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

Week 6: May 1st , 2017

Part A: Nuclear Power (fission and fusion)

Part B: Storage and Grid Options

Paul Belanger, Ph.D.

Announcements

The March


EARTH IS REAL
SCIENCE IS REAL
THE PRESIDENT IS
A LIAR AND A FAKE
We love EARTH
and all beings
We will protect
1 day ago
WE CAN FIX THIS
1 day ago
1 day ago
1 day ago
1 day ago
WE ARE LIVING ON
THIS PLANET AS
IF WE HAVE A
BACK UP
14 hours ago
PEOPLE'S CLIMATE MARCH DENVER
1 day ago
SCIENCE
NOT
SCIENCE
REAL HOPE
IS
STOPPING
CLIMATE CHANGE
DONT BURN
DOWN
THE HOUSE
1 day ago


CITIZENS' CLIMATE LOBBY
Political Will for a Livable World
COLORADO CHAPTER
citizensclimatelobby.org
DUH!
IT'S GETTING HOT
IN HERE
LETS
STOP CLIMATE CHANGE


the
CLIMATE is CHANGING
NOW!
We Should 2 ...
Put a Price
ON CARBON

Energy and Environment

EPA website removes climate science site from public view after two decades

By Chris Mooney and Juliet Eilperin April 29 at 8:28 AM

Most Read

1 EPA website removes climate science site from public view after two decades

2 The most common reason people quit their $200,000 tech jobs

http://www.biocharnow.com/index.php/biochar/climate-change

Backup sites

- http://www.epaarchive.cc/climatechange/
- https://19january2017snapshot.epa.gov/climatechange_.html

Controversy over NY Times hiring

https://www.nytimes.com/2017/04/28/opinion/climate-of-complete-certainty.html?em_pos=large&emc=edit_ty_20170429&nl=opinion-today&nlid=57511464&ref=headline&te=1

Niskanen Center
Sample topics:

- MARCH 23, 2015*THE CONSERVATIVE CASE FOR A CARBON TAX*
- *IN DEFENSE OF CARBON TAXES: MANHATTAN INSTITUTE EDITION*
- *DIRECTING THE ANGER OVER TRUMP'S CLIMATE EXECUTIVE ORDERS*
- *A GUIDE TO THE CLIMATE DEBATE*
- *NUCLEAR'S (4TH GENERATION) COMEBACK TOUR*
- *DIRECTING THE ANGER OVER TRUMP'S CLIMATE EXECUTIVE ORDERS*
- *THE OBAMA CLIMATE LEGACY*

https://niskanencenter.org/https://niskanencenter.org/

The Intercept

- **HOW A PROFESSIONAL CLIMATE CHANGE DENIER DISCOVERED THE LIES AND DECIDED TO FIGHT FOR SCIENCE: - MUST READ**
  - **STORY OF JERRY TAYLOR BROTHER OF HEARTLAND'S LOBBYIST JAMES TAYLOR**

- **HTTPS://THEINTERCEPT.COM/2017/04/28/HOW-A-PROFESSIONAL-CLIMATE-CHANGE-DENIER-DISCOVERED-THE-LIES-AND-DECIDED-TO-FIGHT-FOR-SCIENCE/**

Climate Connections
click on link for more

Worrisome first quarter of 2017 climate trends

The year is off to a toasty start globally ... and not in a comforting way for those concerned about another year of high temperatures, sea ice record lows at both Poles, and mounting risks to coral reefs.

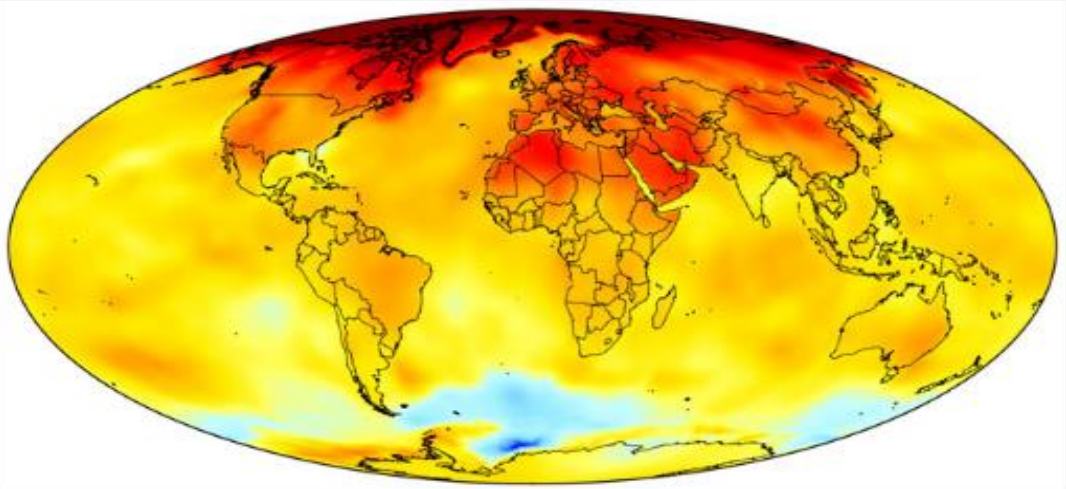
By Zeke Hausfather

Thursday, April 27, 2017

TOPICS
Oceans, Polar Ice, Science

Recent Posts

- Reversing climate change
- Columnist: 'Swamped' coastal Louisiana
- Georgia island confronts 'blue



With the first quarter of 2017 now past, the year is shaping up to be one of climate extremes: high temperatures, low sea ice, and coral bleaching.

https://www.yaleclimateconnections.org/2017/04/worrisome-first-quarter-of-2017-climate-trends/

NREL TOUR MAY 8TH

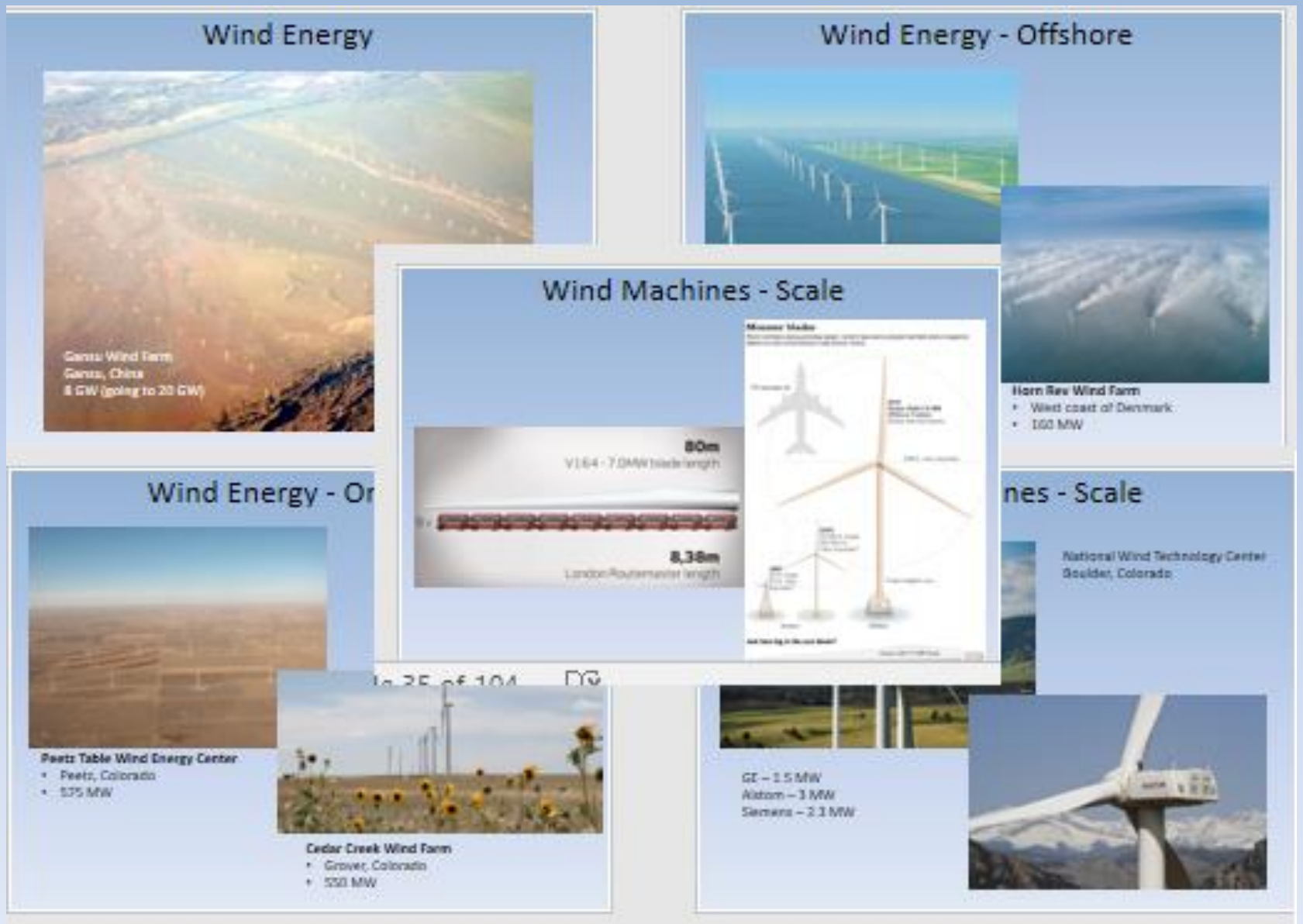
- **Energy Systems Integration Lab**
- **1:30-3:00 p.m.; please aim to be there 12:45 p.m.**
- **GOVERNMENT ID: CDL / passport**
- **Read attachments I sent**

- **NREL Education Center:** 15013 Denver West Parkway Golden, CO 80401
- **Google maps** https://www.google.com/maps/dir//15013+Denver+W+Pkwy,+Golden,+CO+80401/@39.7408398,-105.1729051,16z/data=!3m1!4b1!4m8!4m7!1m0!1m5!1m1!1s0x876b84596aab36ab:0x5eac346d18c1fbe5!2m2!1d-105.1685277!2d39.7408399?hl=en

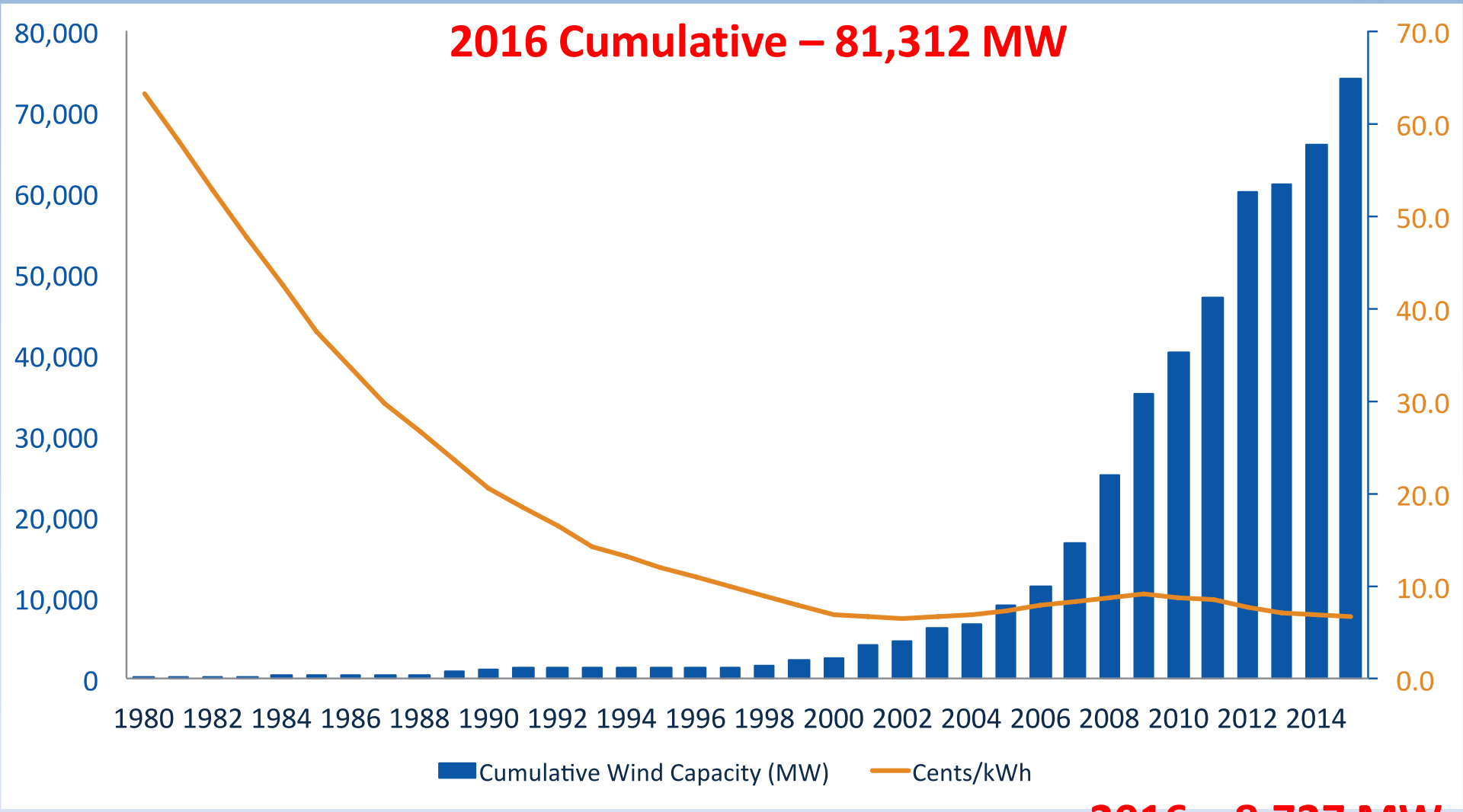
- **PEBelanger@glassdesignresources.com**
- **c. 303-249-7966; h 303-526-7996**

