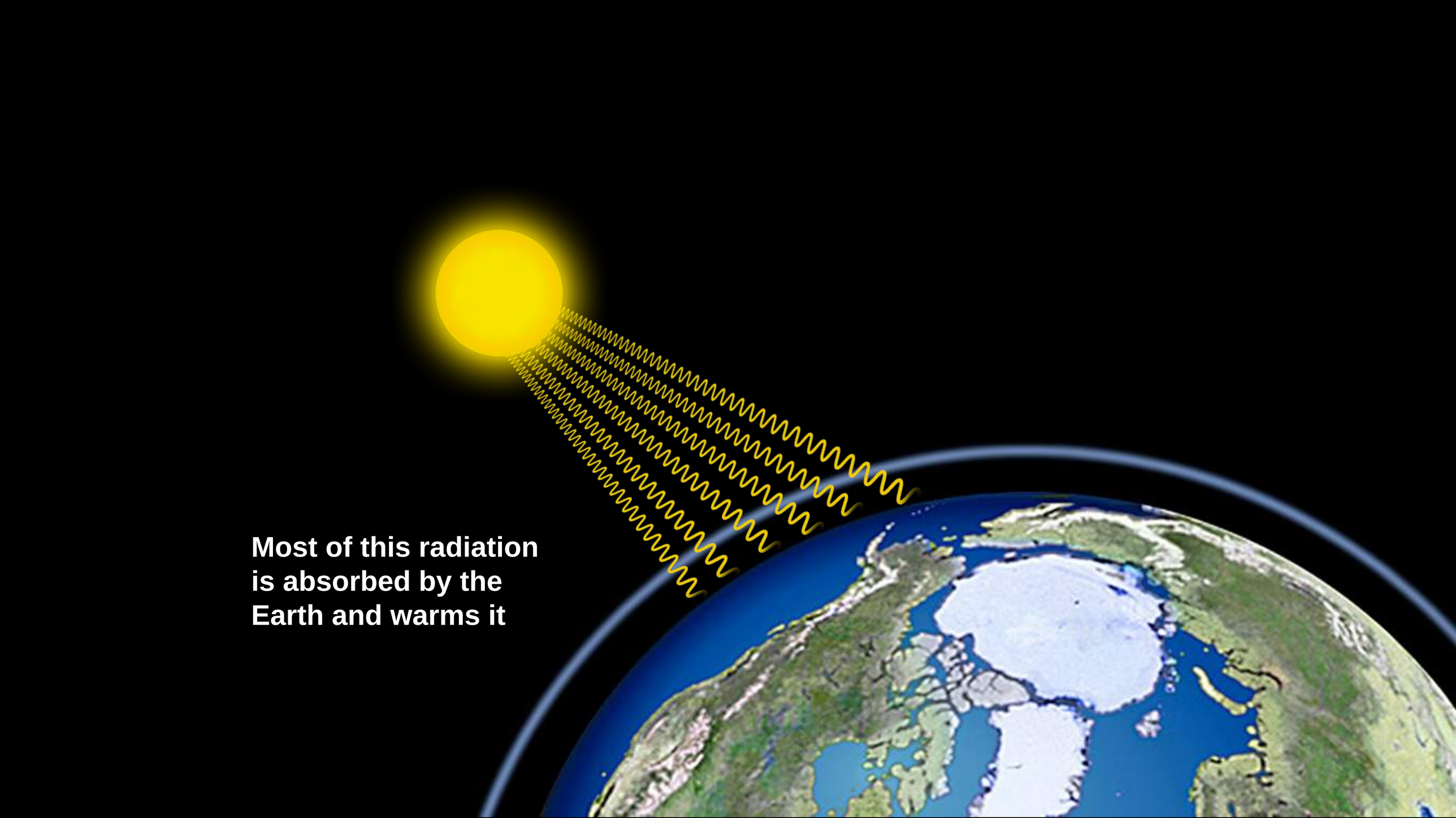
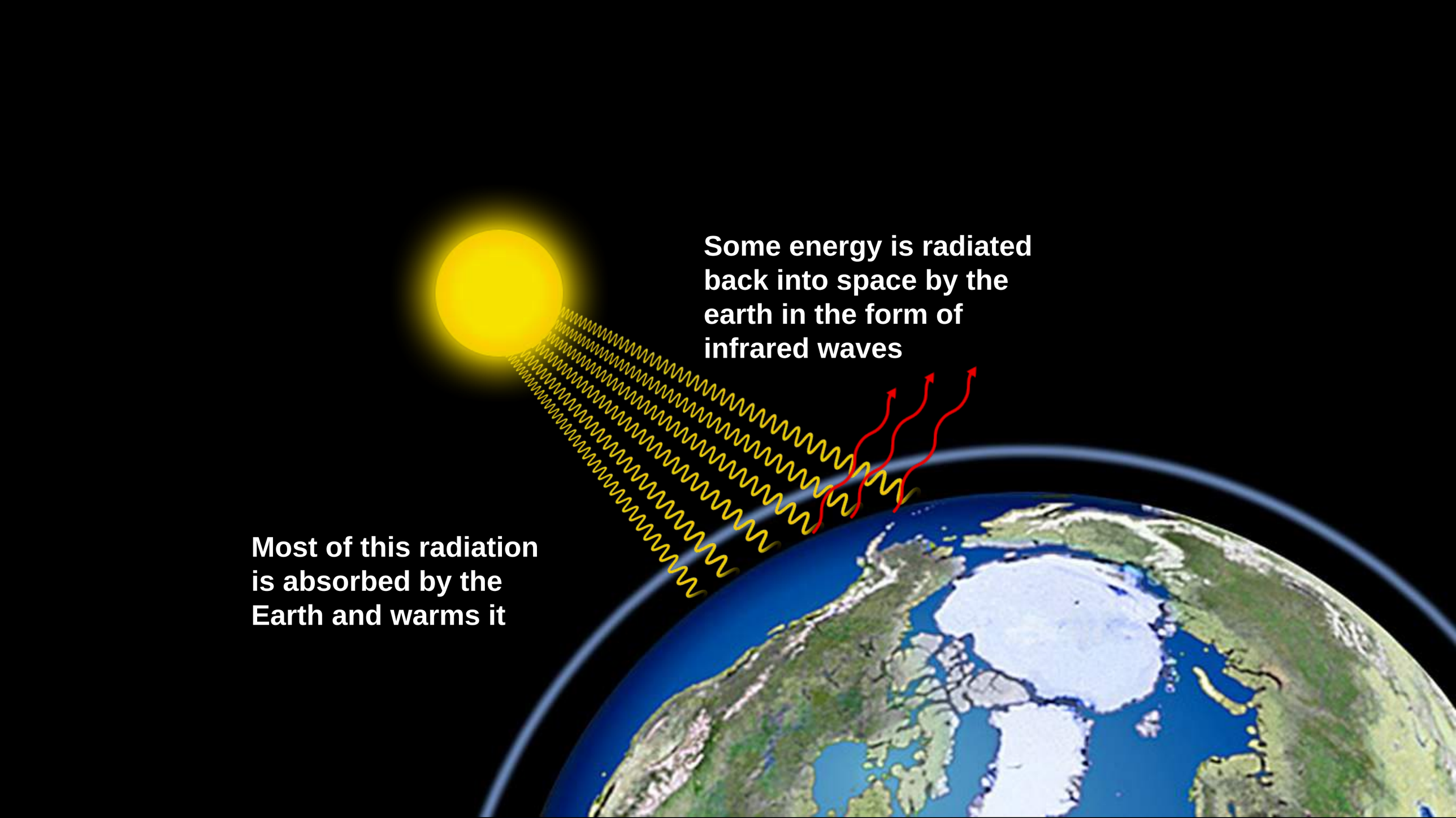
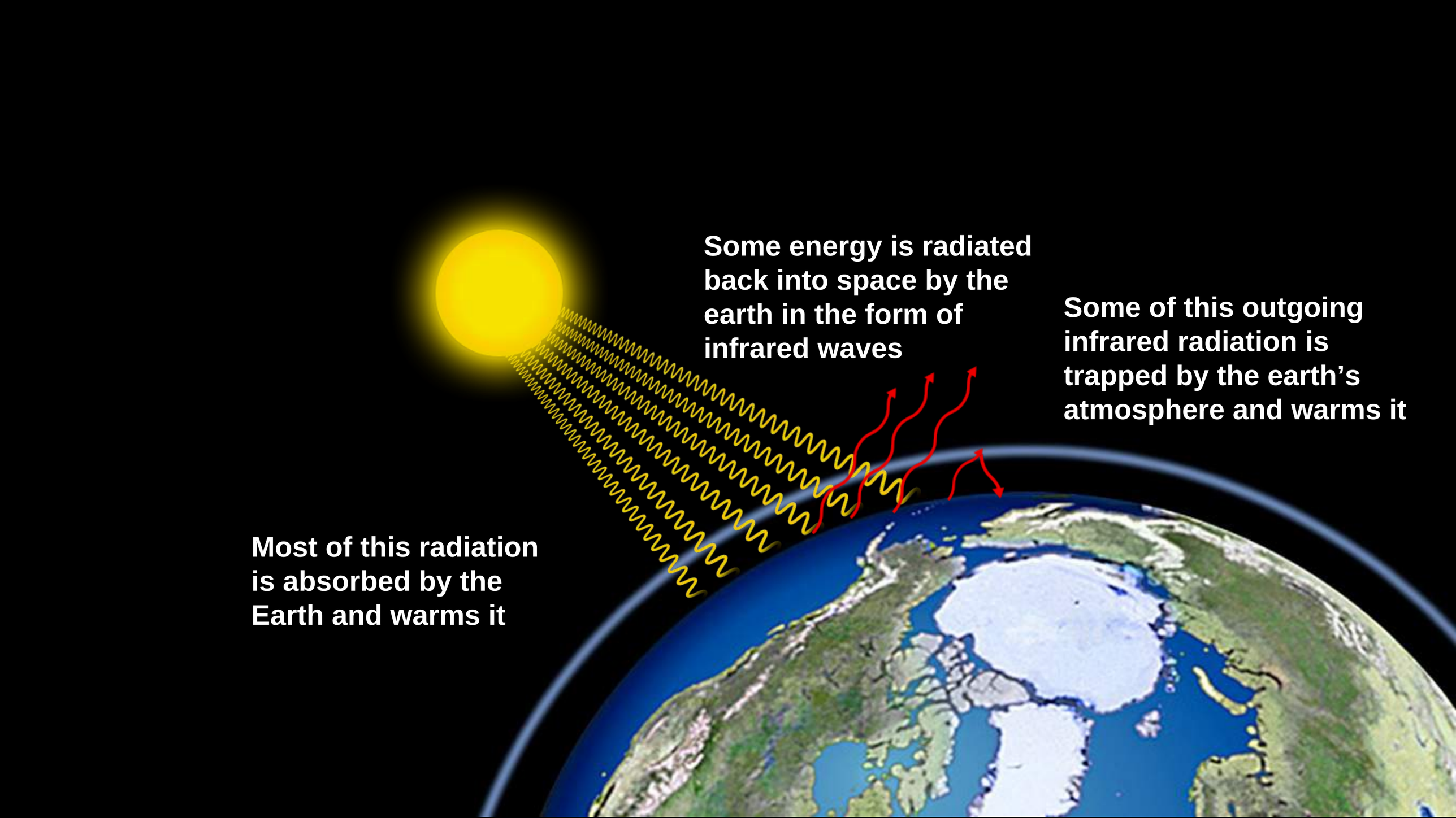
Source: NASA

Source: NASA

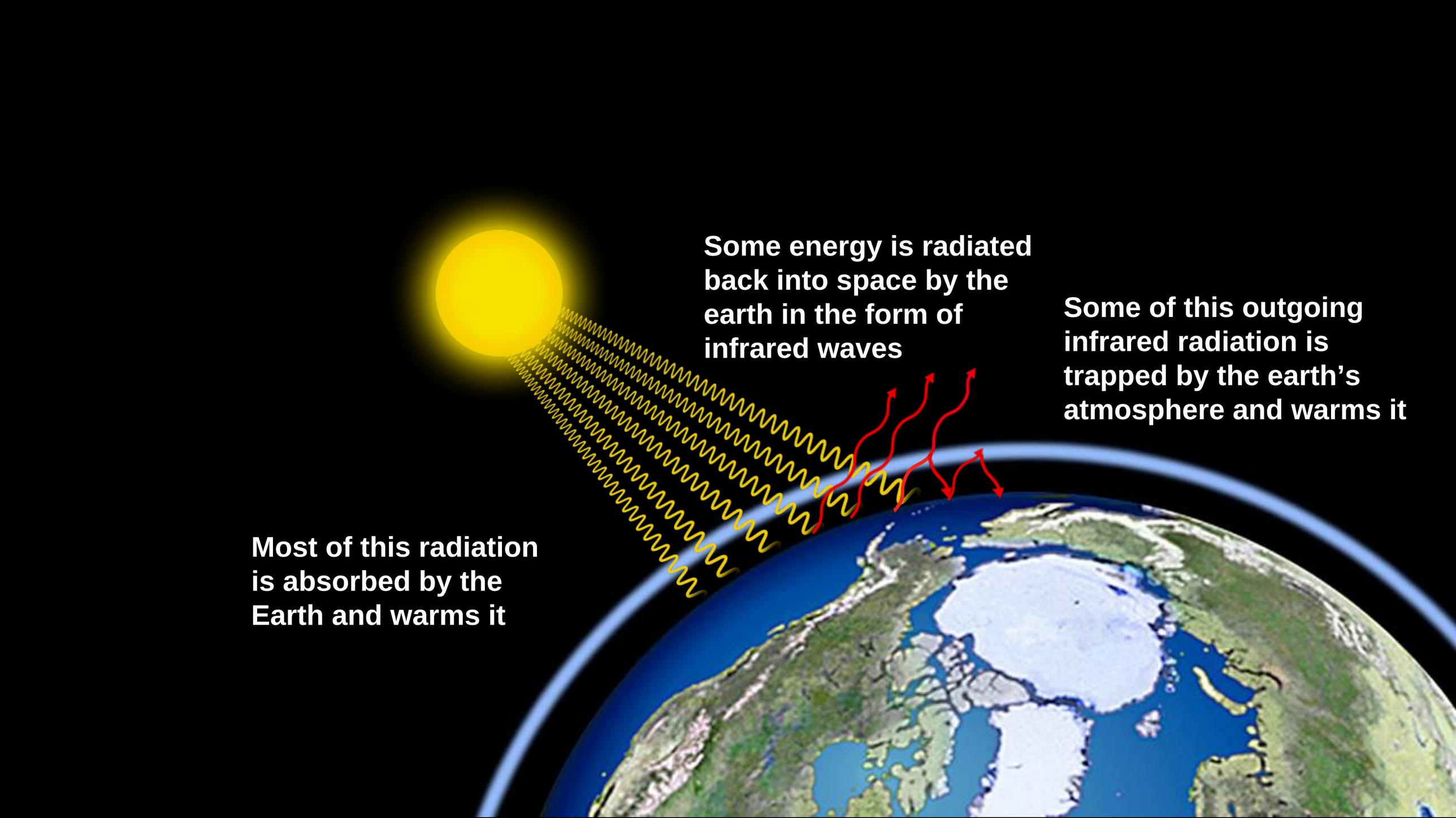
Solar radiation in the form of lightwaves passes through the atmosphere


