# Adapting to Climate change: Extreme Weather Events, a Worldwide Energy Revolution and Geoengineering options

**Week 4, part B: April 17th, 2017**
**Intro to the Energy Revolution**

**Paul Belanger, Ph.D.**

# Announcements

# This Thursday April 20th 7 p.m.

- **Simple, Serious, and Solvable: The Three S's of Climate Change**
- **Scott Denning, Atmospheric Sciences, Colorado State University**
- **Synopsis:** Simple, Serious, and Solvable: The Three S's of Climate Change
- Details: http://coloscisoc.org/

# This Saturday April 22nd

- **DOWNTOWN – March for Science**
  - Citizens Climate Lobby
  - Colorado Scientific Society
  - Others

# Thursday April 29th , 7 p.m.

- **Colorado Renewable Energy Society:**
  - Jeffco chapter presents:

**KK DuVivier: Deep Decarbonization - It's the Rules, Stupid!**

  - https://www.cres-energy.org/

# NREL TOUR MAY 8TH

- Energy Systems Integration Lab
- 1:30-3:00 p.m.; please aim to be there ~1 p.m.
- GOVERNMENT ID: CDL / passport
- Read attachments I sent

- Paul Belanger:
  - PEBelanger@glassdesignresources.com
  - c. 303-249-7966; h 303-526-7996

# Today's paper

## NREL is a driver of cutting-edge research and industry

By Greg Dobbs

What you might already know is, America is closer to energy independence than we've ever been in modern times. What you might not know is, that's thanks in part to a federally funded lab, right here in Colorado, doing cutting-edge energy-increasing research. So it's a shock that in the president's proposed budget, it is on the chopping block.

Of course if you don't want better gas mileage and cheaper electricity and more efficient buildings and sustainable sources of energy that will never melt away (not to mention the eco-

big automakers, including America's Big Three. These private companies, strapped for research and development money, give their vehicles to the federal lab to work with, looking for innovative efficiencies. Out of that, for one example, came the first production-feasible hybrids. For another, they're experimenting to extract more than the 20 percent of gasoline's power that we get from gas today.

Solar energy? Same story. Private industry makes incremental improvements in the efficiency and flexibility of solar panels. But NREL's scientific brain trust has developed what its director, Martin Keller, calls "the game-

Wind turbines operate at NREL's National Wind Technology

Earth's geothermic temperatures into the system that heats and cools workers' cubicles. Hewlett-Packard and Intel built a water-cooled supercomputer, from which NREL then circulates the super-heated water, saving $1 million a year.

A letter-writer to The Denver Post last week wondered where we'd be today if cellphone research in the 1990s had been cut and developers just tried to make old rotary phones better. That's what we're talking about now with renewable energy. We can accept incremental improvement, or insist on innovation. That's not quixotic, it's practical

Don Sorenson

http://www.denverpost.com/2017/04/16/nrel-drives-cutting-edge-research-and-powers-industry/

# CONSEQUENCES OF CLIMATE CHANGE

- Just finished extreme weather events
- First hour with suggested Carbon fee solutions regarding how to encourage reducing emissions

# Phil Discussed Attribution and Risk

## The Attribution Confidence Varies

## There are other factors as well

- Are Consequences Statistically Significant?
- Maybe they are not currently statistical but should we wait for that?

# CONSEQUENCES OF CLIMATE CHANGE

- However I wish to mention in passing 2 other serious consequences:
  - Climate refugees
  - Ocean Acidification

# CONSEQUENCES: Climate Refugees
# We have not seen anything yet!





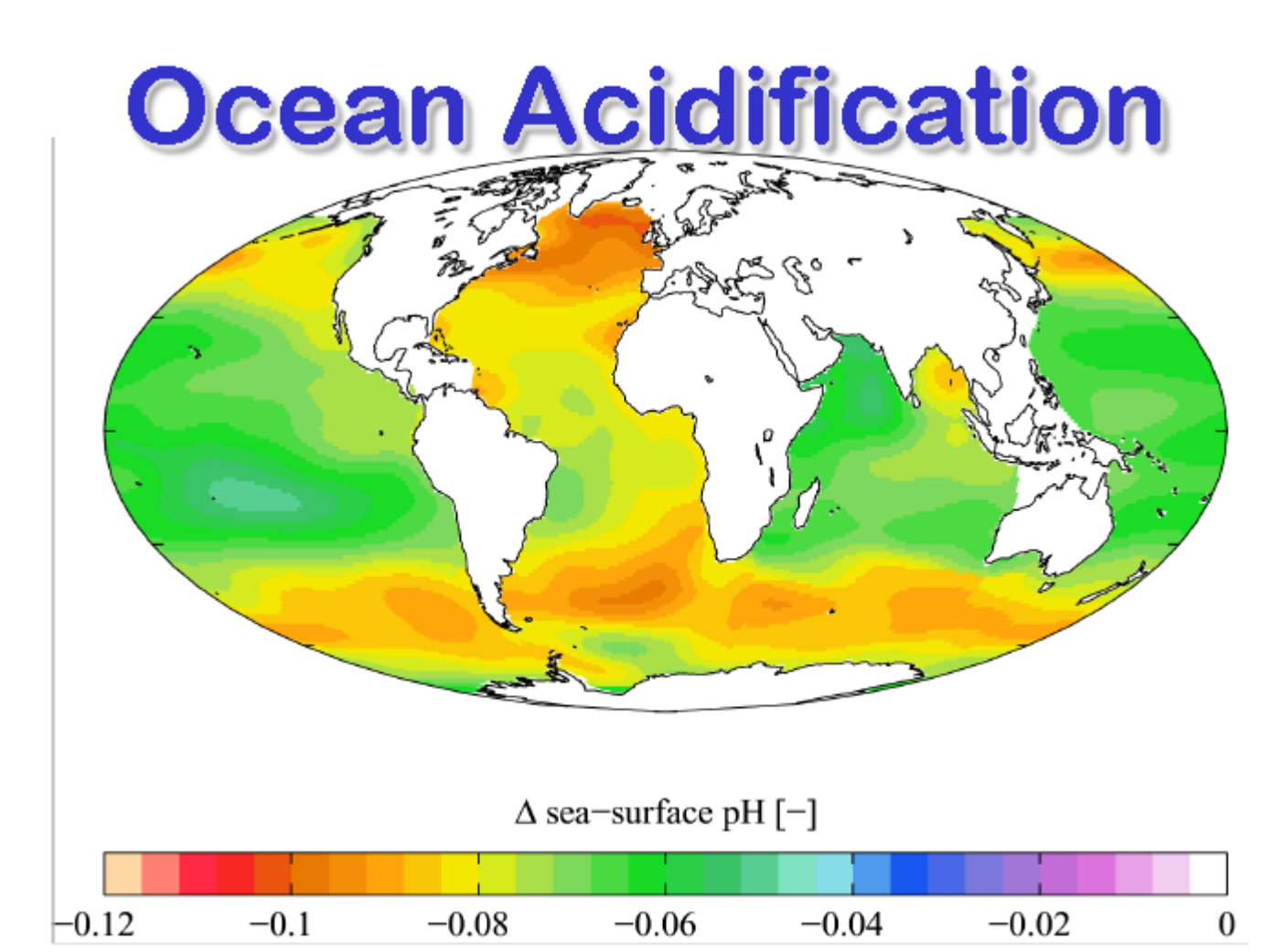





# In the Face of Compassion Fatigue

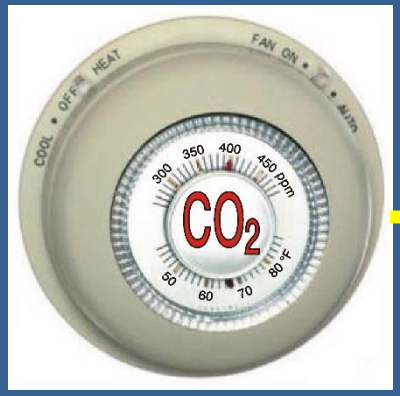
- Will we respond?
- Or will we be nationalistic?

# Another Consequence:
# Ocean Acidification
# What's will be its impact on the food chain?




From Where has all the carbon gone: Scott.Denning@ColoState.edu

# It Boils Down to Degraded Sustainability




More Water Vapor and Clouds

Warmer Air, Warmer Water (Global Warming)

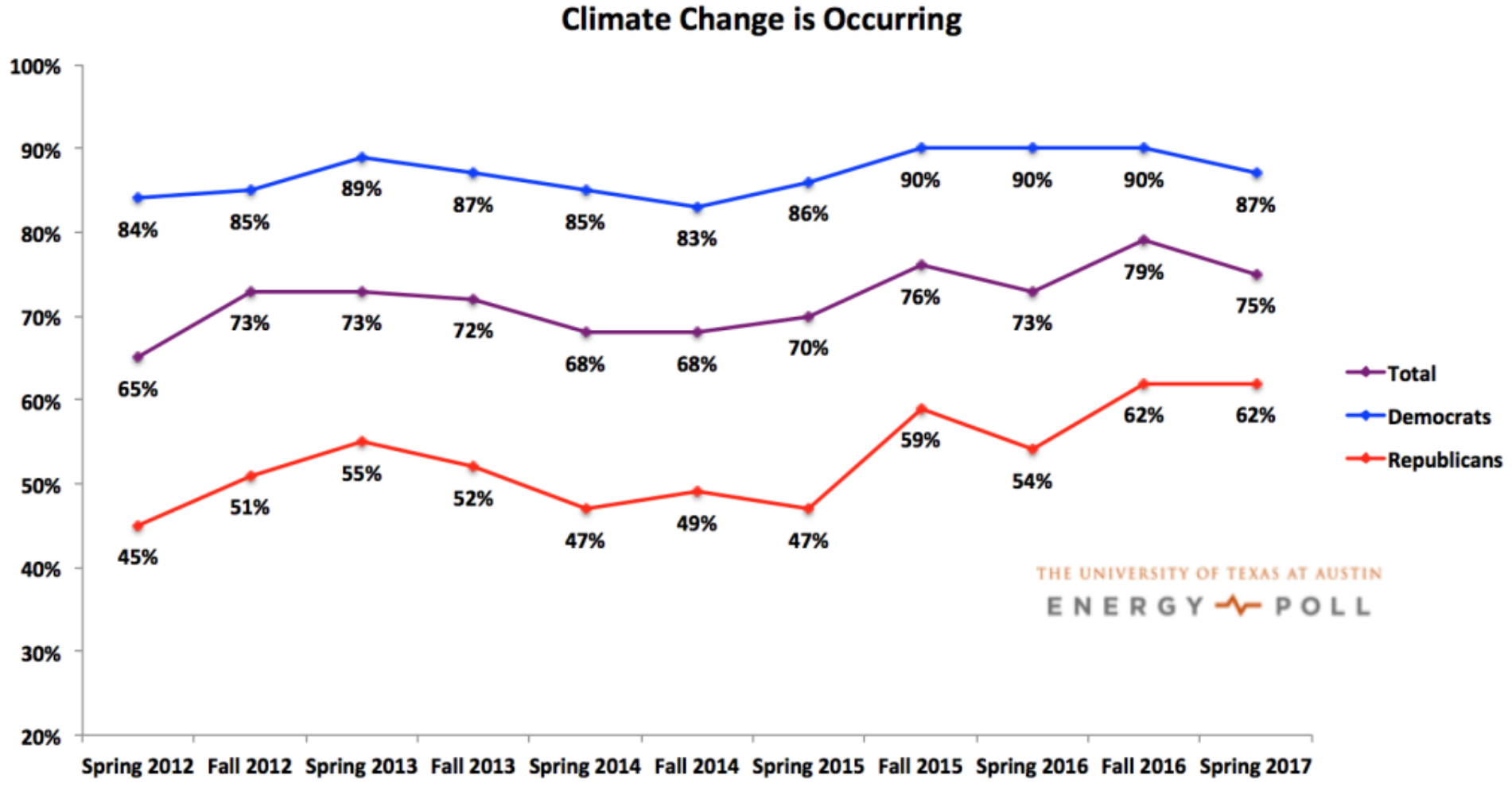
Atmosphere
Biosphere
Hydrosphere
Cryosphere
(Climate Change)

