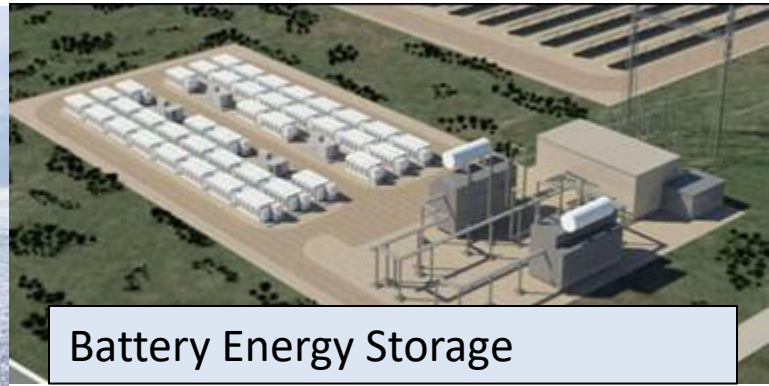
Sustainable Energy

L. David Roper

roperld@vt.edu

http://tinyurl.com/SustainableEnergy



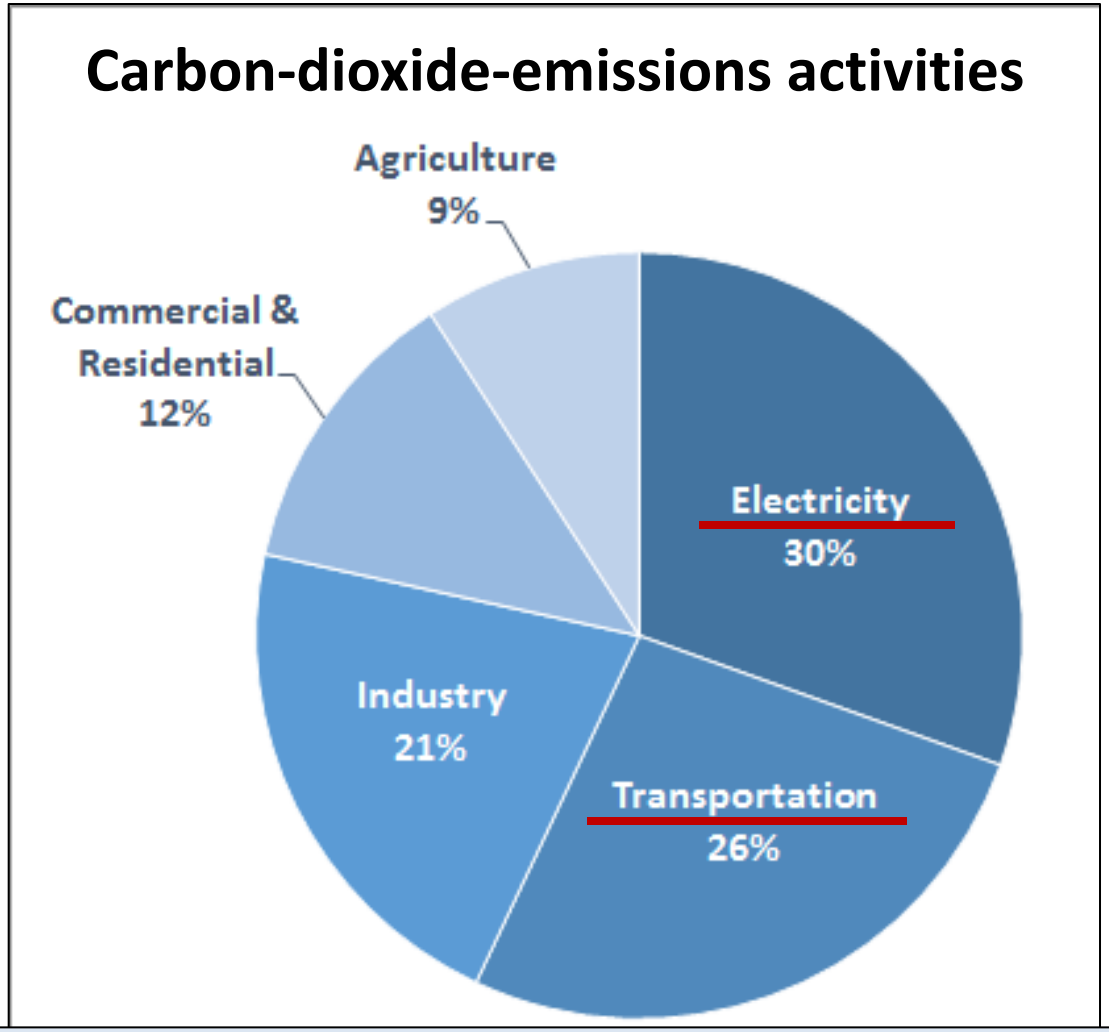
Battery Energy Storage

Agenda

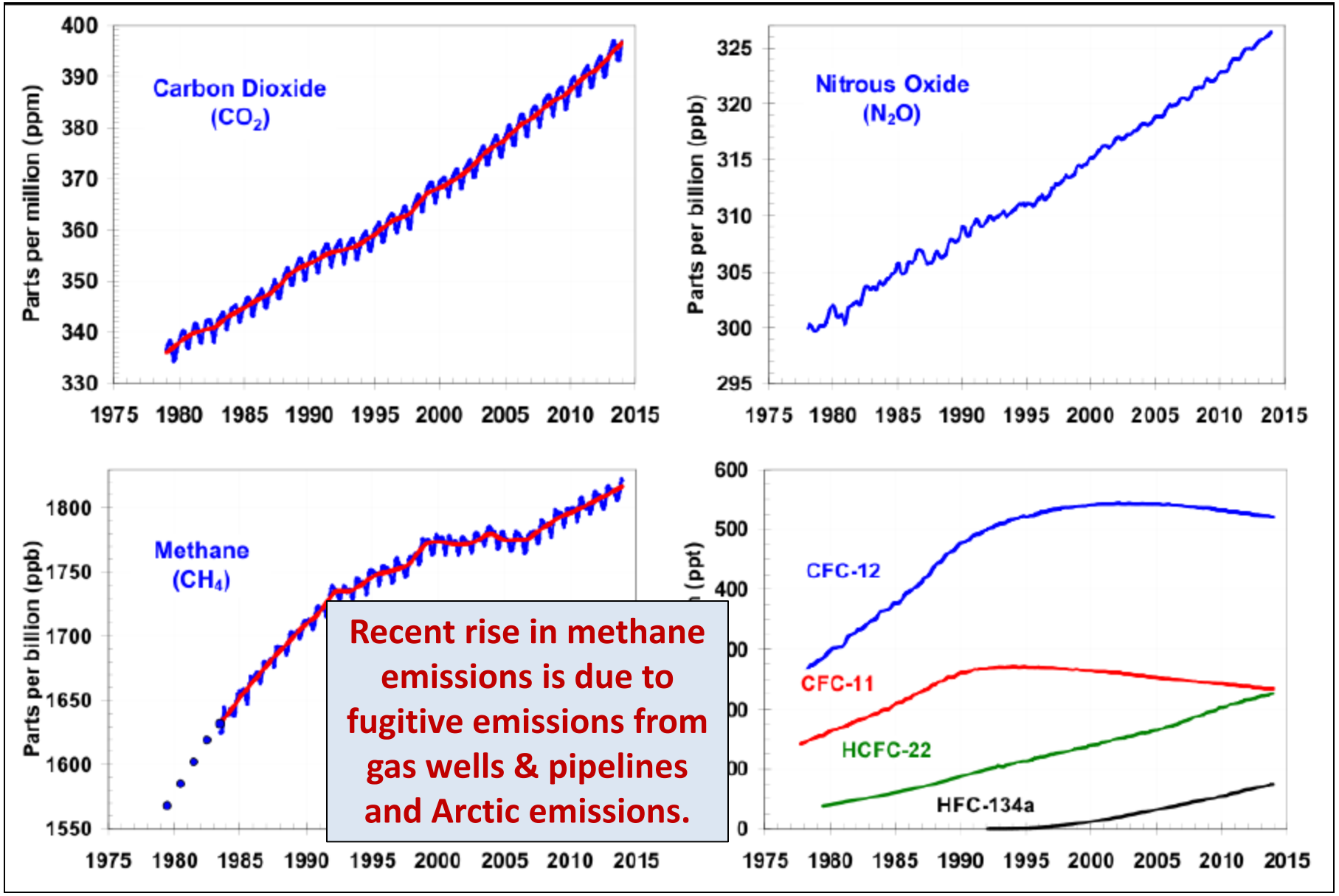
- Global Warming
- Renewable Energy
  - Solar
  - Wind
  - Biofuels
  - Geothermal
- Smoothing renewables with Storage & Smart Grid
- Energy storage
- Locating renewable-energy collection in U.S.
- International renewable-energy progress
- 200-300 miles electric cars
- Fast trains

Causes of Global Warming

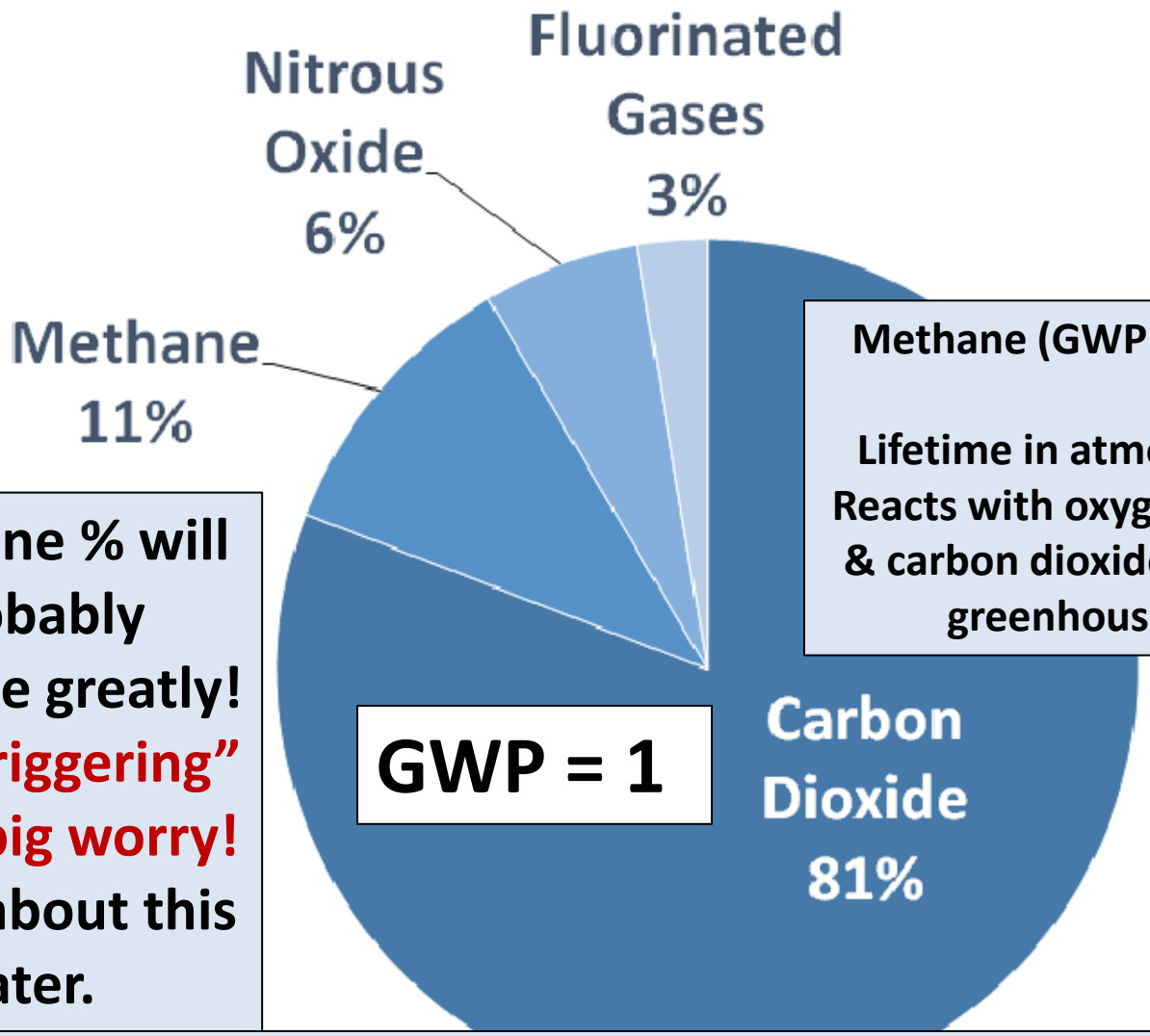
Too many people is basic cause!



We need renewable electrical energy & electric transport!


Carbon Dioxide
(CO_2)
Parts per million (ppm)
400
390
380
370
360
350
340
330
1975 1980 1985 1990 1995 2000 2005 2010 2015
Nitrous Oxide
(N_2O)
Parts per billion (ppb)
325
320
315
310
305
300
295
1975 1980 1985 1990 1995 2000 2005 2010 2015
Methane
(CH_4)
Parts per billion (ppb)
1800
1750
1700
1650
1600
1550
1975 1980 1985 1990 1995 2000 2005 2010 2015
Recent rise in methane emissions is due to fugitive emissions from gas wells & pipelines and Arctic emissions.
600
500
400
0
CFC-12
CFC-11
HCFC-22
HFC-134a
1975 1980 1985 1990 1995 2000 2005 2010 2015

U.S. Greenhouse Gas Emissions in 2014



Methane (GWP = ~85 in 20 years & ~32 in 100 years). Lifetime in atmosphere = 12 years. Reacts with oxygen to produce water & carbon dioxide, both of which are greenhouse gases (GHG).

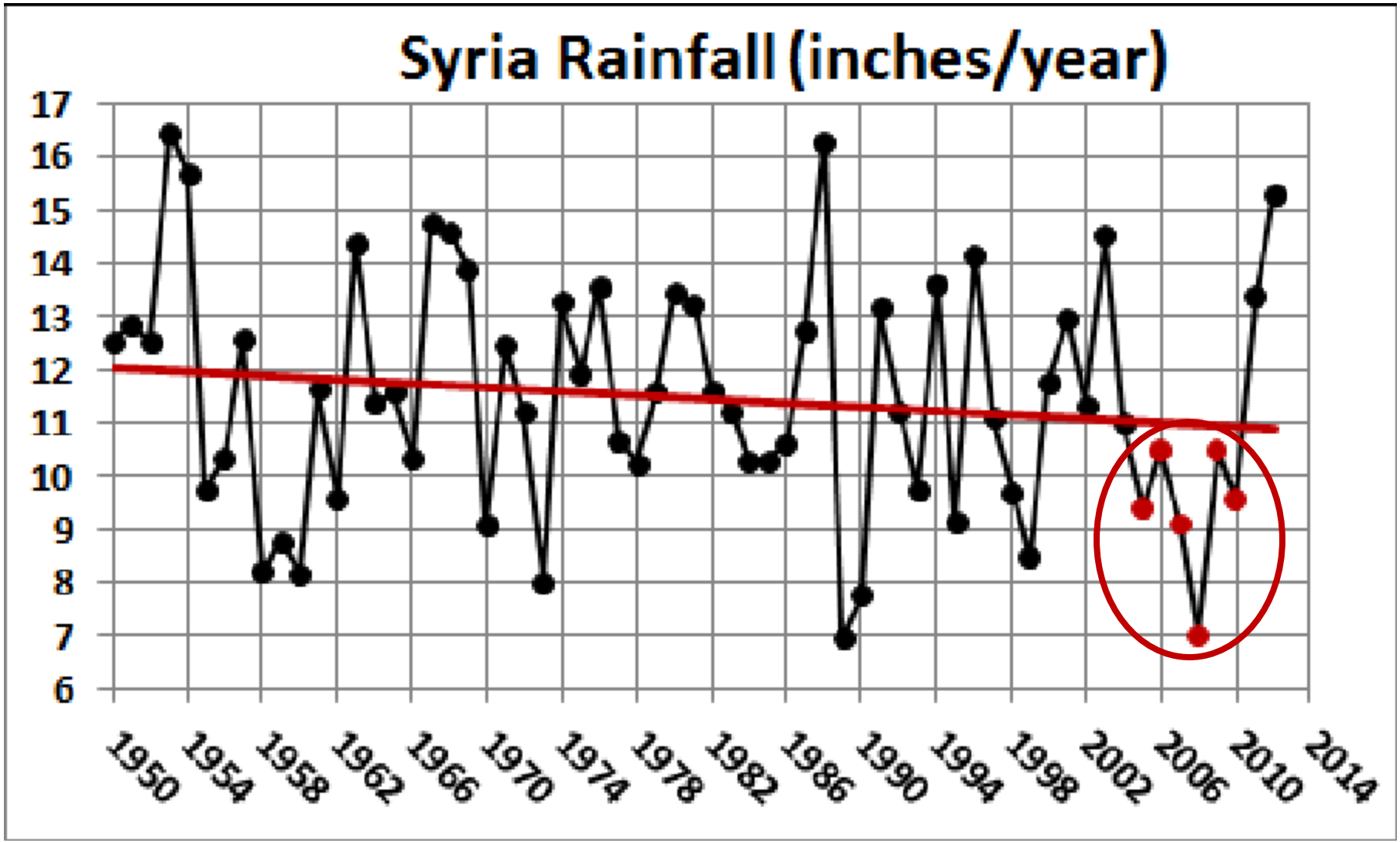
Methane % will probably increase greatly! This "triggering" is the big worry! More about this later.

CO_2 resides in atmosphere 85% in 10 years, 34% in 100 years & 13% in 1000 years.
93% of Global Warming heat resides in oceans to be released into atmosphere!

Effects of Global Warming

- Severe droughts due to high evaporation
- Severe floods due to huge downpours
- Forest fires increase due to droughts.
- Mudslides due to dried bare land and downpours.
- Severe destructive storms (e.g., hurricanes, tornados, high winds, huge snows)
- Rising sea levels
- Acidification of oceans
- Food and water shortages
- Human migrations and **survival wars (E.g. Syria!)**
- Ecosystems shifting northward and upward (mountains)
- Species extinctions
- **Feedbacks leading to increased Global Warming**

2005-2010 Drought in Syria was a major factor in the rebellion.

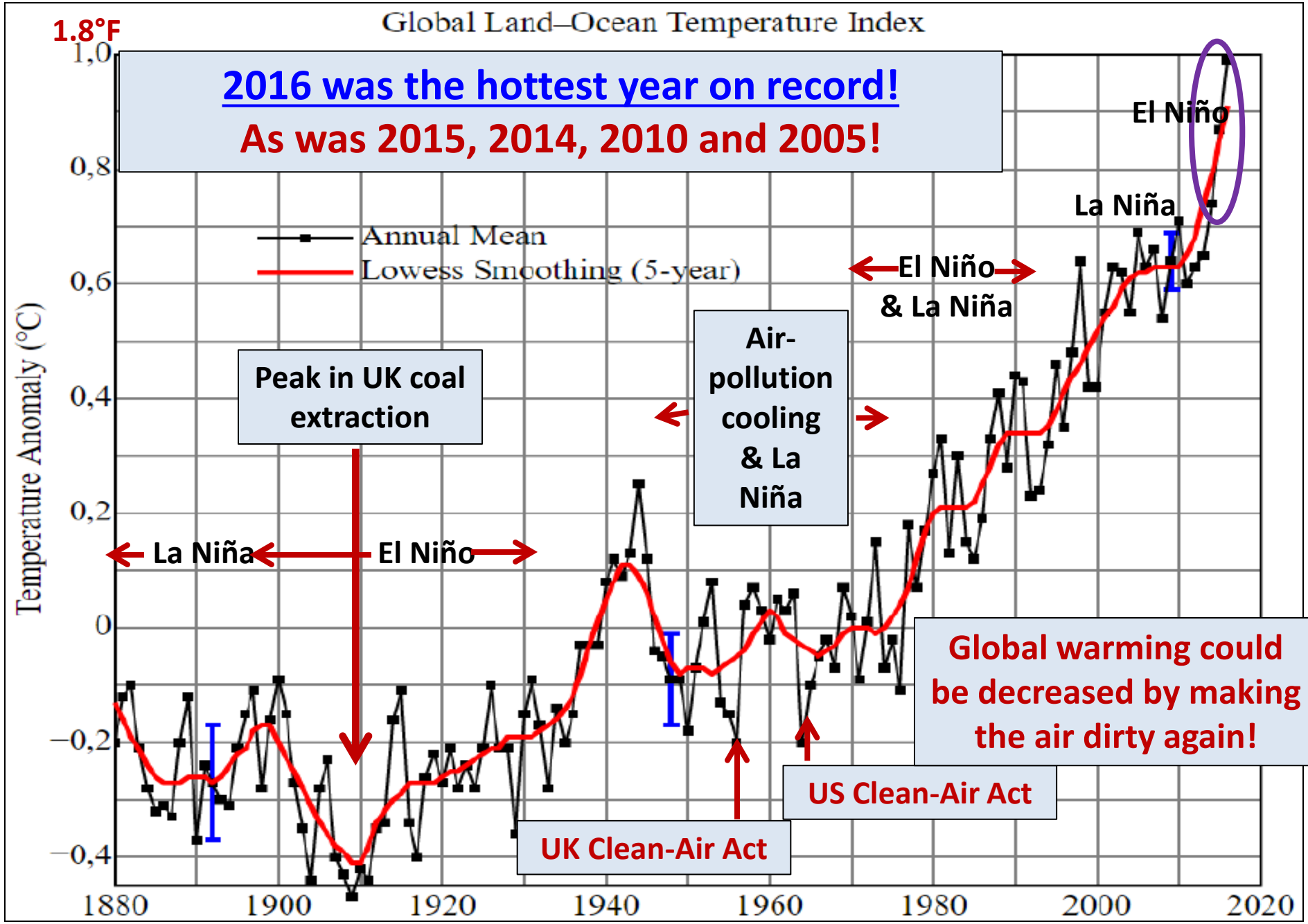


This is one of the reasons the U.S. military is studying global warming.

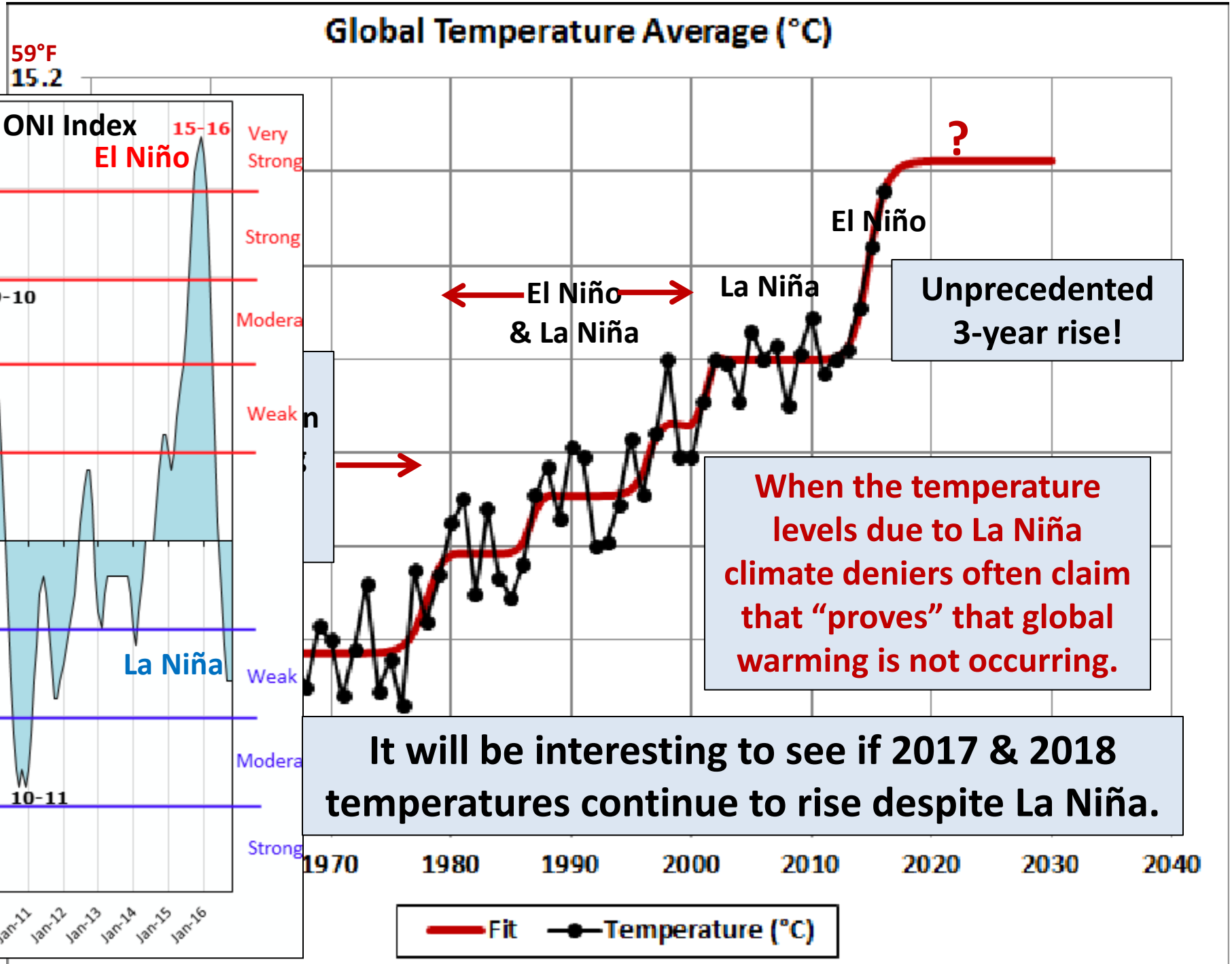
Dangerous Global Warming Feedbacks

- **High temperature** increases moisture in the air, a powerful greenhouse gas. It doubles the temperature increase of CO_2.
- **Forest fires** due to **droughts** stop trees' intake of carbon dioxide and add heat to the atmosphere.
- **Sea ice melting** increases sea area and, thus, solar-energy absorption by a factor of ~6.
- **Sea ice melting** increases sea waves that break up ice causing it to melt faster.
- **Rising sea level** increases water surface to absorb solar energy more than covered land by a factor of ~3.
- Rising **Arctic temperature** causes **tundra** to release **bound carbon dioxide and methane** into the air.
- Rising **ocean temperature** causes **bottom methane structures** to release methane into the air. (More later)

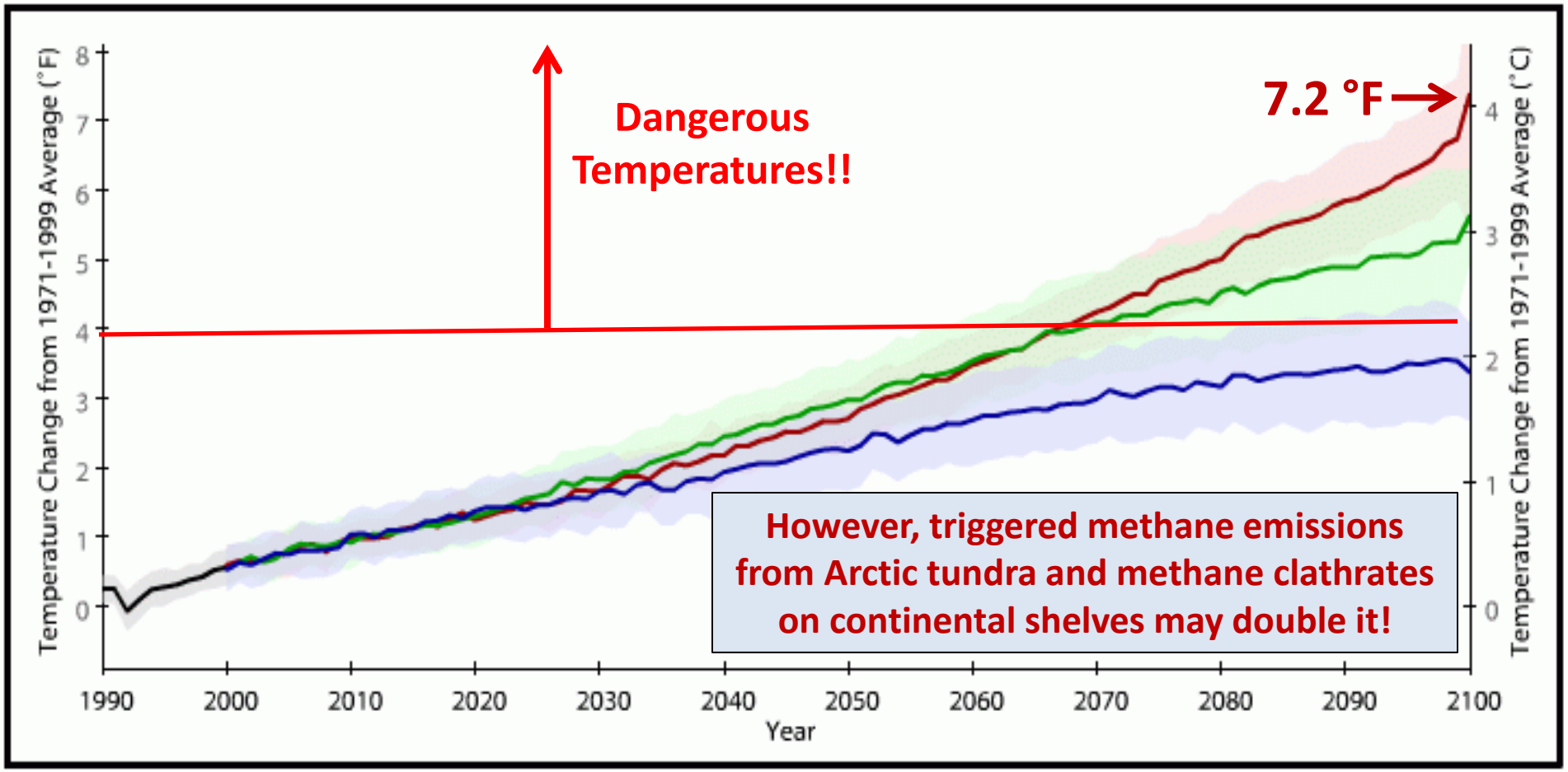
El Niño increases global warming & La Niña decreases global warming.



ONI Index
El Niño
15-16
09-10
10-11
La Niña
Very Strong
Strong
Moderate
Weak
Weak
Moderate
Strong
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16

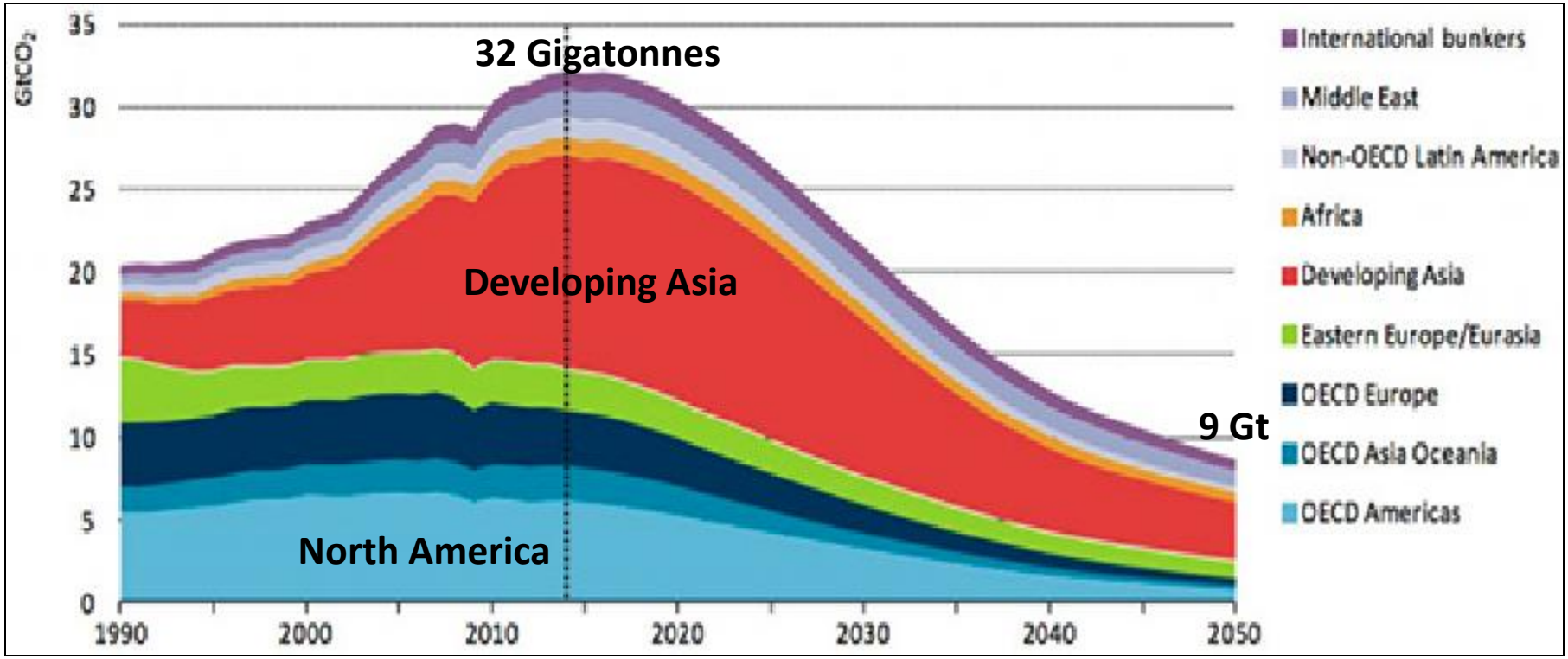

Global Temperature Average (°C)
59°F
15.2
El Niño
& La Niña
La Niña
El Niño
?
Unprecedented
3-year rise!
When the temperature levels due to La Niña climate deniers often claim that "proves" that global warming is not occurring.
It will be interesting to see if 2017 & 2018 temperatures continue to rise despite La Niña.
1970
1980
1990
2000
2010
2020
2030
2040
Fit
Temperature (°C)

This graph shows the average of a set of temperature simulations for the 20th century (black line), followed by projected temperatures for the 21st century based on three greenhouse gas emissions scenarios (colored lines).



