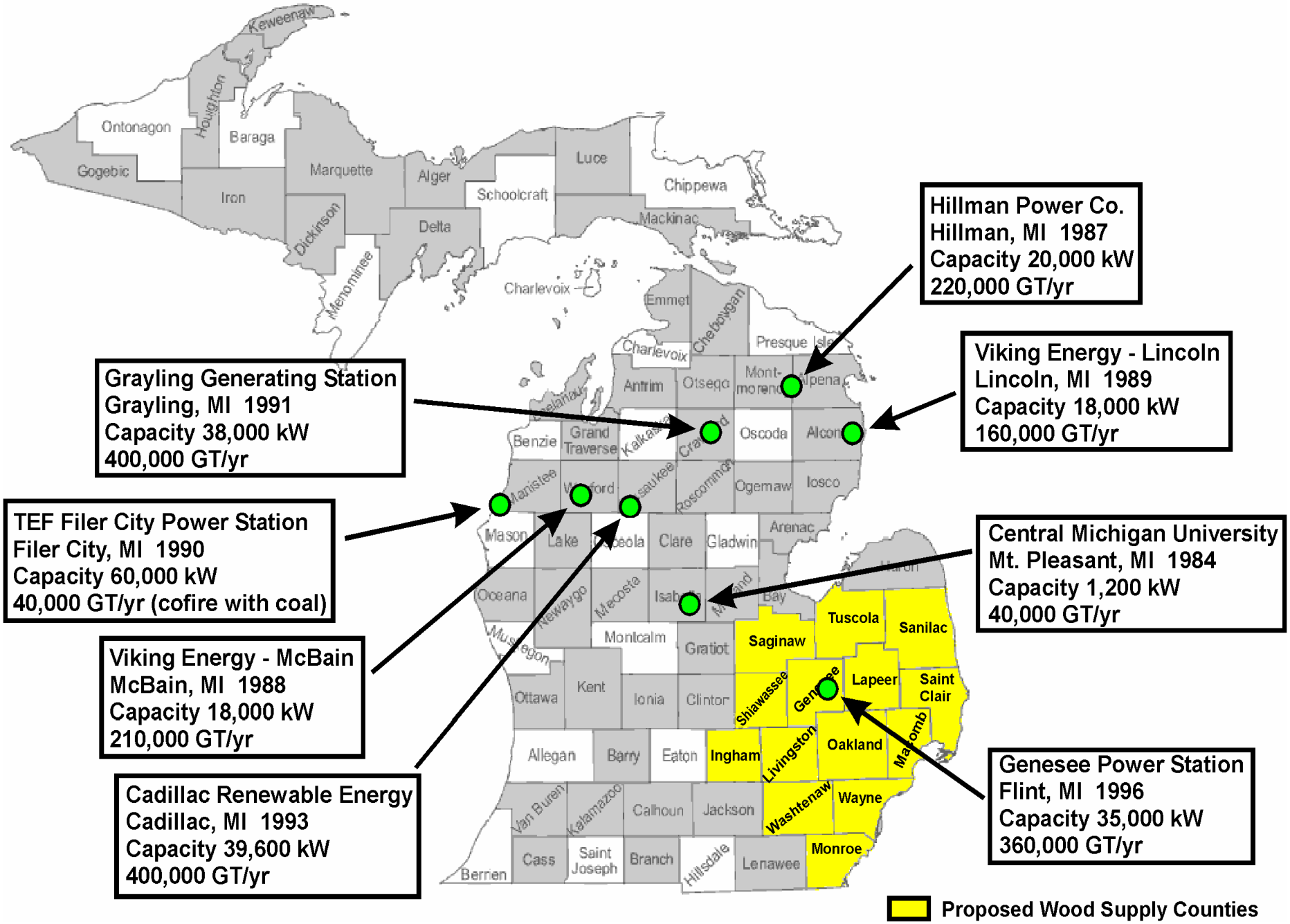
Includes the primary energy used to generate electricity



Source: State Energy Data Report, Energy Information Administration,
Graph prepared by: Energy Data and Security, Michigan Public Service Commission

“About 4 percent of the electricity production in Michigan is currently derived from renewable energy sources. Michigan is a major generator of electricity from wood and wood waste, with about 1 percent of the state's electricity produced at a half dozen wood-burning power plants....”

“In recent years, methane recovered from landfills is being captured and converted to electricity. Electricity from landfill gas and municipal waste incinerators adds almost another 1 percent to Michigan's electric power mix. *- MPSC, 2008*

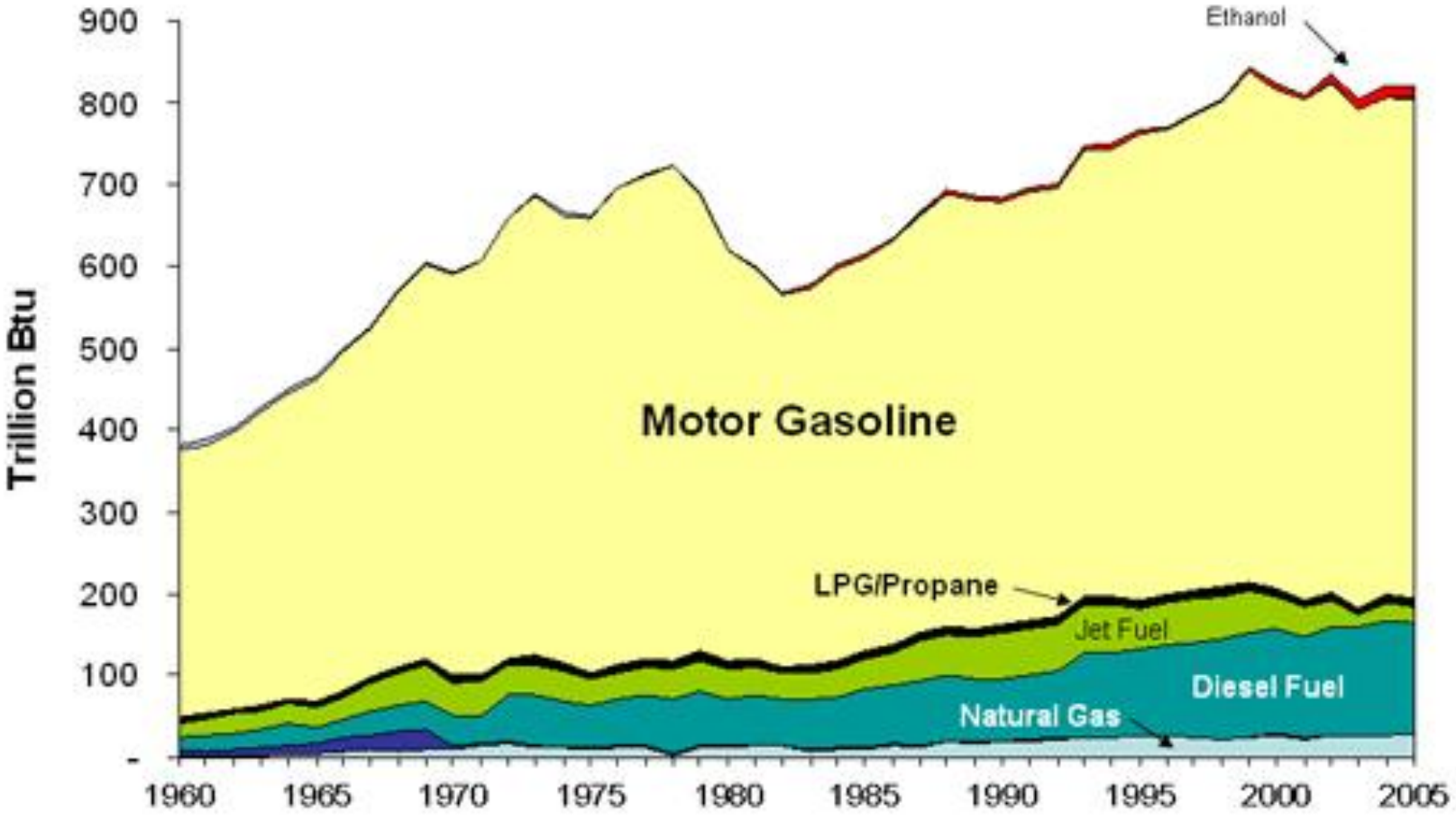

Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Alger
Luce
Chippewa
Iron
Schoolcraft
Mackinac
Dickinson
Delta
Menominee
Charlevoix
Emmet
Cheboygan
Presque Isle
Antrim
Otsego
Montmorency
Alpena
Benzie
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Huron
Muskegon
Montcalm
Gratiot
Saginaw
Tuscola
Sanilac
Ottawa
Kent
Ionia
Clinton
Shiawassee
Genesee
Lapeer
Saint Clair
Allegan
Barry
Eaton
Ingham
Livingston
Oakland
Macomb
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
Saint Joseph
Branch
Hillsdale
Lenawee
Monroe
Hillman Power Co.
Hillman, MI 1987
Capacity 20,000 kW
220,000 GT/yr
Viking Energy - Lincoln
Lincoln, MI 1989
Capacity 18,000 kW
160,000 GT/yr
Grayling Generating Station
Grayling, MI 1991
Capacity 38,000 kW
400,000 GT/yr
TEF Filer City Power Station
Filer City, MI 1990
Capacity 60,000 kW
40,000 GT/yr (cofire with coal)
Central Michigan University
Mt. Pleasant, MI 1984
Capacity 1,200 kW
40,000 GT/yr
Viking Energy - McBain
McBain, MI 1988
Capacity 18,000 kW
210,000 GT/yr
Cadillac Renewable Energy
Cadillac, MI 1993
Capacity 39,600 kW
400,000 GT/yr
Genesee Power Station
Flint, MI 1996
Capacity 35,000 kW
360,000 GT/yr
Proposed Wood Supply Counties

For transportation fuels, Michigan currently has five operating ethanol plants with a combined capacity of 256 million gallons per year and others are under construction.

In 2006 Michigan used 1.3 million gallons of E-85 which is a blend containing 85 percent ethanol. In addition, much of the gasoline sold in Michigan is blended with 10 percent ethanol. Four biodiesel production plants are in operation producing between 25 and 35 million gallons / yr.

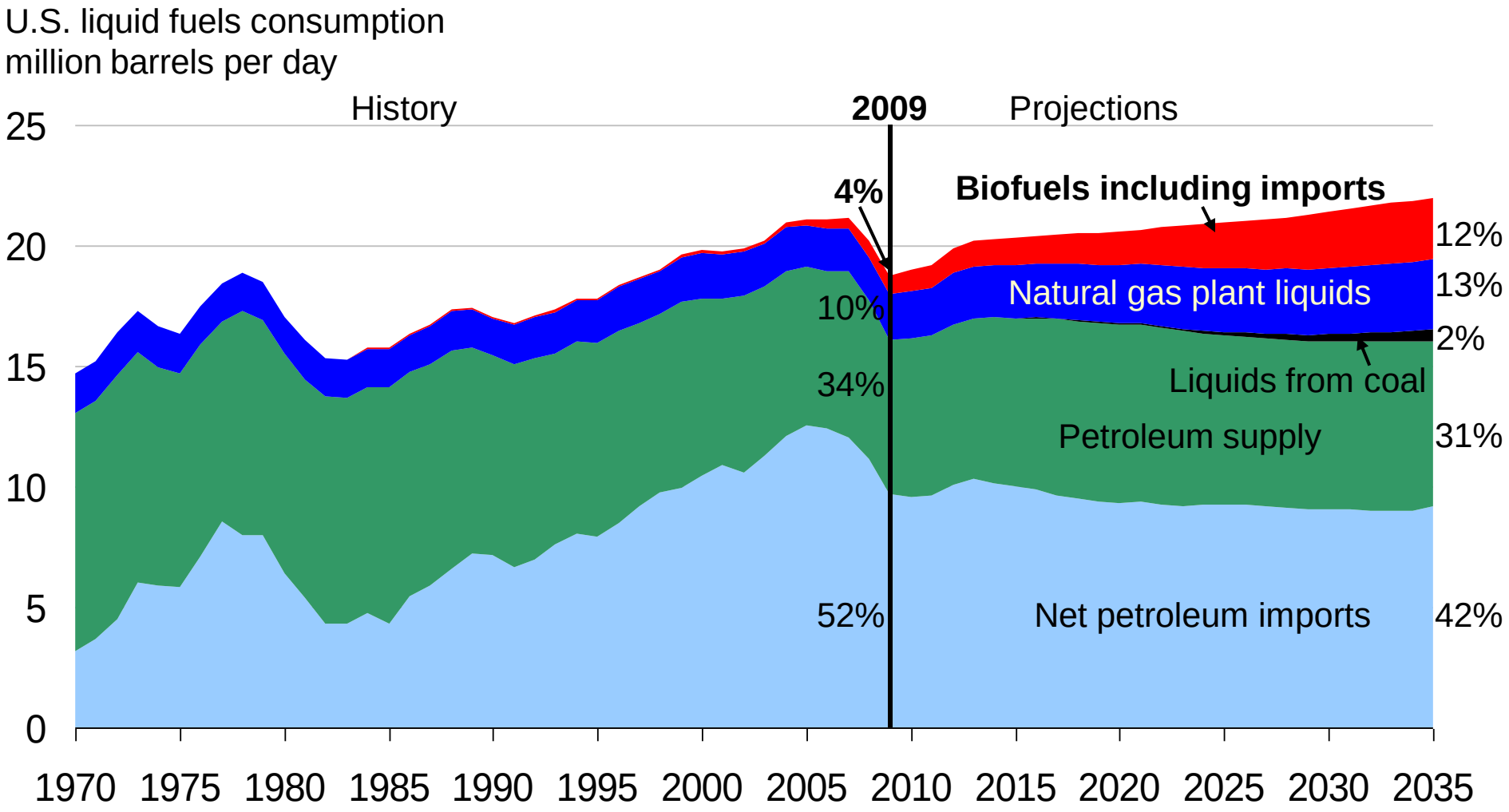
In 2007, Michigan used about 4,600 million gallons of gasoline.

Transportation Energy Use in Michigan



Source: State Energy Data Report, Energy Information Administration,
Graph prepared by: Energy Data and Security, Michigan Public Service Commission

U.S. imports of liquid fuels fall due to increased domestic production—including biofuels—and greater fuel efficiency



Source: EIA, *Annual Energy Outlook 2011*

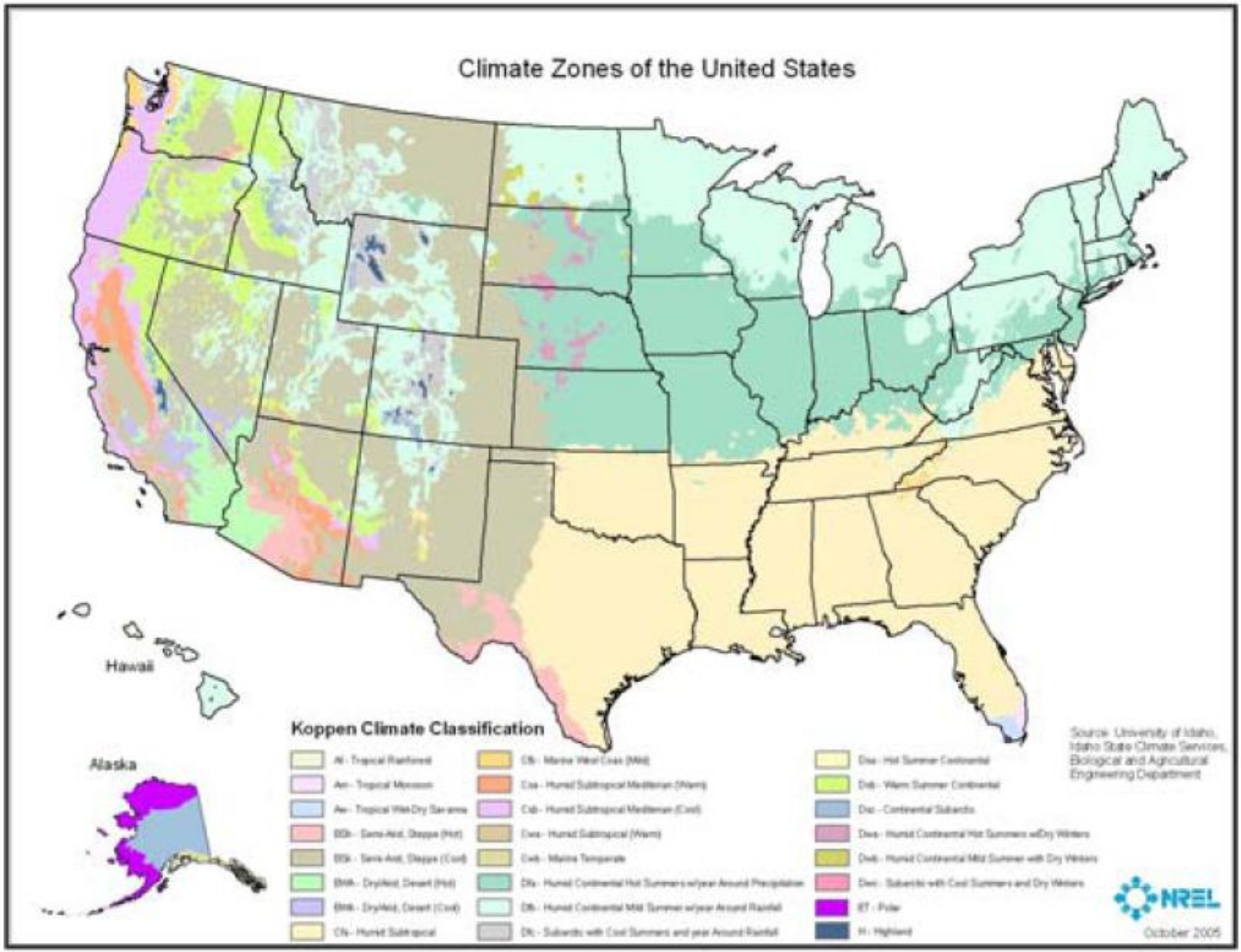
Prospecting for Biomass ?

