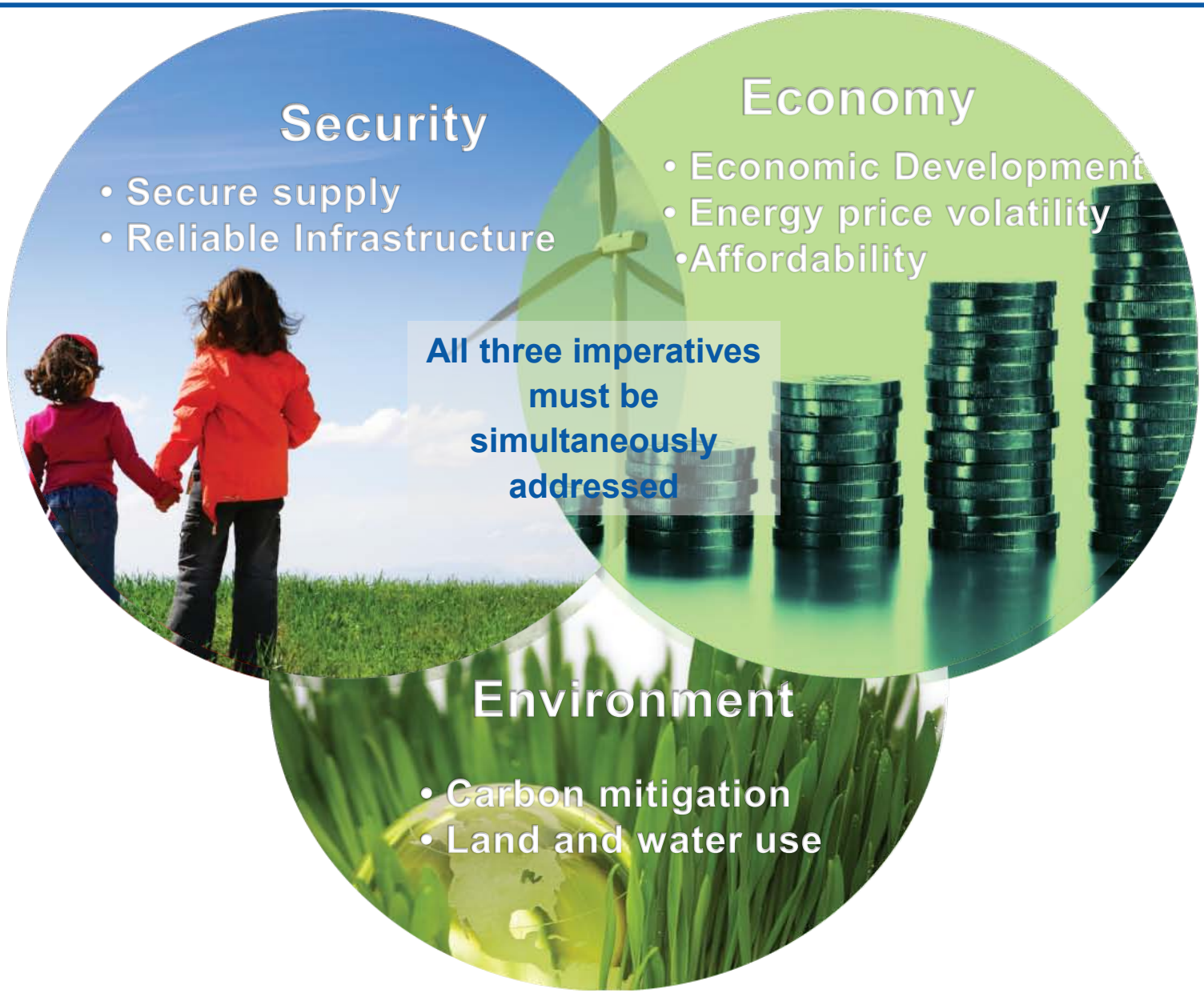
The Role of Renewable Sources of Energy

Military Energy Alternatives

January 19, 2010

Stanley R. Bull
Midwest Research Institute and
National Renewable Energy Laboratory

