HURDLES TO "NET-ZERO" CARBON EMISSIONS™

An Analysis of Clean Energy Objectives

Presented To:

THE ENERGY COUNCIL

09.16.2023

NREL - World Class Research

Hurdles to “Net-Zero” Carbon Emissions

100% CLEAN POWER?

mike
BLOOMBERG2020

100% Clean Power

The power plants that generate our electricity were for many years the biggest source of pollution that causes climate change and serious health problems. One of the biggest success stories in the fight against climate change is the shift from coal power to cleaner sources of energy, a change Mike Bloomberg has helped accomplish.

Instead of building on this progress, President Trump has doubled down on his support for fossil fuels. Mike will propel the United States toward a 100% clean energy future with a plan for 80% of electricity nationwide to come from clean sources by the end of his second term.

Michael Bloomberg's Presidential Website stated:

"80%
Clean Electricity
by 2028"

DEFINITION OF "NET-ZERO" CARBON EMISSIONS

"Net-Zero" Carbon Emissions means a point in time when:

- total human caused CO2 emissions equal zero; or
- total human caused CO2 emissions, less CO2 emissions removed from the atmosphere *(carbon capture)* equal zero.

REMEDIAL CONCEPTS

ATTAINMENT OF "NET-ZERO" CARBON EMISSIONS

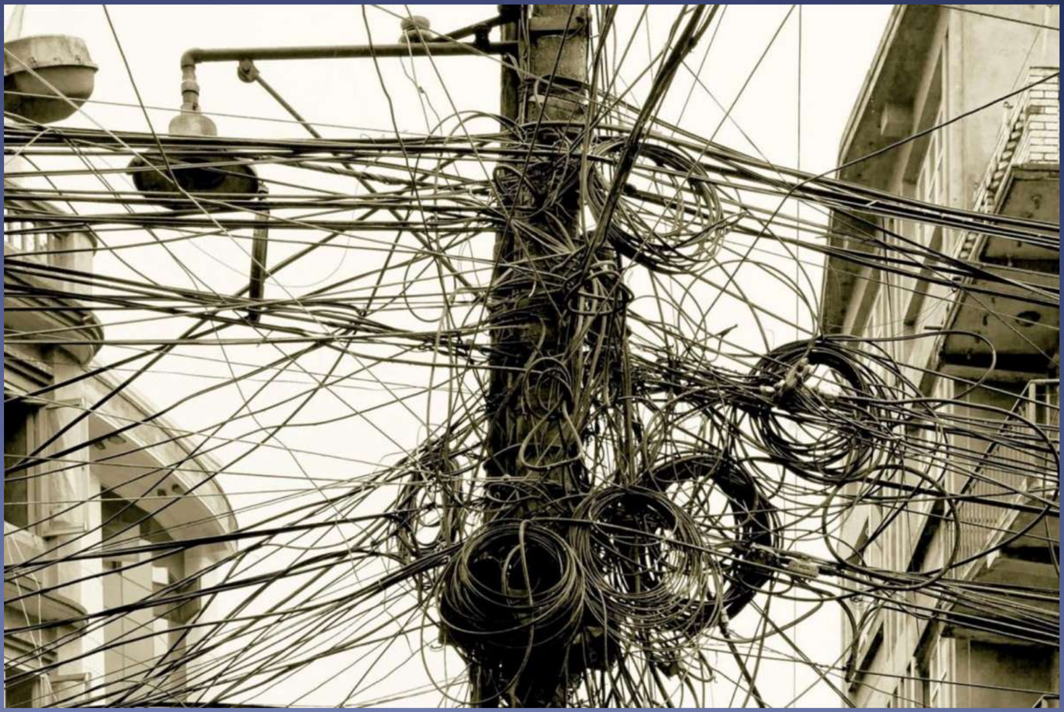
Bill Gates categorizes carbon emissions as follows:

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

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

ELECTRICITY's CHAOTIC ORIGINS

At the inception of urban electrification, many were constructing electricity generating facilities…..wires going everywhere.



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

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

THE ROLE OF PUBLIC UTILITY COMMISSIONS

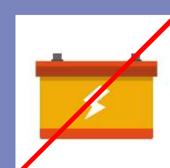
WHY WE NEED "RASER" ELECTRICITY

- **Reliable/Resilient**
- **Affordable/Abundant**
- **Safe**
- **Environmentally Responsible**