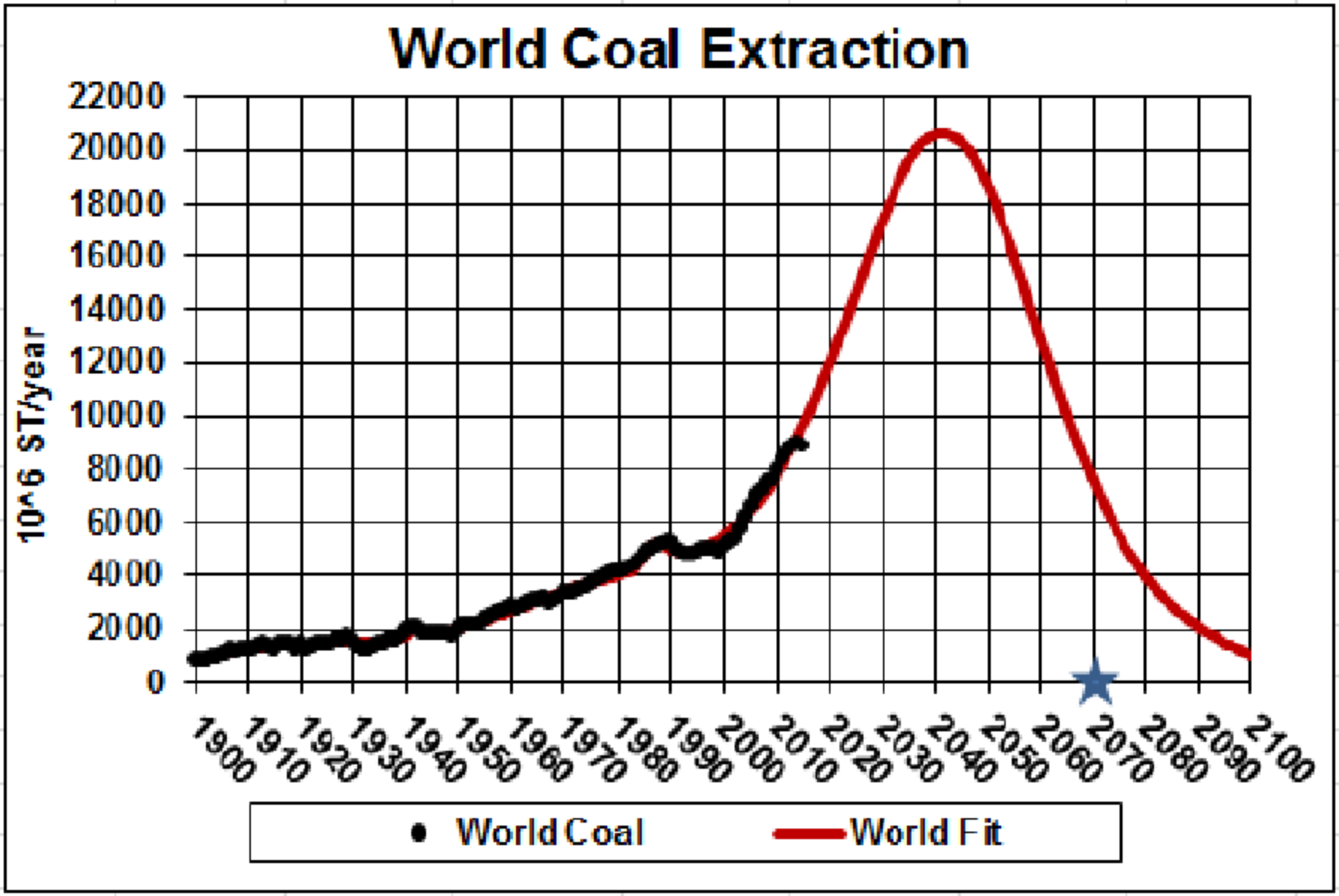
https://en.wikipedia.org/wiki/Effects_of_global_warming

Energy-related CO_2 emissions by region for temp < 2°C. Global CO_2 emissions fall to less than 9 Gigatonnes in 2050.

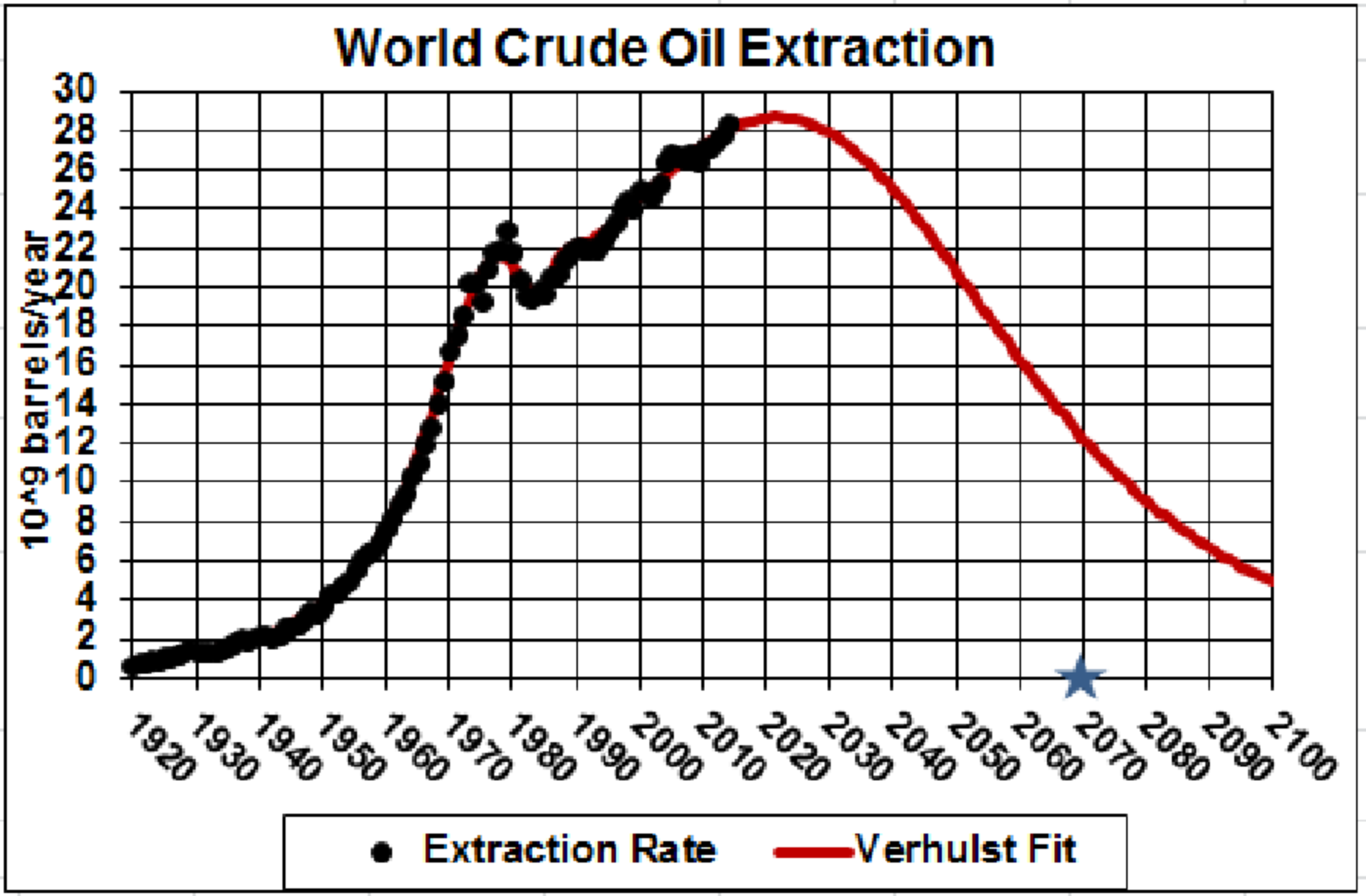


Need to reduce coal, crude-oil and natural-gas extraction for energy by about 1/4th less than current values.

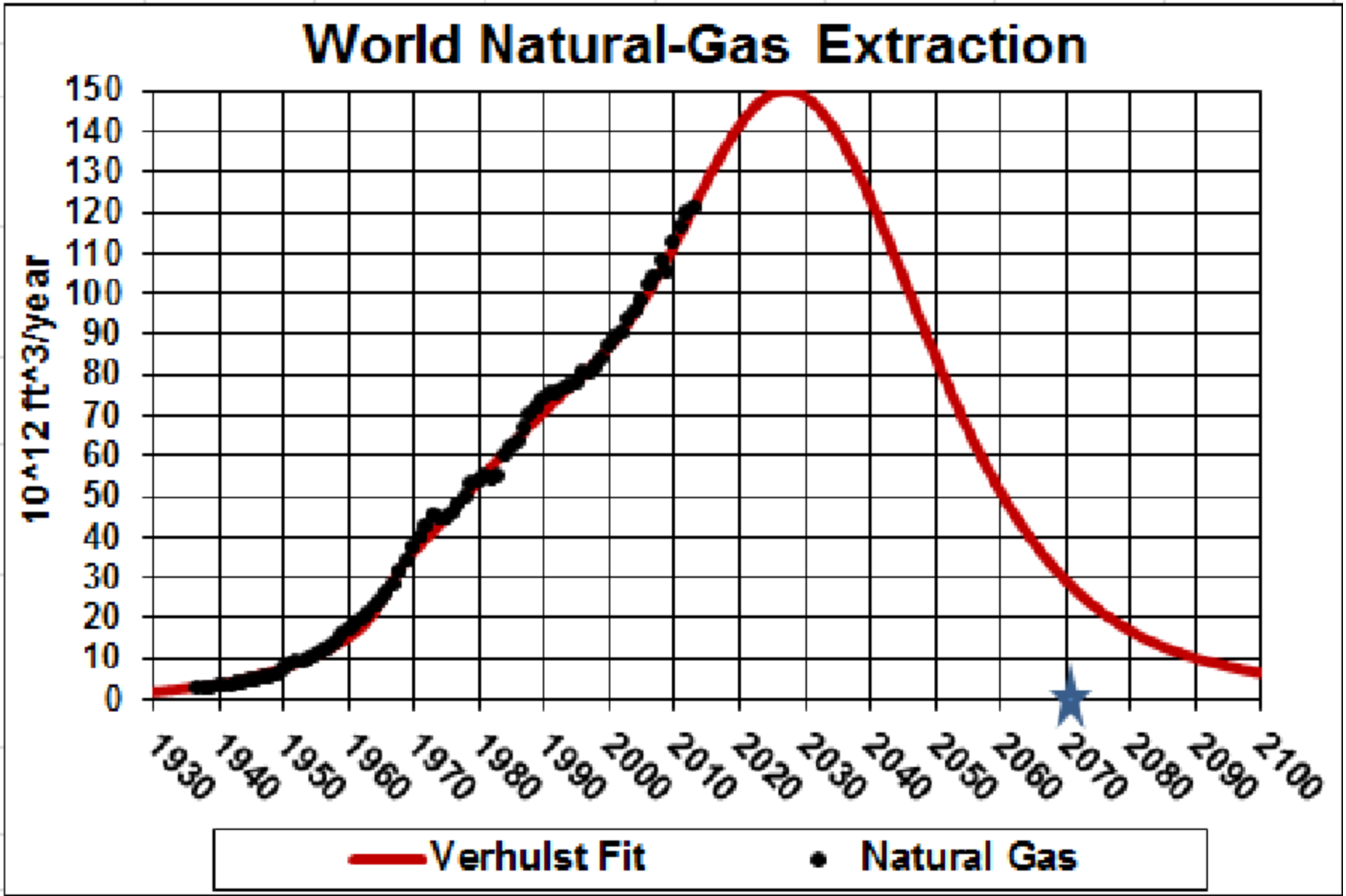
The blue star is necessary coal extraction in 2050 to keep temperature to < 2°C.



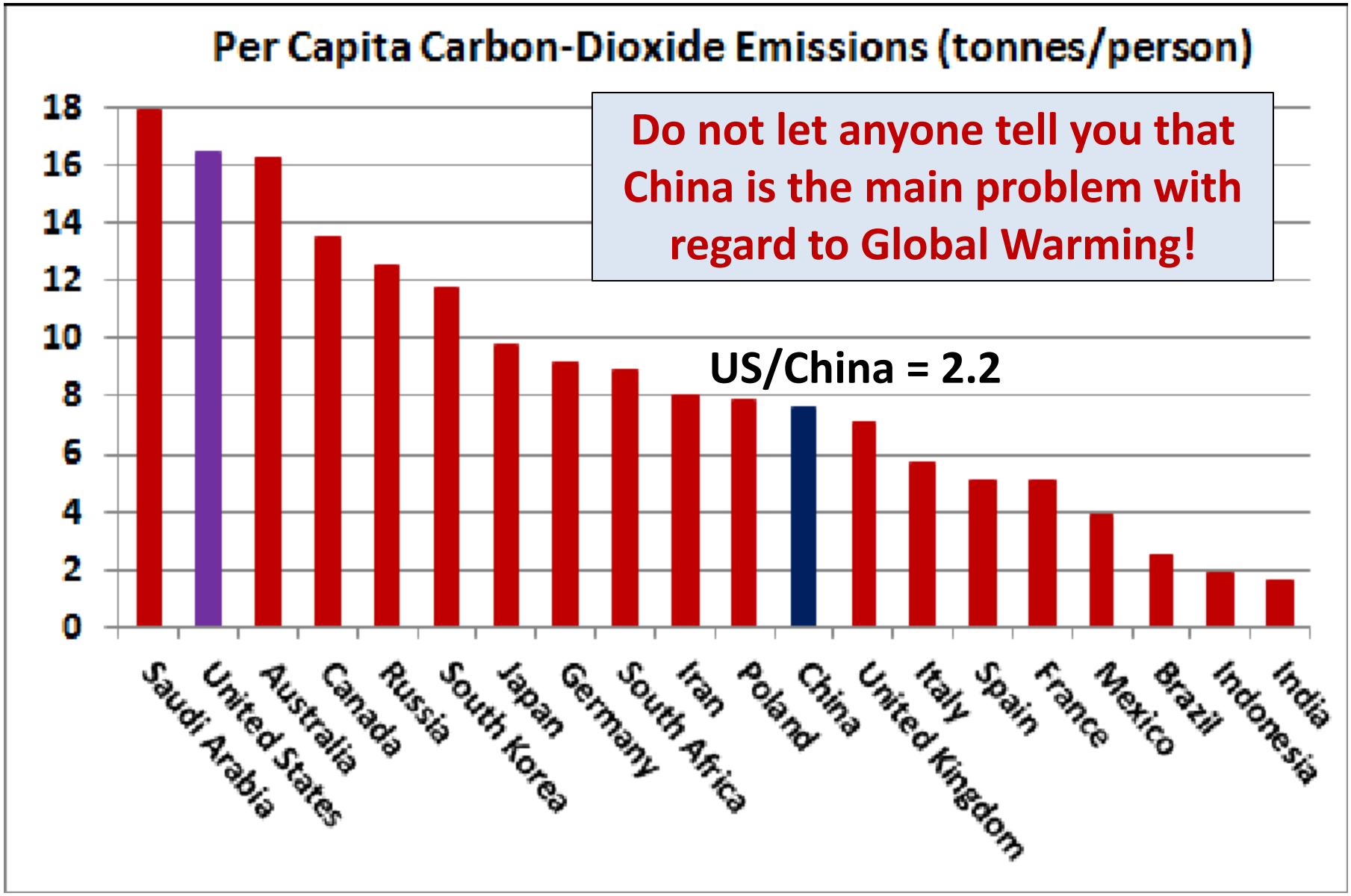
The blue star is necessary crude-oil extraction in 2050 to keep temperature to < 2°C.



The blue star is necessary natural-gas extraction in 2050 to keep temperature to < 2°C.



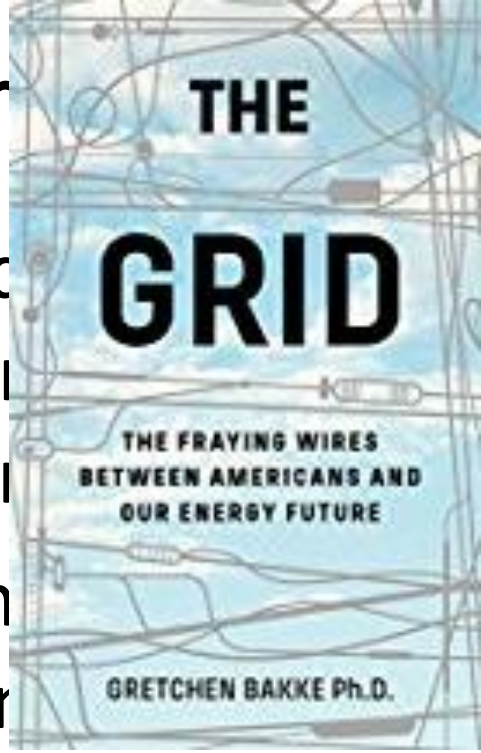
Global Carbon-Dioxide Emissions (1 tonne = 1.102 ton)



Renewable/Sustainable Energy

- Solar
  - Distributed solar photovoltaic (PV) (roofs, parking covers & community/business solar farms)
  - Centralized PV (power-company solar farms)
  - Thermal (solar hot water, parabolic trough, solar tower & thermal storage)
- Wind farms (onshore & offshore)
- Geothermal (power and storage)
- Storage
  - Batteries, including used electric-cars' (BEV) batteries
  - Thermal (e.g., molten salts, earth)
  - Ice storage for air conditioning
- MicroGrids and Smart Grid for electricity
- Biofuels (biodiesel, ethanol, methanol)

MicroGrids and Smart Gr



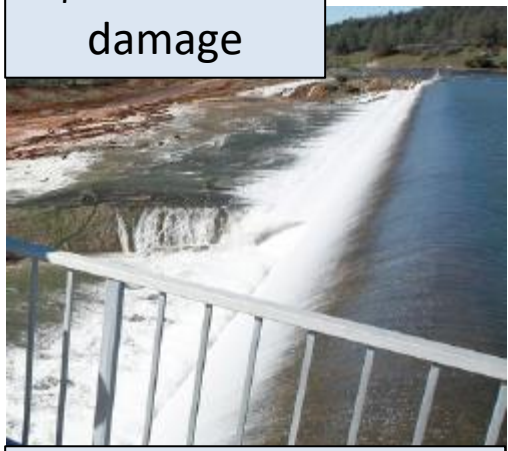
- MicroGrids are smaller, self-containec grids with their own sources of powe preferably distributed renewable sou
- MicroGrids operate independently an conjunction with a regional & main Sr
- When there is an outage of a MicroGrid, it is automatically disconnected from a regional grid and the main Smart Grid.
- Electrical energy is created closer to its usage, cutting down on transmission losses.

What about Hydroelectric Dams?

Hydroelectric is not environmental friendly!

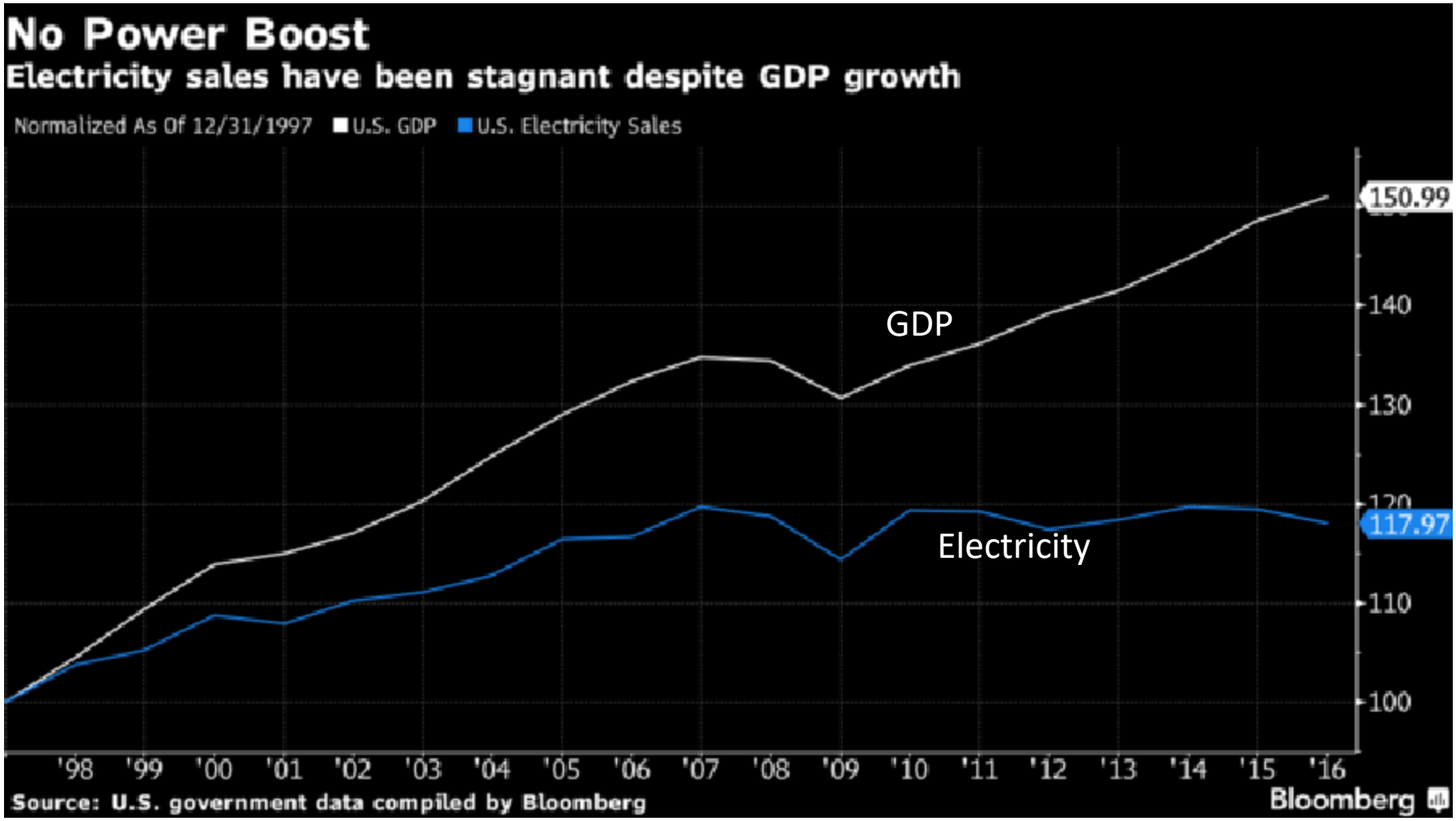
- Dams silt with time, reducing the volume.
- Dams kill trees that absorb CO_2.
- Dams take land out of food production.
- Dams destroy ecosystems & emit methane.
- Global Warming causes oscillations between droughts and floods.
- Oroville Dam, CA example:

~$200-million damage

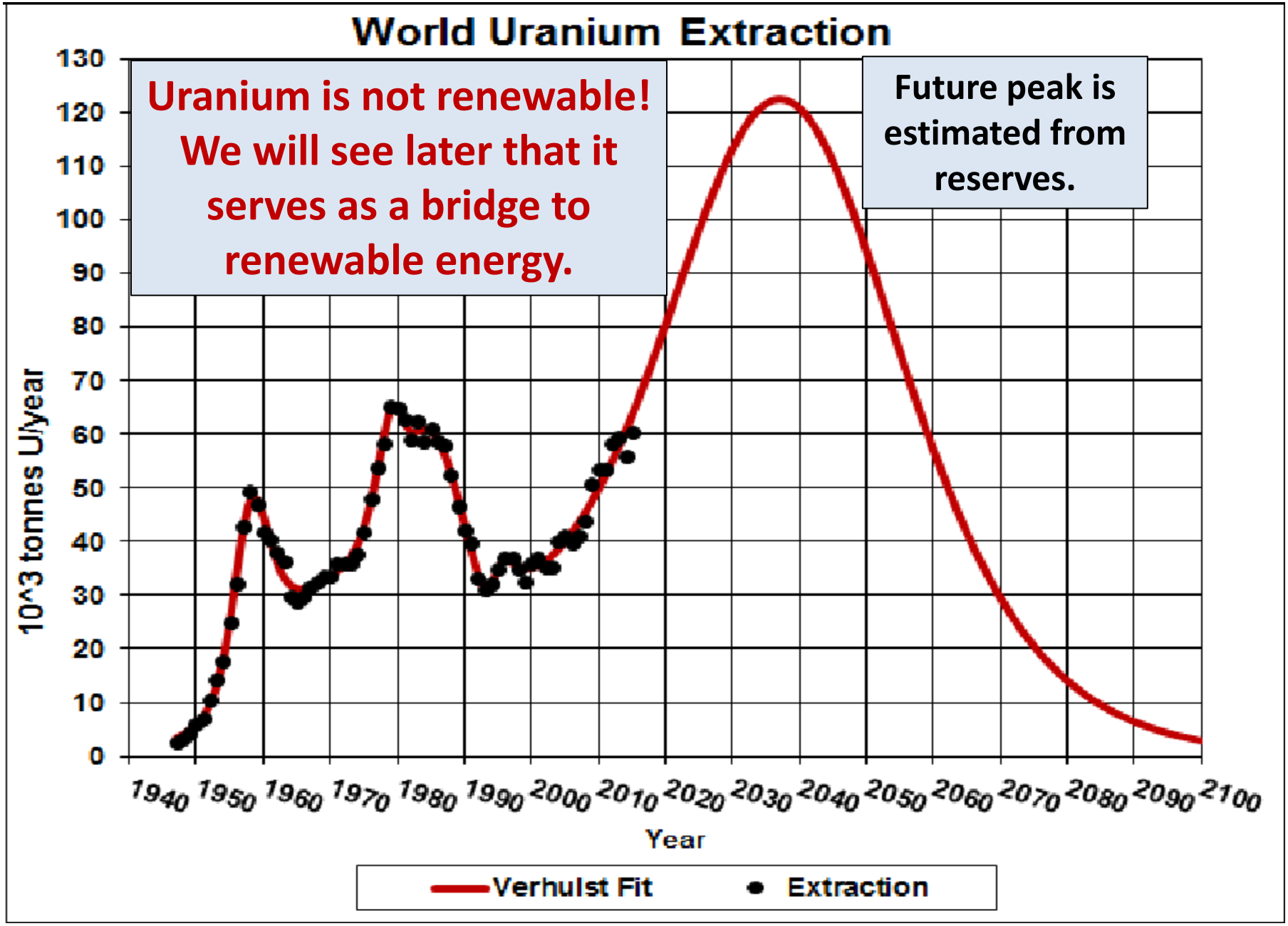


Oroville Dam Overflow 13 February 2017

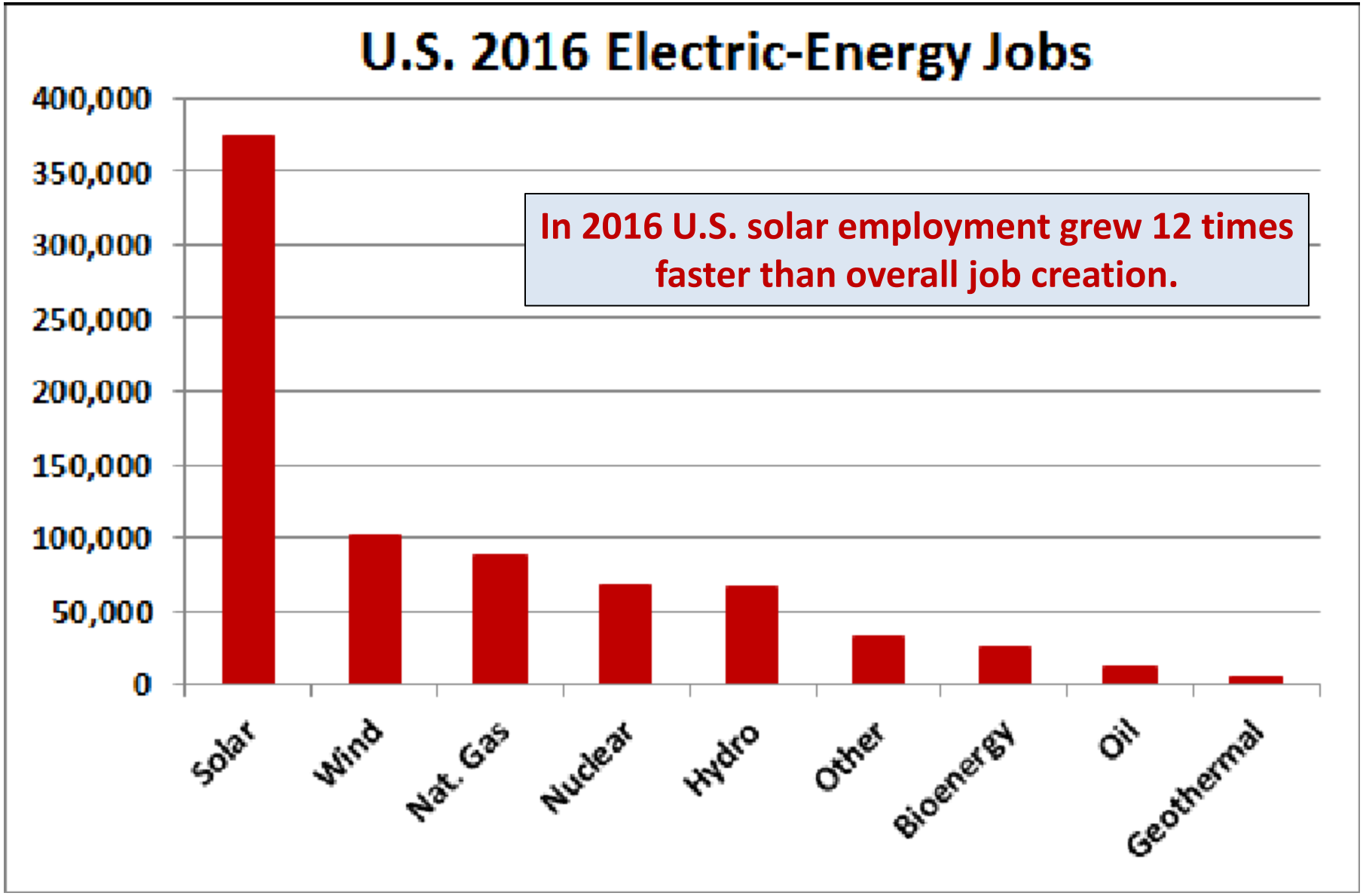
Leveling of U.S. Electricity Usage

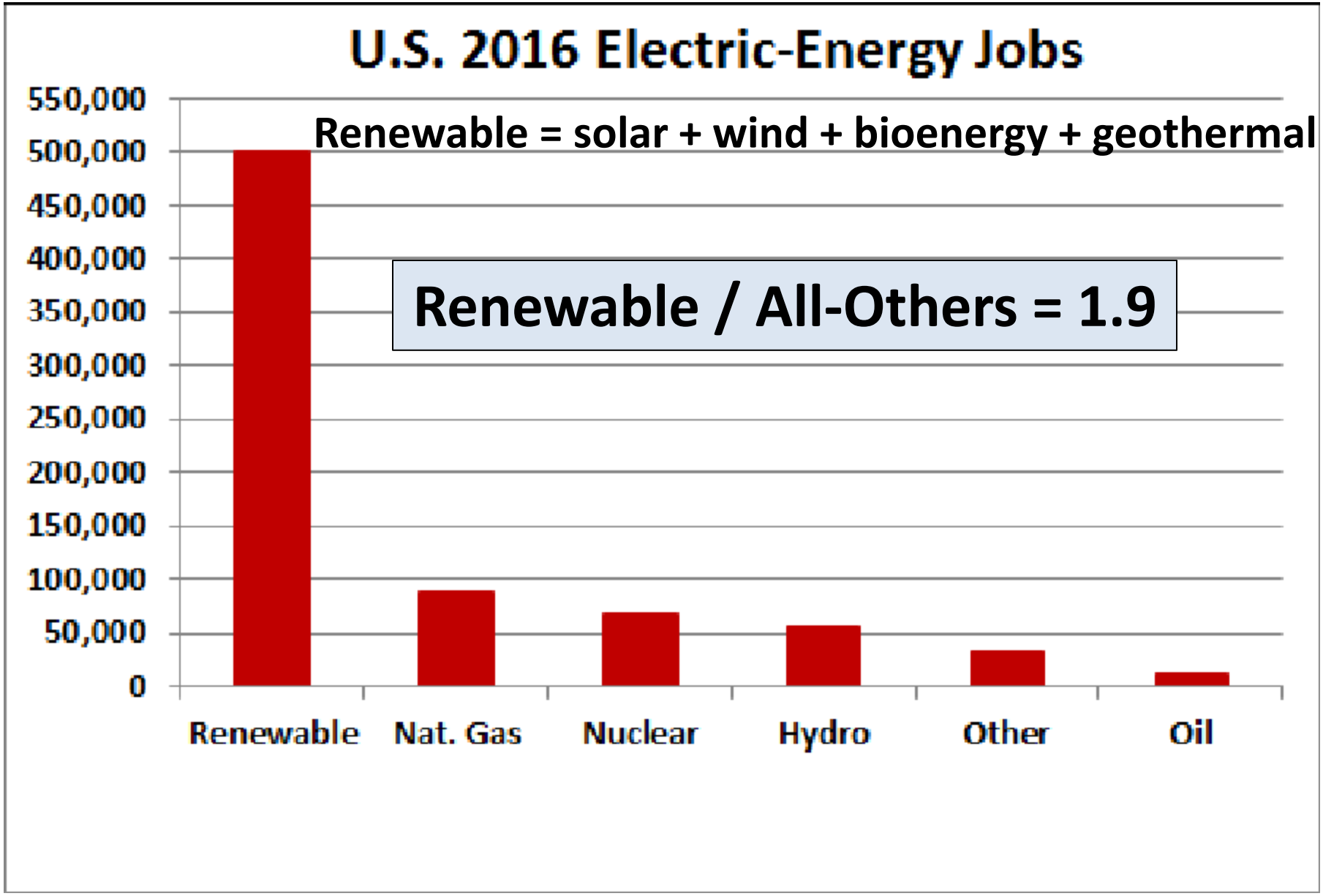


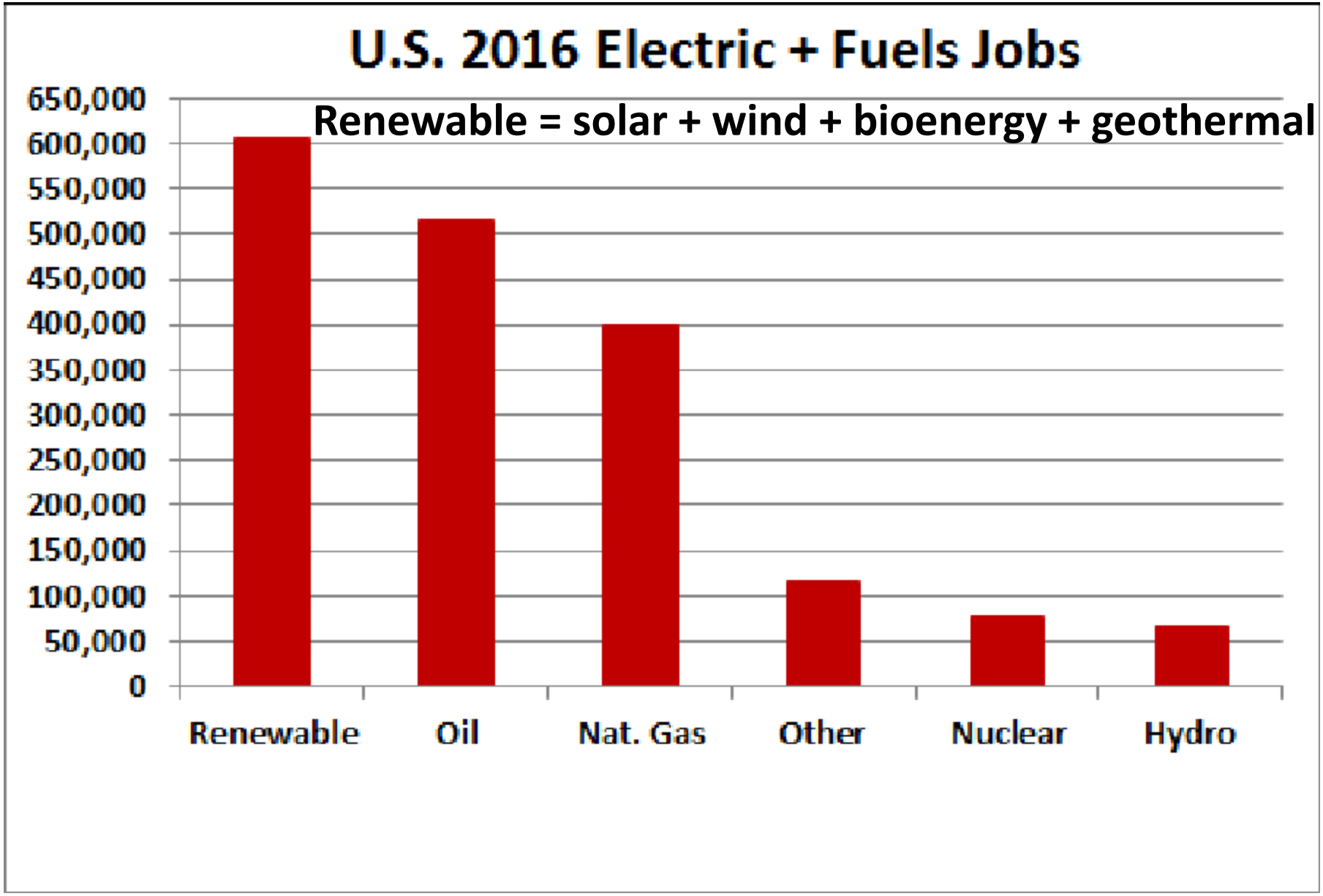
What about Nuclear Energy?