Energy Challenges



Our Energy System

Supply & Conversion

100 Quads

Oil 40%

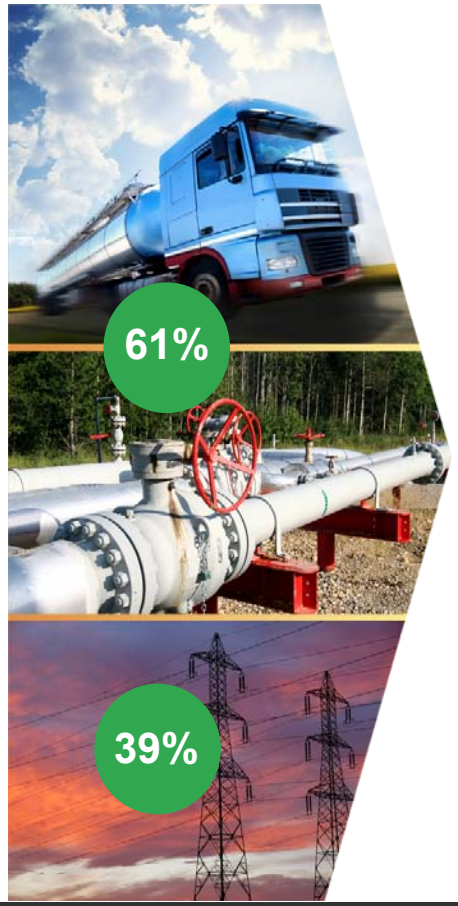
Coal 23%

Natural Gas 23%

Nuclear 8%

Hydro
Wind
Solar
Biomass
Geothermal
6%

Transmission & Distribution



Utilization

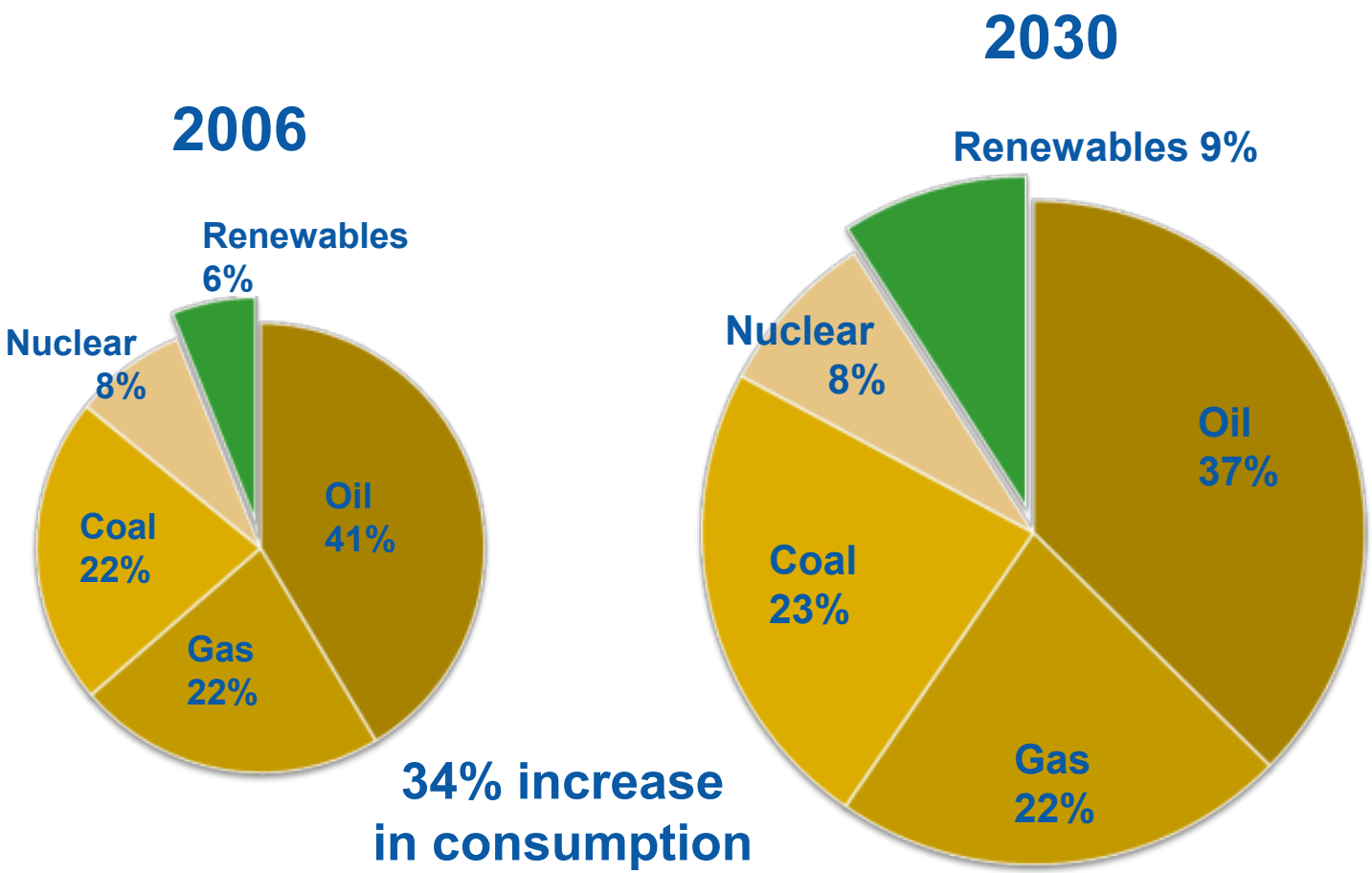
27%

40%

33%

Lost energy as inefficiencies – 62%

U.S. Energy Consumption and the Role of Renewable Energy



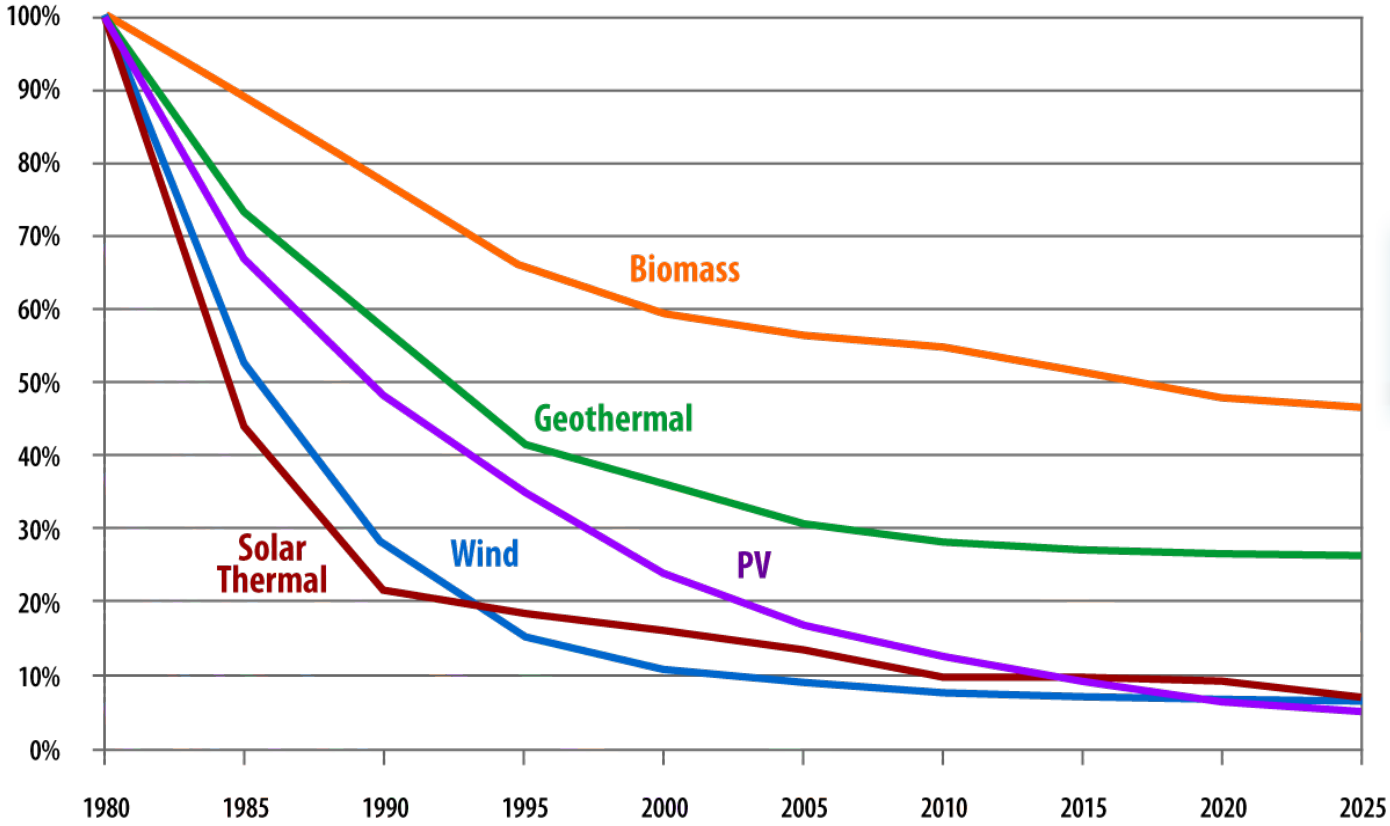
Units = Qbtu/year

Source: Energy Information Administration, *Annual Energy Outlook 2009 early release, Table A1*

http://www.eia.doe.gov/oiaf/aeo/pdf/appa.pdf

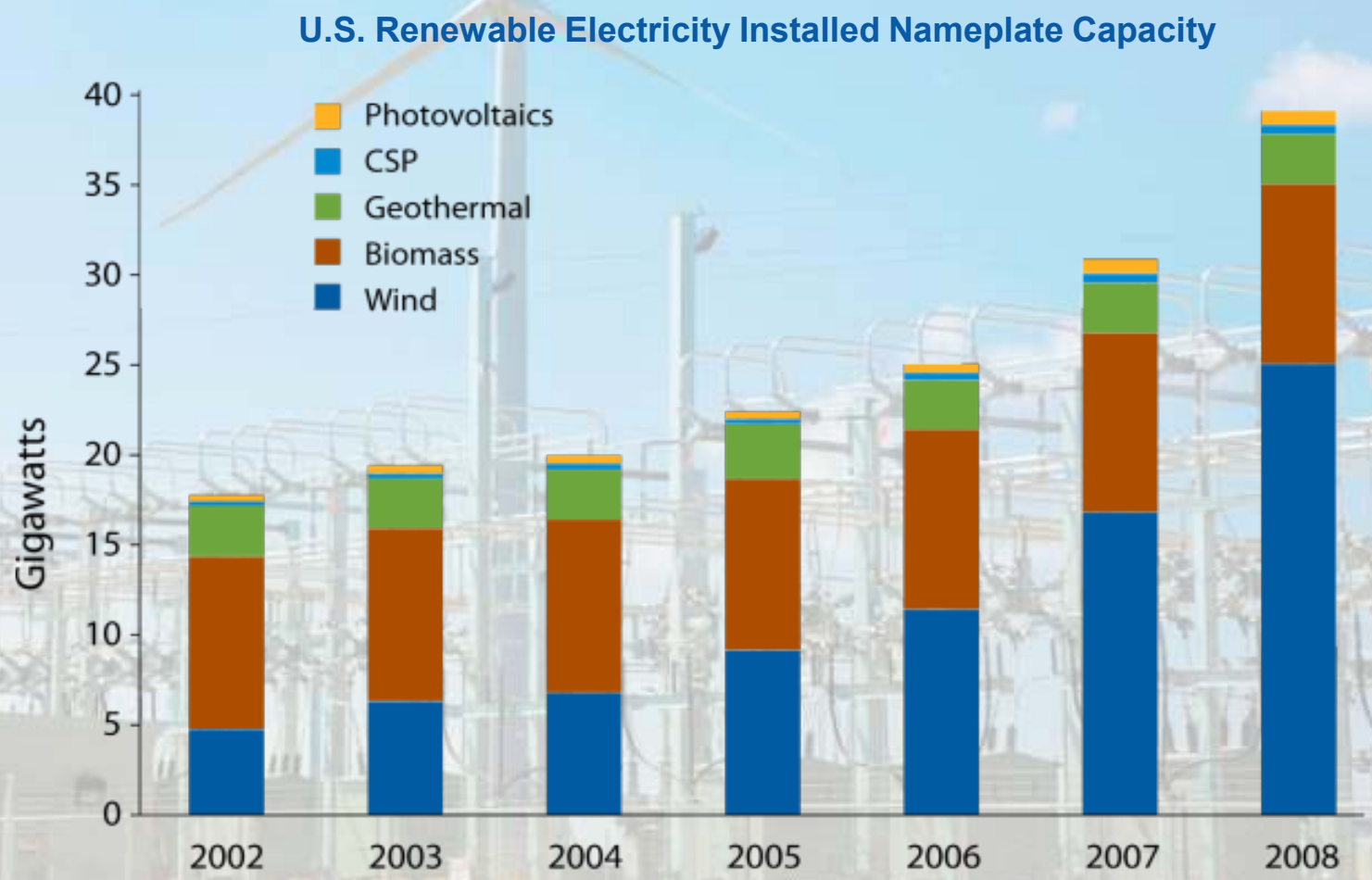
Renewable Energy

Past Investments Have Yielded Impressive Cost Reductions



Economic Stimulus Through Harvesting Past Energy Investments

First Generation Clean Energy Technologies



Source: EIA Annual Energy Outlook 2009 Early Release

Looking Ahead with Optimism— New National Priorities

- Invest $150B in alternative energy over 10 years
- Create green jobs with clean, efficient American energy
- Double production of alternative energy in three years – enough to power 6 million homes
- Upgrade the efficiency of more than 75% of federal buildings and two million private homes
- Put one million PHEVs on U.S. roads by 2015
- Reduce CO_2 emissions by 80% below 1990 levels by 2050
- Transform our economy with science and technology

G8Website/ANSA Photo: Alessandro Di Meo

Energy is a means to an end, not an end in itself

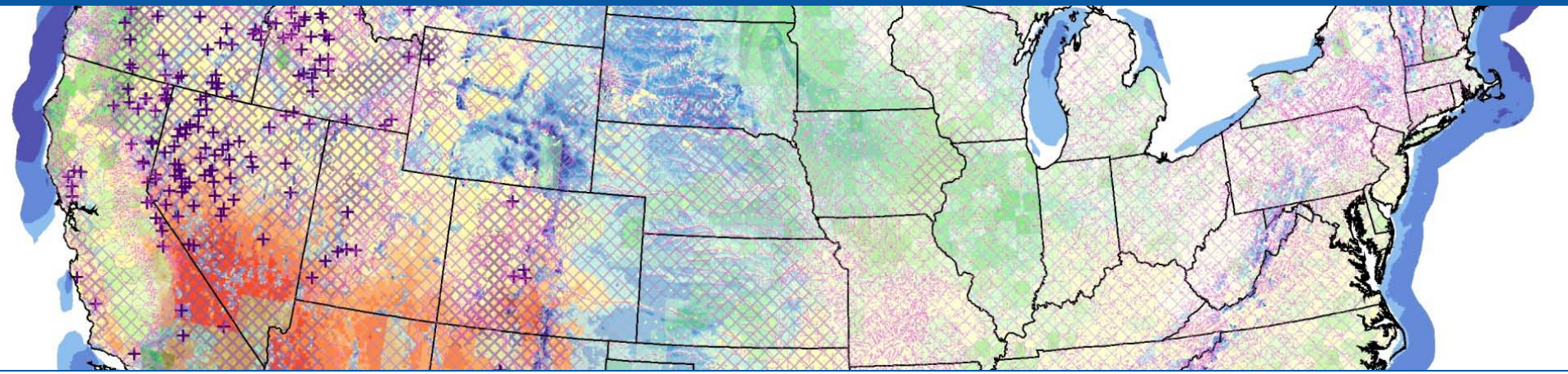
Heat and power for where we live and work

