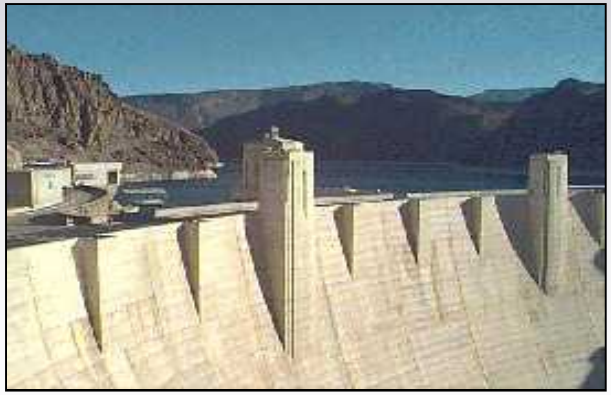
Energy-Water Nexus: Integrated Modeling and Scenario Analysis

SAND2009-6544C

Vincent Tidwell, Peter Kobos, Len Malczynski, Geoff Klise

Sandia National Laboratories

Albuquerque, New Mexico



Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

NNSA National Nuclear Security Administration

Sandia National Laboratories

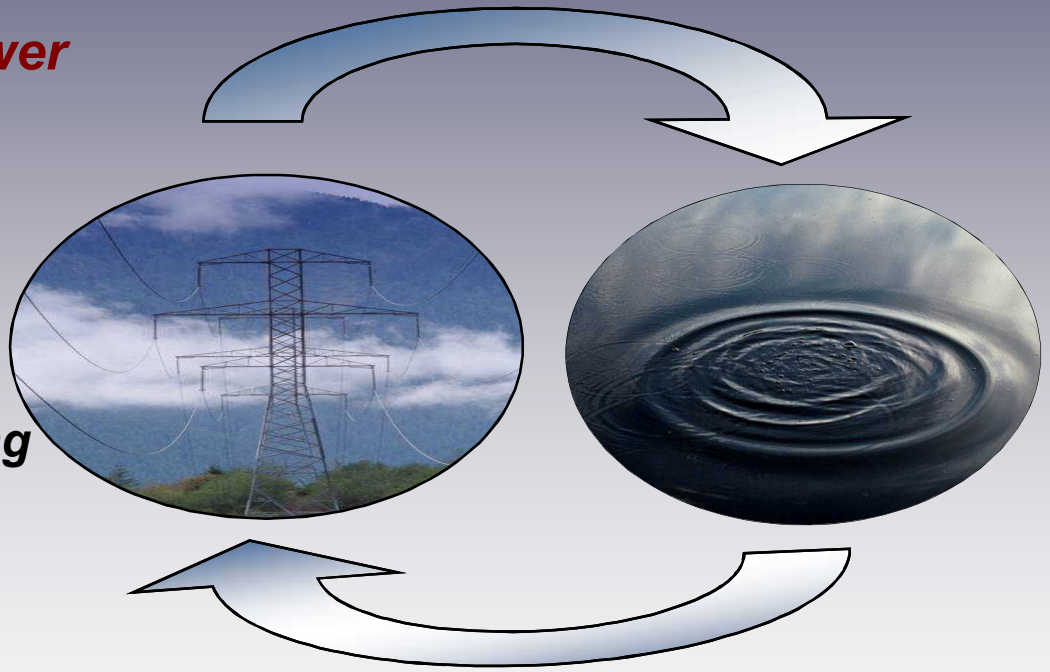
LABOR

Water for Energy

Energy for Water

Energy and power production requires water

- ***Thermoelectric Cooling***
- ***Energy Minerals Extraction/Mining***
- ***Fuel Processing (fossil fuels, H_2,biofuels)***
- ***Emission Control***



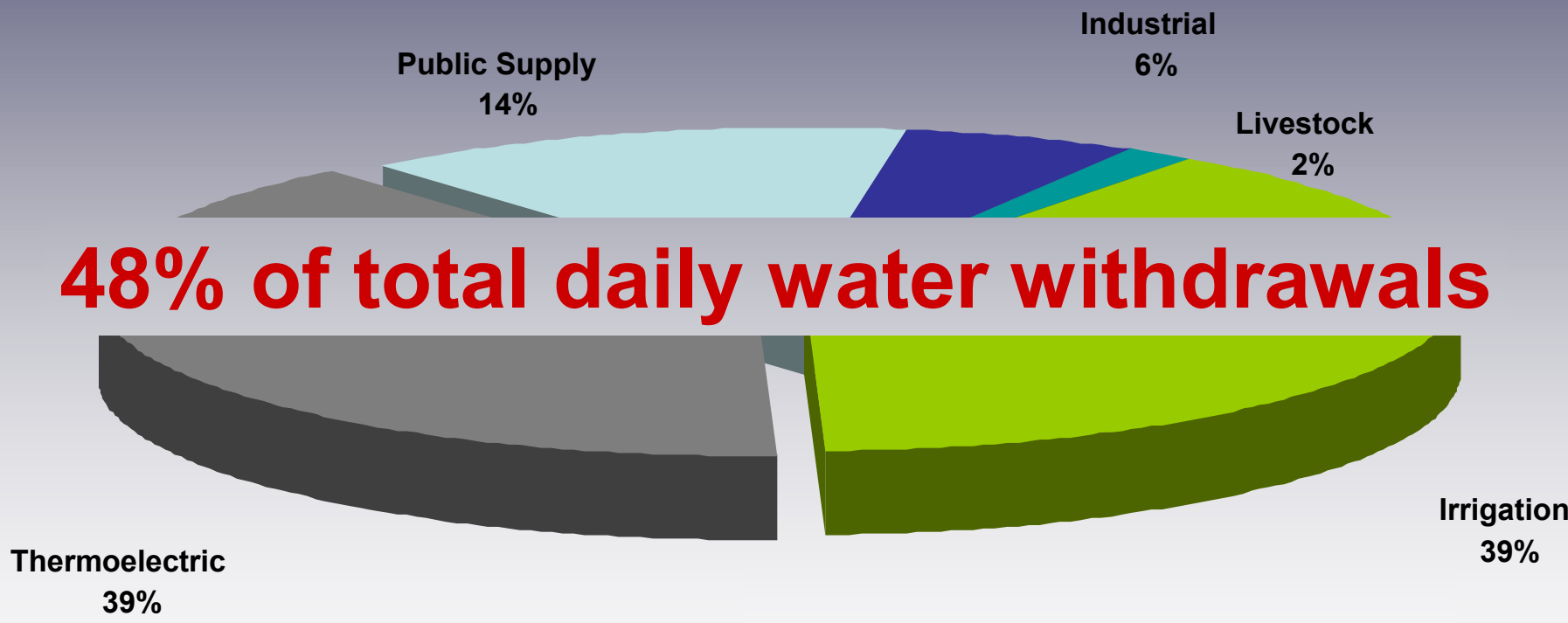
Water production, processing, distribution, and end-use requires energy

- ***Pumping***
- ***Conveyance***
- ***Treatment***
- ***Distribution***
- ***Use Conditioning***

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Estimated Freshwater Withdrawals by Sector: 320 BGD

