ARLINGTON, TEXAS

AAPL 2021 ANNUAL MEETING

PROFESSIONAL DEVELOPMENT AND LAND CONFERENCE

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Douglas Sandridge

ARLINGTON, TEXAS

AAPL 2021 ANNUAL MEETING

HURDLES TO "NET-ZERO" CARBON EMISSIONS

An Analysis of Clean Energy Objectives

Douglas C. Sandridge
Vice President of Fulcrum Energy Capital Funds
& Director of EnergyPolicyUS.org

AAPL 2021 **ANNUAL MEETING**

INTRODUCTORY REMARKS

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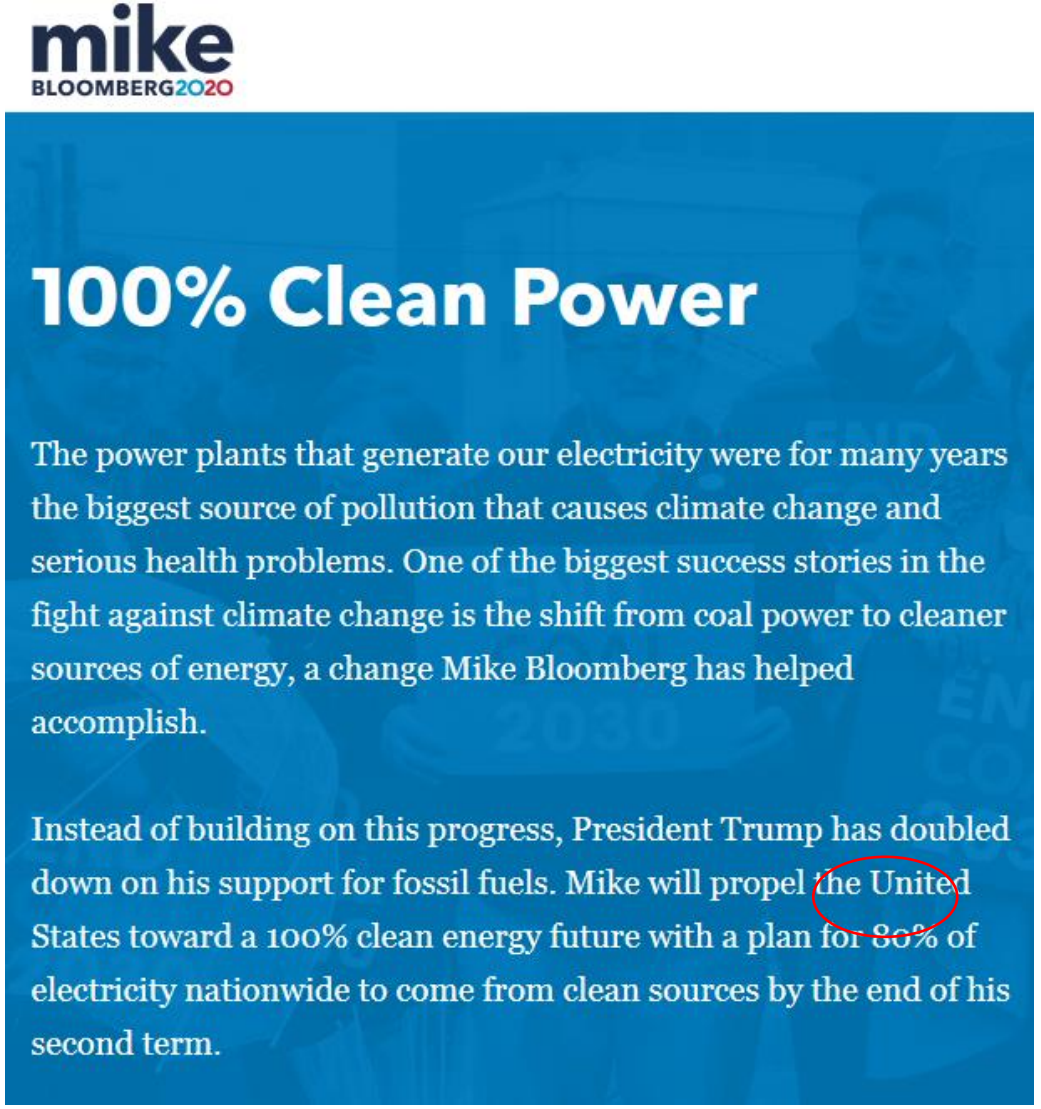
100% “CLEAN” POWER?

“….80% of electricity nationwide to come from clean sources” by 2028?



100% CLEAN POWER?

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NOTABLE 100% RENEWABLE PORTFOLIO STANDARDS

- Massachusetts by 2050
- Colorado by 2050
- Nevada by 2050
- Virginia by 2050
- New York by 2040
- California by 2045
- Hawaii by 2045
- New Mexico by 2045
- Washington DC by 2032

“New Green Deal” 100% by 2029

In July 2008, Al Gore declared that we should make it a national priority to attain 100% renewable energy by 2018

Since 2008 renewables, as a percentage of total U.S. energy, have increased from ~7% to ~11.5%

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PRIMER ON ELECTRICITY

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HOW DO WE CURRENTLY GENERATE ELECTRICITY

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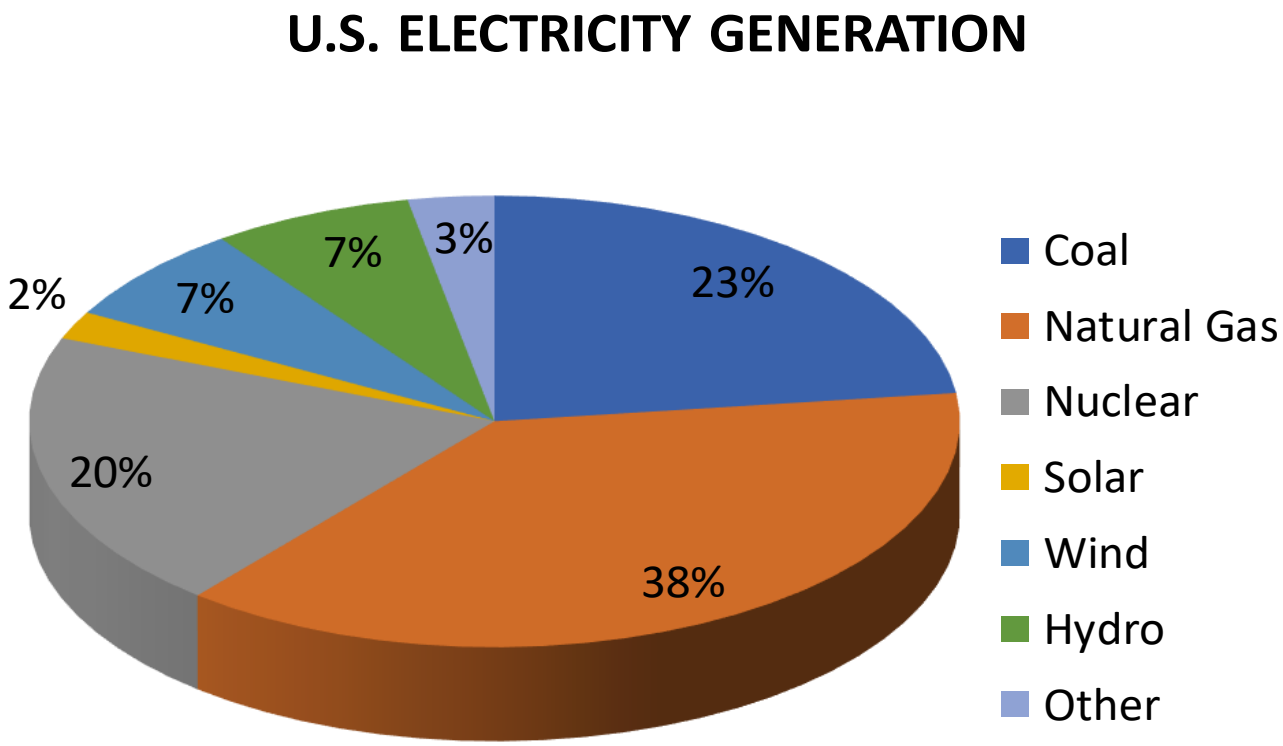

Source: Energy Information Administration 2020 Annual Energy Outlook

ELECTRICITY's CHAOTIC ORIGINS

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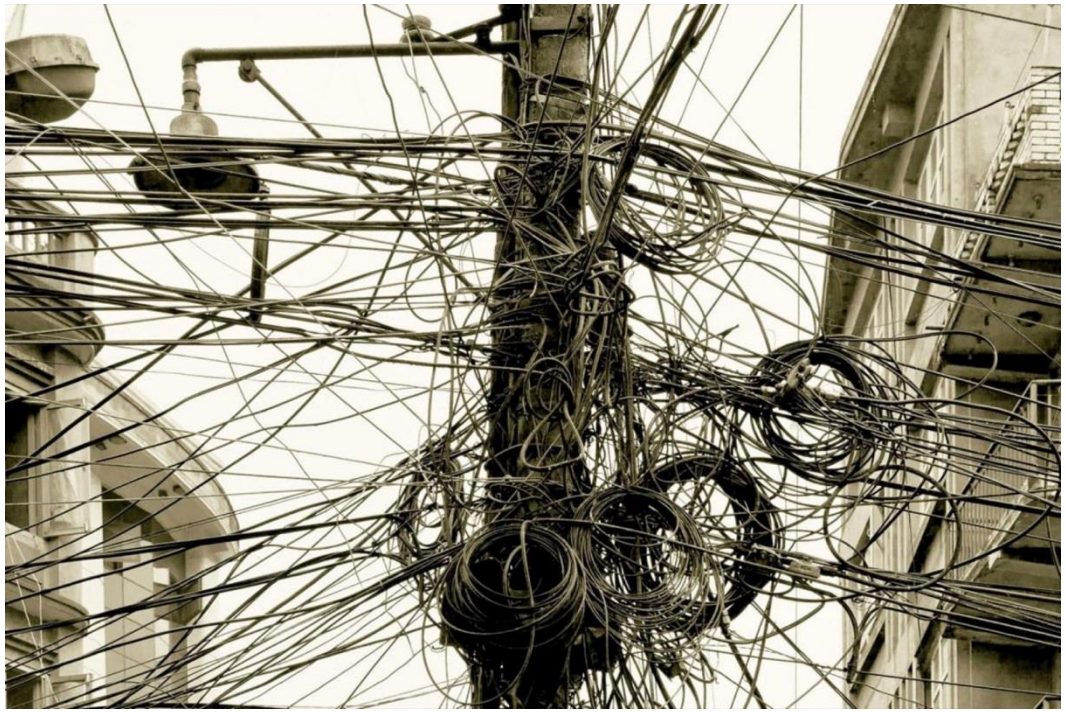
At the inception of electrification, generating facilities were constructed un-systematically and distribution wires were tangled everywhere.



It was quickly realized that unregulated electrical chaos was a dangerous public nuisance.

In order to bring some order & organization out of the chaos, cities began granting "municipal franchises" to utility companies in designated service areas as "natural monopolies."

THE ROLE OF PUBLIC UTILITY COMMISSIONS

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COLORADO
Department of
Regulatory Agencies
Public Utilities Commission

ELECTRICITY MUST BE SAFE & RELIABLE

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ELECTRICITY MUST BE SAFE & RELIABLE

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- **PUC's began to regulate health and safety standards, operating standards and the prices charged to customers**
- **Safety and reliability are the paramount concerns of virtually all PUCs**
- **Likewise, customers also demand electricity to be safe and reliable *(above all other considerations)***
- **Furthermore, businesses also demand electricity reliable**
  (e.g. Data centers require "Fine-Nine Reliability" = 99.999% Availability or they will move their businesses somewhere else)

WHO PAYS FOR UTILITY COSTS?