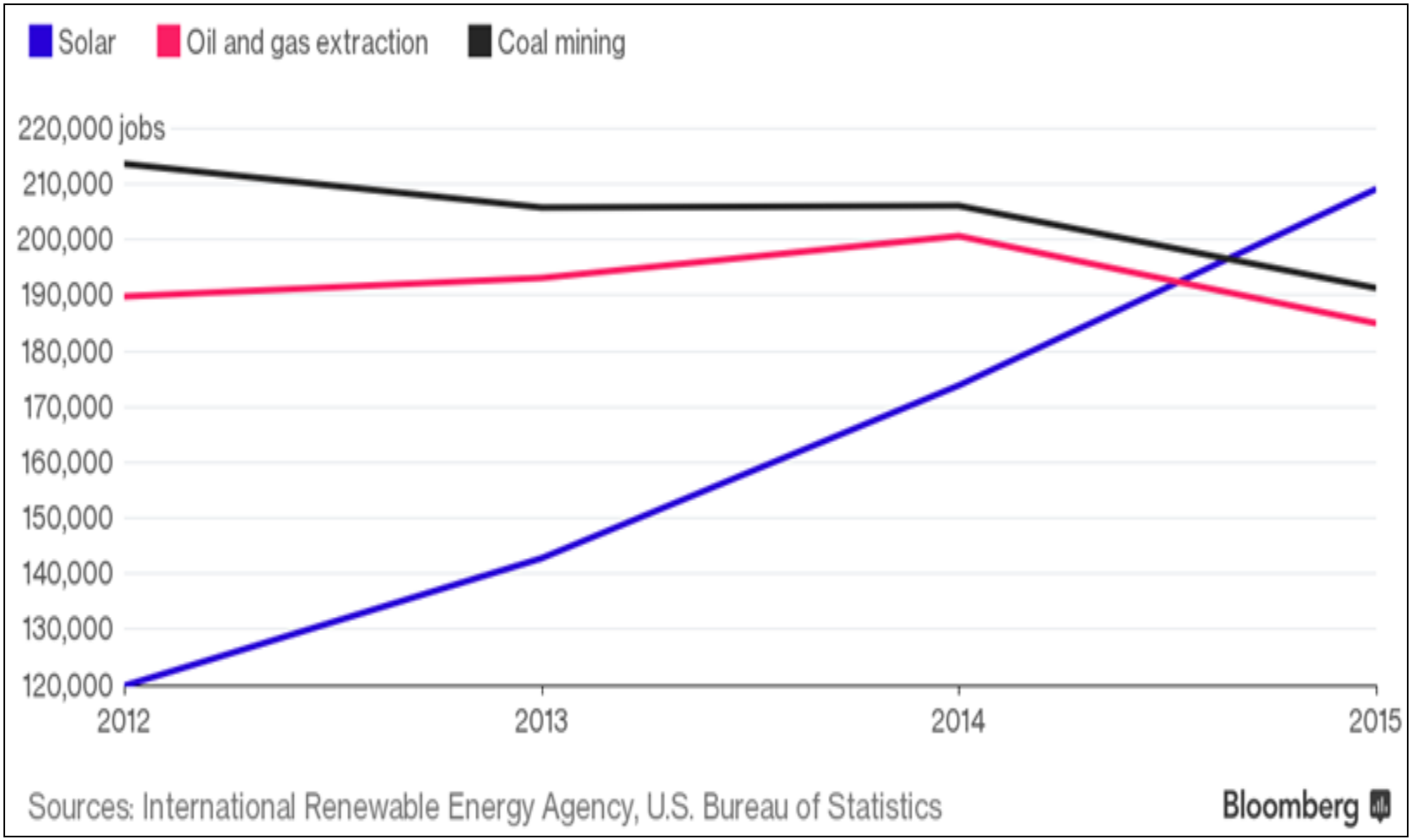
What about Jobs?



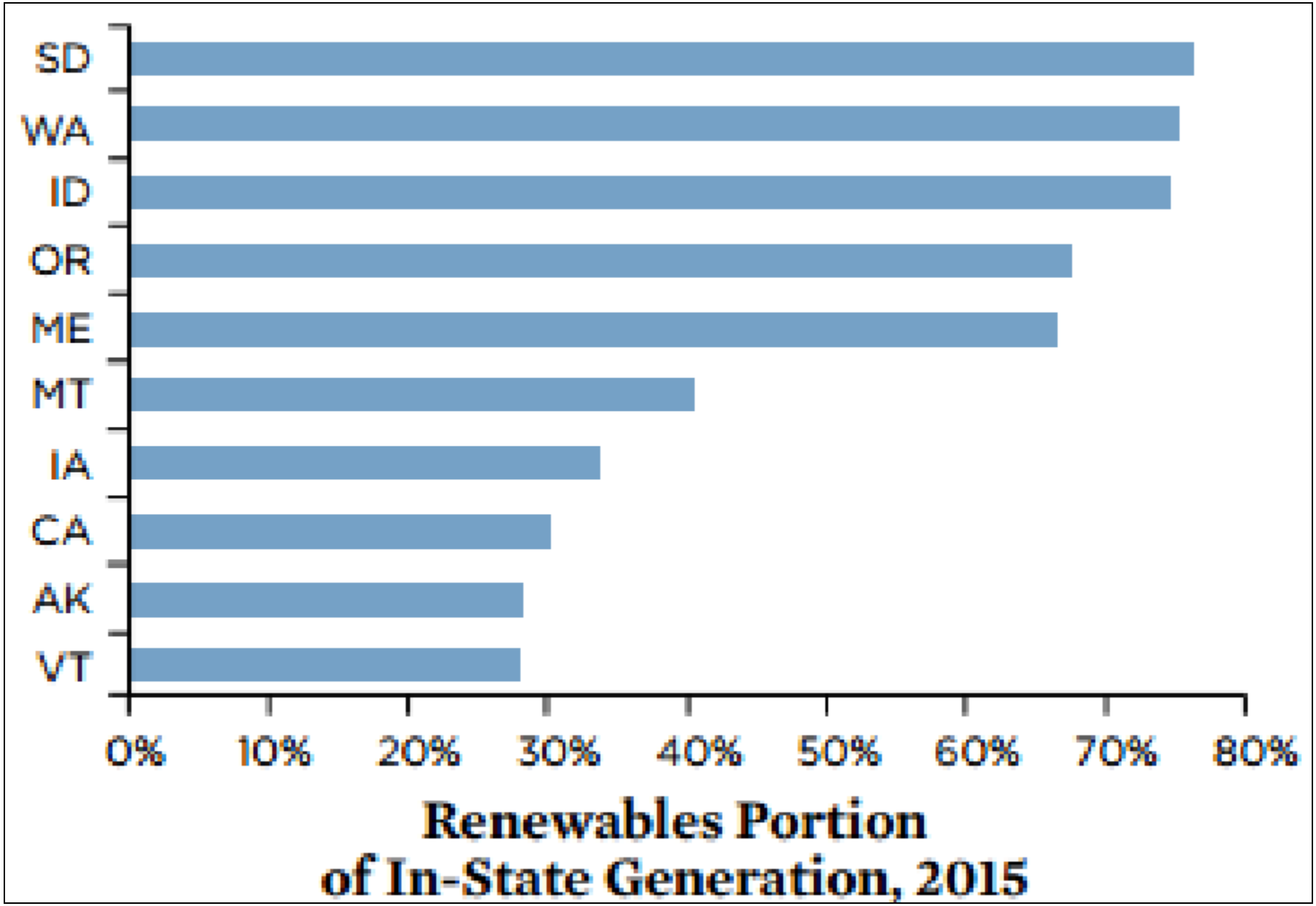

U.S. 2016 Electric-Energy Jobs
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Renewable = solar + wind + bioenergy + geothermal
Renewable / All-Others = 1.9
Renewable
Nat. Gas
Nuclear
Hydro
Other
Oil


U.S. 2016 Electric + Fuels Jobs
Renewable = solar + wind + bioenergy + geothermal
650,000
600,000
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Renewable
Oil
Nat. Gas
Other
Nuclear
Hydro

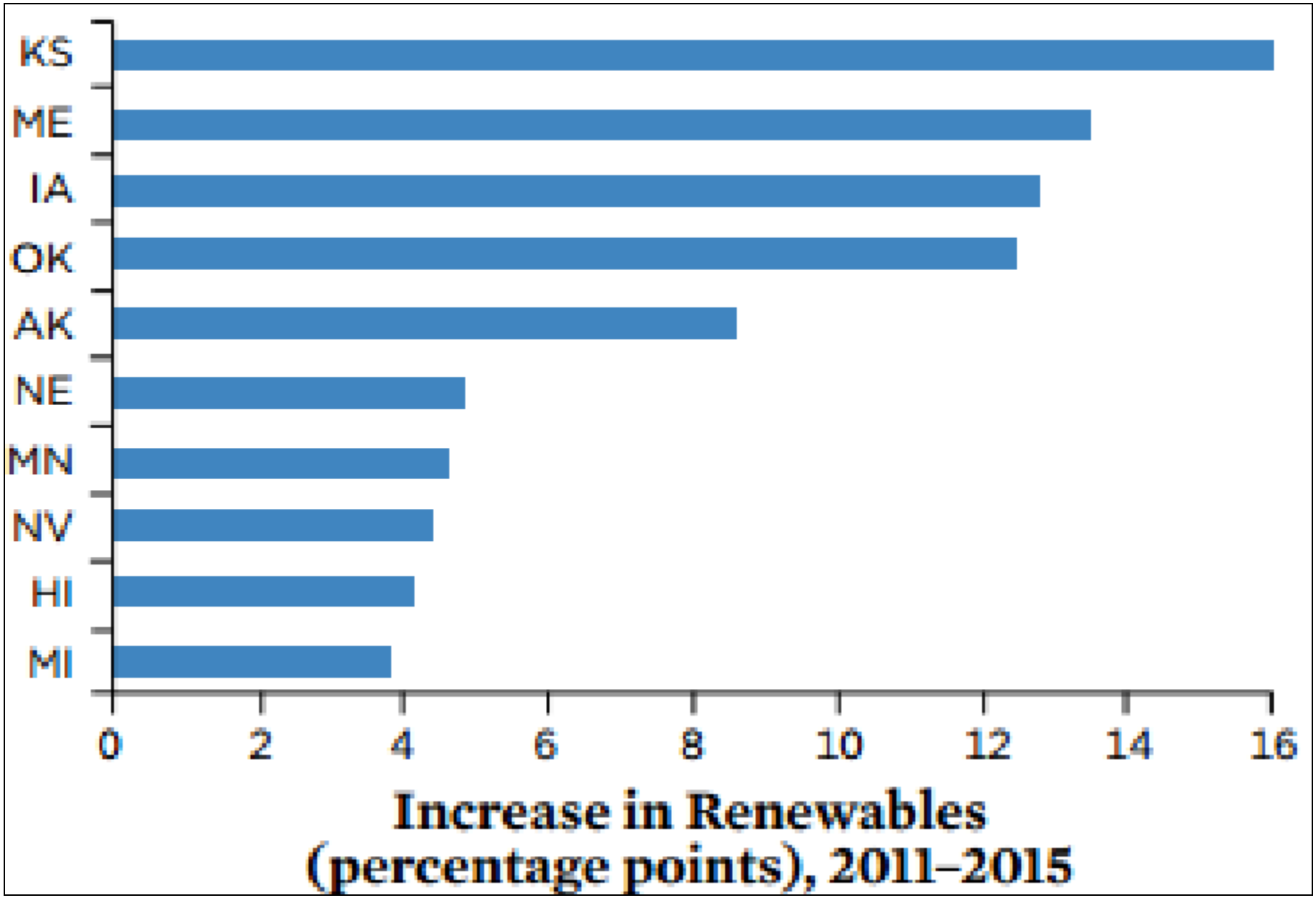
U.S. Energy Jobs



Renewable-Energy U.S. States

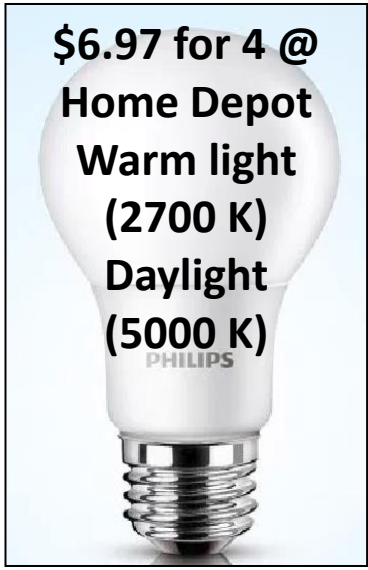


Renewable-Energy-Increase U.S. States



Solar Energy

Negawatts before Solar-PV Kilowatts

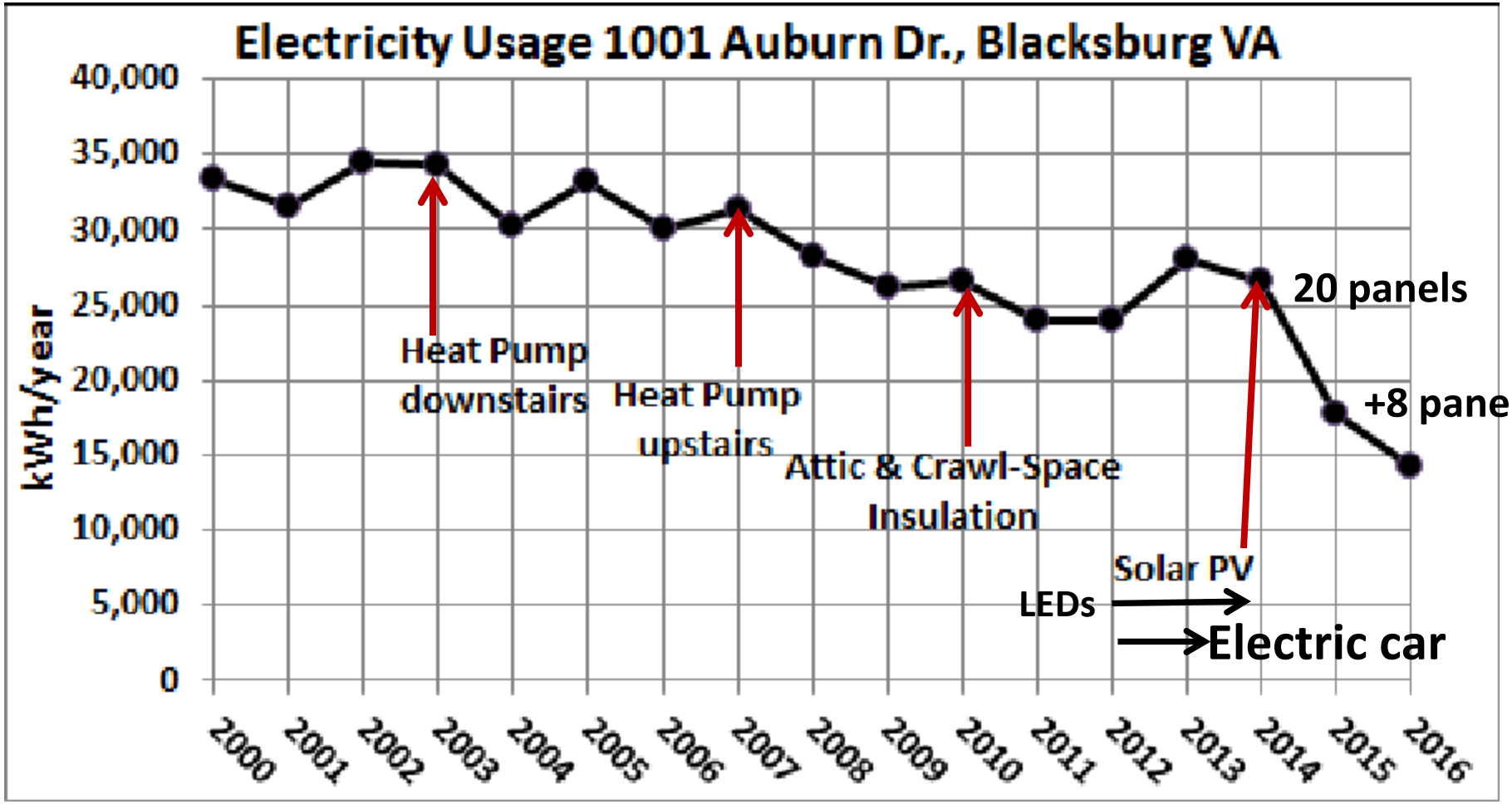


- Insulation, including attics and crawl space
- Programmable thermostats
- Passive solar (new buildings)
- LED lighting
- Efficient windows
- High-efficiency heat pumps (mini-splits new or upgrades)
- Electric cars (2/3rd negawatts compared to gasoline cars)

Energy = kilo-watt-hours = kWh

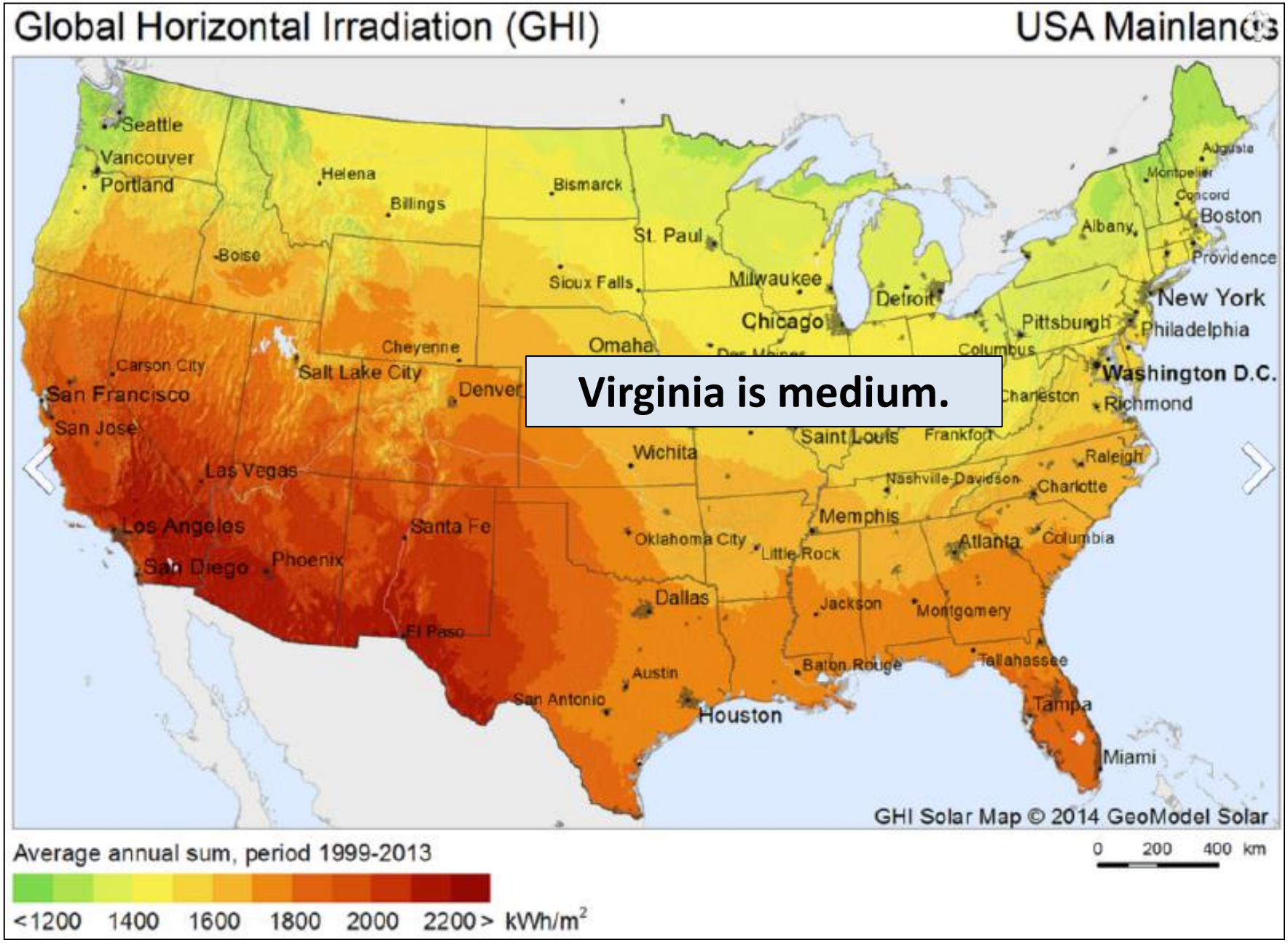
Power = Energy/time = kilo-watts = kW

Roper House Example

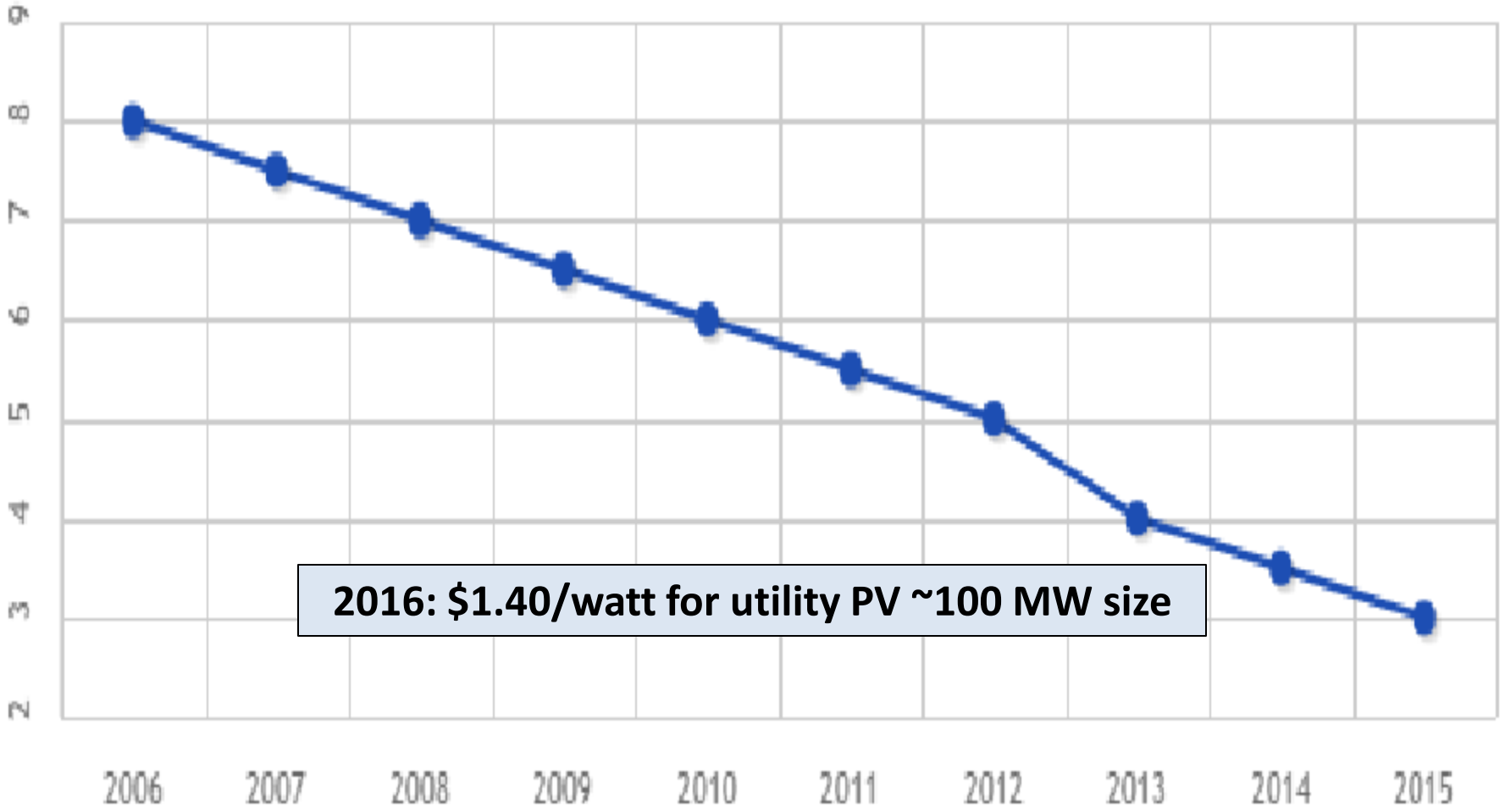


Installation of 28 solar panels (7.7 kW) had a much larger effect that other changes.
2016: Solar = 56% of usage; BEV used 16% of collected solar.

Solar Energy

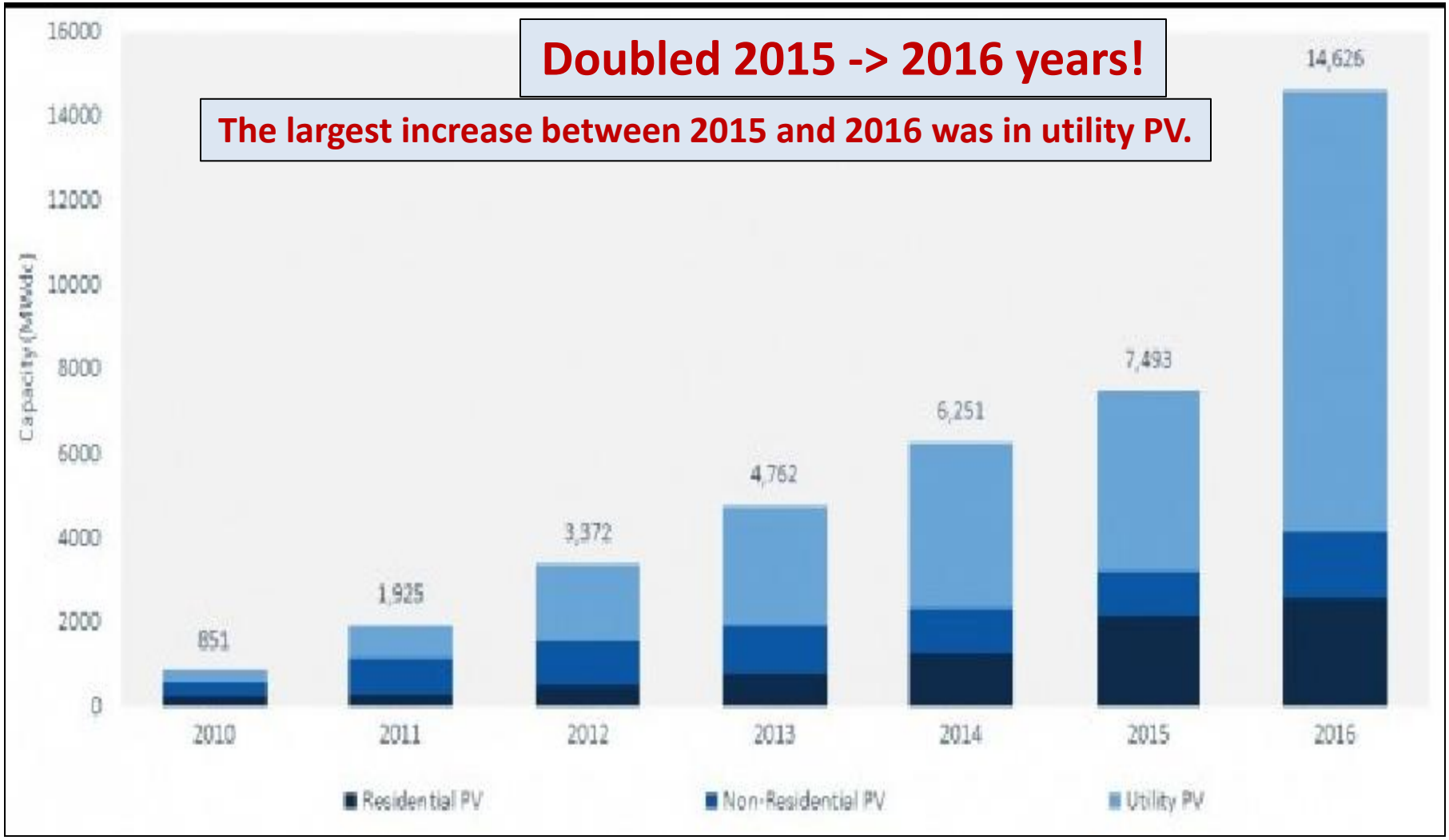


Falling Prices ($/watt) of U.S. Residential Solar PV



Roper 7.7-kW system: $3.70/watt in 2014-2015.
After 30% federal tax credit: $2.59.

Growth of Solar PV in U.S.



3 Megawatts Sun-Tracking Solar Farm in Bedford VA

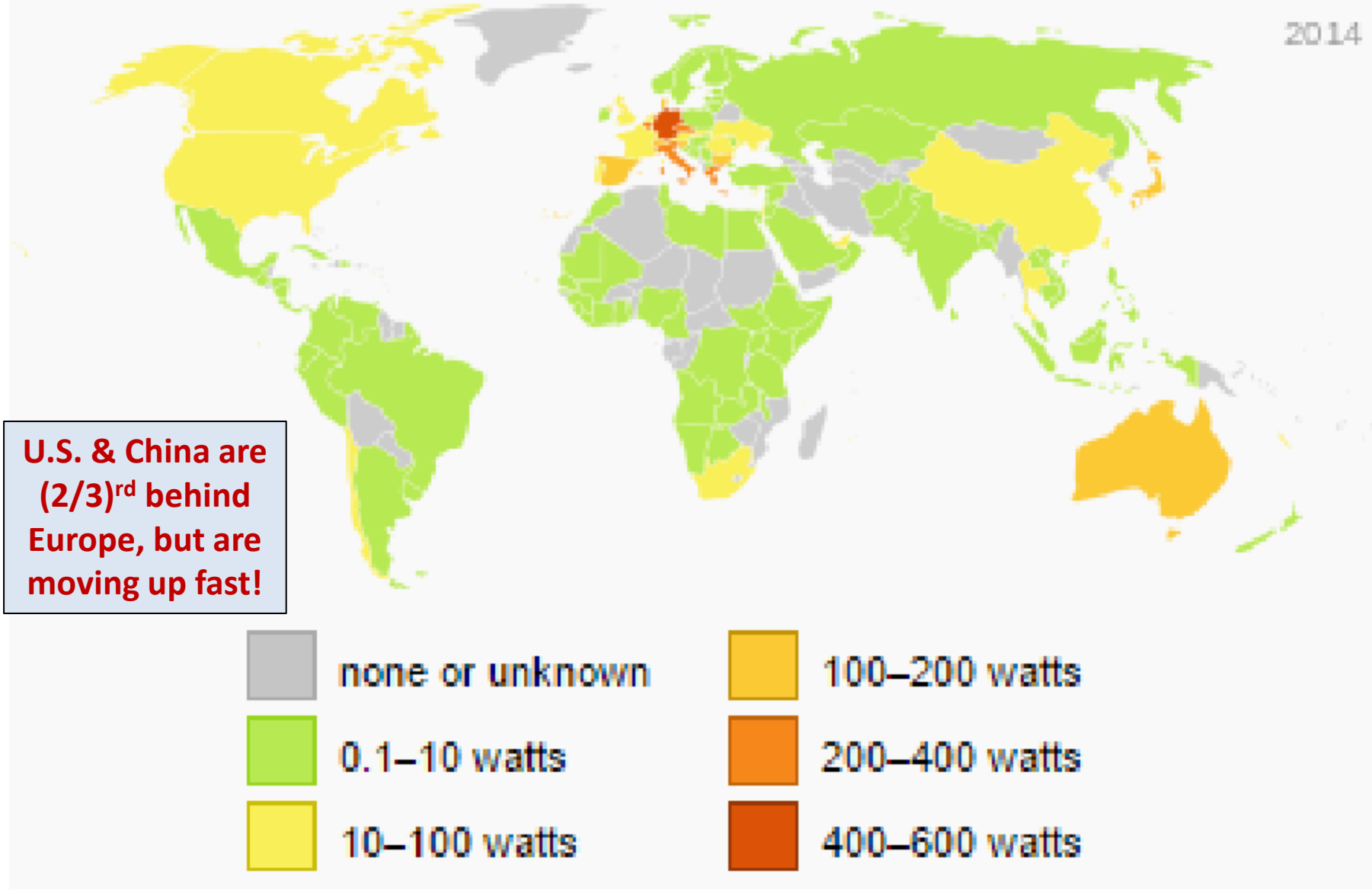
This is possible because Bedford has its own electric power company.

