

# Engineering Our Energy Future

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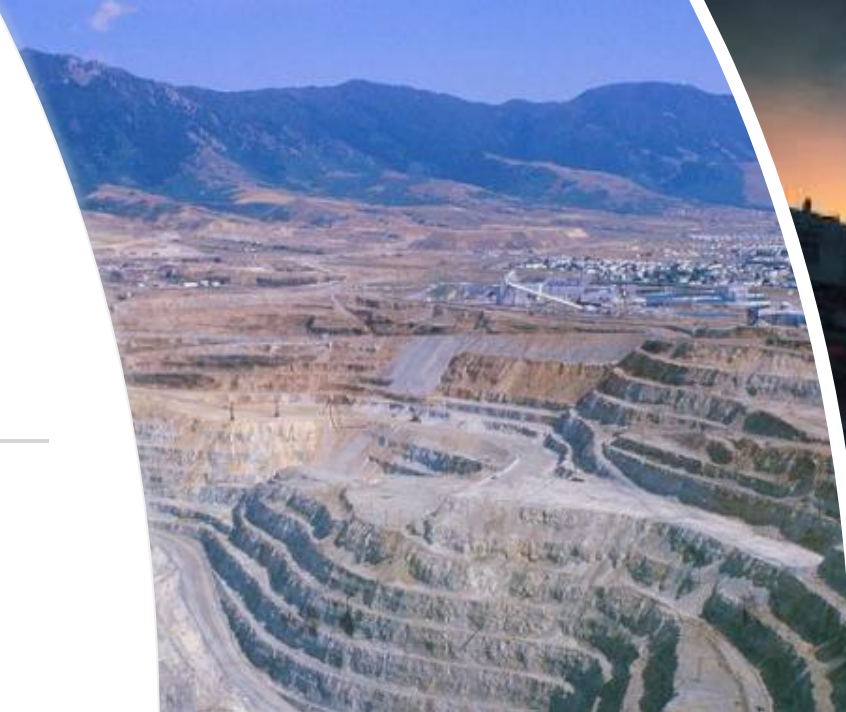
Bob Morris

Power System Consultant

Montana Technological University

SPE Symposium

April 11, 2024



# Lance Energy Chair – A Visionary Concept

Enhance prominence of Montana Tech as a national leader in energy by leveraging private funding and developing partnerships with industry, trade organizations, national labs, and state/federal agencies



# Candidate Background

## Education

B.S. Geophysical Engineering

M.S. Engineering Science

## Industry

- 5 years – oil exploration
- 32 years – electric power
- 3 years – energy and materials consulting

## Academics & Nonprofit

- MT Tech Foundation Board
- MT Tech EE Advisory Board
- University of Idaho College of Engineering Advisory Board
- Palouse Discovery Science Center Board



# Lance Endowed Energy Chair Vision

Establish Montana Tech  
as the worldwide  
recognized leader in  
energy education



# Montana Tech is Perfectly Positioned to Lead

- ✓ 125 years of energy leadership
- ✓ Core programs: Geology, Mining, Metallurgy & Materials, Electrical, Civil, Mechanical, Computer Science, Environmental, Petroleum, Business, Health Science
- ✓ Strong and prominent alumni support
- ✓ Montana Tech pride



# Energy Evolution: Opportunities Abound

- Energy thought leadership across industries
- Drive rational discussions on energy and climate change
- Garner public support
- Attract students
- Benefit humanity

