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 22\textsuperscript{nd}

• **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

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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 economy), 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-changer.”

Wind turbines operate at NREL’s National Wind Technology Center.

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.
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
Human Activity

Warmer Air, Warmer Water (Global Warming)

More Water Vapor and Clouds

Atmosphere
Biosphere
Hydrosphere
Cryosphere (Climate Change)

Courtesy Phil Nelson
HOW IS THE WORLD RESPONDING?

THE WORLDWIDE ENERGY REVOLUTION!
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%
Motivation is Clear – Energy Needs vs. CO$_2$

- Humanity requires $\sim$6 TW of electrical generating capacity, $\sim$2/3 from fossil fuels.
- $[\text{CO}_2]$ $\sim$402 ppm and rising.

Source: 2014 U.S. National Climate Assessment

Nature - 31 March, 2016

Courtesy Greg Wilson, NREL
The Essentials of Energy

- https://www.youtube.com/watch?v=ytwlzy3XuGg&t=41s
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.
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 Calorie = kcalorie), BTU, kWh, calorie (water heating 1 gm, 1 °C)

- SI Rate = watt = 1 joule/second
  - 60*60 = 3600 joules = 1 watt-hour
Efficiency

Be Smart: https://www.youtube.com/watch?v=ytwlzy3XuGg
• Humans = 120W; 1/5 to brain 14W

Be Smart: https://www.youtube.com/watch?v=ytwlzy3XuGg
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
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; 2\textsuperscript{nd} Law of Thermodynamics

Be Smart: https://www.youtube.com/watch?v=ytwlzy3XuGg
Would you like to see President Trump take actions to revive the US coal industry?

- Yes: 43%
- No: 26%
- Not sure: 31%

Poll Spring 2017

http://www.utenergypoll.com/
Poll spring 2017

Climate Change is Occurring

84% 85% 89% 87% 85% 83% 86% 90% 90% 90% 87%
65% 73% 73% 72% 68% 68% 70% 76% 73% 79% 75%
45% 51% 55% 52% 47% 49% 47% 59% 54% 62% 62%

Spring 2012 Fall 2012 Spring 2013 Fall 2013 Spring 2014 Fall 2014 Spring 2015 Fall 2015 Spring 2016 Fall 2016 Spring 2017

Total Democrats Republicans

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
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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=ytwlzy3XuGg
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=ytwlzy3XuGg
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
Figure 5.3. Energy Consumption in Homes by End Uses
quadrillion Btu and percent

1993
- Total 10.01
  - Space heating: 53.1%
  - Air conditioning: 18.3%
  - Water heating: 4.6%

2009
- Total 10.18
  - Appliances, electronics, and lighting: 41.5%
  - Space heating: 34.6%
  - Air conditioning: 17.7%
  - Water heating: 6.2%

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
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
Former Gov. Bill Ritter

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

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

When you have excess power:

Ramping Up Solar to Power the World - Greg Wilson, NREL: https://www.youtube.com/watch?v=7CDPHxcng4c
Geothermal: Personal level or city level

In operation:
- Pagosa Springs
- Glenwood Springs
- Others
Further Solutions

How to Overcome our Inertia and Apathy
70% believe global warming is occurring

55% understand it is caused by human activity

Only 5% believe anything can or will be done
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

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

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
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
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$_2$
Figure 5.3. Energy Consumption in Homes by End Uses
quadrillion Btu and percent

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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?

CLIMATE
SUMMIT

WHAT IF IT'S
A BIG HOAX AND
WE CREATE A BETTER
WORLD FOR NOTHING?

- Energy independence
- Preserve rainforests
- Sustainability
- Green jobs
- Livable cities
- Renewables
- Clean water, air
- Healthy children
- Etc., etc.

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/