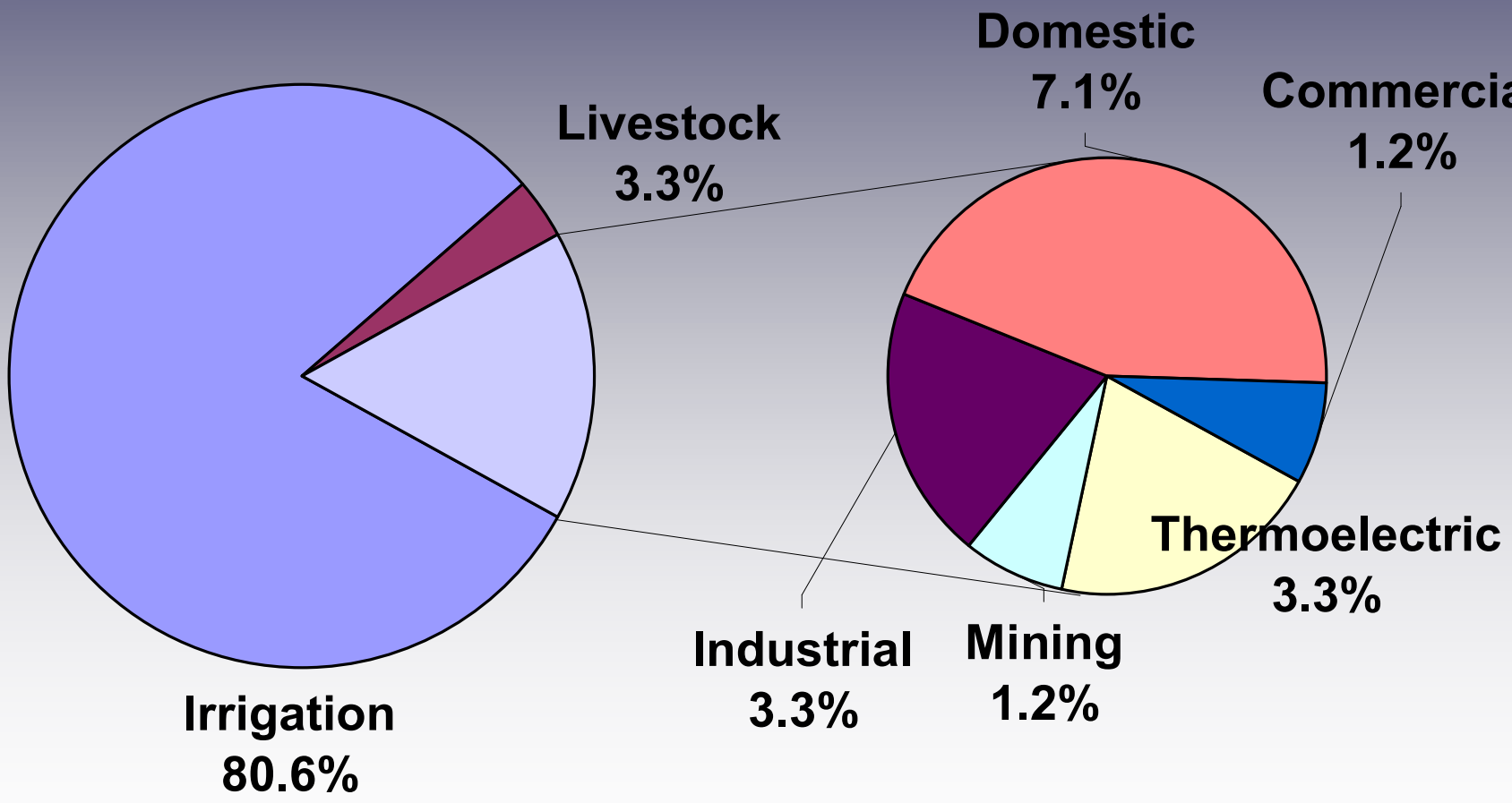


Source: USGS Circular 1268, March, 2004

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

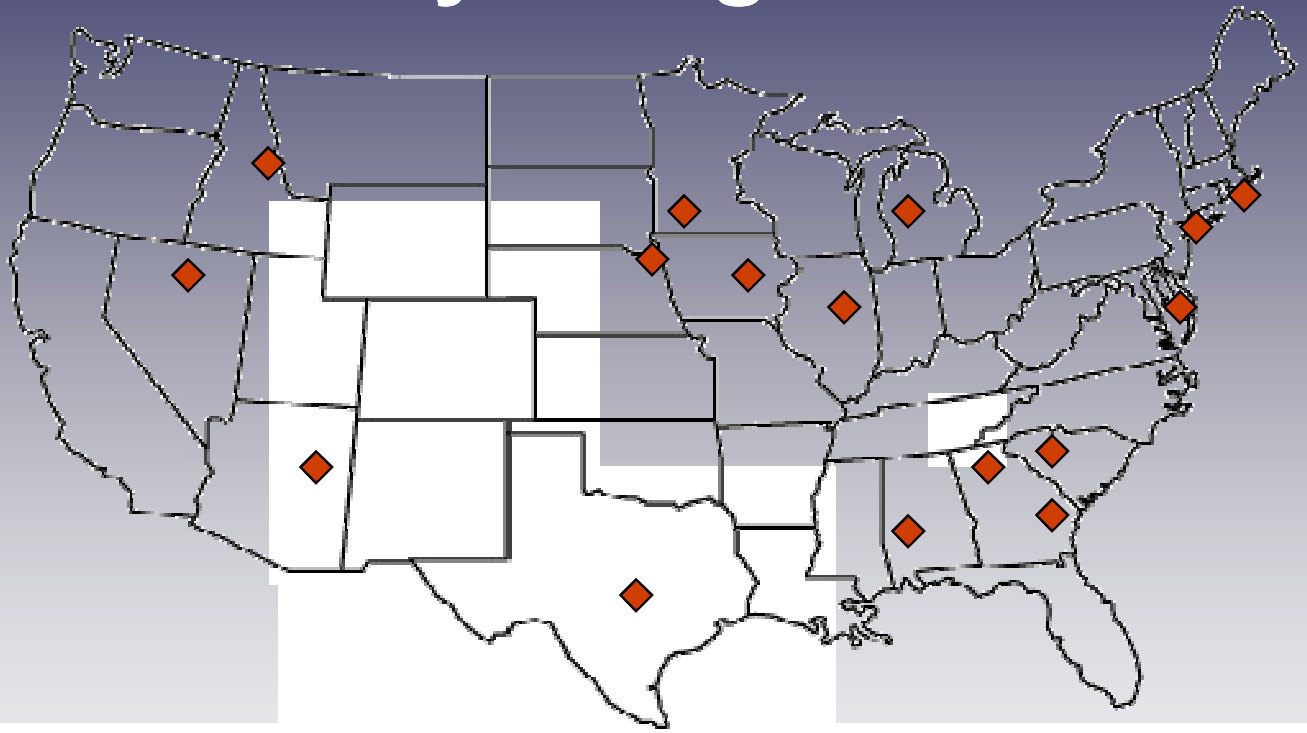
Sandia National Laboratories

U.S. Freshwater Consumption: 100 BGD



Source: Solley et al., 1998

Energy-water nexus issues are already being realized



LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Energy-Water Roadmap

- Three regional needs assessment workshops: Nov 2005 through mid-January 2006

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

National Laboratories

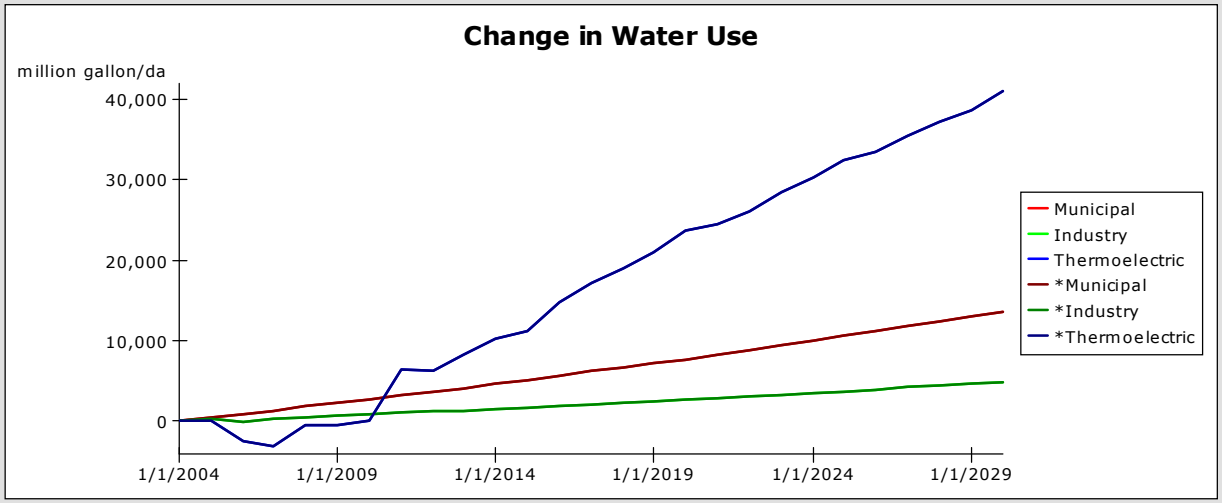
Project Impetus

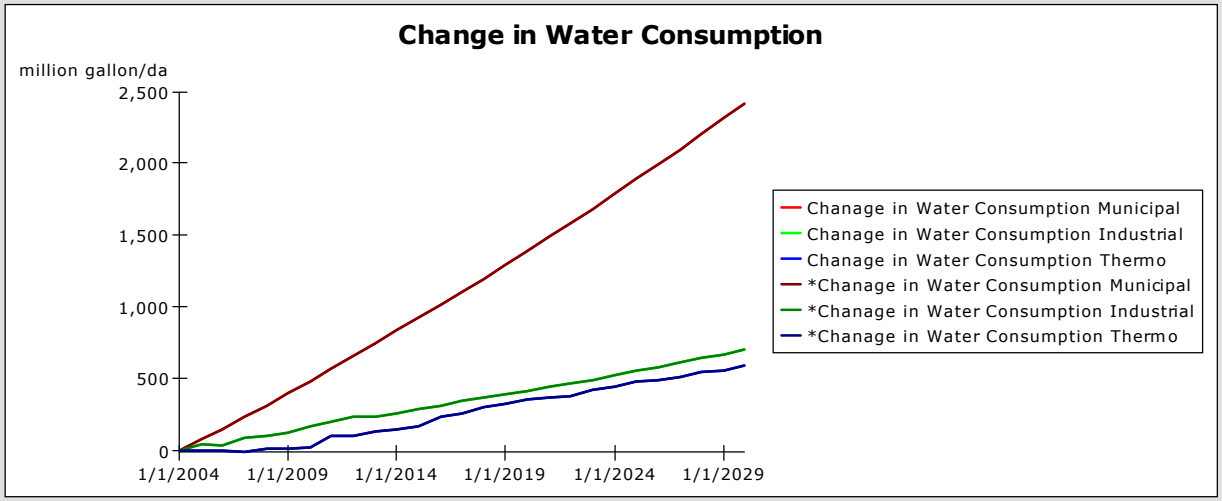
- Energy-Water Roadmap findings:
  - Reduce fresh water consumption in electric power generation
  - Improved water efficiency in alternative fuels production
  - Treatment and use of non-traditional water for energy development
  - *Integrated energy and water resource planning and management*

Create an Energy-Water Planning Framework

Sandia National Laboratories

- Home
- National Totals
- Water for Energy
- Plant Renewal
- Water by Supply
- Energy for Water
- Emissions
- Population
- Gross National Product