**MONTANA**  
**TECHNOLOGICAL UNIVERSITY**

# Energy Leadership Verbs



Listen



Collaborate



Advocate



Recruit



Educate



Fund Raise



Research

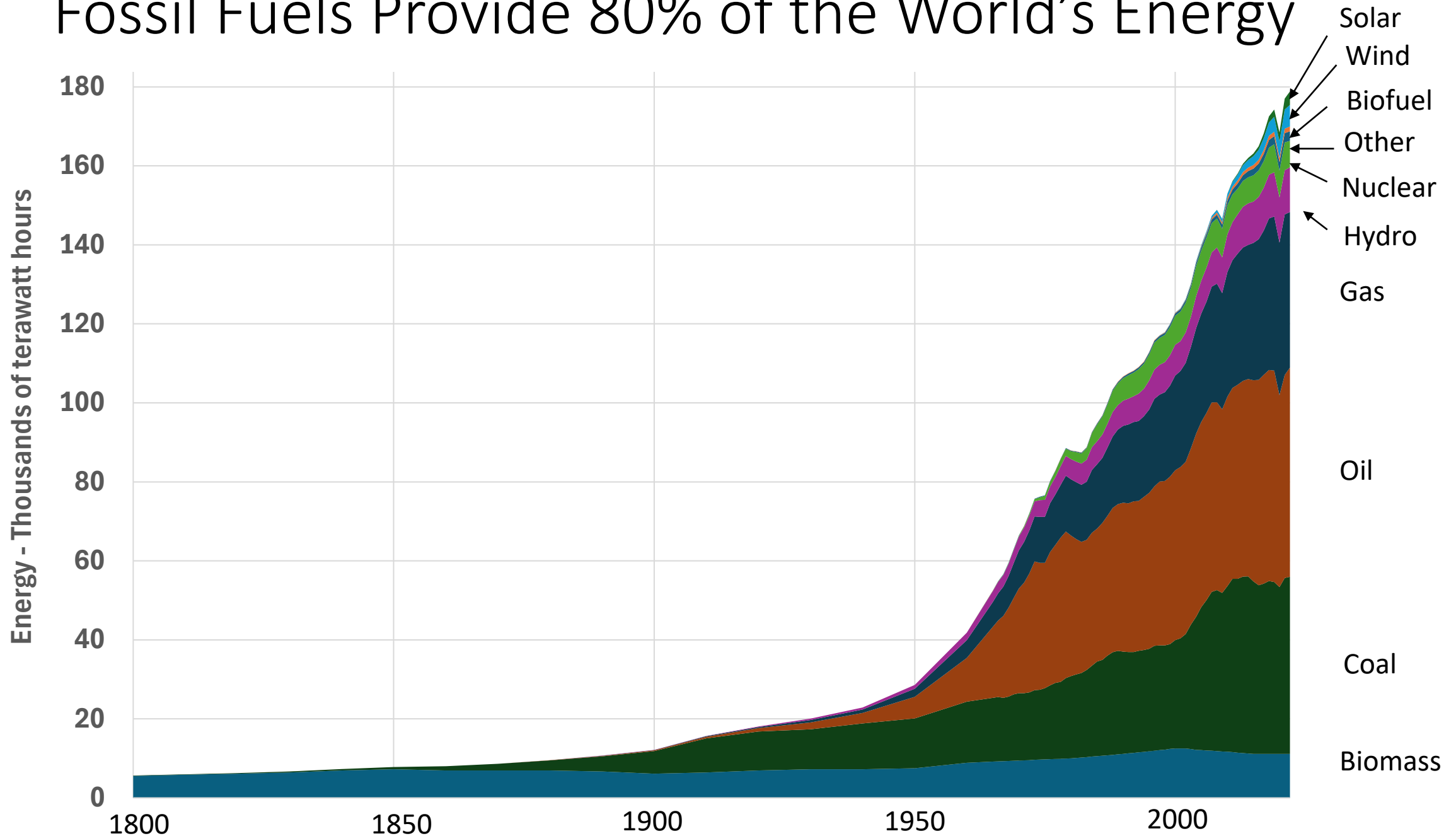


Lead



Sell

# Fossil Fuels Provide 80% of the World's Energy



Source: Our World in Data; Energy Institute - Statistical Review of World Energy (2023); Smil (2017)



# Modern Society is Built on Fossil Fuels

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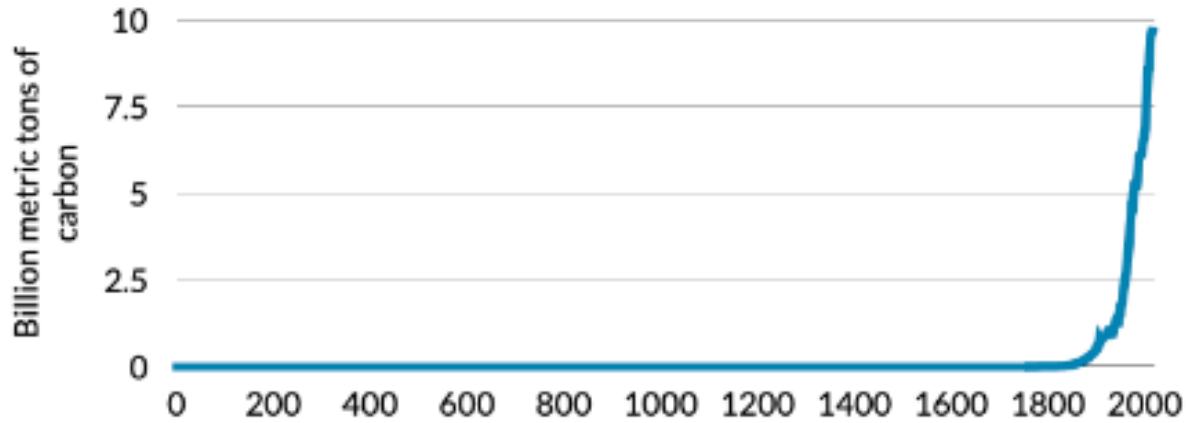
*A century of innovation*