Sustainable Electricity System

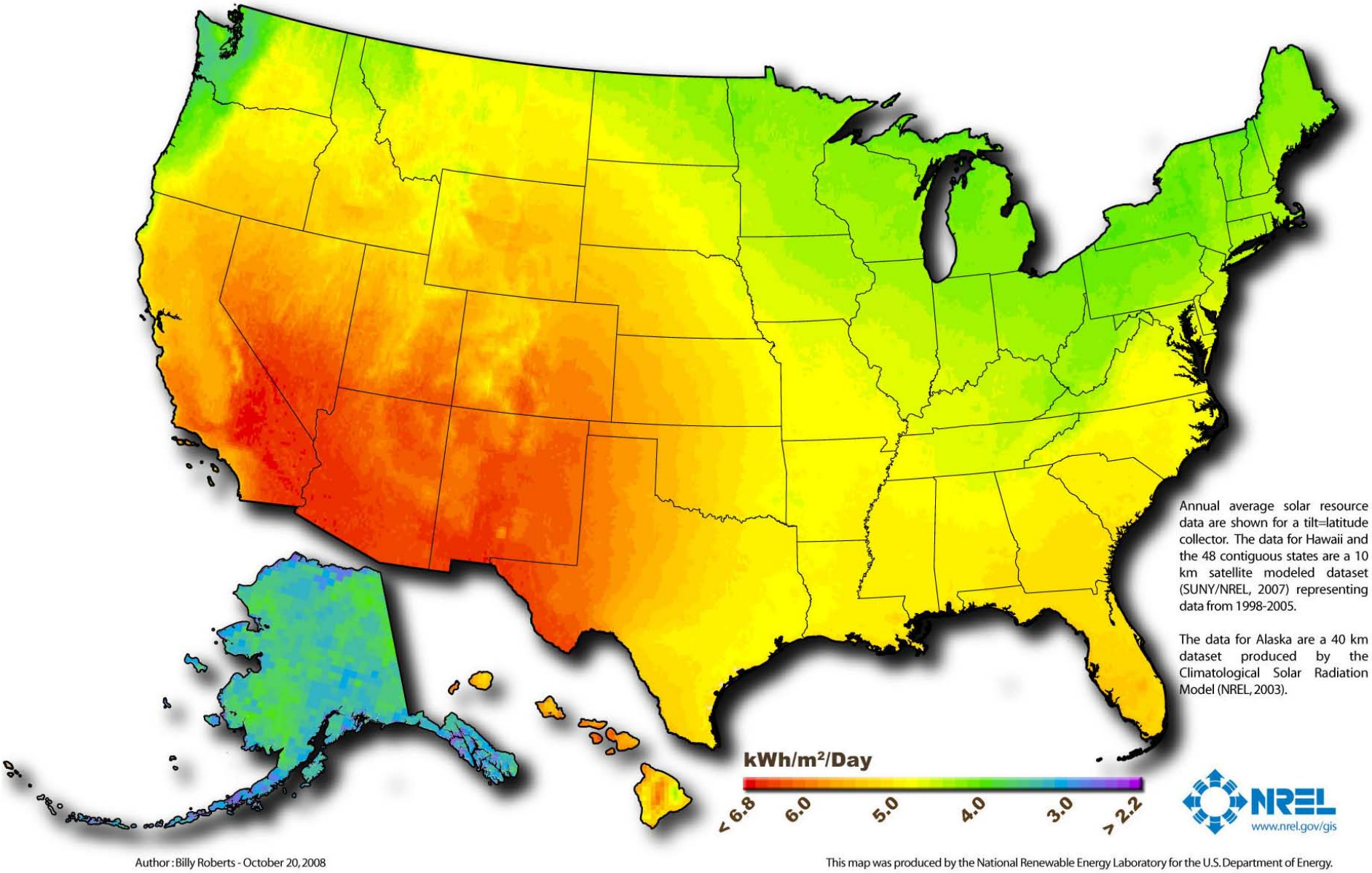
Fuel and power for mobility and access

Sustainable Transportation System

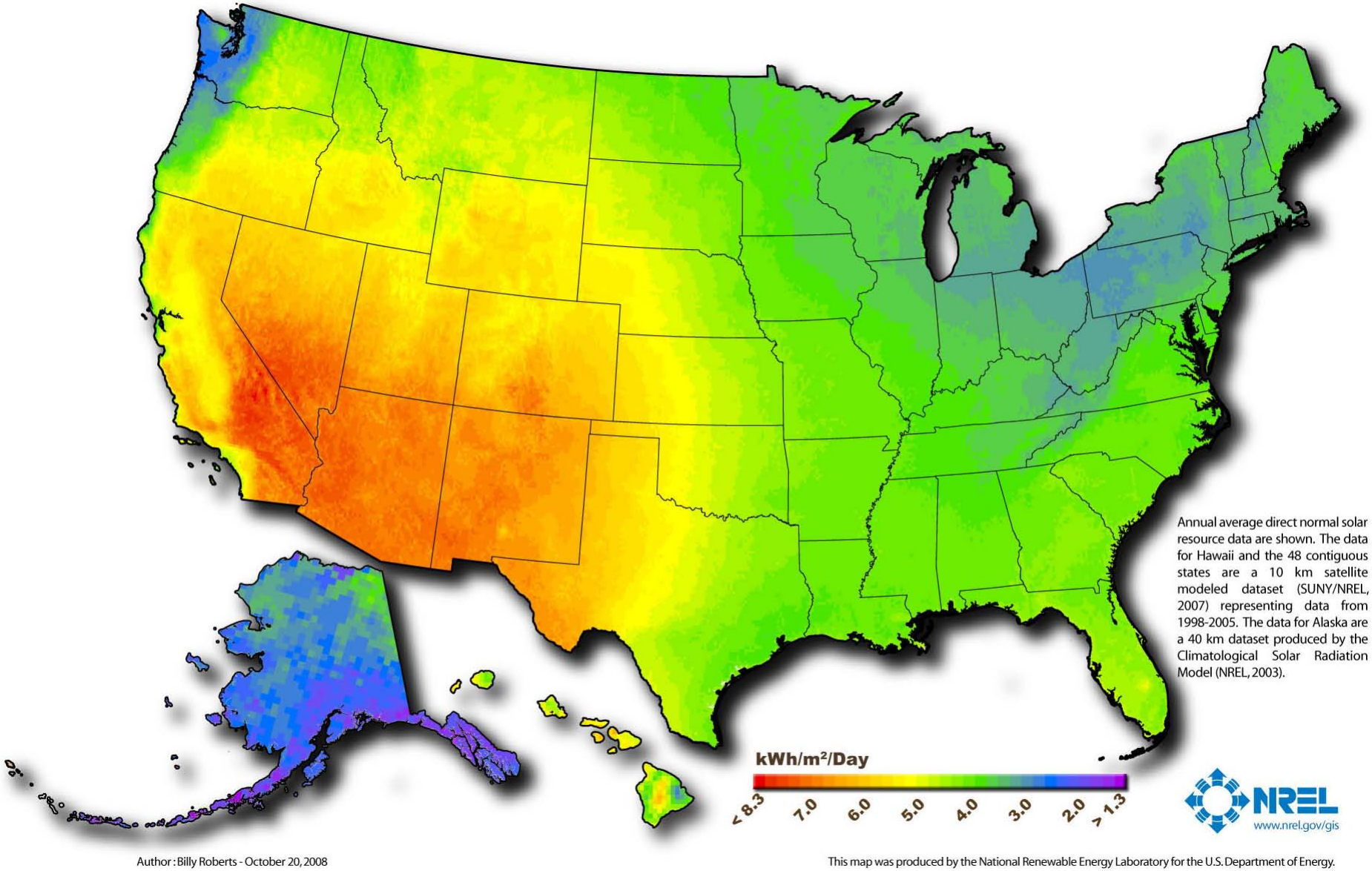
Resource Potential



U.S. Photovoltaic Solar Resource

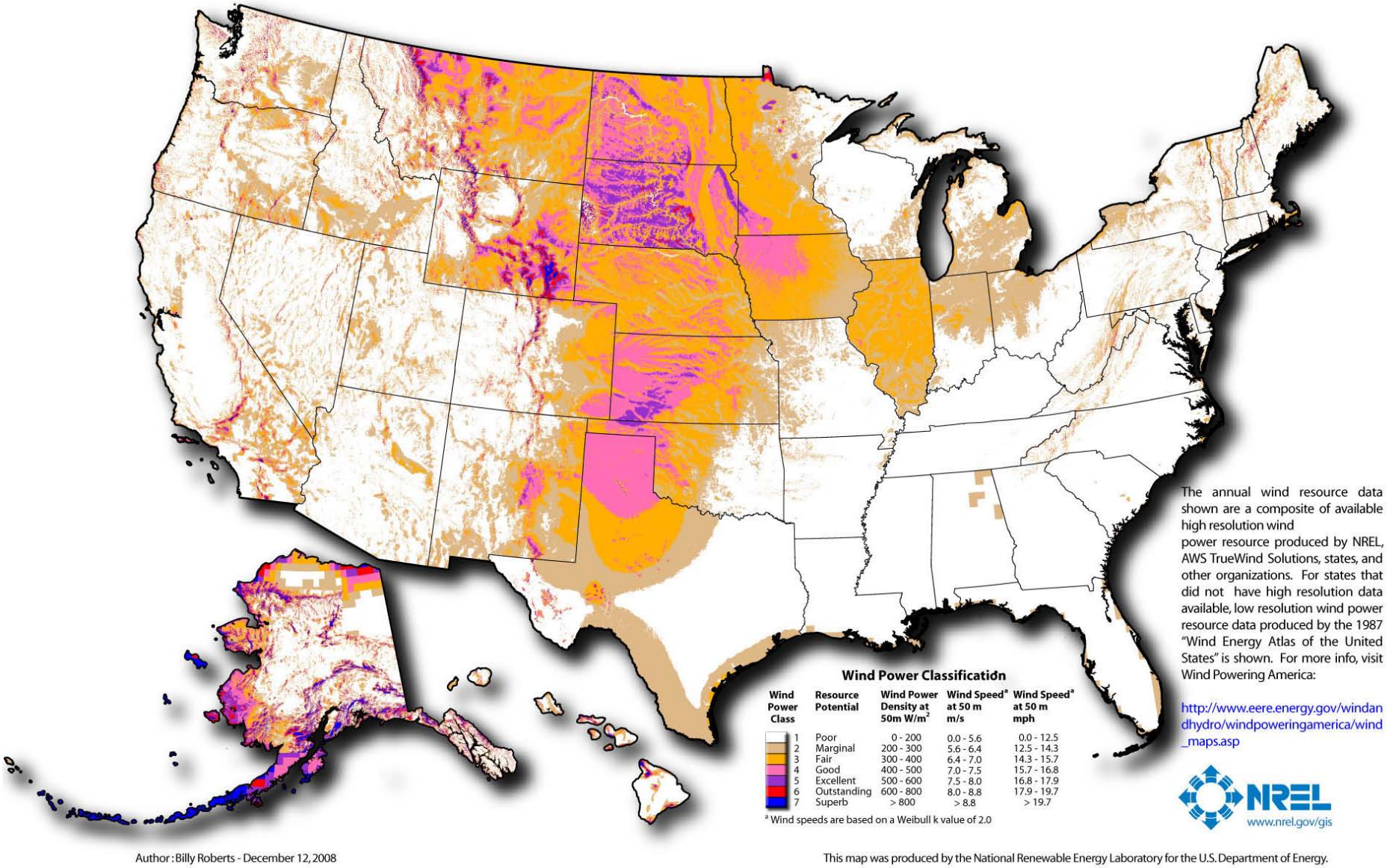


U.S. Concentrating Solar Resource

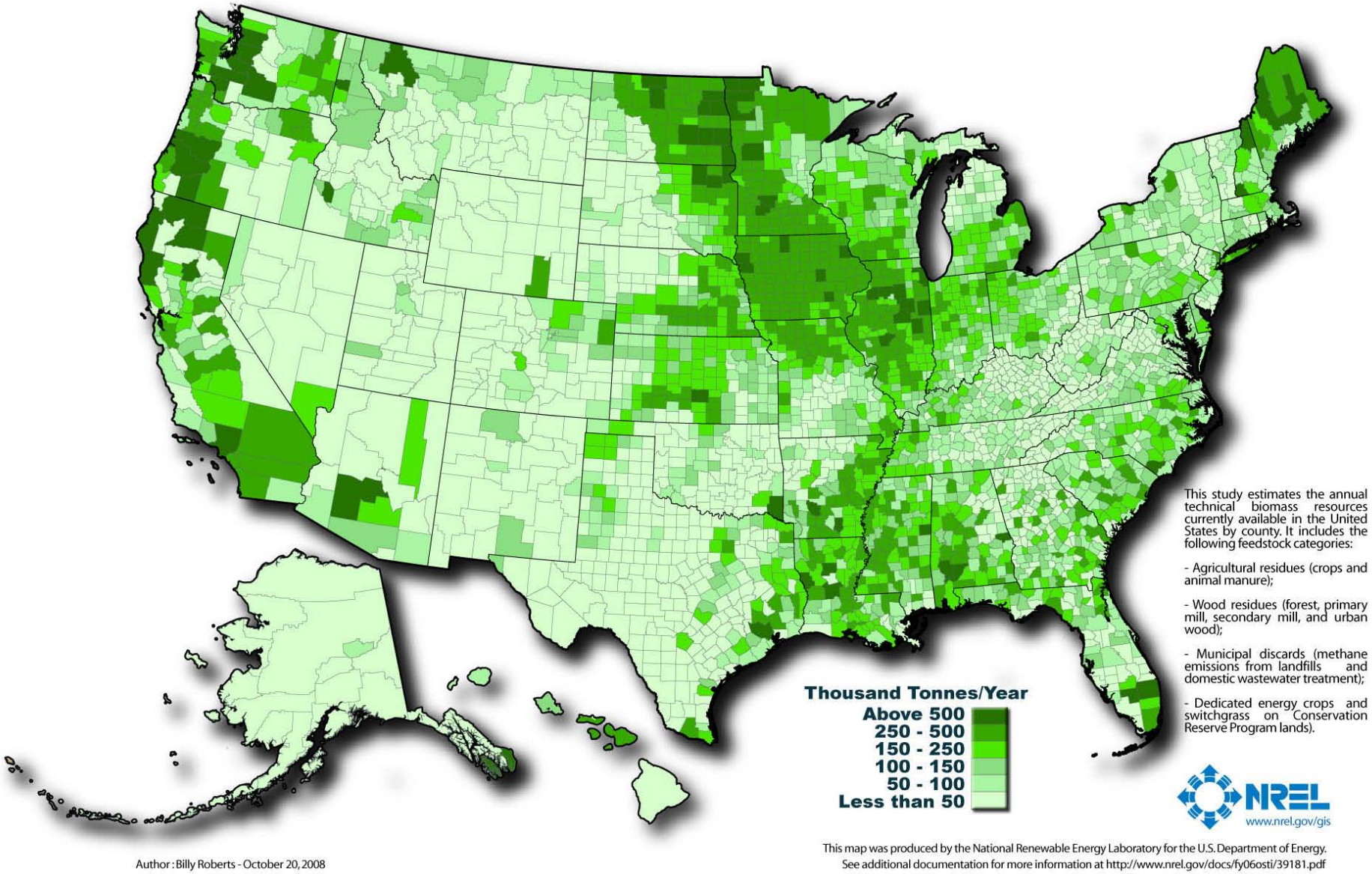


Annual average direct normal solar resource data are shown. The data for Hawaii and the 48 contiguous states are a 10 km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005. The