Hot Science Cool Talks

UT Environmental Science Institute

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Power Trip: The Story of Energy

Dr. Michael Webber

February 20, 2015

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Hot Science Cool Talks

Michael E. Webber

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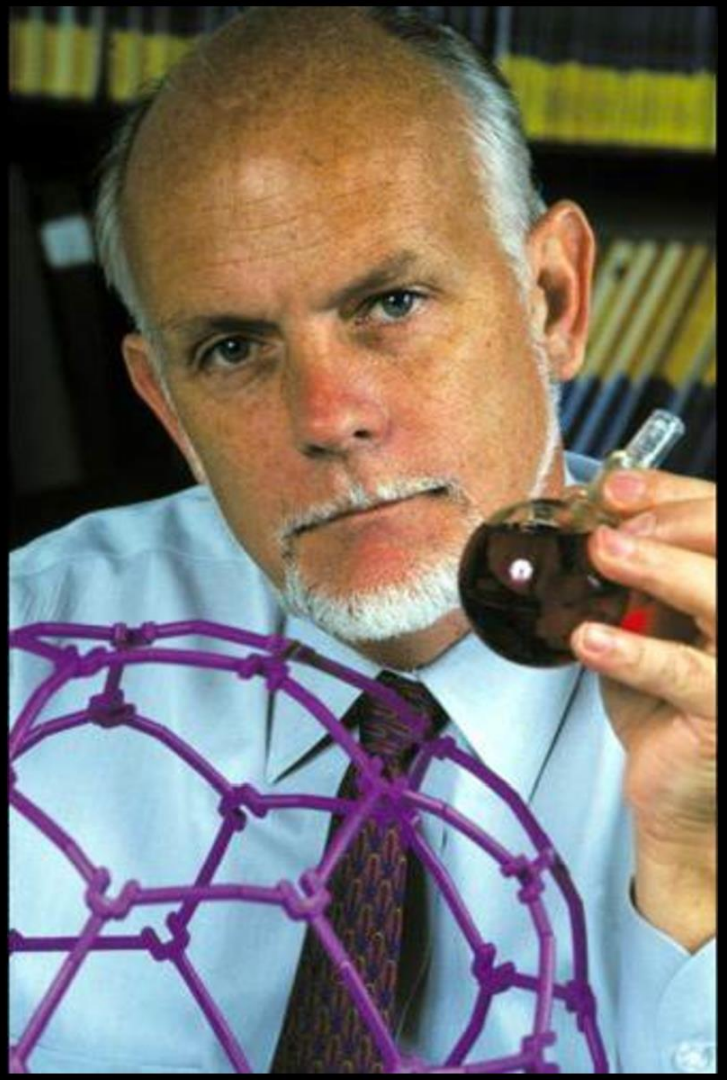
Webber Energy Group

THE UNIVERSITY OF TEXAS AT AUSTIN

Rick Smalley Was A Brilliant Thinker

- Nobel Laureate
- Discovered "Buckyballs"

In the last years of his life, he gave many speeches with a list of the world's top 10 challenges



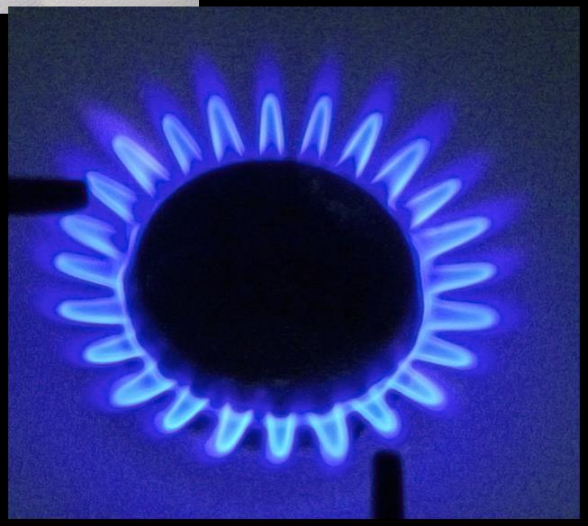
Energy Is At The Top of Rick Smalley's List of Humanity's Ten Grandest Challenges

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism & War
7. Disease
8. Education
9. Democracy
10. Population

Energy is Cross-Cutting: It Touches Just About Every Part of Society

- It is relevant to many sectors
  - Transportation, electricity, food, water, industry, residential, commercial
- It is relevant to societal issues
  - Environment, public health, national security, poverty, education, and our way of life

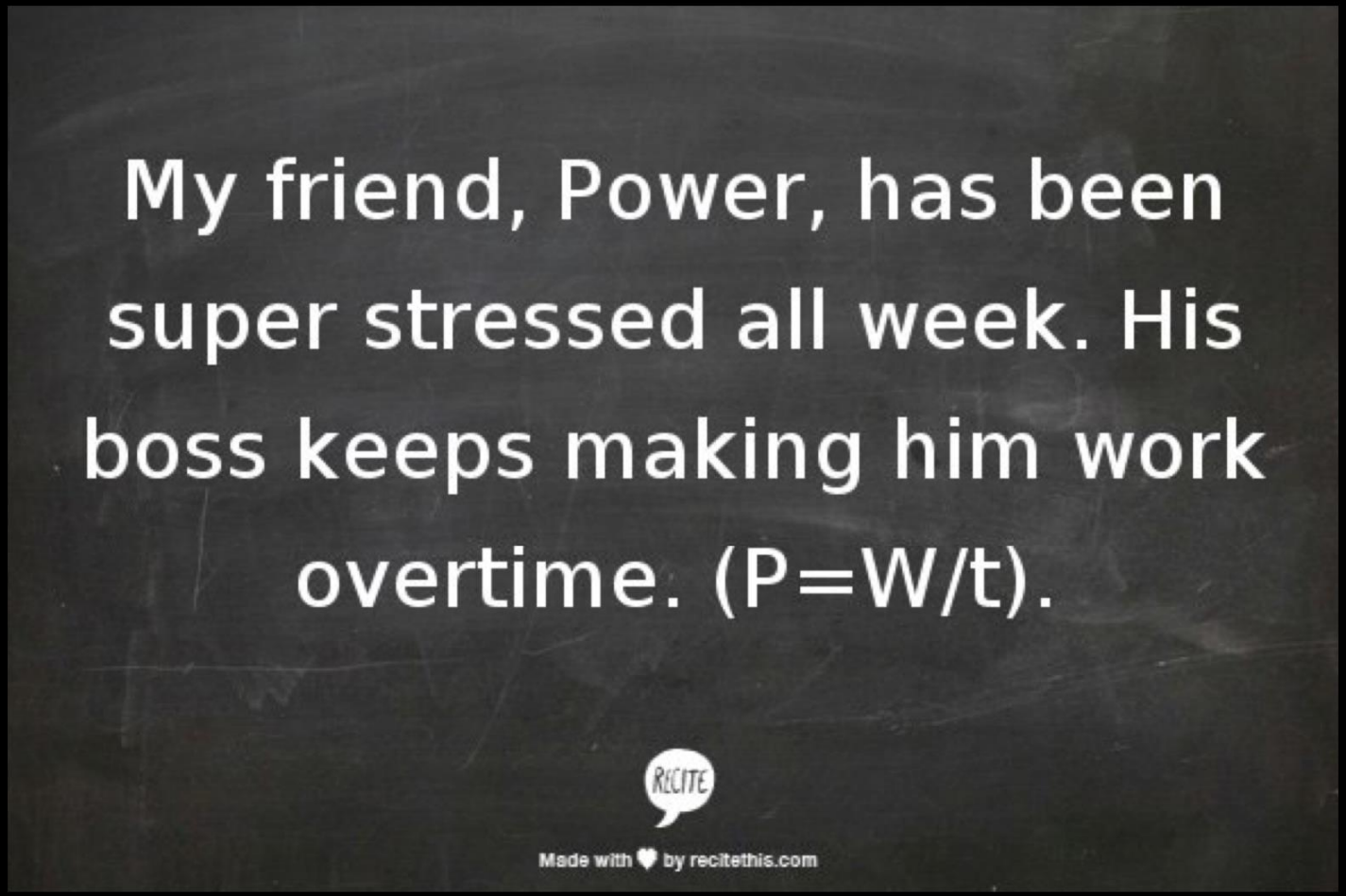
Energy is Good



- Abundant food
- Clean water
- Productive industry
- Mobility
- Comfortable buildings

Power Is The Rate At Which We Produce, Move and Consume Energy

Energy = Power × Time
Power = Energy ÷ Time
Power = Work ÷ Time



Power Is Relevant at Many Scales

- watt
- kilowatt (10^3 watts)
- megawatt (10^6 watts)
- gigawatt (10^9 watts)
- terawatt (10^{12} watts)
- petawatt (10^{15} watts)

Average Person: 100 watts

- Approximate basal metabolic rate of an adult human body
- A trained athlete may generate over 400 watts for a period of time.

Average Horse: 750 watts

- An average horse really does generate 1 horsepower, 746 Watts

1 square meter of sunshine: 750 watts

- On a clear day in March for northern temperate latitudes

Hair Dryer: 1,500 watts

- 1,500 Watts is about the maximum safe amount allowed for a standard U.S. power outlet