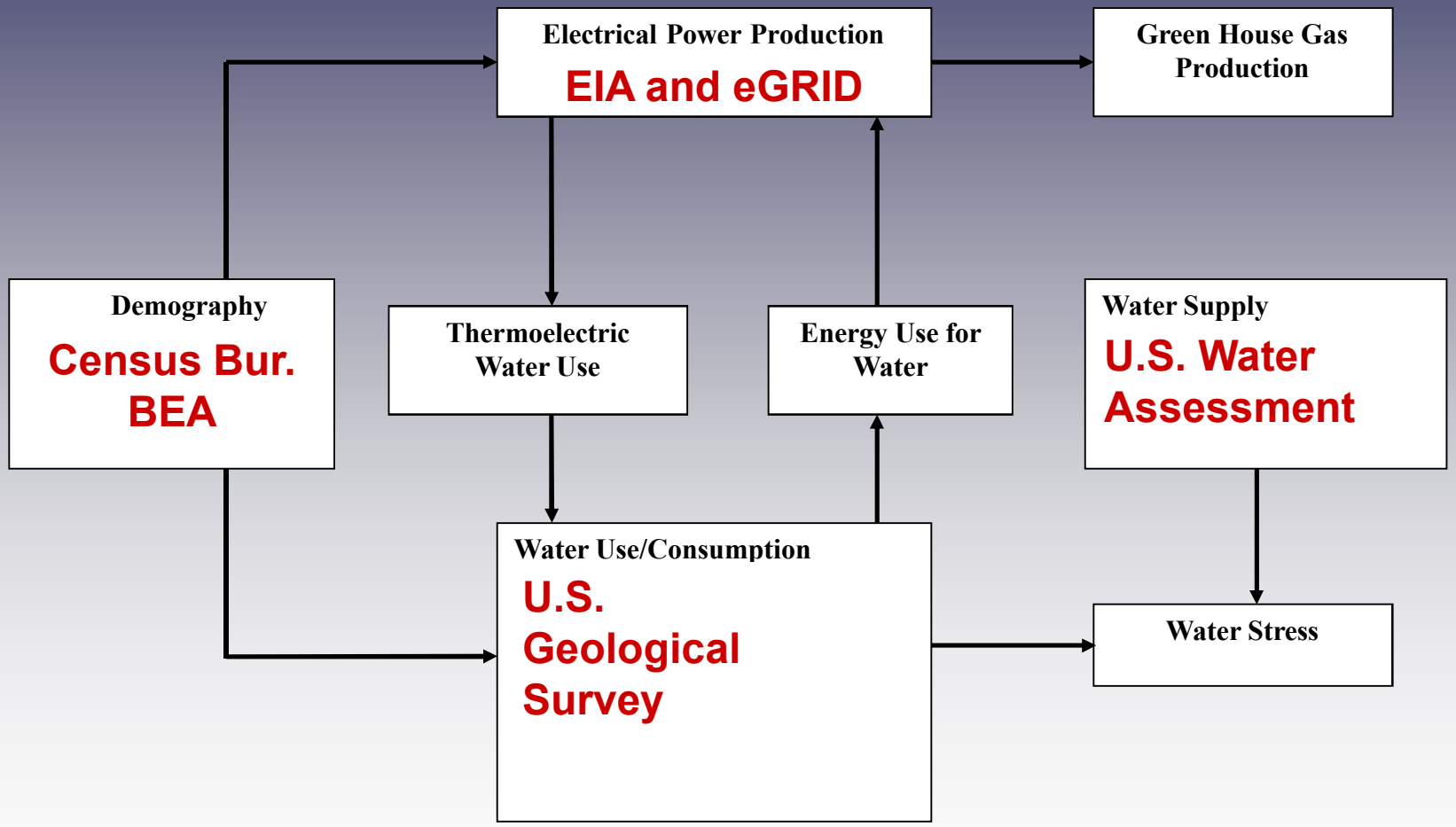




LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

General Model Structure

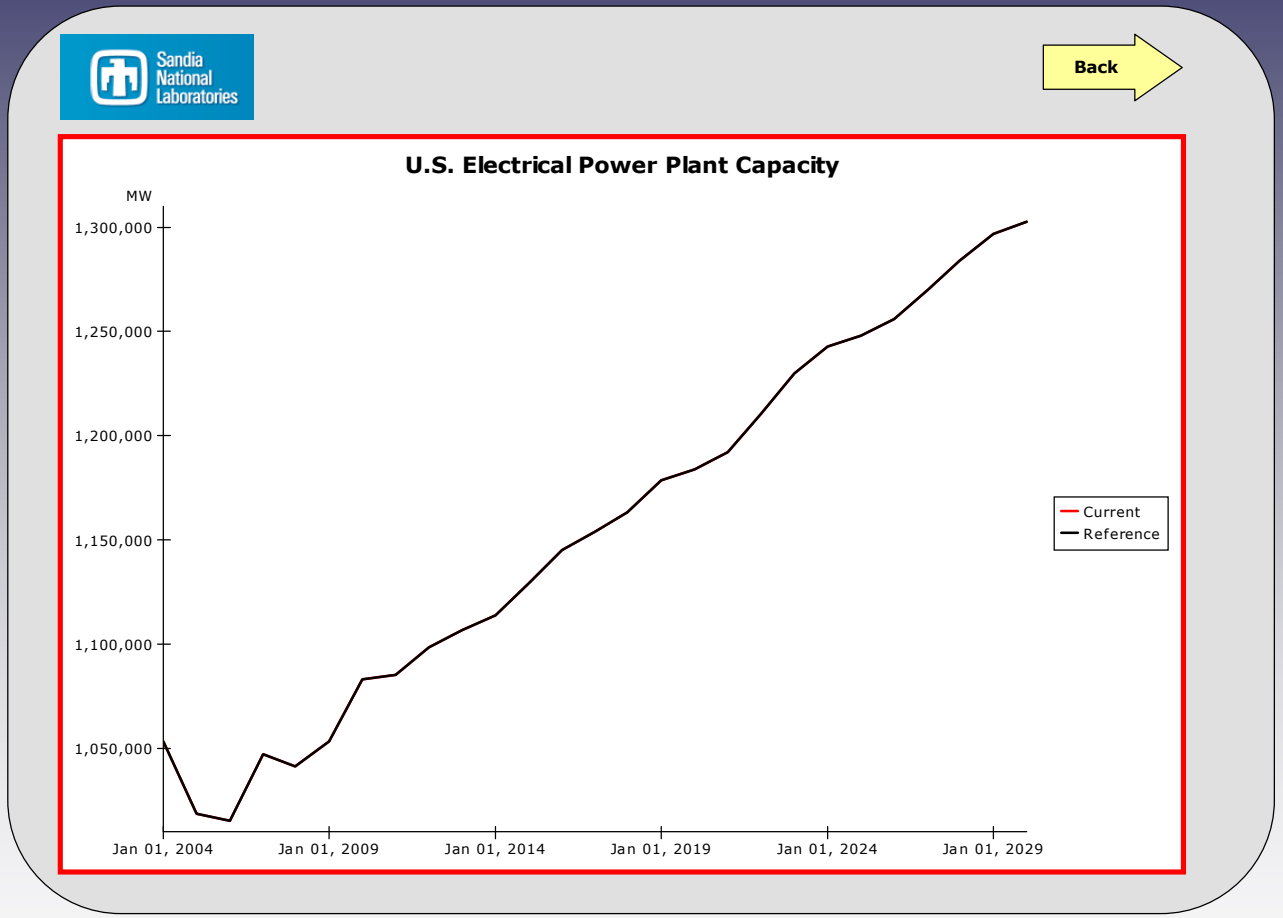


LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Plant Capacity at National Level

- Increase power plant capacity based on EIA projections (~25% in 27 years)
- New plants have same fuel type distribution as current

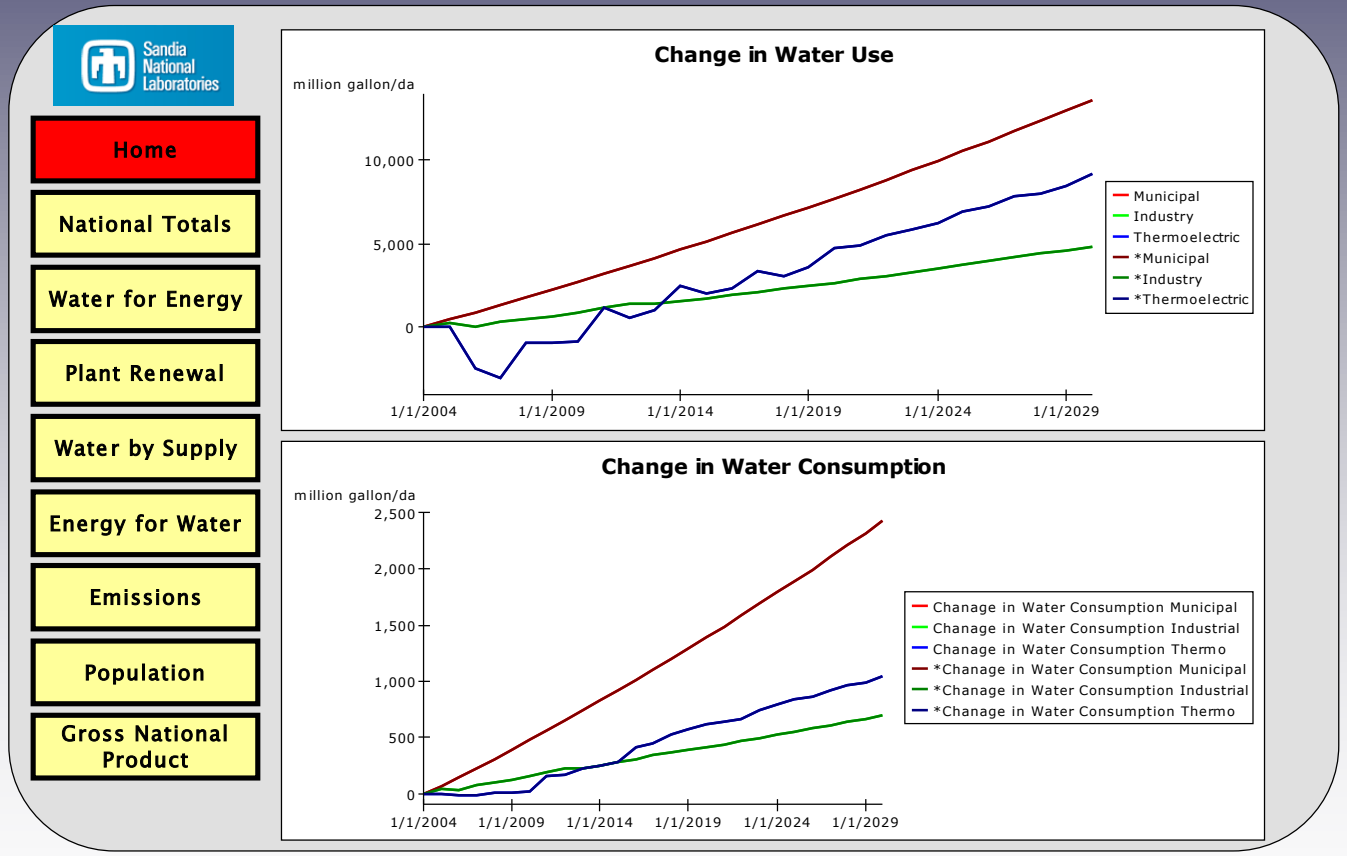


LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Water Use/Consumption at National Level

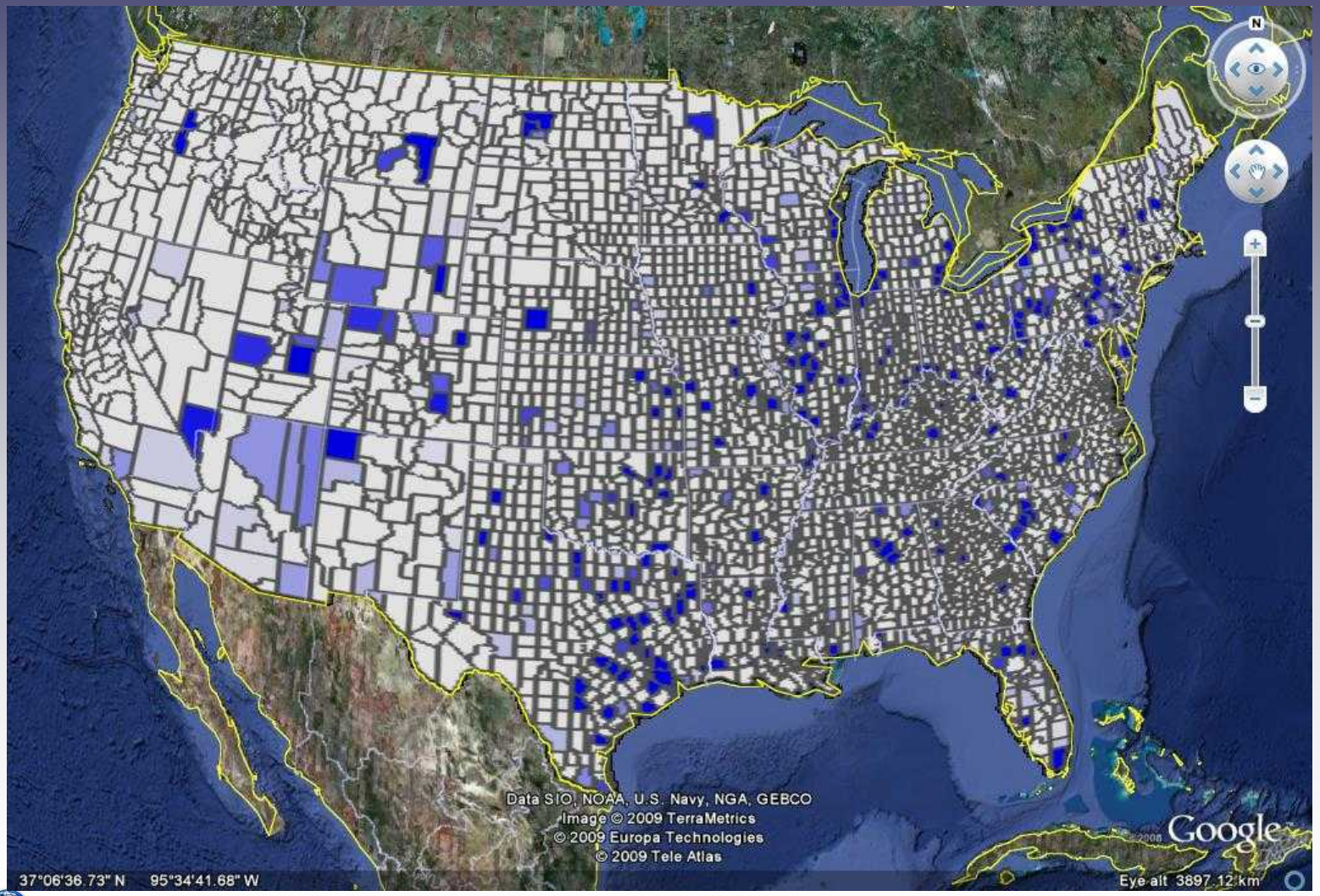
- Under this scenario growth in thermoelectric water use grows from 194.5 to 204.0 BGD (a 5% increase) with a more significant increase in water consumption 3.7 to 4.7 BGD (a 27% increase)



