

Review of Net Zero Policies

*Canadian Society for
Engineering Management*

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Friends of Science Society
February 15, 2023.

Ken Gregory, P.Eng.

- Retired professional engineer
- Studied climate science for 16 years
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- CliSci Newsletter editor
- Science News, Quarterly newsletters
- YouTube videos >540

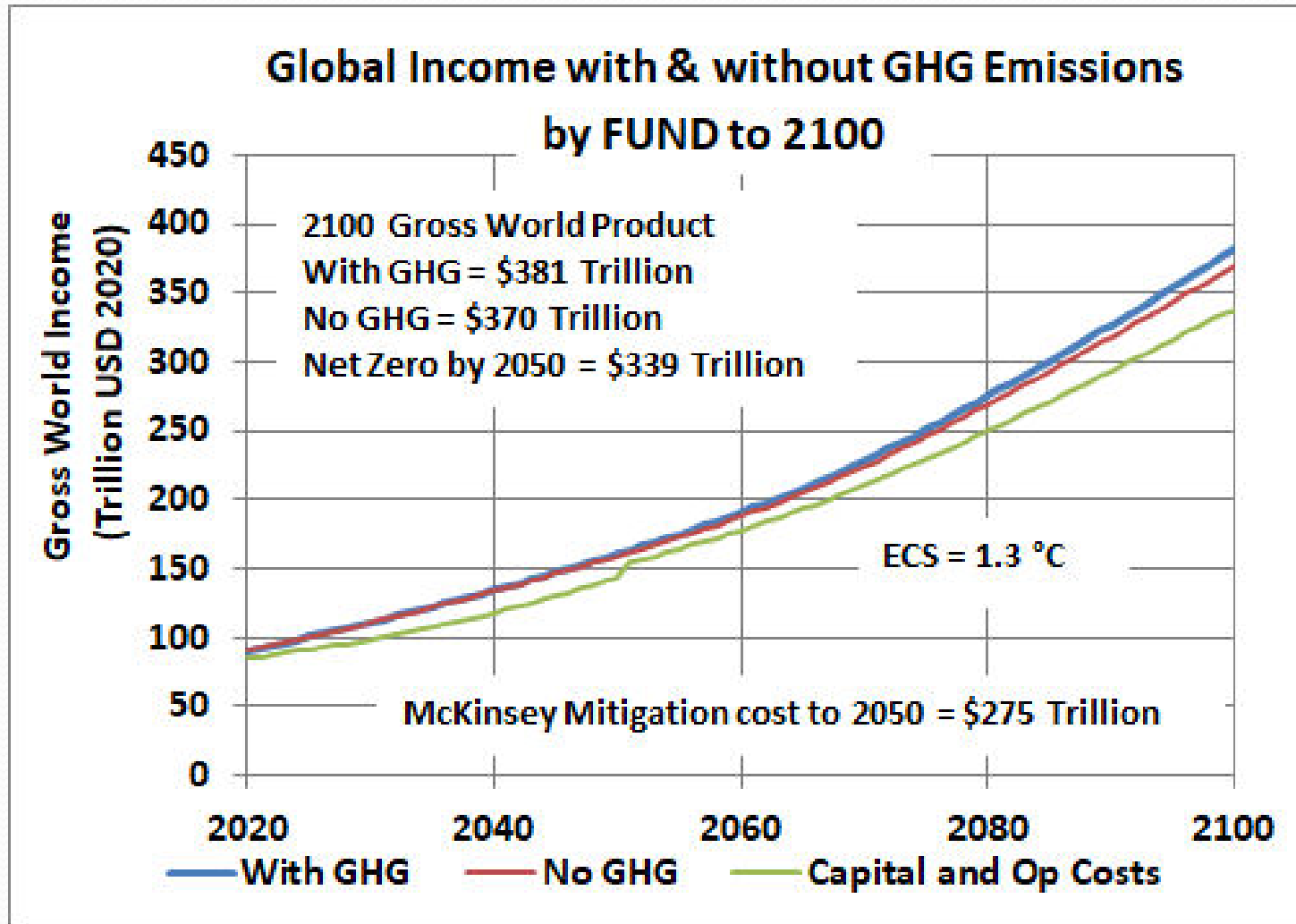
Net Zero Greenhouse Gas Emissions

- Reduce CO₂ emissions
- Carbon Capture and Storage (CCS)
- CO₂ emissions are net beneficial
- NGO; replace all fossil fuels with wind and solar
- Oil is required for over 6000 products
- Global capital cost of Net Zero estimated at US\$ 275 Trillion, [2.9 X Global GWP of \$96 Tr]

NGOs Advocate End of Fossil Fuels



Global Annual Income Prediction



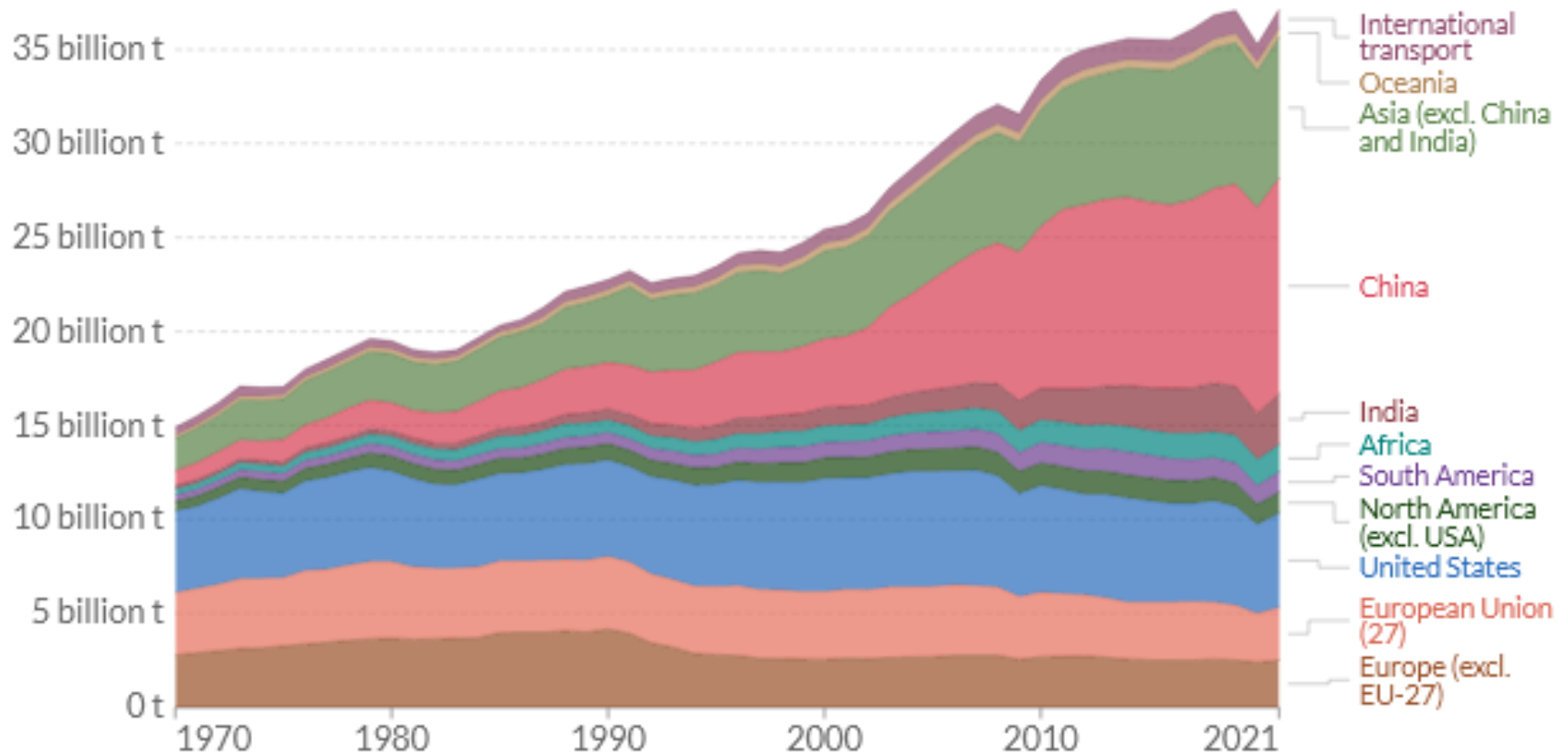
Annual CO2 Emissions by World Region

Annual CO₂ emissions by world region

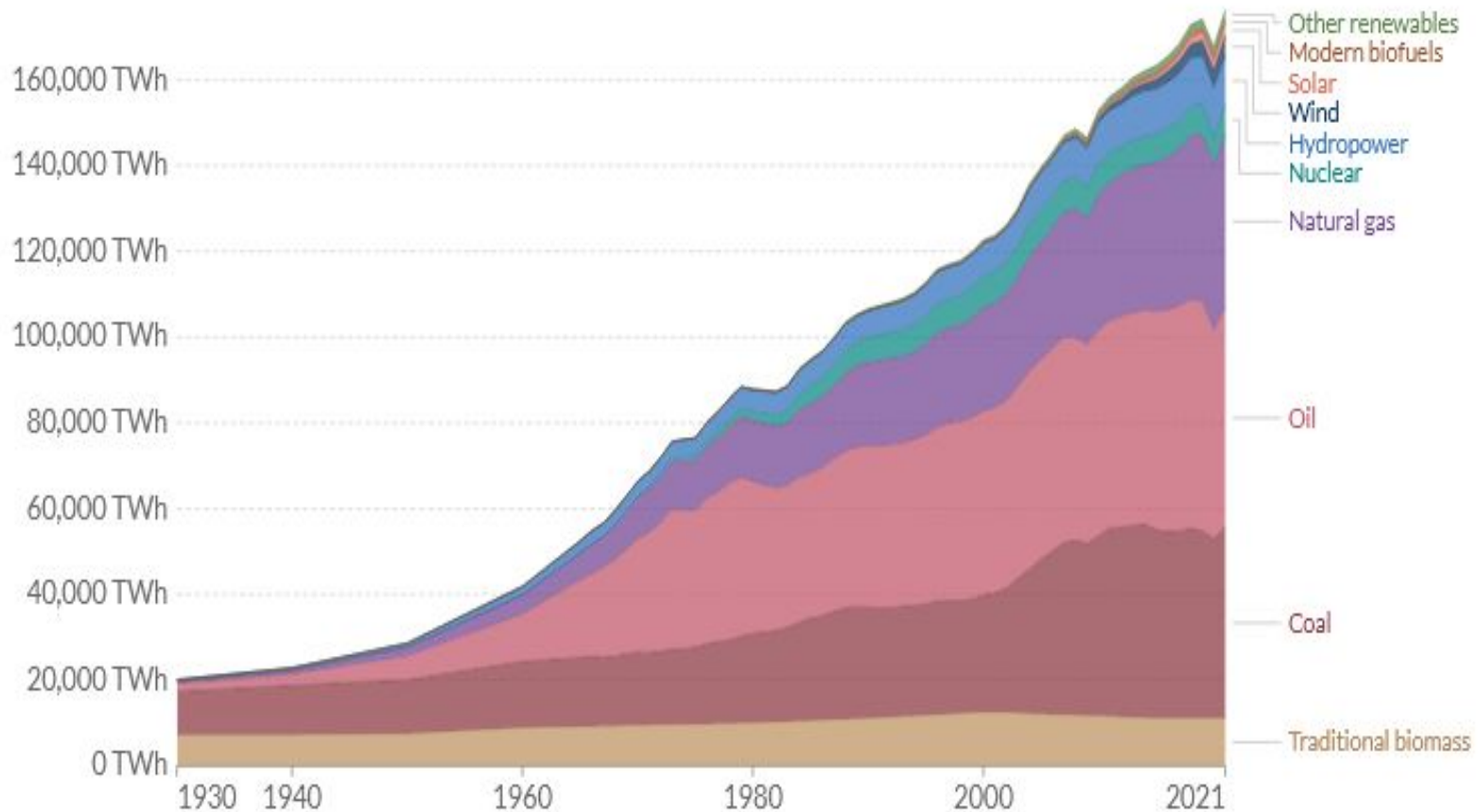
This measures fossil fuel and industry emissions. Land use change is not included.

Our World
in Data

□ Relative



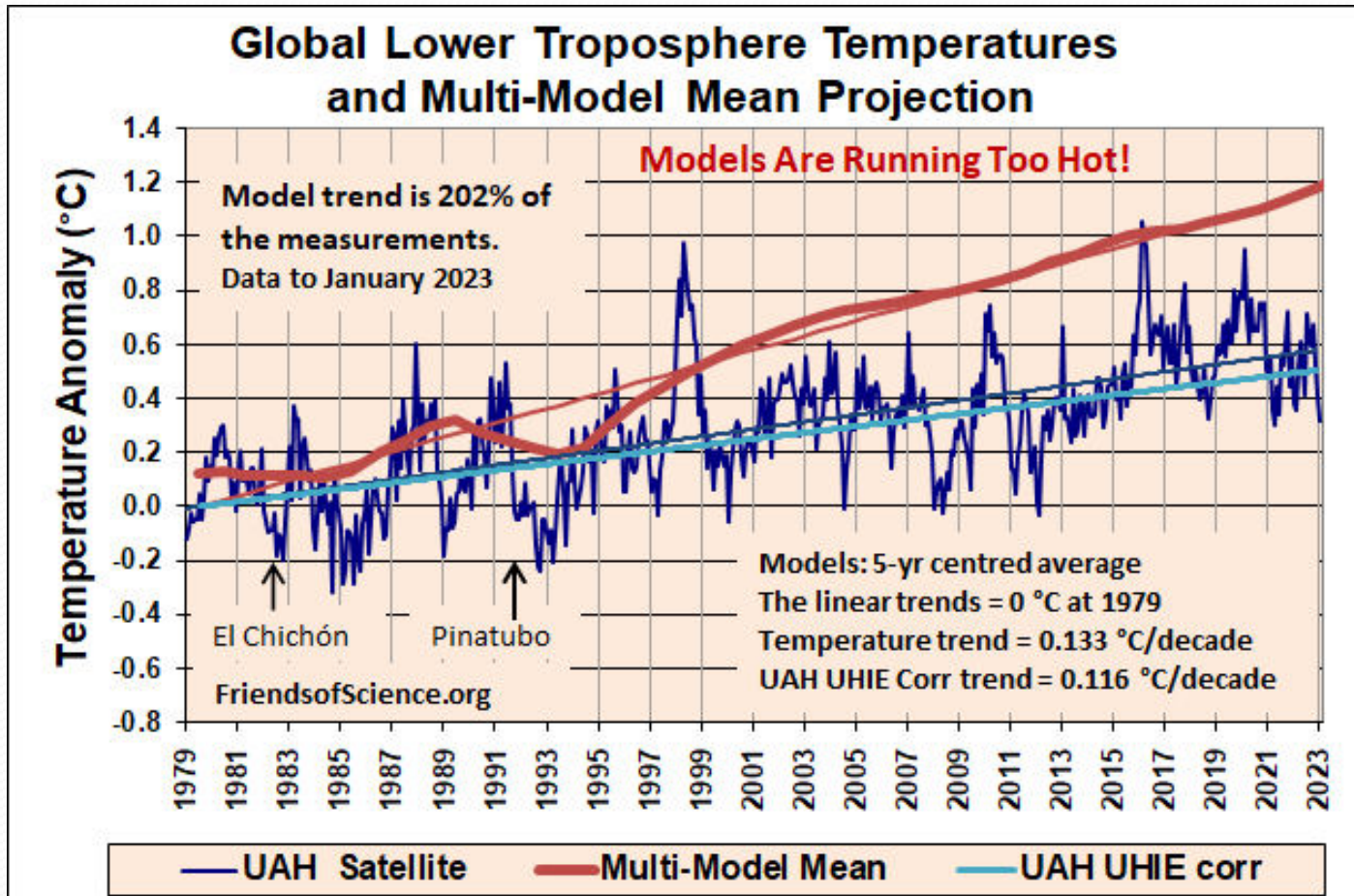
Global Primary Energy Consumption by Source



Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

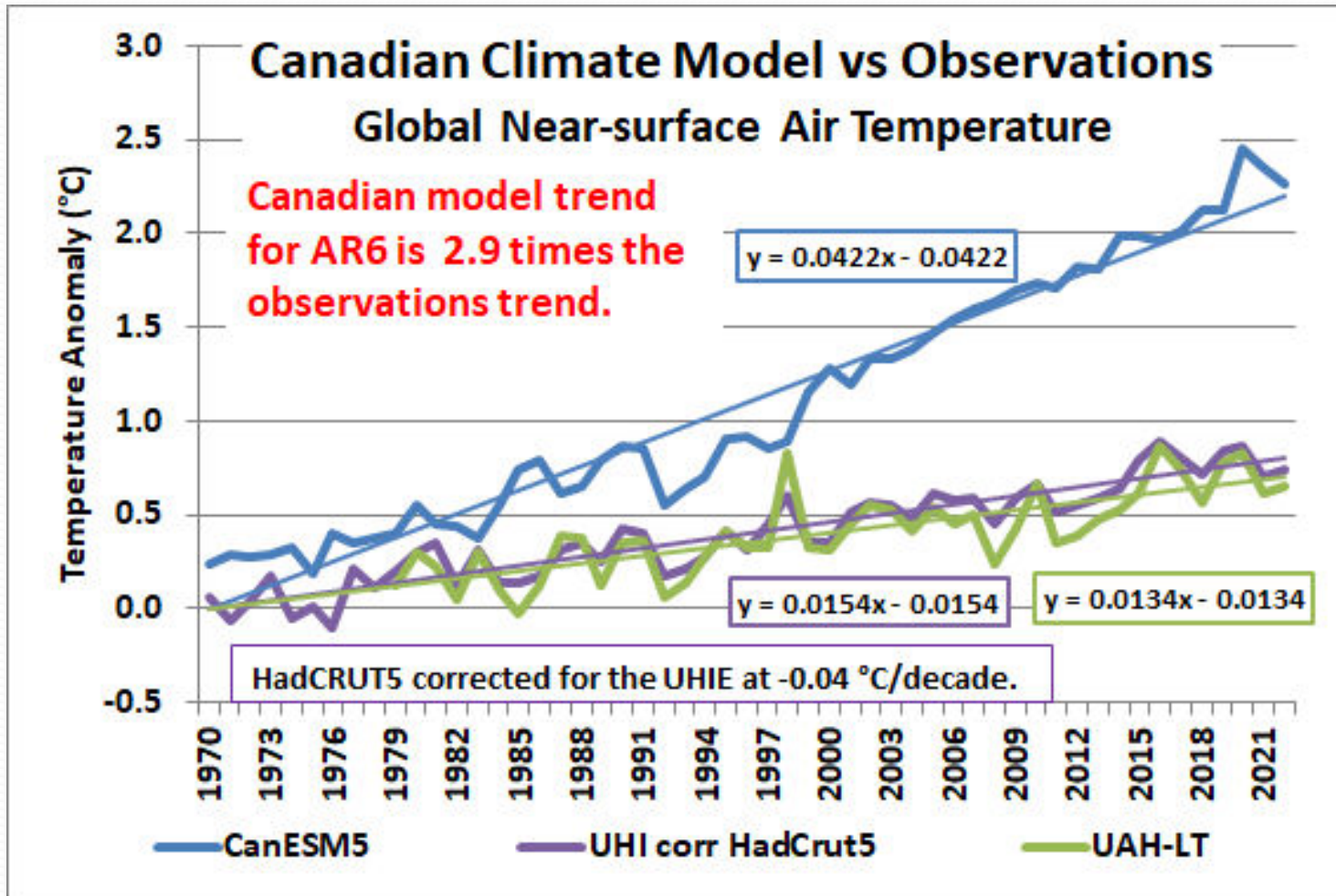
OurWorldInData.org/energy • CC BY

Global Air Temperatures

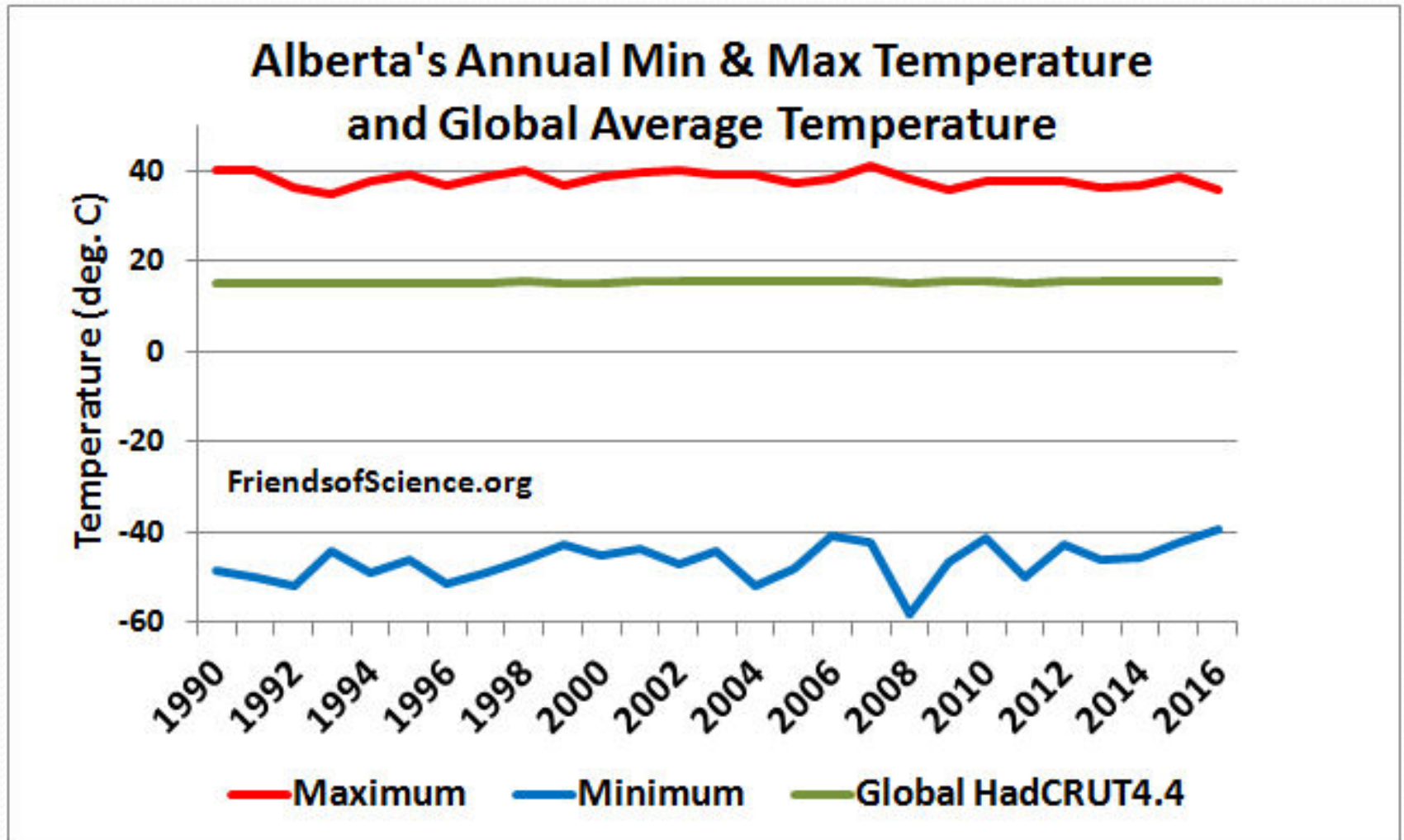


Air temperature trend: $0.13^{\circ}\text{C}/\text{decade}$, half of climate models.

Canadian Climate Model: 2.9 X Wrong!



Alberta and Global Temperatures



Integrated Assessment Models

- SCC is the social cost (benefit) of CO₂ emissions per tonne CO₂. Used to set carbon taxes.
- The U.S. Government uses three economic models:
 - FUND, PAGE and DICE
- PAGE and DICE have almost no CO₂ fertilization effect, ignores benefits.
- The DICE model assumes that the optimum climate at 1900, near end of Little Ice Age.
- PAGE explicitly does not include adaptation.

FUND Errors

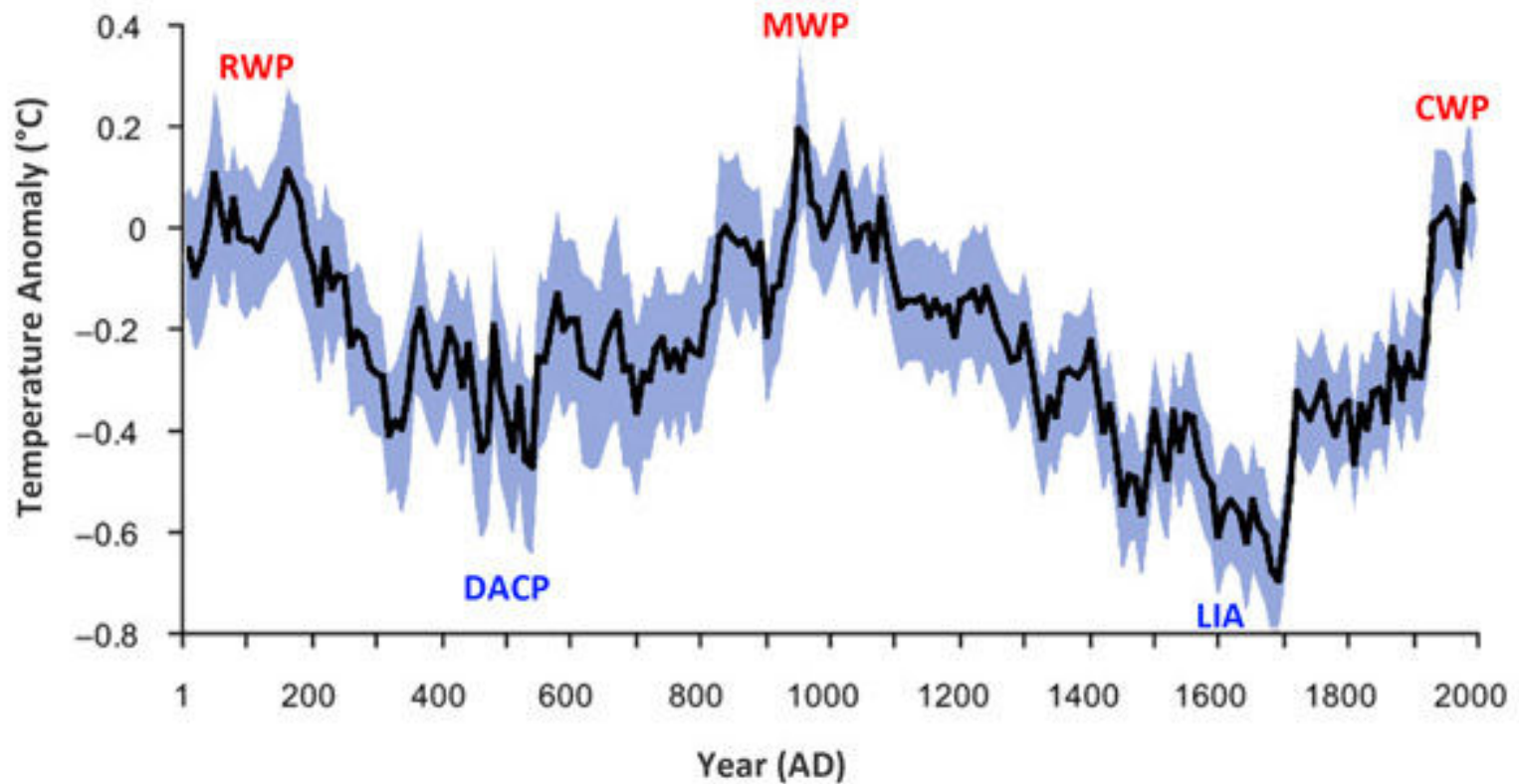
- Integrated Assessment Model (IAM)
- Default climate sensitivity is too high.
- Space heating and cooling are wrong, fails to match data.
- CO₂ fertilization effect is too low.

Climate Sensitivity by Energy Balance

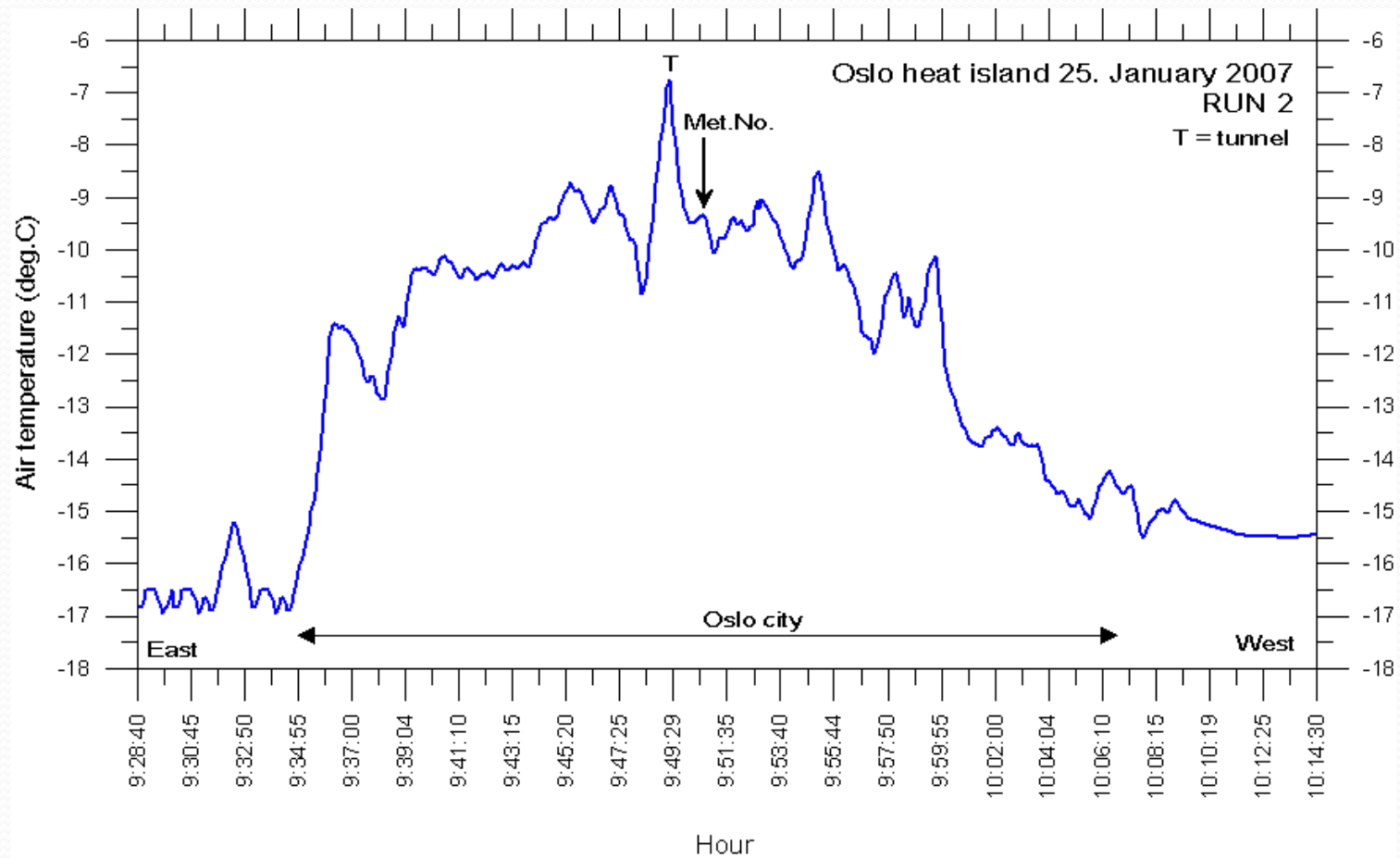
- Lewis&Curry energy balance gives climate sensitivity to CO₂ by comparing greenhouse gas (GHG) forcings to actual temperature changes in air and oceans from 1869.
- L&C assume temperature change due to GHG only.
- Adjust temp change by millennium cycle and Urban Heat Island Effect (UHIE).