2015 Toyota Yaris: 79,000 watts

- 106 horsepower

2015 Dodge Viper: 477,250 watts

- 640 horsepower

GE Standard Wind Turbine: 1,500,000 watts

Diesel-Electric Locomotive: 3,000,000 watts

- 3 MW, 4,000 horsepower

Boeing 747: 140,000,000 watts

- 140 MW

Peak Generation of Hoover Dam: 2,074,000,000 watts

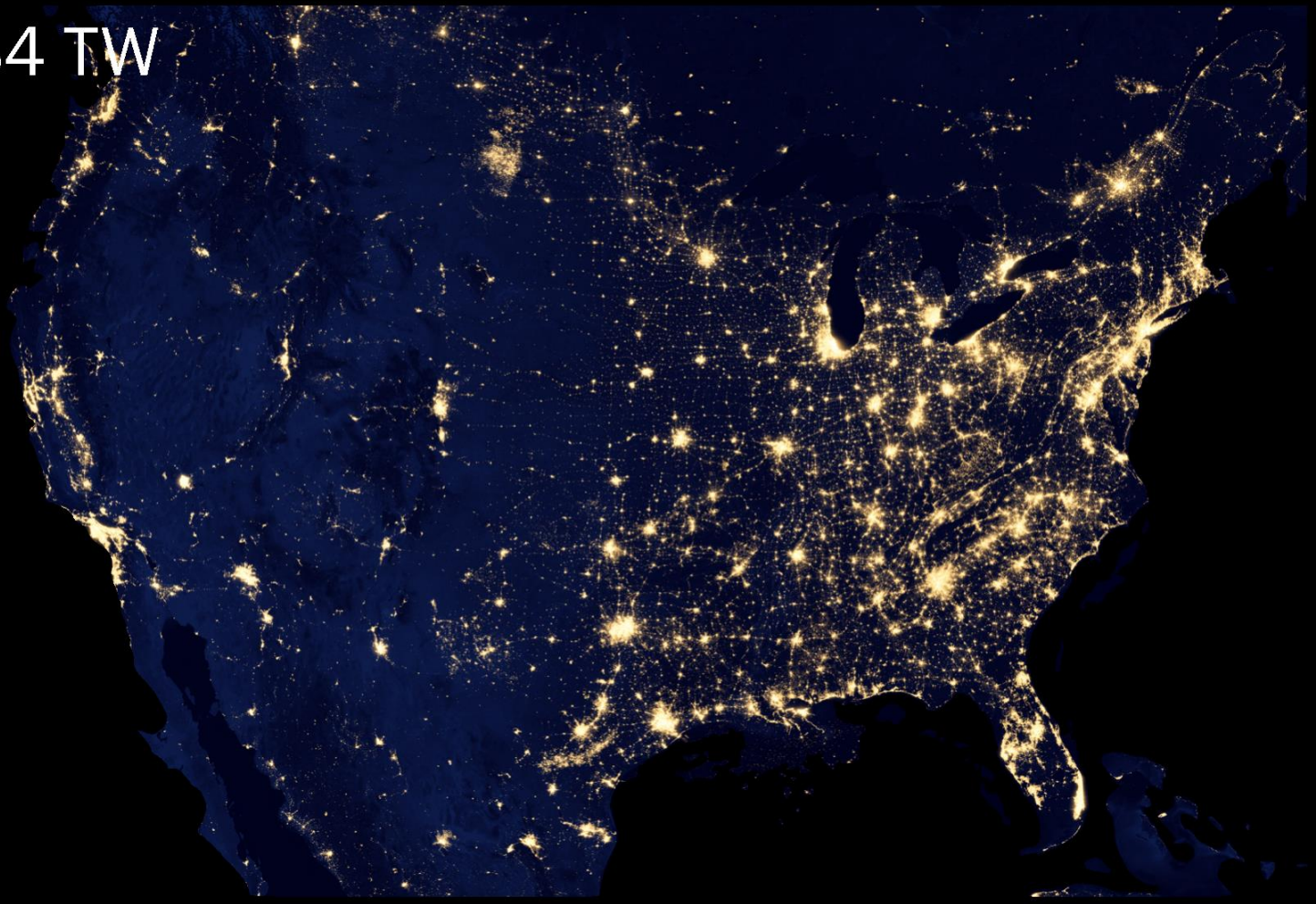
- 2.074 GW

Space Shuttle at Liftoff: 11,700,000,000 watts

- 11.7 GW

U.S. Power Consumption: 3,340,000,000,000 Watts

- 3.34 TW



Global Power Consumption: 17,500,000,000,000 watts

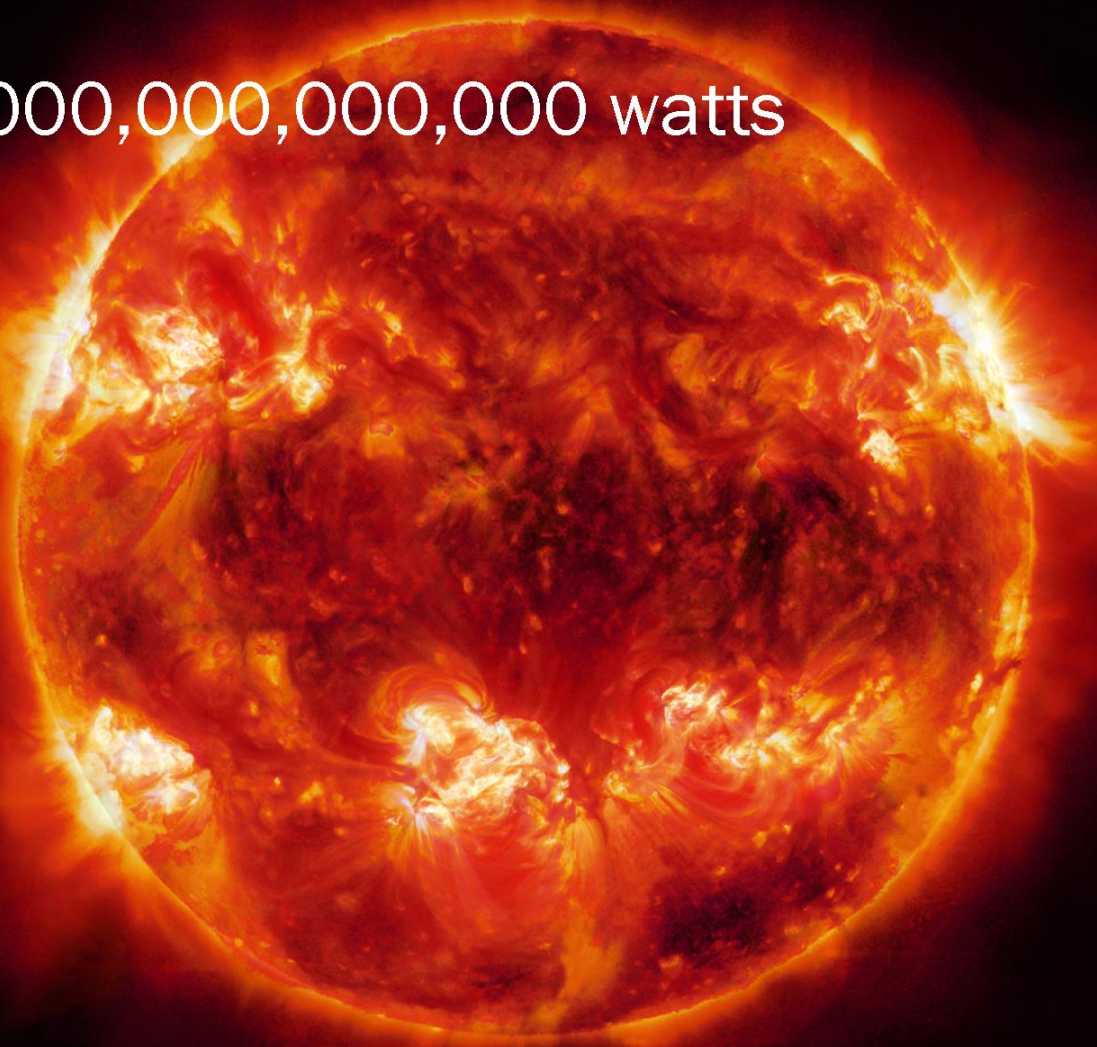
- 17.5 TW

World's most powerful laser pulses by laser still in operation: 1.1 PW

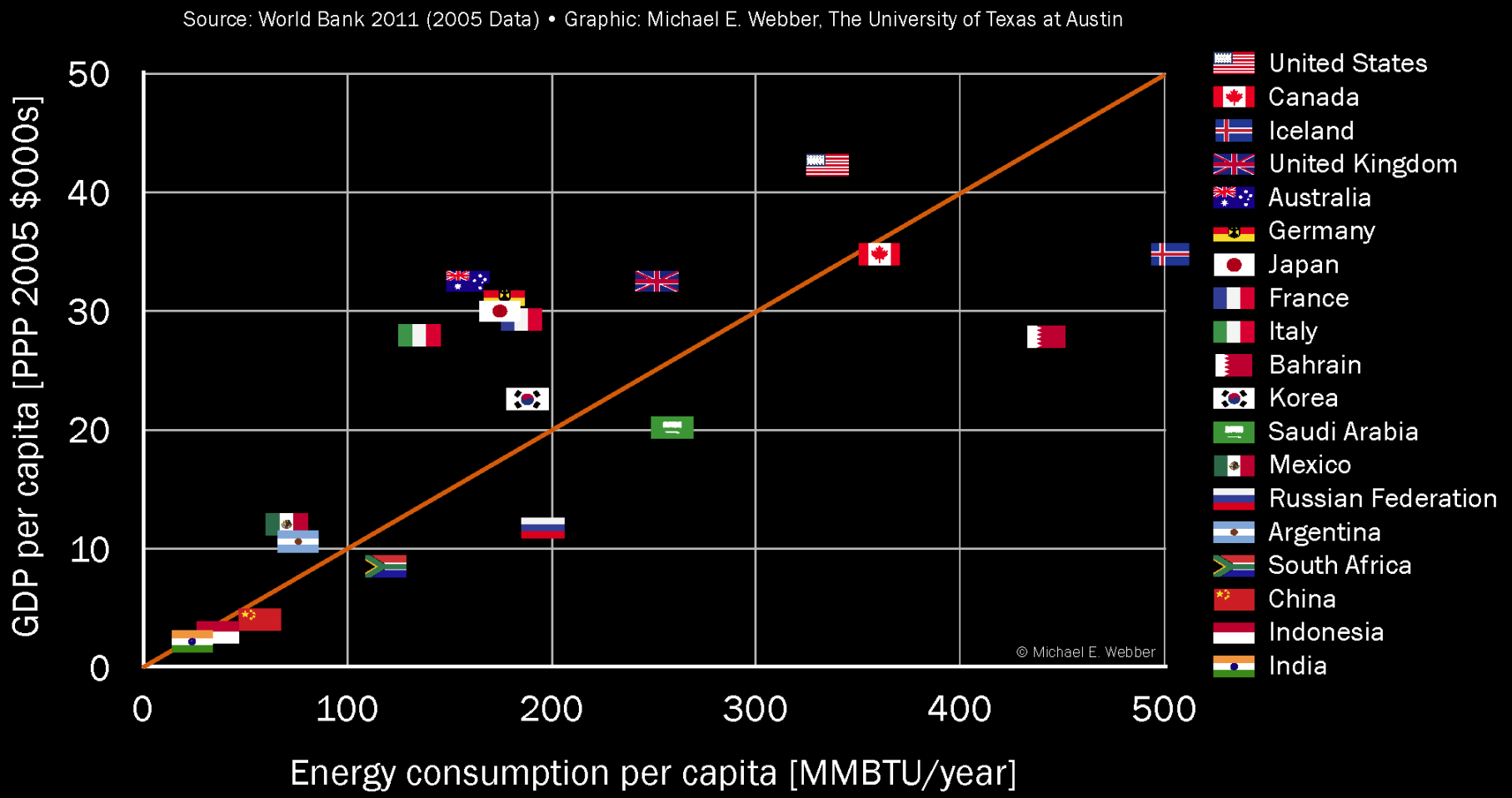
- 1,100,000,000,000,000 watts
- Texas Center for High Intensity Laser Science at The University of Texas at Austin

Total power received by Earth from the Sun: 174 PW

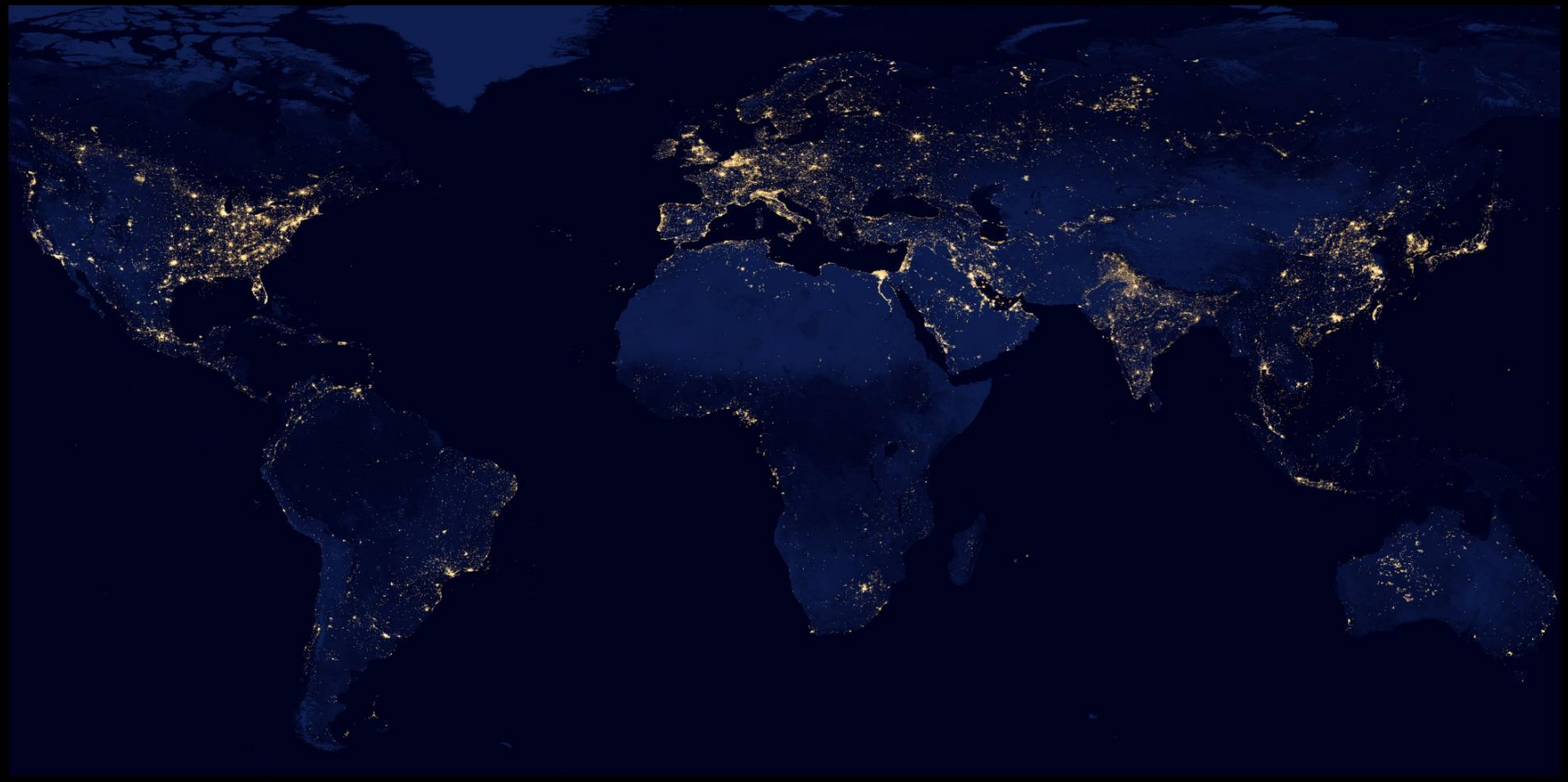
- 174,000,000,000,000,000 watts



Energy Consumption and Affluence Are Correlated



The Global Maps of Electricity Consumption and Wealth are Nearly Identical



Source: NASA 2012

The Energy Problem Is Comprised of Three Converging Crises

Resource Depletion

Flcelloguy at the English language Wikipedia

Environmental Degradation

U.S. Navy

National Security

U.S. Air Force

All three are related and amplify each other.

Managing the Good and Bad of Energy Is the Grand Challenge of the 21st Century

What Is The Status of Energy Today?

Change is afoot…

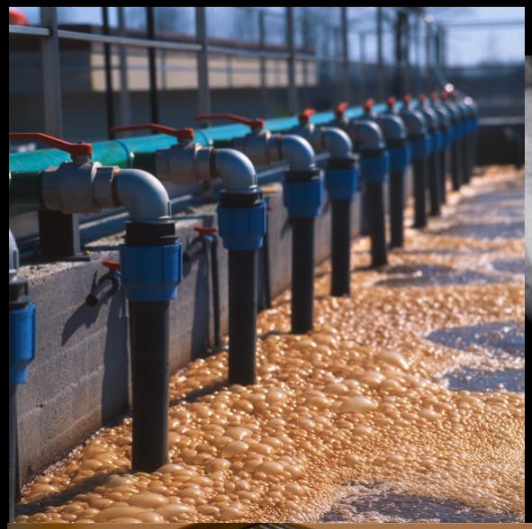
Surprising Energy Facts in the USA

- 10% of all energy is for making, moving, storing, and preparing food
  - –We waste 25-50% of that food
  - –There is more energy in the food we throw away than Switzerland uses in an entire year

Surprising Energy Facts in the USA

- One-third of all energy consumption is just to boil water at power plants to make steam that drives turbines to make electricity.