LOOSE ENDS ON WIND FROM LAST WEEK

I had shown:


Wind Energy
Gansu Wind Farm
Gansu, China
8 GW (going to 20 GW)
Wind Energy - Offshore
Horn Rev Wind Farm
• West coast of Denmark
• 160 MW
Wind Machines - Scale
80m
8,38m
Wind Energy - Or
nes - Scale
National Wind Technology Center
Boulder, Colorado
Peetz Table Wind Energy Center
• Peetz, Colorado
• 575 MW
Cedar Creek Wind Farm
• Grover, Colorado
• 550 MW
GE – 1.5 MW
Alstom – 3 MW
Siemens – 2.3 MW

U.S. Wind Market Growth



2016 – 8,727 MW

(EIA)

Source: DOE 2016: Revolution…now, the future arrives for five clean energy technologies

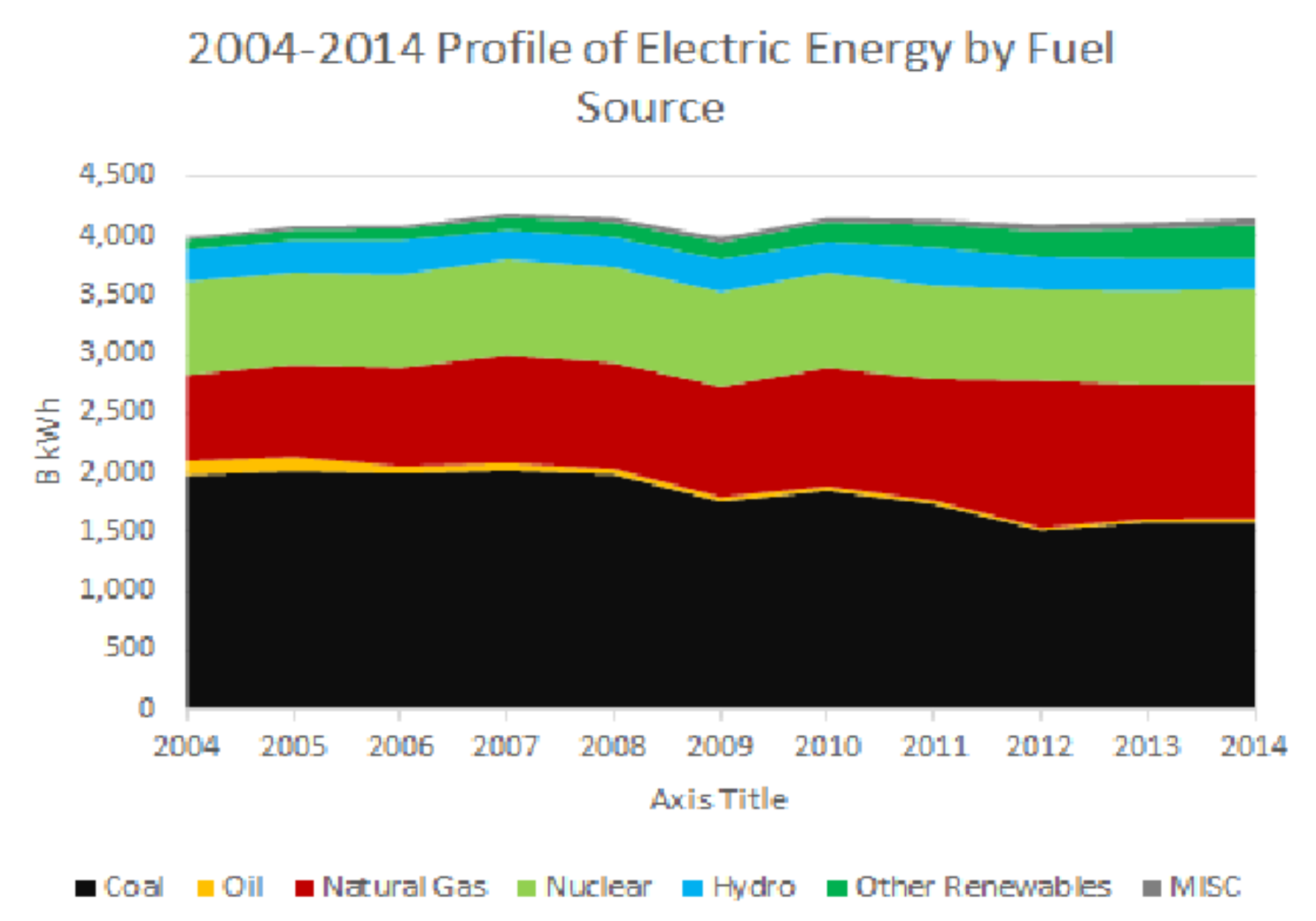
US Electrical Generation per capita/year

Yearly US Per capita Consumption (kWh) by Fuel Source 1999-2014

Year	Population(M)	Fossil Fuel				Nuclear	Renewable							Misc	Total
		Coal	Oil	Gas	sub total		Hydro	Geo Thermal	Solar	Wind	Wood	Bio other	sub Total		
2014	318.857	4,961	95	3,571	8,626	2,500	813	50	55	570	133	68	1,689	190	**13,005**
2013	316.129	5,001	86	3,599	8,686	2,496	850	50	29	531	127	66	1,651	176	**13,010**
2012	313.874	4,824	74	3,944	8,841	2,451	880	50	14	449	120	63	1,576	179	**13,047**
2011	313.85	5,523	96	3,267	8,886	2,518	1,018	49	6	383	119	61	1,636	147	**13,187**
2010	309.33	5,972	120	3,230	9,321	2,609	841	49	3.9	306	120	61	1,382	108	**13,419**
2009	307.01	5,719	127	3,034	8,881	2,602	891	49	2.9	241	117	60	1,361	135	**12,978**
2008	304.38	6,524	152	2,939	9,616	2,649	837	49	2.8	182	123	58	1,252	126	**13,642**
2007	301.58	6,686	218	3,018	9,922	2,674	821	49	2.0	114	129	55	1,170	121	**13,887**
2006	298.59	6,666	215	2,782	9,663	2,636	969	49	1.7	89	130	54	1,292	83	**13,675**
2005	295.75	6,806	413	2,618	9,838	2,644	914	50	1.9	60	131	52	1,209	105	**13,796**
2004	293.05	6,751	413	2,475	9,639	2,691	916	51	2.0	48	130	53	1,199	58	**13,588**
2003	290.33	6,798	411	2,292	9,502	2,631	950	50	1.8	39	129	54	1,224	41	**13,397**
2002	287.80	6,717	329	2,441	9,486	2,710	918	50	1.9	36	134	52	1,193	90	**13,479**
2001	285.08	6,679	438	2,274	9,390	2,697	761	48	1.9	24	123	51	1,009	88	**13,185**
2000	282.17	6,968	394	2,179	9,542	2,672	977	50	1.7	20	133	82	1,263	117	**13,594**
1999	279.04	6,741	423	2,045	9,209	2,610	1,145	53	1.8	16	133	81	1,430	96	**13,345**

1. Gas includes Natural Gas and Other Gases.
2. Solar includes Photovoltaics and Thermal.
3. Misc includes Misc generation, Pumped storage, and Net imports.
4. Bio Other includes Waste, Landfill Gas, and Other.

https://en.wikipedia.org/wiki/Electricity_sector_of_the_United_States



https://en.wikipedia.org/wiki/Electricity_sector_of_the_United_States

U.S. Electrical consumption

Electricity consumption[edit]

- Electricity consumption data in this section is based upon data mined from US DOE Energy Information Administration/Electric Power Annual 2014 files[6] In 2014 the total US consumption of electric energy was 4,146.2 Terawatt hours (TWh) (or million MWh or billion kWh). This is broken down as: (see link below)

https://en.wikipedia.org/wiki/Electricity_sector_of_the_United_States

World vs. U.S.

- World uses ~ 16 TW-yr; U.S. 4.146 TW –yr: i.e. ~ 1/4th
- That's about 4,146 1-GW coal plants
- Wind in previous slide = about 80 GW, or 80 such 1-GW coal plants
- Remember Colorado has 15? coal plants (of varying sizes – some may have been converted to natural gas?
- See: https://www.google.com/maps/d/viewer?mid=1TumKhY_tHju2y2wia0mNO4ersto&hl=en&ll=39.48000145773865%2C-105.56134199999997&z=7

Colorado coal plants

Colorado Coal-fired Pow..

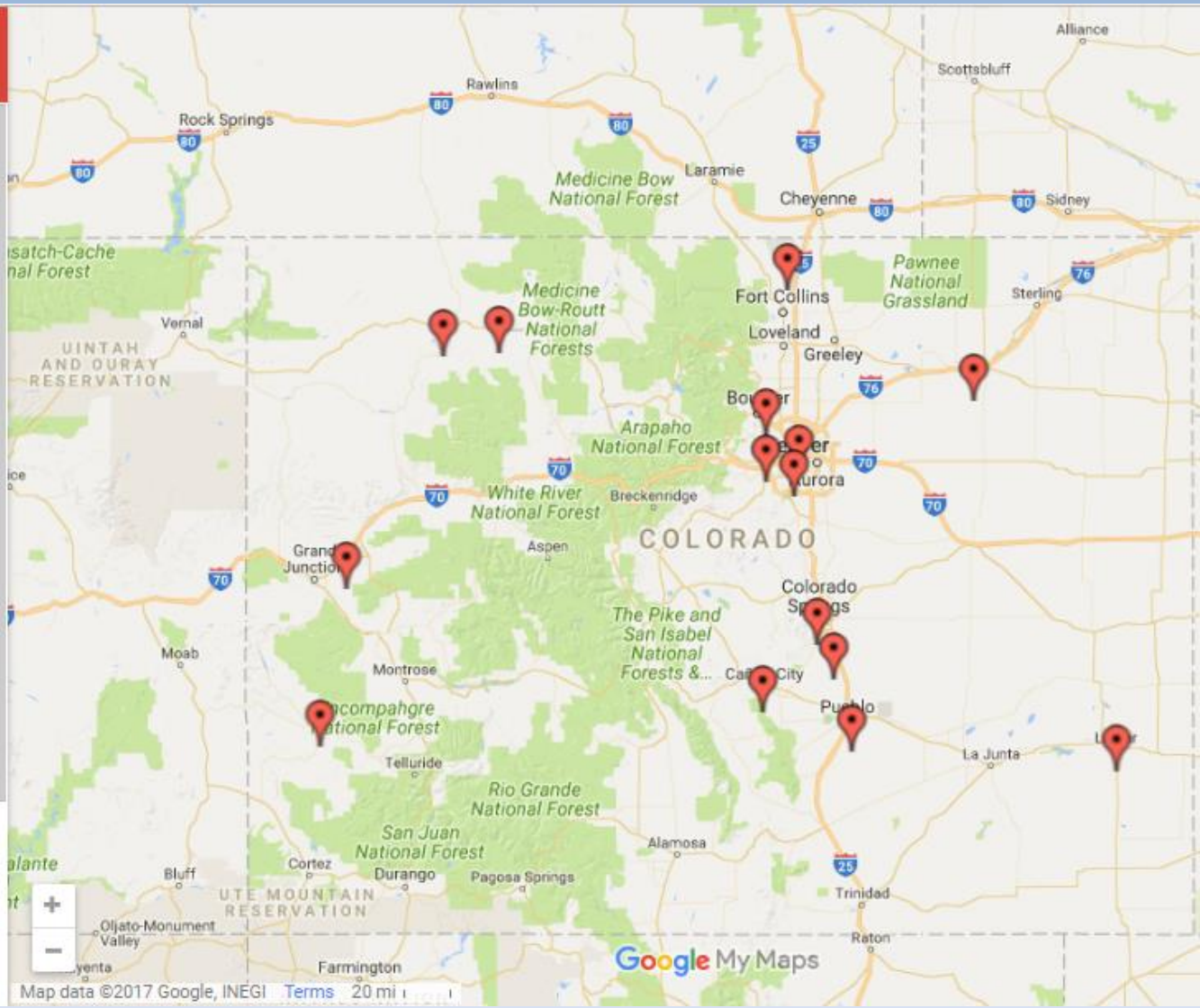
Coal-fired power plants in Colorado that WildEarth Guardians is targeting for clean up, repowering, or retirement.