*Abundant, stored, concentrated*

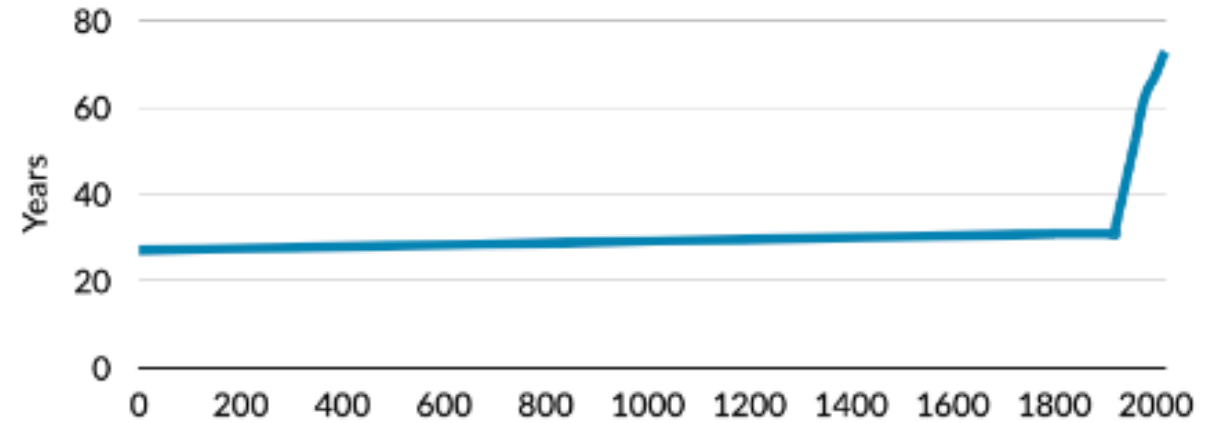


# Fossil Fuels emit Carbon, but Benefit Humanity

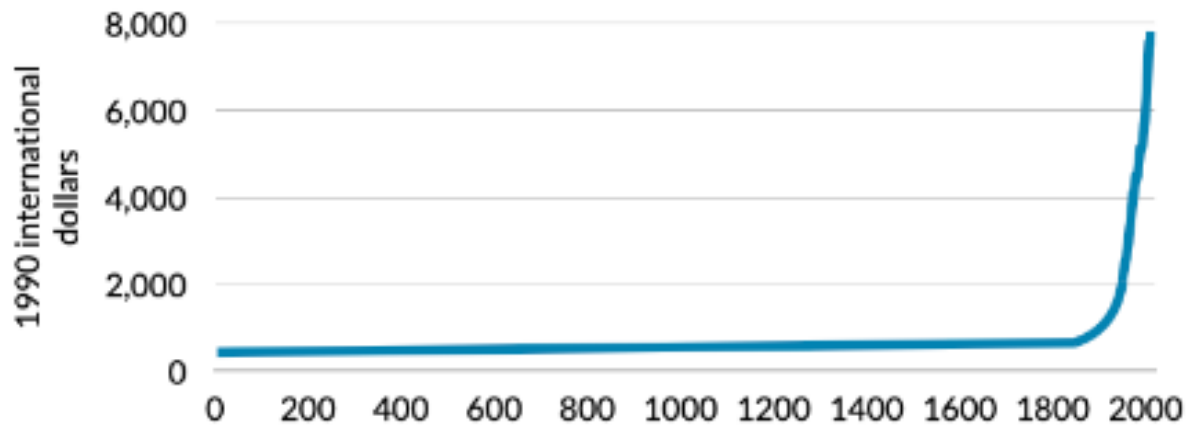
## Global CO<sub>2</sub> Emissions



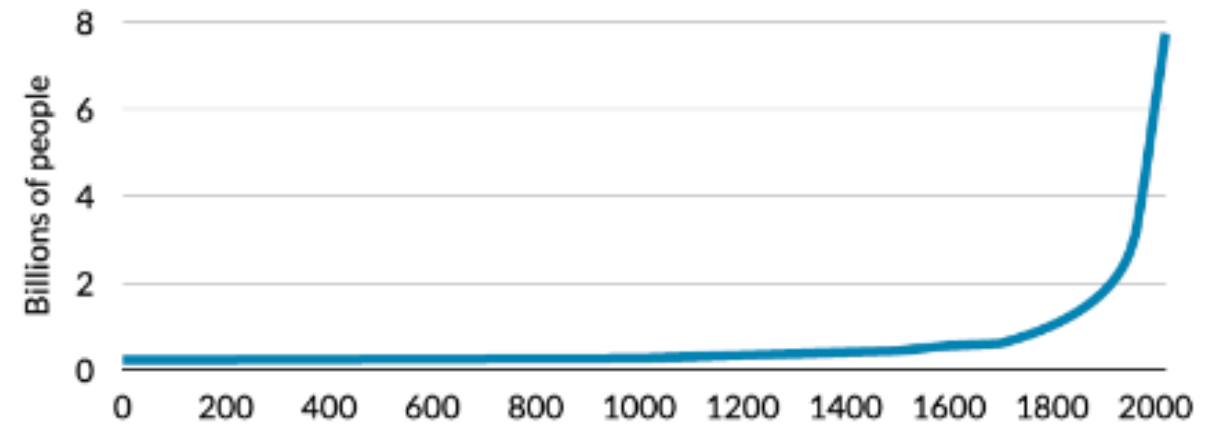
## World Life Expectancy



## World GDP Per Capita



## World Population