data for Alaska are a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

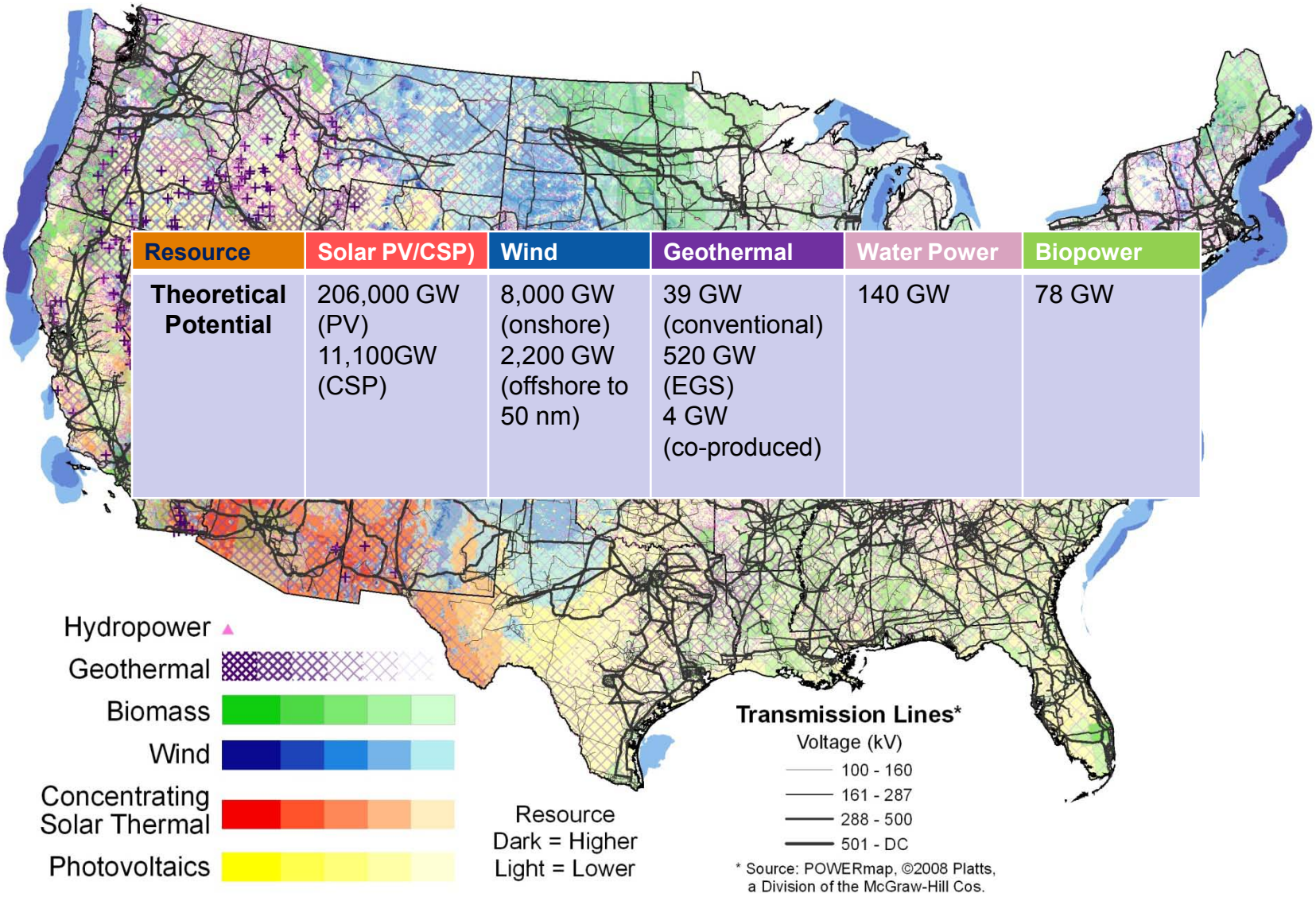
U.S. Wind Resource (50m)



U.S. Biomass Resource



U.S. Renewable Resources



Resource	Solar PV/CSP)	Wind	Geothermal	Water Power	Biopower
Theoretical Potential	206,000 GW (PV) 11,100GW (CSP)	8,000 GW (onshore) 2,200 GW (offshore to 50 nm)	39 GW (conventional) 520 GW (EGS) 4 GW (co-produced)	140 GW	78 GW

Renewable Electricity Supply

Wind

Today's Status in U.S.