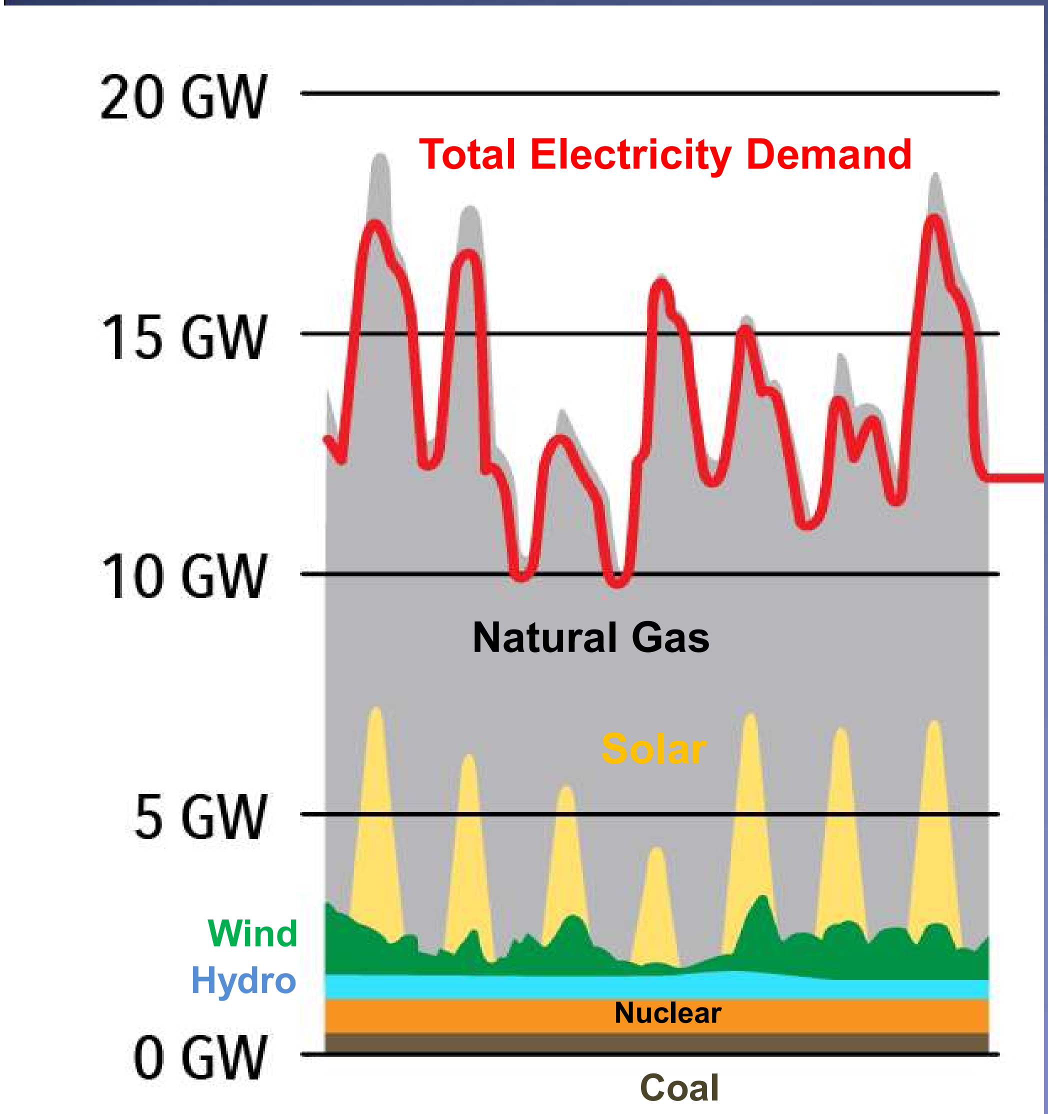
CAPACITY RATING vs. CAPACITY FACTOR

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

Capacity Rating 1 Giga Watt		Capacity Factor	Back-up Needed (for reliability)	
Nuclear		90%+		
Coal or Nat. Gas		90%+		
Wind		~34%		
Solar		~12-24%		

BALANCING THE GRID

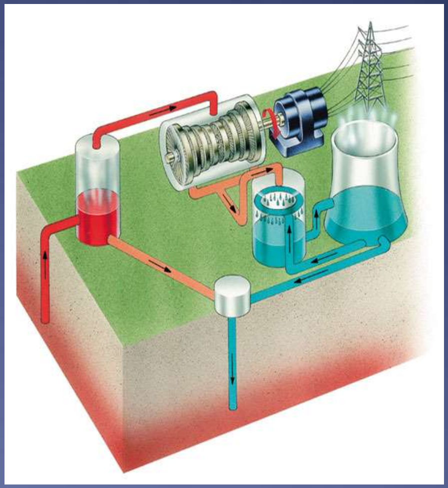


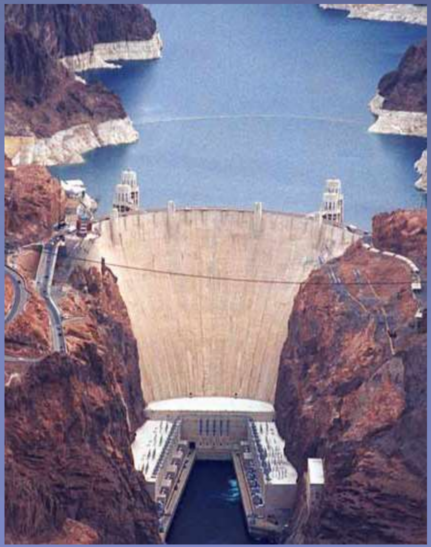
- Electricity supply must be perfectly matched with demand at all times!
- Electricity cannot stored affordably on a utility scale
- Utilities constantly adjusting & balancing supply

RENEWABLES FOR "NET-ZERO"

Hydro power, Bio-Fuels, Geothermal and Solar CSP are not going to grow significantly in the U.S. in next 25 years

<u>Therefore</u>, U. S. growth in renewable energy will primarily result from growth in <u>Wind</u> & <u>Solar PV!</u>





DOUG's 7 HURDLES TO "NET-ZERO"

- *Supply Chain Dilemma*
- *Energy Transition Materials Dilemma*
- *Intermittency Dilemma*
- *Power Density Dilemma*
- *Grid Balancing Dilemma*
- *Transmission Dilemma*
- *Local Distribution Dilemma*