J

Human Activity

Courtesy Phil Nelson

# Poll spring 2017




http://www.utenergypoll.com/

# HOW IS THE WORLD RESPONDING?

**THE WORLDWIDE ENERGY REVOLUTION!**

# ENERGY AND CLIMATE CHANGE

**Earth**

Human Population = 7.3 B

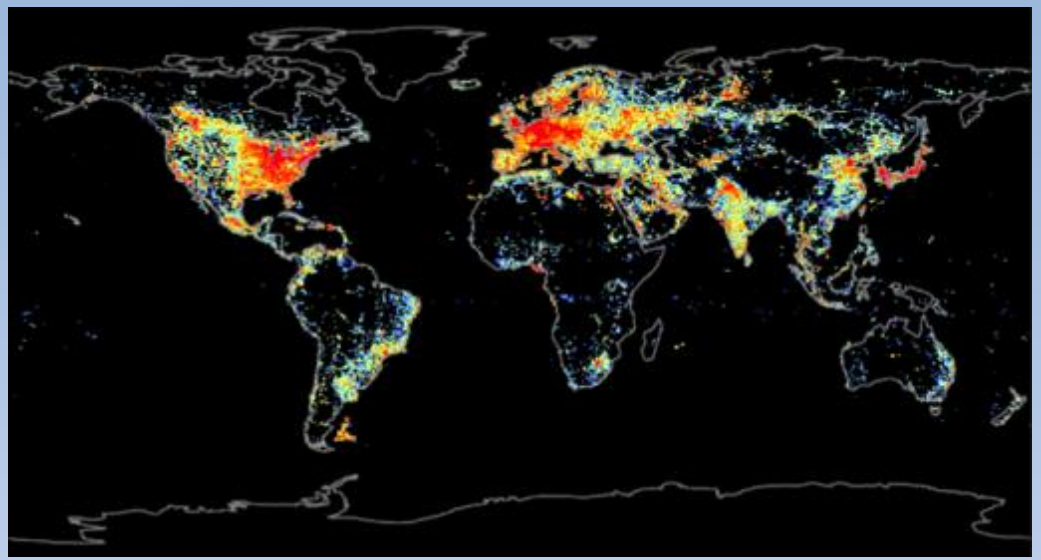
Annual Electricity Demand = 23,300 TWh

Annual CO2 Emissions = 32.2 Gt

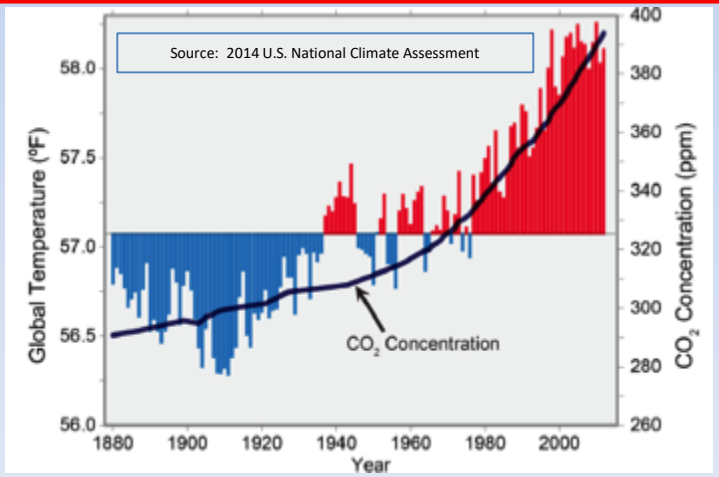
Fraction of GHG Emissions from Energy Use ≈ 68%

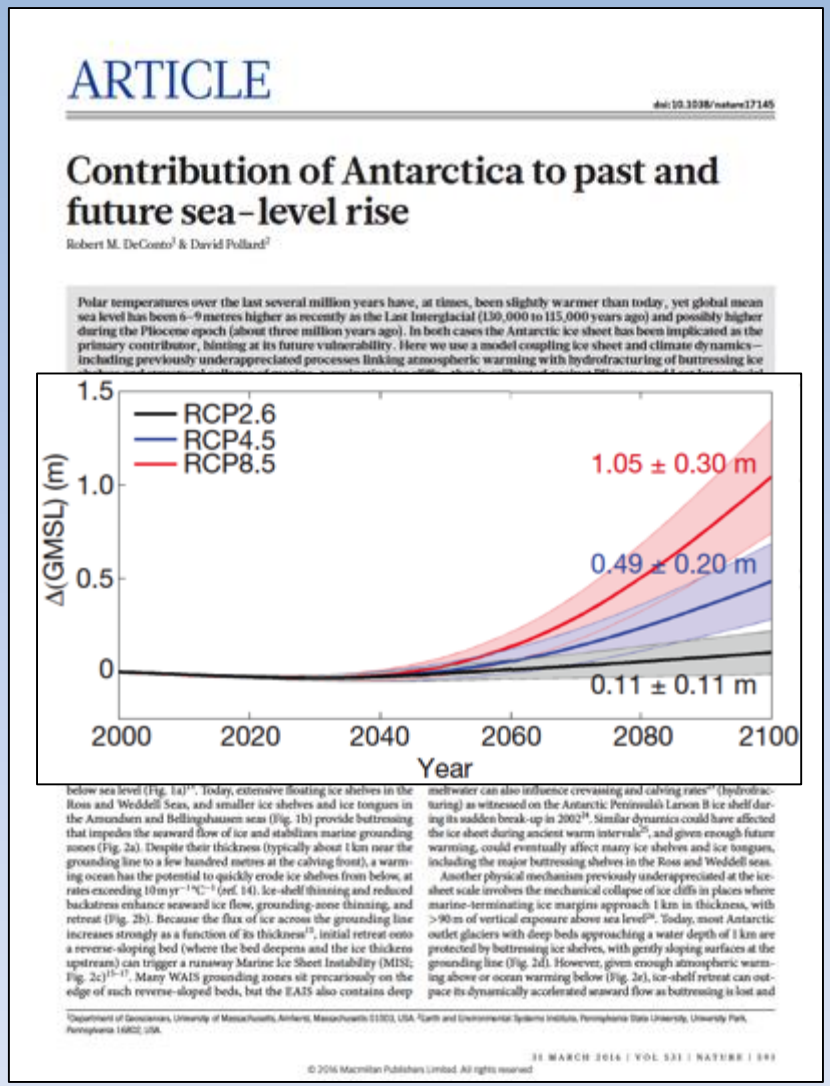
Courtesy Greg Wilson, NREL

# Motivation is Clear – Energy Needs vs. $CO_2$



- **Humanity requires ~6 TW of electrical generating capacity, ~2/3 from fossil fuels.**
- **[$CO_2$] ~402 ppm and rising.**



ARTICLE

doi:10.1038/nature17145

## Contribution of Antarctica to past and future sea-level rise

Robert M. DeConto[1] & David Pollard[2]

Polar temperatures over the last several million years have, at times, been slightly warmer than today, yet global mean sea level has been 6–9 metres higher as recently as the Last Interglacial (130,000 to 115,000 years ago) and possibly higher during the Pliocene epoch (about three million years ago). In both cases the Antarctic ice sheet has been implicated as the primary contributor, hinting at its future vulnerability. Here we use a model coupling ice sheet and climate dynamics—including previously underappreciated processes linking atmospheric warming with hydrofracturing of buttressing ice



Nature - 31 March, 2016

Courtesy Greg Wilson, NREL

# The Essentials of Energy

- https://www.youtube.com/watch?v=ytwIzy3XuGg&t=41s

# Energy

- The discovery of energy is not credited to one particular individual because there are several types of energy, and each was discovered by a different person at a different time.
- For example, Michael Faraday discovered electromagnetic energy and Benjamin Franklin discovered positive and negative electrical charges

https://www.reference.com/history/discovered-energy-e9b1c730fb6722a7#

# The Essentials of Energy

- Energy & Power (not the same)
- Joules (J), calories, BTUs vs. watts (W, kW, MW, GW
- Energy = Power X time = kWh
- 100 W light bulb uses 100 J/s

# Terms & Forms of Energy

- Kinetic
- Potential
- Mechanical
- Electric
- Magnetic
- Gravitational
- Ionization
- Nuclear
- Chromodynamic (quarks to form hadrons)
- Elastic
- Mechanical Wave
- Sound wave
- Radiant
- Chemical
- Thermal

https://en.wikipedia.org/wiki/Energy#Forms

# UNITS

- International System of Units (SI)
  - SI = Joule – force of 1 Newton needed to move one Kg a distance of 1 meter
  - 4.186 Joule = 1 calorie
  - Other: Ergs, calories (food: 1 **C**alorie = kcalorie), BTU, kWh, calorie (water heating 1 gm, 1 $^{o}$C)
- SI Rate = watt = 1 joule/second
  - 60*60 = 3600 joules = 1 watt-hour

# Efficiency


Be Smart: https://www.youtube.com/watch?v=ytwIzy3XuGg

- Humans = 120W; 1/5 to brain 14W

Be Smart: https://www.youtube.com/watch?v=ytwIzy3XuGg

# Before the Industrial Revolution (IR)

- Energy needs modest:
  - Sun, wood, straw, dung
  - Horses, wind, water for transportation & grinding grains, etc.
  - Simple Steam engine – back to days of Alexandria
- Harnessing power of coal led to the Industrial Revolution

http://www.ucsusa.org/clean_energy/our-energy-choices/a-short-history-of-energy.html#.WPN83NLyuUk

# The Industrial Revolution

- Thomas Newcomen and James Watt – mid 1700s gave birth to the modern Steam Engine
  - Powered by coal
    - Locomotives,
    - Factories,
    - Farm implements
    - etc.
  - More reliable
- The Industrial Revolution created the Middle Class

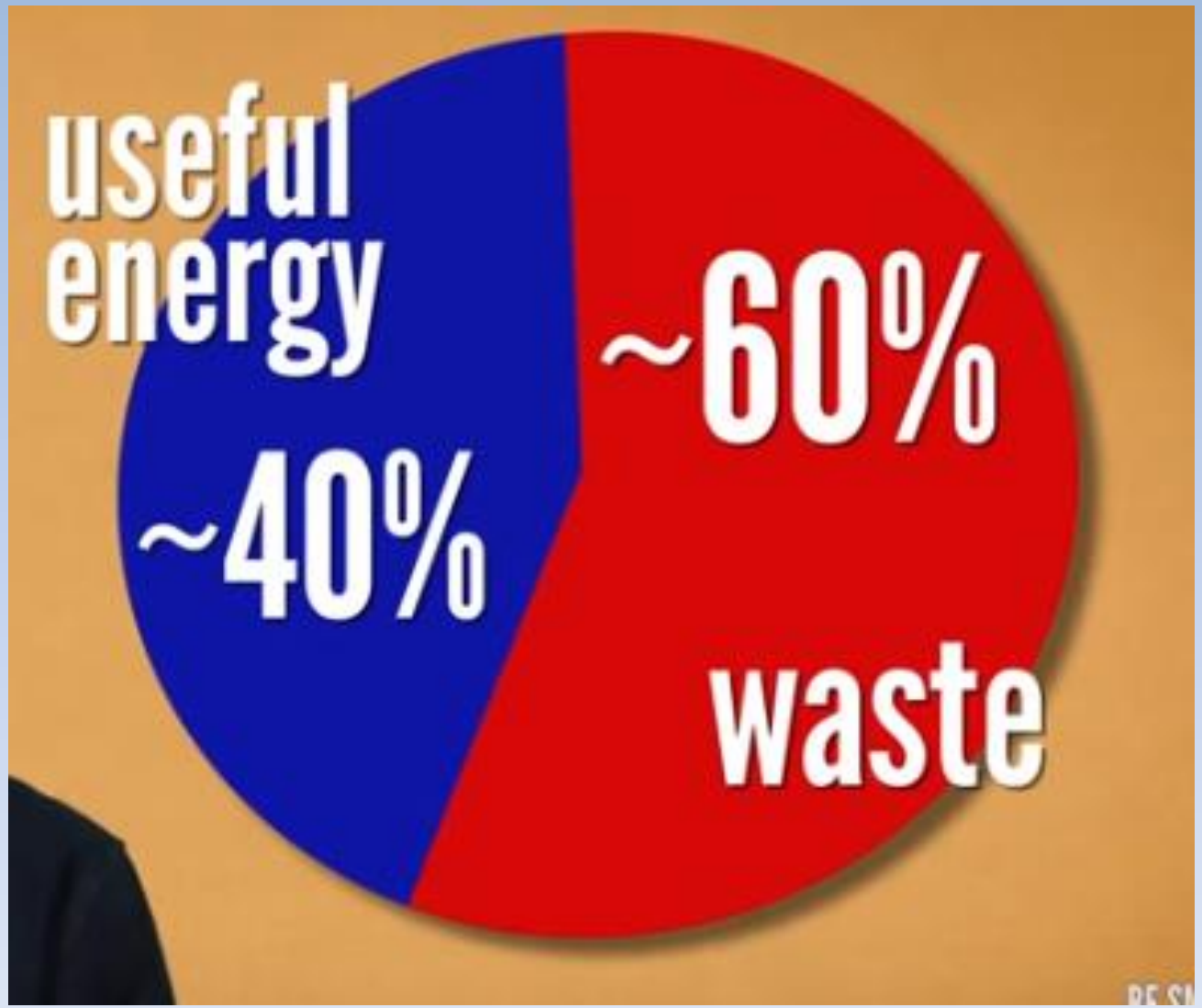
http://www.ucsusa.org/clean_energy/our-energy-choices/a-short-history-of-energy.html#.WPN83NLyuUk