Most of this radiation
is absorbed by the
Earth and warms it

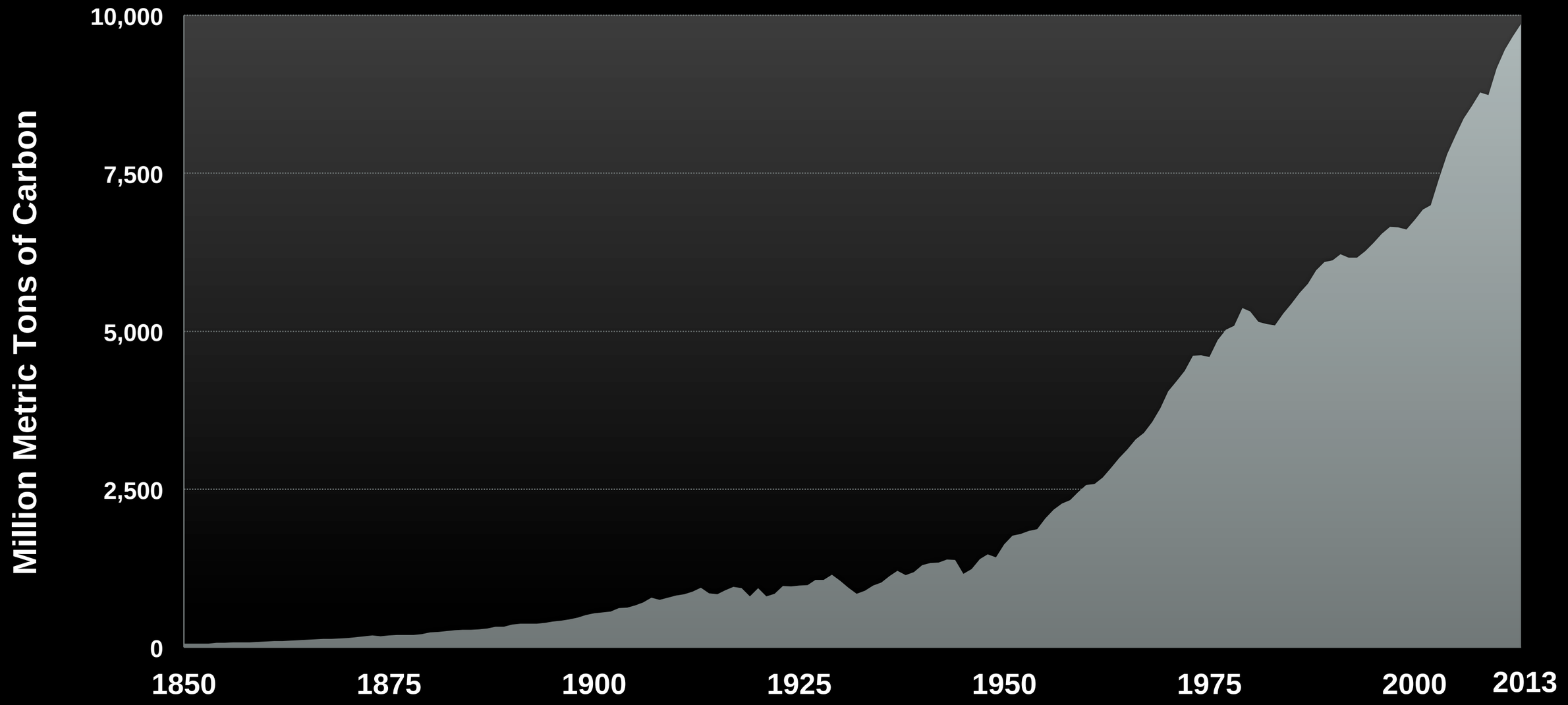

Some energy is radiated back into space by the earth in the form of infrared waves
Most of this radiation is absorbed by the Earth and warms it


Some energy is radiated back into space by the earth in the form of infrared waves
Some of this outgoing infrared radiation is trapped by the earth’s atmosphere and warms it
Most of this radiation is absorbed by the Earth and warms it

The Biggest Sources of Greenhouse Gases


Some energy is radiated back into space by the earth in the form of infrared waves
Some of this outgoing infrared radiation is trapped by the earth’s atmosphere and warms it
Most of this radiation is absorbed by the Earth and warms it

Global Carbon Emissions from Fossil Fuels

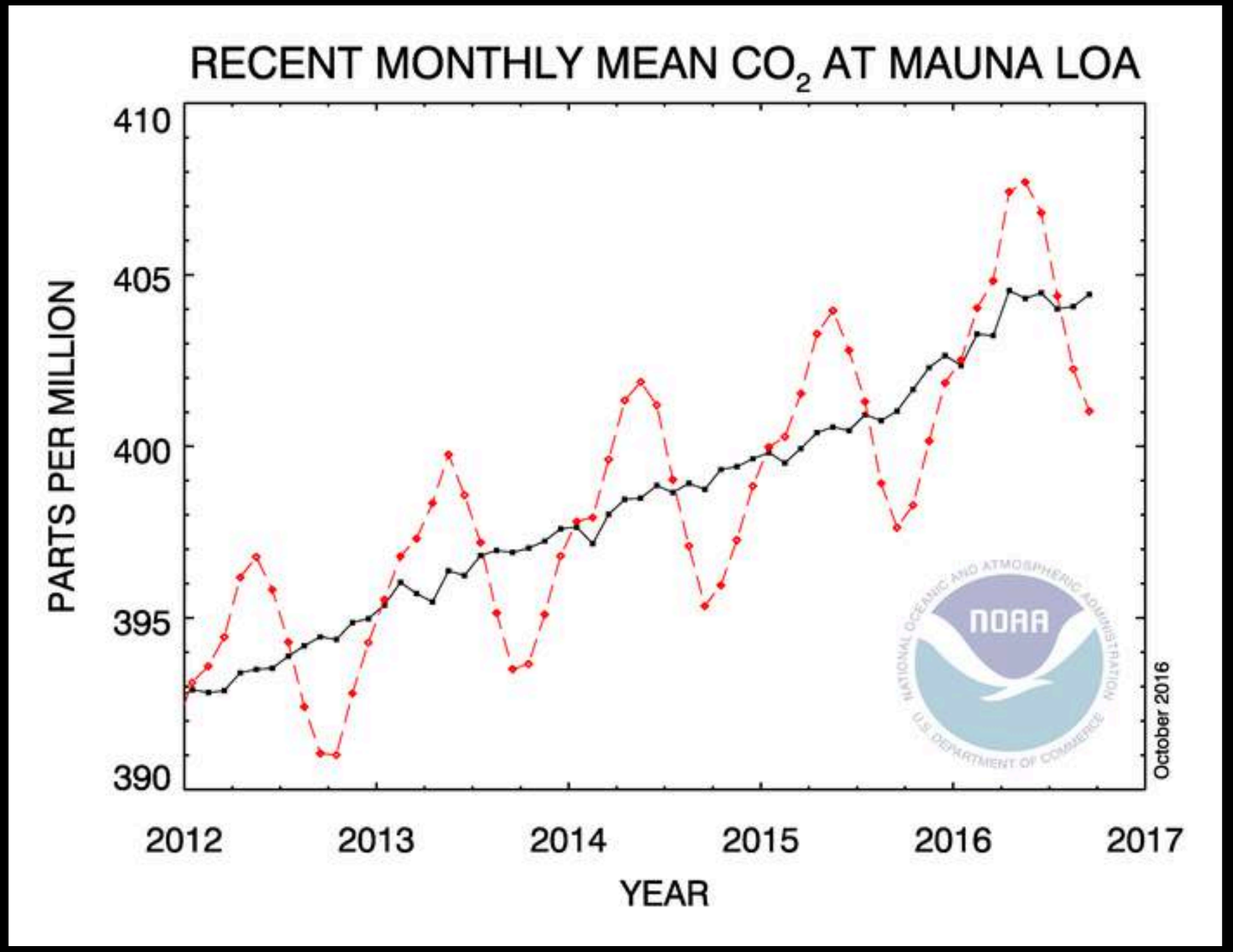


Data: U.S. Department of Energy/CDIAC

CO_2 is being released into the atmosphere faster than at any time in the last 66 million years.

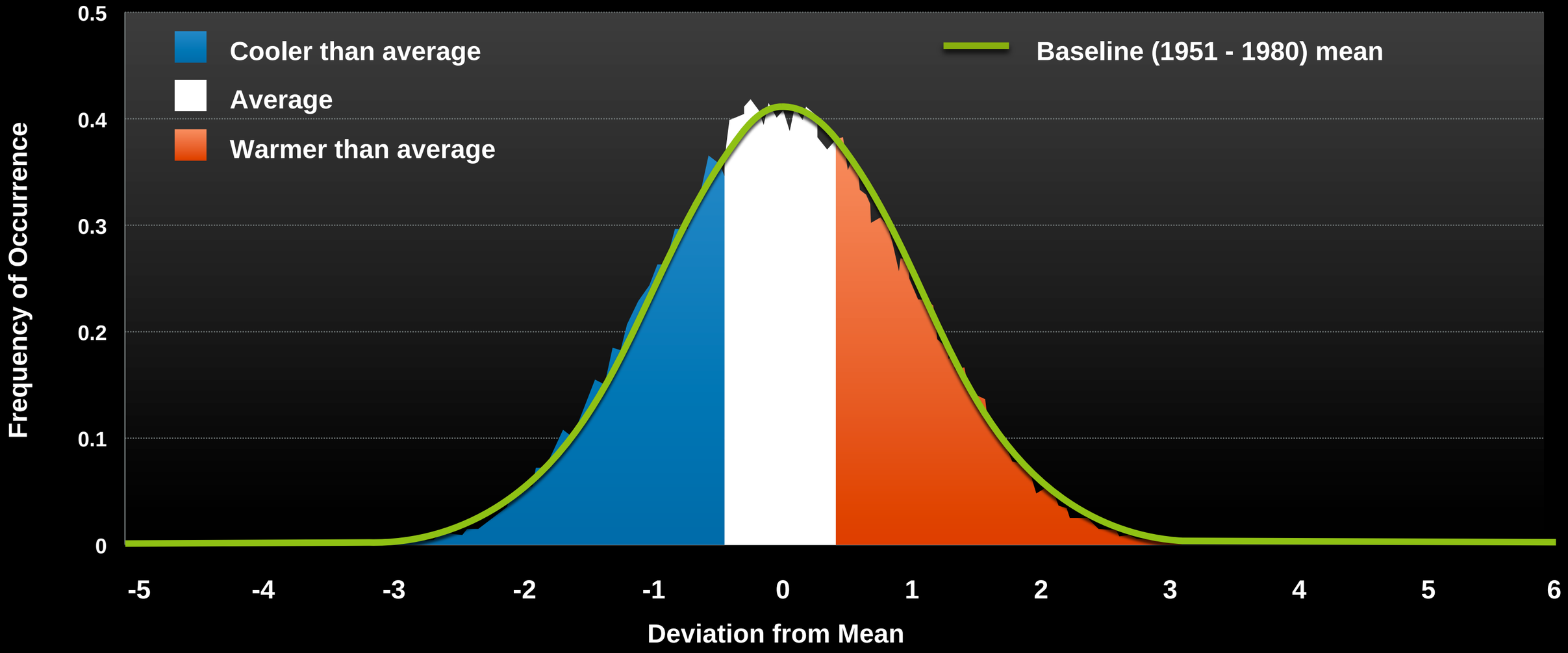
Source: RE Zeebe, et al., *Nature Geoscience,* March 2016

CO_2 in Atmosphere



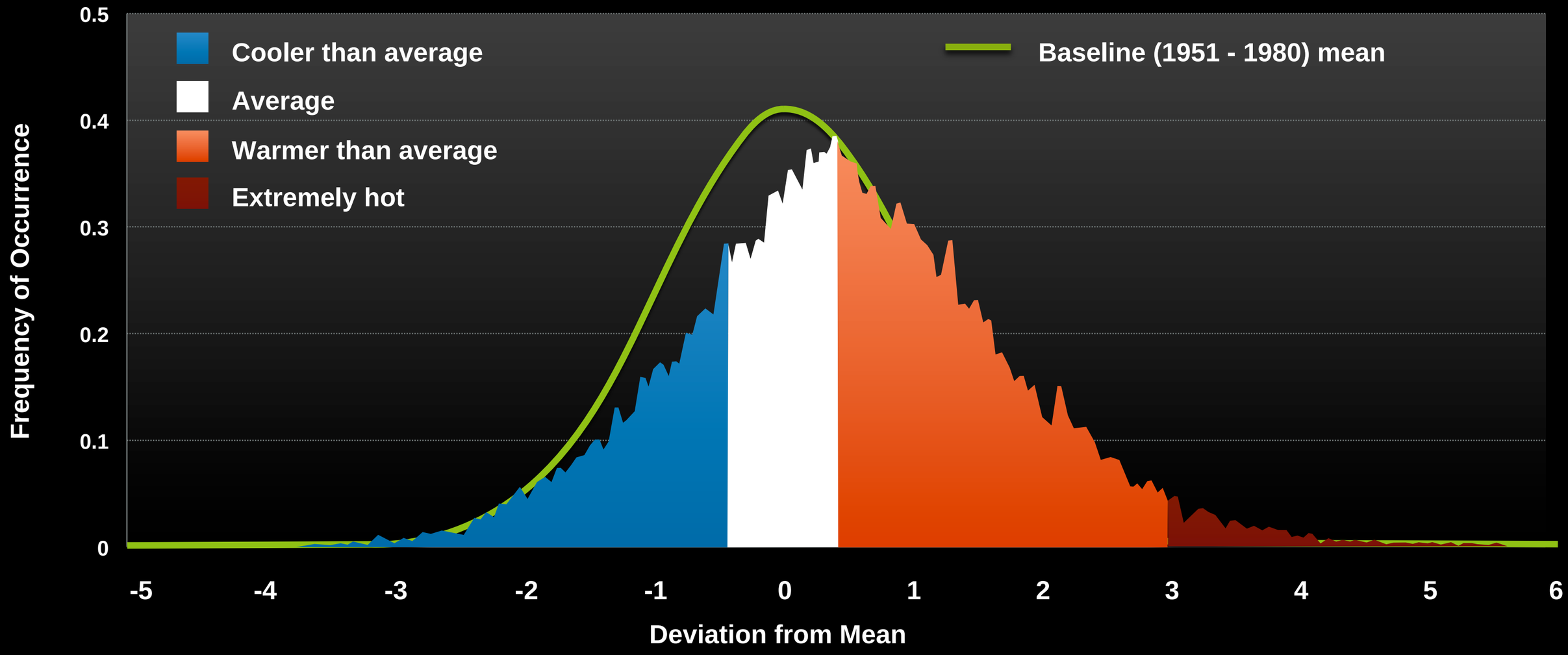
Summer Temperatures Have Shifted

1951 – 1980



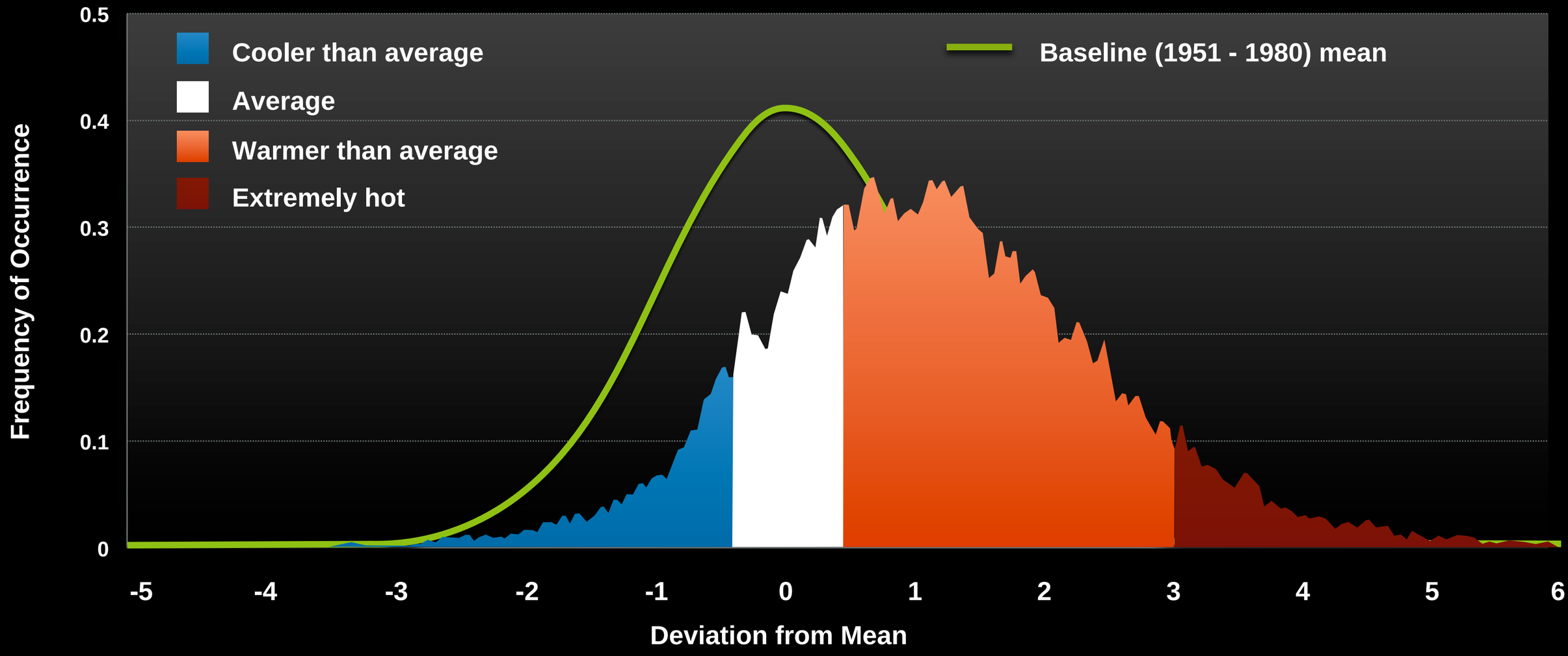
Source: NASA/GISS; Hansen, et al., “Perceptions of Climate Change,” Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