Northern Hemisphere Temperatures

Extra-Tropical Northern Hemisphere (30-90°N) Decadal Mean Temperature
Adapted from Ljungqvist, 2010



Urban Heat Island Effect



Urban Heat Island Effect

- McKittrick and Michaels 2007: About half of warming over land is due to urban development
- IPCC Nonsense: “the locations of greatest socioeconomic development are also those that have been most warmed by atmospheric circulation changes.”
- Reduces global trend from 1980 by 0.042 °C/decade

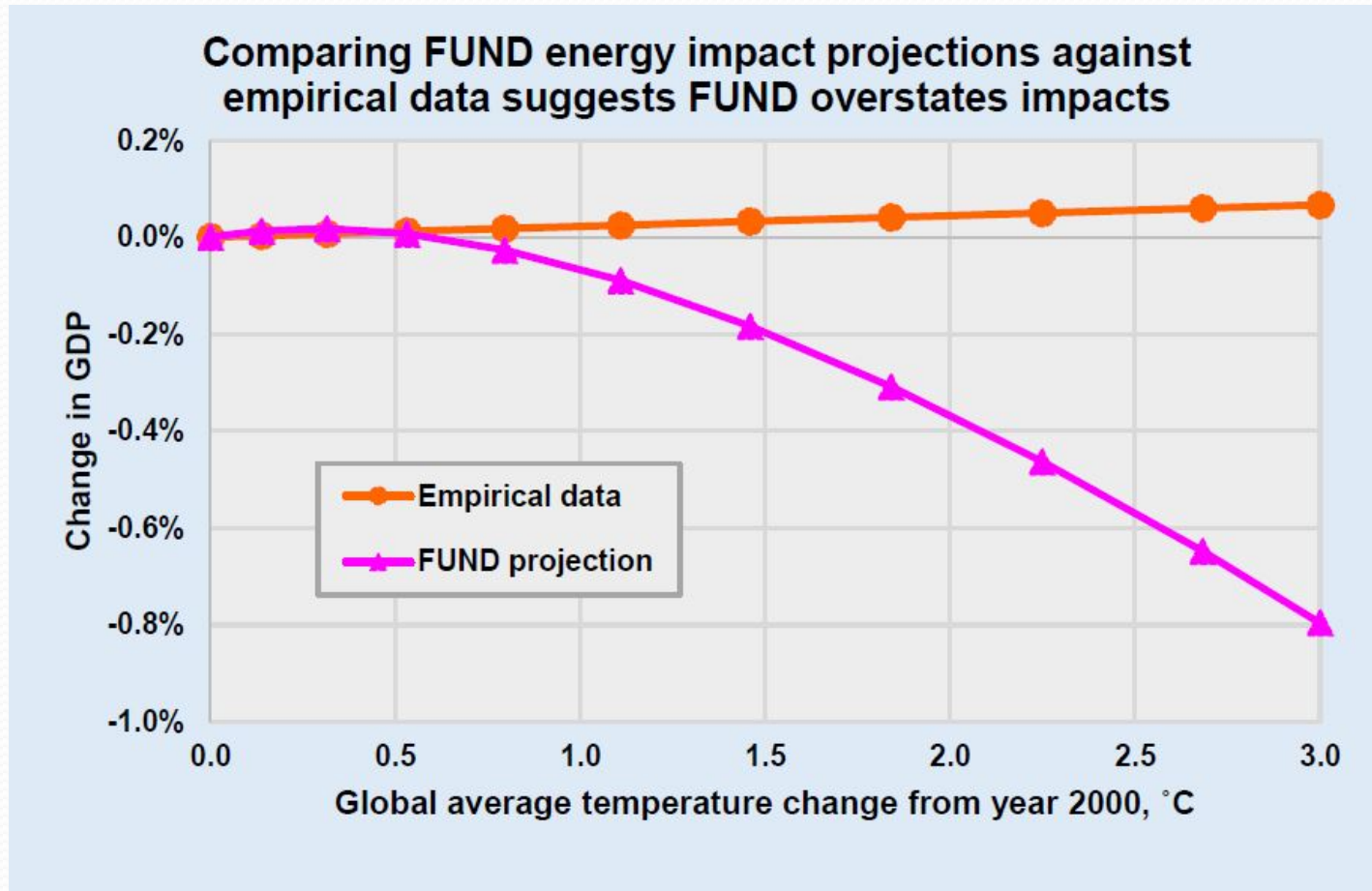
Transient Climate Response Estimates

	TCR BE	TRC Likely 17-83%
UN IPCC AR5	1.8	1.0 – 2.5
Lewis & Curry 2018 Energy Balance	1.33	1.10 – 1.60
With Natural Warming & UHIE	0.95	0.74 – 1.21

TCR is temperature change due to double CO₂ at that time, about 125 years.

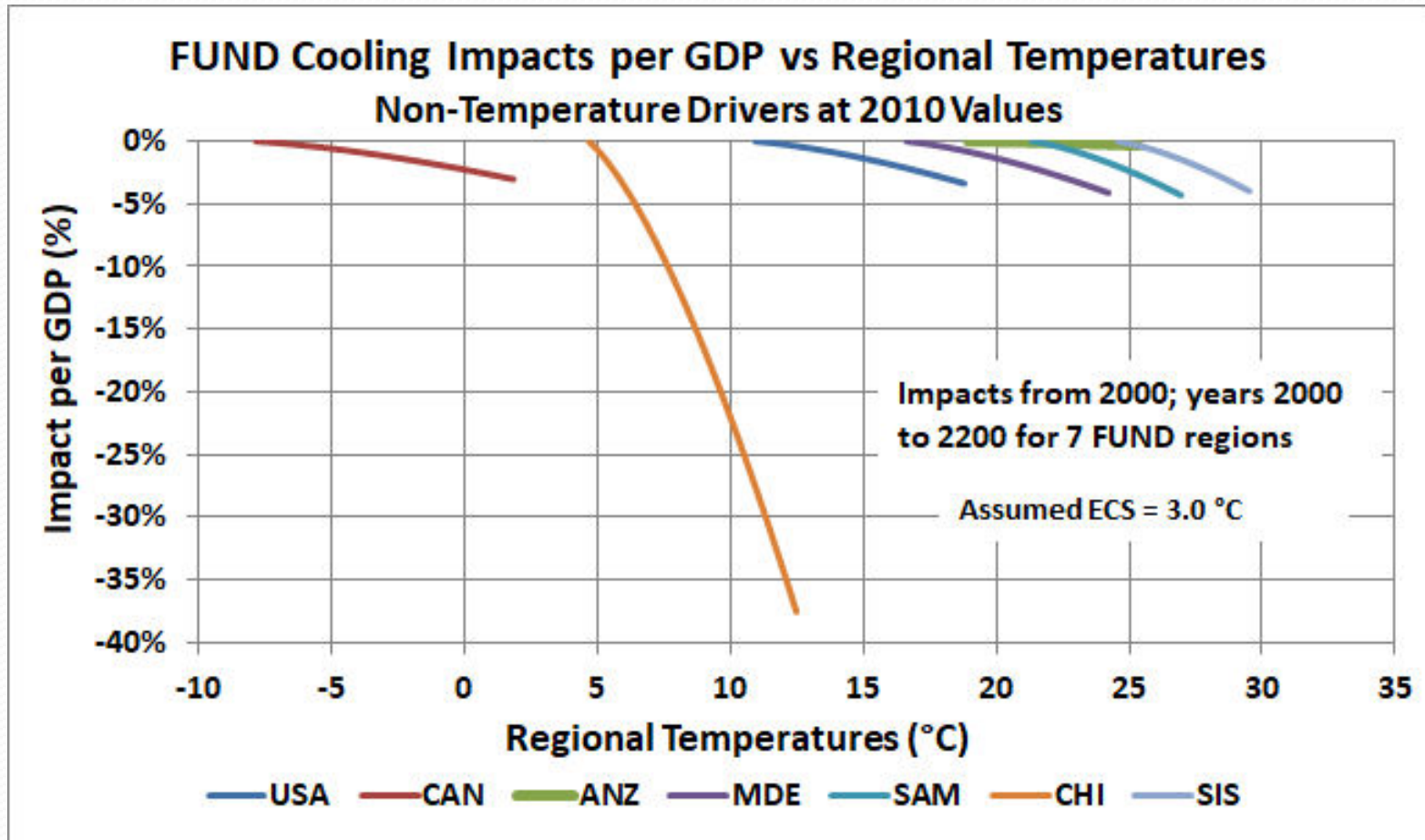
IPCC Best Estimate (BE) of TCR is 1.9 times too high!

Testing FUND with U.S. Empirical Data



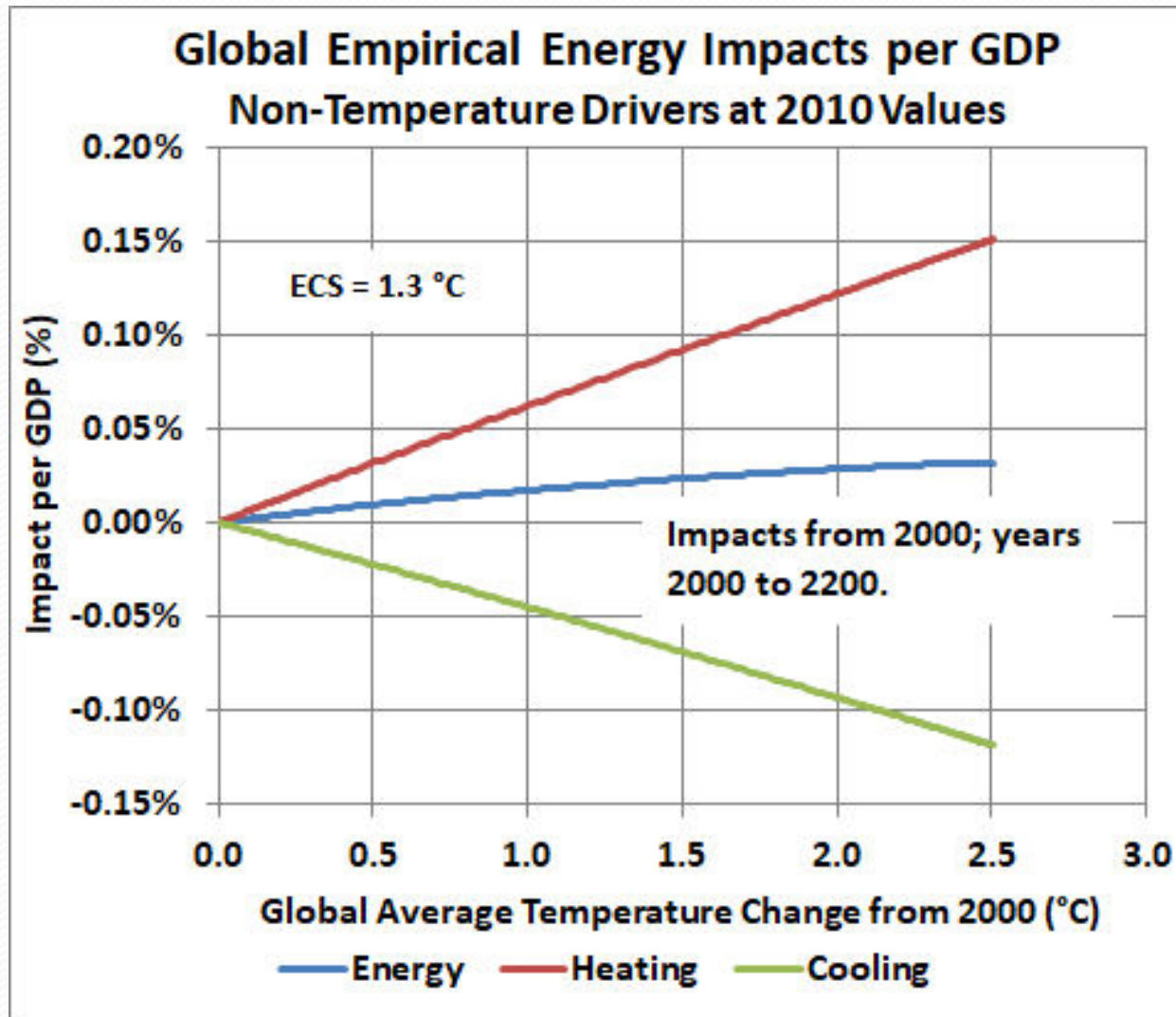
Non-temperature drivers held constant at 2010 values.

FUND Space Cooling Impacts per GDP



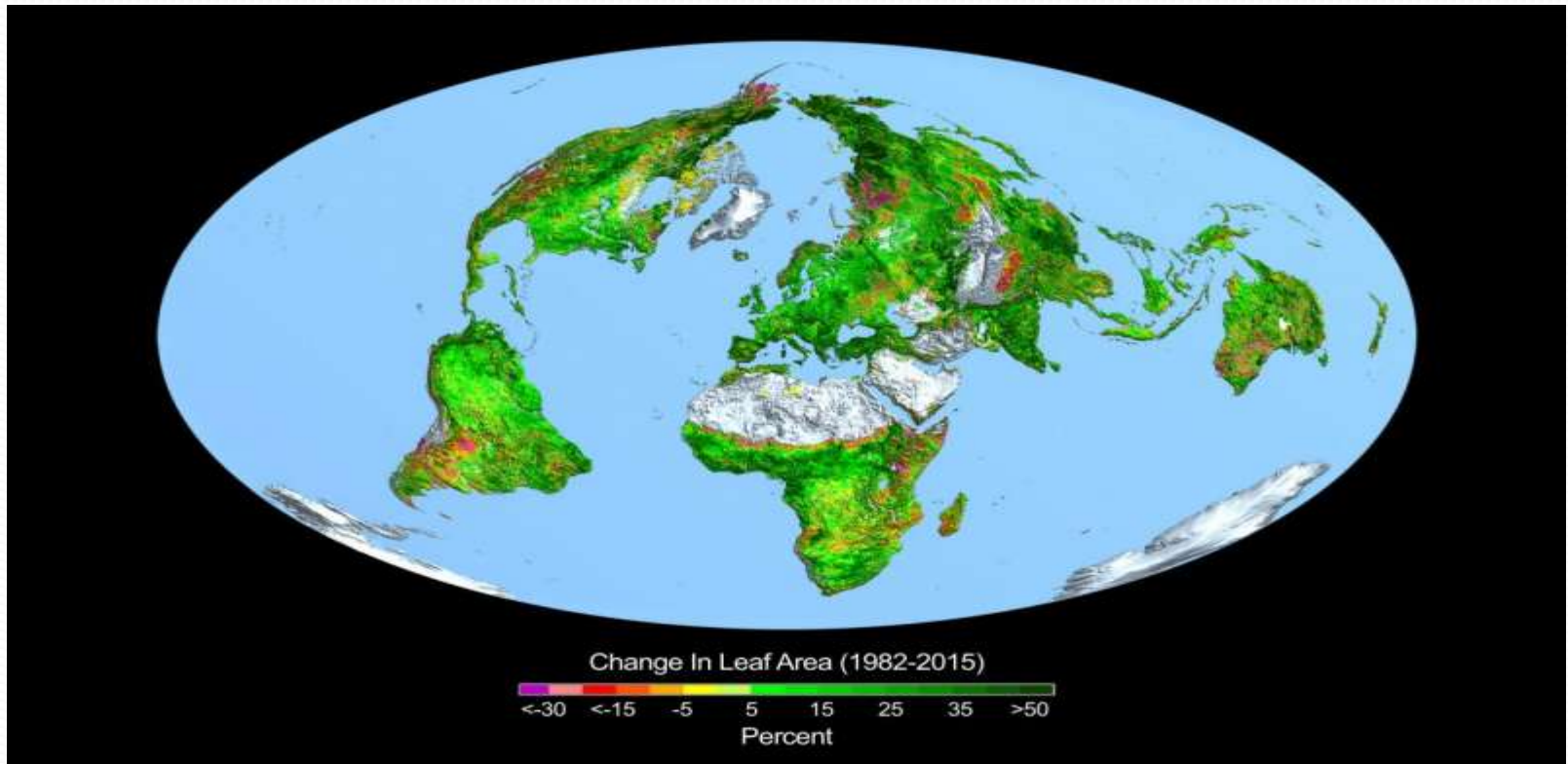
China is spend over 38% of income more on air conditioning by 2200, Australia spends almost none.

Global Energy Impacts per GDP

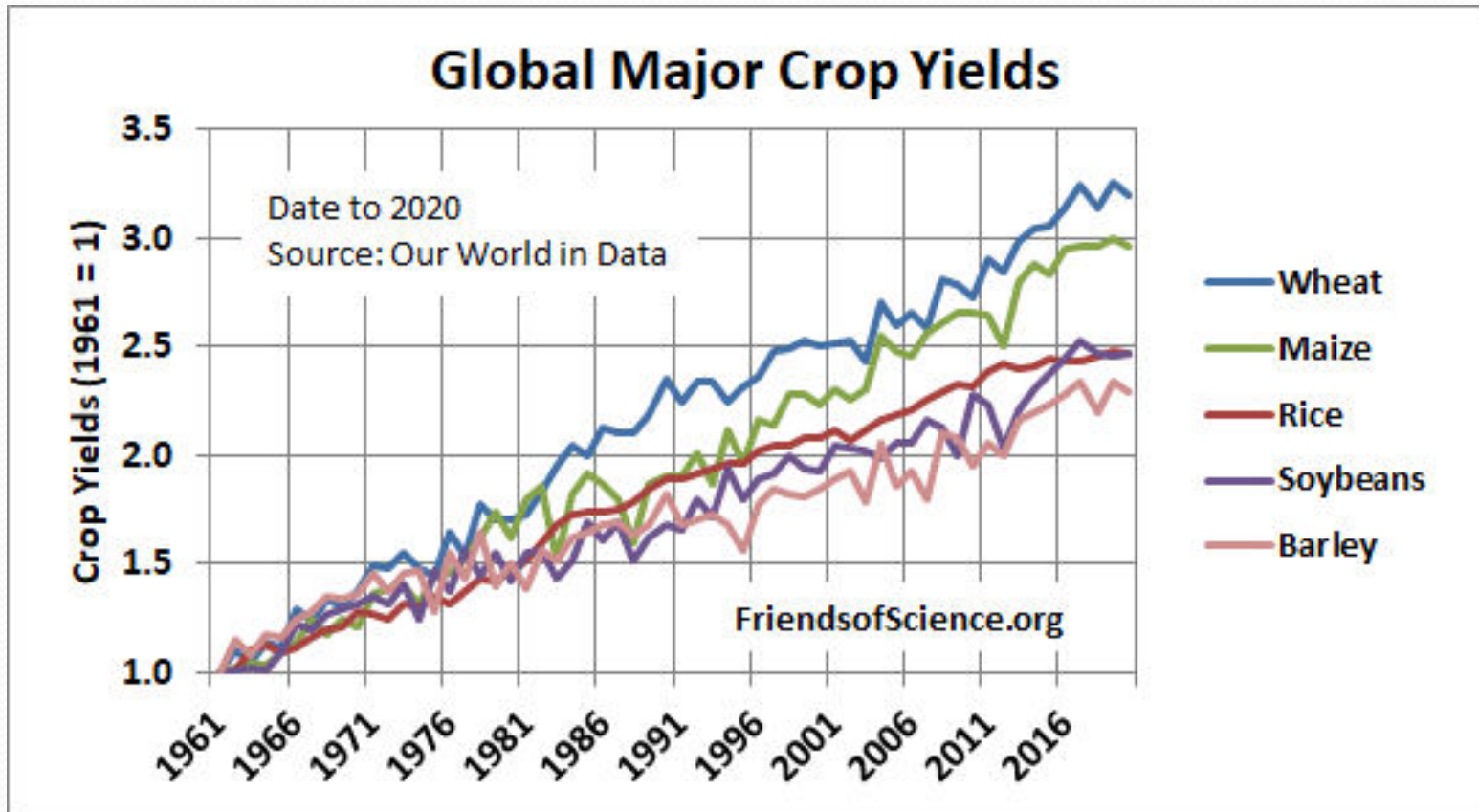


CO₂ is Greening the Planet

- CO₂ fertilization caused a global greening of 12.4% over 33 years.
- Equivalent to adding a green continent twice the size of mainland USA (18 million km²)



Global Crop Relative Yields



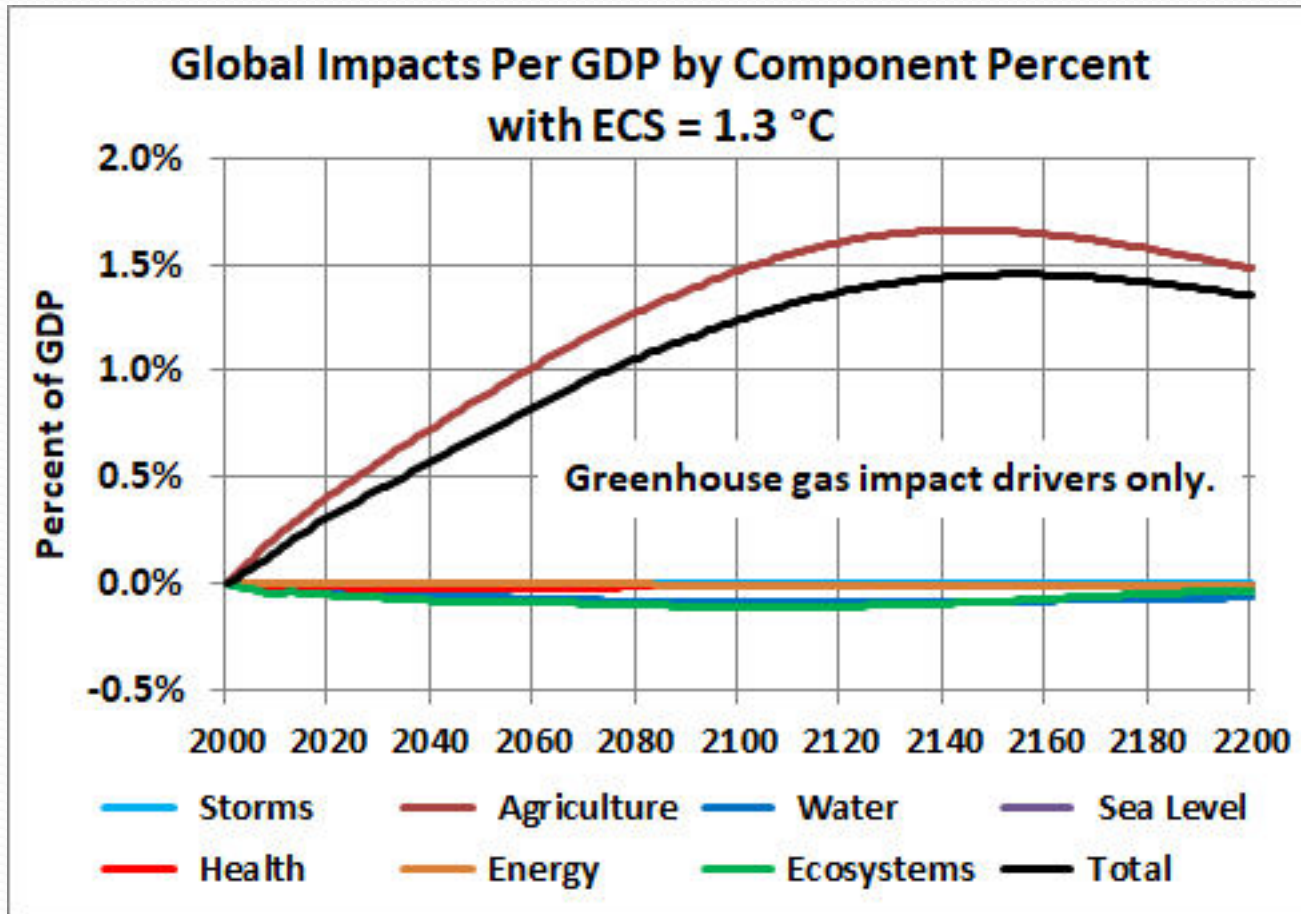
CO₂ increases since 1950 have enhance crop yields by 16%.

Global major crop yield continue to increase, some by over 300% from 1961.

FUND's CO₂ Fertilization increase +30%

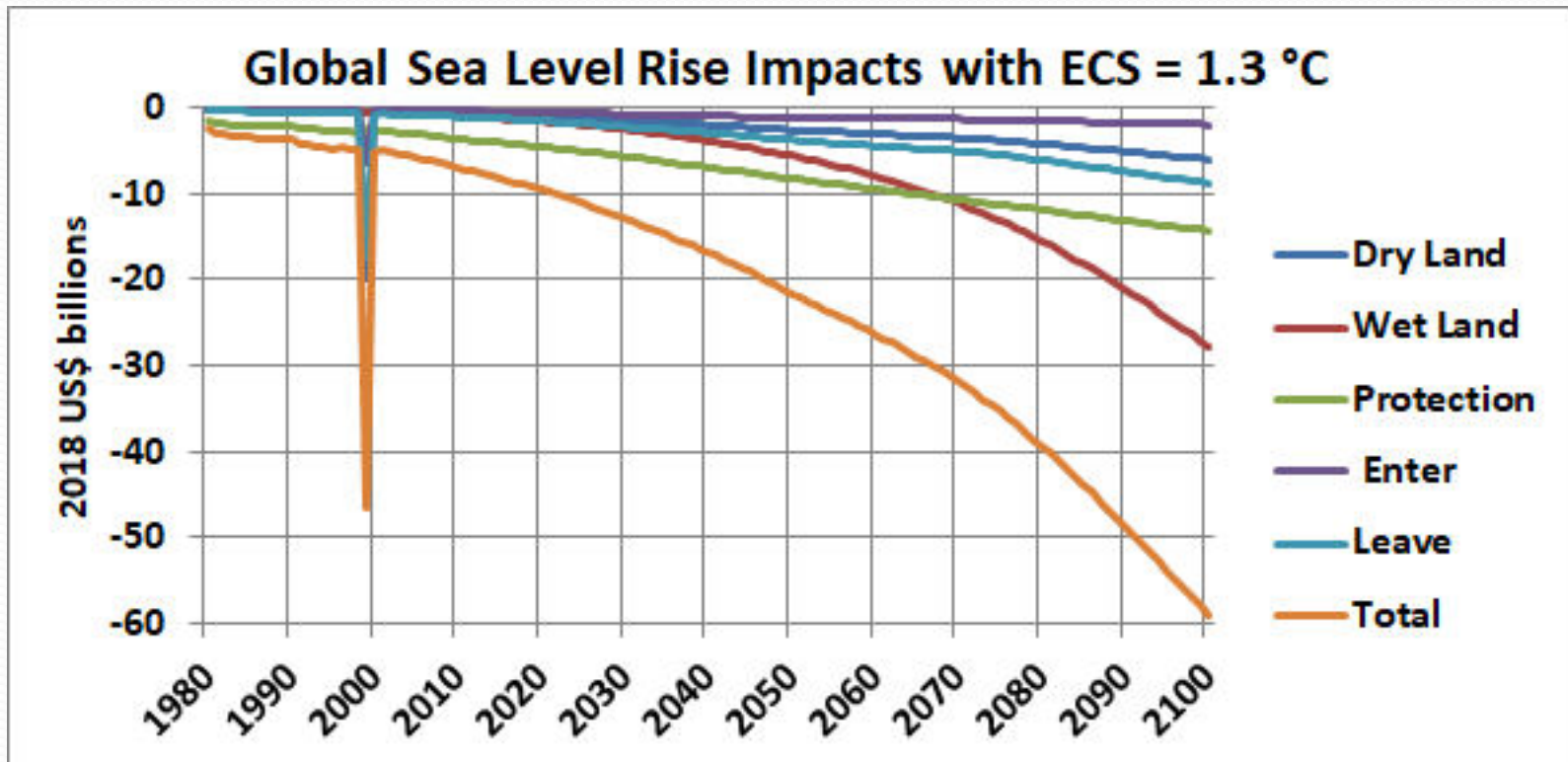
- Dayaratna, McKittrick and Michaels 2020
- Reviewed CO₂ fertilization studies and FUND.
- FUND's CO₂ fertilization by increased by 30%.
- “evidence suggest larger agricultural productivity gains due to CO₂ growth are being experienced than are reflected in FUND.”

GHG Impact GWP% by FUND; ECS = 1.3 °C



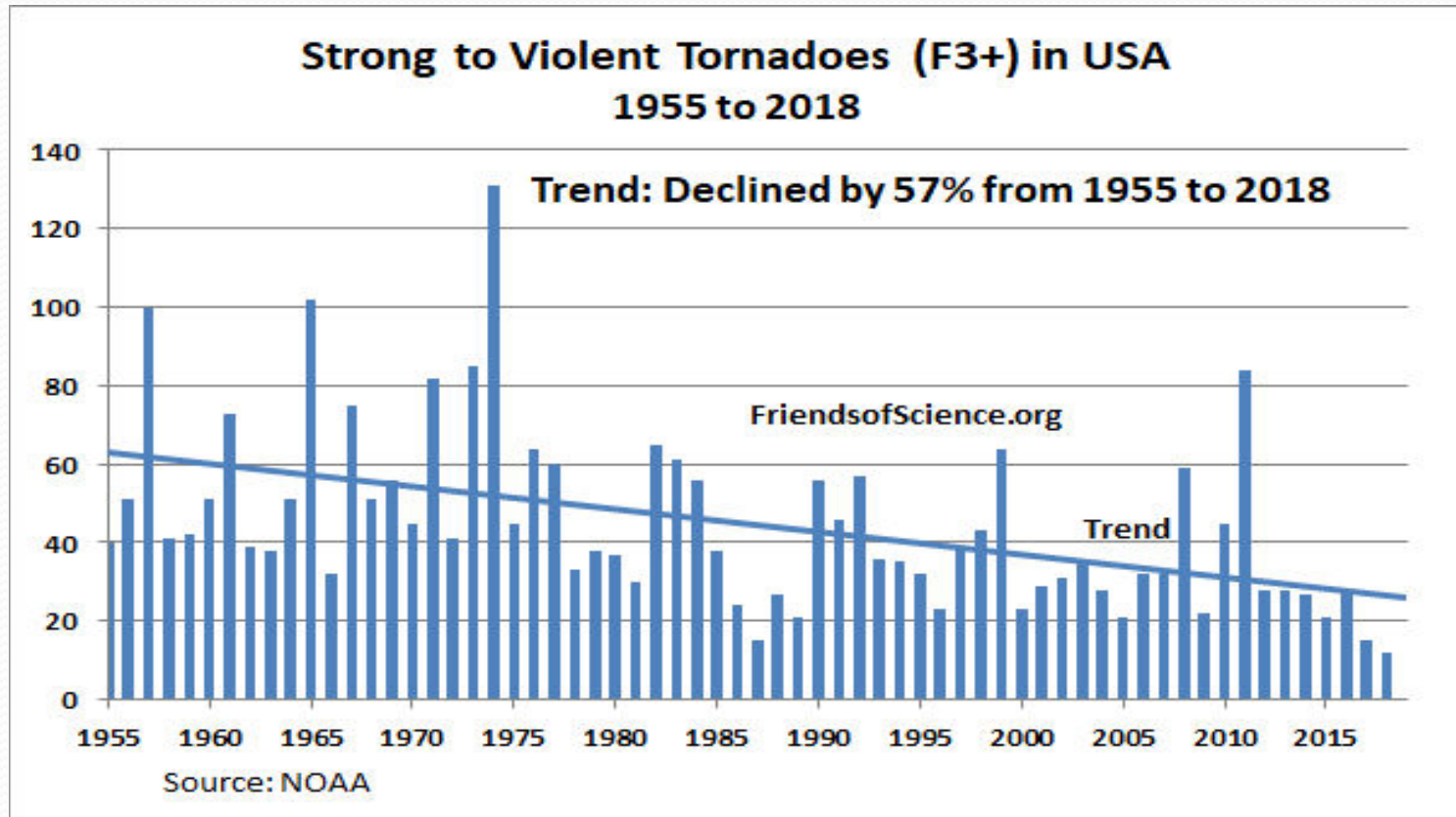
FUND modified energy, +30% CO₂ fert. Maximum positive impact at 2155 from 2000 is 1.5% of global GDP.

Global SLR Impacts by Component



Protection expenditures were determined by cost-benefit analysis to minimize total impacts. Other IAM don't include adaptation measures.
Homework Assignment: What happened in 1999?

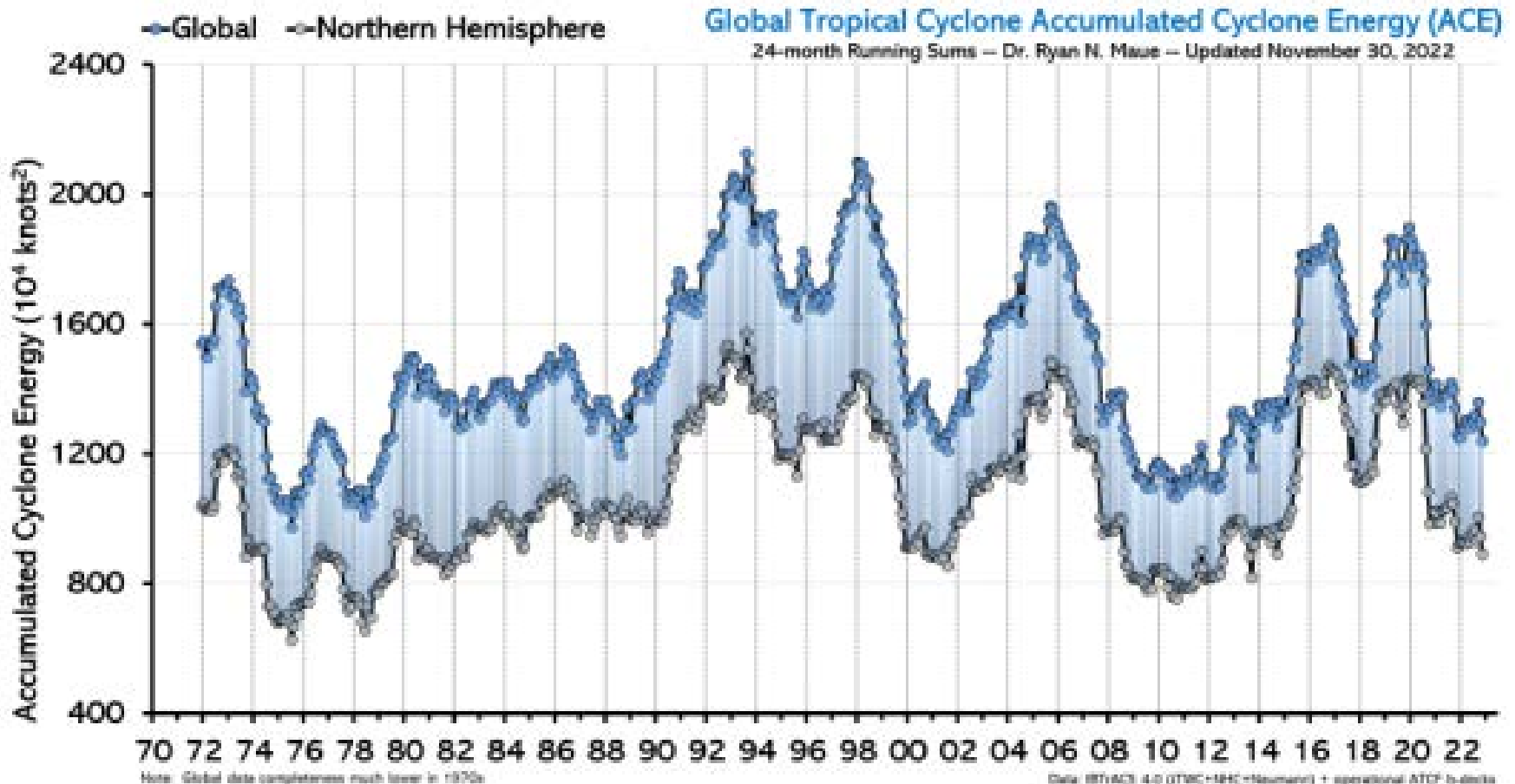
Tornado Trend Declines with Warming



Tornadoes require a cold front colliding with warm air. Northern warming makes tornadoes less likely.

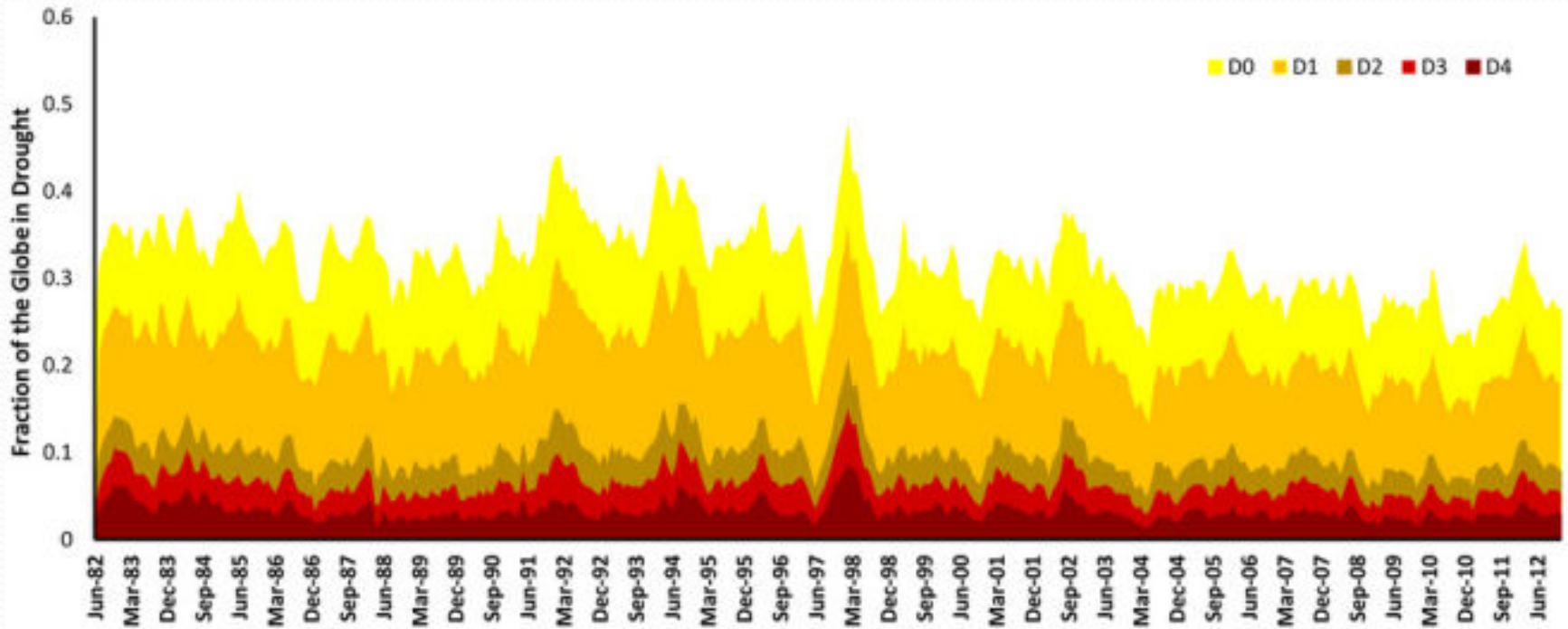
Hurricanes: No Relation to Temperature

No significant trend of hurricane energy

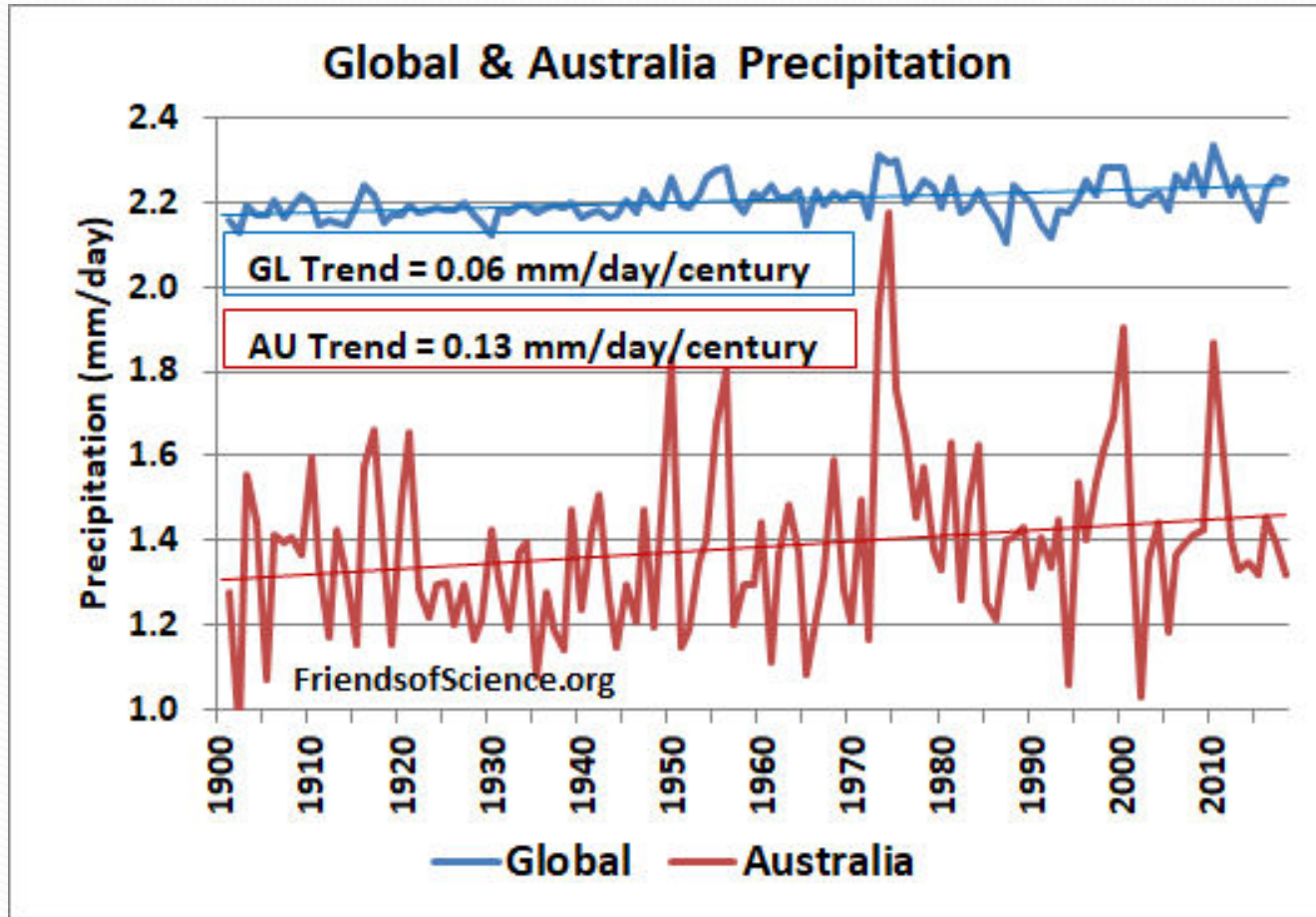


Global Drought Declining

Global Integrated Drought Monitoring and Prediction System
There is a small declining trend of total drought throughout the period

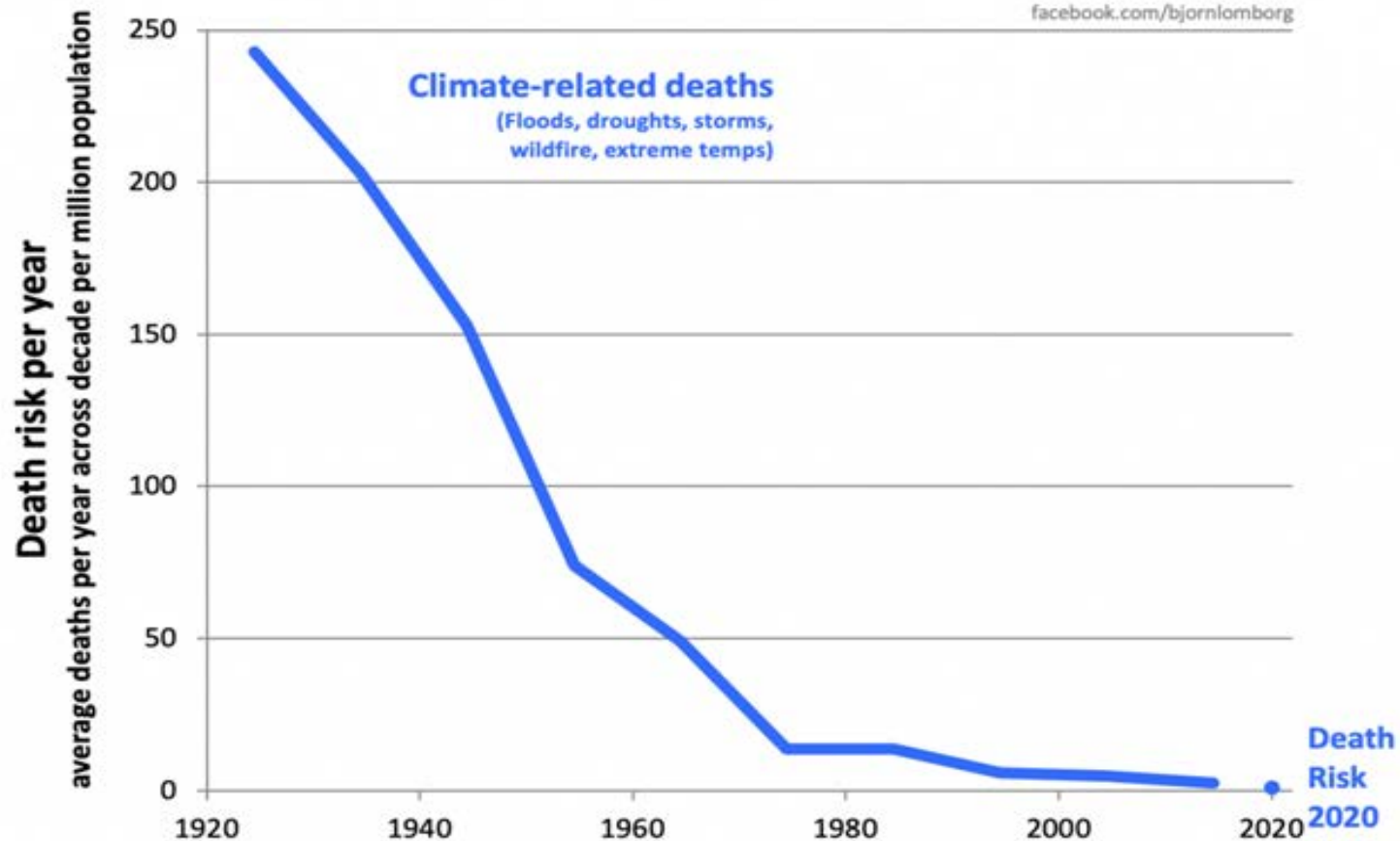


Warming Caused Increasing Precipitation



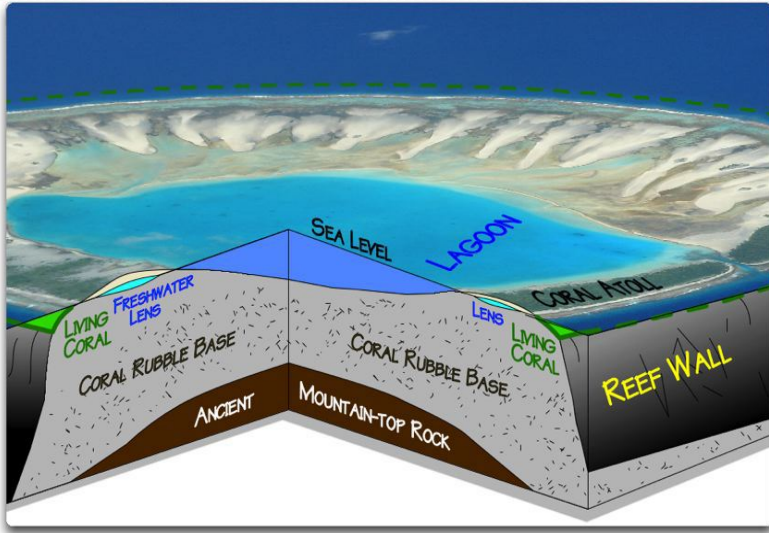
Climate-related Death Risk Drops 99.3% from 1920s to 2020

Climate-related Death Risk 1920-2020



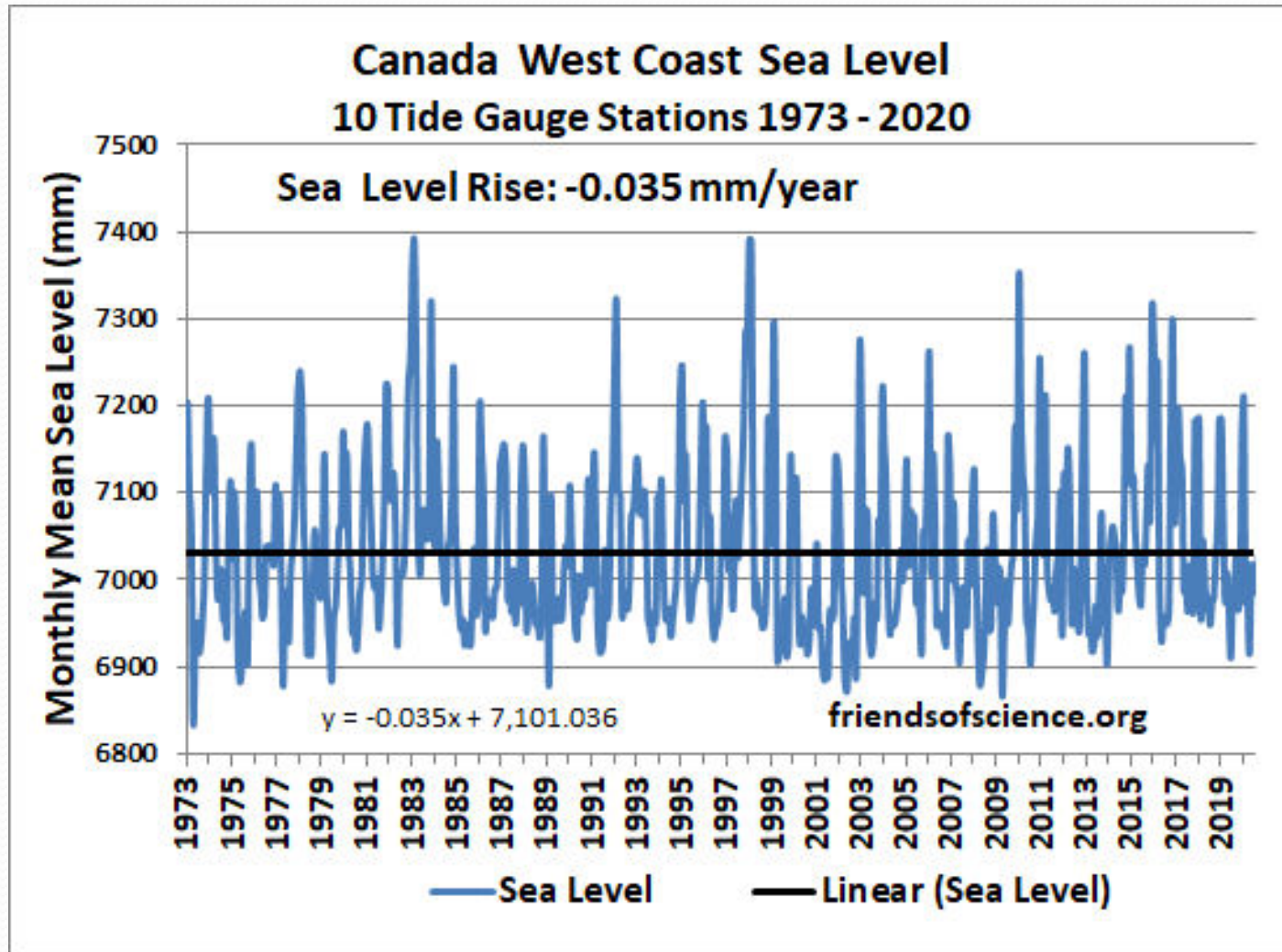
OFDA/CRED International Disaster Database, www.emdat.be, deaths averaged over decades 1920-29, 1930-1939, ... 2010-2019, with data from 2020, as start of next decade, accessed January 1, 2021

Coral Islands and Beaches are Growing

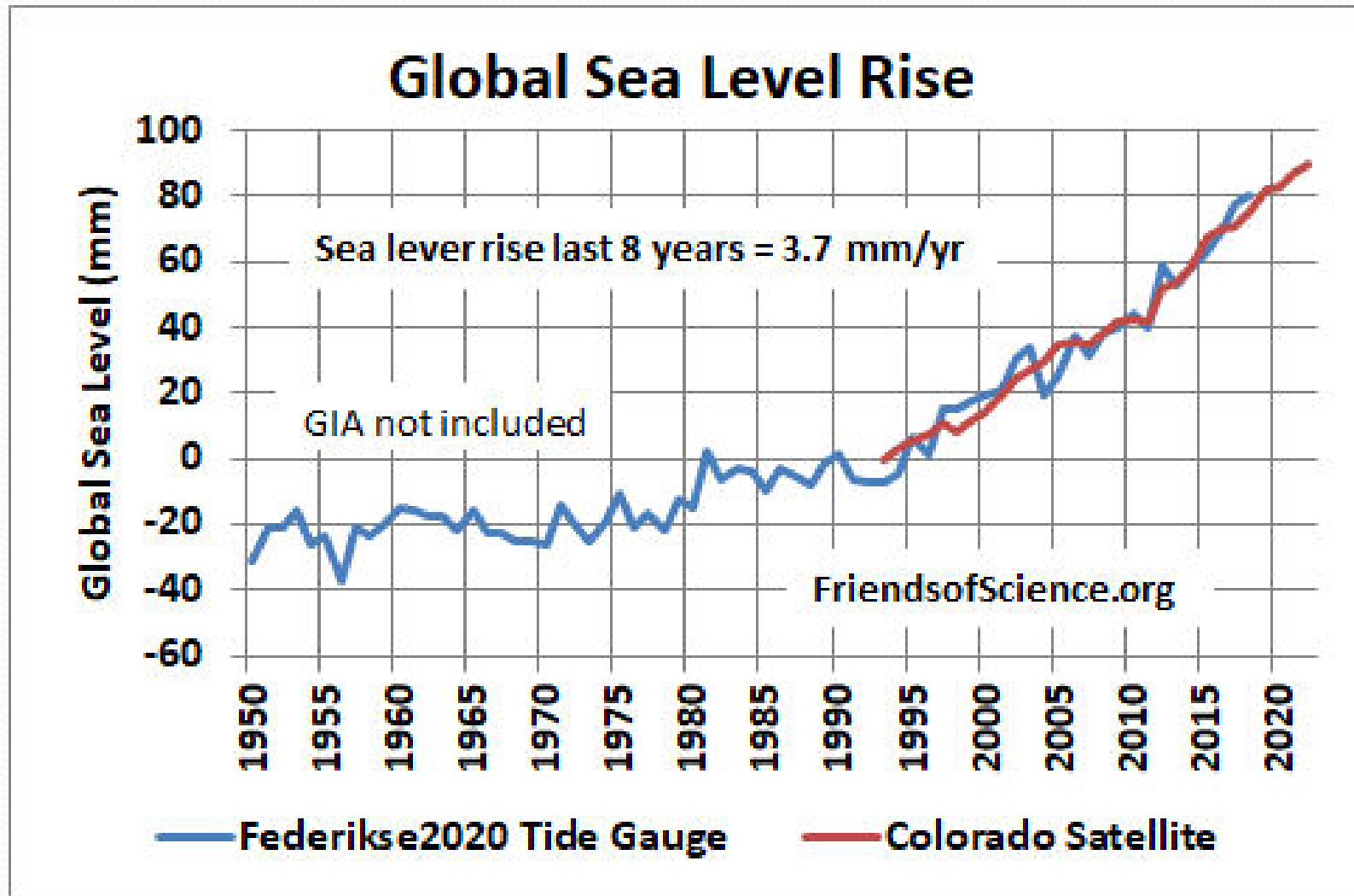


- Tropical coral islands grow as fast as SLR.
- Aerial photos show that 23 of 27 islands grew or stayed the same area since 1950.
- The world's beaches have grown on average 0.33 m/yr or 3,663 km² in 3 years.

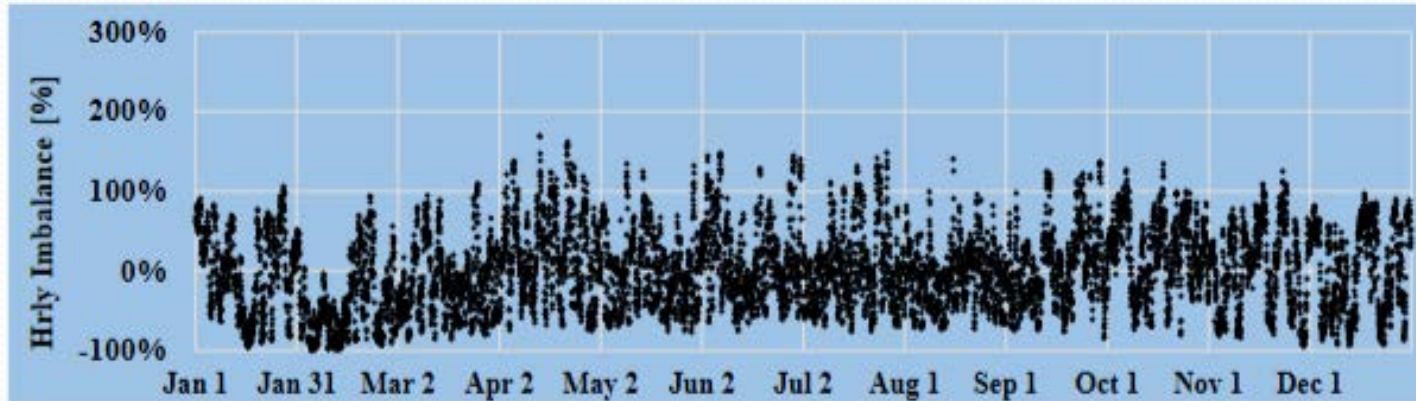
Canada West Coast Sea Level



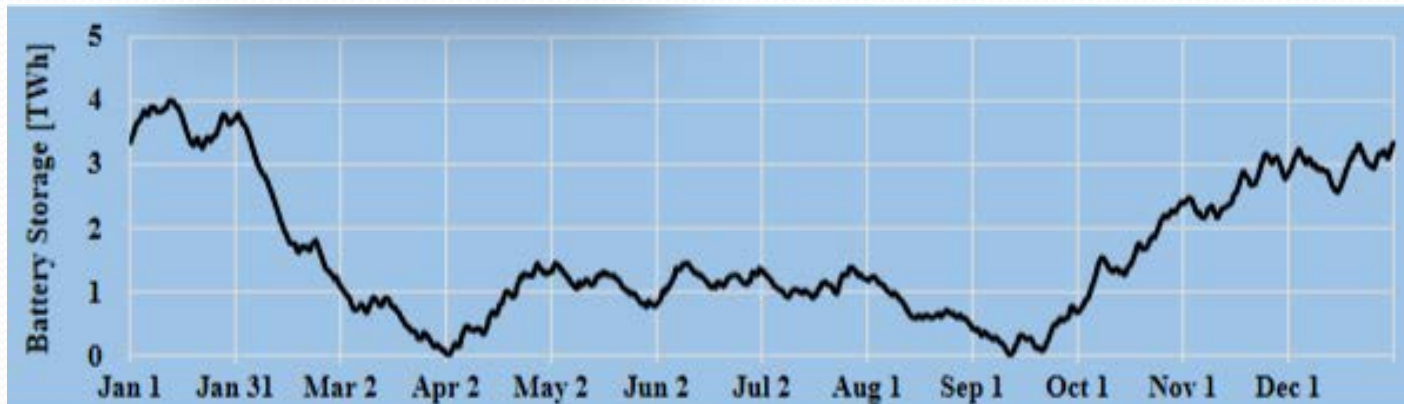
Global Sea Level Rise: Tide Gauge & Altimetry



Alberta Solar & Wind with Batteries



Hourly imbalance as percentage of peak demand



Battery storage levels required: 4.0 TWh

Alberta Solar & Wind with Batteries

Current Electricity Demand Only

	Total	Incremental	Capital Cost
Battery storage	4.0 TWh	4.0 TWh	\$1,900 Billion
Wind capacity	15,834 MW	12,200 MW	\$23 Billion
Solar capacity	6,646 MW	5,500 MW	\$10 Billion

Wind capacity factor = 34%

Solar capacity factor = 12%

Annual cost = \$265 Billion = Equiv. 80% to Alberta's 2019 GDP

Electricity cost is almost 100 X the 10-year average price.

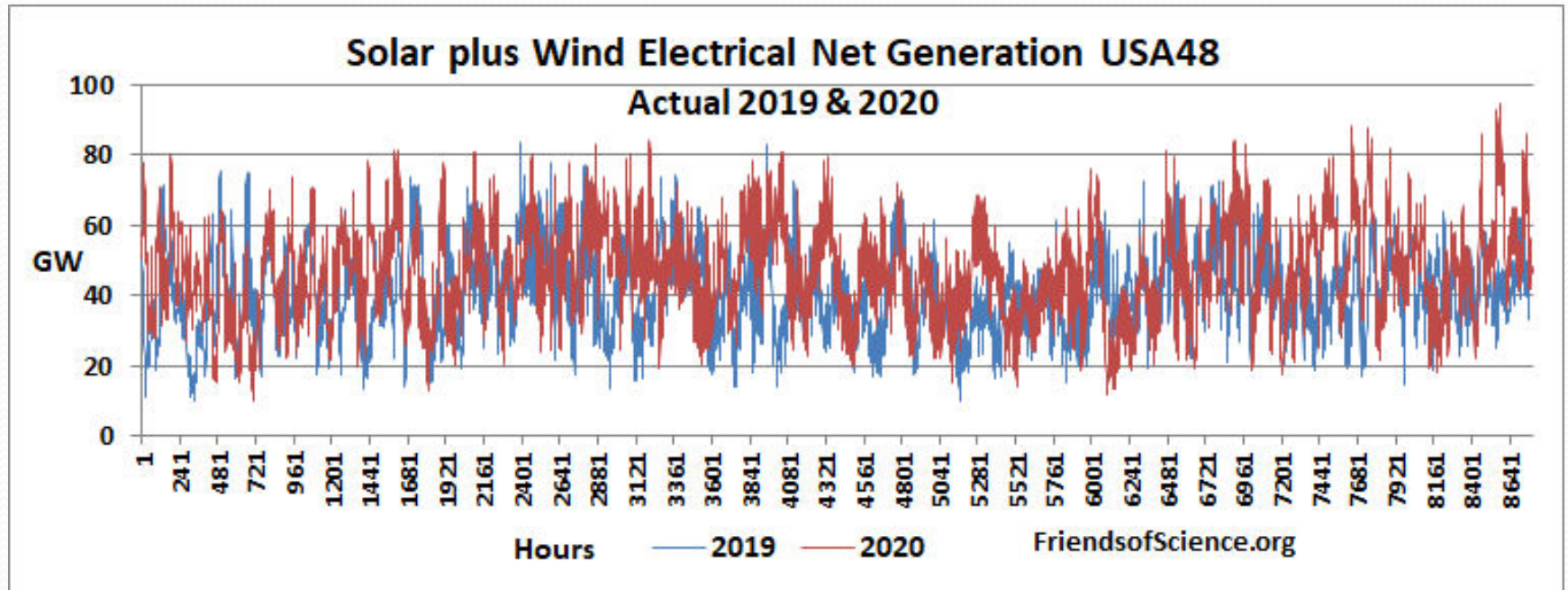
Canada's Emission Reduction Plan

- Reduce emissions to 40-45% below 2005 levels by 2030.
- Reduce emissions to “net-zero” by 2050.
- 2016 to 2022, Federal government spent > \$100 Billion.
- A family of four is paying \$1,800 per year for climate policy measures.
- Carbon tax April 2023 is \$65/tonne CO₂
- Parliamentary Budget Office: GDP growth 2021-2100
 - All countries meet Paris targets: GDP up 388%
 - Do nothing: GDP up 381%

Cost of USA Net Zero Electrification

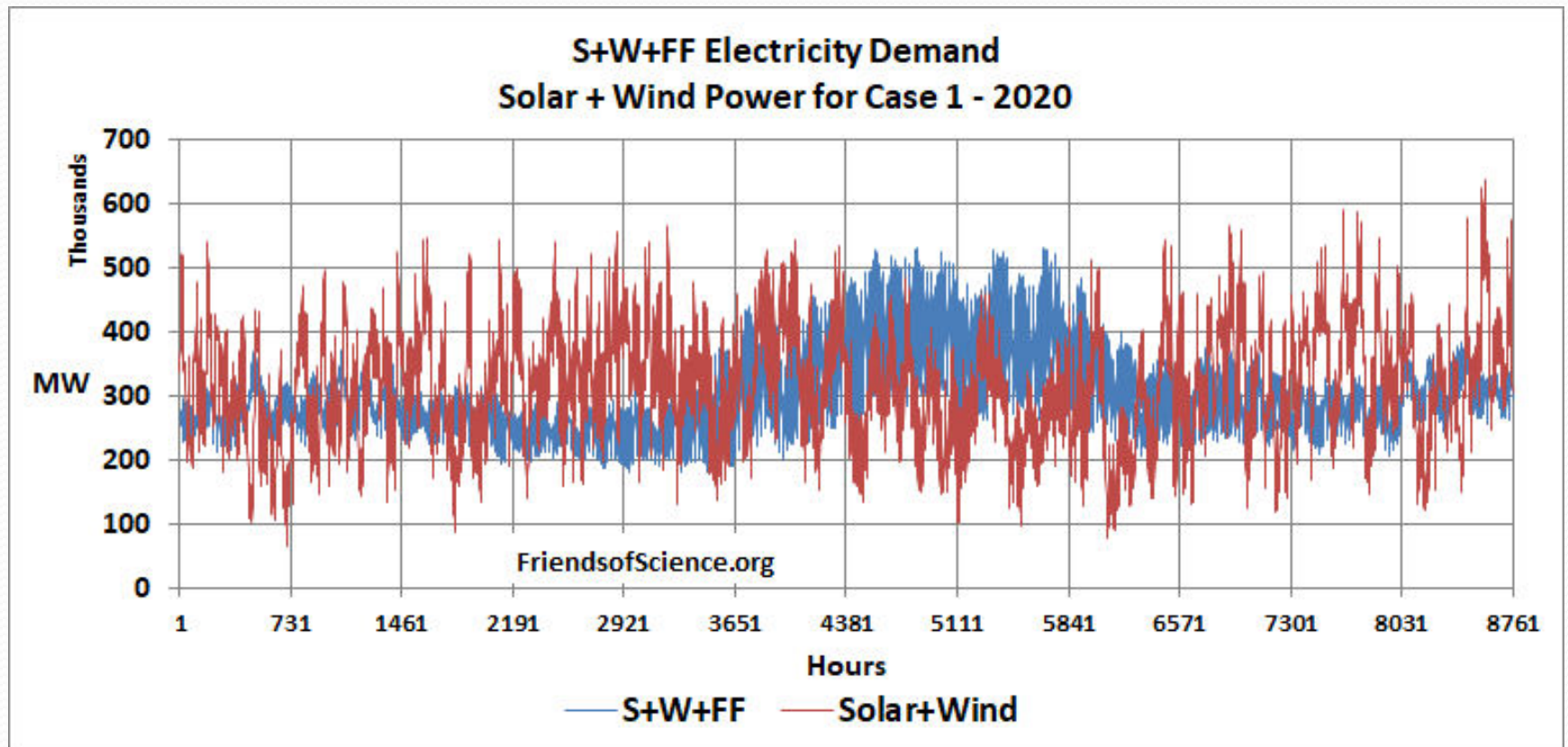
- Over-night analysis, replace fossil fuel for electricity with wind and solar power
- Use Batteries for Storage at US\$ 347/kWh (EIA)
- Enmax Calgary: Energy C\$0.14/kWh, C\$0.23/kWh with adm, delivery
- Gross-up Solar + Wind to replace fossil fuels
- Battery efficiency: 80%
- Carbon Capture & Storage: airplanes, fossil fuels
- Incremental cost of EV, converting buildings to elect
- Considering heat values, EV vs ICE efficiencies ...

USA Actual 2019 and 2020 Solar + Wind

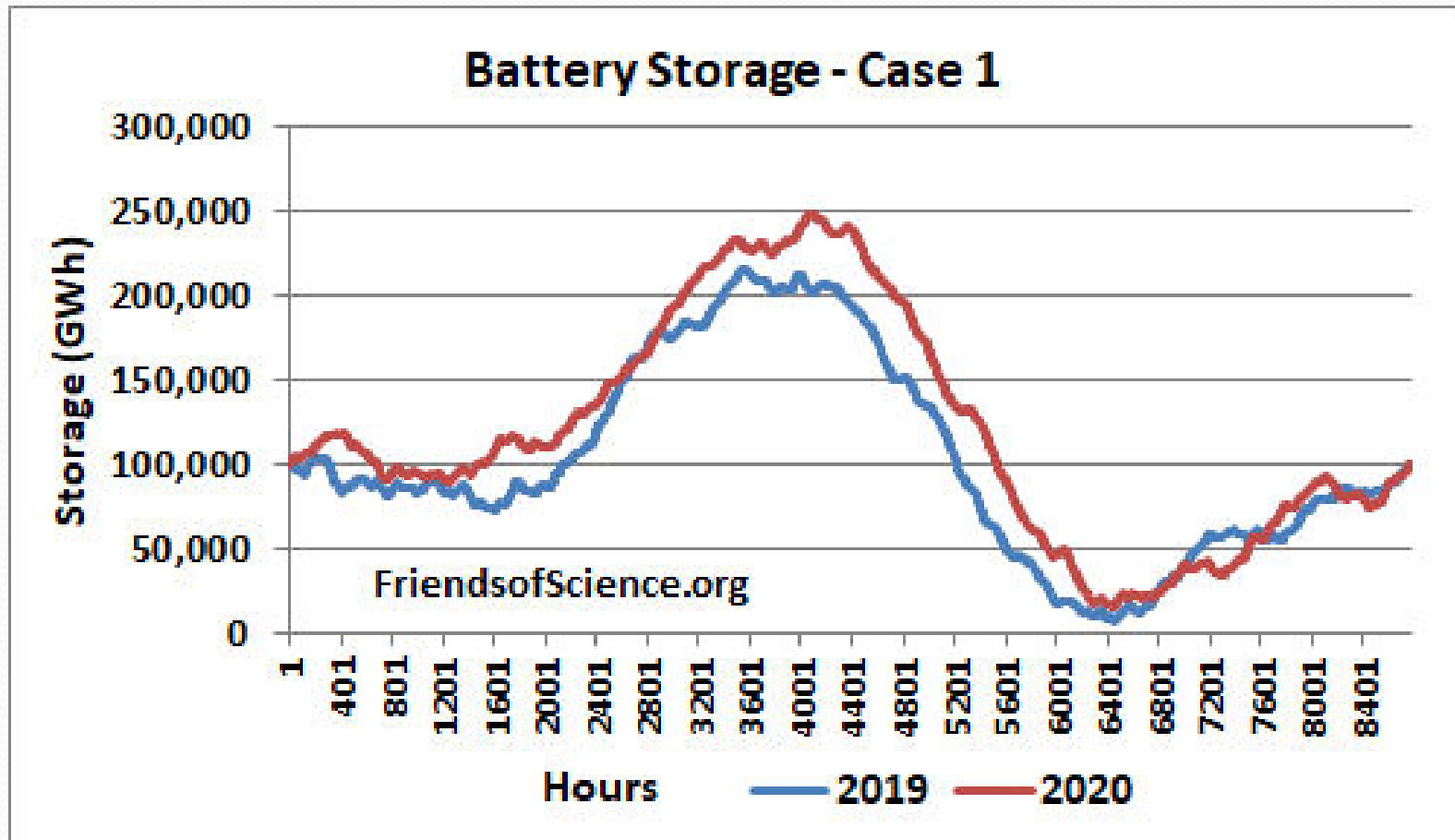


USA Solar + Wind vs Electricity Demand

Solar + wind increased to replace fossil fuel electricity



USA Battery Storage Required without Over-building Solar + Wind



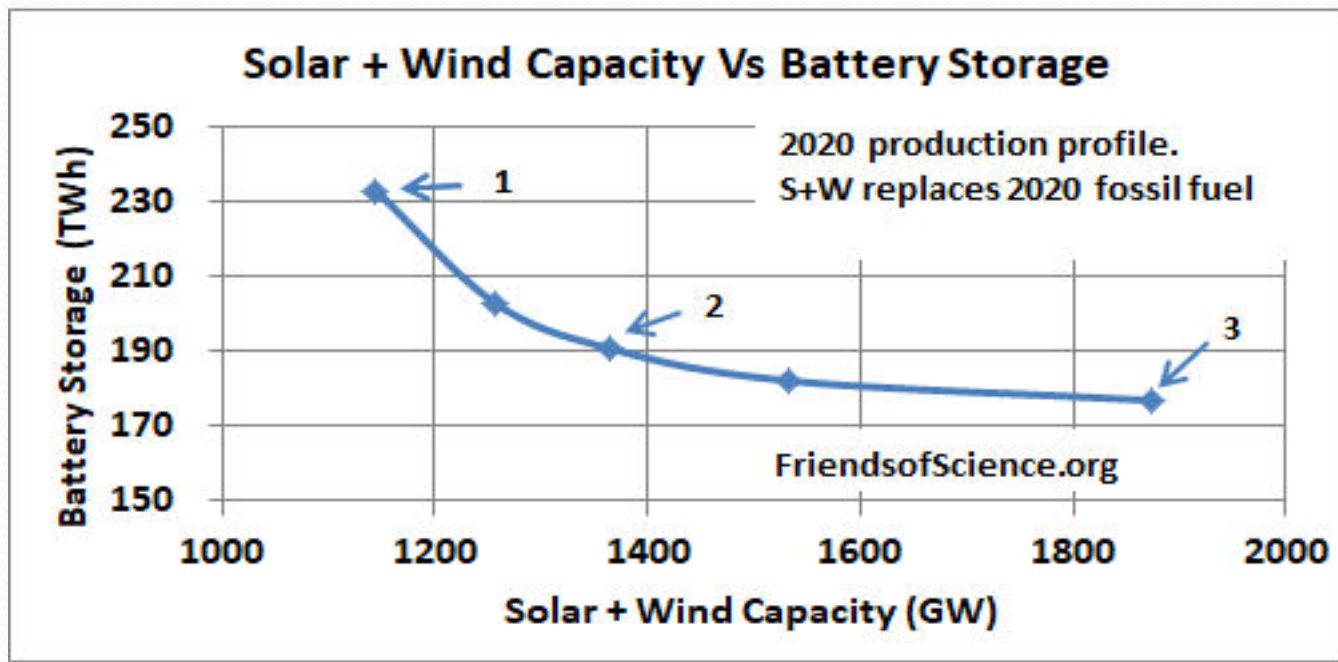
Solar + Wind Replaces Fossil Fuel Electricity: Back up by Batteries