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Utilities construct power plants, power lines, transformers, meters, etc. to serve customers

Public Utility Commissions establish rates which allows the utilities to recover their investment plus a "reasonable" rate of return

Customers pay monthly utility bills which fund virtually all of the costs to operate the utilities

VIRTUALLY ALL UTILITY COSTS ARE PASSED-THRU TO THE RATE PAYING CUSTOMERS!

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WHAT IS THE "GRID"

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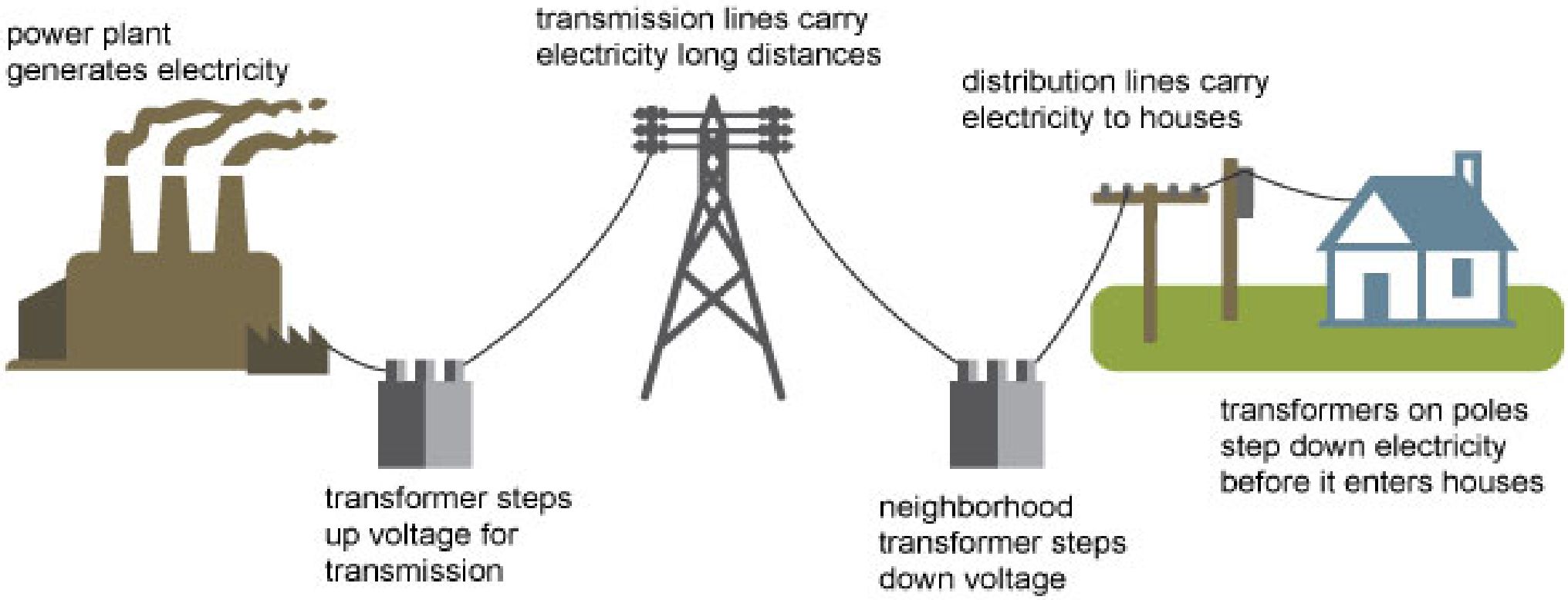
Generation
5.83 Cents per kW/hr.

Transmission
1.35 Cents per kW/hr.

Distribution
3.25 Cents per kW/hr.



Source: Adapted from National Energy Education Development Project (public domain)

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“THE ANGELIC MIRACLE OF THE GRID”

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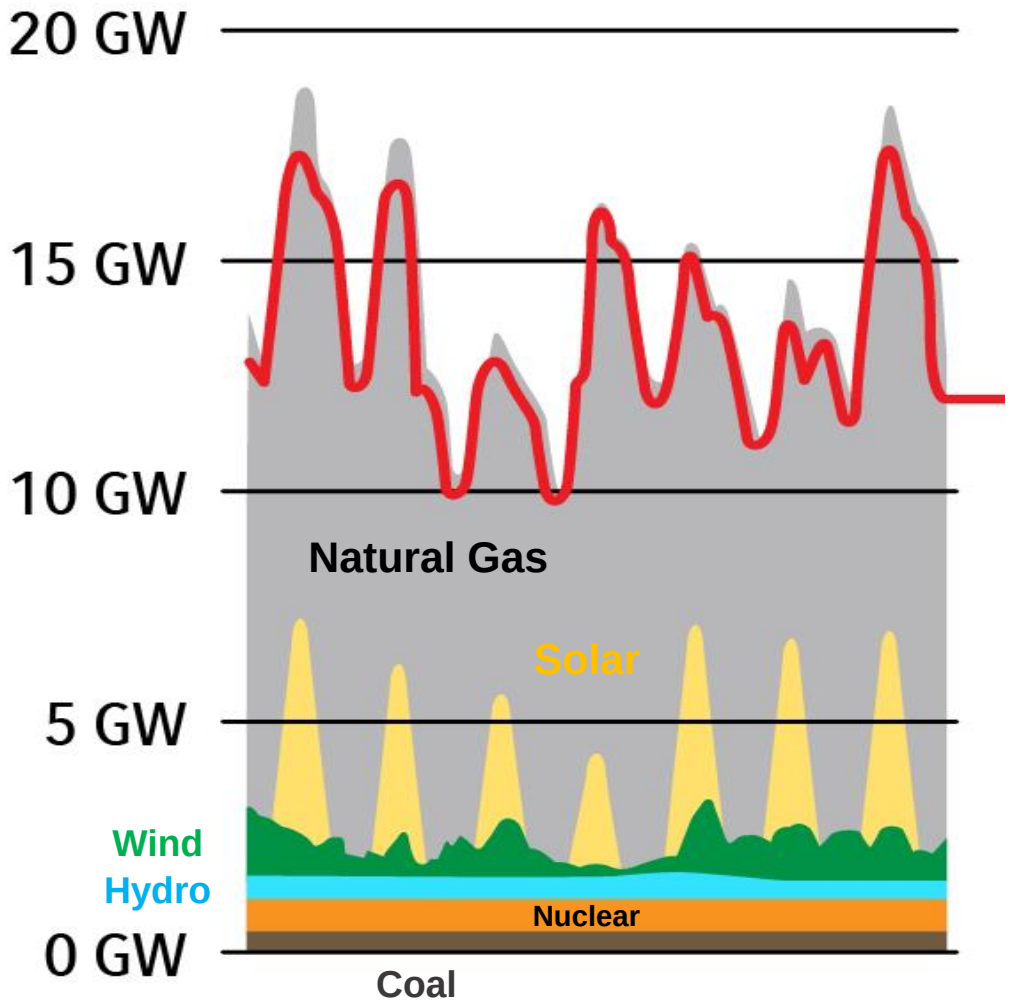
Shorting the Grid” *by Merideth Angwin, 2020*

“The requirements for electricity on the grid are neither constant nor fully predictable, and electricity must be manufactured and then used within milliseconds. Making more or less electricity than is immediately used will mess-up the grid……..”

“Electricity must be made in real time!

BALANCING THE GRID

- **Electricity supply must be perfectly matched with demand at all times!**
- **Electricity cannot stored on a utility scale**
- **Utilities constantly adjusting & balancing supply**



BALANCING THE GRID

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BALANCING THE GRID

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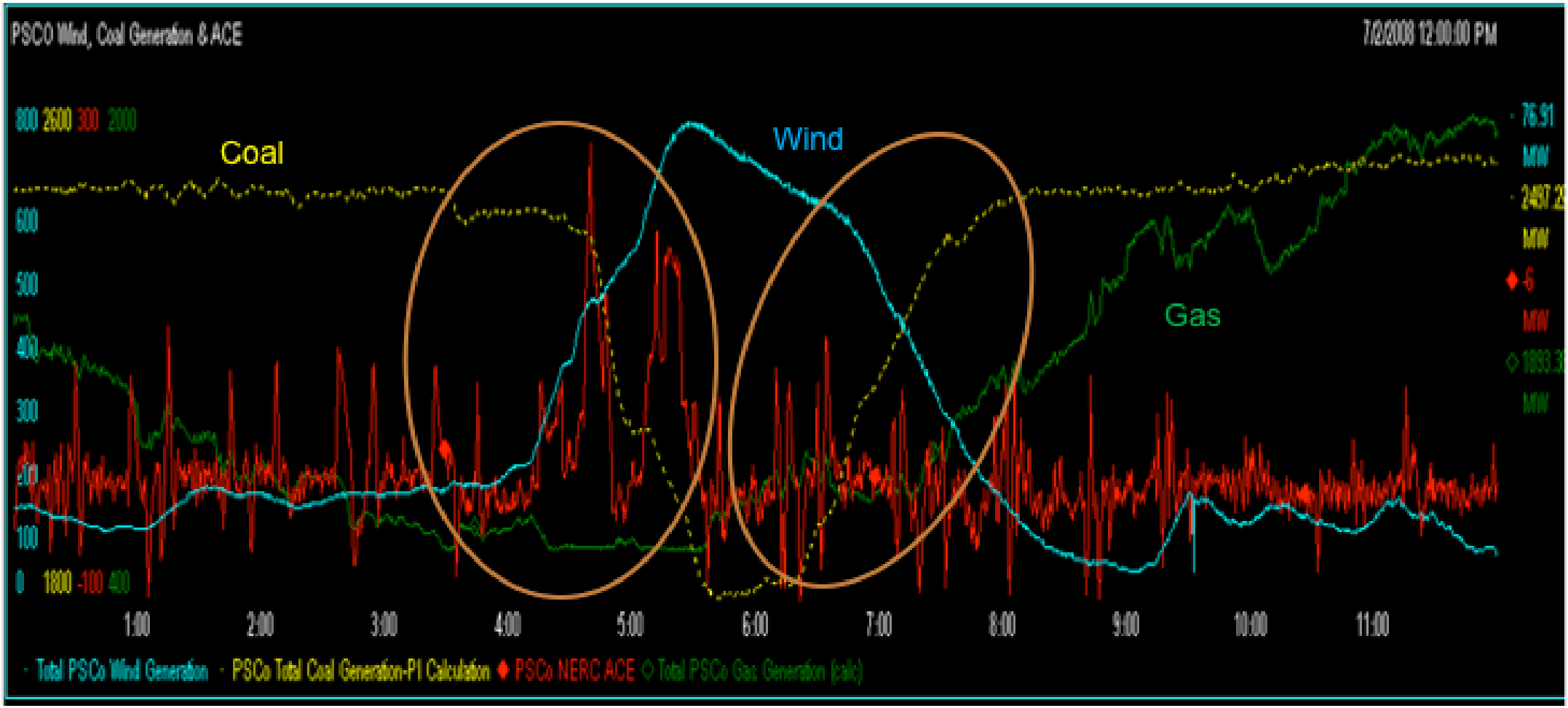

4:00 AM

8:00 AM

July 2, 2008

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CAPACITY RATING vs CAPACITY FACTOR

The ratio of actual energy produced by an energy generating unit or system in a given period, to the hypothetical maximum possible *(i.e. energy produced from continuous operation at full rated power)*

COMPARISON OF CAPACITY FACTORS IN ELECTRICITY GENERATION

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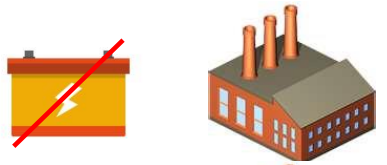
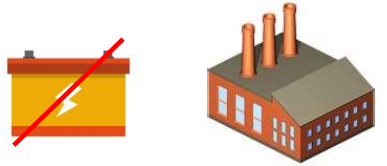
	Capacity Rating (e.g. 1 Giga Watt	Capacity Factors	Back-up Needed
Nuclear		95%+	
Coal or Nat. Gas		95%+	
Wind		~34%	
Solar		~24%	