Most places In Virginia are not allowed to do this by state law that allows only APCO or Dominion to provide their power.

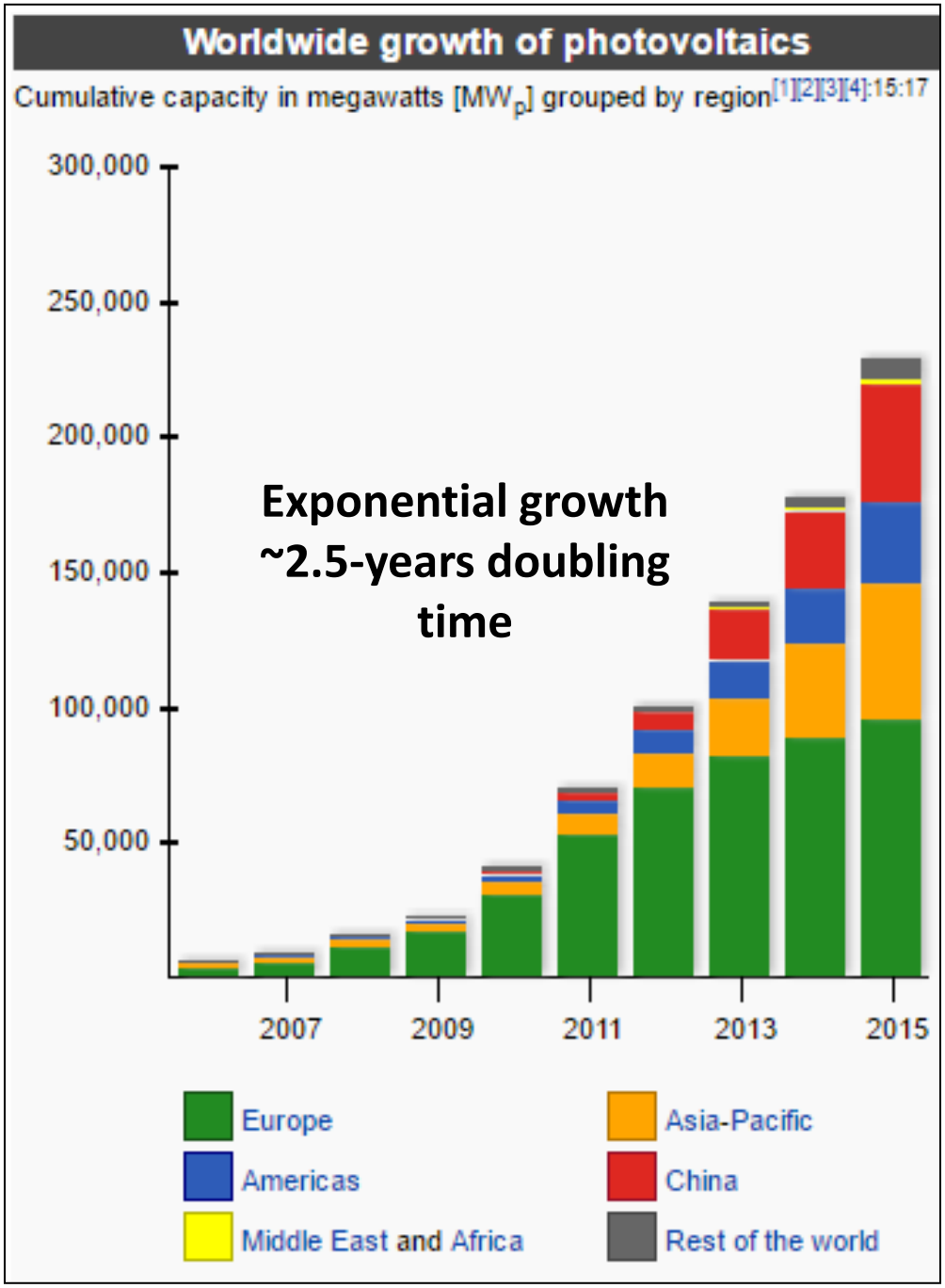
However, Bedford does not allow net metering for individual buildings as APCO does grudgingly.

Salem, Virginia has its own power company. It allows net metering and receives power from the Veterans Hospital's 2.3-MW array and the Roanoke Valley Wine's 1.02-MW array.

Installed PV in watts per capita

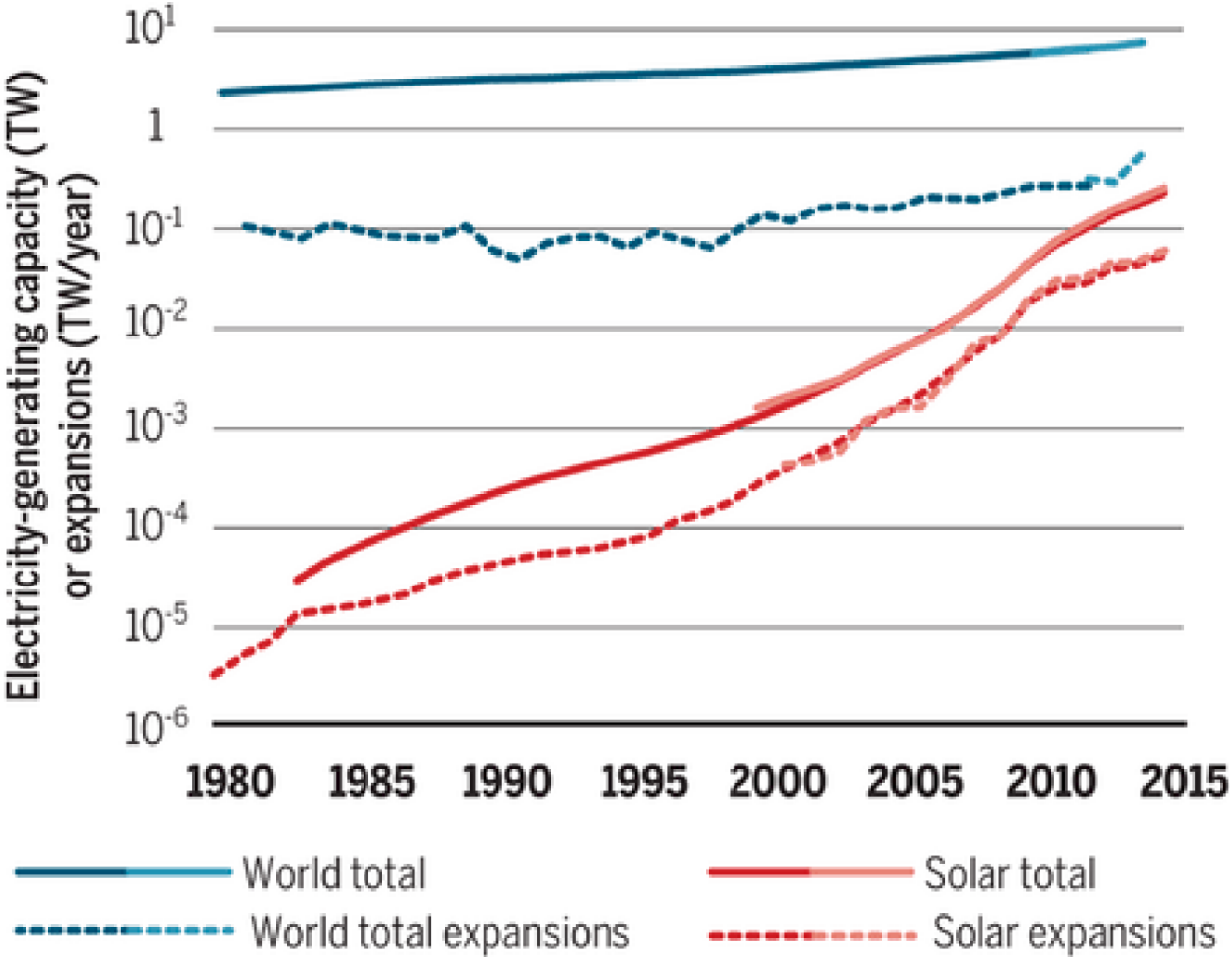


U.S. & China are (2/3)rd behind Europe, but are moving up fast!


Worldwide growth of photovoltaics
Cumulative capacity in megawatts [MWp] grouped by region[1][2][3][4]:15:17
300,000
250,000
200,000
150,000
100,000
50,000
Exponential growth
~2.5-years doubling
time
2007
2009
2011
2013
2015
Europe
Asia-Pacific
Americas
China
Middle East and Africa
Rest of the world

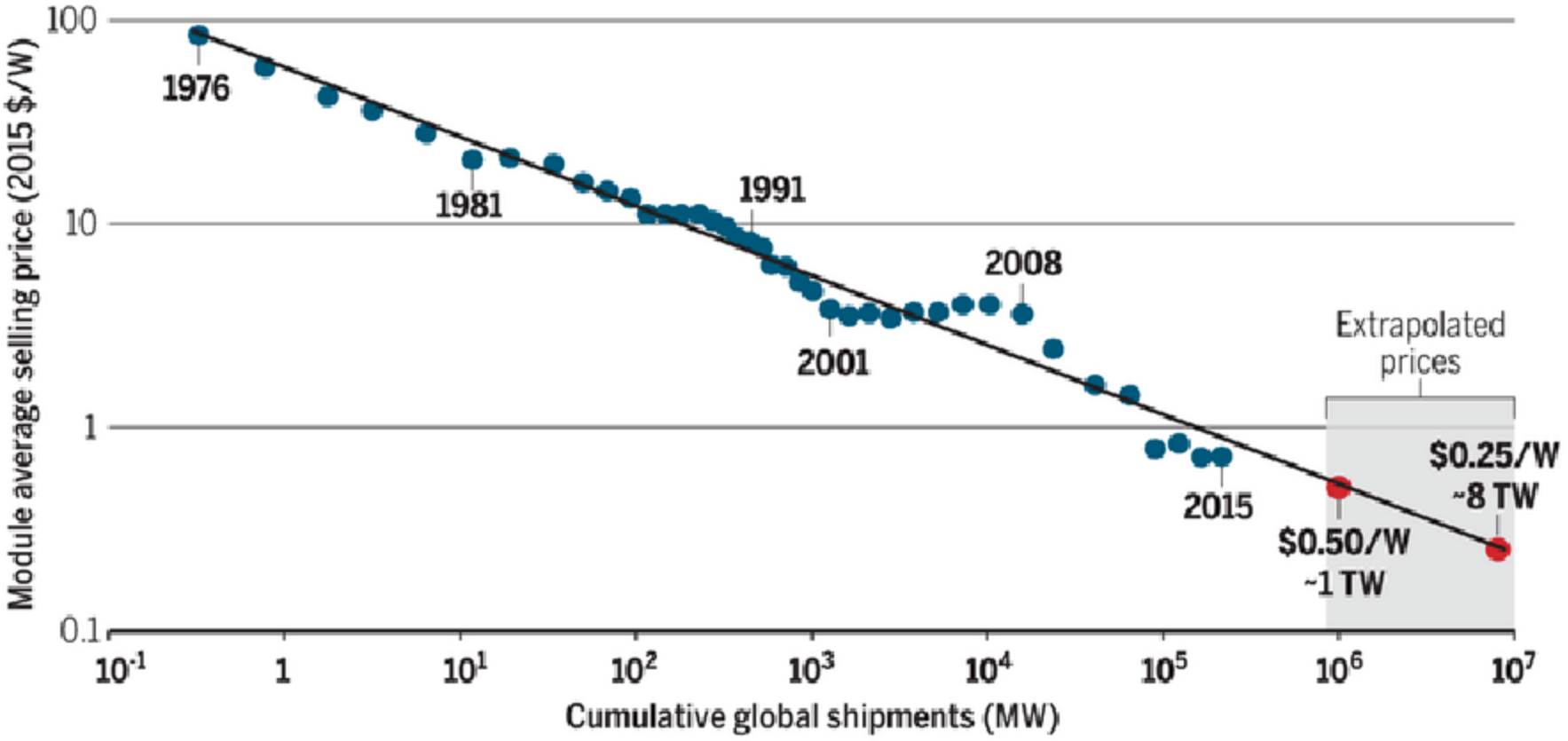
Global electricity-generating capacity

See supplementary materials for data sources.



PV module experience curve

Historically, module prices have decreased as a function of cumulative global shipments (blue dots reflect historical data, red dots reflect extrapolated prices for 1 TW and 8 TW based on the historical trend line). See supplementary materials for data sources.

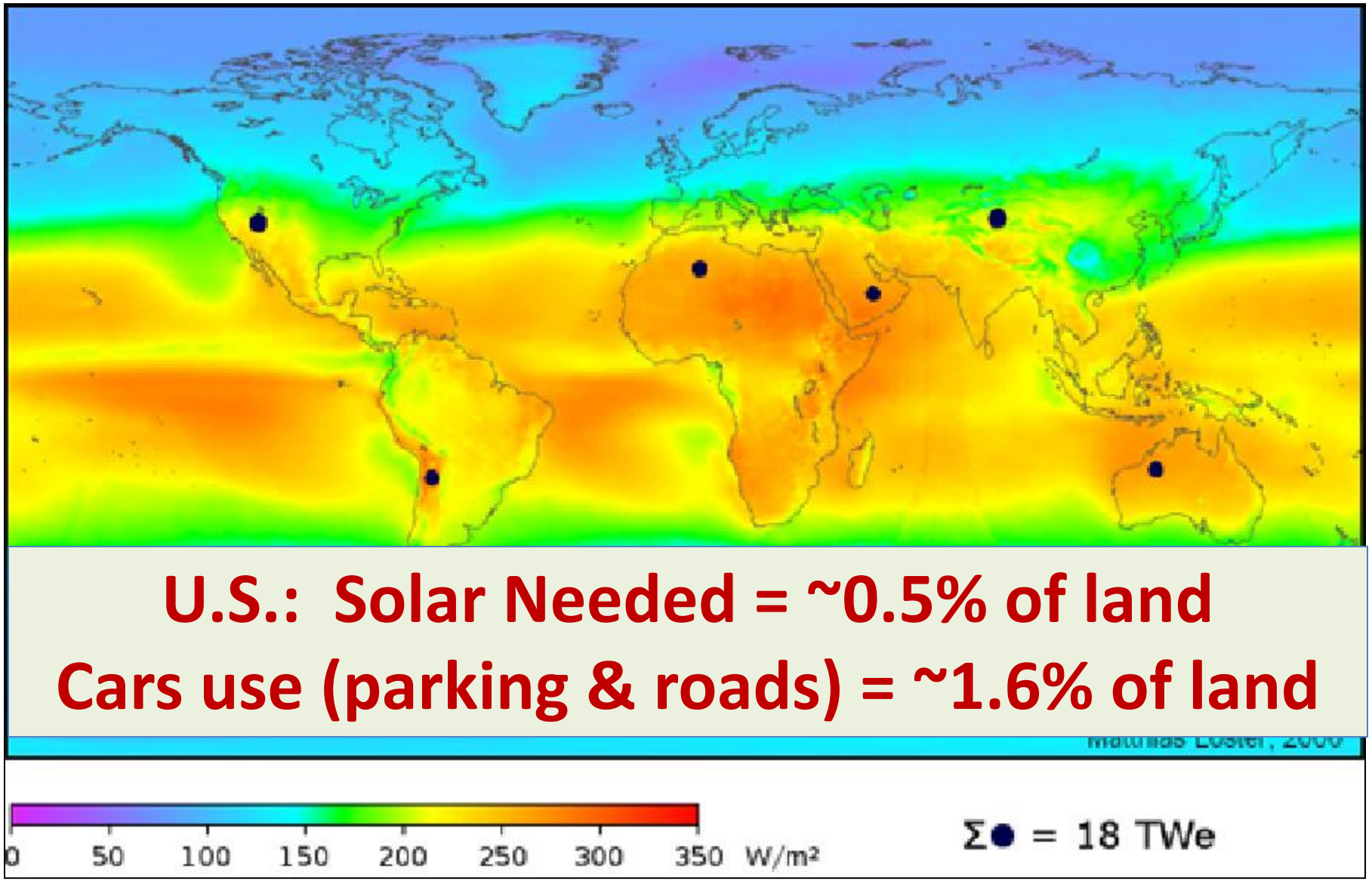


World Solar-Energy Potential

(PetaWattHours = 10^{12} kilowatt-hours)

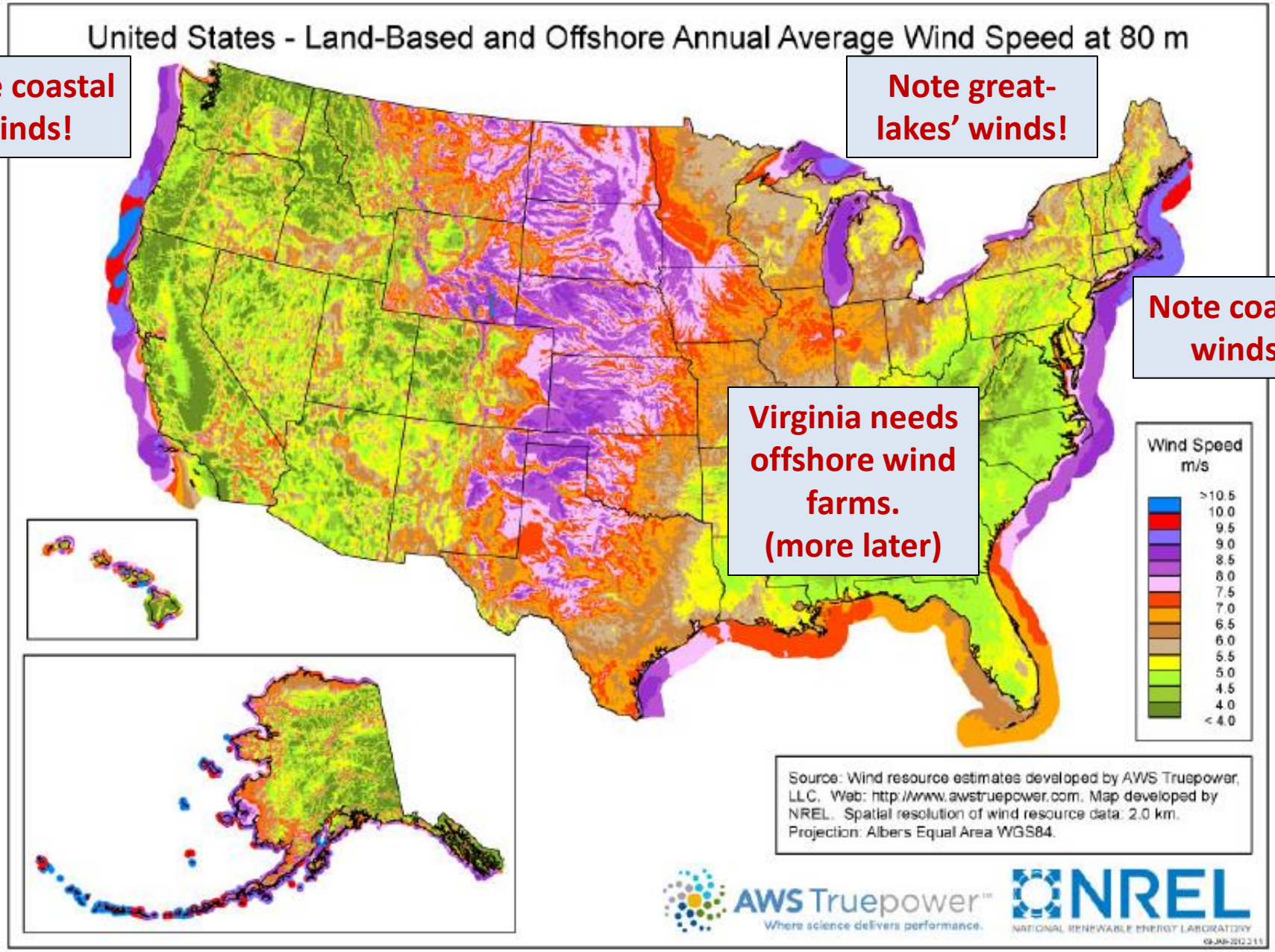
- World energy consumption = ~150 PWh
- Solar energy potential = ~6,950 PWh
- Solar/Consumption = 6950/150 = ~46
- S/C projected for 2050 = ~30
- S/C projected for 2100 = ~22
- S/C will probably be >1 for hundreds of years.

Area to be covered by solar cells to provide world's 2013 energy consumption @ 8% efficiency.



Wind Energy

Wind Energy

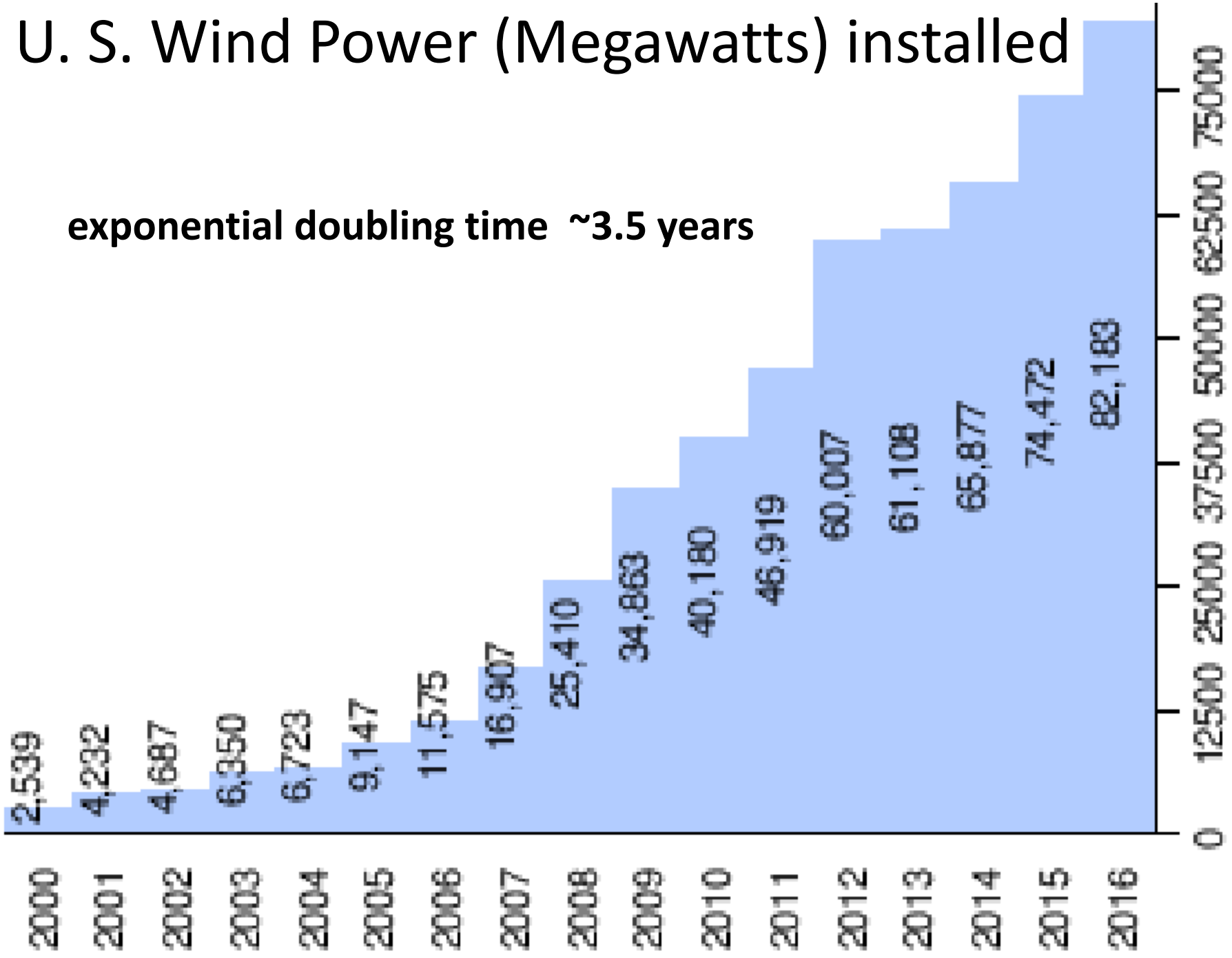

United States - Land-Based and Offshore Annual Average Wind Speed at 80 m
Note coastal winds!
Note great-lakes' winds!
Note coastal winds!
Virginia needs offshore wind farms. (more later)
Wind Speed m/s
>10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
< 4.0
Source: Wind resource estimates developed by AWS Truepower, LLC. Web: http://www.awstruepower.com. Map developed by NREL. Spatial resolution of wind resource data: 2.0 km. Projection: Albers Equal Area WGS84.
AWS Truepower
Where science delivers performance.
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

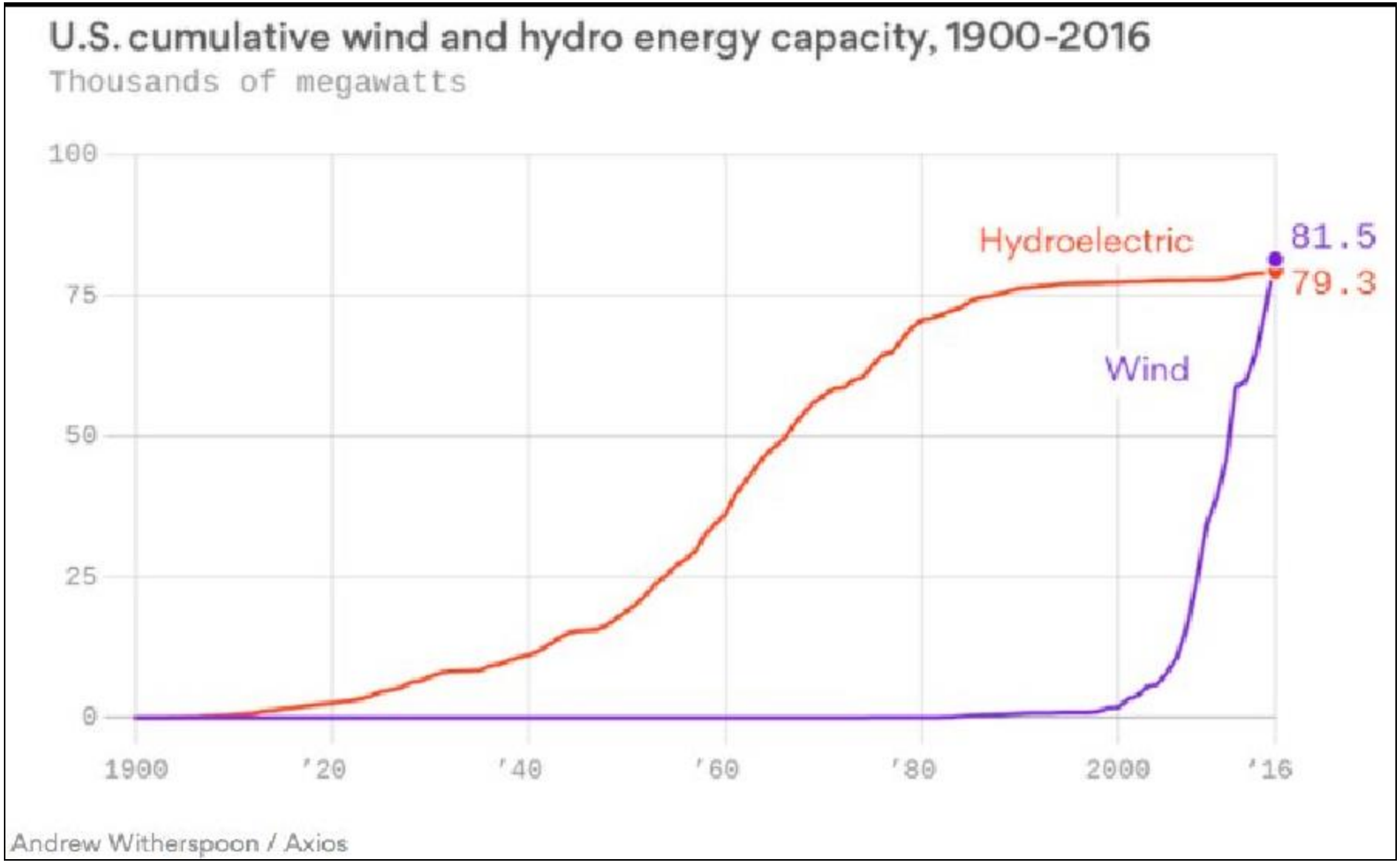
U.S. Wind-Power Potential

- 10,500 GW (10.5 TW) in contiguous U.S.
- 37 petawatt-hours/year = 9 times larger than current U.S. consumption (Pwatts = 1,000,000 Gwatts)
- Also large wind resources in Alaska & Hawaii

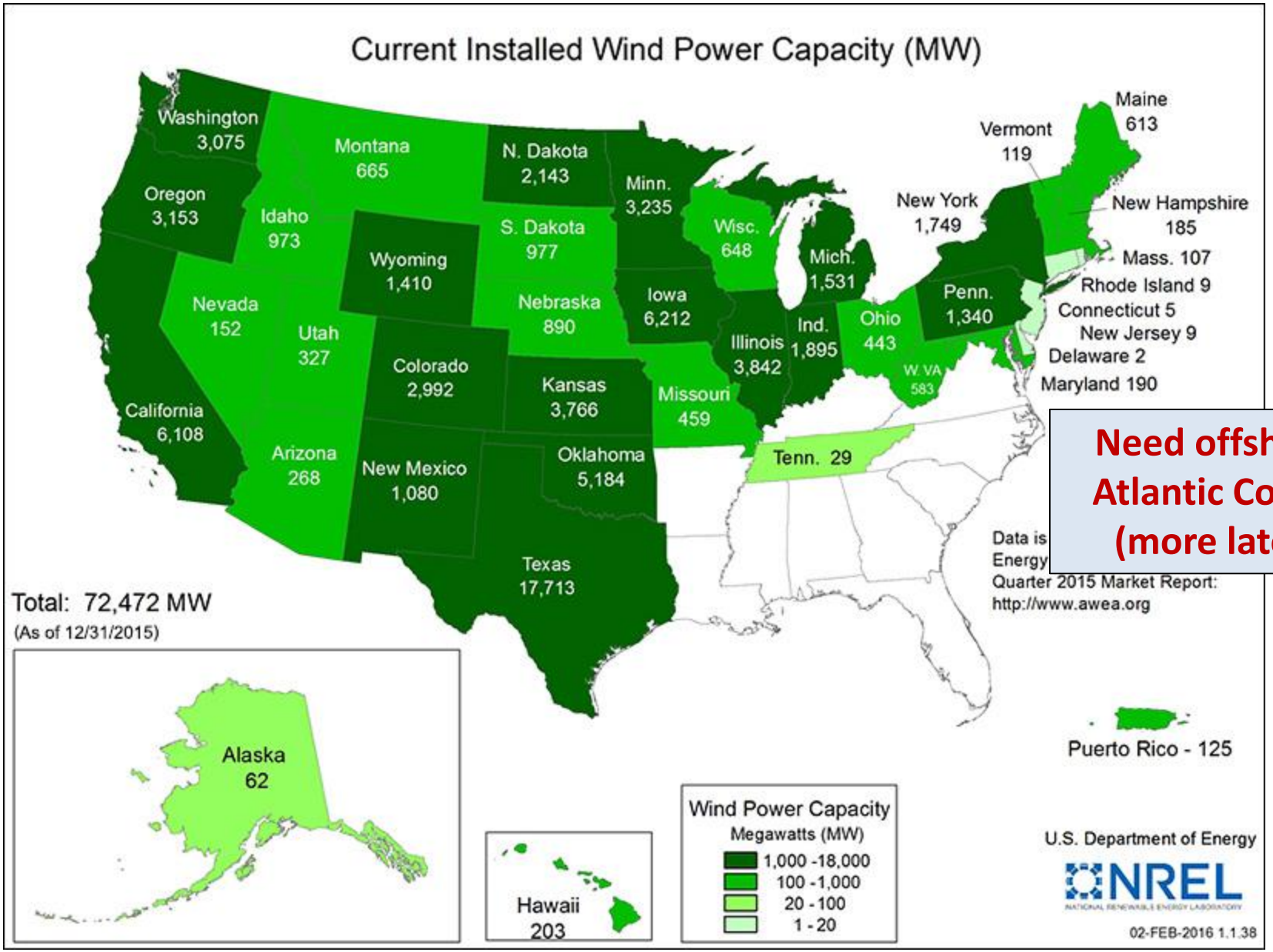
U. S. Wind Power (Megawatts) installed

exponential doubling time ~3.5 years

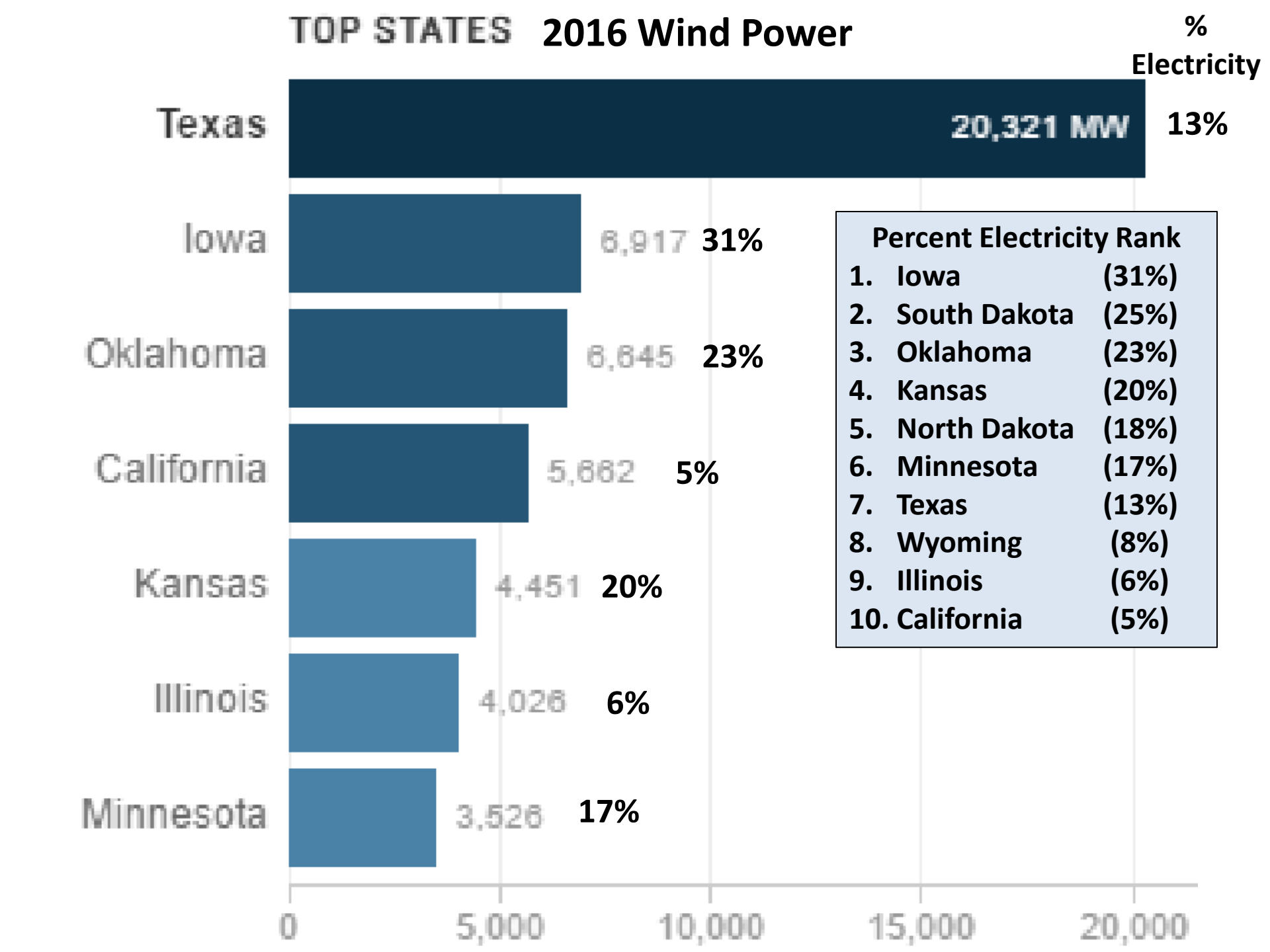



U.S. cumulative wind and hydro energy capacity, 1900-2016
Thousands of megawatts
100
75
50
25
0
1900
'20
'40
'60
'80
2000
'16
Hydroelectric
81.5
79.3
Wind
Andrew Witherspoon / Axios