1983 – 1993



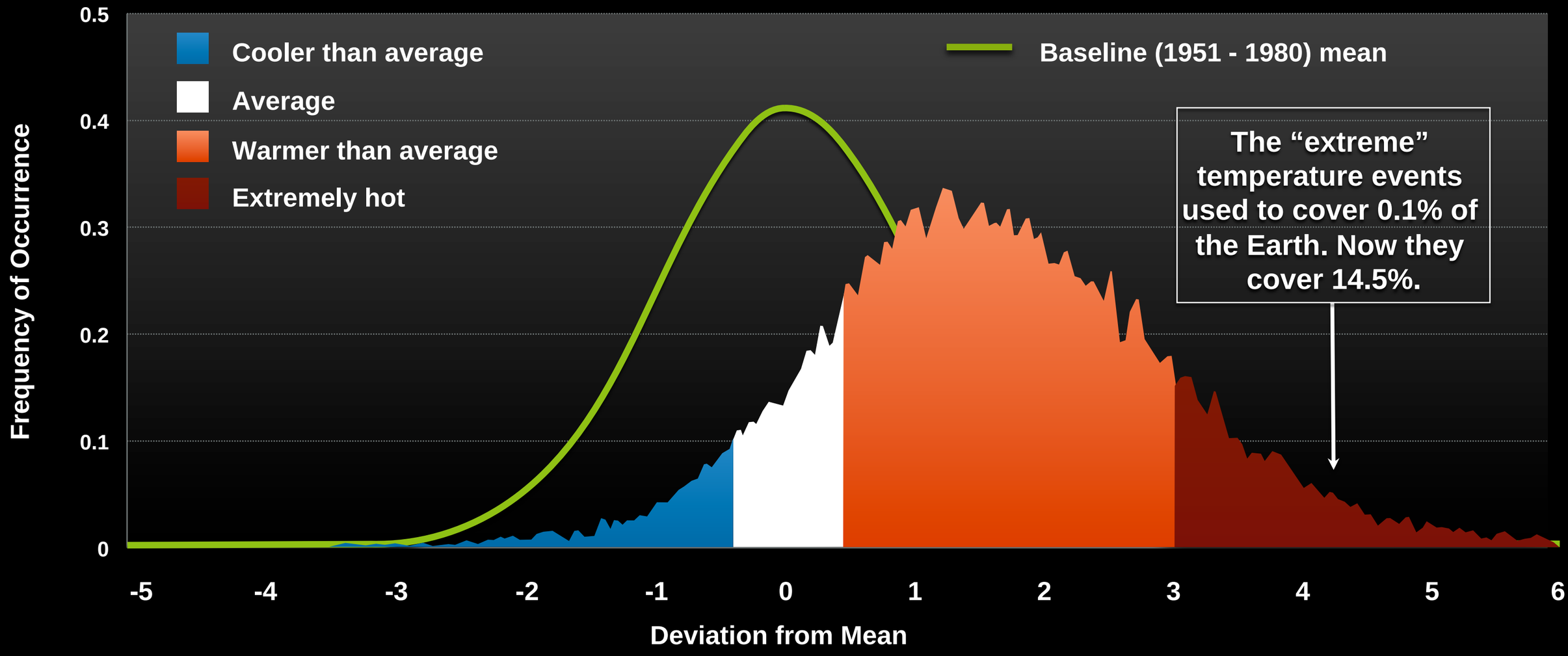
Source: NASA/GISS; Hansen, et al., “Perceptions of Climate Change,” Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

1994 – 2004



Source: NASA/GISS; Hansen, et al., “Perceptions of Climate Change,” Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

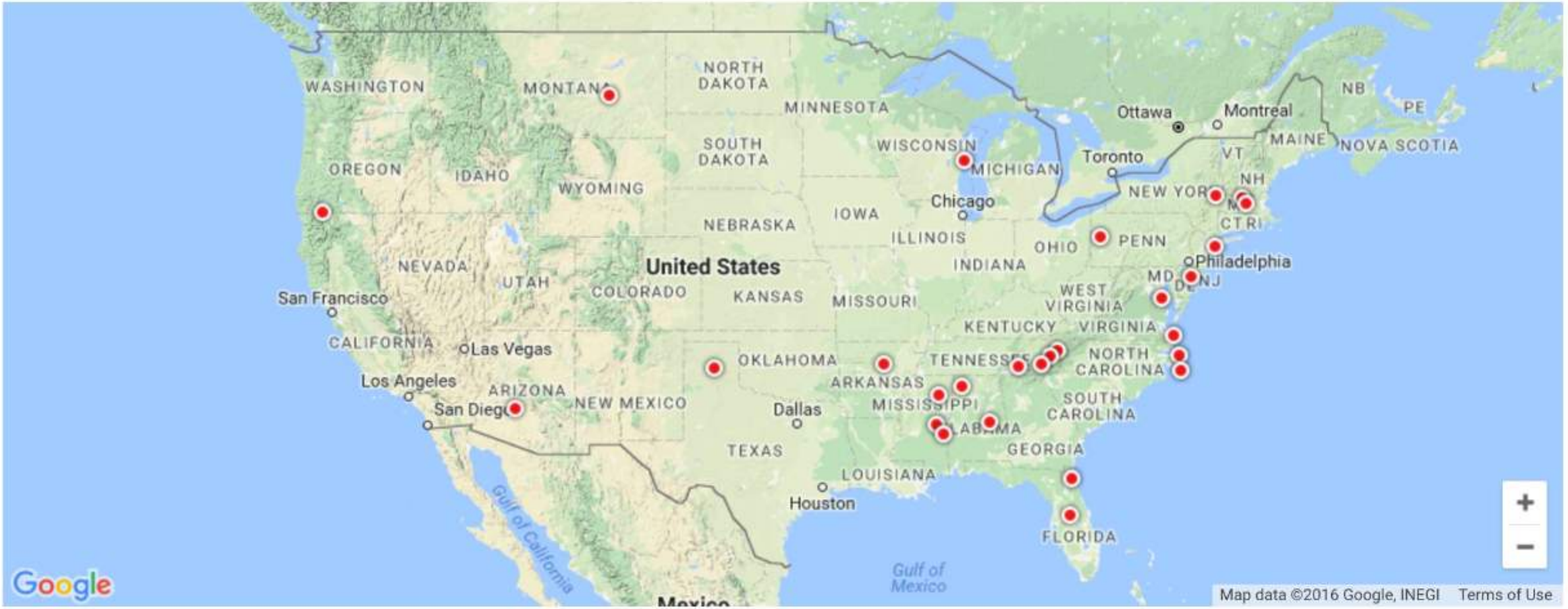
2005 – 2015



Source: NASA/GISS; Hansen, et al., “Perceptions of Climate Change,” Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

2015 was the 39th consecutive year with a global temperature above the 20th century average

Highest Minimum Temperature – August 2016

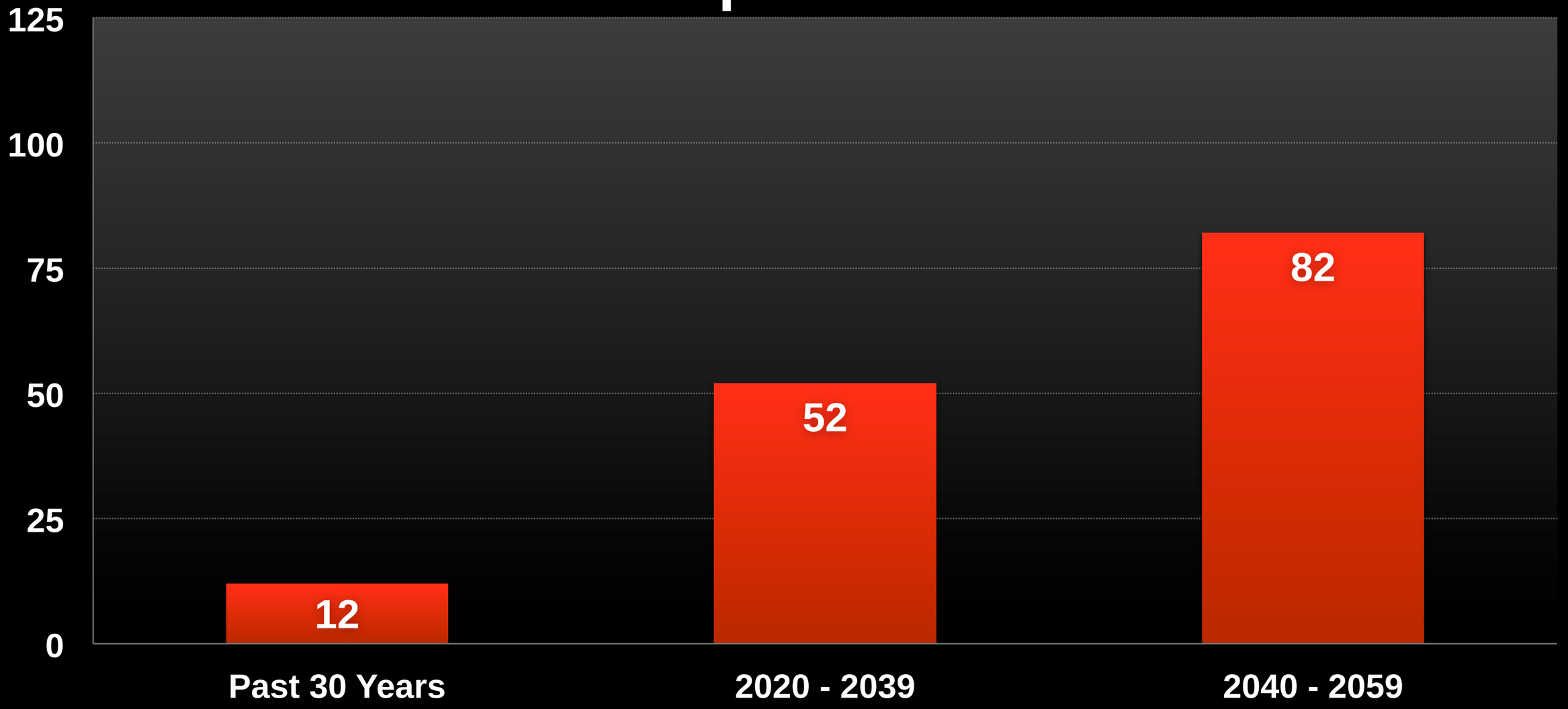


POTENTIAL	TIED	BROKEN	TOTAL
121838	30	13	43

Highest Maximum Temperature – August 2016

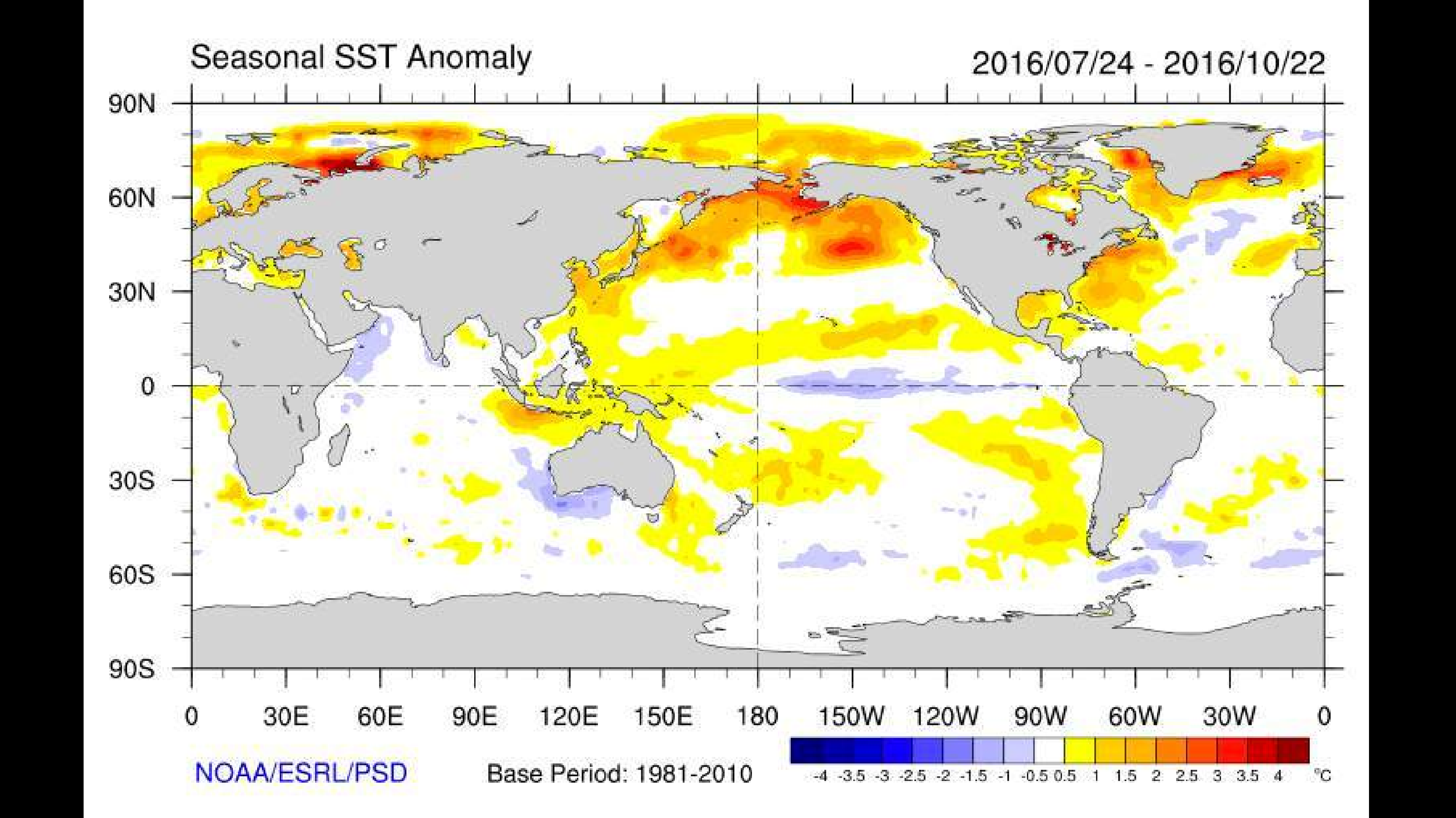
POTENTIAL	TIED	BROKEN	TOTAL
122520	0	4	4

How Many 95° F + Days Does the Average Louisianan Experience Per Year?



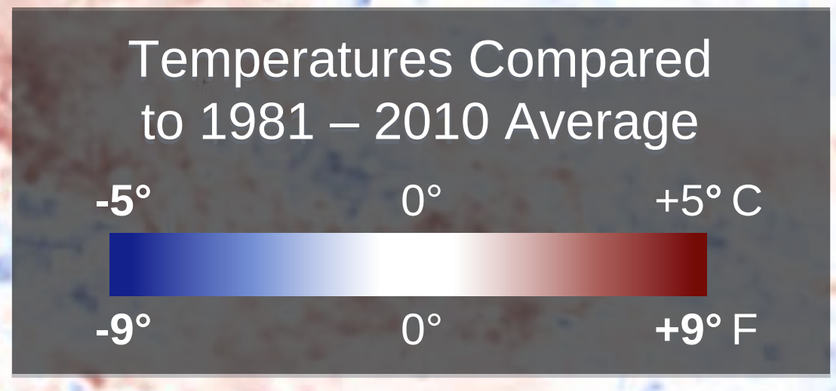
Source: *Risky Business Project, Come Heat and High Water: Climate Risk in the Southeastern U.S. and Texas*, July 2015

93% of the extra **Heat**
Trapped goes into the
Ocean


Seasonal SST Anomaly
2016/07/24 - 2016/10/22
90N
60N
30N
0
30S
60S
90S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
0
NOAA/ESRL/PSD
Base Period: 1981-2010
-4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0.5 1 1.5 2 2.5 3 3.5 4
°C

Sea Surface Temperature Anomaly

October 29, 2012



Source: 2012 NOAA

Hurricane Sandy
October 29, 2012
© 2012 NASA Photo via Getty Images

© 2013 AP Photo/Mel Evans

Manhattan, New York

October 29, 2012

© 2012 Christos Pathiakis/Getty Images

Pass Christian, Mississippi

August 31, 2005

Hurricane Katrina destroyed 90% of the homes in Pass Christian and the US 90 bridge over Bay St. Louis.

© 2005 White House/Paul Morse

New Orleans, Louisiana

August 30, 2005

Hurricane Katrina flooded 80% of New Orleans, breaching nearly every levee in the metro area.

© 2005 U.S. Coast Guard/Cangemi

There is already 4% more water vapor over the oceans than there was only 30 years ago.

With each additional 1° (C) of temperature, the atmosphere's capacity to hold water vapor increases by 7%.

Warmer air can hold a lot more water vapor.

Source: K. Trenberth, "Changes in Precipitation with Climate Change," *Climate Research,* March 2011

“Global warming
is contributing to an
increased incidence of
extreme weather
because the environment
in which all storms form has
changed
from human activities.”

Kevin Trenberth

U.S. National Center for Atmospheric Research

June 15, 2011

Haughton, Louisiana

March 9, 2016

© 2016 AP Photo/Mike Silva

Lafayette, Louisiana

August 12, 2016

In August 2016—Louisiana's wettest month on record—7.1 trillion gallons of water fell on south Louisiana. That's enough to fill more than 10.4 million Olympic-sized swimming pools.

