Climate Change:
The Latest Science,
Why It’s Serious,
What We Can Do About It

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Note: Any opinions expressed are my own.
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.
Part 1.
The Latest Science
The Greenhouse Effect

Net solar in – IR out ≈ 0.50-0.75 W/m²
Energy of 4-6 Hiroshima atom bombs every second
The Runaway Greenhouse Effect
Venus

Atmosphere: 96% CO₂
Surface temperature: 870°F
Global land-Ocean Temperature Index

- **Annual Mean**
- **5-year Running Mean**

Temperature Anomaly (°C)

1880 1900 1920 1940 1960 1980 2000

NASA Goddard Institute for Space Studies
Change In Earth’s Total Heat Content

Polar Ice Sheet Loss

Massive ice melt 'appears unstoppable

Could cause higher sea-level rise

The melting of a major section of Antarctic ice sheet could lead to higher global sea levels than previously expected, researchers said. FULL STORY

- See the ice sheet melt
- Climate report | Nations most at risk
- Global warming skeptics
- Iceberg twice the size of Atlanta
The Culprit
EACH DAY HUMBLE SUPPLIES ENOUGH ENERGY TO MELT 7 MILLION TONS OF GLACIER!

This giant glacier has remained unmelted for centuries. Yet, the petroleum energy Humble supplies—if converted into heat—could melt it at the rate of 80 tons each second! To meet the nation's growing needs for energy, Humble has applied science to nature's resources to become America's Leading Energy Company. Working wonders with oil through research, Humble provides energy in many forms—to help heat our homes, power our transportation, and to furnish industry with a great variety of versatile chemicals. Stop at a Humble station for new Enco Extra gasoline, and see why the "Happy Motoring" Sign is the World's First Choice!
Temperature and CO$_2$ Record

![Graph showing temperature and CO$_2$ levels over thousands of years.](graph.png)
2013
10,885 peer-reviewed climate articles
2 reject man-made global warming
Part 2.
Why is it serious?
Post-Glacial Sea Level Rise
Holocene Temperatures
Global Temperature Relative to 1800-1900 (°C)
Climate Change Is Happening Now!
Flooding: Bangladesh
Increase in Heavy Precipitation Events

National Climate Assessment 2014
Extreme Rainfall


Long Island, 8/12/14: 13” in 24 hrs.
Typhoon Haiyan
Caribbean coral suffers record die-off

World's coral reef loss 'an underwater holocaust'
NOAA Coral Bleaching Outlook
September-December 2015
Heat Waves

2003 European heat wave: 70,000 dead

2010 Russian heat wave: 15,000 dead
Droughts

2011 East Africa Drought
Death toll: 50,000 – 260,000

California: 2013-2015
Probability of Megadrought in U.S.

There aren't enough firefighters to fight all the Western wildfires

A burned structure outside Chelan, Wash., is one of dozens destroyed in a spate of Western wildfires. (Ted S. Warren / Associated Press)

By MATT PEARCE
contact the reporter

AUGUST 18, 2015, 1:25 PM

The wildfires torching the West have gotten so bad that the nation's military has stepped in.
Predicted Increase in Very Large Fires by Mid-Century
Who believes climate change is serious?
“The national security risks of projected climate change are as serious as any challenges we have faced.”

“The days of climate change as a future concern are over.”
2011 NOAA Study: Human-caused climate change a major factor in more frequent Mediterranean droughts

“Anthropogenic greenhouse gas and aerosol forcing are key attributable factors for this increased drying.”
“No natural cause is apparent for these trends, whereas the observed drying and warming are consistent with model studies of the response to increases in greenhouse gases.”

Syrian Refugees

218,000 have applied for asylum in Europe.

7.6 MILLION are still in Syria, but no longer in their homes.

3.8 MILLION have moved to neighboring countries.
FOREIGN POLICY Survey of America’s Top International Relations Scholars
What are the three most important foreign-policy issues facing the United States today?