# Fossil Fuel Use Produces 4% of Annual Carbon Emissions

80 GT  
Ocean Outgassing



Dissolution  
Photosynthesis

8GT  
Fossil Fuel Use

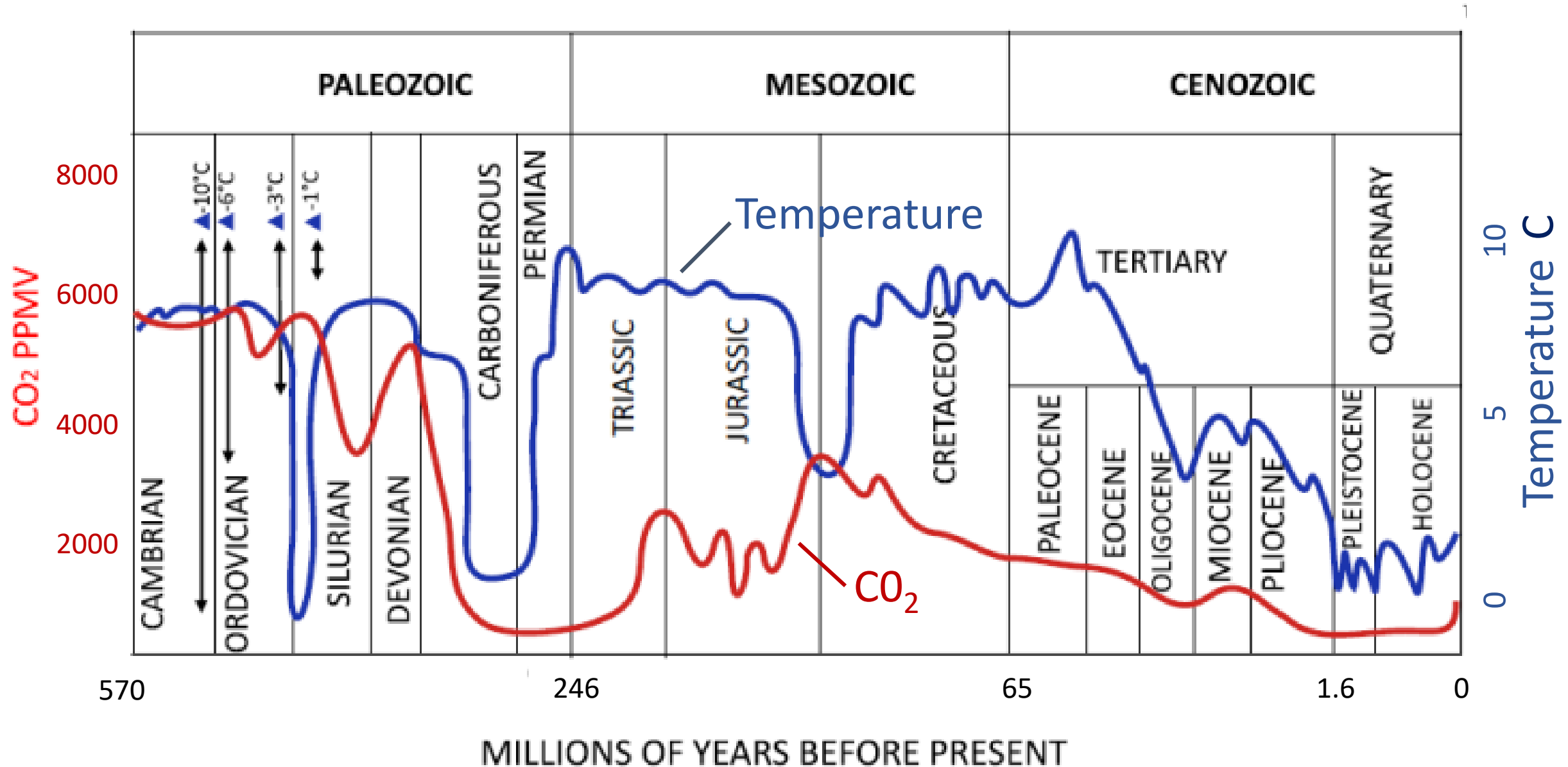


120 GT  
Respiration



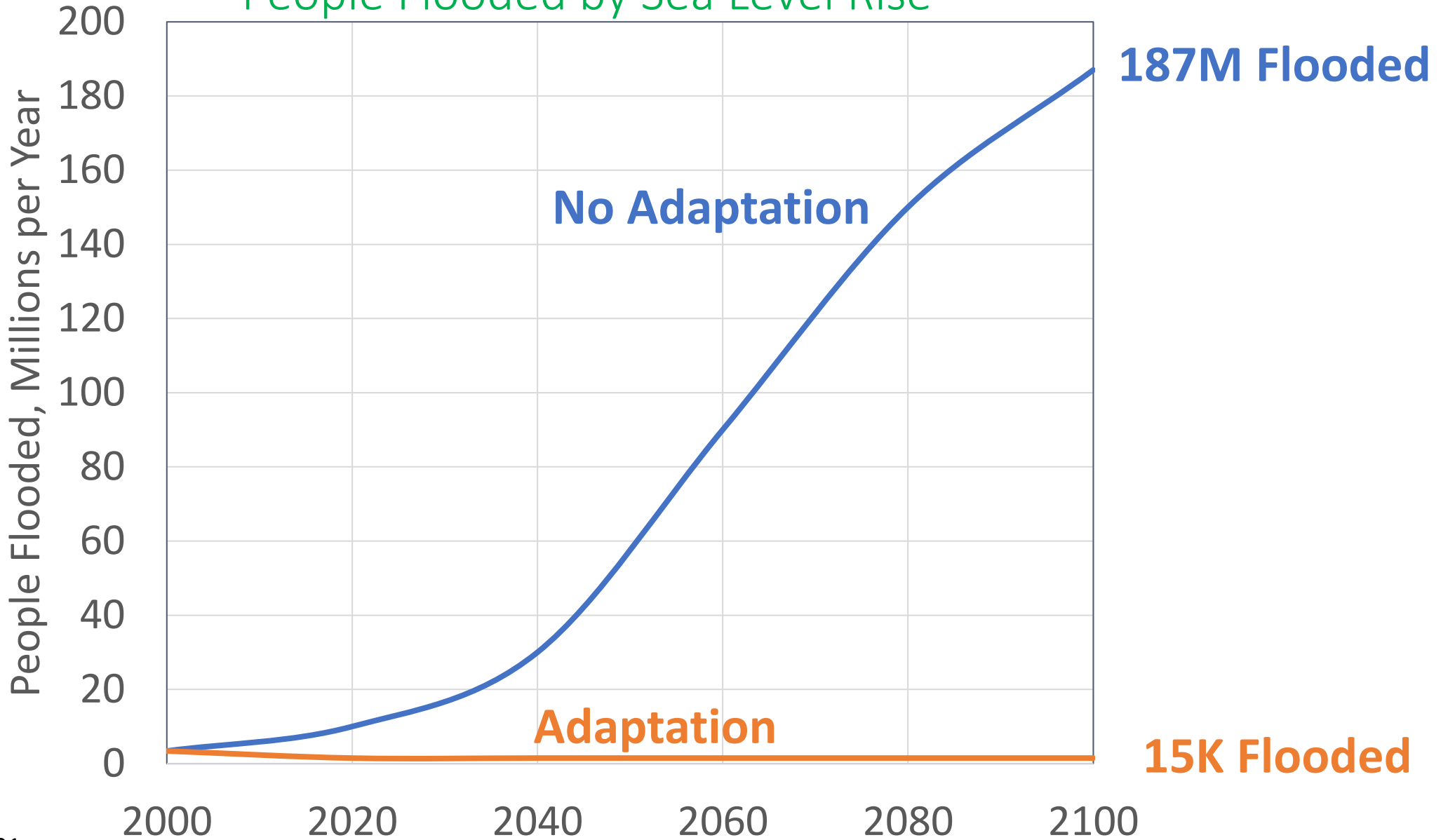
Photosynthesis

# Earth's Records Show Wide Temperature and CO2 Variations



# Modern Society Can Adapt to Moderate Climate Variations

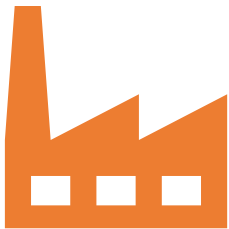
People Flooded by Sea Level Rise



Lomborg, False Alarm, 2021

Hinkel, et al, Coastal Flood Damage and Adaptation Costs Under 21<sup>st</sup> Century Sea-Level Rise, Proceedings of the National Academy of Sciences 111, No 9. 2014