# The Industrial Revolution

- 1880 – first steam engine connected to Electric Generator
- Thomas Edison Plant:
  - First electric light to Wall Street and N.Y. Times
- 1881 – first hydroelectric

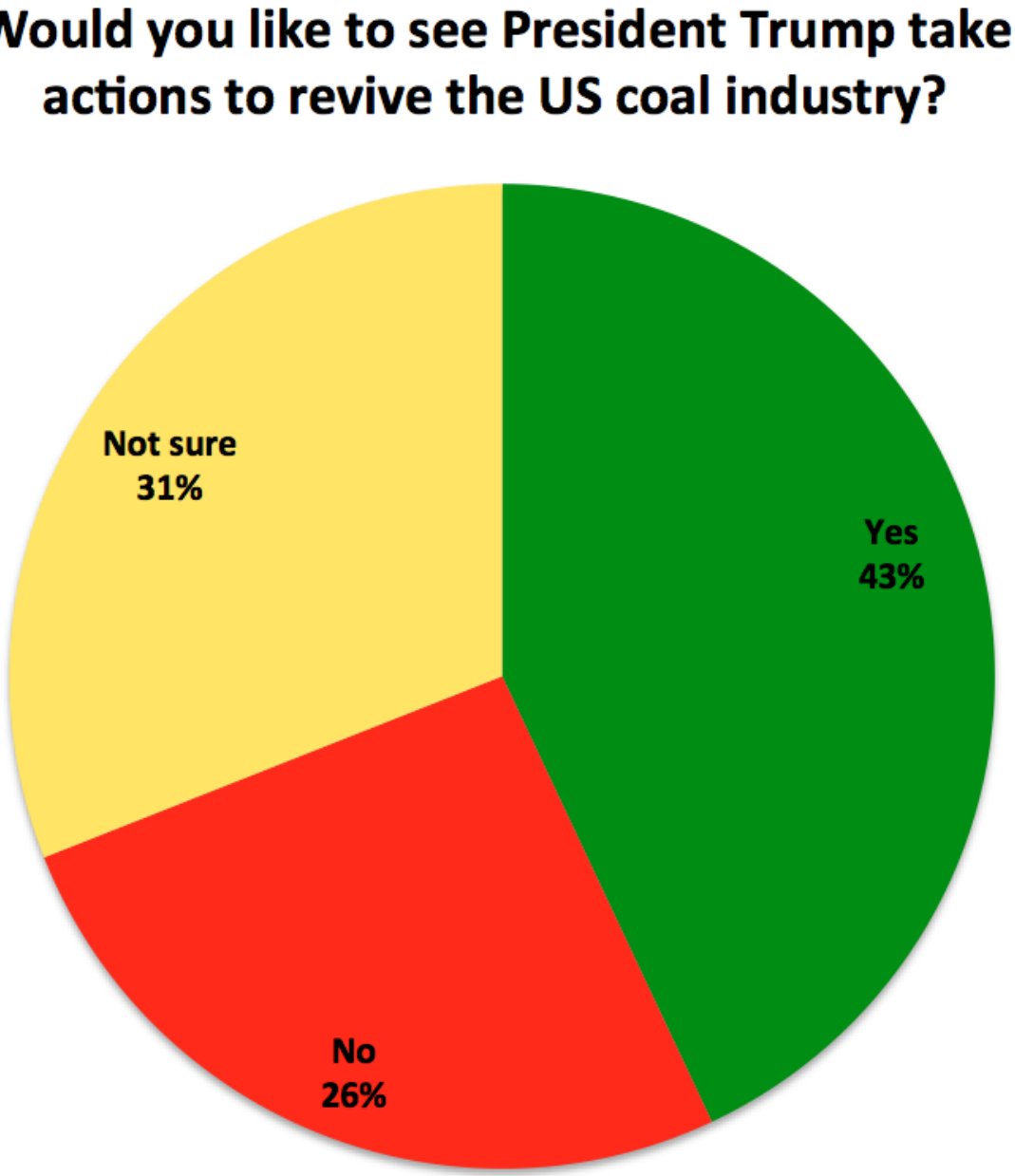
http://www.ucsusa.org/clean_energy/our-energy-choices/a-short-history-of-energy.html#.WPN83NLyuUk

# Entropy; 2nd Law of Thermodynamics




Be Smart: https://www.youtube.com/watch?v=ytwIzy3XuGg

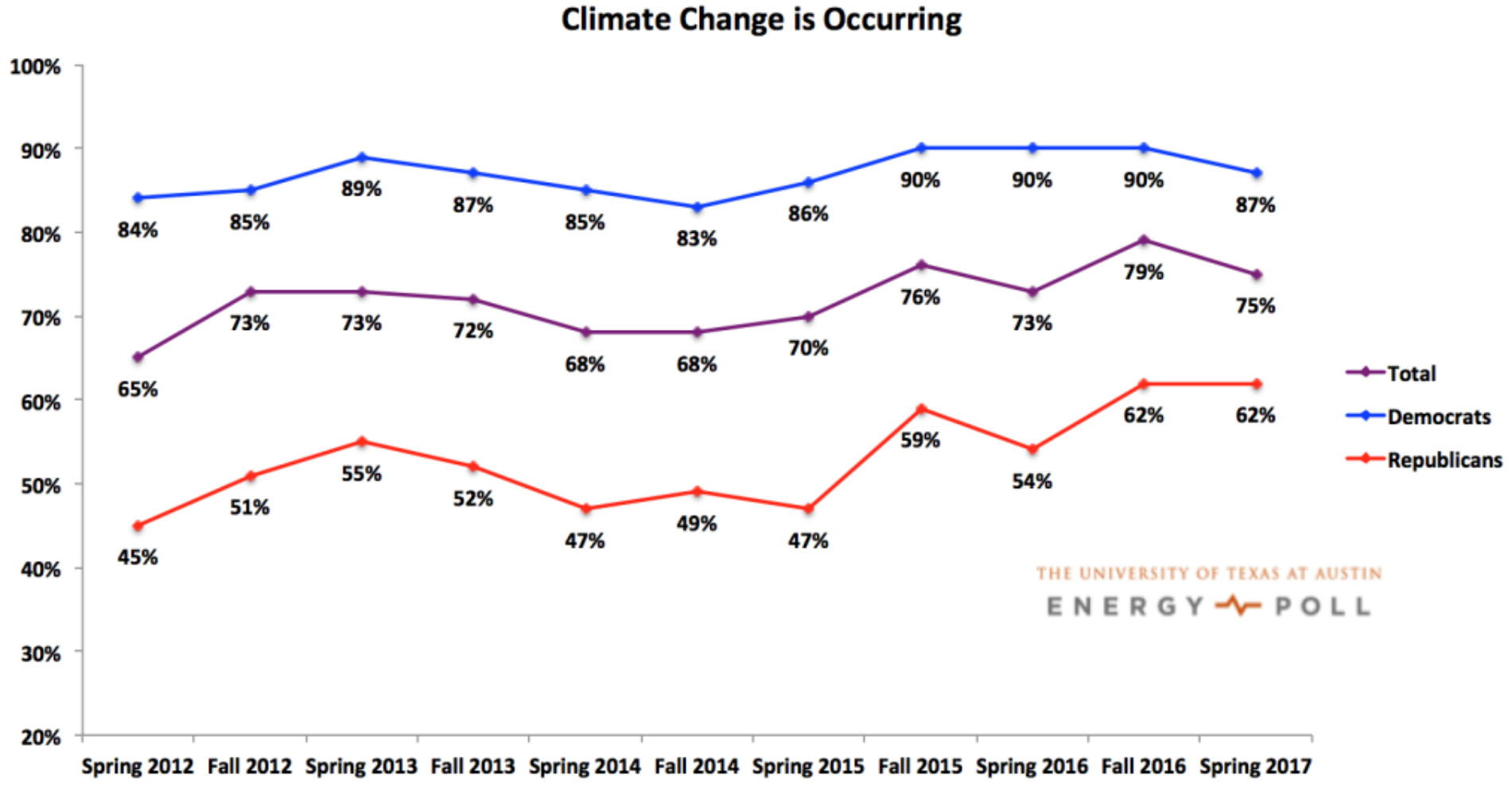
- Poll Spring 2017




http://www.utenergypoll.com/

THE UNIVERSITY OF TEXAS AT AUSTIN
ENERGY POLL

# Poll spring 2017

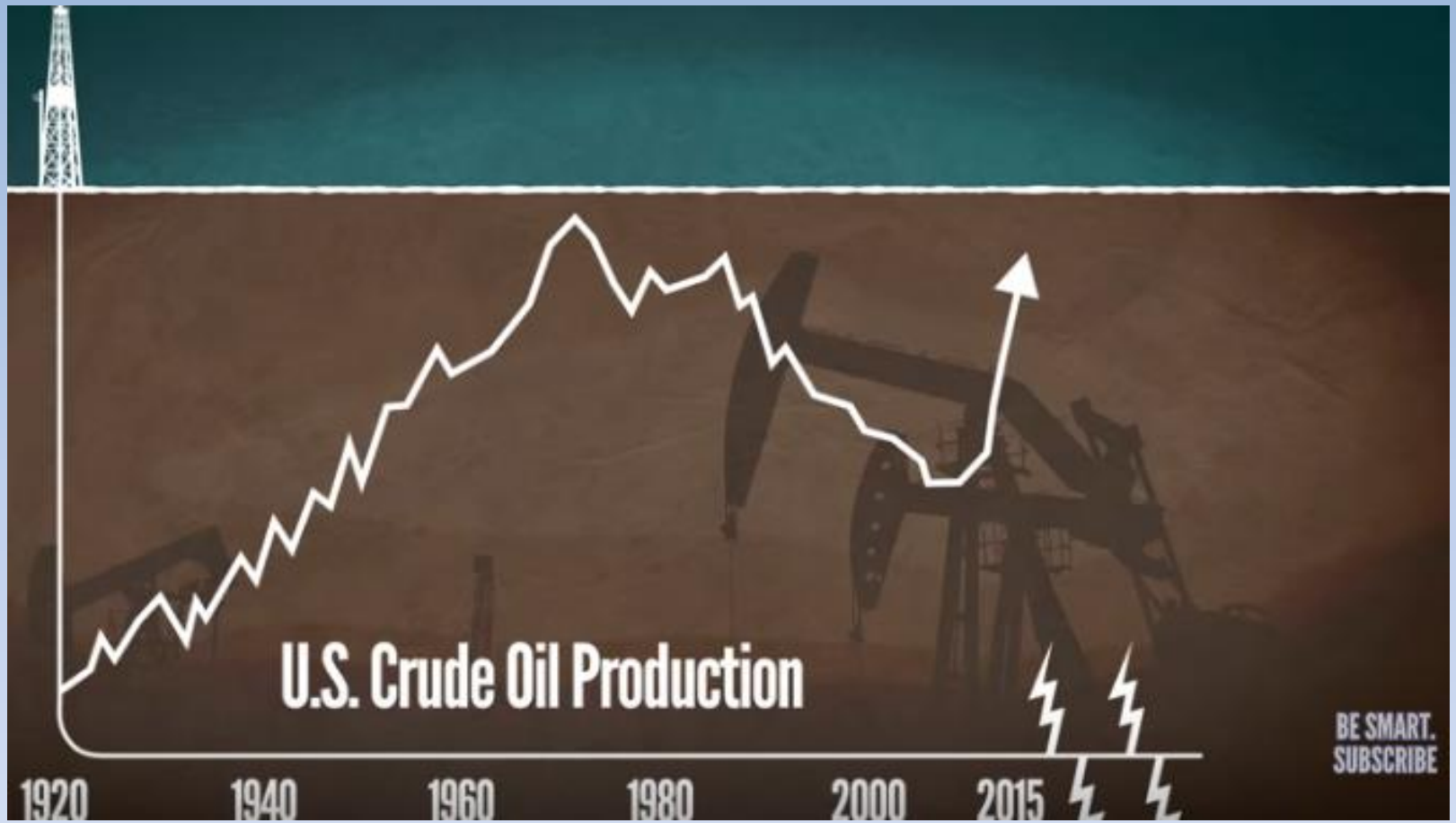



http://www.utenergypoll.com/

# When will we stop using oil

- 95 million barrels oil (bbls 1= 42 gallons)/day
- > 1 trillion bbls remaining – but not all economic


https://www.youtube.com/watch?v=Fjbx5Xq_ULc&t=10s




https://www.youtube.com/watch?v=Fjbx5Xq_ULc&t=10s

# Considering environment and global warming:

- When will we be done with oil – at least in a major way?


https://www.youtube.com/watch?v=Fjbx5Xq_ULc&t=10s

# Depends on other Energy options we have HISTORY:

- 1620: 820 million acres virgin forest
  - 1926 – 138 Million acres
  - Replaced by coal
- 1846 Whale oil
  - Replaced by Kerosene – from Oil