1. Global climate change 40.96%
2. Armed conflict in Middle East 26.81%
3. Failed or failing states 22.29%
4. China's rising military power 21.54%
5. Transnational terrorism 21.23%
6. Renewed Russian assertiveness 17.47%
7. Global poverty 16.42%
8. Global wealth disparities 15.66%
9. China's economic influence 15.51%
10. Proliferation of WMD 14.01%
10. Transnational political violence 14.01%
So why aren’t we doing more about it?
Ipsos poll: Climate change caused by humans
U.S. Climate Change Research Budget: $2 billion

ExxonMobil

Annual Profit: ~$40 billion
"140 foundations funneled $558 million to almost 100 climate denial organizations from 2003 to 2010."

Follow the Money
New Climate Change Study Just 400 Pages Of Scientists Telling Americans To Read Previous Climate Change Studies

NEWS IN BRIEF · Science & Technology · Science · ISSUE 51·02 · Jan 14, 2015
Part 3.
What can we do about it?
(The good news part!)
Emissions Reduction
Cumulative Emissions to Stay Below 2°C Temperature Rise

Data: Friedlingstein et al. 2014

CO₂ budget from 1870
(Uncertainty is about ±300 GtCO₂)

Projected growth 2014-2019
-22 years

2014
-30 years

2019

1000 Gt
1200 Gt

Cumulative CO₂ emissions (GtCO₂)

1960 1980 2000 2020 2040

Historical emissions
Emissions continue at 2014 rate
Emissions grow to 2019 and then continue at 2019 rate
A word about the 2°C temperature rise target
Climate Tipping Points vs. Temperature Increase

WAIS: 0.85°C rise, May 2014

GIS: Temp?, Date?

EAIS: Temp?, Date?

Permafrost methane: Temp?, Date?
New studies deepen concerns about a climate-change ‘wild card’

By Joby Warrick  September 7 at 10:41 AM  💌 Follow @jobywarri

Iceberg, with Mount Dundas in the background, in the Qaasuitsup municipality in west Greenland, Denmark. (DeAgostini/Getty Images)
The Goal:
Reduce all carbon emissions to zero as rapidly as possible!
Carbon-Free Energy Options

- Carbon capture & storage
- Nuclear
- Efficiency
- Renewable Energy
Carbon-Free Energy Options

- Carbon capture & storage
- Nuclear
- Efficiency
- Renewable Energy
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

57% Energy Efficiency, 43% Renewables
Energy Efficiency
Average US Home Refrigerator Energy Use, Volume and Price vs. Time

Sources: Association of Home Appliance Manufacturers (AHAM) for energy consumption and volume; U.S. Census Bureau for price.
U.S. Electricity Consumed by Buildings

74%

U.S. Energy Information Administration
Energy Performance-Based Contracting: NREL Research Support Facility
WHY CITIES?

Ending Climate Change Begins in the City

Source: C40 Cities
The World’s Population is Shifting to Urban Areas:

North America
2014: 82%

Cities are responsible for 70% of the world’s fossil fuel CO$_2$ emissions

Source: Cities and Climate Change: an urgent agenda, World Bank, 2010

Image: NASA
By 2030

900 billion ft$^2$

of new and rebuilt buildings will be constructed worldwide

Cities signed onto the Mayors’ Climate Protection Agreement
1,060 as of 8/19/15
Net Zero Energy Districts: The Next Step in Building Energy Efficiency

Net Zero Energy Buildings

Net Zero Energy Districts
FORT ZED
FORT COLLINS
OUR PATH TO A BETTER ENERGY FUTURE
Denver National Western Center

- Redevelop 130 acres of the National Western Complex and Denver Coliseum sites
- Net zero district: energy, water, waste
Denver Sun Valley Neighborhood

- Denver Housing Authority to demolish existing public housing, re-build at 3 times density
  - 1/3 public housing, 1/3 low-income, 1/3 market rate
Photovoltaics (PV)
NREL PV Systems
South Table Mountain Campus