LDRD LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

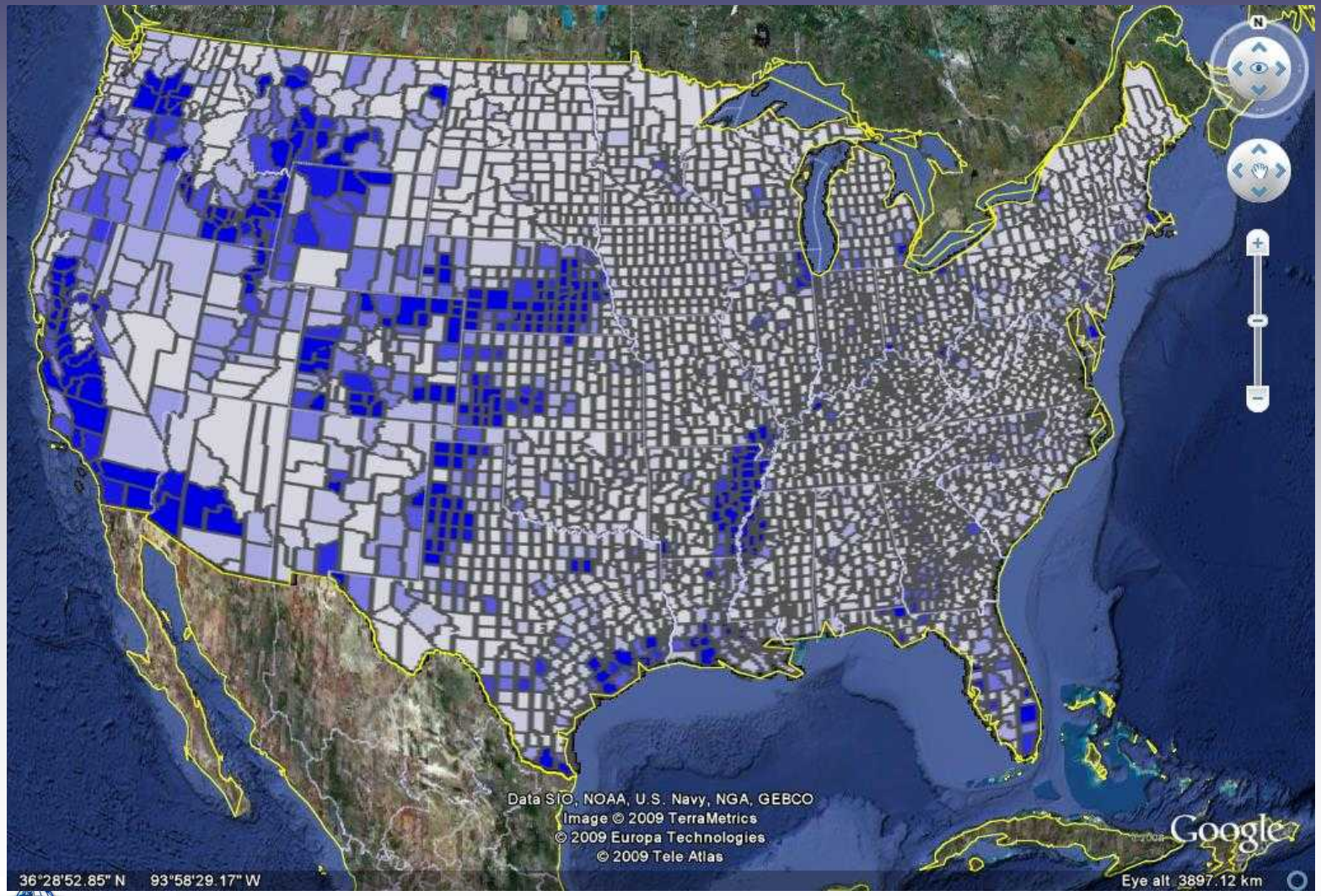
Thermoelectric Water Consumption in the Continental United States: 2004



LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Total Water Consumption in the United States: 2004

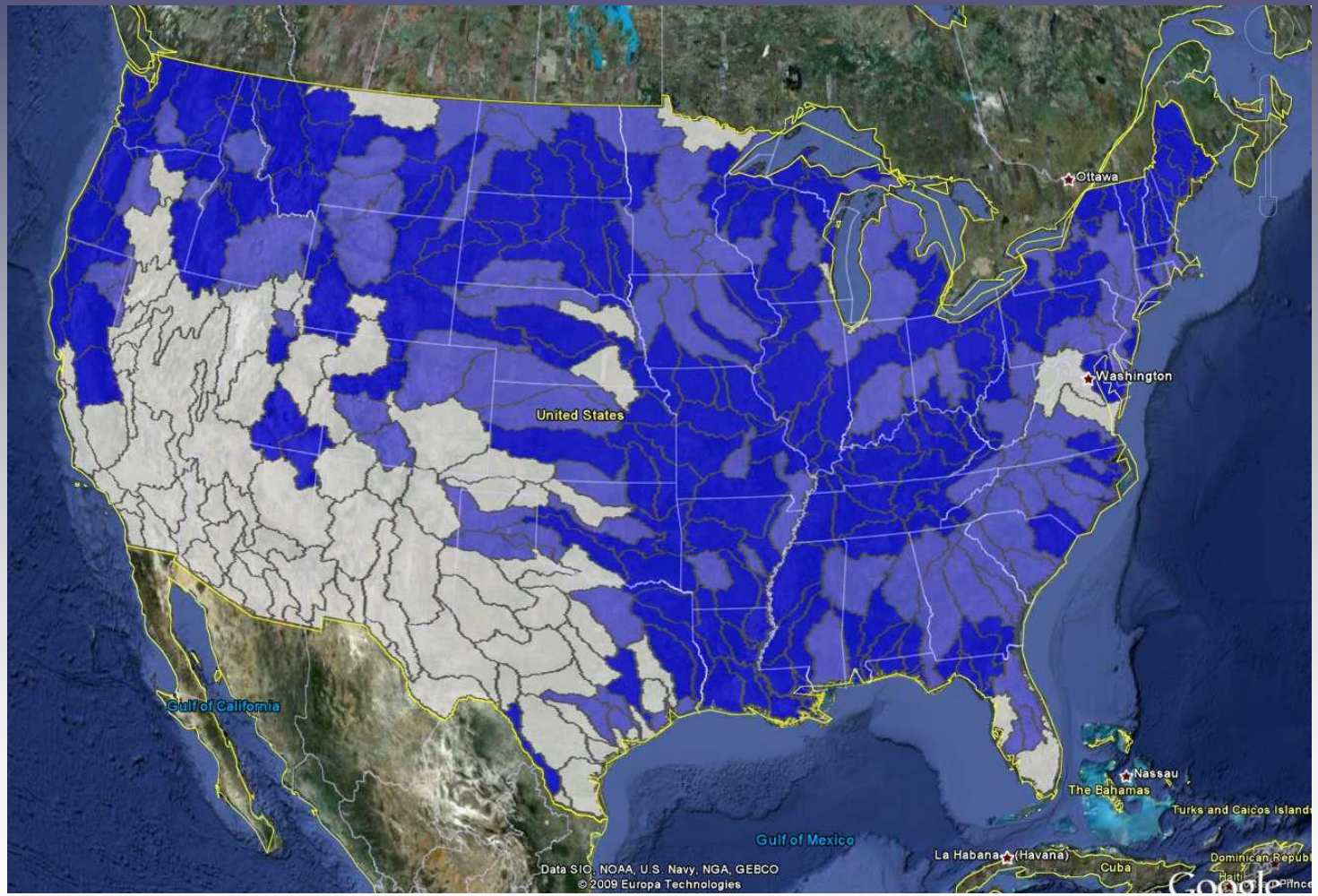


LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Ratio of Water Supply to Demand