© 2016 Louisiana DOTD/Reuters

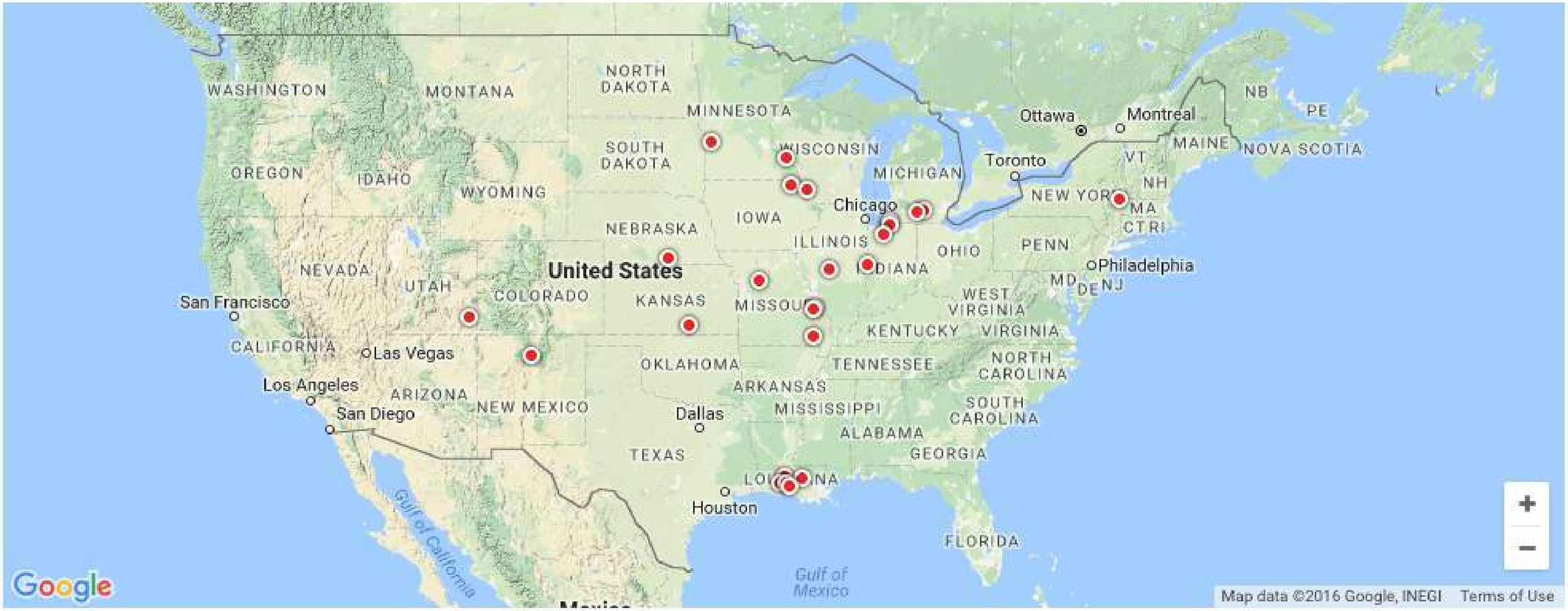
Baton Rouge, Louisiana

August 14, 2016

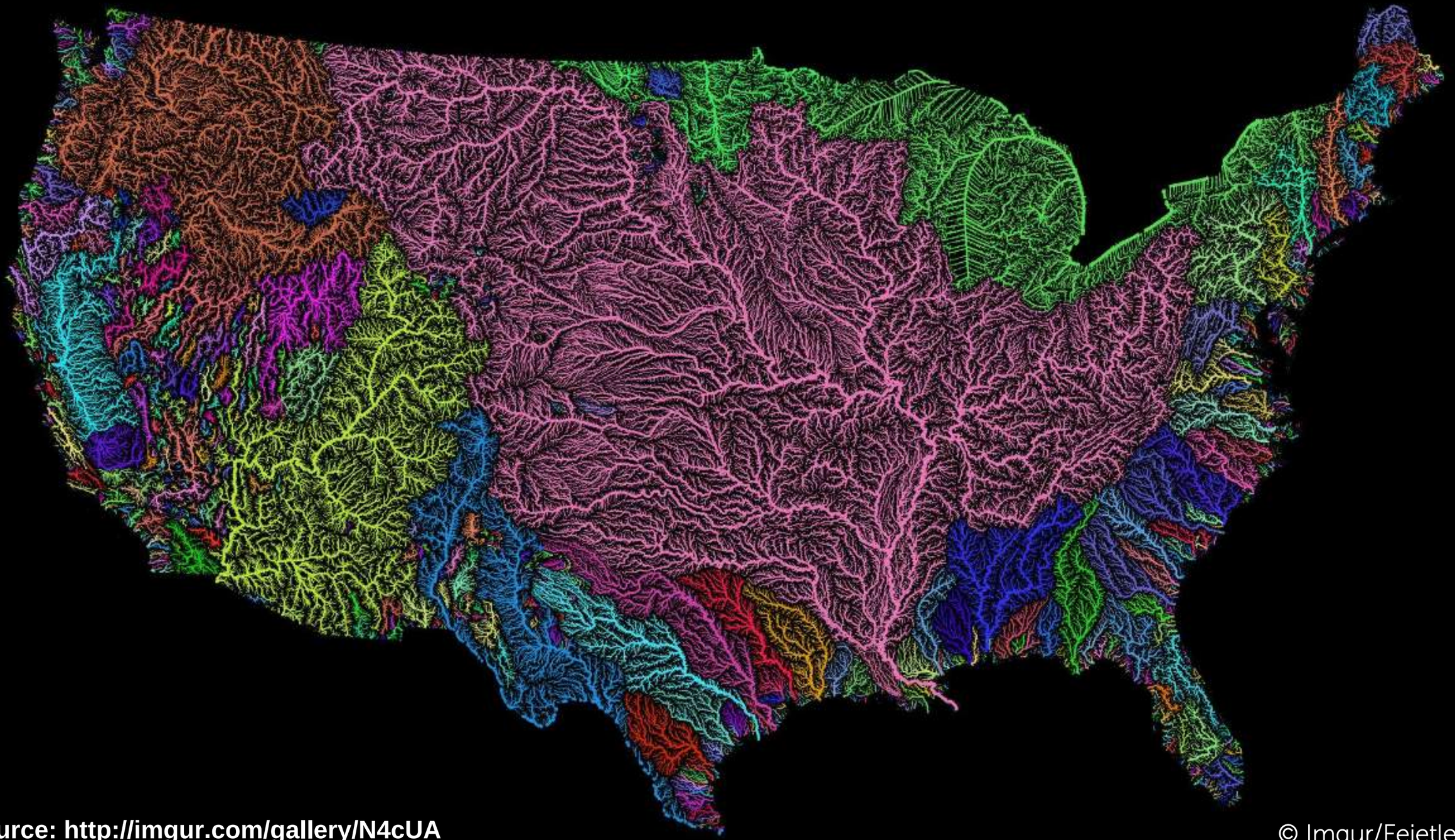
© 2016 The Advocate/Bill Feig

Baton Rouge had a 120% increase in heavy downpours (cloudbursts) from 2005 – 2014 compared to 1950 – 1959.

Precipitation Records – August 2016



POTENTIAL	TIED	BROKEN	TOTAL
171289	0	26	26



Source: http://imgur.com/gallery/N4cUA

© Imgur/Fejetlenfej

Houston, Texas

April 18, 2016

© 2016 Brett Coomer/Houston Chronicle via AP

White Sulfur Springs, West Virginia
June 23, 2016
Video: © 2016 Amanda Carper/Facebook via Storyful

Pensacola, Florida

April 29, 2014

61 centimeters of rain in 26 hours

© 2014 Chrissy Magaw via Storyful

Baltimore, Maryland
April 30, 2014
One Day Later…
© 2014 Nicholas Reyes/Defy Media

Wuhan, Hubei Province, China

July 8, 2016

© 2016 Reuters/Darley Shen

Adra, Spain
September 7, 2015
© 2015 Francisco/ViralHog.com

Courtesy of ViralHog.com

March 26, 2015

Nairobi, Kenya

April 29, 2016

© 2015 Tony Karumba/AFP/Getty Images

Appleby, Cumbria, England

December 5, 2015

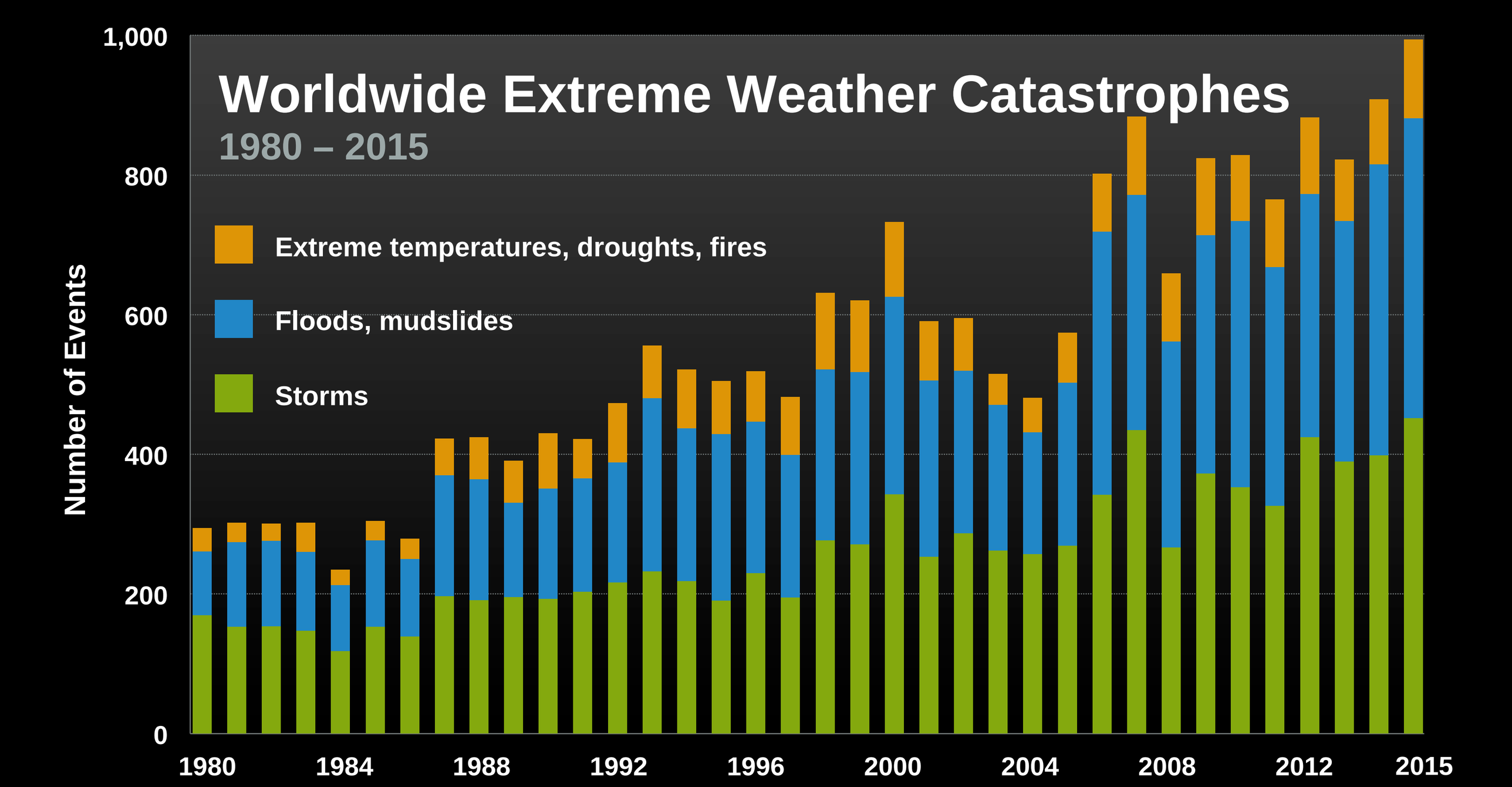
13.4 inches (34.1 cm) of rain fell in 24 hours; the UK’s heaviest 24 hour rainfall on record.

© 2015 Owen Humphreys/PA Wire via AP

York, England

December 28, 2015

© 2015 Justin Tallis/AFP/Getty Images



Data: 2016 Munich Re, Geo Risks Research, NatCatSERVICE. As of January 2016.

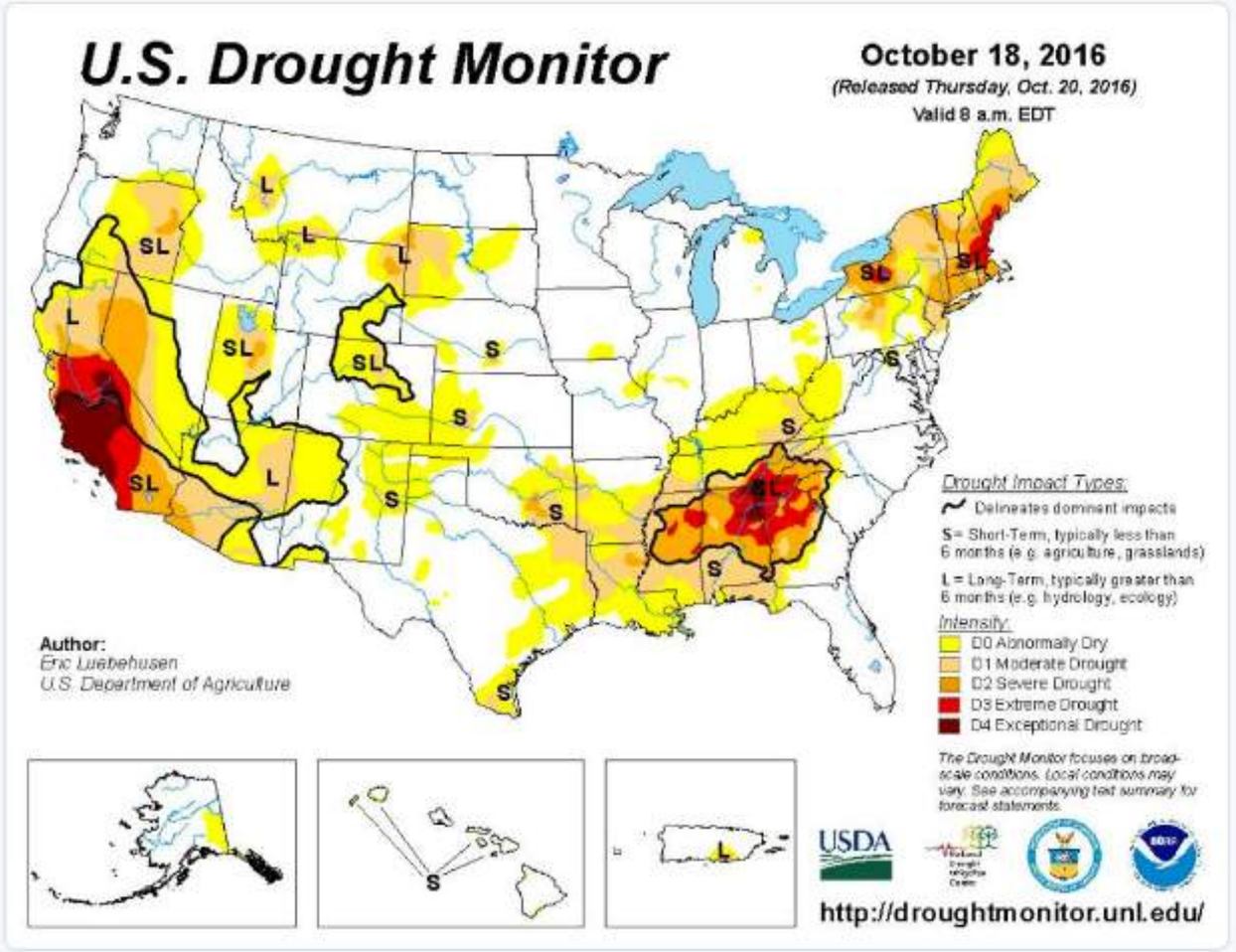
The same extra heat that evaporates more water from the ocean, causing bigger downpours and floods…

…pulls moisture even more quickly from the soil, causing longer and deeper droughts.

An Inconvenient Truth © 2006 by Paramount Classics, a Division of Paramount Pictures. All Rights Reserved.

NOAA NCEI Climate @NOAANCEIclimate · Oct 21

ICYMI October 18 #DroughtMonitor Update: Moderate to exceptional drought covers 22.1% of the contiguous U.S. bit.ly/1MCIsCK



The southern U.S. endured a severe drought from 2010 – 2013. 2011 was the driest year on record in Texas and the second driest year on record in Louisiana.

© 2011 Scott Olson/Getty Images

Canadian, Texas, July 28, 2011

Jaguari Reservoir, São Paulo, Brazil

October 16, 2014

Over 140 cities in Brazil rationed water in 2014.

Almost 1/5 of Brazil's population was affected by the drought in 2015.

© 2014 Luis Moura/Estadao Conteudo/Agencia Estado via AP Images

© 2013 AP Photo/Jae C. Hong

Los Angeles, California

June 20, 2016

© 2016 AP Photo/Ringo H.W. Chiu

Fort McMurray, Alberta

May 3, 2016

© 2016 CBC Licensing

55,000 people died

Four months later...

World food prices reached record highs
after Russia
halted grain exports
and Ukraine restricted them after the
record drought and fires.