6,886 views

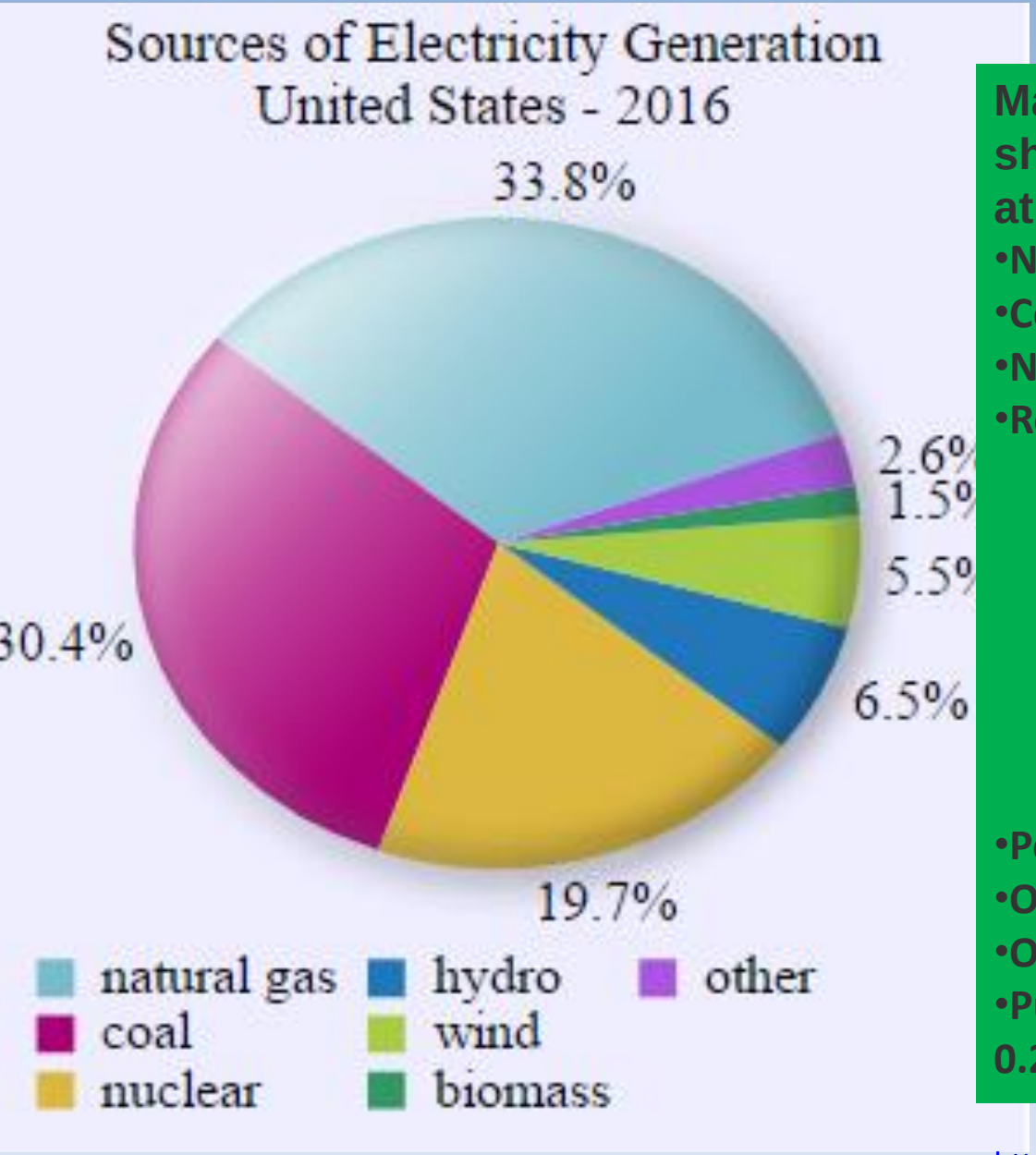
SHARE

Untitled layer

- Comanche Station
- Ray D. Nixon Station
- Martin Drake Power Plant
- Cherokee Station
- Cameo Station
- Craig Station
- Hayden Station
- Nucla Station
- Pawnee Station
- Rawhide Power Plant
- WN Clark Station
- Valmont Station
- Arapahoe Station



See:https://www.google.com/maps/d/viewer?mid=1TumKhY_tHju2y2wia0mNO4ersto&hl=en&ll=39.48000145773865%2C-105.56134199999997&z=7



https://en.wikipedia.org/wiki/Electricity_sector_of_the_United_States

Major energy sources and percent shares of U.S. electricity generation at utility-scale facilities in 2016[1]

- Natural gas = 33.8%
- Coal = 30.4%
- Nuclear = 19.7%
- Renewables (total) = 14.9%
  - Hydropower = 6.5%
  - Wind = 5.6%
  - Biomass = 1.5%
  - Solar = 0.9%
  - Geothermal = 0.4%
- Petroleum = 0.6%
- Other gases = 0.3%
- Other nonrenewable sources = 0.3%
- Pumped storage hydroelectricity = -0.2%[4]

https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

Top 5 states with electricity generation from renewable energy sources (thousands of Megawatt-hours)

Texas	39,978
California	35,822
Oklahoma	12,677
Iowa	12,413
Kansas	9,184

Source: EIA Electric Power Monthly. Values for year to date August 2016

Scotland joined a small list of nations with the capacity to power their entire country on alternative fuels.

Business Insider, 20 Oct 2016

On one day in August, Scotland generated enough wind power to provide electricity to its entire population. Of course, August 7 happened to be an exceptionally windy day in Scotland. But it demonstrated for the first time that the country could be capable of using 100% renewable power in the near future.

The milestone also put Scotland on a short but growing list of countries on their way to achieving that feat. Among them are Costa Rica… and Denmark, which also operated solely on wind power for one day in September 2015.

The Whitelee Windfarm near Eaglesham, East Renfrewshire, in Scotland David Moir/Reuters

Off Long Island, Wind Power Tests the Waters.

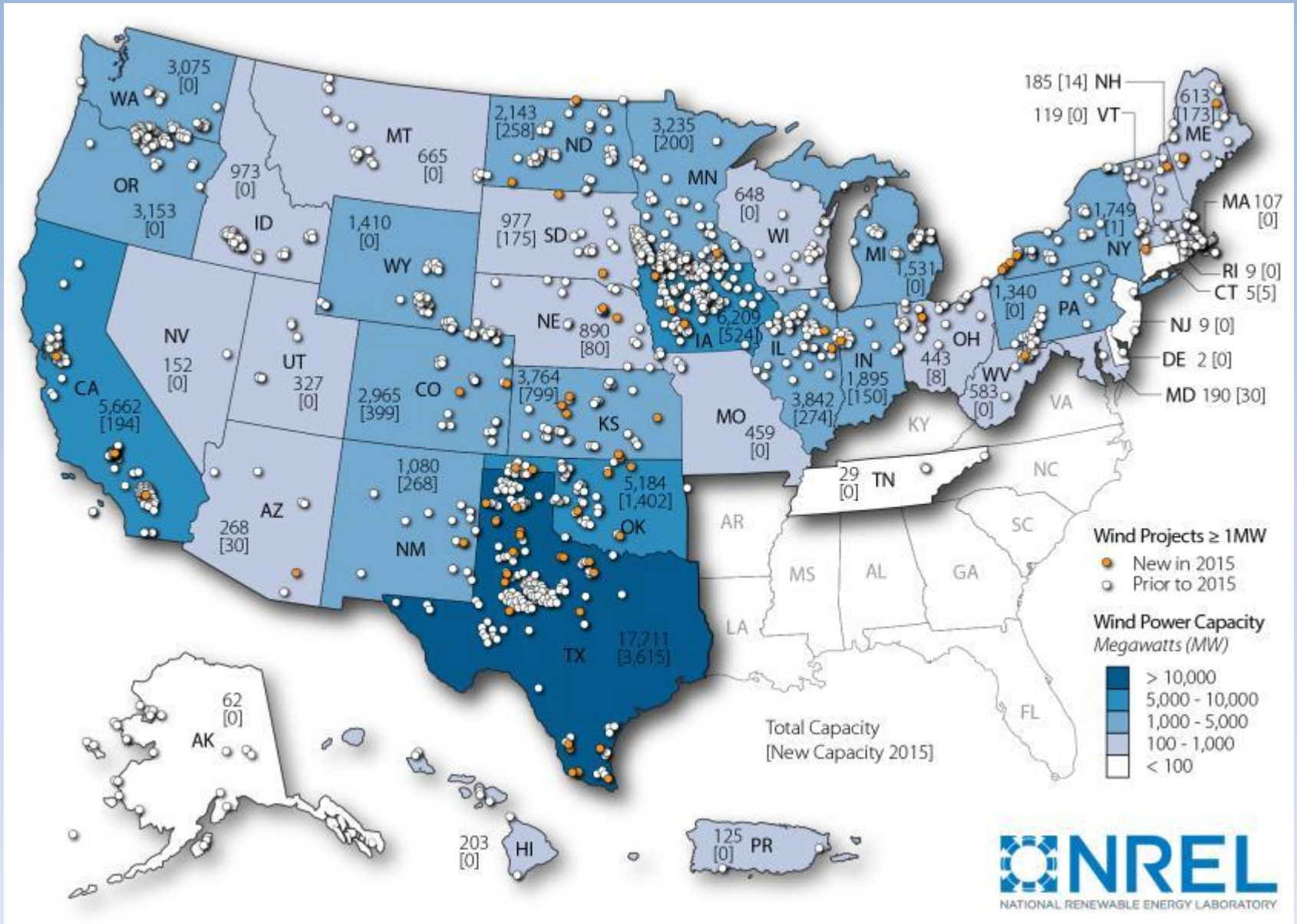
By DIANE CARDWELLJAN. NYT, Jan 21, 2017

Last fall, five turbines in the waters of Rhode Island — the country's first offshore farm — began delivering power to the grid…. And in New York, after years of stymied progress, the Long Island Power Authority has reached an agreement with Deepwater Wind, which built the Rhode Island turbine array, to drop a much larger farm — 15 turbines capable of running 50,000 average homes — into the ocean about 35 miles from Montauk.

If approved by the utility board on Wednesday, the $1 billion installation could become the first of several in a 256-square-mile parcel, with room for as many as 200 turbines, that Deepwater is leasing from the federal government.

Wind turbines off Block Island, R.I. A larger wind farm, planned off Long Island, is up for approval this week.
Credit Kayana Szymczak for The New York Times

Geographic Distribution of Wind Plants



Colorado Wind Development

STATE WIND FACTS

Wind Projects

- **Installed wind capacity:** 3,026 MW
- **State rank for installed wind capacity:** 10th
- **Number of wind turbines:** 1,913
- **State rank for number of wind turbines:** 8th
- **Wind projects online:** 25 (Projects over 10 MW: 17)
- **Wind capacity under construction:** 76 MW
- **Wind capacity in advanced development:** 600 MW

Current Wind Generation

For the 12 month period ending October 2016, wind energy provided 16.87% of all in-state electricity production.

