National Renewable Energy Laboratory
Innovation for Our Energy Future

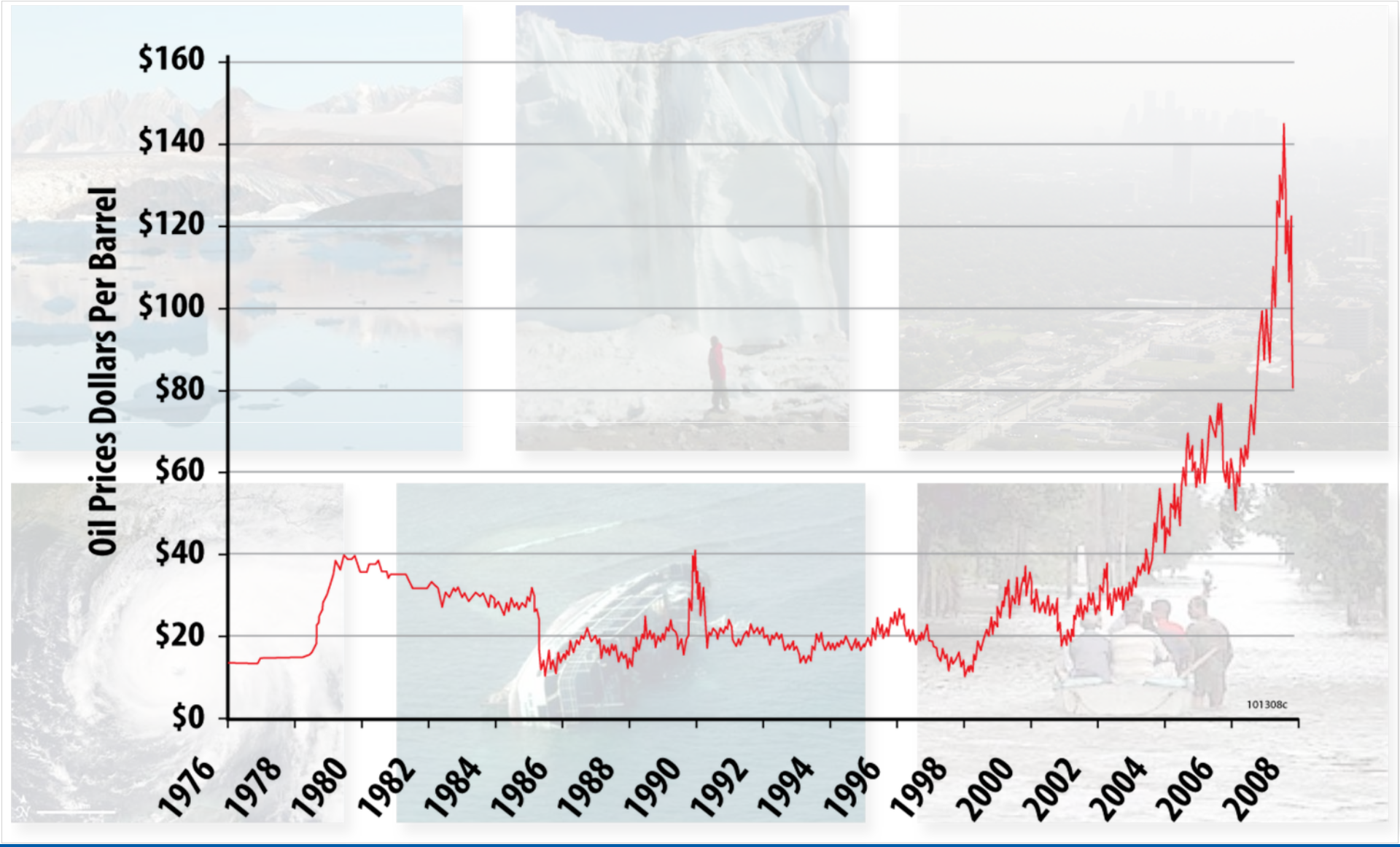
Climate Change: The Role of a Future Energy Economy

Kansas City Civic Council

Dr. Dan E. Arvizu
Laboratory Director

October 23, 2008

Mounting Evidence

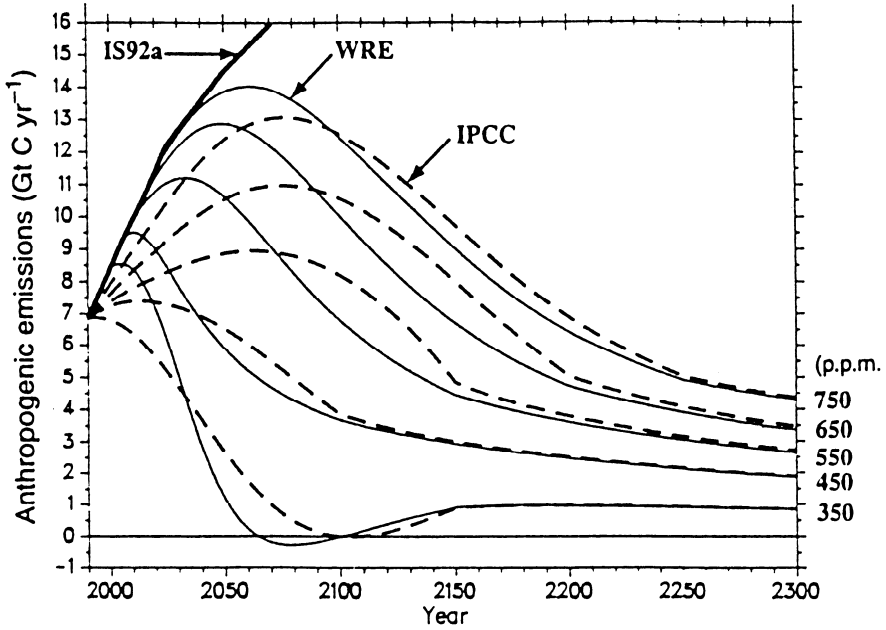


Latest IPCC Report

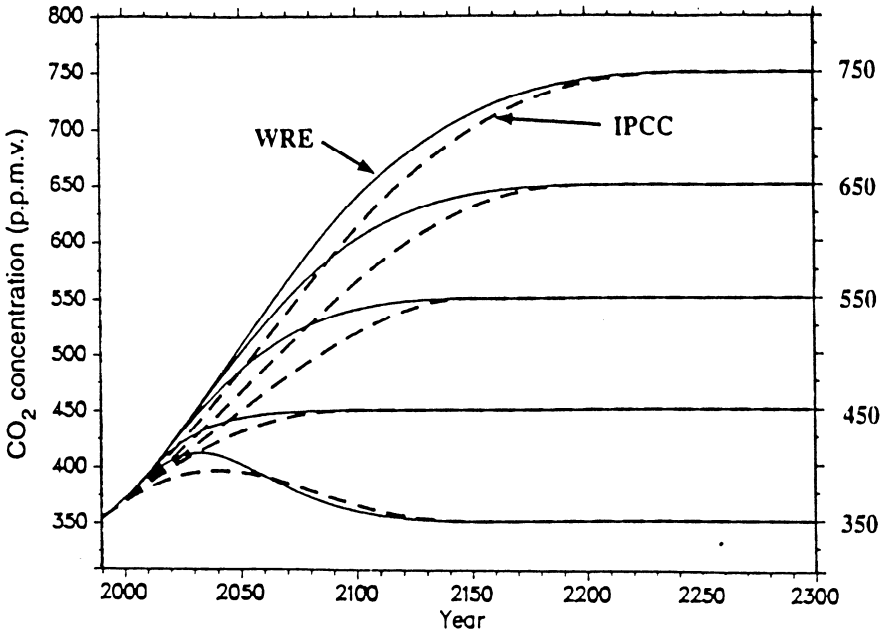
- “Warming of the climate is unequivocal.”
- “..very likely due to anthropogenic greenhouse gas concentrations.”

Scope of Global Challenge

Emissions



Concentrations

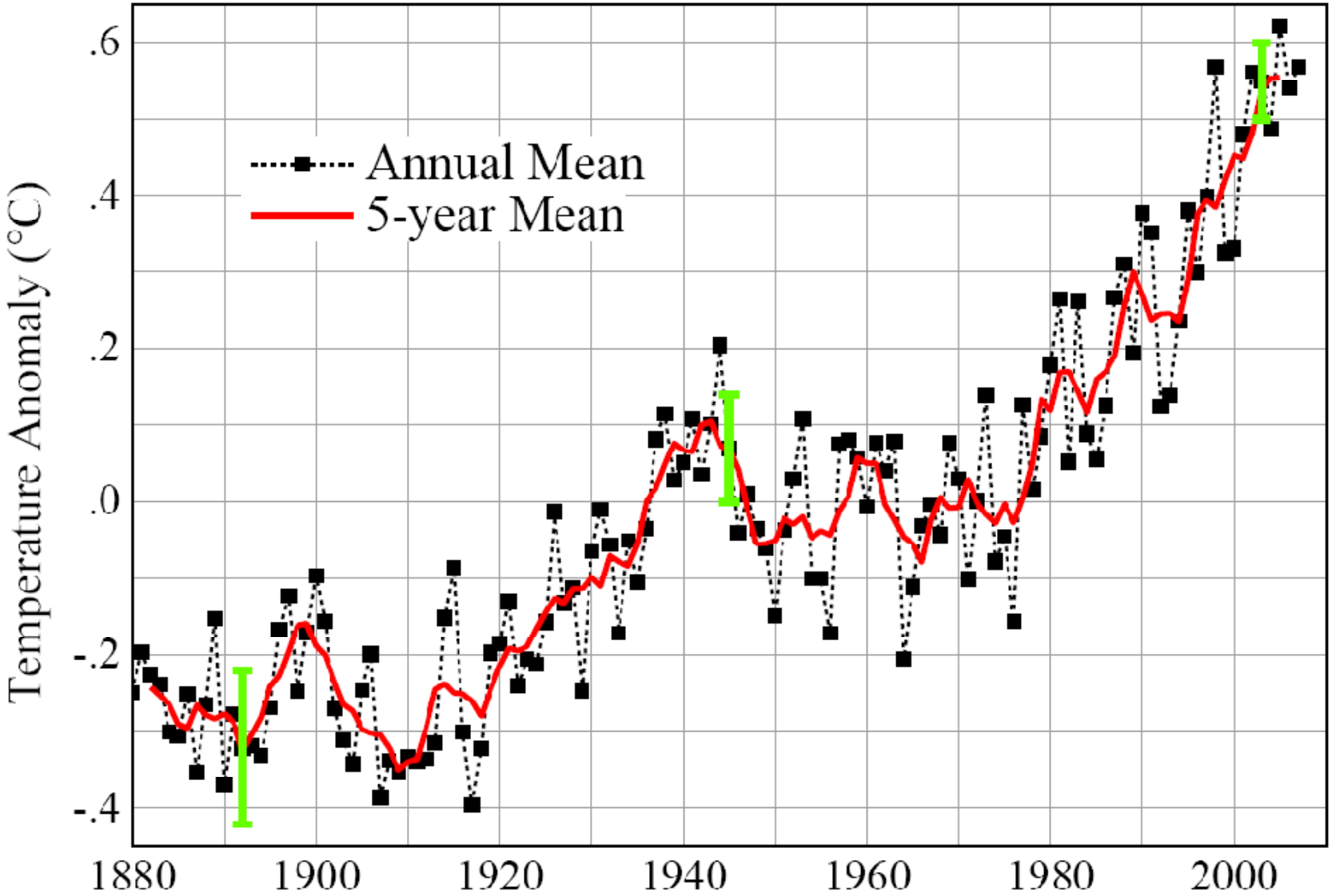


T.M.L. Wigley, R. Richels, & J.A. Edmonds (WRE),
Nature, January 18, 1996, "Economic and Environmental Stabilization of Atmospheric Concentrations"

What is the Scientific Evidence?

- Paleoclimatic data (ice cores and other evidence)
- Agreement between much improved climate models from around the world
- Today’s field measurements

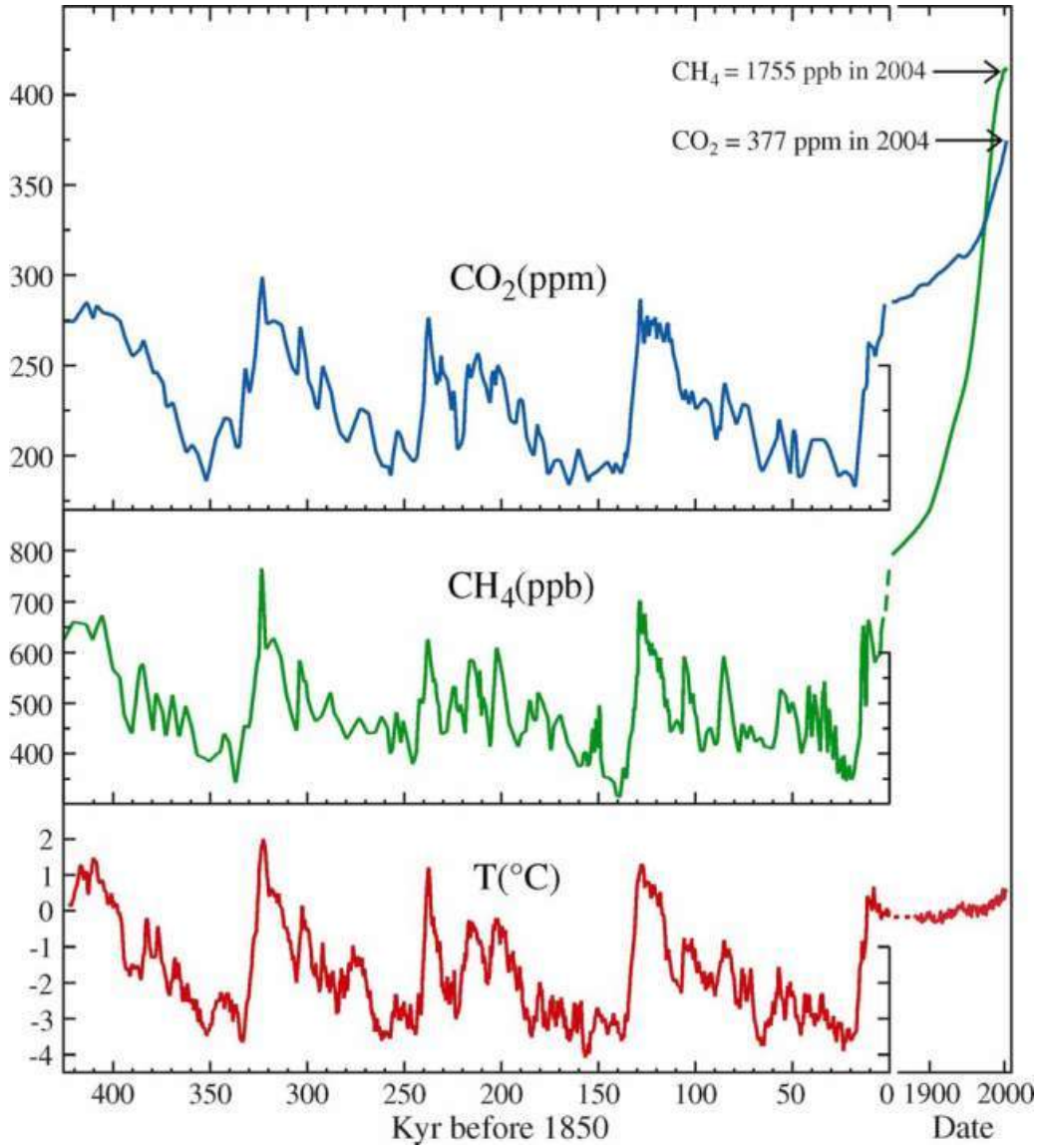
Global Temperature Land-Ocean Index



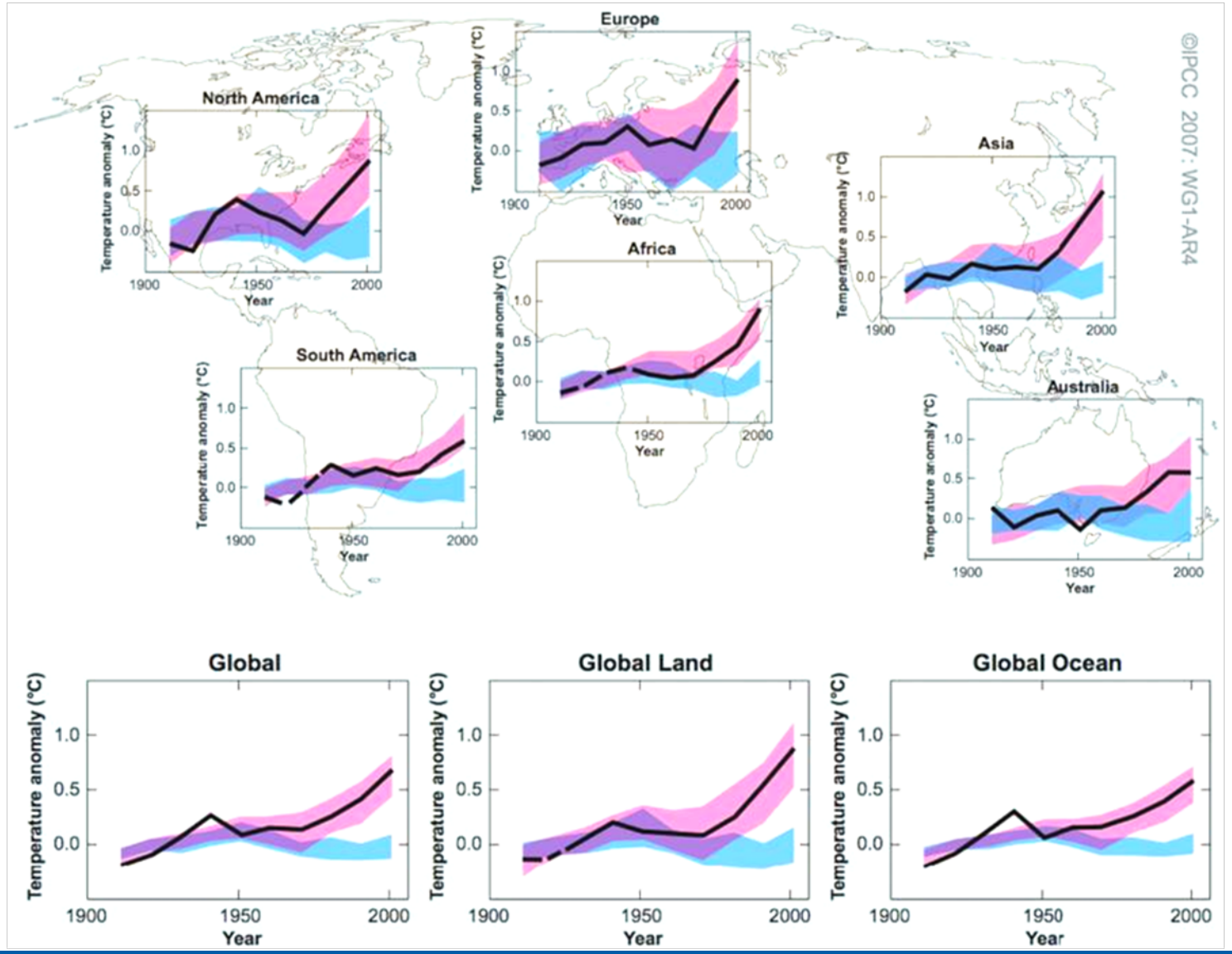
Ice Core Data

CO_2 today – 380 ppm

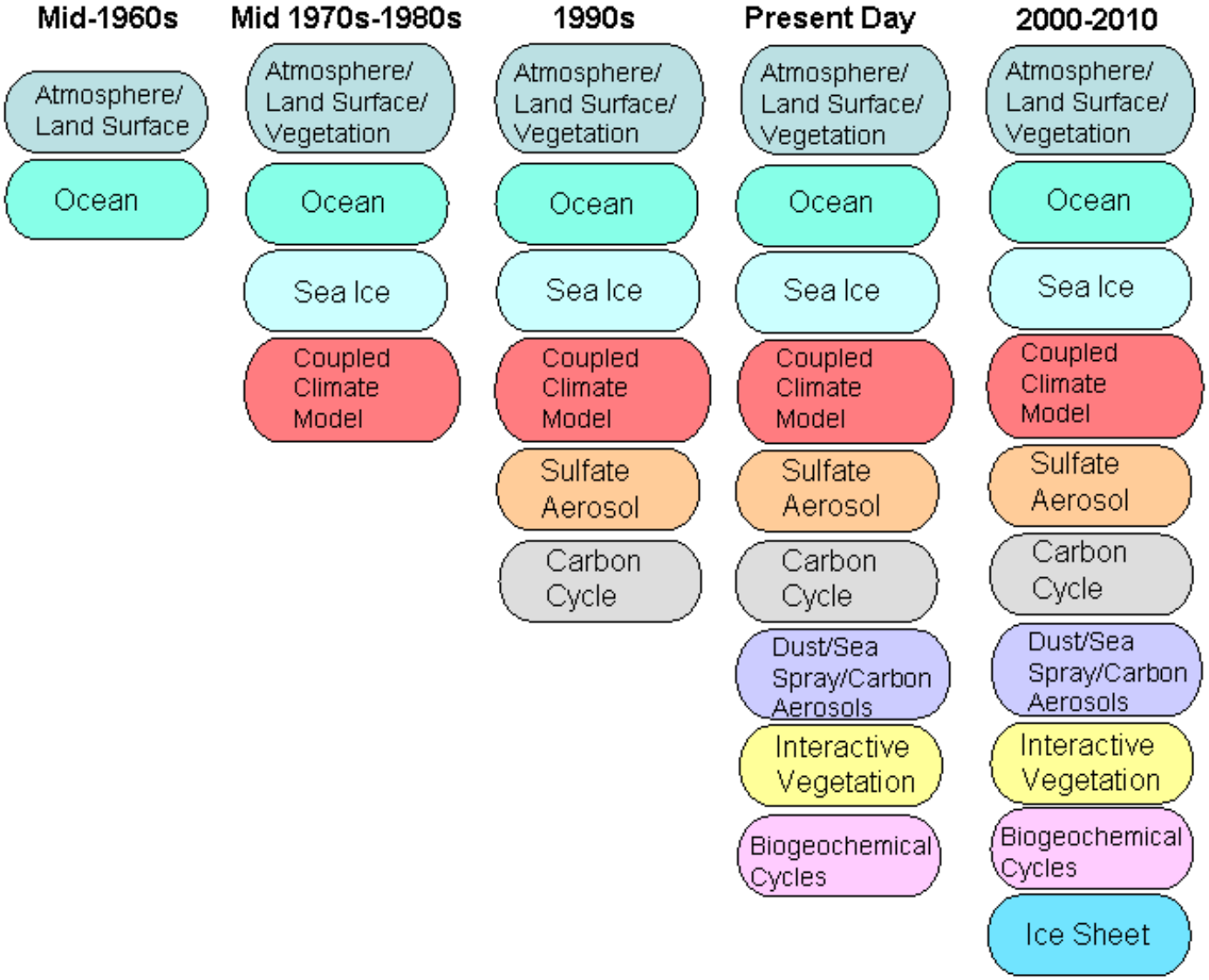
Rising approx 2 ppm/yr



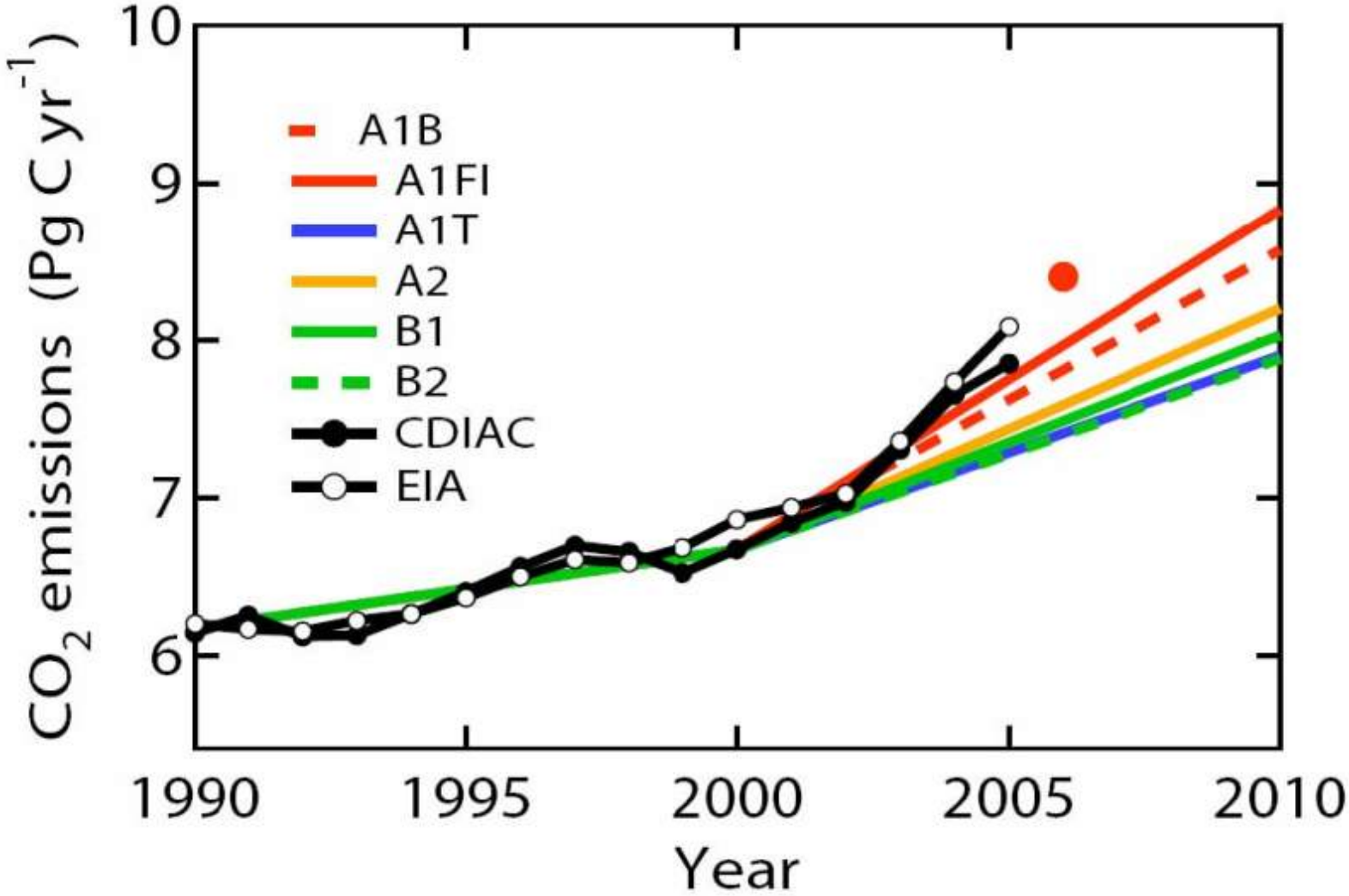
Global and Continental Temperature Change



Climate Model Capability



IPCC Scenarios vs. Actual Emissions



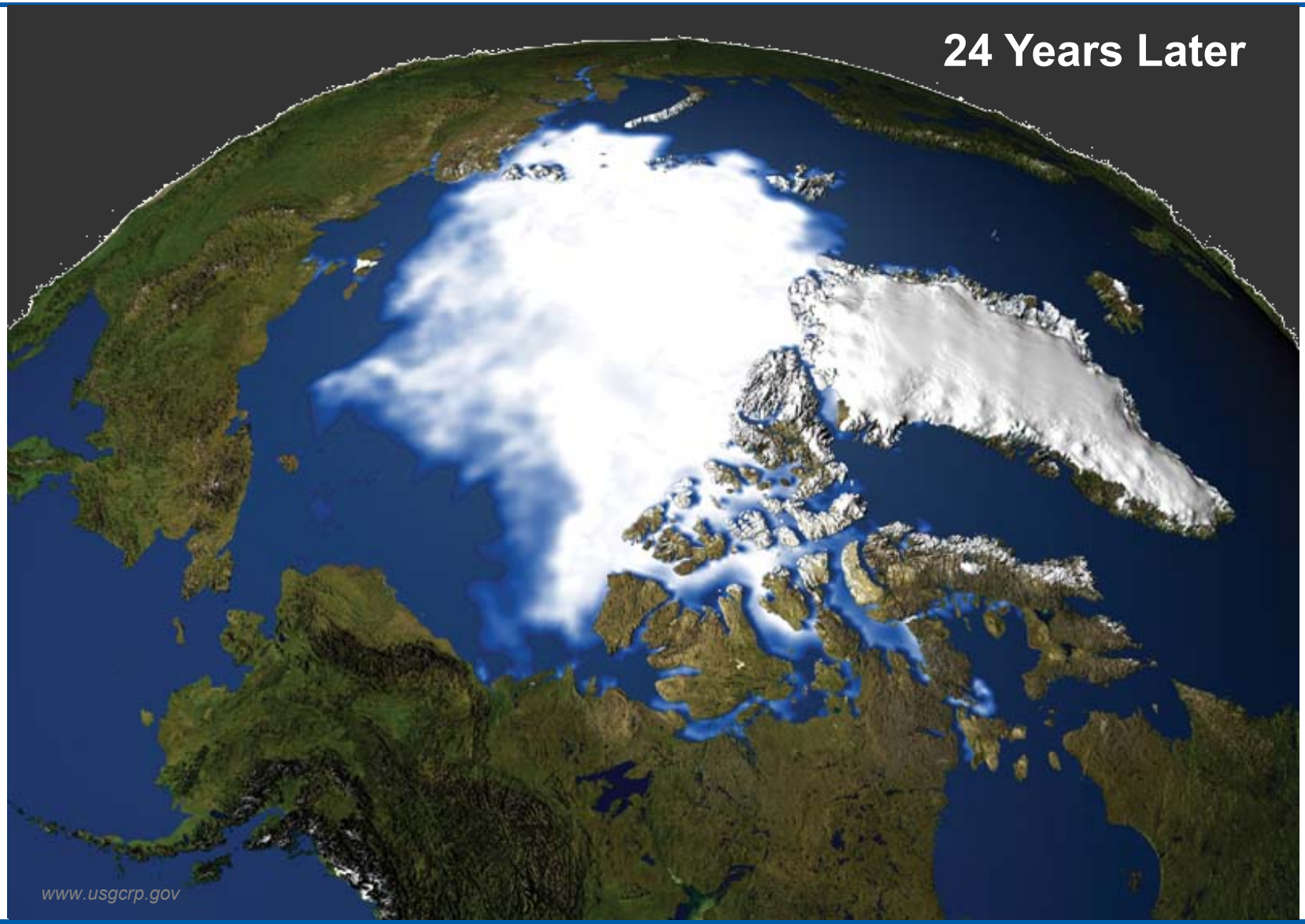
Consequences of Global Warming

- Sea level rise, storm surge, flooding of coastlines
- Early runoff, summer droughts/famine, wildfires
- More frequent weather extremes, e.g., heat waves and heavy precipitation events
- Increased hurricane intensity
- Loss of mountain glaciers and drinking water
- Spread of tropical diseases, increased plant and crop disease
- Extinction of plants, corals, and other animal species

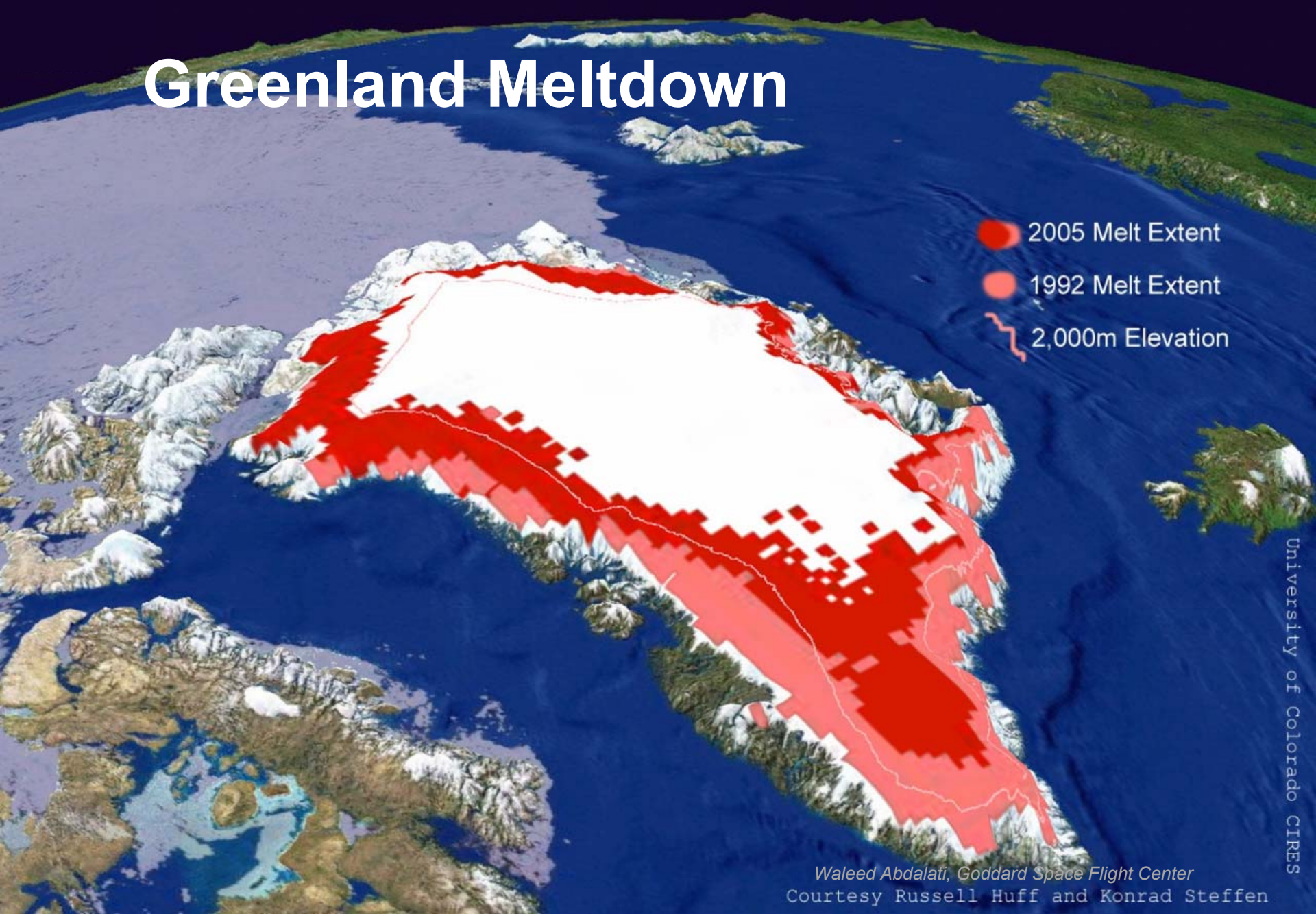
What the latest IPCC study does <u>not</u> include:

…future rapid dynamical changes in ice flow.

Arctic Meltdown

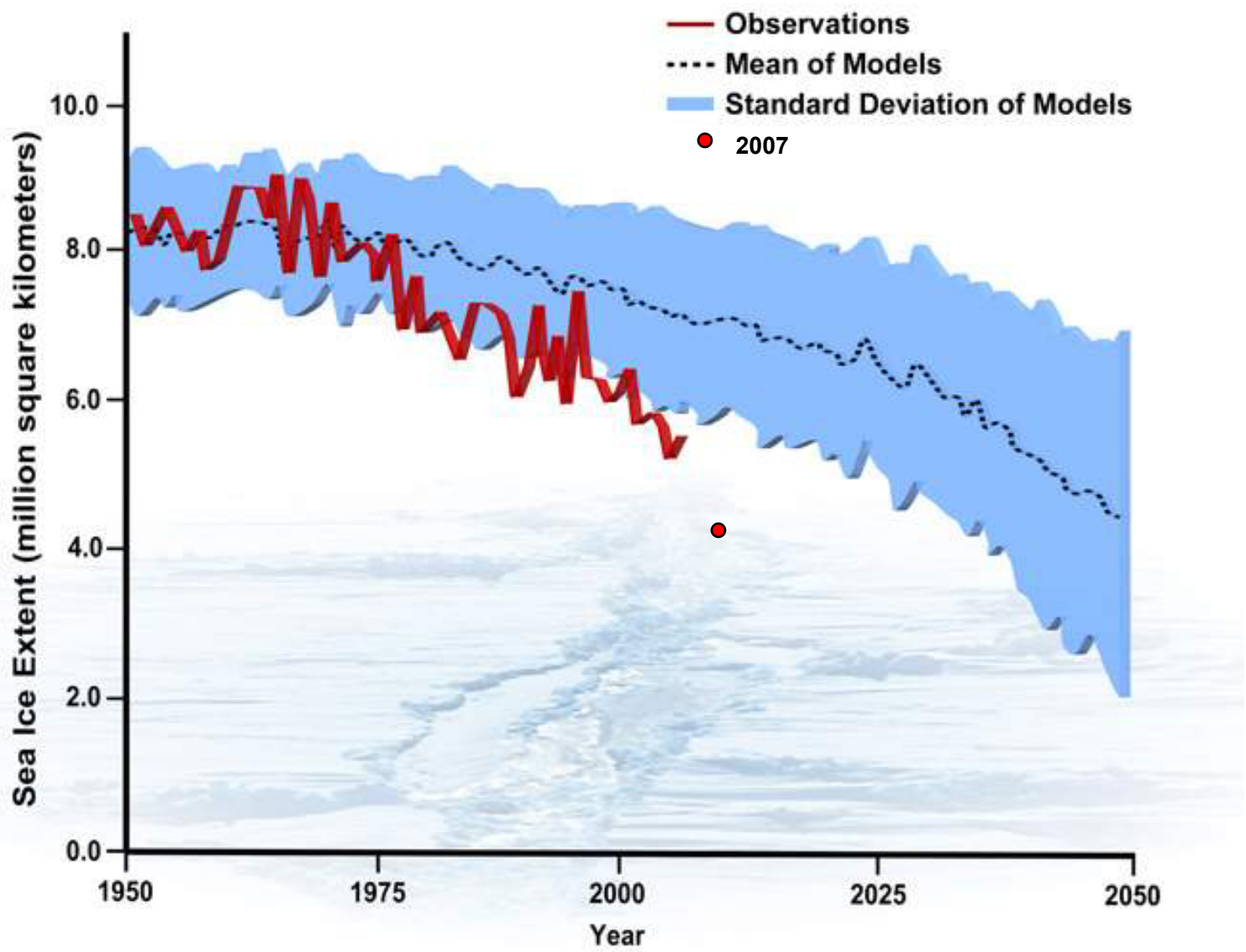


Greenland Meltdown



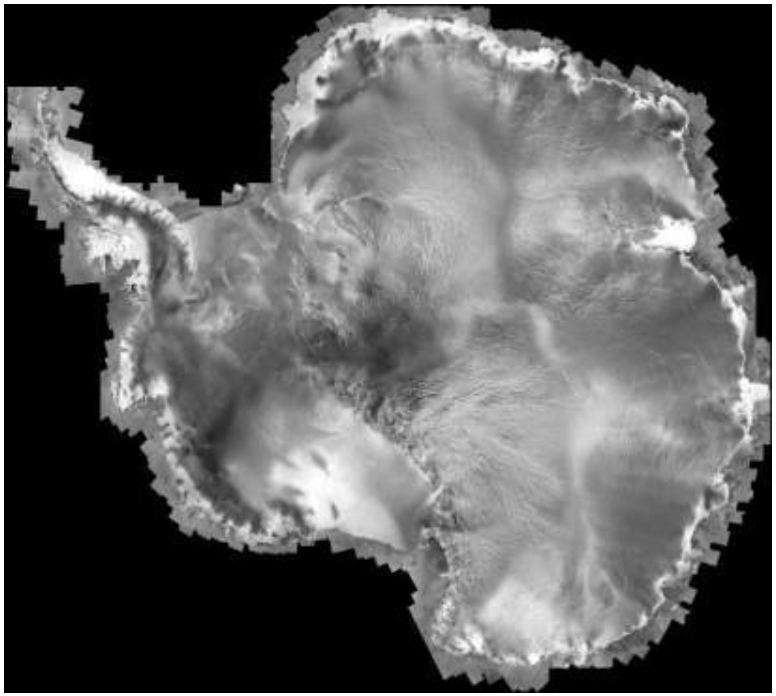
All melt records were exceeded in 2005.

Arctic September Sea Ice – Observations and Model Runs



Sea Level Indicators

West Antarctica:
5 to 6 m sea level rise



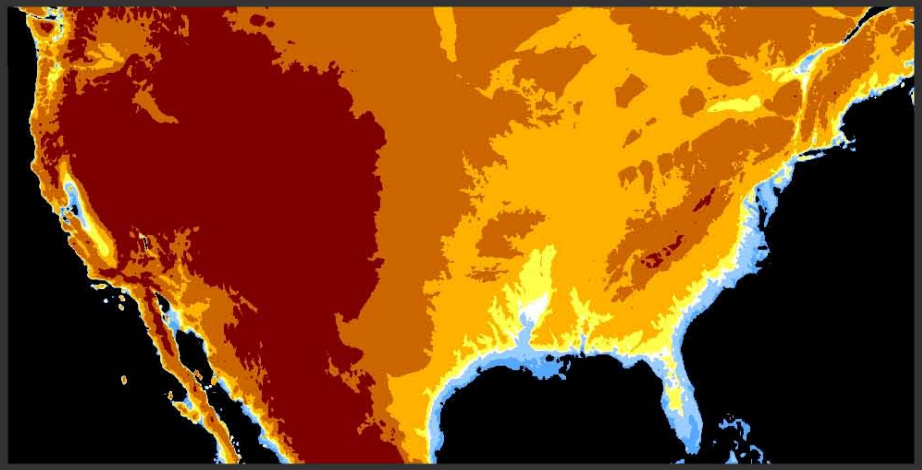
Greenland:

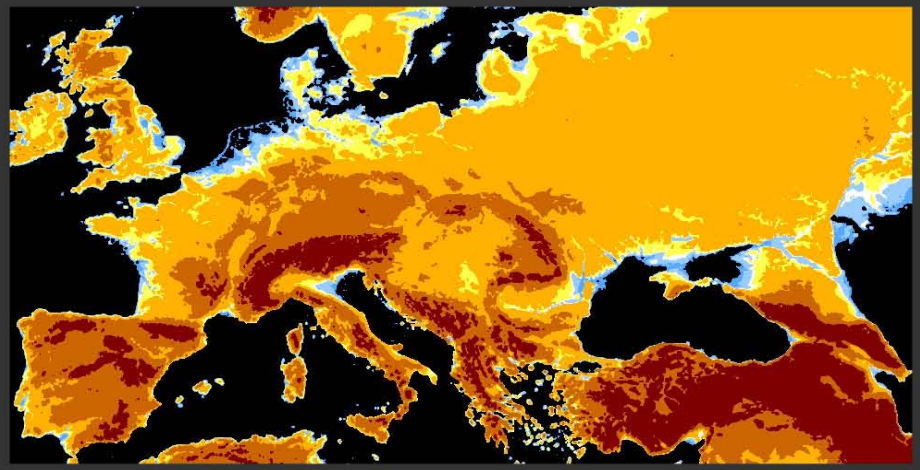
6 to 7 meter sea level rise

East Antarctica :
55 to 60 m sea level rise

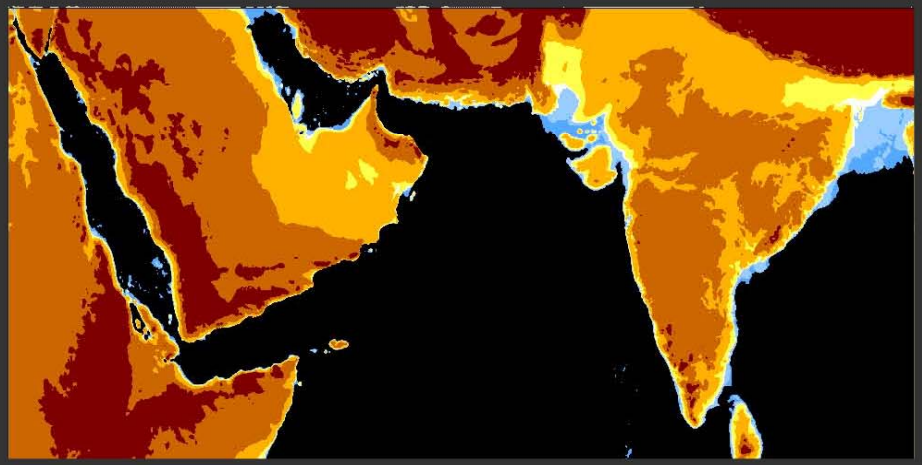
Courtesy of Robert Bindschadler, NASA

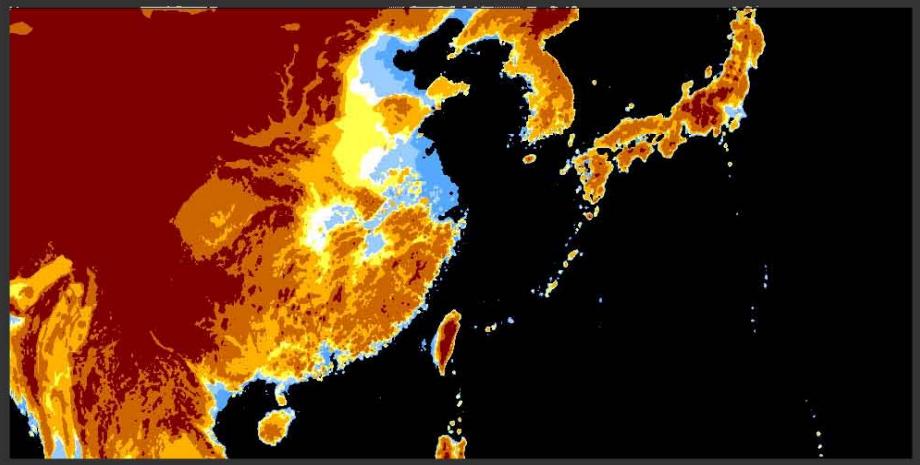
Greenland Takes Out FL, NJ, NYC





Greenland is 22 Feet of Ocean Height





What If We Stop Increasing Our Greenhouse Emissions Today?

Additional temperature rise "in the pipeline" accounting for….

"Fast" feedbacks (water vapor, sea ice, desert dust):

+ 0.5°C

"Slow" feedbacks (ice sheet loss, vegetation migration, gas release from melting permafrost):

+ 2°C

What We Have to Do

To limit sea level rise to 1 m and species loss to 20% this century

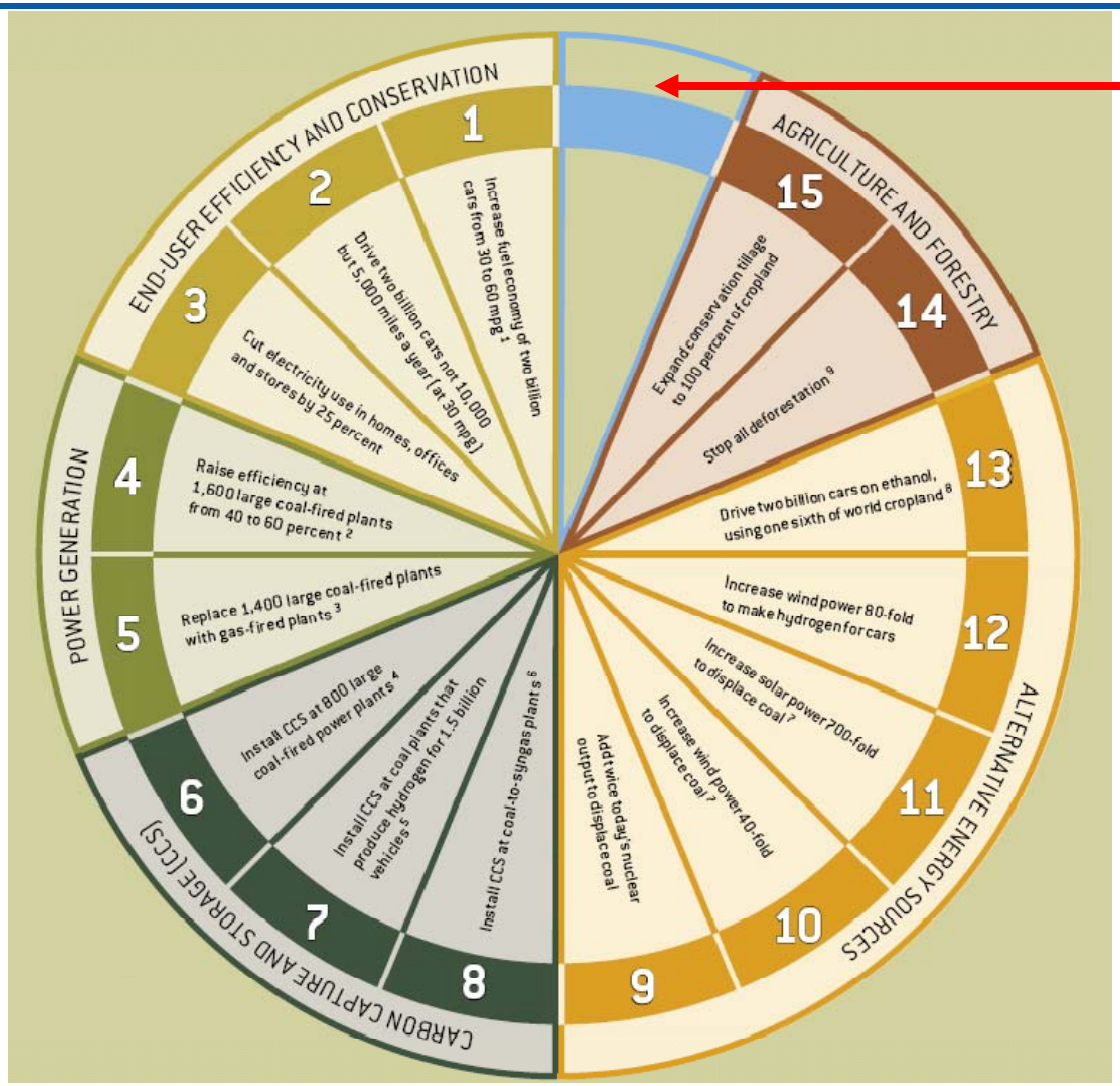
- Limit additional warming to 1°C beyond 2000
- Reduce U.S. CO_2 emissions 60%–80% (?) by 2050

Total savings needed by 2030: ~1,200 MtC/yr

Key Options

- Energy Efficiency
- Renewable Energy
- Coal with carbon capture and storage
- Nuclear power

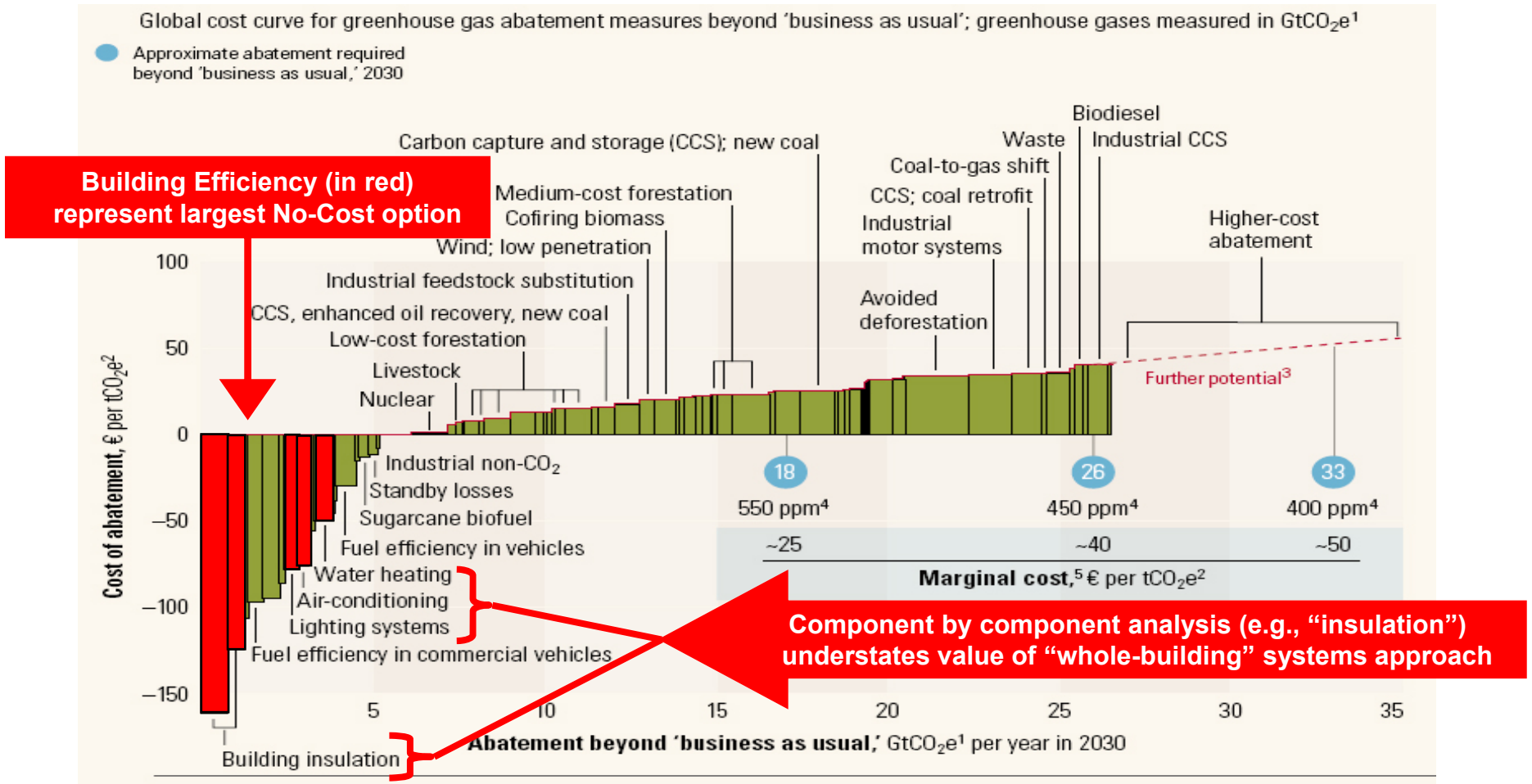
Socolow's Wedges – Carbon Reduction Strategies



Industrial energy efficiency
"Upstream" investment
Other renewables
Methane mitigation
Population
Capture of CO_2 from air (?)

Source; Socolow and Pacala, *Scientific American*, September 2006, p.54

Energy Efficiency Offers Low or No-Cost Carbon Reduction Options



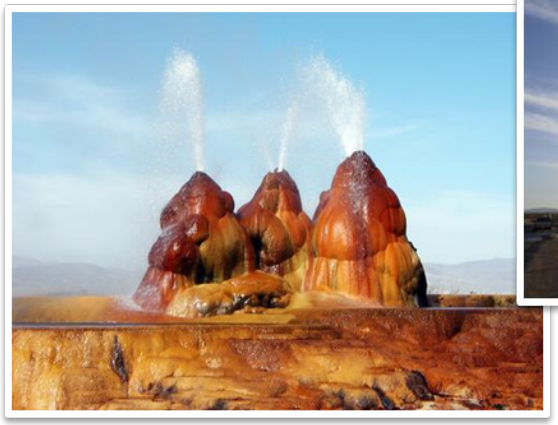
[1] $GtCO_2e$ = gigaton of carbon dioxide equivalent; "business as usual" based on emissions growth driven mainly by increasing demand for energy and transport around the world and by tropical deforestation.
[2] tCO_2e = ton of carbon dioxide equivalent.
[3] Measures costing more than €40 a ton were not the focus of this study.
[4] Atmospheric concentration of all greenhouse gases recalculated into CO_2 equivalents; ppm = parts per million.
[5] Marginal cost of avoiding emissions of 1 ton of CO_2 equivalents in each abatement demand scenario.

Source: McKinsey Global Institute, 2007

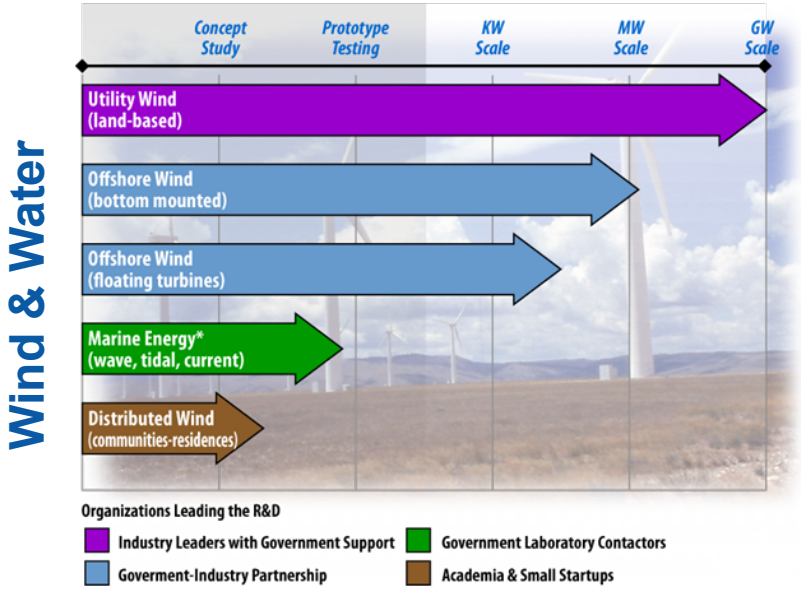
Energy Efficiency

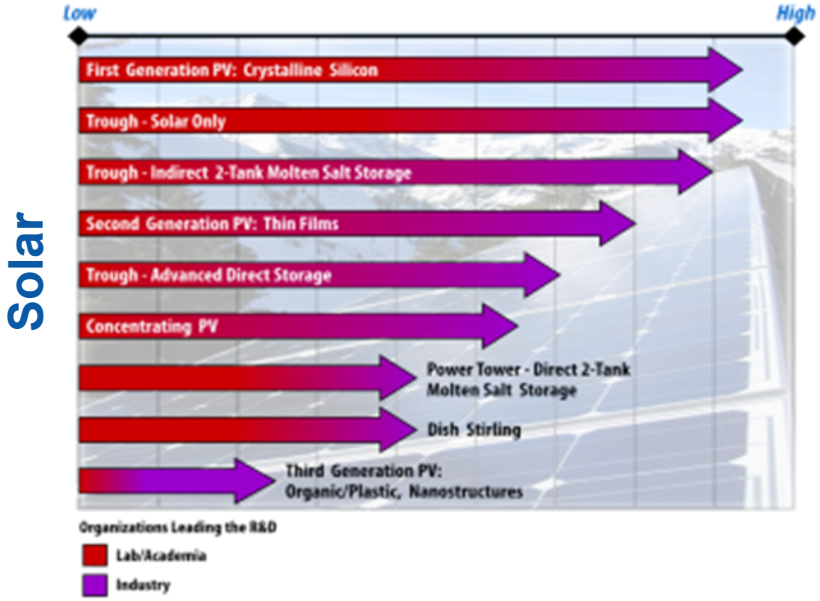
- Buildings (40%) – envelope design, daylighting, better lights, building and appliance efficiency standards
- Transportation (30%) – lighter weight vehicles, public transportation, better propulsion, PHEVs
- Industry (30%) – heat recovery, better motors, CHP

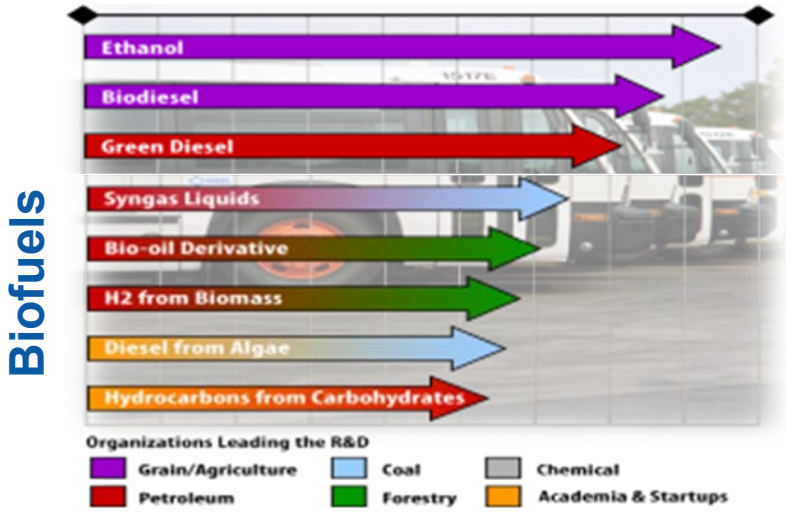
Renewable Energy

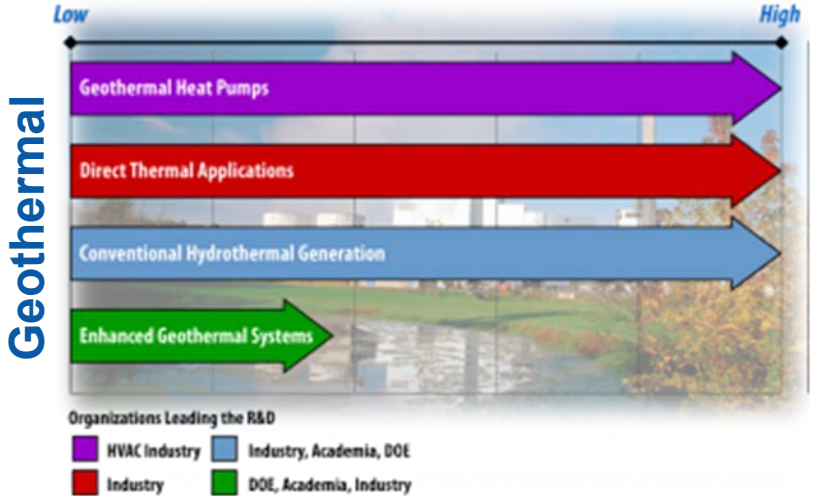


Technology Options Are Evolving

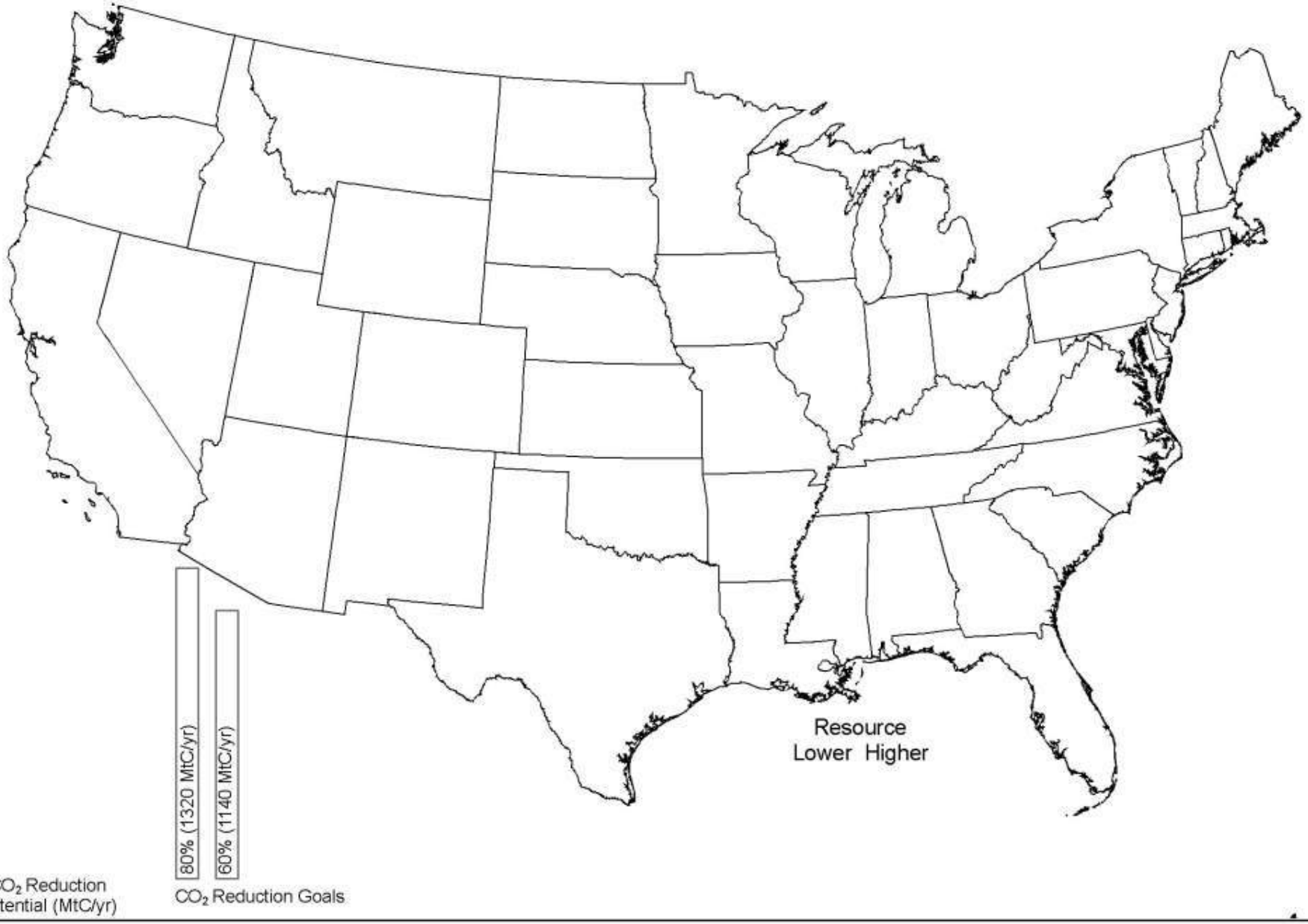








Potential Reduction in U.S. Carbon Emissions



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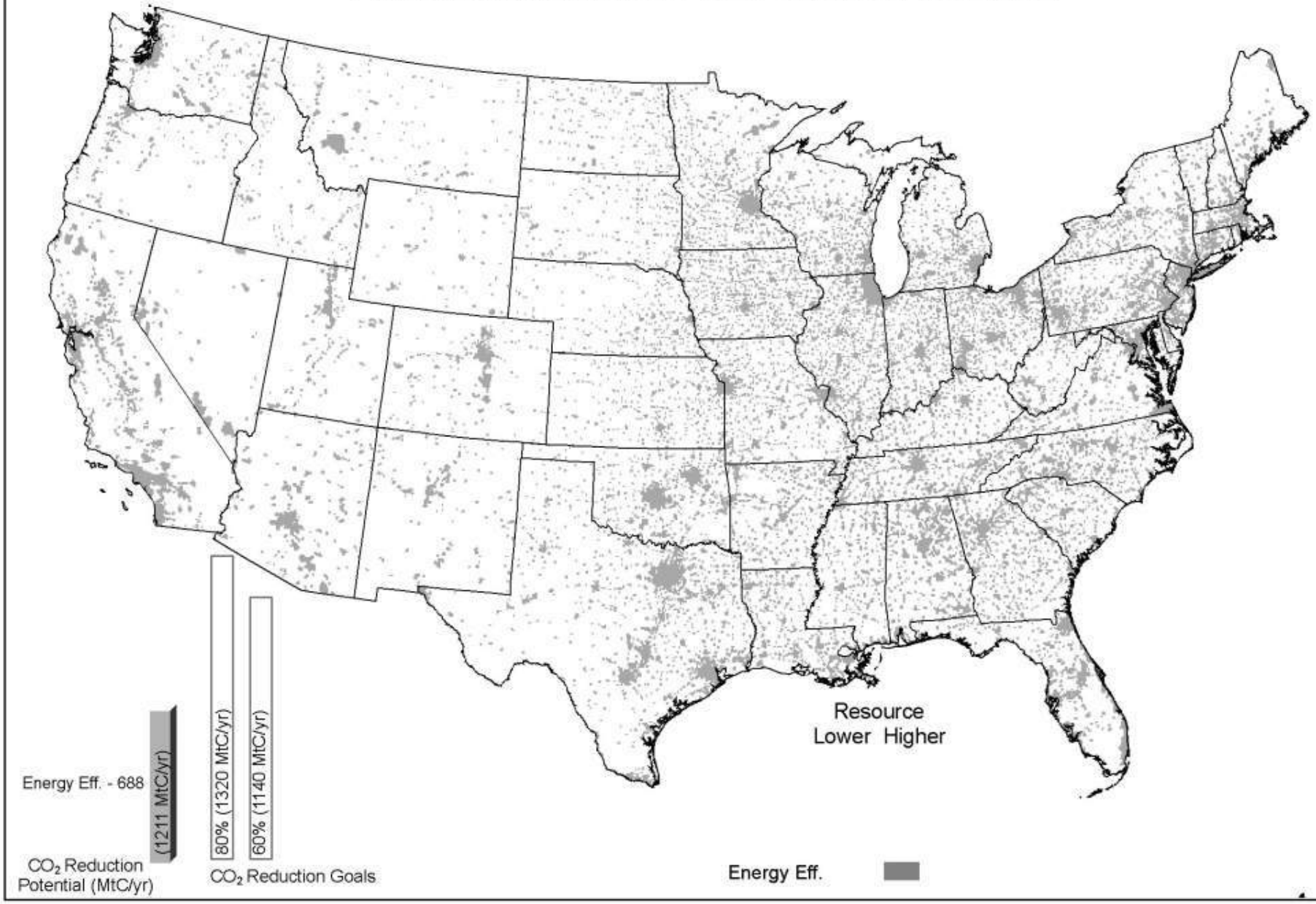

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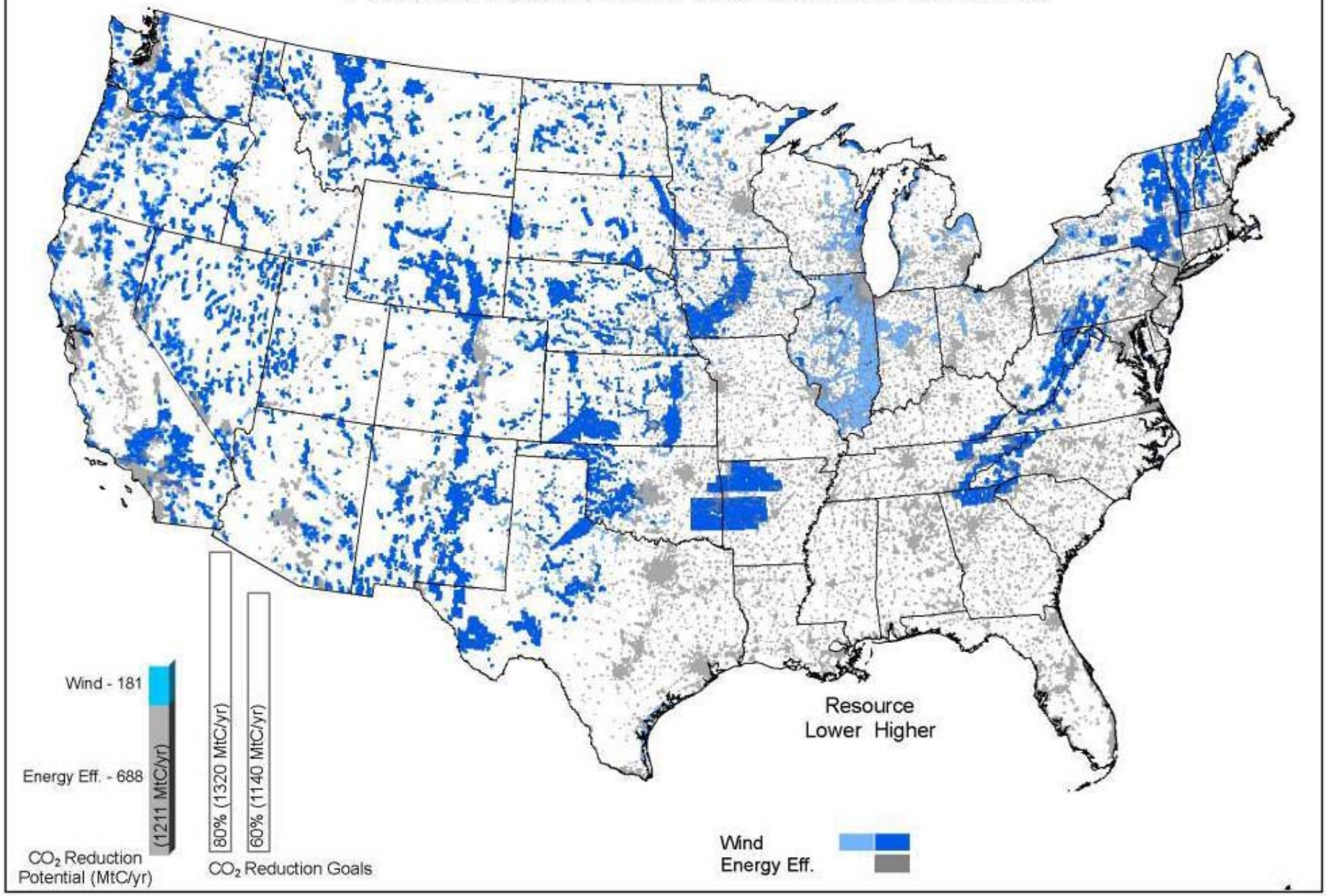

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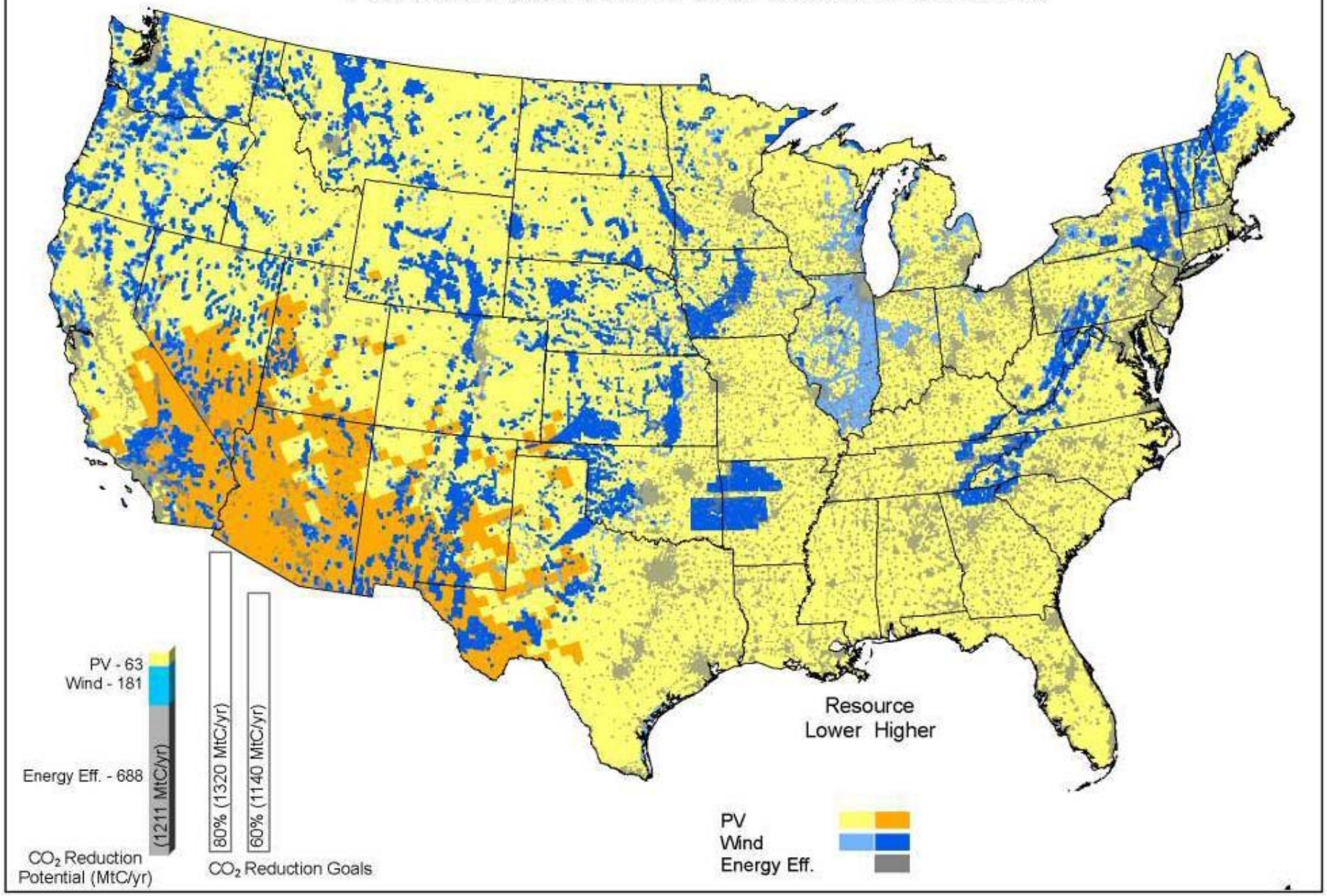

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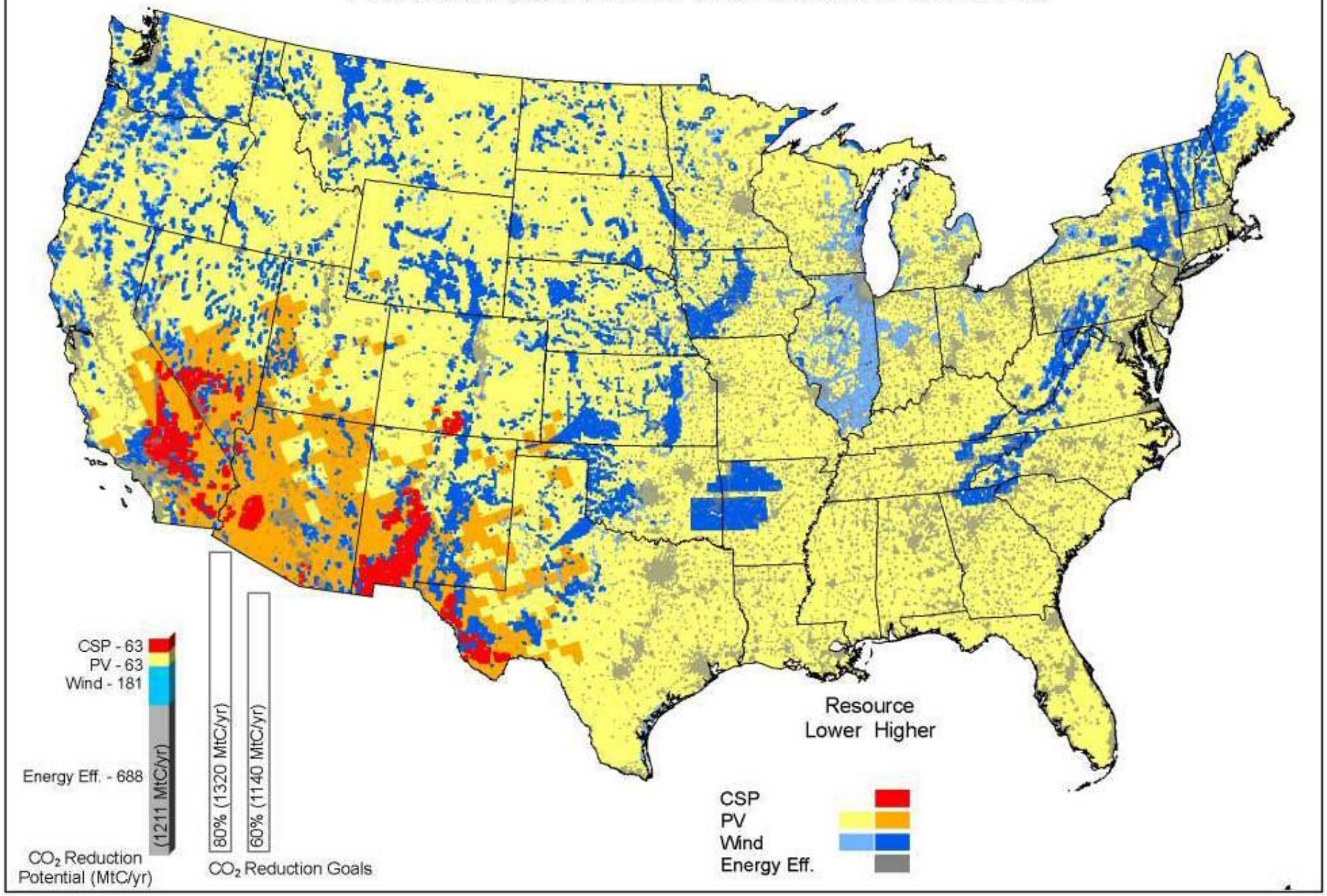

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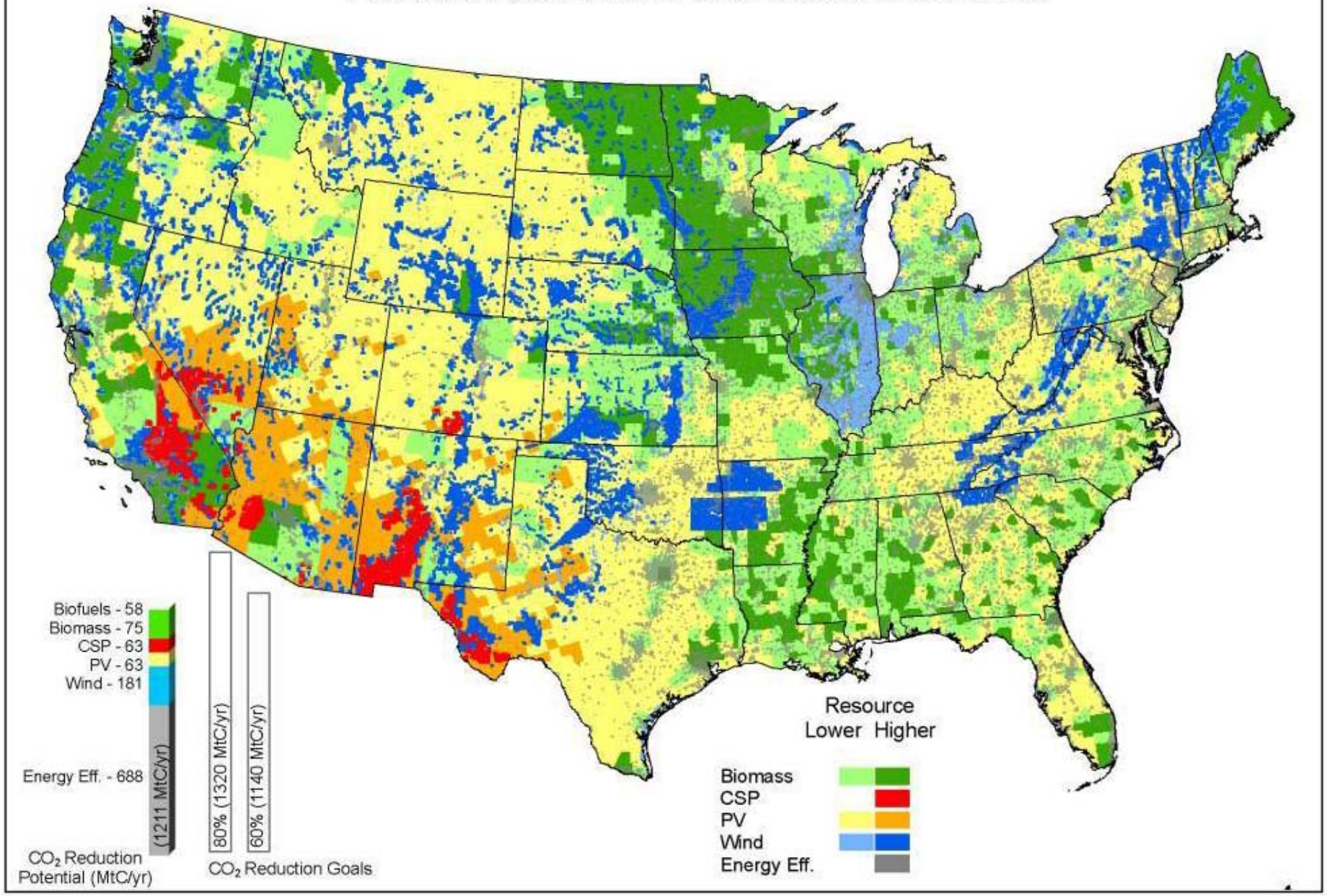

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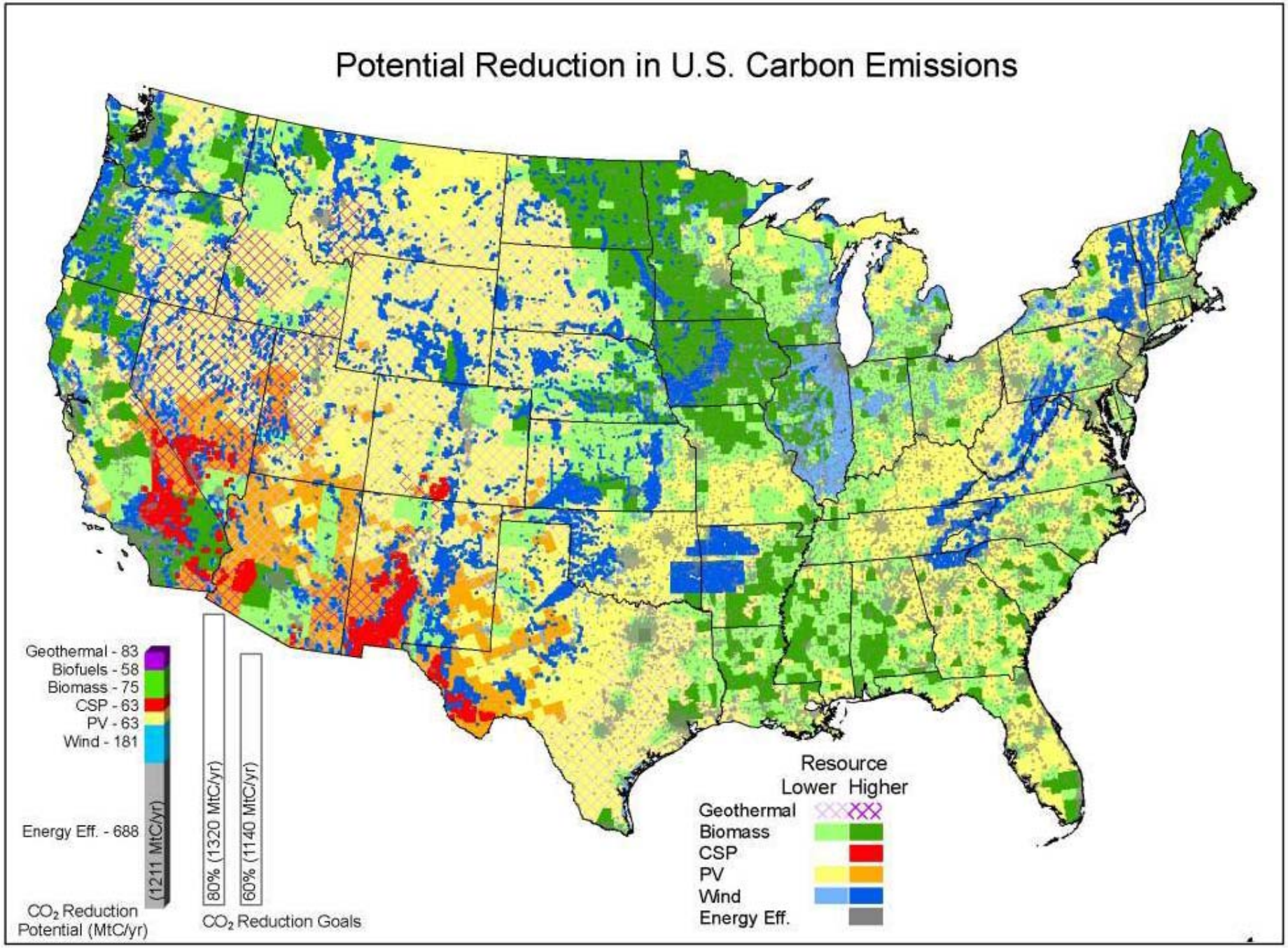
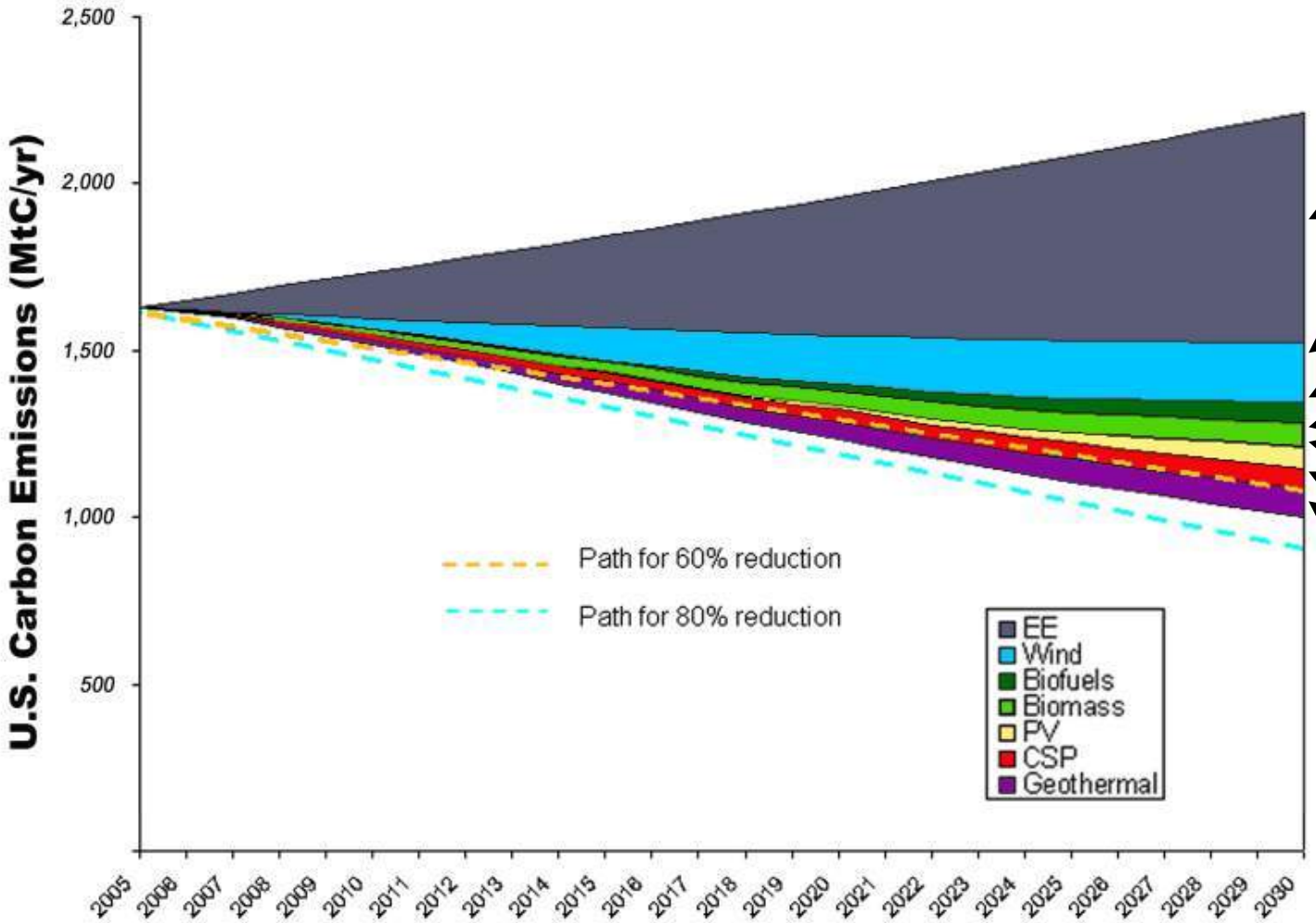


Potential U.S. Carbon Reductions



What does it cost?

-$108B/yr

$0B/yr

$9B/yr

$3B/yr

$5B/yr

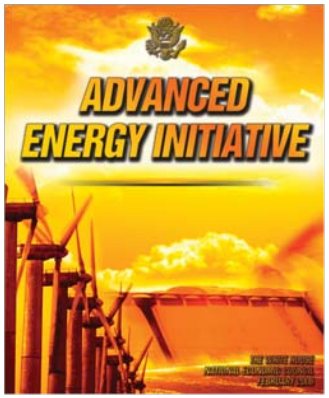
$7B/yr

$2B/yr

Total:
Savings
of $82B/yr

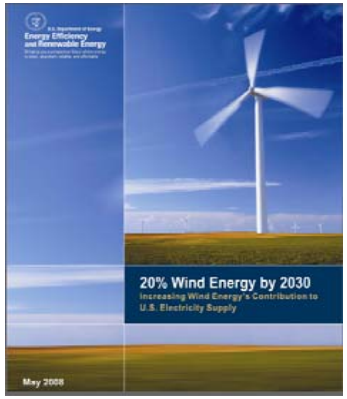
57% energy efficiency | **43% renewables**

Setting the Bar Higher – Gigawatt-Scale Renewables



Solar Vision

10% U.S. electricity by 2025



Wind Vision

20% U.S. electricity by 2030

Energy Independence & Security Act 2007

36 billion gallons of renewable fuels by 2022

Requires investment in new infrastructure:

- Overall in U.S. = $2 trillion
- Worldwide = $22 trillion
  - Biofuels
  - Wind
  - Solar

  } $2 trillion (est.)

Getting to "Speed and Scale" – Key Challenges

Implementing Renewable Gigawatts at Scale

NREL 140-1

BARRIERS

- Cost of renewable electricity
- Performance and reliability
- Infrastructure robustness and capacity
- Dispatchability of renewables

Displacement of Petroleum-Based Fuels

NREL 139-1

BARRIERS

- Cellulosic ethanol cost
- Life cycle sustainability of biofuels
- Fuels infrastructure, including Codes/Standards
- Demand and utilization, including intermediate blends

Reducing Energy Demand of Buildings, Vehicles, and Industry

NREL 196-1

BARRIERS

- Coordinated implementation of model building codes
- Market does not value efficiency
- Cost of energy efficient technologies
- Performance and reliability of new technologies

Making Transformational Change

Requires an integrated approach

Unleashing market-driven innovation

FILL technology pipeline

INFORM decision makers about choices

ENSURE appropriate market price signals

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