- 25,300 MW installed capacity
- Cost 6-9¢/kWh at good wind sites*

DOE Cost Goals

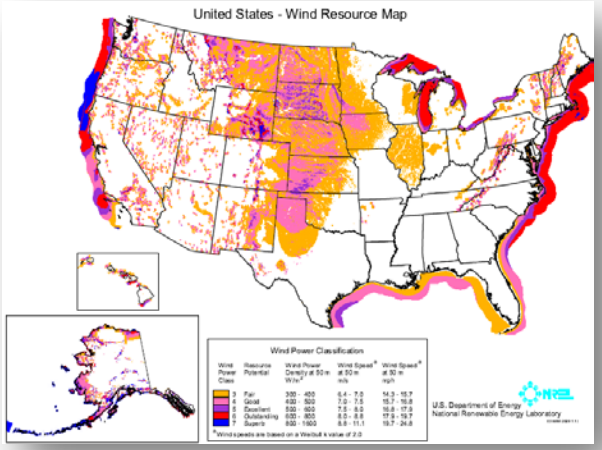
- 3.6¢/kWh, onshore at low wind sites by 2012
- 7¢/kWh, offshore in shallow water by 2014

Long Term Potential

20% of the nation's electricity supply

* With no Production Tax Credit
Updated May 8, 2009
Source: U.S. Department of Energy, American Wind Energy Association

Wind Energy Technology



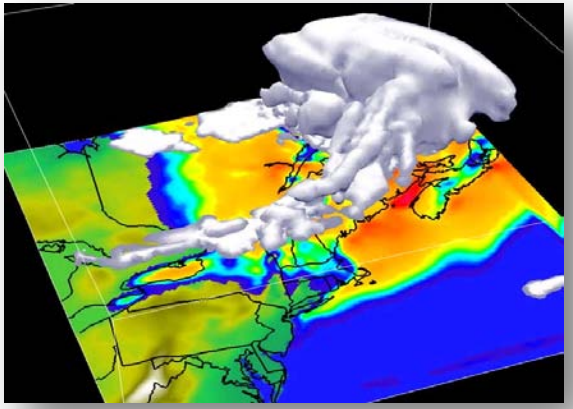
US Wind Resource Exceeds Total Electrical Demand

Offshore Wind

Advanced Blades

Innovative Tall Towers

Giant Multi-megawatt Turbines



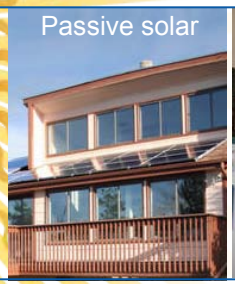
Courtesy:WindLogics, Inc. St. Paul, MN

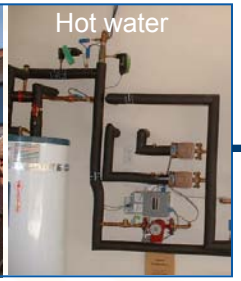
Wind Forecasting

GE WindEnergy
3.6 MW Turbine
Boeing 747-200
Arklow Banks Windfarm
The Irish Sea
Photo: R. Thresher

Applications of Solar Heat and Electricity

Solar Thermal





Photovoltaics (PV)

Concentrating Solar Power (CSP)

Distributed Generation, on-site or near point of use

Centralized Generation, large users or utilities

Transportation

Residential & Commercial Buildings

Industrial

Solar – Photovoltaics and CSP

Status in U.S.

PV
- 1,106 MW installed capacity
- Cost 18-23¢/kWh

CSP
- 419 MW installed capacity
- Cost 12¢/kWh

Potential:

PV
- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

CSP
8.5 ¢/kWh by 2010
6 ¢/kWh by 2015

Source: U.S. Department of Energy, IEA
Updated 11/09

Concentrating Solar Power

Power Tower

Parabolic Trough

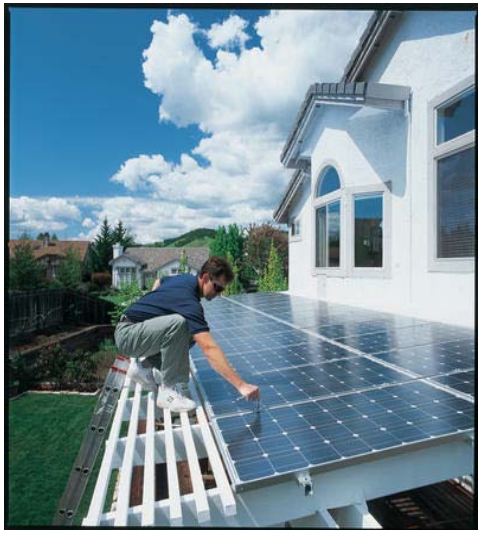
Concentrating Photovoltaics

Dish/Stirling

PV System Applications/Markets

Off-grid

Grid-connected



3.2 MWp, Rancho Seco, CA.,SMUD
20 years of successful operation

Geothermal

Today's Status in U.S.

- 2,800 MWe installed, 500 MWe new contracts, 3000 MWe under development
- Cost 5-8¢/kWh with no PTC
- Capacity factor typically > 90%, base load power

DOE Cost Goals:

- <5¢/kWh, for typical hydrothermal sites
- 5¢/kWh, for enhanced geothermal systems with mature technology

Long Term Potential:

- Recent MIT Analysis shows potential for 100,000 MW installed Enhanced Geothermal Power systems by 2050, cost-competitive with coal-powered generation

NREL Research Thrusts:

- Analysis to define pathways to commercialization of enhanced geothermal systems (EGS)
  Systems engineering/integration to enable fast track development of EGS and other Program goals
  Geothermal energy conversion RD&D
  Low temperature geothermal, direct use, and ground source heat pump RD&D

Updated 6/09

Biomass Power

Biopower status in U.S.

- 2007 capacity – 10.5 GWe
  - 5 GW Pulp and Paper
  - 2 GW Dedicated Biomass
  - 3 GW MSW and Landfill Gas
  - 0.5 GW Cofiring
- 2004 Generation – 68.5 TWh
- Cost – 8-10¢/kWh

Potential

- Cost – 4-6¢/kWh (integrated gasification combined cycle)
- 2030 – 160 TWh (net electricity exported to grid from integrated 60 billion gal/yr biorefinery industry)

Updated 7/09

Biofuels

Biofuels

Current Biofuels Status in U.S.

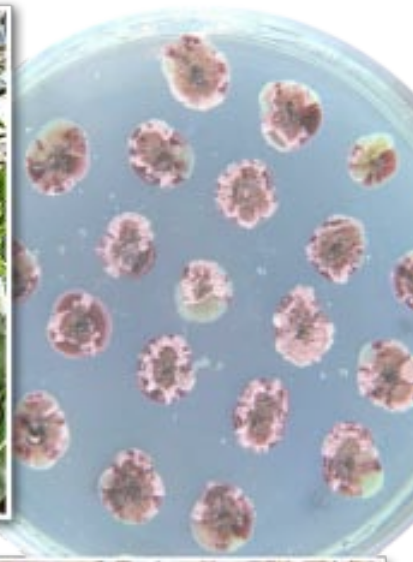
Biodiesel – 171 companies; 2.2 billion gallons/yr capacity1

Corn ethanol

- 174 commercial plants2
- 10.8 billion gal/yr. capacity2
- Additional 2.4 billion gal/yr planned or under construction

Cellulosic ethanol (current technology)

- Projected commercial cost ~$3.50/gge



Key DOE Goals

- 2012 goal: cellulosic ethanol $1.33/ETOH gallon or ~$1.99/gge
- 2022 goal: 36B gal Renewable Fuel; 21B gal "Advanced Renewable Fuel"– 2007 Energy Independence and Security Act
- 2030 goal: 60 billion gal ethanol (30% of 2004 gasoline)

NREL Research Thrusts

- The biorefinery and cellulosic ethanol
- Solutions to under-utilized waste residues
- Energy crops
- New biofuels

Updated February 2009
Sources: 1- National Biodiesel Board
2 - Renewable Fuels Association, all other information based on DOE and USDA sources

The New Bio-Industry

Biomass Feedstock

- Trees
- Grasses
- Agricultural Crops
- Agricultural Residues
- Animal Wastes
- Municipal Solid Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Combustion
- Co-firing