- **Equivalent number of homes powered by wind:** 846,000

Wind Generation Potential

The DOE Wind Vision Scenario projects that Colorado could produce enough wind energy by 2030 to power the equivalent of average American homes.

- **Land based technical wind potential at 80 m hub height**: 274,353 MW
- **Land based technical wind potential at 110 m hub height**: 262,878 MW (Source: NREL)

Environmental Benefits

Generating wind power creates no emissions and uses virtually no water.

- **2015 annual state water consumption savings*:** 4.4 billion gallons
- **2015 equivalent number of water bottles saved:** 33.1 billion
- **2015 annual state carbon dioxide (CO_2) emissions avoided:** 8.0 million metric tons
- **2015 equivalent cars worth of emissions avoided:** 1.7 million

*Based on national average water consumption factors for coal and gas plants

Source: AWEA

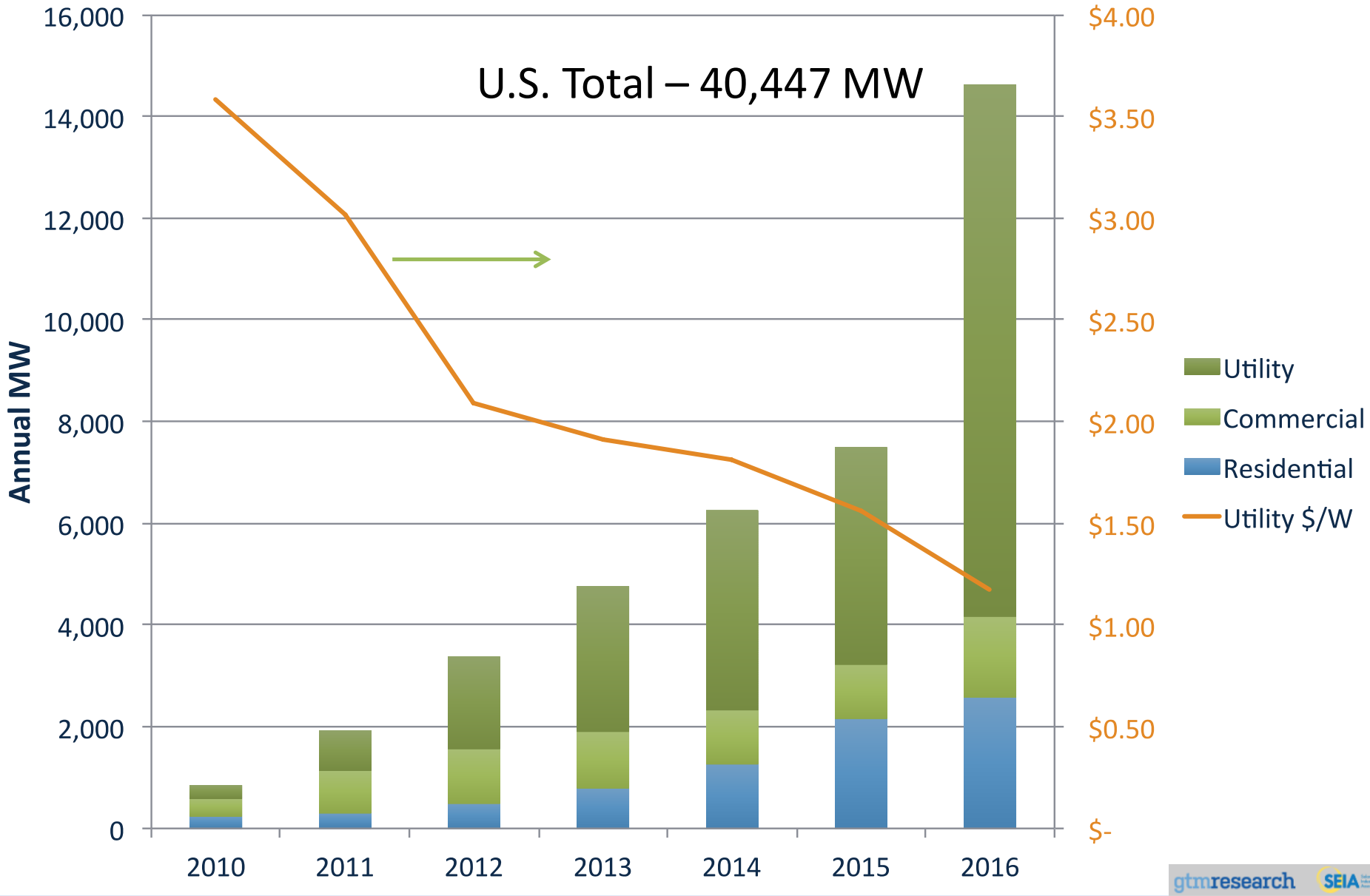
Colorado's Renewable Energy Standard

- 2004, Colorado passed the first voter-led Renewable Energy Standard (RES)
- legislature increased the amount of renewable energy required three times since 2004,
  - including HB10-1001 which required investor-owned utilities to generate 30% of their electricity from renewable energy by 2020,
  - of which 3% must come from distributed energy resources.

- recent update, SB 13-252, requires cooperative utilities to generate 20% of their electricity from renewables.
  - The RES has sparked the development of hundreds of new renewable energy projects across the state,
  - generating thousands of jobs and helping to reduce the state's greenhouse gas emissions.

https://www.colorado.gov/pacific/energyoffice/renewable-energy-standard accessed Nov 2016
RES Statute (§40-2-124, C.R.S.)

Trends in PV Power



Colorado's Public Utility Commission

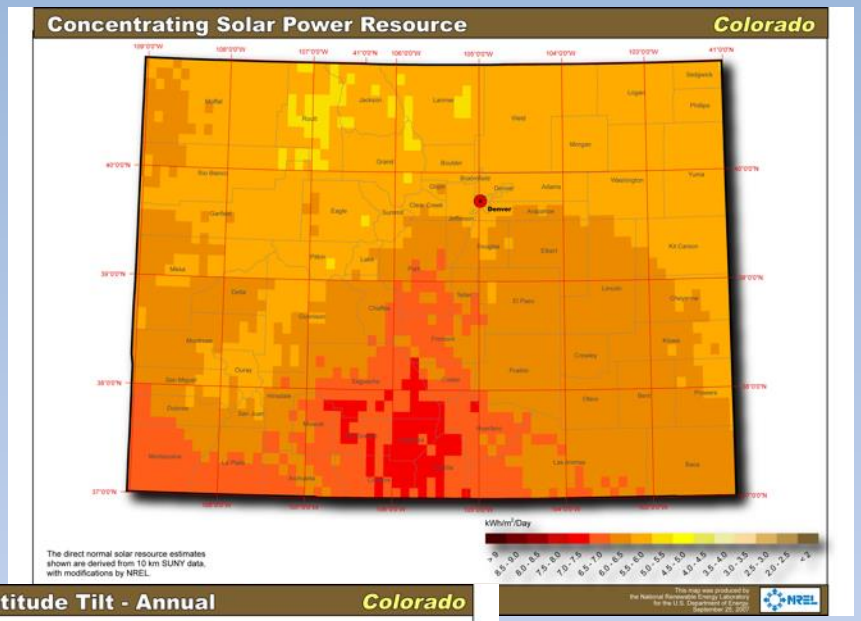
The Colorado PUC has full economic and quality of service regulatory authority over investor-owned electric and gas utilities, as well as partial regulatory control over municipal utilities and cooperative electric associations.

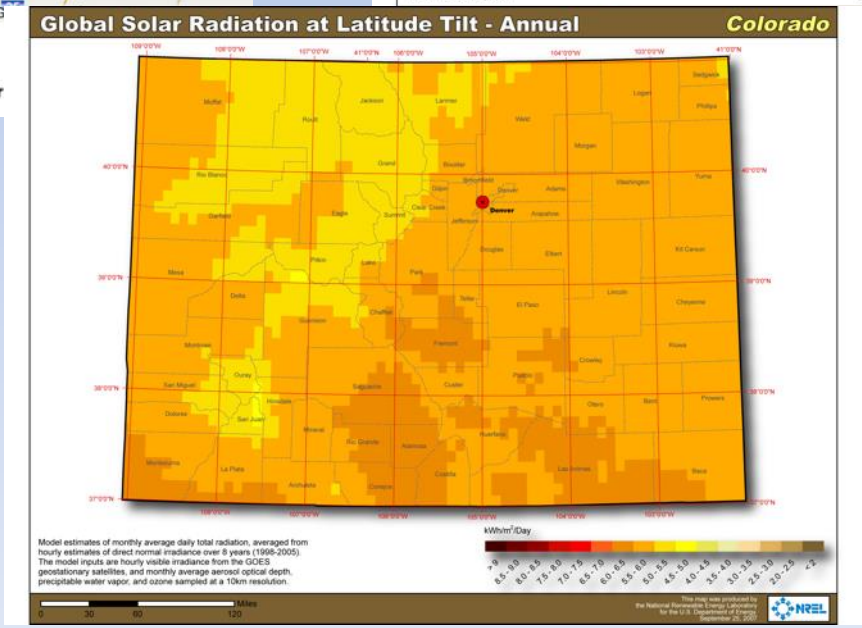
The PUC's mission is to serve the public interest by effectively regulating utilities and facilities so that the people of Colorado receive safe, reliable, and reasonably-priced services consistent with the economic, environmental and social values of the state.

Along with the Colorado General Assembly, the PUC plays a central role in determining the details of electric and gas policy in Colorado.

https://www.colorado.gov/pacific/energyoffice/regulatory-information accessed Nov 2016

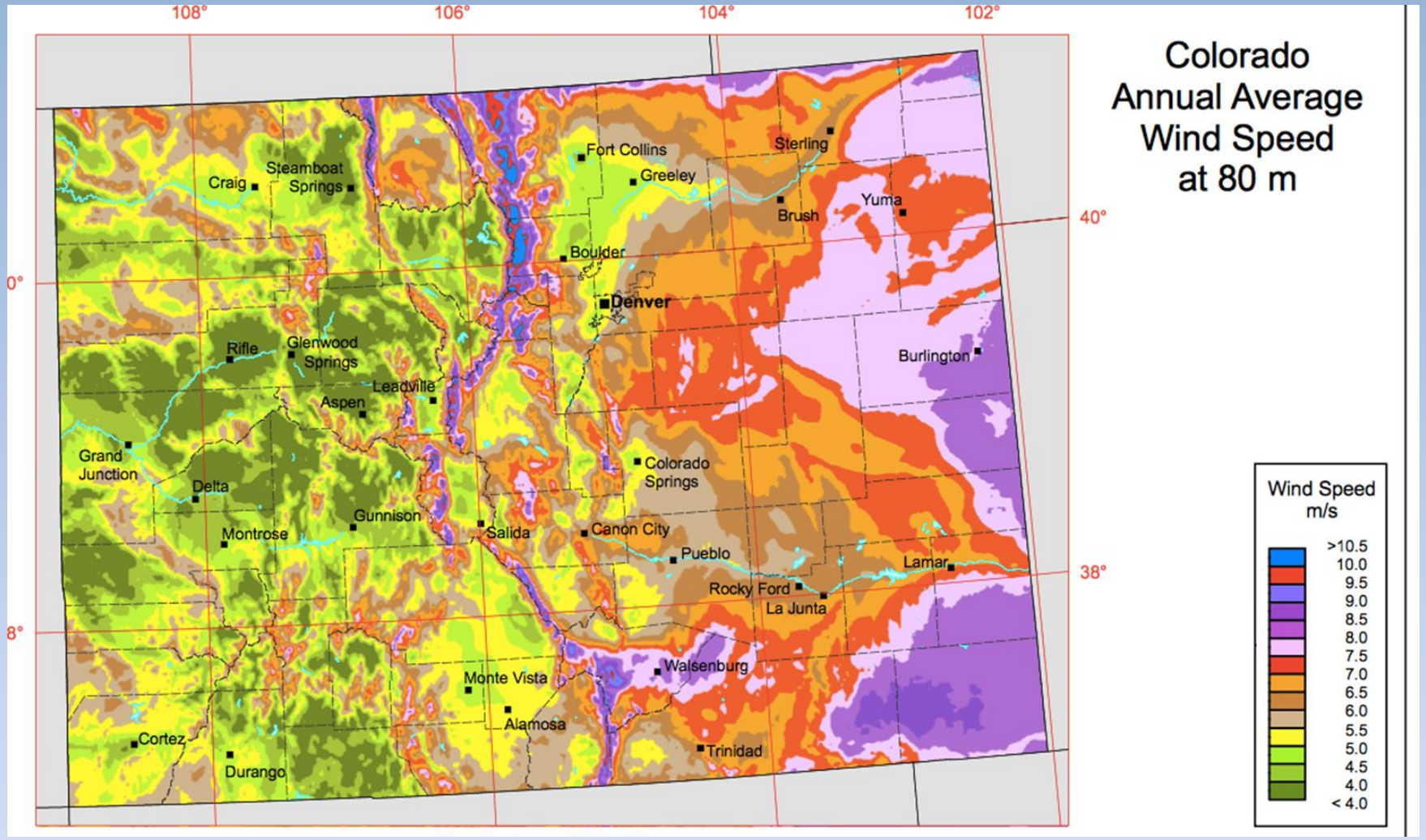
Colorado Solar Development





Technical Potential
PV – 4,500 GW
CSP – 3,100 GW

Sources: NREL and AWEA



Steve Stevens

Golden Oldy Cyclery

Wind Generation Facilities in Eastern Colorado, 2016
Total Nameplate Capacity: 2,905 MW