COMPARISON OF CAPACITY FACTORS IN ELECTRICITY GENERATION

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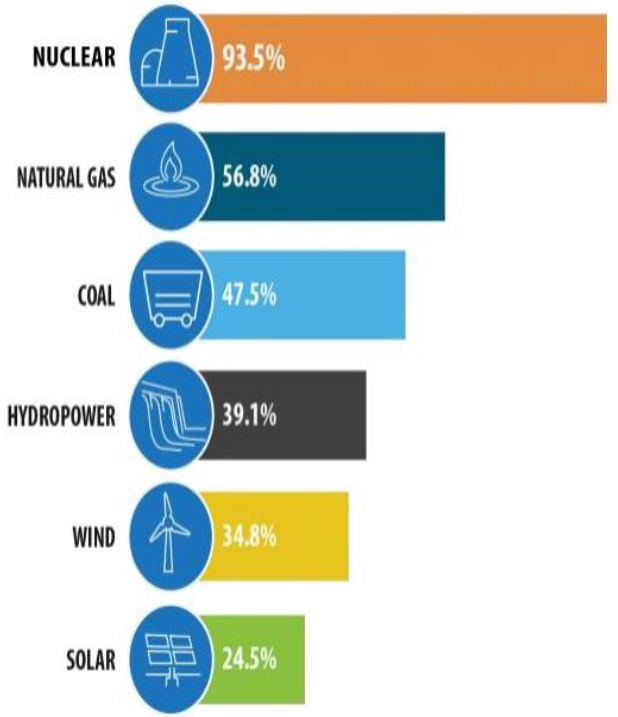
	Capacity Rating 1 Giga Watt	Capacity Factors "Curtailment Adjusted"
Nuclear		95%+
Coal or Nat. Gas		95%+
Wind		~34%
Solar		~24%

Capacity Factors U.S. EIA 2020 Energy Outlook



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HYDRO-POWER

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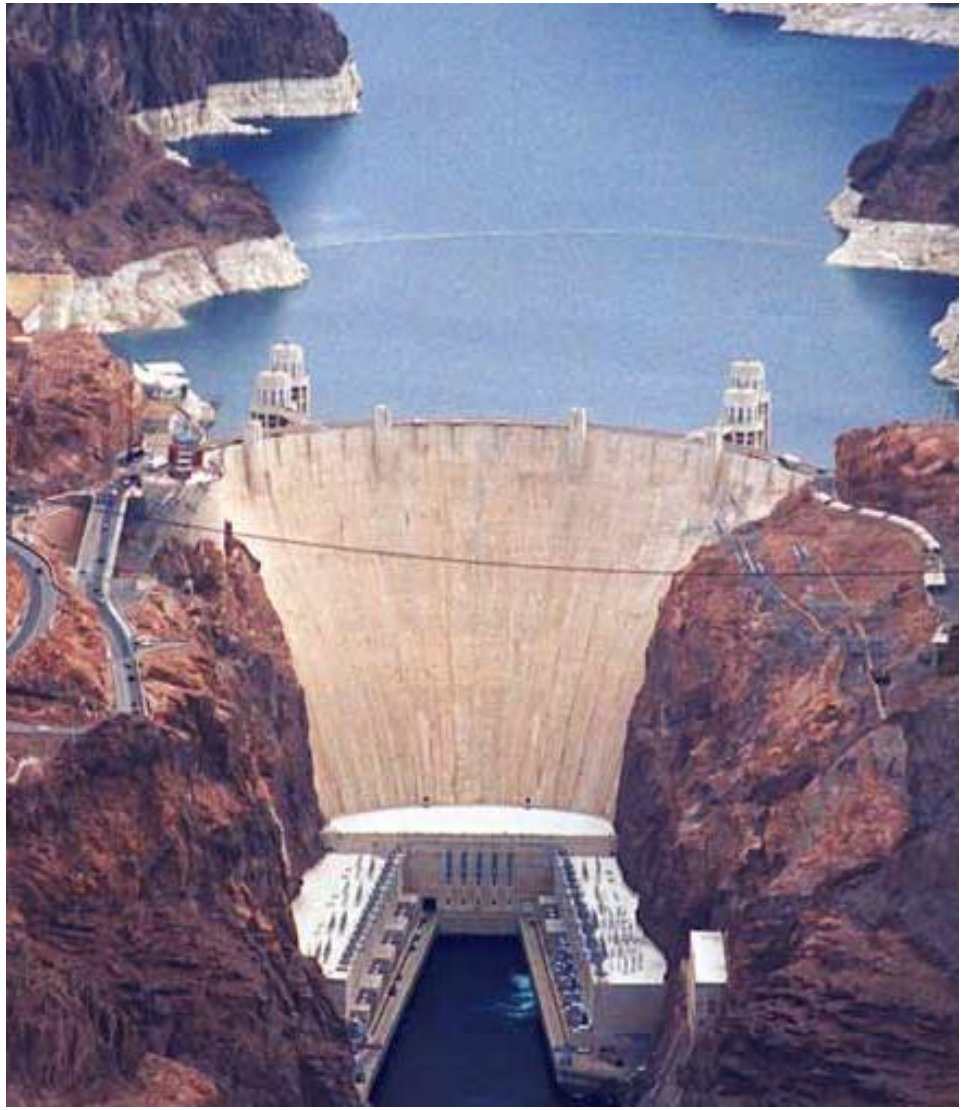
Hydo-Power is a very good renewable resource

However, environmental and social concerns make it extremely unlikely for any significant growth in U. S.

U.S. Hydro-Power will continue diminishing as a percentage of energy use over the next 25 years

Increased use of Hydro-Power will not play a significant role in the U.S. expansion of renewables



GEOTHERMAL POWER

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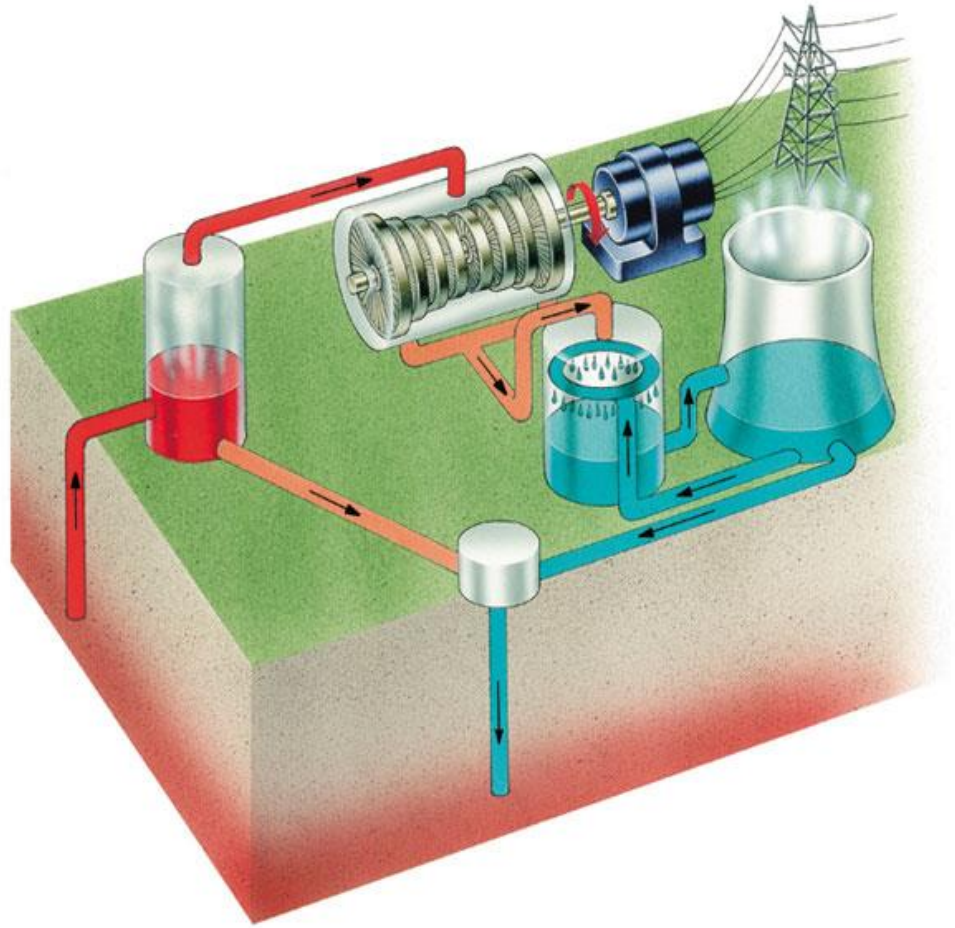
Geothermal is an excellent renewable energy resource

However, siting issues and environmental concerns make it very unlikely that geothermal power will grow significantly in the U. S. over the next 25 years

Increased use of Geothermal power will not play a significant role in the U.S. expansion of renewables



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CONCENTRATED SOLAR POWER a/k/a CSP or Solar Thermal

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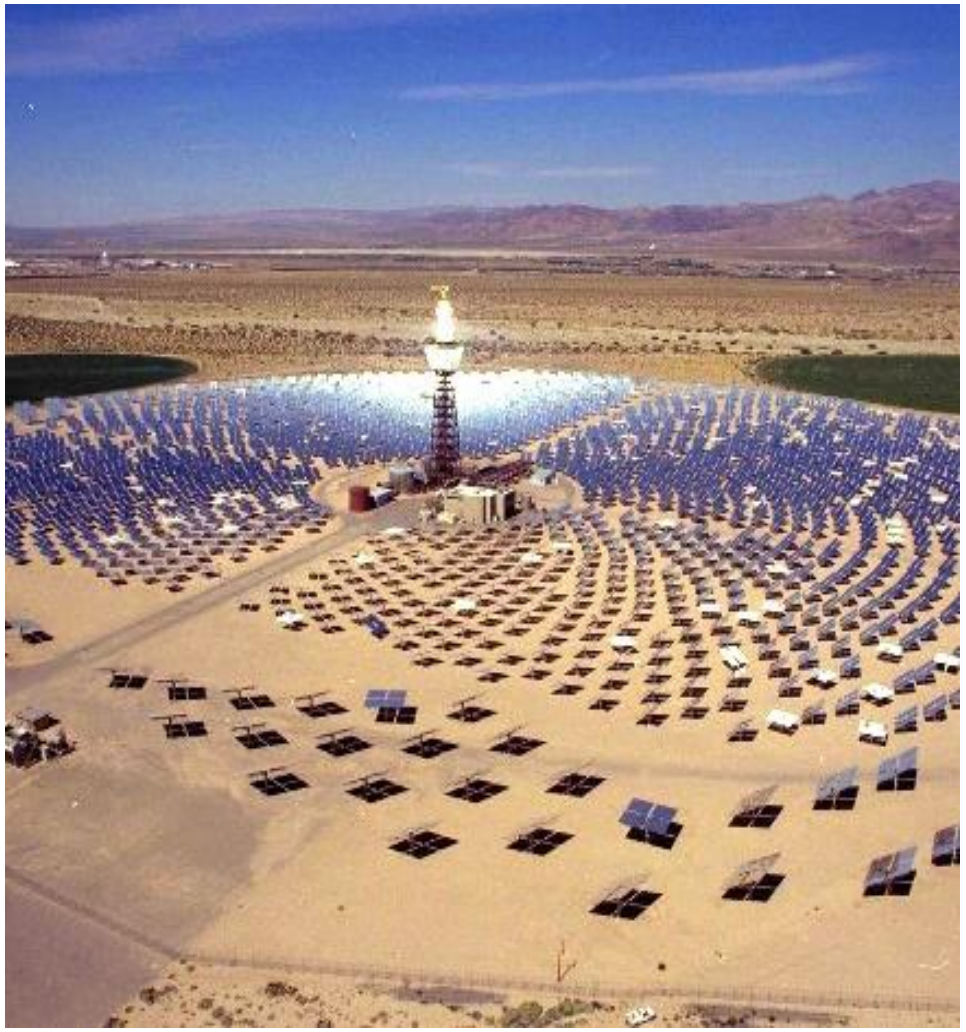
CSP has the advantage of creating heat to generate electricity; thus, the heat can be stored

However, environmental concerns and other siting issues will make it difficult for any significant growth in U. S.