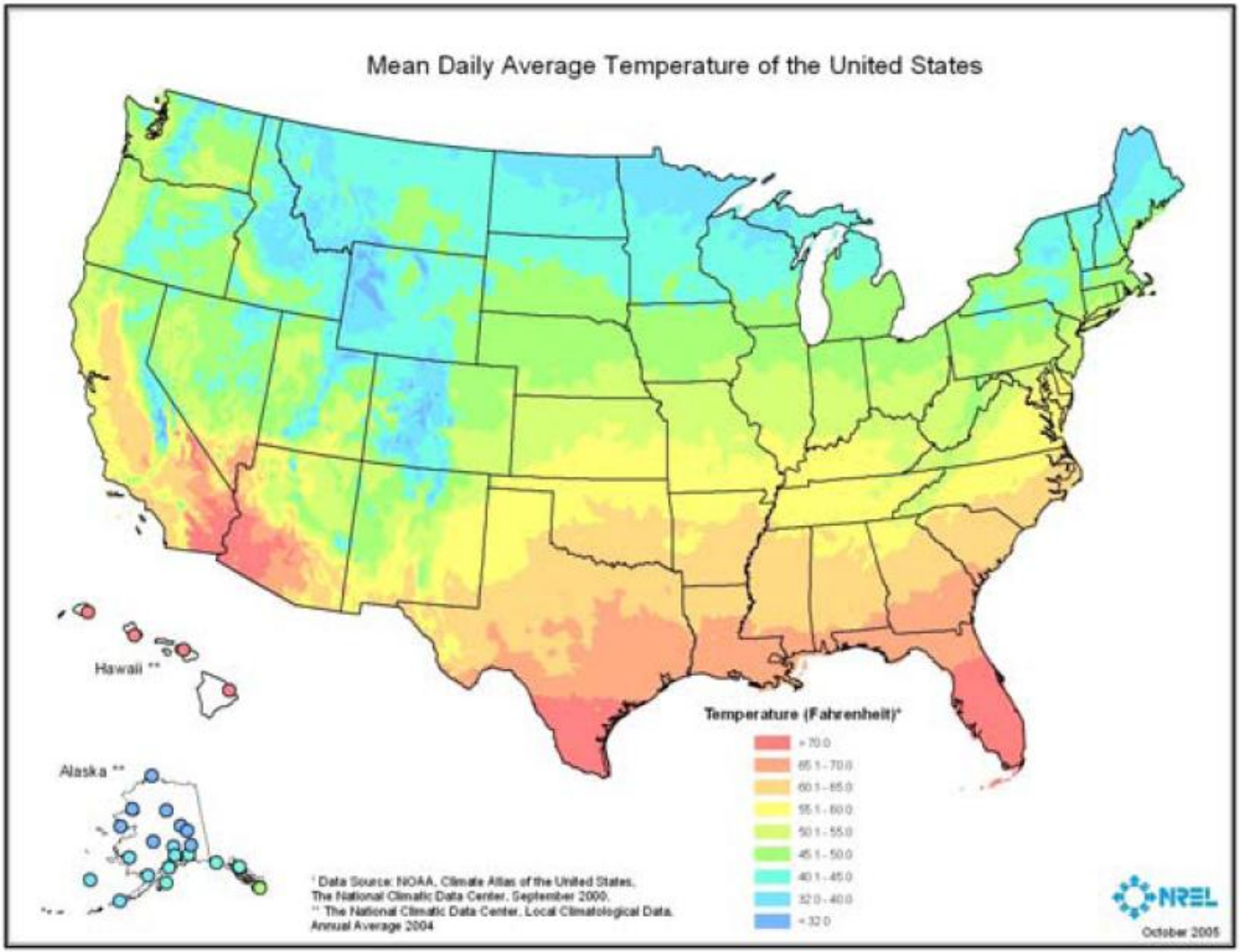
A Geographic Perspective on the Current Biomass Resource Availability in the United States

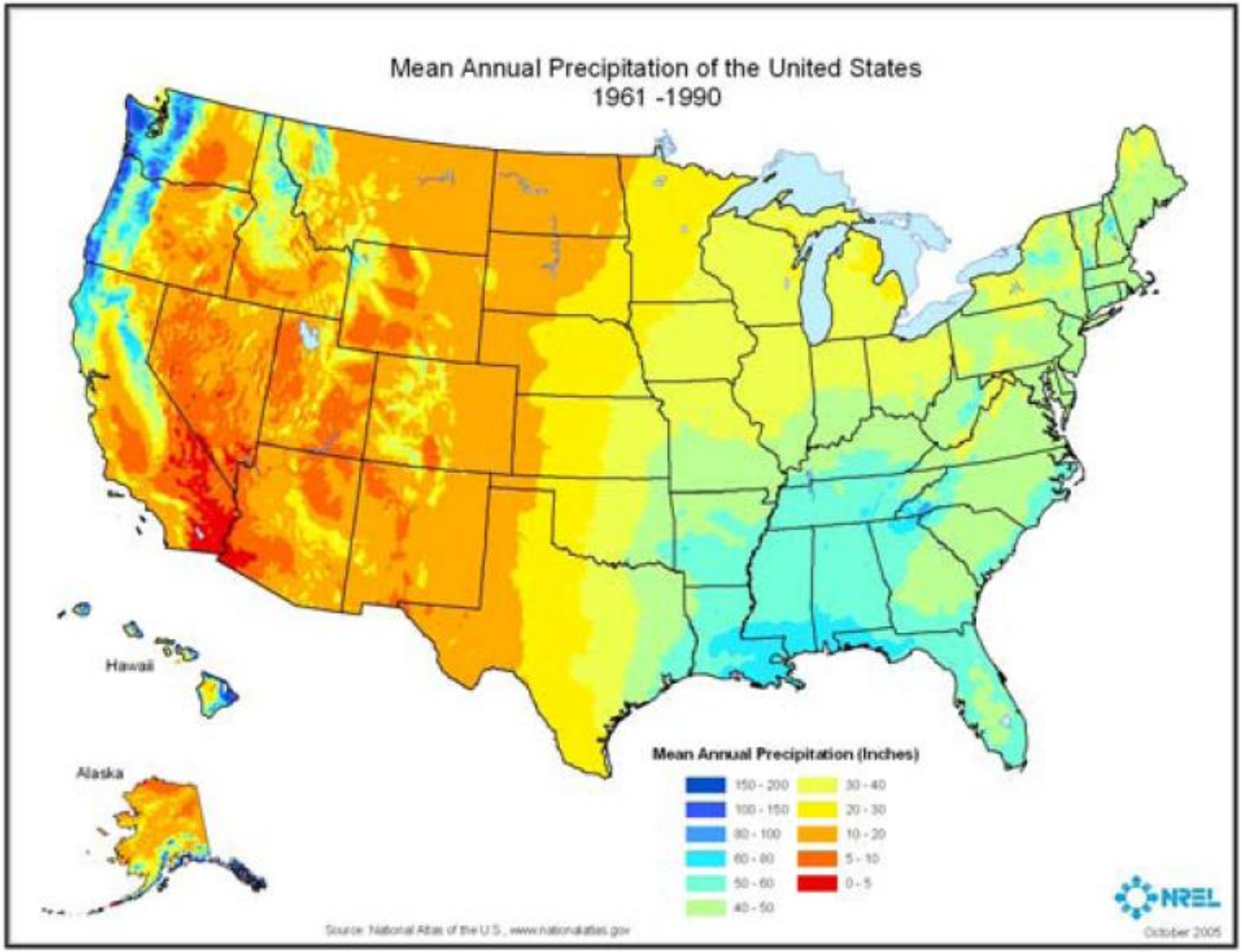
A. Milbrandt

(2005)

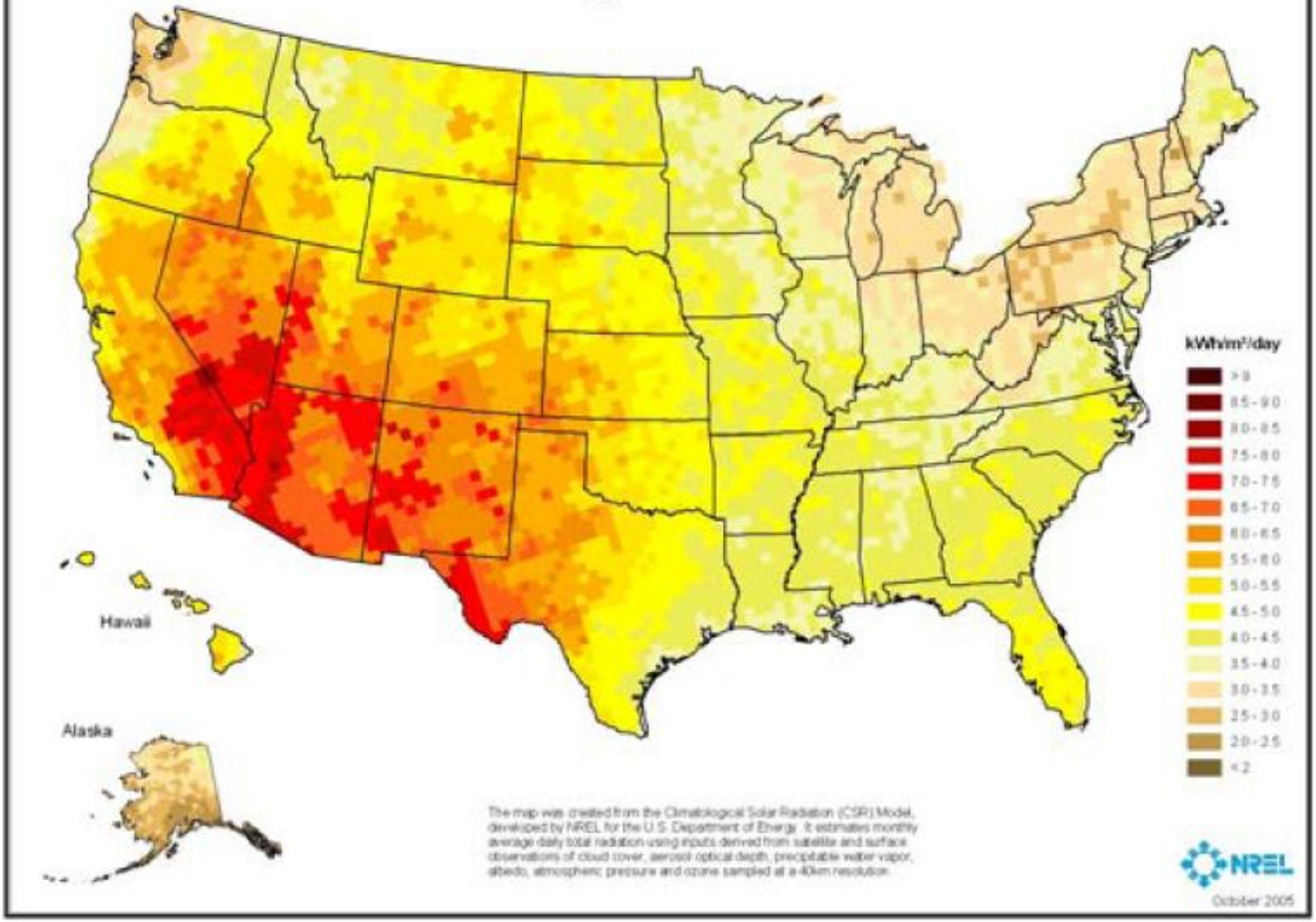
NREL National Renewable Energy Laboratory


Climate Zones of the United States
Hawaii
Alaska
Koppen Climate Classification
Source: University of Idaho, Idaho State Climate Services, Biological and Agricultural Engineering Department
NREL
October 2005


Mean Daily Average Temperature of the United States
Hawaii **
Alaska **
Temperature (Fahrenheit)*
> 70.0
65.1 - 70.0
60.1 - 65.0
55.1 - 60.0
50.1 - 55.0
45.1 - 50.0
40.1 - 45.0
32.0 - 40.0
< 32.0
* Data Source: NOAA, Climate Atlas of the United States, The National Climatic Data Center, September 2000.
** The National Climatic Data Center, Local Climatological Data, Annual Average 2004
NREL
October 2005


Mean Annual Precipitation of the United States
1961 -1990
Hawaii
Alaska
Mean Annual Precipitation (Inches)
150 - 200
100 - 150
80 - 100
60 - 80
50 - 60
40 - 50
30 - 40
20 - 30
10 - 20
5 - 10
0 - 5
Source: National Atlas of the U.S., www.nationalatlas.gov
NREL
October 2005

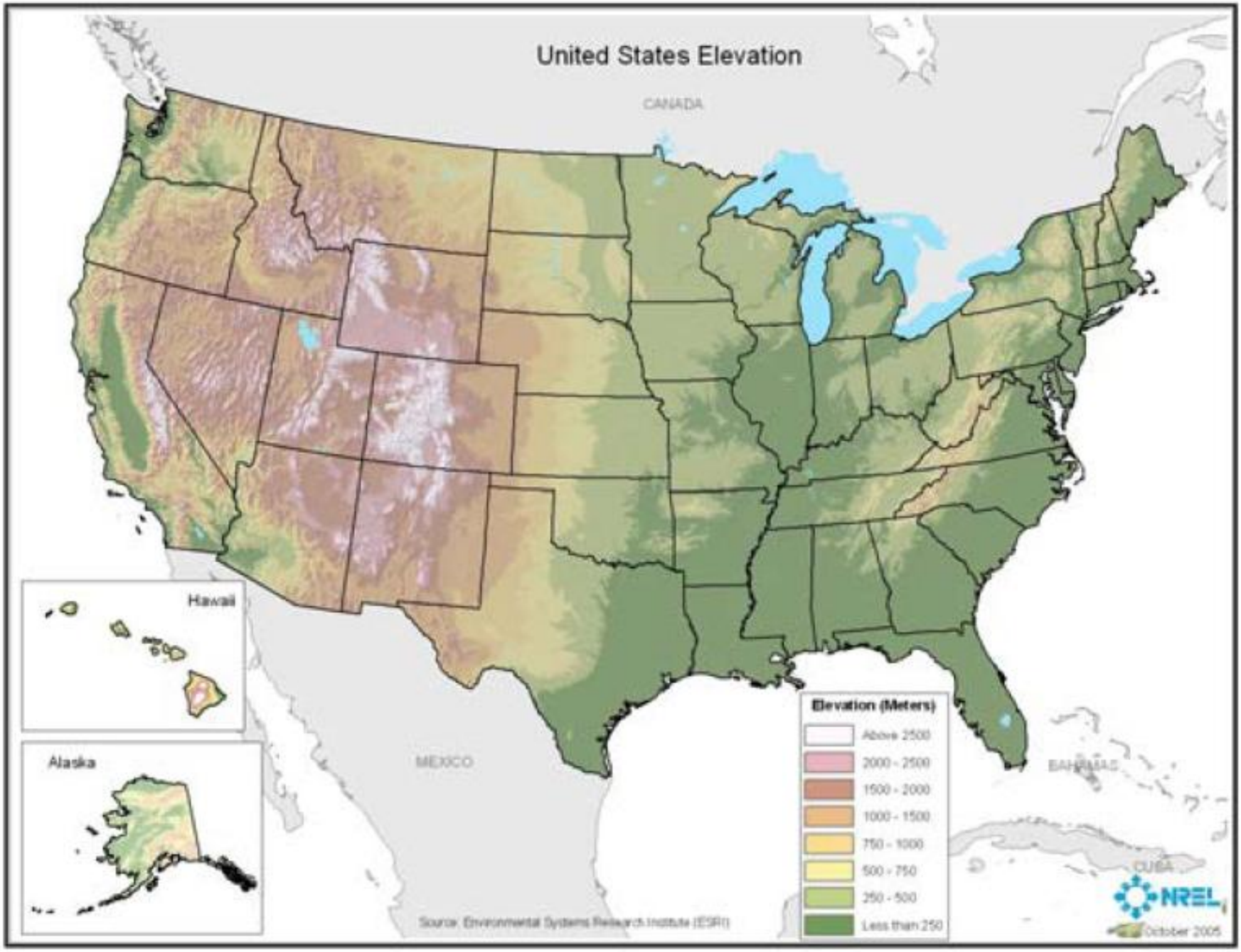
Annual Average Direct Normal Solar Radiation

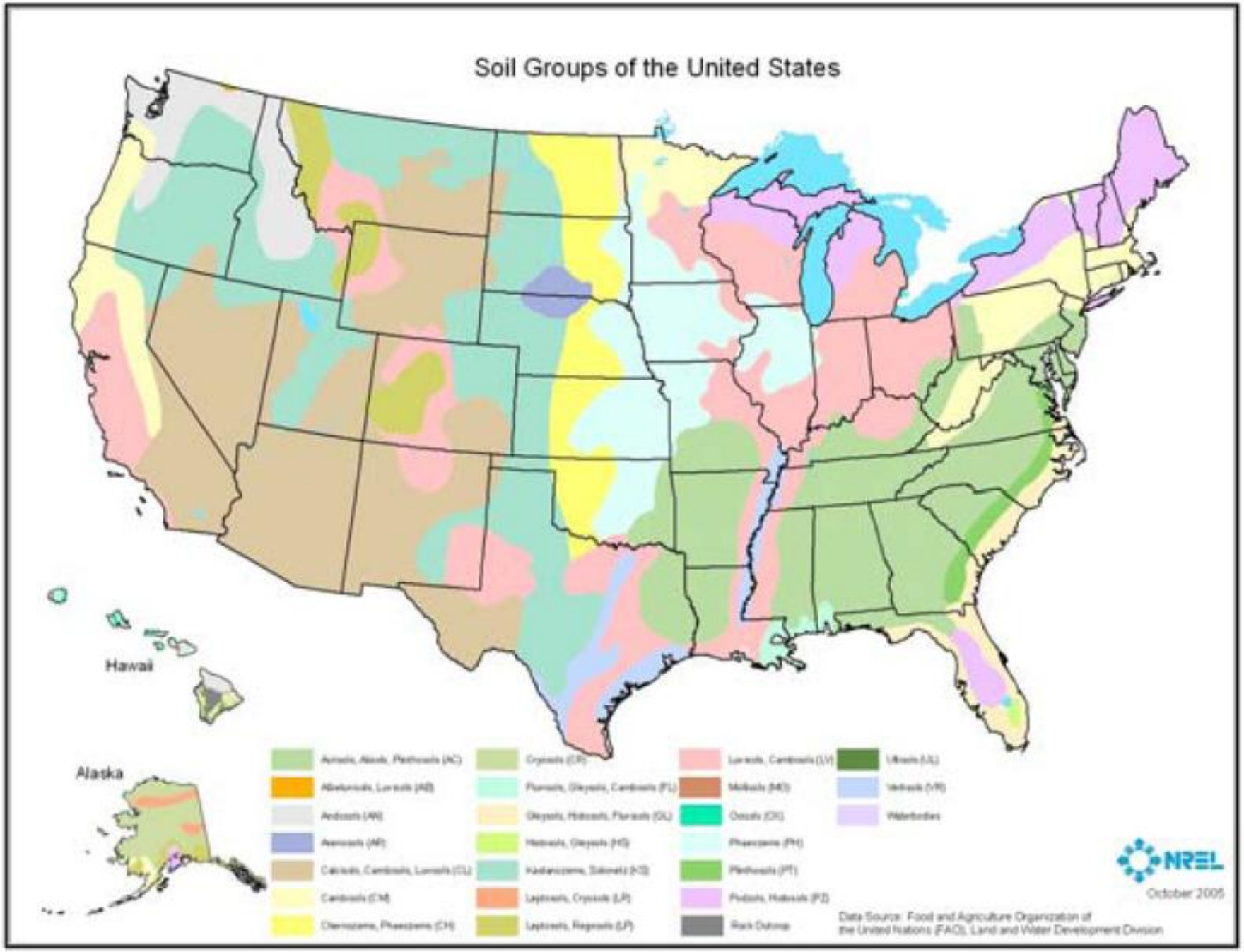


The map was created from the Climatological Solar Radiation (CSR) Model, developed by NREL for the U.S. Department of Energy. It estimates monthly average daily total radiation using inputs derived from satellite and surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone sampled at a 40km resolution.