Mean Gauged River Flow



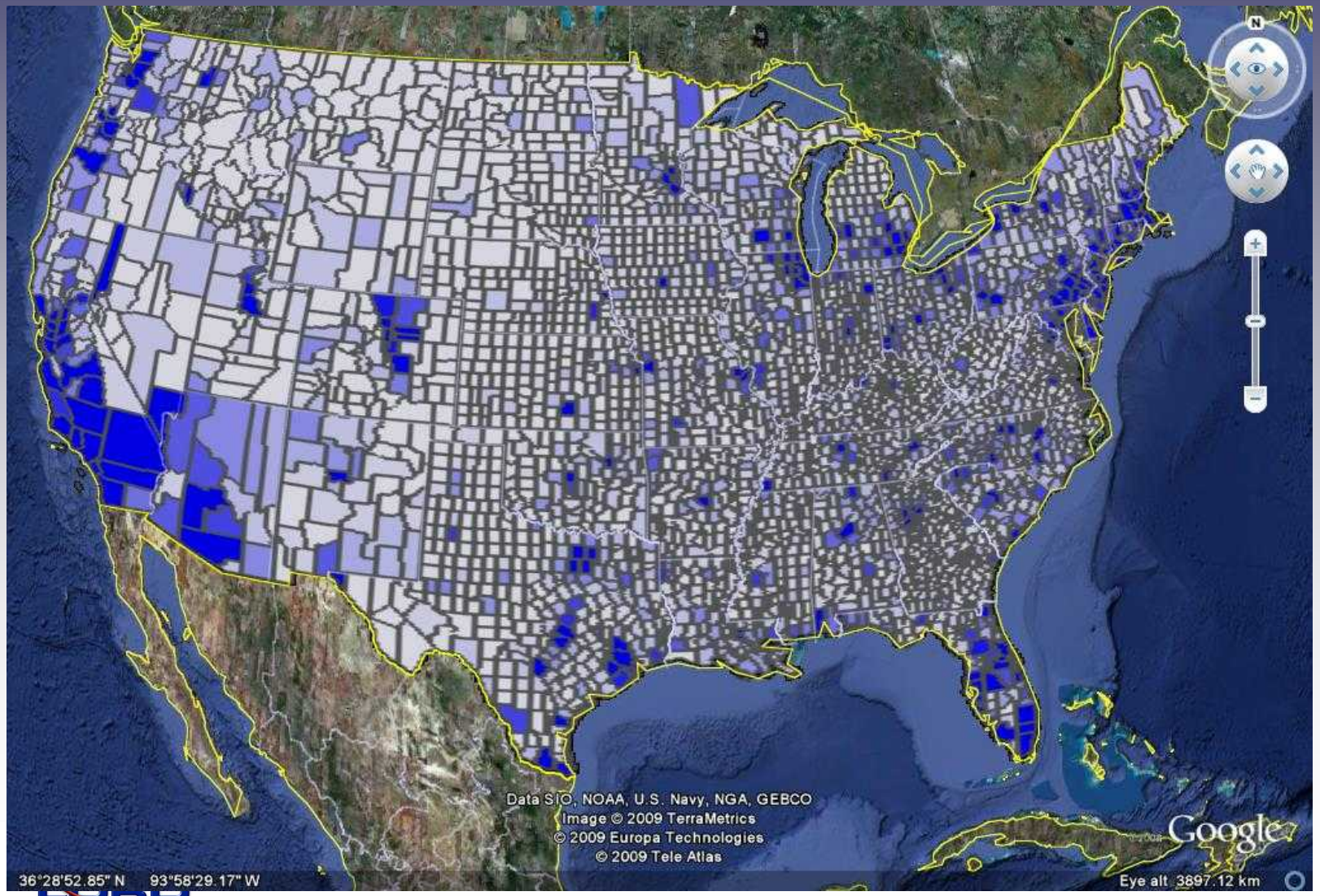
Supply/Demand

- <3
- 3-10
- >10

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Projected Population Change 2004-2030



Population

0

30K

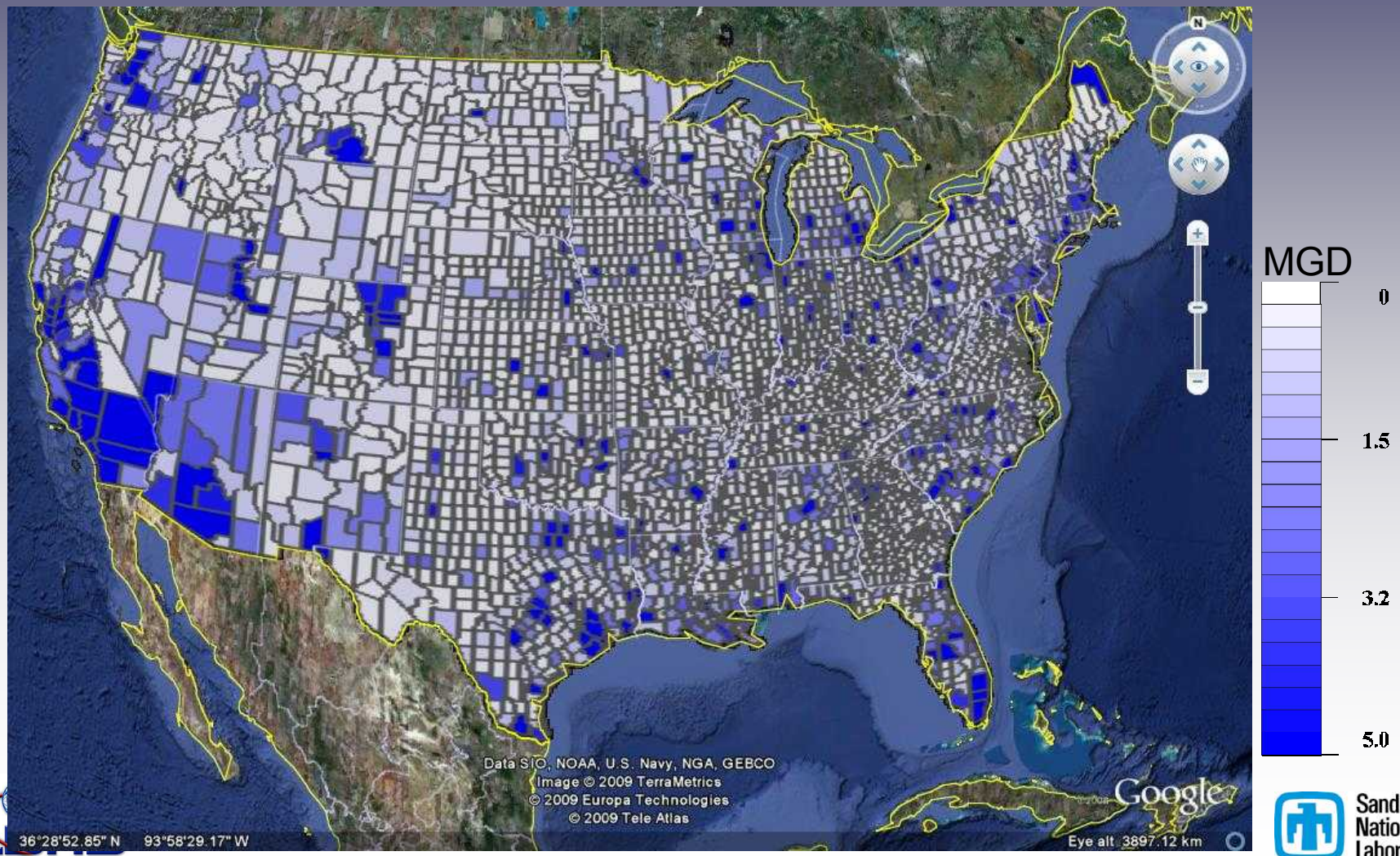
65K

100K

LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

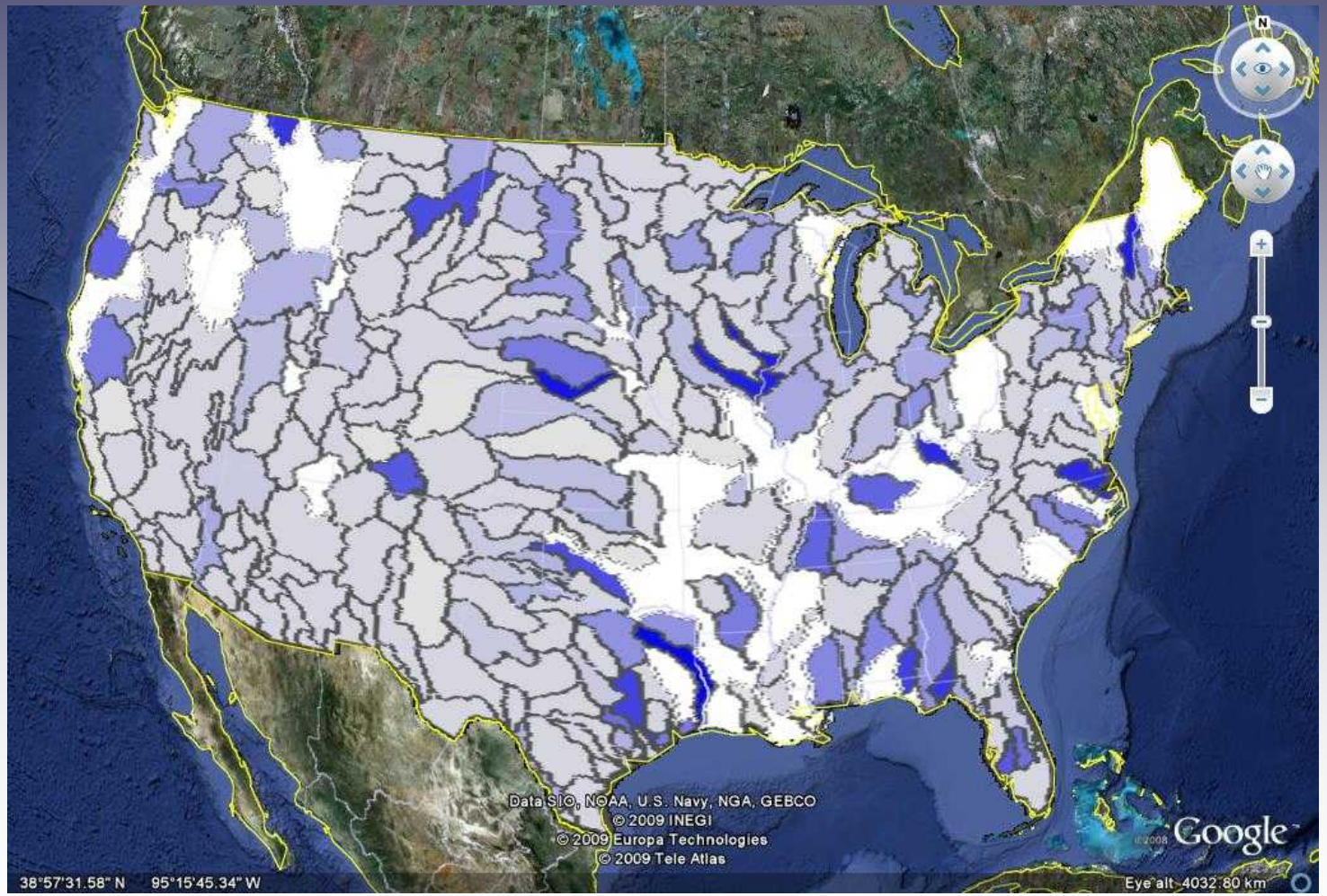
Projected Increase in Non-Thermoelectric Water Consumption 2004-2030

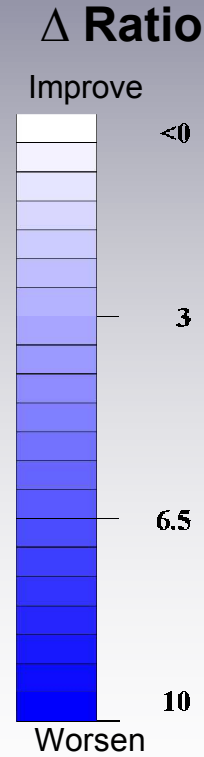


LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Change in Supply vs. Demand Ratio 2004 to 2030