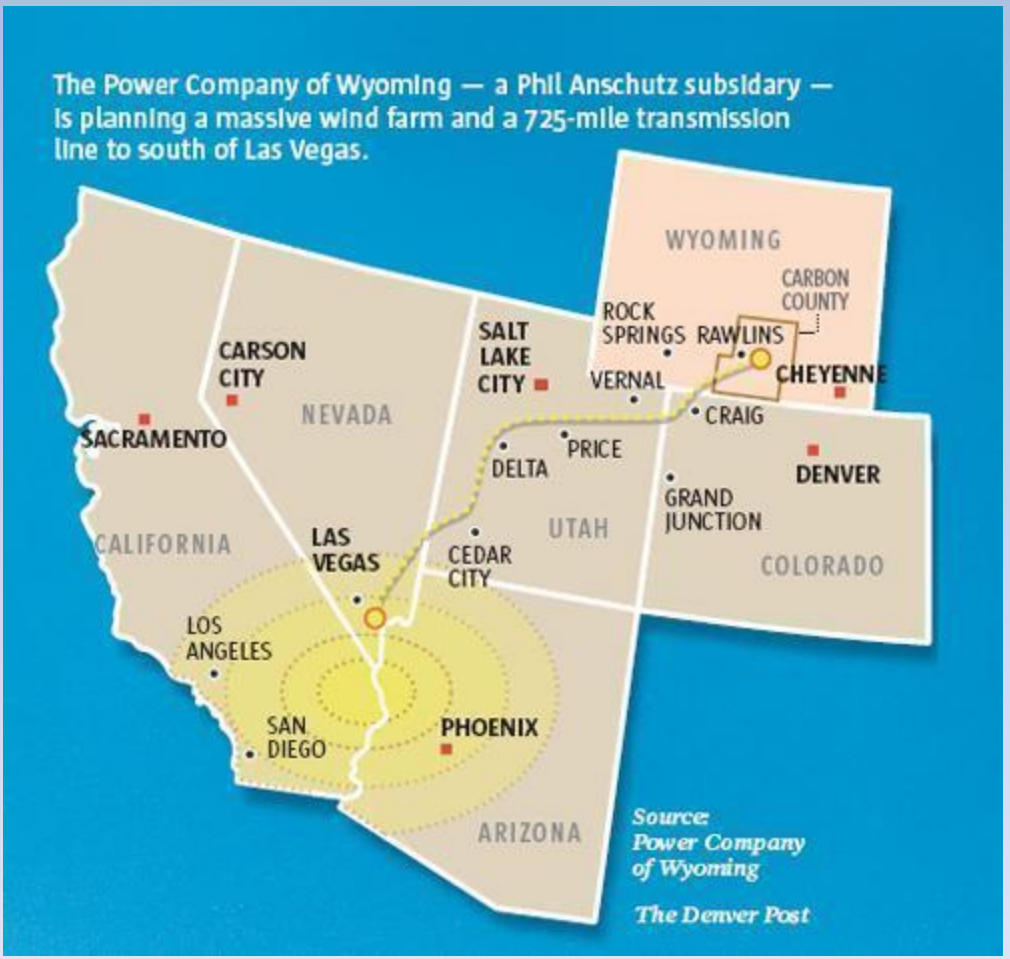
PROJECT	COUNTY	CAPACITY (MW)	DATE ONLINE
Ridge Crest	Logan	30	2000
Colorado Green Wind	Prowers	162	2004
Peetz Wind Farm	Logan	200	2007
Logan Wind Energy	Logan	201	2007
Twin Buttes Wind	Bent	75	2007
Northern Co Wind Energy	Logan	174	2009
Kit Carson Wind	Kit Carson	51	2010
Cedar Creek	Weld	551	2010
Cedar Point	Lincoln	250	2011
Co Highlands Wind	Logan	91	2013
Spring Canyon Wind	Logan	120	2014
Limon Wind	Lincoln	601	2014
Golden West Wind	El Paso	249	2015
Carousel Wind Power	Kit Carson	150	2016
		2905	

Taken from: The Benefits of the Renewable Energy Industry in Eastern Colorado, by Development Research Partners, May 2016

Limon wind

- 601 MW
- Total Colorado 2905 MW (2.9 GW) =~~ 3 coal plants

Anschutz and Wind Energy-WY



- 500 square miles
- Chokecherry and Sierra Madre, which at 3,000 megawatts would be the country's largest wind project.
- He plans to build 1,000 turbines, each of them 262 feet high, along with a 730-mile power line to get the electricity to California.
- He needs to send the energy out of state because Wyoming doesn't have enough people to use it.
- California is ideal because of its huge population, and because it's trying to get half of its electricity from renewable sources by 2030, part of a wide-ranging strategy to fight climate change.

Impacts - yes

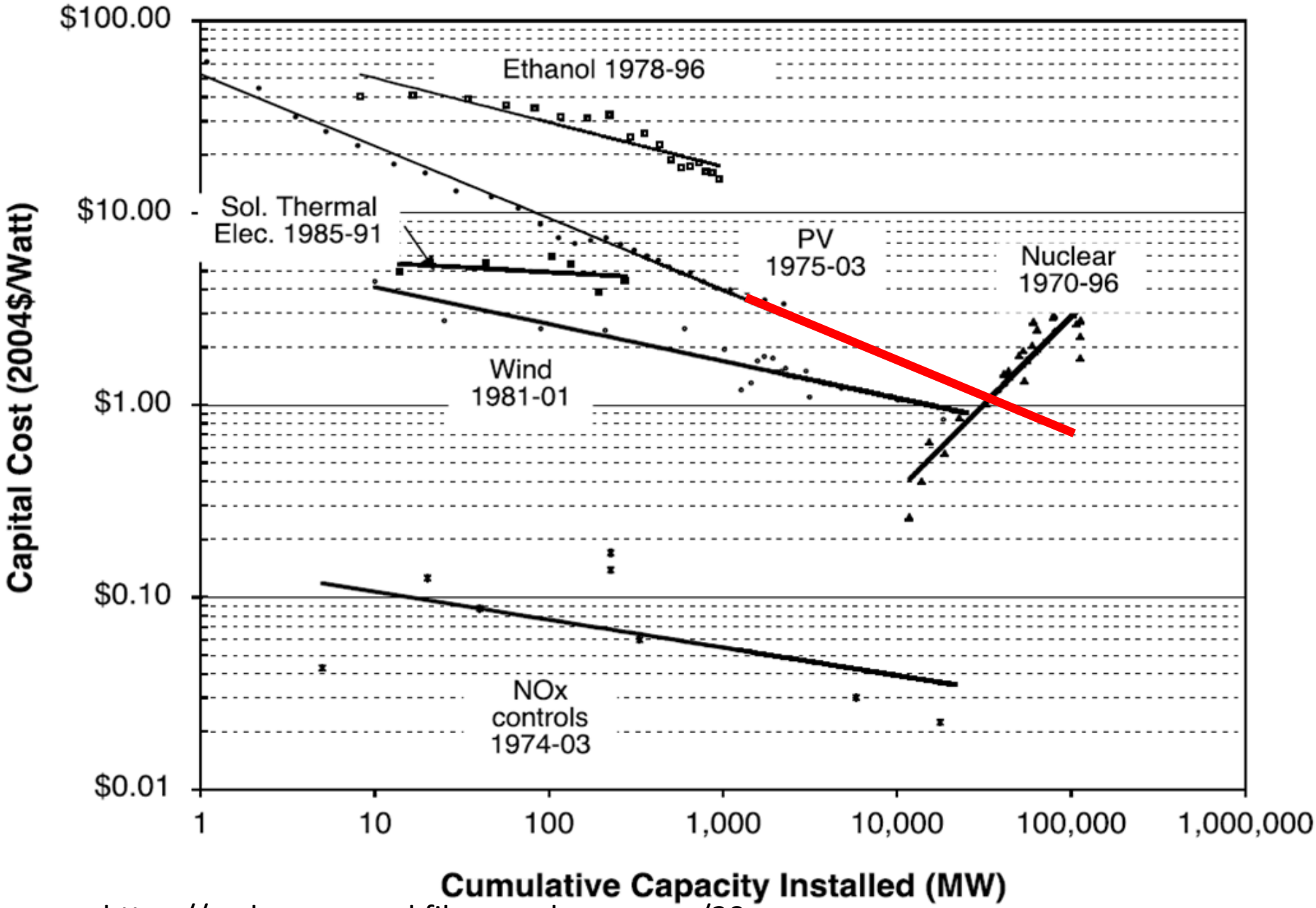
Impacts - YES

It’s our responsibility to develop as wisely and ethically as possible

PV Markets – greater rooftop development should help

Credit: IKEA

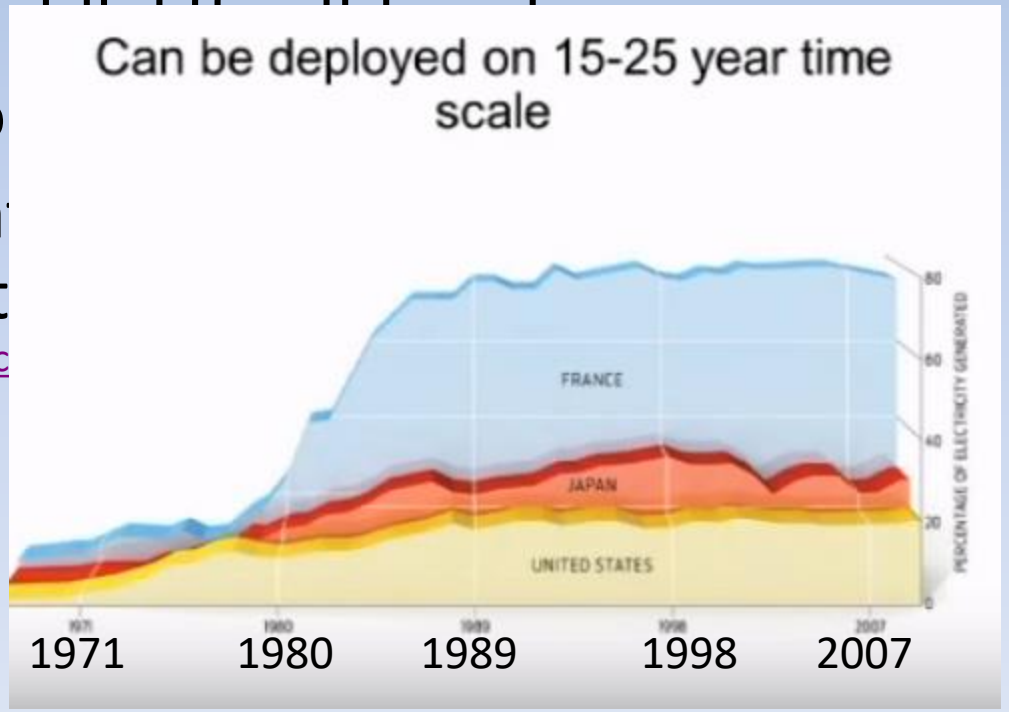
WEEK 6 - PART A
Nuclear Power: Fission and Fusion
Possibilities, Concerns, Costs



https://carbonremoval.files.wordpress.com/2014/12/energy-learning-curves.png

IT IS A Non-Carbon Sourced of Energy to Consider

- Nuclear (fission and fusion)
  - Fission: Very Controversial
  - Fusion: clean / is
  - Need national po
  - See Kerry video a
    and conclusions t
    https://www.youtube.com/watc