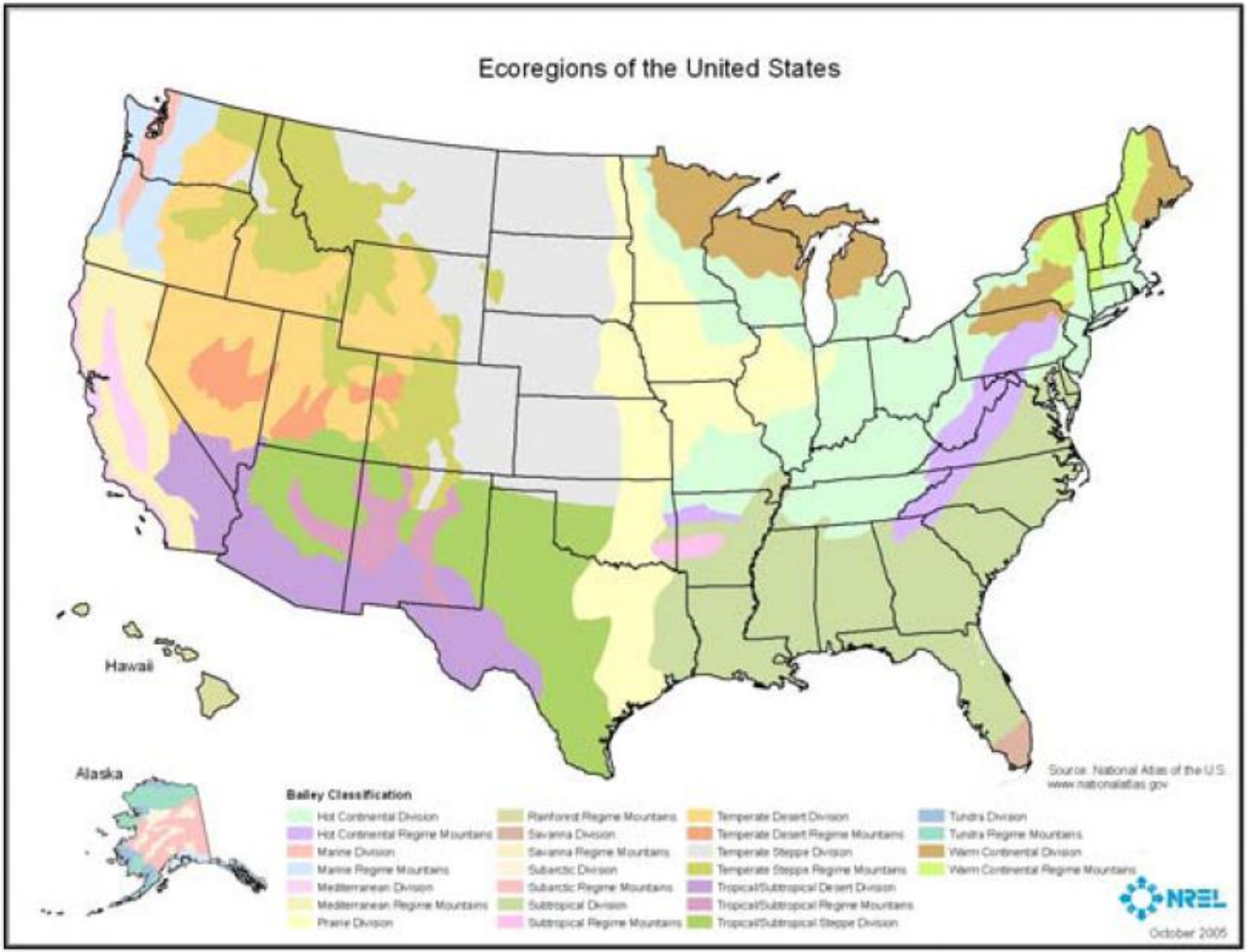
NREL

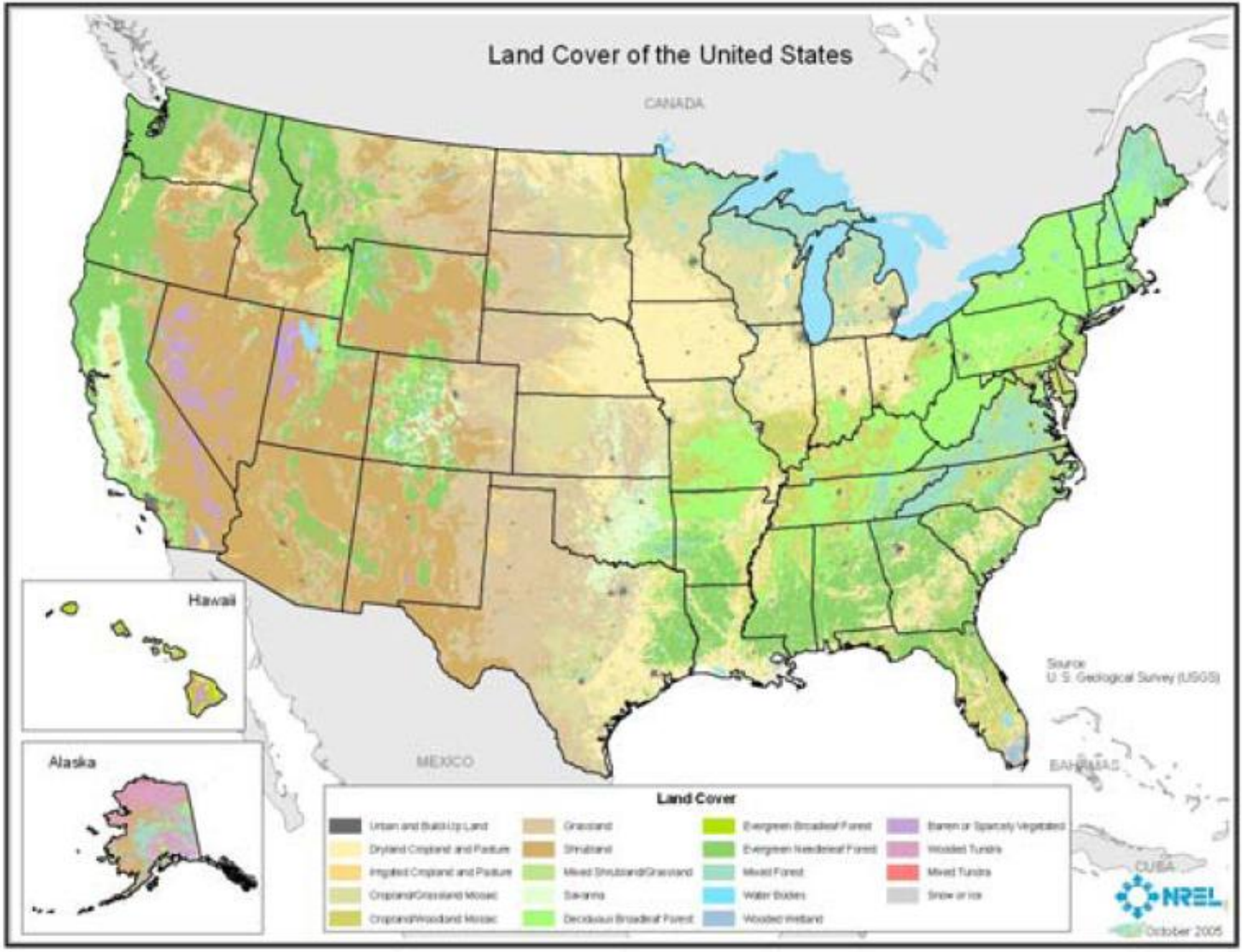
October 2005

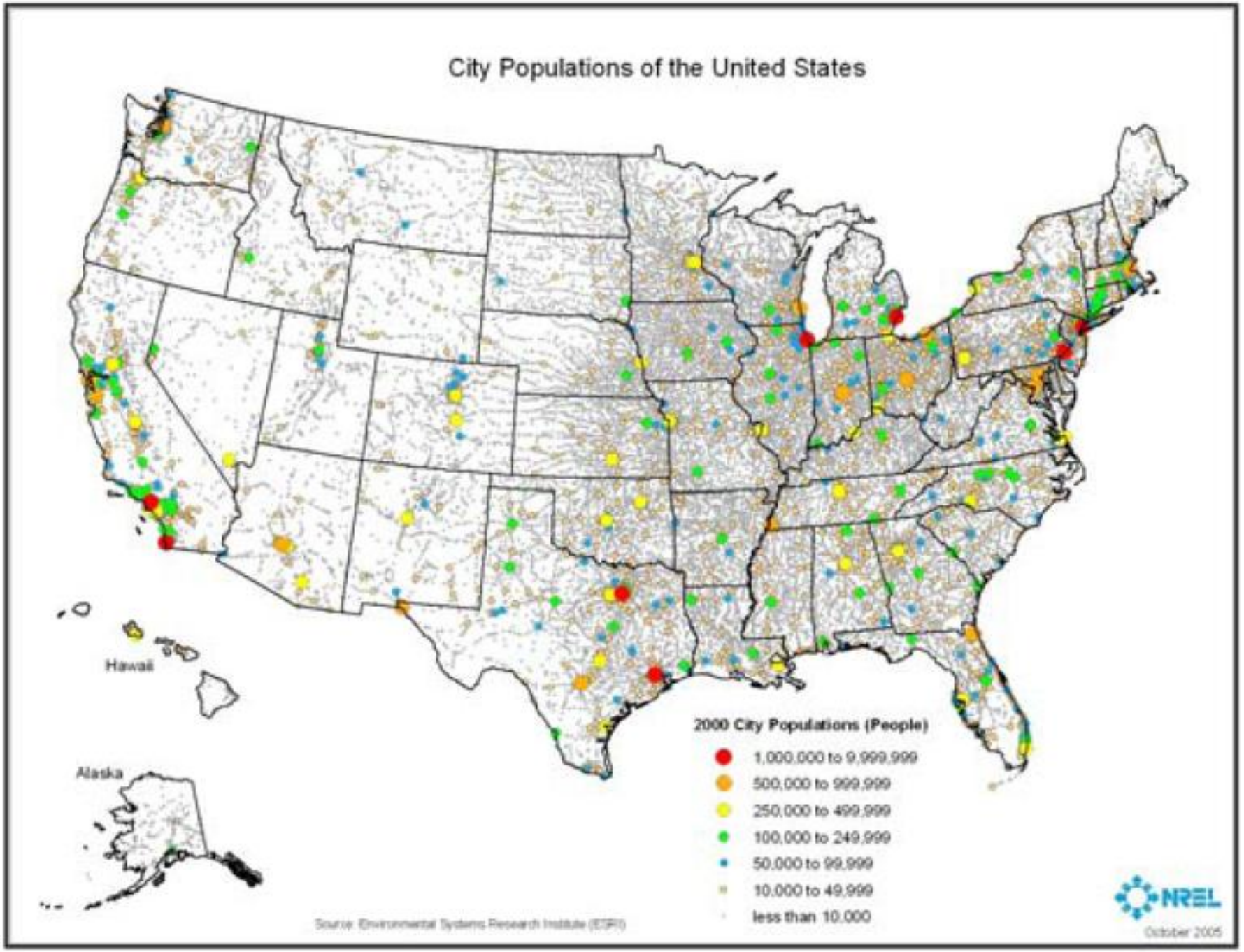

United States Elevation
CANADA
MEXICO
CUBA
BAHAMAS
Hawaii
Alaska
Elevation (Meters)
Above 2500
2000 - 2500
1500 - 2000
1000 - 1500
750 - 1000
500 - 750
250 - 500
Less than 250
Source: Environmental Systems Research Institute (ESRI)
NREL
October 2005

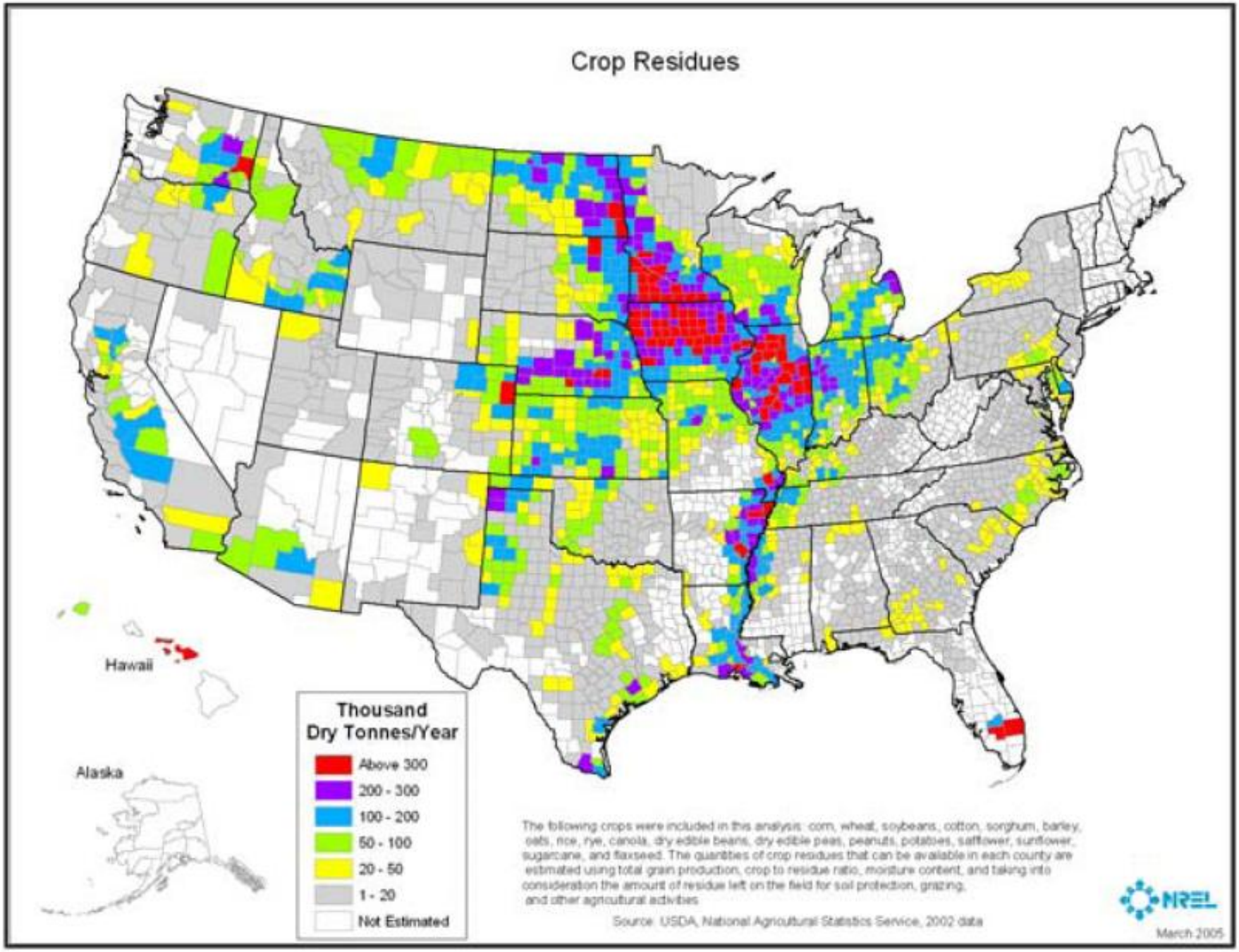

Soil Groups of the United States
Hawaii
Alaska
Aridisols, Alfisols, Mollisols (AC)
Andisols (AN)
Aridisols (AR)
Cambisols (CM)
Chernozems, Phaeozems (CH)
Cryosols (CR)
Gleysols, Histosols, Fluvisols (GL)
Histosols, Gleysols (HG)
Leptosols, Cryosols (LP)
Leptosols, Regosols (LP)
Luvisols, Cambisols (LV)
Mollisols (MO)
Oxisols (OX)
Phaeozems (PH)
Plinthosols (PT)
Podzols, Histosols (PZ)
Rock Outcrop
Ultisols (UL)
Vertisols (VR)
Waterbodies
NREL
October 2005
Data Source: Food and Agriculture Organization of the United Nations (FAO), Land and Water Development Division