ATTAINMENT OF "NET-ZERO" QUANTIFICATION TOOLS

TV = Technical Viability

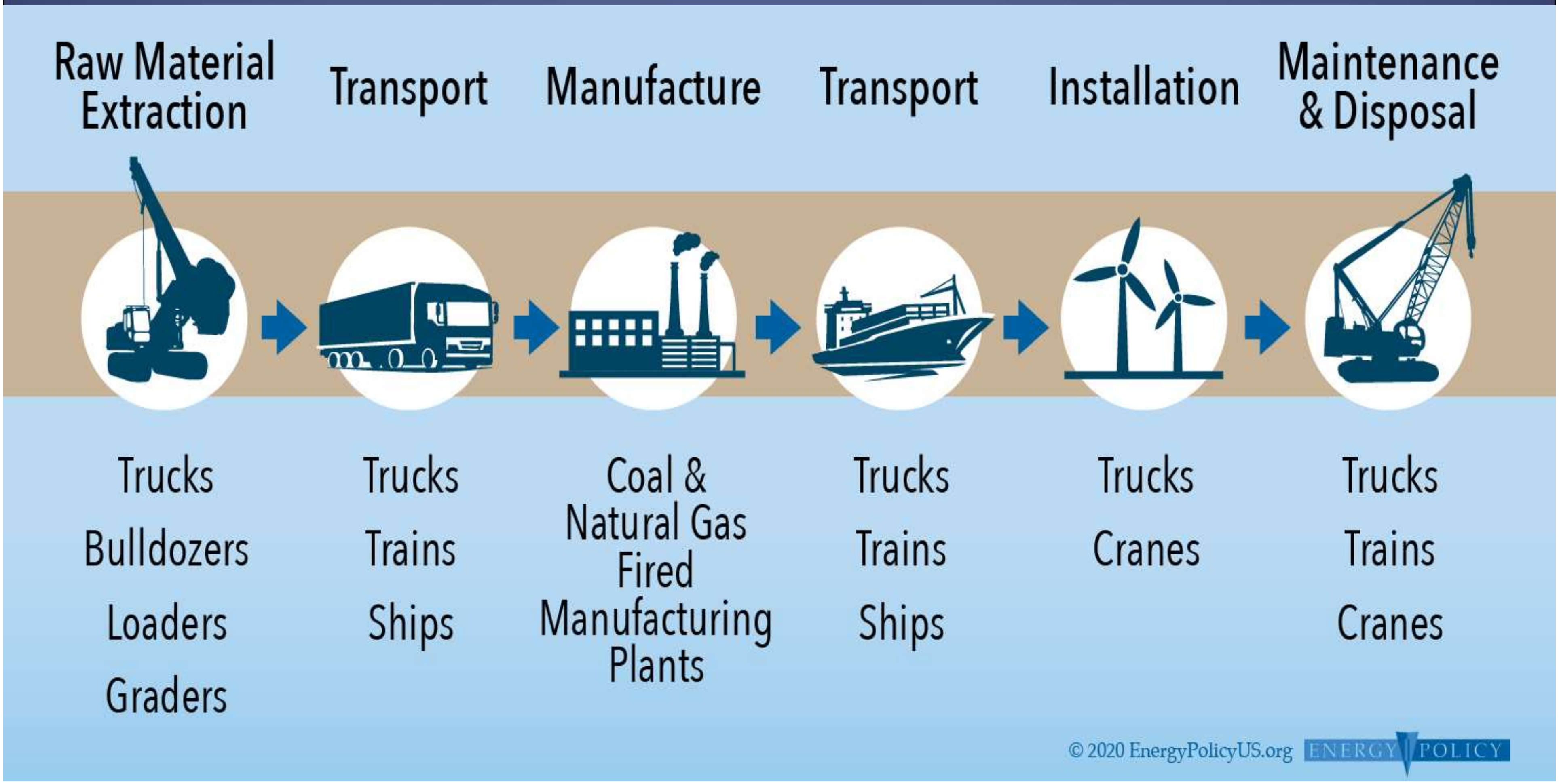
Definition: What are the chances of technical viability of a given problem without regard to costs or social-political considerations.

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 DILEMMA (#1)

Life Cycle of Energy used to Facilitate Renewable Energy



ENERGY TRANSITION MATERIALS DILEMMA (#2)

"Energy Transition Minerals" are a wide variety of minerals needed for electric vehicle batteries, solar panels, wind turbine and other renewable and "clean" energy related technologies

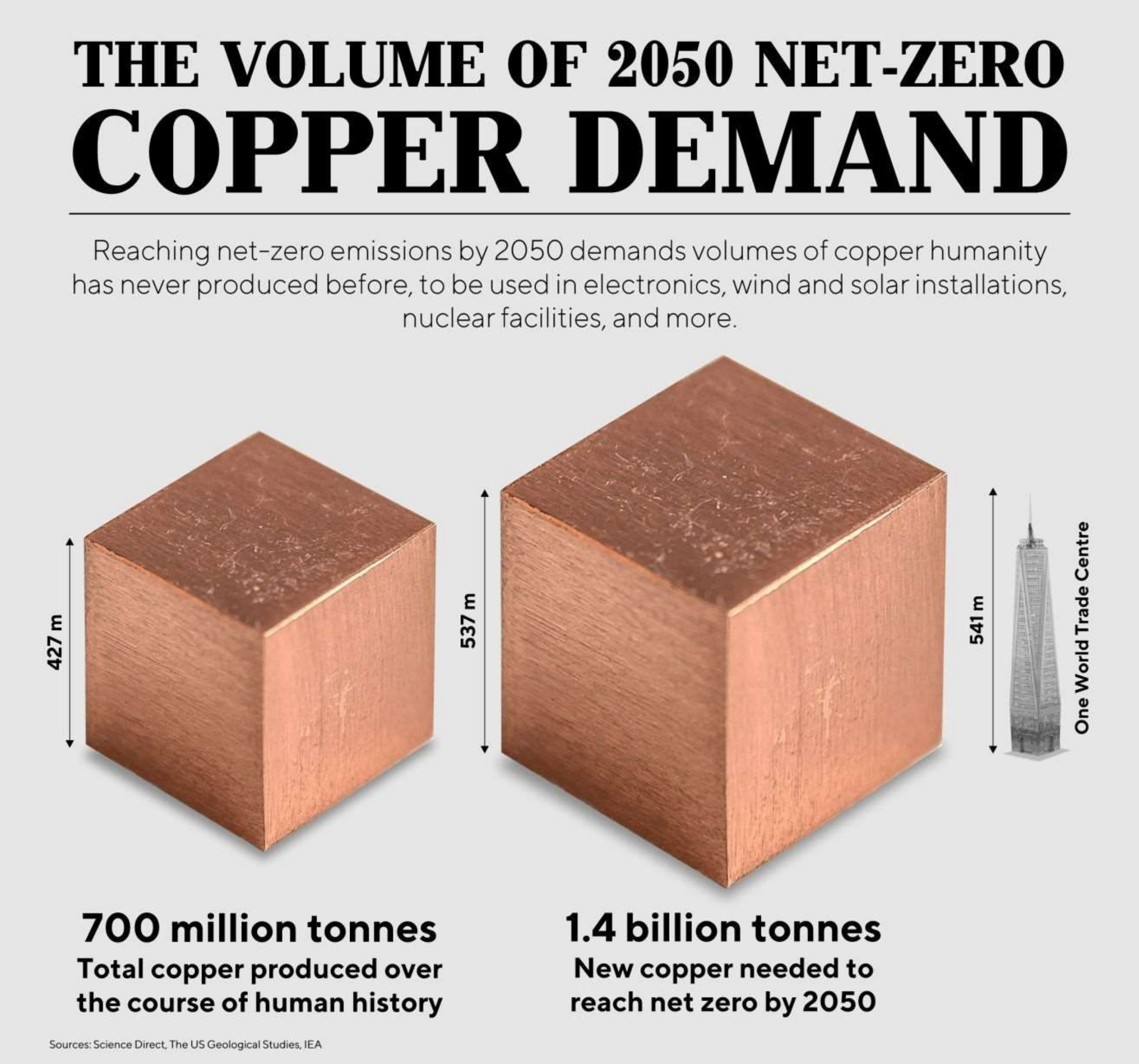
ENERGY TRANSITION MATERIALS DILEMMA (#2)