Fusion Power

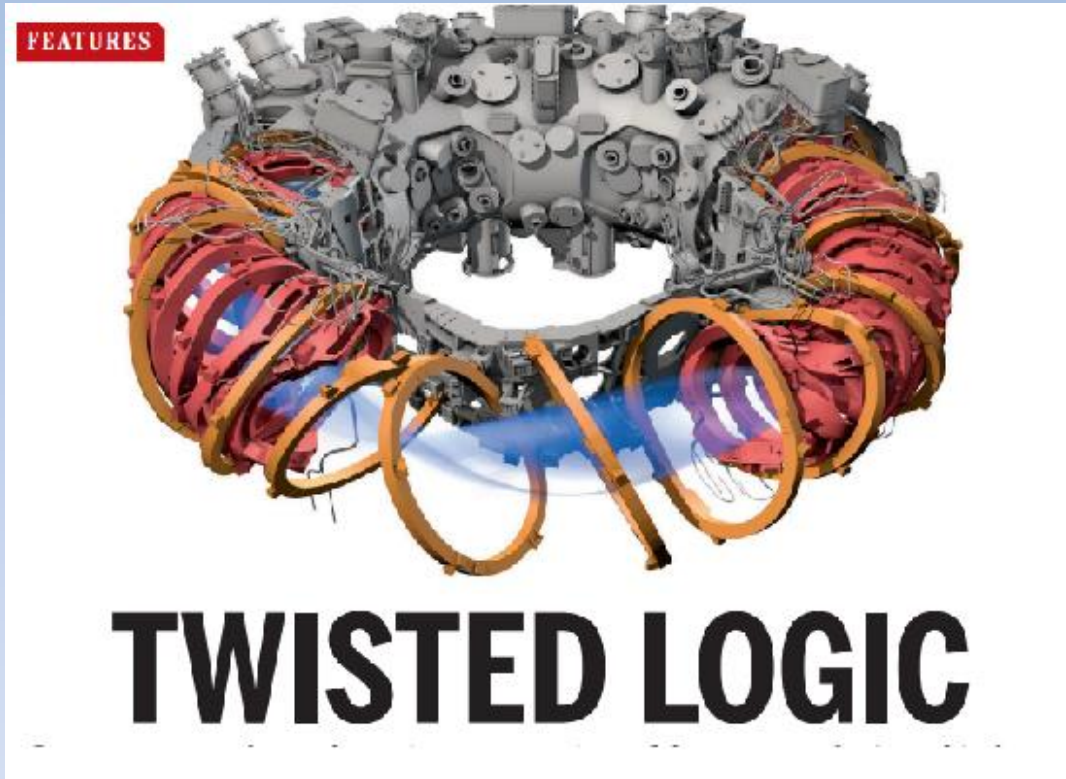
Powering Forward, Ritter, 2016

1. Energy – from fusion

Lockheed Martin Compact Fusion breakthrough?

- http://www.lockheedmartin.com/us/products/compact-fusion.html
- http://aviationweek.com/blog/high-hopes-can-compact-fusion-unlock-new-power-space-and-air-transport
- http://aviationweek.com/fusion-podcast

1. More on Fusion:



Fusion article in Science: Twisted Logic Science-2015-Clery-369-7

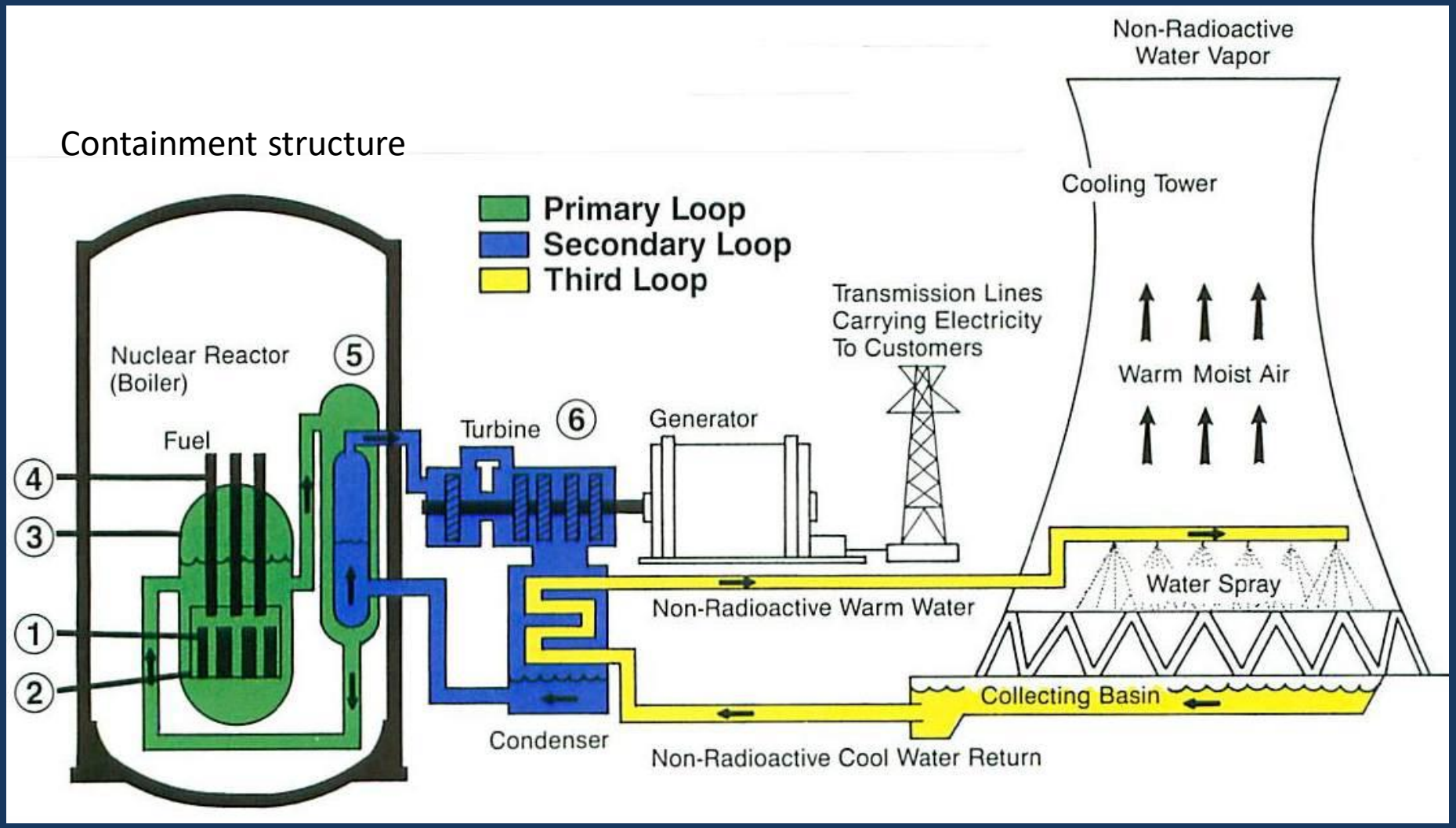
Will we ever get there?

- **Fusion reactors: Not what they're cracked up to be**
  - http://thebulletin.org/fusion-reactors-not-what-they%E2%80%99re-cracked-be10699
  - State not able to replicate Sun
  - State Tritium cannot be fully replenished
  - Huge parasitic power consumption
  - Some forms (deuterion-tritium) do have radiation damage and waste
  - Etc.

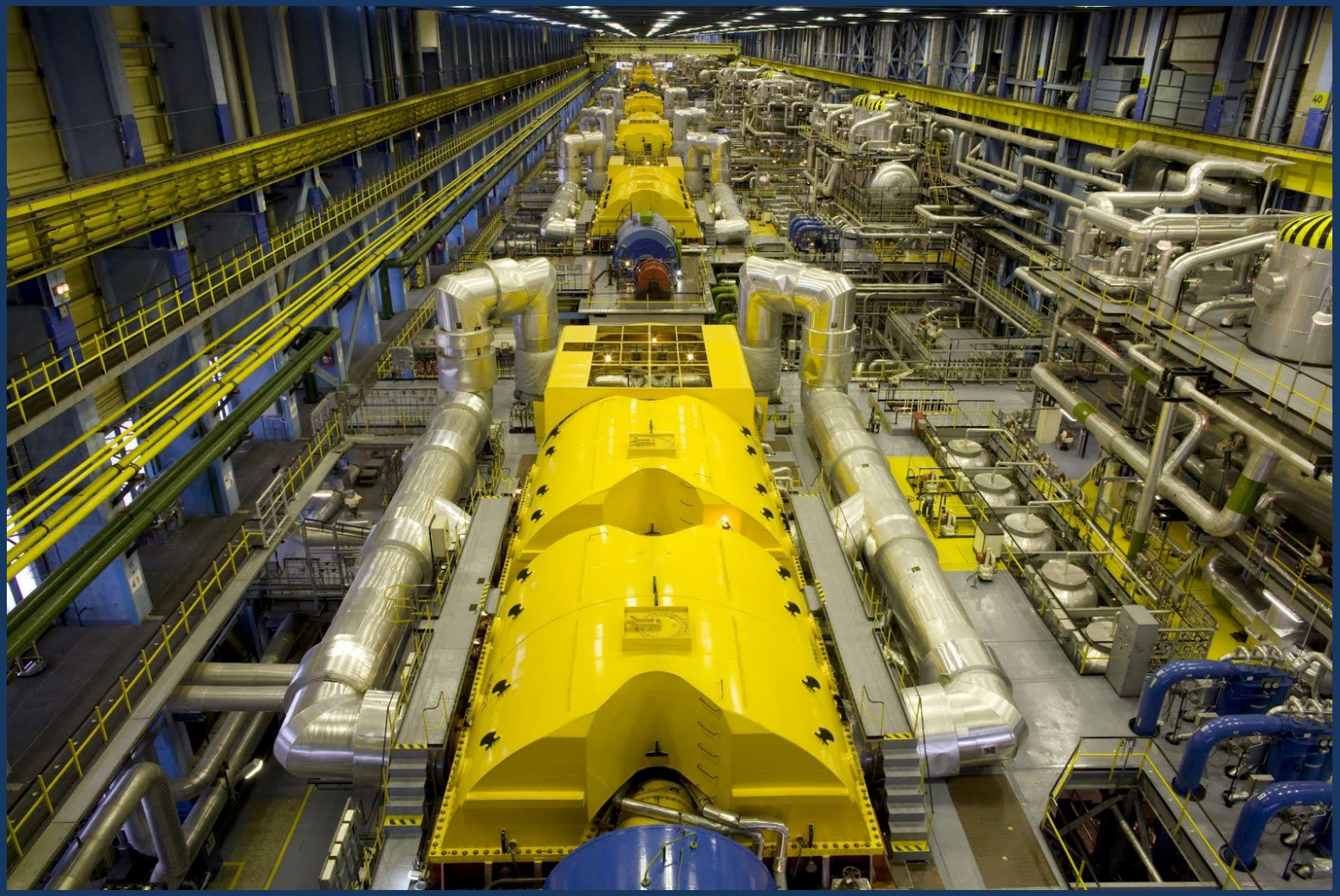
Fission Power

- U.S.
  - 1/2015 61 commercial plants
  - In 30 states
  - 2014: provided 19% electrical power
  - Most built in 1960s and 1970s – AGING! (20 more years?)
- World:
  - Nuclear Energy Around the World. As of November 2016, 30 countries worldwide are operating **450 nuclear** reactors for electricity generation and **60** new nuclear plants are under construction in 15 countries. Nuclear power plants provided 10.9 percent of the world's electricity production in 2012.
  - France ~80% of their electricity

Diagram of a nuclear reactor and electrical power generation plant



Turbine hall in a nuclear power plant



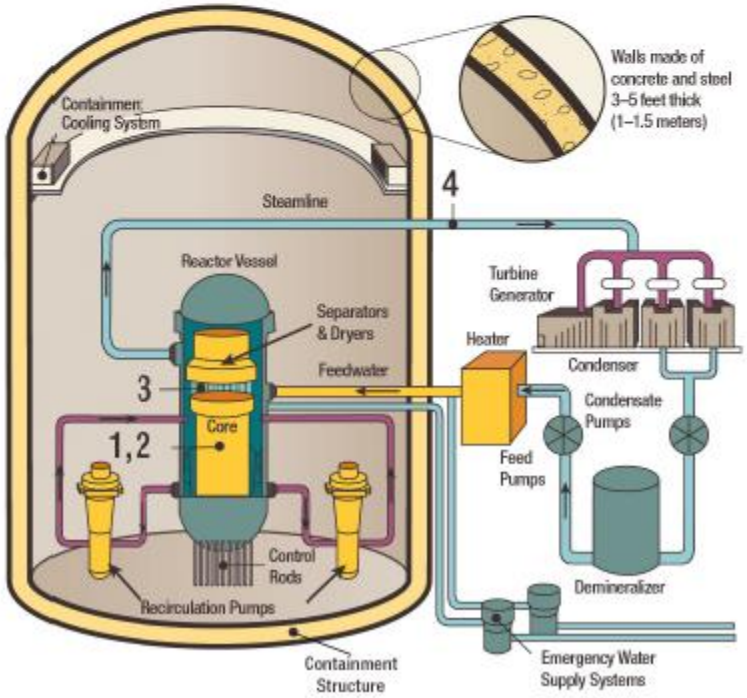
Typical Boiling-Water Reactor

How Nuclear Reactors Work

In a typical design concept of a commercial BWR, the following process occurs:

1. The core inside the reactor vessel creates heat.
2. A steam-water mixture is produced when very pure water (reactor coolant) moves upward through the core, absorbing heat.
3. The steam-water mixture leaves the top of the core and enters the two stages of moisture separation where water droplets are removed before the steam is allowed to enter the steamline.
4. The steamline directs the steam to the main turbine, causing it to turn the turbine generator, which produces electricity.