# We Will Continue to Reduce Carbon Emissions



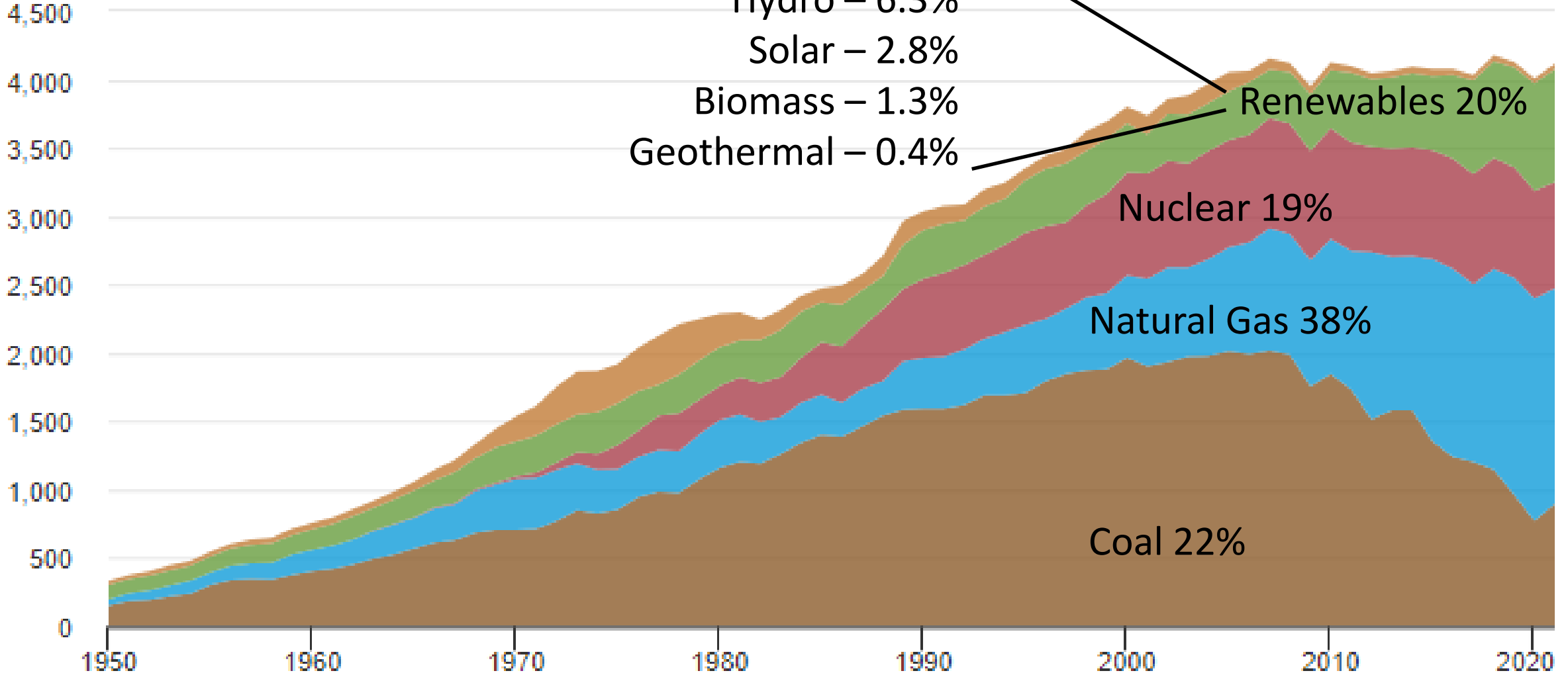
Electric Power Generation: 28%



Transportation: 31%

# We are Changing our U.S. Electrical Energy Sources

billion kilowatthours



# Energy Source Dynamics are Changing

**Fossil Fuel, Nuclear**



**Wind, Solar**



- High Density
- Dispatchable
- >80% capacity factor
- High Inertia