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%

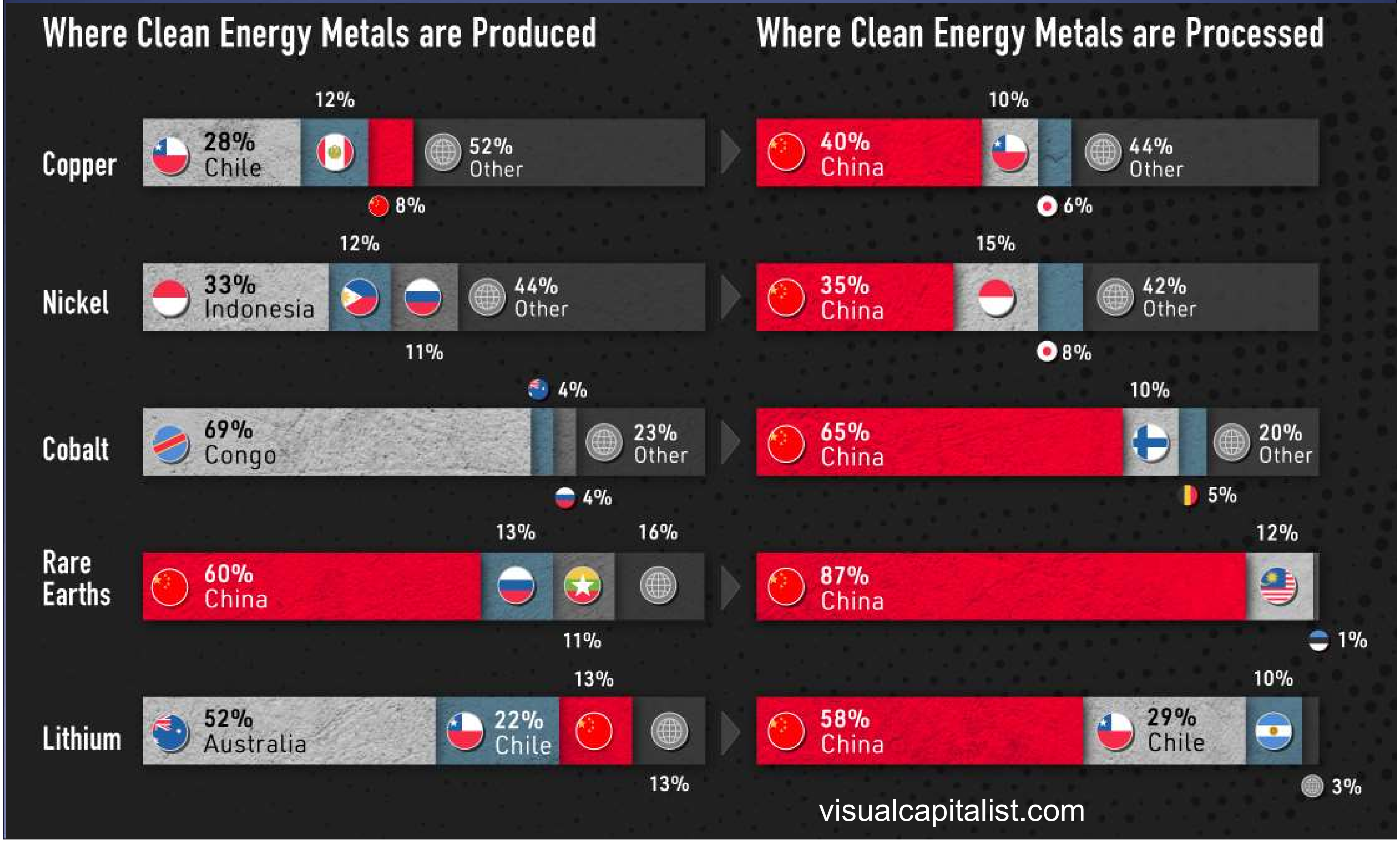
www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

ENERGY TRANSITION MATERIALS DILEMMA (#2)



Over the next 27 years, the world would demand twice the volume of copper as the world has produced over the past 3000 years!