Be Smart: https://www.youtube.com/watch?v=ytwIzy3XuGg

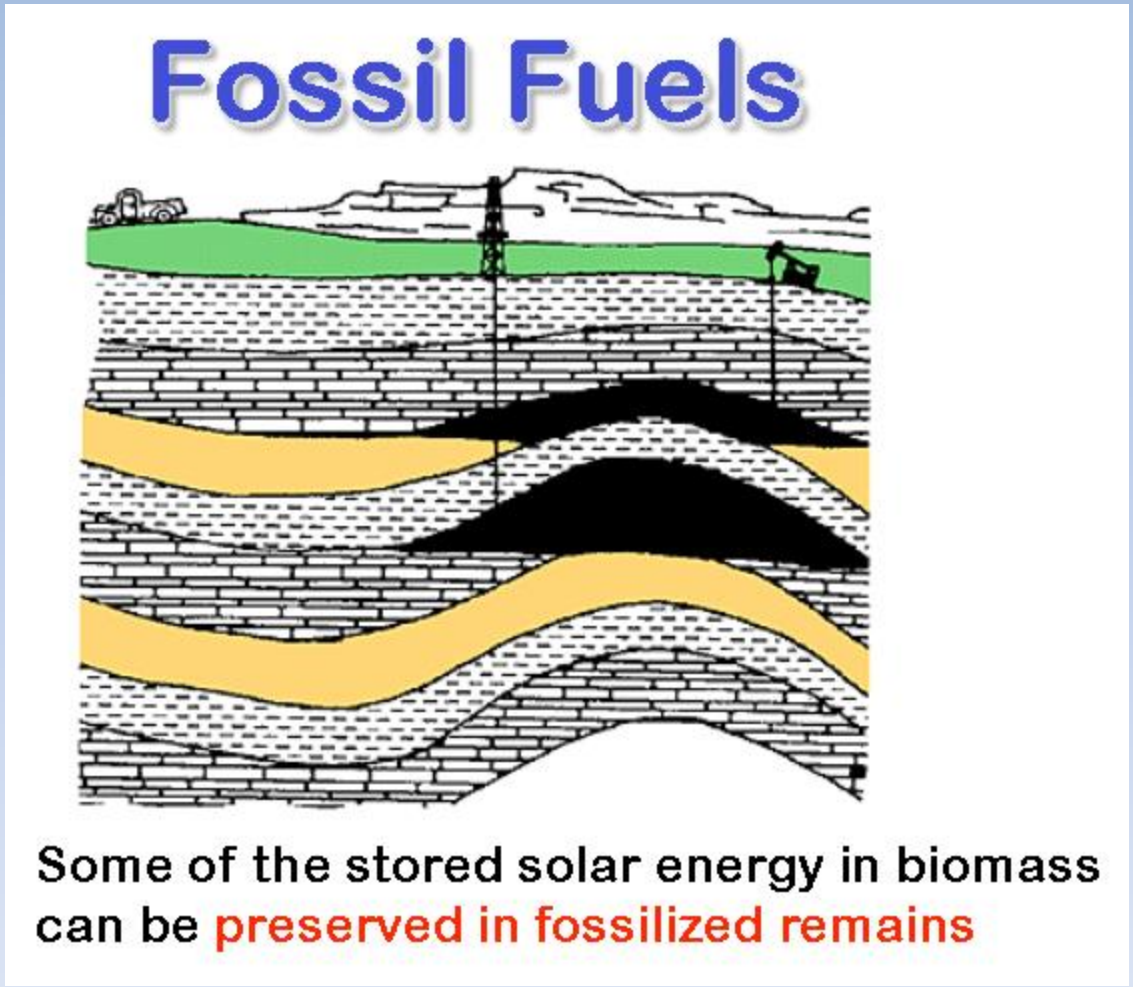
# SOLVING one problem by introducing another - TRENDS

- Steam engine
- Industrial revolution
- History of consuming more energy not just because of population but PER CAPITA

Be Smart: https://www.youtube.com/watch?v=ytwIzy3XuGg

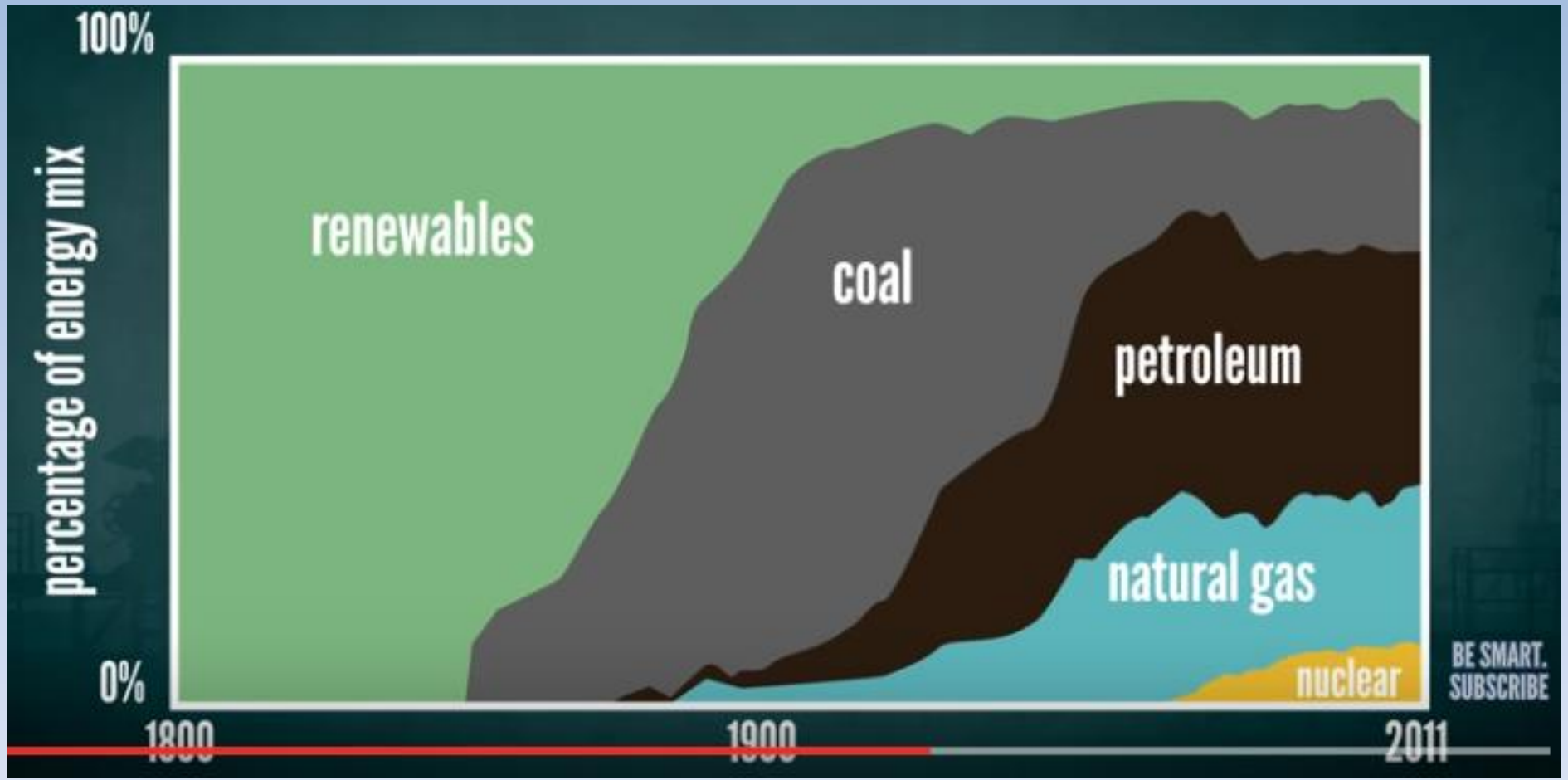
# Fossil fuels: oil, gas, coal

- We owe a lot to fossil fuels
- It's only recently we've fully appreciated it's consequences
- It's time for change!