… and new concepts from plants to products

USES

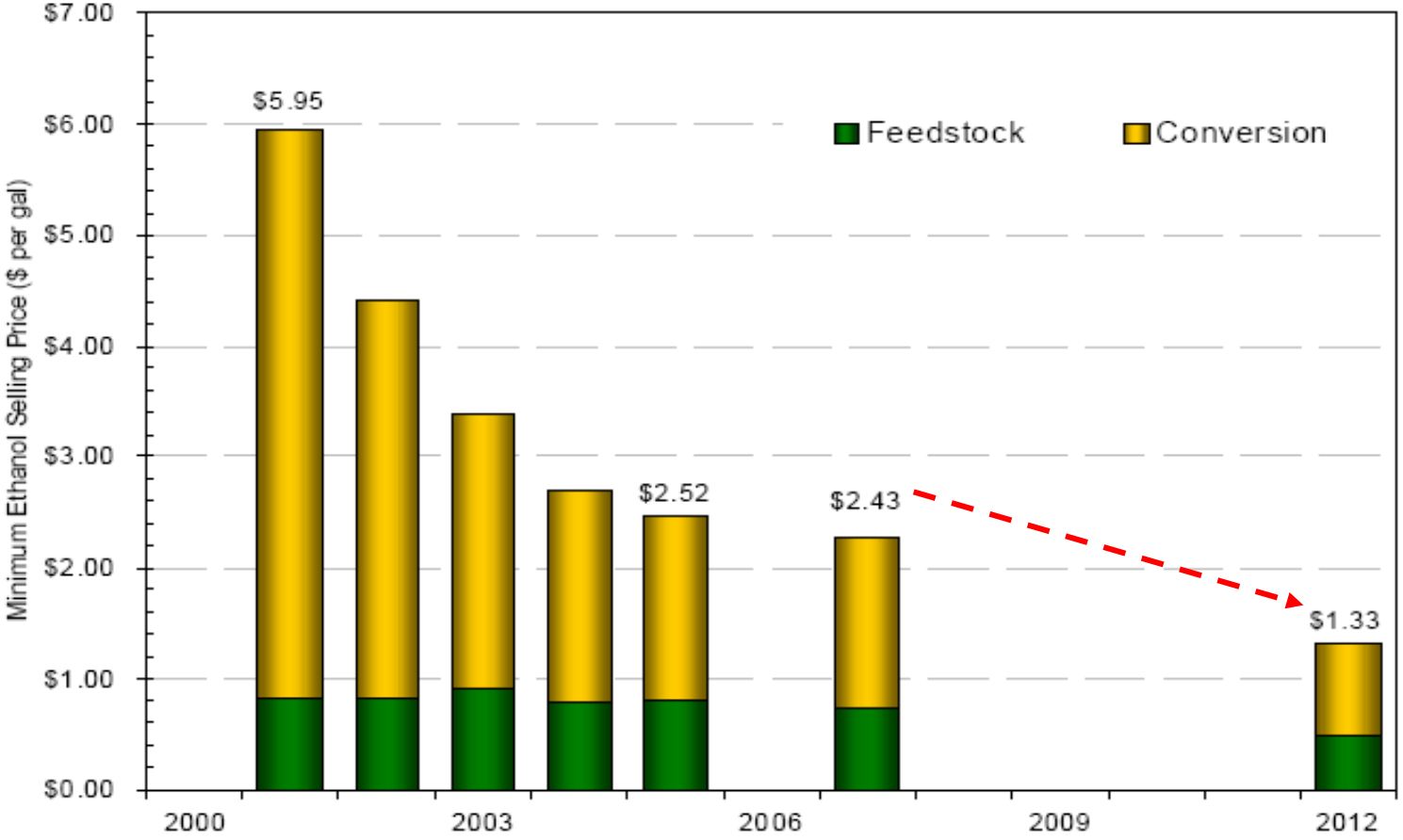
Fuels:
Ethanol
Renewable Diesel

Power:
Electricity
Heat

Chemicals
Plastics
Solvents
Chemical Intermediates
Phenolics
Adhesives
Furfural
Fatty acids
Acetic Acid
Carbon black
Paints
Dyes, Pigments, and Ink
Detergents
Lubricants
Etc.

Food and Feed and Fiber

State of Technology—Biochemical Conversion

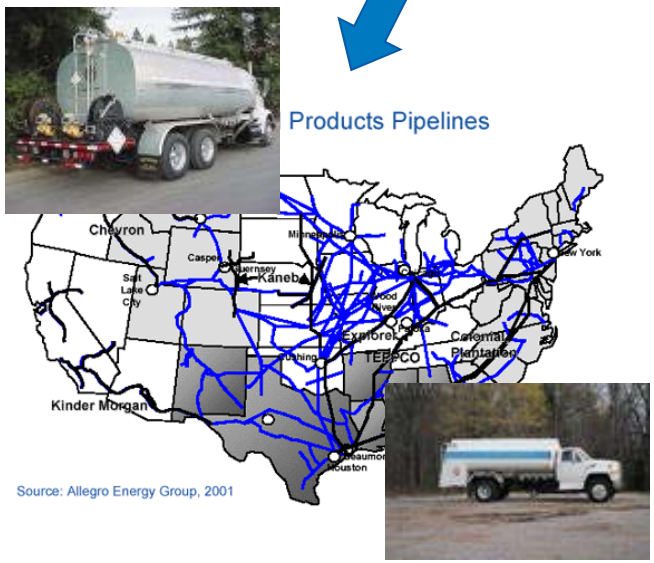


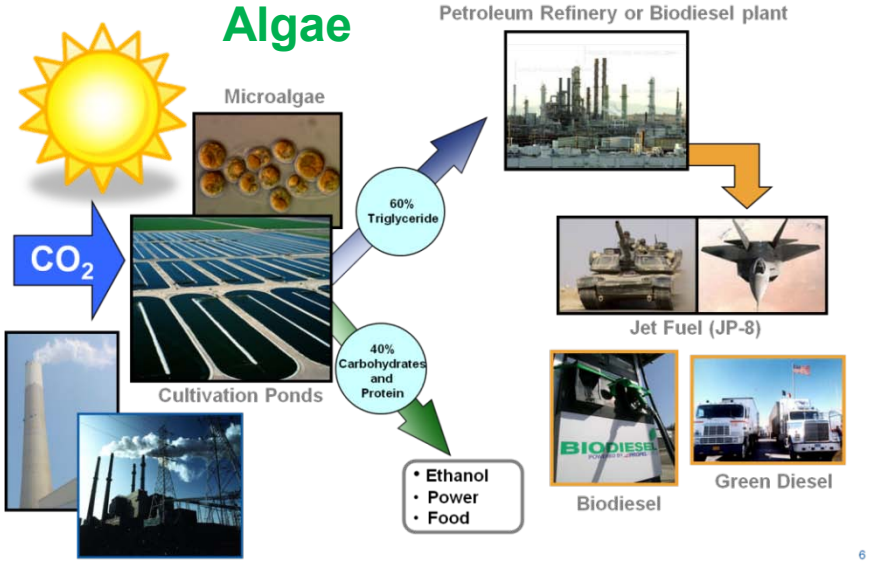
STATE OF TECHNOLOGY PROGRESS TOWARD THE 2012 GOAL (ESTIMATED 2007 DOLLARS)

Why Follow-On Generations?

3rd & 4th Generations – "beyond ethanol"

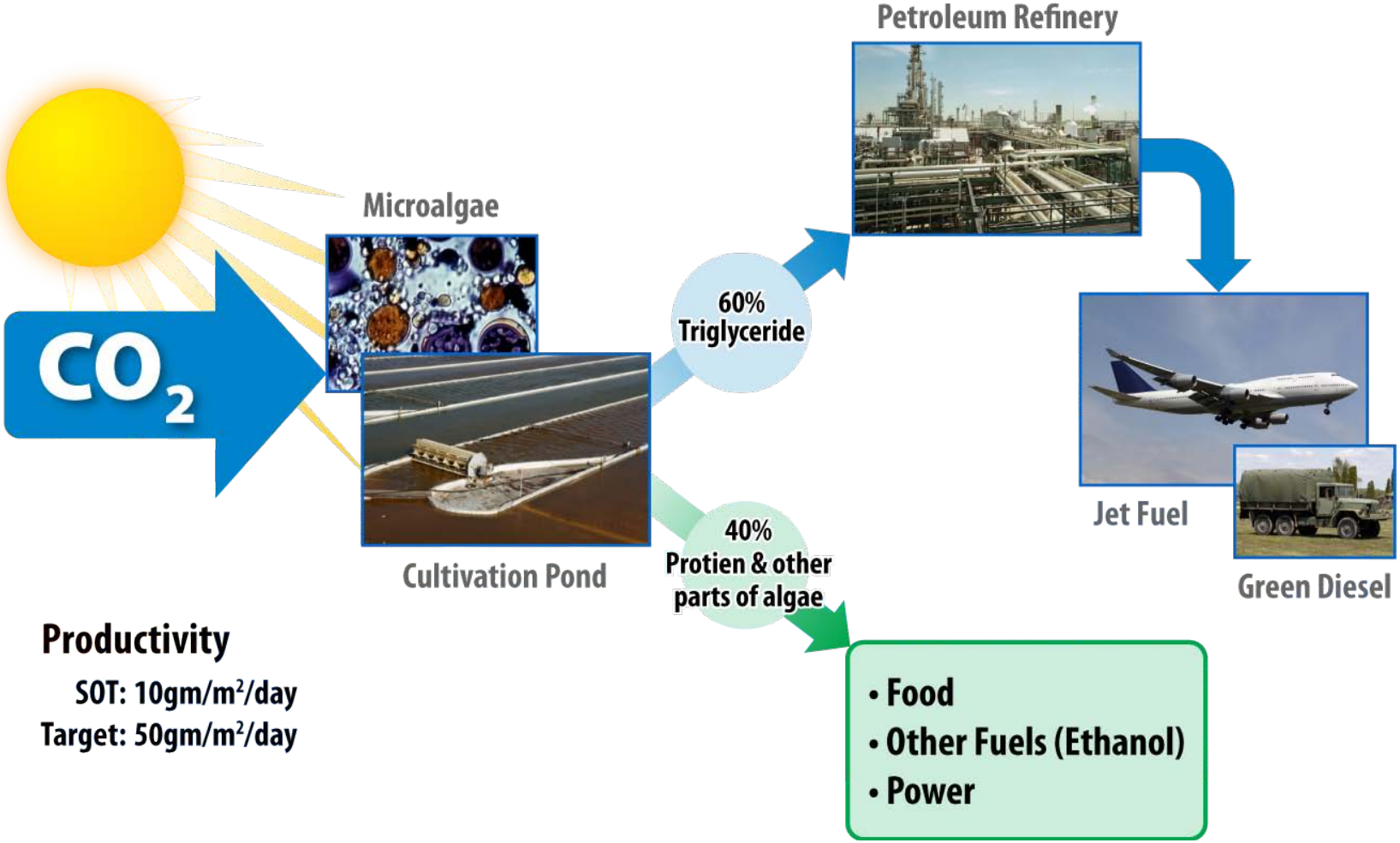
- Higher energy density/suitability
- Better temp and cold start ability
- Energy and tailored feedstocks
- Infrastructure compatibility





A Novel Approach for making Fuel from Biomass

Combine two technologies: Algae & Green Diesel



Productivity

SOT: 10gm/m²/day

Target: 50gm/m²/day

Sustainable Transportation

Advanced Vehicles and Fuels Options

Conventional Vehicles

Hybrid Electric Vehicles

Plug-in Hybrid Vehicles

Hydrogen Vehicles—ICE or Fuel Cell

Corn Ethanol, Cellulosic Ethanol

Biodiesel, Fischer-Tropsch Diesel

Natural Gas other Petrochemicals

Electricity from Grid

Distributed Renewable Electricity

Hydrogen from Natural Gas

Renewable Hydrogen

Plug-In Hybrid Electric Vehicles (PHEV)

Status:

- PHEV-only conversion vehicles available
- OEMS building prototypes
- NREL PHEV Test Bed

NREL Research Thrusts

- Energy storage
- Advanced power electronics
- Vehicle ancillary loads reduction
- Vehicle thermal management
- Utility interconnection
- Vehicle-to-grid

Key Challenges

- Energy storage – life and cost
- Utility impacts
- Vehicle cost
- Recharging locations
- Tailpipe emissions/cold starts
- Cabin heating/cooling
- ~33% put cars in garage