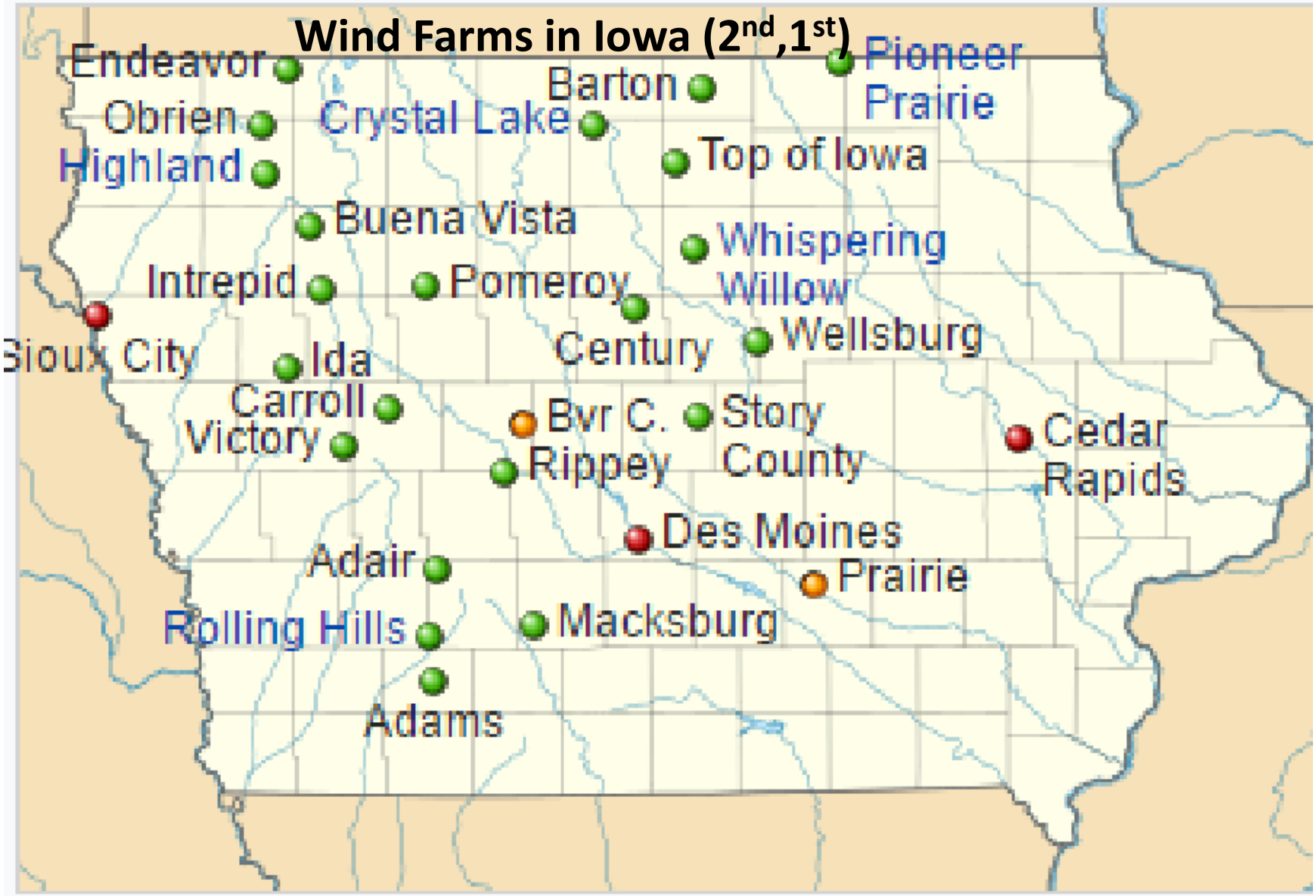
Wind Farms in U.S.



Need offshore Atlantic Coast! (more later)

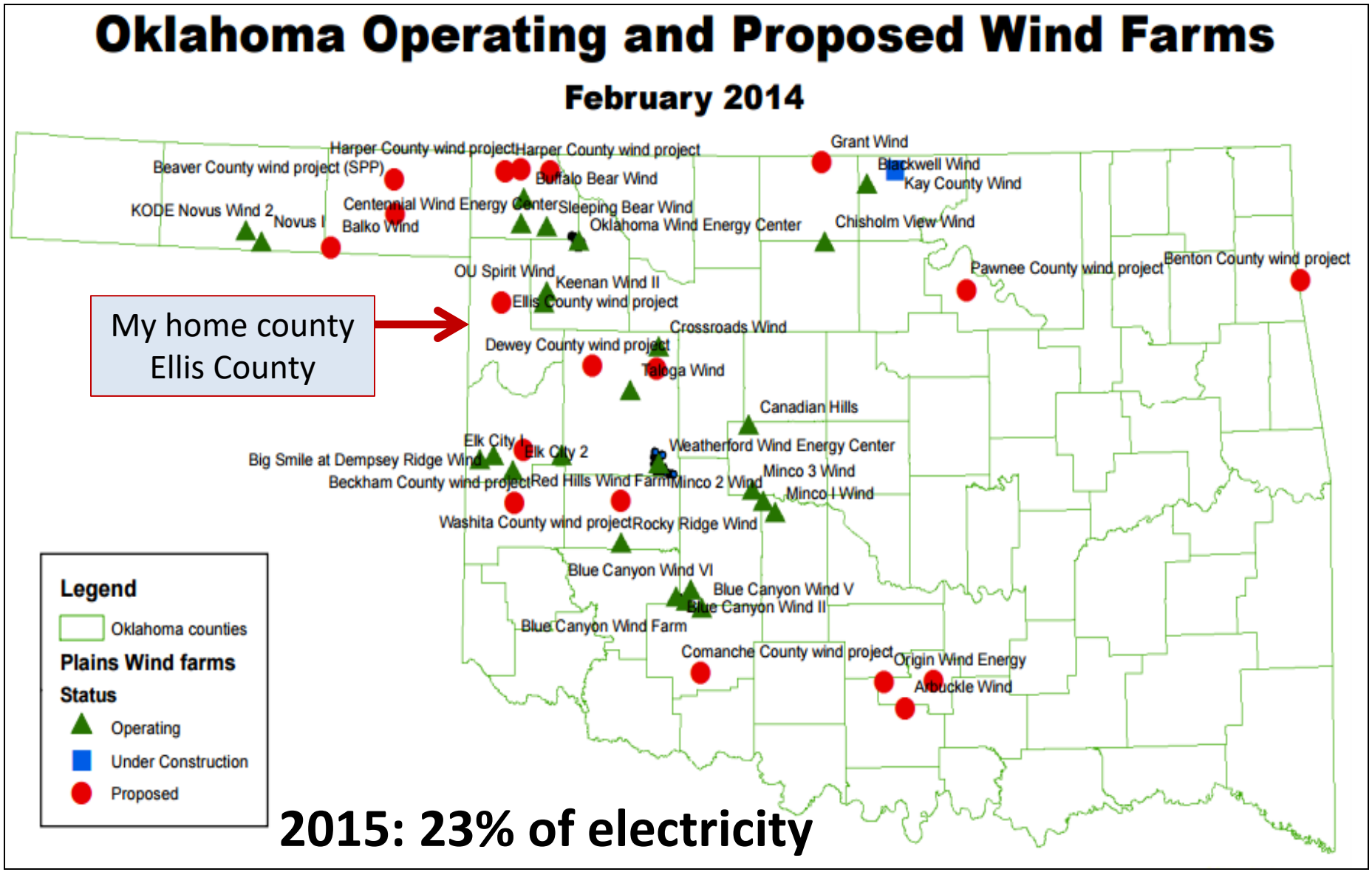

TOP STATES
2016 Wind Power
% Electricity
Texas
20,321 MW
13%
Iowa
6,917
31%
Oklahoma
6,645
23%
California
5,662
5%
Kansas
4,451
20%
Illinois
4,026
6%
Minnesota
3,526
17%
0
5,000
10,000
15,000
20,000
Percent Electricity Rank
1. Iowa (31%)
2. South Dakota (25%)
3. Oklahoma (23%)
4. Kansas (20%)
5. North Dakota (18%)
6. Minnesota (17%)
7. Texas (13%)
8. Wyoming (8%)
9. Illinois (6%)
10. California (5%)

Wind Farms in Iowa (2nd,1st)



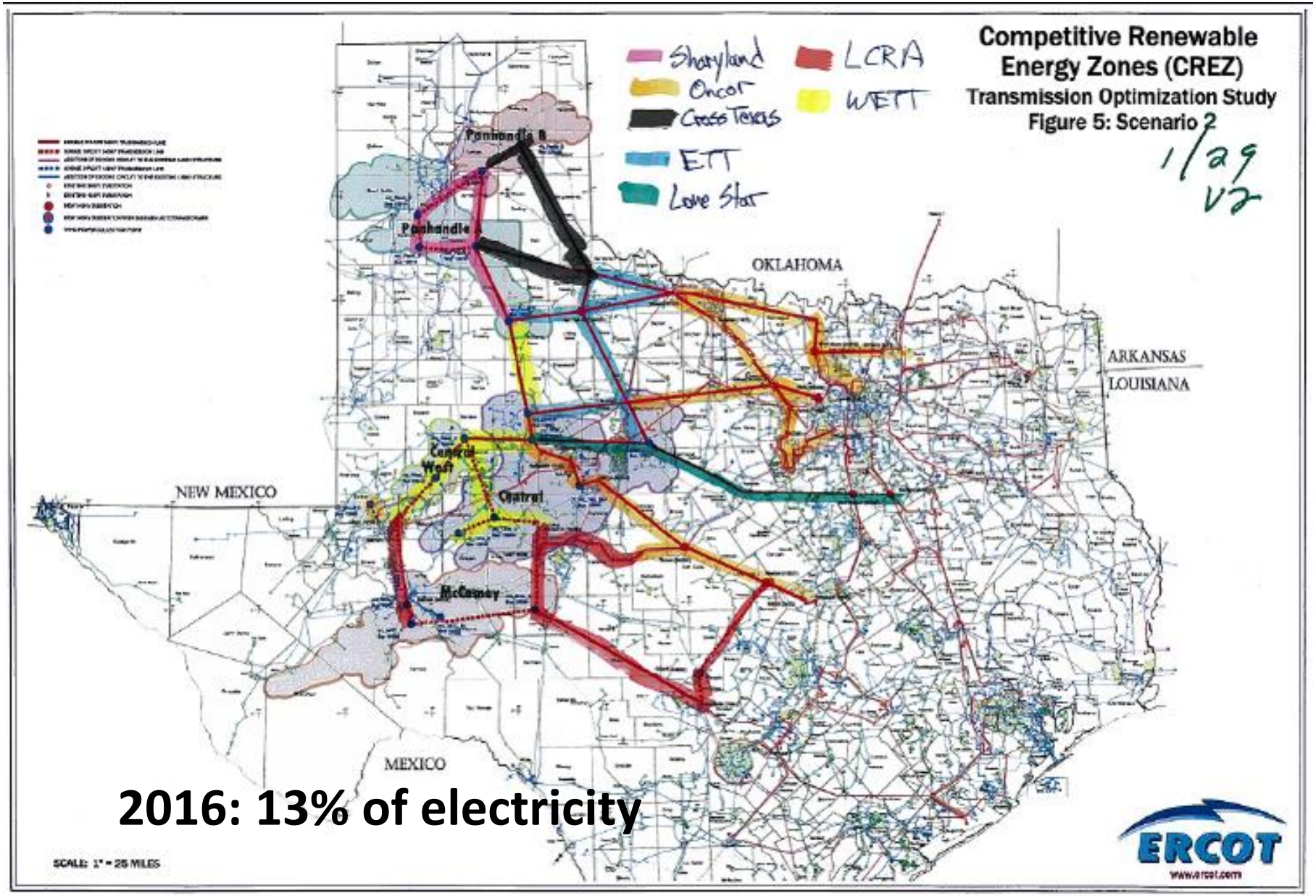
2016: 31% of electricity

Wind Farms in Oklahoma (3rd,3rd)



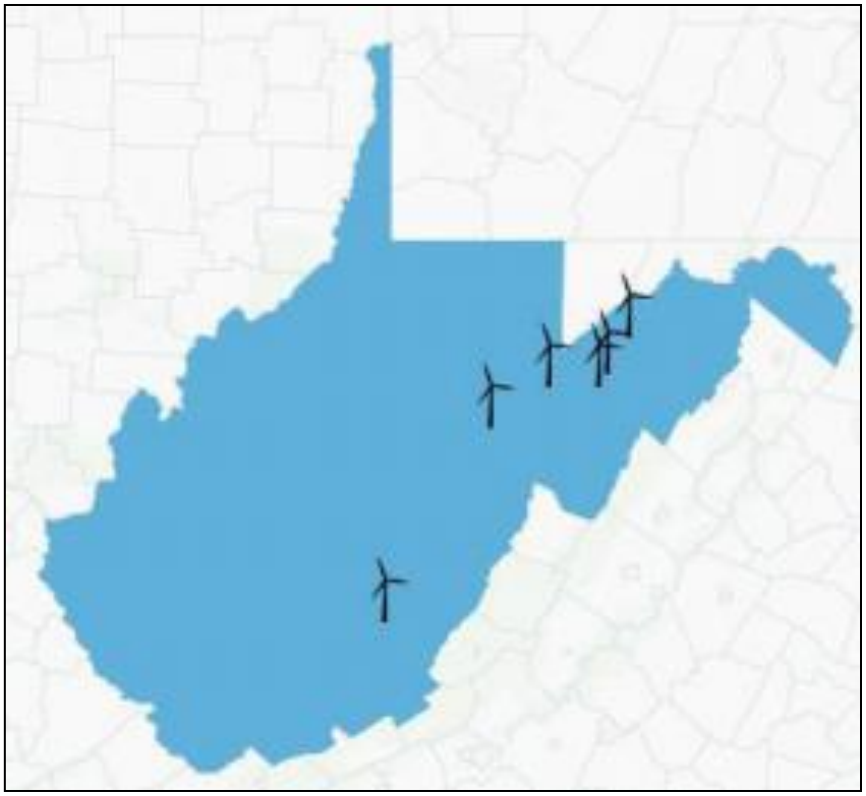
2015: 23% of electricity

Wind Power Lines in Texas (1st,7th)

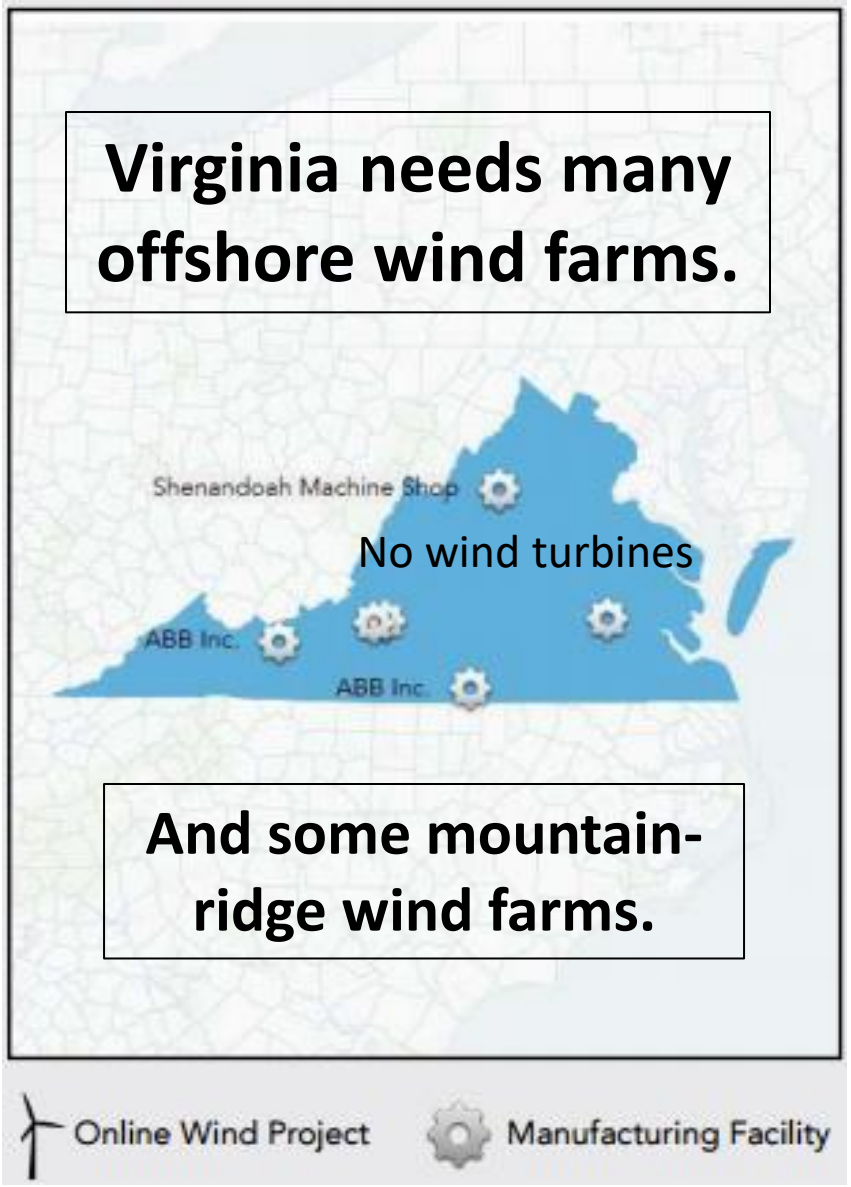


2016: 13% of electricity

Wind Facilities in West Virginia & Virginia



327 turbines in 2014.
1.84% of electricity in 2016.



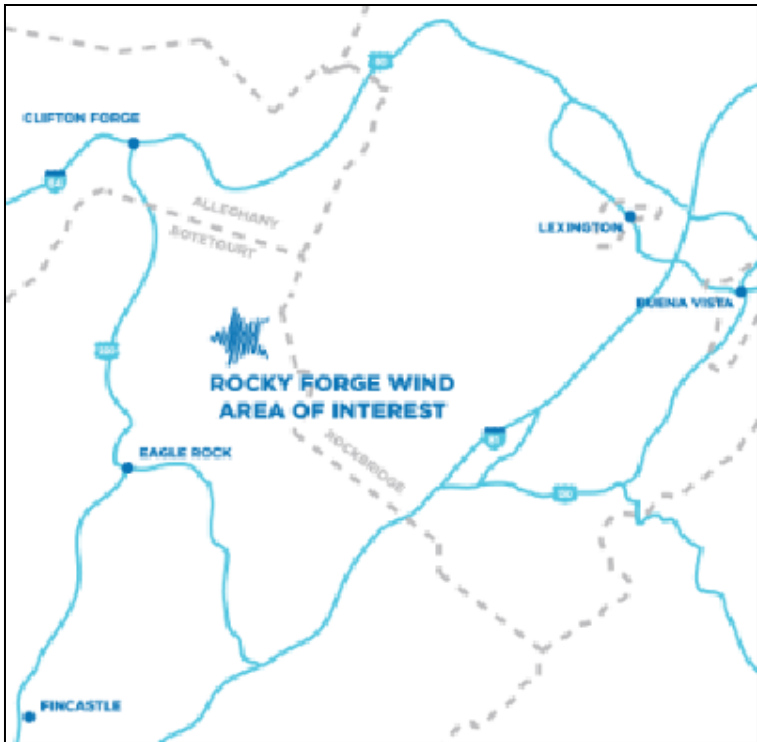
Birds Killed by Energy Systems

A U.S. News and World Report chart shows estimates of how many birds are killed each year by different fuel sources.

CREDIT: U.S. NEWS & WORLD REPORT

Rocky Forge Wind Farm

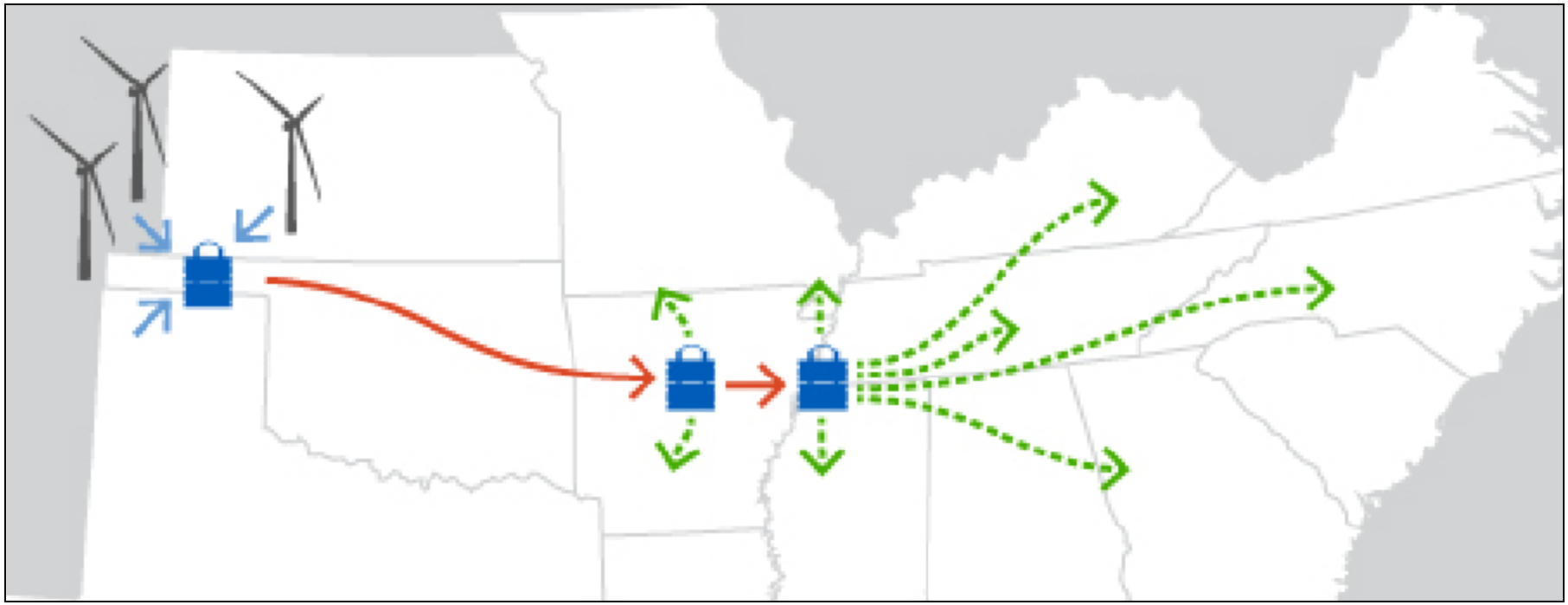
- **First Virginia Wind Farm**
- In rural Botetourt Co. on private land
- Adjacent to existing high-voltage power line
- Power for ~20,000 homes
- 25 ~75-MegaWatts turbines
- ~550-feet tall
- ~150 construction jobs
- ~7 maintenance jobs
- $20-$25 million in taxes



Clean Line Energy Project

NW Oklahoma Wind Farms to Memphis TN TVA

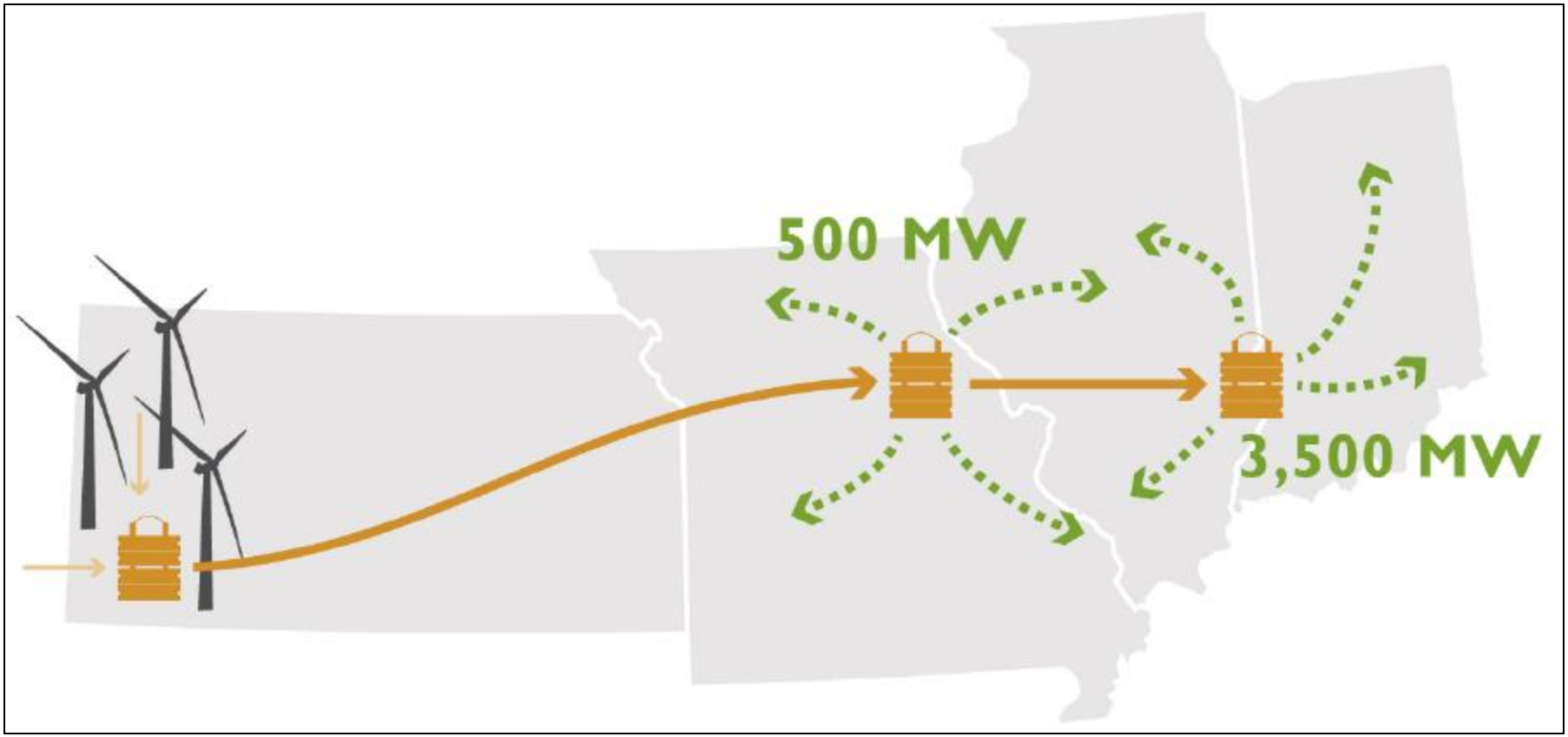
High-Voltage DC Power Line 720 miles $2.5 Billion



Grain Belt Express Clean Line

SW Kansas Wind Farms to Indiana

High-Voltage DC Power Line 780 miles $2 Billion

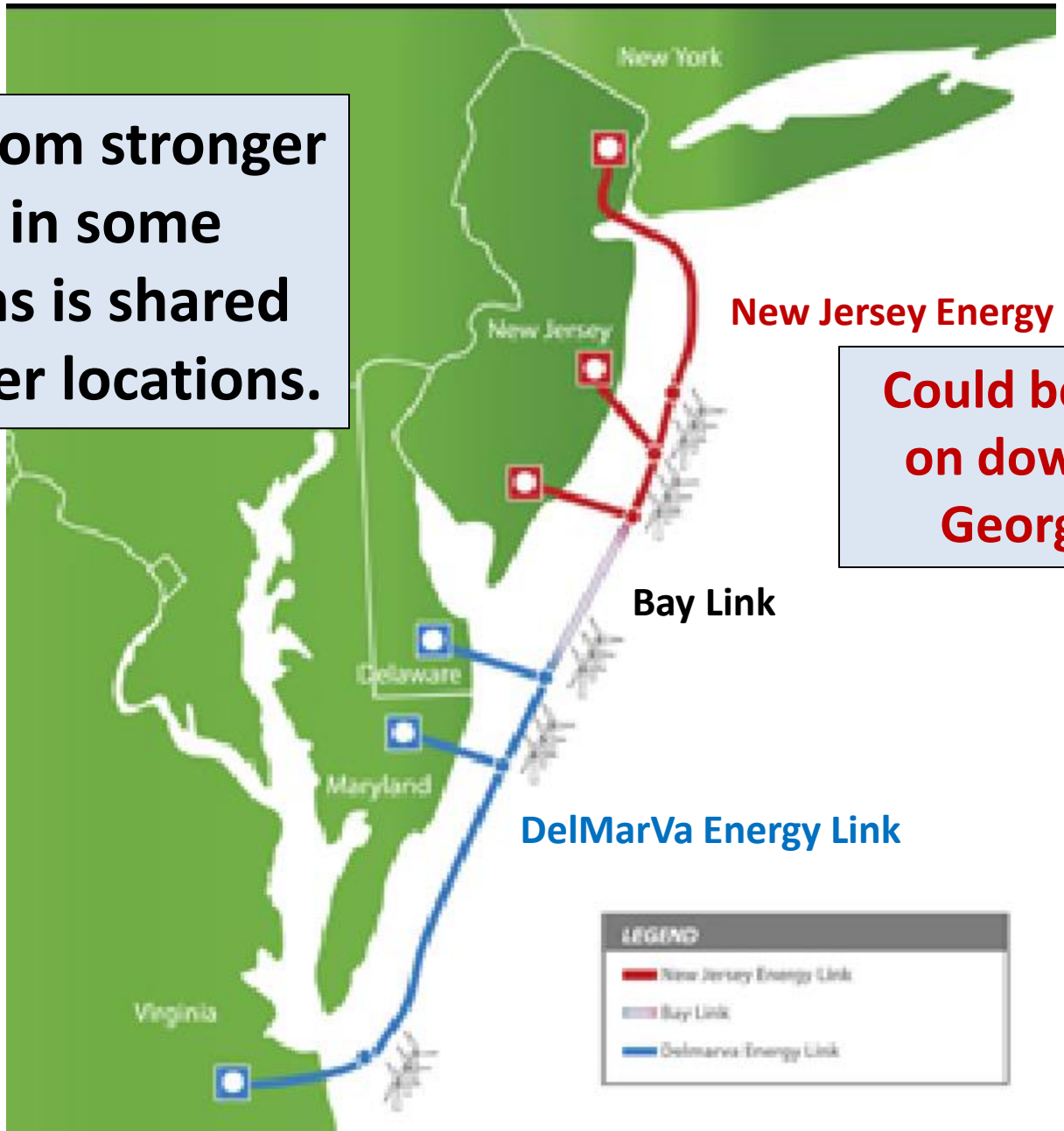


Offshore Wind (OSW)

- 1991: World's first offshore wind farm Denmark
- >3,000 offshore wind turbines in >80 locations
- U.S. could have 4 x electricity used from OSW.
- Two types
  - Continental shelf rigidly attached to sea floor
  - Deep water cabled to sea floor
- **Shore electrical stations should plan for sea-level rise!**

Atlantic Wind Connection Project

Energy from stronger wind in some locations is shared with other locations.



New Jersey Energy Link

Could be expanded on down through Georgia coast.