Surprising Energy Facts in the USA

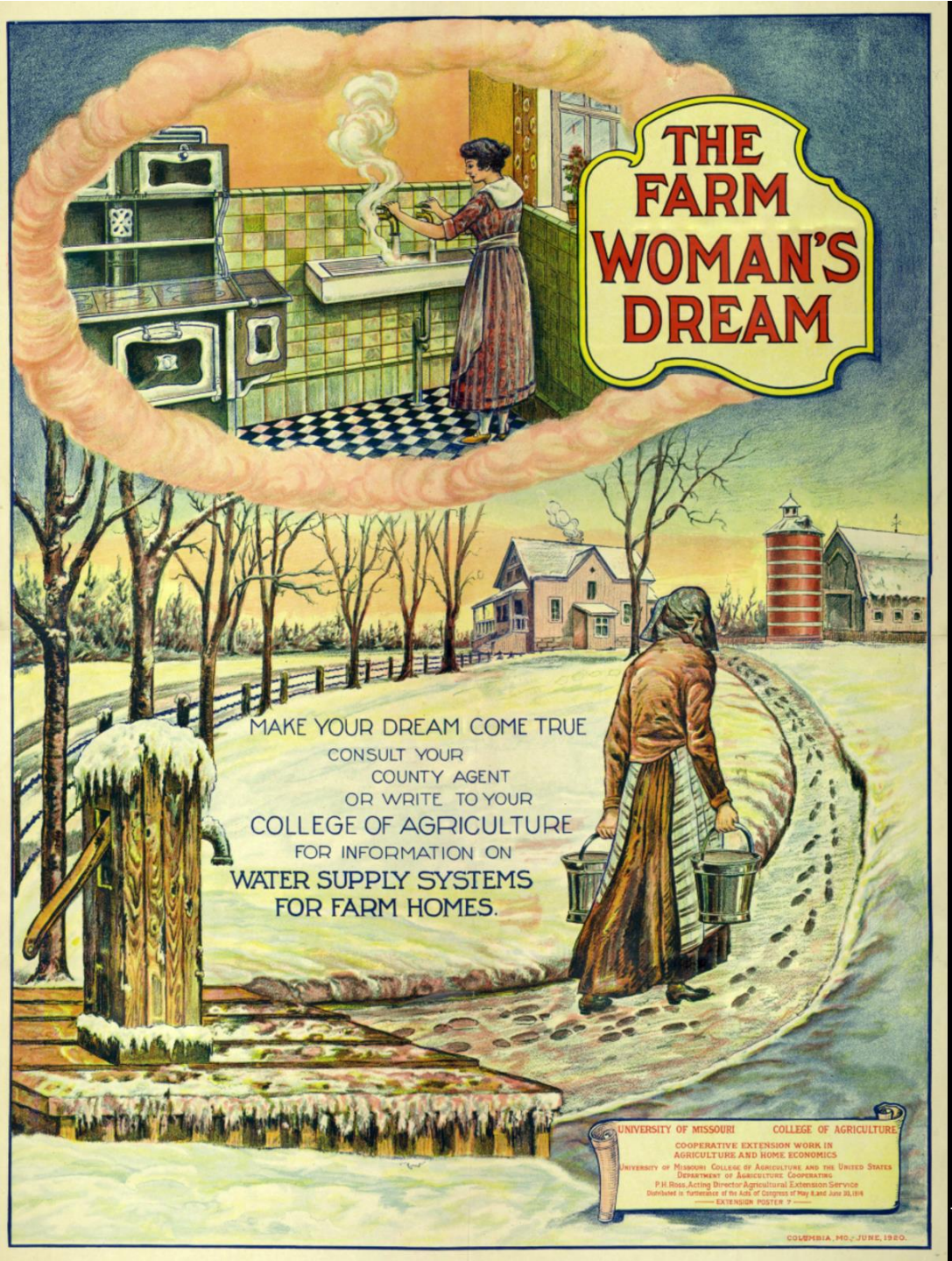


- 13% of all energy is for heating, treating and pumping water
  - We use more water for our light switches and outlets than our taps, shower heads and toilets

In Many Parts of the World, It Is The Woman's Responsibility To Fetch Water

Source: Corbis Images

Source: QT Luong



Less Than A Century Ago, That Woman Was American

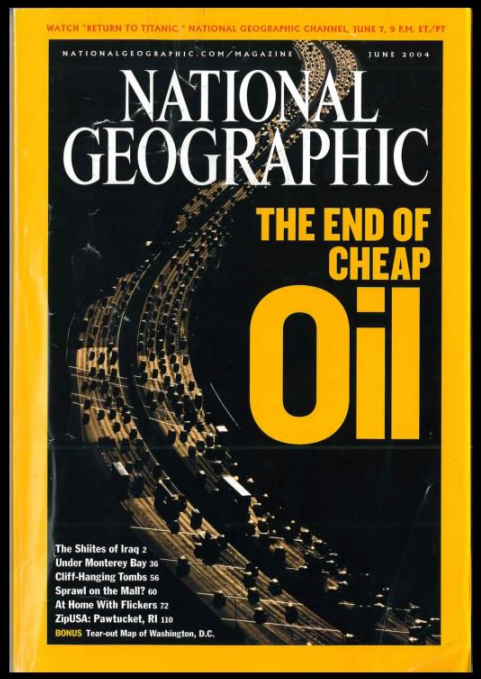
Piped water systems liberate women

Source: Univ. of Missouri & U.S. Department Of Agriculture, 1920

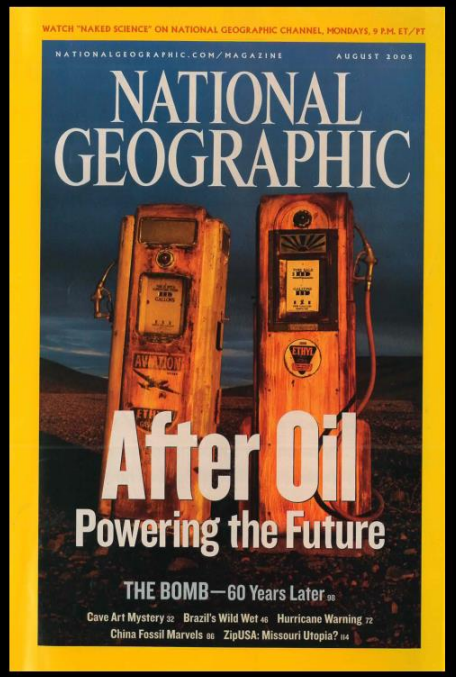
Energy situations change…

For the First Decade of the 21st Century, Headlines Declared the End of Oil

October 2003



June 2004



August 2005

This Decade's Headlines are Very Different

March 2013

May 2013

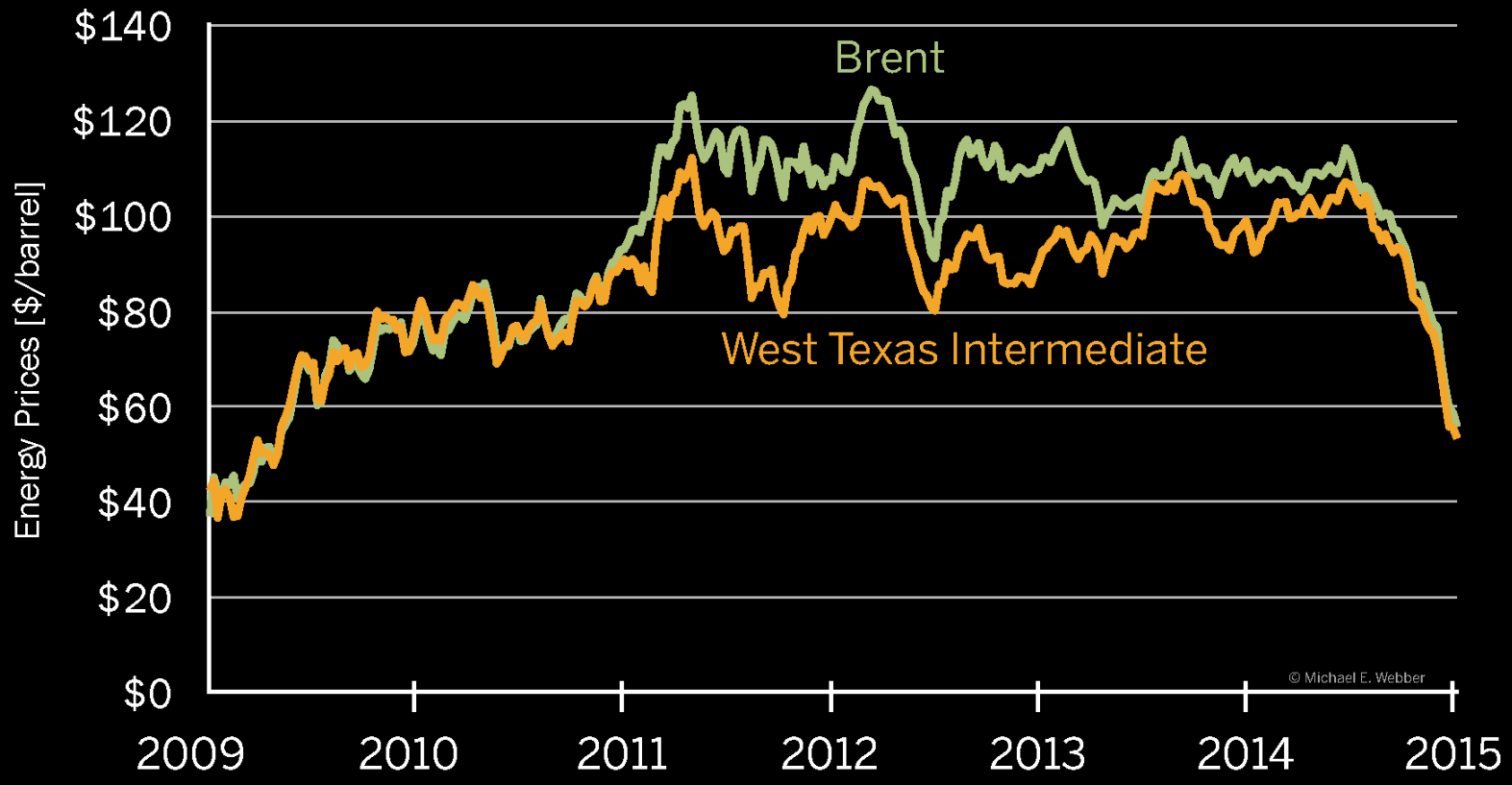
This Decade's Headlines are Very Different

December 2014

Crude Oil Prices Fell Sharply in Fourth Quarter of 2014

2009–2014 Brent and West Texas Intermediate Crude Oil Prices

Source: U.S. Energy Information Administration • Graphic: Michael E. Webber, The University of Texas at Austin



Flaring Is A Growing (Glowing?) Problem in the Bakken and Eagle Ford Shales

In North Dakota, Flames of Wasted Natural Gas Light the Prairie

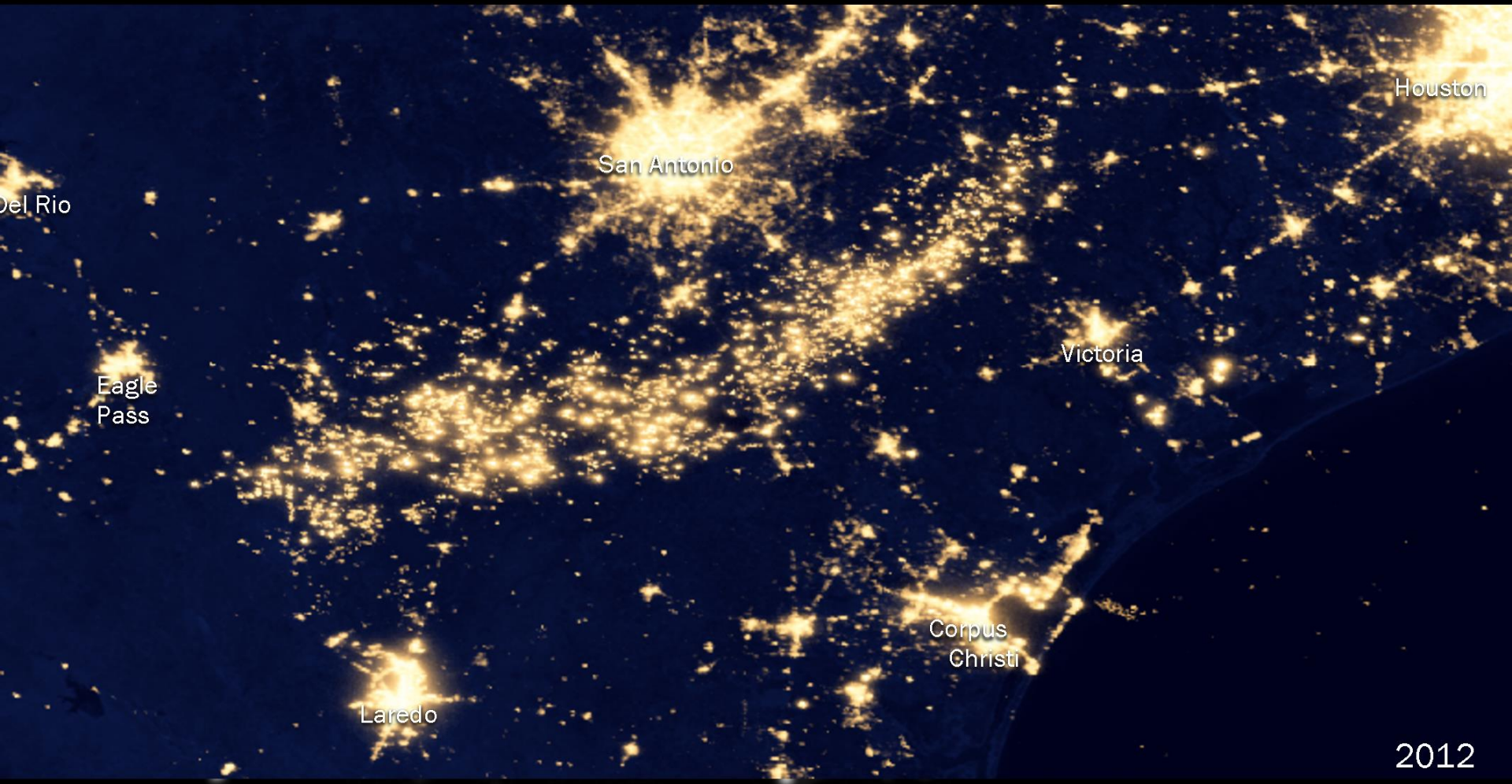
Jim Wilson/The New York Times

Thirty percent of the natural gas extracted in North Dakota is flared off, like this gas near Ray. More Photos »

By CLIFFORD KRAUSS
Published: September 26, 2011

Flaring From Shale Production Is Visible From Space

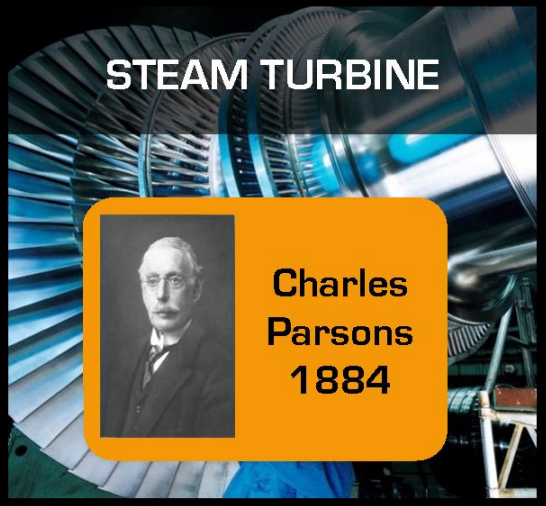
The Stars at Night, Are Big and Bright…

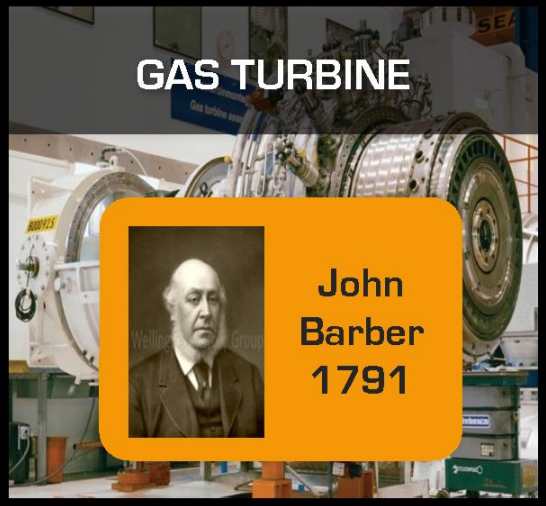


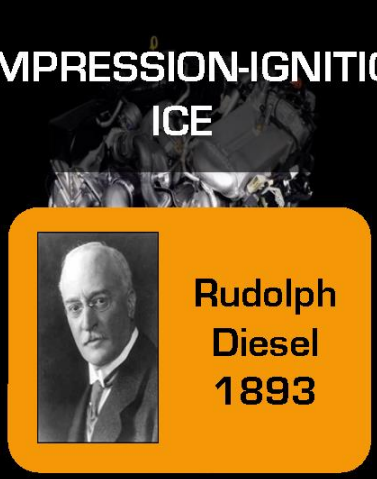
Bakken Shale

Energy Technologies Change Very Slowly…

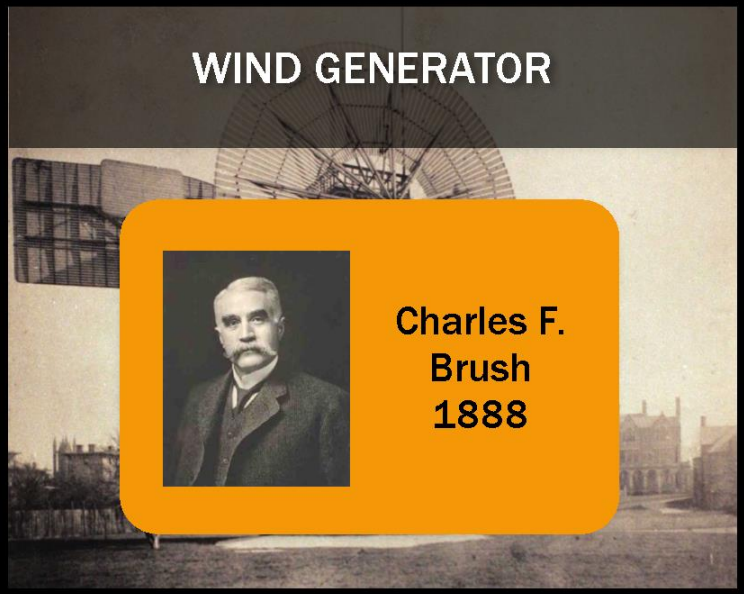
Four Technologies Are Responsible for >60% of U.S. Energy Consumption

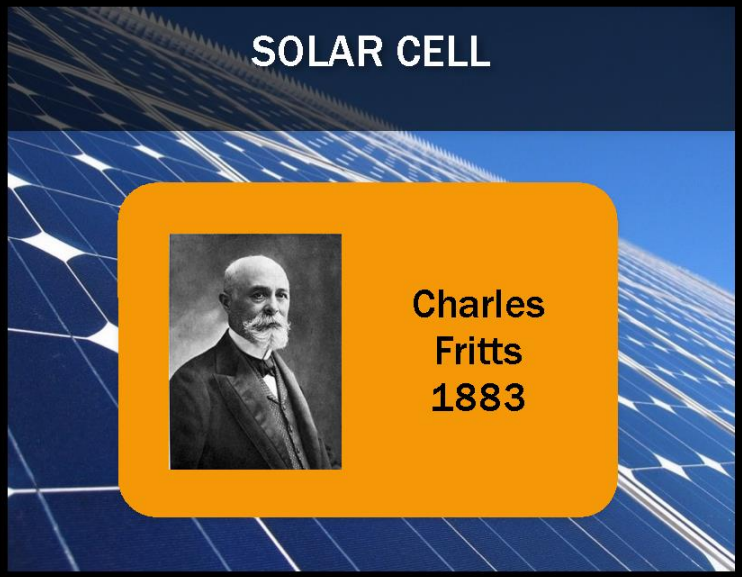






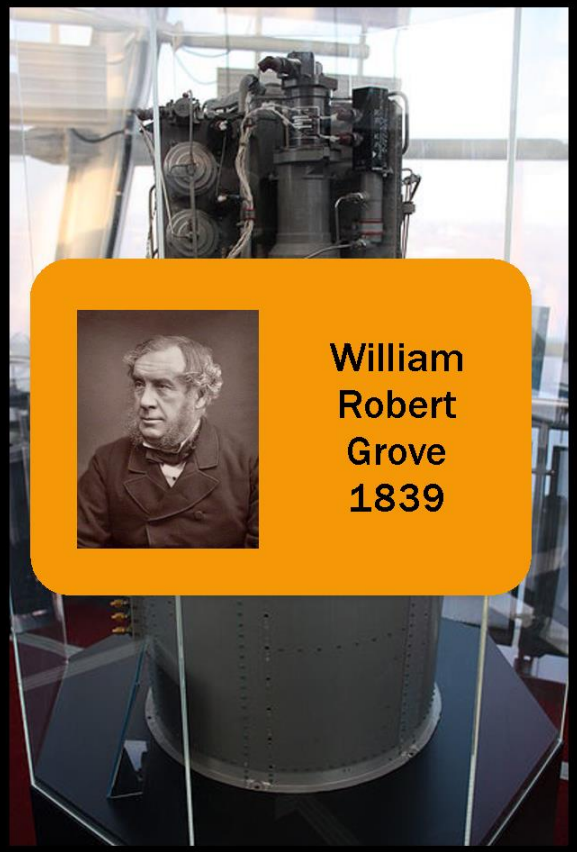
Modern Renewable Energy Isn't That Modern





Space-Age Energy Was Developed Long Before the Space Age

Three of these fuel cells powered the Apollo Command/Service Module to and from the Moon.



James Humphreys – SalopianJames • Wikimedia Commons

The Transition to Electric Vehicles Has Been a Long Time Coming

"I can hardly doubt that electro-magnetism will ultimately be substituted for steam to propel machinery."

James Prescott Joule, 1839

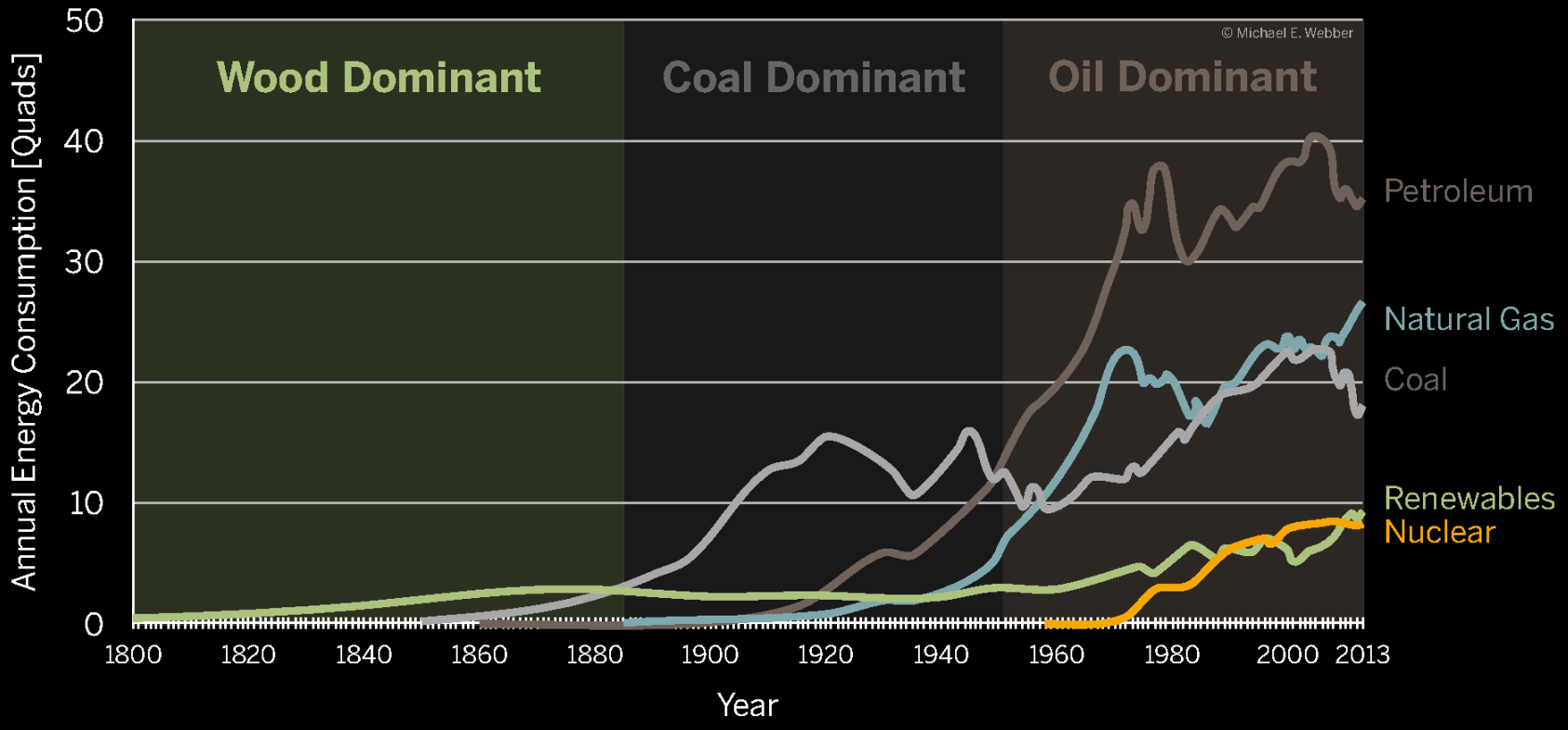
[Source: *Pursuing Power and Light*, Bruce Hunt]

Energy transitions have happened before.

The U.S. Fuel Mix Has Changed With Time

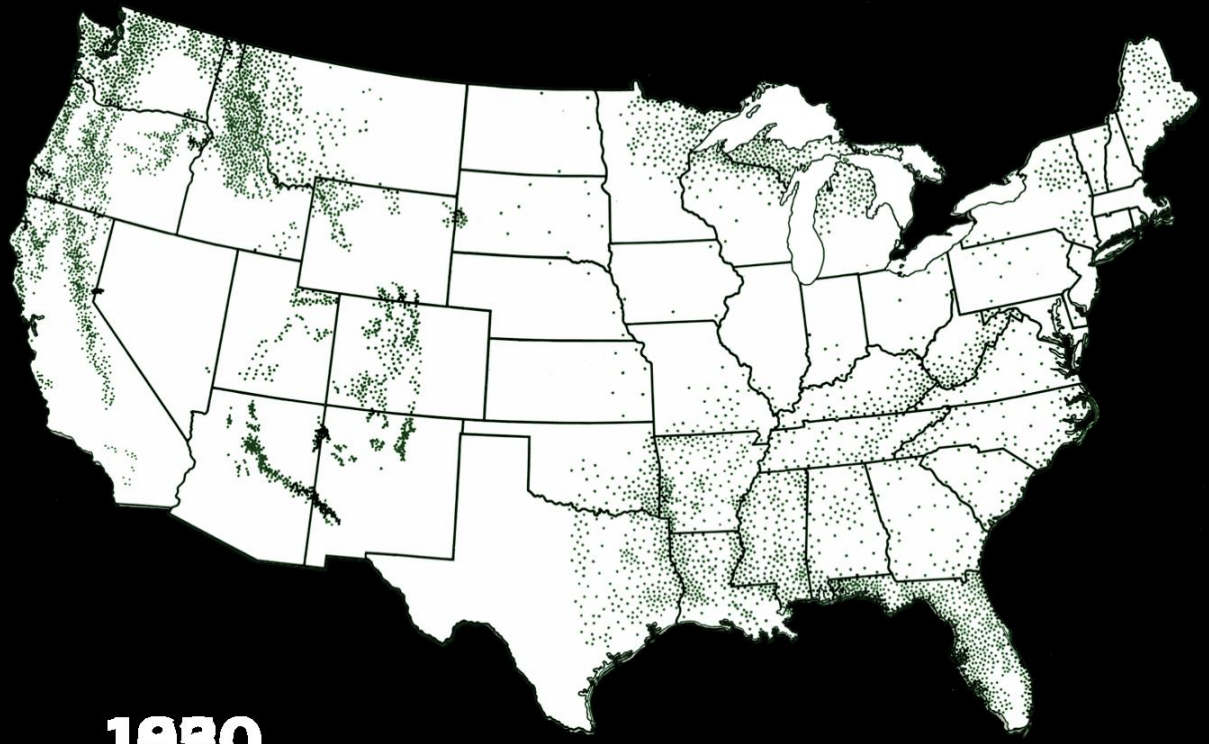
1800–2013 U.S. Energy Consumption by Source

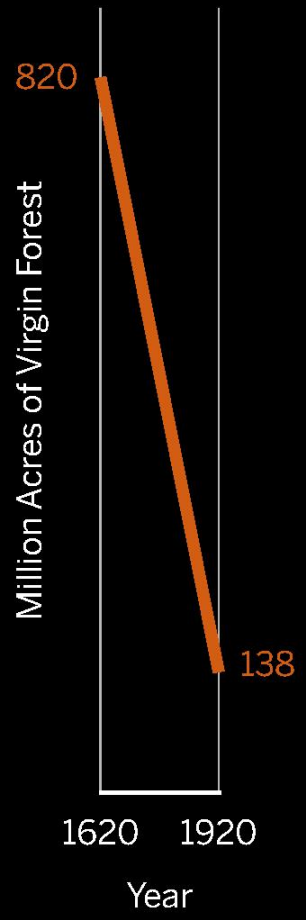
Source: U.S. Energy Information Administration / *October 2014 Monthly Energy Review* • Graphic: Michael E. Webber, The University of Texas at Austin



The Use of Wood as a Fuel and Feedstock Caused Widespread Deforestation Between 1620–1920

Source: *The Relation of Geography to Timber Supply*, William B. Greeley, 1925 • Graphic: Michael E. Webber, The University of Texas at Austin

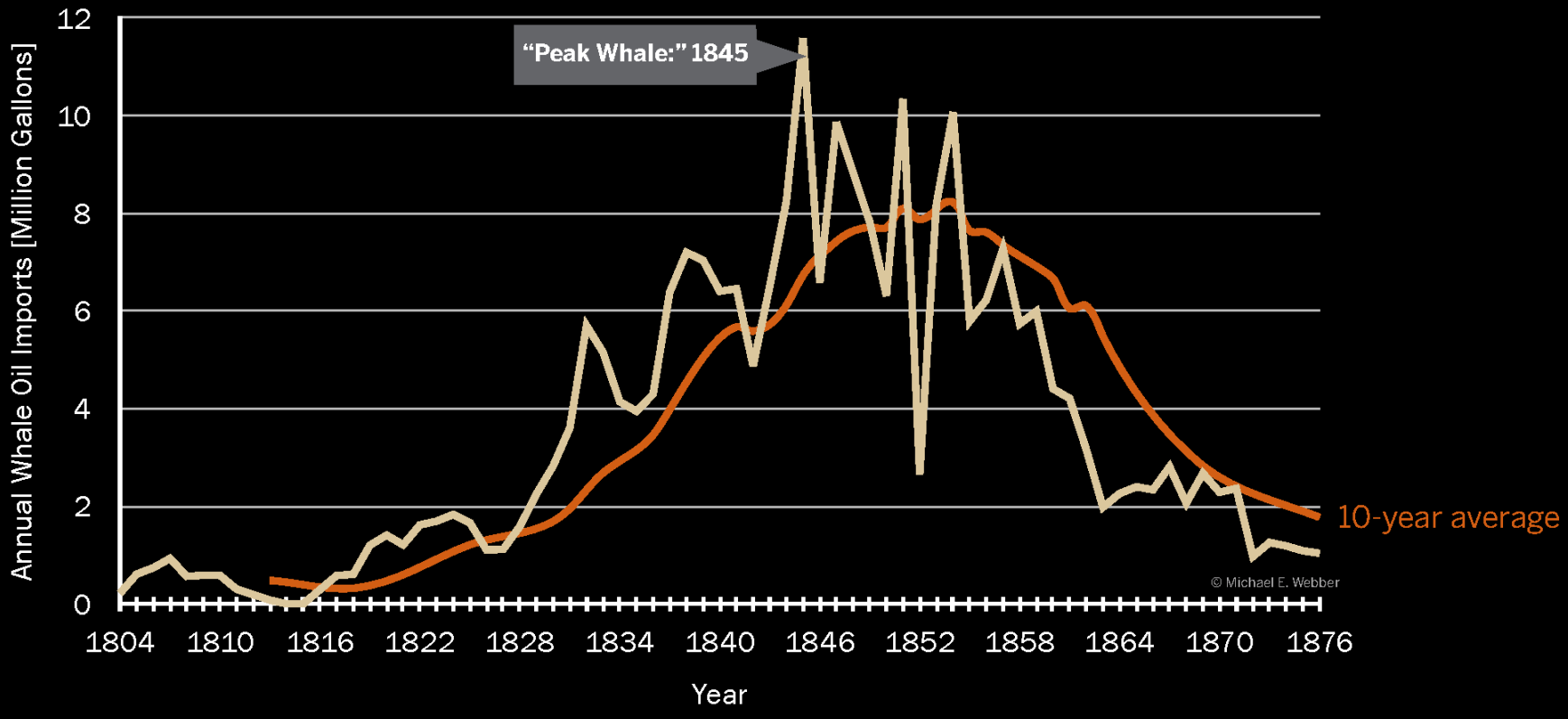




Whale Oil Supplies Peaked in the Mid-1800s

1804–1876 U.S. Whale Oil Imports from Whaling Ships

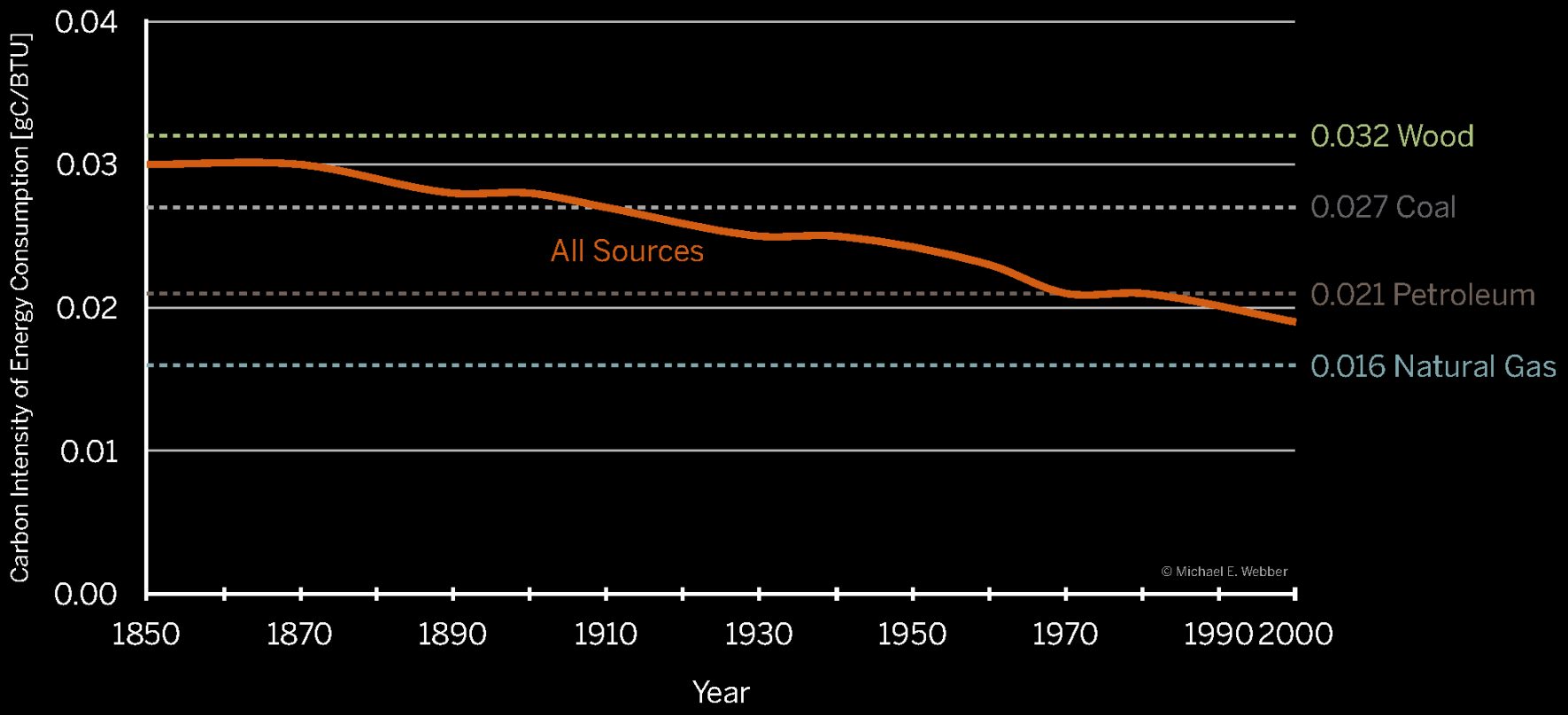
Source: Alexander Starbuck, *History of the American Whale Fishery*, 1878, pp. 660–661 • Graphic: Michael E. Webber, The University of Texas at Austin



Energy Transitions Show a Trend Toward Decarbonization

1850–2000 U.S. Carbon Intensity of Energy

Source: A. Grübler and N. Nakicenovic, *Technol. Forecast. Soc. Change*, 1996, 53, 97–110 • Graphic: Michael E. Webber, The University of Texas at Austin



How we use energy has changed from antiquity to the Industrial Revolution.

There Were Several Old Forms and Applications of Kinetic Energy

- Medieval forms of kinetic energy
  - –Dutch and Flemish windmills
  - –Medieval water wheels
  - –Sails
  - –Muscle power
- Medieval uses of kinetic energy
  - –Sawing wood
  - –Grinding grain
  - –Polishing glass
  - –Transportation

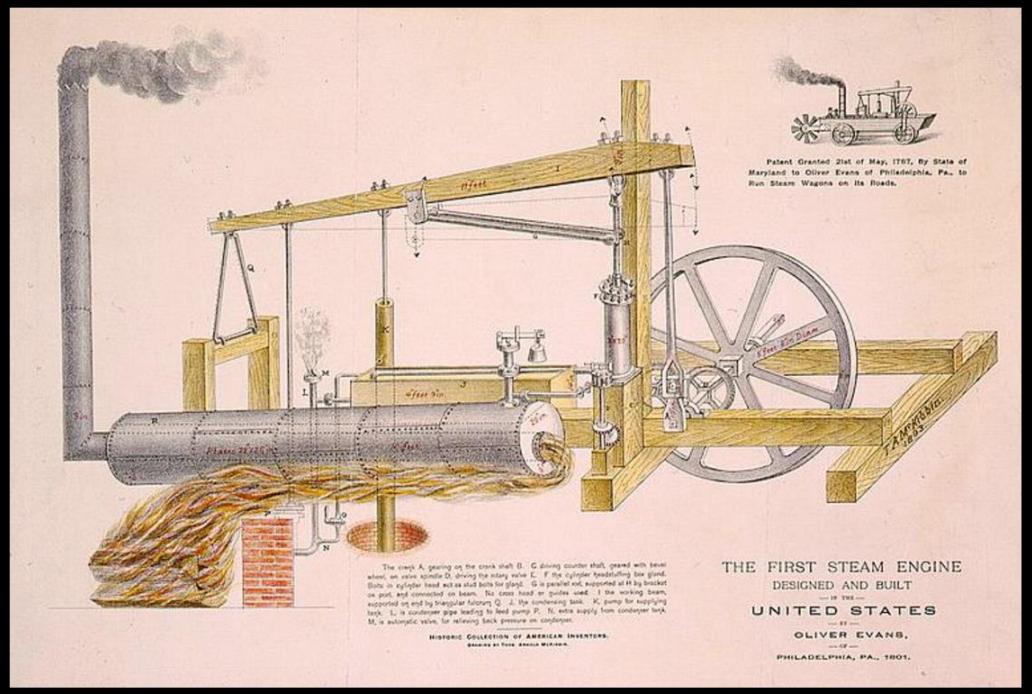
There Were Several Old Forms and Applications of Thermal Energy

- Medieval forms of thermal energy
  - Wood
  - Charcoal
  - Peat
  - Dung
  - Straw
- Medieval uses of thermal energy
  - Cooking
  - Making glass
  - Boiling soap
  - Making lime

Frau beim Brotbacken, 1854

The Industrial Revolution's Main Enabler was a Breakthrough in Energy Conversion

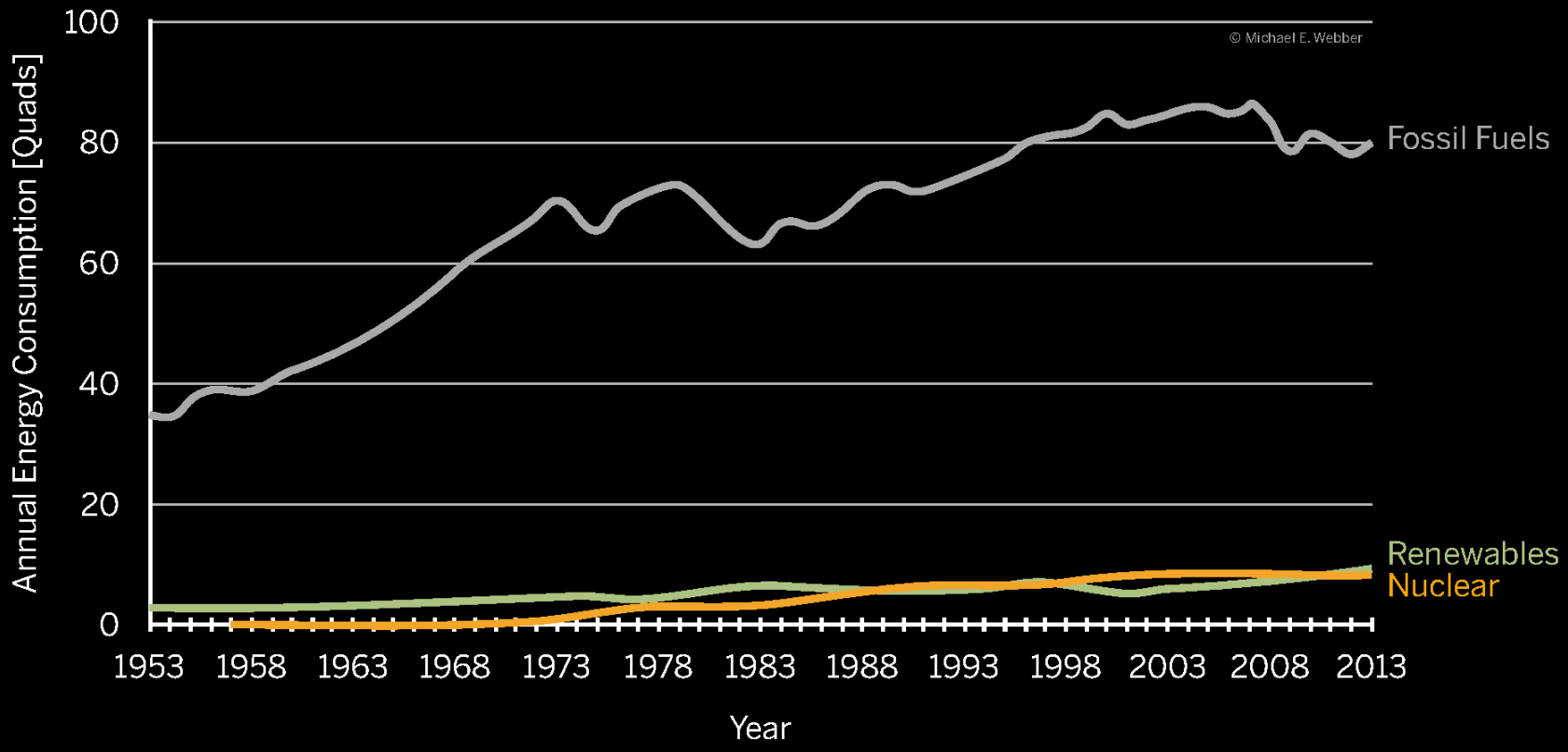
- Invention of steam engine in 1700s enables conversion of thermal energy to kinetic energy
- Electricity in 1800s allows thermal to electrical to kinetic energy



Fossil Fuels are the Dominant Primary Energy Source in Modern History

1953–2013 U.S. Energy Consumption by Source

Source: U.S. Energy Information Administration / October 2014 Monthly Energy Review • Graphic: Michael E. Webber, The University of Texas at Austin

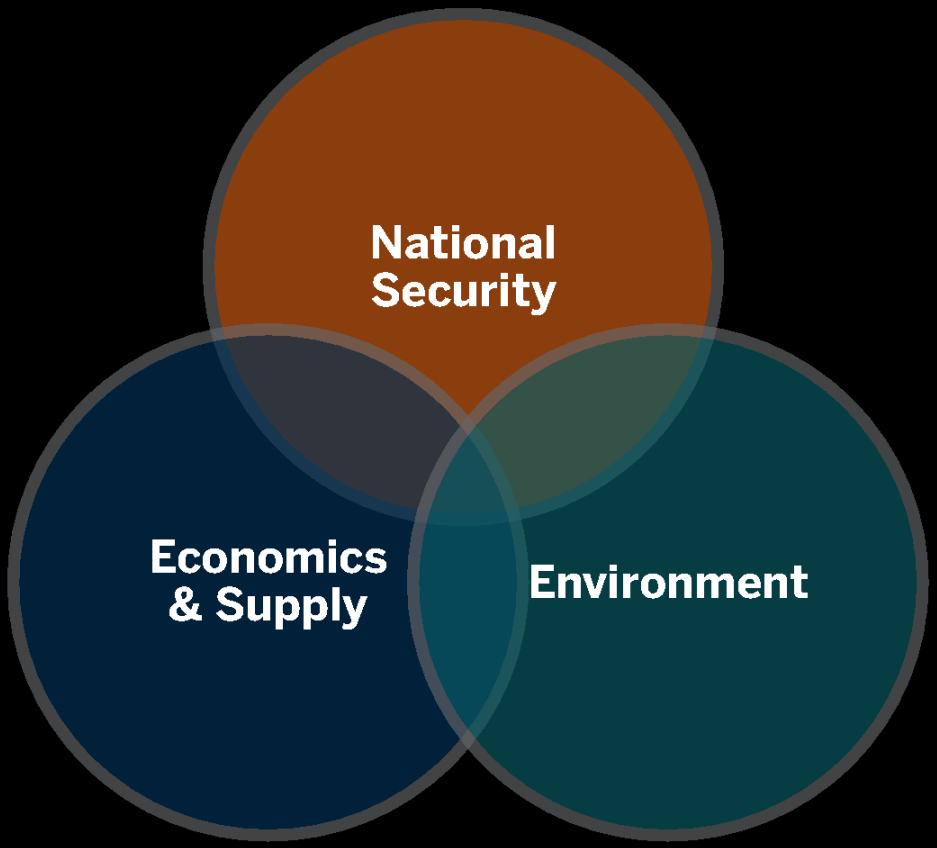


What About The Future of Energy?

"It's tough to make predictions, especially about the future."

—Yogi Berra

We Must Balance Three Priorities While Addressing the Energy Problem



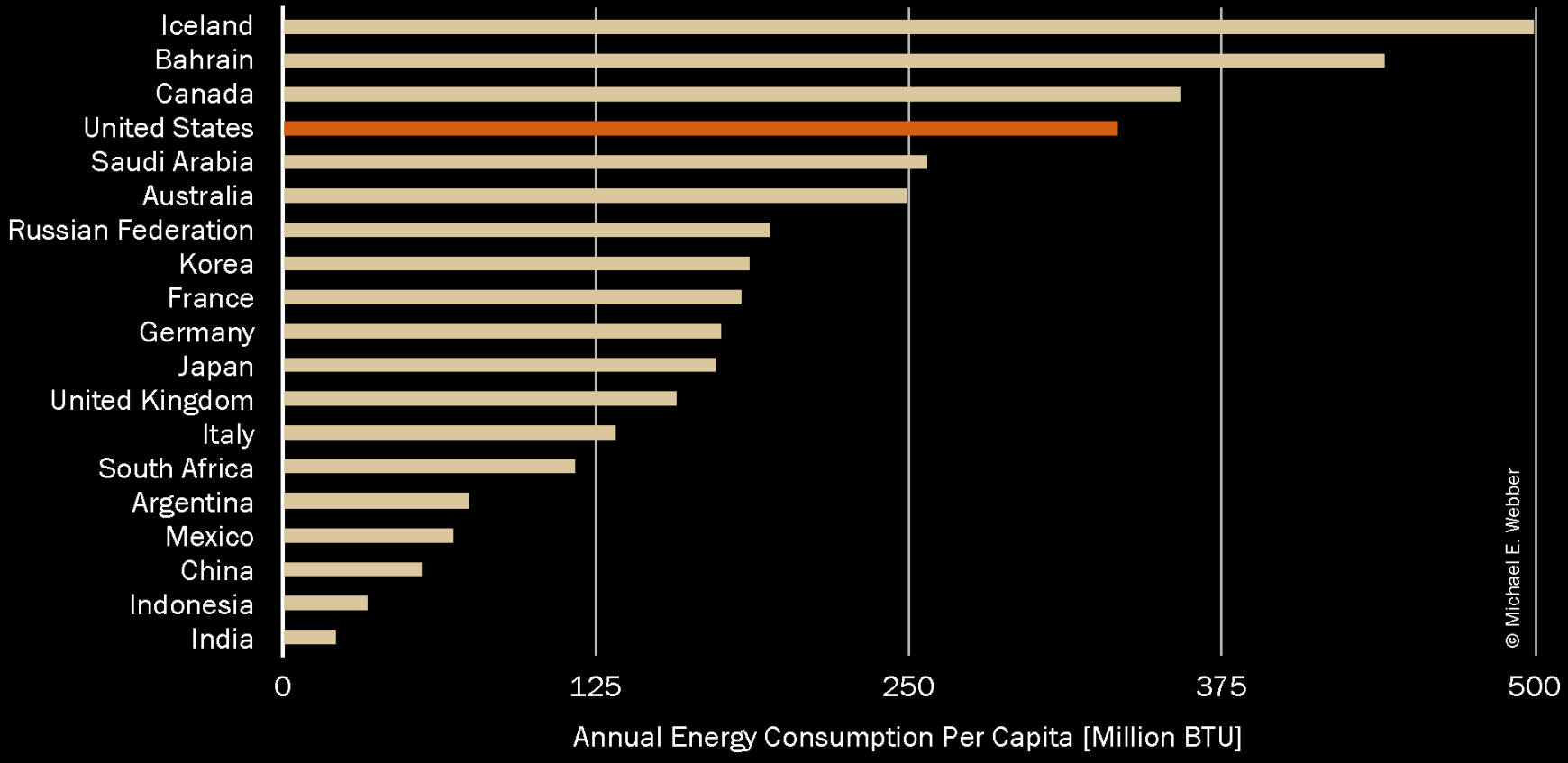
Most options for new fuels or technologies solve any one or two priorities, but not all three.

Energy Inequities Remain A Vexing Problem

There Are Great Inequities In Global Energy Consumption

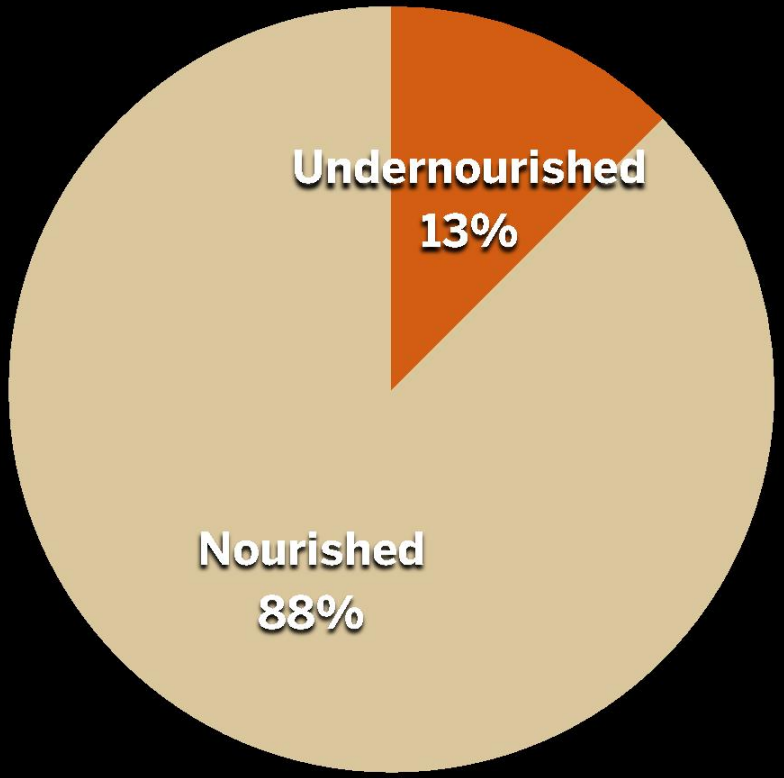
2012 Worldwide Per Capita Energy Use

Source: International Energy Agency • Graphic: Michael E. Webber, The University of Texas at Austin



More Than 12% of World Population Is Undernourished

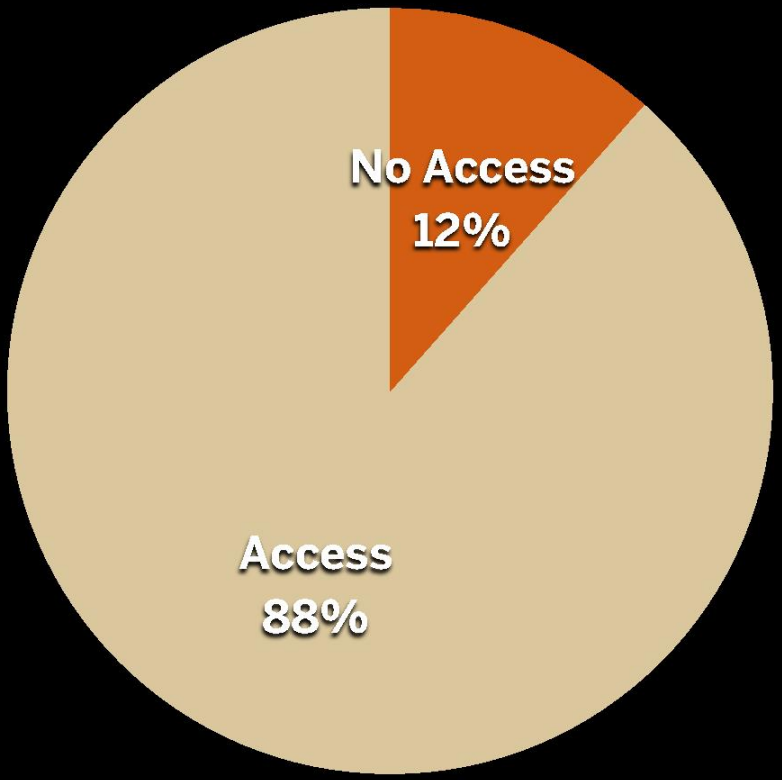
Source: Food and Agriculture Organization of the United Nations, *The State of Food Insecurity in the World 2012* • Graphic: Michael E. Webber, The University of Texas at Austin



CDC/ Dr. Lyle Conrad

12% of World Population Lacks Access to an Improved Drinking Water Source

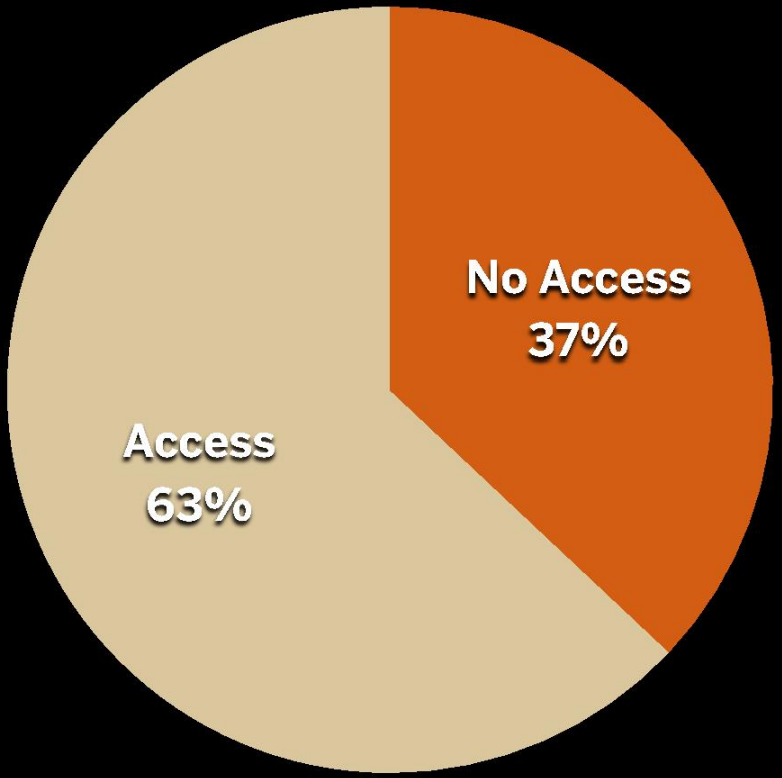
Source: Food and Agriculture Organization of the United Nations, *The State of Food Insecurity in the World 2012* • Graphic: Michael E. Webber, The University of Texas at Austin



Bob Metcalf, Wikipedia Commons

37% of World Population Lack Access to Sanitation Facilities

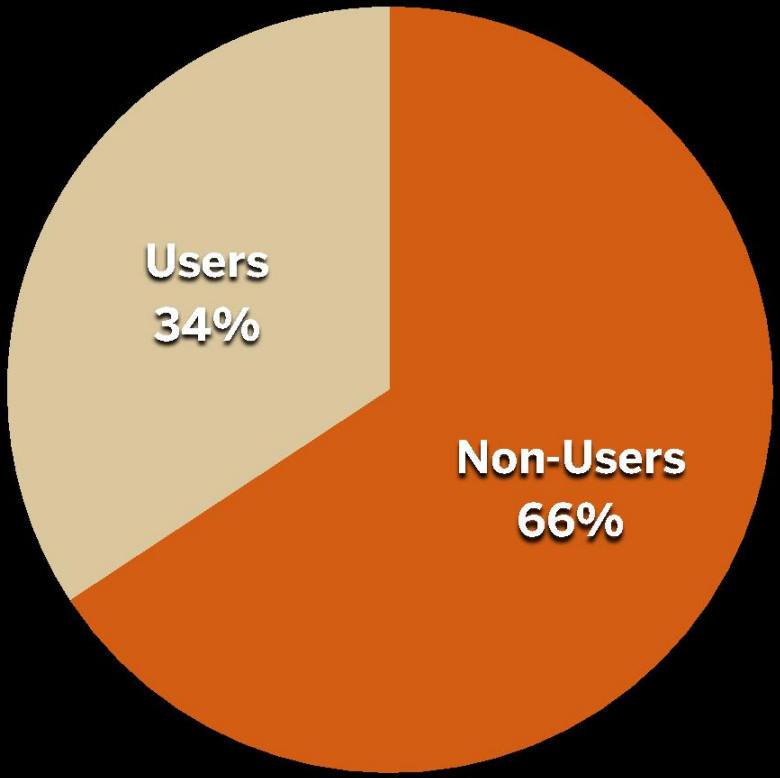
Source: Food and Agriculture Organization of the United Nations, *The State of Food Insecurity in the World 2012* • Graphic: Michael E. Webber, The University of Texas at Austin

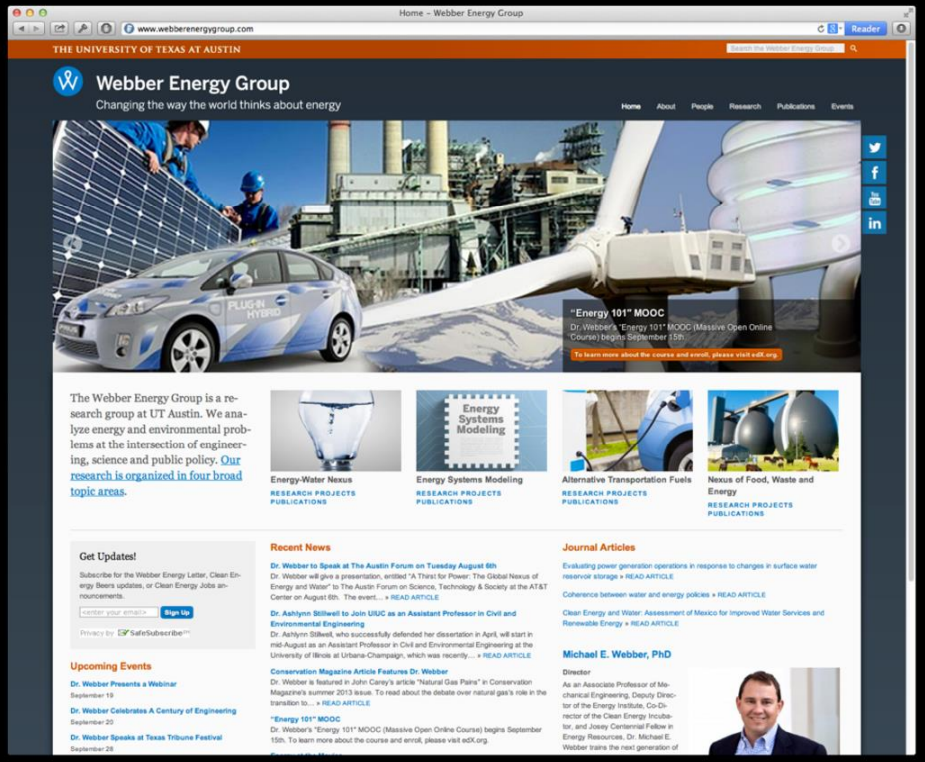


Centers for Disease Control

Two-Thirds of World Population Are Not Using the Internet

Source: www.internetworldstats.com, 2013 • Graphic: Michael E. Webber, The University of Texas at Austin



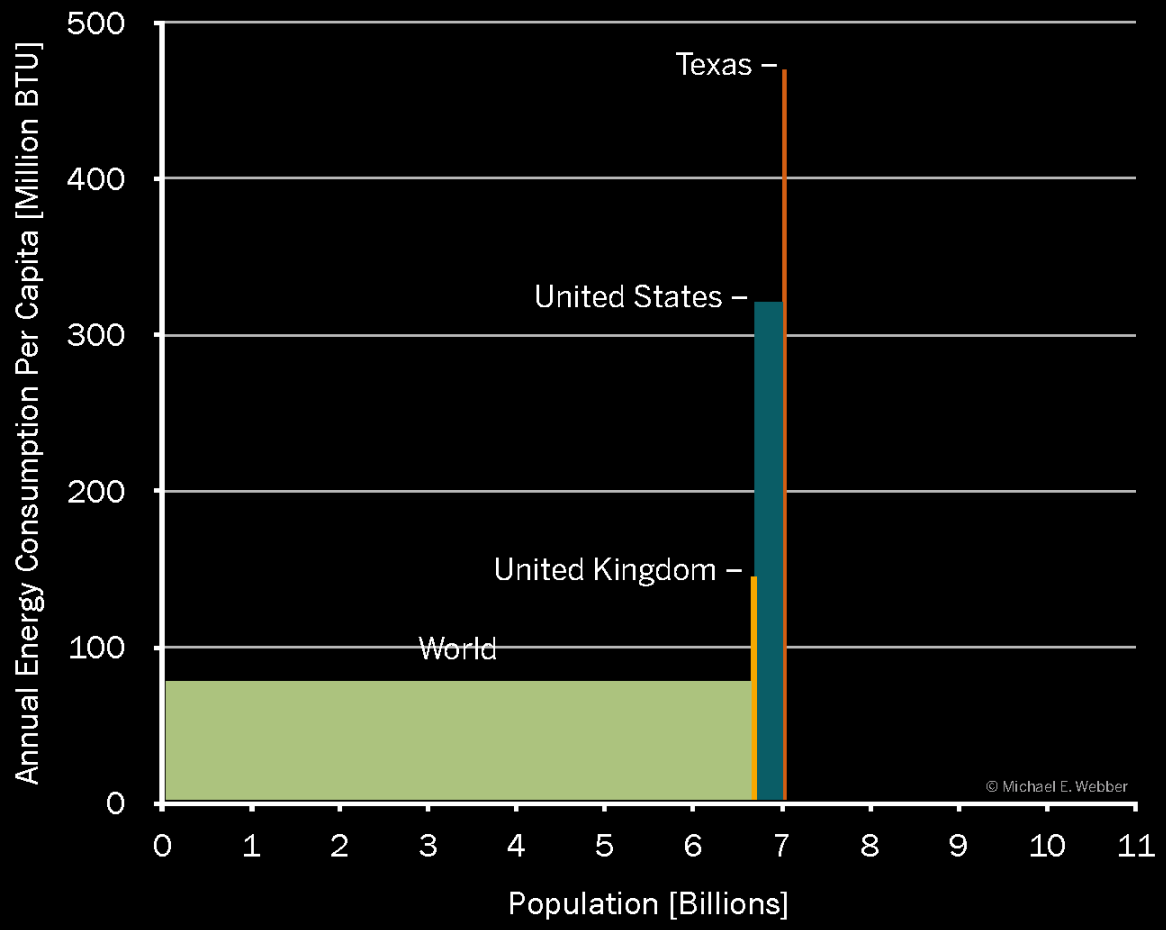


There are Only 600 Million Cars and 250 Million Trucks Worldwide

Source: WorldMapper

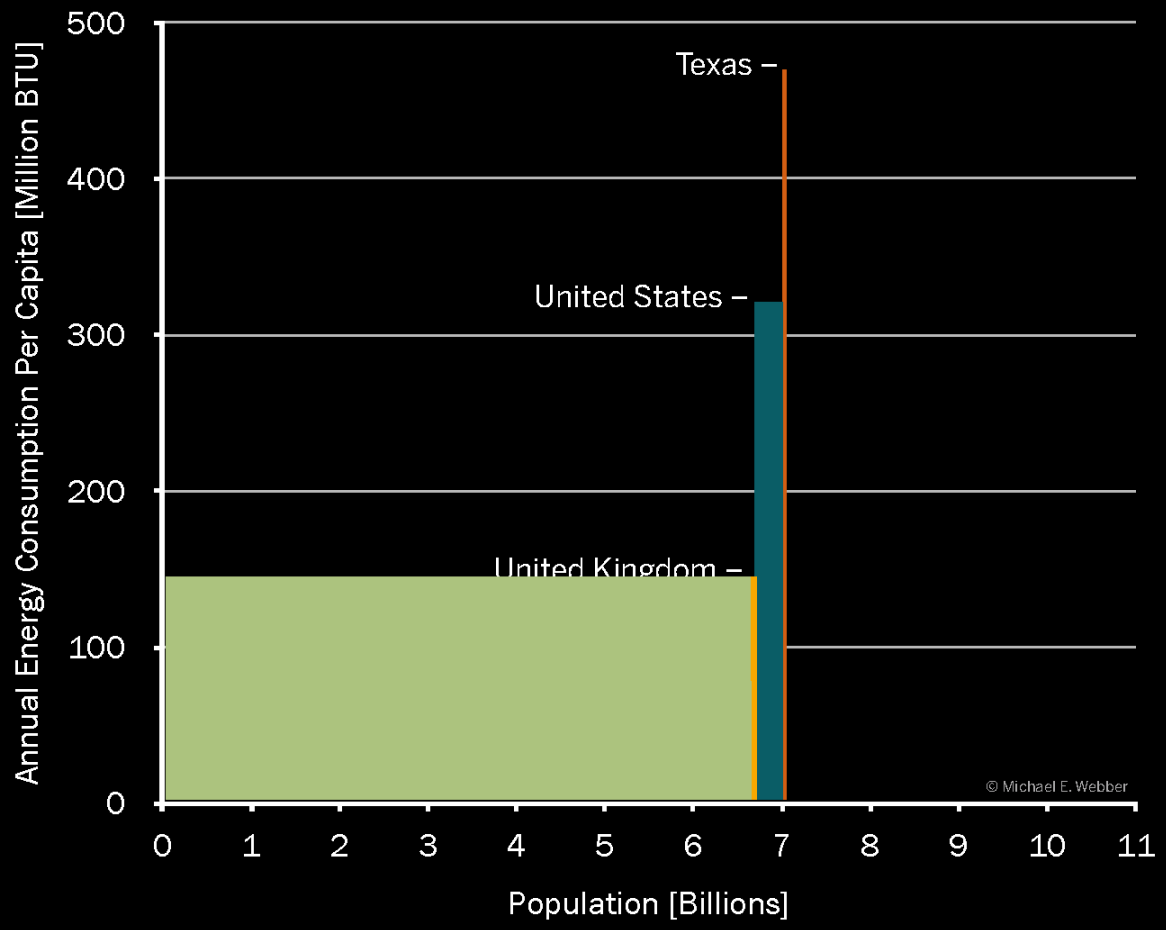
Warren Gretz / NREL

There Are Great Inequities In Global Energy Consumption



Global Energy Consumption

There Are Great Inequities In Global Energy Consumption



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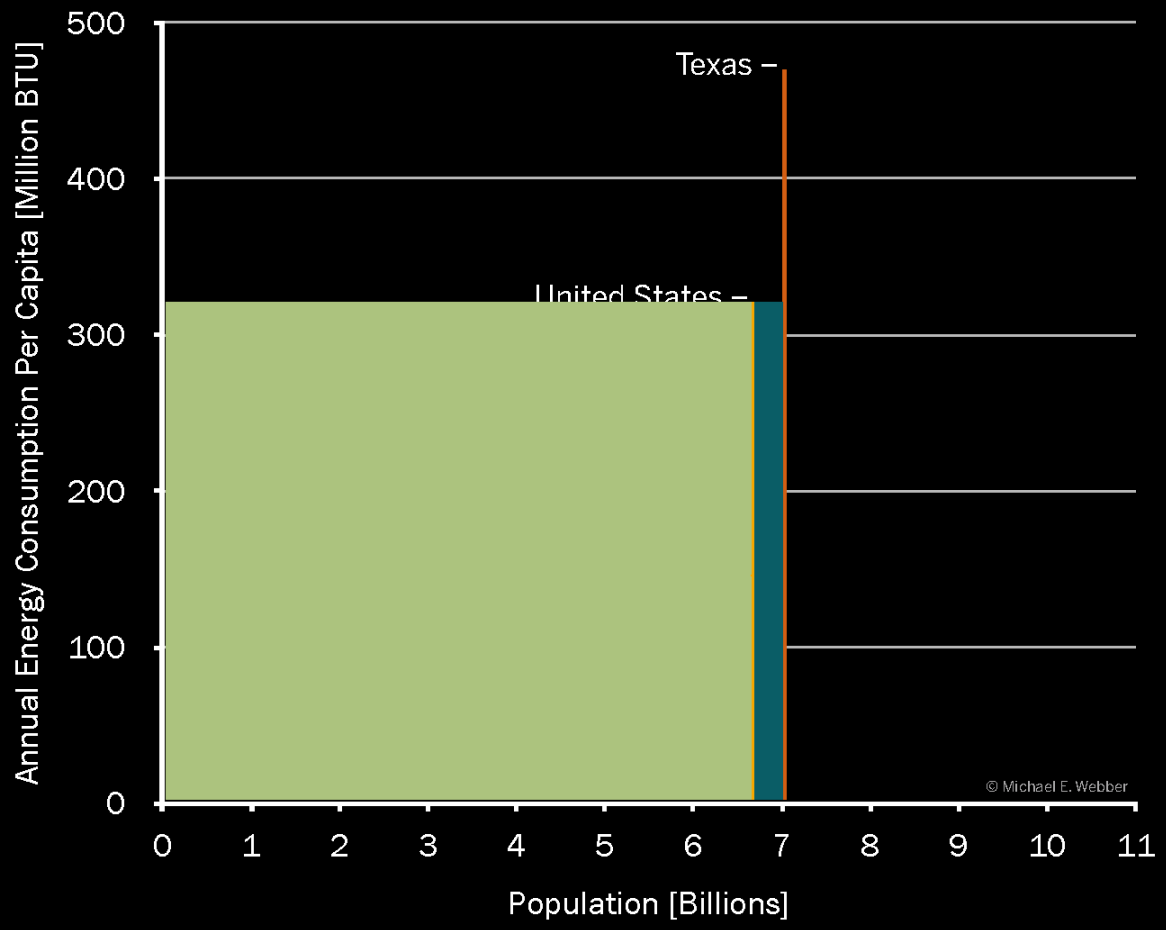
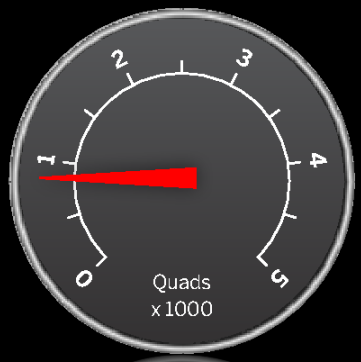
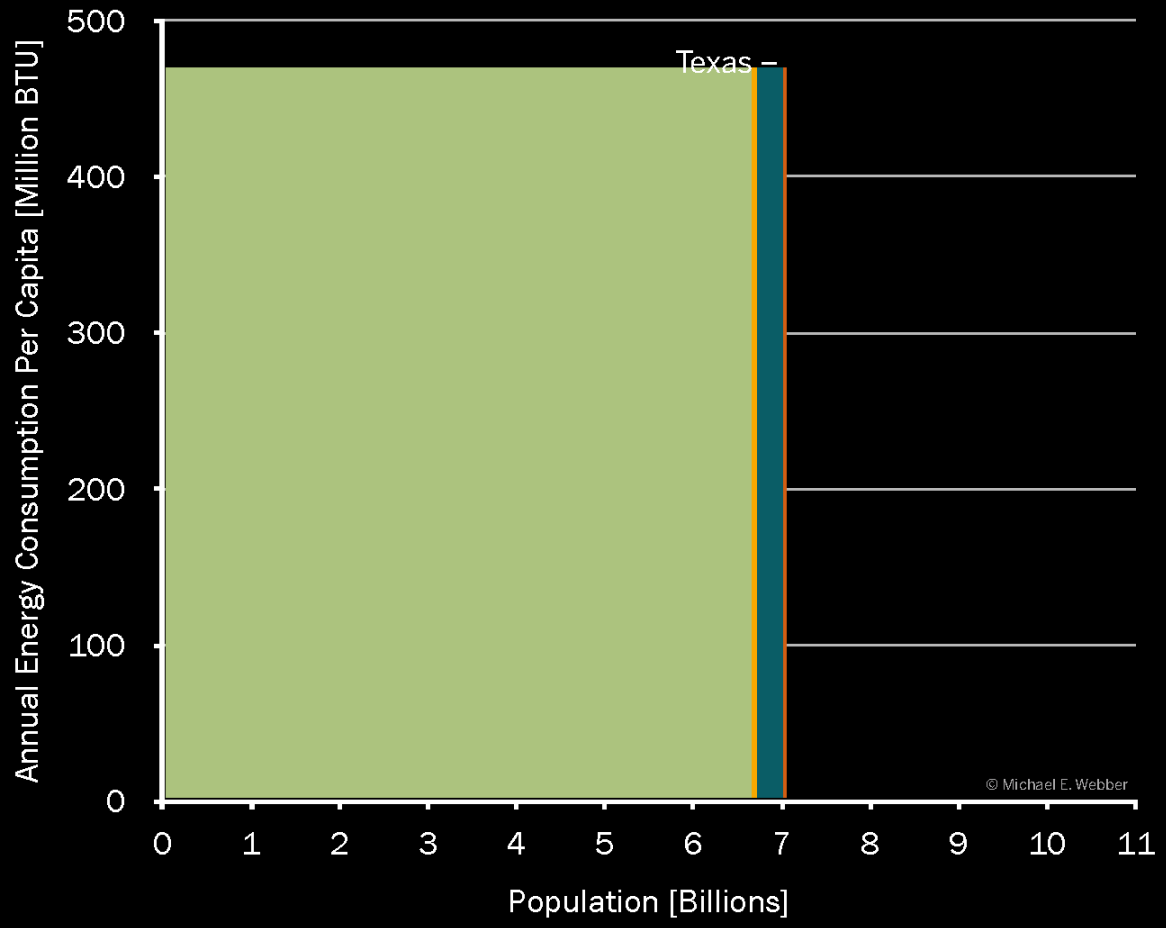


Global Energy Consumption

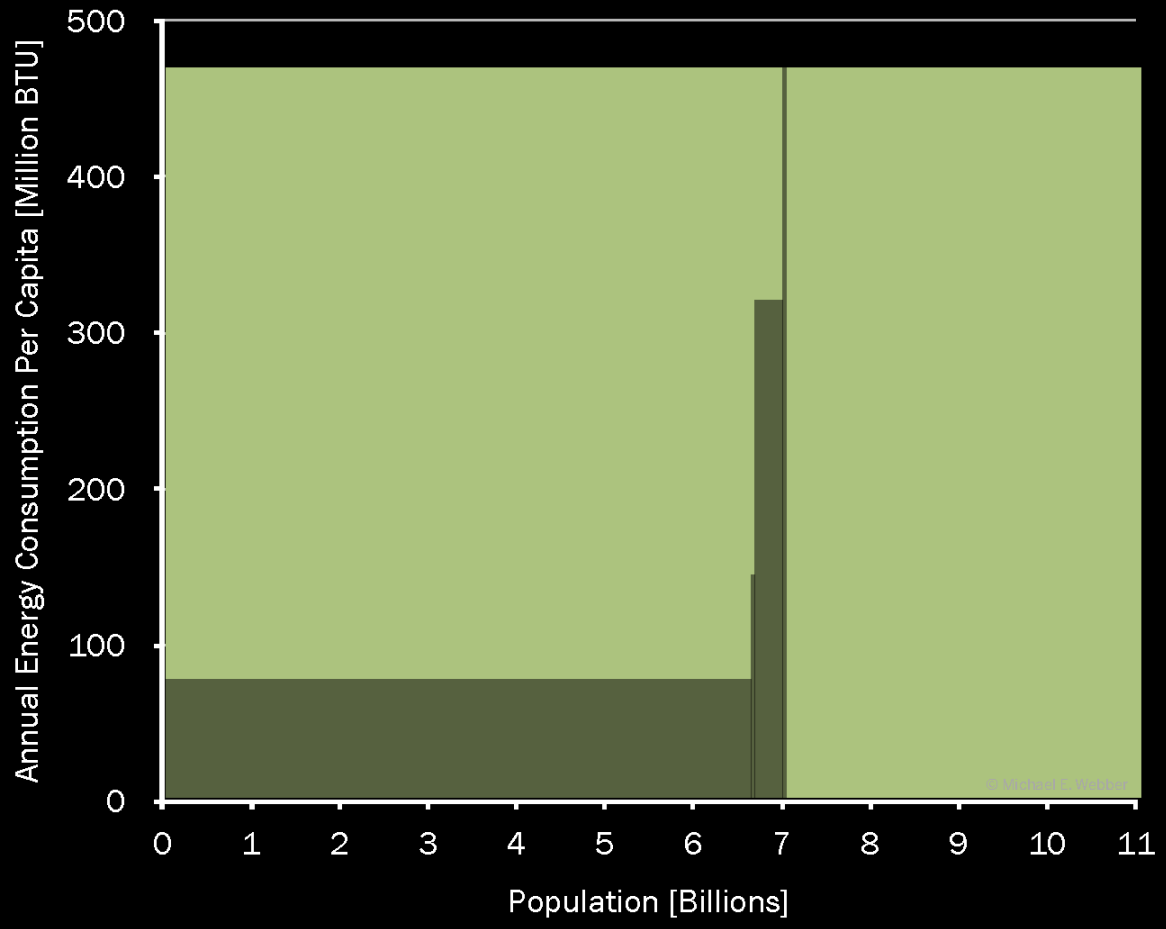


There Are Great Inequities In Global Energy Consumption



Global Energy Consumption

There Are Great Inequities In Global Energy Consumption



Global Energy Consumption

Energy is going through a global transition.

Several Global Trends are Driving the Energy System

- Population growth
- Economic growth
- Urbanization
- Industrialization
- Electrification
- Motorization

Technology Trend 1: Decreasing Resource Intensity

Products and services will get leaner

Technology Trend 2: Increasing Information Intensity

Products and services will get smarter

Technology Trend 3: Increasing Customization

Products & services to be distributed, on-site, tailored

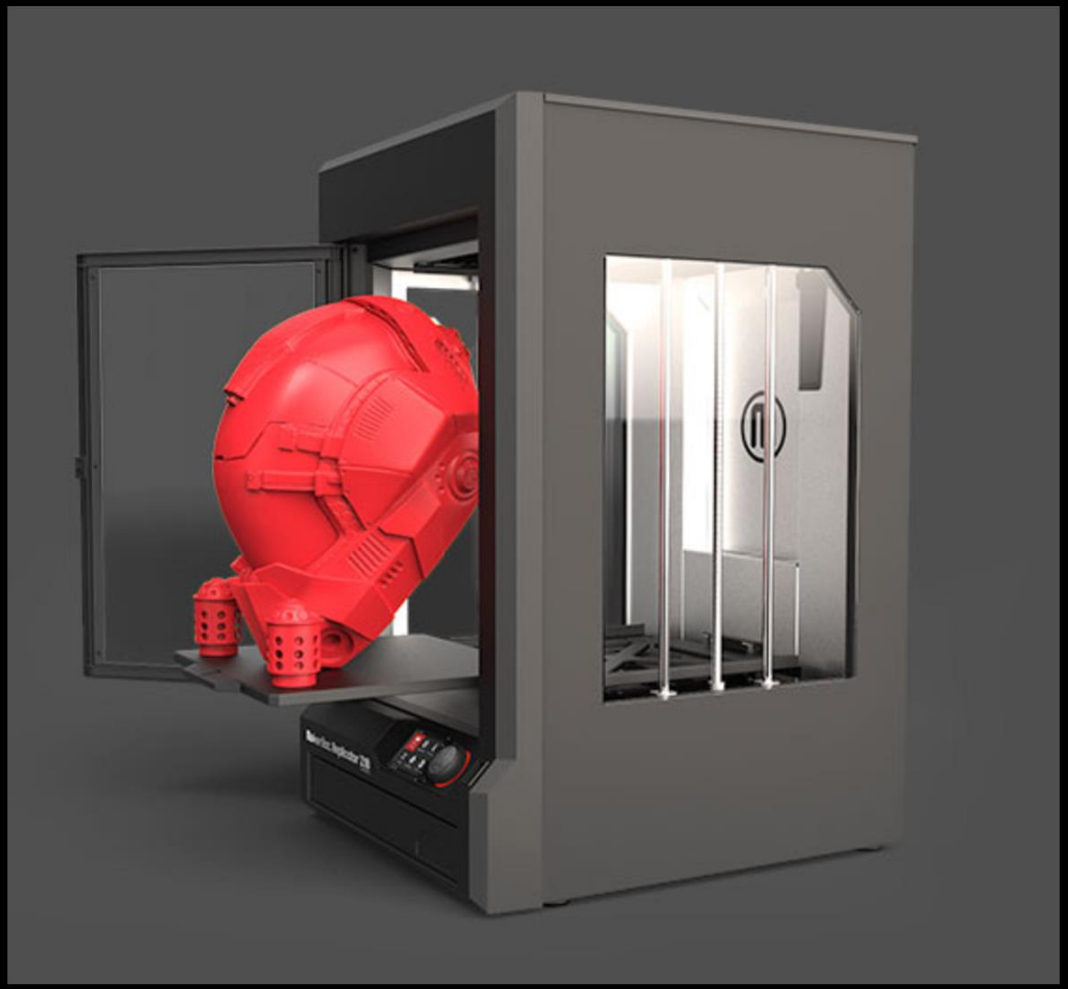
There Are Several Technology Winners

- On-site energy production with solar panels

There Are Several Technology Winners

- On-site water production with rainwater harvesting, re-use and treatment

There Are Several Technology Winners



- On-site manufacturing with 3-D printers

There Are Several Technology Winners

- On-site healthcare with local sensors and remote diagnosis

There Are Several Technology Winners

Increasing democratization of resource decisions will liberate society as a whole, which is a good thing

So what do we do first while waiting for new technologies?

We Need More Time

"Turn off the water, Daddy. The scientists need time."

—Evelyn Webber, 7 years old, March 2007

Conservation Works At Many Scales

- Small scale:
  - –Turn off the water when you brush
  - –Turn off the lights when you leave the room
- Medium scale:
  - –Drive an energy-efficient car
  - –Reduce, reuse and recycle
- Large scale:
  - –Make cities more compact and smart
  - –Make power plants more efficient

The world needs resource-conscious people who can lead us to a better path.

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