Food Price Protest, Lahore, Pakistan

June 9, 2008

© 2008 Reuters/Mohsin Raza

Tunis, Tunisia

January 14, 2011

© 2011 Reuters/Zohra Bensemra

© 2010 Julien Goldstein/The New York Times/Redux

The 2006 – 2010 drought turned 60% of Syria's fertile land into desert

…and drove 1.5 million people into Syria's already crowded cities

October 13, 2014

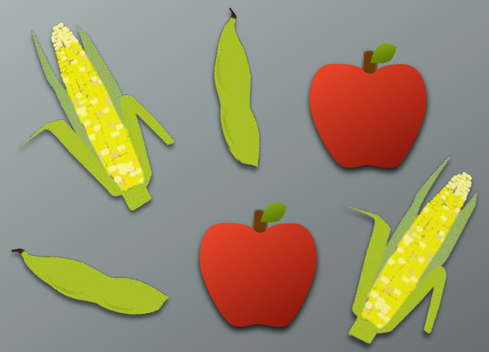
U.S. Department of Defense

2014 Climate Change Adaptation Roadmap

Climate change
"will likely lead to
food and water shortages,
pandemic disease,
disputes over refugees and resources,
and destruction by natural disasters in
regions across the globe."

Global Systems Vulnerable to Climate

Disruptions May Lead to Political or Societal Instability



Food Supply

Water

Global Health

Infrastructure

© iStockphoto/Ryan Burke

Global Systems Vulnerable to Climate

Disruptions May Lead to Political or Societal Instability

Food Supply

Water

Global Health

Infrastructure

© iStockphoto/Ryan Burke

Climate-related Crop Losses

By 2060, Louisiana Could See Declines of Up To:

Cotton	23%

Soybeans	39%

Corn	26%

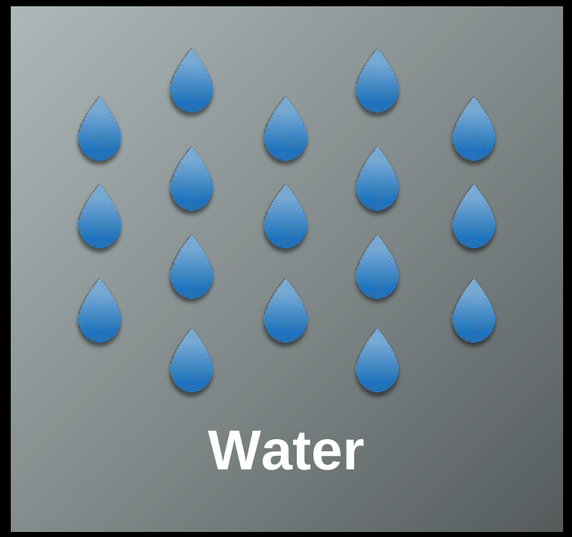
Source: Risky Business Project, *Come Heat and High Water: Climate Risk in the Southeastern U.S. and Texas*, July 2015

Photos: © Shutterstock: Fotokostic: ConstantinosZ; Jiang HongYan

Global Systems Vulnerable to Climate

Disruptions May Lead to Political or Societal Instability

Food Supply



Water

Global Health

Infrastructure

© iStockphoto/Ryan Burke

As Temperatures Rise, So Does Water Use

People

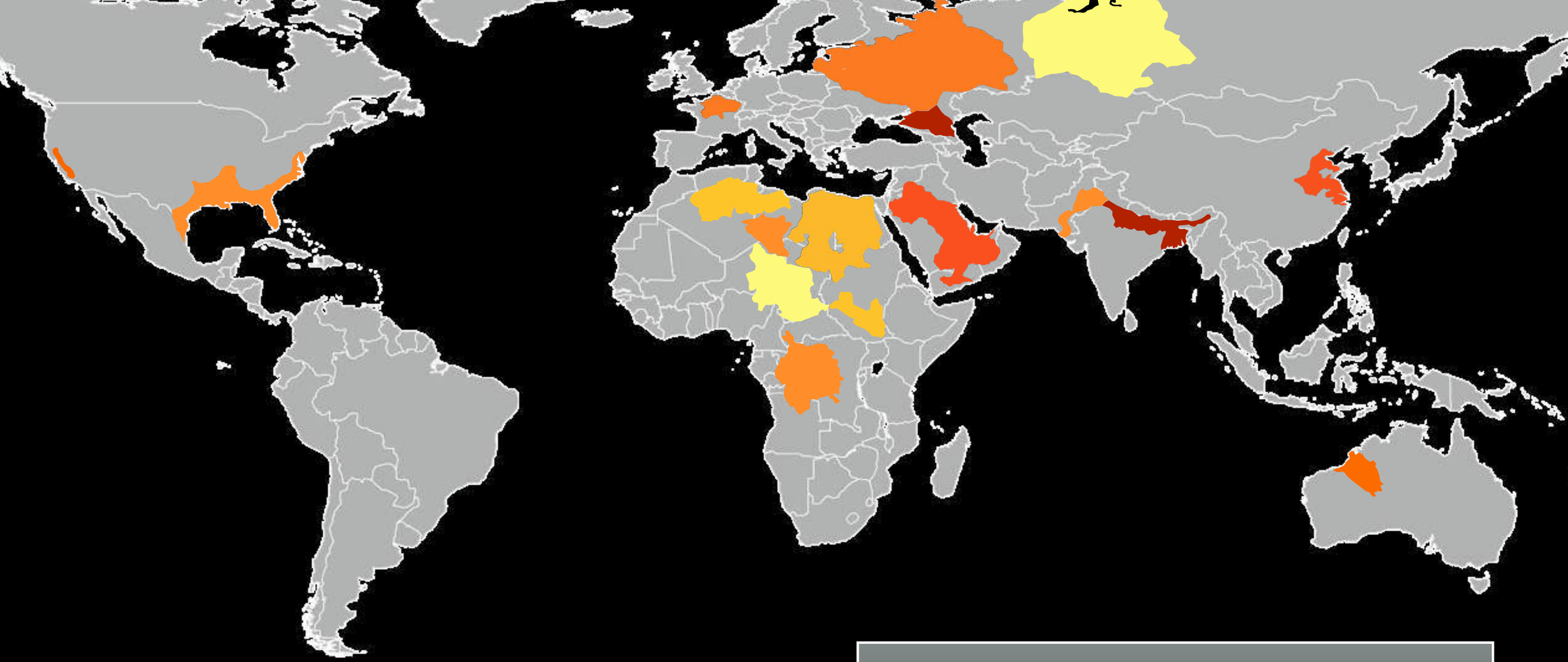
Crops

Energy

Industry

Animals

iStockphoto: © tazytazl, © PhotographyPerspectives, © acilo, © Olivier Lantzendörffer, © 25StockMedia



Major Groundwater Aquifers Losing Water

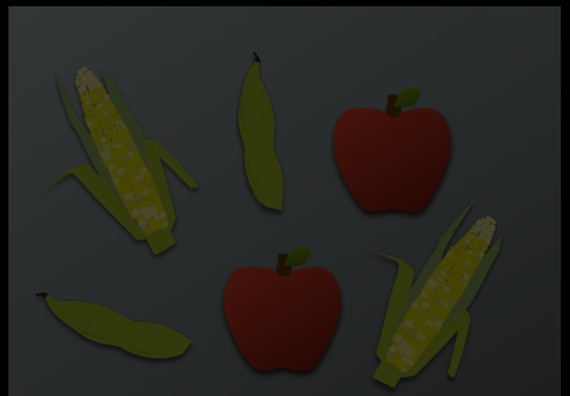
Source: Richey, et al., “Quantifying Renewable Groundwater Stress with GRACE,” *Water Resources Research,* 2015.
Graphic: UC Irvine/NASA/JPL-Caltech

Upsala Glacier, Argentina

© Greenpeace/De Agostini/Daniel Beltra

Global Systems Vulnerable to Climate

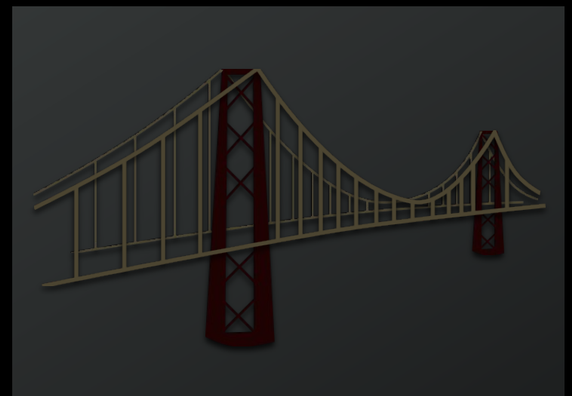
Disruptions May Lead to Political or Societal Instability



Food Supply

Water

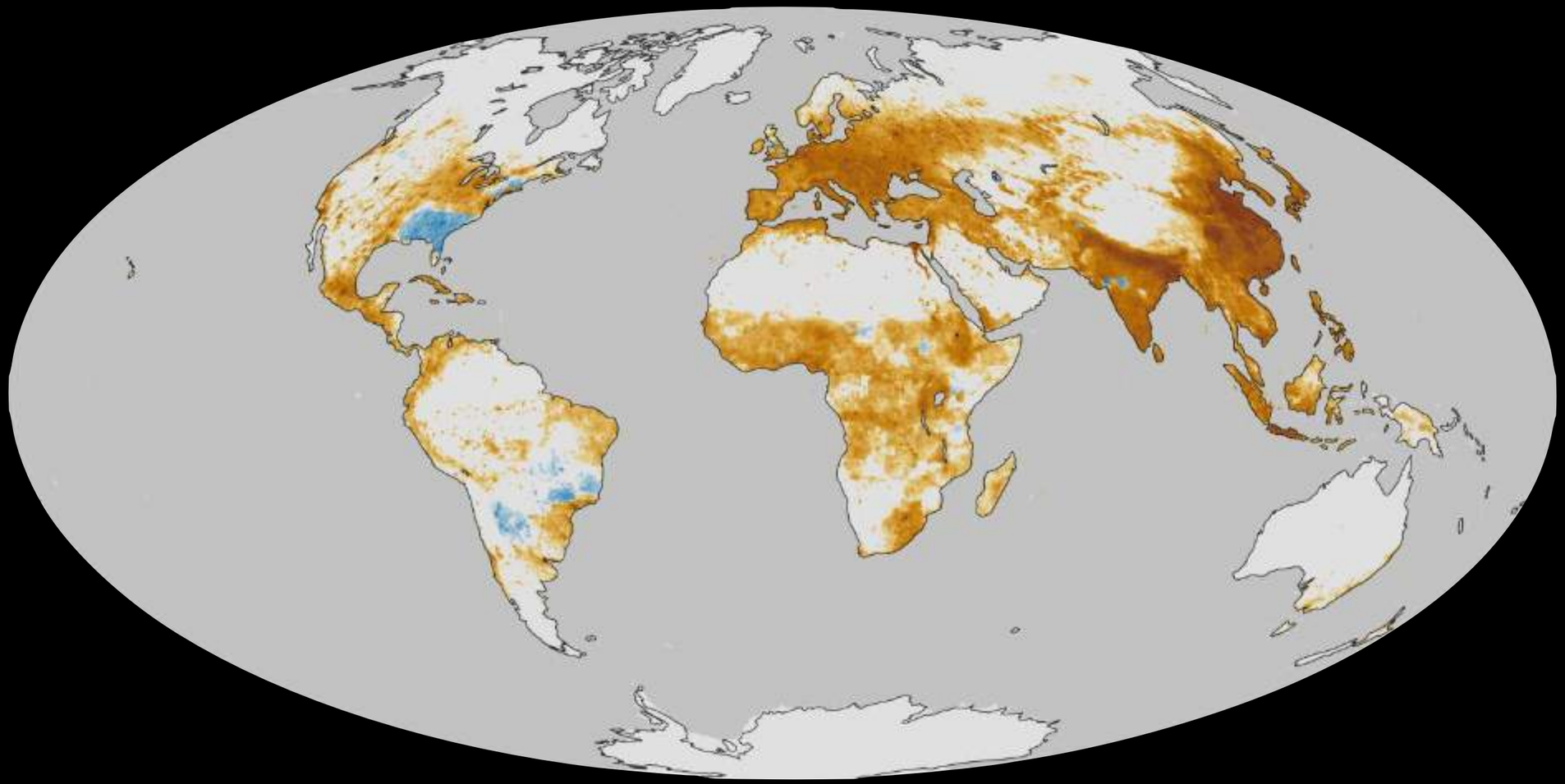
Global Health



Infrastructure

© iStockphoto/Ryan Burke

Global Air Pollution Deaths



Premature Deaths per Year per 1000 km^2

-1,000 **1,000**

Relative to pre-industrial levels

Source: NASA

Beijing, China

January 15, 2013

© 2013 Reuters

Beijing, China

January 28, 2013

© 2013 Reuters/China Daily

Air pollution has been shown to affect mental health and cognitive ability, particularly in children.

Source: A. Oudin, et al., *BMJ Open*, September 2015
Photo: © 2015 Cheng XueHu - Imaginechina via AP Images

Hebei Province, China

“Climate Change is a Medical Emergency.”

Professor Hugh Montgomery, Co-Chair,

The 2015 Lancet Commission on Health and Climate Change

June 2015

Tropical Diseases on the Move

© James Hastings-Trew

*The exact point of origin of many diseases is uncertain

We now risk losing up to **50% of all living species** in this century

Source: Nicholas Stern, The Economics of Climate Change
Photo: © Ursula Dubrick/Audubon Photography Awards

Jakobshavn Glacier, Greenland

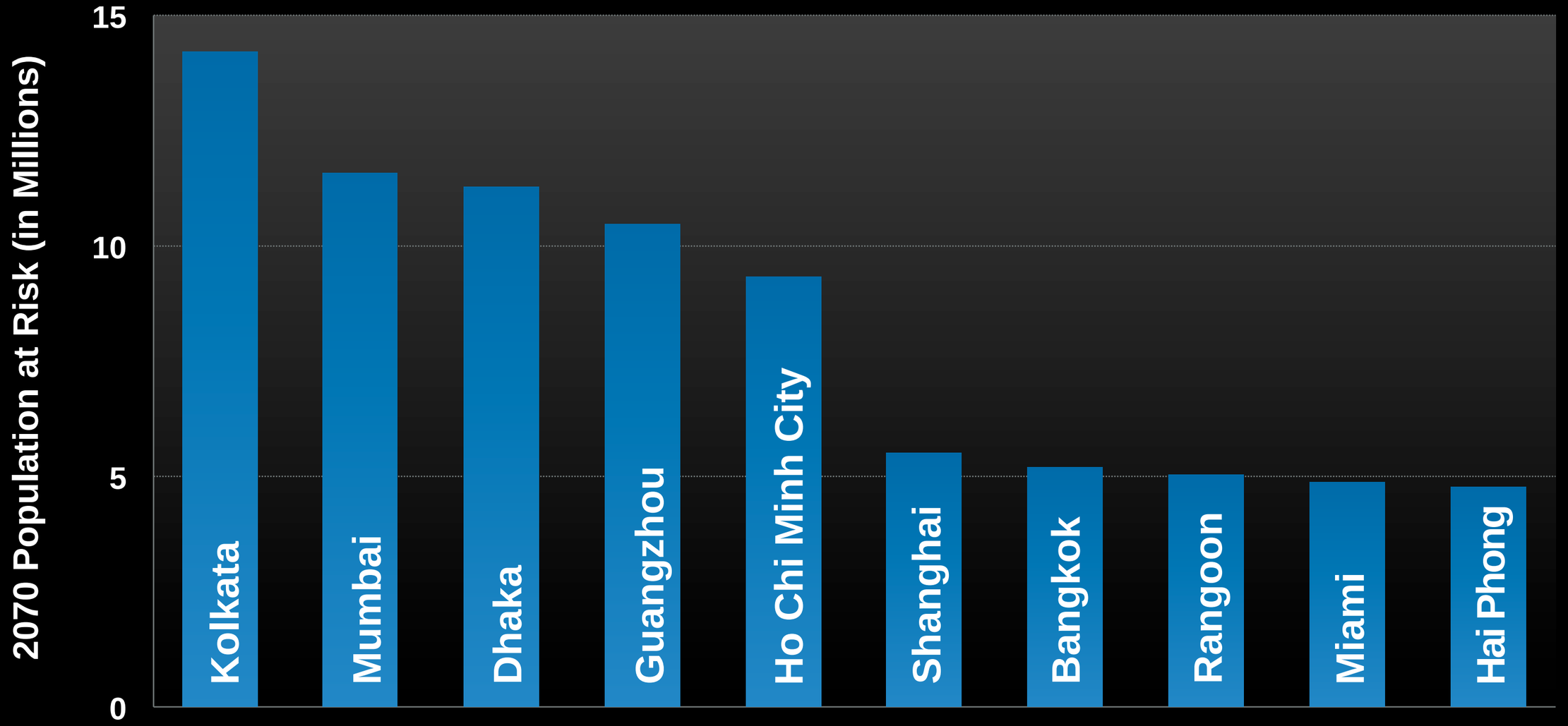
May 10, 2008 **67 minutes compressed to 28 seconds**

© University of Alaska, Fairbanks/University of New Hampshire/ETH-Zürich

Source: NBC Learn and the National Science Foundation (NSF)