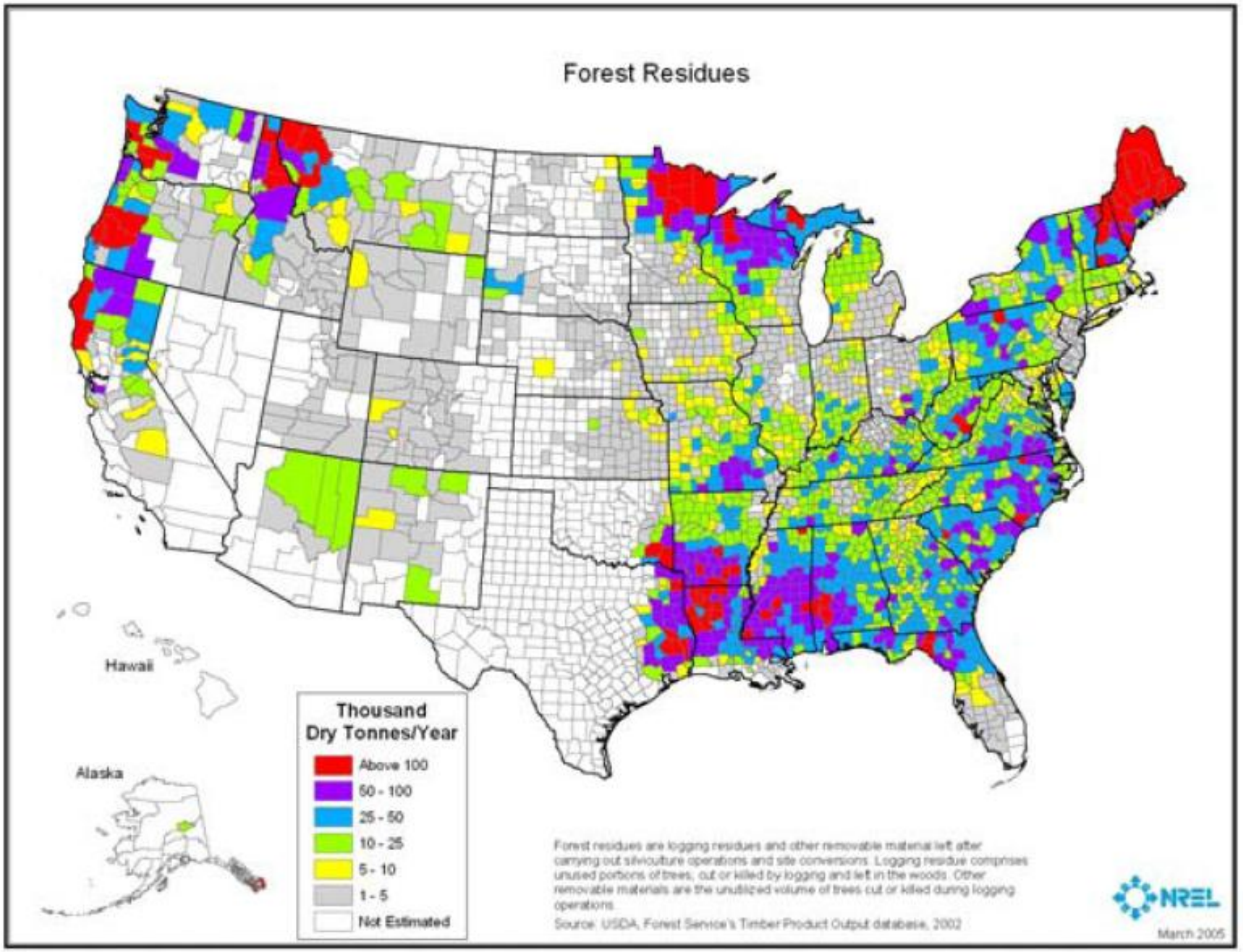
Ecoregions of the United States




Land Cover of the United States
CANADA
MEXICO
CUBA
BAHAMAS
Hawaii
Alaska
Source:
U.S. Geological Survey (USGS)
Land Cover
Urban and Built-Up Land
Dryland Cropland and Pasture
Irrigated Cropland and Pasture
Cropland/Grassland Mosaic
Cropland/Woodland Mosaic
Grassland
Shrubland
Mixed Shrubland/Grassland
Savanna
Deciduous Broadleaf Forest
Evergreen Broadleaf Forest
Evergreen Needleleaf Forest
Mixed Forest
Water Bodies
Wooded Wetland
Barren or Sparsely Vegetated
Wooded Tundra
Mixed Tundra
Snow or Ice
NREL
October 2005


City Populations of the United States
Hawaii
Alaska
2000 City Populations (People)
1,000,000 to 9,999,999
500,000 to 999,999
250,000 to 499,999
100,000 to 249,999
50,000 to 99,999
10,000 to 49,999
less than 10,000
Source: Environmental Systems Research Institute (ESRI)
NREL
October 2005


Crop Residues
Hawaii
Alaska
Thousand Dry Tonnes/Year
Above 300
200 - 300
100 - 200
50 - 100
20 - 50
1 - 20
Not Estimated
The following crops were included in this analysis: corn, wheat, soybeans, cotton, sorghum, barley, oats, rice, rye, canola, dry edible beans, dry edible peas, peanuts, potatoes, safflower, sunflower, sugarcane, and flaxseed. The quantities of crop residues that can be available in each county are estimated using total grain production, crop to residue ratio, moisture content, and taking into consideration the amount of residue left on the field for soil protection, grazing, and other agricultural activities
Source: USDA, National Agricultural Statistics Service, 2002 data
NREL
March 2005

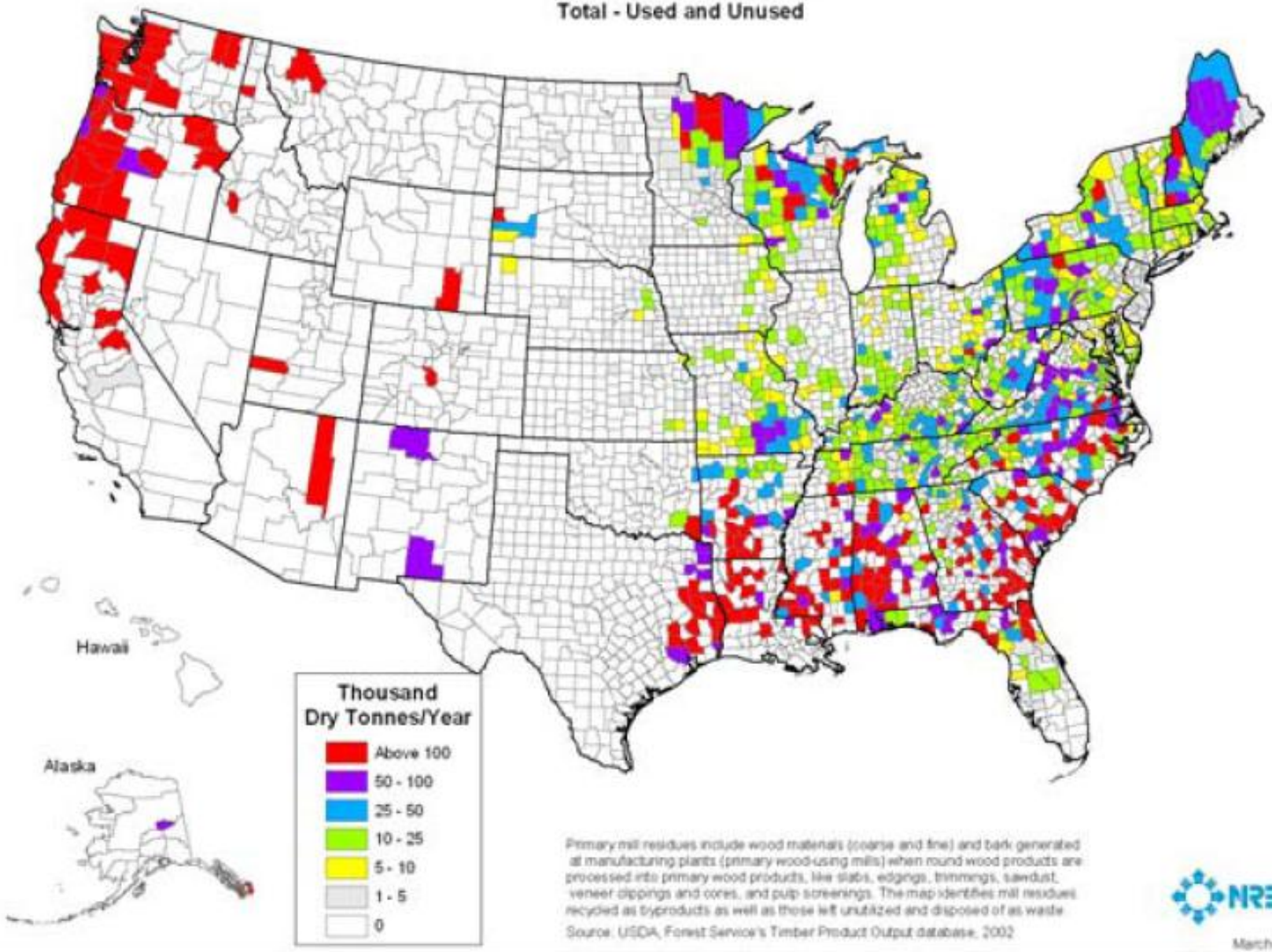

Forest Residues
Hawaii
Alaska
Thousand
Dry Tonnes/Year
Above 100
50 - 100
25 - 50
10 - 25
5 - 10
1 - 5
Not Estimated
Forest residues are logging residues and other removable material left after carrying out silviculture operations and site conversions. Logging residue comprises unused portions of trees, 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

Primary mill residue data by county was derived from the USDA Forest Service's Timber Product Output database for 2002. Primary mill residues are composed of 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. It includes mill residues recycled as byproducts as well as those left un-utilized and disposed of as waste[5]. Figure 14 shows the primary mill residues recycled as byproducts (fuel or fiber) as well as those left un-utilized and disposed of as waste. Figure 15 depicts mill residues not being used for any byproduct. This includes mill residues burned as waste or landfilled. Table 4 illustrates the results by state. Refer to the Analysis Methodology section of this paper for more information on the applied methodology (page 51).

Primary Mill Residues

Total - Used and Unused



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.

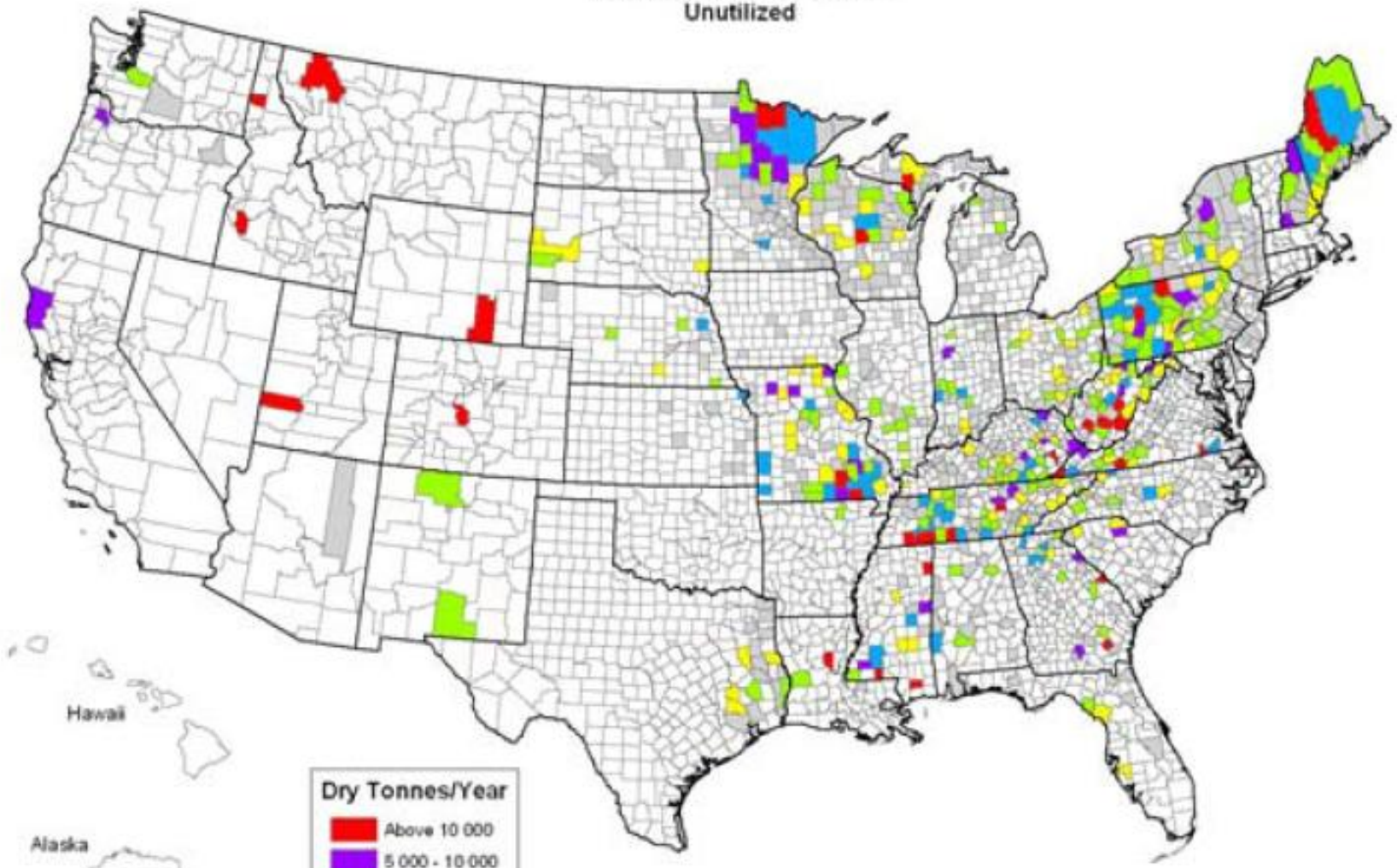
Source: USDA, Forest Service's Timber Product Output database, 2002

NREL

March 2005

Primary Mill Residues

Unutilized



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

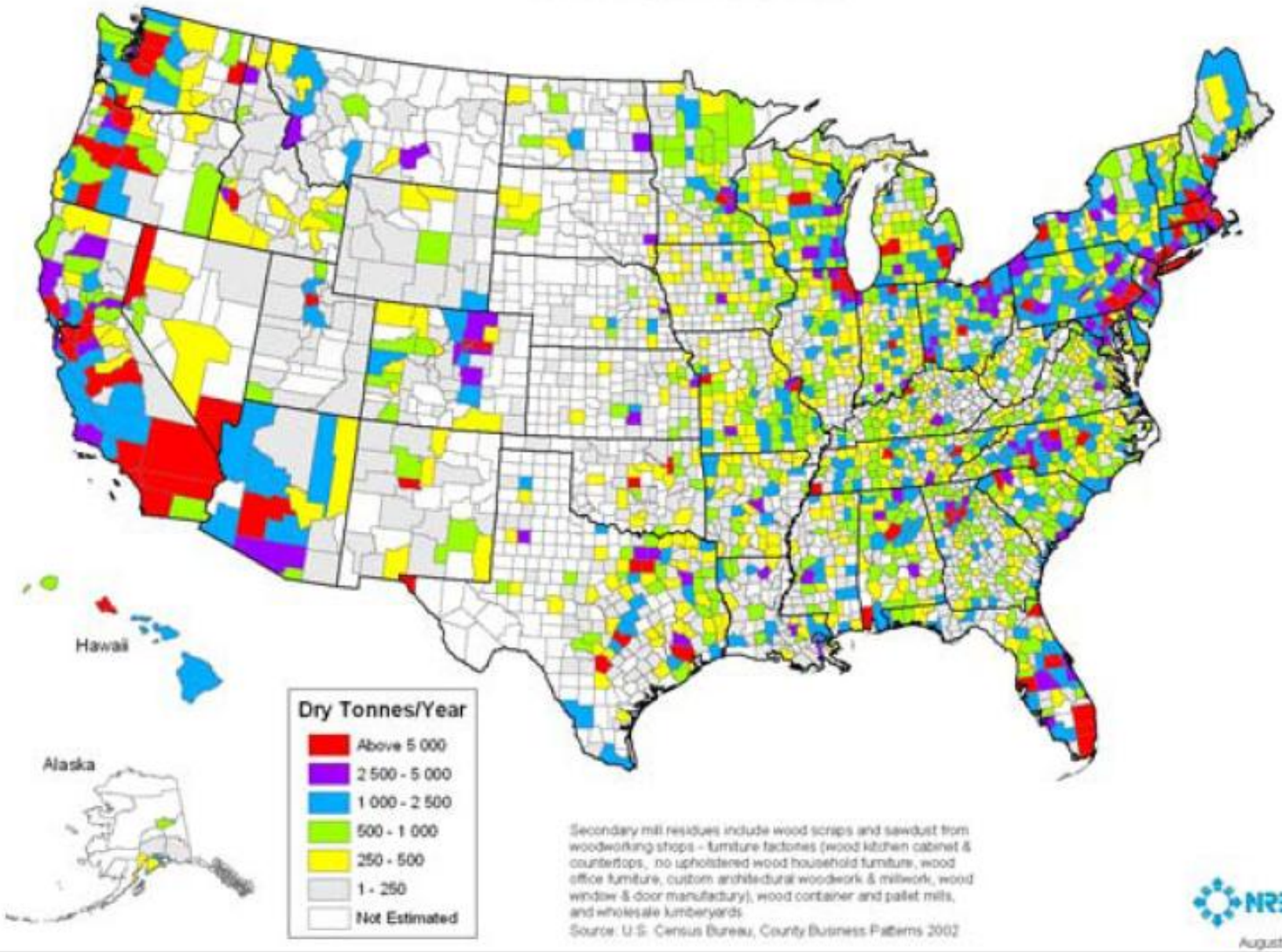
March 2005

Secondary Mill Residues

Secondary mill residues include wood scraps and sawdust from woodworking shops—furniture factories, wood container and pallet mills, and wholesale lumberyards. The following business categories were included in this analysis:

- Furniture factories: wood kitchen cabinet and countertop, non upholstered wood household furniture, wood office furniture, custom architectural woodwork and millwork, and wood window and door manufacturers
- Millwork: cut stock, re sawing lumber and planning, and other millwork (including flooring)
- Truss manufacturing
- Wood container and pallet manufacturing
- Lumber, plywood, millwork and wood panel wholesale companies

Secondary Mill Residues



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

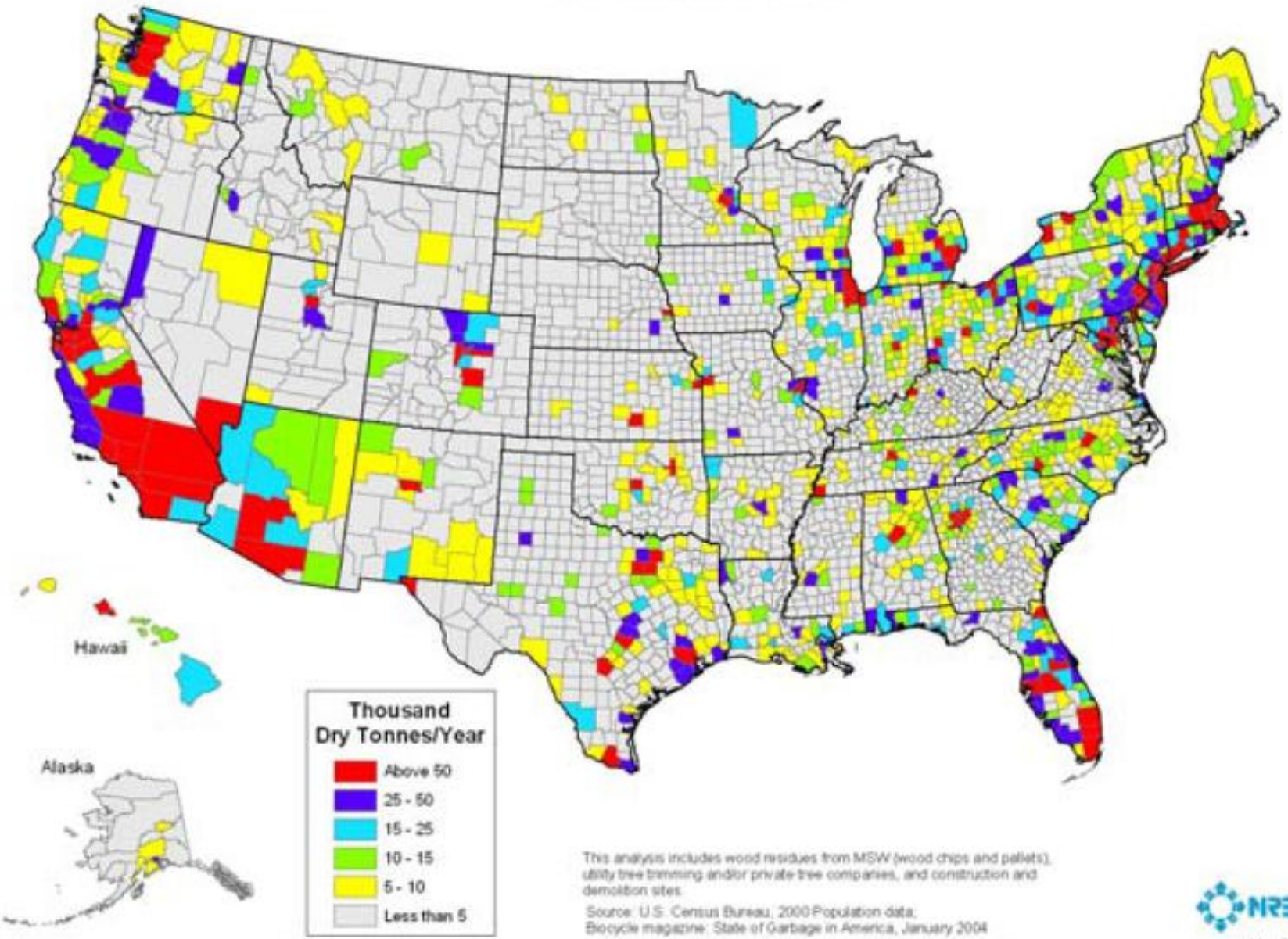
Urban Wood Residues - Definition

Three major categories of urban wood residues were considered in this study:

- MSW wood—wood chips, pallets, and yard waste
- Utility tree trimming and/or private tree companies
- Construction/demolition wood

Data on the collected urban wood waste are not available; thus numerous assumptions were applied for estimation. Please, refer to the Analysis Methodology section of this paper for more information (page 51). The results of this analysis are shown on Figure 17 and Table 6.