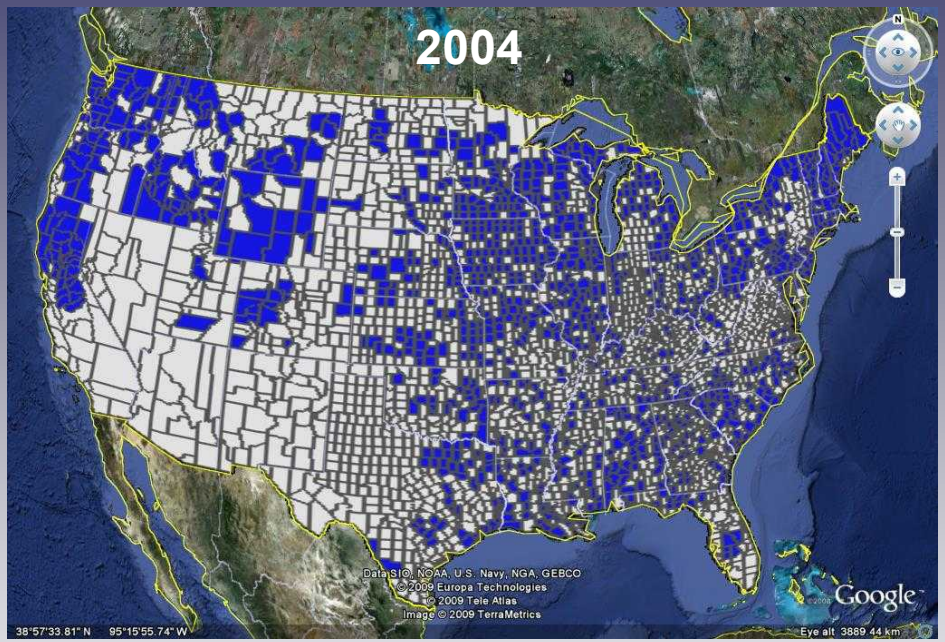




LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Counties Meeting Siting Requirements



- Siting requirements
  - Supply vs. demand ratio above 5
  - At least one power plant sited in county in 2004
  - No more than 5 new plants sited in any one county

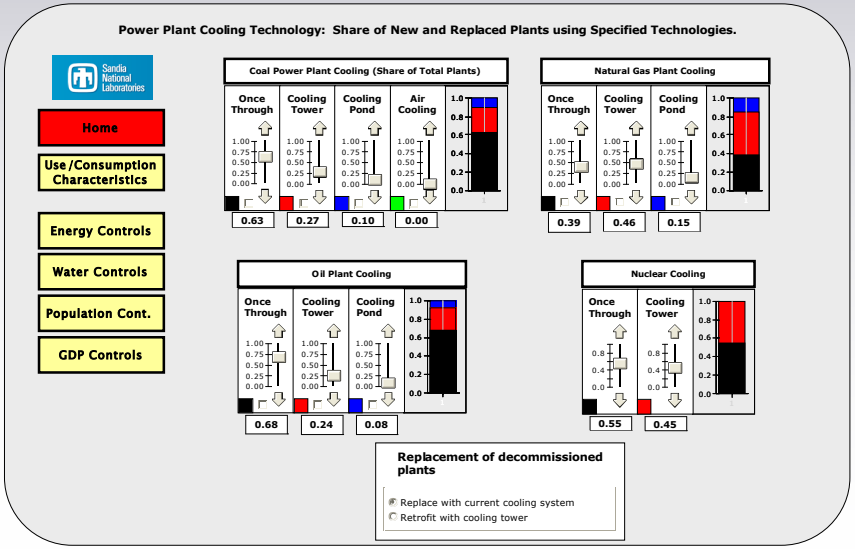
LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Cooling Technology Scenarios

Investigated three different scenarios

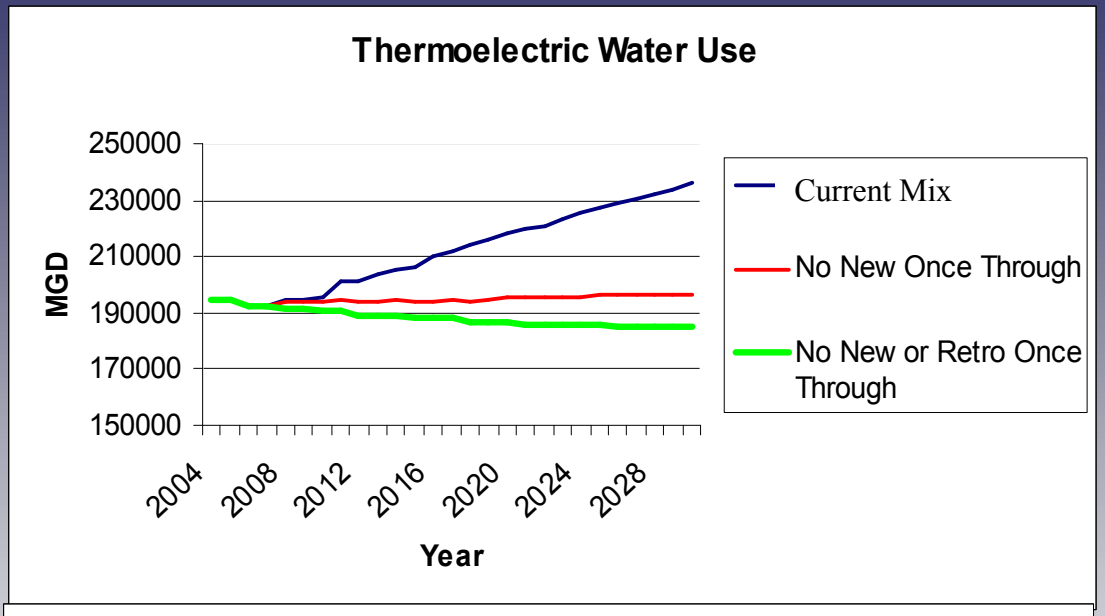
1. Current case which assumes 2004 mix of cooling technology into the future.
2. Assumes all new plants are equipped with recirculating cooling tower technology.
3. Assumes all new plants and retrofitted plants are equipped with recirculating cooling tower technology.

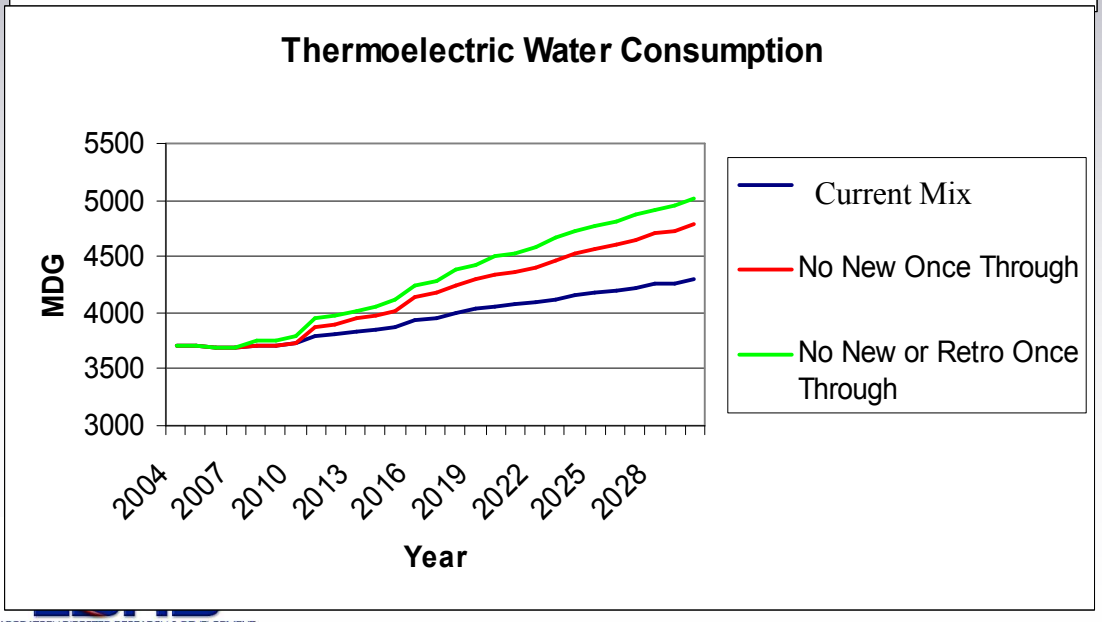


LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

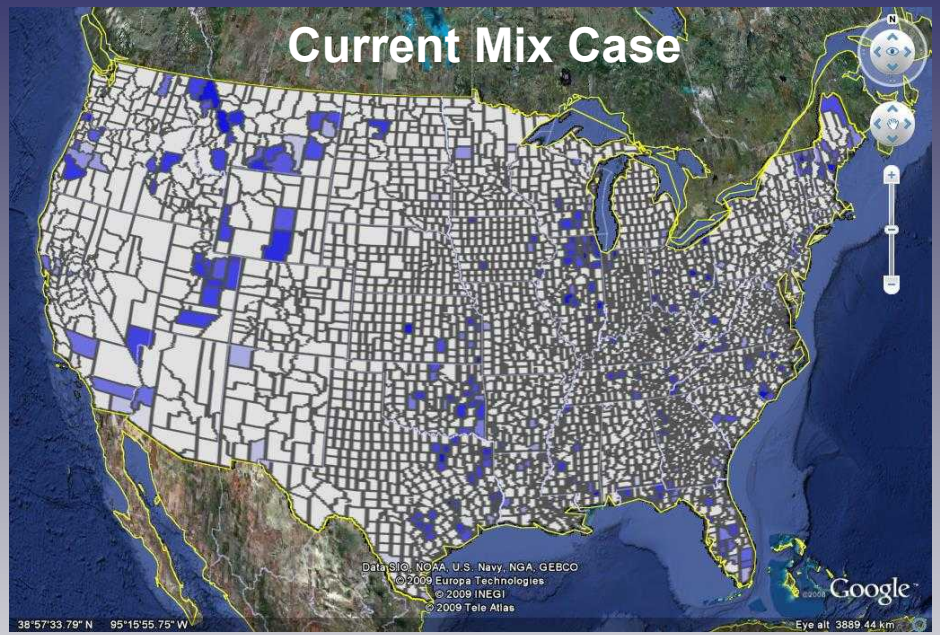
Cooling Technology Scenarios

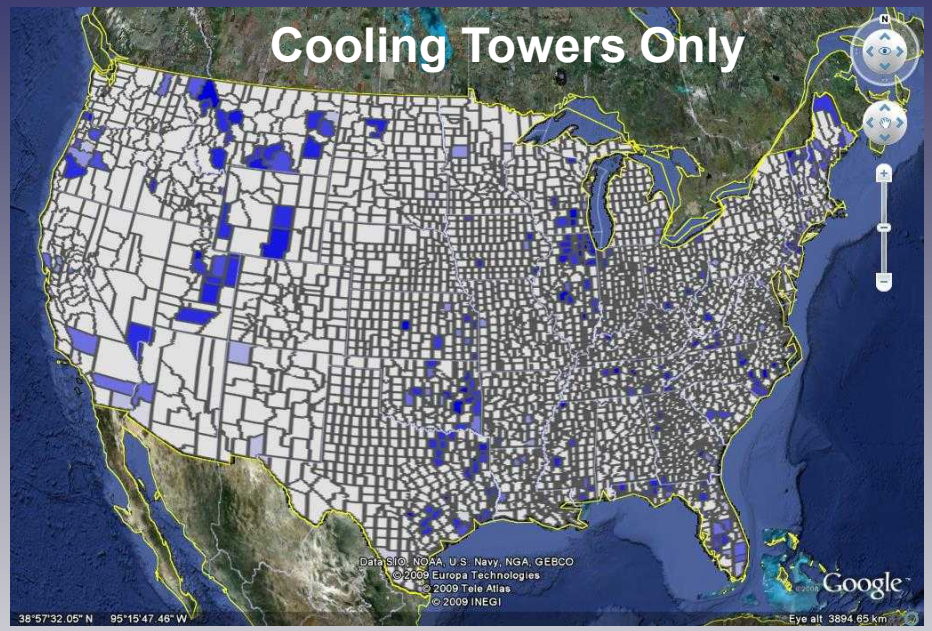


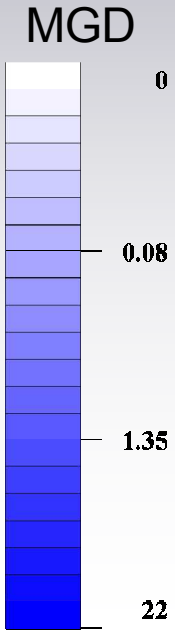


- Current mix has the highest water use, 236.1 BGD in 2030 and lowest water consumption, 4.3 BGD.
- Recirculating cooling towers in all new construction and recommissioned plants has the lowest water use, 184.8 BGD but highest consumption, 5.0 BGD.