Top 10 Cities at Risk from Sea Level Rise in 2070

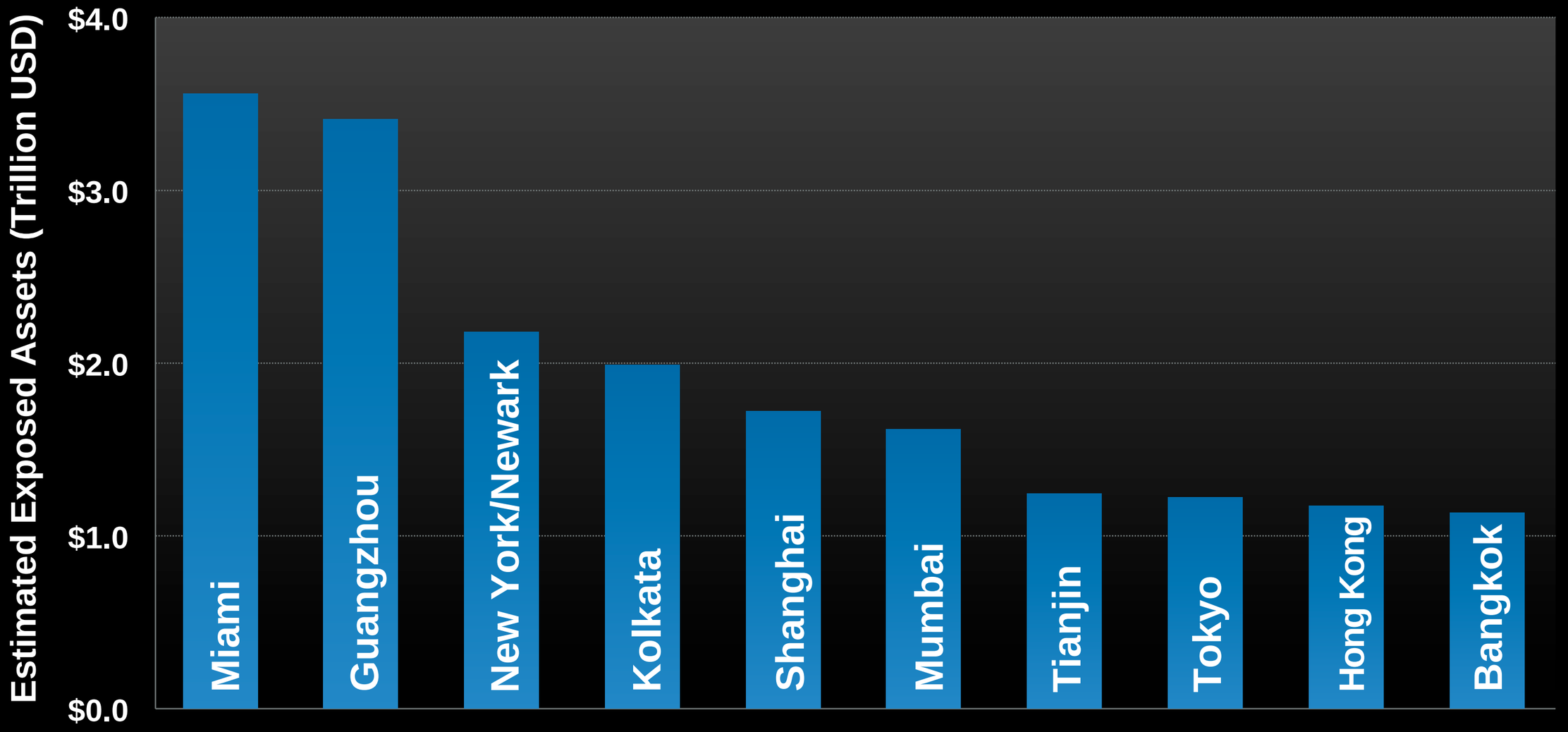
By Population at Risk



Data: Nichols, et al., 2007, OECD

Top 10 Cities at Risk from Sea Level Rise in 2070

By Assets at Risk



Data: Nichols, et al., 2007, OECD

Miami, Florida

© Wilson Araujo via Shutterstock

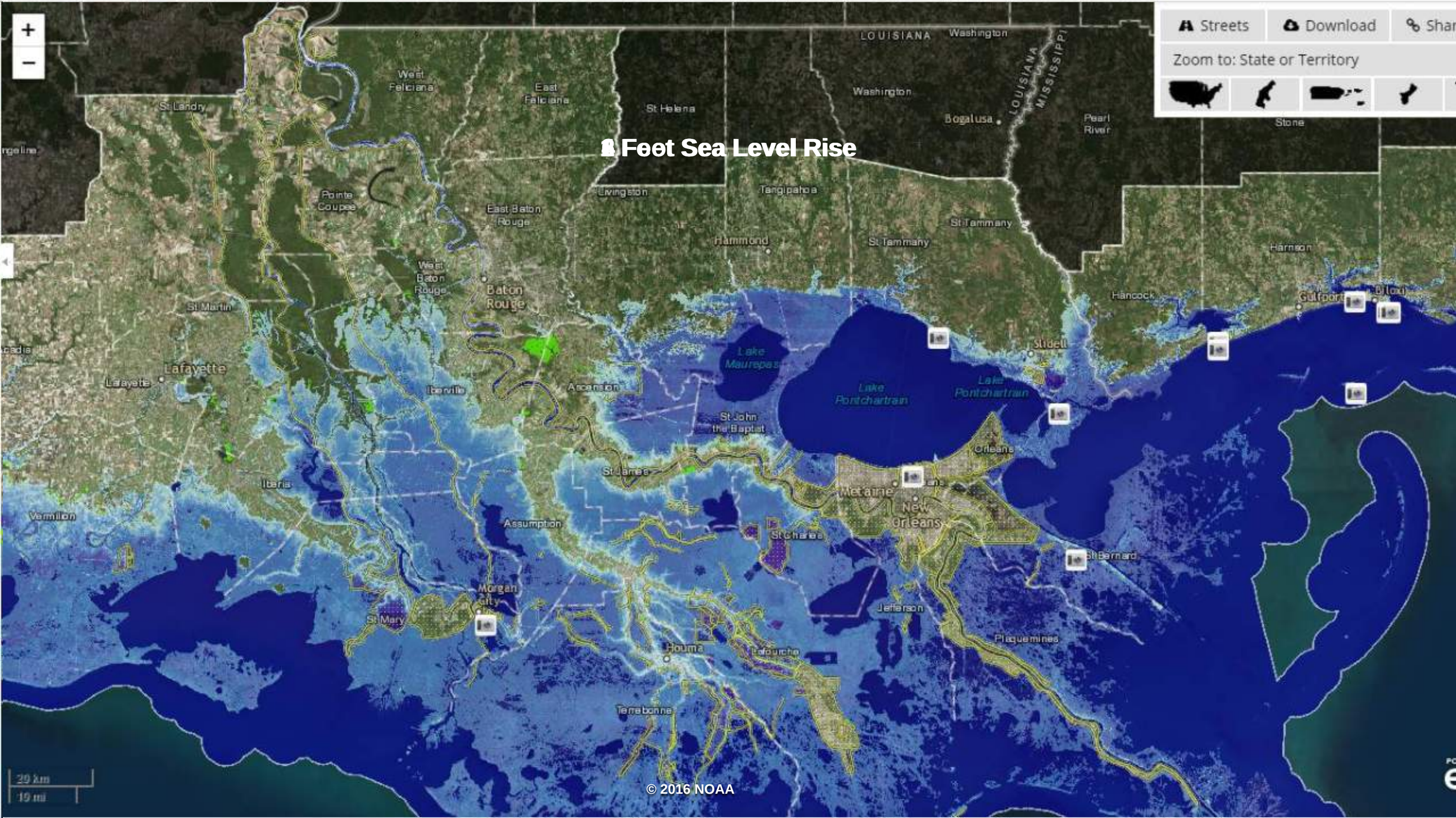
High tides now regularly flood parts of Miami Beach, Florida

© 2013 Chris Julin/BURN + SoundVision Productions CC-BY 3.0

$129 Billion Worth Of New York City Real Estate Now Lies In Flood Zones

© Leonardo Patrizi/Getty Images

Source: Business Insider, 2014


Streets
Download
Zoom to: State or Territory
1 Foot Sea Level Rise
LOUISIANA
Washington
LOUISIANA
MISSISSIPPI
West Feliciana
East Feliciana
St Helena
St Landry
Bogalusa
Pearl River
Stone
Livingston
Tangipahoa
St Tammany
Hammond
Harrison
Pointe Coupee
East Baton Rouge
West Baton Rouge
Baton Rouge
St Martin
Hancock
Gulfport
Biloxi
Slidell
Lake Maurepas
Lake Pontchartrain
Lafayette
Iberville
Ascension
St John the Baptist
Orleans
St James
Metairie
New Orleans
Iberia
Vermilion
Assumption
St Charles
St Bernard
Morgan City
St Mary
Jefferson
Houma
Lafourche
Plaquemines
Terrebonne
20 km
10 mi
© 2016 NOAA

In Louisiana, 800,521 homes are currently at risk from storm surge flooding with a total reconstruction cost value of $184 billion.

Source: CoreLogic/ESRI
Photo © 2005 Wunderground.com

Slidell homes destroyed by Hurricane Katrina, 2005

Global Systems Vulnerable to Climate

Disruptions May Lead to Political or Societal Instability

Food Supply

Water

Global Health

Infrastructure

© iStockphoto/Ryan Burke

Dawlish, Devon, England

February 6, 2014

© 2014 Reuters/Toby Melville

Killington, Vermont
August 30, 2011
© 2011 AP Photo/The Rutland Herald, Vyto Starinskas

A Road Melts in the Heat

Delhi, India

May 24, 2015

© 2015 Sanjeev Verma/Hindustan Times via Getty Images

The Cost of Carbon

- $ *Political Instability*
- $ *Floods & Mudslides*
- $ *Wildfires*
- $ *Drought*
- $ *Storm Damage*
- $ *Ocean Acidification*
- $ *Infrastructure Loss*
- $ *Climate Refugees*

- $ *Species Extinction*
- $ *Melting Glaciers*
- $ *Famine*
- $ *Water Scarcity*
- $ *Ecosystem Loss*
- $ *Our Way of Life*
- $ *Infectious Diseases*
- $ *Sea Level Rise*

… And much, much more

$ *"The #1 Threat to the Global Economy"*

© 2005 iStockphoto/themoog

We have
the solutions
at hand...

Approaches for Mitigation

Renewable Energy Sources

Resilient Infrastructure

Water Management

Smart Growth and Low Impact Development

Green Energy Progress

How Do Projections Compare With Reality?

2000 Projection

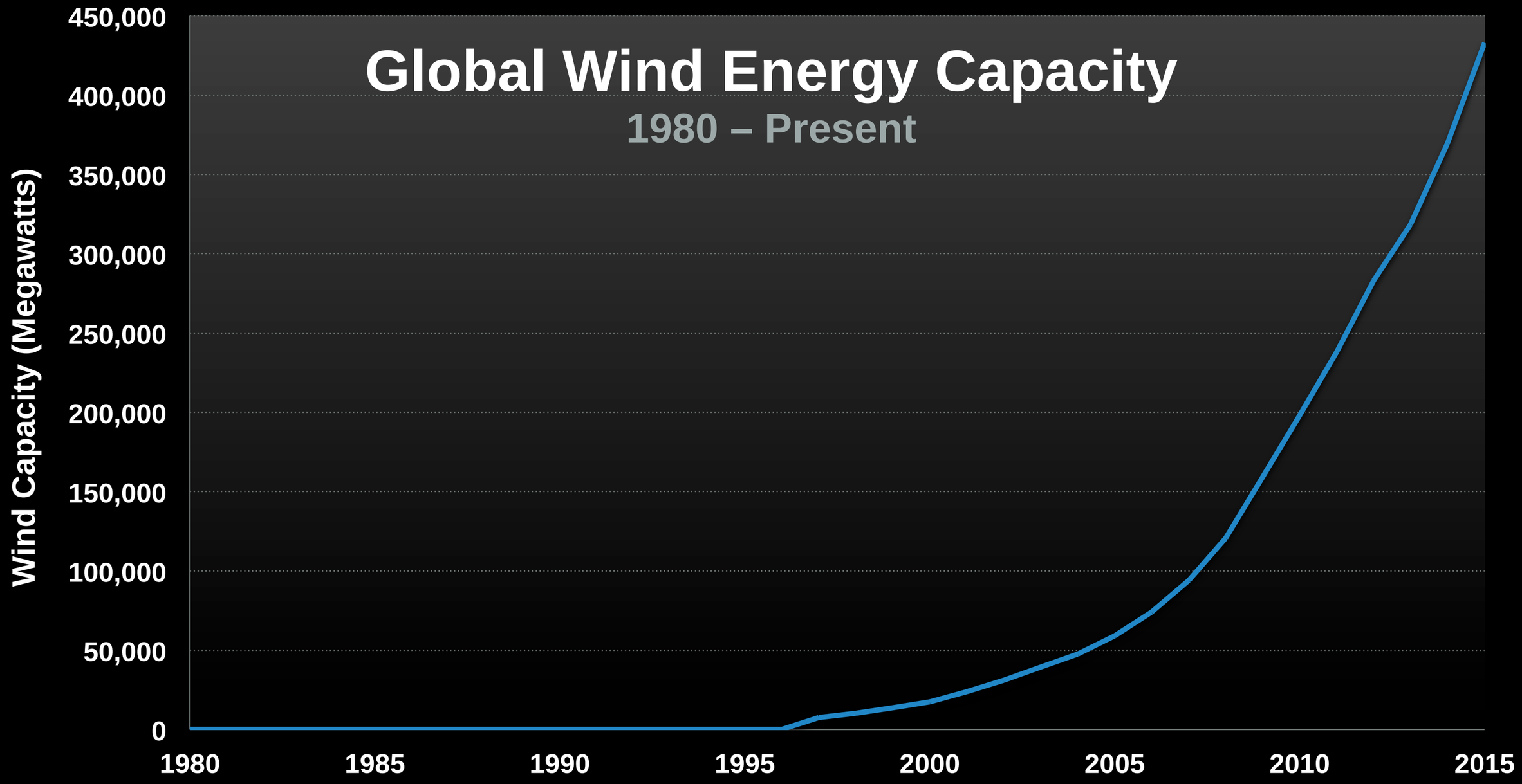
Worldwide wind capacity will reach 30 GW by 2010