It is unlikely that increased U.S. use of CSP will play a significant role in the expanded use of renewables



BIO-FUELS

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Corn-based bio-fuels are NOT a great renewable resource in the U.S.

Uses a lot of land and water which results in increased food prices

In the U.S., it takes about one gallon of energy to produce an equivalent one gallon of corn-based bio-fuel

Corn-based bio-Fuels are a political quagmire and promoting the use of bio-fuels made in U.S. is terrible public policy!

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HURDLES TO “NET-ZERO”

ATTAINMENT OF "NET-ZERO" CARBON EMISSIONS

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Bill Gates categorizes carbon emissions as follows:

❑ Plugging In (all things electric….lights, computers, etc.)	27%
❑ Getting Around (cars, trucks, planes, cargo ships, etc.)	16%
❑ Keeping Warm/Cool (heating, air conditioning, refrigeration)	7%
	50%
❑ Making Things (cement, steel, plastic)	31%
❑ Growing things (plants, animals)	19%

"How to Avoid a Climate Disaster" by Bill Gates 2021

ATTAINMENT OF "NET-ZERO" CARBON EMISSIONS

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"Getting Around" (16%)

- Internal combustion engines *(car, trucks, airlines, ships, trains, tractors, bull dozers, lawnmowers, snowblowers, etc.)* must **ALL** be replaced with electric motors or hydrogen fuel cells

Note: All new electric motors and fuel cells would need to be operated with renewable electricity and clean hydrogen

ATTAINMENT OF "NET-ZERO" CARBON EMISSIONS

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"Plugging In" (27%)

- **All** electricity must be generated using renewable energy or nuclear energy *(including all the additional electricity that will be needed to replace all internal combustion engines)*

  Virtually All new electricity generated from renewable sources would have to come from wind, solar and existing hydro-power

To the extent that all of this is not possible, we would have to develop an economically viable and scalable carbon capture and sequestration program!

ATTAINMENT OF "NET-ZERO" CARBON EMISSIONS

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"Making Things" (31%)

- Industrial processes including **ALL** manufacturing must be converted to electricity *(including the manufacture of wind turbines & solar panels, etc.)*

We don't really have practical methods of making steel and cement without CO_2

7 PRINCIPLE HURDLES TO OVERCOME

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- *Supply Chain Hurdle*
- *Construction Materials Hurdle*
- *Intermittency Hurdle*
- *Power Density Hurdle*
- *Grid Balancing Hurdle*
- *Transmission Hurdle*
- *Local Distribution Hurdle*

ATTAINMENT OF "NET-ZERO" QUANTIFICATION TOOLS

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TV = Technical Viability

Definition: What are the chances of technical viability of a given problem without regard to costs or social-political considerations.

SEPV = Social-Economic-Political Viability

Definition: What are the chances of social, economic and political viability of a given problem without regard to technical viability.

SUPPLY CHAIN HURDLE (#1)

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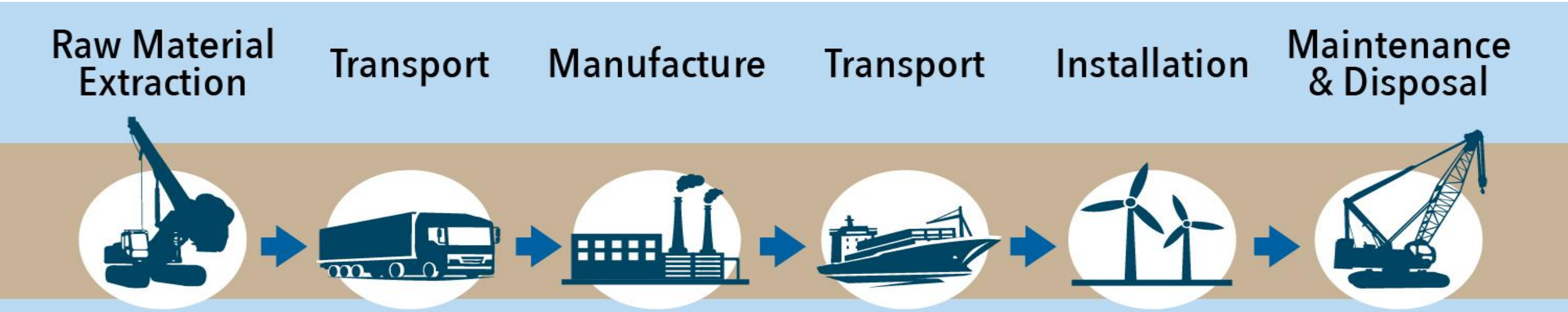
Life Cycle of Energy used to Facilitate Renewable Energy



Raw Material Extraction	Transport	Manufacture	Transport	Installation	Maintenance & Disposal
Trucks Bulldozers Loaders Graders	Trucks Trains Ships	Coal & Natural Gas Fired Manufacturing Plants	Trucks Trains Ships	Trucks Cranes	Trucks Trains Cranes

SUPPLY CHAIN HURDLE (#1)

Solutions

- ❑ Convert ALL mining operations & heavy equipment to renewable electricity, biofuels or fuel cell technology
- ❑ Convert ALL manufacturing operations to renewable energy *(including wind turbine, solar panel and electric vehicle manufacturing)*
- ❑ Convert ALL shipping, trucking and train transportation to renewable electricity, biofuels or fuel cell technology

Technical Viability = Moderate to Very High

Social-Political-Economic Viability = Very Low to Moderate

CONSTRUCTION MATERIALS HURDLE (#2)

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Massive amounts of concrete, steel, glass & energy transition minerals will be required for solar panels, wind turbines, electric vehicle batteries & other renewable and "clean" energy related technologies

CONSTRUCTION MATERIALS HURDLE (#2)

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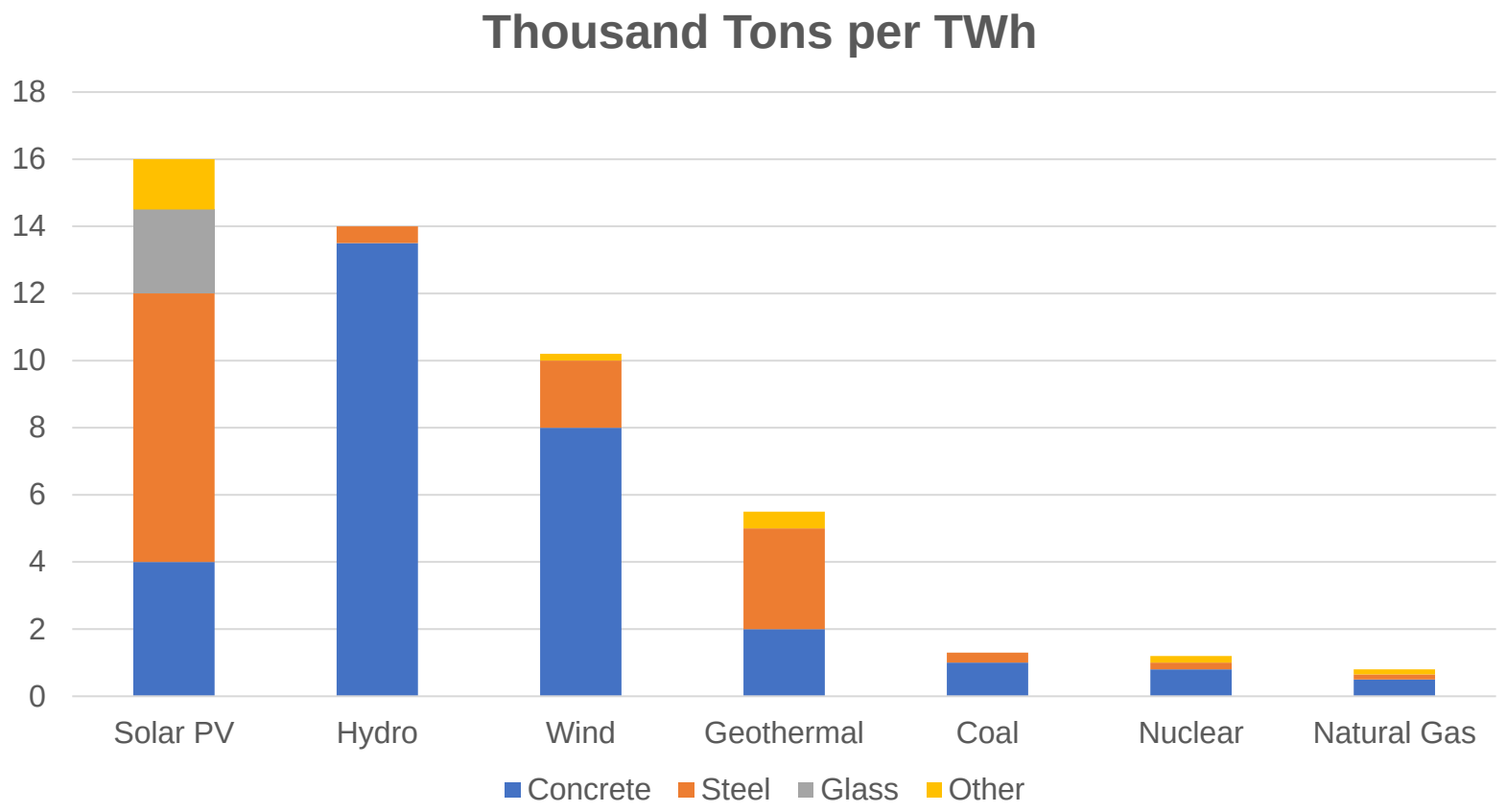
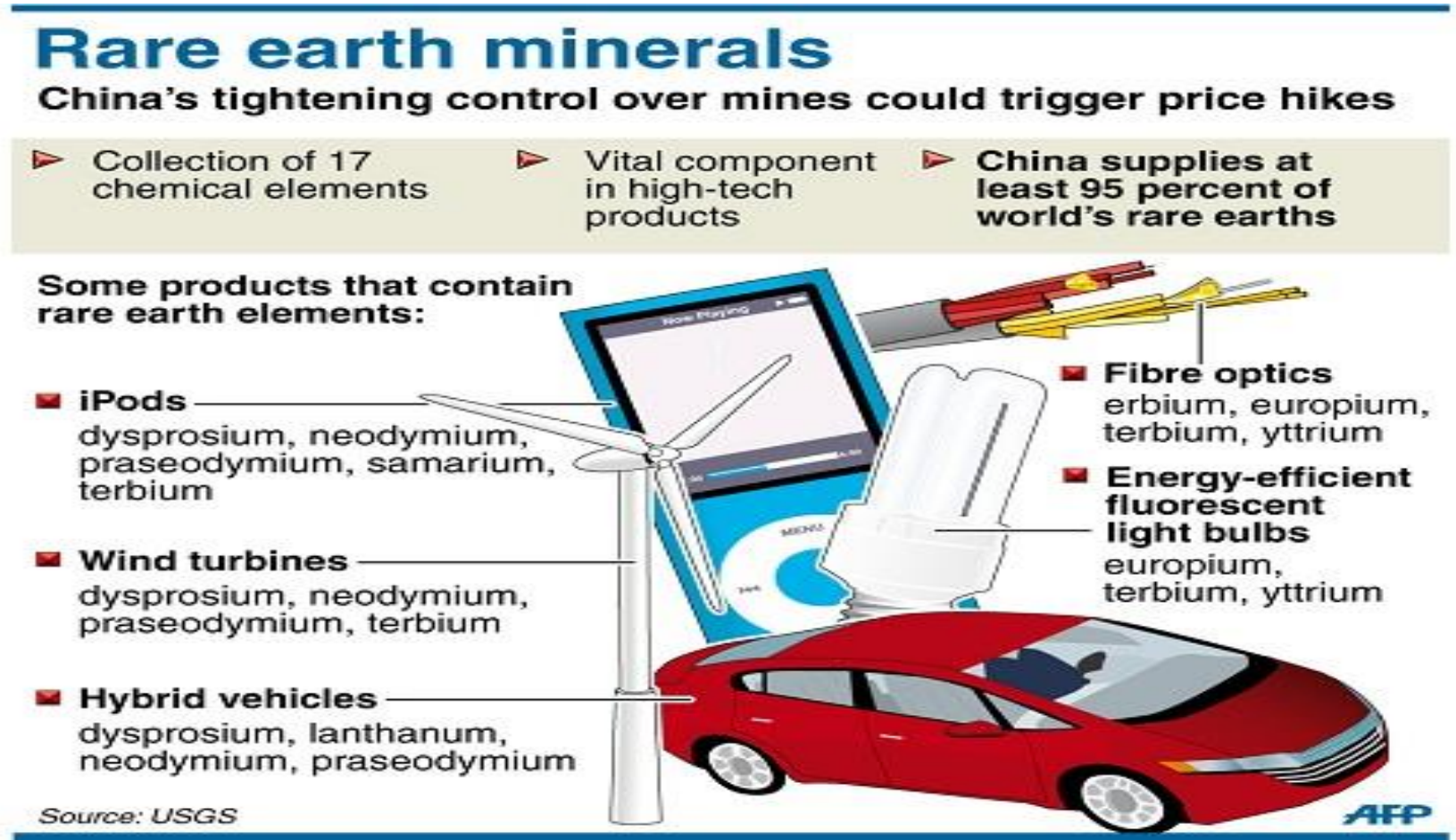
"How Much Stuff Does it Take to Build and Run a Power Plant?"