Urban Wood Residues

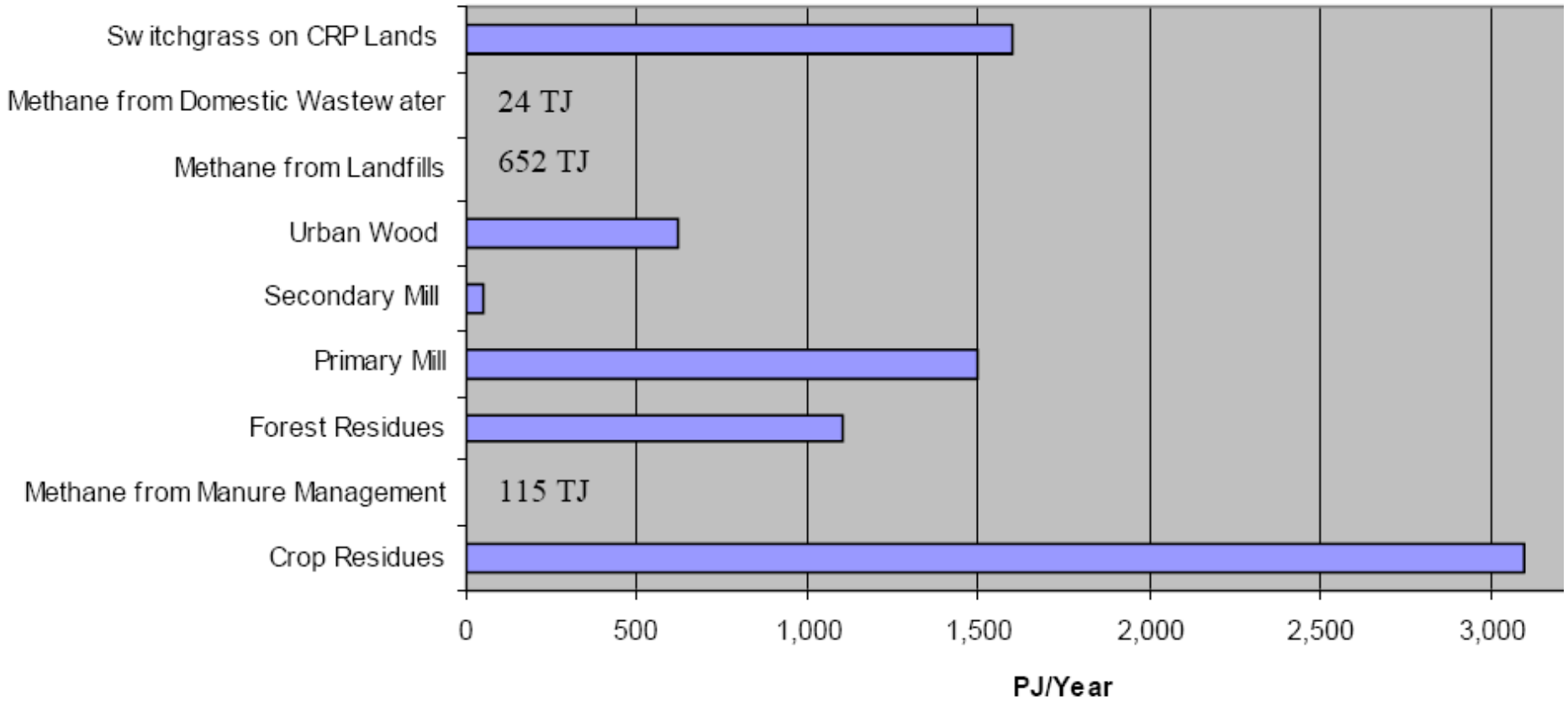


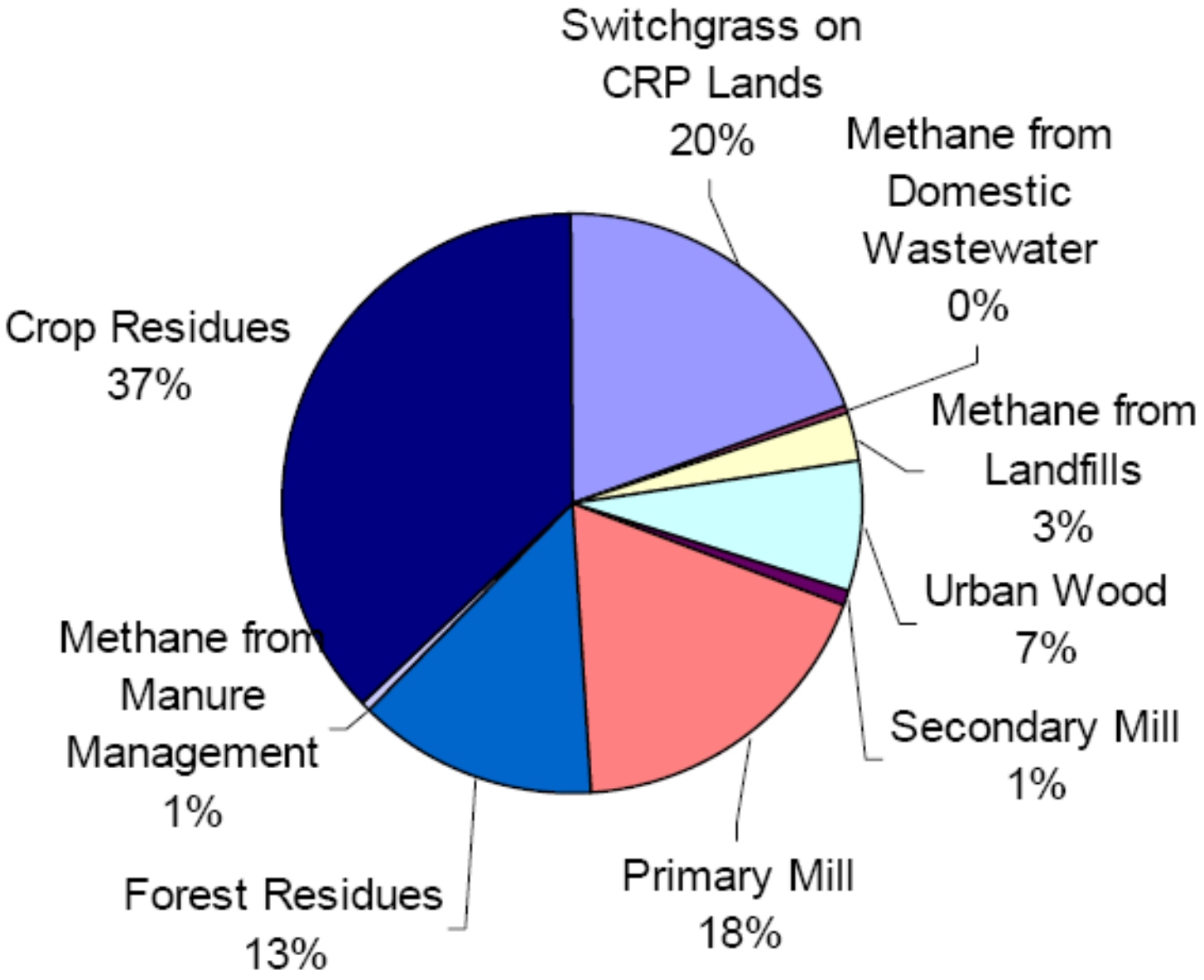
This analysis includes wood residues from MSW (wood chips and pallets), utility tree trimming and/or private tree companies, and construction and demolition sites.

Source: U.S. Census Bureau, 2000 Population data;
Biocycle magazine: State of Garbage in America, January 2004

NREL

May 2005


Estimated Total Biomass Available in the United States
Switchgrass on CRP Lands
Methane from Domestic Wastewater
Methane from Landfills
Urban Wood
Secondary Mill
Primary Mill
Forest Residues
Methane from Manure Management
Crop Residues
24 TJ
652 TJ
115 TJ
0
500
1,000
1,500
2,000
2,500
3,000
PJ/Year


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%


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
Miscanthus
Switchgrass
Hybrid Poplars
Silver Maple
Reed Canarygrass
Black Locust
Sorghum
Eucalyptus
Eucalyptus

Forest residues

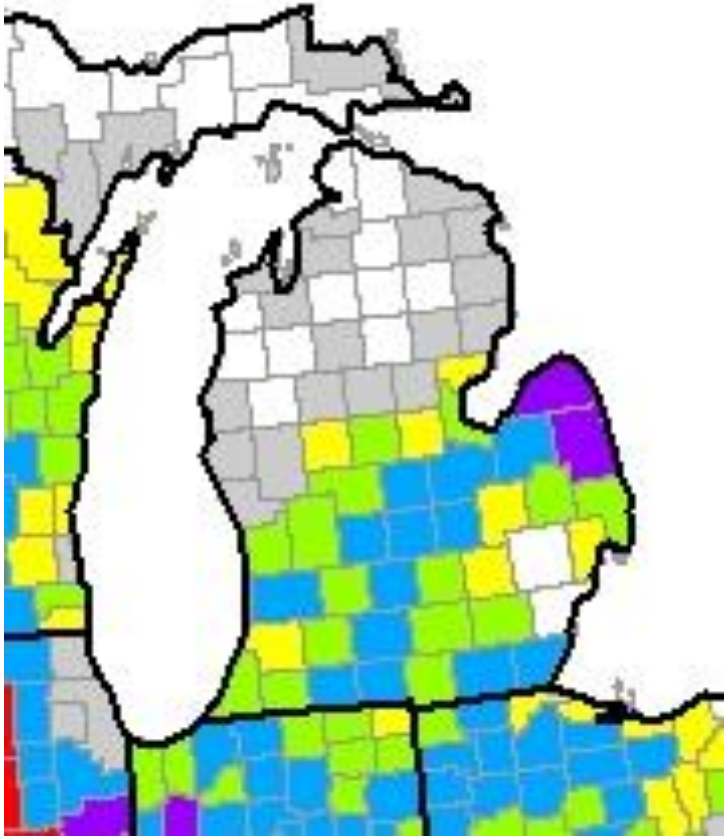
Primary mill residues

Secondary mill residues

Urban waste wood

“Potential” willow or hybrid poplar production on USDA Conservation Reserve program lands,

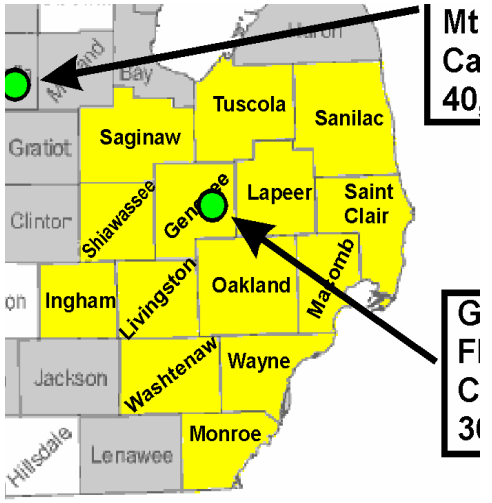
“Potential” switchgrass production on USDA Conservation Reserve program lands, by county



Crop residues

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

(South East Michigan 14 County Data)



County Name	Area sq miles	Yr 2000 population people	Forest residues ton/yr	Primary mill residues ton/yr	Secondary mill residues ton/yr	Urban wood residues ton/yr	TOTAL RESIDUES ton/yr
Genesee	649	436,141	3,277	0	1,697	57,250	**62,223**
Ingham	561	279,320	1,129	74	2,493	37,409	**41,104**
Lapeer	663	87,904	1,389	2,504	1,103	11,758	**16,754**
Livingston	586	156,951	1,952	0	882	20,758	**23,592**
Macomb	483	788,149	6,005	0	5,121	103,433	**114,559**
Monroe	556	145,945	688	0	1,098	19,023	**20,810**
Oakland	908	1,194,156	2,504	353	13,091	157,455	**173,403**
Saginaw	816	210,039	1,820	10,392	1,921	27,578	**41,712**
Sanilac	964	44,547	959	0	819	5,807	**7,584**
Shiawassee	541	71,687	1,156	0	283	9,444	**10,884**
St. Clair	724	164,235	1,634	6,380	841	22,208	**31,063**
Tuscola	814	58,266	1,505	1,134	27	7,795	**10,461**
Washtenaw	722	322,895	2,944	0	1,139	43,089	**47,172**
Wayne	617	2,061,162	8,194	0	10,193	268,665	**287,052**
Fourteen County Total	**9,605**	**6,021,397**	**35,157**	**20,838**	**40,707**	**791,670**	**888,371**

“Measures of Wood Resources in Lower Michigan: Wood Residues and the Saw Timber Content of Urban Forests”
(May, 2007)

Measures of Wood Resources in Lower Michigan:
Wood Residues and the Saw Timber Content of Urban Forests

May, 2007

This study was funded by the Southeast Michigan Resource Conservation and Development Council and the U.S. D.A. Forest Service.

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MSU – Univ. of Cincinnati Study

14 County Wood Residue Volumes Generated in 2005

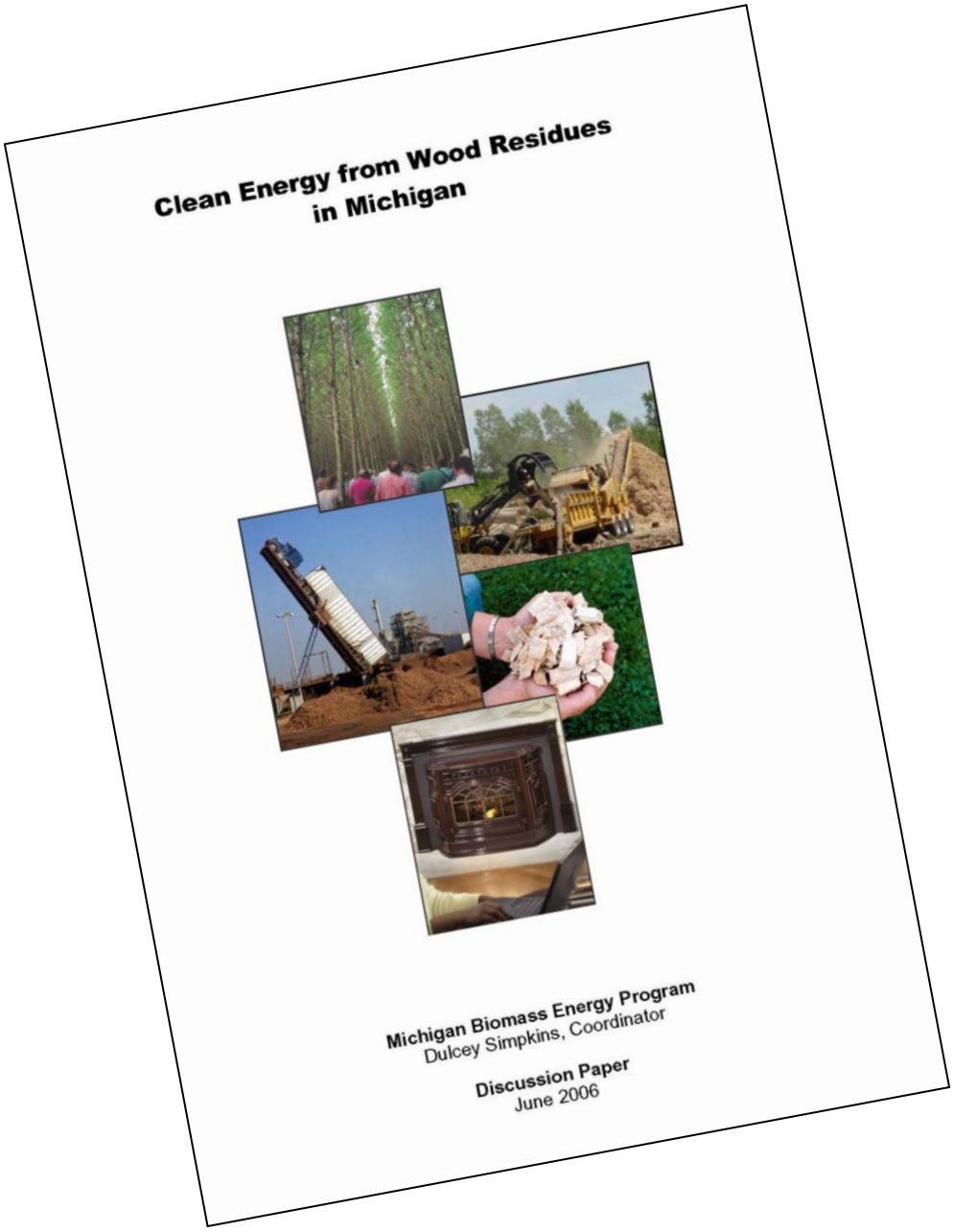
Residue Type	Total volume generated	Percent Discarded	Total volume discarded	Percent landfilled	Volume landfilled
	cubic yard	*%*	*cubic yard*	*%*	*cubic yard*
Palltets, Skids, Shipping Crates	505,000	16%	81,000	3%	15,000
Edgings and Cutoffs	2,646,000	60%	1,588,000	26%	675,000
Chips, Shavings, Sawdust	480,000	52%	250,000	23%	108,000
Construction Debris	3,828,000	63%	2,412,000	34%	1,302,000
Tree Trunks, Limbs, Stumps	84,000	47%	39,000	6%	5,000
Total volume (in cubic yards per year)	7,543,000	58%	4,370,000	28%	2,105,000
	tons		***tons***		***tons***
Total weight (tons per year)	**1,508,600**	**58%**	**874,000**	**28%**	**421,000**