The unused steam is exhausted to the condenser, where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps, reheated, and pumped back to the reactor vessel. The reactor's core contains fuel assemblies that are cooled by water circulated using electrically powered pumps. These pumps and other operating systems in the plant receive their power from the electrical grid. If offsite power is lost, emergency cooling water is supplied by other pumps, which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need electric power. BWRs contain between 370–800 fuel assemblies.



Courtesy of Henriks (Hank) Zeile, fall 2015

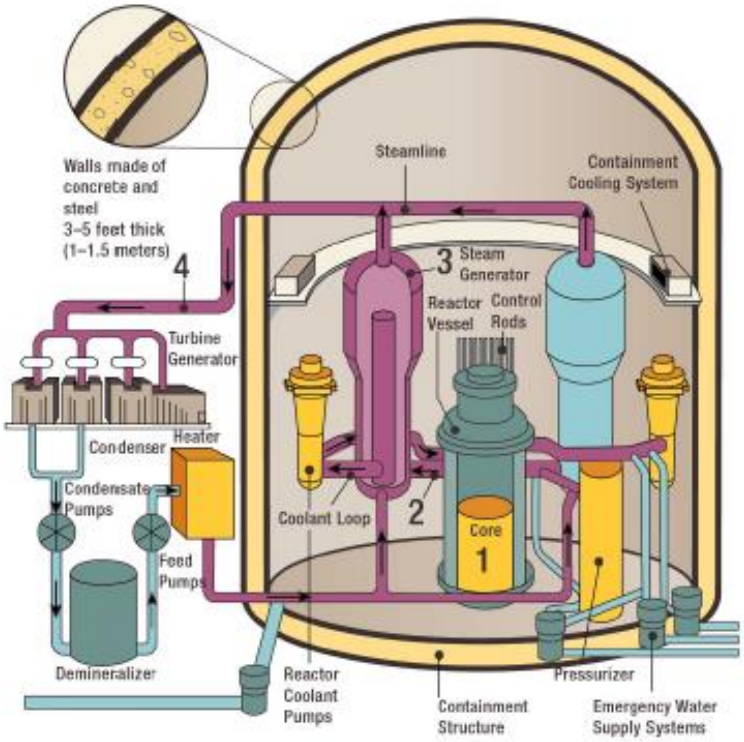
Typical Pressurized-Water Reactor

How Nuclear Reactors Work

In a typical design concept of a commercial PWR, the following process occurs:

1. The core inside the reactor vessel creates heat.
2. Pressurized water in the primary coolant loop carries the heat to the steam generator.
3. Inside the steam generator, heat from the primary coolant loop vaporizes the water in a secondary loop, producing steam.
4. The steamline directs the steam to the main turbine, causing it to turn the turbine generator, which produces electricity.

The unused steam is exhausted to the condenser, where it is condensed into water. The resulting water is pumped out of the condenser with a series of pumps, reheated, and pumped back to the steam generator. The reactor's core contains fuel assemblies that are cooled by water circulated using electrically powered pumps. These pumps and other operating systems in the plant receive their power from the electrical grid. If offsite power is lost, emergency cooling water is supplied by other pumps, which can be powered by onsite diesel generators. Other safety systems, such as the containment cooling system, also need electric power. PWRs contain between 150–200 fuel assemblies.

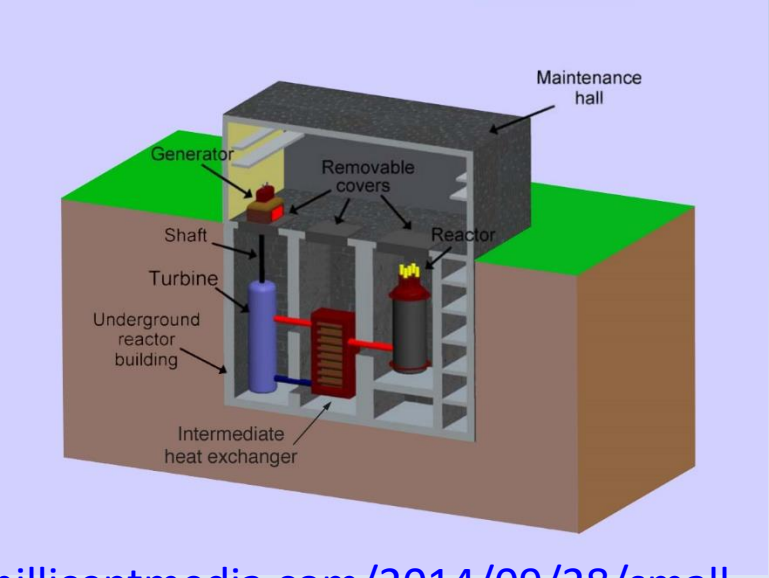


Courtesy of Henriks (Hank) Zeile, fall 2015

Other Reactor types

- Thorium
- Breeder reactors
- Small scale sealed units

https://peswiki.com/directory:hyperions-small-scale-nuclear-reactors



https://millicentmedia.com/2014/09/28/small-nuclear-reactors-going-round-in-circles/

NUCLEAR POWER INDUSTRY PERFORMANCE

65 YEARS - 14,500 REACTOR YEARS COMMERCIAL OPERATION

- MAJOR ACCIDENTS

  THREE MILE ISLAND UNIT-2 1979

  CHERNOBYL 1986

  FUKUSHIMA 2011

- 31 FATALITIES (CHERNOBYL)
- CORE MELT CAUSES NO INJURIES TO PUBLIC
- LARGE NUMBER OF CANCERS PREDICTED
- FEW CANCERS IF ANY ATTRIBUTED TO ACCIDENT

Courtesy of Henriks (Hank) Zeile, fall 2015

WORLD-WIDE NUCLEAR ACCIDENTS SINCE 1957

LEVEL	DEFINITION	NUMBER	EXAMPLE
7	MAJOR ACCIDENT	1	CHERNOBYL, UKRAINE, 1986
6	SERIOUS ACCIDENT	1	MAYAK, RUSSIA, 1957
5	ACCIDENT W/WIDE CONSEQUENCES	4	WINDSCALE, UK, 1957; THREEMILE ISLAND, U.S.A, 1979; FUKUSHIMA, JAPAN, 2011
4	ACCIDENT W/LOCAL CONSEQUENCES	4	FLEURUS, BELGIUM, 2006
3	SERIOUS INCIDENT	4	SELLAFIELDS, UK, 2005
2	INCIDENT	5	ATUCHA, ARGENTINA, 2005
1	ANOMALY	12	6 IN U.S, 2 GERMANY, 1 CANADA, 1 YUGOSLAVIA, 1 JAPAN, 1 U.K.

INTERNATIONAL NUCLEAR EVENT SCALE (INES) DEVELOPED BY IAEA AND OECD IN 1990

Courtesy of Henriks (Hank) Zeile, fall 2015

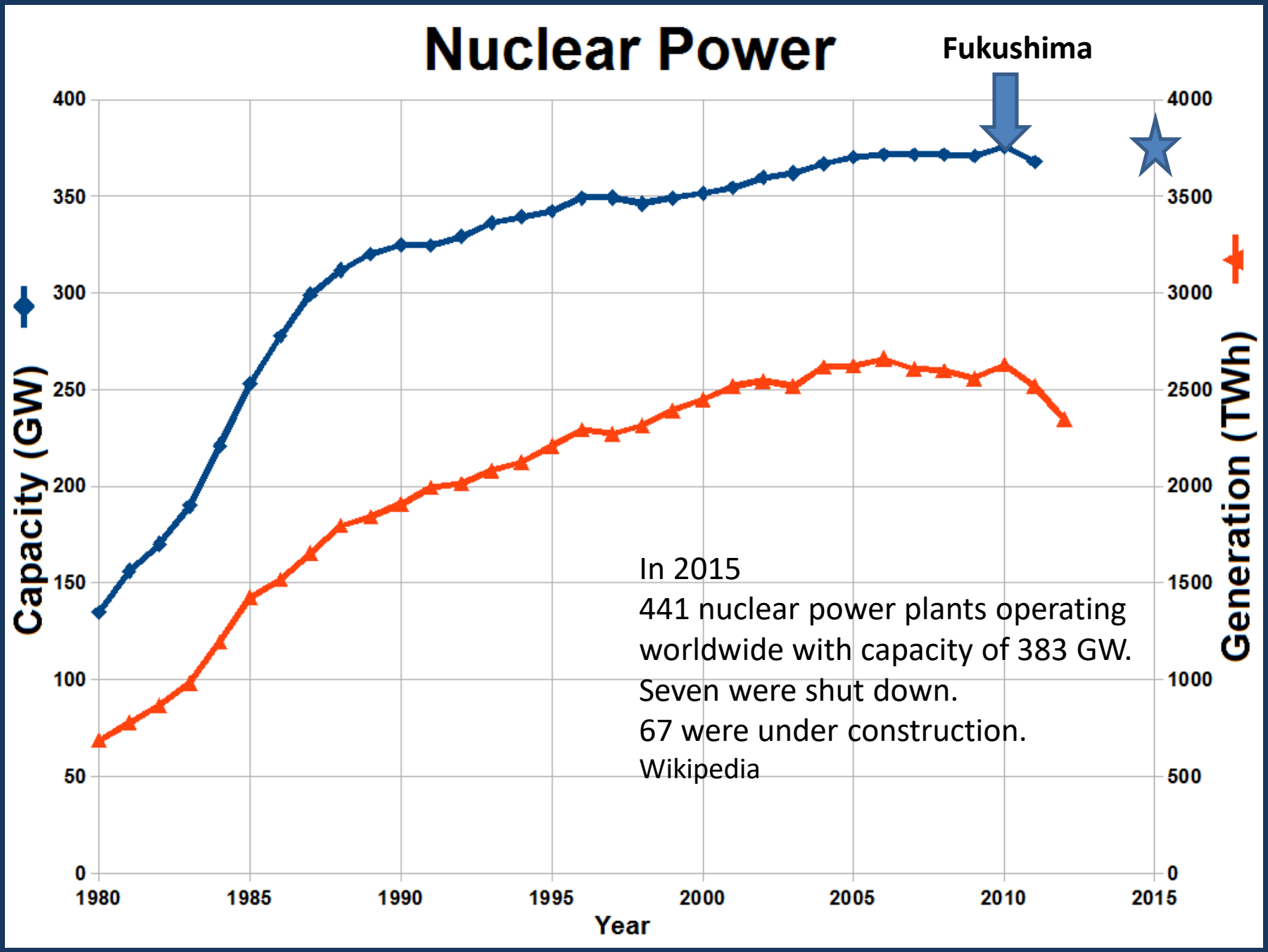
RADIATION RELEASE

	FUKUSHIMA	CHERNOBYL
Max. radiation detected	72.9 Sv/h	300 Sv/h
Radioactivity released	340 to 940 PBq	5.2 EB1 (5,200 PBq)
Exclusion zone	13.3 mi	20 mi
Population relocated	~ 100,000	~ 335,000
Fatalities	2 drowned	31 - 64

80% of Fukushima radionuclides released fell into the ocean. Near 100% of Chernobyl radionuclides fell on land. Fukushima continues to leak radionuclides to the ocean.