U. S. Department of Energy



CONSTRUCTION MATERIALS HURDLE (#2)

Rare Earth Elements are part of the ETM; Although abundant in the planet surface, REE are not found in concentrated forms, thus making them challenging to mine and economically valued.



CONSTRUCTION MATERIALS HURDLE (#2)

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According to the International Energy Agency, staggering quantities of Energy Transition Minerals will be required by 2040 in order to attain "Net-Zero" carbon emissions:

Rare Earth Elements	+700%
Nickle	+1900%
Graphite	+2500%
Cobalt	+3000%
Lithium	+4200%

www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

CONSTRUCTION MATERIALS HURDLE (#2)

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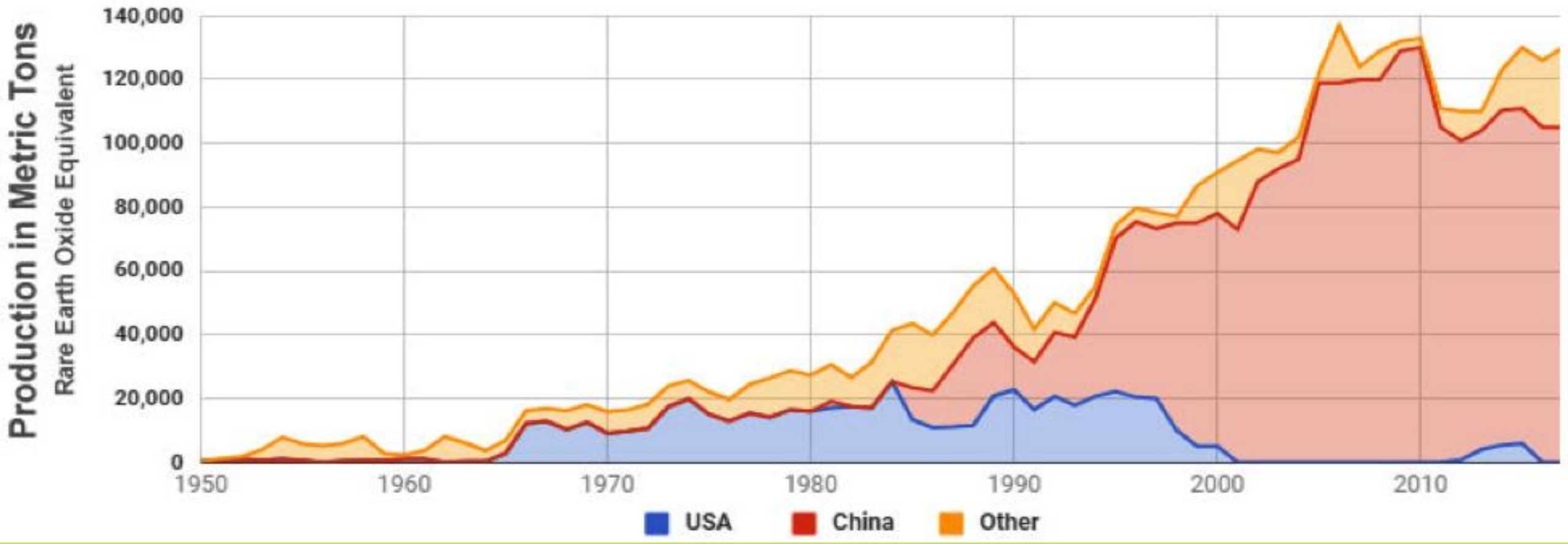
Currently, approximately 80% of Rare Earth Elements are imported from China

USGS



CONTRUCTION MATERIALS HURDLE (#2)

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Mining Energy Transition Minerals ("ETM") in the quantities needed *(10-40 times current levels)* for batteries, solar panels, wind turbines and other "clean" energy technologies will be extremely difficult

ETM mining has high emissions intensity *(very difficult to mine cleanly)*

ETM mining often requires high volumes of water *(lithium & copper in particular)* is areas that are already water deprived

ETM mining will likely take place in countries with little environmental governance and high levels of corruption

The massive amount of ETMs required for "Net-Zero" will cause prices to soar, making the "clean" energy technologies much more expensive

ETMs *(especially REE)* are not widely produced in the U.S.; most are processed in China *(will they be available to the U.S.?)*

CONSTRUCTION MATERIALS HURDLE (#2)

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Possible Solutions

- ❑ Develop better/cleaner mining techniques *(so that mining can be undertaken in the U. S.)*
- ❑ Find new deposits of Construction Materials & Energy Transition Minerals
- ❑ Develop alternatives to reduce or replace Energy Transition Minerals

Technical Viability = Low to Moderate

Social-Political-Economic Viability = Low to High

CONSTRUCTION MATERIALS HURDLE (#2)

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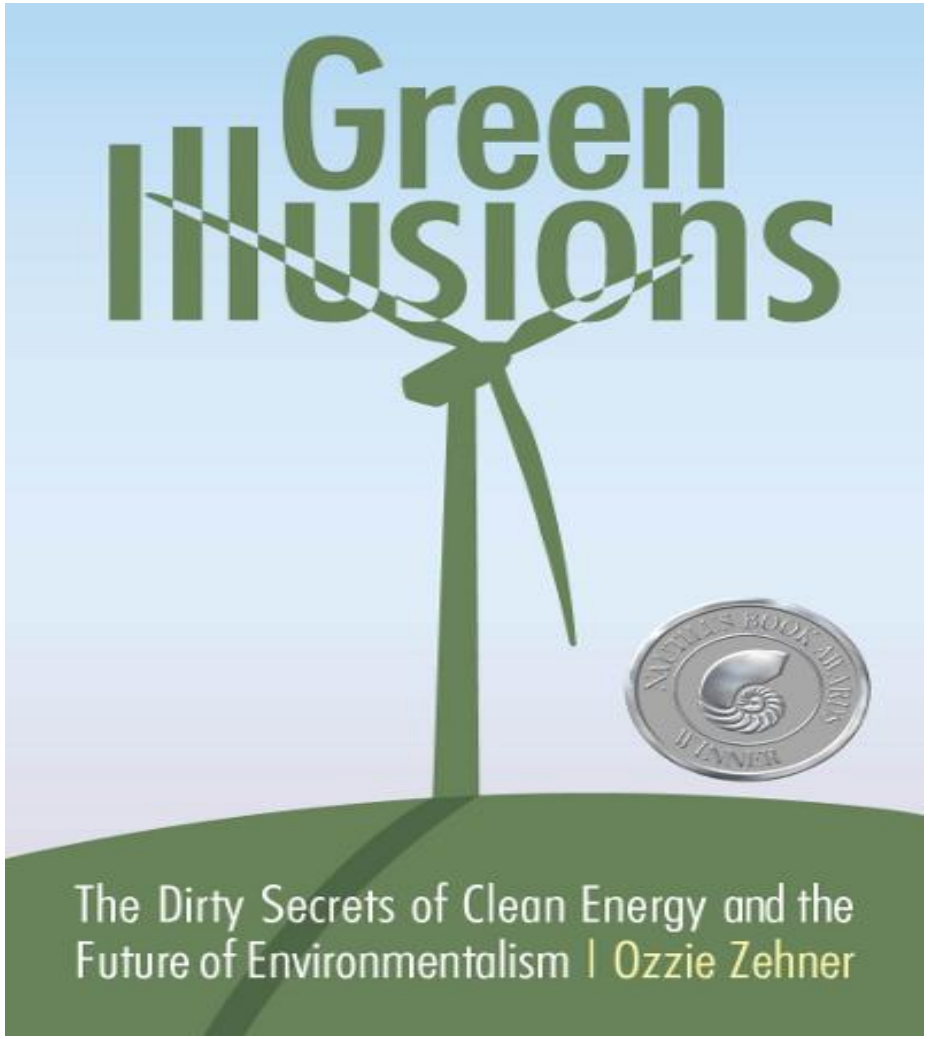
Read Chapter 1 to learn about the devastating environmental effects of mining rare earth minerals



INTERMITTENCY HURDLE (#3)

INTERMITTENCY HURDLE (#3)

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Intermittency of wind and solar results in low capacity factors (low reliability) – 3 options to make wind & solar "reliable" for generation of electricity

- ***Build massive amounts of wind & solar capacity so that the sun is shining or sufficient wind in blowing somewhere in sufficient amounts***
  - ***Utilize massive amounts of batteries***
  - ***Back-up wind/solar with another power source***

INTERMITTENCY HURDLE (#3)

Making Wind Reliable (using only wind)

- **If wind farm has a capacity factor is 33% - why not just build 3 wind farms to provide 99% reliability?**
  - **3 Times Cost**
  - **One wind farm doesn't come online at the exact moment the wind farms go off-line**

❖**3 wind farms would only provide 70% reliability**

❖**6 wind farms would provide ~ 91% reliability**

❖**10 wind farms provide ~ 98% reliability**

INTERMITTENCY HURDLE (#3)

Making Wind & Solar Reliable w/ Batteries

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According to a 2018 analysis by Stephen Brick, an energy analyst for Clean Air Task Force *(a Boston-based energy policy think tank)* for California to get 80% of its electricity from renewables, the state would need 9.6 terawatt-hours of storage *(= 700 million Tesla Powerwalls)*

- **700 million Tesla Powerwalls (17 Powerwalls per man, woman & child in California)**
  - **17 Tesla Powerwalls X $6,700 = $114,000 per person or $456,000 per household of four**
  - **Batteries last about 10-15 years**

Source: A Question of Power by Robert Bryce

INTERMITTENCY HURDLE (#3)

Make Wind & Solar Reliable w/ Car Batteries

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If all internal combustion engine cars, trucks & SUVs were replaced in US with Electric Vehicles, we would have 280* million EV batteries storing electricity at night

- **Since all cars, trucks & SUVs would use electricity, the amount of electricity needed would increase 2X-3X**
  - **This scenario only makes sense if/when we can produce 100% clean electricity and affordable batteries**
    - **Cost, Range, Batteries, Performance & Reliability of EVs remain obstacles to 100% EV penetration**