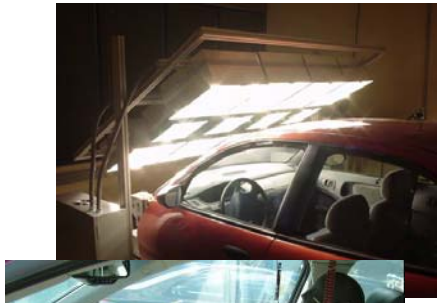
Advanced Vehicle Technologies

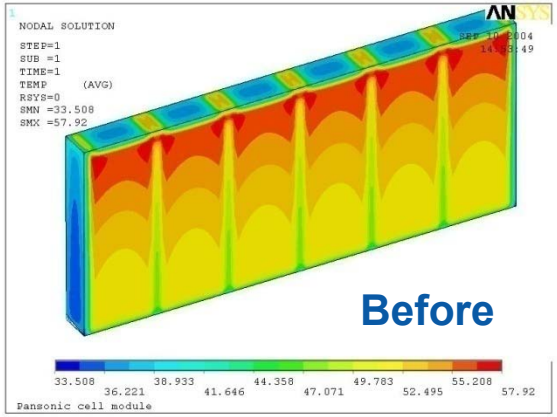
Energy Storage

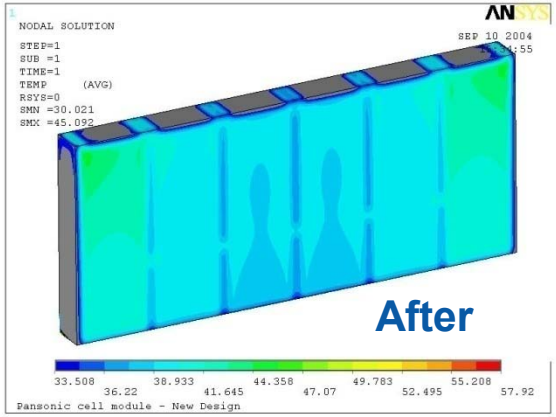
UltraCaps

Advanced Power Electronics

Vehicle Ancillary Loads Reduction







Hydrogen and Fuel Cells

U.S. Status

- 400+ fuel cell vehicles on the road
- 58 hydrogen fueling stations

Goals

Hydrogen Production

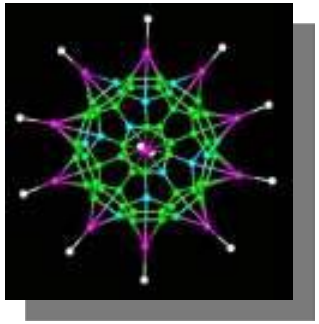
- $2-3/Kg for all pathways
- Renewables in $5-10/Kg range

Fuel Cells

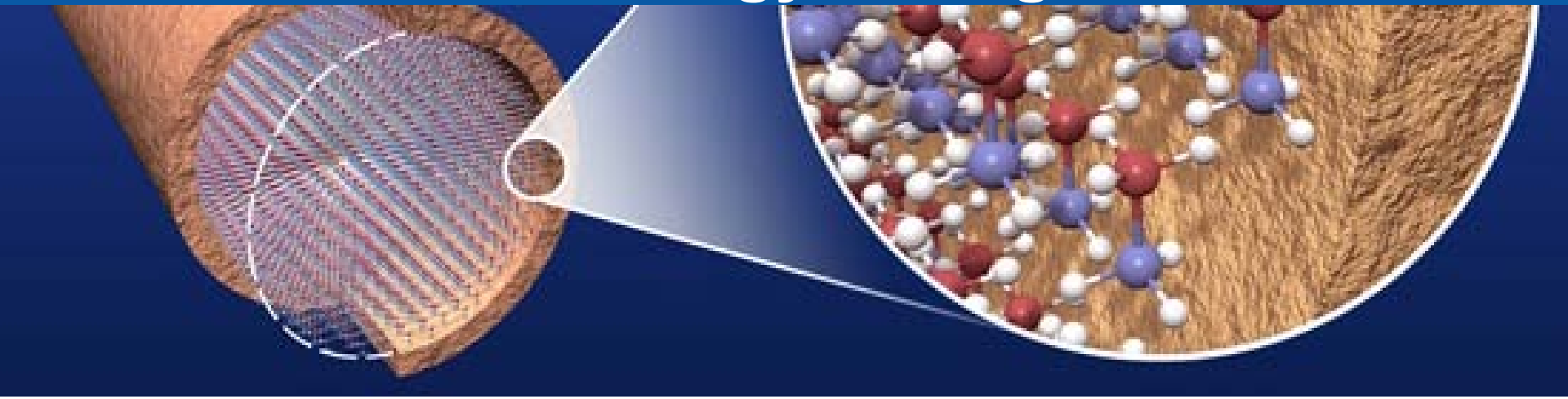
- $30/kW by 2015
- 5,000 hour stack life

NREL Research Thrusts

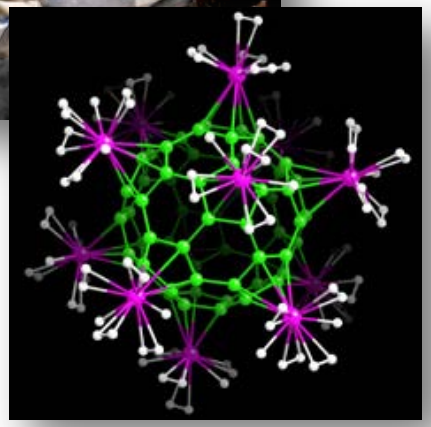
- Renewable H2 production
- Safety/codes/standards
- Early market introduction



Energy Storage



Designer Nanostructured Materials are Critical to Enabling Energy Storage Systems for Renewables



Organometallic Buckyballs for Hydrogen Storage

State-of-the-art processing to create novel nanomaterials for energy storage:

- Hydrogen storage: porous carbons, boro-carbons, metcars, macromolecules
- Batteries: novel electrolytes and metal oxides for cathodes and anodes
- Ultracapacitors: nanotubes and high dielectric materials
- Dynamic smart windows

NREL leads DOEs hydrogen sorption Center of Excellence

- Develops high surface area, low-weight and low-cst materials
- 15 projects: 4 national labs, 10 universities, and on industrial parnter

Energy Efficiency

Energy Efficiency - Buildings

Van Geet home located in Idaho Springs, CO

08226

21st Century Performance home

12245

11269

NREL's Solar Energy Research Facility

10229

Solar Patriot House

Buildings

Status U.S. Buildings:
- 39% of primary energy
- 71% of electricity
- 38% of carbon emissions

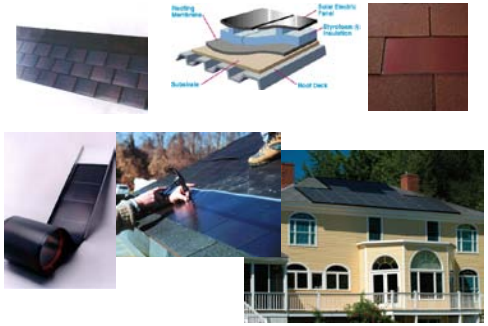
DOE Goal:
- Cost effective, marketable zero energy buildings by 2025
- Value of energy savings exceeds cost of energy features on a cash flow basis

NREL Research Thrusts
- Whole building systems integration of efficiency and renewable features
- Computerized building energy optimization tools
- Building integrated PV

April 10, 2008

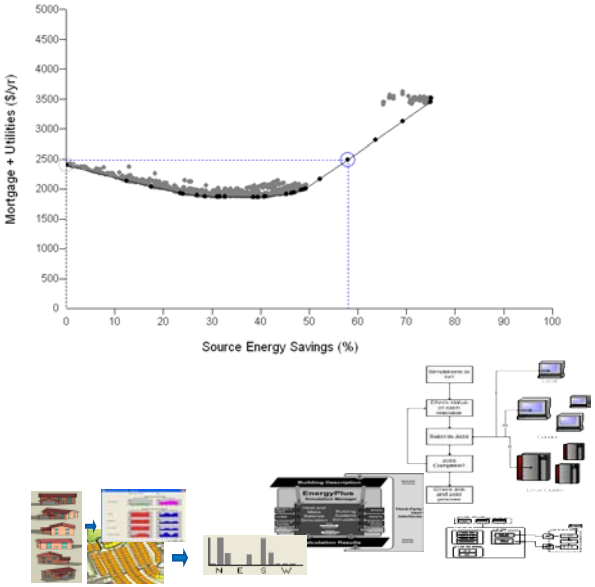
Technology for Cost Effective Zero Energy Buildings