Reality

By 2015 that goal was exceeded b y a factor of

14.5 x

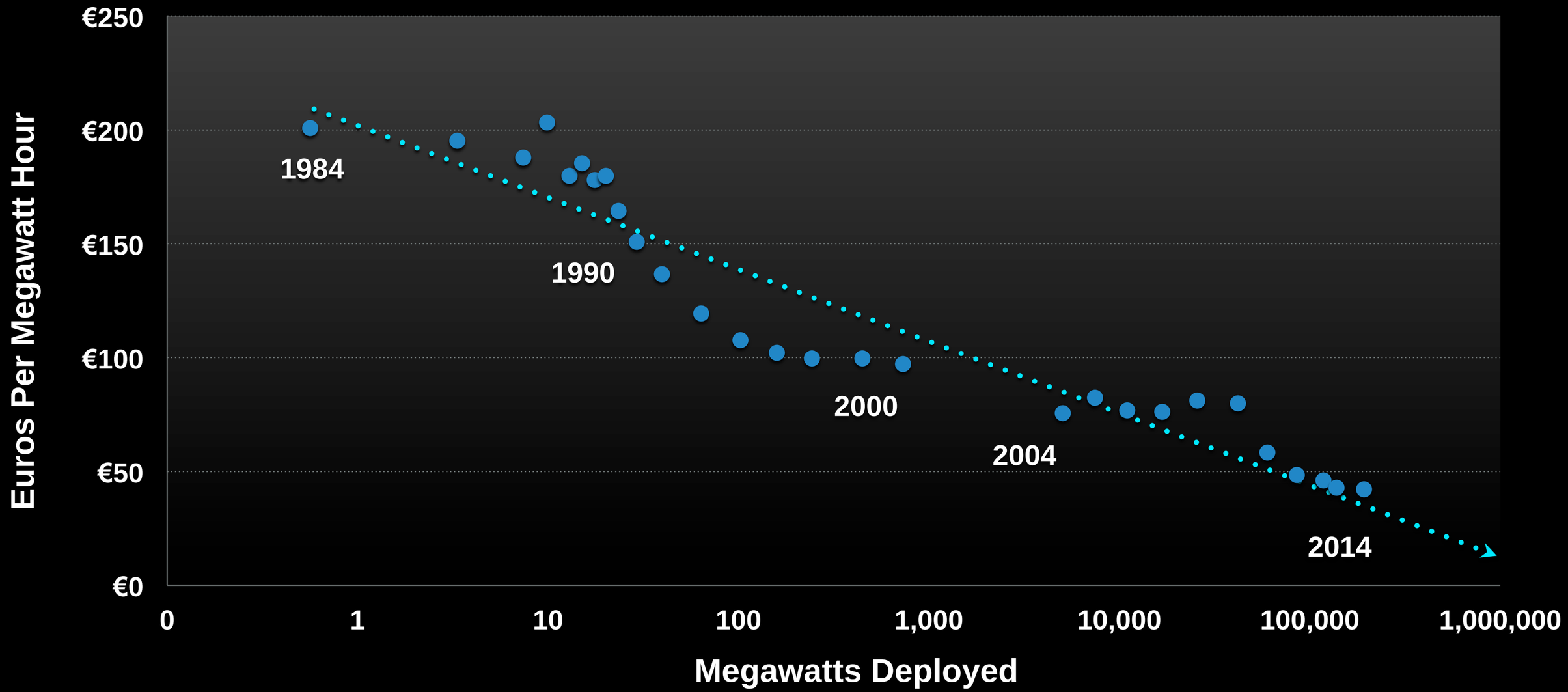
Data: IEA; Global Wind Energy Council



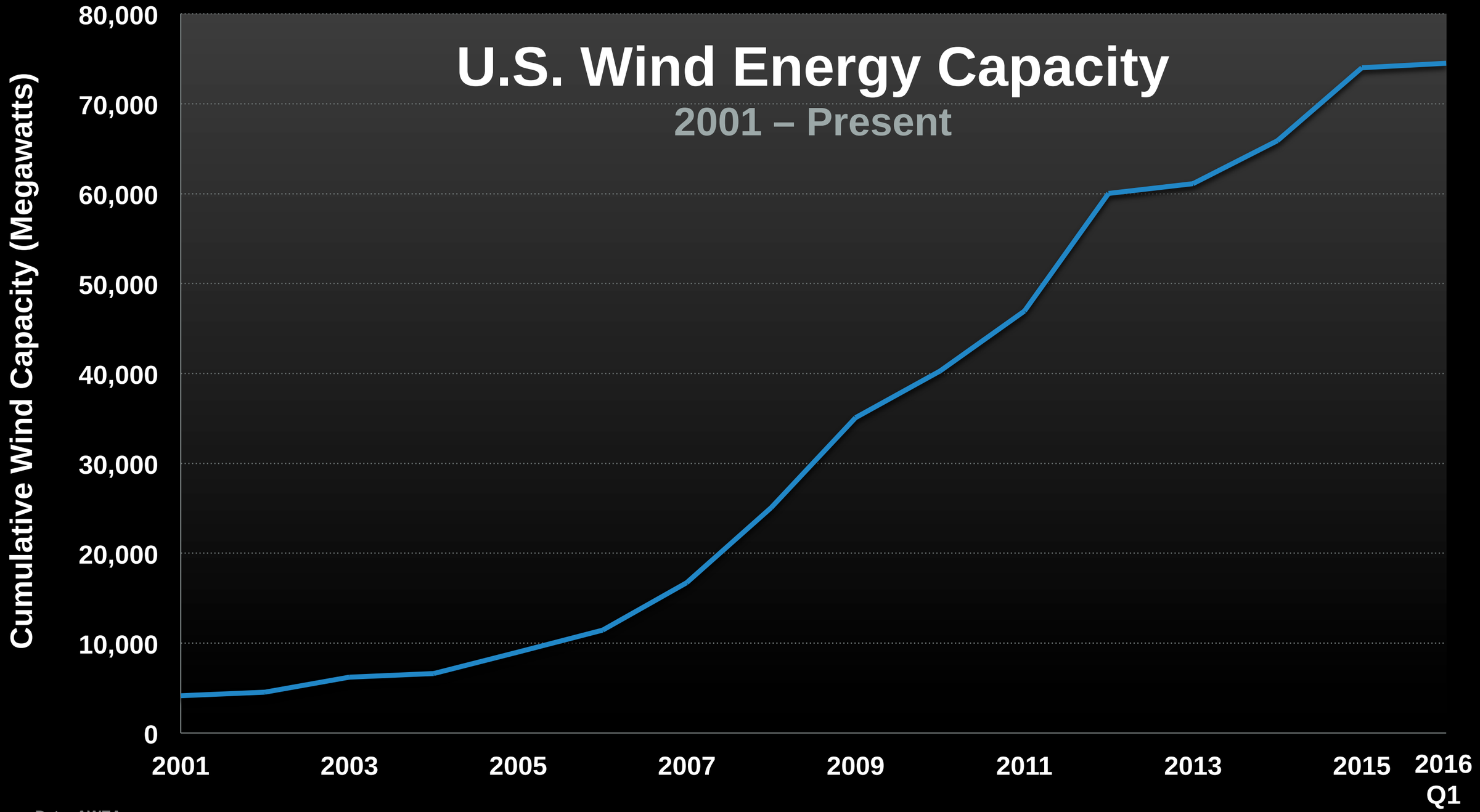
Data: Earth Policy Institute

Onshore Wind Cost

1984 – 2014



Data: Bloomberg New Energy Finance


U.S. Wind Energy Capacity
2001 – Present
Cumulative Wind Capacity (Megawatts)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
2001
2003
2005
2007
2009
2011
2013
2015
2016 Q1
Data: AWEA

Colorado City, Texas

Wind power met 48.3% of Texas' electricity needs on March 23, 2016

Source: Utility Dive/ERCOT
Photo: © 2016 Spencer Platt/Getty Images

U.S. Cities Using 100% Renewable Energy

© Oleg_P via Shutterstock

Corpus Christi, Texas

More than 24,000 Texans are employed in the wind industry.

Source: AWEA
Photo: © 2012 Eddie Seal/Bloomberg via Getty Images

Some utilities in Texas are offering
free electricity at night
because wind energy is so abundant.

Globally, wind could supply worldwide electricity consumption **40 times over**

“Solar-plus-batteries
is set to begin
a dramatic transformation
of human civilization.”

Bloomberg View
April 8, 2015

Solar industry jobs now outnumber coal mining jobs in the U.S.

© 2012 Joshua Lott/Bloomberg via Getty Images

Green Energy Progress

How Do Projections Compare With Reality?

2002 Projection

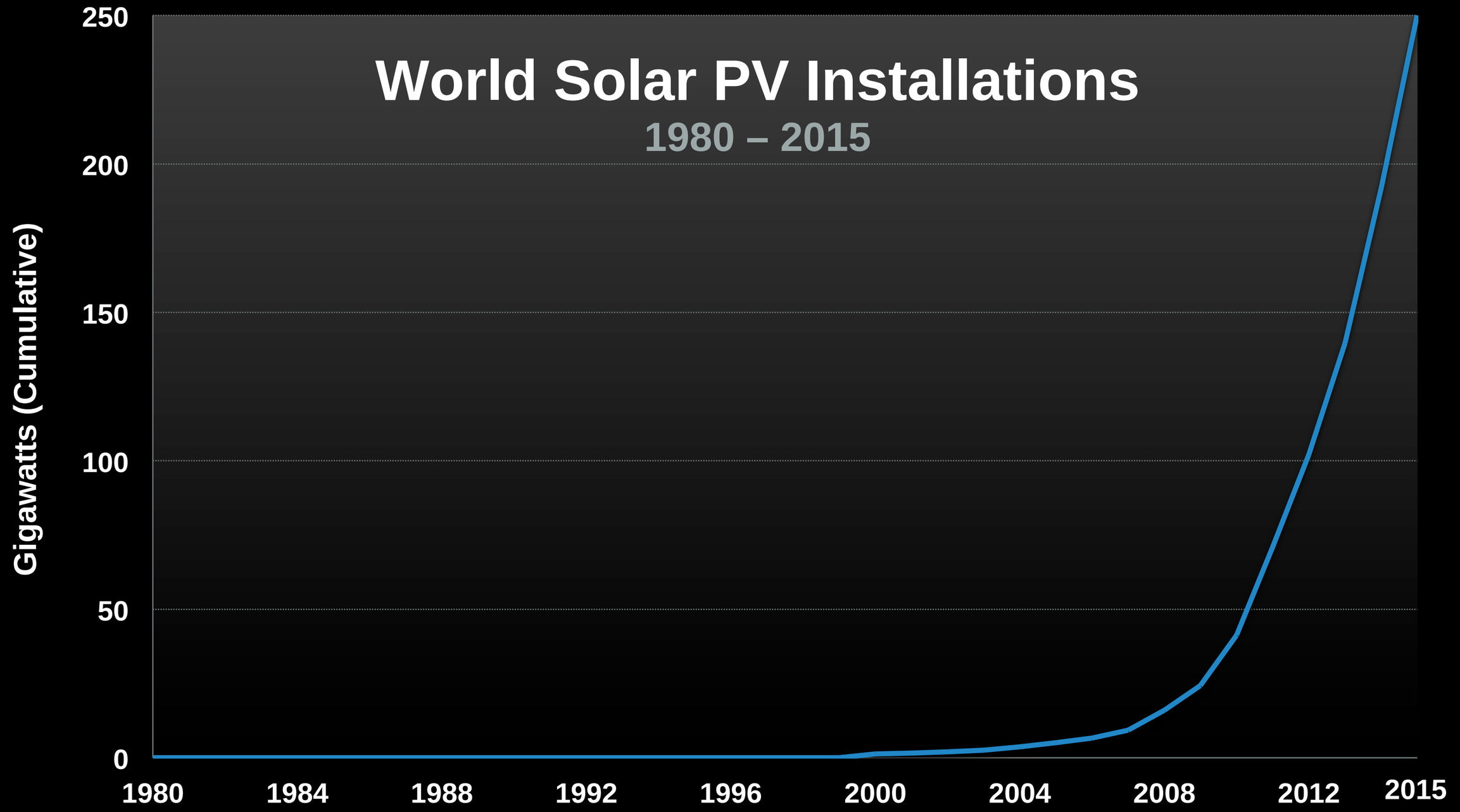
The solar energy market will grow 1 GW per year by 2010

Reality

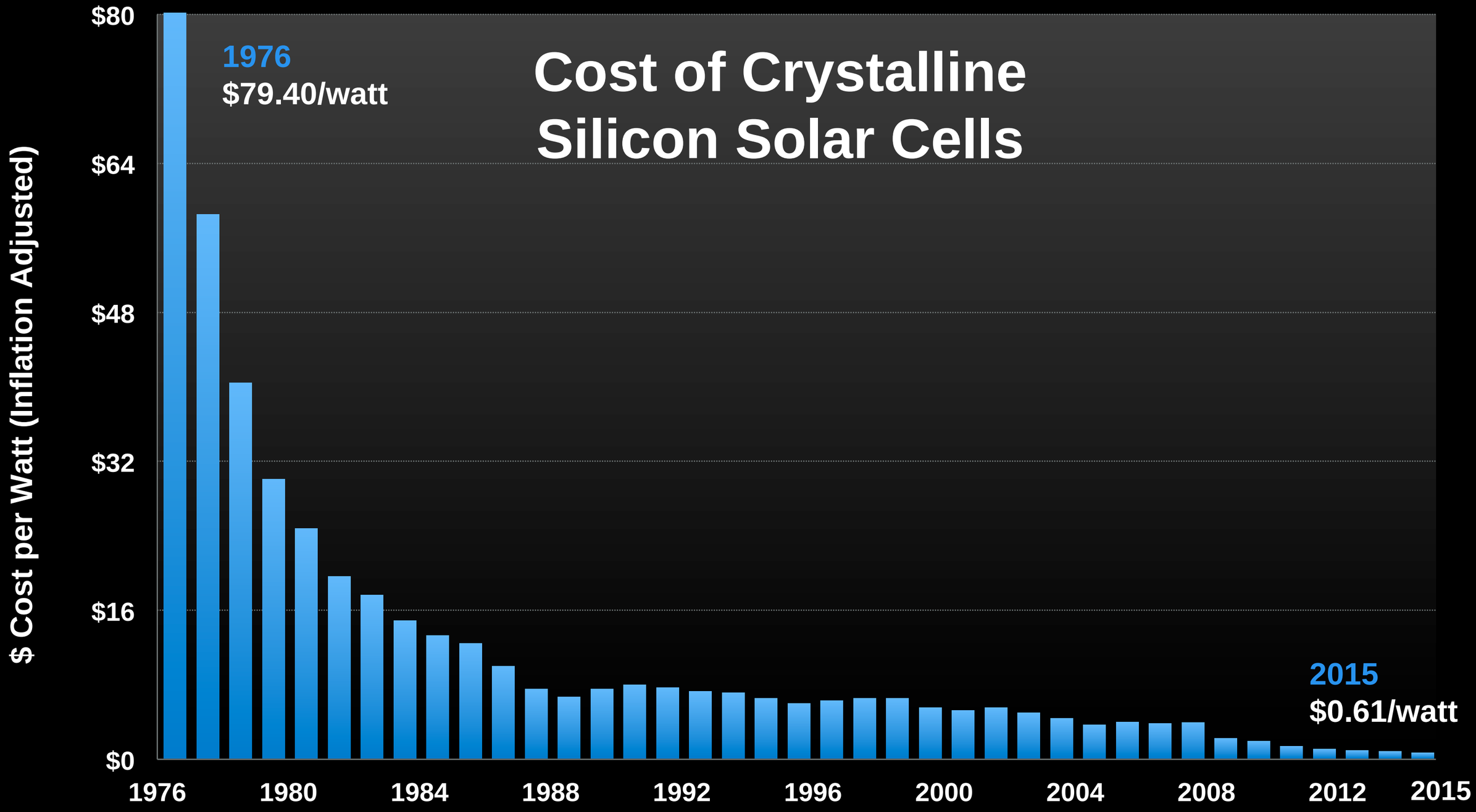
In 2015 it was exceeded by

58 x

Data: Fresh-Energy; Bloomberg



Data: Earth Policy Institute/BP, *Statistical Review of World Energy June 2014* (London: 2014).



Data: Bloomberg New Energy Finance

Is there any
precedent
for such a rapid adoption
of a new technology?

In 1980 AT&T commissioned a study to forecast cell phone use by the year 2000

They projected 900,000 users

The actual figure was

109 million

120 x higher

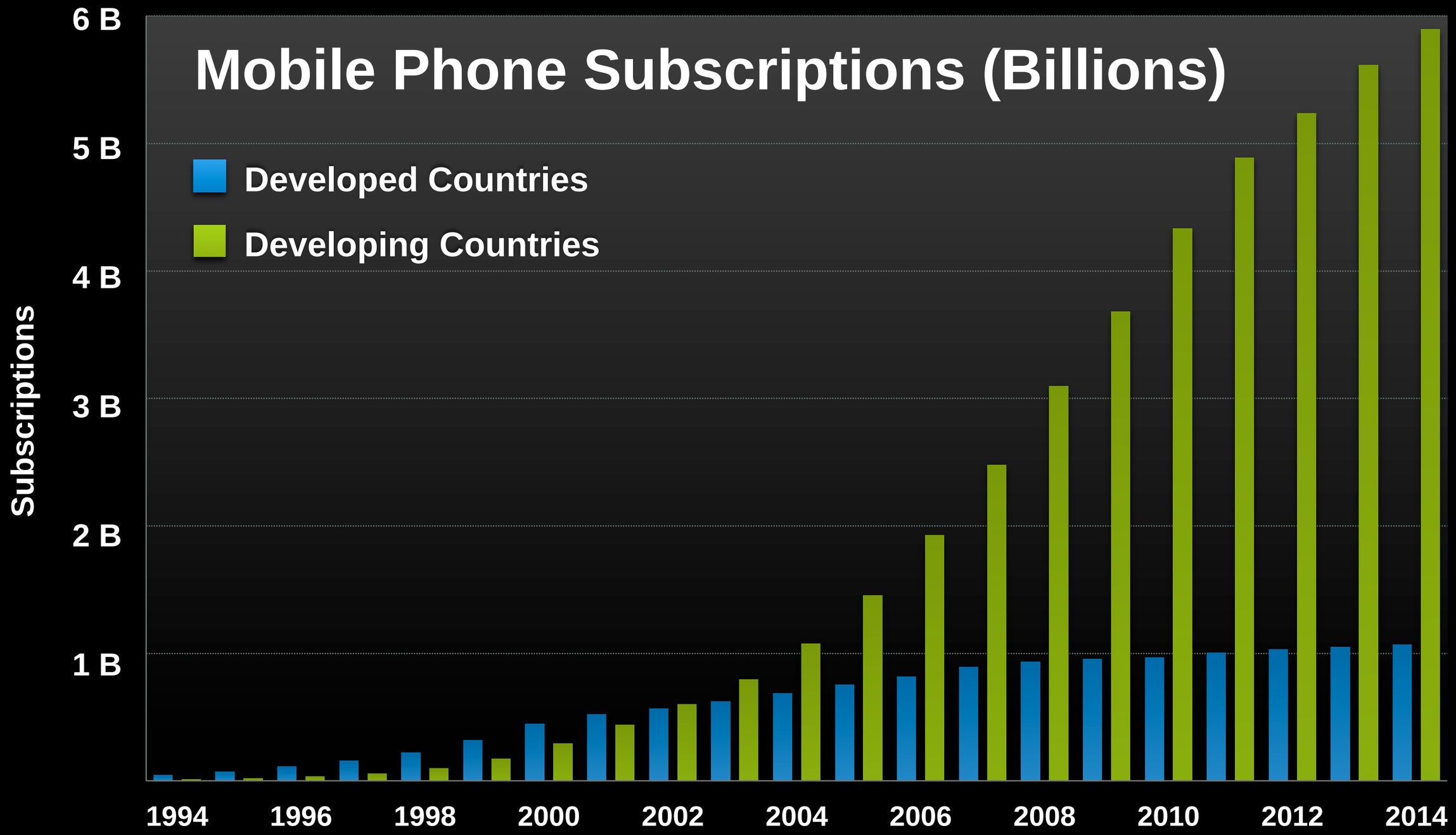
There are now
7.8 Billion
cell-phone connections

So why were they not only wrong,
but WAY wrong?