*Statisica.com

EIA PROJECTIONS FOR LIGHT-DUTY VEHICLE SALES 2050

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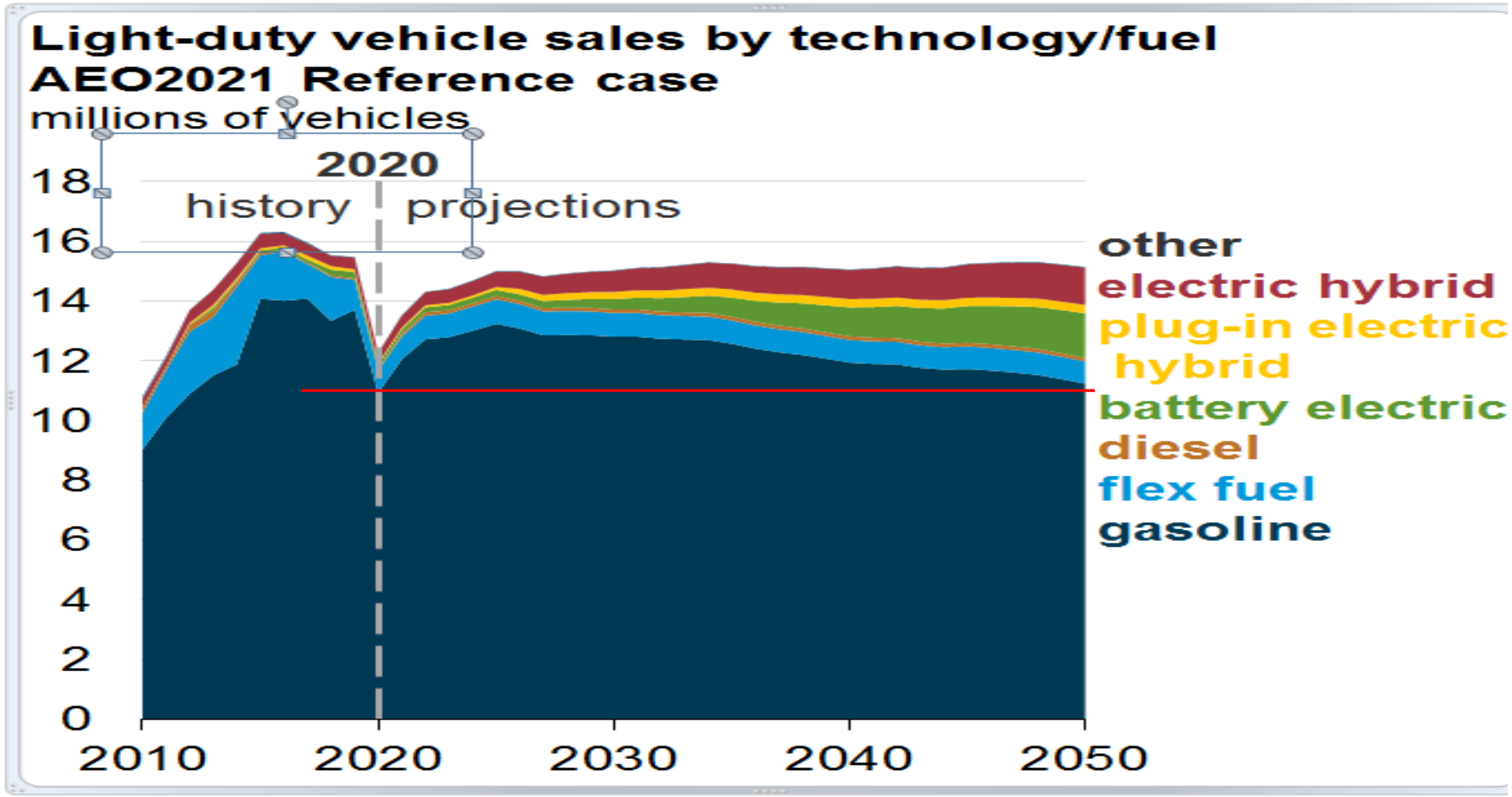

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Source: U.S. Energy Information Administration

INTERMITTENCY HURDLE (#3)

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Why natural gas is the best choice for backing-up renewable generated electricity?

- **Batteries prohibitively expensive**
- **Natural Gas is Clean *(approximately ½ the CO_2 of coal; 90% less particulates than coal; 99% less SO_2 & NO_X)***
  - **Natural Gas is Dispatchable Instantaneously *(coal, nuclear take time to ramp up)***
  - **Natural Gas is Affordable & Domestically Abundant *(no geopolitical disruptions)***

INTERMITTENCY HURDLE (#3)

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Possible Solutions

- ❑ **Develop massive amounts of wind and solar** ***(including more offshore wind capacity)***
- ❑ **Develop affordable large scale batteries or other storage solutions to back-up wind & solar**
- ❑ **Nuclear Energy**

Technical Viability = Low to Very High

Social-Political-Economic Viability = Very Low to High

POWER DENSITY HURDLE (#4)

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Crude oil, natural gas, coal and nuclear power provide dense power potential utilizing a relatively small amount of land space.

Whereas, wind and solar require much larger land areas to provide the equivalent amounts of power.

POWER DENSITY HURDLE (#4)

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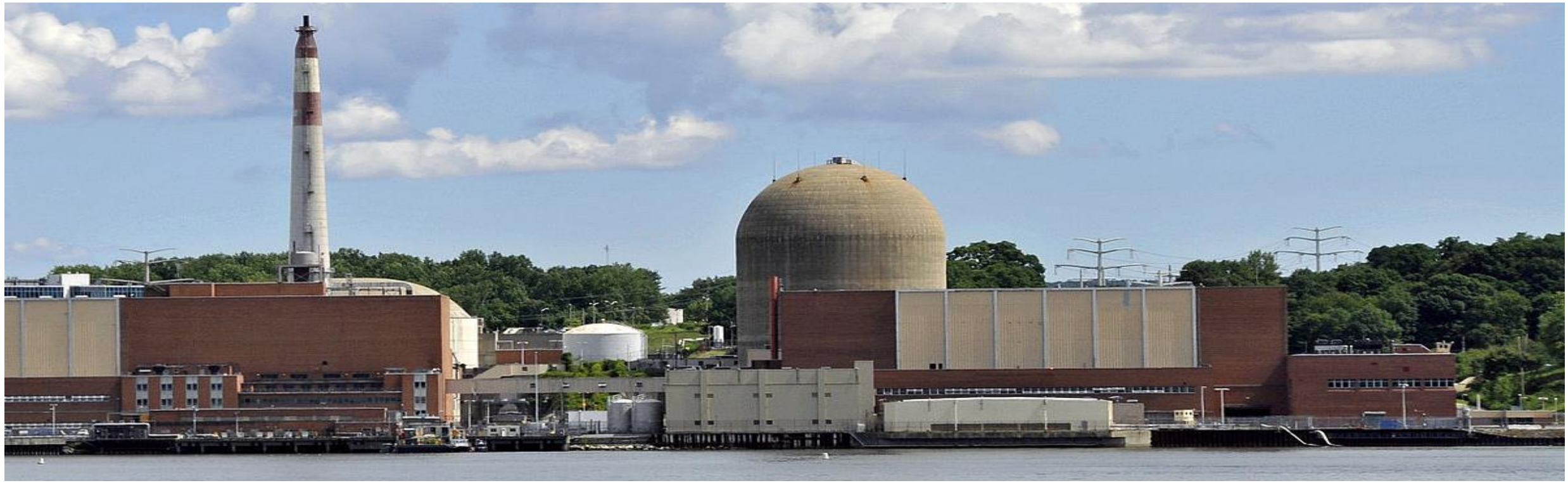

Indian Point Nuclear Power Plant in New York produces 16.4 terawatt hours/year using an area of ~250 acres (less than ½ square mile)

POWER DENSITY HURDLE (#4)

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It would take an area of ~515 sq/miles (330,000 acres) to produce an equivalent amount of electricity using wind [1300 times larger area than an equivalent nuclear power plant]

Source: A Question of Power by Robert Bryce

POWER DENSITY HURDLE (#4)

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It would take an area of ~690 sq/miles (442,000 acres) to produce an equivalent amount of electricity using offshore wind [1750+ times larger area than an equivalent nuclear power plant]

POWER DENSITY Hurdle (#4)

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Petroleum is the perfect energy dense fuel to power airlines

Solar power and nuclear power are not practical for airlines

Currently no easily scalable & affordable alternative for jet fuel

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POWER DENSITY HURDLE (#4)

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Growing resistance to large scale Wind Projects

- Eye sores over large swaths of land
- Disposal of wind turbine blades
- Noise & Light
- Destruction of adjacent Property Values

Growing resistance to large scale Solar Projects

- Solar Thermal (CSP) uses lots of water
- Destruction of environmental ecosystems

Wind & Solar both kill lots of birds and bats

POWER DENSITY HURDLE (#4)

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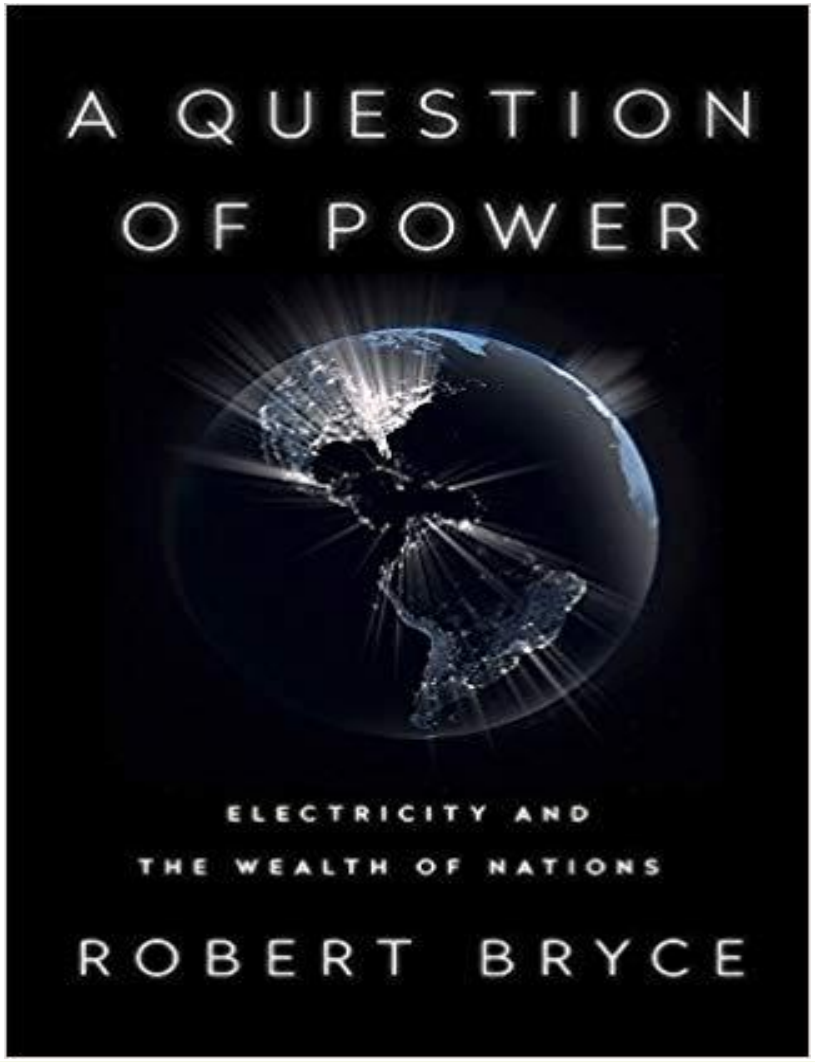
For a deeper analysis and understanding of the emerging land use issues, read Chapter 18 in Robert Bryce's

"A Question of Power"



POWER DENSITY HURDLE (#4)

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In an analysis of the area required in order to supply the UK with 100% renewable energy, McKay concluded:

"…..in a decarbonized world that is renewable powered, the land area required to maintain today's British energy consumption would have to be similar to the area of Britain."