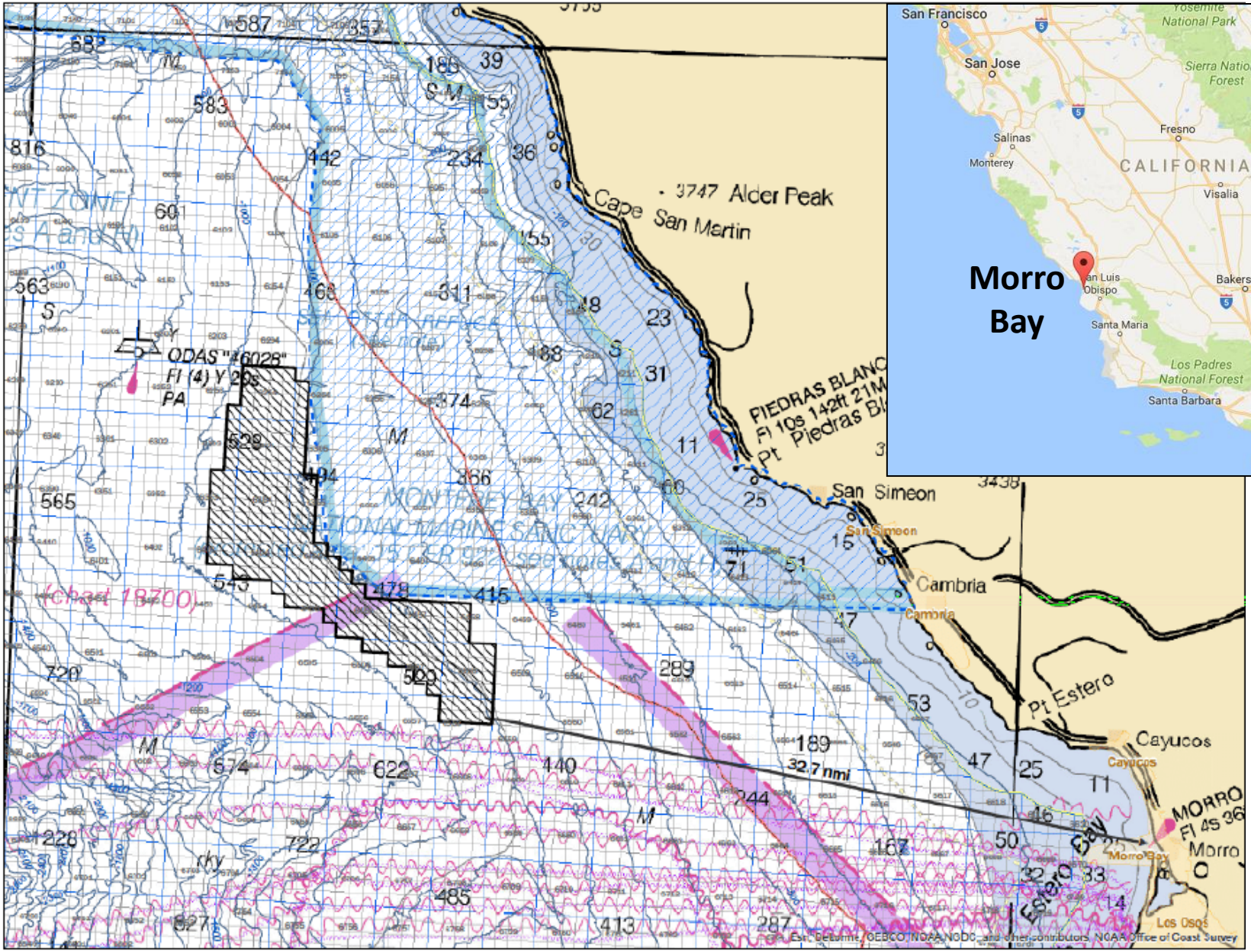
Bay Link

DelMarVa Energy Link

Atlantic Wind Connection Project

- Northern New Jersey to Southern Virginia in 3 phases over 10 years
- Reduce variability of wind energy.
- Provide fast transport of all electrical energy.
- Wind farms 10 miles off coast out of land sight.
- Phase 1: New Jersey Energy Link
- Phase 2: DelMarVa Energy Link (3 gigawatts, 1 million homes)
- Phase 3: Bay Link
- Total: 6 gigawatts, 2 million homes
- Thousands of construction jobs
- Improving reliability and resiliency of grid

Trident Winds Project



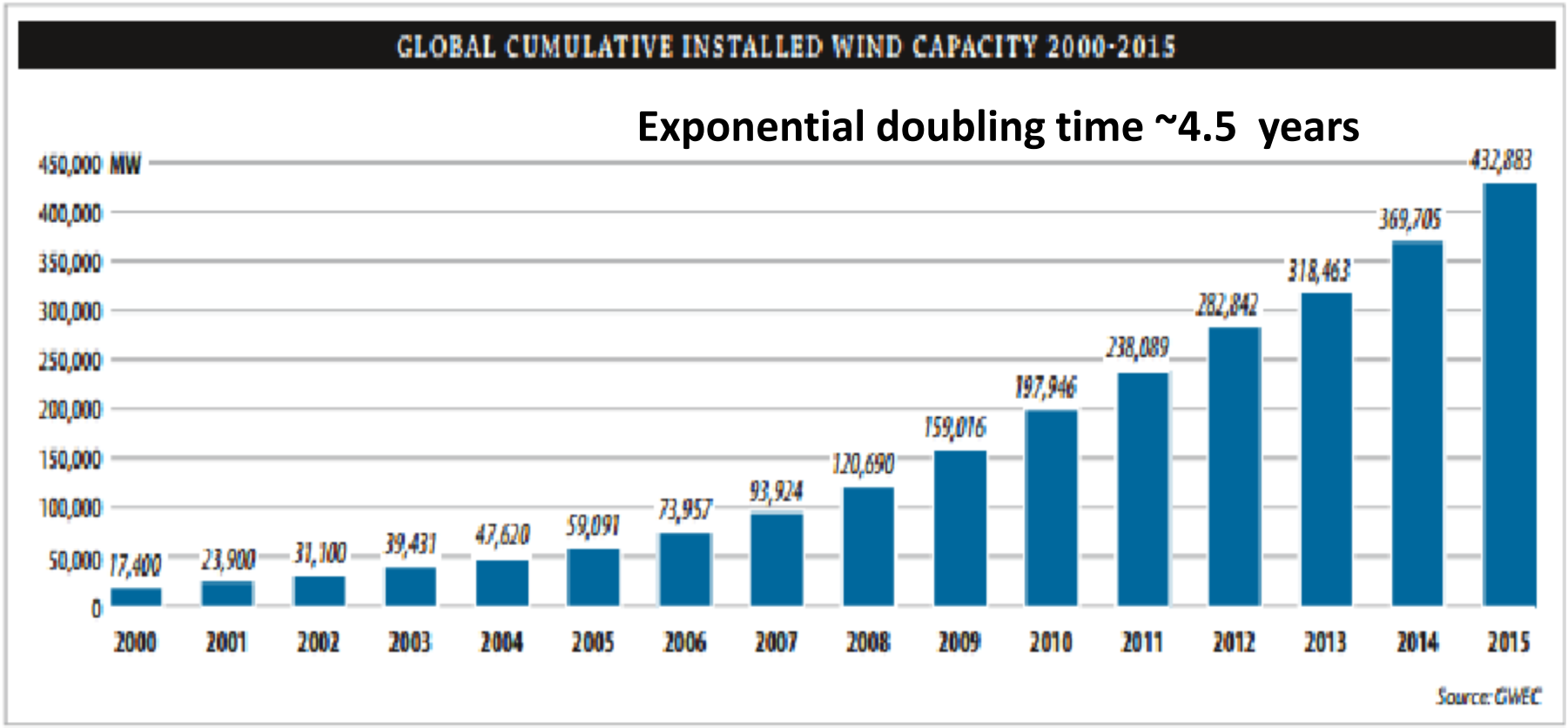
Trident Winds Project

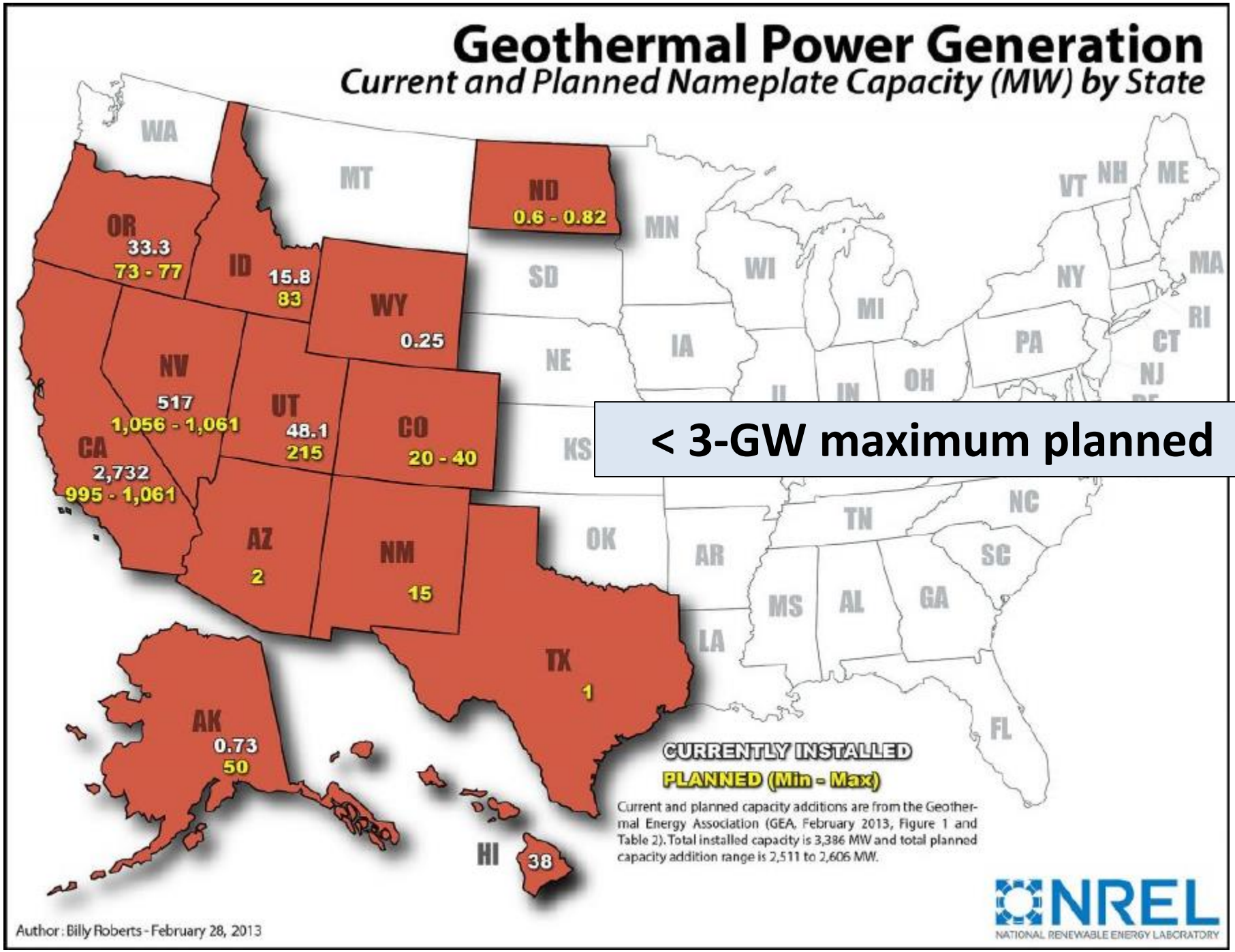
- ~25 miles offshore of central California
- ~100 6-megawatts wind turbines in deep water
- ½ miles apart on 40,000 acres
- Turbines moored by cables at ~3,000-ft water depth
- Floating electricity substation
- Underwater cables to shore
- Completion planned by 2025

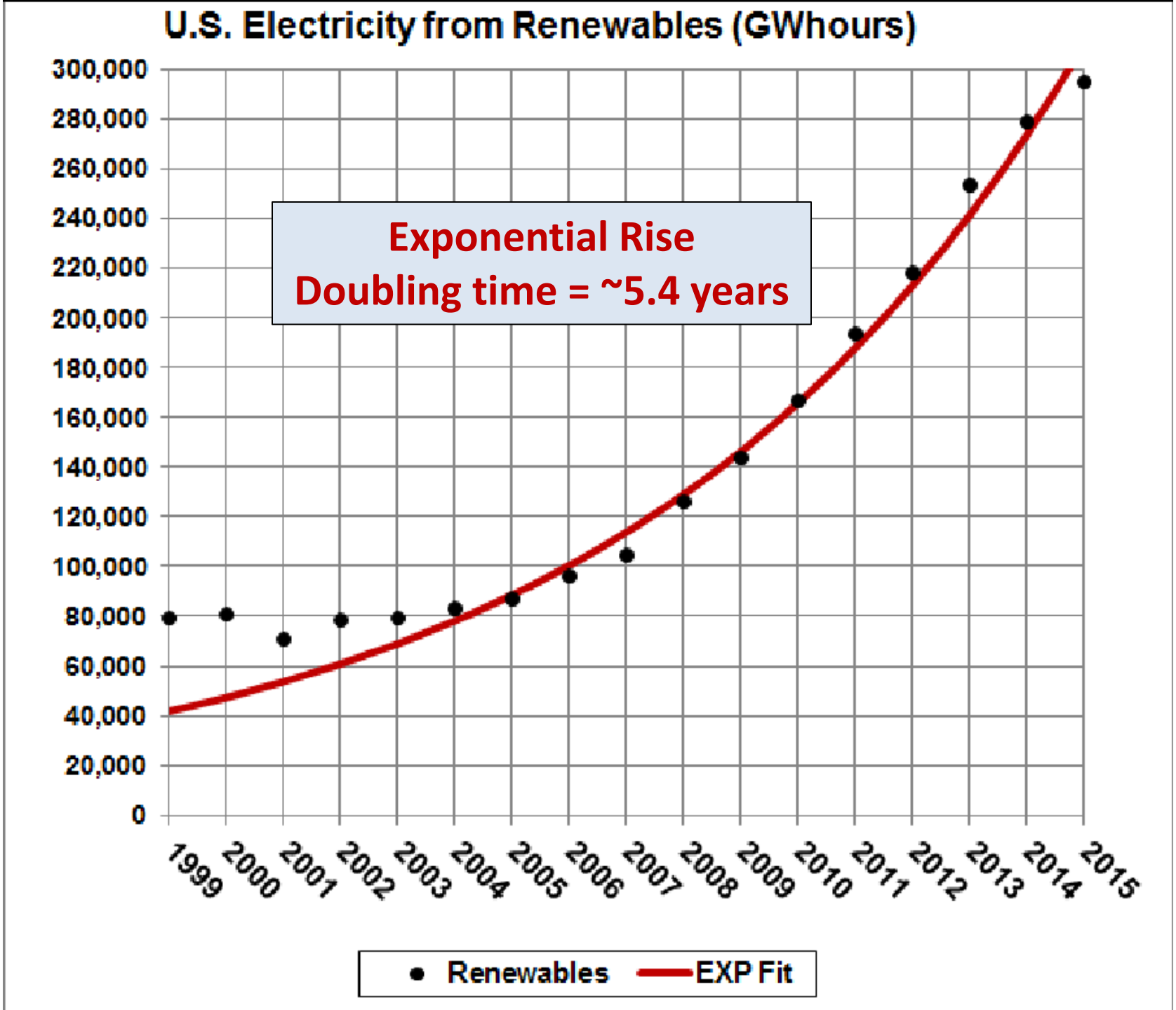
Trident Winds Project

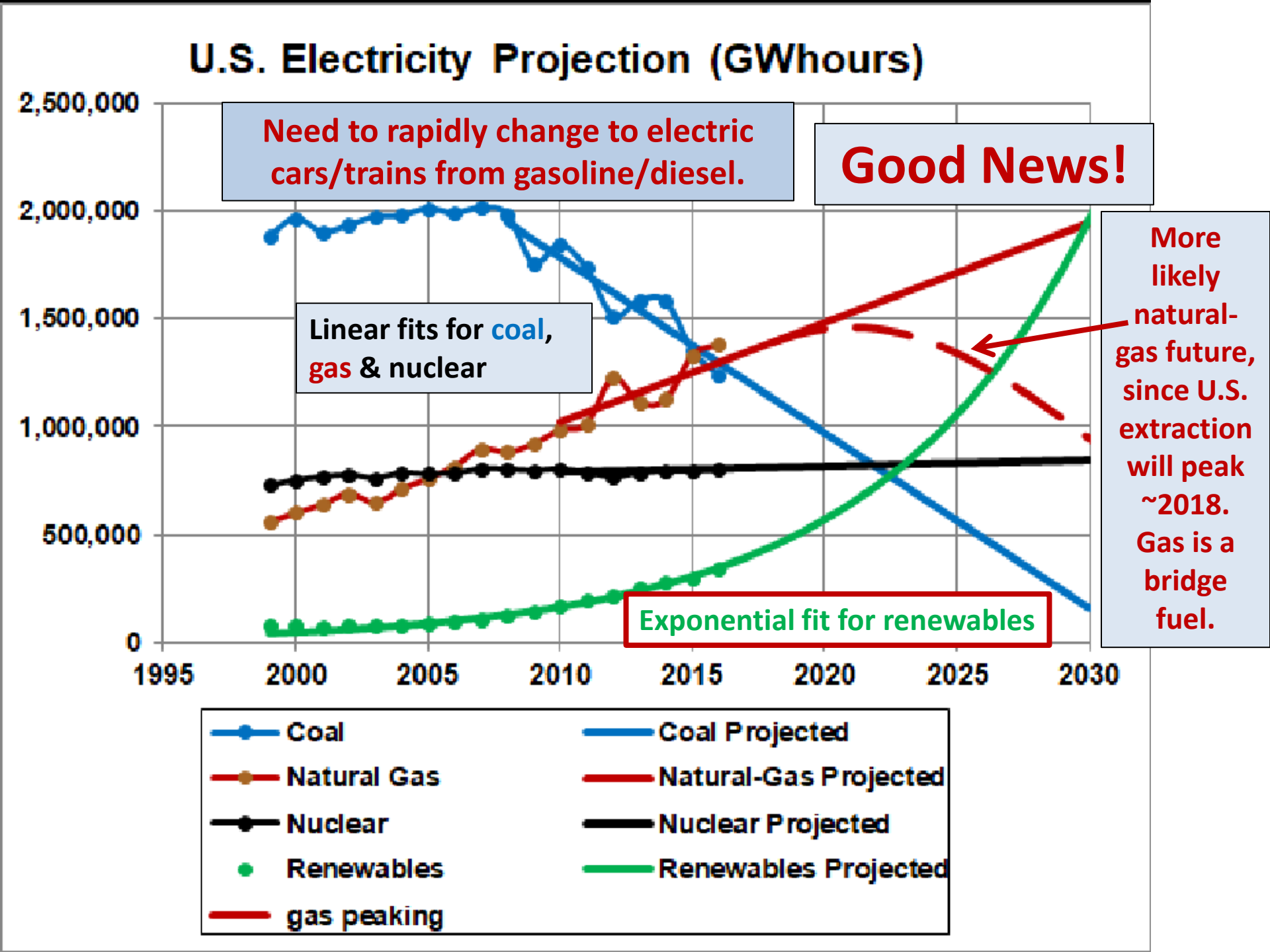
Left turbines on continental shelf; right turbines cabled to ocean floor.

World Cumulative Installed Wind Power 2000-2015

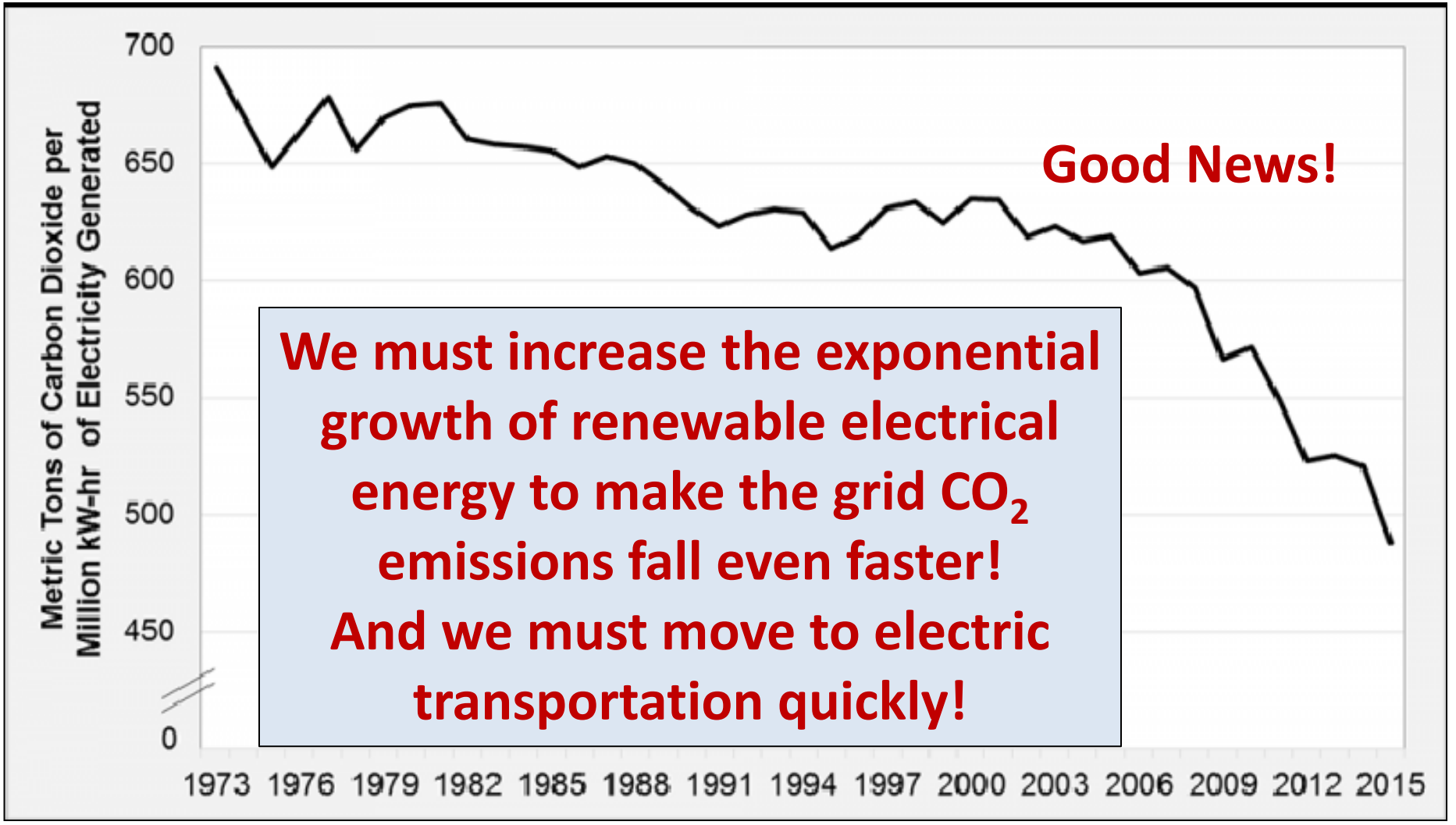



Geothermal Power Generation
Current and Planned Nameplate Capacity (MW) by State
WA
OR
33.3
73 - 77
CA
2,732
995 - 1,061
ID
15.8
83
NV
517
1,056 - 1,061
MT
WY
0.25
UT
48.1
215
AZ
2
CO
20 - 40
NM
15
ND
0.6 - 0.82
SD
NE
KS
OK
TX
1
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
AL
OH
GA
FL
SC
NC
TN
PA
NY
VT
NH
ME
MA
RI
CT
NJ
AK
0.73
50
HI
38
< 3-GW maximum planned
CURRENTLY INSTALLED
PLANNED (Min - Max)
Current and planned capacity additions are from the Geothermal Energy Association (GEA, February 2013, Figure 1 and Table 2). Total installed capacity is 3,386 MW and total planned capacity addition range is 2,511 to 2,606 MW.
Author: Billy Roberts - February 28, 2013
NREL
NATIONAL RENEWABLE ENERGY LABORATORY


U.S. Electricity from Renewables (GWhours)
300,000
280,000
260,000
240,000
220,000
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Exponential Rise
Doubling time = ~5.4 years
Renewables
EXP Fit

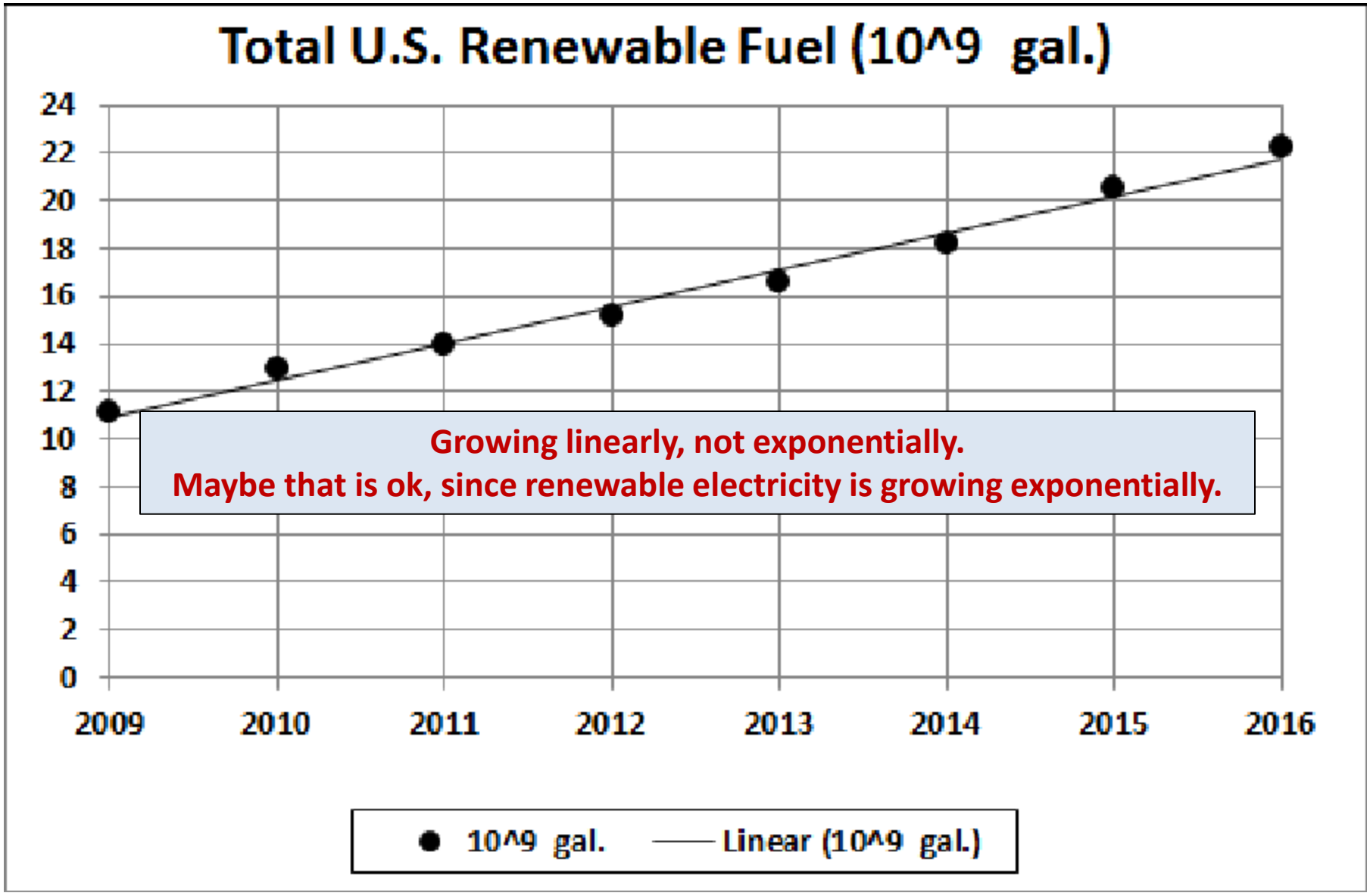

U.S. Electricity Projection (GWhours)
Need to rapidly change to electric cars/trains from gasoline/diesel.
Good News!
Linear fits for coal, gas & nuclear
Exponential fit for renewables
More likely natural-gas future, since U.S. extraction will peak ~2018. Gas is a bridge fuel.
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1995
2000
2005
2010
2015
2020
2025
2030
Coal
Natural Gas
Nuclear
Renewables
gas peaking
Coal Projected
Natural-Gas Projected
Nuclear Projected
Renewables Projected

U.S. Reduced Grid CO_2 Emissions

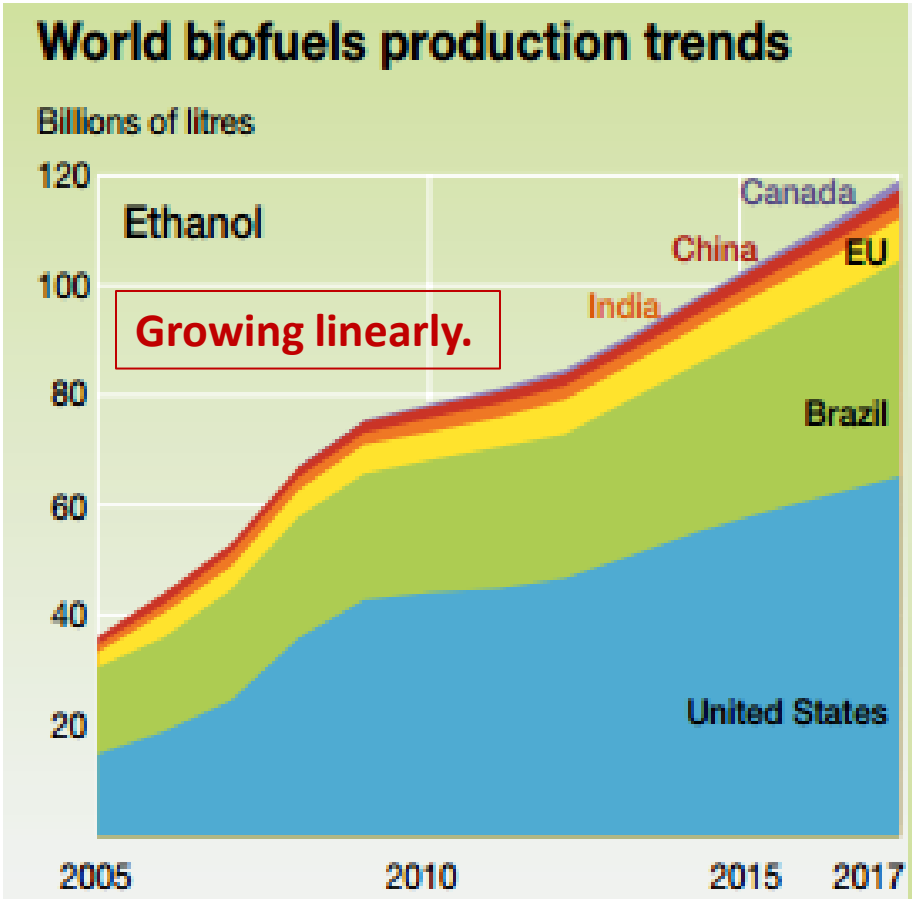


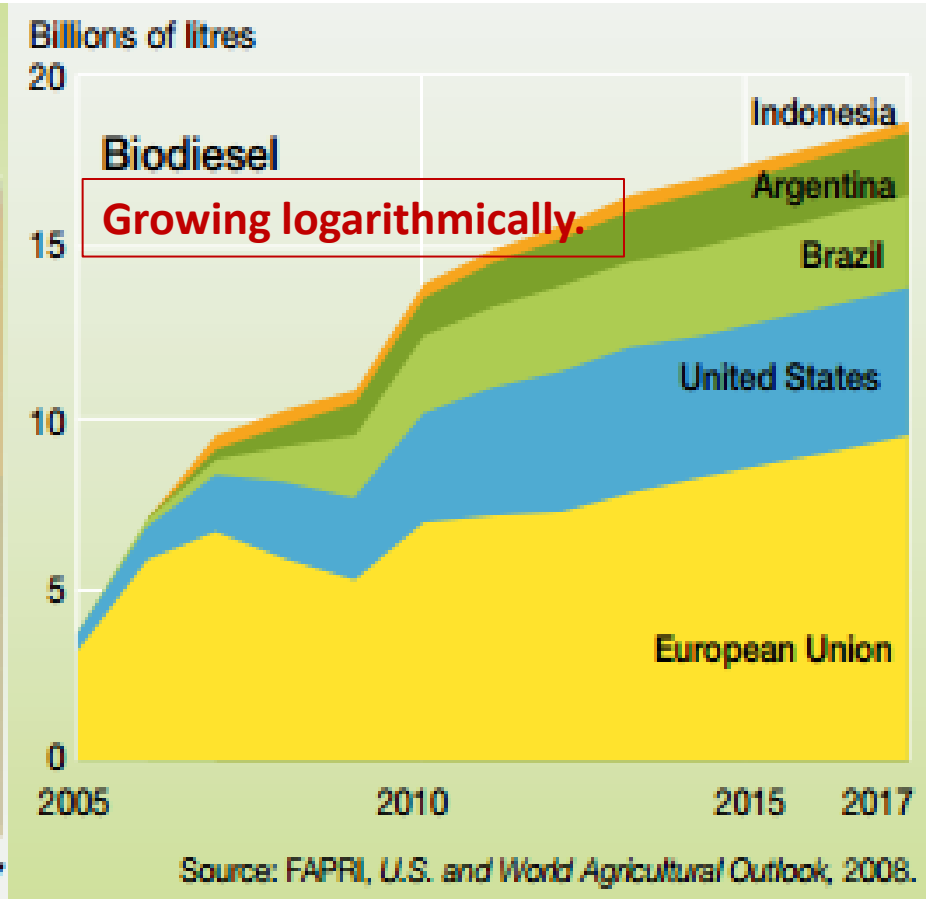
Fuels for Transportation

- Gasoline and diesel
- Propane and Natural gas
- Biofuels
  - Ethanol from corn
  - Ethanol from cellulose
  - Biodiesel from crops (soy beans, canola, palm oil, etc.)
  - Biodiesel from algae and bacteria
- Electricity (solar, wind, natural gas, coal, uranium & biowaste)
- Small nuclear reactors (for large ships)

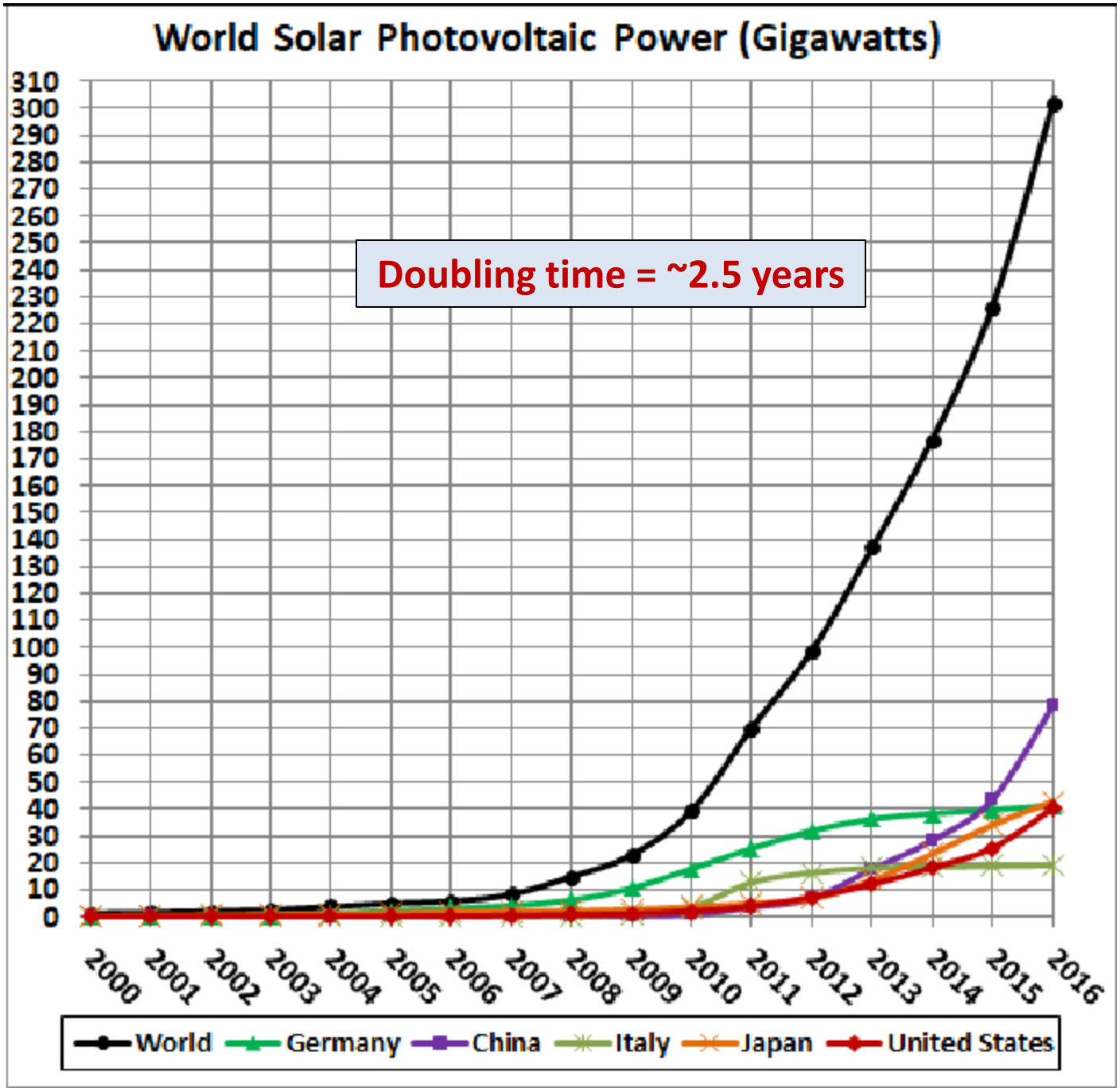

Total U.S. Renewable Fuel (10^9 gal.)
24
22
20
18
16
14
12
10
8
6
4
2
0
2009
2010
2011
2012
2013
2014
2015
2016
Growing linearly, not exponentially.
Maybe that is ok, since renewable electricity is growing exponentially.
10^9 gal.
Linear (10^9 gal.)