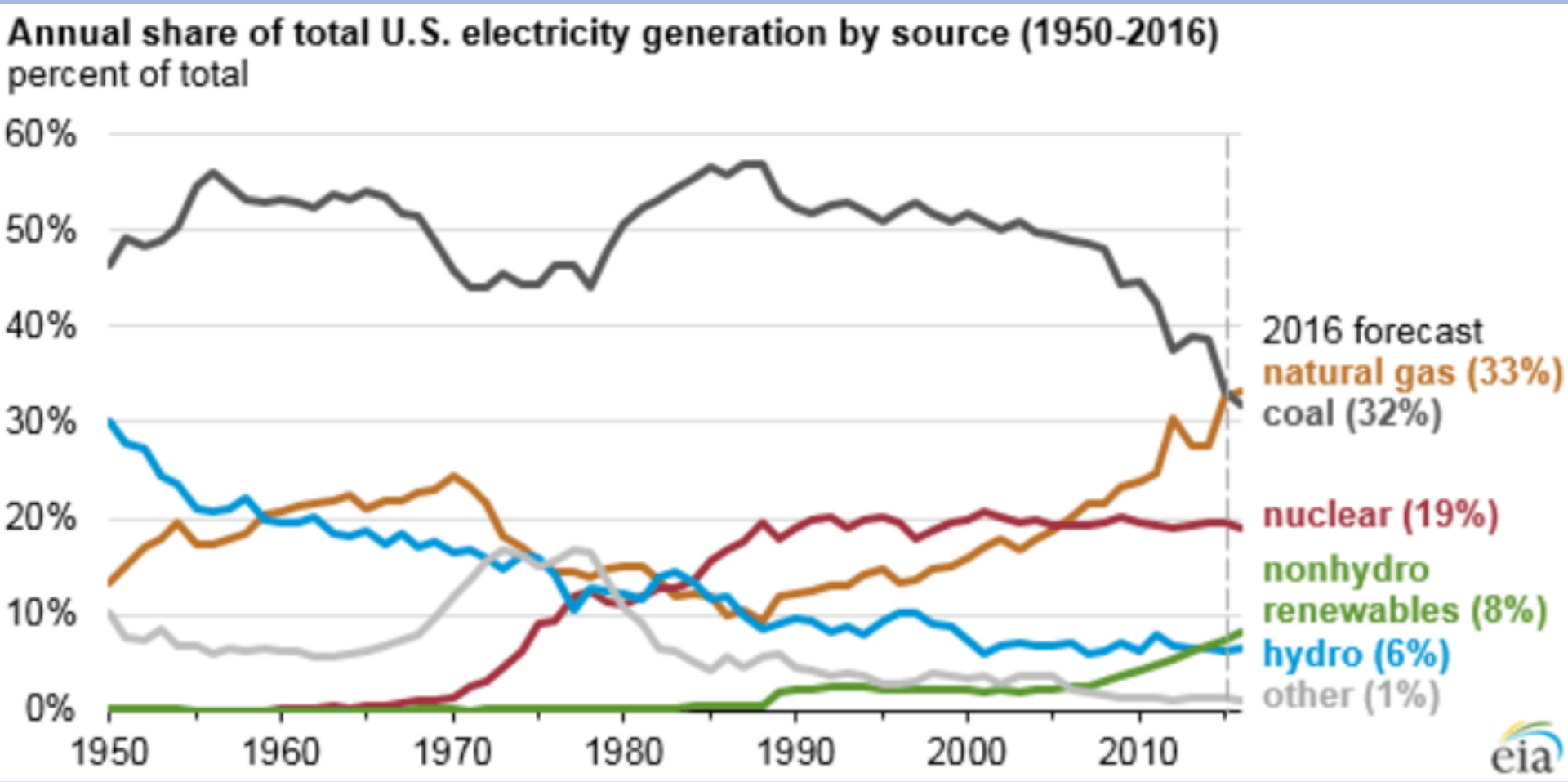

From Where has all the carbon gone: Scott.Denning@ColoState.edu

# COAL – to OIL – to Renewables



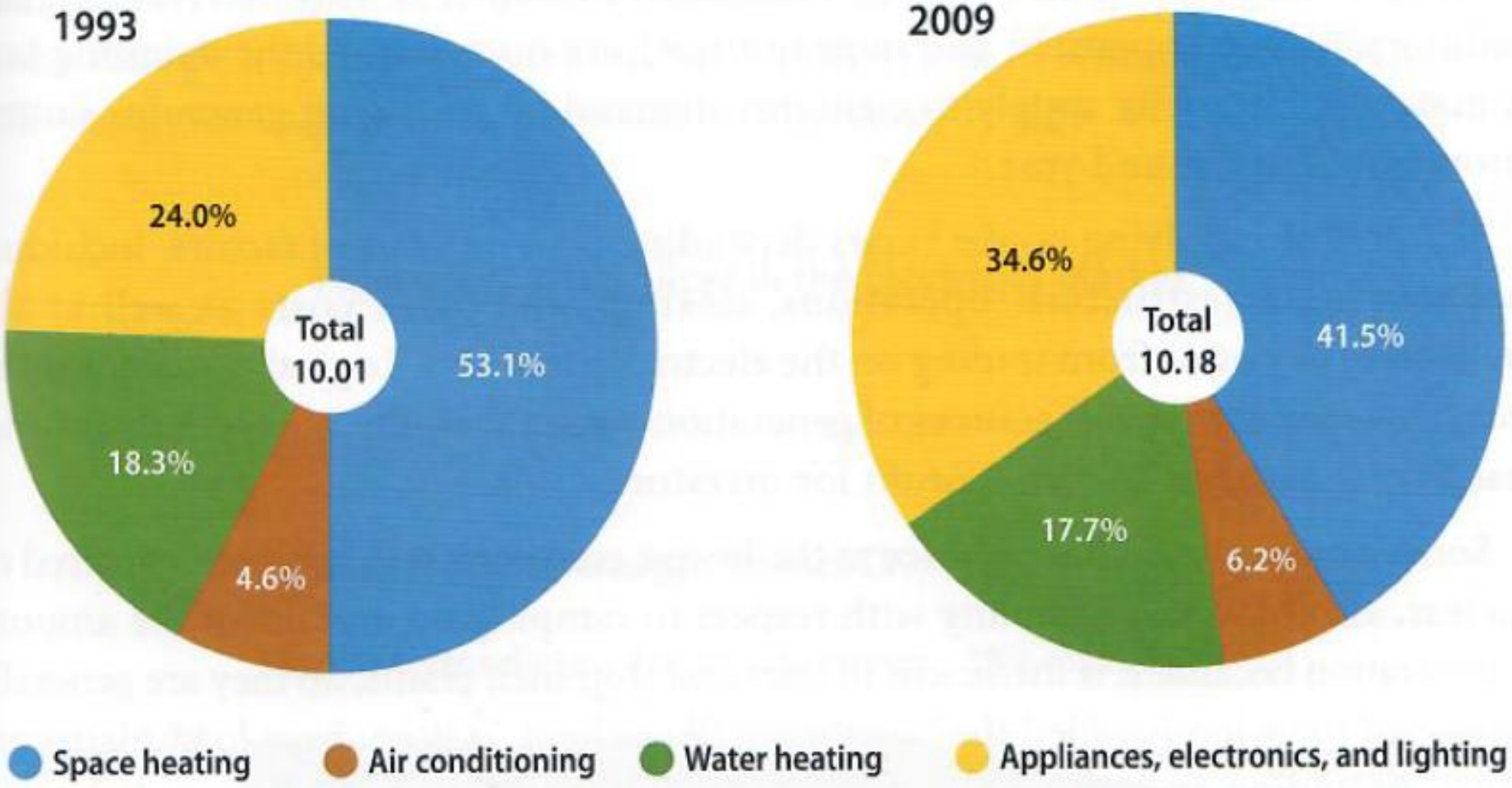

https://www.youtube.com/watch?v=Fjbx5Xq_ULc&t=10s

# Latest DOE


Annual share of total U.S. electricity generation by source (1950-2016)
percent of total
60%
50%
40%
30%
20%
10%
0%
1950
1960
1970
1980
1990
2000
2010
2016 forecast
natural gas (33%)
coal (32%)
nuclear (19%)
nonhydro renewables (8%)
hydro (6%)
other (1%)
eia

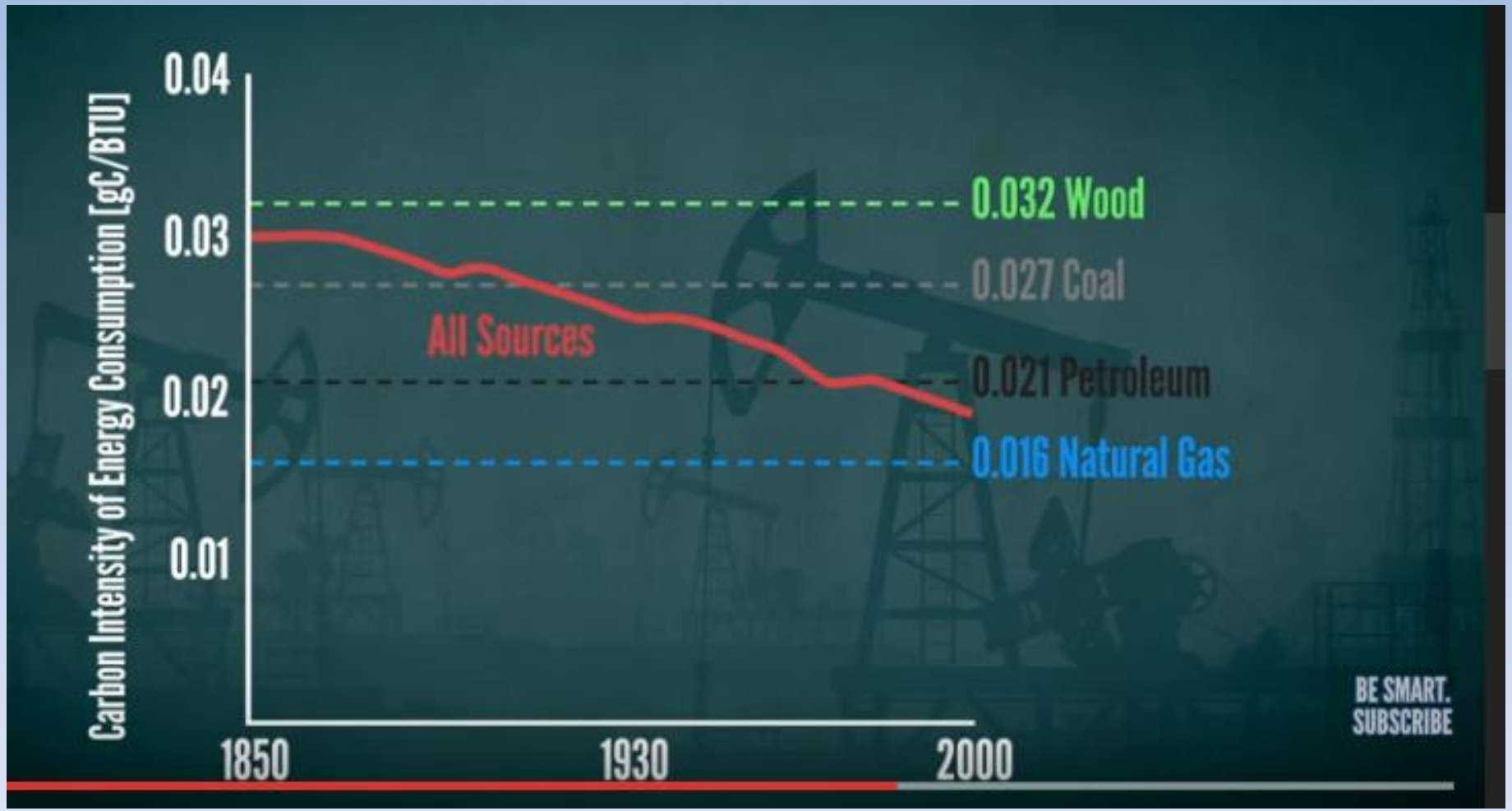
## Figure 5.3. Energy Consumption in Homes by End Uses

quadrillion Btu and percent



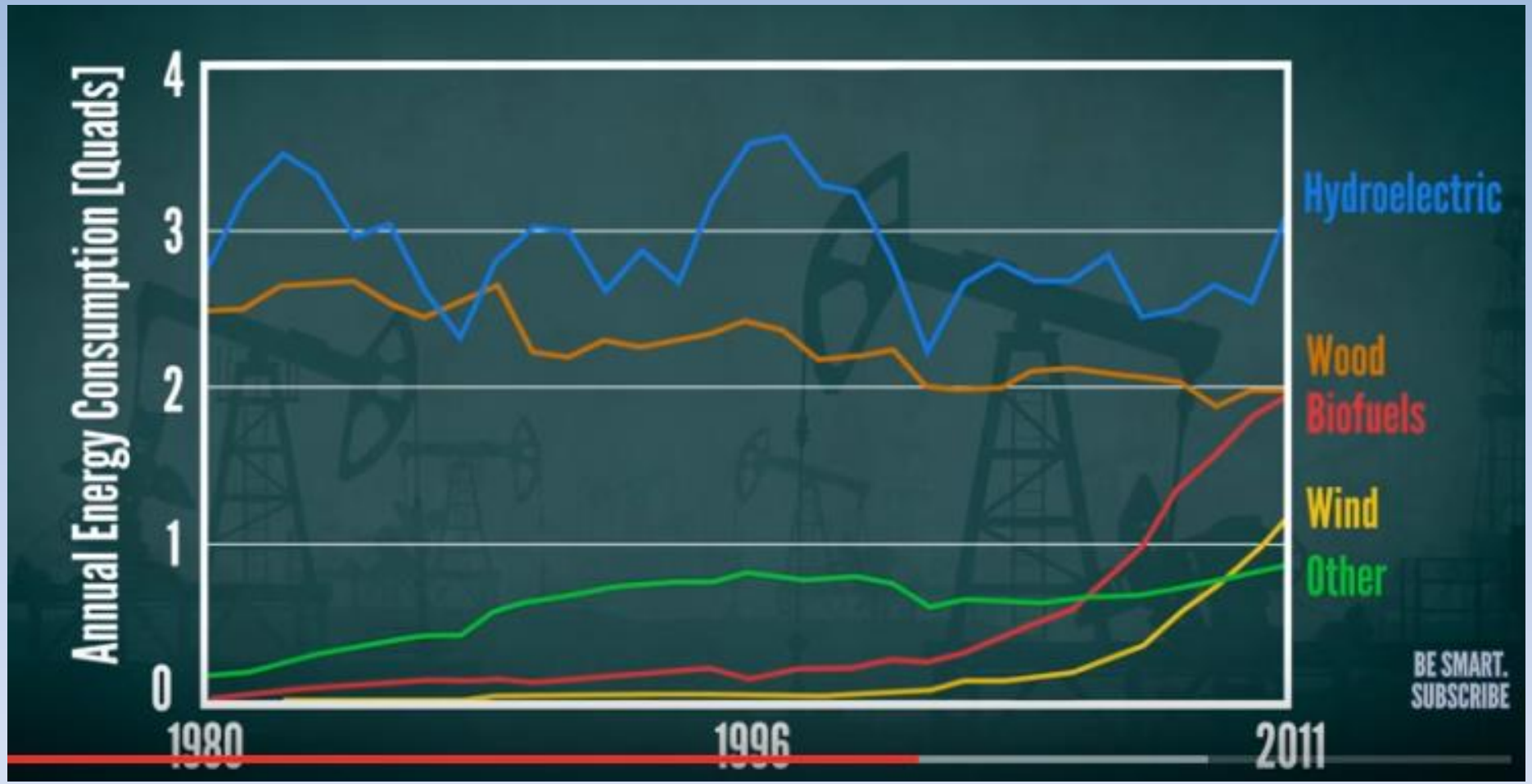

Source: U.S. Energy Information Administration, http://www.eia.gov/todayinenergy/detail.cfm?id=10271.