based on 5 cubic yards per ton

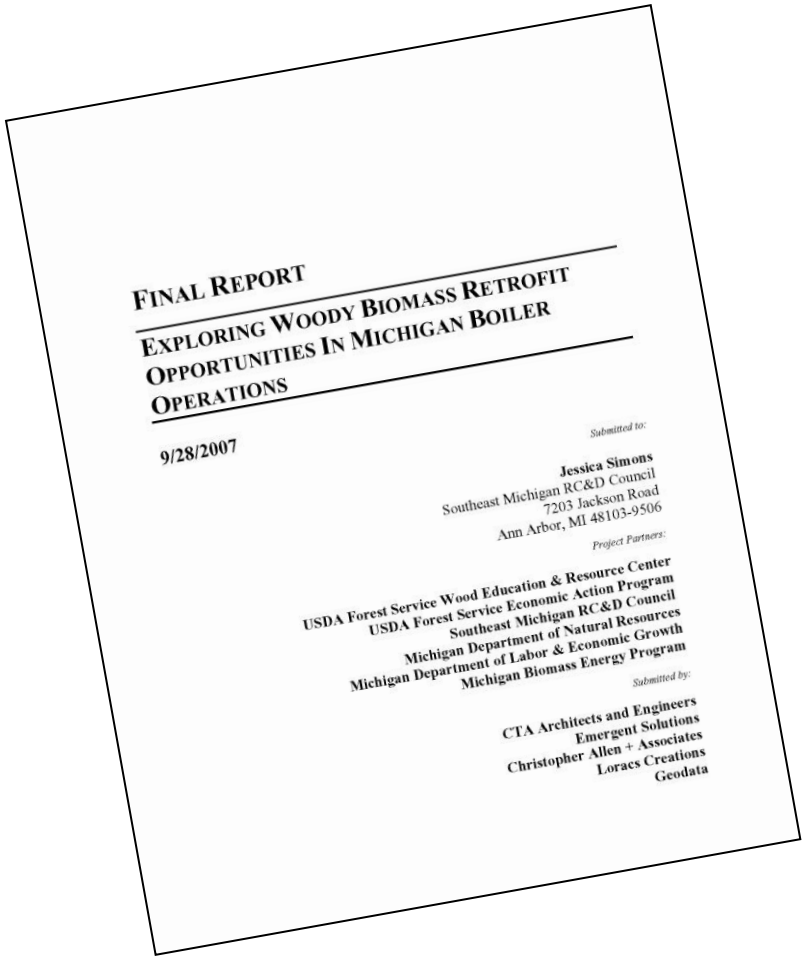
MI Energy Office

Biomass Energy Program

Clean Energy from Wood Residues in MI (2006)



Prospecting for Project Sites ?



FINAL REPORT

EXPLORING WOODY BIOMASS RETROFIT OPPORTUNITIES IN MICHIGAN BOILER OPERATIONS

9/28/2007

Submitted to:

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Project Partners:

USDA Forest Service Wood Education & Resource Center
USDA Forest Service Economic Action Program
Southeast Michigan RC&D Council
Michigan Department of Natural Resources
Michigan Department of Labor & Economic Growth
Michigan Biomass Energy Program

Submitted by:

CTA Architects and Engineers
Emergent Solutions
Christopher Allen + Associates
Loracs Creations
Geodata

FINAL REPORT

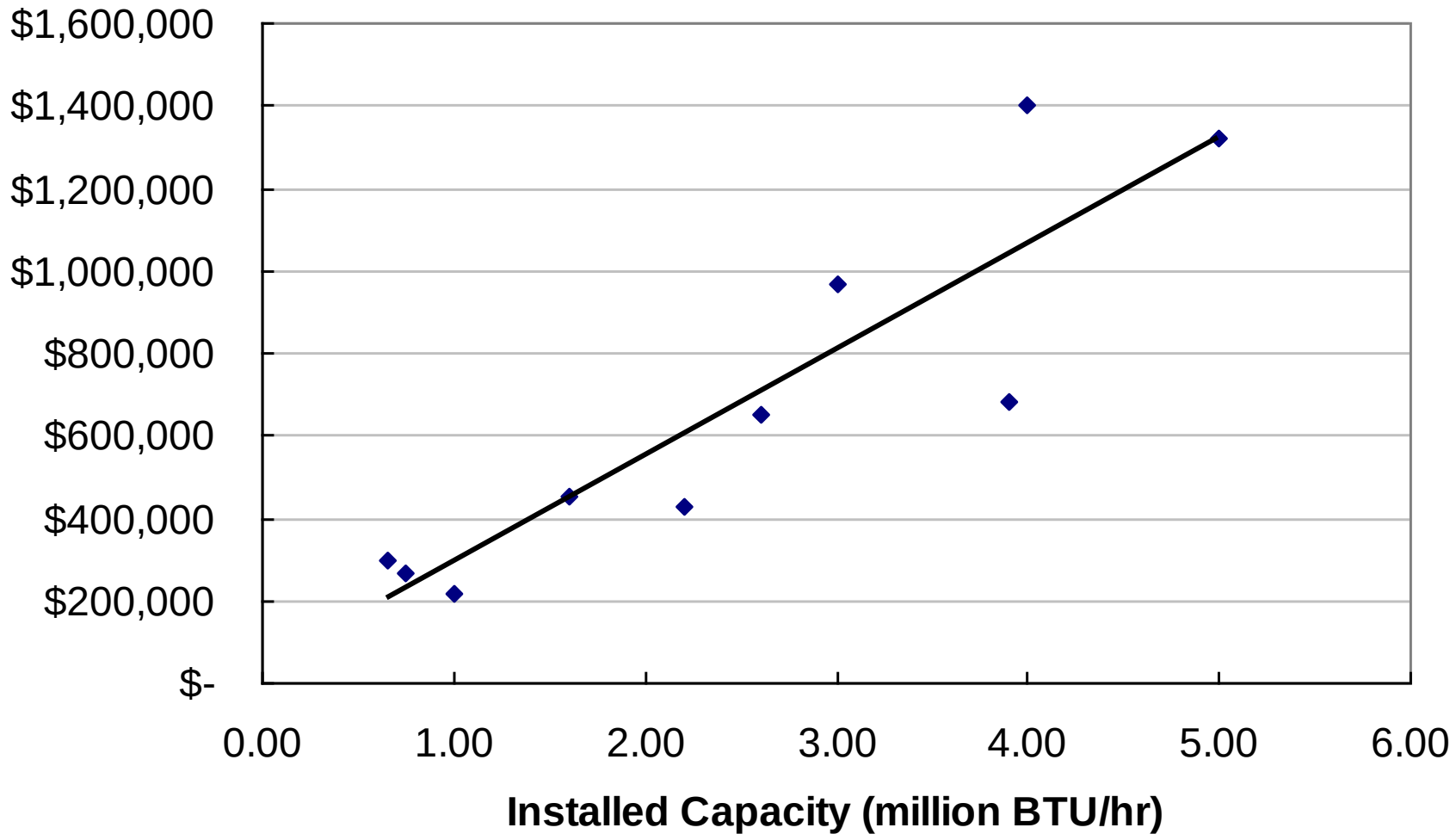
EXPLORING WOODY BIOMASS RETROFIT OPPORTUNITIES IN MICHIGAN BOILER OPERATIONS

(2007)

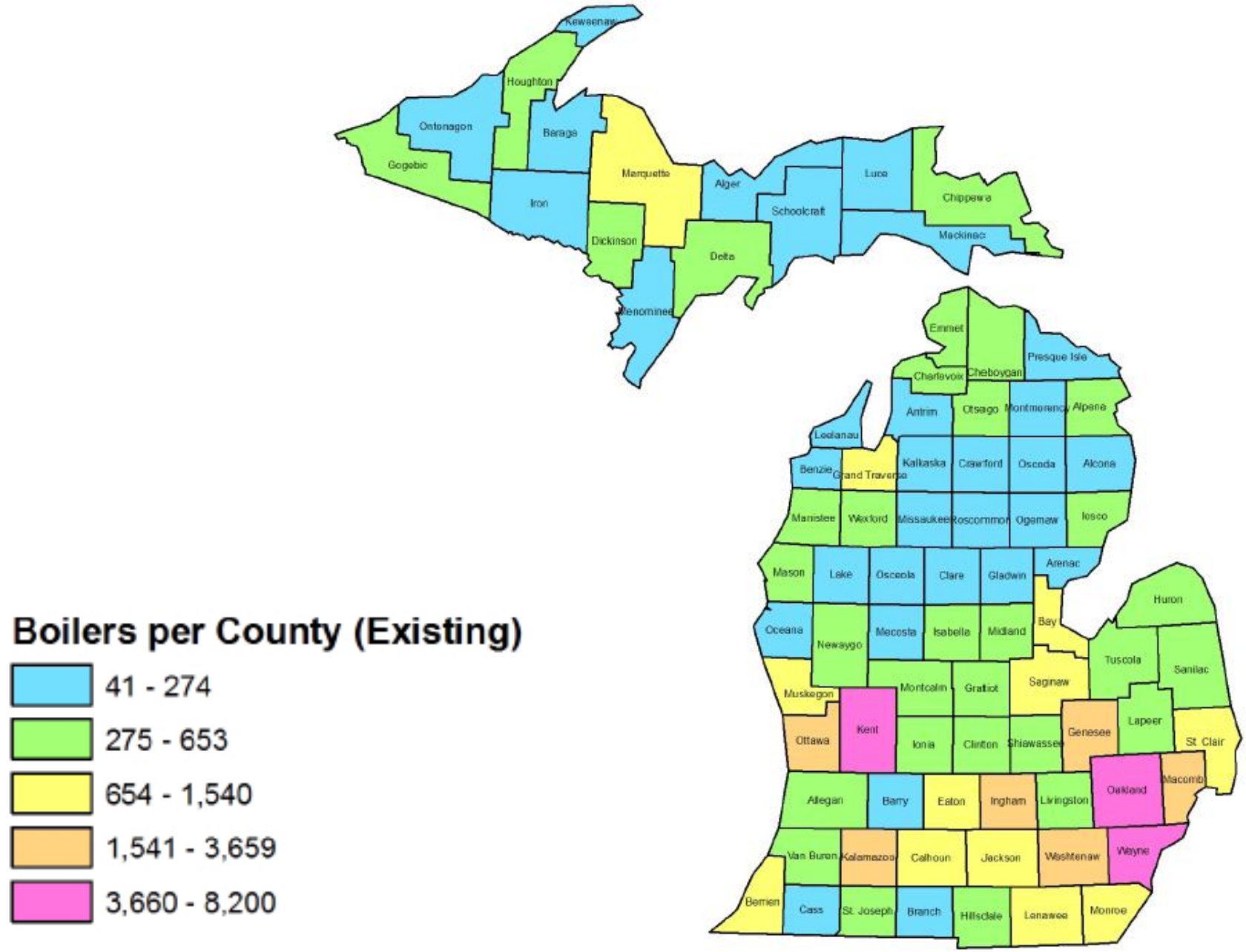
Michigan Air Pollution Reporting System (MAPRS) file: michigan_boilers.mbd

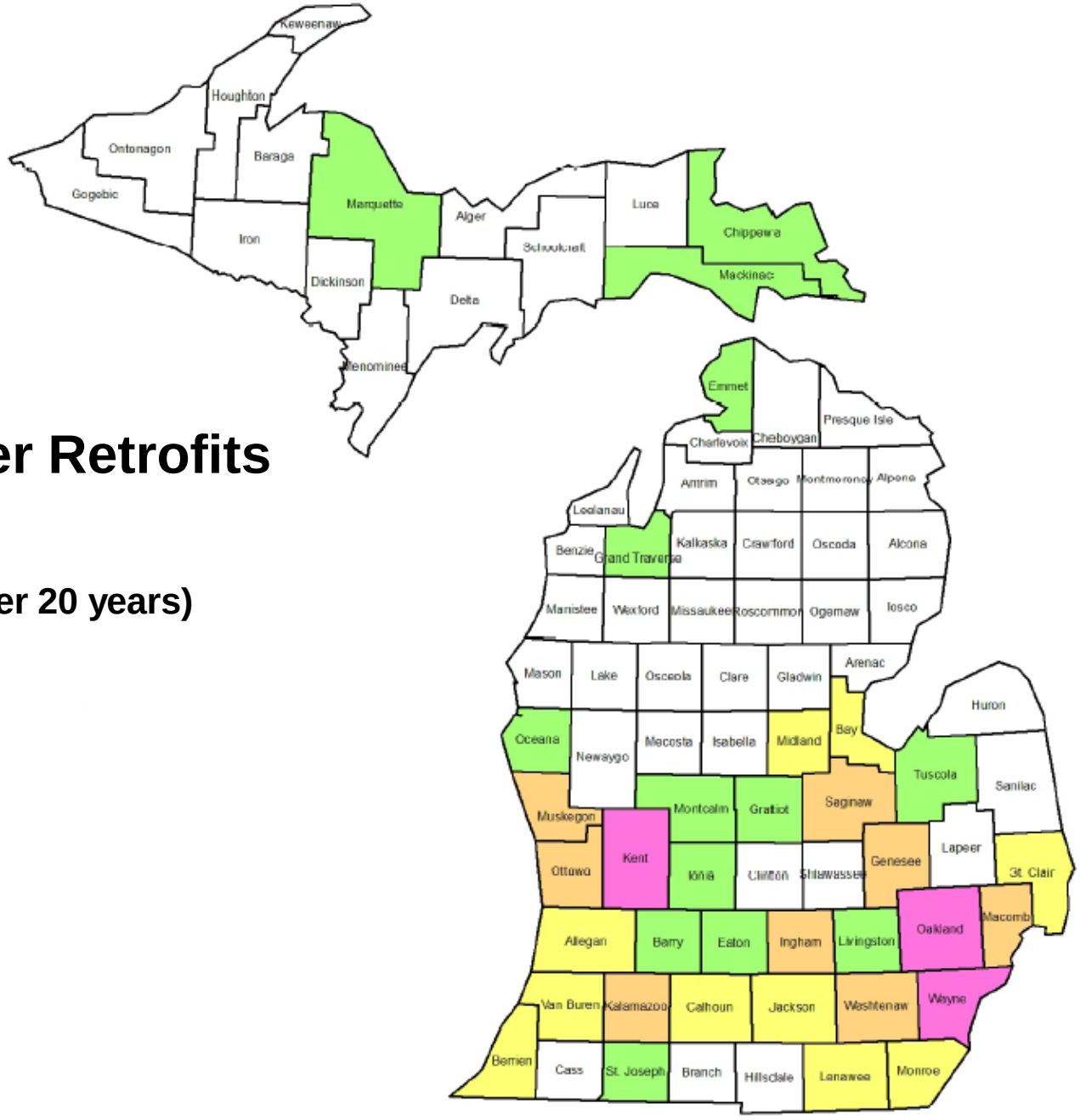
- *Boiler Number*
- *Year Installed (and year of manufacture)*
- *Fuel (Coal, Gas, Propane, Oil, Waste, Wood)*
- *Boiler Use (Hot Water, Steam, Power)*
- *Location Name*
- *City/State*
- *Boiler Size (BTU input)*

Review of Recent Wood Boiler Installations in the U.S. - This figure shows the cost per Million BTU/hr of installed capacity for the complete system



Reference: "Exploring Woody Biomass Retrofit Opportunities in Michigan Boiler Operations", Southeast Michigan RC&D Council, 2007


Boilers per County (Existing)
41 - 274
275 - 653
654 - 1,540
1,541 - 3,659
3,660 - 8,200
Keweenaw
Houghton
Ontonagon
Baraga
Gogebic
Marquette
Alger
Luce
Chippewa
Iron
Schoolcraft
Mackinac
Dickinson
Delta
Menominee
Emmet
Presque Isle
Charlevoix
Cheboygan
Antrim
Otsego
Montmorency
Alpena
Leelanau
Benzie
Grand Traverse
Kalkaska
Crawford
Oscoda
Alcona
Manistee
Wexford
Missaukee
Roscommon
Ogemaw
Iosco
Mason
Lake
Osceola
Clare
Gladwin
Arenac
Huron
Oceana
Newaygo
Mecosta
Isabella
Midland
Bay
Tuscola
Sanilac
Muskegon
Montcalm
Gratiot
Saginaw
Ottawa
Kent
Ionia
Clinton
Shiawassee
Genesee
Lapeer
St. Clair
Allegan
Barry
Eaton
Ingham
Livingston
Oakland
Macomb
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Berrien
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe



Potential Boiler Retrofits per County

(simple payback under 20 years)