Solar Energy in the Context of Energy Use, David J.C. McKay, 2013

POWER DENSITY HURDLE (#4)

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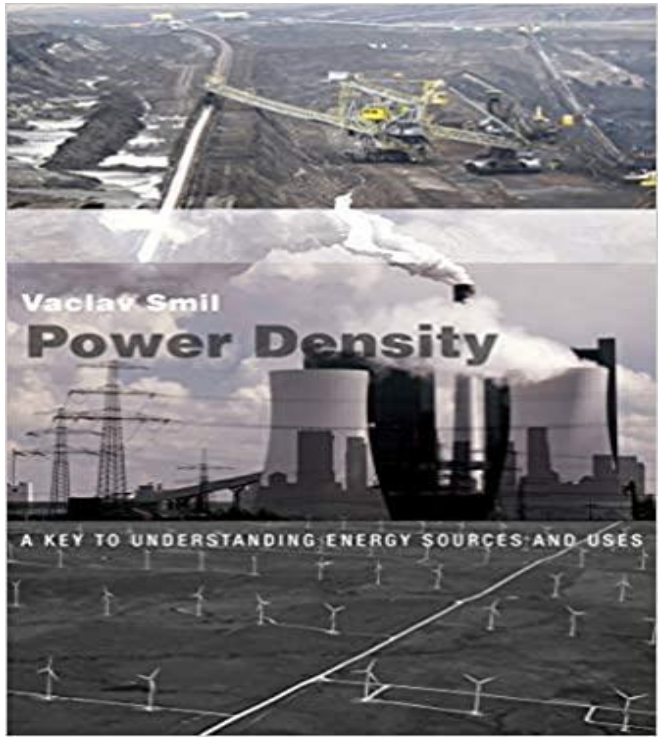
Vaclav Smil, Distinguished Professor Emeritus of Environmental Science more recently analyzed the impacts of massive electrification of the United States to eliminate the use of crude oil, natural gas and coal. Smil concluded:

"……an entirely renewable energy system would occupy roughly 25%-50% of the country's territory (U. S.), compared to about 0.5% of the land claimed by today's fossil fuel-hydro-nuclear system."

Power Density, Vaclav Smil 2016

POWER DENSITY Hurdle (#4)



The authoritative book on power density was written by Vaclav Smil, the probably the world's foremost authority on power density.

"Smil is one of my favorite authors. The term 'polymath' was made for people like him……I learn more by reading Vaclav Smil than just about anyone else"

Bill Gates

ARLINGTON, TEXAS

http://vaclavsmil.com/

POWER DENSITY HURDLE (#4)

Possible Solutions

- ❑ Offshore siting of Wind
- ❑ Expanded use of Nuclear Energy
- ❑ Develop scalable biofuels and green/pink hydrogen as alternate fuel for airlines

Technical Viability = Moderate to High (Nuclear)
Social-Political-Economic Viability = Low to Moderate

GRID BALANCING HURDLE (#5)

Must be Stable & Maintained in Equilibrium

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The electric grid is very sensitive and must be maintained in near perfect equilibrium. The U. S. Grid operates at 60 Hz and instability begins to occur once there is a variation of <1%

When power becomes unstable, utilities only have a matter of seconds or minutes to stabilize the system before it collapses

The more intermittent wind & solar introduced into the Grid, the more difficult it becomes to maintain a stable and reliable Grid

GRID BALANCING HURDLE (#5)

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It is more than just intermittency……renewables lack "Inertia." Traditional electricity generation (spinning turbines) provides "Inertia" which allows the Grid to navigate brief periods of instability (few second to few minutes)

Whereas, wind & solar lack Inertia; when wind & solar stop suddenly, it is much more difficult to maintain Grid stability

As more intermittent sources wind power and solar power (without Inertia) are added to the Grid, the more unstable and difficult it becomes to manage

GRID BALANCING Hurdle (#5)

The Grid Must be Stable & Maintained in Equilibrium

There is considerable debate about the limits of intermittent renewable energy that can be used while maintaining a stable grid

Experts that I trust believe that 25-35% is currently the maximum % of renewable power we can use and maintain grid integrity. With much expanded transmission and improved technology, possibly incorporate 50% in 25 years

It may not ever be possible to safely and reliably manage the Grid using 100% intermittent wind and solar power

GRID BALANCING HURDLE (#5)

Possible Solutions

- ❑ Construct massive amounts of wind and solar in highly disbursed locations
- ❑ Construct substantial additional transmission and interconnect different regions
- ❑ Develop better grid management technology and techniques

Technical Viability = Low to High

Social-Political-Economic Viability = Very Low to Moderate

GRID BALANCING HURDLE (#5)

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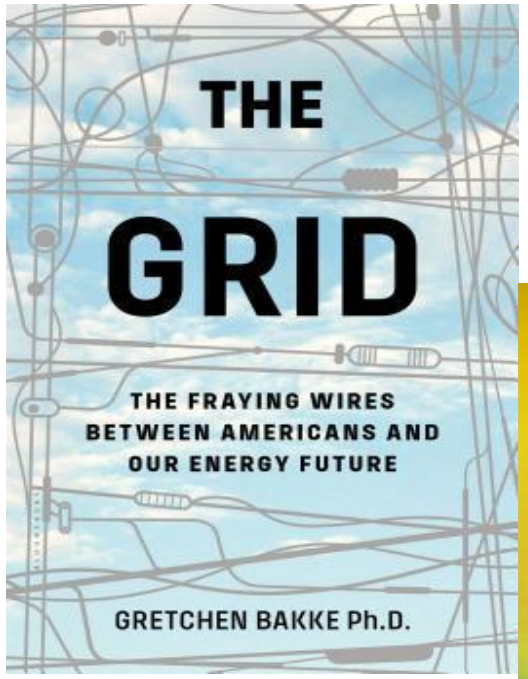

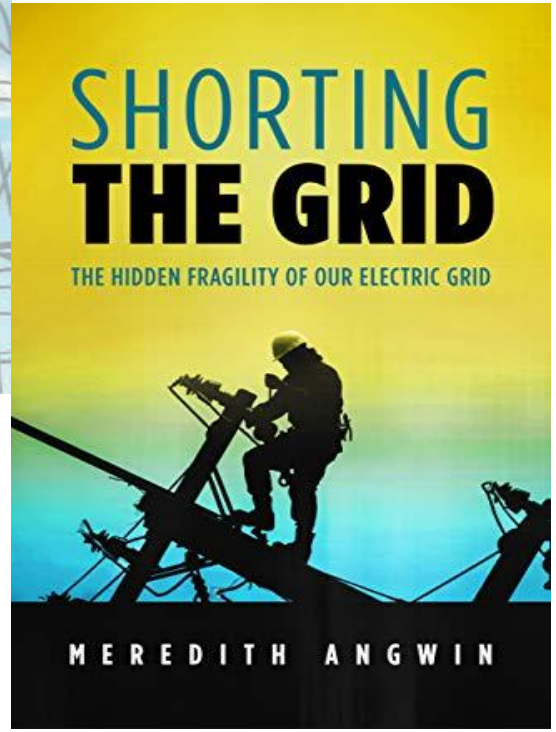

“The Grid”
by Gretchen Bakke

“Shorting the Grid”
by Merideth Angwin

TRANSMISSION HURDLE (#6)

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TRANSMISSION HURDLE (#6)

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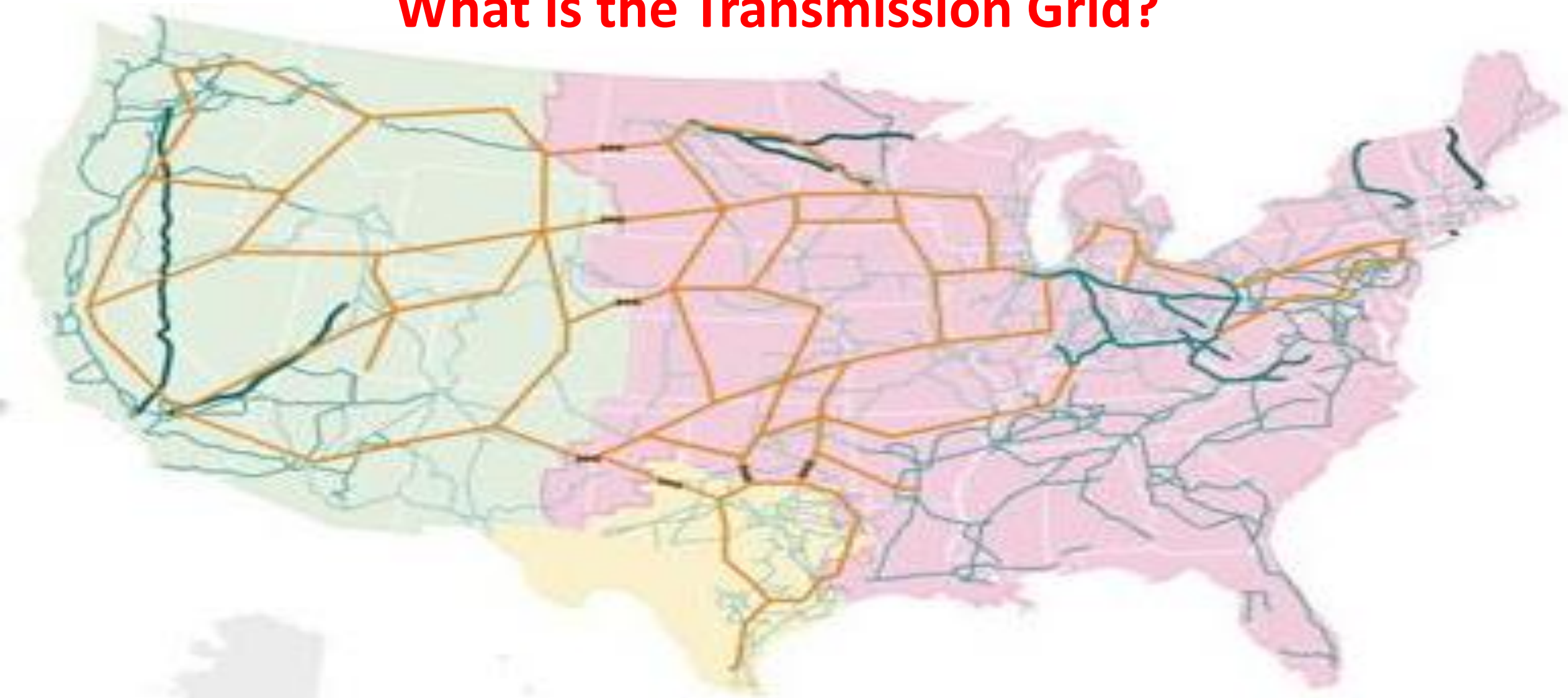
What is the Transmission Grid?



TRANSMISSION HURDLE (#6)

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The U.S. "Transmission Grid" comprises the infrastructure required to transport electricity from the places where electricity is generated to the communities that use it

3300+ public & private electric utilities and coops

160,000 miles of High Voltage transmission lines

Millions of miles of smaller low voltage power lines

In many respects, most of today's transmission grid is scarcely different than the grid 100 years ago!

TRANSMISSION HURDLE (#6)

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The existing electric "Transmission Grid" is a mess and can barely handle our existing load

Major improvements and expansion needed just to reliably handle existing load

If we replace all internal combustion engines and convert all heavy industry to electricity, then we will have to double or triple the amount of electricity generated, transported and used

If we want all that additional electricity to be Zero-Carbon,
"How will we get all that renewable energy from the remote locations where it is generated to the population centers where it will be used?" Very Hard!