Total relocated due to tsunami and Fukushima is ~270,000

Courtesy of Henriks (Hank) Zeile, fall 2015


Nuclear Power
Fukushima
Capacity (GW)
Generation (TWh)
Year
400
350
300
250
200
150
100
50
0
4000
3500
3000
2500
2000
1500
1000
500
0
1980
1985
1990
1995
2000
2005
2010
2015
In 2015
441 nuclear power plants operating worldwide with capacity of 383 GW.
Seven were shut down.
67 were under construction.
Wikipedia

Paying Nuclear Losers for 'Clean' Power Upends U.S. Markets

Bloomberg, 25 April 2017

New York and Illinois have cleared the way for nuclear power to be subsidized with higher fees on buyers -- aid normally reserved for renewable energy like solar and wind. One reason policy makers gave was to protect jobs at aging plants teetering on closure. Another was nuclear's emission-free electricity…..

Controversies

- Proliferation / dirty bombs
- Waste disposal
- Costs of retiring old plants
- Environmental risks

Nuclear waste storage

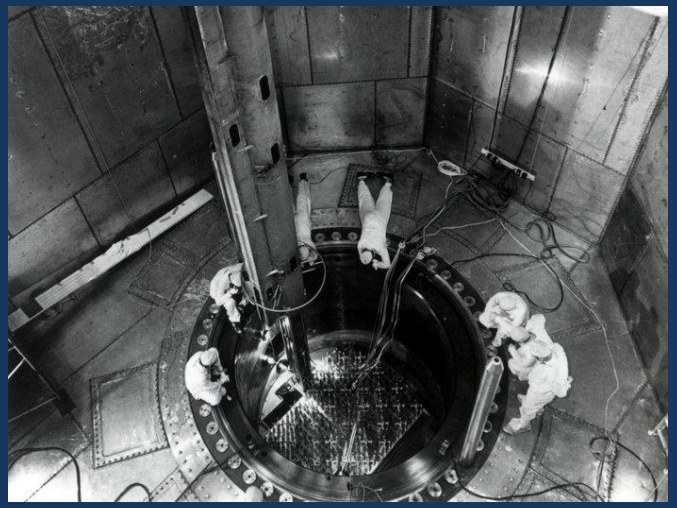
Waste, Families Left Behind As Nuclear Plants Close

NPR Morning Edition Oct 24, 2016

The Fort Calhoun plant cranked out electricity for 43 years, and it was licensed for another 17. Decommissioning will cost up to $1.5 billion, and take up to 60 years to complete. Still, Tim Burke figures eating all of that is cheaper than keeping the plant in production.

Burke runs the Omaha Public Power District, which owns Fort Calhoun. He says operating a small plant like this one, especially in a region with abundant wind power and natural gas, just doesn't make sense.
Though Burke has many energy options, his customers are not using more power. Across the U.S. demand has been flat for a decade. New capacity drives down the price. Nuclear power, with its stiff regulations and fixed expenses, can have a hard time competing.

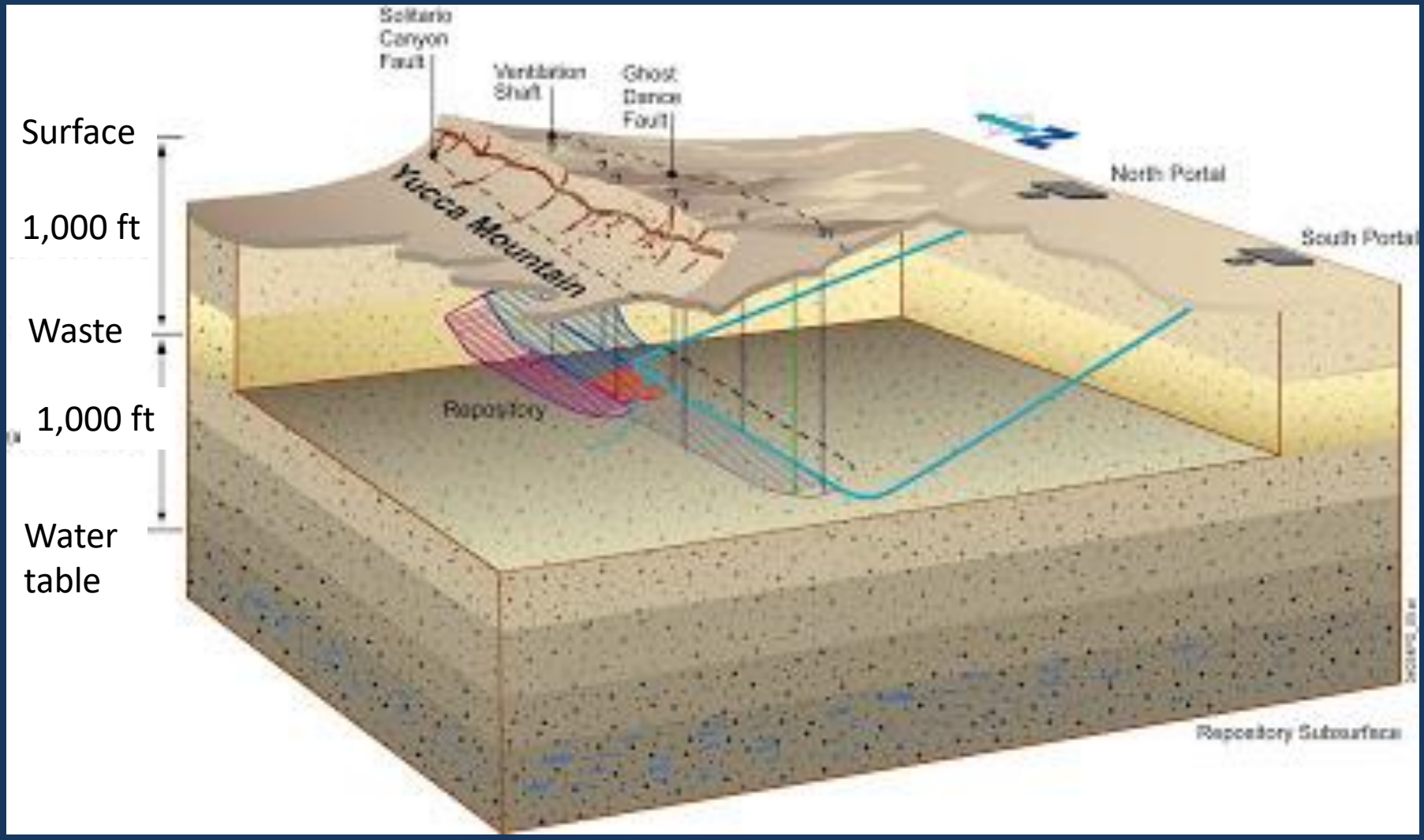
"There's certainly accelerated decommissioning. There's a lot more decommissioning than there was say, 10 or 15 years ago," says Allison Macfarlane, a former chairwoman of the Nuclear Regulatory Commission.



Loading of nuclear fuel in the Fort Calhoun Station's reactor, Unit 1, began in May 1973. As the plant closes the radioactive waste will be stored on site
United States Department of Energy/Flickr

Yucca Mountain, Nevada
Site of a proposed nuclear waste repository

Yucca Mountain Nevada
Site of a potential nuclear waste repository



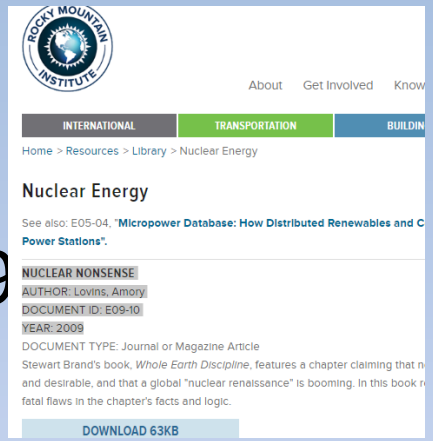
Nuclear concerns

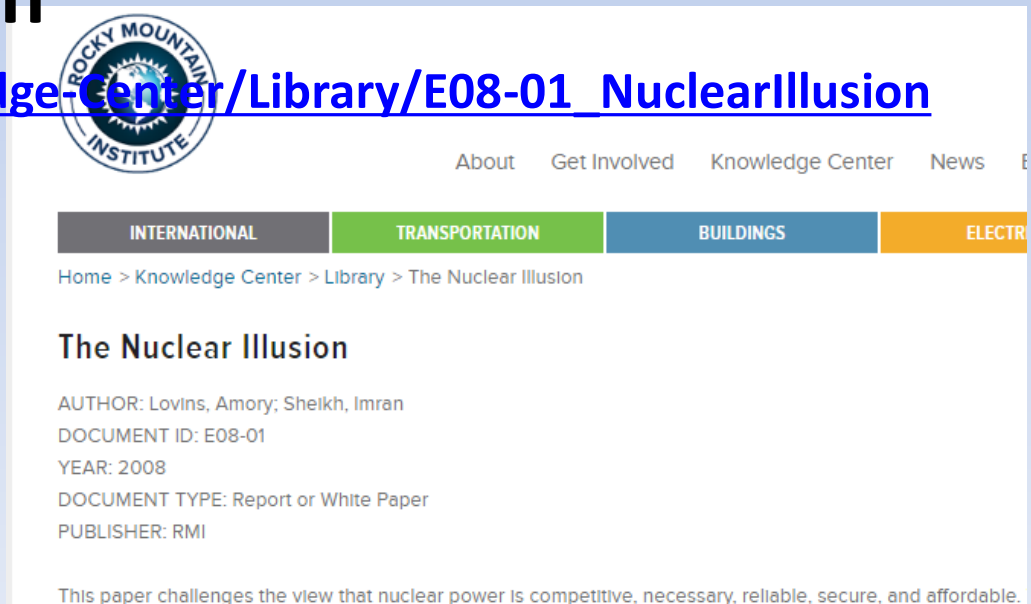
- **Colorado and nation face 70,000-ton nuclear waste burden**
- The government has paid utilities $4 billion as court-ordered compensation for storing nuclear waste

- By **BRUCE FINLEY** | bfinley@denverpost.com | The Denver Post
- PUBLISHED: May 24, 2016 at 3:14 pm | UPDATED: June 3, 2016 at 6:17 pm
- http://www.denverpost.com/2016/05/24/feds-favor-mini-nuke-power-plants-but-still-face-70k-ton-disposal-burden/

Nuclear concerns

- **<u>RMI: NUCLEAR NONSENSE</u>**
- AUTHOR: Lovins, Amory
- DOCUMENT ID: E09-10; YEAR: 2009
  http://www.rmi.org/pid257 /
- **The Nuclear Illusion**
- http://www.rmi.org/Knowledge-Center/Library/E08-01_NuclearIllusion





Niskanen Center on Nuclear

- *NUCLEAR'S (4TH GENERATION) COMEBACK TOUR*
  - *HTTPS://NISKANENCENTER.ORG/BLOG/NUCLEARS-4TH-GENERATION-COMEBACK-TOUR/*
- **Sustainability**: Generation that meets clean air objectives and promotes long-term availability of systems and effective fuel utilization for worldwide energy production. These systems will minimize and manage their nuclear waste and notably reduce the long-term stewardship burden, thereby improving protection for the public health and the environment.
- **Economics:** Systems will have a clear life-cycle cost advantage over, and level of financial risk comparable to, other energy sources.
- **Safety and Reliability**: Operations will excel in safety and reliability, will have a very low likelihood and degree of reactor core damage, and will eliminate the need for offsite emergency response.
- **Proliferation:** Systems will increase the assurance that they are the least desirable route for diversion or theft of weapons-usable materials, and provide increased physical protection against acts of terrorism.

https://niskanencenter.org/https://niskanencenter.org/

However it is a non-carbon source of Energy

- Cost effective?
- Do we subsidize current ones to extend life?