1,156 kW

720 kW

94 kW

857 kW

524 kW
Germany sets solar record, meets half of electricity demand

By Ian Steadman  |  28 May 12
PV Resource: Germany vs. U.S.
Concentrating Solar Power (CSP)
250 MW Solana Plant with 6 hrs Storage
Wind
Horns Rev Offshore Wind Farm
North Sea, Denmark

• Photo used by permission of Uni-Fly A/S
Biomass and Biofuels

Wood chips

Switch grass

Poplars

Fats and Oils

Municipal solid waste

Corn Stover
BECCS

Conventional Biomass Power
Carbon Neutral

BECCS
Carbon Negative
Geothermal
Enhanced Geothermal Systems

Step 1: Locate Site
- Characterize and Select Site
- Drill and Log Exploratory Well

Step 2: Create Reservoir
- Drill Injection Well
- Stimulate/Create Reservoir
- Drill Production Well

Step 3: Operate System
- Install Operating Equipment
- Complete and Verify Circulation Loop

Source: NREL
Potential Reductions in U.S. Carbon Emissions
Potential U.S. Carbon Reductions

57% Energy Efficiency, 43% Renewables

-$108B/yr

Total: Savings of $82B/yr

What does it cost?

+$26B/yr

Year

2005 2010 2015 2020 2025 2030

U.S. Carbon Emissions (MtC/yr)

500 1,000 1,500 2,000 2,500

Path for 60% reduction
Path for 80% reduction

EE
Wind
Biofuels
Biomass
PV
CSP
Geothermal

57% Energy Efficiency, 43% Renewables
Net Jobs Created: 4.5 million

1944: Ford Motor Company Willow Run, MI plant produced one B-24 bomber every 63 minutes, 24 hours/day, 7 days/week
The Cost of Not Addressing Climate Change
Projected Cost to US of Climate Change Damage by Year 2025:

$271 Billion/yr

– Ackerman and Stanton, 2008
ENERGY DARWINISM II
Why a Low Carbon Future Doesn’t Have to Cost the Earth
World Cost of Climate Action (over next quarter century)

Fossil fuel subsidies: $4 trillion per year
World Cost of Inaction
(over next quarter century)

0% discount rate

1.5°C
-$20 trillion

Change in global GDP
-0.7%

Source: OECD

2.5°C
-$44 trillion

4.5°C
-$72 trillion

-1.1%

-2.5%
An enormous, disruptive transition is underway!
Early 20th Century:

Early 21st Century:
World Wind Power (MW)
PV Module Prices

The Swanson effect
Price of crystalline silicon photovoltaic cells, $/watt

1977 price $76.67/watt

2013 price $0.74/watt

Source: Bloomberg, New Energy Finance
New solar installations in the United States (in megawatts)

Source: SEIA
Change in net generation, 2013-2014

Generation of electricity from wind and solar energy increased much more than from coal and natural gas in 2014. Figures are in thousand megawatt hours.

Source: Energy Information Administration
Emissions cap-and-trade program is working well in California

Michael Hiltzik
LOS ANGELES TIMES
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FOLLOW MICHAEL HILTZIK

California's oil and gas industry had predicted that the regulation would drive up gas prices by 16 to 76 cents per gallon. But experts accurately put the increase at closer to nine to 10 cents. Above is Valero's Wilmington refinery. (Christina House, For The Times)
People’s Climate March
New York City, Sept. 21, 2014
PRESIDENT OBAMA'S TRIP TO ALASKA:
THE FRONTLINES OF OUR FIGHT AGAINST CLIMATE CHANGE
Pope Francis blasts global warming deniers in leaked draft of encyclical

Pope Francis delivers his message with participants of Rome's diocese convention in St. Peter's Square at the Vatican on Sunday. (Gregorio Borgia/AP)
China: The Emerging World Renewable Energy Economic Powerhouse
Chuck Kutscher, Ph.D., P.E.
Director, Buildings and Thermal Systems Center