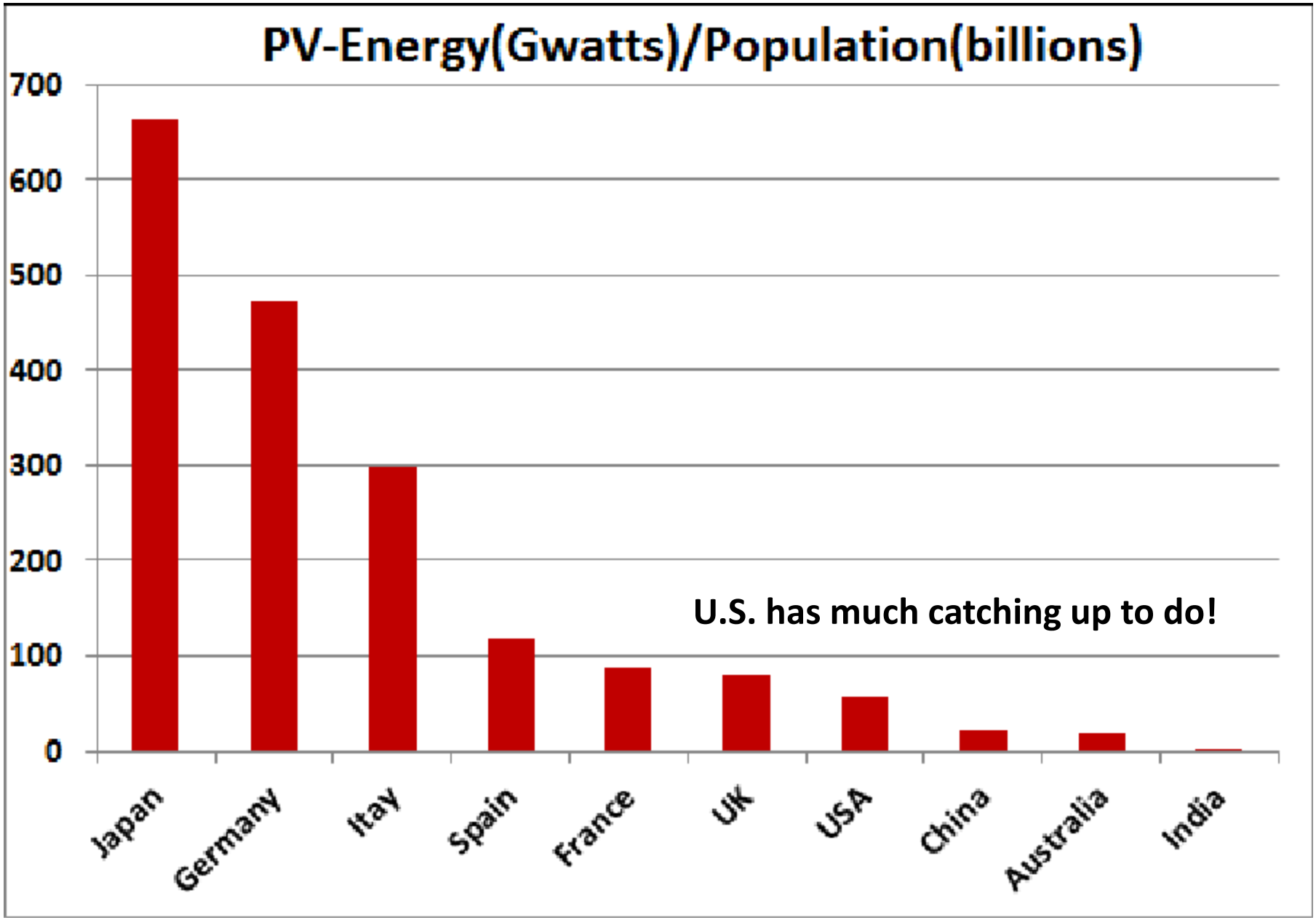
Global Ethanol and Biodiesel

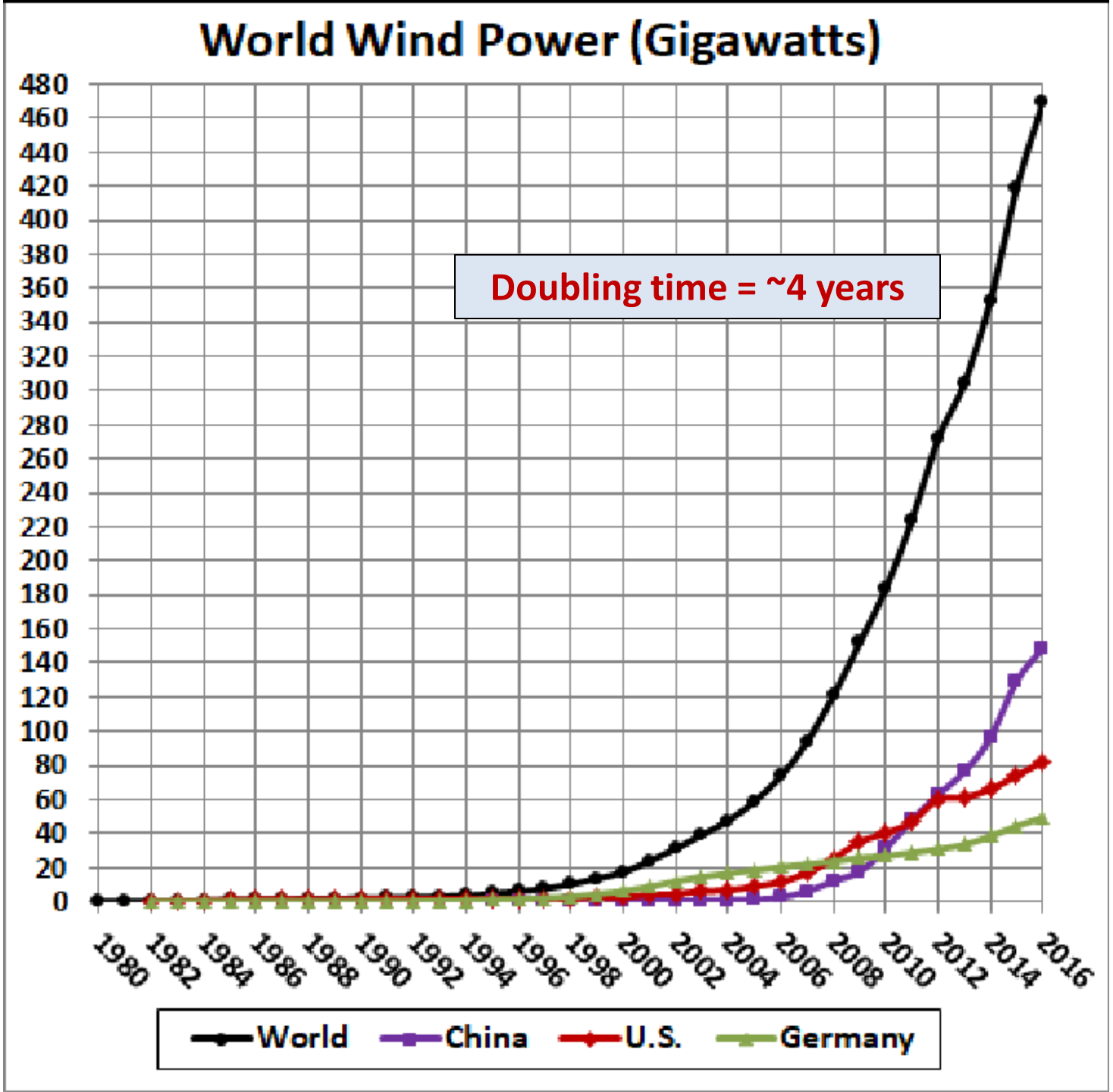


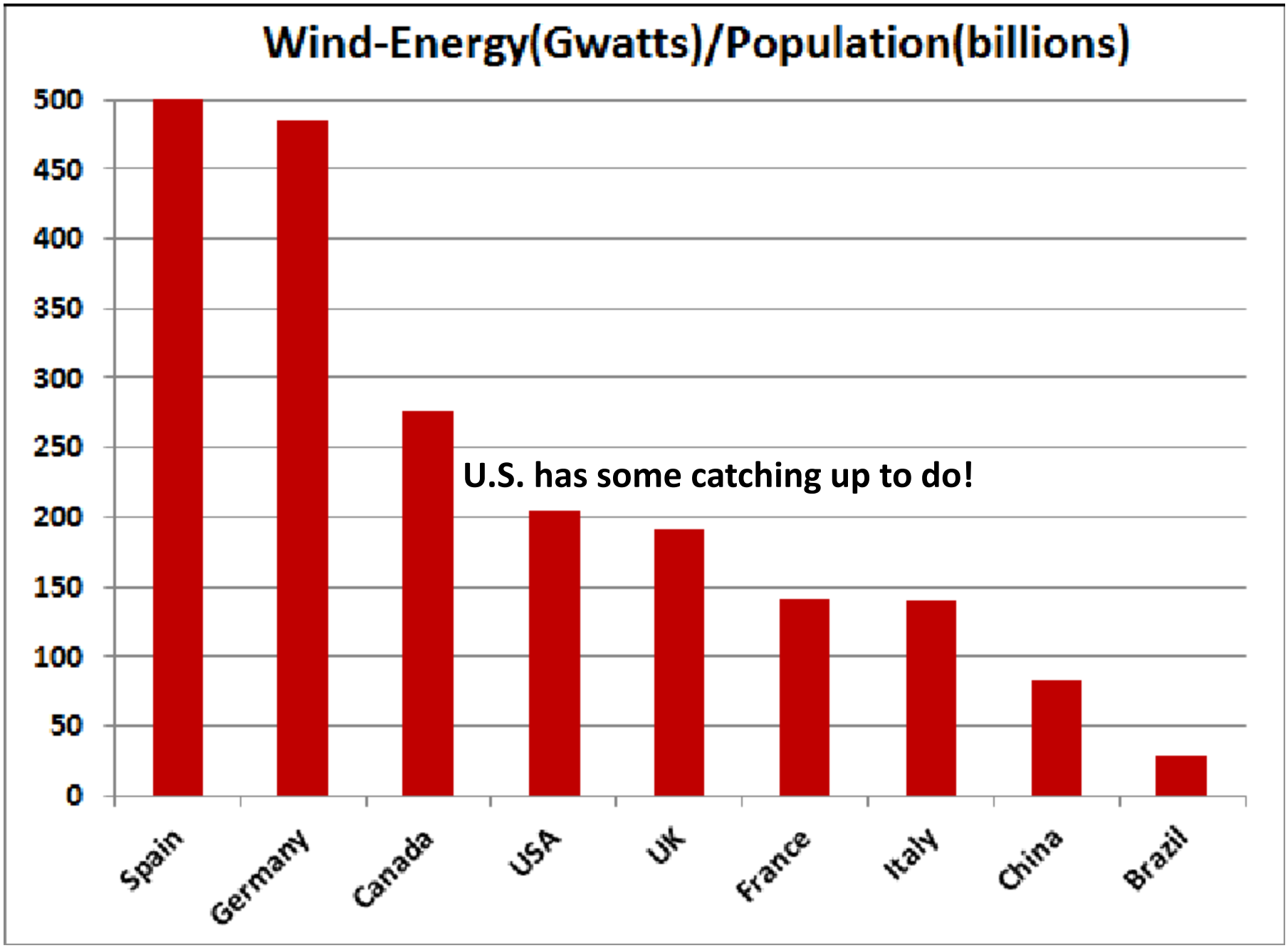


1-gallon = 3.785 litres


World Solar Photovoltaic Power (Gigawatts)
Doubling time = ~2.5 years
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
World
Germany
China
Italy
Japan
United States


PV-Energy(Gwatts)/Population(billions)
700
600
500
400
300
200
100
0
U.S. has much catching up to do!
Japan
Germany
Italy
Spain
France
UK
USA
China
Australia
India

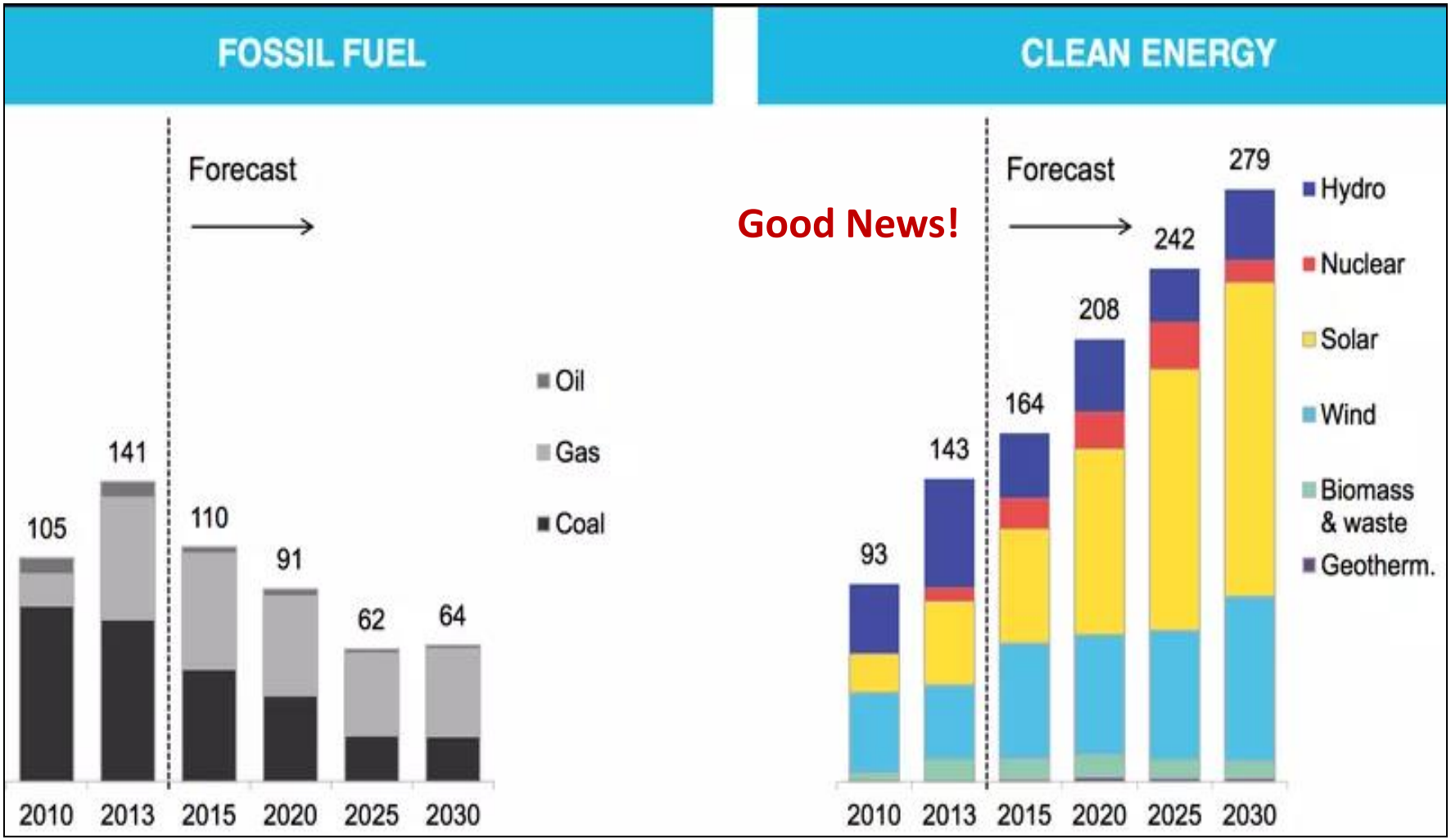

World Wind Power (Gigawatts)
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Doubling time = ~4 years
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
World
China
U.S.
Germany


Wind-Energy(Gwatts)/Population(billions)
500
450
400
350
300
250
200
150
100
50
0
U.S. has some catching up to do!
Spain
Germany
Canada
USA
UK
France
Italy
China
Brazil

Renewable Electric Energy by Country

- **Italy**: 38% in 2014
- **Spain**: 30% in 2010
- **Germany**: 30% in 2014
- **U.S.**: 17% in 2016
- **Australia**: Plans for 23% by 2020
- **U.K.**: Plans 15% by 2020
- **Brazil**: Plans for 42% by 2023
- **Mexico**: Plans for 35% by 2025

World Electricity Sources



Power generation capacity additions (GW)

Monopoly Power Company & Renewables

- Require monopoly power companies to provide incentives for increasing energy efficiency (negawatts) of house and commercial buildings.
- Require power companies to provide incentives for increasing solar PV at homes and commercial locations.
- Require power companies to increase the % of renewable power each year, including customers' renewable power.

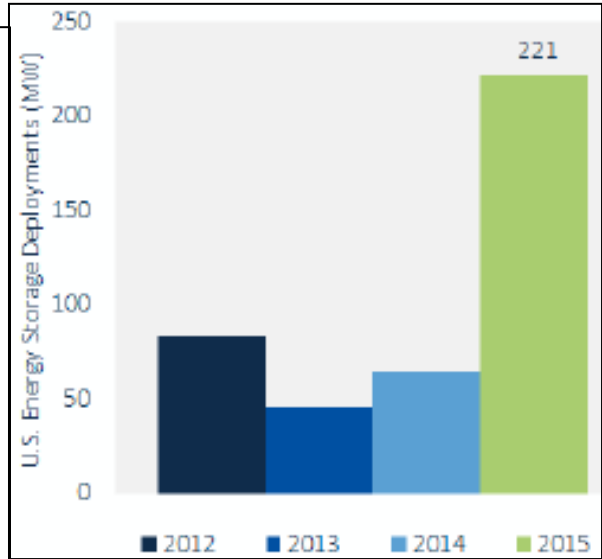
Smoothing Renewables

- Wind farms connected over a continent
- Wind farms connected along a long coast
- Large solar farms connected over a continent
- Community solar farms connected to microgrids
- Buildings and parking lots with solar PV connected to microgrids
- Smart microgrids, regional grids & national grid
- **Energy Storage**

Storage for Renewable Energy

- Solar PV and wind energy storage
  - New and used lithium-ion batteries
  - Large-scale liquid-flow batteries
  - Generate hydrogen to power fuel cells in buildings
  - Electric-car's batteries when cars are not being used (V2H & V2G)
- Solar Thermal
  - Molten salts
  - geothermal

US Energy Storage Market Grew 243% to 221 MWh in 2015. Expected to reach 1.7 GWH by 2020.



Example Solar/Storage Systems

Battery storage is the linchpin of solar-PV and wind energy.

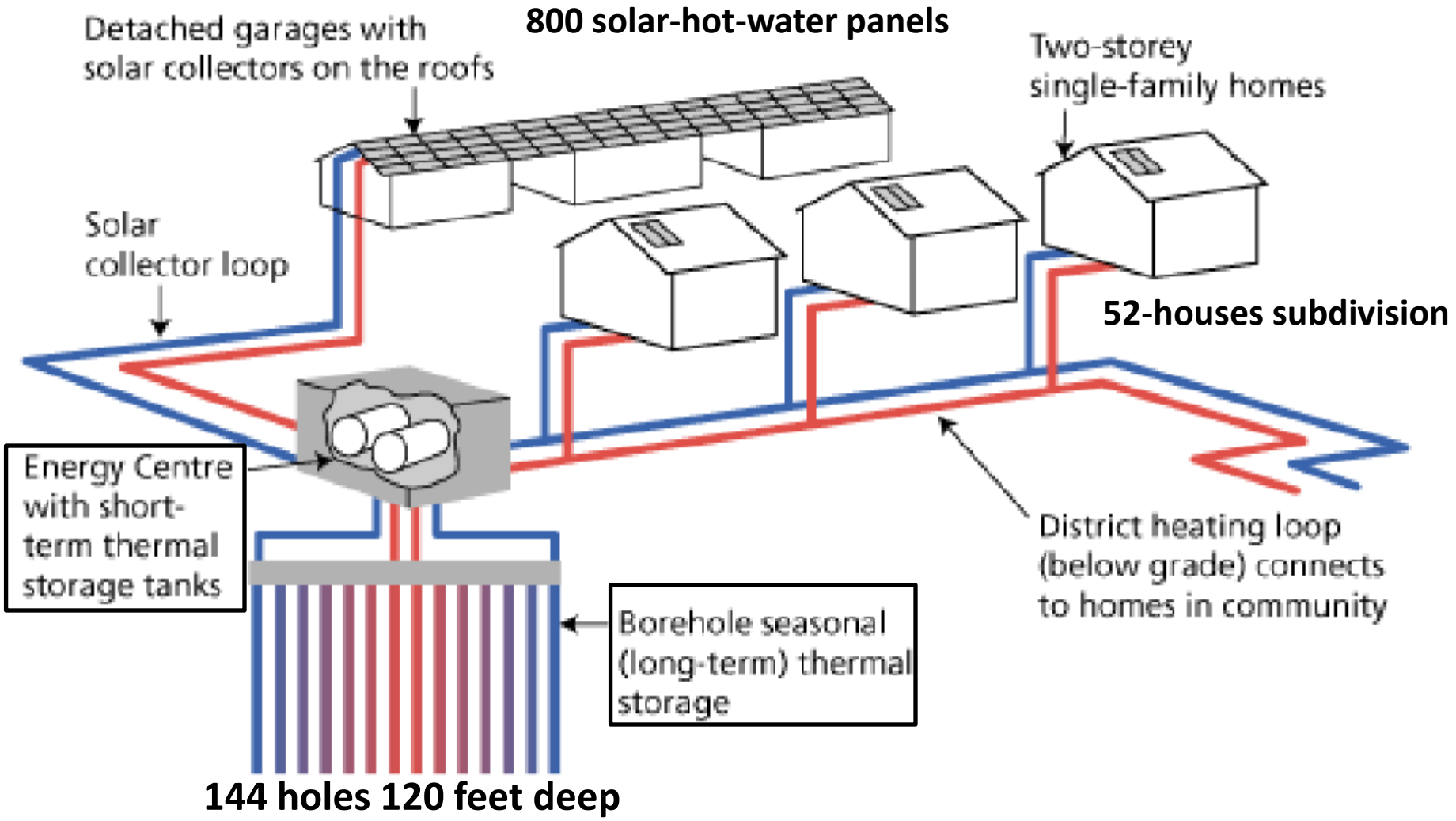
- Kauai, Hawaii
  - 55,000 Tesla solar panels (13 MegaWatts)
  - 272 Tesla PowerPacks (52 MegaWattHours & 13 MegaWatts)
  - 50 acres of land
  - $0.139 per kiloWattHour

- Southern California Edison
  - 400 Tesla PowerPacks (80 MWh & 20 MW)
  - Charged off-peak to provide power on-peak.
  - Largest battery storage so far

- **AES Energy Storage 120-MWh station for San Diego Gas & Electric (world's largest)($1/watt)**

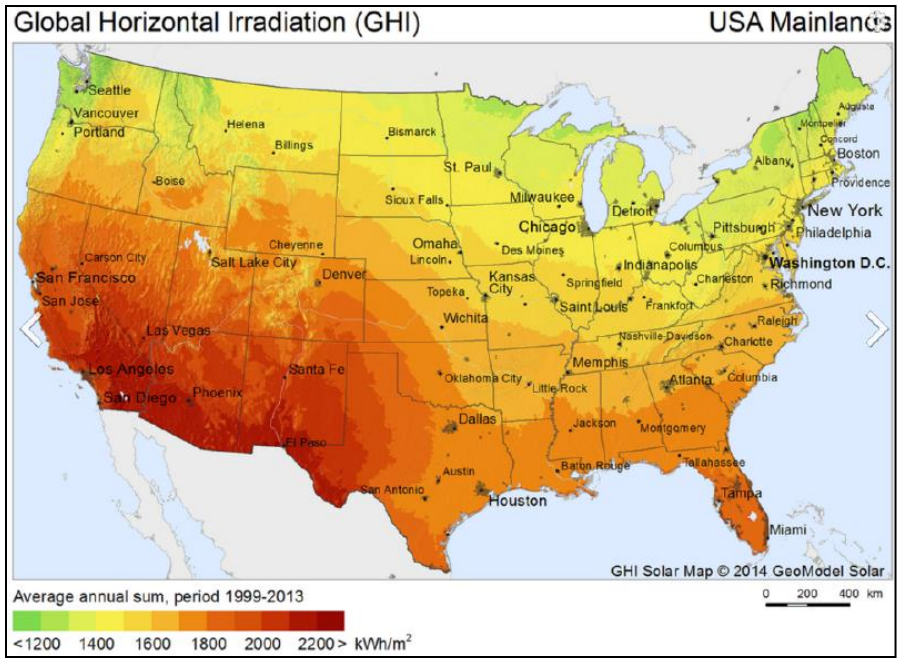
Kauai Hawaii PV & Storage

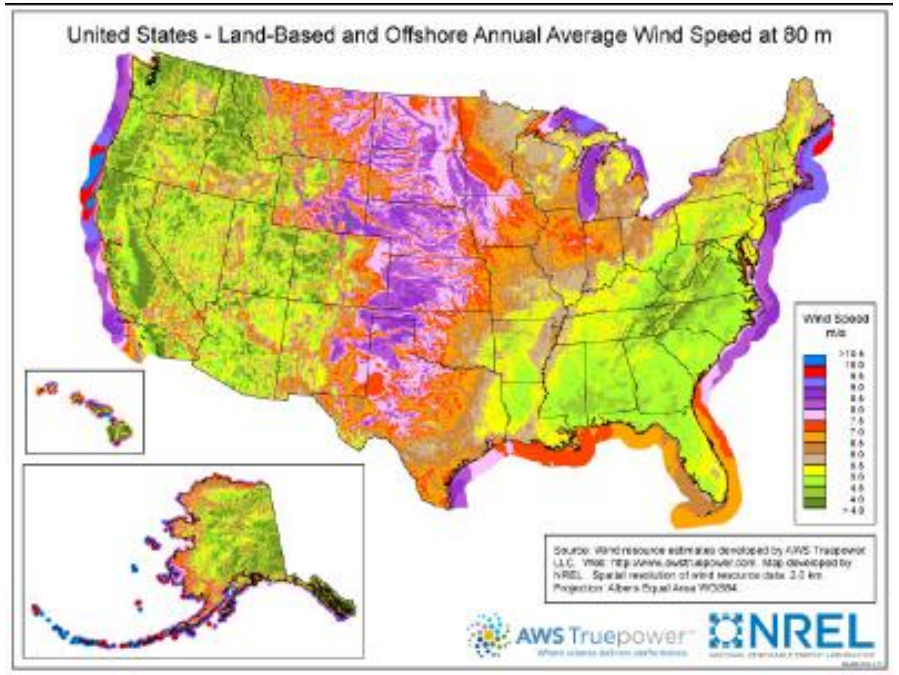
Solar Thermal Storage and District Loop



Drake Landing in Okotoks, Alberta, Canada

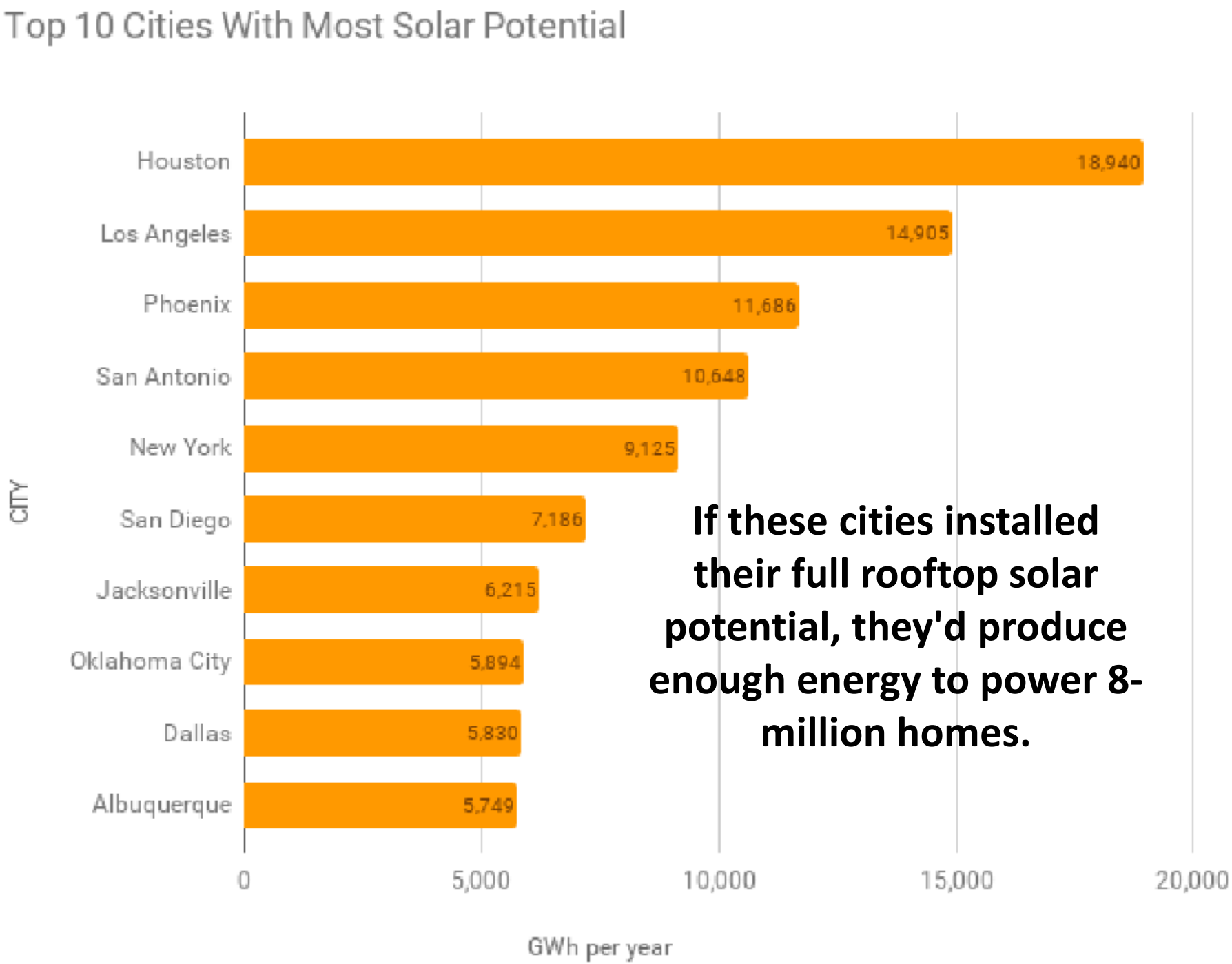
Weather: Winter -27°F; Summer 83°F

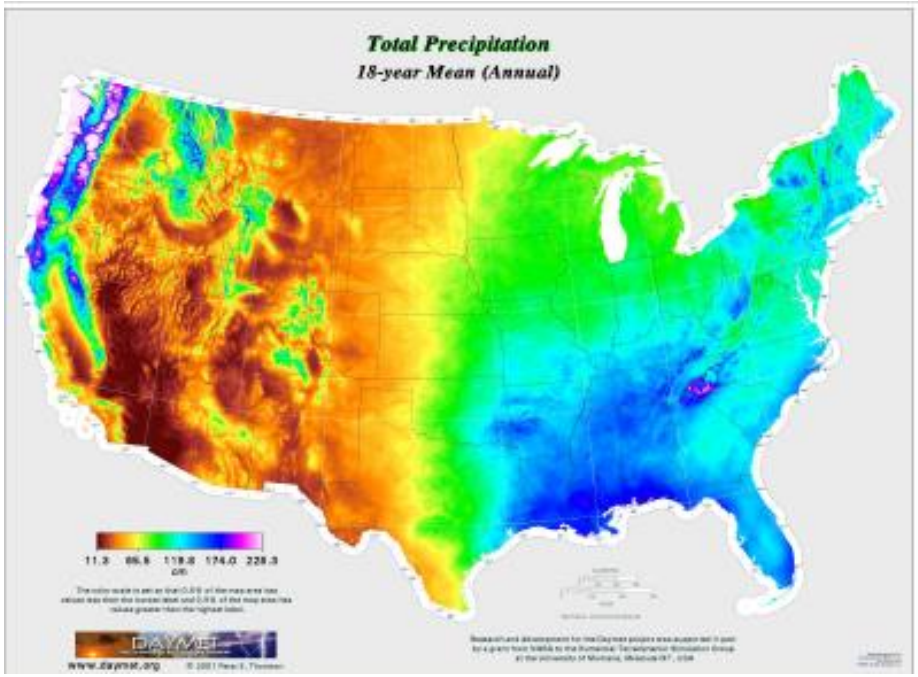


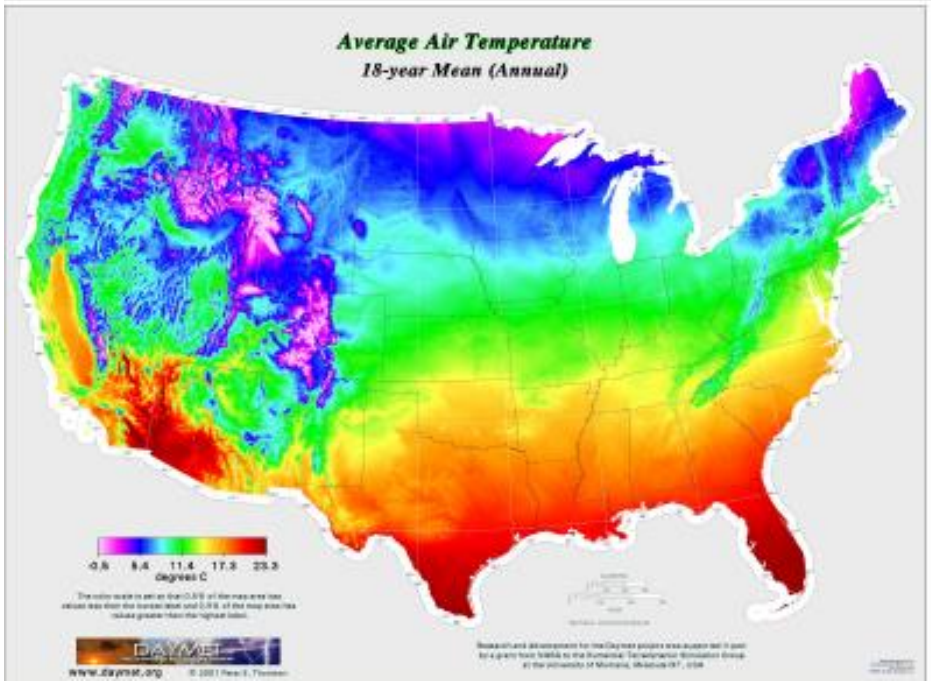


What are best locations for factories?