TRANSMISSION HURDLE (#6)

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3 States **Thousands Private Land Owners** **~6 Federal Agencies**

15 State Agencies **Environmental Groups** **26 Counties**

TRANSMISSION HURDLE (#6)

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Possible Solutions

- ❑ Public/Private Partnerships to construct transmission
- ❑ Improved stakeholder engagement
- ❑ Buried HVDC transmission and other high tech solutions

Technical Viability = Low to Very High

Social-Political-Economic Viability = Very Low to Moderate

TRANSMISSION HURDLE (#6)

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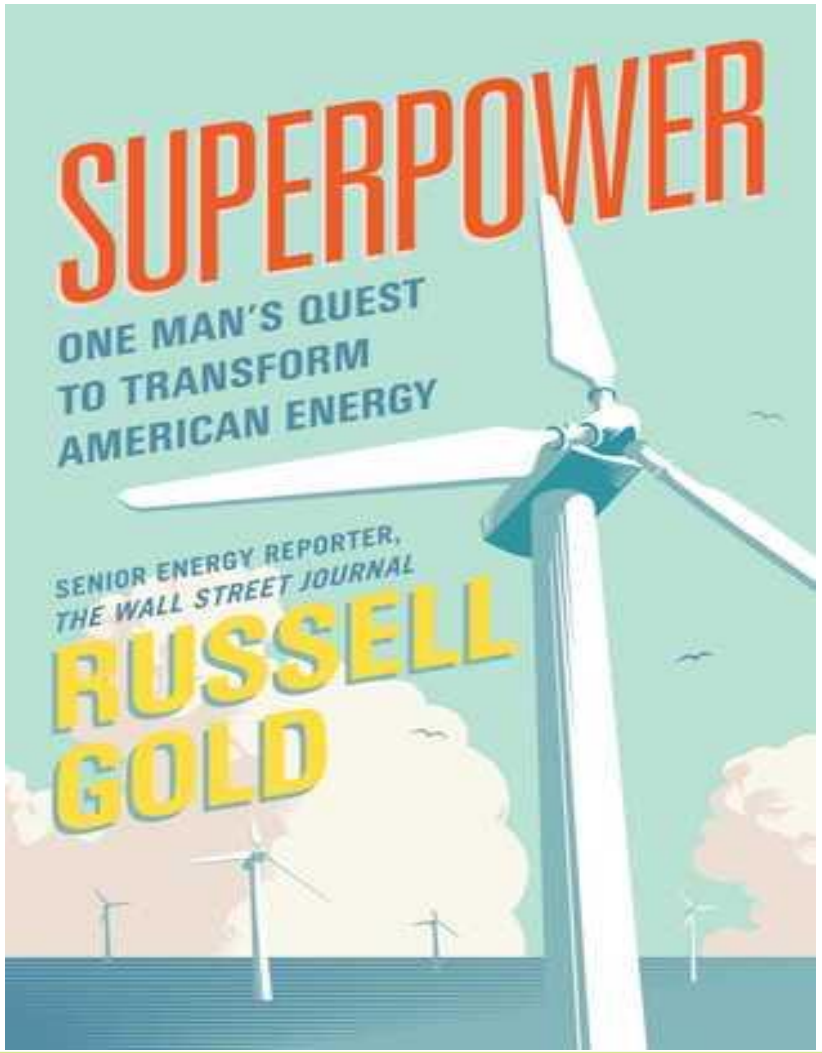
To better understand the extreme difficulty of planning, permitting, acquiring rights-of-way & constructing new electric transmission in U. S., read “SuperPower” Chapters 9 - 16



LOCAL DISTRIBUTION HURDLE (#7)

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Assume that we figure out how to generate 100% renewable electricity *(highly unlikely);* *and*

Assume that we all trade-in our internal combustion engines for electric vehicles *(highly unlikely)*, how are we going to be able to charge them all?!

Typically EVs would be charged at night at home when excess electricity is available and inexpensive.

A typical U.S. neighborhood utility transformer can currently only facilitate charging a few EVs (2-3) with existing infrastructure.

LOCAL DISTRIBUTION HURDLE (#7)

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LDC are going to have to undertake massive upgrades to their local distribution systems

Tremendous cost for every utility to upgrade every neighborhood in every city in every state

If all LCDs were granted unlimited funds and started upgrading today, it would realistically take 20-30 years to make the required infrastructure improvements

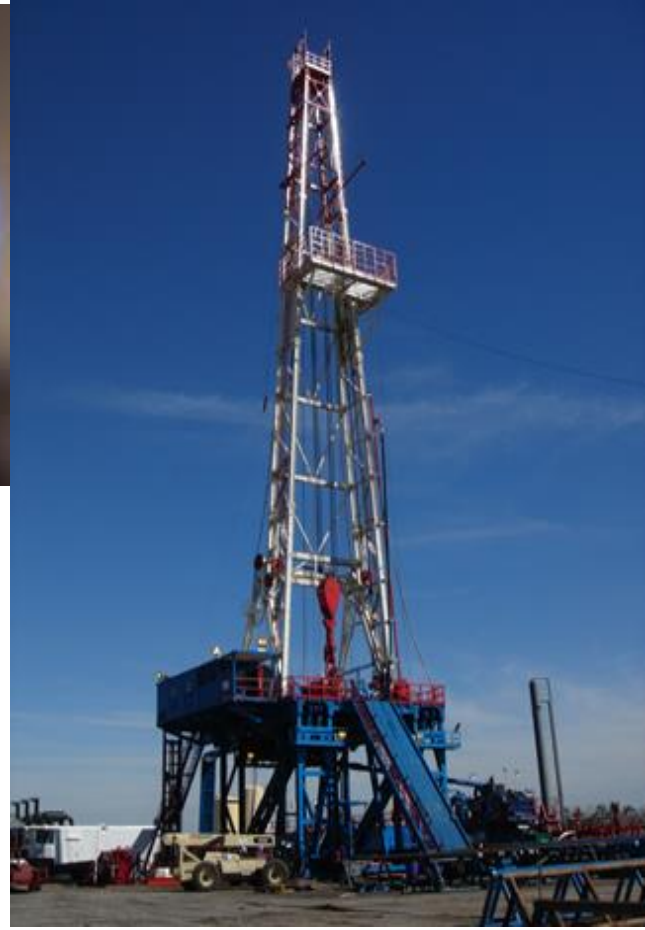
LOCAL DISTRIBUTION HURDLE (#7)

Possible Solutions

- ❑ Install more rooftop solar
- ❑ Improved & affordable battery technology
- ❑ Improved local distribution technology
- ❑ Accelerate LCD & homeowner infrastructure upgrades

Technical Viability = Low to Very High

Social-Political-Economic Viability = Low to High



Conclusions

In order to achieve Net-Zero Carbon Emissions
All 7 Hurdles must be overcome

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I LOVE RENEWABLES…….
BUT I AM ALSO PRO-ARITHMETIC!

David J. C. MacKay, Physicist,
University of Cambridge

NET-ZERO SUMMARY OF CONCLUSIONS

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- ***Some of the 7 Hurdles may be resolved, but it will take a long time***
- ***Some of the 7 Hurdles can technically be resolved, but the cost may be too high***
- ***Some of the 7 Hurdles may never be resolved***
- ****Increased use of Nuclear energy is probably the only method of attaining Net-Zero emissions****

- ***CONCLUSION – It is going to be very difficult, expensive and time intensive to attain Net-Zero; it is NOT feasible to attain Net-Zero using renewable energy alone!***

CHINA HURDLE

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China's consumption = 2 bbl oil* per person/per year

China's consumption will grow at much higher rate

Its unlikely that China (and the other developing) nations would be willing or able achieve Net-Zero carbon emissions even if Europe & North America do so

FINAL *EDITORIAL* MESSAGE

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- *The fact that it is probably not possible to reach Net-Zero Carbon Emissions using only renewable energy does NOT mean that we should stop trying to de-carbonize*
- *Purpose of this presentation is not to discourage development and use of renewables energy…….rather to highlight obstacles to Net-Zero Carbon Emissions so as to provide a better road map for overcoming as many obstacles as possible and practical*
- *Public policy decisions based on science & common sense are better than relying on hope and dishonest political fear tactics*
  - *Natural gas still has an incredibly important role in reducing carbon emissions as a bridge fuel and back-up to renewables*
  - *Nuclear could play a vital role in reducing carbon emissions if we overcome the unfounded fear & hysteria about safety*

EIA PROJECTIONS FOR ELECTRICITY GENERATION 2050

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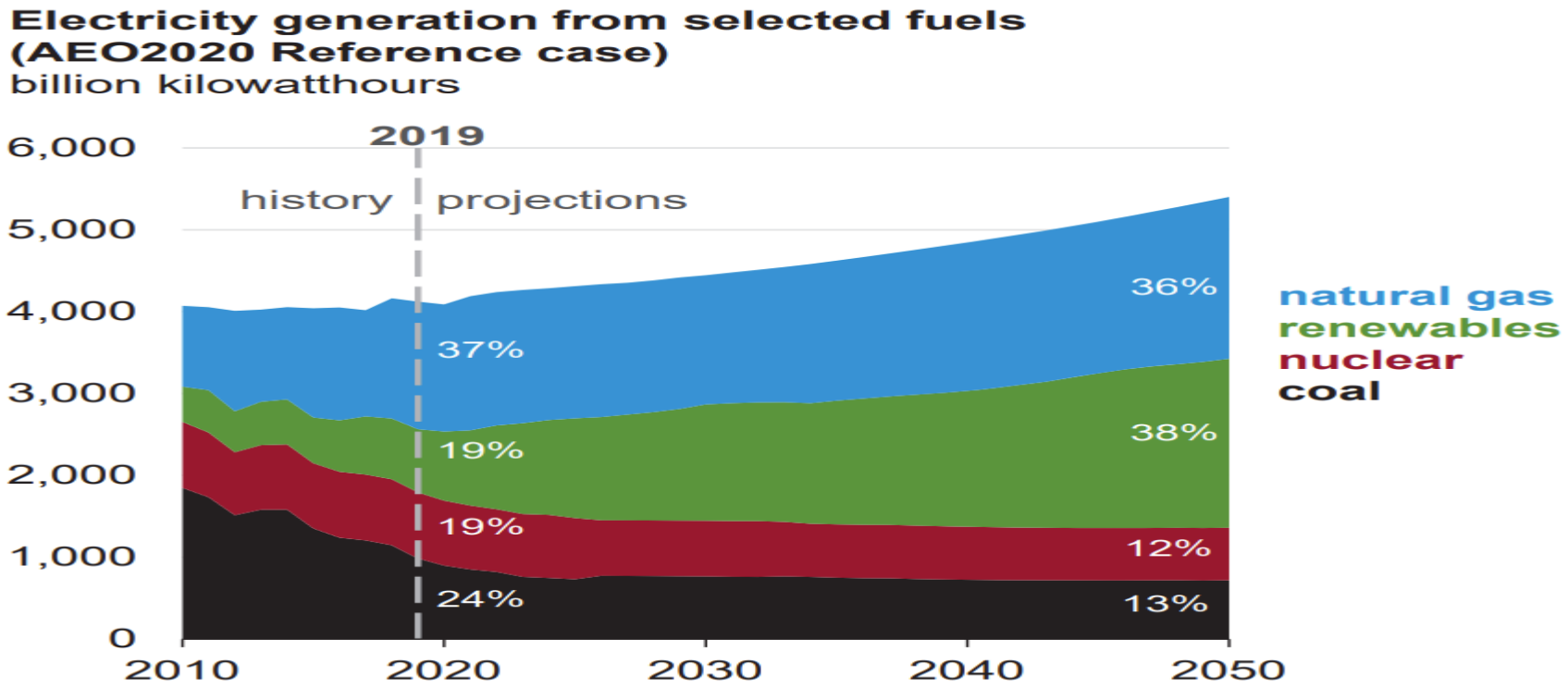

U.S. Energy Information Administration

ARLINGTON, TEXAS

AAPL 2021 ANNUAL MEETING

Comments, Suggestions and Questions?

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