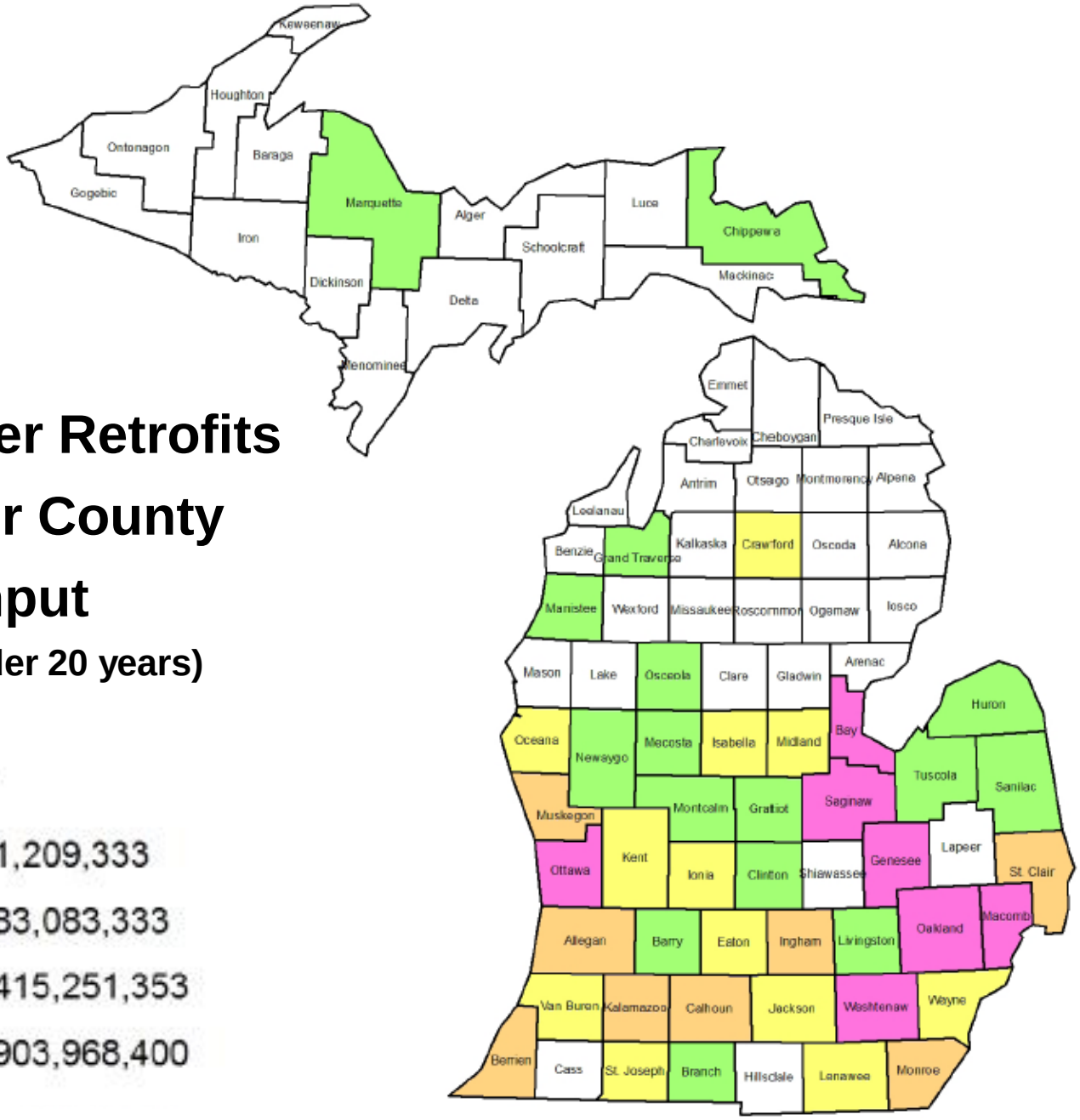
- 0 - 9
- 10 - 24
- 25 - 51
- 52 - 123
- 124 - 316

Potential Boiler Retrofits

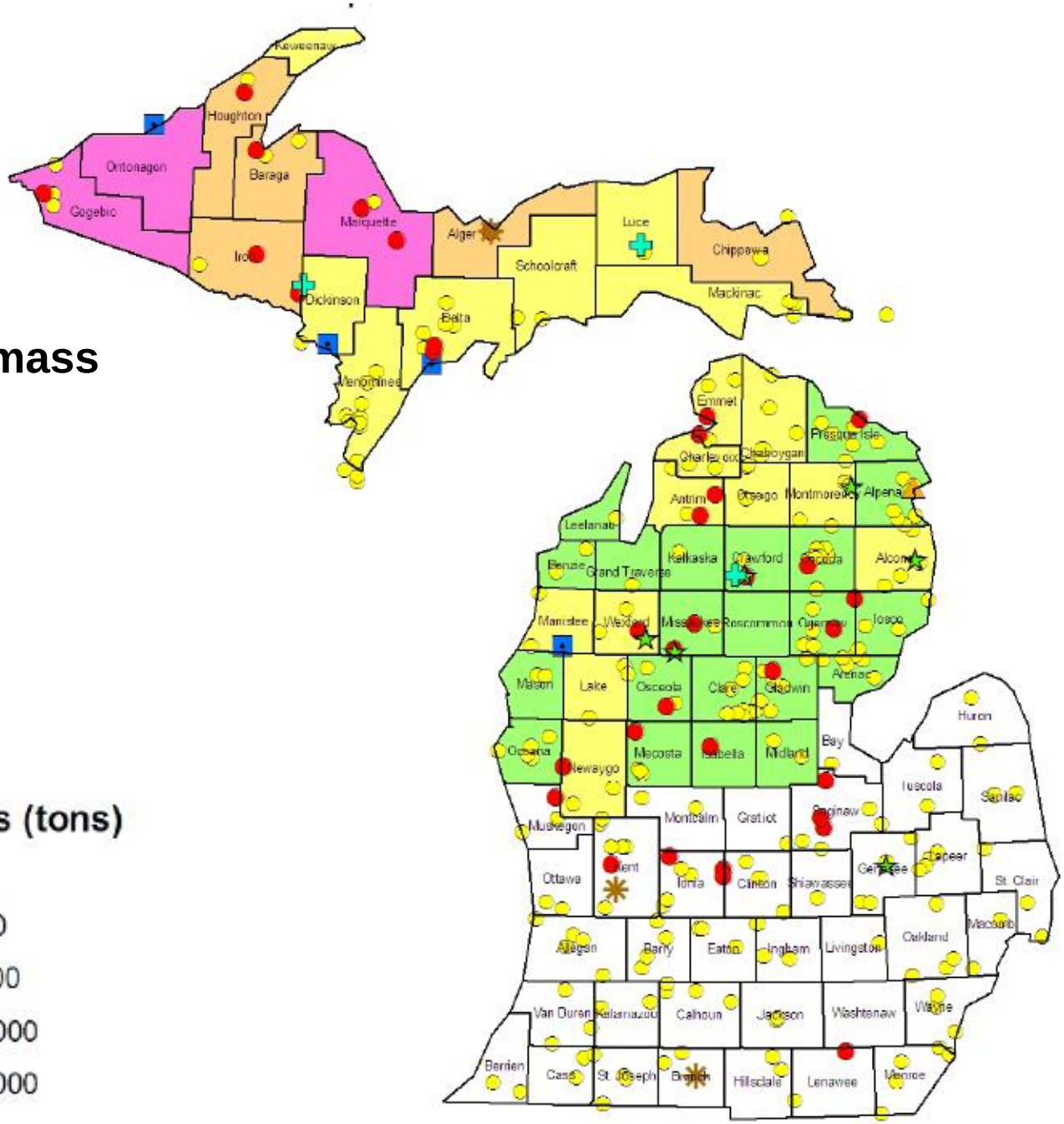
Boiler Size per County

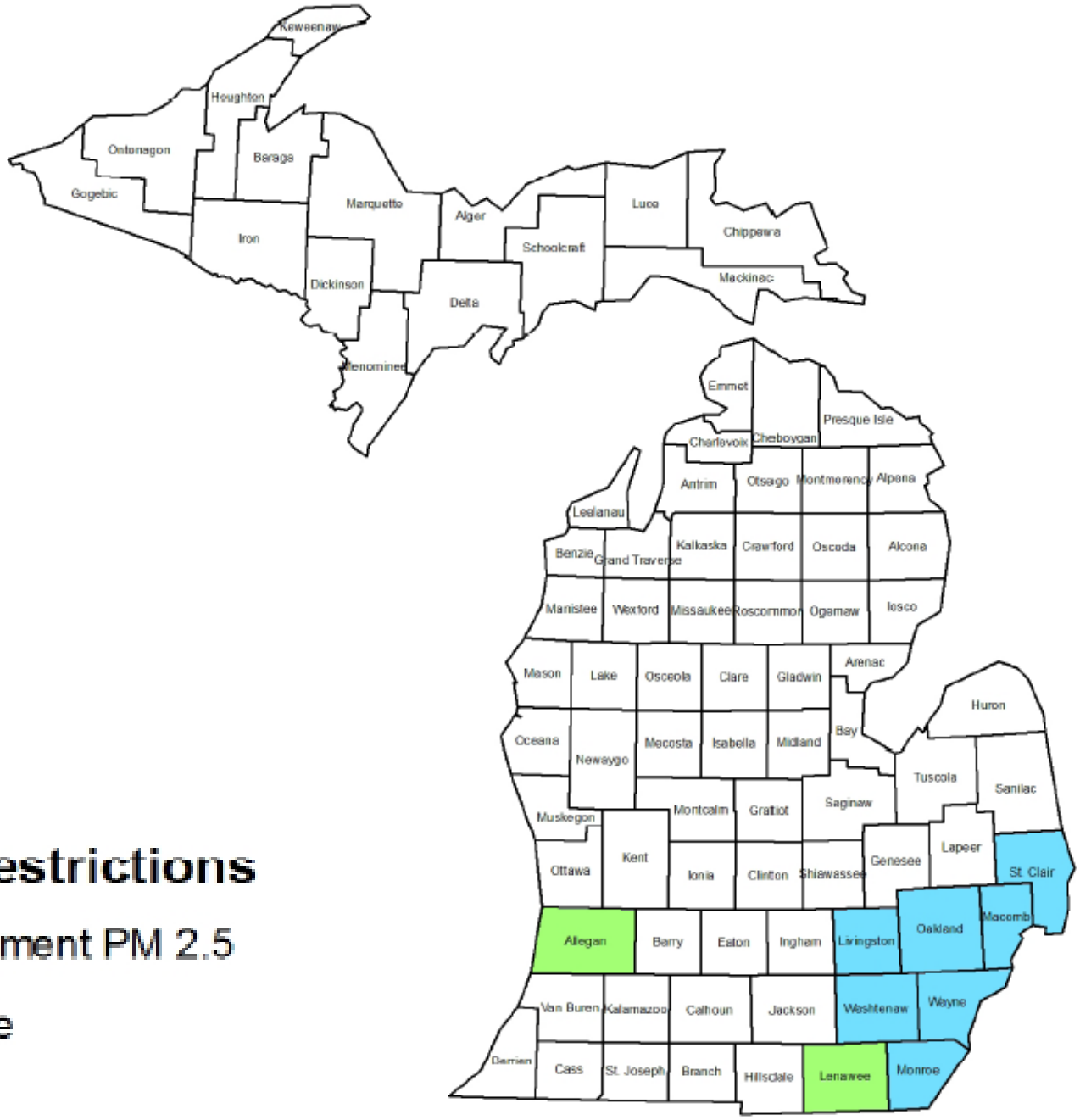
Units: BTU input

(simple payback under 20 years)



Forest Product Primary Mills & Total Woody Biomass





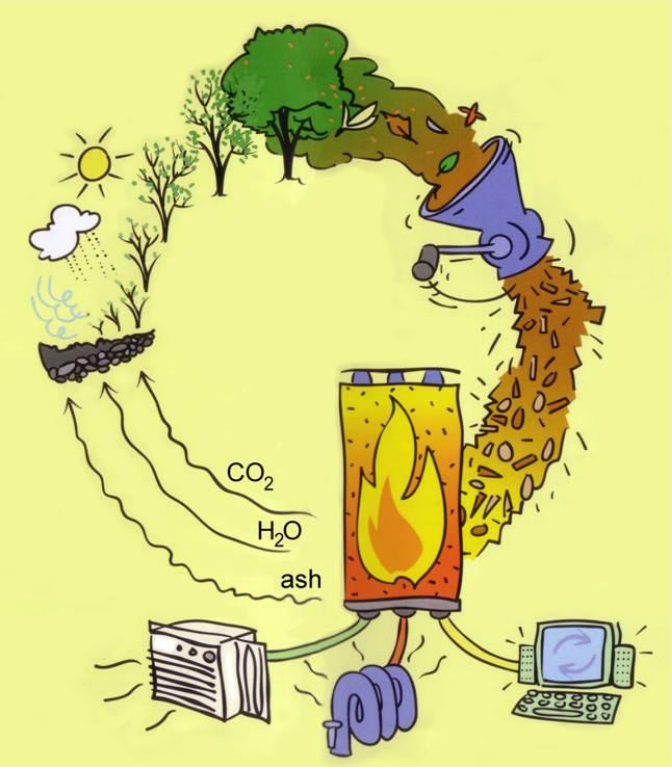
Air Quality Restrictions

- Non-Attainment PM 2.5
- 8 Hr Ozone

BioEnergy Technologies

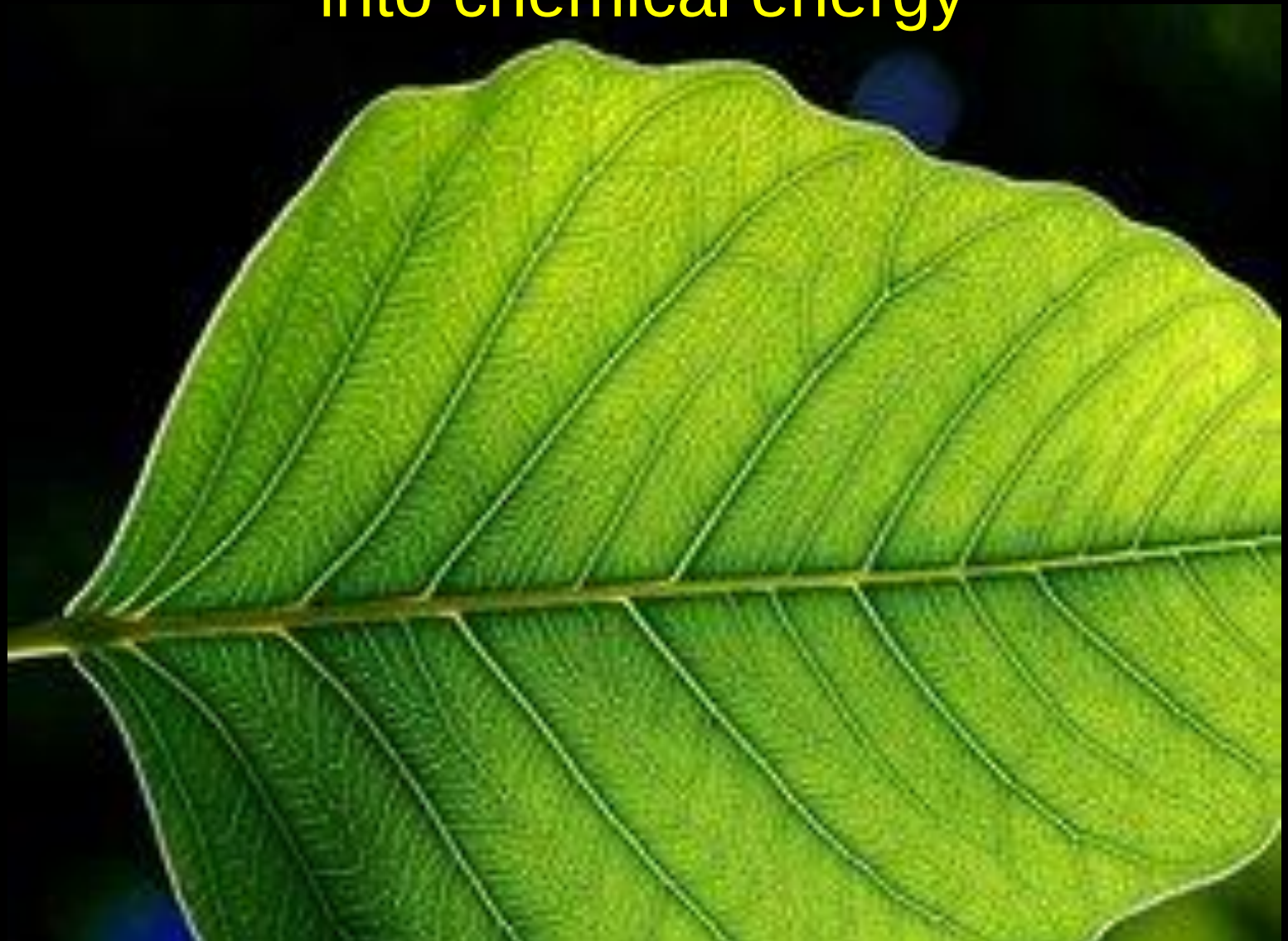
Technologies:

- **Photosynthesis**
- **Energy Flow**
- **Available Technologies**

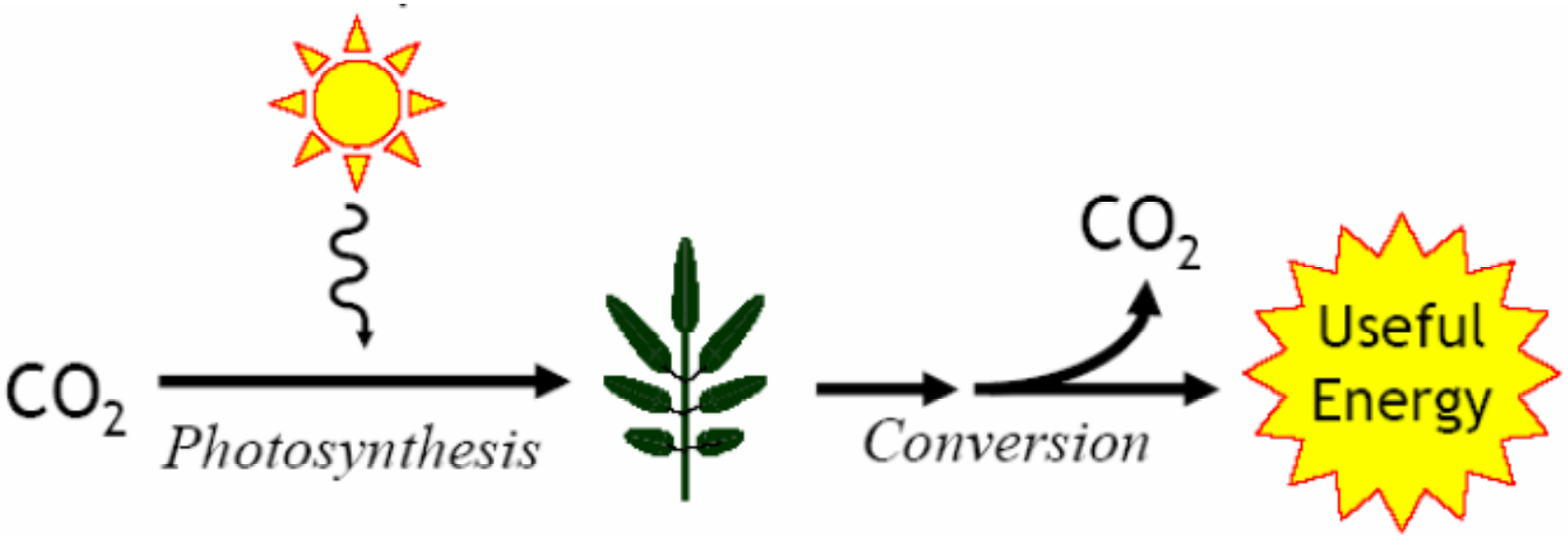


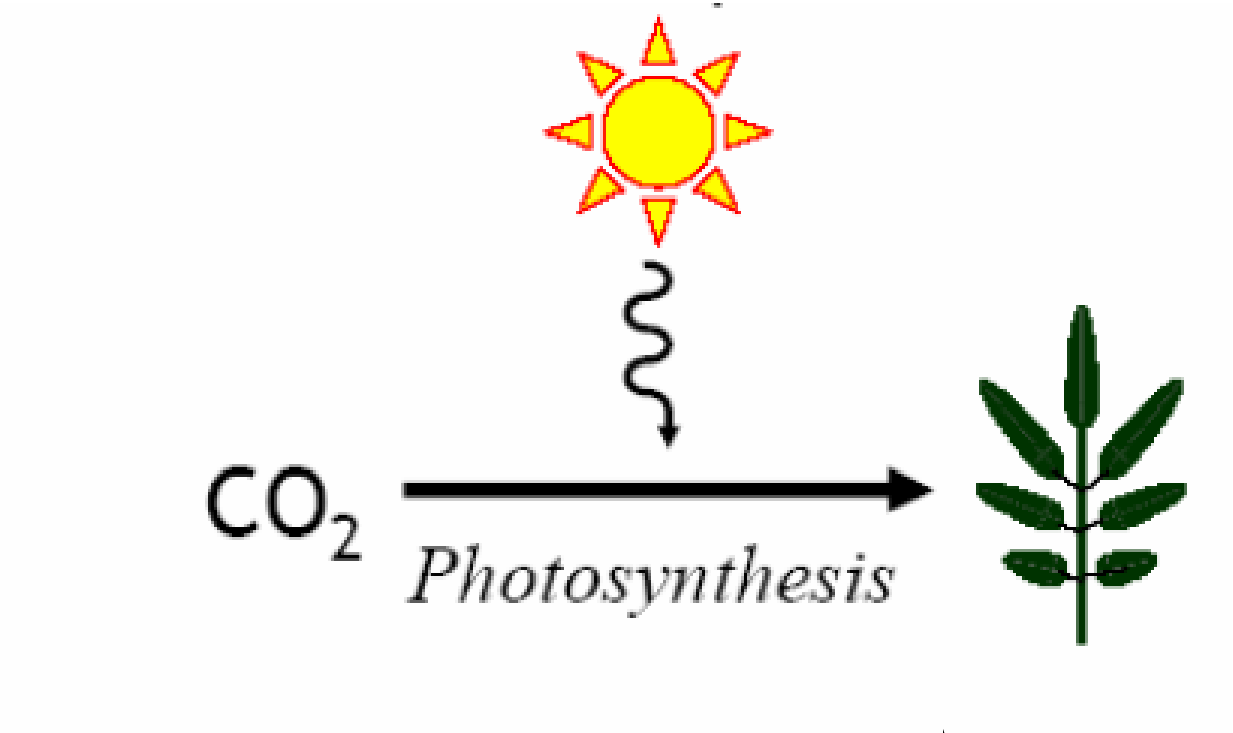
CLEAN ENERGY RESEARCH CENTER

Photosynthesis: Nature has found a way to convert sunlight, CO_2, water and nutrients into chemical energy