# More energy per unit CO2




https://www.youtube.com/watch?v=Fjbx5Xq_ULc&t=10s

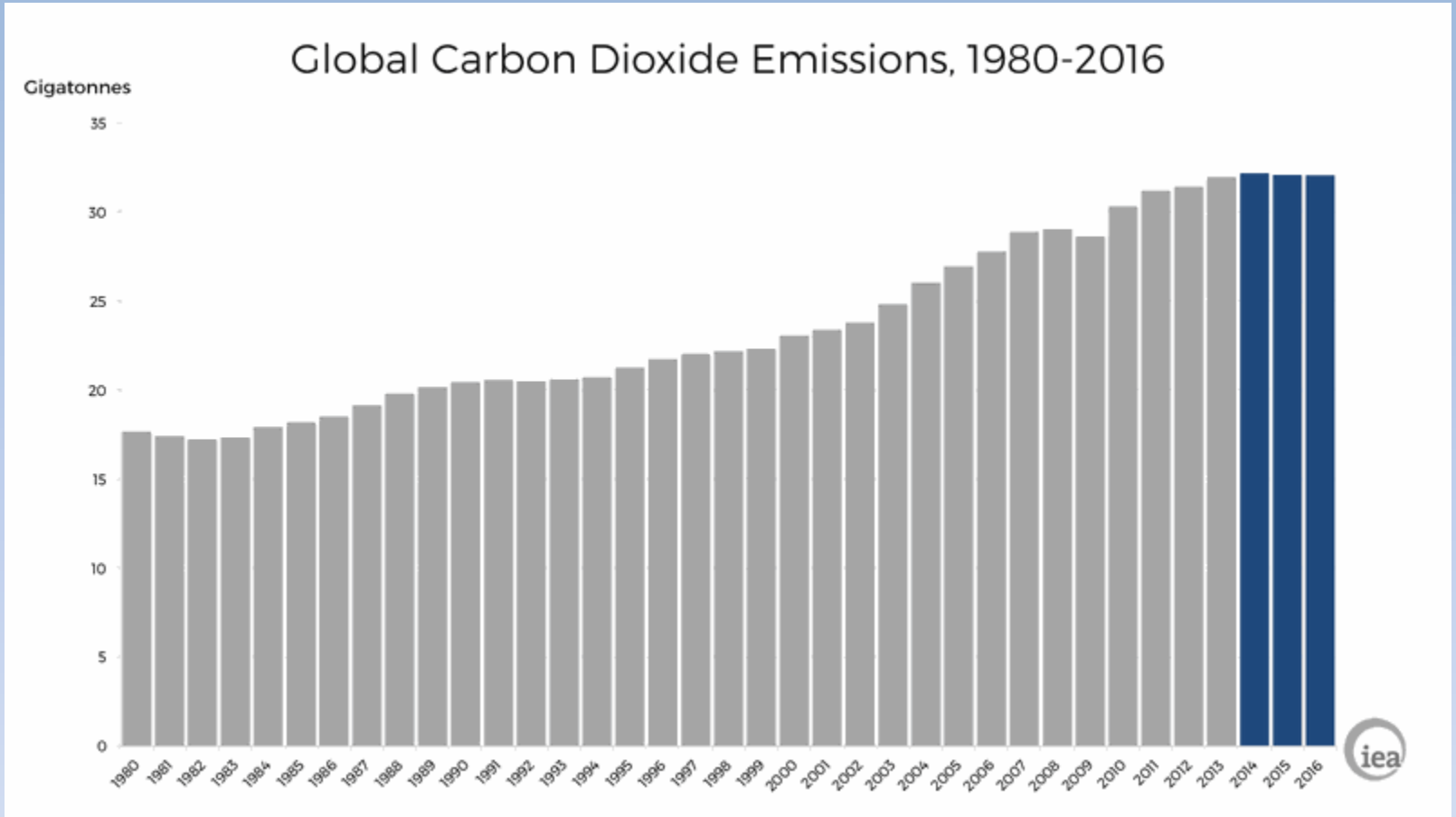
# DESPITE this – Overall Total Consumption Going Up




https://www.youtube.com/watch?v=Fjbx5Xq_ULc&t=10s

# A Slowdown in Global Carbon Emissions

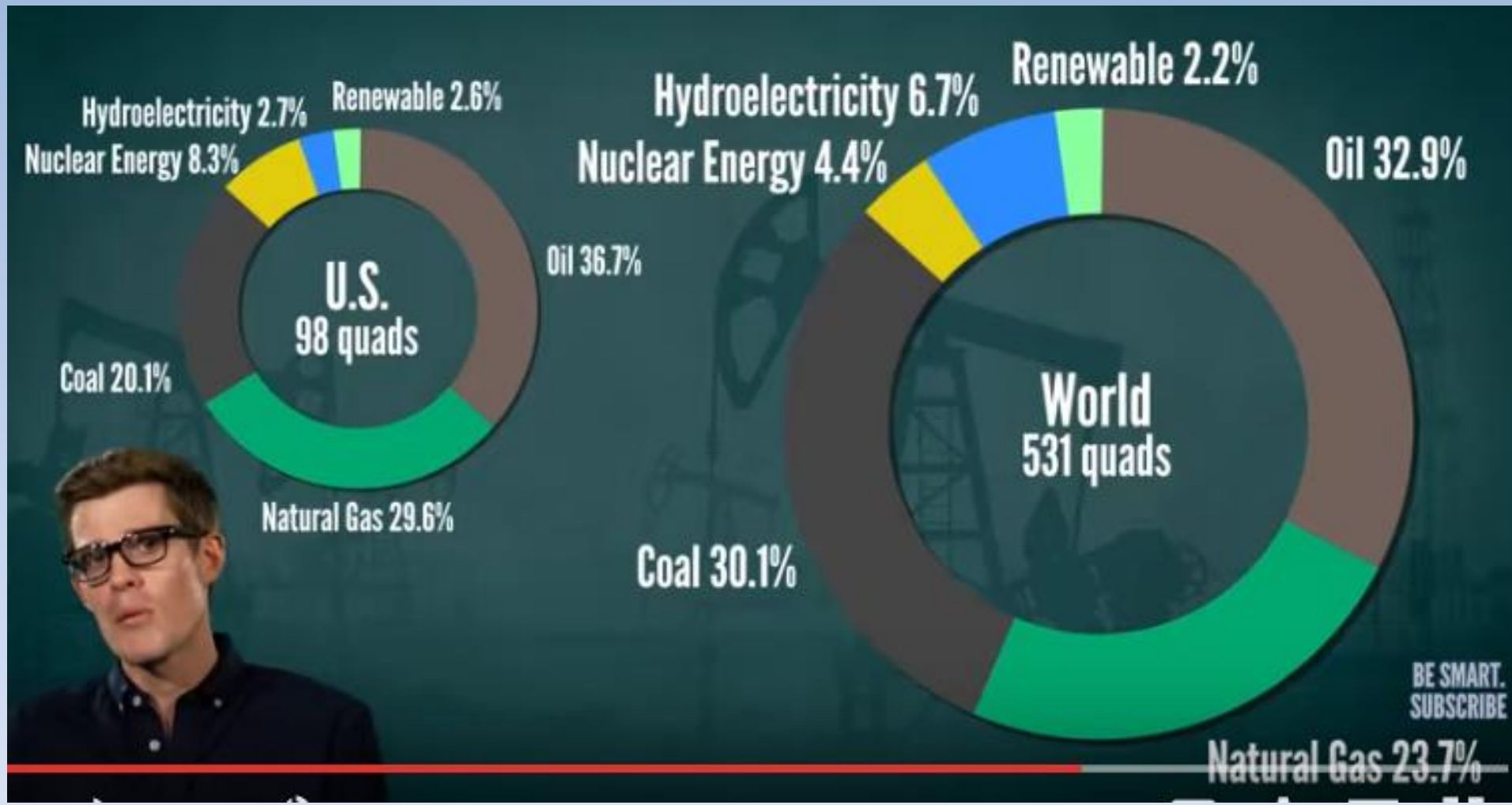
**Vox, 21 March 2017**




International Energy Agency

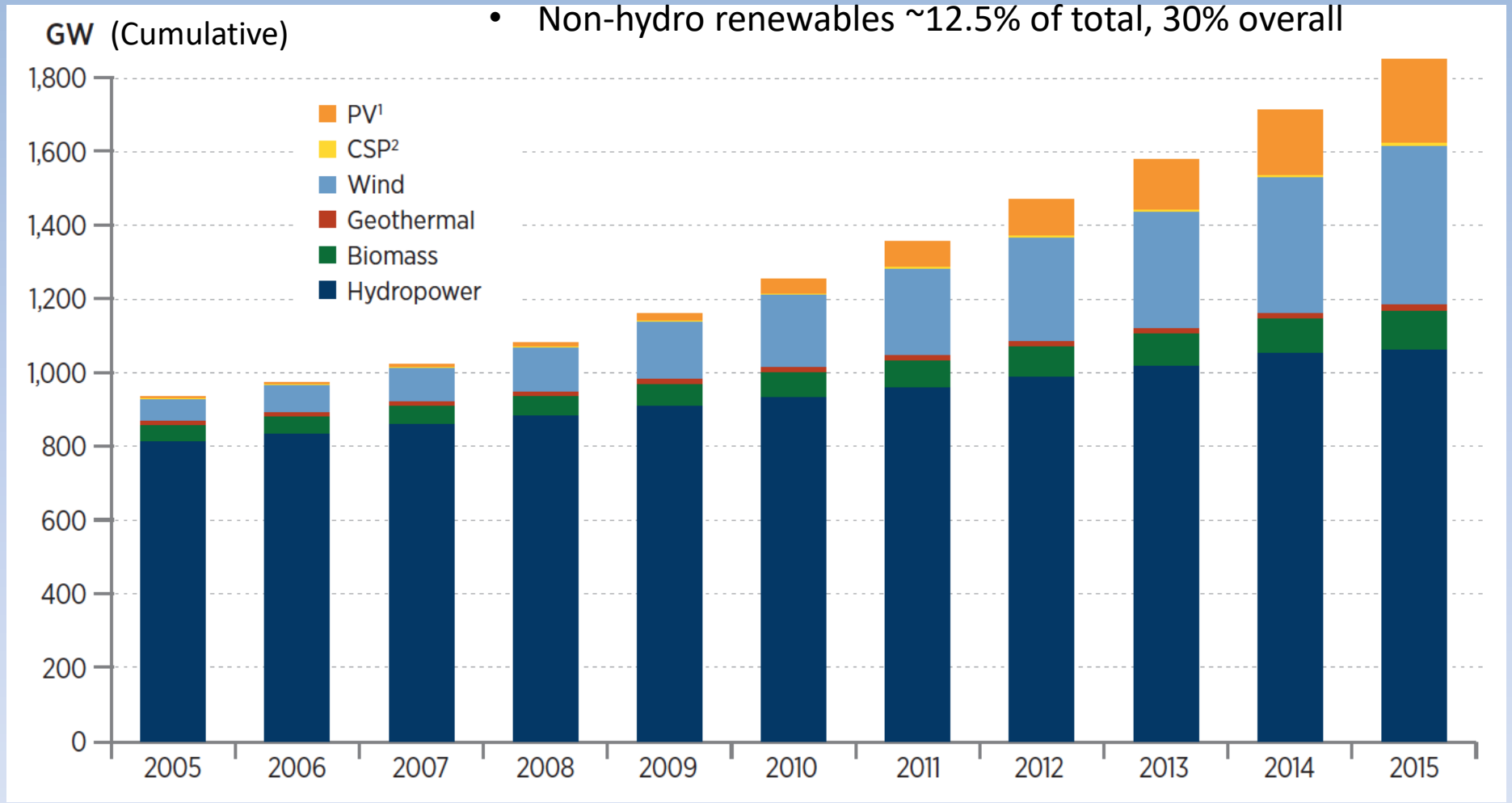
Over the past three years, something genuinely shocking has been happened. Global CO2 emissions from energy have stayed flat, even as the world economy has kept chugging along.

# U.S. Use Matches World in Proportion



# Global Renewable Energy Capacity

- Total global electricity gen capacity - ~5,900 GW
- Non-hydro renewables ~12.5% of total, 30% overall

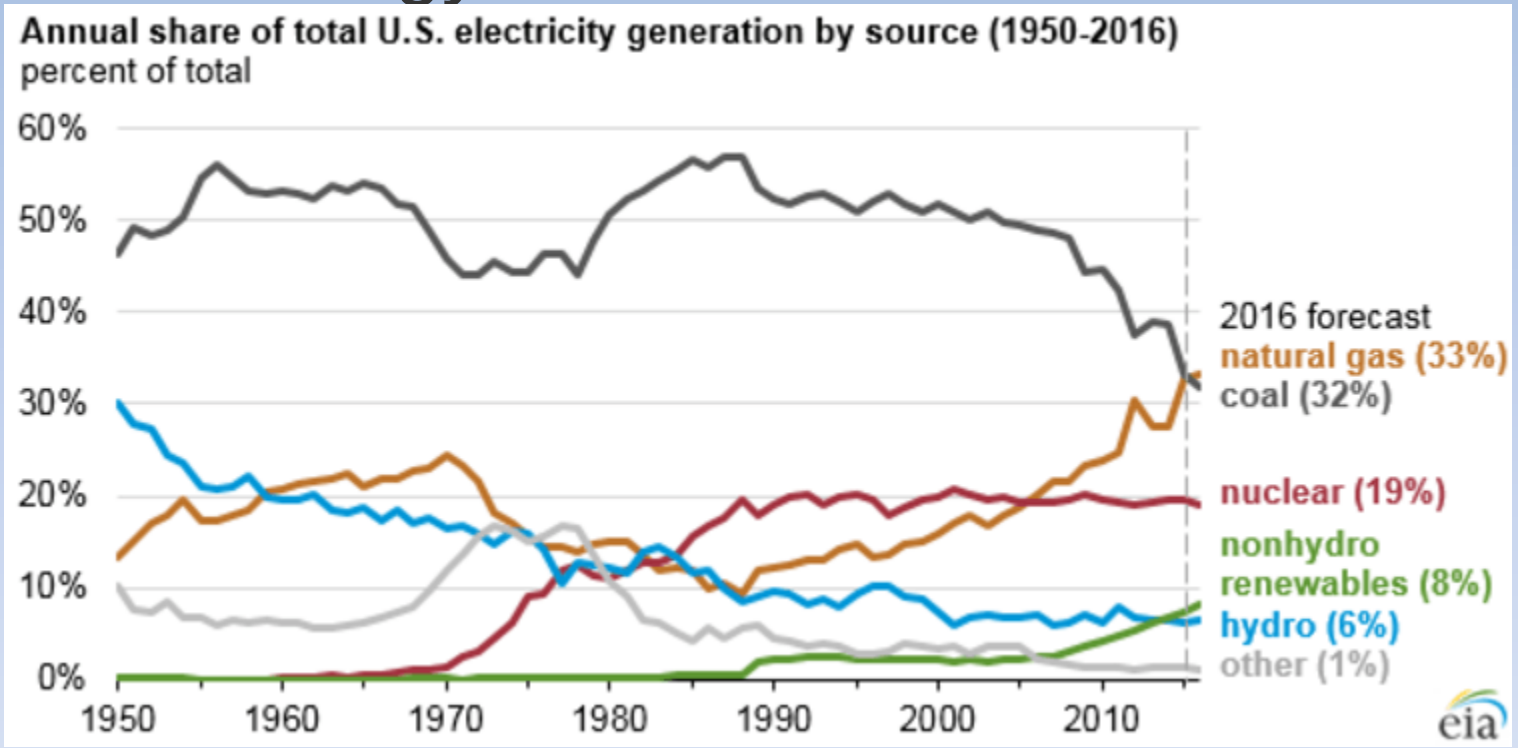



BCRES: NREL'S David Mooney Presentation

Source: Renewable Energy Policy Network for the 21st Century (REN21)

# Former Gov. Bill Ritter

- One in 50 new jobs in America is now in solar energy.



