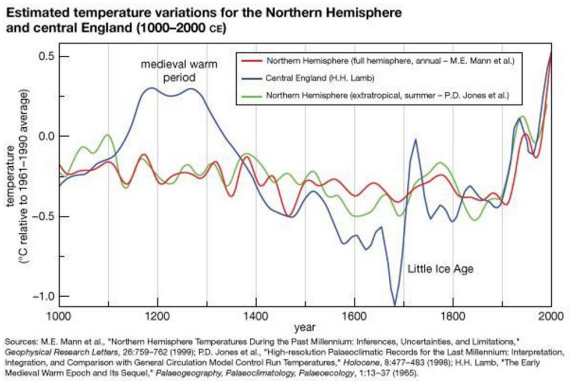
The Hot and Cold of Climate

Osher Lifelong Learning Institute
University of Richmond, October 2024 - Part III



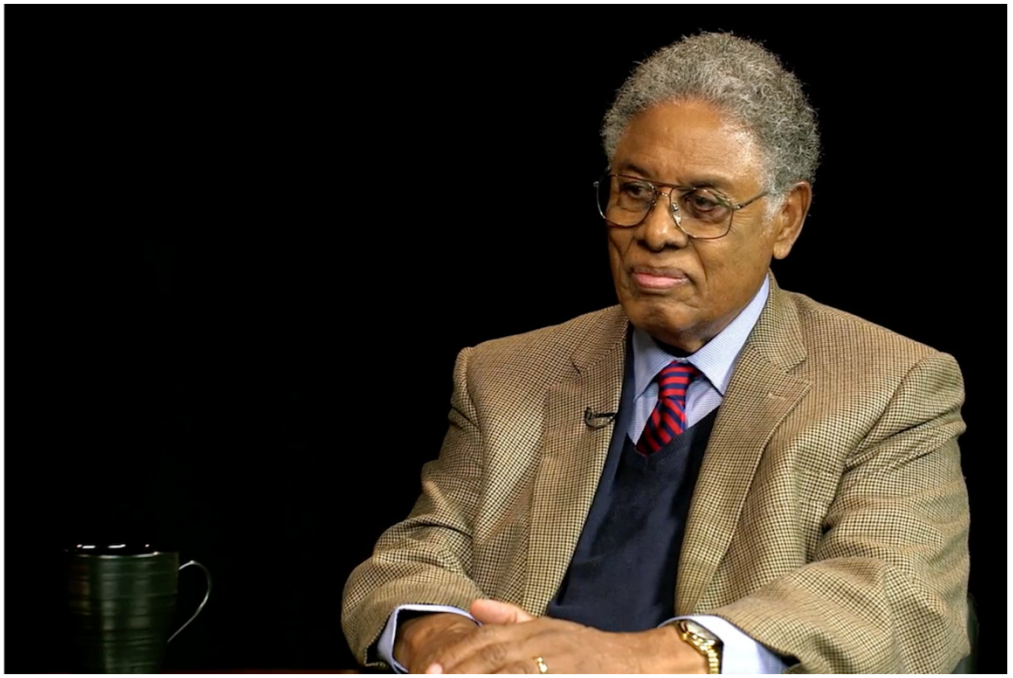
ACKNOWLEGEMENTS

The presenter gratefully acknowledges the contributions of Dr. Sama Bilbao y León in the preparation of this course. “Dr. Sama” was the first Director of Nuclear Engineering Programs of the Department of Mechanical and Nuclear Engineering at VCU. She is presently the Director General of the World Nuclear Association.

The presenter would also like to acknowledge William L. Thompson, retired Manager of Electrical Engineering at Dominion Energy and author of the book *Living on the Grid: The Fundamentals of the North American Power Grid in Simple Language*, for much of the material related to the electric power grid presented herein.

Assuming AGW Is REAL What Should We Do About It?

One should always consider regarding any proposed action…



What are possible **BAD** consequences associated with the proposed action?

-- Thomas Sowell

THREE BROAD POLICY OPTIONS

I. Mitigation

II. Sequestration

III. Adaptation

Note: Geo-engineering can fall under either sequestration or adaptation

I. MITIGATION

That is, CUT EMISSIONS

IPCC Working Group II:

GHG emissions must be cut by between 40% and 70% from 2010 levels by 2050 to prevent ~2°C of warming (since preindustrial times) that would otherwise occur by that year.

(Estimate based on model predictions)

MITIGATION METHODS

1. **Conservation** (as long as net energy saved)
2. **Switch to non-fossil-fuel energy sources**:
   Hydroelectric, Nuclear, Wind, Solar, Biofuels

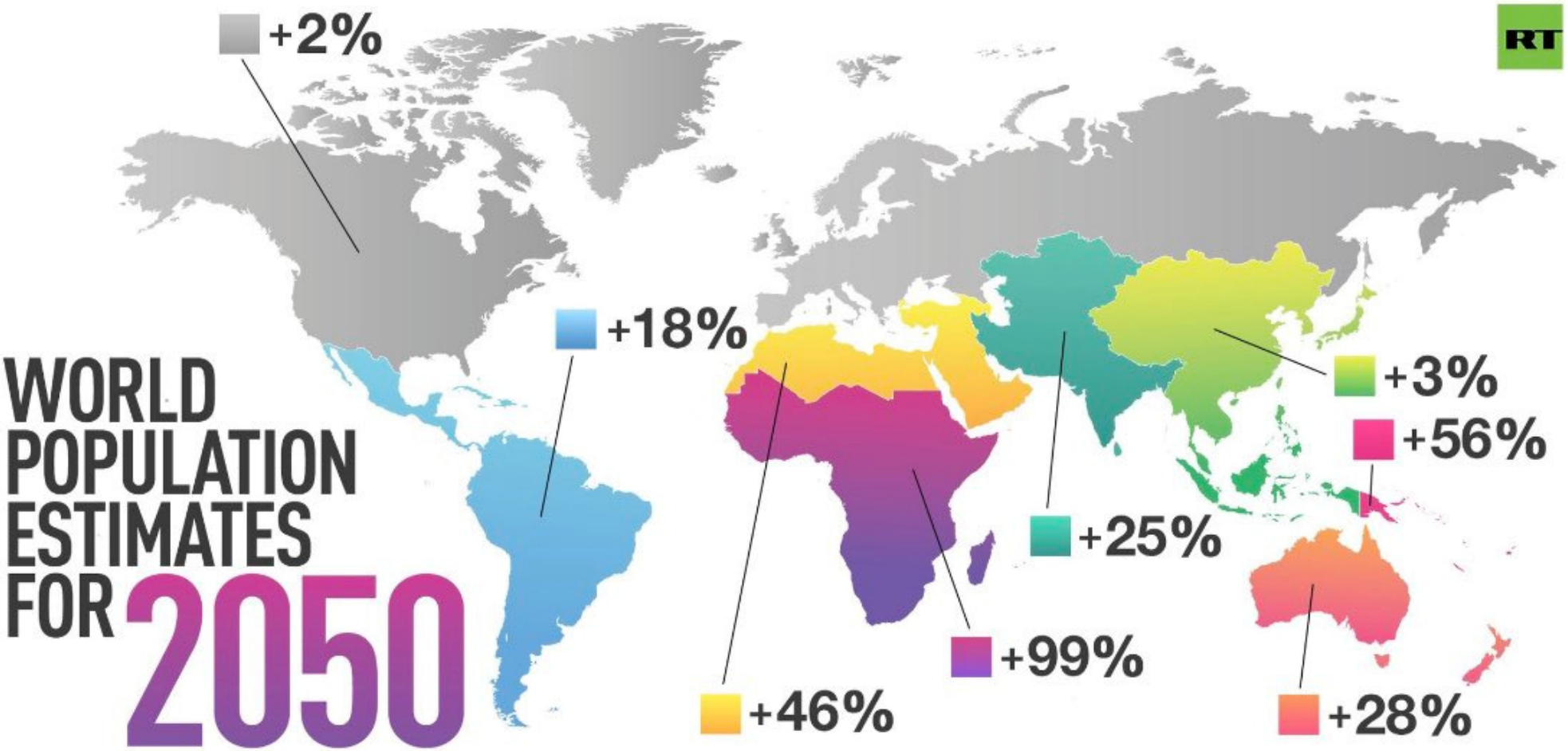
In switching to non-fossil fuel energy sources,

WHAT TO DO ABOUT …

TRANSPORTATION?

~1/3 OF ENERGY USE

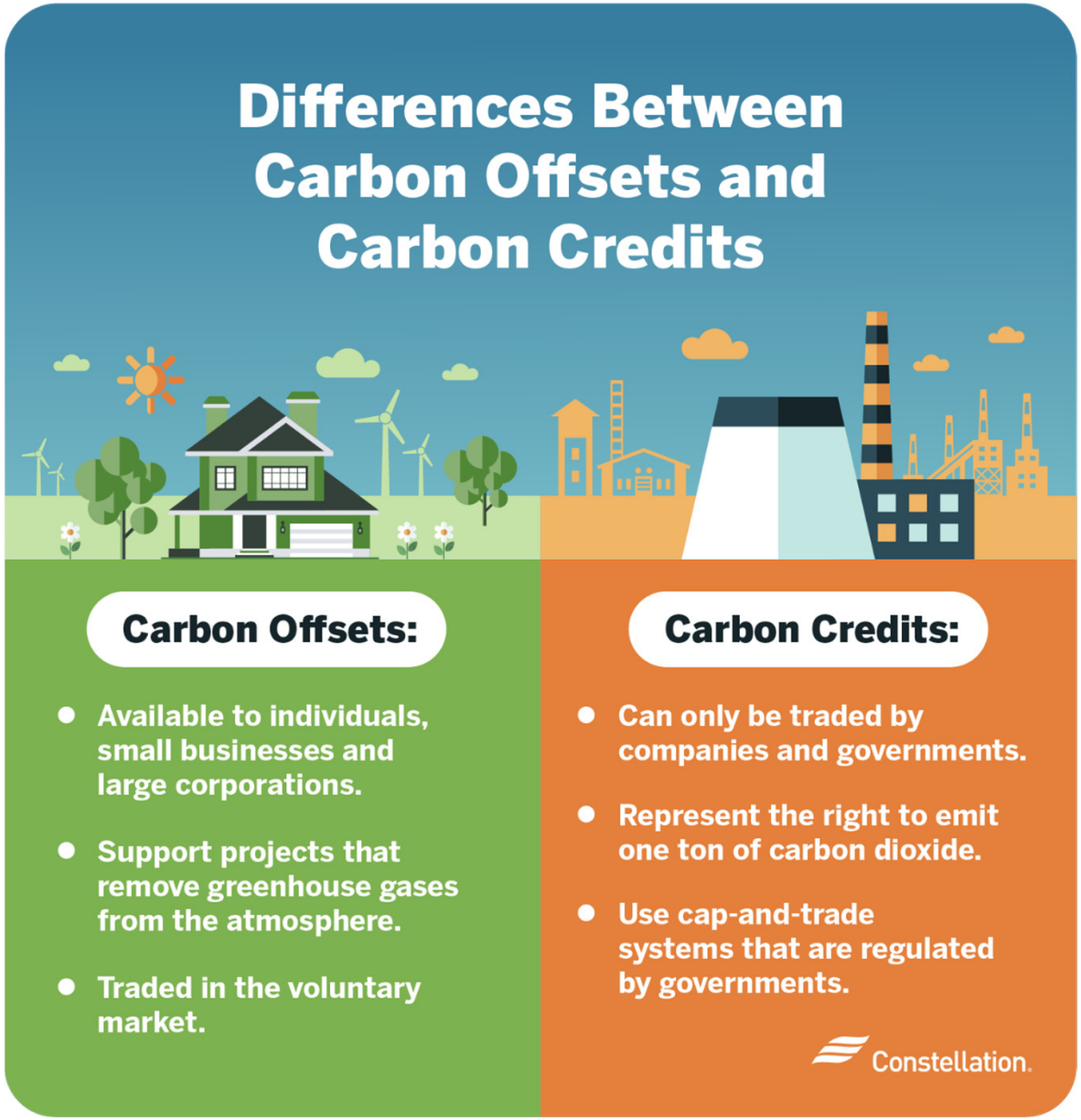
AND
WHAT ABOUT
DEVELOPING NATIONS?


+2%
+18%
+3%
+56%
+25%
+99%
+46%
+28%
RT
WORLD POPULATION ESTIMATES FOR 2050

3. Rationing access to fossil energy or taxing it.

A. 2015 Paris Agreement assigns an **Emission Quota** to each nation → i.e., RATIONING

B. **Trading Schemes**



Predictions:

- Reducing GHGs to 70% below 2010 levels by 2050 would lower world GDP in 2050 by 21% from baseline forecasts.
- Controlling GHG emissions by any method extremely costly, distorts economic decisions, destroys jobs, is difficult to monitor, and practically impossible to enforce.
- Some scientists say it will be …

Too Little, Too Late

II. Sequestration

- Planting giant plantations of fast-growing trees. Based on roughly one ton of carbon sequestration per hectare of trees per year (Nordhaus 1991)
- Absorbing current emissions would requires an area of ~20 million mi^2 (Area greater than Asia)
- Fertilizing parts of the oceans with nitrogen, phosphorous, and iron can cause algae blooms which then die and carry absorbed CO_2 to ocean floor. Could sequester ~15% of annual CO_2 emissions (Harrison 2017).

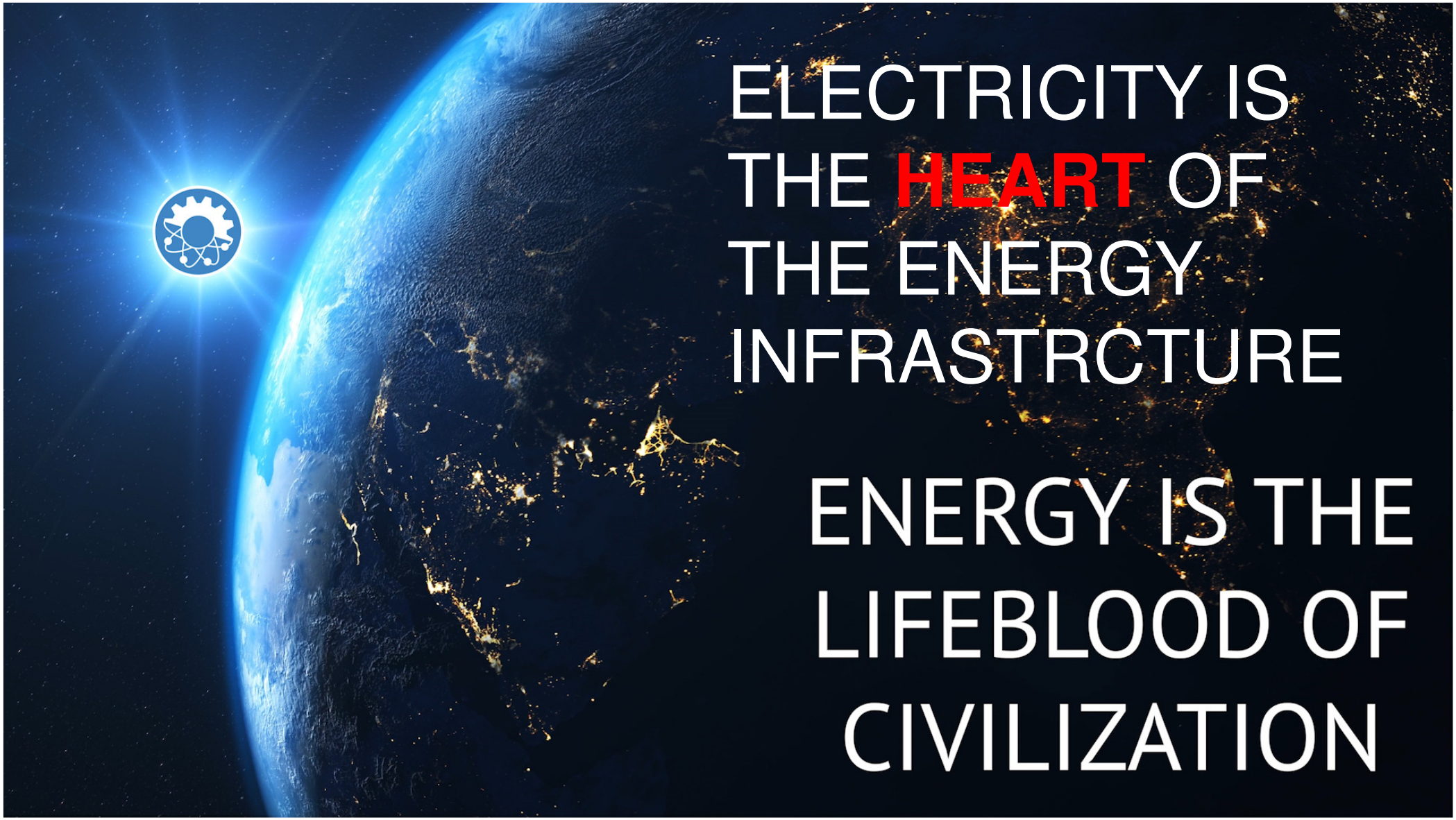
III. Adaptation

- What humans have done throughout history
- Generally easier for technologically advanced societies and for societies with resources
- For example, Bjorn Lomborg proposed solutions.

Major Mitigation Strategies

1. Replace fossil fuel electricity with wind and solar
2. Electric vehicles
3. Green hydrogen
4. More nuclear

CAN RENEWABLES (WIND, SOLAR, AND HYDROELECTRIC) POWER THE PLANET?


ELECTRICITY IS
THE HEART OF
THE ENERGY
INFRASTRCTURE
ENERGY IS THE
LIFEBLOOD OF
CIVILIZATION

Units of Energy and Power

- Joule – unit of energy. Approximately the energy required to lift an apple one meter.
- Watt – Unit of power equal to the expenditure of one Joule of energy in a second
- kW – Kilowatt. 1000 Watts of power.
- MW – Megawatt. One million Watts of power.
- GW – Gigawatt. One billion Watts of power.
- kWh, MWh, etc. – Units of energy

Power = Energy Use Per Time

Energy Expended = Power × Time

IT'S ALL ABOUT POWER (ENERGY) DENSITY

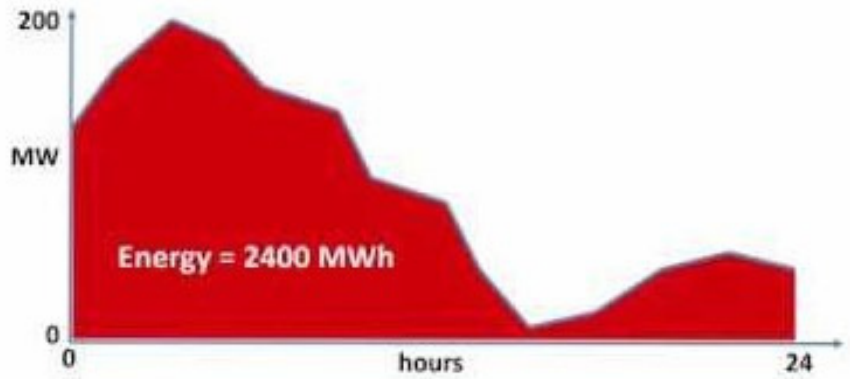
Energy Source	Energy Density (MJ/kg)
Wood	16
Coal	18 - 25
Gasoline	45
Natural gas	50 - 55
Hydrogen	5
Li-ion battery	0.46 – 0.72
Enriched uranium	3,800,000
Breeder Rx uranium	28,000,000

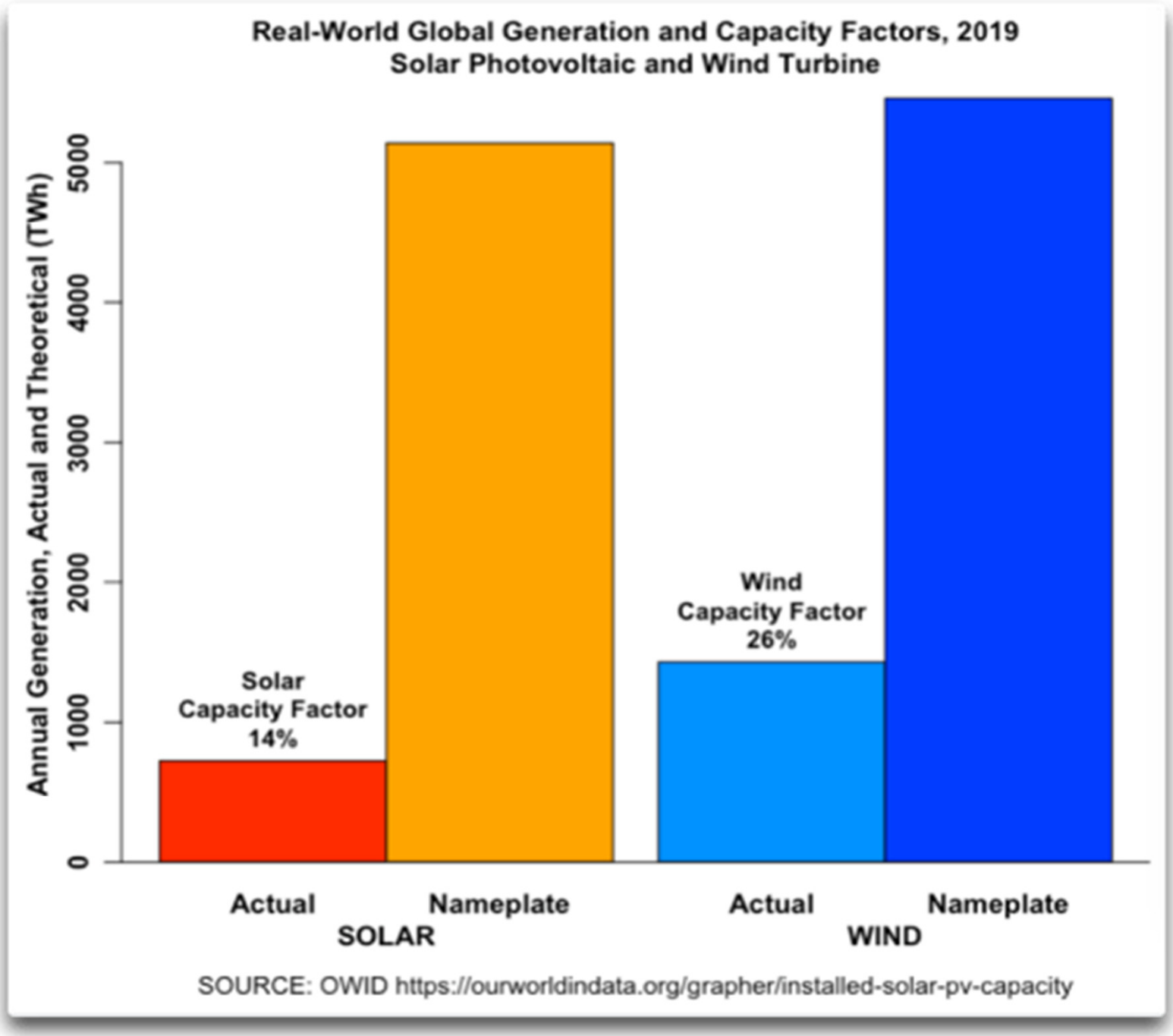
… for Power Plants It's All About

Capacity Factors

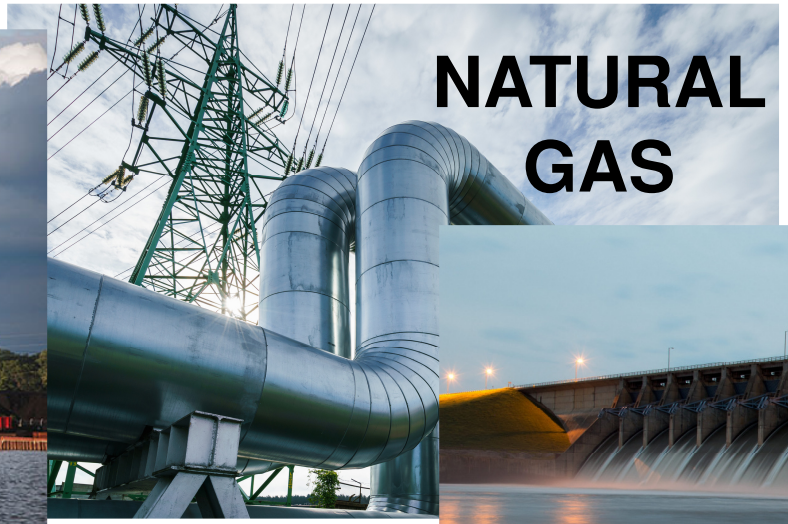
- Measures the performance of a power plant
- Equals the amount of energy produced by a plant during some time period (typically a year) to the total amount of energy that would have been produced during that same time period had the plant operated at 100% power capacity.

$$\text{Capacity Factor} = \frac{\text{Actual ENERGY Generated (MWh)}}{\text{CAPACITY (MW) x TIME Period (h)}}$$




Real-World Global Generation and Capacity Factors, 2019
Solar Photovoltaic and Wind Turbine
Annual Generation, Actual and Theoretical (TWh)
0
1000
2000
3000
4000
5000
Solar
Capacity Factor
14%
Wind
Capacity Factor
26%
Actual
Nameplate
SOLAR
Actual
Nameplate
WIND
SOURCE: OWID https://ourworldindata.org/grapher/installed-solar-pv-capacity

ELECTRICITY IS AN ENERGY CARRIER NOT AN ENERGY SOURCE



IS THE FUTURE OF ELECTRICITY WIND AND SOLAR?

A utopia, not anymore: 100% renewable energy now achievable!

Can Renewables power the planet?

The "Mark Jacobson Paper”

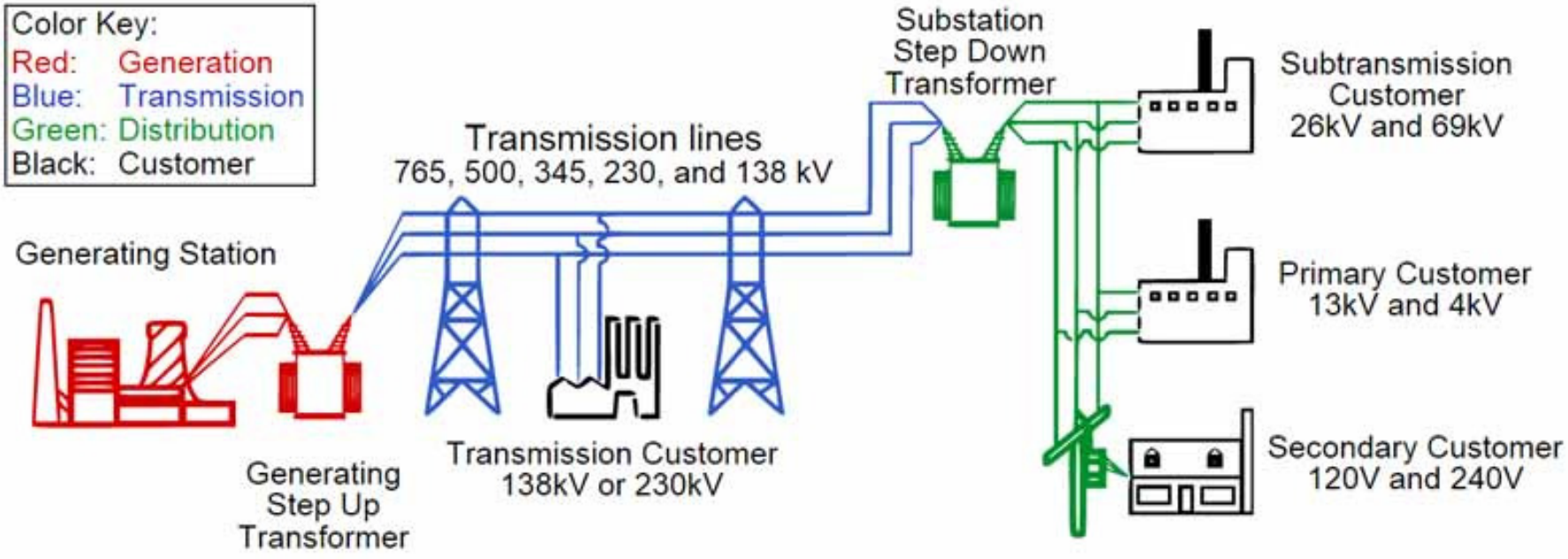
- Entire U.S. energy sector could be electrified completely by wind, solar, and hydro by 2050-55
- “Social cost" less than that for fossil fuels
- 21 “experts” published a review in 2017 that **savaged** Jacobson’s arguments
- Jacobson sued the National Academy of Sciences (NAS) and lead author for $10 million in damages

The Jacobson Paper Summarized

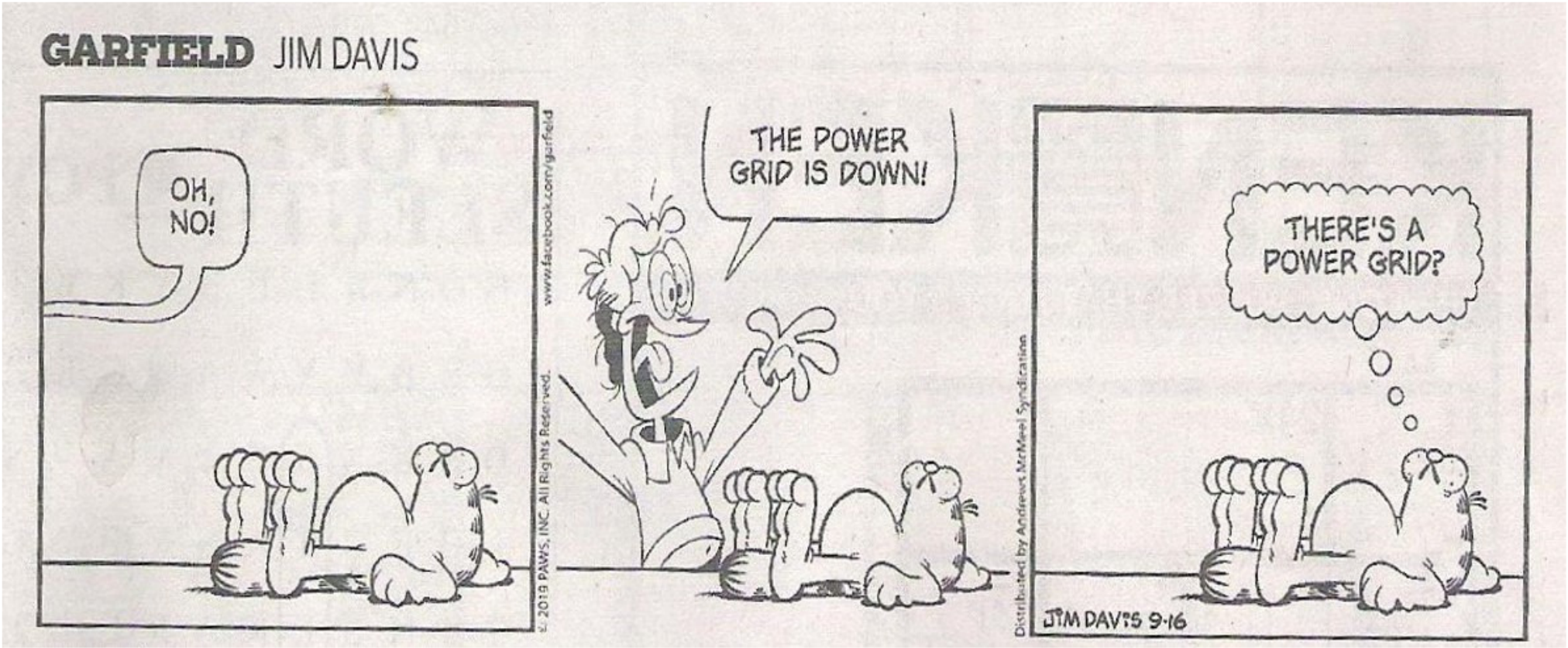
“There are some ideas so absurd that only an intellectual could believe them.” – George Orwell

“It is a tale told by an idiot, full of sound and fury, signifying nothing.” -- Macbeth

THE ELECTRIC POWER GRID



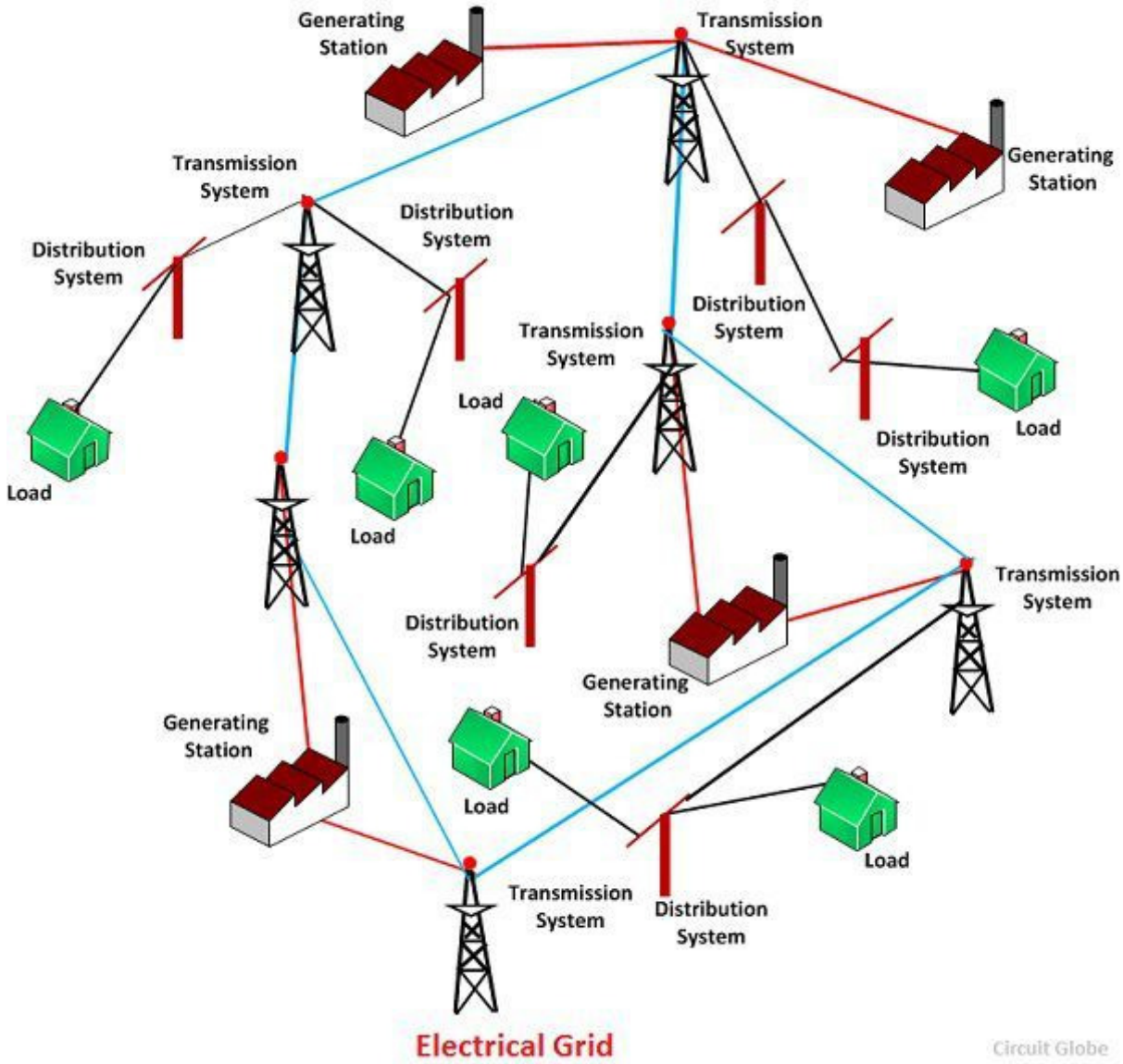
LARGEST "MACHINES" EVER MADE



U.S. Electric Power Grid:

- > 9,200 electric generating units
- > 1 million MW electric capacity
- > 300,000 miles of transmission lines

What happens at any point on the grid affects what happens everywhere else on the grid



ELECTRICAL POWER TRANSMISSION

- Electricity is an **energy carrier**
- The grid does **NOT STORE ENERGY**
- Electrical power generation must instantaneously match the electric power demand $Power_{produced} = Power_{consumed}$
- Storing electrical energy on a large scale is very **DIFFICULT** and **EXPENSIVE**!
- Frequency of the grid alternating current **MUST BE** maintained at **60 Hertz**
- System operators are constantly engaged in a delicate balancing act

Although not easy to understand, the concepts of grid **SYSTEM INERTIA and REACTIVE POWER** are key to maintaining grid reliability and preventing power blackouts!

SYSTEM INERTIA

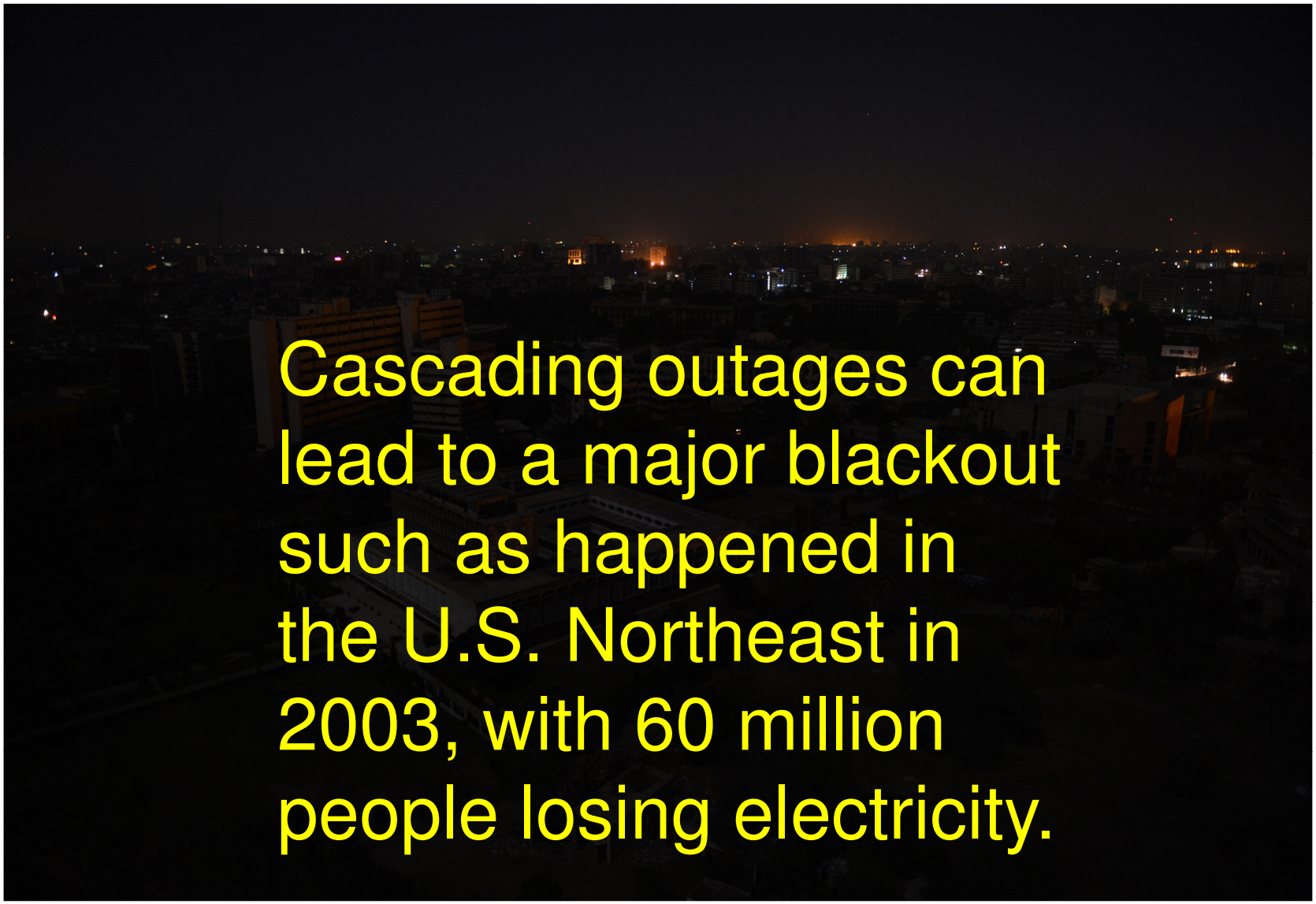
- Supplied by fossil and nuclear power plants and hydroelectric dams → Turbines spin at 60 Hertz
- **Helps maintain grid stability** by maintaining the 60 Hertz frequency during system events
- **Wind and solar do NOT provide inertia**

If demand exceeds the production capacity of the grid, stability can only be maintained by **Load Shedding**:

Brownouts (voltage drop 10% - 25%)

Rolling Blackouts

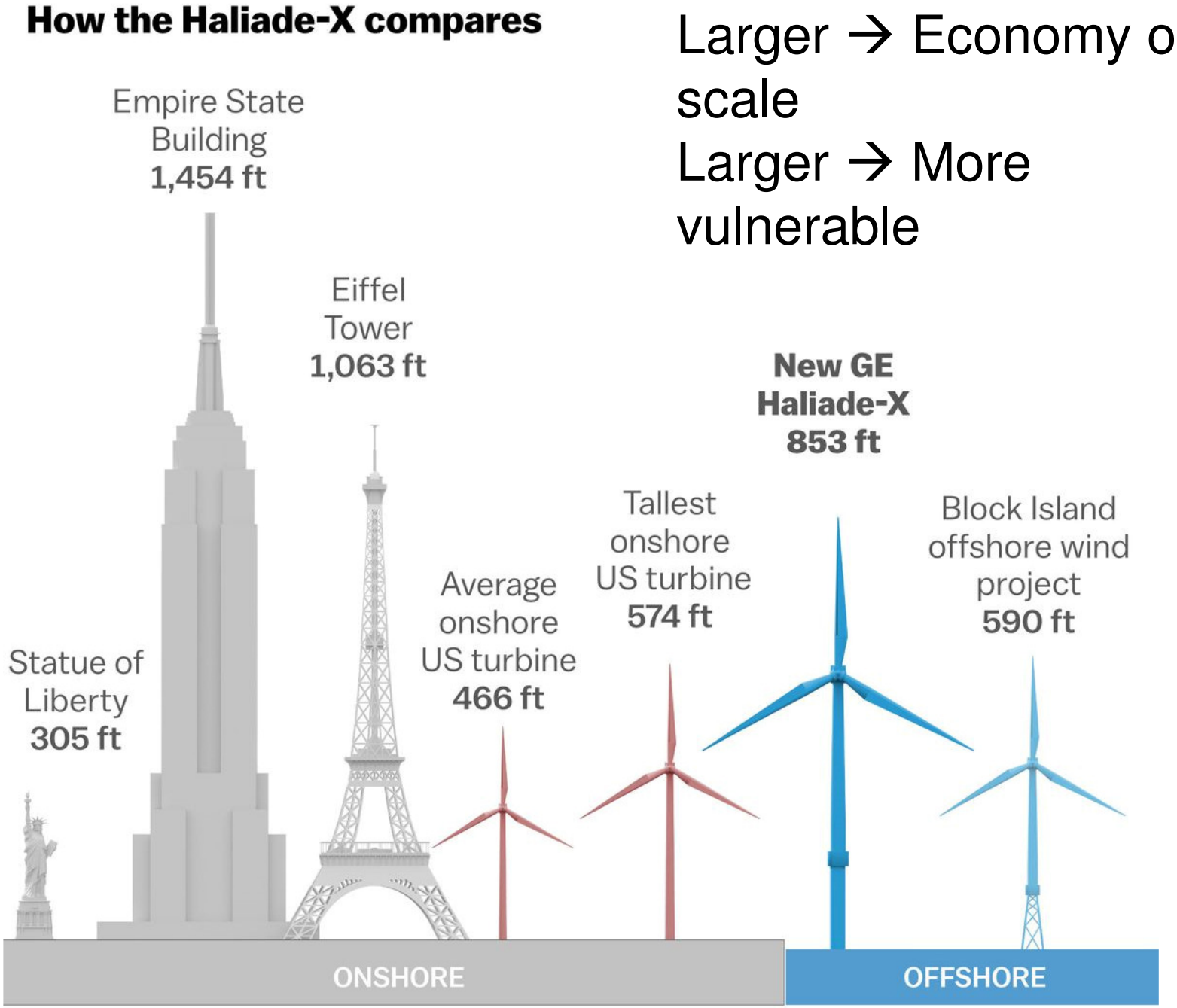
Load shedding can result in a domino effect → Shutting down a part of the customers can produce a severe strain on the rest of the network



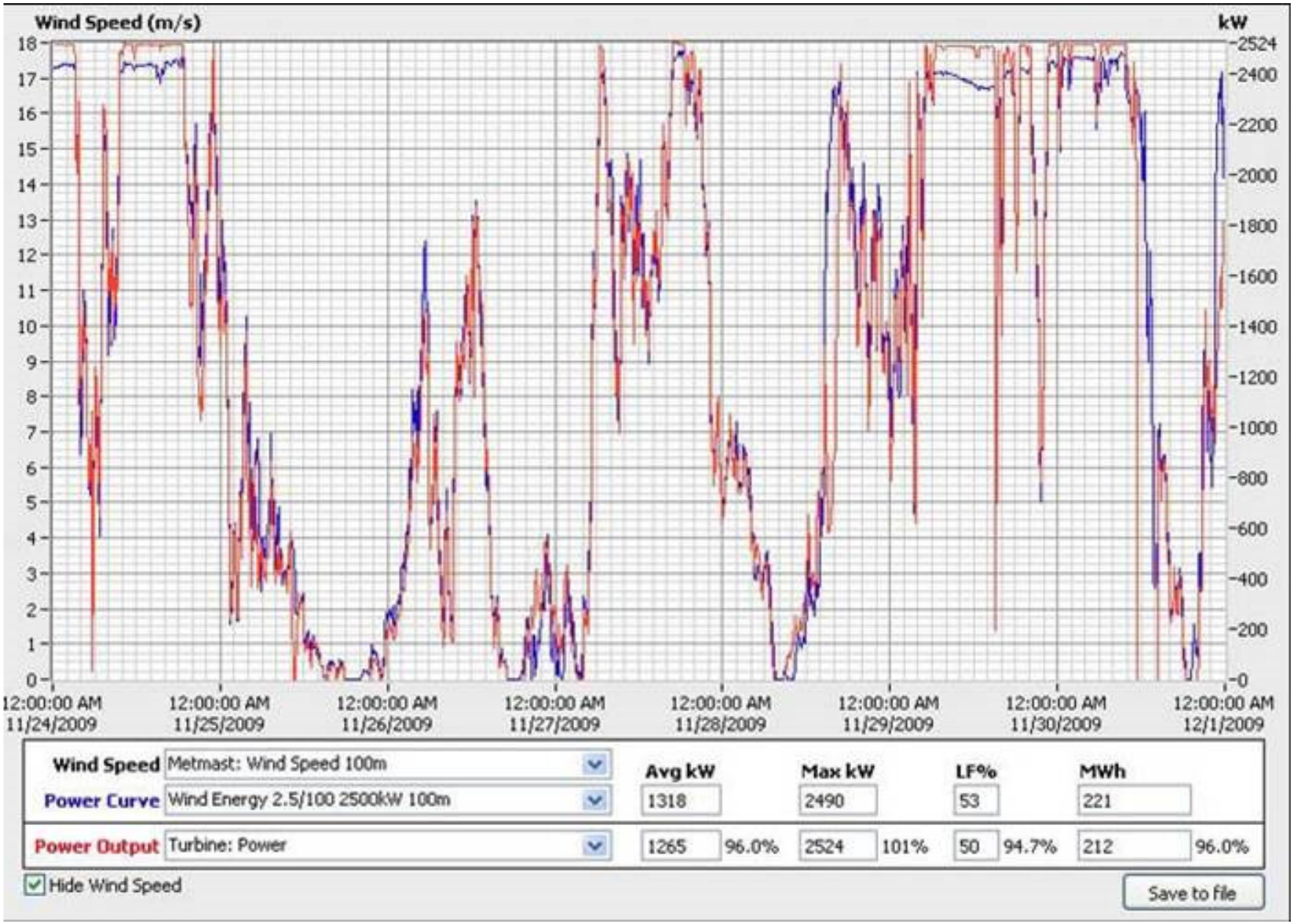
Wind and Solar Cons

1. Unpredictable → Not dispatchable
2. Low capacity factors
3. Provide no system inertia
4. Low power density
5. Expensive! Need Dispatchable Backup. Grid Restructuring
6. Significant environmental impact
   - Wildlife: birds, bats, whales
   - Raw material requirements including **Land**
   - Disposal requirements

Larger → Economy of scale
Larger → More vulnerable



Wind and solar power can vary widely and unpredictably over time

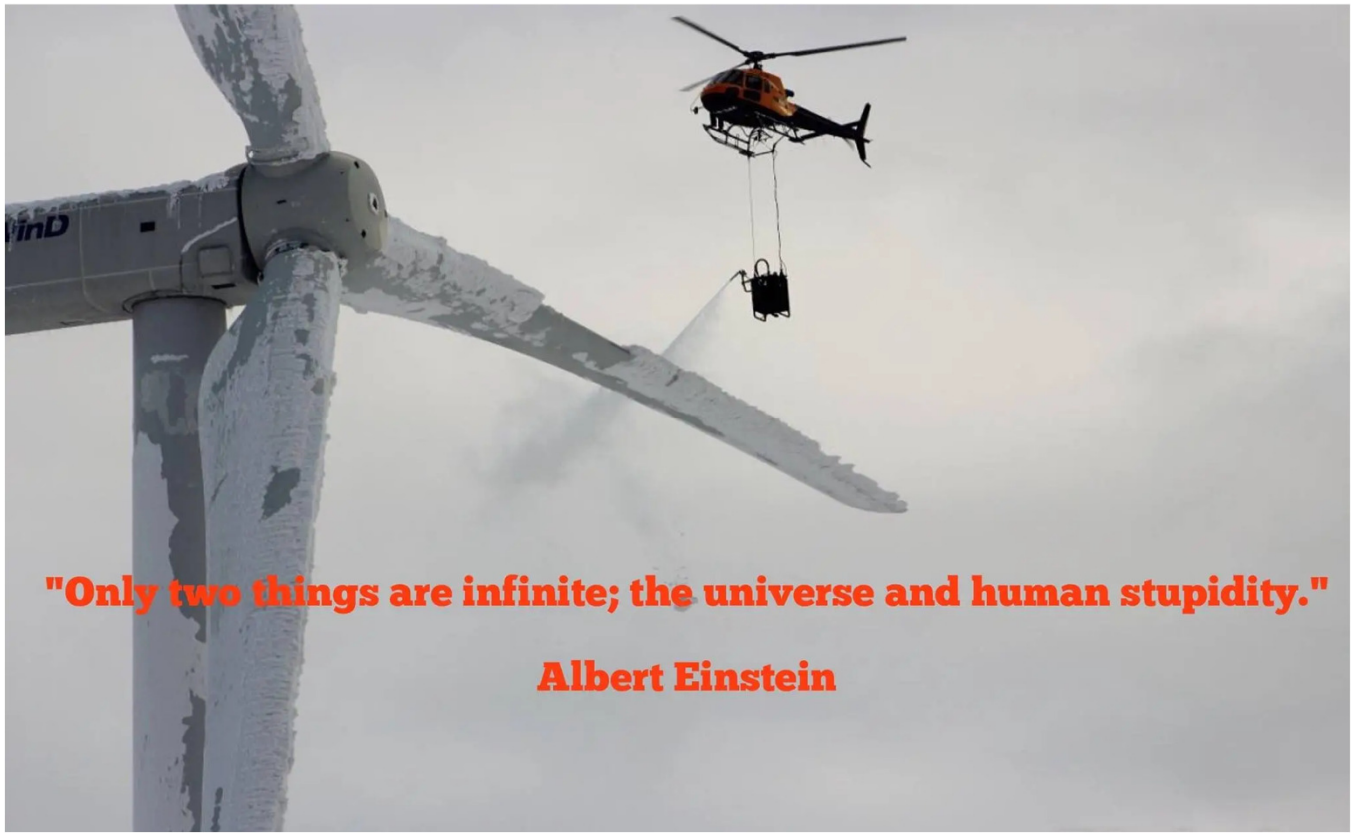


TOO GREAT A RELIANCE ON WIND AND SOLAR CAN CAUSE THE GRID TO COLLAPSE

Texas Extreme Cold Event (Feb. 2021)

- Over 200 deaths, over $195 billion damage
- Market cost rose to a peak of $9000 per MWh!

→ 90x typical residential cost of electricity



ERCOT = Electric **RELIABILITY** Council of Texas

Texas power grid was **< 5 MINUTES** from collapse.
Black start of the grid would require at least 8 days.

Irony: Solution to AGW (Adverse Weather) Is to Build Energy Sources Dependent on the **Weather**!?

Wind turbines damaged by Typhoon Yagi (Sept. 2024)

10,000+ acre Texas solar farm obliterated by hail storm (March 2024)

Why then do we continue to build Wind and Solar?

In many countries Wind and Solar:

- Heavily promoted by politicians and environmentalists
- Receive various forms of government subsidies
- Are mandated by law
- 2023 global new renewable investment ~$735 billion (IEA)

"For example, on wind energy, we get a tax credit if we build a lot of wind farms. That's the only reason to build them. They don't make sense without the tax credit."
– Warren Buffet

The PLAN to make Wind and Solar Reliable

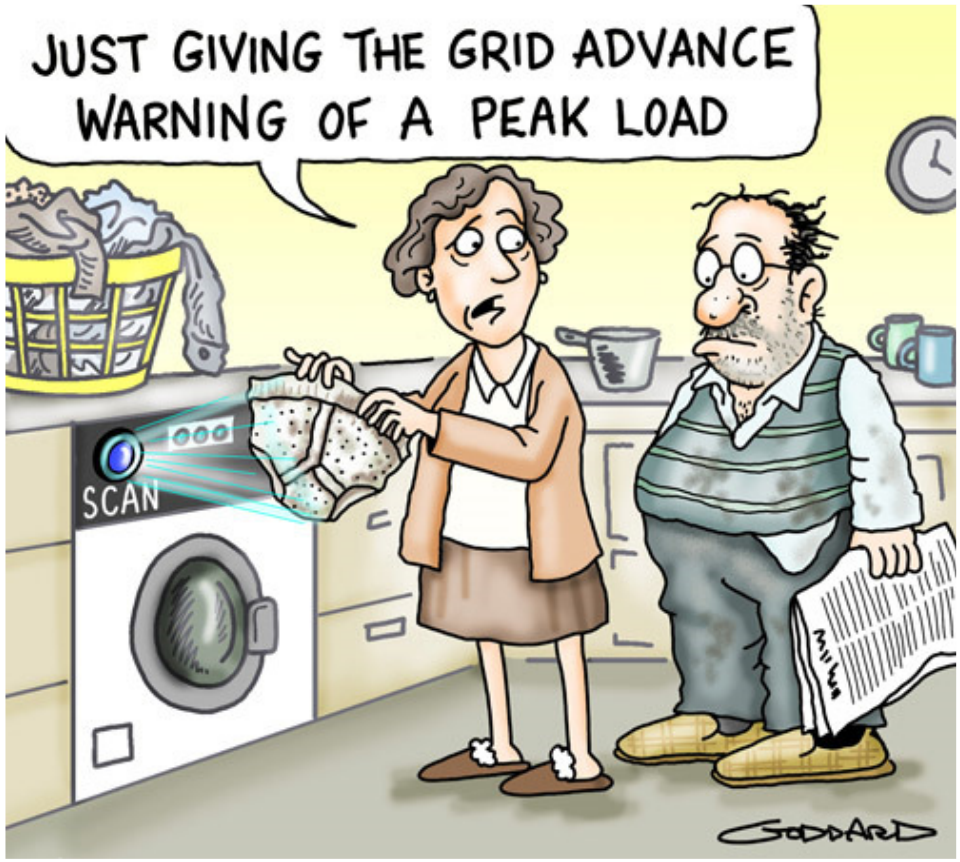
- The Smart Grid
- Energy Storage (Batteries!)
- Wishful Thinking

The laws of physics have no respect for ignorance or wishful thinking.

"We live at a time when emotions and feelings count more than truth and there is a vast ignorance of science." – James Lovelock

THE SMART GRID

- Allows two-way communication between the customer and the utility
- Monitoring of transmission lines
- Major benefits: More resilient response to prevent blackouts and balance demand and supply
- Example: Cheaper rates for EV owners charging during off hours
- Are benefits worth the cost?
- Major drawback: Control individual's power usage



Can battery backup solve Wind and Solar's Reliability Problems?

Lithium Requirements for Battery Backup

- Li-ion battery requirements to store 100 hours of energy from a single 1000 MW plant.
- Requires 32,000 tons of lithium.
- In 2018, the global production of lithium was 62,000 tons! (Angwin)
- 2022 global production of lithium was 130,000 tons, up 21% from 2021. (Statista)

Note: Energy Institute has 95,000 tons (2018) and 158,000 tons (2022)

ANSWER: NO!

MIT Li-ion Battery Study

Meeting 80% of US electricity demand with wind and solar would require either a nationwide high-speed transmission system, which can balance renewable generation over hundreds of miles, or ***12 hours(!)*** of electricity storage for the whole system.

At current prices, a battery storage system that size would cost $2.5 trillion.

(James Temple, MIT Technology Review, July 27, 2018)

"Sustainable development scenario" by 2040 would require:

- 42-fold increase in lithium demand,
- 25-fold increase in graphite demand,
- 21-fold increase in cobalt demand,
- 19-fold increase in nickel demand, and
- 7-fold increase in rare earth demand

(IEA, 2023)

Cost of adequate battery backup for U.S. powered by wind and solar **>$23 trillion**

[Source: Michael Shellenberger testimony before the U.S. Senate Committee on Energy and Natural Resources – 3/11/2021]

U.S. 2022 GDP:	$25.5 trillion
U.S. National Debt (Oct. 2023)	$33.6 trillion

It is nonsense to talk about power consumption.

Power is **not** consumed

Energy is consumed

The size of a power plant is given by its power or capacity rating—e.g., 1000 MW (megawatt) plant.

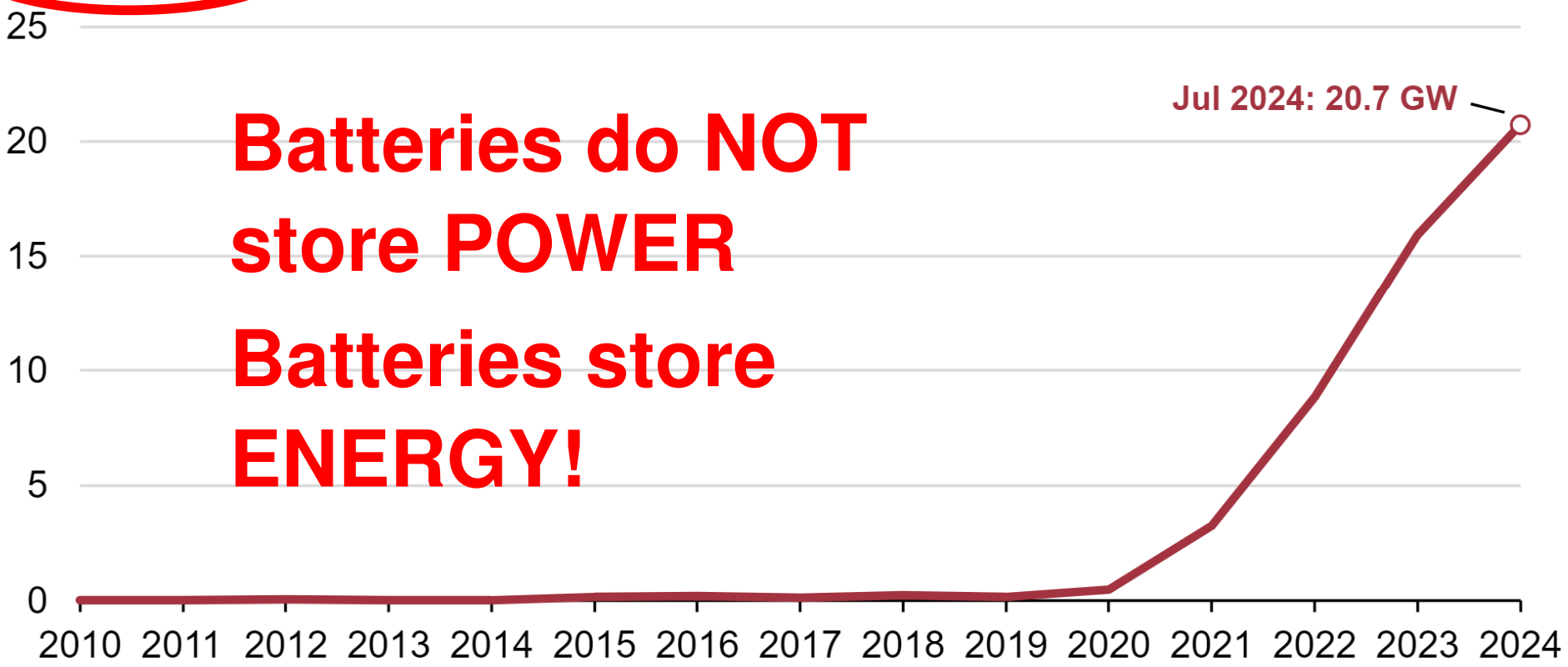
What's important is how much energy a plant produces.

A plant that doesn't run produces **NO** energy.

What does this mean?

Cumulative U.S. utilty-scale battery power capacity (2010–Jul 2024)

gigawatts (GW)



Batteries do NOT store POWER

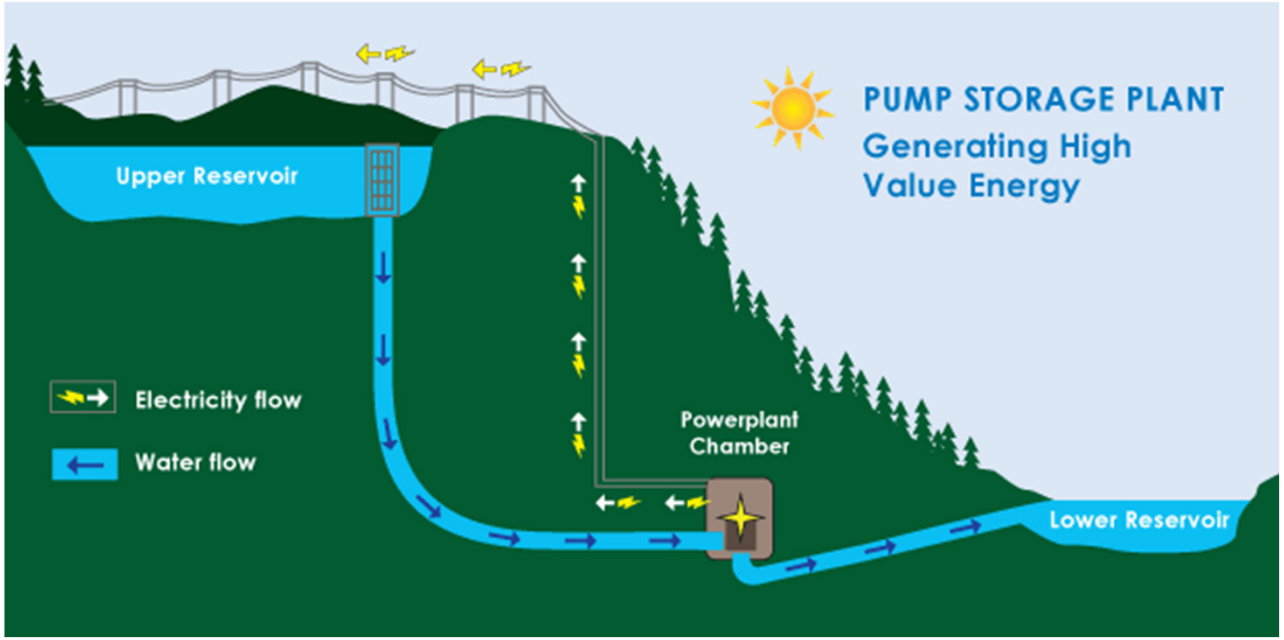
Batteries store ENERGY!

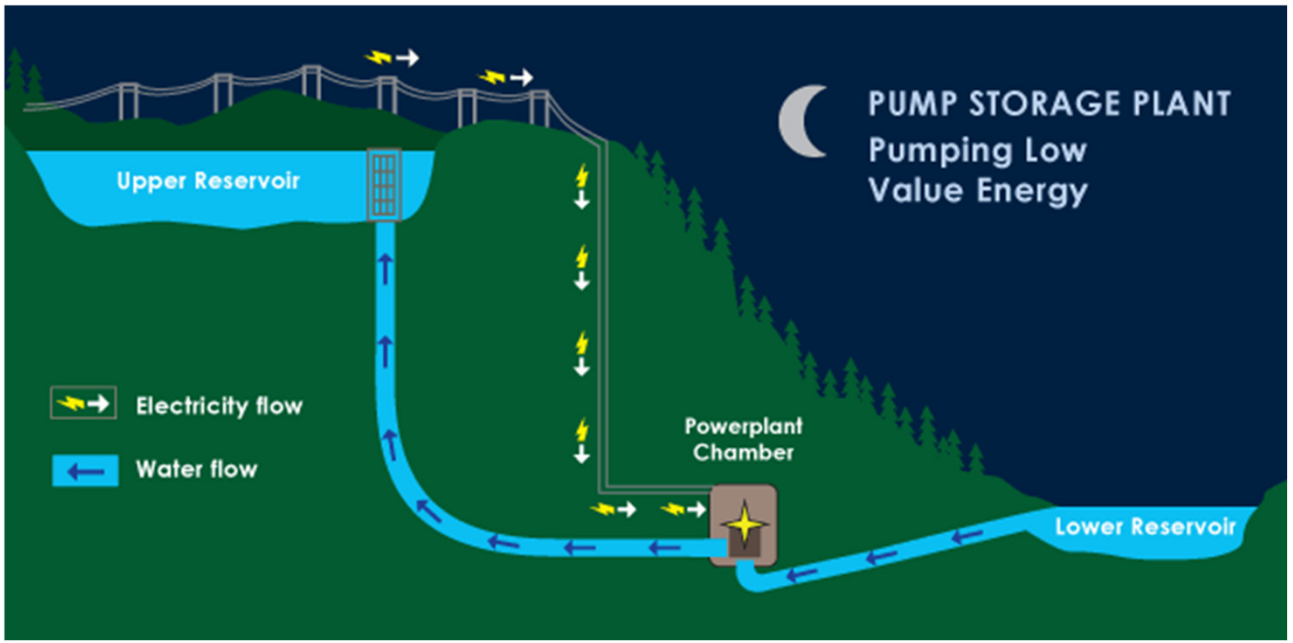
Why is Dominion Energy building a 2.6 GW $10 billion offshore wind farm?

Clean Economy Act passed by **Virginia** State Legislature in March, 2020:

- Dominion Energy be 30% carbon-free electricity by 2030, 100% by 2045
- >16 GW solar/wind by 2035 with 5.2 GW offshore wind by 2034
- **3.1 GW storage by 2035 (This makes no sense! Batteries store energy, not power.)**

Pumped Storage Hydropower





Only practical storage But…

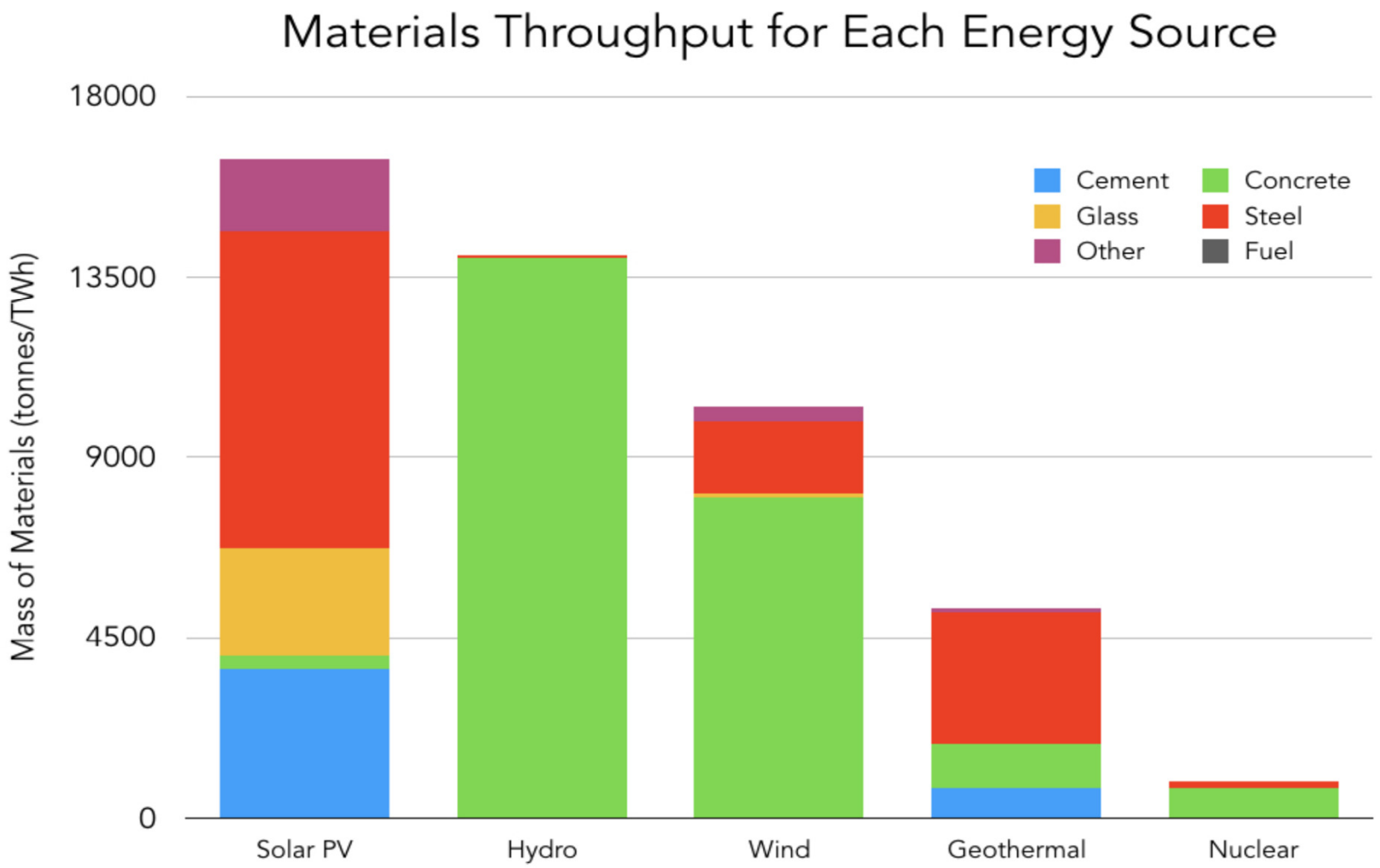
- Limited locations due to geology
- Heavy opposition by environmental movement

Bath County, VA 24,000 MWh (Largest until 2021, now Fengning, China)

To maintain grid stability in meeting increased power demand:

Every MW of new wind and solar capacity added requires an additional MW of reliable conventional power capacity (fossil or nuclear) to be added!

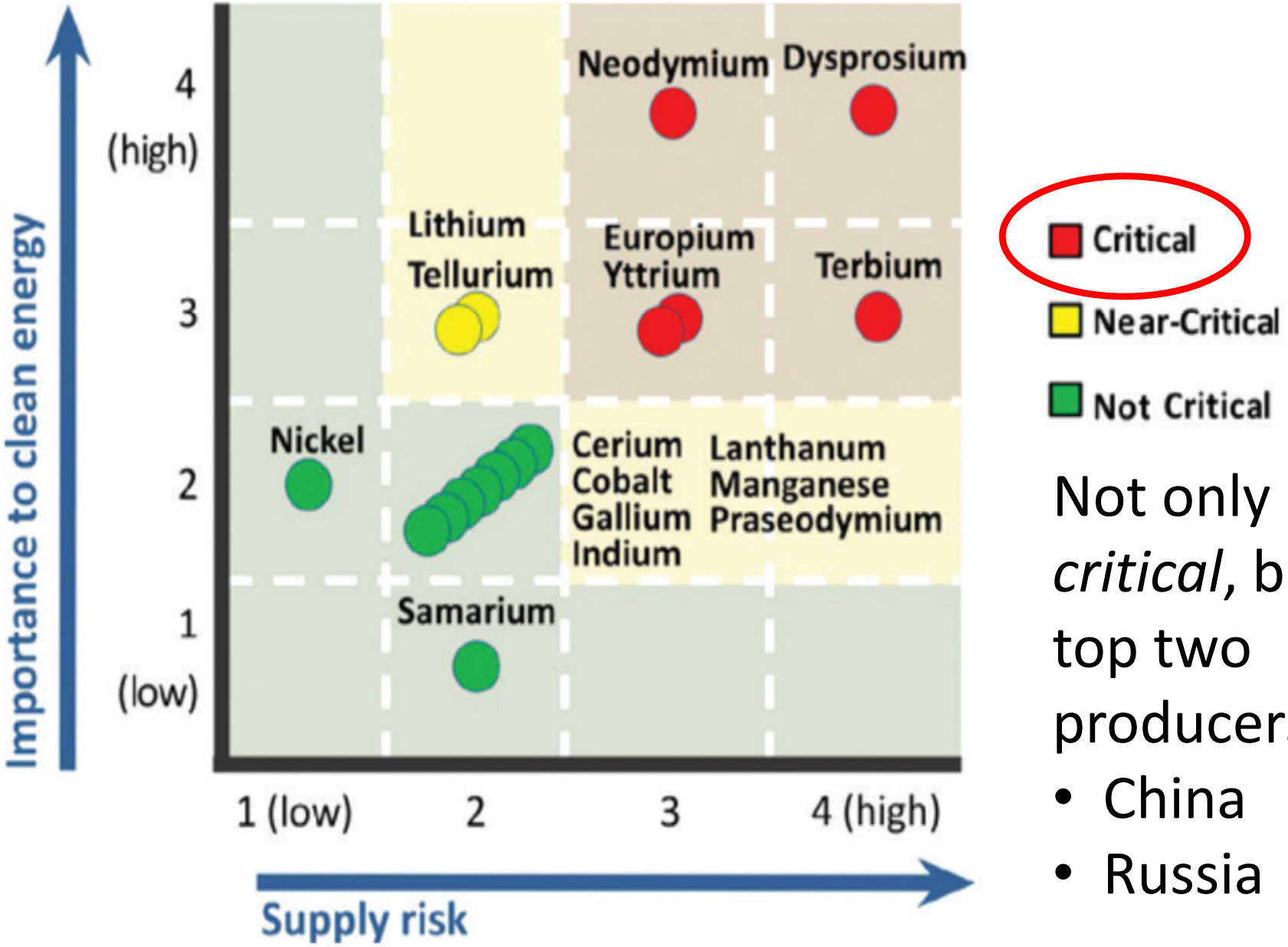
RESOURCE AND WASTE DISPOSAL REQUIREMENTS FOR SOLAR AND WIND



ENVIRONMENTAL PROGRESS

Sources: DOE Quadrennial Technology Review, Table 10.4
Murray, Raymond L. Holbert, Keith E.. (2015). Nuclear Energy - An Introduction to the Concepts, Systems, and Applications of Nuclear Processes (7th Edition). Elsevier.

Omits Solar/Wind Backup Requirements



Not only *critical*, but the top two producers are:

- China
- Russia

Natural resources of importance for wind and solar energy production

Solar PV Cells contain TOXIC MATERIALS

Boy in Guiyu, China, atop a pile of electronic waste

Disposal of used wind turbines and PV cells?

Playground, Rotterdam

South Point, Hawaii, wind farm (*UK Daily Mail*, 3/18/2012)

- Wind turbine rotor blades contain glass and carbon fibers that give off dust and toxic gases.
- U.S. ~1.2 million tons of blade material to dispose of by 2040 (EIA, 2016)

Former site of the Connecticut Yankee Nuclear Power Plant

Requirements for an Effective Electric Power Generation

Requirement	Coal	Gas	Hydro	Wind -Solar	Nuke
Dispatchable	XX	XX	XX		XX
Provide unlimited % of generation	XX	XX		X	XX
Minimize environmental impact		X	X		XX
Little backup	XX	XX	XX		XX
Support grid stability	XX	XX	XX		XX
Long turn sustainable	X	X	X	X	XX
Fuel on site	X		X		XX
Close to customers	XX	XX			XX

XX = Excellent X = So-so Blank = Poor

Can We Even Power A Grid With Only Wind and Solar?

Before building a Zero Emissions National Power Grid, should we not first have a demonstration that such a thing is actually feasible?

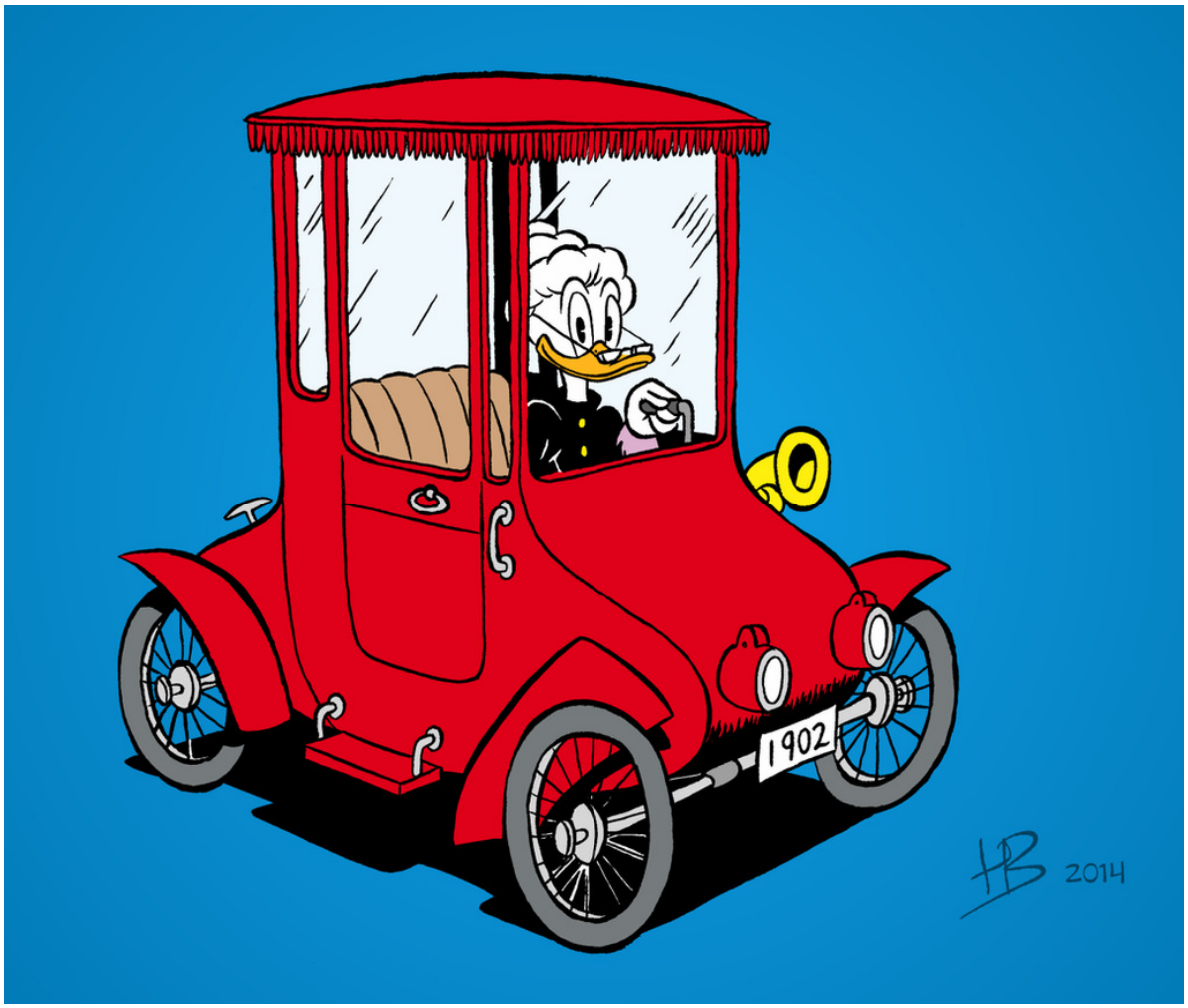
Gorona del Viento Project on El Hierro Island (Canary Islands) – On-line 2014

- 5 Wind Turbines (11.5 MW each)
- Pumped-storage hydro backup (270 MWh → 54-68 hours on average)
- 10,000 customers
- Average electricity demand 4-5 MW
- Peak demand ~7.5 MW

Results

- In 2023, system supplied 35%
- 65% from backup diesel generators
- Best performance, July 62%
- Poorest performance, October 10%

Electric Vehicles



Nothing new about Electric Vehicles (EVs)

Electric Battery Vehicle (EV) Pros

- Can 'refuel' from home
- Faster acceleration
- Quiet
- Simpler maintenance
- Lower fuel costs (?)

Electric Battery Vehicle (EV) Issues

- More expensive (may change with time)
- Limited range
- Longer refueling time
- Performance decreases with temperature
- Batteries require many rare materials
- Shorter lifetime (battery replacement)?
- Requires new infrastructure (e.g., fast charging stations)

Li-ion batteries classified as dangerous goods for transportation.

Wind, Solar and EV Issues

- Although no emissions during operation, they export emissions elsewhere.
- Mining of ~500,000 lb of materials required to make one typical EV 1000 lb battery
- Present plans require demand for such materials as lithium, cobalt and zinc to increase between 400% and 4000%

35% of all new cars and trucks sold in Virginia with a 2026 model year must be EVs (100% by 2035)

Samsung Oxide All-Solid-State EV Battery

- 600-mile charge in 9 minutes, 20-year lifetime
- Company estimates production ready by 2027
- Smaller, lighter, and safer than Li-ion batteries
- Less sensitive to cold temperatures

Energy density of 500 Wh/kg versus 270 Wh/kg of present EV batteries

Need increased electricity supply (larger grid) → more Fossil plants

Rapid Falloff In EV Sales

Europe

- 4th consecutive month drop in EV sales (Sept. 24)
- Germany August EV sales dropped 68.8%
- Italy August EV sales dropped 33.1%
- Smaller, lighter, and safer than Li-ion batteries
- Volkswagen may close factory, 15,000 job loss

US

- ~40% of EVs are in California
- Ford EV divison lost $4.7 billion in 2023, project 2024 loss ~$5 billion → Company has slashed EV production
- 2023 total auto sales $15.5 million, up 11.5%, highest since 2019

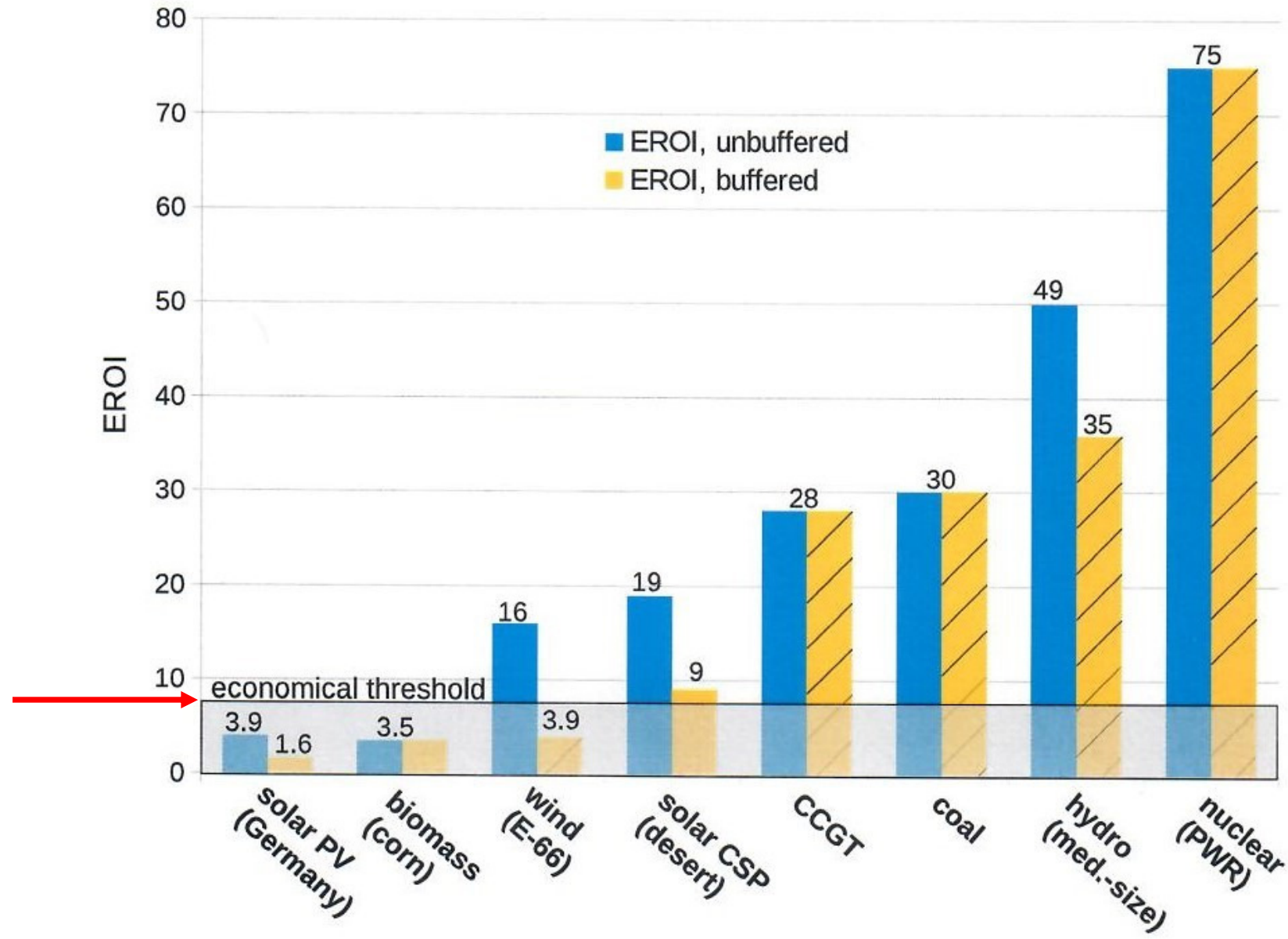
2023 global gasoline consumption exceeded 2019 peak (IEA)

ECONOMICS

LCOE (levelized cost of energy) often reported.
Poor metric in that it looks at plant in isolation.
A better metric is the EROI.
EROI, Energy Return on Investment, is the ratio of the usable energy delivered from a particular energy source to the amount of energy used to obtain that energy source.

$$EROI = \frac{Energy\ delivered}{Energy\ required\ to\ deliver\ that\ energy}$$

EROI reflects a more complete comparison of the economics of various types of energy sources.



Economic Threshold

CSP – Concentrated Solar Power

CCGT – Combined Cycle Gas Turbine

Source: Weissbach et al (2013)

Summary of Wind/Solar Issues

- Low power density
- Significantly larger resource requirements than other sources including land, materials and strategic minerals
- Environmental impact—mining, land use, and wildlife
- Few plans for decommissioning and recycling and disposal of materials, including many toxic
- Hidden costs—e.g., need reliable replacement power (overall electric bills rise with penetration of wind/solar), low EROI
- Power is unreliable and not dispatchable
- Wind turbine and solar PV efficiency degrades over time
- Energy storage both expensive and impractical

HYDROGEN

GREEN HYDROGEN

THE HYDROGEN ECONOMY

- An energy carrier → NOT an energy source
- Generation of hydrogen takes energy
- Difficult to store and transport due to small size of hydrogen molecule (takes even more energy)
- Hydrogen embrittlement (HE) – reduces ductility of metal by lowering stress required to form cracks
- Unless contained, hydrogen gas escapes into space
- Potentially explosive when mixed with oxygen
- Requires whole new infrastructure—production, storage, transportation and end-use appliances

FUEL CELL EVs

- A fuel cell converts the chemical energy of its fuel, typically hydrogen, to electrical.
- Hydrogen powered fuel cells are the most common.
- Operate with higher efficiencies (up to 60%) than combustion engines (20% - 30%) and have lower emissions.
- The byproduct of hydrogen fuel cells is …

WATER!

Sounds Great!
So, what's the catch?

TANSTAAFL

"There ain't no such thing as a free lunch."

Hydrogen and Transportation

- Electric fuel cell vehicles → bulkier and heavier than gasoline vehicles
- Hydrogen storage may be more compact than battery electricity storage, but not more than for liquid fuels or natural gas.
- Large infrastructure required to support hydrogen transportation.
- **Enormous increase in electricity demand** if hydrogen generated by electricity, or
- **Huge increase in natural gas demand** if hydrogen generated from natural gas.

What is the difference between hydrogen and GREEN hydrogen?

GREEN hydrogen economy does not produce CO_2 either during the production of hydrogen or in its transportation and use.

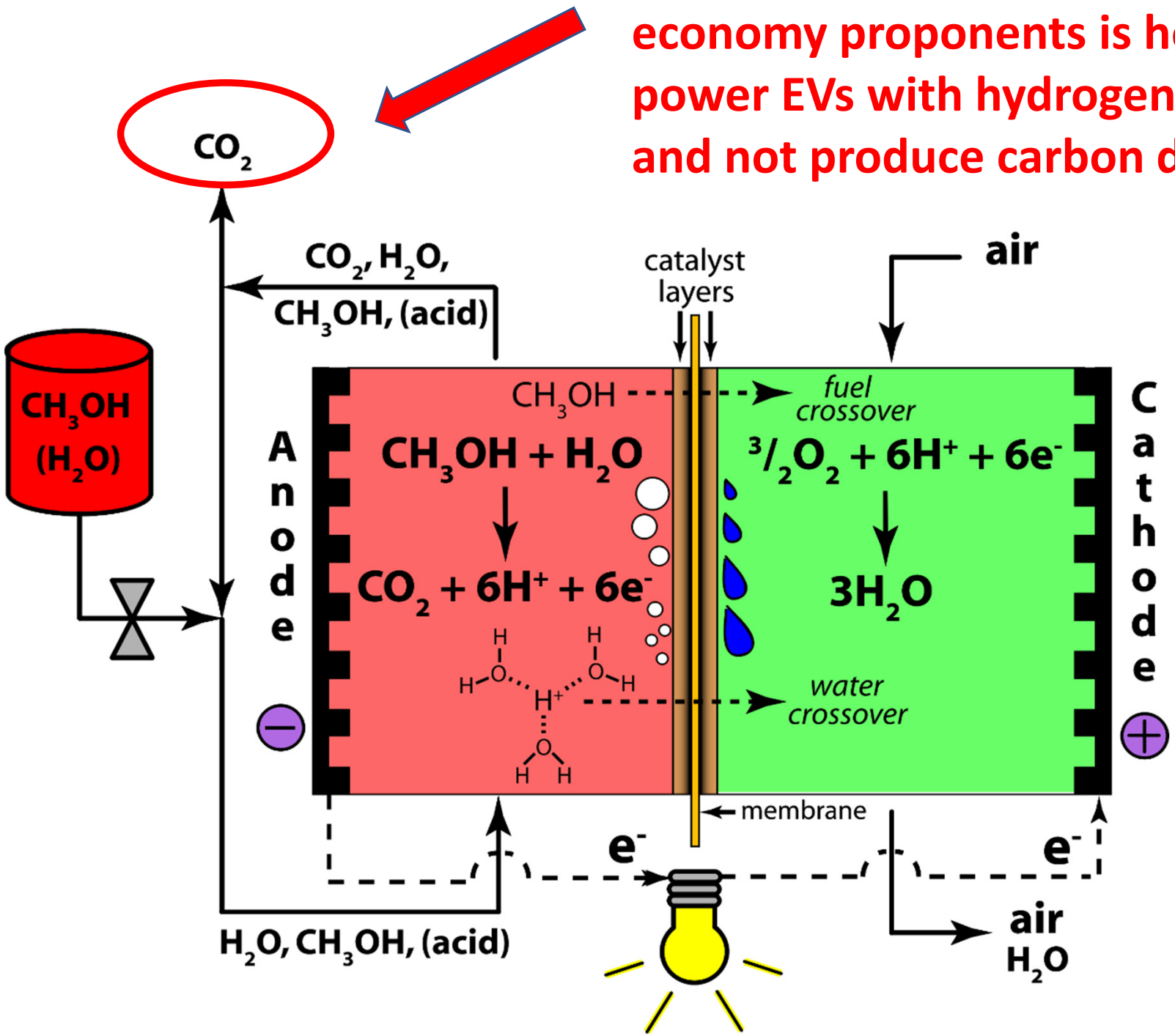
GREEN hydrogen economy: Hydrogen produced by a nuclear or renewable power plant and transported to the place of use by pipeline.

Electrical energy required to make, package, transport, store and transfer hydrogen may easily be double the actual hydrogen energy delivered.

Hydrogen Fuel Cells for Transportation
The Promise and the Reality

- Are EVs powered by hydrogen fuel cells practical? The answer is probably a 'qualified' YES.
- At present, a **green** hydrogen economy for transportation is probably **not** practical.
- Hydrogen fuel cells with direct generation of the hydrogen using carbon materials presently the most feasible.

The problem for the green hydrogen economy proponents is how do you power EVs with hydrogen fuel cells and not produce carbon dioxide?



Recent EPA Ruling

New GHG standard for fossil-fueled plant to be phased in starting in 2024

- Note: Coal plants with pollution controls reduce nitrogen oxides (NO_x) by 83%, SO_2 by 98%, and particulate matter by 99.8%
- From 1995-2022, SO_2 emissions fell by 93%, NO_x emissions by 87%
- New rule requires gas & coal-fired plants to cut CO_2 emissions by 90% by 2032 if they wish to stay open past 2039
- New rule imposes expensive new standards on construction of new gas fired plants.
- EPA rule assumes that new replacement power will always be available to replace lost capacity.
- Rule finalized April 2024

Electric Power Utilities Response (9/17/2024)

- Amicus brief states that the EPA rules will ***jeopardize Americans' ability to reliably secure sufficient amounts of power***
- Rules will force retirement of units that possess critical reliability attributes at the very time when such generation is needed
- Rules will jeopardize the available of adequate back-up generation to support an increasing amount of intermittent generation (i.e., wind and solar)
- Filed by Midcontinent Independent System Operator (MISO), PJM, Southwest Power Pool (SPP) and the Electric Reliability Council of Texas (ERCOT)
- Supply a combined 156 million customers

U.S. Wind and Solar

- Inflation Reduction Act tax credits cover 30% or more of new offshore wind project costs
- Inflation, higher borrowing costs, logistical problems and supply chain issues
- Newer, larger turbines face more mechanical issues
- Since start of 2023, ~60% of new U.S. offshore wind projects cancelled. (Cancelled Offshore Wind Projects since start of 2023: Two in New Jersey, Two in Maryland, Three in New England cancelled, Major New York project)
- GE renewable business lost $2.24 billion in 2022, $1.44 billion in 2023 (Wall Street Journal)
- Solar prices no long falling, but rising, prices nearly doubling since 2020 (Level Ten Energy Consulting)
- 32 U.S. Offshore Wind projects under development
- Global wind and solar installed capacity still growing

California

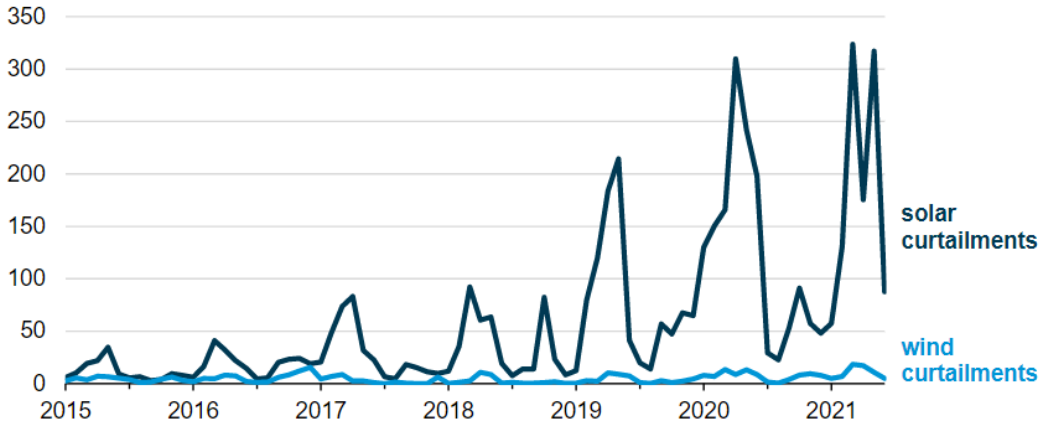
- CA cost of electricity: $0.36/kWH.
- National average cost of electricity: $0.19/kWh
- Summer, 2020: Over 800,000 California customers without power for over two days.
- August 2022, legislature bans sale of new gas automobiles by 2035.
- Days later state residents advised not to charge EV between 4 pm and 9 pm due to **power shortage**!
- As of August 2023, California has had **99 power outages in past 5 years**. Only Texas had more.

California (cont.)

AUGUST 24, 2021

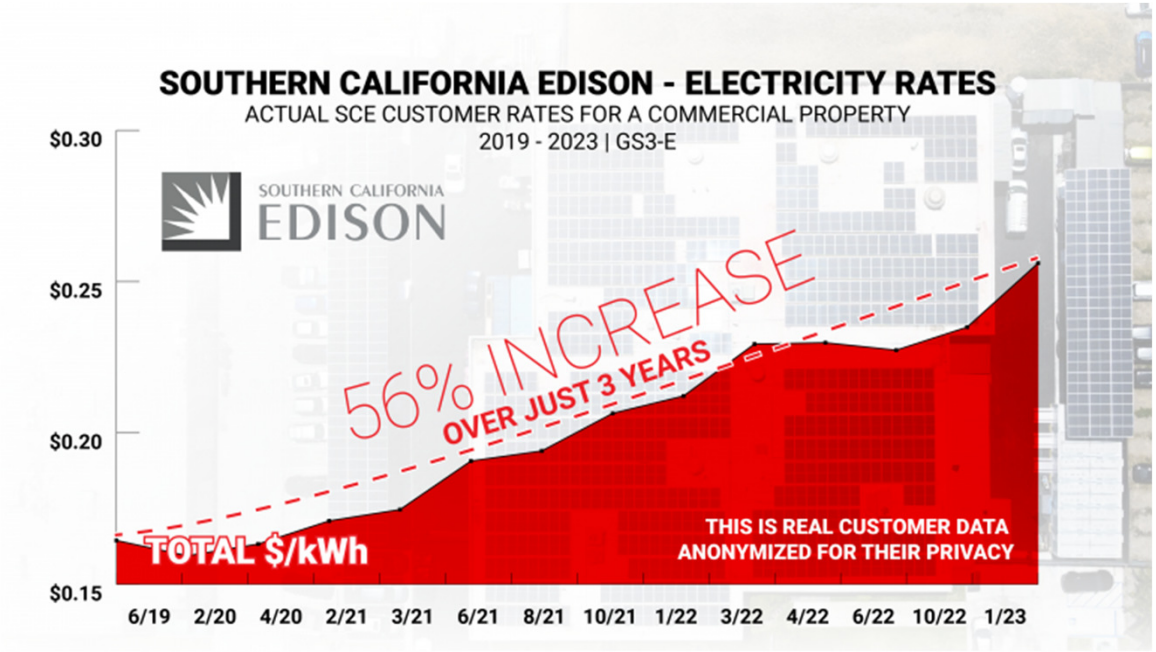
California's curtailments of solar electricity generation continue to increase

Monthly curtailments by the California Independent System Operator (Jan 2015–Jun 2021)
thousand megawatthours



Source: Graph by the U.S. Energy Information Administration, based on data from the California Independent System

"In politics, stupidity is not a handicap." – Napoleon Bonaparte



Germany

- ~44% wind and solar electricity in 2023
- Goal is 80% by 2030
- Electricity prices have risen ~60% since 2007, $0.38/kWh (Virginia $0.14/kWh)
- 25% of heavy industrial users considering leaving

- Shutdown 17 emission free reactors
- 2022 solar capacity factor ~10%
- GDP in decline since peak of Q3 2022
- 10 GWh of backup storage →
  10 minutes of backup
- Need estimated 21 to 42 days

United Kingdom

- Closing last coal plant, Ratcliffe
- Jan. 2024, Ratcliffe "ramped up" to deal with a windless cold snap with low sunshine. Provided 3.4% of load.
- UK's goal: decarbonize by 2030
- Building lots of solar. Encouraging rooftop solar.
- UK average sunshine per year = 1403 hours ≈ 117 days per year = 32% of days of year *
- 2023 solar capacity factor ~10%
- **Energy Security** and **Net-Zero** Secretary

* Richmond, 206 sunny days (up to 30% cloud cover), 106 partly sunny (40% - 70% cloud cover).

The Future Looks Promising

- Overall global quality of life is increasing
- Global food production ~10% greater than demand
- Infant mortality is decreasing
- Average life expectancy is increasing

- Global energy demand projected to increase 50% in the next 30 years (even not accounting for EVs and Artificial Intelligence demands?)
- Global population increasing by 80 million people every year.
- Energy choices are:

Everything we eat, wear, live in, or otherwise use was both produced and delivered through utilization of fossil fuels

Fossil Fuels

- Plentiful and reliable.
- Supports electric power grid stability.
- Supporting infrastructure already exists or is feasible to build.
- Has large environmental impact and political baggage.
- Has a multitude of other uses instead of being consumed for energy.
- Continue to be the important for transportation.
- Electricity and thermal power.

… and NUCLEAR POWER

Positives

- Rate of population increase is decreasing
- Nuclear fission promises energy for tens of thousands of years
- Nuclear fusion → no foreseeable limit to energy supply

In Summary

What is the actual existential threat?

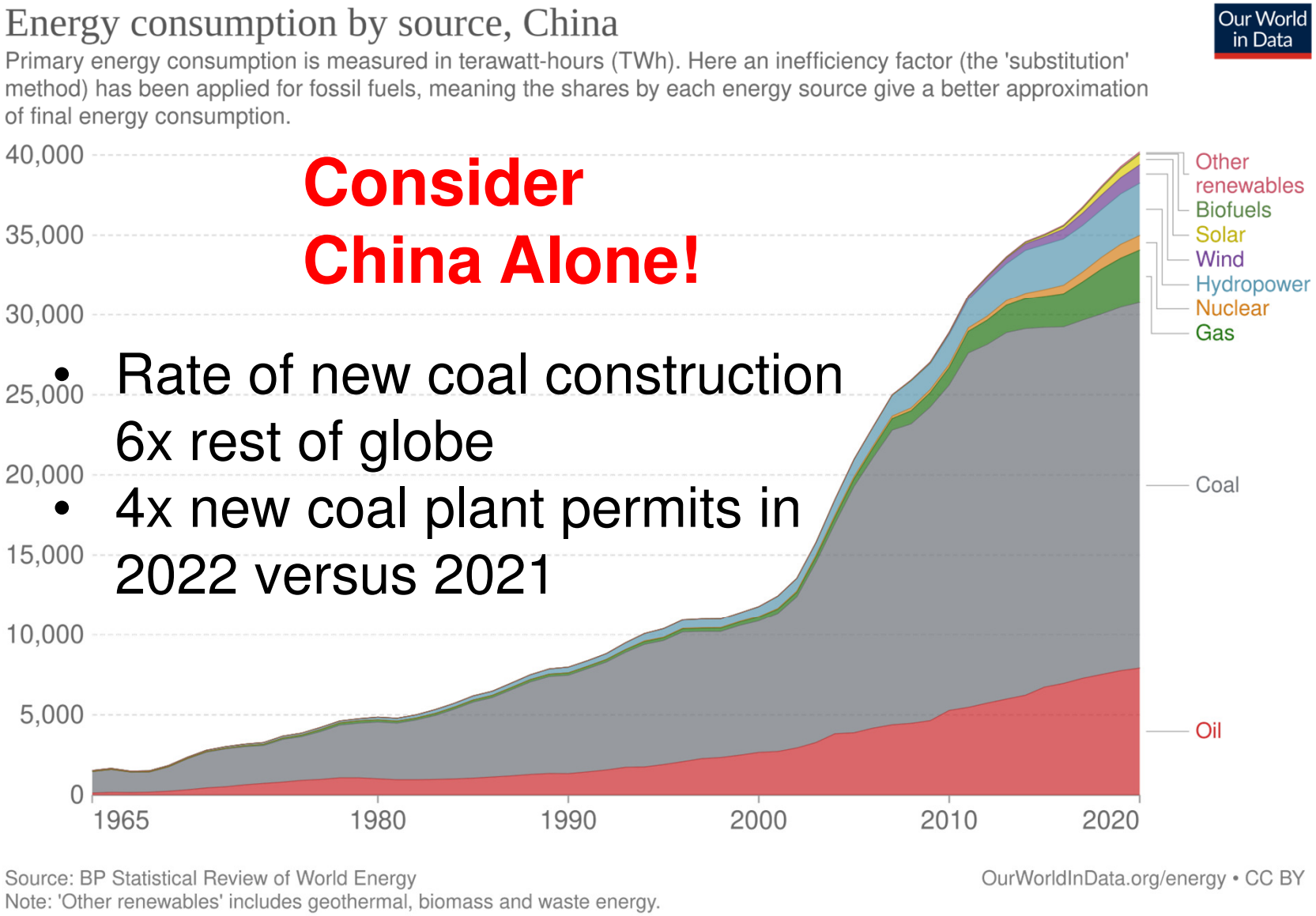
AGW

Or

the Proposed Solution?

What U.S. & Europe do doesn't matter!

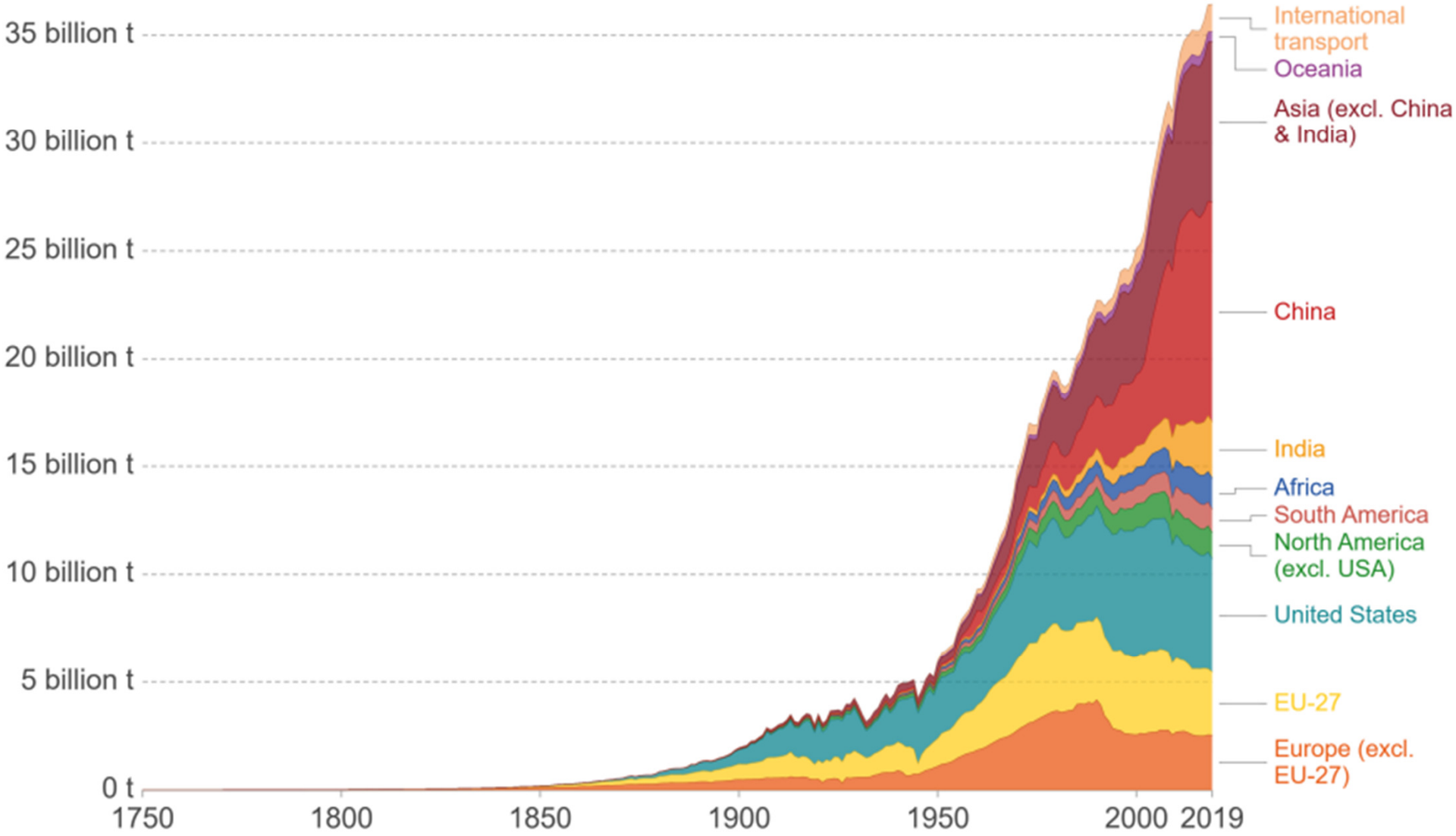
Increased Global Use of Fossil Fuel



Annual total CO_2 emissions, by world region

This measures CO_2 emissions from fossil fuels and cement production only – land use change is not included.

Our World in Data

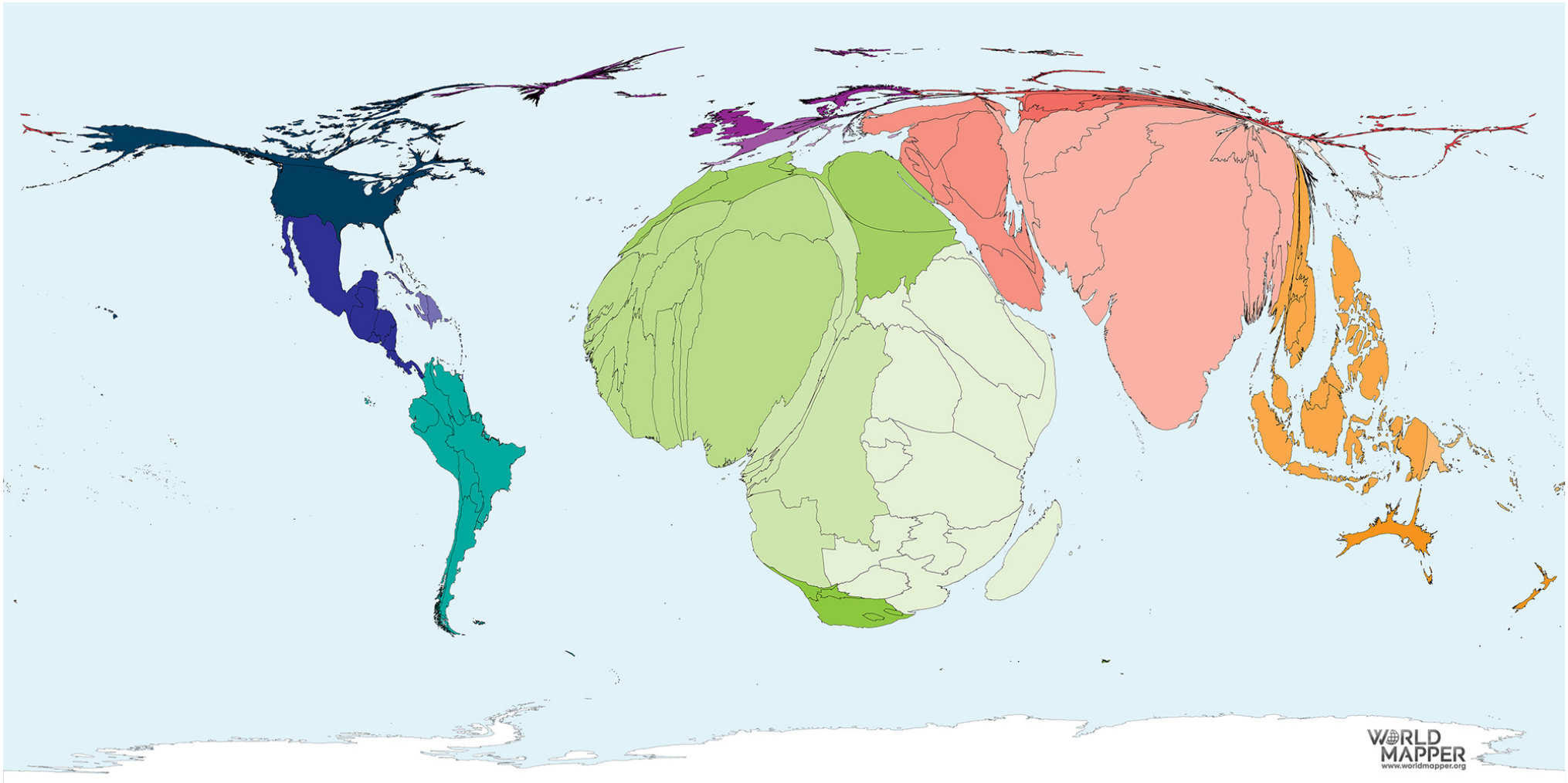


Source: Our World in Data based on the Global Carbon Project

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

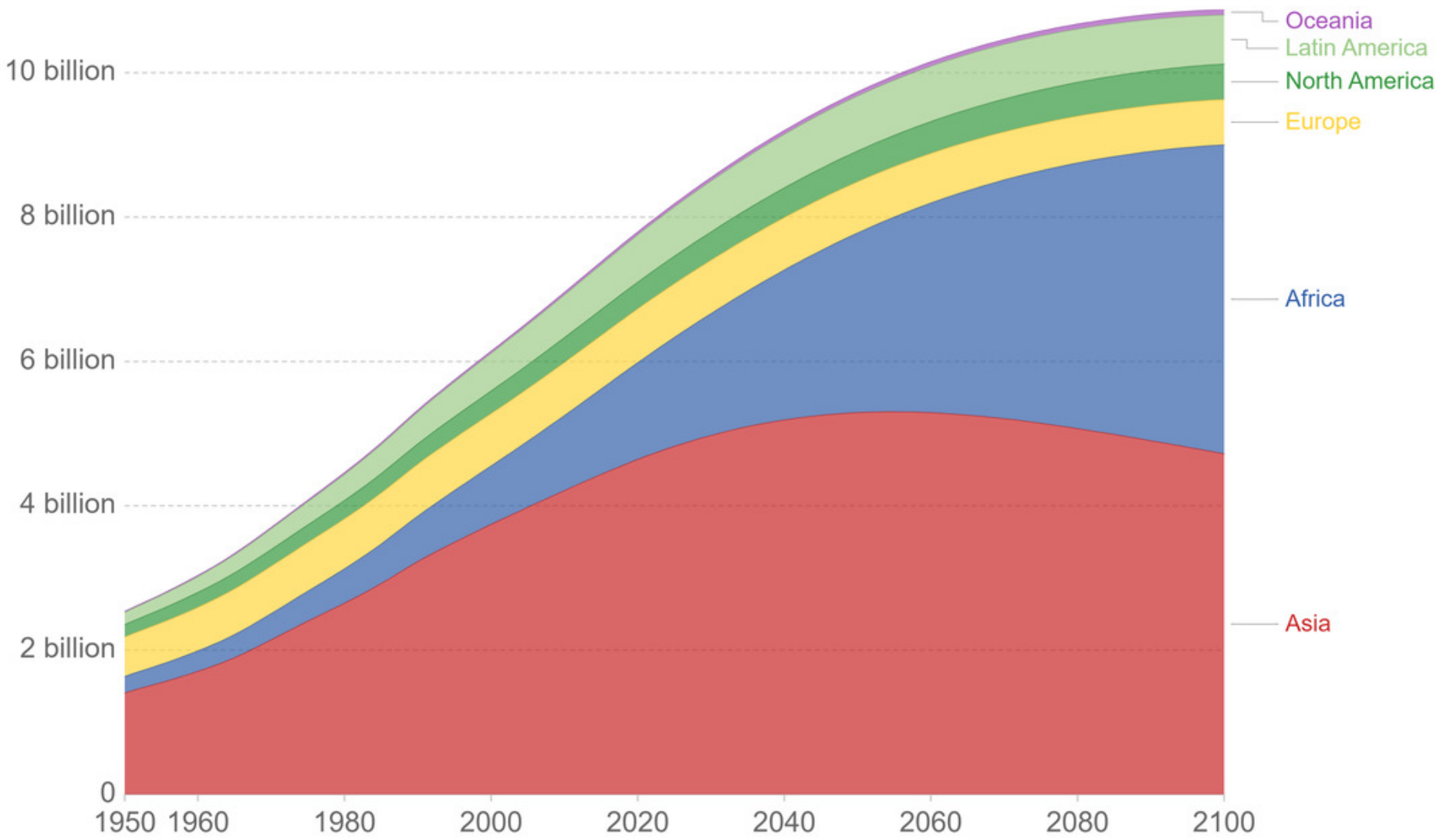
Note: 'Statitistical differences' included in the GCP dataset is not included here.

World Map by Population



World population by region, 1950 to 2100

Projected population to 2100 is based on the UN's medium population scenario.



Source: HYDE (2016) & UN, WPP (2019)

OurWorldInData.org/world-population-growth • CC BY

- Michael Shellenberger:
- Time Magazine's "Hero of the Environment," in 2008.
- Over the years he helped lobby for the U.S. government to spend more than $150 billion on renewable energy.

"Now that we know that renewables can't save the planet, are we going to stand by and let them destroy it?" – Michael Shellenberger

“The science shows us that fears of a climate apocalypse are unfounded. Global warming is real, but it is not the end of the world. It is a manageable problem.

If we don’t say stop, the current, false climate alarm, despite its good intentions, is likely to leave the world much worse off than it could be… We need to dial back on the panic, look at the science, face the economics, and address the issue rationally.”

-- Bjorn Lomborg

Summary of Key Points

1. Climate data trends for most metrics do not appear to be a cause for concern
2. Food production, longevity, standard of living and poverty rates are all improving
3. CO_2 is plant food, essential for life on Earth
4. Impact of natural variability versus human activity on climate is unknown
5. Climate is complex, nonlinear, and chaotic. Dominated by UNCERTAINTY
6. Because of (5), we can neither predict the future climate nor its impact with any certainty
7. Real THREAT is the fragility of the electric power Grid
8. **Focus needs to be on GRID Resilience and Adaptation to Climate Change**

“Some things are believed because they are demonstrably true. But many other things are believed simply because they have been asserted repeatedly—and repetition has been accepted as a substitute for evidence.”

“There are no solutions, there are only trade-offs…”

– Thomas Sowell