The Astonishing Drop in Cost of Renewables: Can Economics Save the Climate?

CLS Marist GS4 & SS4 Sept. 28, 2022 Poughkeepsie NY Lect4: can Economics save climate?

- World 3C likely Future – 40C heat waves ramping till Net Zero CO2 achieved
  - Spectacularly Small Response over 40 years <0.3% of Gross Domestic Product (US & others)
- Disruptive Miracle: Wind, Solar, Battery costs fall exponentially
  - **Renewables are rushing in Breaking the bleak backdrop of the past 40 years**
- Renewables: 20% yearly increases, 755B$ approaching 1% of World GDP
  - Major 2022 Reports: BloombergNEF Ember McKinsey IEA Renewables
  - Driven by China – Solar, Wind, Batteries, Control of Rare Earths, Congo Cobalt, Nickel, Copper
  - US just starting to follow: Surprise August 2022 passage of historic IRA emphasizing renewables
- **Perspective:**
  →Explosive growth of renewables – world going from budgetary rounding error amount 0.3% of GDP investment to almost 1% of GDP.
  → >7% of GDP needed to stabilize climate at whatever CO2 level the world arrives at, per McKinsey 2022 report
  Renewables major progress! Short in magnitude by 7X But train has moved out of the station!

“The 3C Future”

Likely outcome under policies in place

https://www.economist.com/briefing/2021/07/24/three-degrees-of-global-warming-is-quite-plausible-and-truly-disastrous

Economist’s projected impact at 3C:

*Accelerated heating 3.5-5C Arctic, Russia, India, China

*Tropical nights America, Europe, Asia

Drives deaths from heatwaves

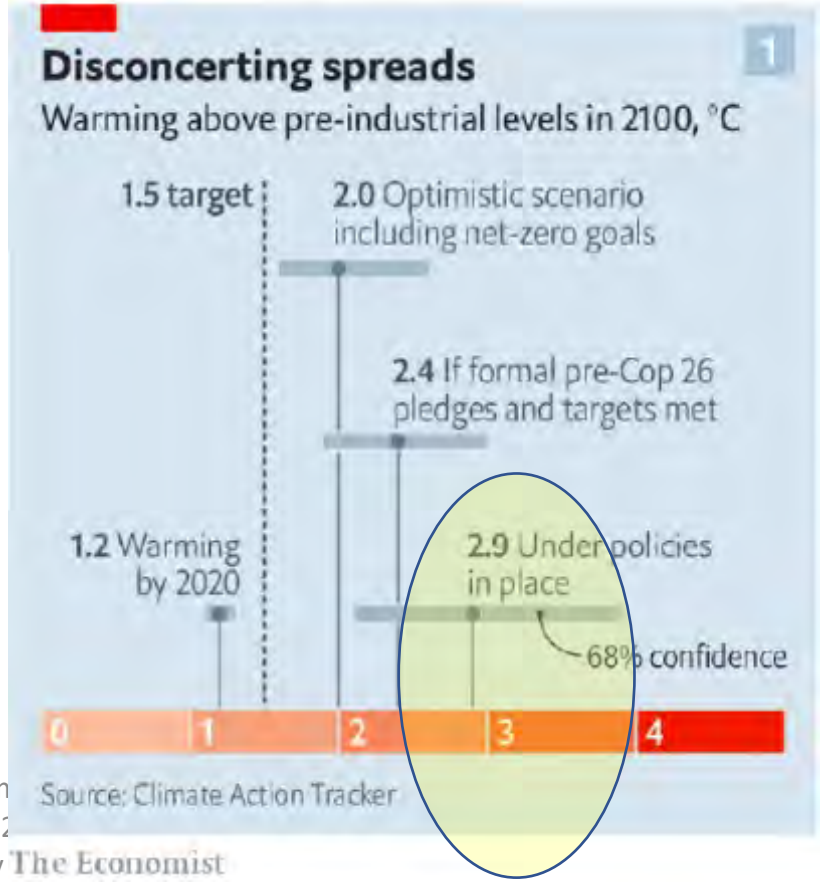
*Wet bulb temperatures become more common → 35C

*Exceptional 100 year drying →every 2-5 years

glimpsed by California’s megadrought

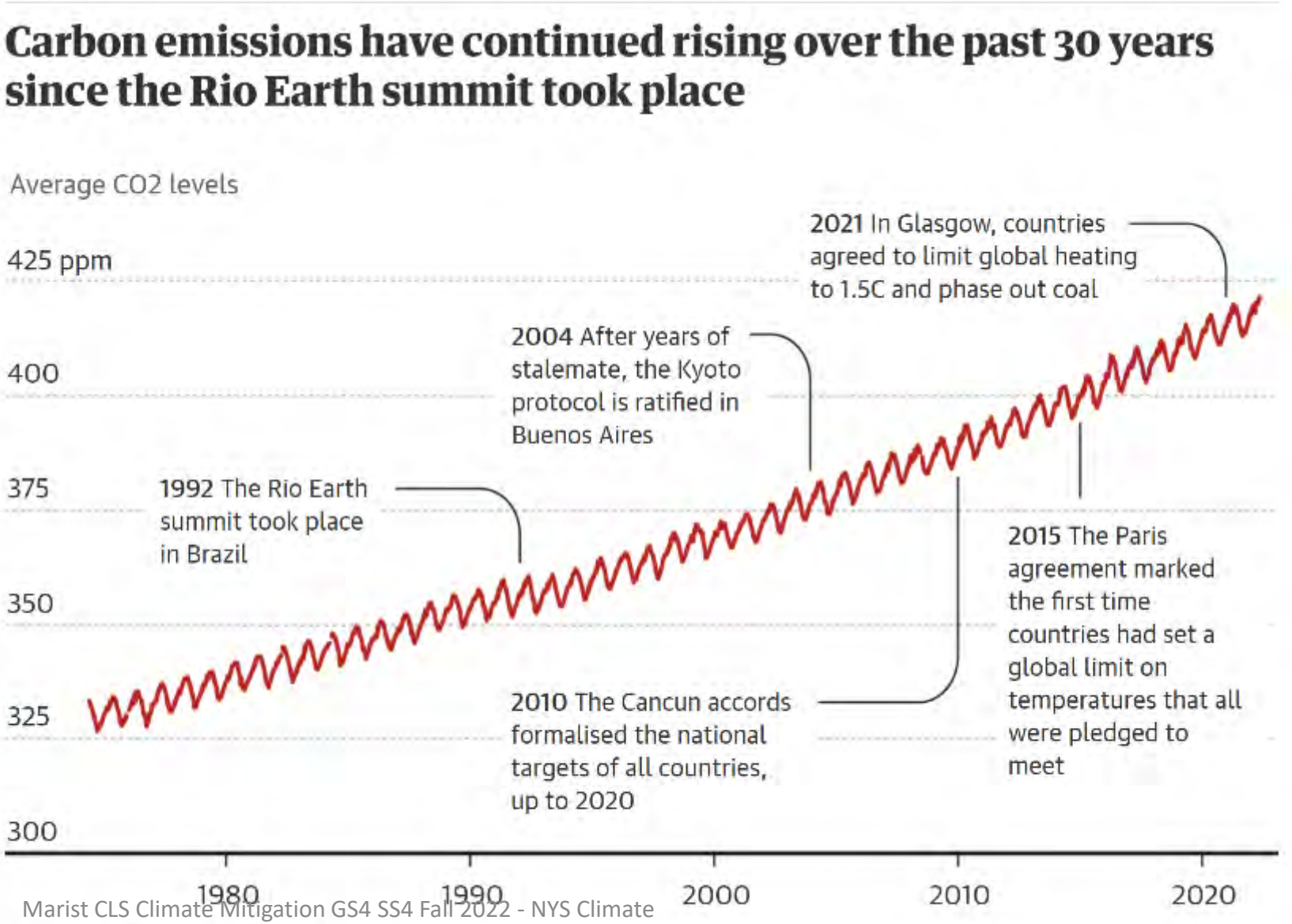
3C West Antarctica & Greenland, could break down quickly

Disappearance of coral reefs, of Amazon rainforest



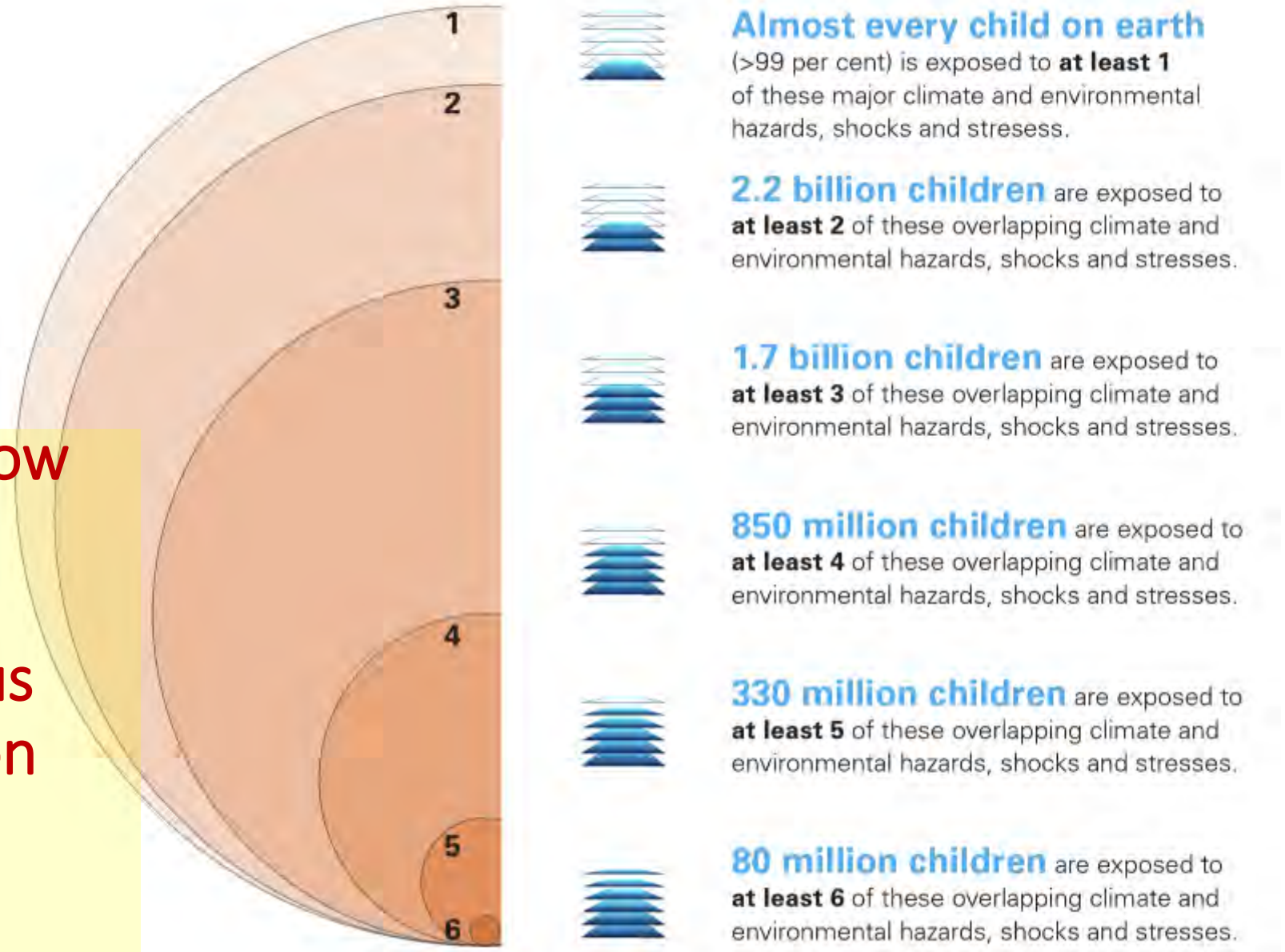
CO2 Levels since 1975 No Progress at All

https://www.theguardian.com/environment/2022/jun/11/cop-climate-change-conference-30-years-highlights-lowlights



ONE BILLION CHILDREN AT ‘EXTREMELY HIGH RISK’ OF THE IMPACTS OF THE CLIMATE CRISIS –UNICEF

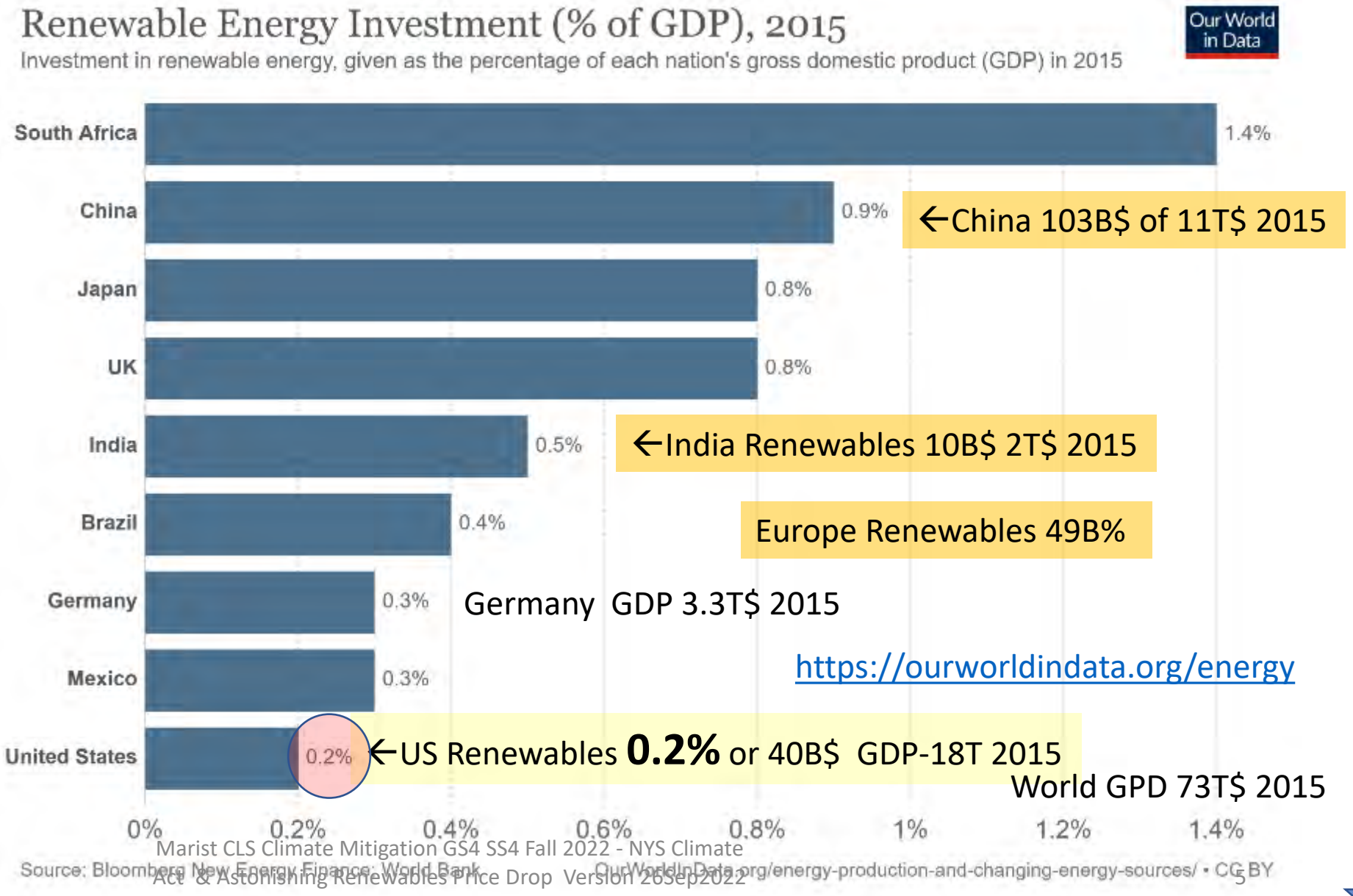
https://www.unicef.org.uk/press-releases/onebillion-children-at-extremely-high-risk-of-the-impacts-of-the-climate-crisis-unicef/
20Aug2021 *‘The Climate Crisis Is a Child Rights Crisis: Introducing the Children’s Climate Risk Index’*



It is not given to us to know what will happen a generation from now. Instead, projections tell us what problems to work on

We can and have to change the world

Point of this slide: show tiny (0.3% GDP) world investment in renewables over past 40 years



←China 103B$ of 11T$ 2015

←India Renewables 10B$ 2T$ 2015

Europe Renewables 49B%

Germany GDP 3.3T$ 2015

https://ourworldindata.org/energy

←US Renewables **0.2%** or 40B$ GDP-18T 2015

World GPD 73T$ 2015

Climate efforts past 40 years tiny relative to economy size

All renewables efforts of past 40 years extremely tiny compared to economy size
in 2015 as percentages of GDP: **Germany-0.3%** **US-0.2%** **China-0.9%**

Inflation Reduction Act IRA of Aug. 2022 – tiny compared to economy size
0.19% of Gross Domestic Product of 20 trillion
3% of US Energy Expenditure's of 1.2T$ in 2017 from EIA
New York State Climate Plan – also tiny compared to NY State economy size

- **Net costs are small relative to economy's size**: $15 billion, or **.6% - .7%** of Gross State Product (GSP) in 2030; $45 billion, or **1.4% of GSP** in 2050. Net costs are small relative to economy's size.

McKinsey report 26Jan2022, unflinching about costs needed for Net Zero
9.2 T$ or 10% of world GDP

https://elements.visualcapitalist.com/ranked-the-top-10-countries-by-energy-transition-investment/ 5Feb2022

755B$ World low Carbon Investment in 2021
World GDP 84,710B$ 2020
Investment is 0.89% of World GPD much higher than past 40 years

Energy Transition Investment by Country

The top 10 countries together invested **$561 billion** in the energy transition, nearly **three-fourths** of the world total.

Country	2021 Energy Transition Investment (US$)		% of World Total
China	$266B	17.7T$ → 1.5% of GDP China	35.2%
U.S.	$114B	22.99T$ → 0.49% US	15.1%
Germany	$47B	4.4T$ → 1.1% Germany	6.2%
U.K.	$31B	3187B$ → 1.1% UK	4.1%
France	$27B	2937B$ → 0.92% France	3.6%
Japan	$26B	4937B$ → 0.52% Japan	3.4%
India	$14B	3050B$ → 0.46% India	1.9%
South Korea	$13B		1.7%
Brazil	$12B		1.6%
Spain	$11B		1.5%
Total	**$561B**	96T$	74.3%
	*/0.75→748T$	**96T** → 0.77% World	

China increased its overall energy transition investment by **60%** from 2020 levels, further cementing its position as a global leader. The country's wind and solar capacity increased by 19% in 2021, with electrified transport also accounting for a large portion of the investment.

Energy transition investment higher than the past 40 years!

Now approaching 1% of world or country GDP

Think a much higher level (7%) of investment needed to change climate outcome!

Spiritual Problem Highlighted by Economics
Spending as fraction of Gross Domestic Product

- "Stadium" of 15,000 children die each day
  - Official Development Aid ODA is 0.2% of Gross Domestic Product
- Lack of concern for those not yet born
  - Renewables spending 0.3% of GDP for past forty years
- As a boy I saw decisions yielding 1 billion cumulative tobacco deaths in 100 years
- Upon retiring I examined my own charitable spending as ratio of salary
  A Tolstoy self examination https://en.wikipedia.org/wiki/The_Death_of_Ivan_Ilyich
  the spiritual problem is not "out there"
  - Charities a small percentage of my income
    https://www.givewell.org/ save a life for $4000
  - Wrote **"Ethical Vision with Math at its Center"** and ongoing "Humanity's Future" series
- Our society makes terrible choices. But also makes exceptionally good choices. A paradoxical trend to greater world flourishing over past 200 years: a billion rise out of deep poverty https://www.gapminder.org/factfulness-book/

Distant Suffering Problem & Invisible Hand

Enlightenment Economist Adam Smith's economic solution to the problem of suffering

Adam Smith, Theory of Moral Sentiments, part 3 chapter 1

https://en.wikiquote.org/wiki/Adam_Smith "Wealth of Nations" all time most important economics book

… Let us suppose that the great empire of China, with all its myriads of inhabitants, was suddenly swallowed up by an earthquake, and let us consider how a man of humanity in Europe, who had no sort of connection with that part of the world, would be affected upon receiving intelligence of this dreadful calamity. He would, I imagine, first of all, express very strongly his sorrow for the misfortune of that unhappy people, …..

… If he was to lose his little finger to-morrow, he would not sleep to-night; but, provided he never saw them, he will snore with the most profound security over the ruin of a hundred millions of his brethren, and the destruction of that immense multitude seems plainly an object less interesting to him, than this paltry misfortune of his own. …

Climate Change – "Invisible Hand" addresses Future Suffering Problem

We've squandered forty years, the climate deteriorates and seems lost.

Fall of renewables prices – sudden renewables projects – the Invisible Hand

Disruptive Factor: Stunning drop in Renewables Prices;
Explosion of investment in renewables. We are following a new path

Cost vs. Installed Capacity

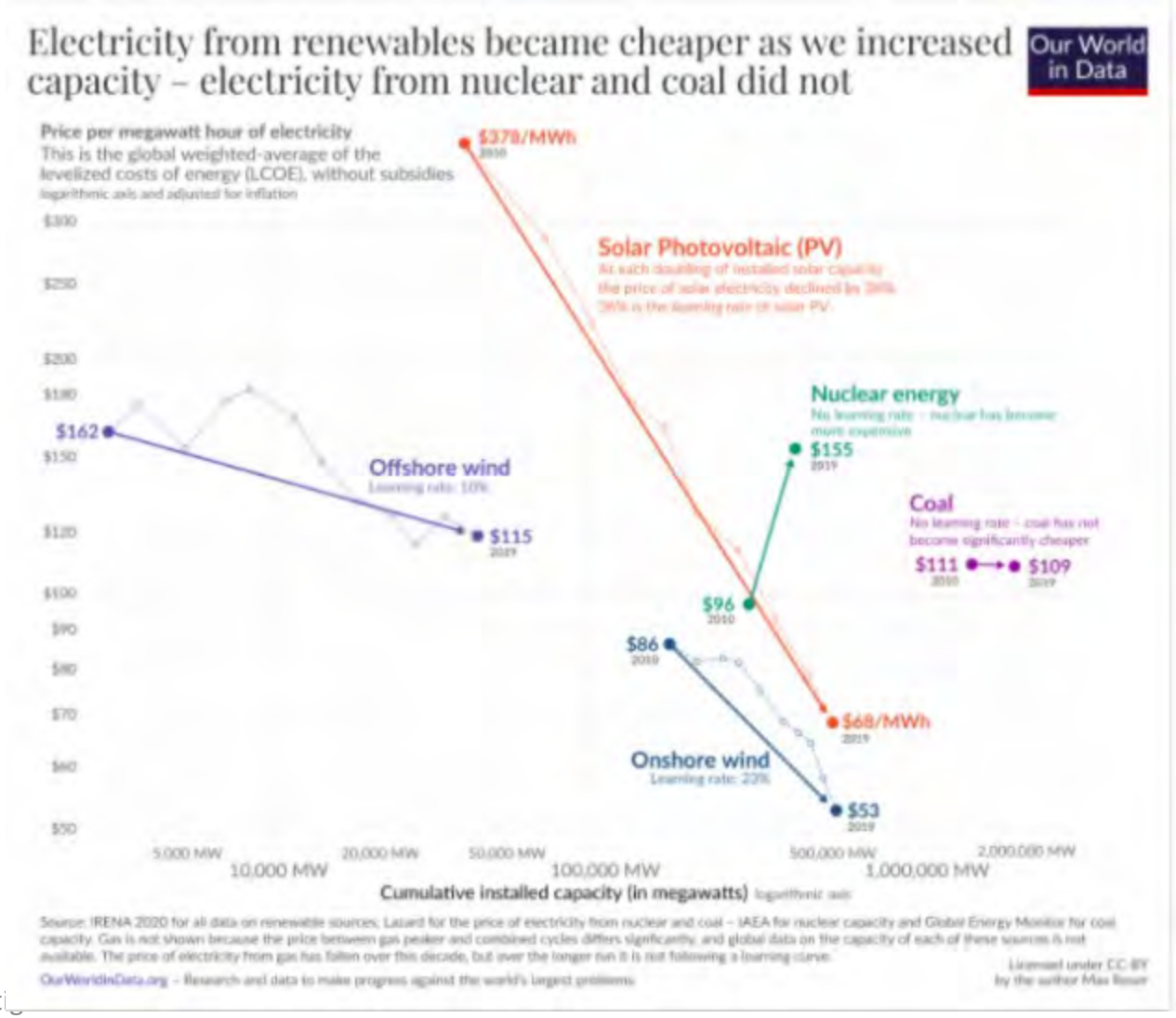
Miracle of astonishing drop in renewable prices

Learning curve – price drops with installed capacity

https://ourworldindata.org/cheap-renewables-growth

Dec. 2020 Max Roser

Very clear and important article – I suggest that you read, especially if you want a more positive outlook!



Logarithmic drop in Renewables Prices

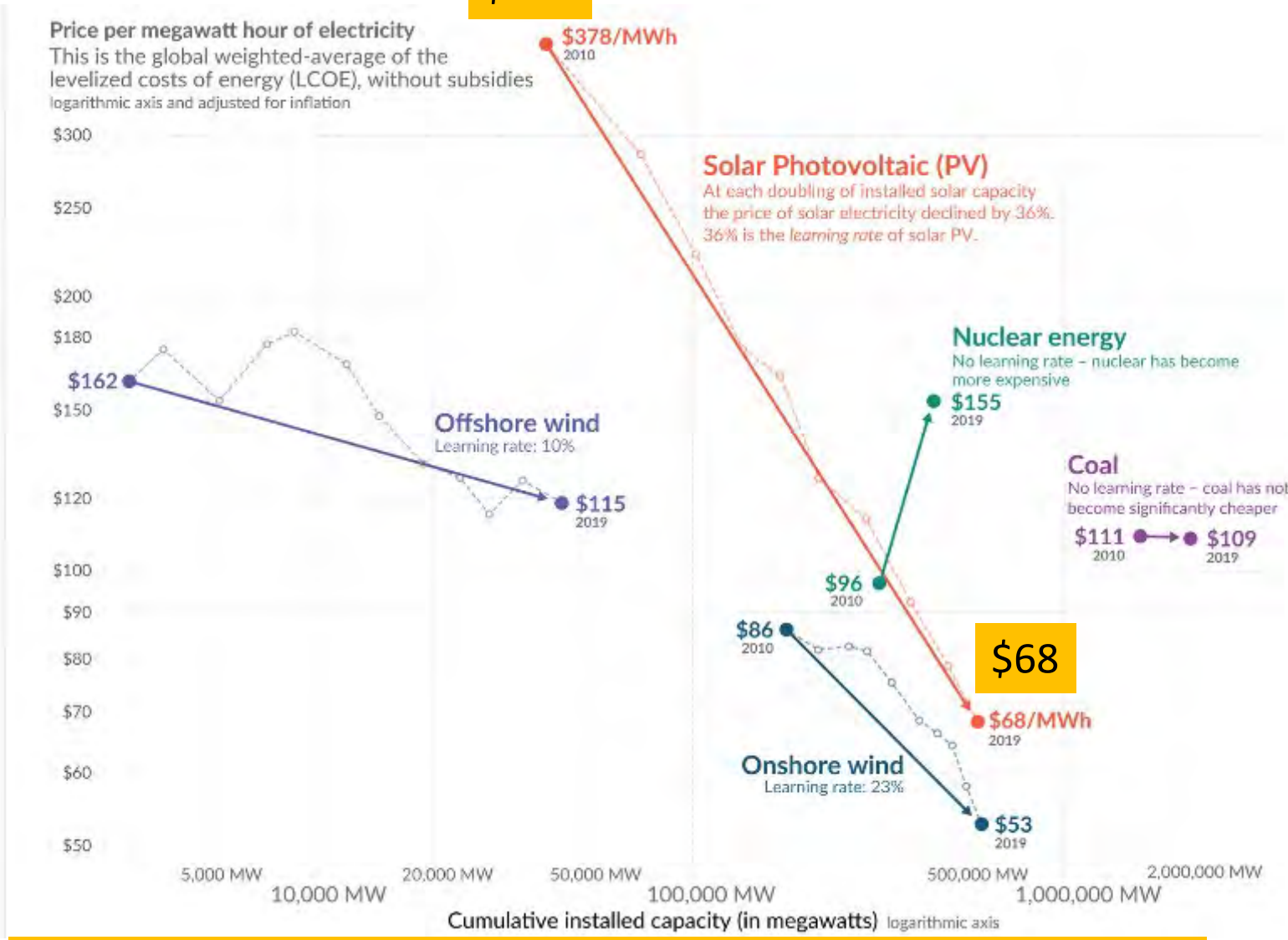
$300----

PRICE

$100---

$50--

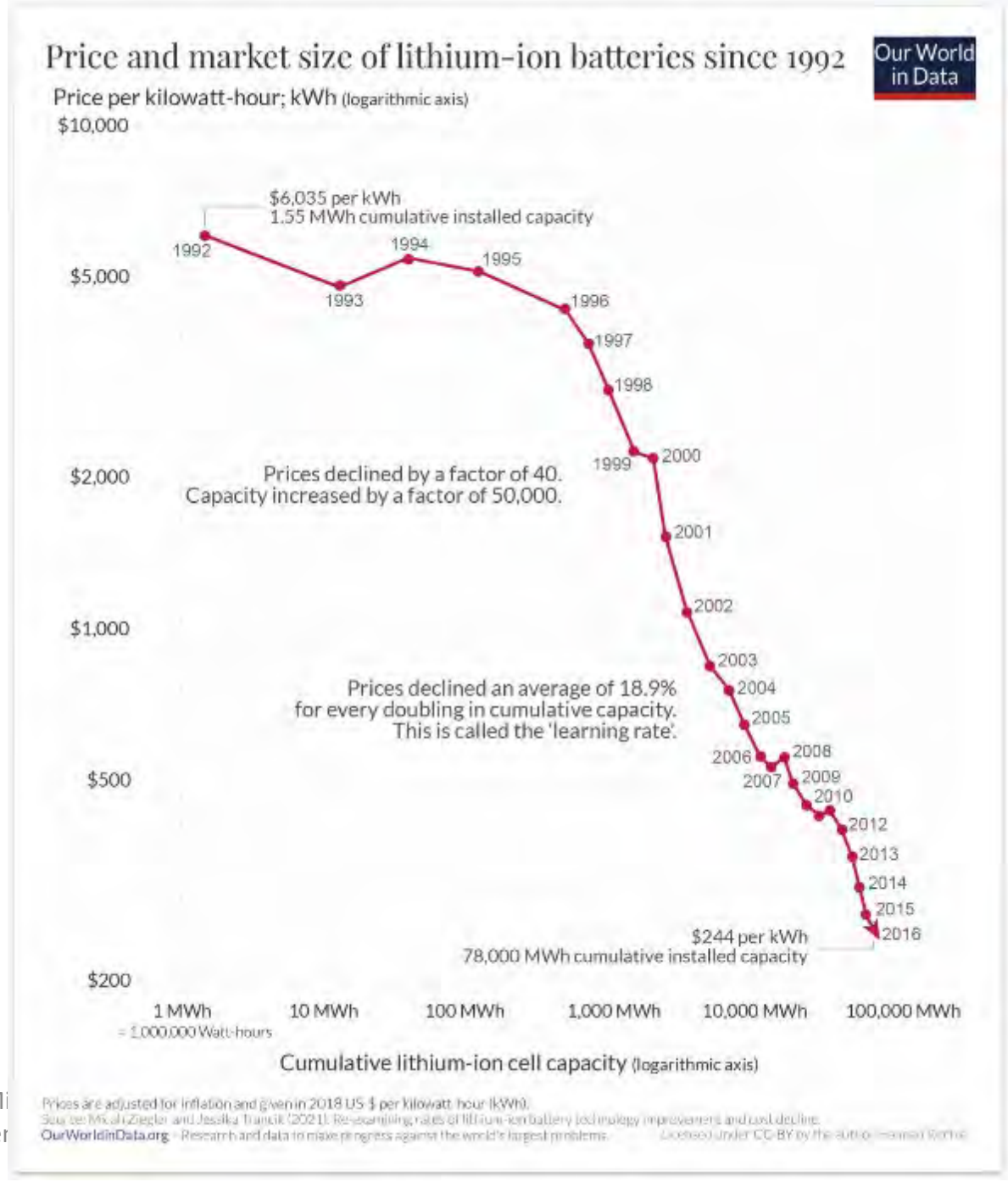
$378



|5000 | |100,000 | 1million

INSTALLED CAPACITY = Experience

Lithium Batteries Prices



https://ourworldindata.org/cheap-renewables-growth

Dec. 2020 Max Roser

Moore's Law and earlier Wright's Law

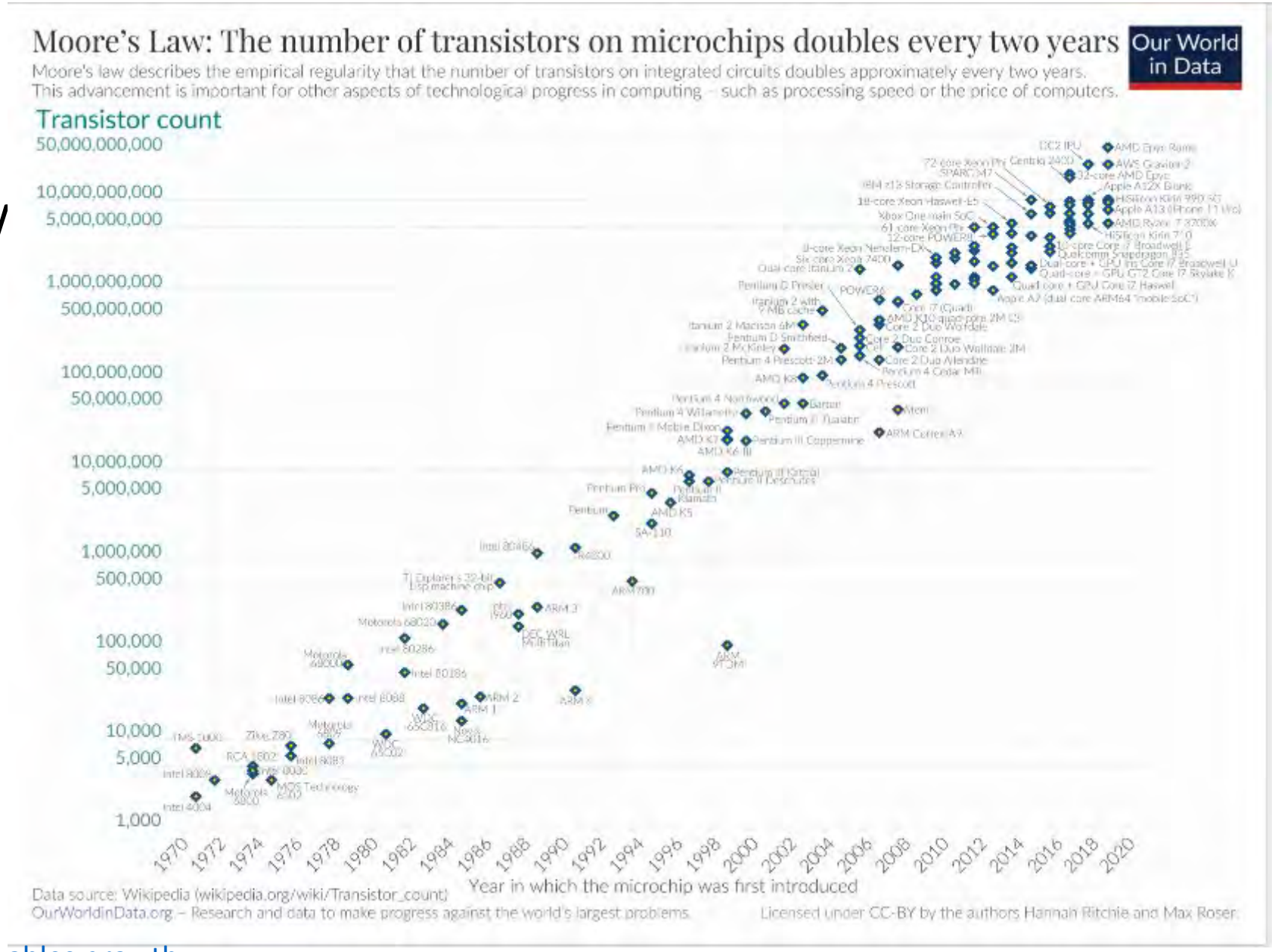
Cost falls with **experience**

Transistor Count

1000 bottom left

50 million top left

From 1970 to 2020



https://ourworldindata.org/cheap-renewables-growth

Dec. 2020 Max Roser

Point of this slide: Renewables Taking off suddenly because of cost drop

BloombergNEF

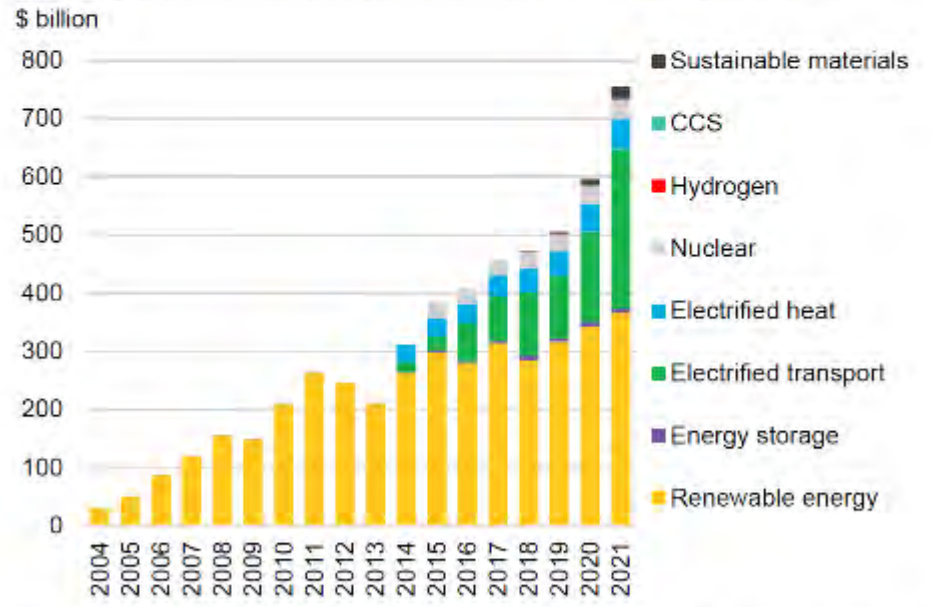
https://about.bnef.com/energy-transition-investment/
https://assets.bbhub.io/professional/sites/24/Energy-Transition-Investment-Trends-Exec-Summary-2022.pdf

Renewables investment suddenly jumping from 0.3% GDP over past 40 years to 0.8% driven by Cost Drop

$755 billion Global energy transition investment in 2021

$165 billion Global climate-tech equity investment in 2021

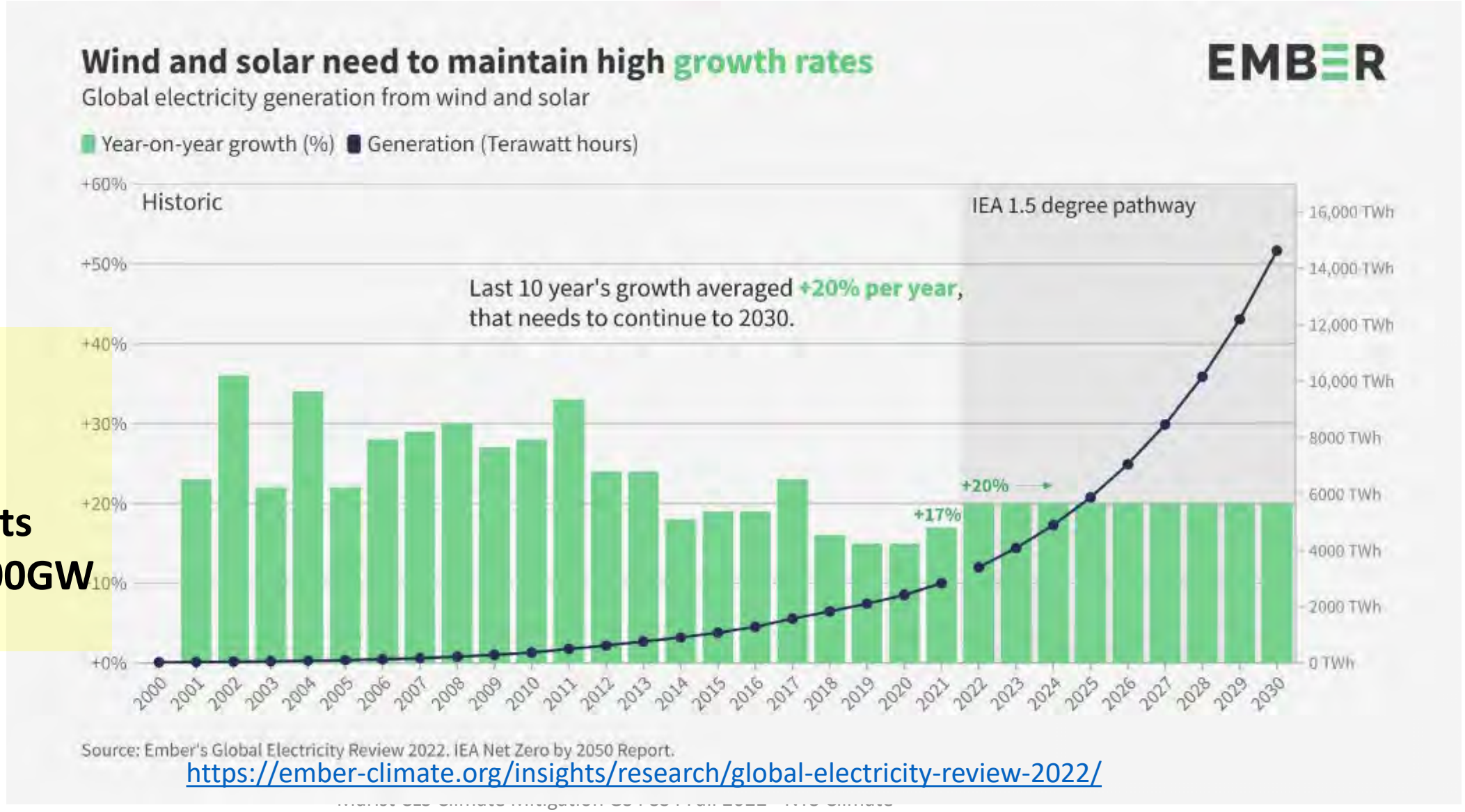
27% Increase in energy transition investment 2020-2021



Source: BloombergNEF. Note: start-years differ by sector but all sectors are present from 2019 onward; see Appendix for more detail.

BloombergNEF

Wind and Solar Growth Rates – extrapolated in hopeful manner



https://ember-climate.org/insights/research/global-electricity-review-2022/

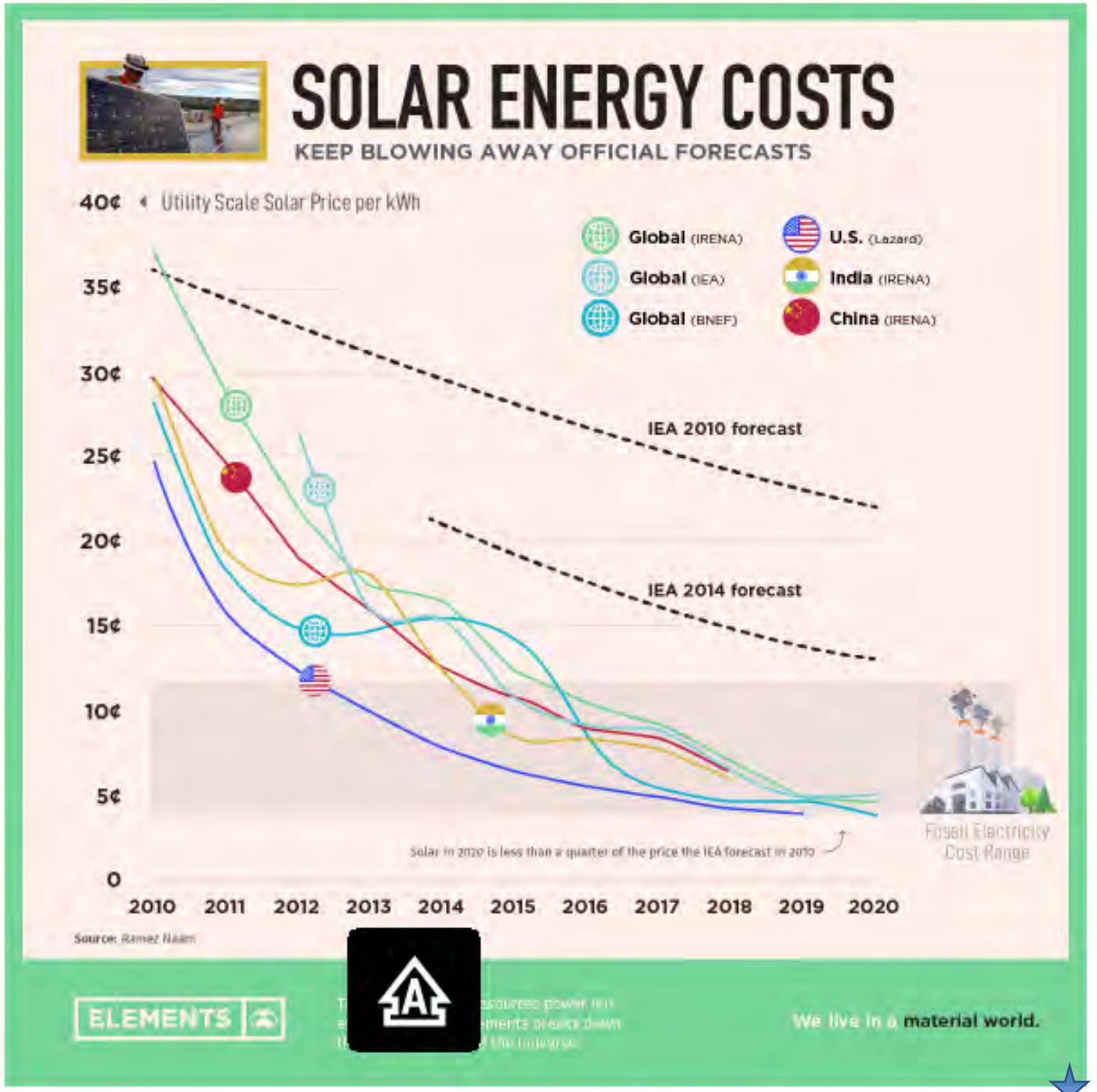
World Renewables

2030 in TWatts

1.6TW or 1600GW

=14300/24/365

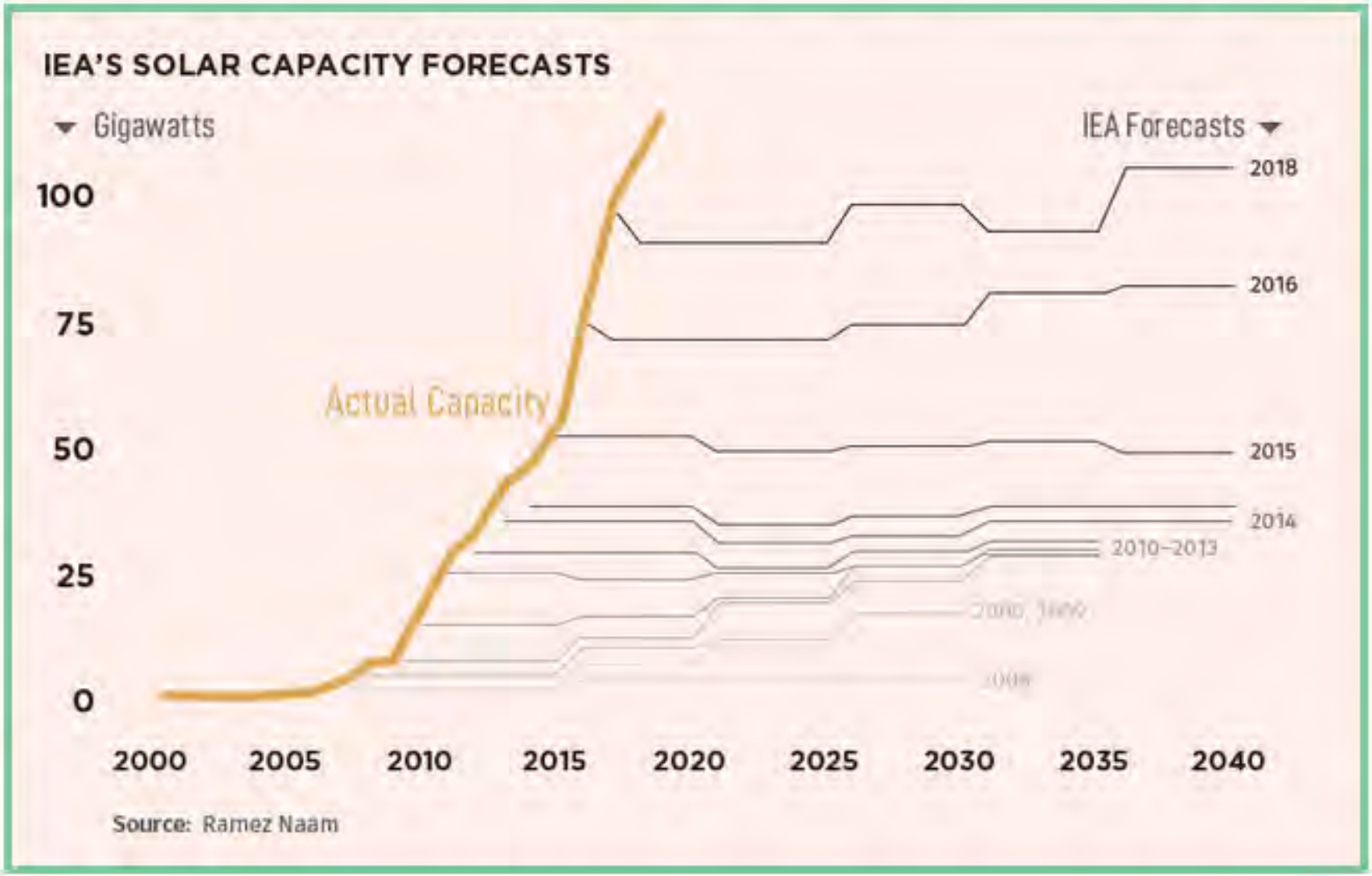
https://elements.visualcapitalist.com/the-exponential-view-of-solar-energy/
25June2021



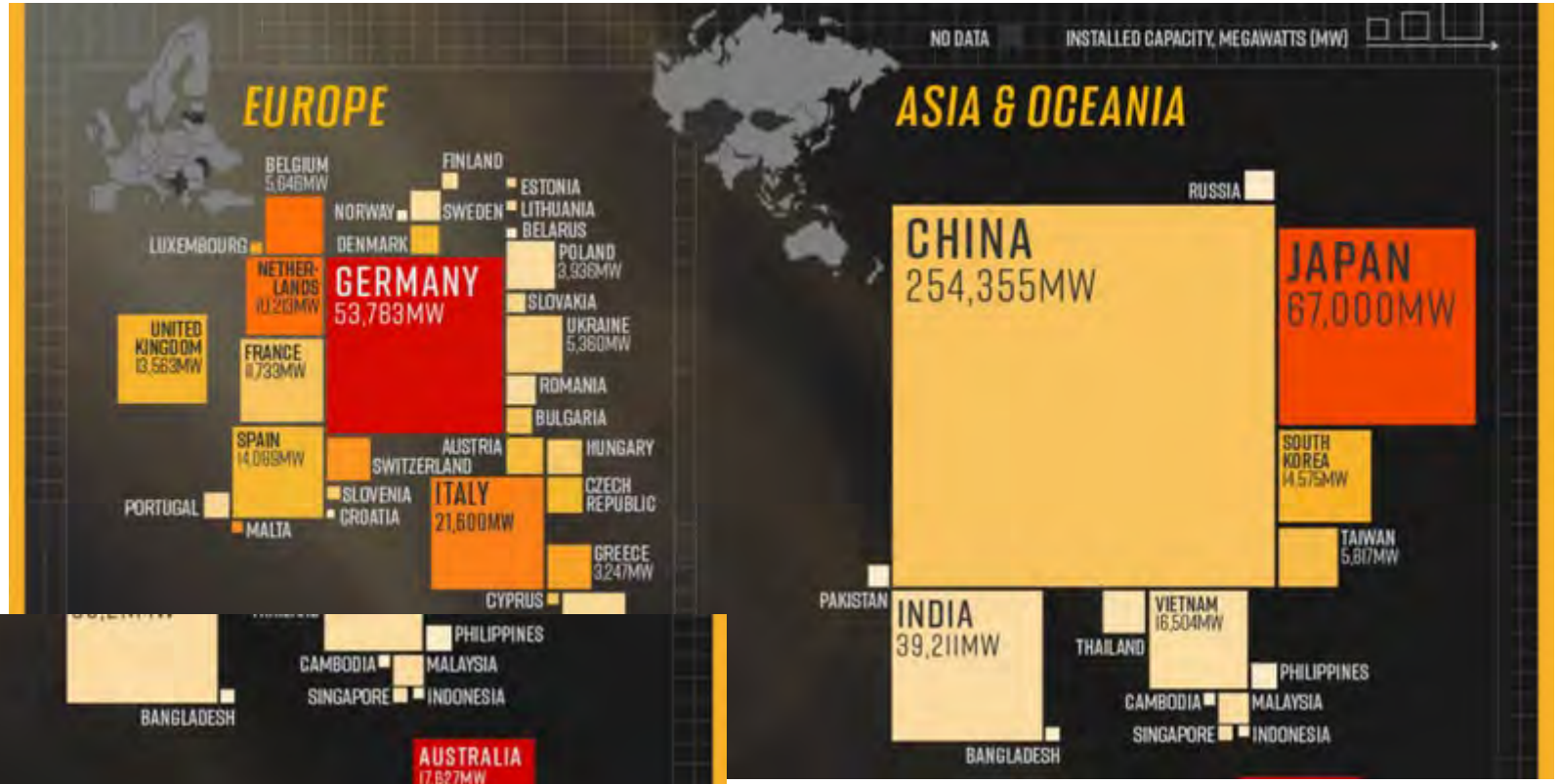
https://elements.visualcapitalist.com/the-exponential-view-of-solar-energy/ 25June2021

Underestimate Solar No More?

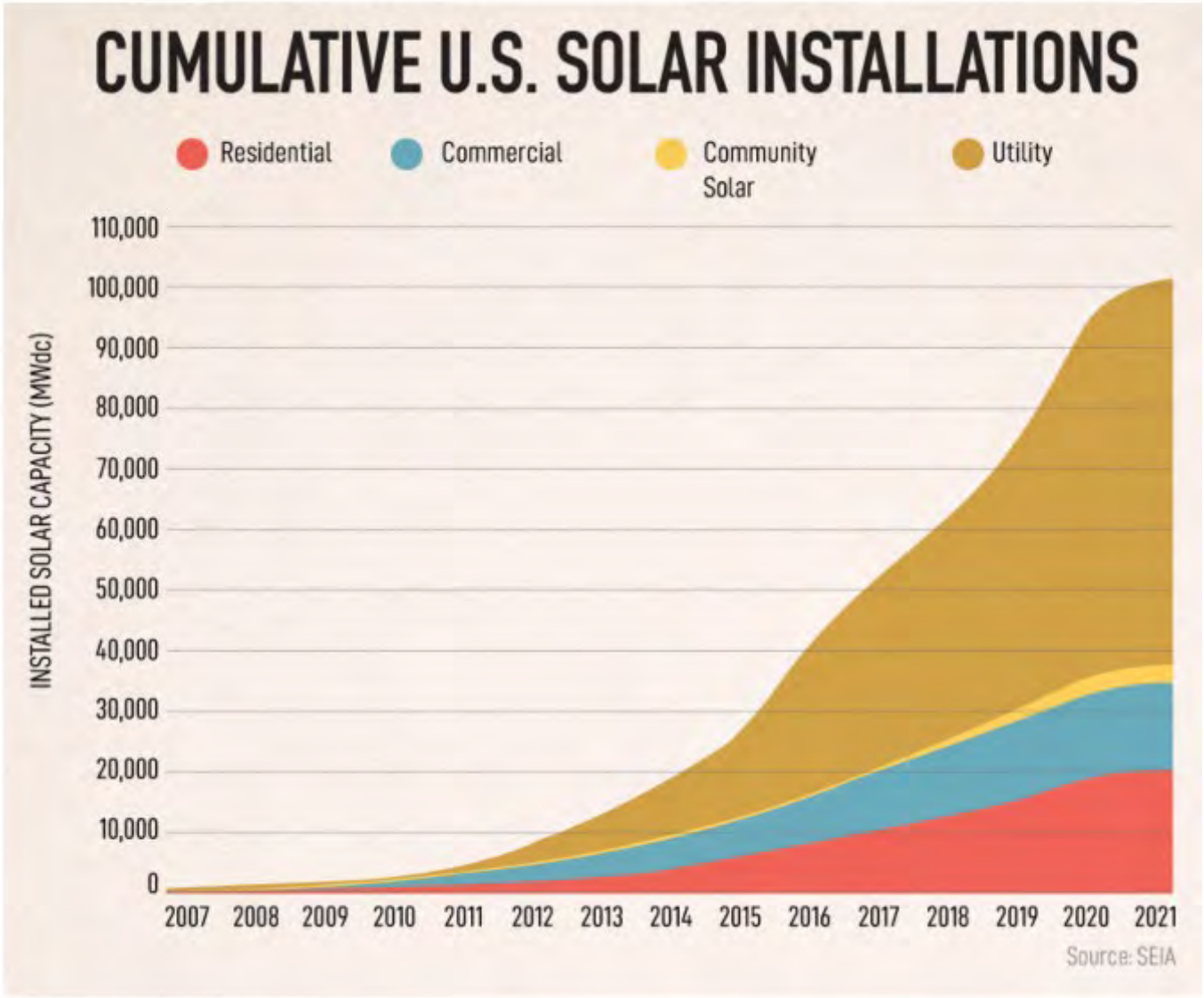
For fun, here's a final look at how IEA projections have constantly underestimated solar installations, which are one of the key factors dictating the "learning rate" under Wright's Law:



https://elements.visualcapitalist.com/mapped-solar-power-by-country-in-2021/ 15Nov2021



https://elements.visualcapitalist.com/how-much-land-power-us-solar/ 11Aug2021



https://www.nrel.gov/docs/fy13osti/56290.pdf Land-Use Requirements for Solar Power Plants in the United States June 2013

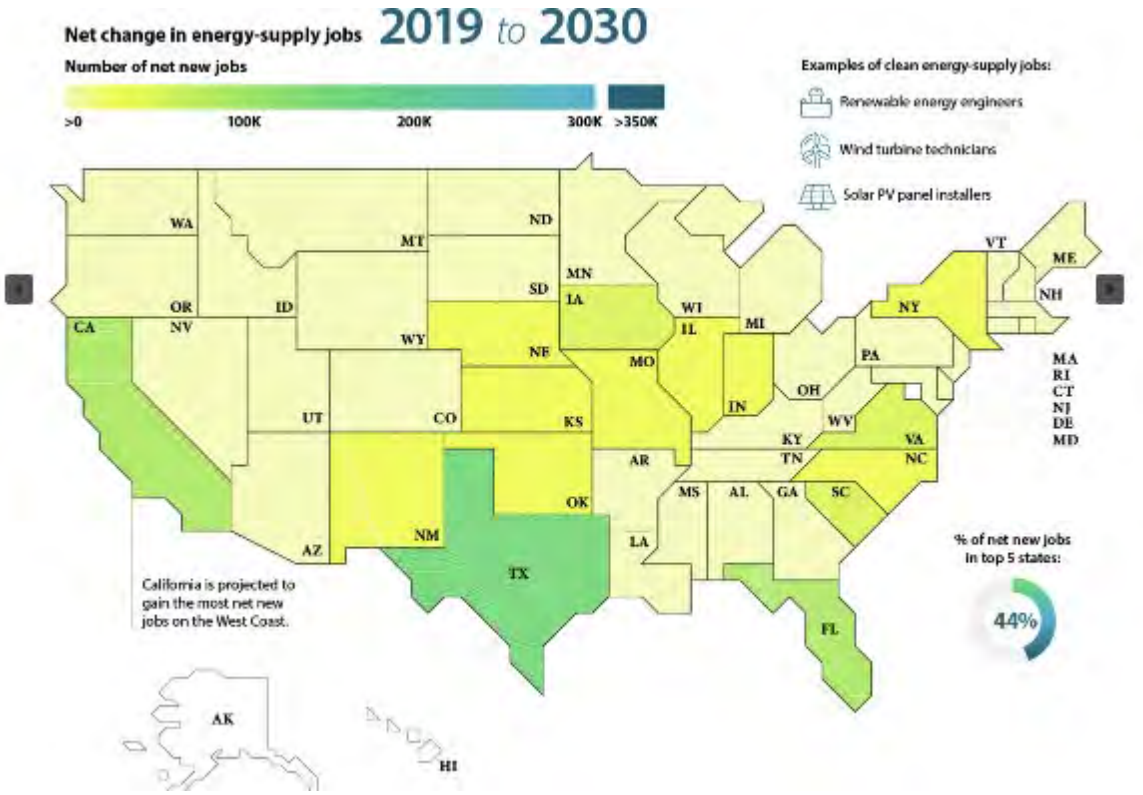
https://www.energy.gov/eere/solar/solar-energy-united-states generic, not dated

https://elements.visualcapitalist.com/forecasting-u-s-clean-energy-job-creation-by-state-2019-2050/
17June2022

Search:

State	Forecasted Net Change in Energy-supply Jobs (2019-2030)
Texas	134,446
California	73,259
Florida	65,754
South Carolina	55,058
Iowa	46,295
Virginia	43,250
New Mexico	39,548
Indiana	38,908
Missouri	33,786
Oklahoma	30,953
Total U.S.	**852,651**

Previous Next



Search: new york

State	Forecasted Net Change in Energy-supply Jobs (2019-2030)
New York	26,063
Total U.S.	**852,651**

Previous Next

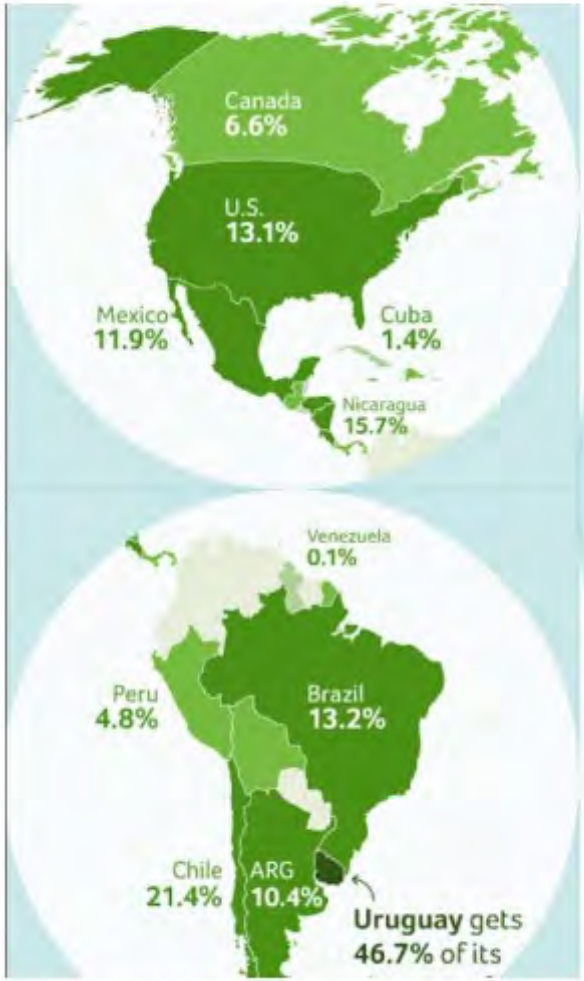
Texas leads in net change in energy supply jobs
Texas also very big in Wind

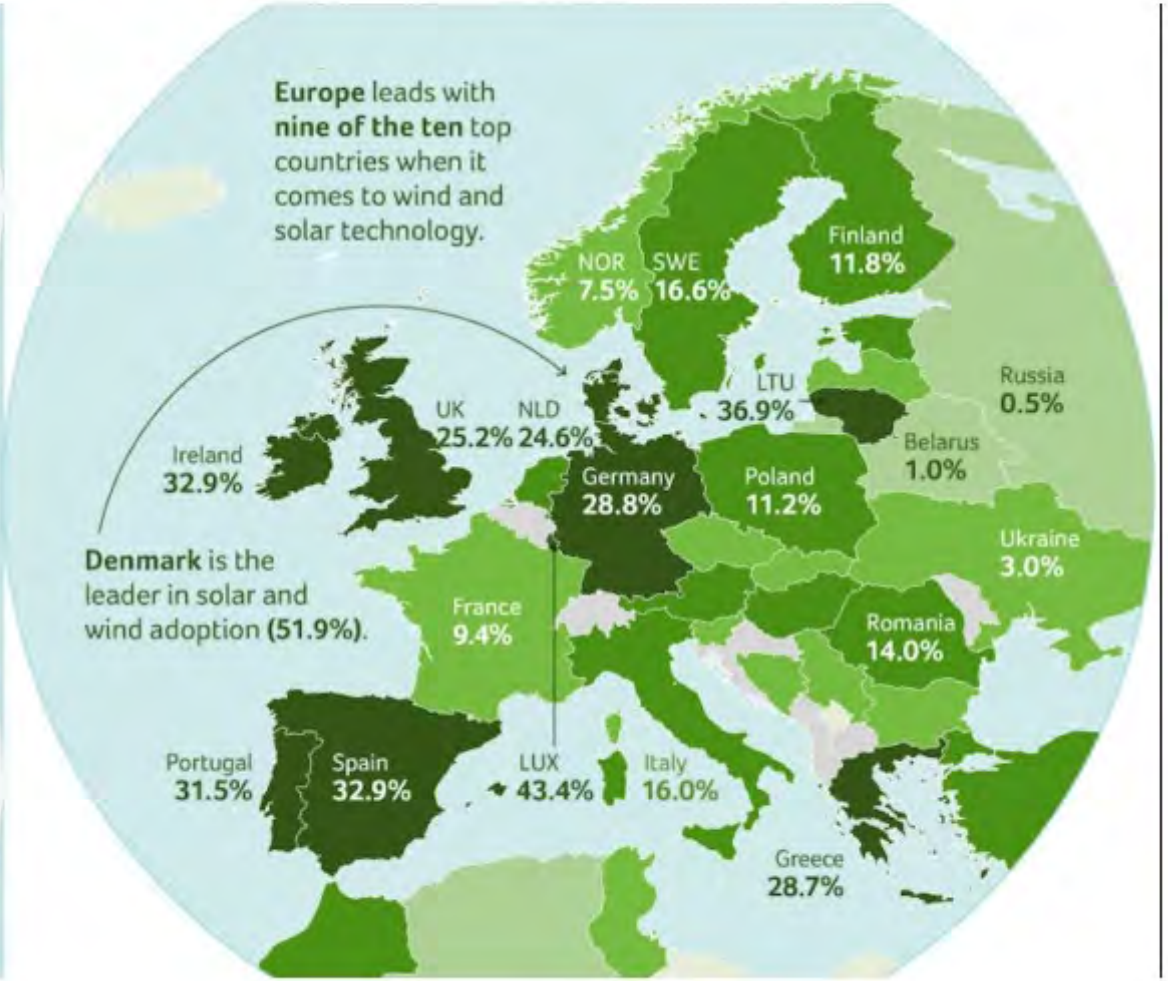
New York rather small at 26,063

https://bigthink.com/strange-maps/wind-solar-world-map/ 2June2022

World map reveals wind and solar power winners (and losers)

Best in class: Denmark and Uruguay. Worst in class: Papua New Guinea, Venezuela, and Russia.





Best in class: Denmark and Uruguay. Worst in class: Papua New Guinea, Venezuela, and Russia. (Credit: Visual Capitalist)

https://bigthink.com/strange-maps/wind-solar-world-map/ 2June2022

Wind and solar at 70% by 2050

That rapid escalation provides some hope that, for once, an international climate target might be met.

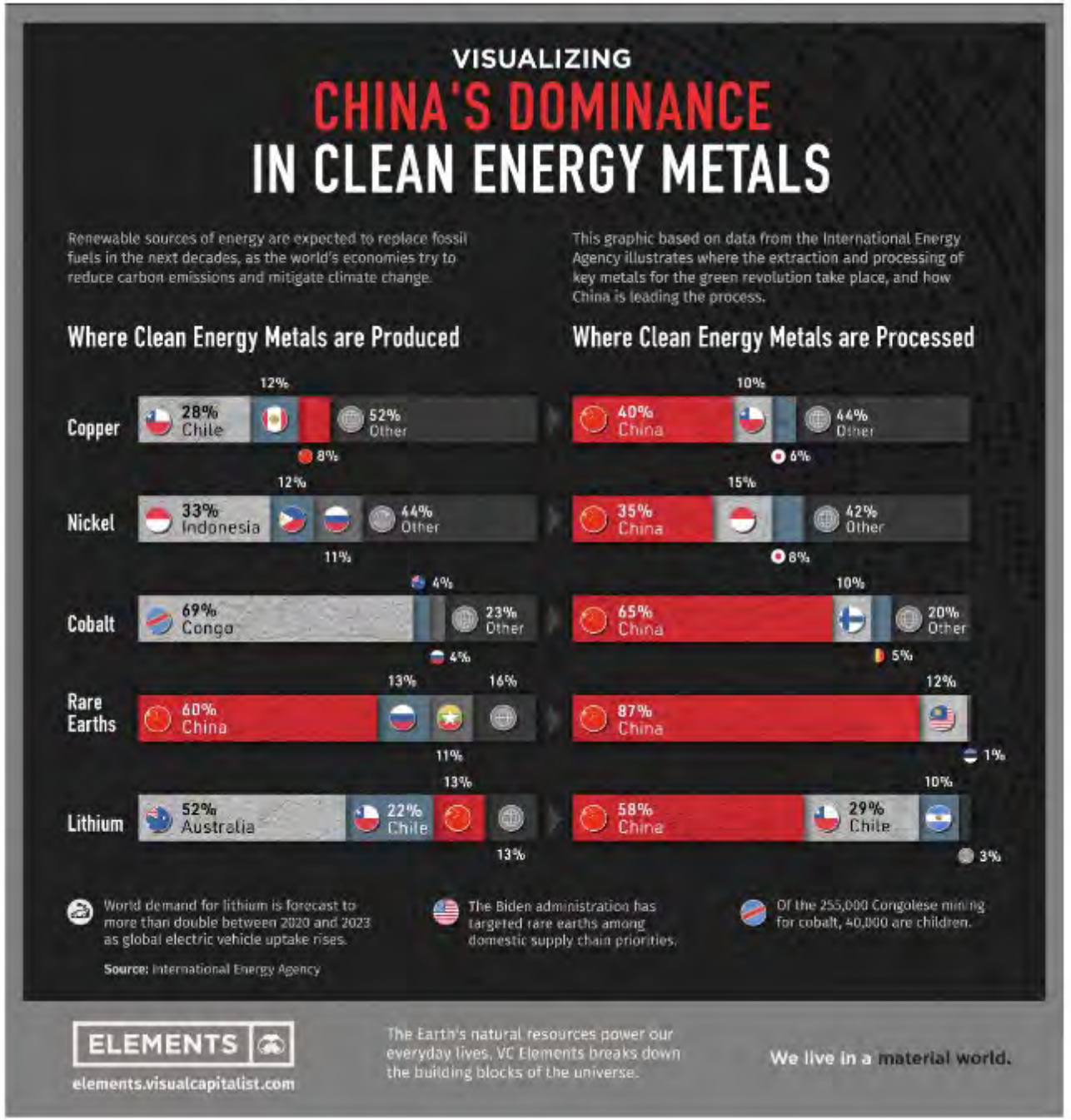
In 2020, electricity generation emitted more greenhouse gases than any other industry. According to the International Energy Agency, wind and solar must hit 20% of global energy by 2025 (and 70% by 2050) if we want to reach overall net-zero carbon by the 2050 target set by the Paris Agreement.

China – careful to dominate all aspects of the clean energy transition

China snapped up Congo Cobalt

China controls rare earths used for wind power

China gets copper and nickel from elsewhere and dominates refining

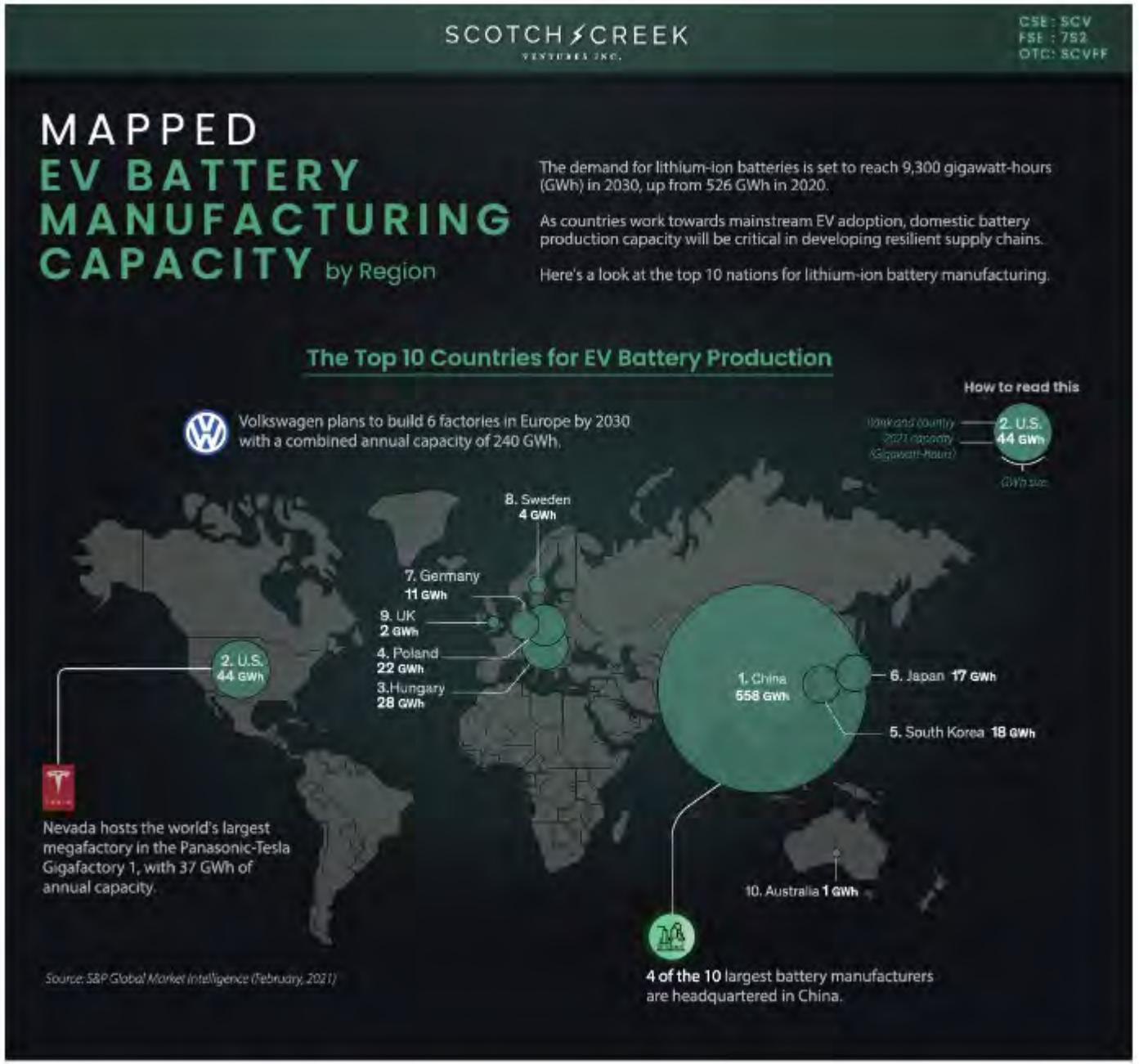


https://www.visualcapitalist.com/chinas-dominance-in-clean-energy-metals/

China – careful to dominate all aspects the clean energy transition

EV Batteries

https://www.visualcapitalist.com/mapped-ev-battery-manufacturing-capacity-by-region/



China – coal plants and massive solar and wind

https://oilprice.com/Energy/Energy-General/China-Accounts-For-Nearly-Half-Of-The-Worlds-Renewable-Energy-Capacity.html 21Aug2022

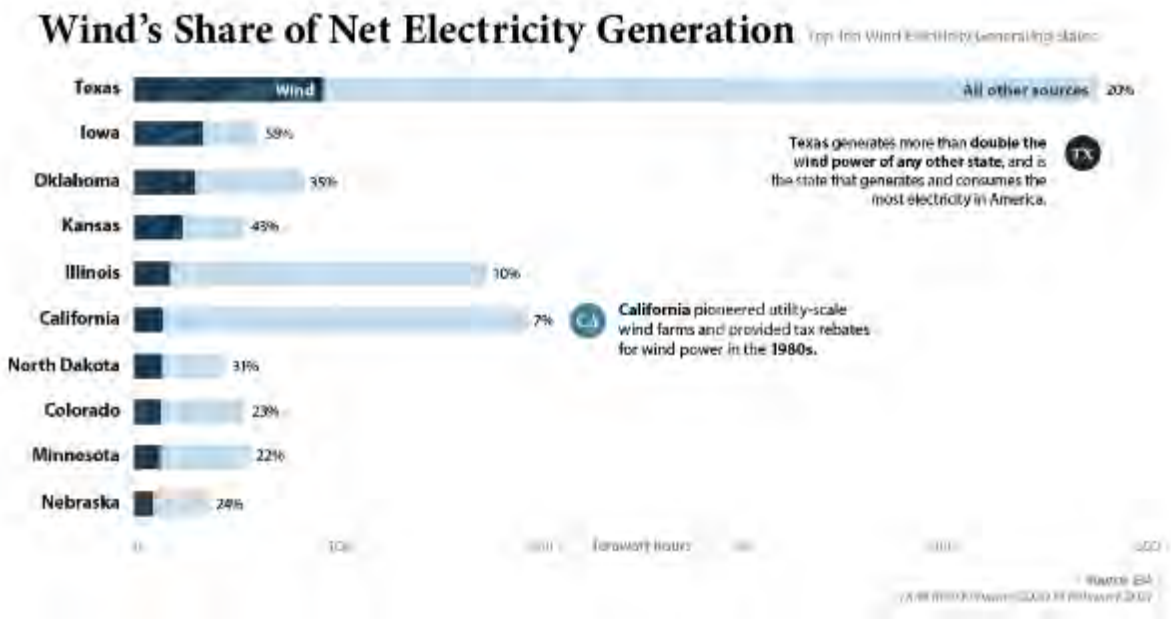
https://www.pv-magazine.com/2022/07/22/chinese-pv-industry-brief-china-may-install-up-to-100-gw-of-solar-this-year/

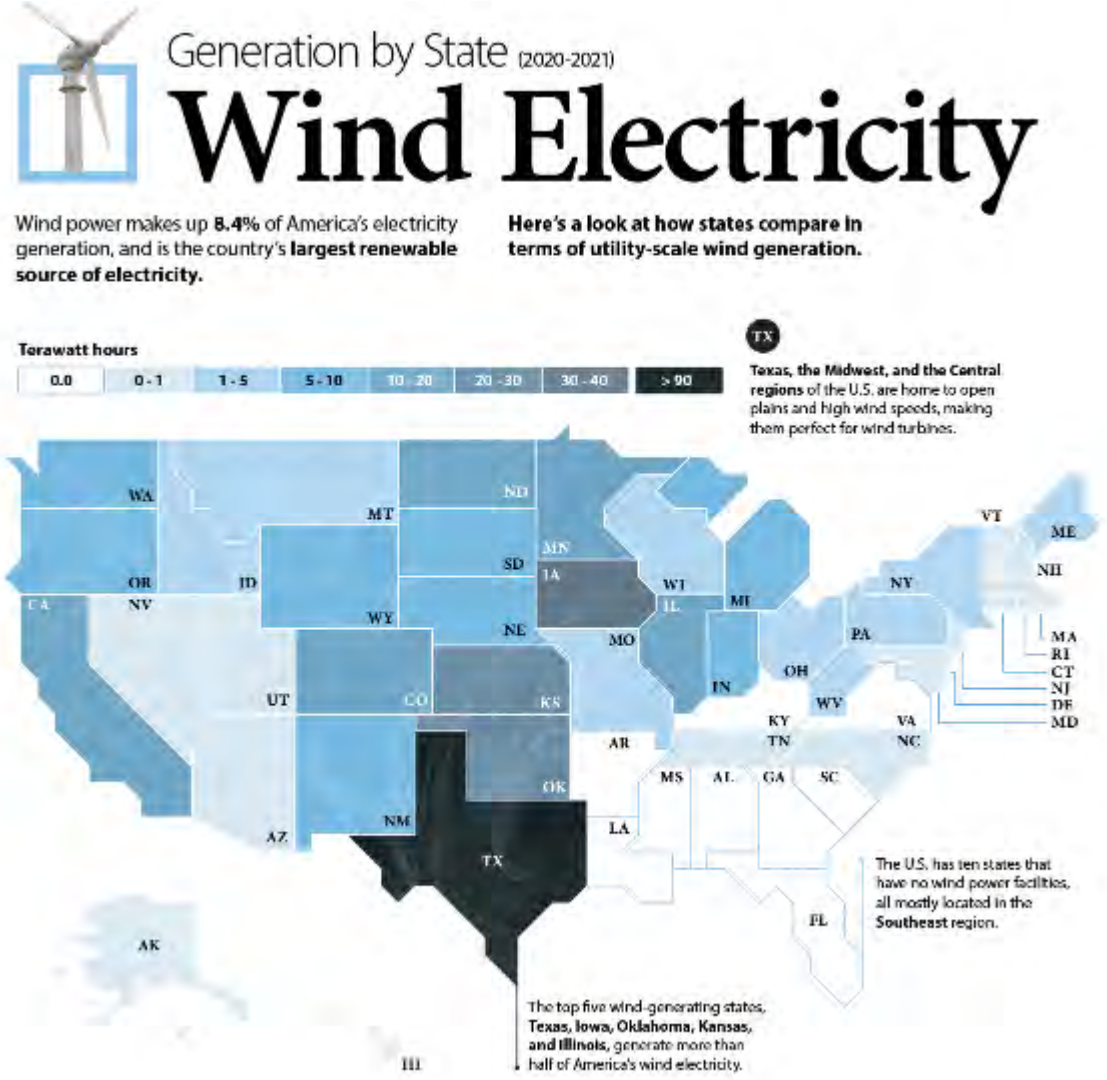
However, China achieved $380 billion in public and private sector clean energy investments in 2021 alone. In addition, thanks to its strong manufacturing and construction industries, China can build large-scale wind and solar farms at a rapid pace. And this is just the latest in China's green energy achievements, having been investing in clean energy for years.

BloombergNEF (BNEF) head of China analysist Nannan Kou stated "Green infrastructure is the most important investment area that China is relying on to boost its weak economy in the second half of 2022." China has seen $41 billion in solar investments in the first six months of 2022, supporting its goal of 1,200 GW of wind and solar capacity by 2030. By comparison, the U.S. invested $7.5 billion in solar over the same period.

Chinese PV Industry Brief: China may install up to 100 GW of solar this year

https://elements.visualcapitalist.com/mapping-u-s-wind-electricity-generation-by-state/ 14Apr2022





Texas 92.9 TWh Wind
/365 /24 → **10.6GW**
or 20% of usage

Texas usage 464TWh
/365/24 → 53GW
28.64Million pop
1870Watts/person

US electricity usage 2020

452 GWatts or 1400 Watts per US person

Renewables was 95 GWatt

Renewables growth explosive

Substantial offshore wind power coming online

30-40 GWatts up-coming Offshore Wind East Coas

27 GWatts Midwest Wind 2020

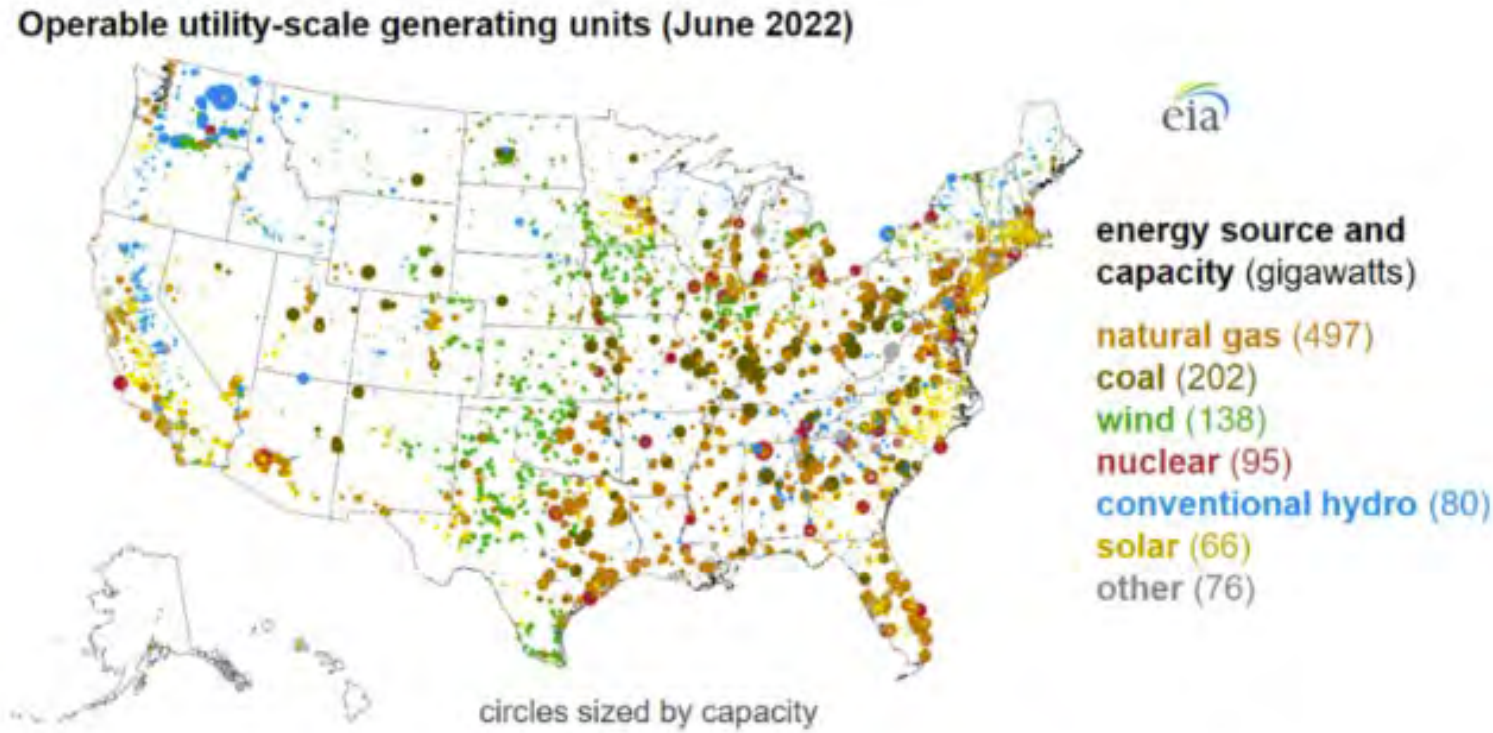
28 GWatts Texas 2020

US 118 GWatts by end of 2020 (eia)

25 GWatts California deep water offshore by 2045

https://cleantechnica.com/2022/08/04/the-u-s-power-grid-added-15-gw-of-capacity-in-1st-half-of-2022/

https://www.eia.gov/todayinenergy/detail.php?id=48896 834 billion kilowatthours (kWh) of electricity, or about95 GWatts renewables in 2020



Marist CLS (
Act & Astor
C. Park

Next-generation deep offshore turbines

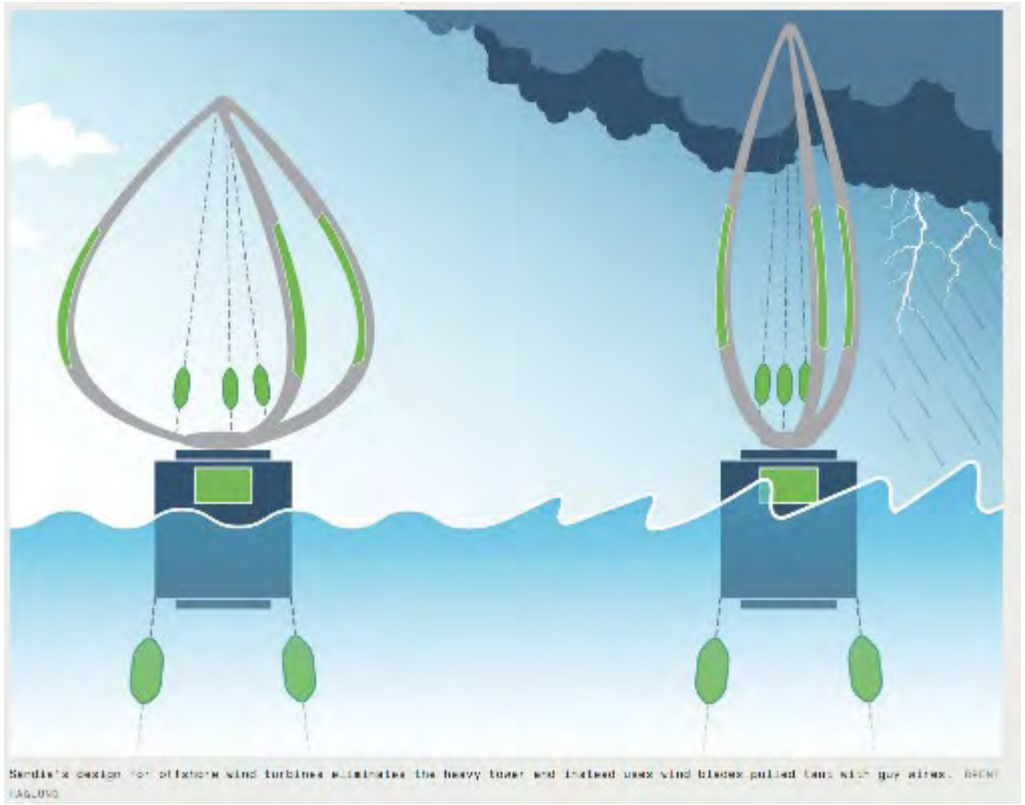
Standard design has very top heavy tower
& requires lots of C-intensive steel and materials

A period of wild innovation is coming in all areas

The company says this design leaves much less turbulence behind it, allowing a much higher density of towers per given site. World Wide Wind

https://newatlas.com/energy/coaxial-vertical-floating-wind-turbines/

30Aug2022 World Wide Wind Contra Rotating Turbines



https://spectrum.ieee.org/vertical-axis-wind-turbine

24Aug2022 Sandia Labs towerless design

Vaclav Smil: cement, steel, plastics and ammonia – … need enormous fossil fuels indefinitely

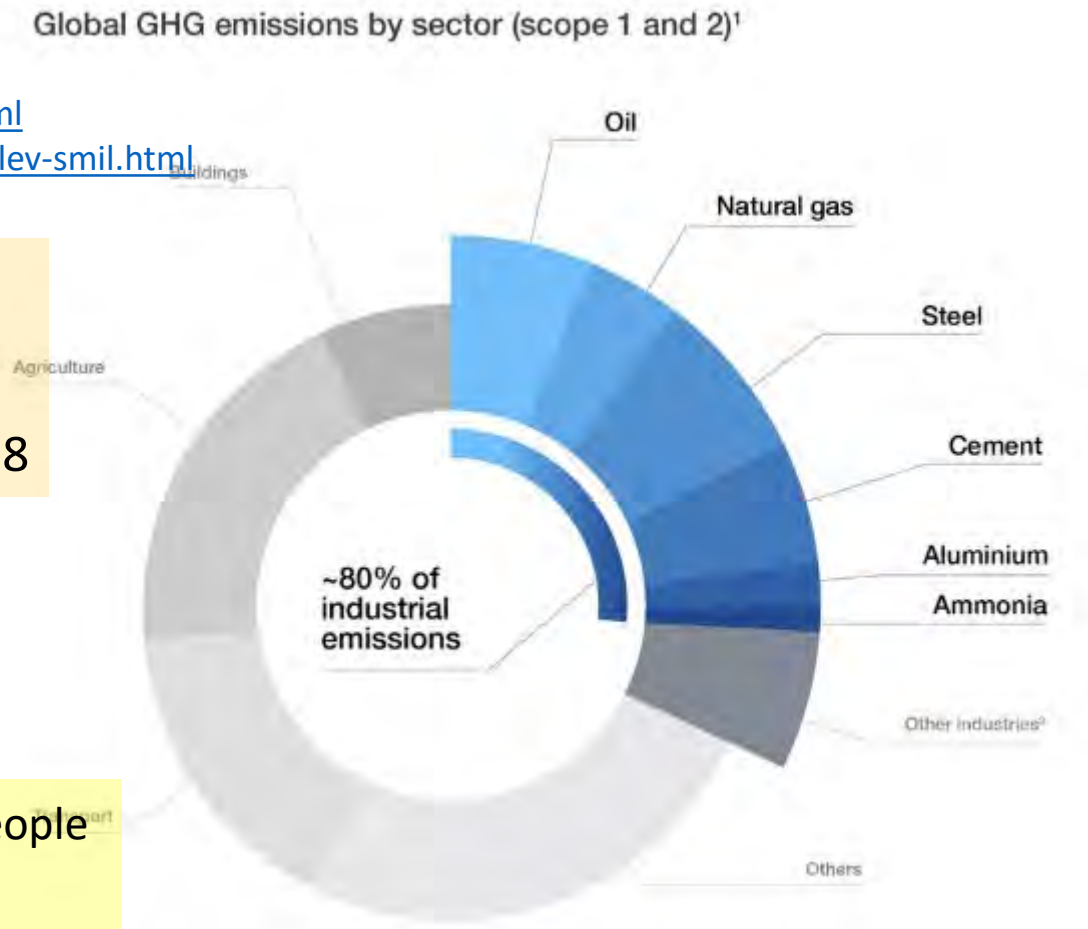
Smil rains on the parade – surge in renewables may not much change CO2 trajectory

https://www.weforum.org/agenda/2022/08/climate-emissions-speed-scale-tracker-net-zero/

https://www.nytimes.com/interactive/2022/04/25/magazine/vaclav-smil-interview.html
https://www.nytimes.com/2022/05/11/books/review/how-the-world-really-works-vaclev-smil.html

… loaf of sourdough … 5.5 tablespoons of diesel fuel,
… supermarket tomato … about six tablespoons of diesel.

1kg sourdough -> 250ml diesel 1kg chicken -> 300ml oil p58



Catastrophists wrong, time after time ..
Techno-optimists .. similarly poor record
p211 ***Smil has no confidence in our ability to project a generation out***

Africa population boom mid 21st century – 1-2 billion extra people
Consuming vast amounts of cement, steel, plastics, and ammonia
→ huge CO2 burden

https://elements.visualcapitalist.com/what-are-the-five-major-types-of-renewable-energy/ 8June2022

When Will Renewable Energy Take Over?

…

The IEA forecasts that, by 2026, global renewable electricity capacity is set to grow by **60%** from 2020 levels to over 4,800 gigawatts—equal to the current power output of fossil fuels and nuclear combined.

…

https://www.iea.org/news/renewable-electricity-growth-is-accelerating-faster-than-ever-worldwide-supporting-the-emergence-of-the-new-global-energy-economy 1Dec2021

IEA 2021 Forecast to 2026 – enormous renewable growth, but significantly short of Net Zero by 2025

IEA Renewables Forecast to 2026

International Energy Agency confirms enormous growth of renewables

Level needed for Net Zero

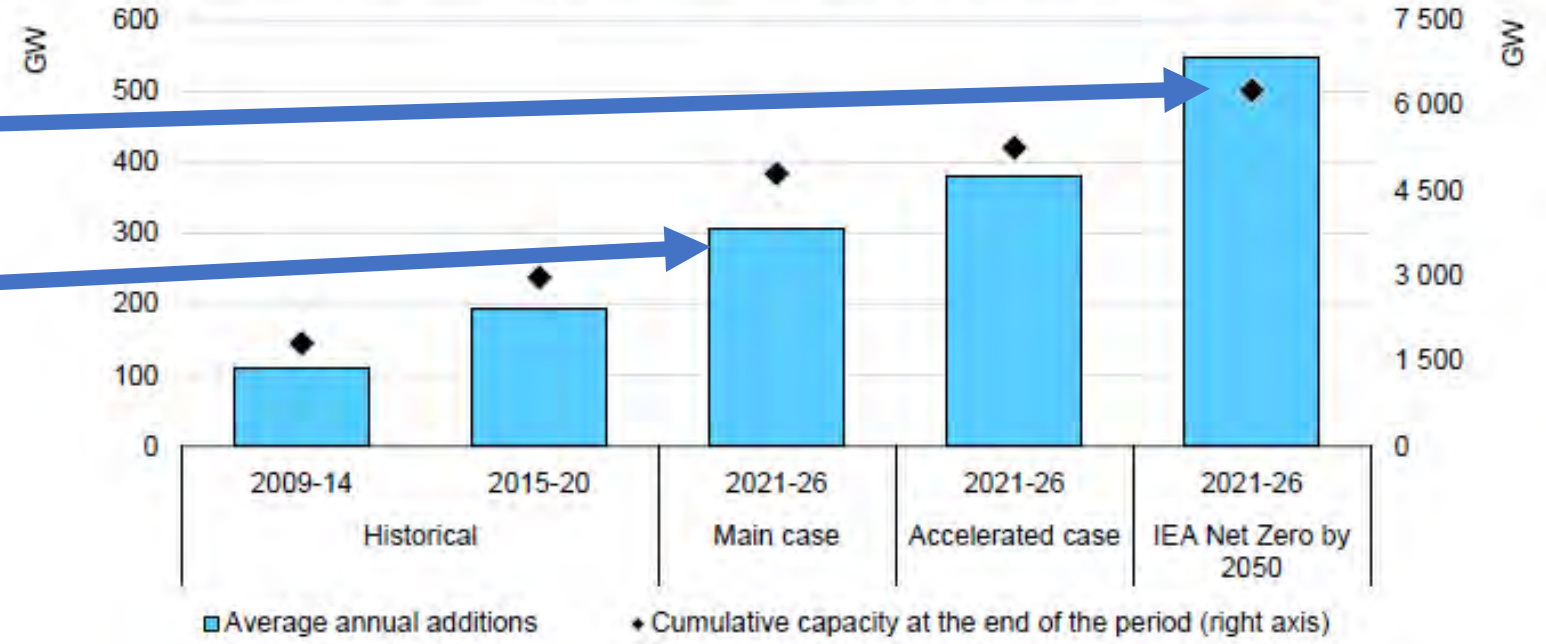
"Main Case Forecast" levels are much lower than needed to stabilize the climate

Forecast summary

Renewable capacity additions are set to grow faster than ever in the next five years, but the expansion trend is not on track to meet the IEA Net Zero by 2050 Scenario

Annual additions to global renewable electricity capacity are expected to average around 305 GW per year between 2021 and 2026 in the IEA main case forecast.

Figure 1.1 Average annual renewable capacity additions and cumulative installed capacity, historical, forecasts and IEA Net Zero Scenario, 2009-2026



https://www.iea.org/reports/renewables-2021/renewable-electricity?mode=market&region=World&publication=2021&product=Total
International Energy Agency Analysis and Forecast to 2026

IEA 2021 Forecast to 2026 – enormous renewable growth, but significantly short of Net Zero by 2025

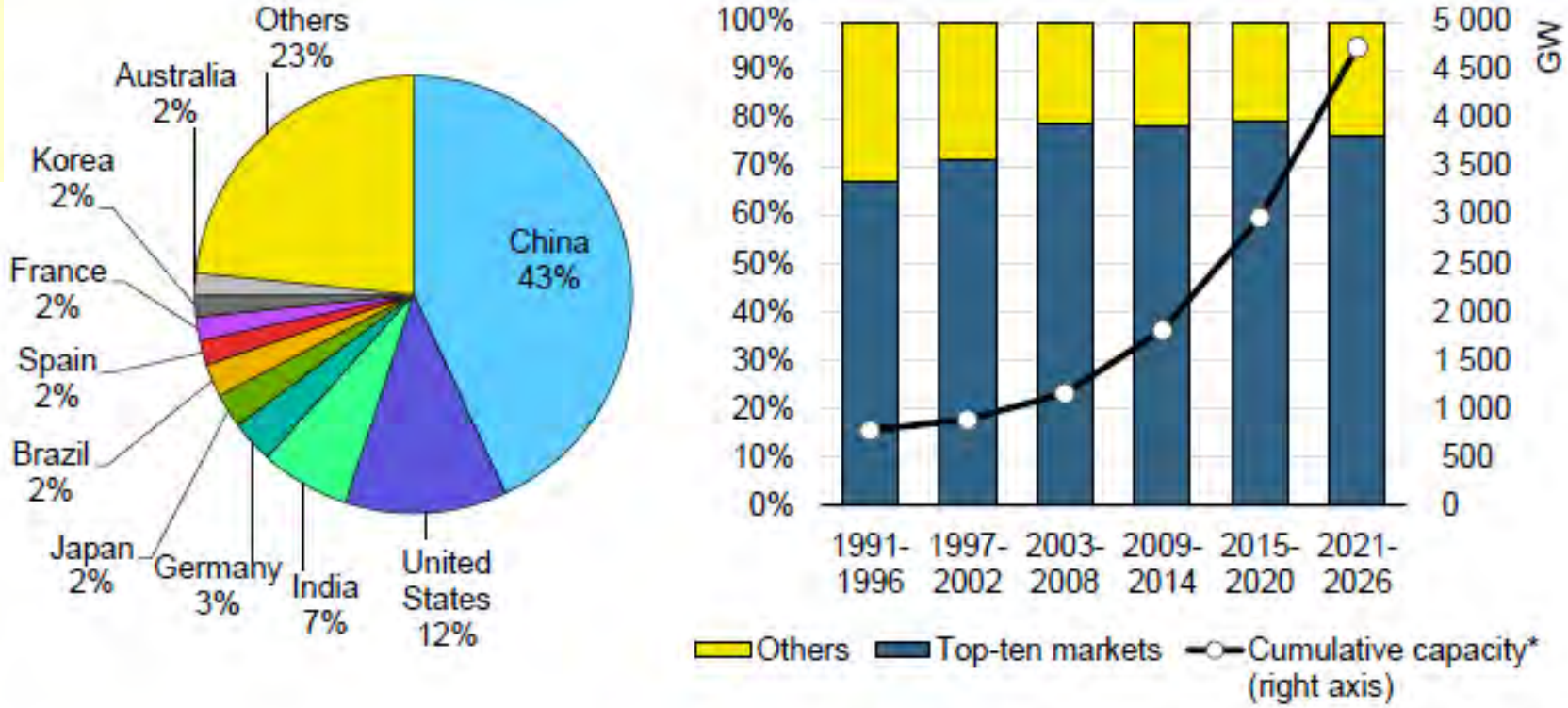
IEA Renewables Forecast to 2026

China dominates total installed renewable capacity

5000 GWatts coming soon

that's a lot!
5 TeraWatts

Figure 1.5 Top-ten countries' share of total installed renewable capacity, historical and main case forecast, 1991-2026



* Cumulative capacity = installed renewable capacity at the end of each five-year period.

5000GWatts / 1000watts/person → "1 billion people" if used energy like in US
Want energy for 10 billion people, or the Net Zero Scenario 6500GWatts by 2026

https://www.iea.org/reports/renewables-2021/renewable-electricity?mode=market&region=World&publication=2021&product=Total
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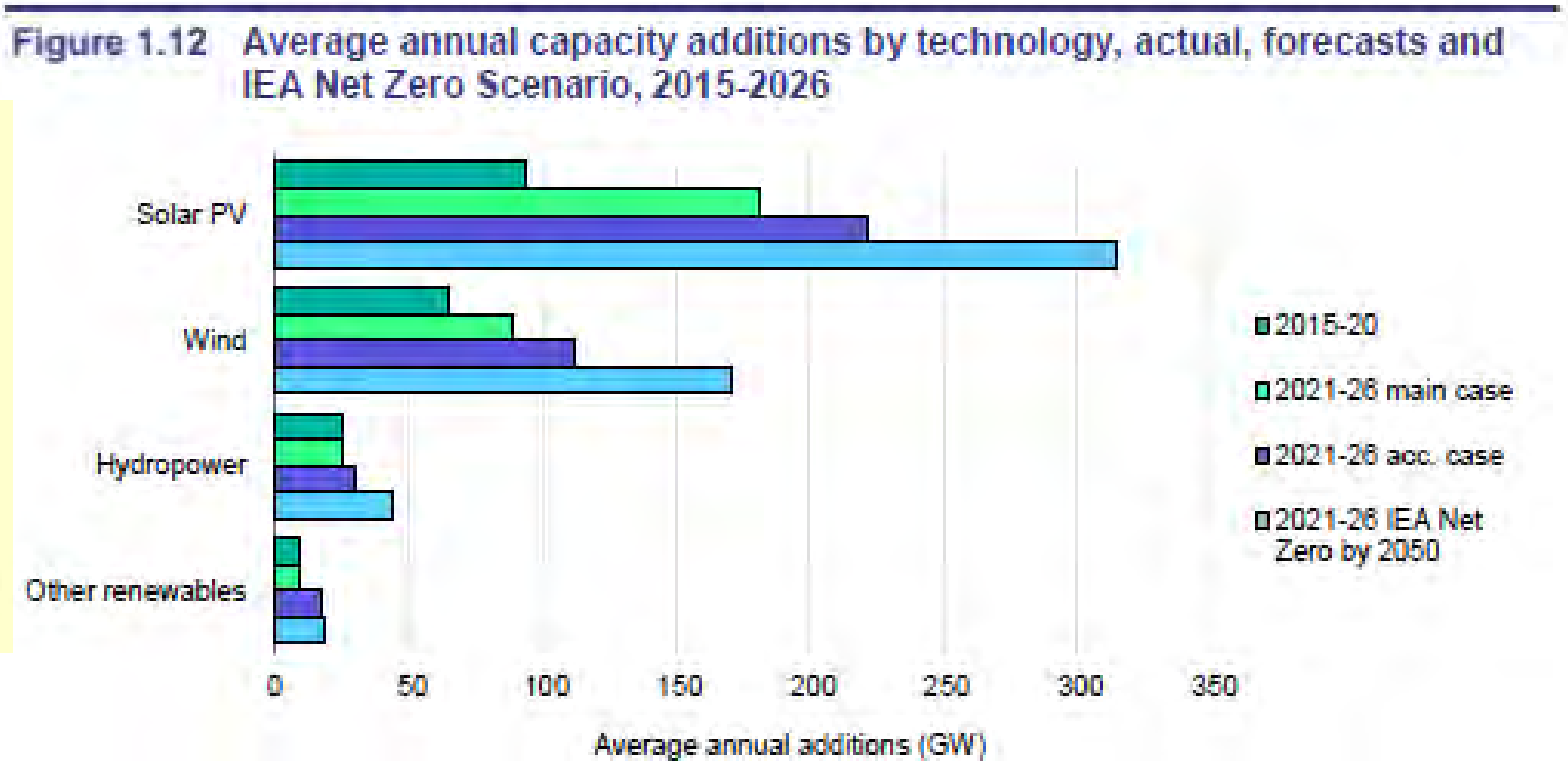
IEA 2021 Forecast to 2026 – enormous renewable growth, but significantly short of Net Zero by 2025

IEA Renewables Forecast to 2026

Large additions of Solar and Wind

Hydro is very important but is maxed out already



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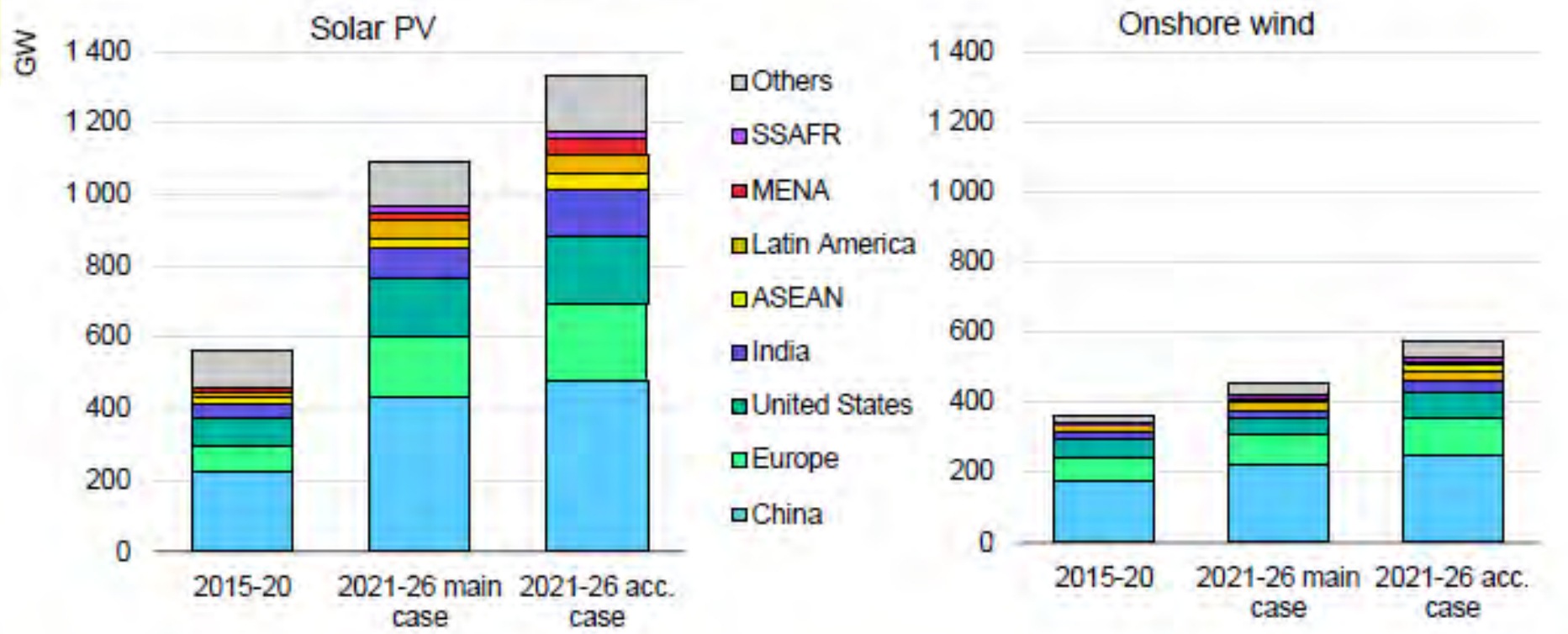
International Energy Agency Analysis and Forecast to 2026

IEA 2021 Forecast to 2026 – enormous renewable growth, but significantly short of Net Zero by 2025

IEA Renewables Forecast to 2026

Solar is much larger wind

Figure 1.7 Solar PV and onshore wind capacity additions, actual and forecast by country/region, 2015-2026



Note: acc. case = accelerated case; ASEAN = Association of Southeast Asian Nations; MENA = Middle East and North Africa; SSAFR = sub-Saharan Africa.

https://www.iea.org/reports/renewables-2021/renewable-electricity?mode=market&region=World&publication=2021&product=Total
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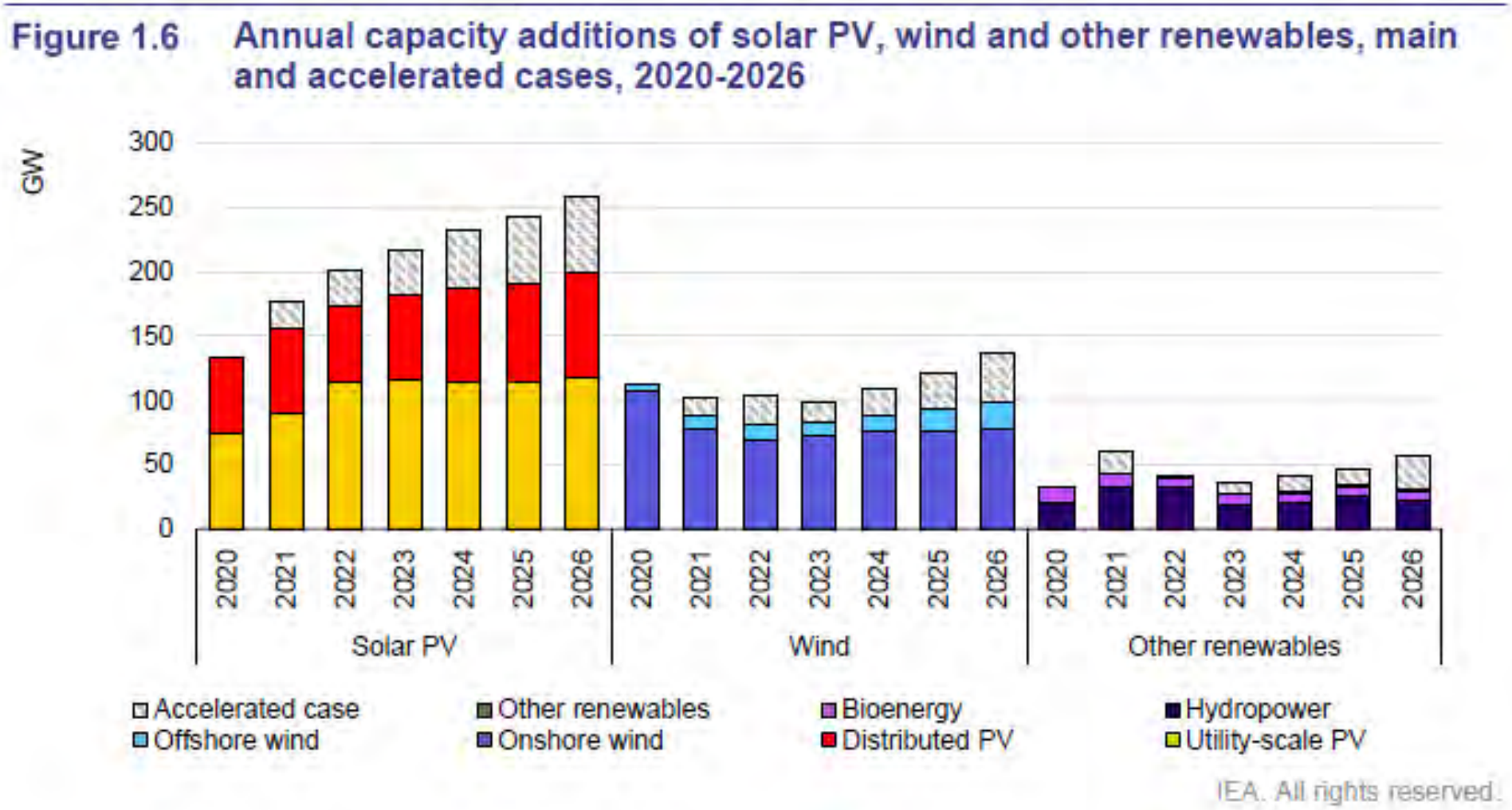
IEA 2021 Forecast to 2026 – enormous renewable growth, but significantly short of Net Zero by 2025

IEA Renewables Forecast to 2026

Greatest opportunity for Distributed PhotoVoltaics



https://www.iea.org/reports/renewables-2021/renewable-electricity?mode=market&region=World&publication=2021&product=Total
International Energy Agency Analysis and Forecast to 2026

Disruptive Factor: Stunning drop in Renewables Prices;
Explosion of investment in renewables. We are following a new path

Cost vs. Installed Capacity

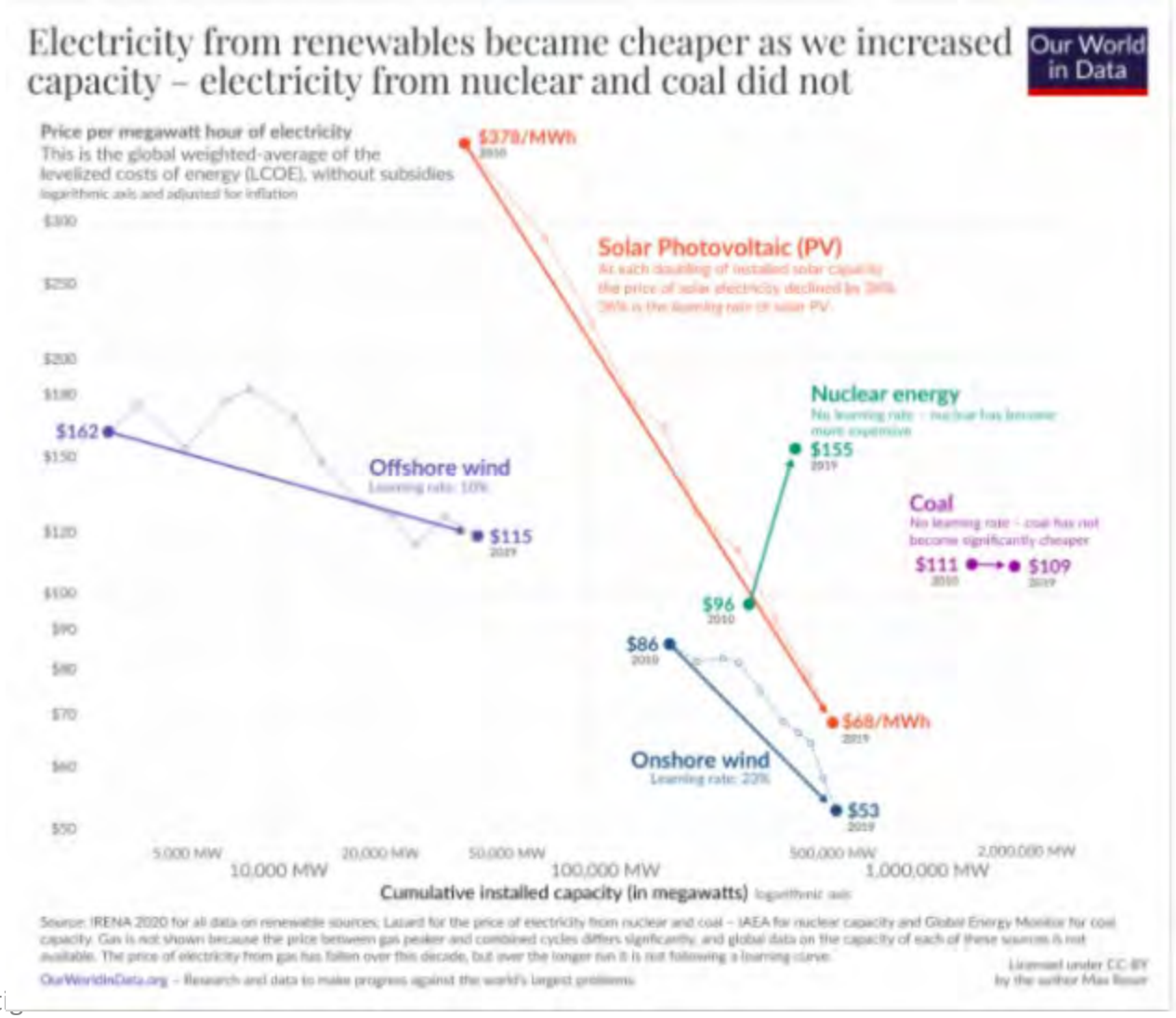
Miracle of astonishing drop in renewable prices

Learning curve – price drops with installed capacity

https://ourworldindata.org/cheap-renewables-growth

Dec. 2020 Max Roser

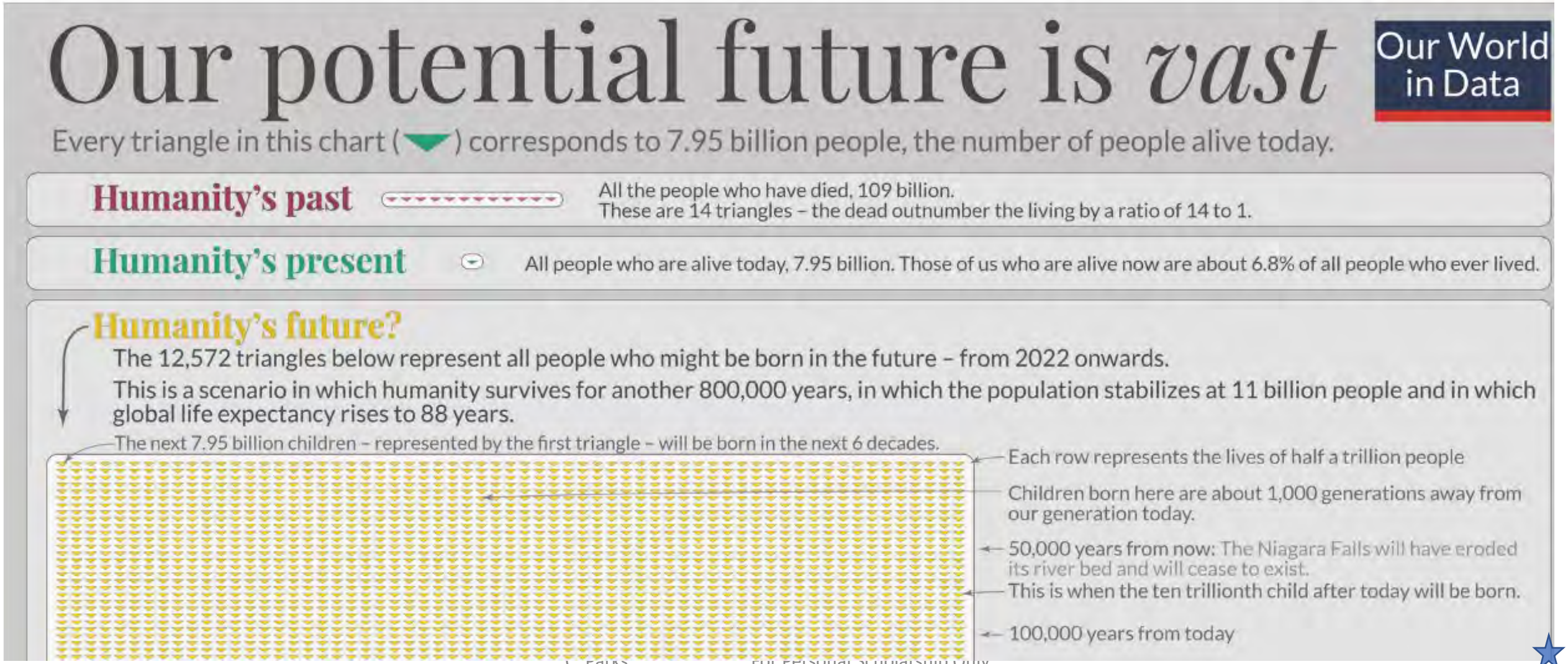
Very clear and important article – I suggest that you read, especially if you want a more positive outlook!



Alternate perspective of hope - Longtermism

"Longtermism" – smarter people than me (ccp) think we'll get through current crises like Climate Change, and humanity is at the start of a vast productive & positive period!

https://ourworldindata.org/longtermism Max Roser 15Mar2022 fascinating article and links



Alternate perspective of hope – "Longtermism"

https://ourworldindata.org/longtermism Max Roser 15Mar2022

https://www.whatweowethefuture.com/ book coming out late 2022 by William MacAskil Max Roser:

MacAskil's manuscript very much inspired this post and I very much recommend his book. It has changed how I think about my time on Earth. https://en.wikipedia.org/wiki/What_We_Owe_the_Future

Our opportunities are vast too Perspective by Max Roser March 2022

So far I've only spoken about the risks that we face. But our large future means that there are large opportunities too.

Problems are solvable. This is for me the most important insight that I learned from writing Our World in Data over the last decade.

Compared to the vast future ahead, the two centuries shown in this chart here are only a brief episode of human history. But even in such a short period we have made substantial progress against many large problems.

Given enough time we can end the horrors of today. Poverty is not inevitable; we can achieve a future where people are not suffering from scarcity. Diseases that are incurable today might be curable in just a few generations; we already have an amazing track record in improving people's health. And we can achieve a world in which we stop damaging the environment and achieve a future in which the world's wildlife flourishes.

Our children and grandchildren can continue the progress we are making, and they may create art and build a society more beautiful than we can even imagine.

The Astonishing Drop in Cost of Renewables: Can Economics Save the Climate?

CLS Marist GS4 & SS4 Sept. 28, 2022 Poughkeepsie NY Lect4: can Economics save climate?

- World 3C likely Future – 40C heat waves ramping till Net Zero CO2 achieved
  - Spectacularly Small Response over 40 years <0.3% of Gross Domestic Product (US & others)
- Disruptive Miracle: Wind, Solar, Battery costs fall exponentially
  - **Renewables are rushing in Breaking the bleak backdrop of the past 40 years**
- Renewables: 20% yearly increases, 755B$ approaching 1% of World GDP
  - Major 2022 Reports: BloombergNEF Ember McKinsey IEA Renewables
  - Driven by China – Solar, Wind, Batteries, Control of Rare Earths, Congo Cobalt, Nickel, Copper
  - US just starting to follow: Surprise August 2022 passage of historic IRA emphasizing renewables
- **Perspective:**
  →Explosive growth of renewables – world going from budgetary rounding error amount 0.3% of GDP investment to almost 1% of GDP.
  → >7% of GDP needed to stabilize climate at whatever CO2 level the world arrives at, per McKinsey 2022 report
  Renewables major progress! Short in magnitude by 7X But train has moved out of the station!