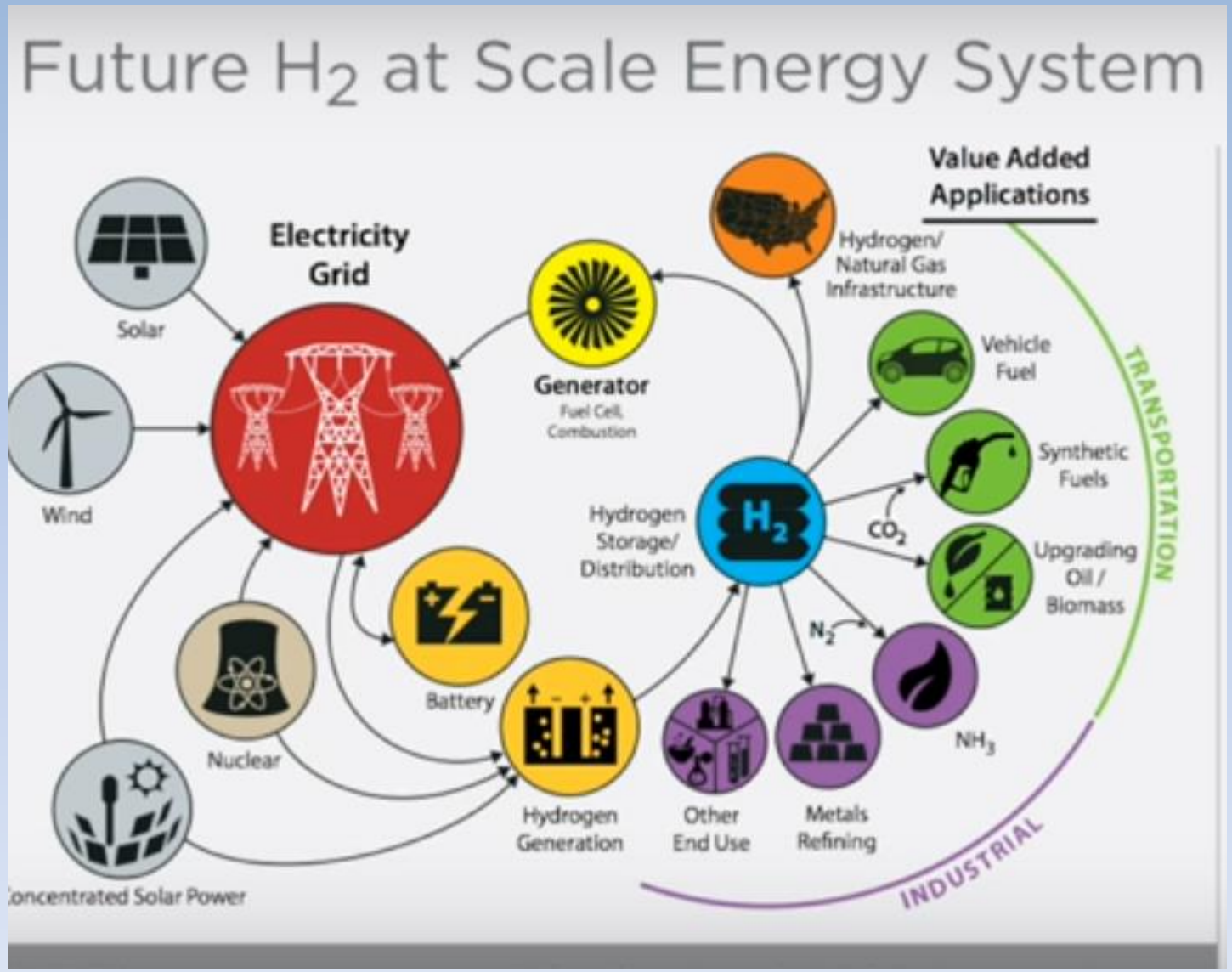

http://www.coloradoindependent.com/164687/bill-ritter-colorado-clean-energy-trump-coal

# BREATHE EASY:
# COAL is not coming back
# Renewables win!

- **RENEWABLES are cheaper!**
  - **Wind especially**
  - **PV next – but will become even cheaper**
  - **Battery backup**
  - **Concentrated Solar Power for Thermal backup**

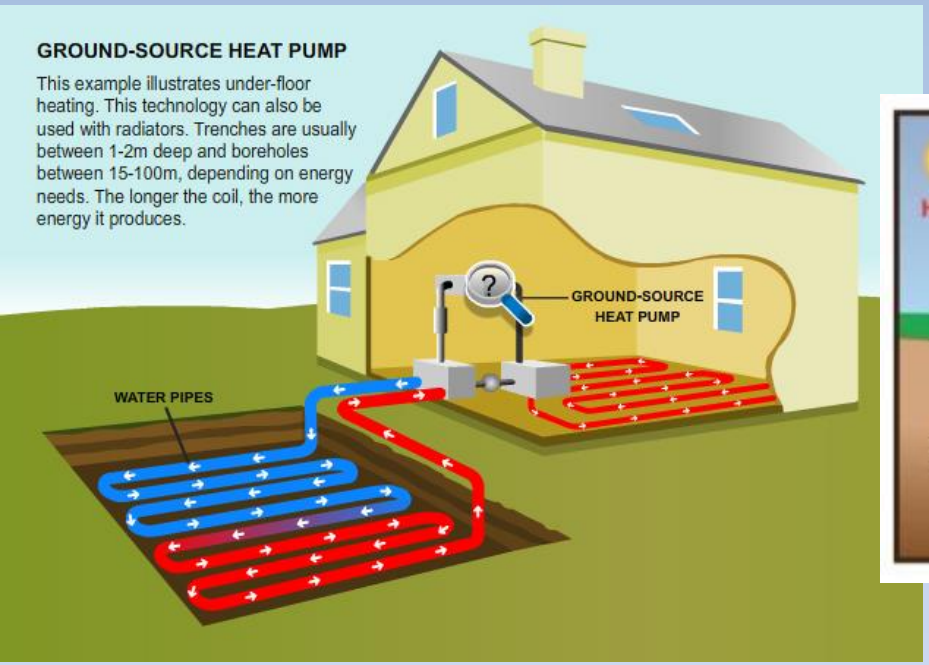
http://www.coloradoindependent.com/164687/bill-ritter-colorado-clean-energy-trump-coal

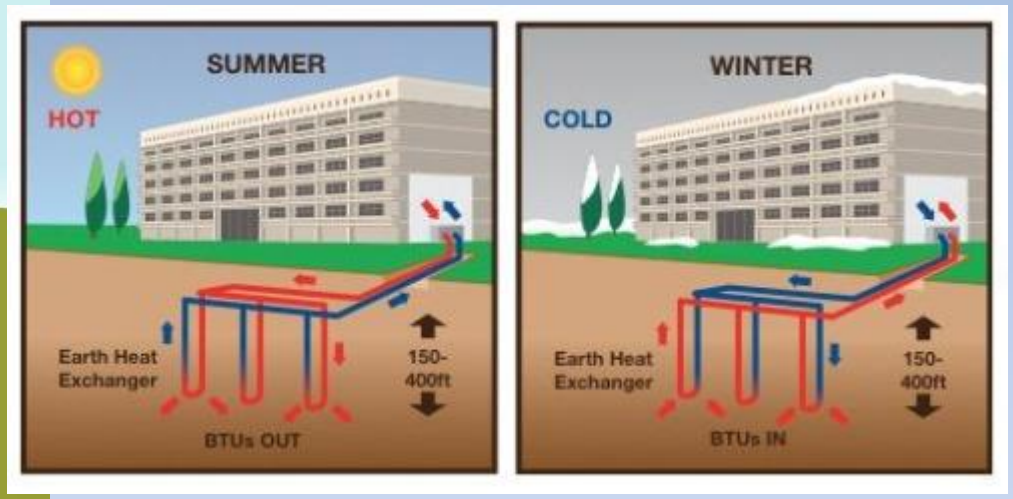
# When you have excess power:




Ramping Up Solar to Power the World - Greg Wilson, NREL: https://www.youtube.com/watch?v=7CDPHxcnq4c

# Geothermal:
# Personal level or city level




In operation:

- Pagosa Springs
- Glenwood Springs
- Others

# Further Solutions

# How to Overcome our Inertia and Apathy

# The American Public and Climate Change

**Yale Program on Climate Change Communication**

Climate Change and the American Mind
- November, 2016

- 70% believe global warming is occurring
- 55% understand it is caused by human activity
- Only 5% believe anything can or will be done

http://climatecommunication.yale.edu/

# APATHY / INERTIA

## WHY?

- IT'S too late
- It's too big a problem
- It's up to the government
- I'm not long for here anyway
- It's too expensive
- I'm too busy

https://eos.org/articles/climate-scientists-new-hurdle-overcoming-climate-change-apathy

# APATHY / INERTIA

## vs. good motives:

- IT'S our planet
- It's the right thing to do
- I CARE FOR FUTURE GENERATIONS!
- It's for our grandkids, or dogs or cats
- I believe in promoting the best of human values by example

https://eos.org/articles/climate-scientists-new-hurdle-overcoming-climate-change-apathy

# SOLUTIONS TO APATHY

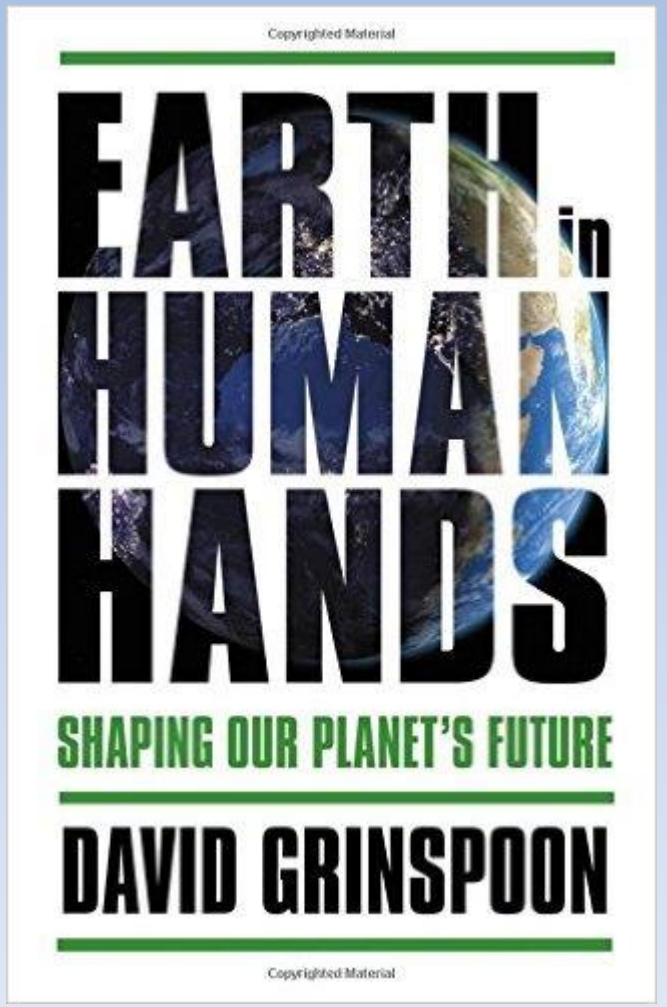
## #1 - CHANGE OUR WAY OF THINKING

# Earth in human hands

- Kerry Emanuel, MIT Prof. Meteorology:
- "…there are few, if any, historical examples of civilizations consciously making sacrifices on behalf of descendants two or more generations removed"
- NEEDED CABINET POSTION:
  - **Secretary of the future**

# We are a planet with brains

- Climate change is only the most visible of the modifications we've made--up until this point, inadvertently--to the planet.
- And our current behavior threatens not only our own future but that of countless other creatures.
- ….shows what a strange and novel development it is for a species to evolve to build machines, and ultimately, global societies with world-shaping influence.