Energy production isn't restricted

	Units	2020
Existing Demand (ED)	TWh	2764
Storage Amount	Days	31
ED Storage Cost	US\$ Trillion	87
Total Storage	US\$ Trillion	267
Total Cost	US\$ Trillion	291
Total Cost / GDP		13.5
Cost per Adult	US\$	1,100,000

Solar + Wind with Overbuild Replaces Fossil Fuel Electricity for Existing 2020 Demand

	Overbuild	Capacity GW	Storage TWh	Load Factor	Cost US\$ Trillion
1	0%	1145	233	28%	291
2	19%	1363	191	23%	240
3	64%	1874	177	16%	221



Solar + Wind Replaces 50% Fossil Fuel Electricity

		S+W energy production is not limited	S+W energy is limited to 57% of capacity
Existing Demand	US\$ Trillion	1.5	1.5
Total S+W Capacity	GW	3,329	3,627
Total Cost	US\$ Trillion	22.0	22.0
Cost per adult	US\$	85,000	85,000

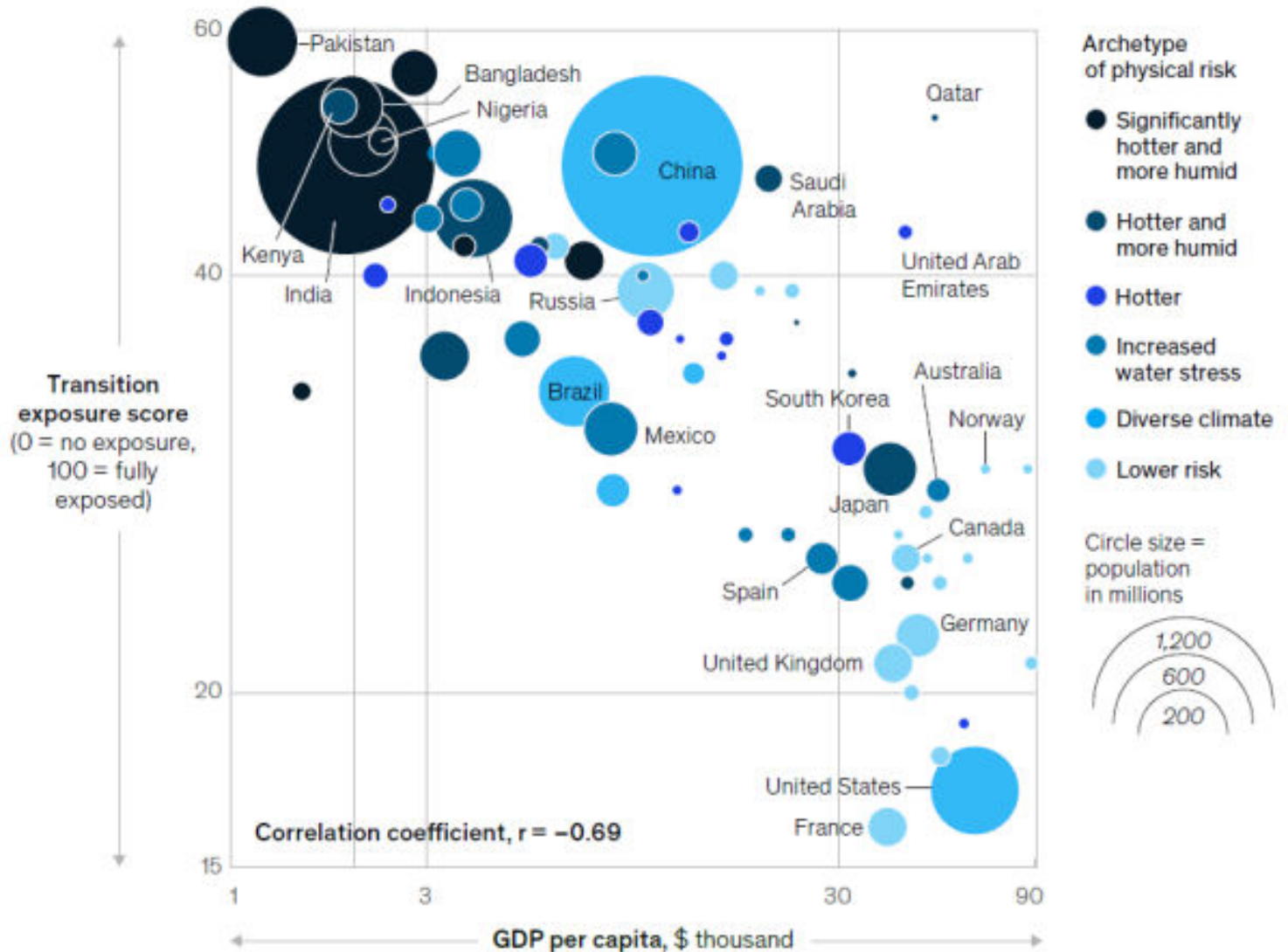
- Fossil fuel electricity with CCS provided backup services for solar and wind.
- Solar + wind energy = actual solar + wind + fossil fuel electricity.

McKinsey Net Zero Report

- Global Capital Cost; us\$ 275 Trillion
- Equals 2.8 X Global GDP
- Reduced oil production by 55%, natural gas by 70%
- Real operating costs increase by 25% by 2040
- US\$300/tonne CO₂ for direct air capture
- US\$50 – \$100/tonne CO₂ for coal and cement
- Biofuels would increase 10 X by 2050

Transition Exposure vs GDP/capita

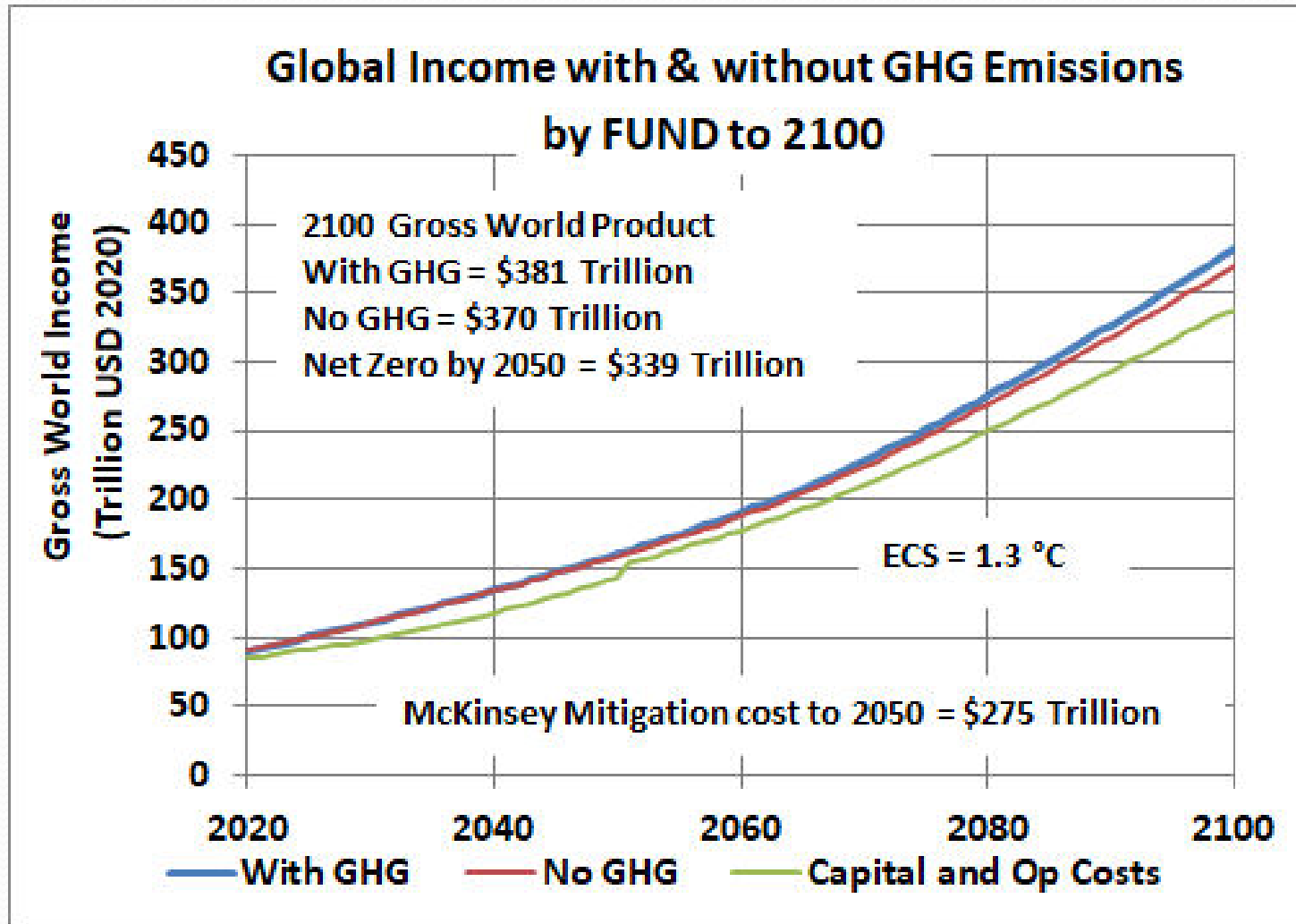
McKinsey
Report;
Emissions
intensive
operations



McKinsey Net Zero Report

- Russia, Ukraine, Commonwealth of Independent States to spend 21% of GDP 2021-2050
- USA to spend 6.4% of GDP
- USA capital spending with GDP growth = \$51 trillion.

Global Income Prediction



Global Cost & Benefit of Net Zero

McKinsey: Capital Cost	US\$ 275 Trillion
Operating Cost	US\$ 150 Trillion
Lost Net Benefit of CO ₂ Emissions 2022 to 2050	US\$ 20 Trillion
Net Zero Total Loss	US\$ 445 Trillion

Materials for Net Zero

- Lithium is a critical material for electric vehicles
- EV banned from parking garages and ships; fire hazard.
- IEA says lithium shortages by 2025. Lithium in a few places; Australia, China, Chile
- Lithium price +10 X Jan. 2020 to Jan. 2023
- Copper demand to double by 2035 to 50 Mt/yr
- Rare earth minerals required are largely in China

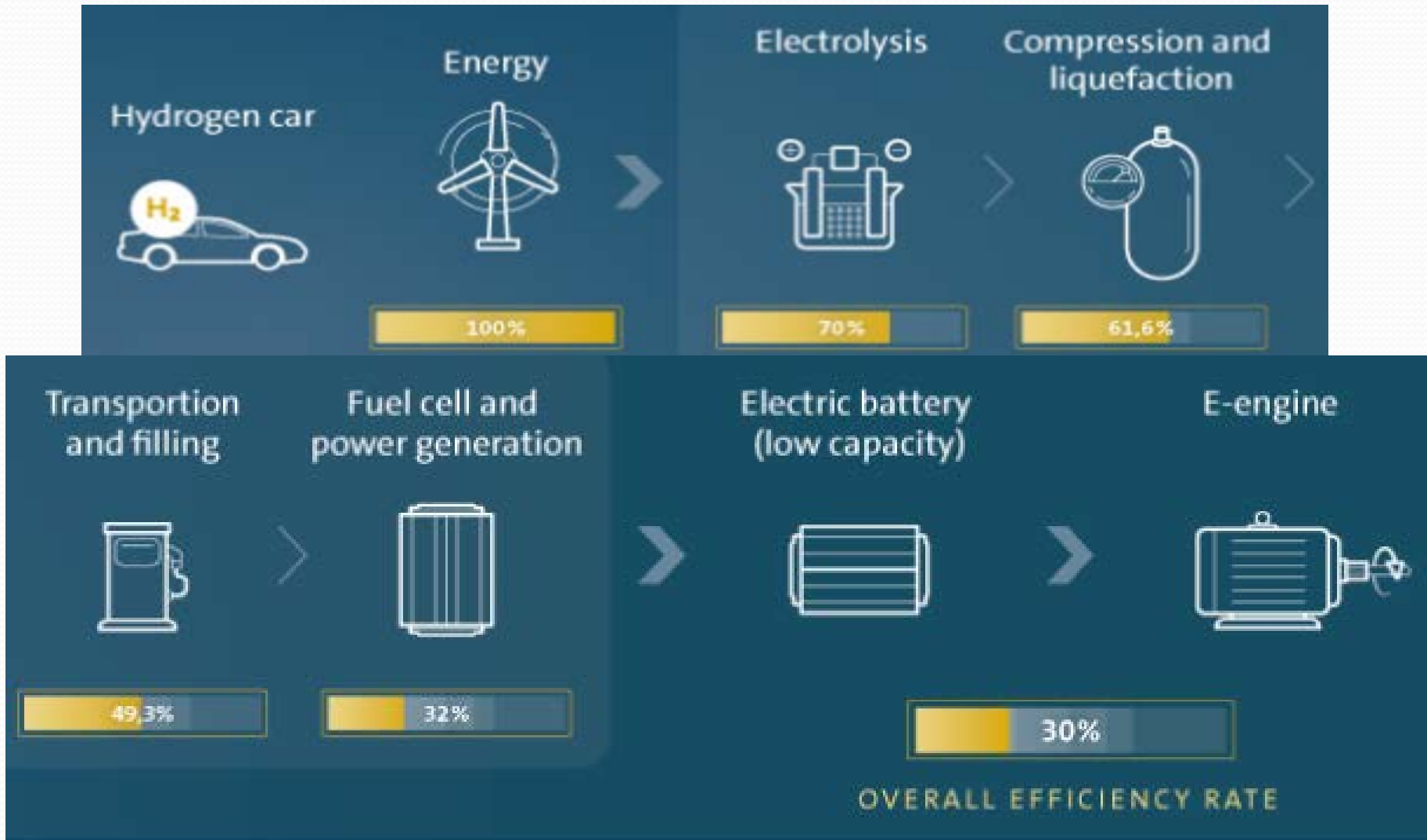
Years of 2019 Production for One Generation of Renewable Technologies

Metal	One Generation Million tonnes	Years to Produce at 2019 Production Rates
Nickel	940	400
Lithium	944	9920
Cobalt	218	1730
Graphite	8974	3290
Vanadium	681	7100

Based on the United States economy, the European (EU-28) economy and the Chinese economy.

Mineral discovery to first mine production takes at least 15 years if there is no opposition.

Hydrogen Car System is only 30% Efficient



Hydrogen Policy Fiasco

- Hydrogen can produce energy by combustion or fuel cell.
- 99% of the hydrogen used in Canada is produced from natural gas with 2.2 times the GHG emissions.
- Hydrogen from wind or solar power in fuel cells cost 17 times the cost of natural gas.
- ECCC ignores transmission lines costs.
- Assumed buyers of natural gas switch to a 7.3% hydrogen-natural gas blend by 2030 at \$500/tonneCO₂.
- Hydrogen embrittlement and safety was ignored.

Friends of Science Event May 2, 2023 with Dr. Ian Clark and Robert Lyman at Red & White Club. Visit FriendsOfScience.org



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Climate Change 101 also provides similar context but with a less scientific style.

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