Thermoelectric Water Consumption in 2030



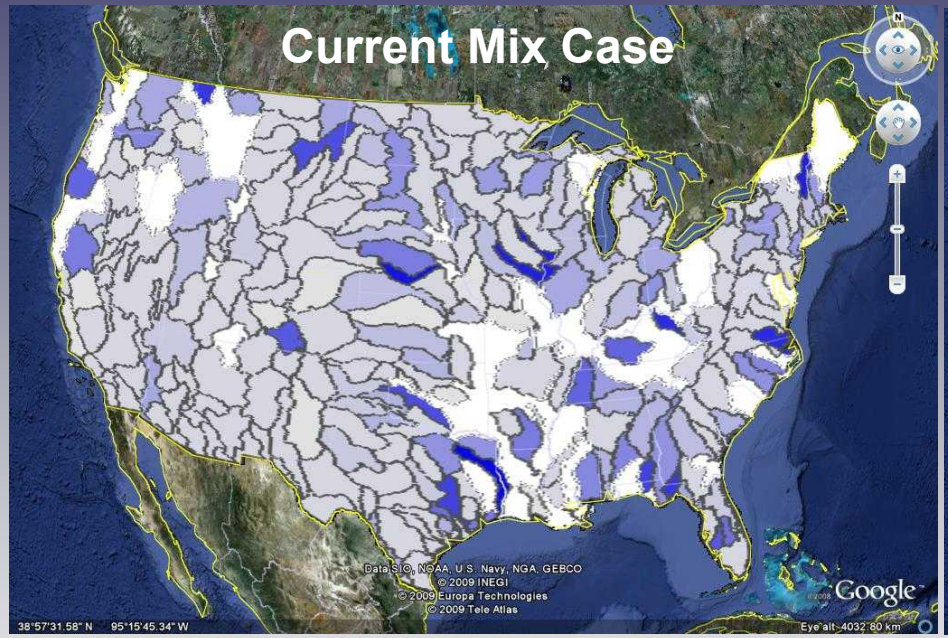




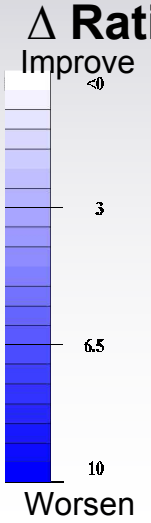
LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Change in Supply vs. Demand Ratio 2004 to 2030



- The fact that water use is the basis for calculating demand while consumption plays heavily into supply, changes offset each other.



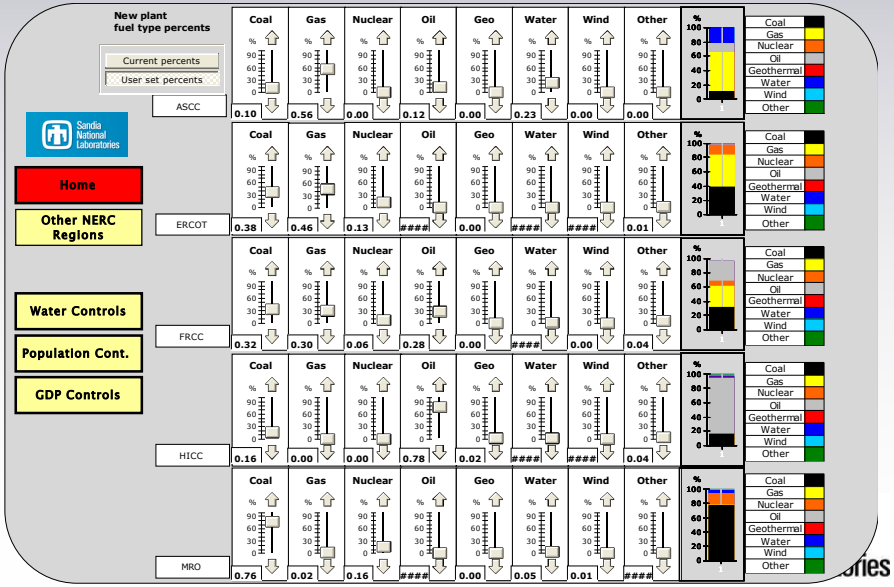
LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Fuel Mix Scenarios

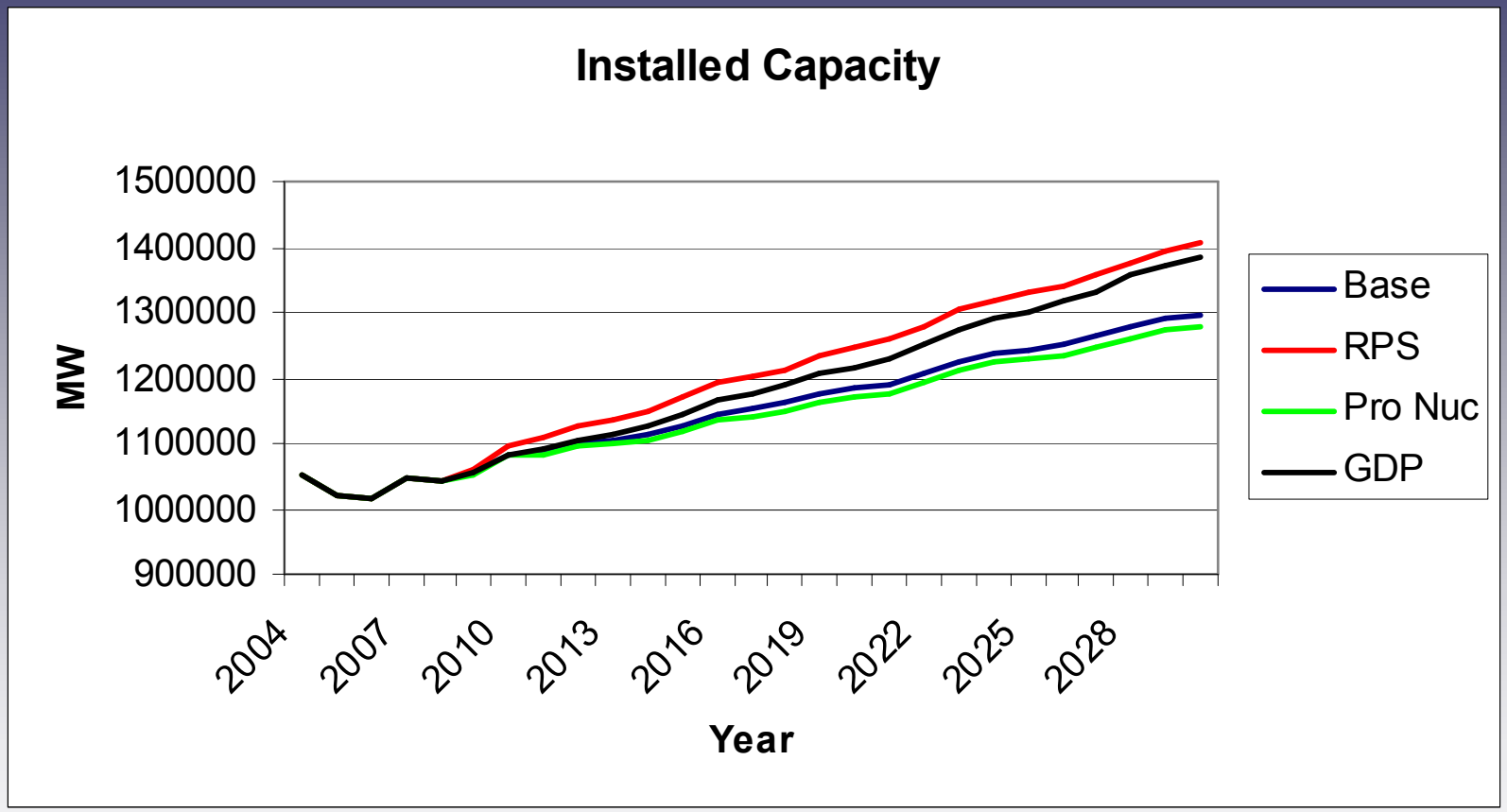
Investigated four different scenarios

1. Base case which assumes current mix of fuel type into the future (but no new hydro).
2. Assumes a federal RPS of 25% by 2030.
3. Assumes a minimum of 25% nuclear by 2030 with states currently meeting mark increasing to 30%.
4. Assumes the base case but with GDP projection at AEO “high case”.



LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

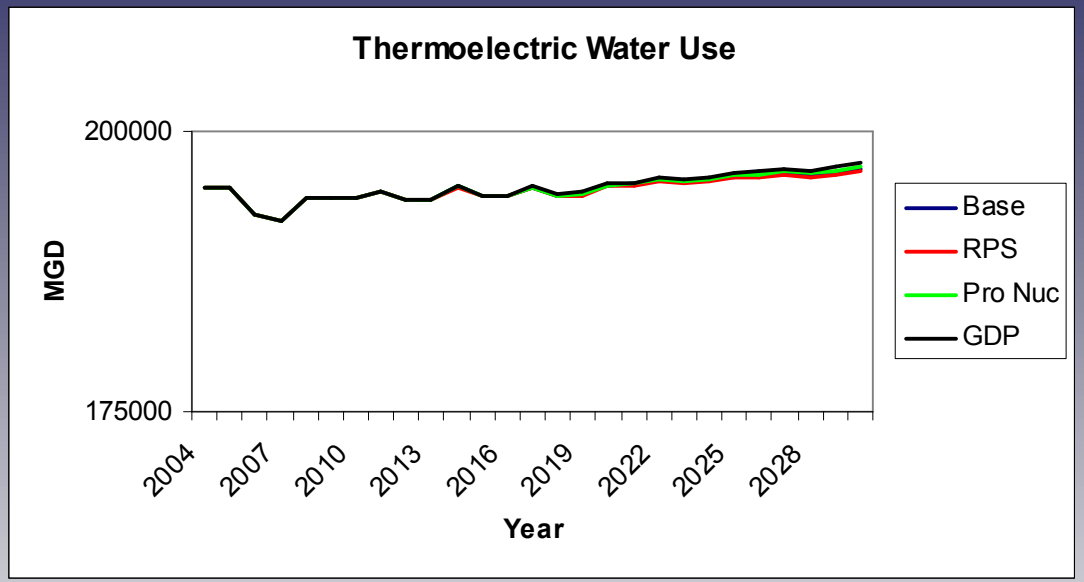
Fuel Mix Scenarios

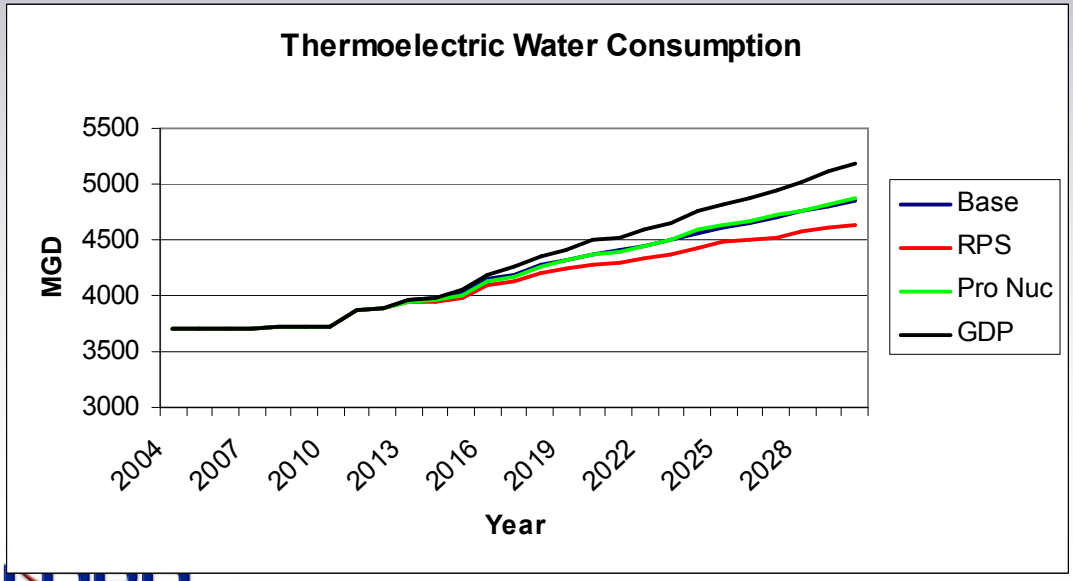


LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

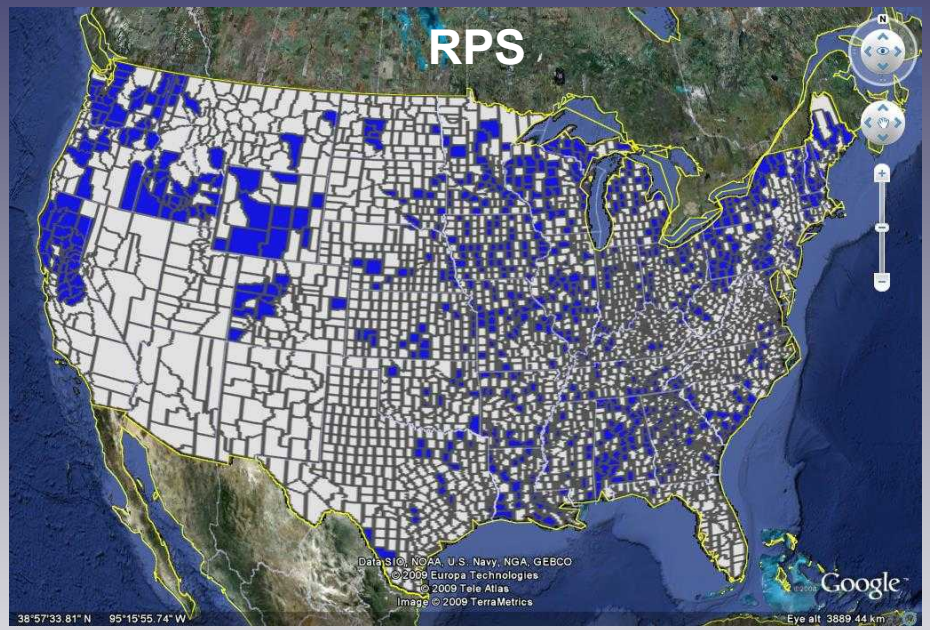
Fuel Mix Scenarios

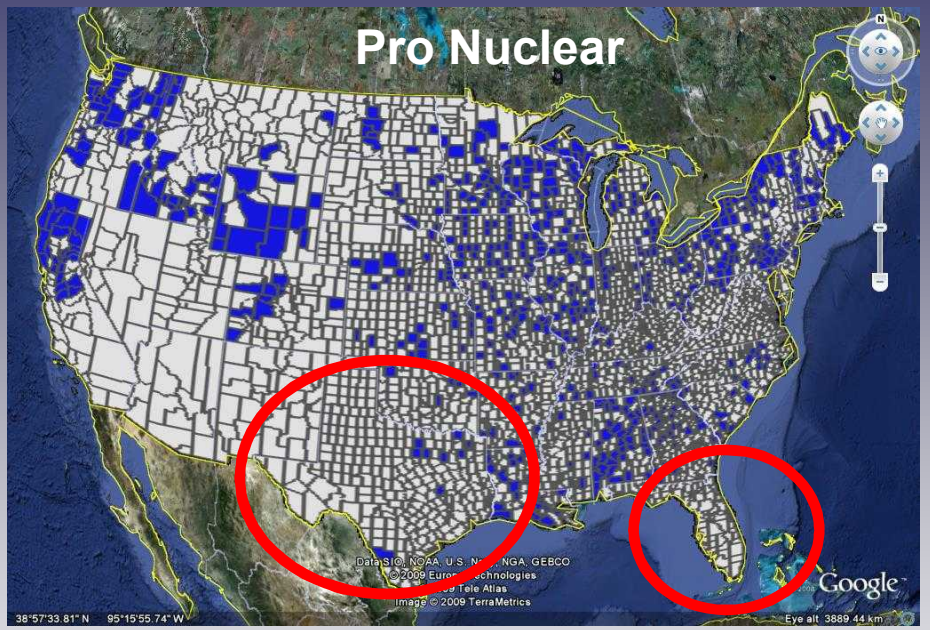




- The GDP case (increase of 6% in electricity demand) yields the highest water consumption at 5.2 BGD.
- RPS case yields the least at 4.6 BGD.
- Shift toward a richer renewables mix is capable of reducing overall thermoelectric water consumption by 5% in 2030, or 23% in terms of total post 2004 water consumption.

Counties Meeting Siting Requirements in 2030



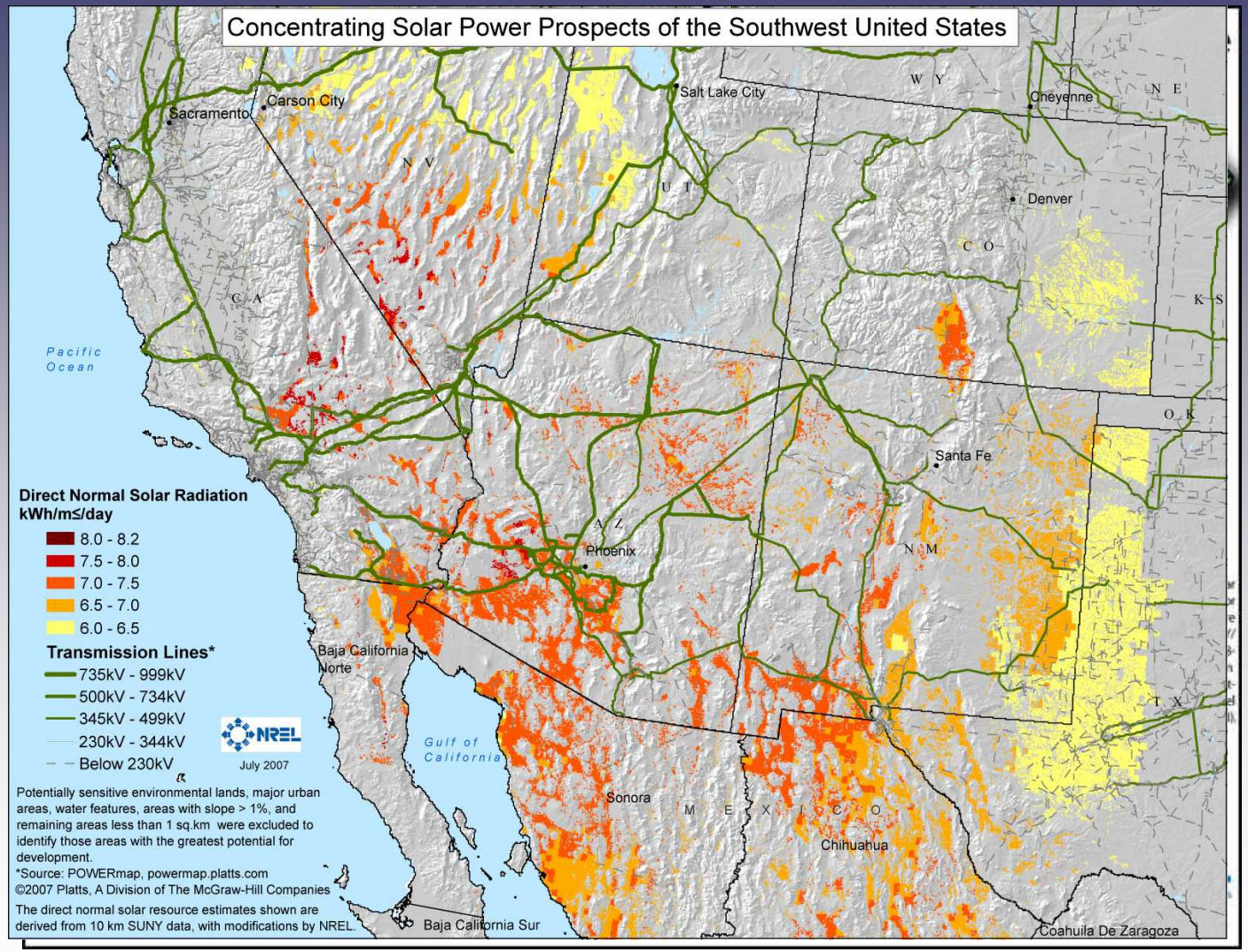


- Florida Reliability Coordinating Council (FRCC) and Texas Regional Entity (TRE) have effectively exhausted siting counties by 2030
- There are large areas of the country with few or no suitable sites.
- While this does not suggest there is nowhere to place a new plant, it does suggest that new sitings will need to consider successively less attractive construction locations.

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Next Steps: Constraining Siting



LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

Next Steps: Emissions Control

Capture of 90% of carbon emissions using current near-commercial capture and storage (CCS) technologies will:

- Effectively double water consumption for coal-fired generators
- IGCC with CCS would require less water than current PC plants with no CCS
- Exploring potential options with waters produced through injection

NETL 2007

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories