Climate Change: 
Bad News/Good News 

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National Renewable Energy Laboratory  
April 5, 2013
Report: Global Warming Issue From 2 Or 3 Years Ago May Still Be Problem

WASHINGTON—According to a report released this week by the Center for Global Development, climate change, the popular mid-2000s issue that raised awareness of the fact that the earth's continuous rise in temperature will have catastrophic ecological effects, has apparently not been resolved, and may still be a problem.
The Science
Air
Ice
Average Monthly Arctic Sea Ice Extent
September 1979 - 2012

National Snow and Ice Data Center
Gravity Satellite Ice Sheet Mass Measurements

Greenland Ice Sheet

Antarctic Ice Sheet

Ocean
Change in Earth’s Total Heat Content

- Ocean Heating
- Land + Atmosphere + Ice Heating

The Culprit
Sea Level vs. CO$_2$
For Last 550,000 Years
Pre-industrial CO$_2$ Level

Today's CO$_2$ Level

Foster and Rohling, *Proceedings of the National Academy of Sciences*, January 22, 2013
Rising Seas

MEASURED SEA LEVEL RISE

Tide gauge data  Satellite data

PROJECTED SEA LEVEL RISE

Sources: PNAS; Martin Vermeer, Aalto University; Stefan Rahmstorf, Potsdam Institute for Climate Impact Research; NASA; CNES
USA: Florida

Weiss and Overpeck
The University of Arizona
Extreme Weather
U.S. June Temperature Records Broken
Waldo Canyon Fire
The ten top high-water events at lower Manhattan (NYC/Battery Park, 1900–2012)

10.5 feet = NYC subway system floods

fraction of high water attributable to sea level rise since 1900

storm surge

tide level
“We can’t afford to fix it.”
Projected Cost to US of Climate Change Damage by Year 2025:

$271 Billion/yr

– Ackerman and Stanton, 2008
The Good News: Solutions!
(and Challenges)
Tackling Climate Change in the U.S.

Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030

American Solar Energy Society
Charles F. Kutscher, Editor
January 2007
Potential U.S. Carbon Reductions

What does it cost?

- $108B/yr

+ $26B/yr

Total: Savings of $82B/yr

57% Energy Efficiency, 43% Renewables
The Challenge:
Grid Integration
Operations during mid-April

No Wind/Solar

From Western Wind and Solar Integration Study, courtesy of Debra Lew, NREL
Operations during mid-April

High renewables case

- Gas turbine
- PV
- Combined cycle
- hydro
- CSP
- wind
- coal
- nuclear

From *Western Wind and Solar Integration Study*, courtesy of Debra Lew, NREL
Spatial Diversity Smooths Wind Farm Output

- 1 Site
- 2 Sites
- 25 Sites

% full output vs. Hours at output
Solar and Wind Complementary: Diurnal

![Graph showing the complementarity of solar and wind energy over a diurnal cycle.](image)
Grid Integration Costs (Arizona Public Service)
80% RE Scenario

Increased variability requires:
- increased supply- and demand-side flexibility
- new transmission
New Transmission Needs

Source: Renewable Electricity Futures (2012)
New NREL
Energy Systems Integration Facility
Hardware-in-the-Loop: Connecting Experiments to Simulations

Simulation validated with real field data

Actual hardware at ESIF

Simulation and Visualization at ESIF

Device Under Test (e.g. inverter, energy storage, EV, load, etc.)

Simulation loop closed with actual hardware

Replicated into Larger Simulation

Load Banks

Grid Simulator

Visualization Interface

HIL I/O Interface

Replicated into Larger Simulation

Utility Substation

Subdevelopment with PV at end of circuit
ESIF - Energy System Simulated Operations

A Flight Simulator for Energy System Operators
The Really Good News:

Rapid Change is Happening!
New EPA Fuel Efficiency Standard

Miles per gallon equivalent, by model year

- Passenger cars
- Light trucks

New standards

54.5 mpg fleetwide average by 2025
Shift From Coal to Gas

Net Generation from Coal and Gas

January 2001 - May 2012

Source of data: EIA
Germany sets solar record, meets half of electricity demand

By Ian Steadman  |  28 May 12
PV Resource: Germany vs. U.S.
Abengoa power towers

Gemasolar power tower

US trough plant

Spanish trough plant
World Wind Power (MW)
Current Installed Wind Power Capacity (MW)

Total: 51,630 MW
(As of 09/30/2012)

Data is from the American Wind Energy Association Third Quarter 2012 Market Report: http://www.awea.org

U.S. Department of Energy
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
25-OCT-2012 1.1.23
January 2013
New U.S. Generating Capacity Added:
1,231 MW
Percent from Renewables: 100%
California's New Cap-and-Trade Law: A Model for the Country?

Although cap-and-trade programs to curb global warming are a nonstarter in Washington, an ambitious plan in California could renew interest.

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By Coral Davenport

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December 13, 2012 | 4:00 p.m.
Australian Carbon Tax
“We will respond to the threat of climate change, knowing that the failure to do so would betray our children and future generations.”

- President Barack Obama, January 21, 2013
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