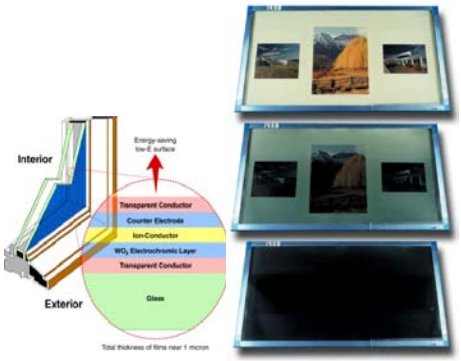
NREL Zero Energy Habitat House



BIPV Products & PV-T Array

Compressorless Cooling





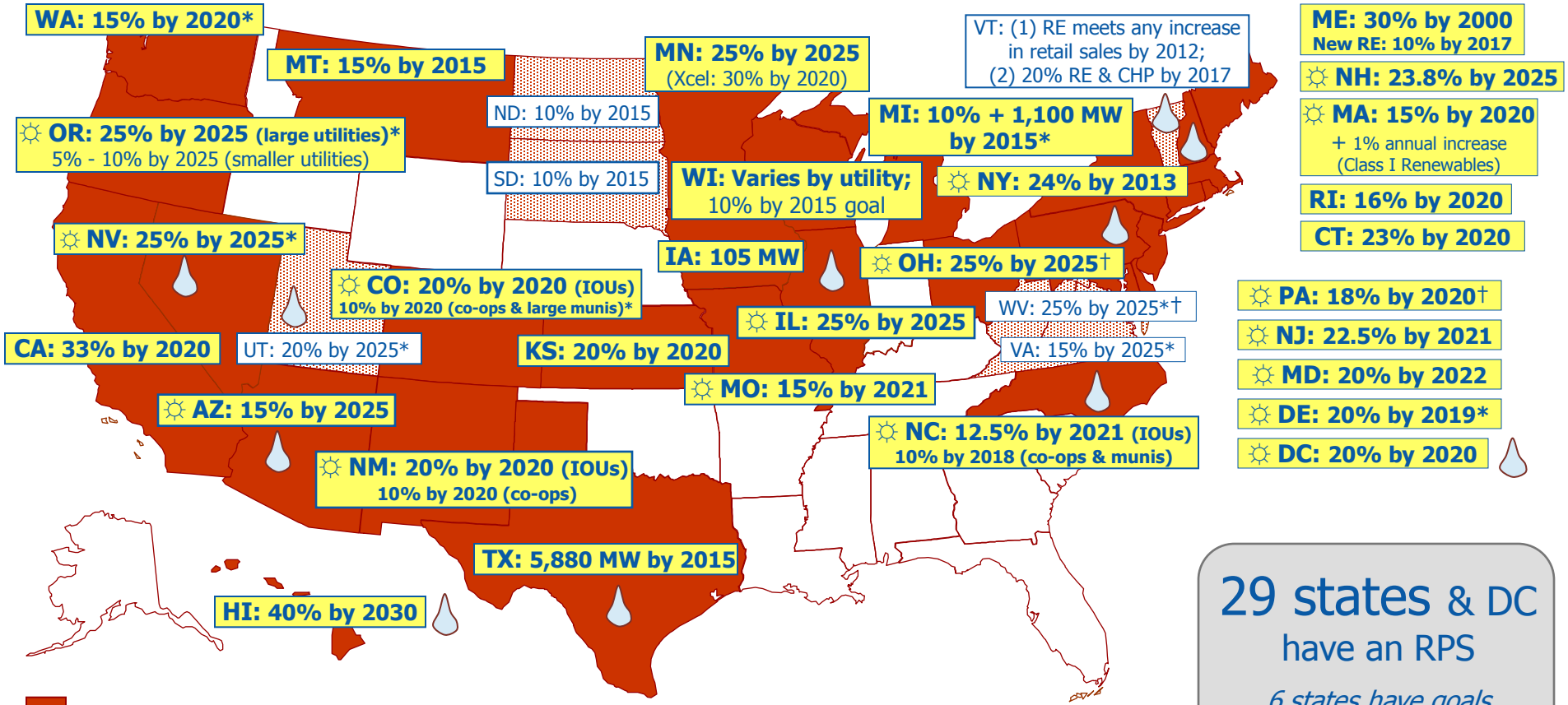
Electrochromic Windows

Polymer Solar Water Heaters

Computerized optimization & simulation Tools

Renewable Portfolio Standards

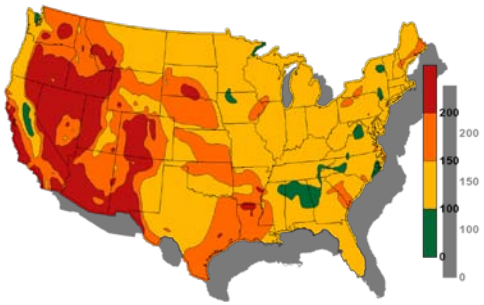
www.dsireusa.org / January 2010

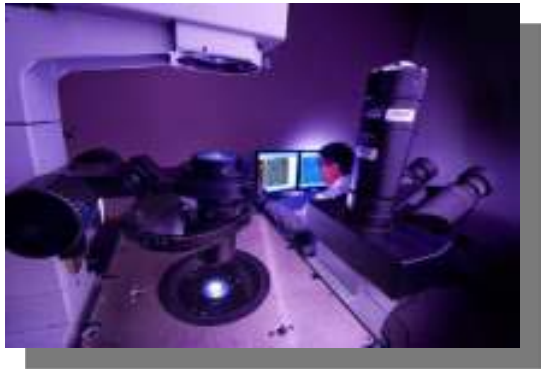


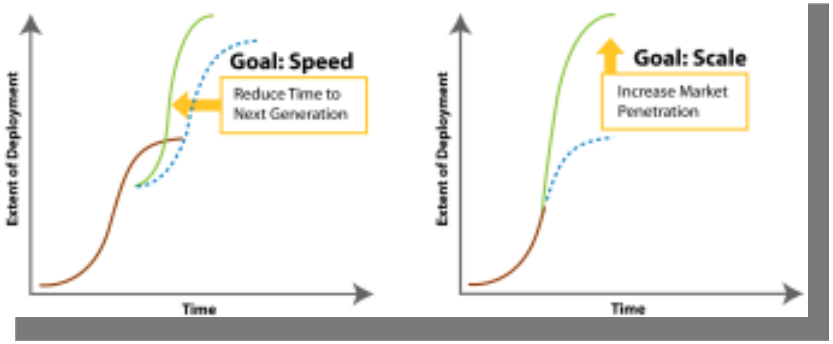
New Directions

New Emerging Programmatic Areas

- Enhanced Geothermal Systems
- Ocean/tidal
- Smart Grid
- Focus on translational science
- New business models for commercialization and deployment
- Analysis evaluation/validation
- International cooperation

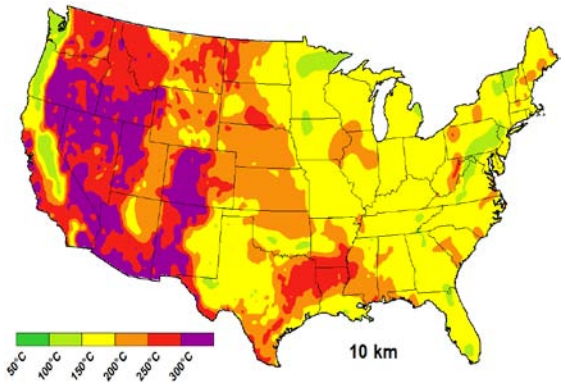


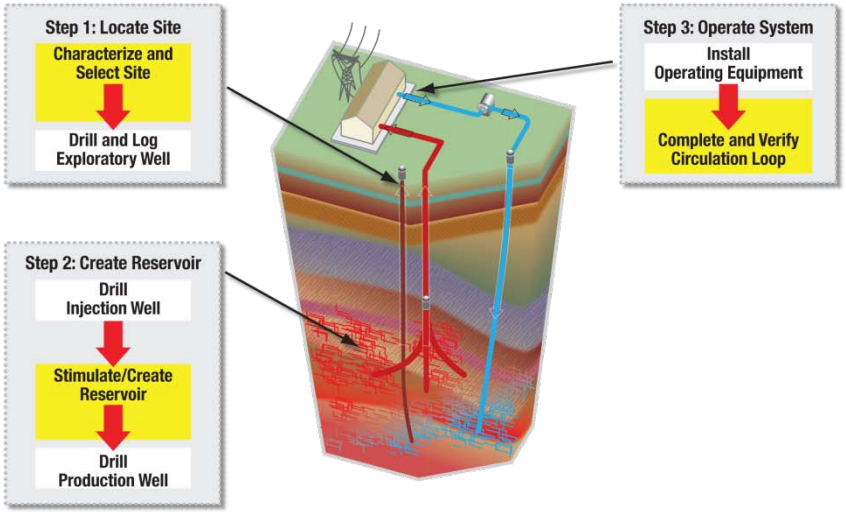




Evaluating Potential New Directions

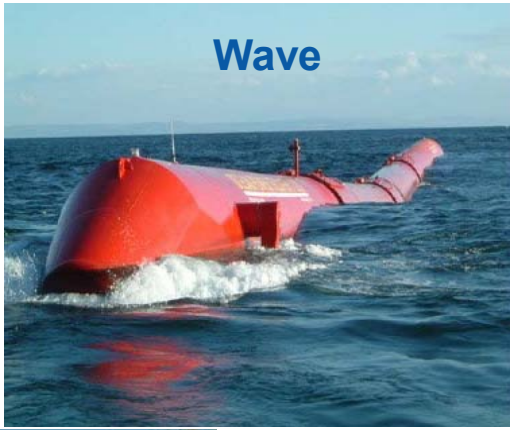
Enhanced Geothermal Systems





Ocean Kinetic Energy

Wave



Tidal

Pelamis—Ocean Power Delivery

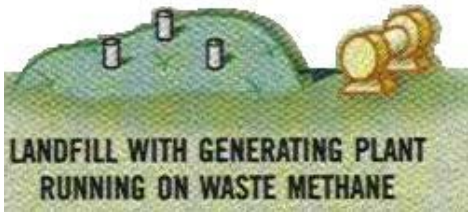
Verdant—Power RITE Turbine

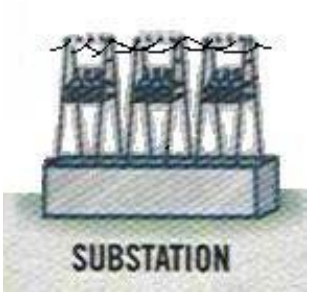
Future Electric System

Key Challenges:

Power flows both directions

Intermittency of some Renewables



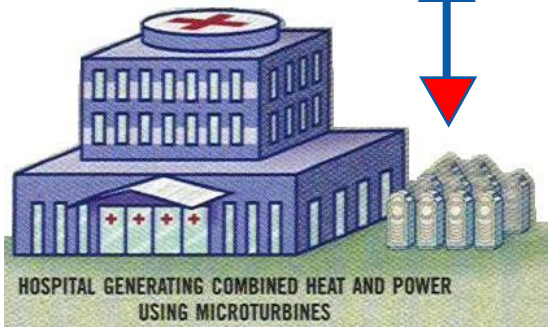


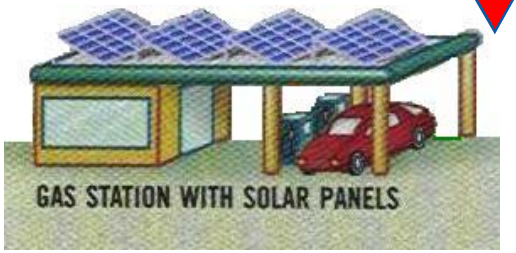
Red Arrows:

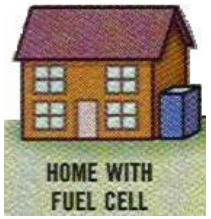
Power sold by central generators to homes and commercial buildings

Green Arrows:

Power flowing from distributed generators back to substations







An Integrated Approach is Required