- Low Density
- Intermittent
- 10-30% capacity factor
- No Inertia

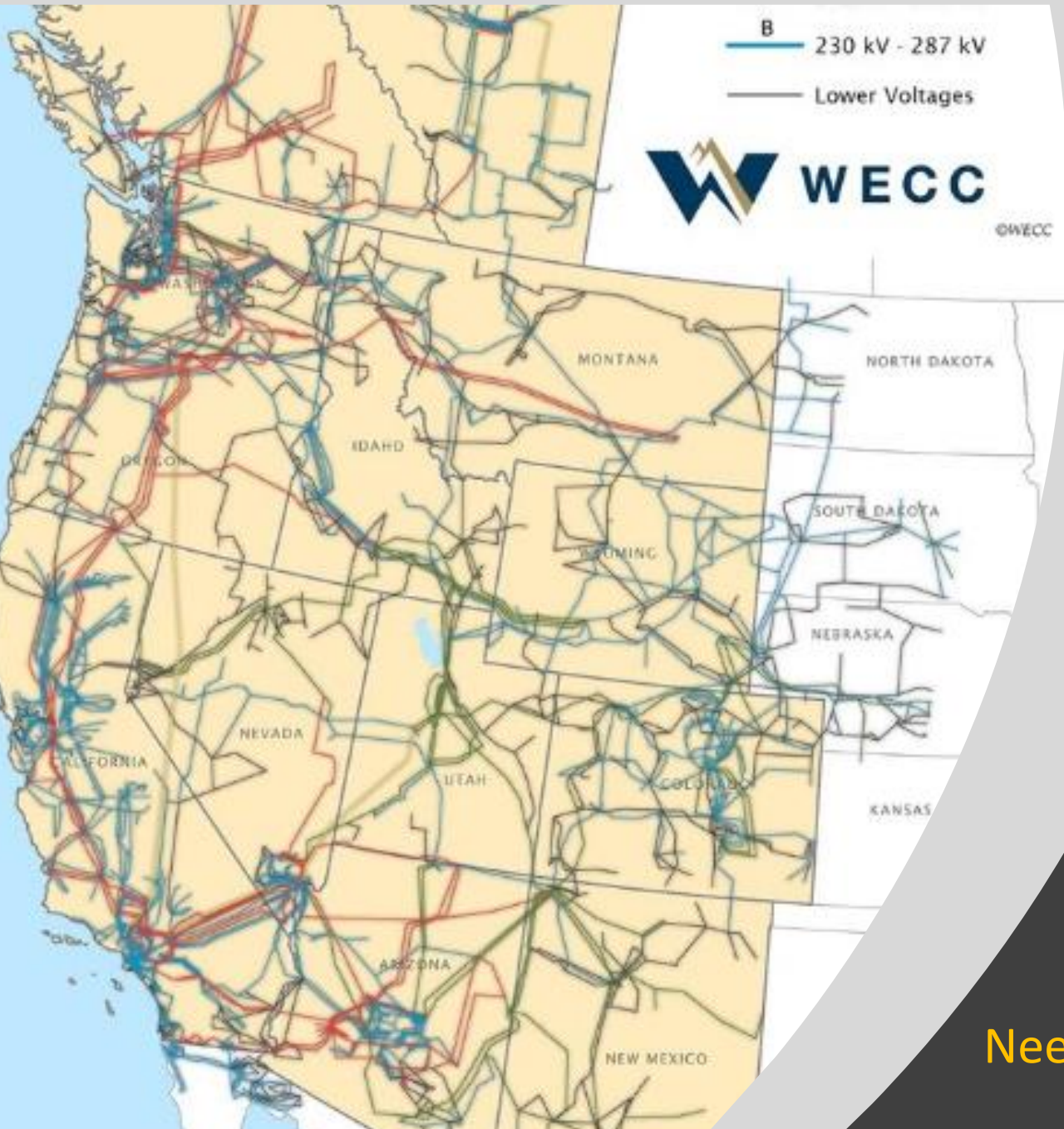




Traditional Sources  
Stabilize the Grid

High Inertia

$$F = mA$$

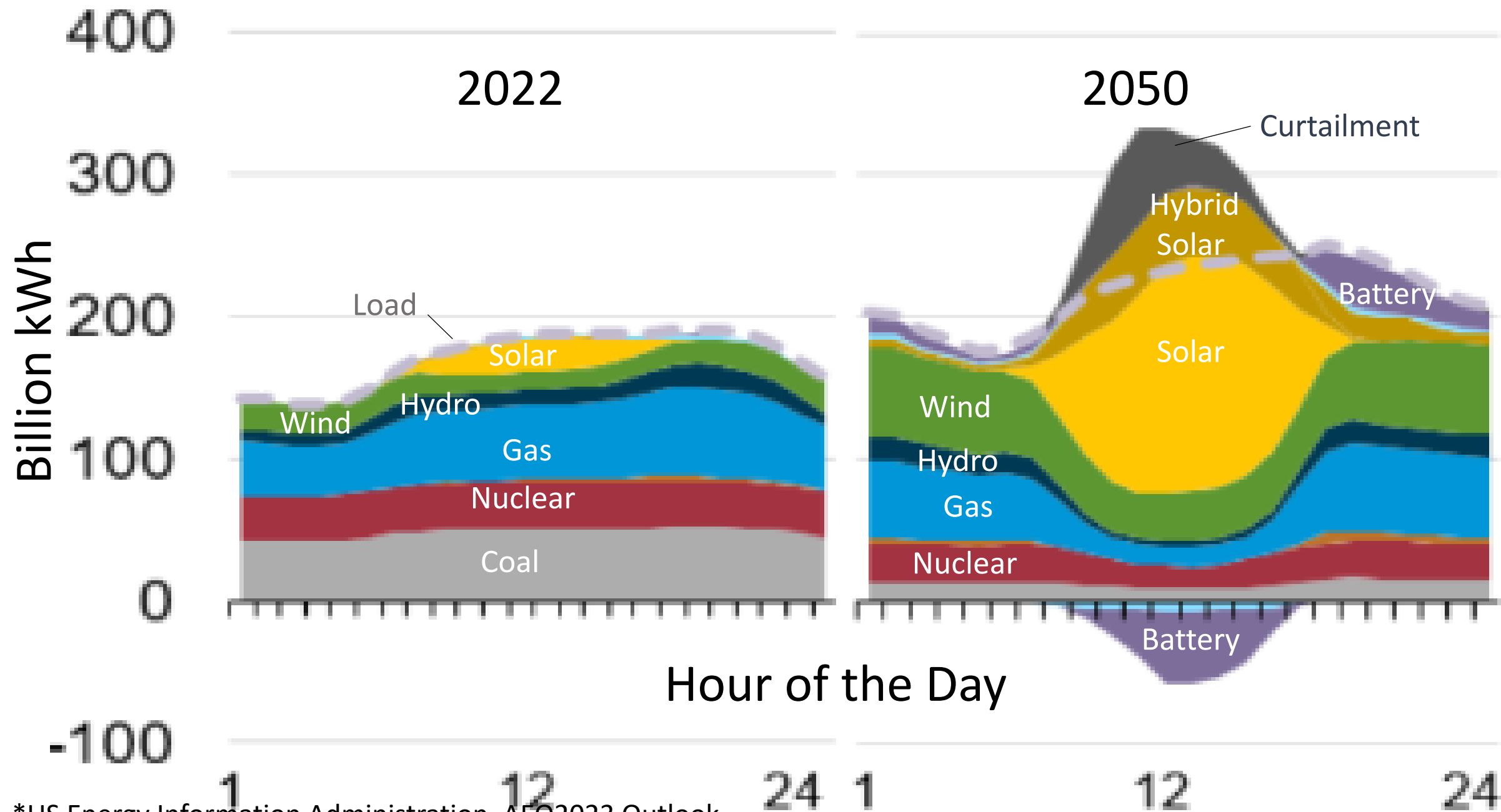


# US Electric Transmission Network: Delivering Energy at the Speed of Light

- 700,000 miles
- 115kV - 765kV AC, 1M VDC
- Reliable, redundant
- 1% annual growth