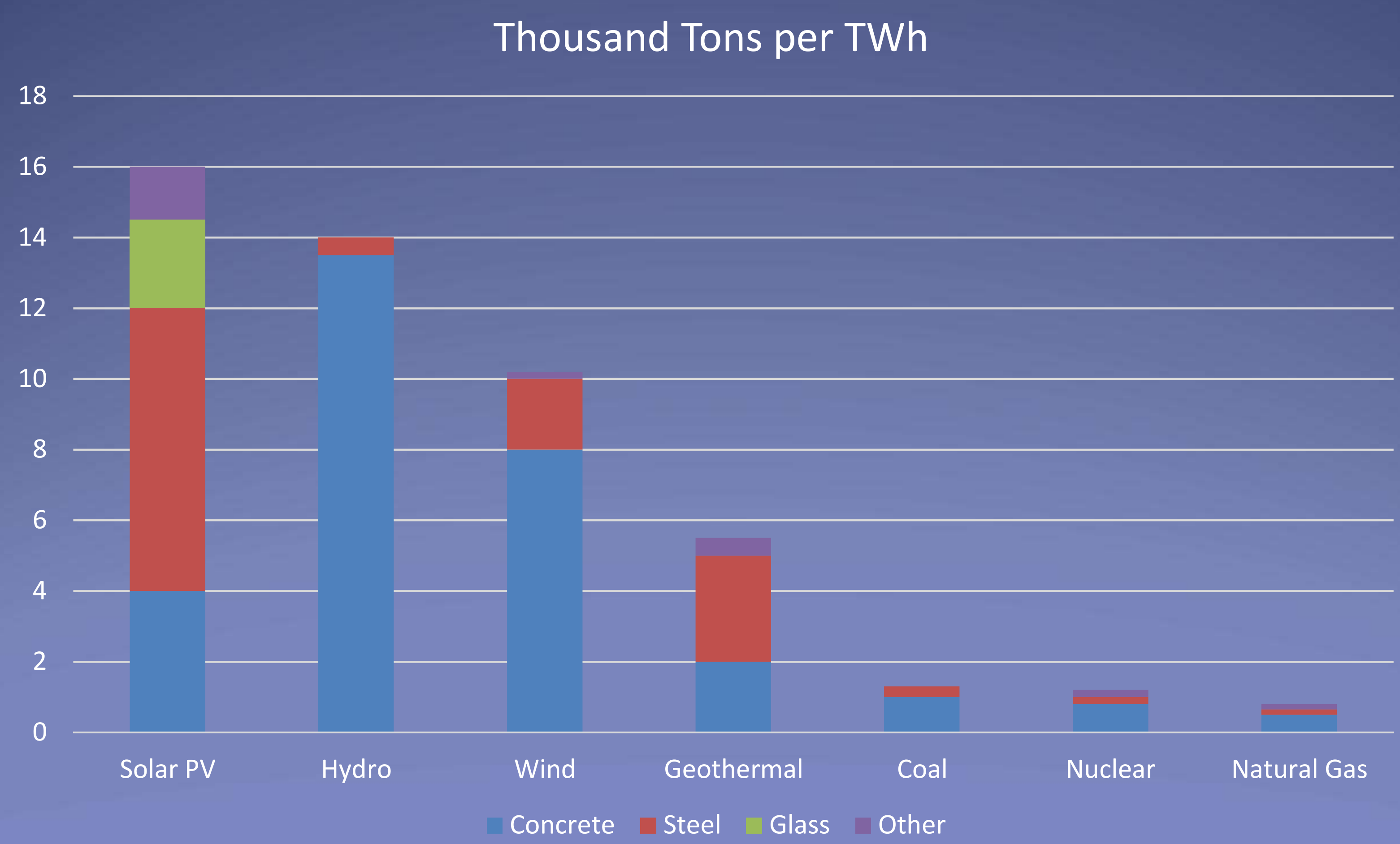
ENERGY TRANSITION MINERALS DILEMMA (#2)



ENERGY TRANSITION MATERIALS DILEMMA (#2)

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

U. S. Department of Energy (2021)



ENERGY TRANSITION MATERIALS DILEMMA (#2)

The so-called "energy transition" which is often characterized as a transition from <u>fossil fuels</u> to <u>renewables</u>

is in reality a transition from
mining <u>fossil fuels</u> to
mining <u>minerals & metals</u>

INTERMITTENCY DILEMMA (#3)

INTERMITTENCY DILEMMA (#3)

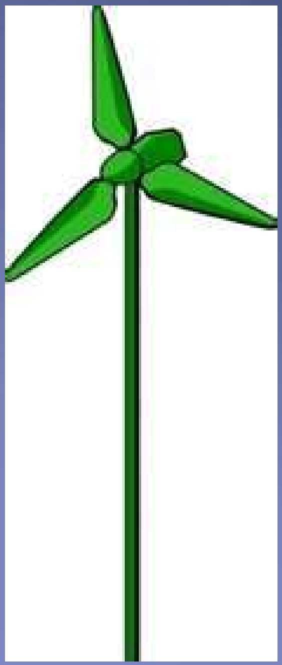
Making Wind Reliable (using only wind)

- 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 would provide ~ 98% reliability



INTERMITTENCY DILEMMA (#3)

Making Wind & Solar Reliable w/ Batteries

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 <u>80%</u> 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

POWER DENSITY DILEMMA (#4)

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 DILEMMA (#4)

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

POWER DENSITY DILEMMA (#4)

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

Source: A Question of Power by Robert Bryce

POWER DENSITY DILEMMA (#4)

Growing resistance to large scale Wind & Solar Projects

- Eye sores over large swaths of land
- Disposal of wind turbine blades & solar panels
- Noise & Light concerns with wind
- Destruction of environmental ecosystems (solar)
- Wildlife concerns, note notably bird & bat mortality
- Destruction of adjacent Property Values

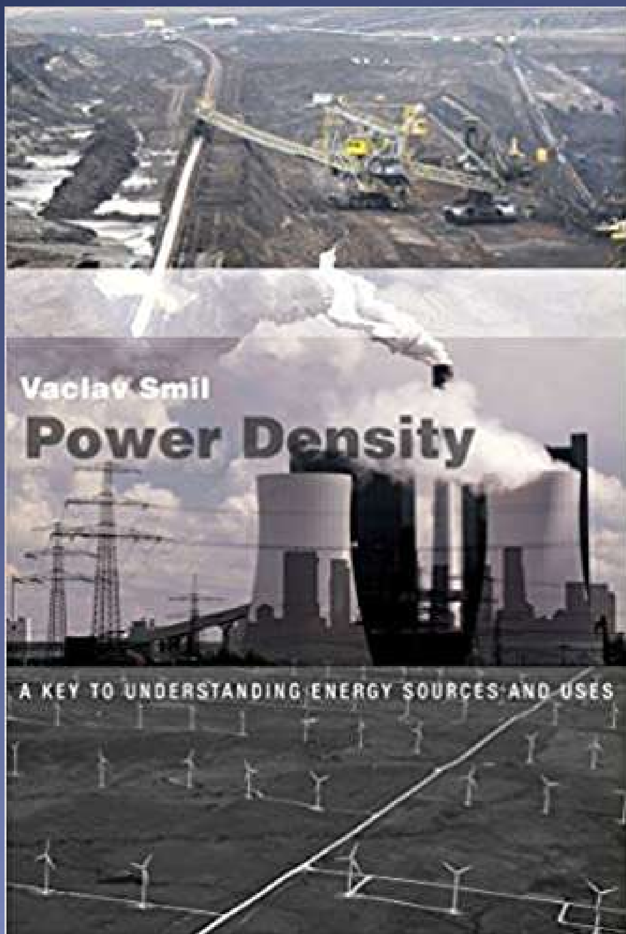
POWER DENSITY DILEMMA (#4)

Vaclav Smil, Distinguished Professor Emeritus of Environmental Science recently analyzed the impacts of massive electrification of the U. S. to eliminate 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 DILEMMA (#4)



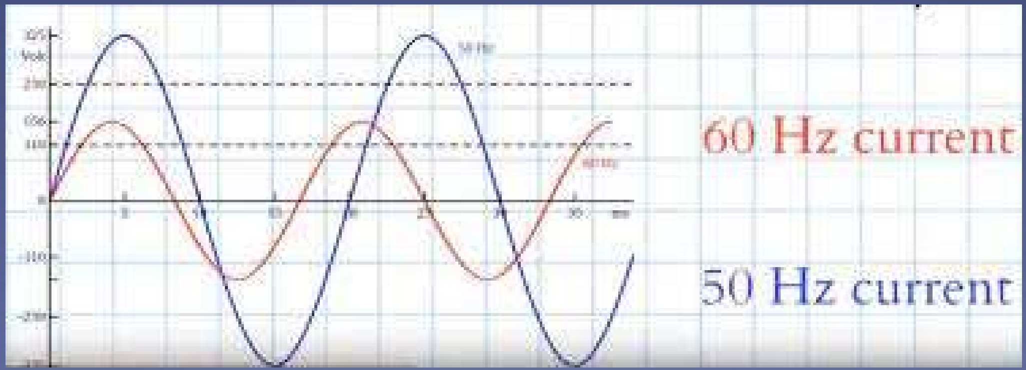
http://vaclavsmil.com/

The authoritative book to better understand 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

GRID BALANCING DILEMMA (#5)

The Grid Must be Stable & Maintained in Equilibrium



The electric grid is very sensitive & 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 <u>reliable</u> Grid

TRANSMISSION DILEMMA (#6)

TRANSMISSION DILEMMA (#6)

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

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

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?

If we triple the amount of electricity generation, we might need to construct 5X the amount of transmission.

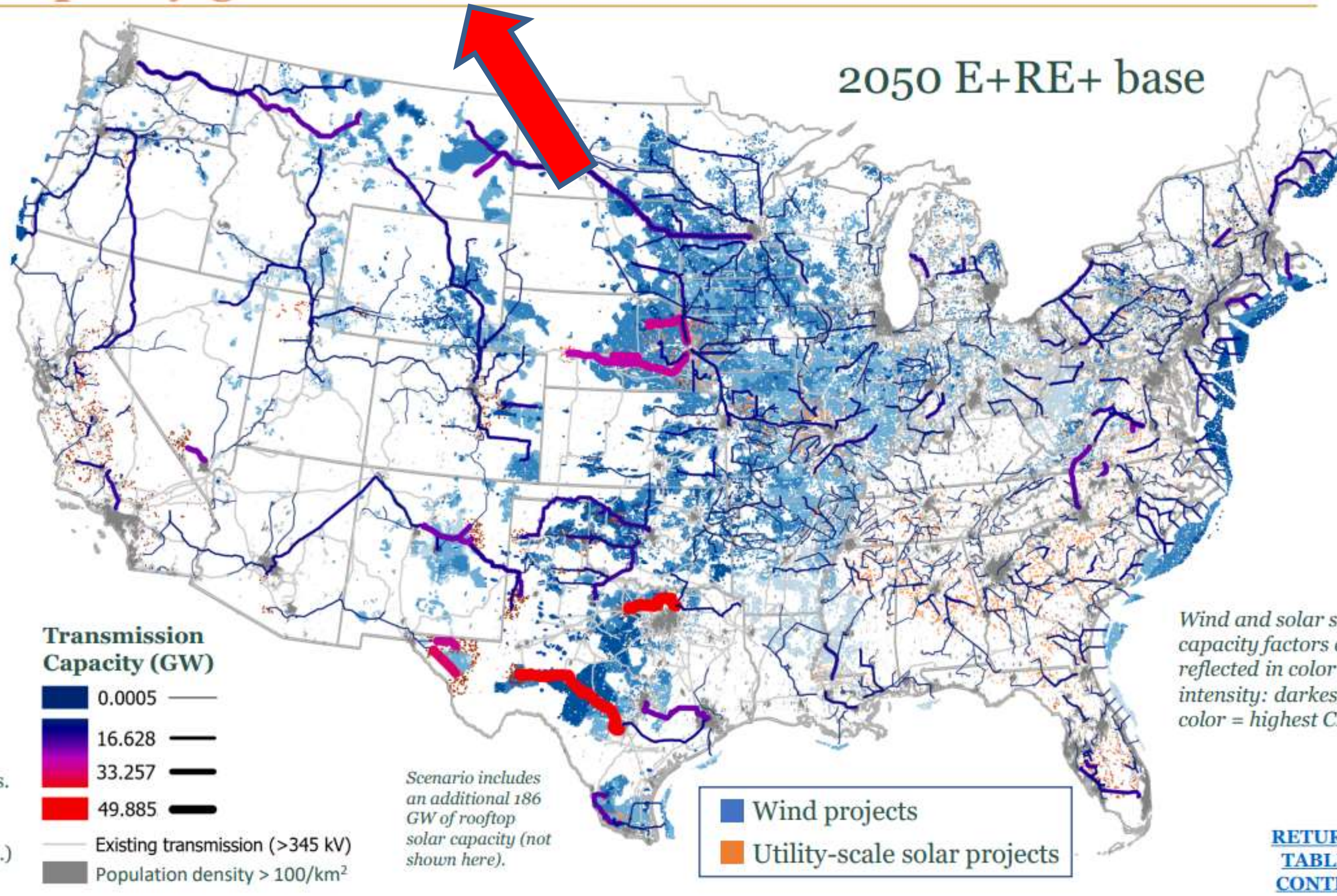
TRANSMISSION DILEMMA (#6)

E+ RE+: 5.9 TW of wind and solar capacity operating in 2050; transmission capacity grows to 5.1x the 2020 level.

2050		
	Wind	Solar
Capacity installed (TW)		
	3.07	2.75
Land used (1000 km²)		
Total	1,003	61.2
Direct	10.0	55.7
Capital invested (Billion $_{2018}$)*		
Solar	-	2,684
Onshore wind	3,010	-
Offshore wind	594	-
Transmission added vs. 2020**		
Capacity (GW-km)		1,309,000
Increase over 2020		409%
Capital in serv (B$_{2018}$)		3,560

* Excludes investments associated with 2020 pre-existing capacity. Capital is for additional capacity required to meet total modeled wind & solar generation levels.

** Transmission expansion is mapped to follow existing rights of way (>160 kV); paths are indicative not definitive. Spur lines from solar and wind projects to substations are not shown, but are included in GW-km and investment totals. Capital in service includes capital for transmission expansions and "sustaining capital" (for end-of-life line replacements.)



Wind and solar site capacity factors are reflected in color intensity: darkest color = highest CF.

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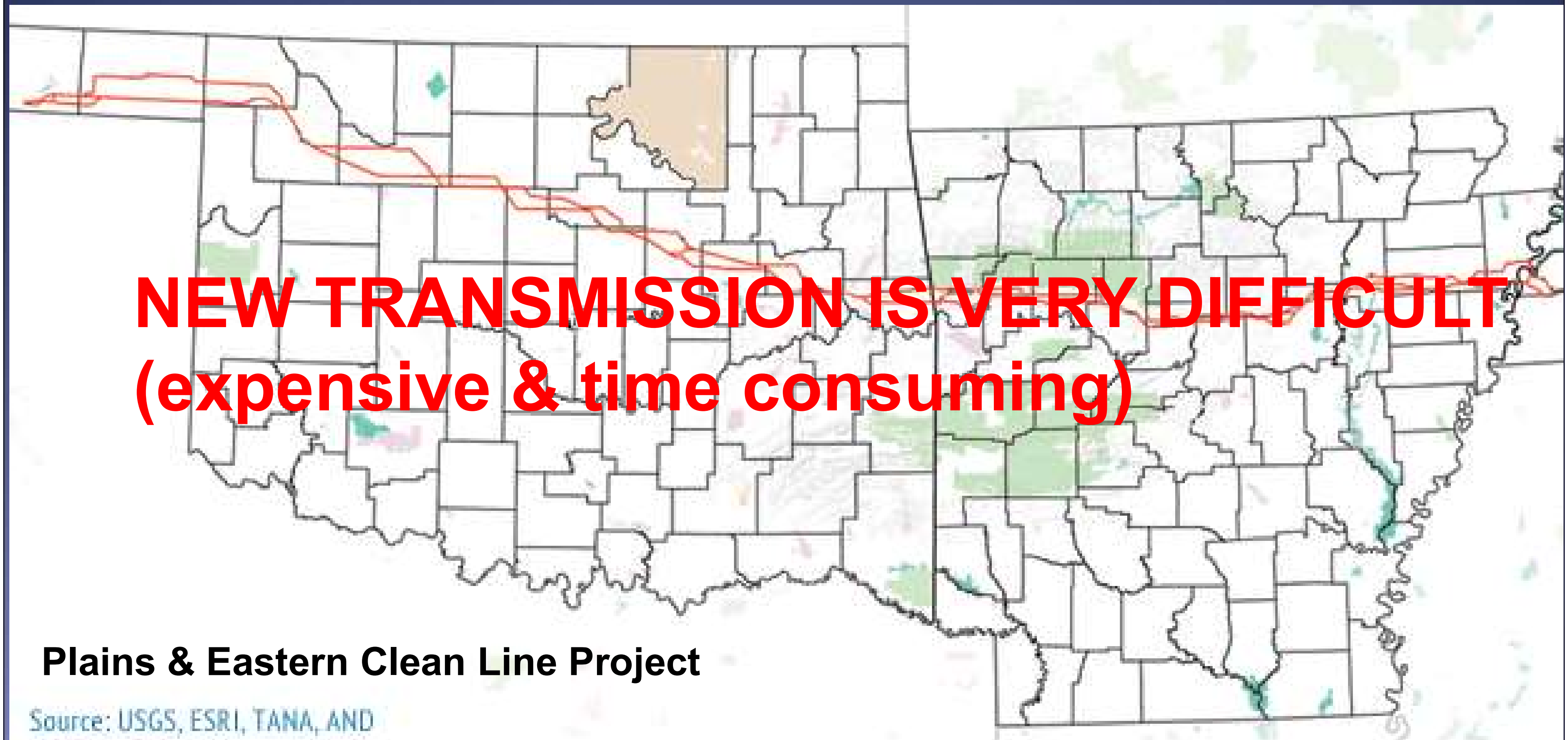
TRANSMISSION DILEMMA (#6)



NEW TRANSMISSION IS VERY DIFFICULT
(expensive & time consuming)

Plains & Eastern Clean Line Project

3 States Thousands Private Land Owners ~6 Federal Agencies

15 State Agencies Environmental Groups 26 Counties

LOCAL DISTRIBUTION DILEMMA (#7)

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

Assume that we can increase the size of our transmission grid by a factor of 5X *(highly unlikely); and*

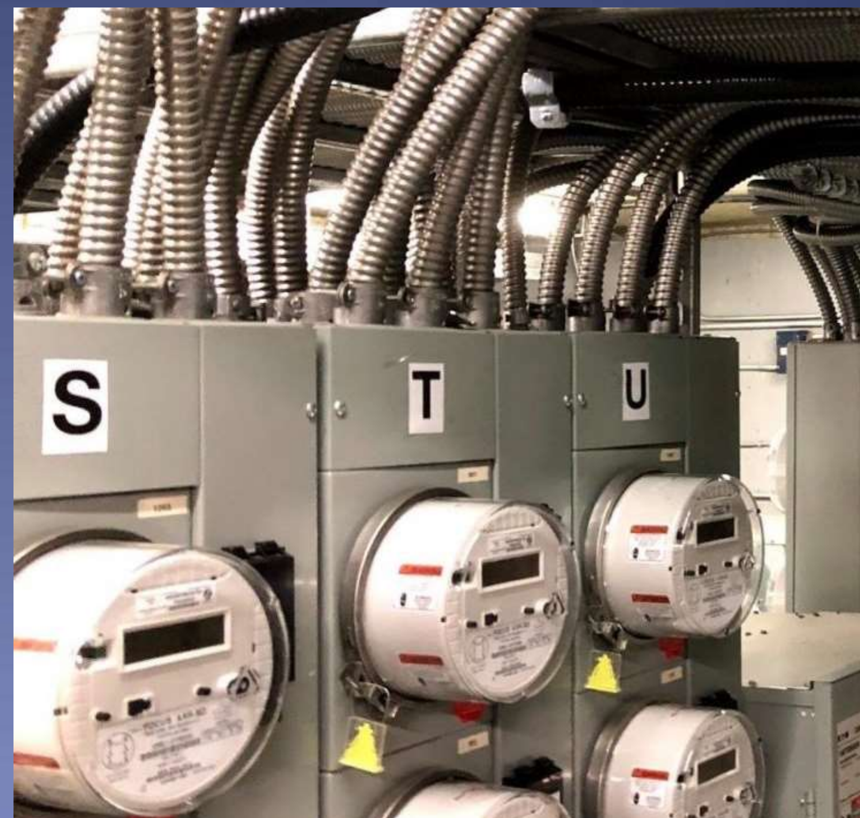
Assume that we all trade-in our internal combustion engines for electric vehicles *(highly unlikely)*,

How are we going to be able to charge them all?!

LOCAL DISTRIBUTION DILEMMA (#7)

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




Conclusions about Energy Transition & “Net-Zero”


CONCLUSIONS

Purpose of this presentation is not to discourage development and use of renewables energy or to discourage the goal of reducing carbon emissions!

Rather, the purpose of this presentation is to highlight obstacles to attaining "Net-Zero" Carbon Emissions, so as to provide a better road map for overcoming as many obstacles as possible and practical.

In order to achieve "Net-Zero," all 7 of the dilemma's will have to be solved (plus many more).

It seems unlikely that any of the dilemmas will be solved by 2050, much less all of them….therefore , "Net-Zero" is not likely by 2050!

CONCLUSIONS

- *I strongly object to the characterization that renewables are cheaper*
- *Natural gas still has an incredibly important role in reducing carbon emissions as a bridge fuel and back-up to renewables*
- *Nuclear could/should play a vital role in reducing carbon emissions*

COMPARISON OF LEVELIZED COST OF ELECTRICITY w/ BACKUP

		Capacity Factor	Levelized Cost	Back-up Needed	Backup Costs
Nuclear		95%+	3 cents/kWh (existing) 9 cents/kWh (new)		
Coal or Nat. Gas		95%+	3.3 cents/kWh		
Wind (Onshore)		34%	3.2 cents/kWh		+5 cents/kWh
Solar		24%	2.9 cents/kWh		+4 cents/kWh

Note: LCOE & Capacity Factors are pro forma for illustrative purposes & not specific to a date or location

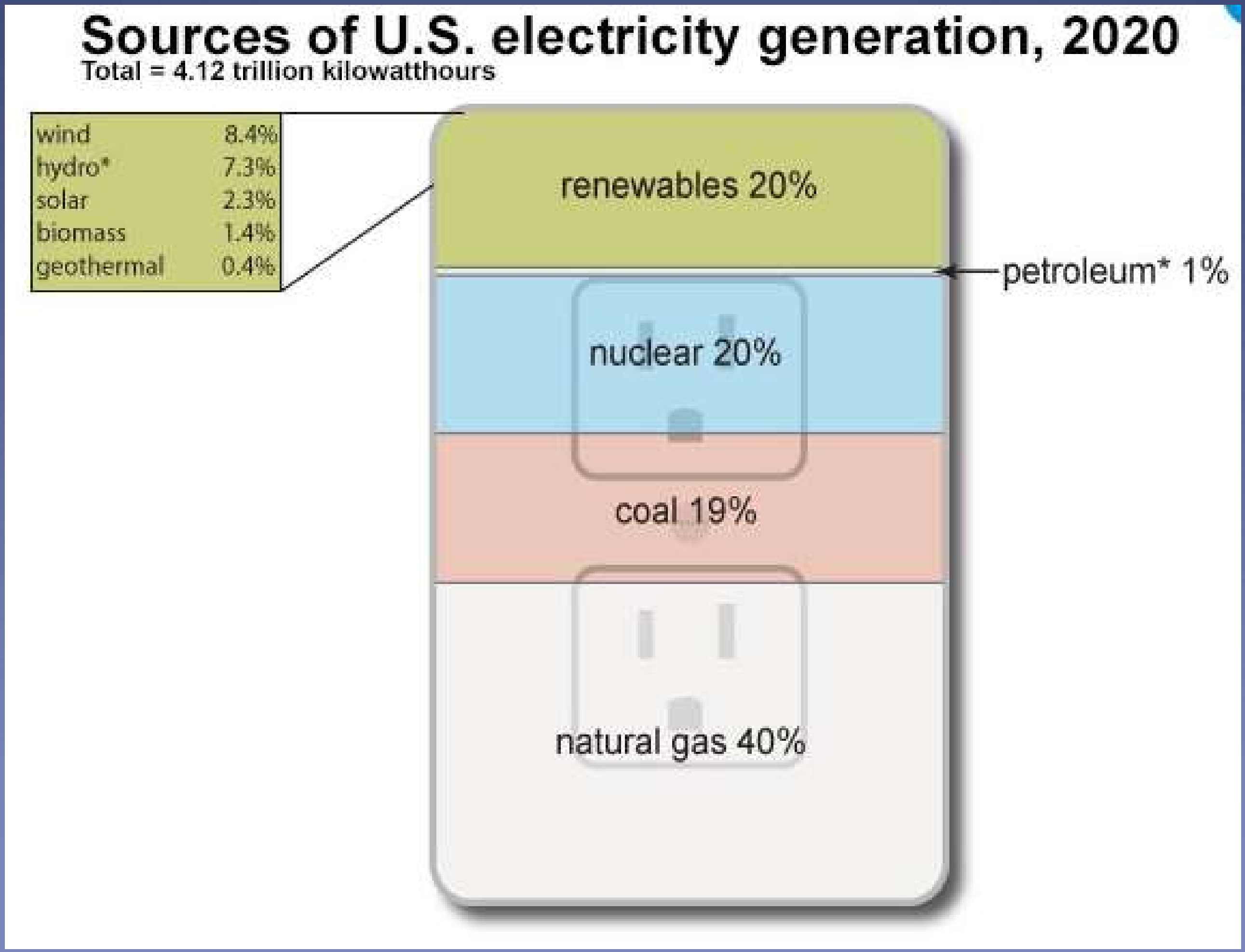
I LOVE RENEWABLES…….

BUT I AM ALSO PRO-ARITHMETIC!

David J. C. MacKay, Physicist,

University of Cambridge

HOW DO WE CURRENTLY GENERATE ELECTRICITY?



Source: Energy Information Administration 2021

Comments, Suggestions and Questions?

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