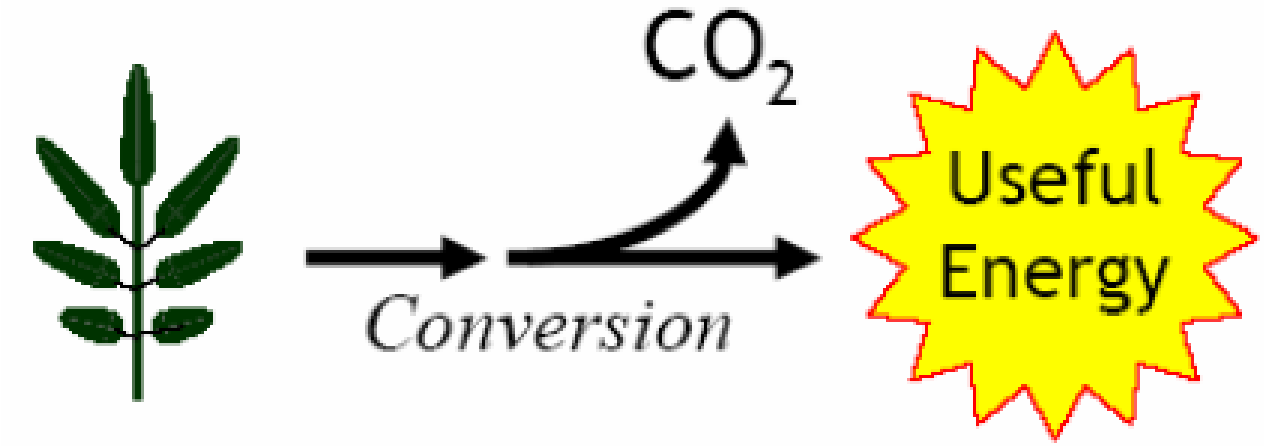
Biomass Starts with Photosynthesis





$6CO_2 + 6H_2O$ + solar energy ⇒ $6O_2$ + glucose

Glucose = $C_6 H_{12}O_6$



$6O_2$ + glucose ⇒ $6CO_2 + 6H_2O$ + heat energy

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

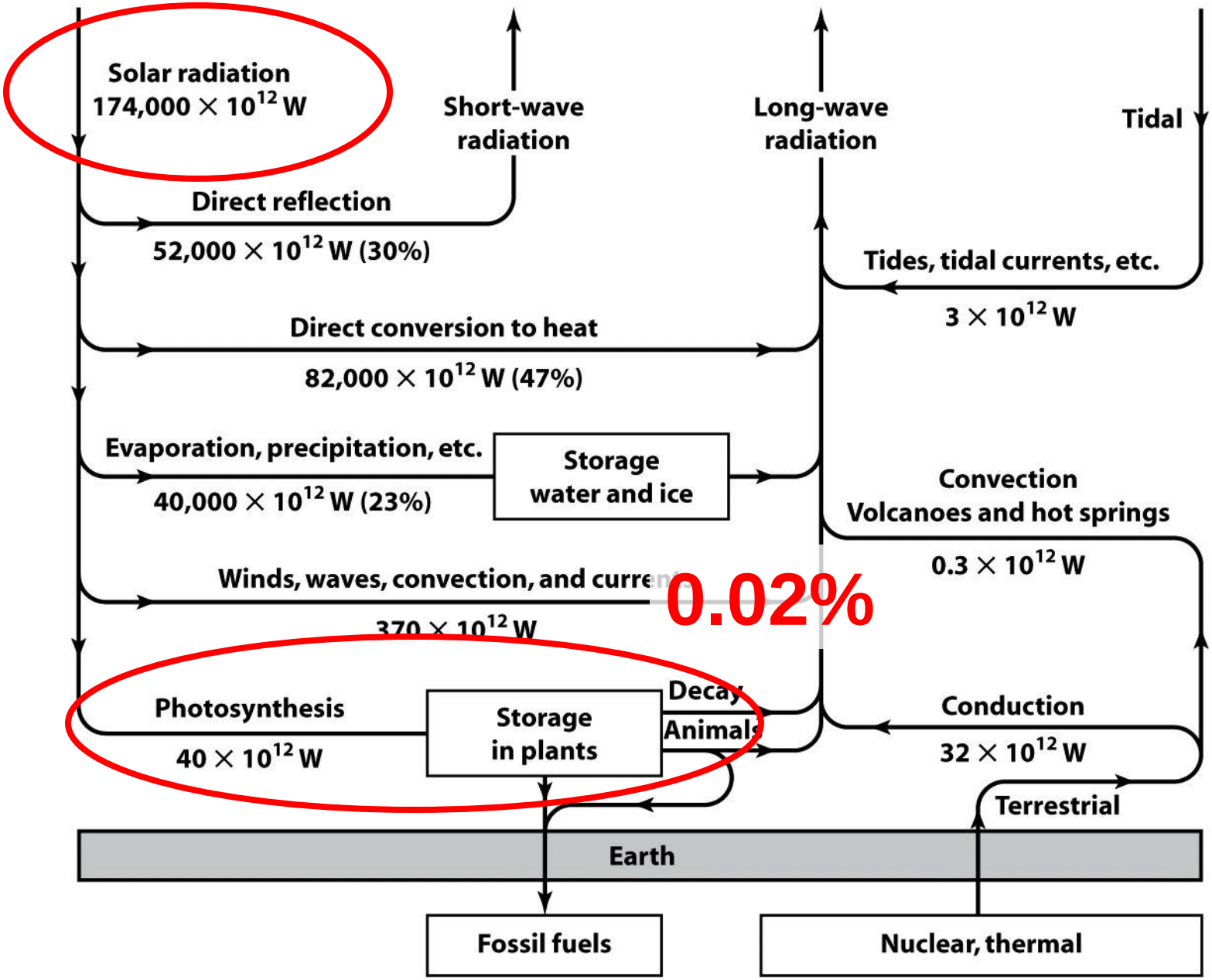
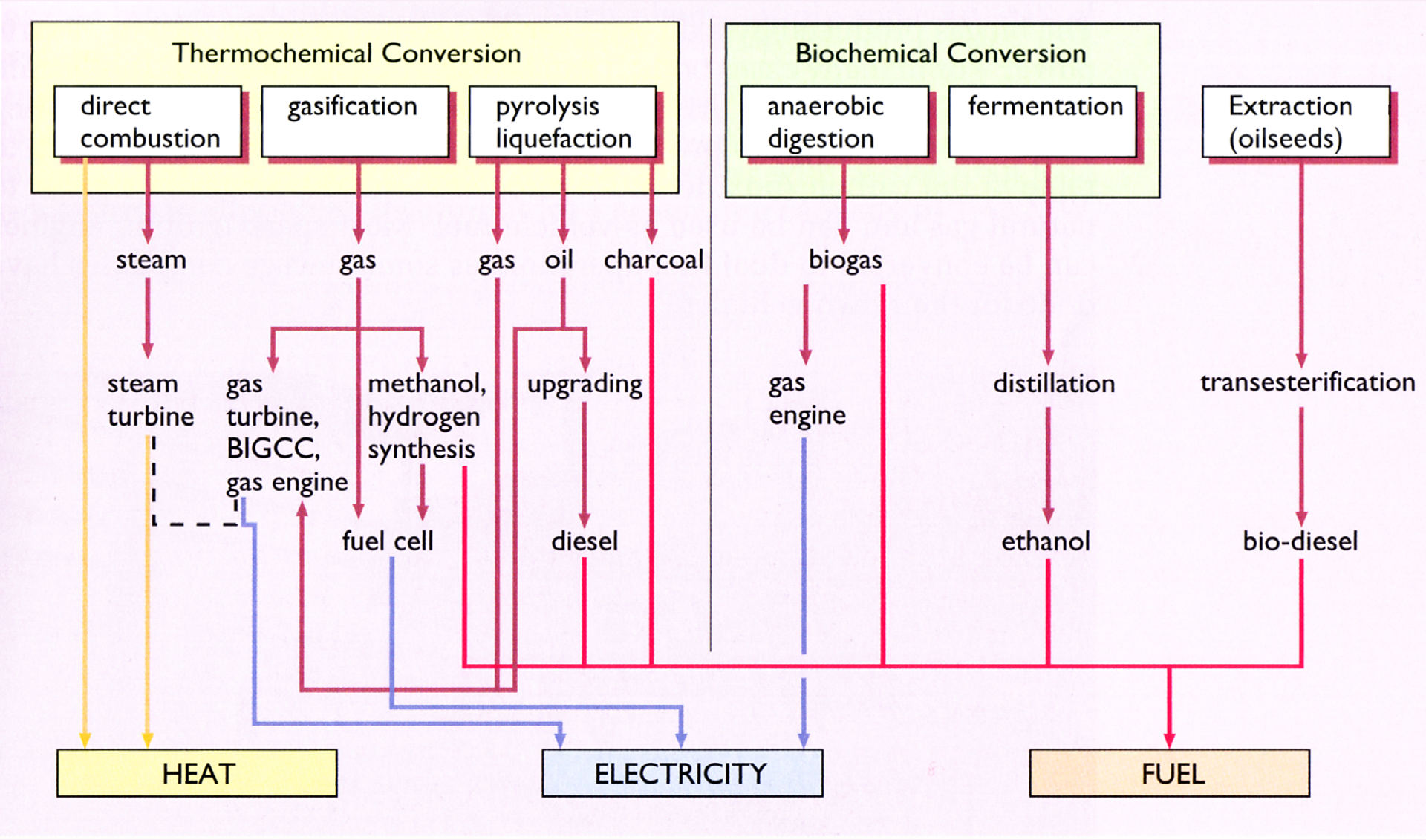
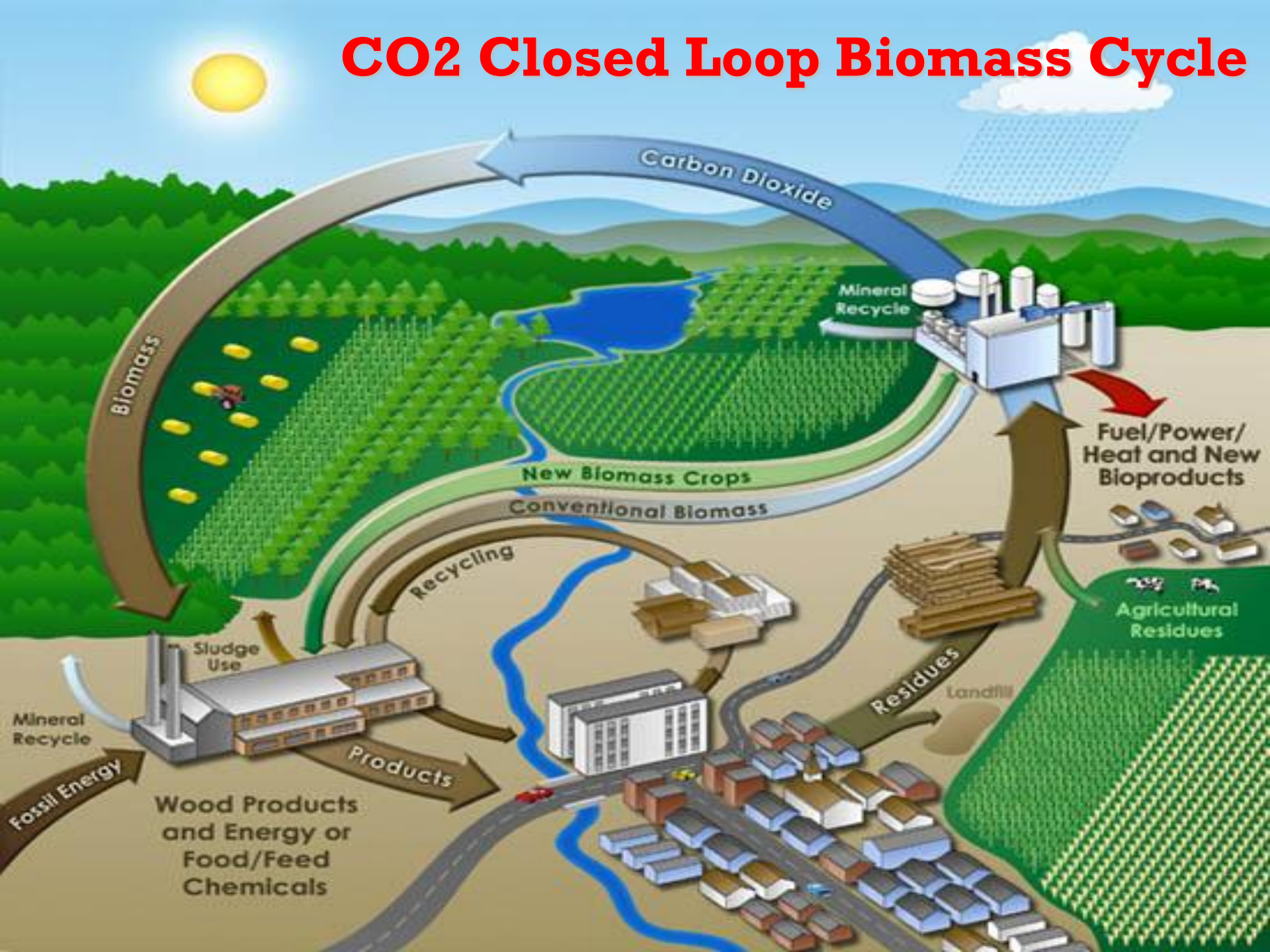


Figure 5-1 Energy and the Environment 2e

BioEnergy Technologies



CO2 Closed Loop Biomass Cycle



Michigan Energy Use, Biomass Resources & Tech

OU Clean Energy Research Center

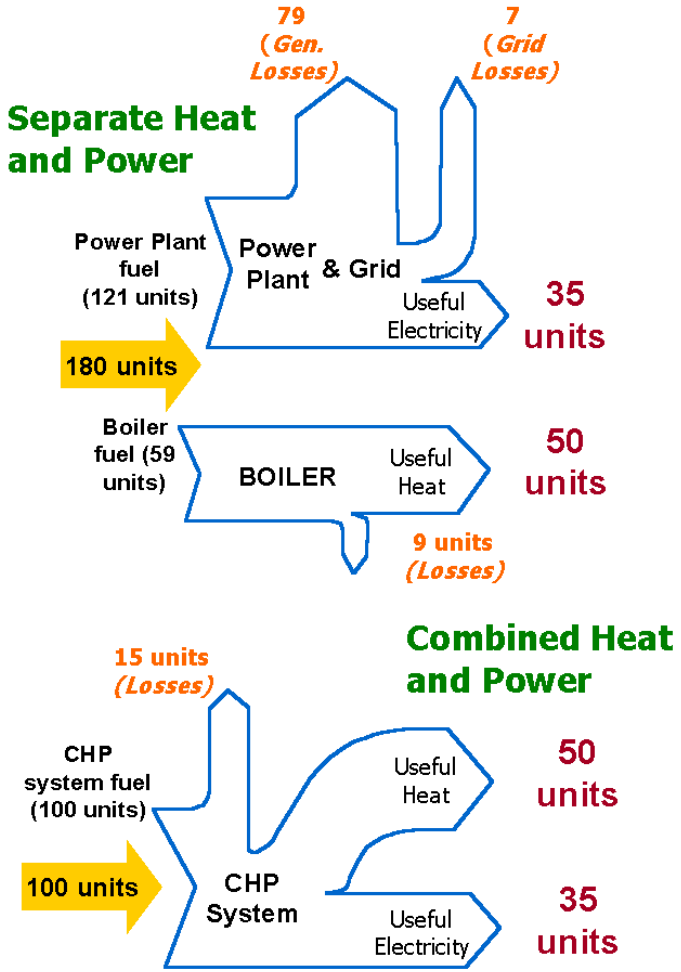
GOAL:

10% BioEnergy for Michigan?

Estimates for solar and wind for 100% of Michigan electrical.

Solar $60B @$5,500 / kW and 14.5% CF
Wind $10B @$2,200 / kW and 30% CF
Biomass $??B @$2,500 / kW and 90% CF

Combined Heat & Power



Thank you

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