1. The Cost Dropped Sharply, as

2. The Quality Improved Dramatically, and

3. All the Low-Income Nations With No Land-Line Grids Leap-frogged the Old Technology.



Source: World Bank

Pay-as-you-go Solar Power

Low initial costs make small solar systems affordable in developing countries

Photo courtesy Azuri Technologies

Nimule, South Sudan

Copiapó, Chile

June 2014

This 100 MW solar farm is one the largest in Latin America

© SunEdison

Home Solar Panels

Bangladesh

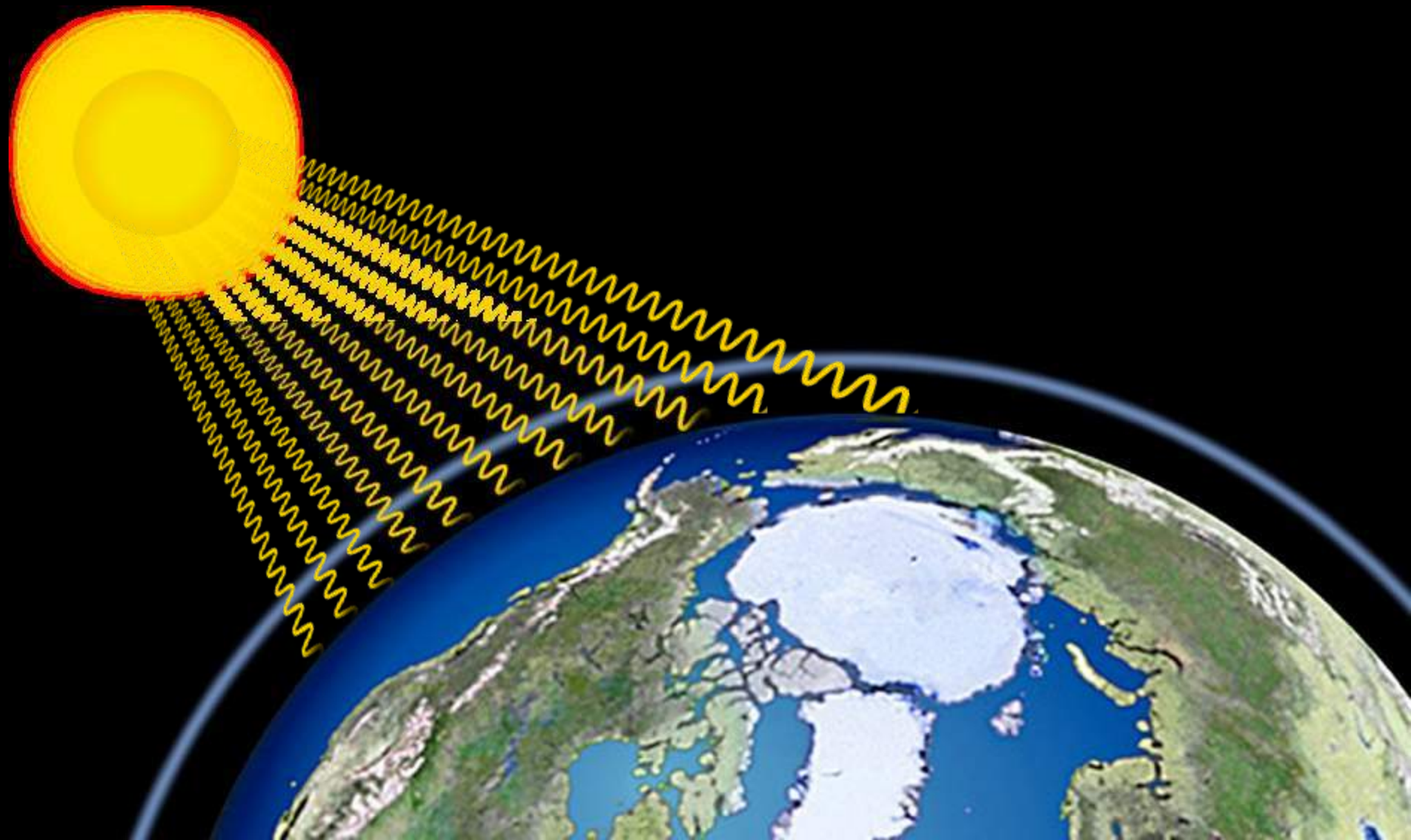
Bangladesh is now installing solar PV systems at the rate of two per minute, 24 hours a day

© 2009 Majority World/UIG via Getty Images

Near Siem Reap, Cambodia

© 2015 Steven Sinofsky, medium.learningbyshipping.com

Enough solar energy reaches Earth every hour to fill all the world's energy needs for a full year



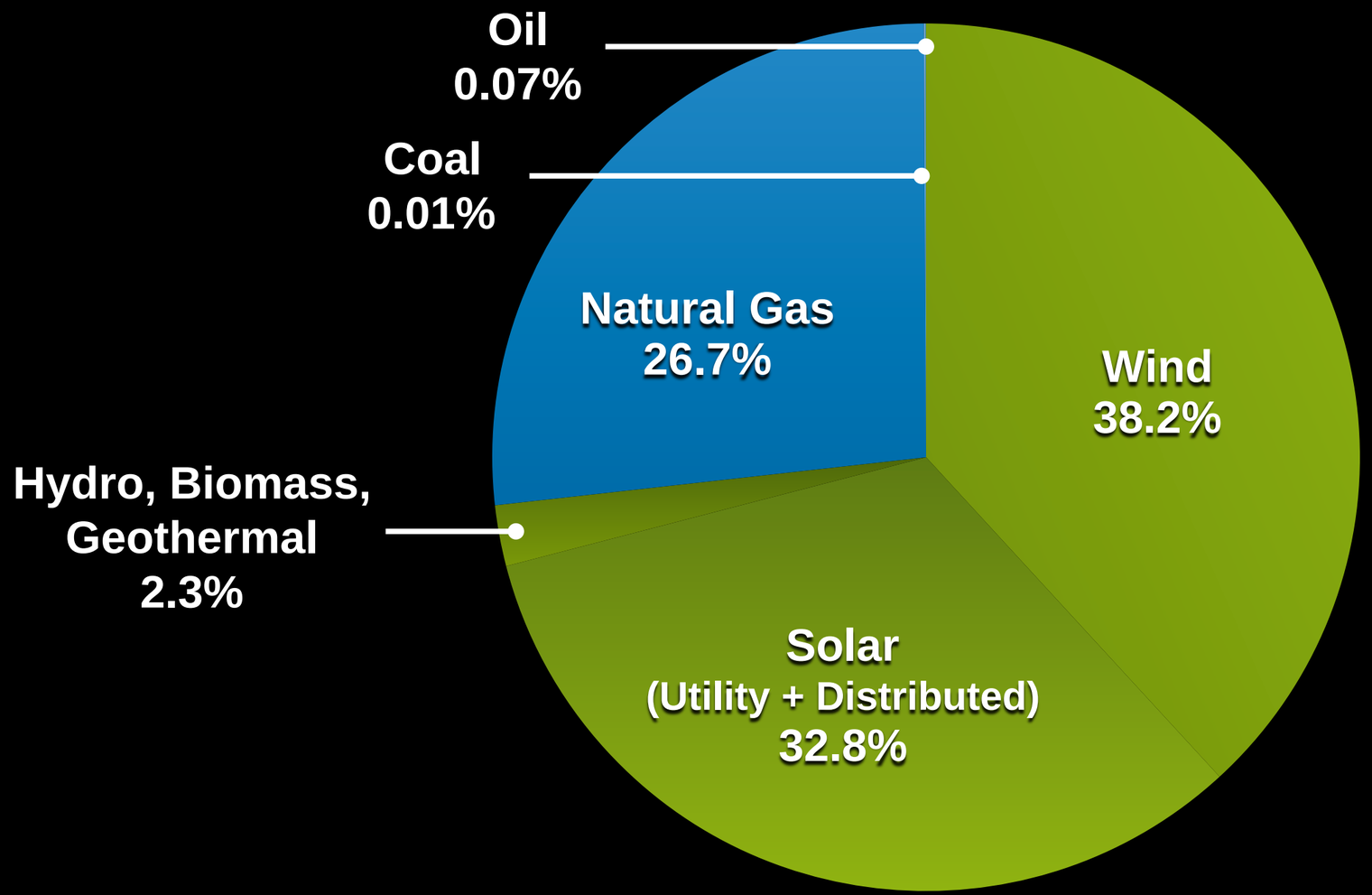
Parstein, Germany

Globally, 8.1 million people work directly or indirectly in the renewable energy sector

© 2014 Patrick Pleul/picture-alliance/dpa/AP Images

New Electric Generation Capacity in the U.S.

2015



Data: U.S. Department of Energy/FERC, February 2016; BNEF

© 2016 Fred Chartrand/The Canadian Press via AP

On June 29, 2016 the U.S., Mexico and Canada pledged that North America will get half its electricity from zero-emissions sources by 2025.

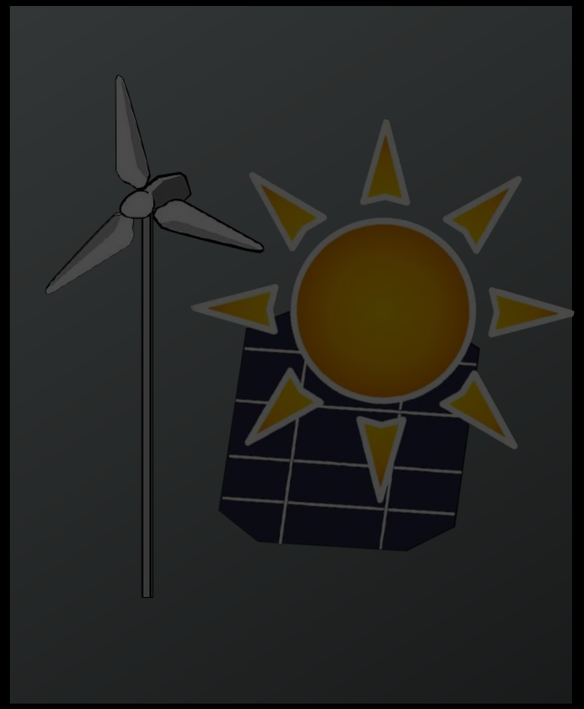
© SevArt/Pond5

© 2014 People's Climate March

Source: NASA

Approaches for Adaptation

Disruptions May Lead to Political or Societal Instability



Renewable Energy Sources

Resilient Infrastructure

Water Management

Smart Growth and Low Impact Development

RETENTION
DETENTION
BASF SITE
PINO SITE
BLOCK 12 SITE
CONSTRUCTED WETLANDS
SUBSURFACE STORAGE
GREEN ROOFS
RAINWATER HARVESTING
INFILTRATION
BIOSWALES
STORMWATER PLANTERS

2030s National Infrastructure

Featuring measures designed to reduce the effects of the negative impacts of climate change and exploit the opportunities. This illustration is designed to provoke thought about what good adaptation to climate change could entail – it does not attempt to provide any definite answers or solutions, as the most appropriate adaptive action will often depend on local circumstances. To allow inclusion in the illustration some features are shown closer together than they might ideally be situated.

Rail

Higher standards of rail used to prevent track buckling in increased temperatures, and earthworks strengthened to reduce embankment instability due to moisture fluctuation caused by wetter winters and drier summers.

Stronger bridges

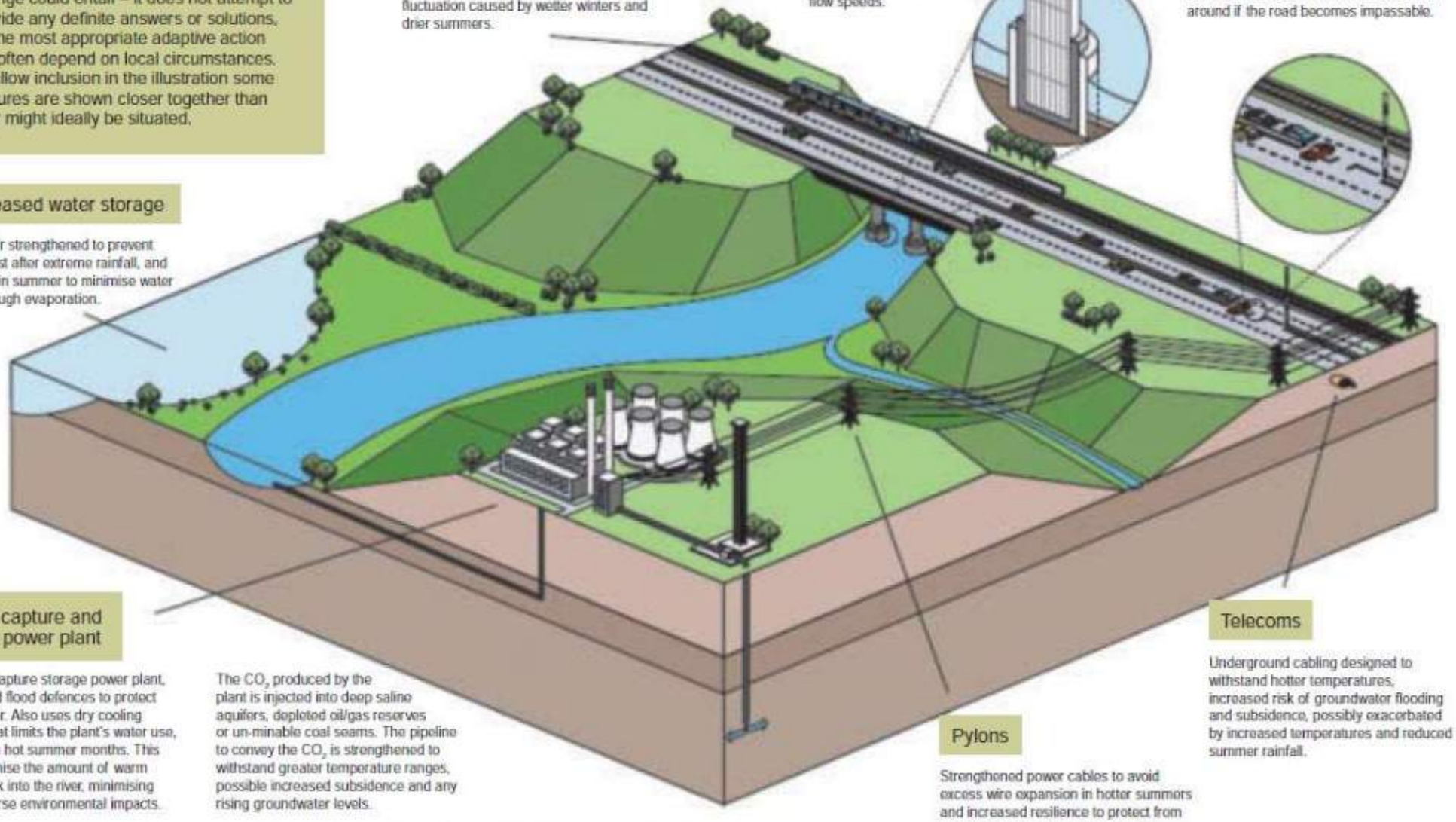
Bridges built higher than currently required to accommodate larger tidal ranges due to sea level rise over their lifespan, and foundations reinforced to cope with higher magnitude flood events leading to increased river flow speeds.

Motorway

Road Surface is made from materials that are able to cope with hotter temperatures and intense rainfall. Emergency gates in the central reservation allow traffic to turn around if the road becomes impassable.

Increased water storage

Reservoir strengthened to prevent dam-burst after extreme rainfall, and covered in summer to minimise water loss through evaporation.



Carbon capture and storage power plant

New carbon capture storage power plant, with increased flood defences to protect it from the river. Also uses dry cooling technology that limits the plant's water use, in particular in hot summer months. This will also minimise the amount of warm water put back into the river, minimising possible adverse environmental impacts.

The CO_2 produced by the plant is injected into deep saline aquifers, depleted oil/gas reserves or un-minable coal seams. The pipeline to convey the CO_2 is strengthened to withstand greater temperature ranges, possible increased subsidence and any rising groundwater levels.

Pylons

Strengthened power cables to avoid excess wire expansion in hotter summers and increased resilience to protect from increased extreme weather events.

Telecoms

Underground cabling designed to withstand hotter temperatures, increased risk of groundwater flooding and subsidence, possibly exacerbated by increased temperatures and reduced summer rainfall.

This illustration does not necessarily depict past, present or future Government policy. The illustration concentrates on adaptation actions and does not highlight mitigation and other sustainable development measures.

Source: NASA