- Cover the southwest, central-west & southeast US with solar farms.
- Cover the three coasts with offshore wind farms designed for future sea-level rise.
- Cover Great Lakes with wind farms.
- Cover the central US with wind farms.
- Locate battery storage across US.
- Locate energy-intensive factories in areas of wind & solar farms.


Top 10 Cities With Most Solar Potential
Houston
Los Angeles
Phoenix
San Antonio
New York
San Diego
Jacksonville
Oklahoma City
Dallas
Albuquerque
18,940
14,905
11,686
10,648
9,125
7,186
6,215
5,894
5,830
5,749
CITY
0
5,000
10,000
15,000
20,000
GWh per year
If these cities installed their full rooftop solar potential, they'd produce enough energy to power 8-million homes.





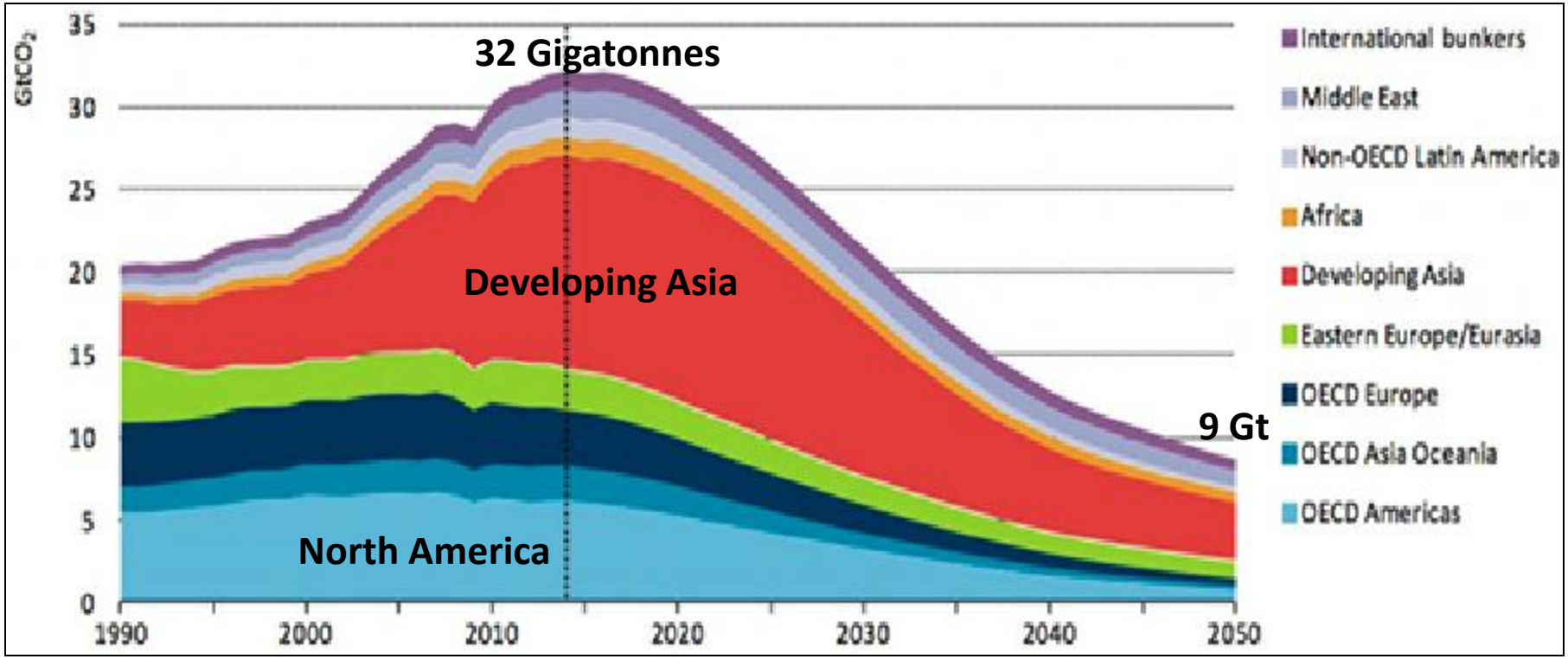
What are best locations for population?

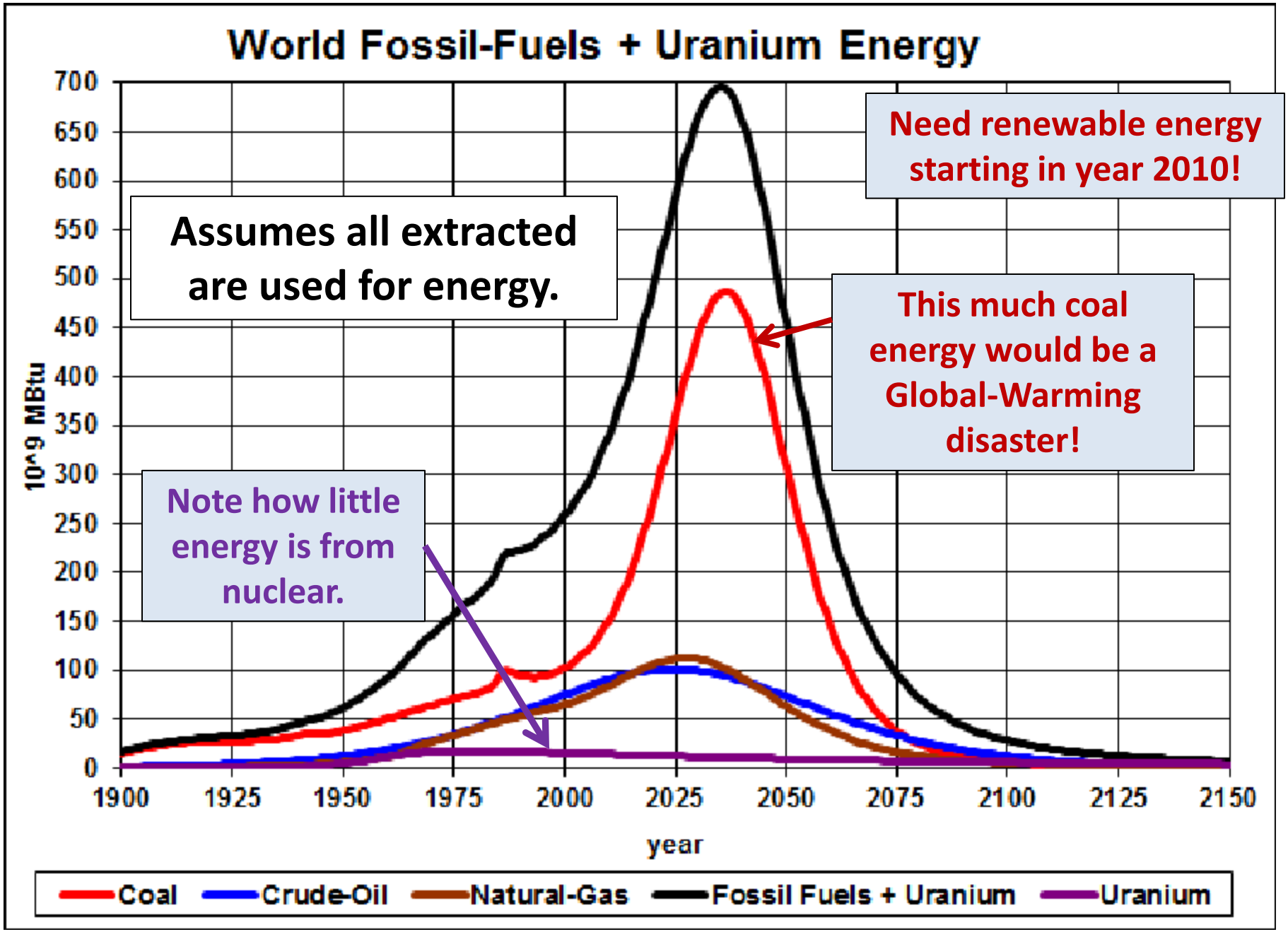
Stimulate population location in northwest coastal, central & central-east U.S. for moderate precipitation and temperature nearest as possible to renewable energy sources.

Summary

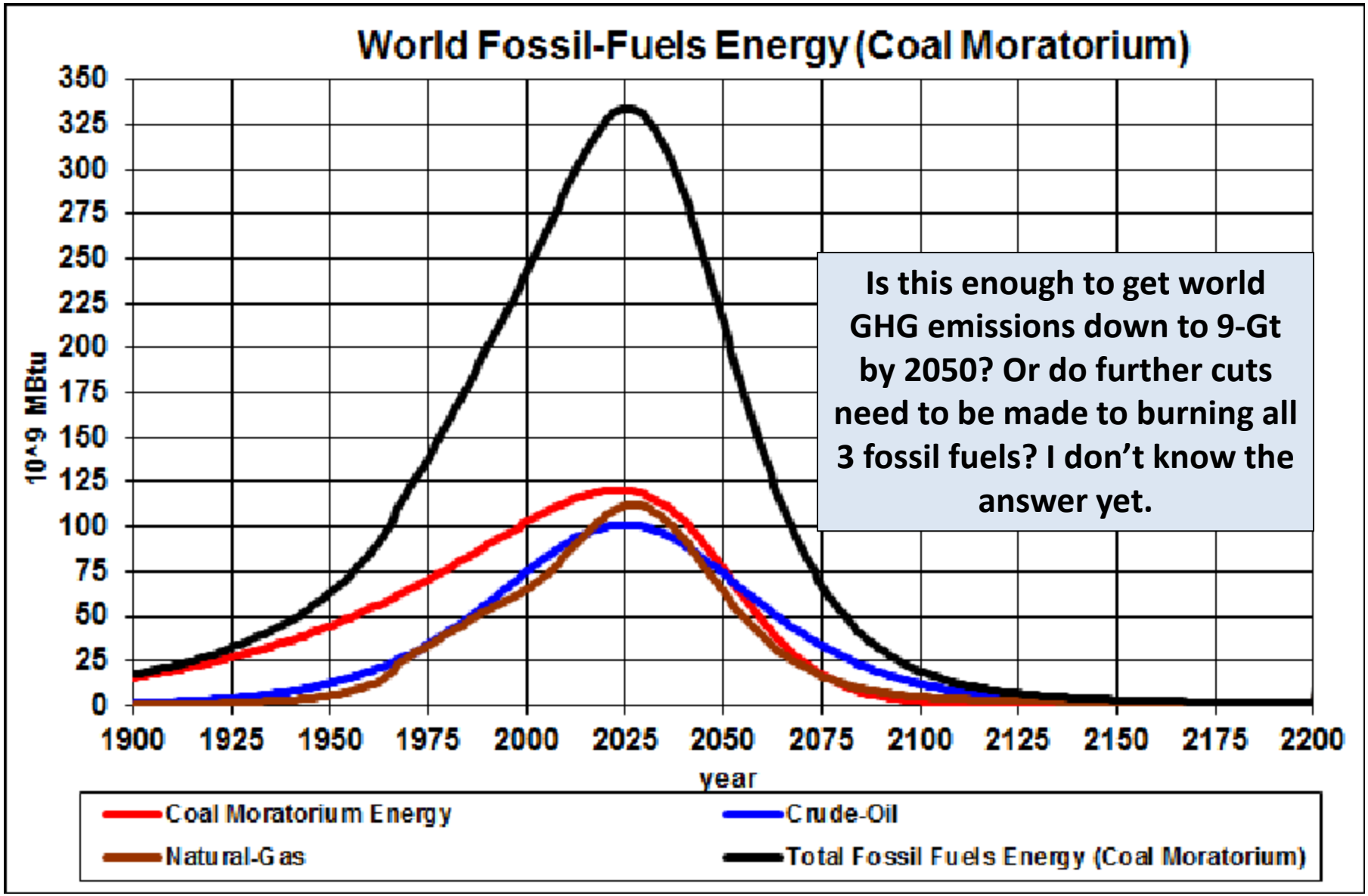
- **Must quit burning fossil fuels.**
  - Causes global warming.
  - Extraction will decline after about 2040.
- **Must make buildings highly energy efficient.**
- **Must speed up creating infrastructure for renewable energy.**
  - Solar PV and thermal
  - Wind farms onshore and offshore
- **Must move transportation to electric quickly.**
  - Electric cars
  - Fast trains across continent
  - Hydrogen-electric & biodiesel trucks, ships & planes

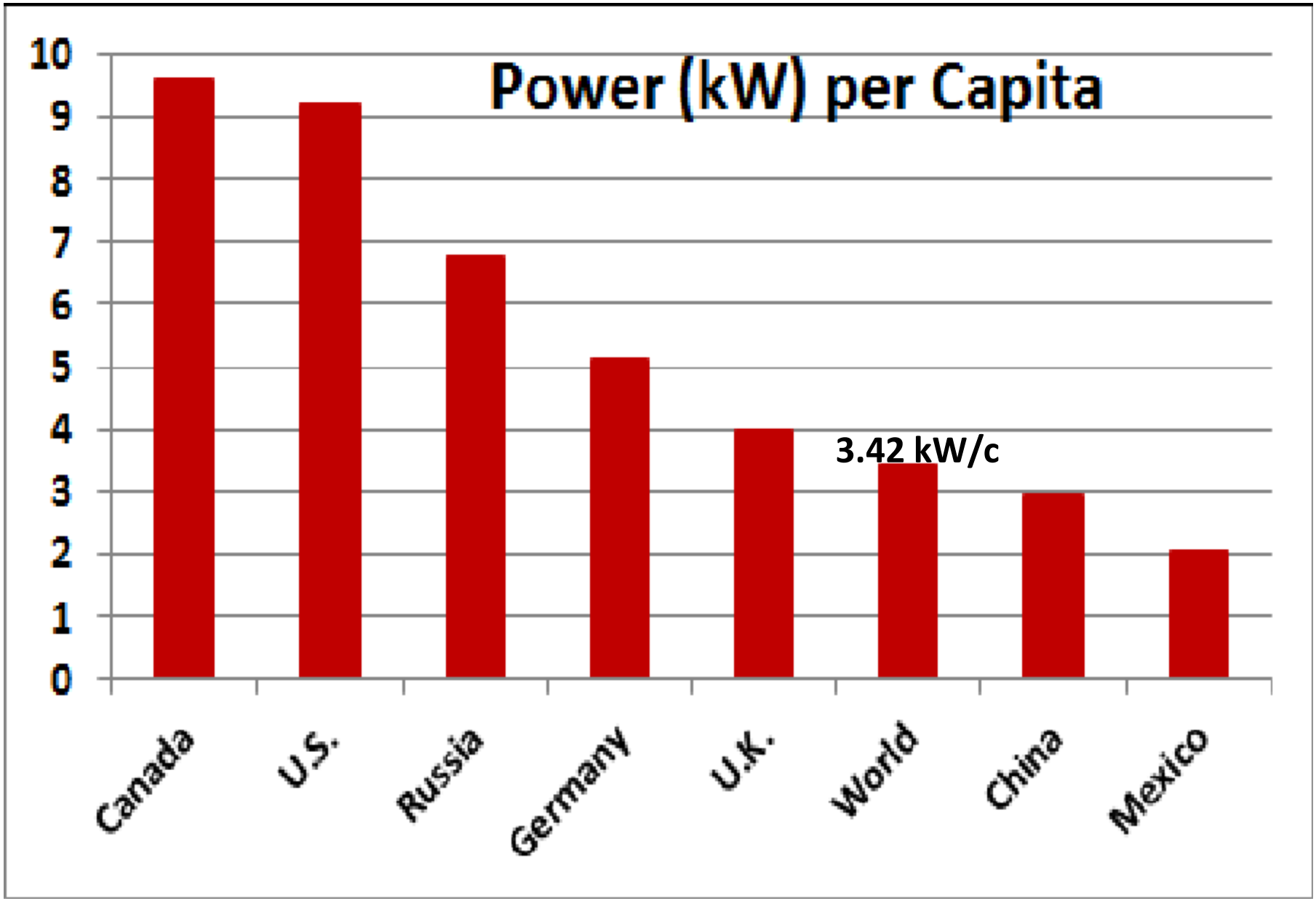
Energy-related CO_2 emissions by region for temp < 2°C. Global CO_2 emissions fall to less than 9 Gigatonnes in 2050.




World Fossil-Fuels + Uranium Energy
Need renewable energy starting in year 2010!
Assumes all extracted are used for energy.
This much coal energy would be a Global-Warming disaster!
Note how little energy is from nuclear.
10^9 MBtu
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1900
1925
1950
1975
2000
2025
2050
2075
2100
2125
2150
year
Coal
Crude-Oil
Natural-Gas
Fossil Fuels + Uranium
Uranium

Suppose there were a coal moratorium, which may be underway, that reduced the coal peak to one-fourth of the case if all reserves were burned.




Power (kW) per Capita
10
9
8
7
6
5
4
3
2
1
0
3.42 kW/c
Canada
U.S.
Russia
Germany
U.K.
World
China
Mexico

Future Power (TW = 10^{12} watts)

- Assume World kW/c (now 3.42 kW/c) to be eventually **5 kW/c after all fossil fuels are no longer being burned for energy**.
- Assume sources will be divided **2 kW/c for solar, 2 kW/c for wind and 1 kW/c for biofuels**.
- If population levels off at **10 billion people**, the total power would be **50 terrawatts (TW)**.
- The division for sources would be **20 TW for solar, 20 TW for wind and 10 TW for biofuels**.
- **At current doubling rates it would take over 150 years; so we need to cut by one-quarter the doubling rates. Cut final population to 5 billion?**

Far Future

- Without global warming the global temperature would be dropping the Earth into the **next ~100,000-years ice age.**
- After fossil fuels are gone, the temperature drop into the next major ice age may be faster than it would have been without global warming.
- If a nuclear war, say between Pakistan and India, occurs or a large asteroid collides with the Earth, a “nuclear winter” may cause global cooling for a decade or longer and may trigger the next ice age.
- **Should we be storing the carbon dioxide due to burning fossil fuels to release it later to slow down the entry into the next ice age?**

What We Must Do!

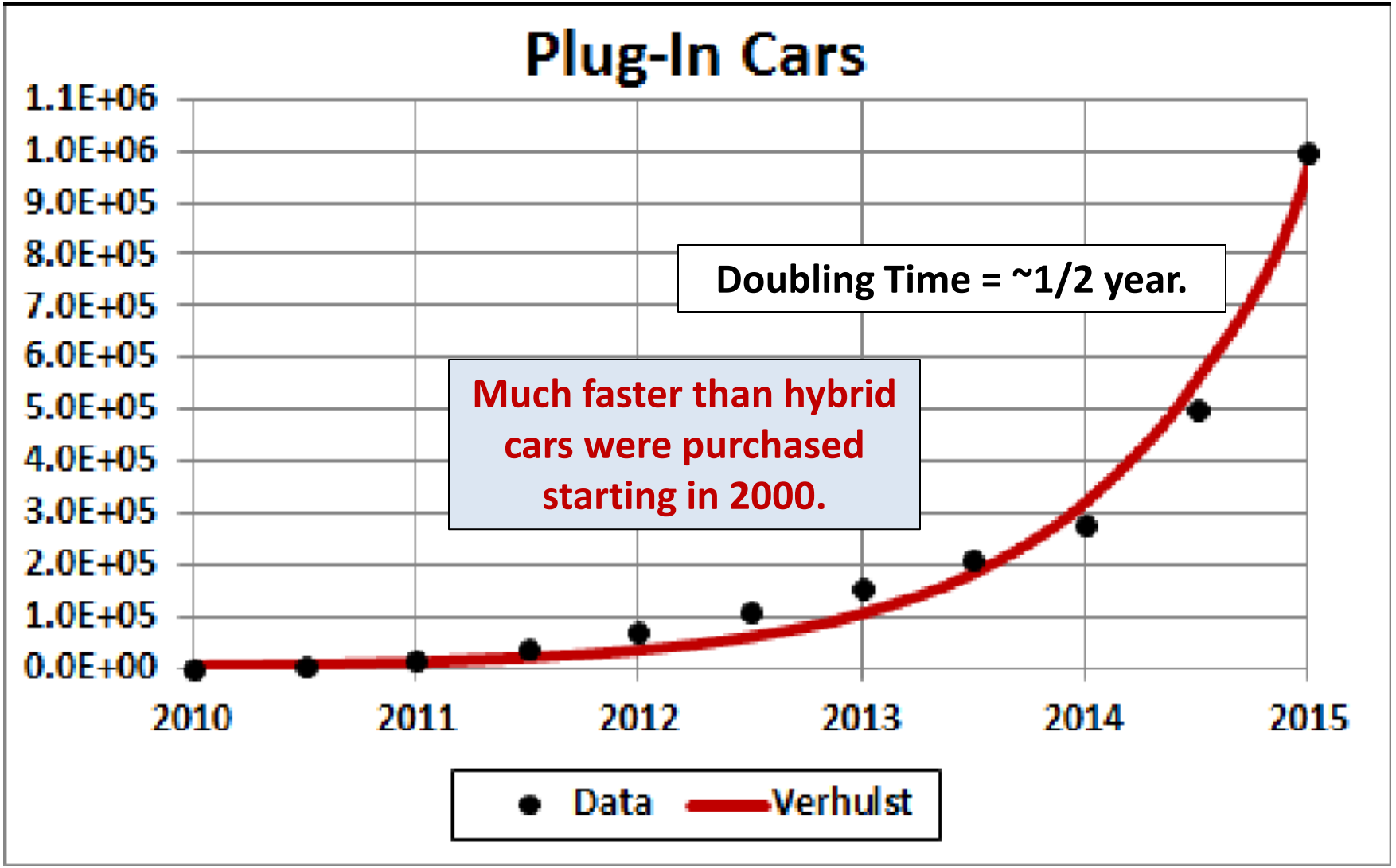
- Provide free birth control world wide.
- Build a fast electric train and bus system.
- Move to electric cars and fast charging stations.
- Move to biodiesel or fuel-cell trucks.
- Cover all appropriate parking lots and building roofs with solar panels.
- Build solar farms near communities.
- Cover the Midwest, Offshore and Great Lakes with wind farms.
- Build microgrids all over the U.S.
- Build smart high-power electric transmission lines.
- Locate industries where solar and wind are strongest.

200-300-Miles Mid-Size BEVs

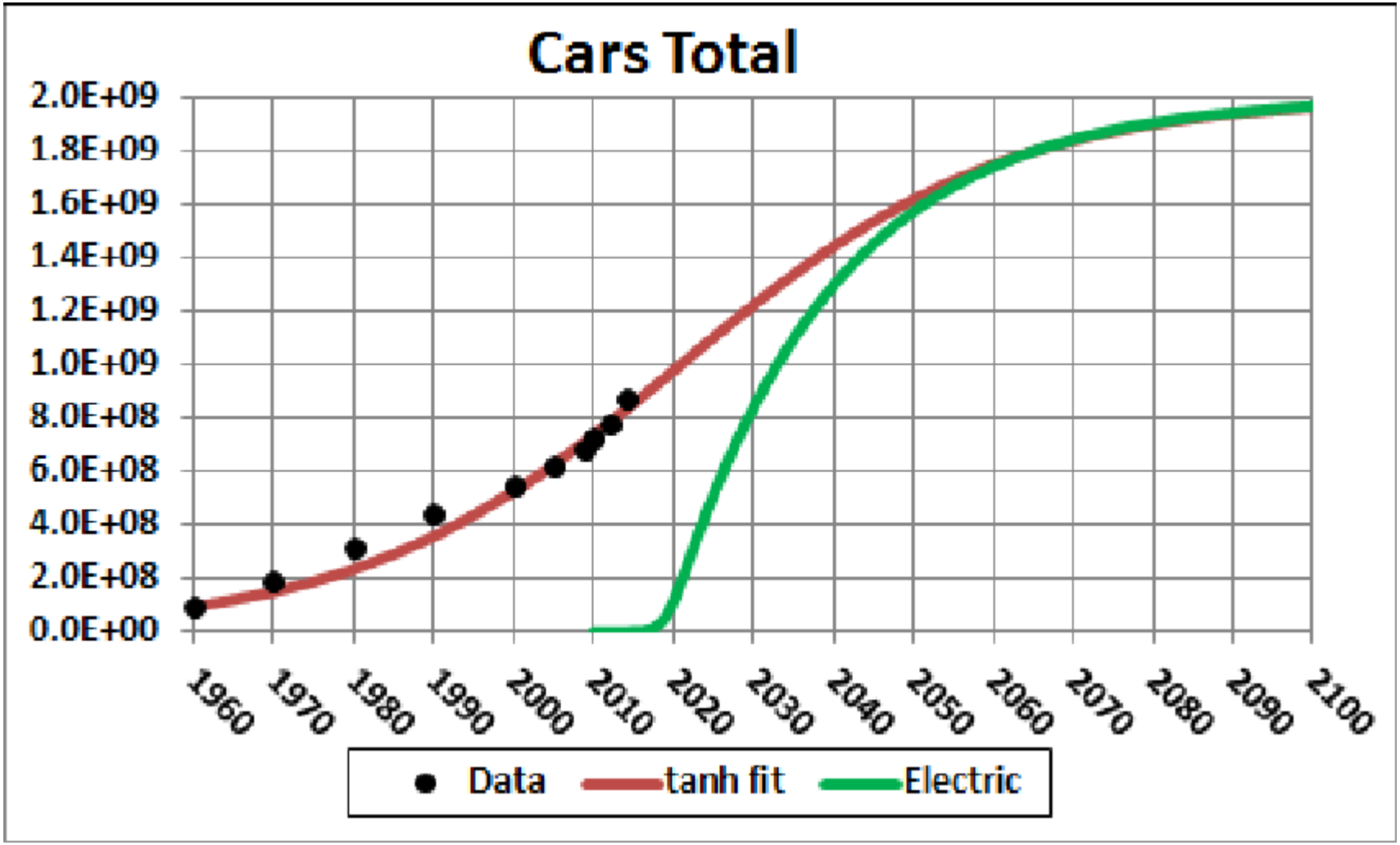
HEV = Hybrid Electric, PHEV = Plug-in Hybrid Electric, BEV = Battery Electric

- **Chevrolet Bolt EV** (2017, 238-miles range)
- Nissan ? (2018, >200-miles range)
- **Tesla Model 3** (2018, >215-miles range)
- Ford Model E (2019, >200-miles range)
- VW ? (2019, >200-miles range)(diesel controversy promised)
- Audi SUV EV (2019, >200-miles range)
- Volvo ? (?, >200-miles range)

Exponential Fit to Plug-ins (BEVs & PHEVs)



Reasonable Prediction when all Cars will be Plug-ins (BEVs & PHEVs)



Autonomous Vehicles (AV)

- **Audi**: AV by 2017
- **Tesla**: AV by 2018
- **Google**: AV by 2018
- **VW**: AV by 2019
- **Nissan**: AV by 2020
- **Ford**: AV by 2020
- **GM**: AV by 2020
- **Toyota**: AV by 2020
- **BMW**: AV in 2021
- **Worldwide**: AV in 2025
- **Uber: Driverless by 2030**
- **IEEE: 75% AV by 2040**

Automation could replace 1.7 million American truck drivers in the next decade.

Hybrids, PHEVs & BEVs LLI Course

2017-2018 Fall Semester

- Hybrid-Electric Cars (HEV)
  Example: Toyota Prius
- Plug-in Hybrid-Electric Cars (PHEV)
  Example: Chevrolet Volt
- Battery-Electric Cars (BEV)
  Example: Chevrolet Bolt EV
- Instructor: L. David Roper

World's 10 Fastest Trains

- **Maglev in Shanghai China**
  - First magnetic levitation
  - 19 miles track
  - 267 mph max. speed
- **Harmony CRH 380A**
  - Beijing – Shanghai, China
  - 819 miles track
  - 236 mph max. speed

World's 10 Fastest Trains

- **AGV Italo**
  - Napoli – Milano, Italy
  - 359 miles track
  - 224 mph max. speed
- **Siemens Velaro E/AVS 103**
  - Barcelona- Madrid, Spain
  - 624 miles track
  - 217 mph max. speed

World's 10 Fastest Trains

- **Talgo 350 (T350)**
  - Madrid – Lleida, Spain
  - 286 miles track
  - 227 mph max. speed

- **E5 Series Shinkansen Haya**
  - Tokyo – Aomori, Japan
  - 419 mil
  - 249 mp

Japan's Shinkansen started in 1964, 1,717 miles, 150-250 mph

World's 10 Fastest Trains

- **Alstom Euroduplex**
  - Rhine & Rhone LGV line
  - Many miles track
  - 199 mph max. speed

- **TGV Duplex**
  - Paris – Marseille, France
  - 482 miles track
  - 193 mph max. speed

Netherlands trains started running on 100% wind energy in 2017!

World's 10 Fastest Trains

- **ETR 500 Frecciarossa**
  - Rome - Milan
  - 359 miles track
  - 224 mph max. speed
- **THSR 700T**
  - Taipei - Kaohsiung, Taiwan
  - 225 miles track
  - 186 mph max. speed

Where are U.S. fast trains?!!

Amtrak's Acela Express

- Washington DC – Boston MA
- 456 miles track
- 150 mph maximum
- **68 mph actual !**

Existing miles of high-speed rail

China	Europe	Japan	U.S.?
6,917 miles	4,699 miles	1,717 miles	456 miles

California High-Speed Rail

- San Francisco/Sacramento – San Diego
- 800 miles track
- 220 mph top speed
- Phase 1 SF- LA 520 miles
- Phase 1 finished in 2029
- Phase 2 uncertain

Locations of planned California High-Speed Rail route and stations. Phase I: blue; Phase II: gold. The separate XpressWest system is shown in cyan. Station and route locations are approximate in some cases.

Florida High-Speed Rail

- Orlando – Miami
- 235 miles track
- 81 mph average speed
- 125 mph top speed
- 2017 finish

Texas High-Speed Rail

- Dallas – Houston
- 240 miles track
- 205 mph top speed
- 2021 finish

Cover commercial buildings with Solar PV.

Cover parking lots with Solar PV.

And fast-charging stations for BEVs and PHEVs.

Cover all new house roofs with Solar PV.

Add Solar PV to old homes after increasing energy efficiency.

Roper House

Community Solar PV

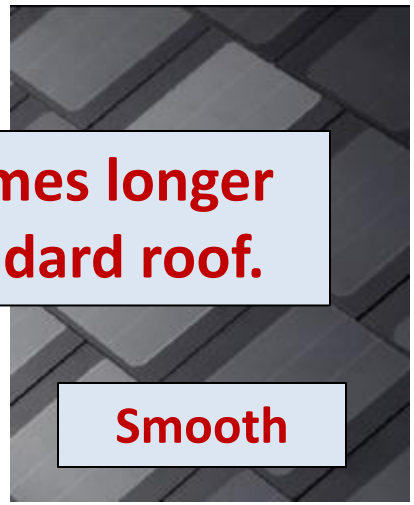
Forbidden in Virginia!!

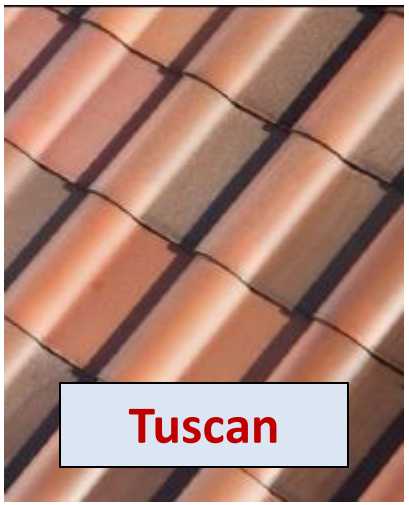
Build solar farms on mountain-top-removal sites!!

Build Wind Farms in Coal Fields

Tesla Solar System

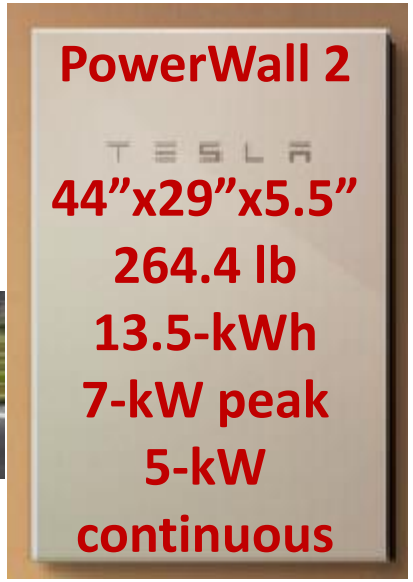
- Solar glass roof tiles (98% of standard efficiency)





Lasts 2-3 times longer than a standard roof.

- Powerwall-2 battery storage (13.5-kWh)
- Electric car (Tesla Model S, X or 3)



Quotes

- ***Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*** by Jason W. Moore
  - "Multiple planetary boundaries are now being crossed – or soon will be."
  - "Crises are not easily understood by those who live through them."
- **Jay Enslee, Governor of Washington**
  - "We are the first generation to feel the sting of climate change, and the last generation to do something about it."

Quotes

- ***This Changes Everything: Capitalism vs. The Climate*** by Naomi Klein
  - "…a crisis we have been studiously ignoring is hitting us in the face – and we are doubling down on the stuff that is causing the crisis in the first place."
  - "…there is a very high chance that our children will spend a great deal of their lives fleeing and recovering from vicious storms and extreme droughts."
  - "…we have not done the things that are necessary to lower emissions because those things fundamentally conflict with deregulated capitalism."