BTW – David Grinspoon will be at Conf. World Affairs (CWA), Boulder NEXT week of 4/8: http://www.colorado.edu/cwa/

# SOLUTIONS TAKE AWAY:

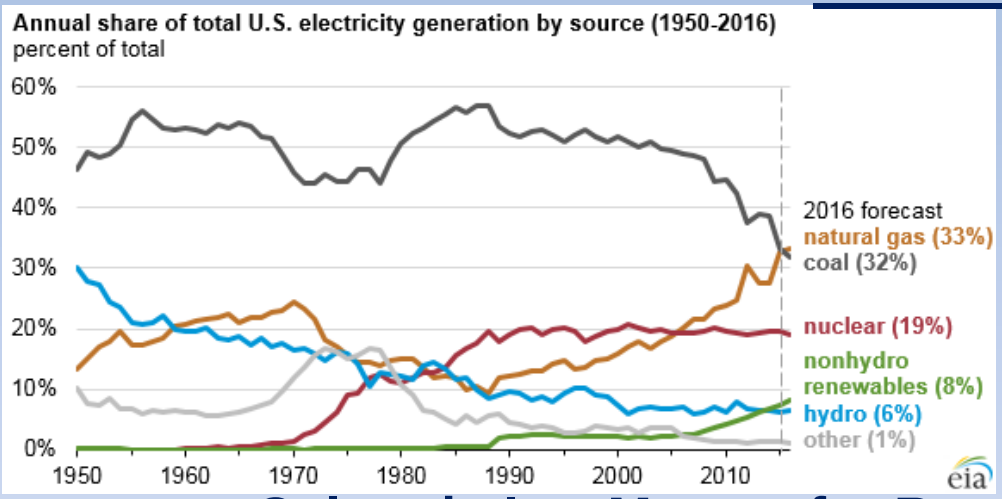
**ELECTRIFY EVERYTHING BY NON-CARBON SOURCED ELECTRICAL GENERATION!**

**OR SOLAR THERMAL**

# Sources of Electricity in Colorado: 2015

- 60% coal
- 22% natural gas
- 18% renewable energy

## NATIONALLY:




- 32% coal
- 33% natural gas
- 19% nuclear
- 8%+6% renewable/hydro
- 1% other

## Colorado Is a Magnet for Renewable Energy Companies:

- Colorado 6th in nation overall potential
- Denver 5th in clean-tech employment
- Fastest growing industry in the region

https://www.eia.gov/todayinenergy/detail.php?id=25392

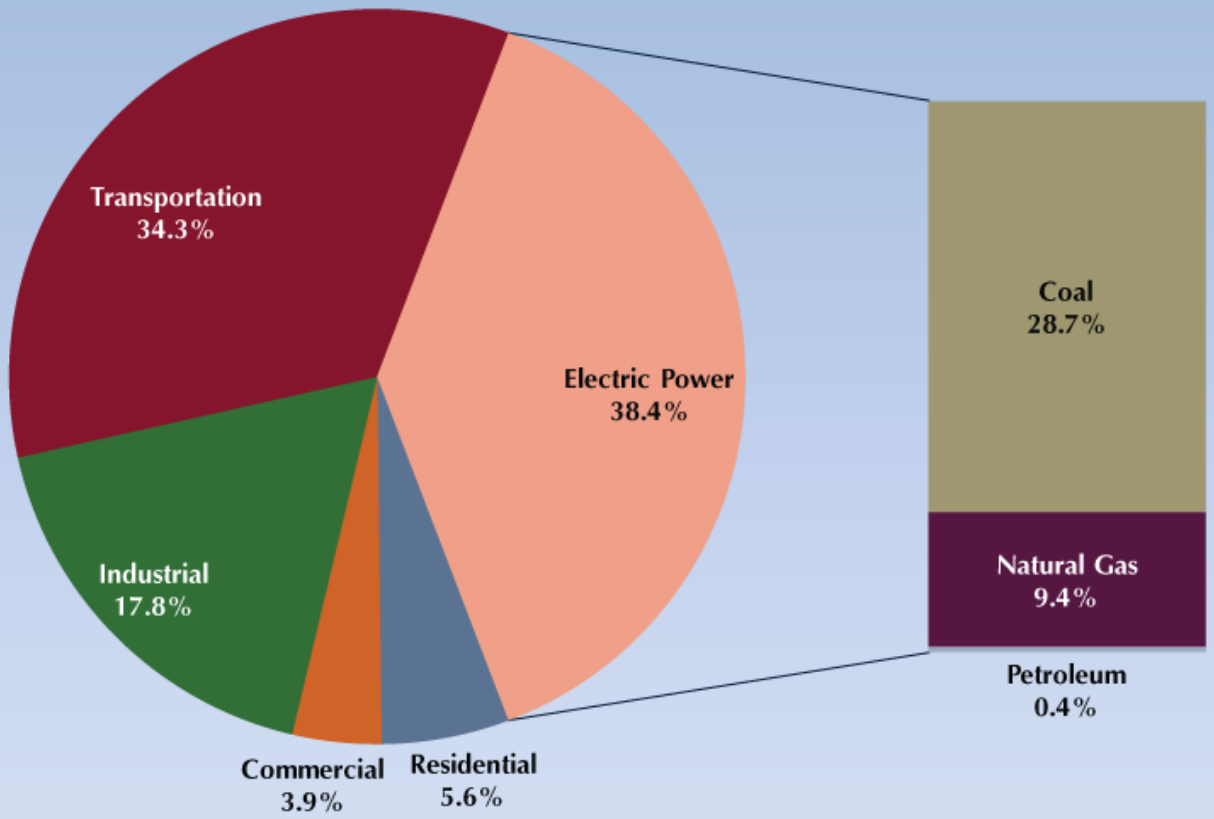
Kathleen Wells, Denver CCL, 2017

# SOLUTIONS

## Part A: - REDUCE OUR GREENHOUSE GAS (GHGs) EMISSIONS

- Electric Generation
- Transportation
- in Heating

# Source of $CO_2$ Emissions

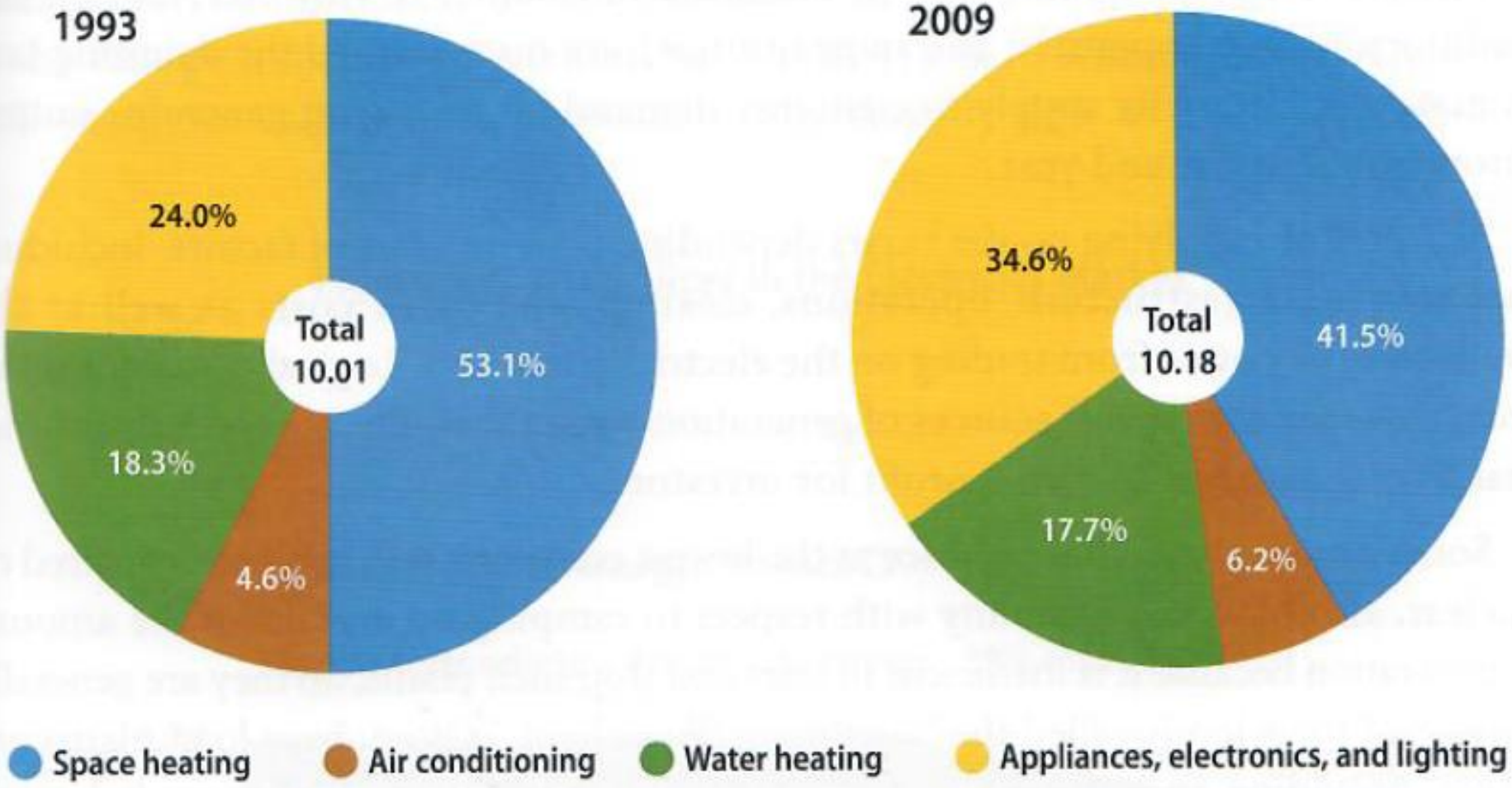



With coal/gas ~ 50/50, it means that coal produces about 3X $CO_2$

EIA: https://www.eia.gov/

## Figure 5.3. Energy Consumption in Homes by End Uses

quadrillion Btu and percent




Source: U.S. Energy Information Administration, http://www.eia.gov/todayinenergy/detail.cfm?id=10271.

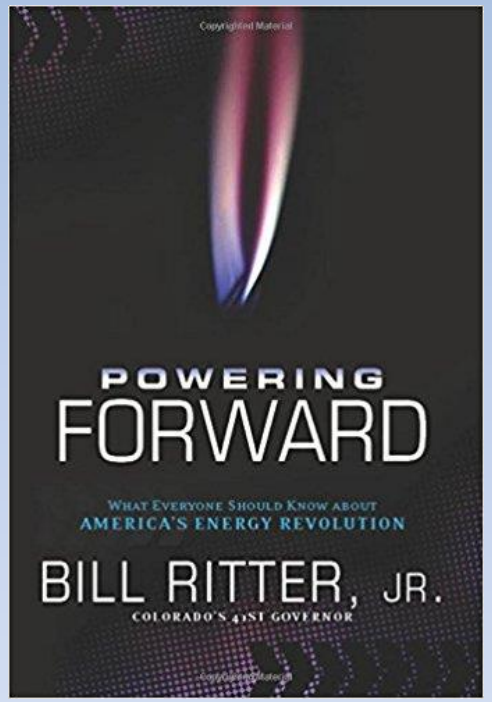
# SOLUTIONS TAKE AWAY:

**ELECTRIFY EVERYTHING BY NON-CARBON SOURCED ELECTRICAL GENERATION!**

**OR SOLAR THERMAL**

# Powering Forward: …America's Energy Revolution

- **A historic energy revolution is underway in the United States & THE WORLD:**
  - **Wind, sunlight, and other sustainable resources**
  - **Power plants on their roofs**
  - **Entire communities are switching to 100 percent renewable energy; Hawaii has such a commitment!**
  - **Urgent need to prevent climate change is causing people around the planet to question their reliance on carbon-intensive oil, coal, and natural gas.**



# What if?


Joel Pett

# OTHER LINKS

- https://www.eia.gov/
- https://www.eia.gov/totalenergy/
- https://www.eia.gov/energyexplained/
- https://www.eia.gov/tools/faqs/
- https://www.eia.gov/environment/

https://i.kinja-img.com/gawker-media/image/upload/t_original/ihsllhptnnm4vb7wuvgq.jpg