Need 10X annual growth for green energy transition

# Government Subsidies: More Solar, Wind, and Batteries



\*US Energy Information Administration, AEO2023 Outlook

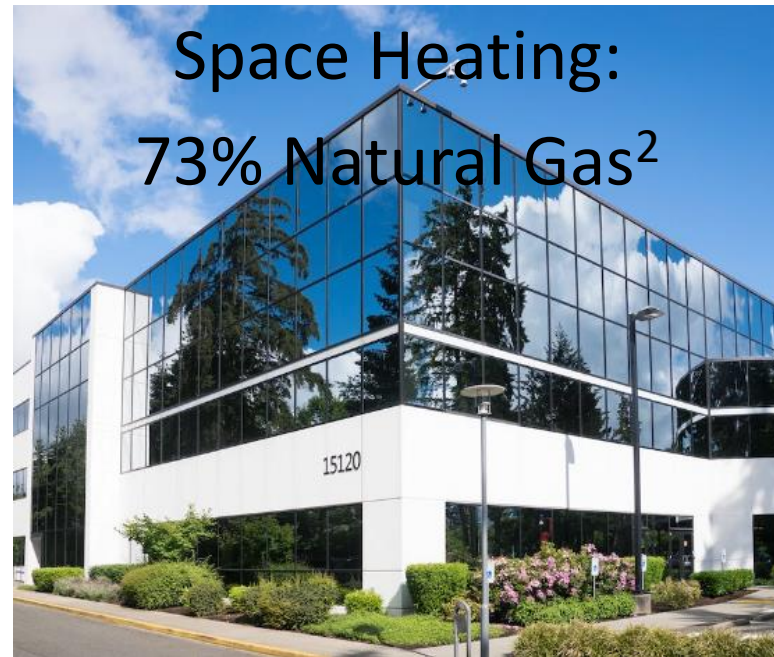
# Electric Demand is Growing Rapidly

EV Charging and Space Heating Mandates Could Double Electricity Demand

EV Charging: +45%  
Residential Load<sup>1</sup>

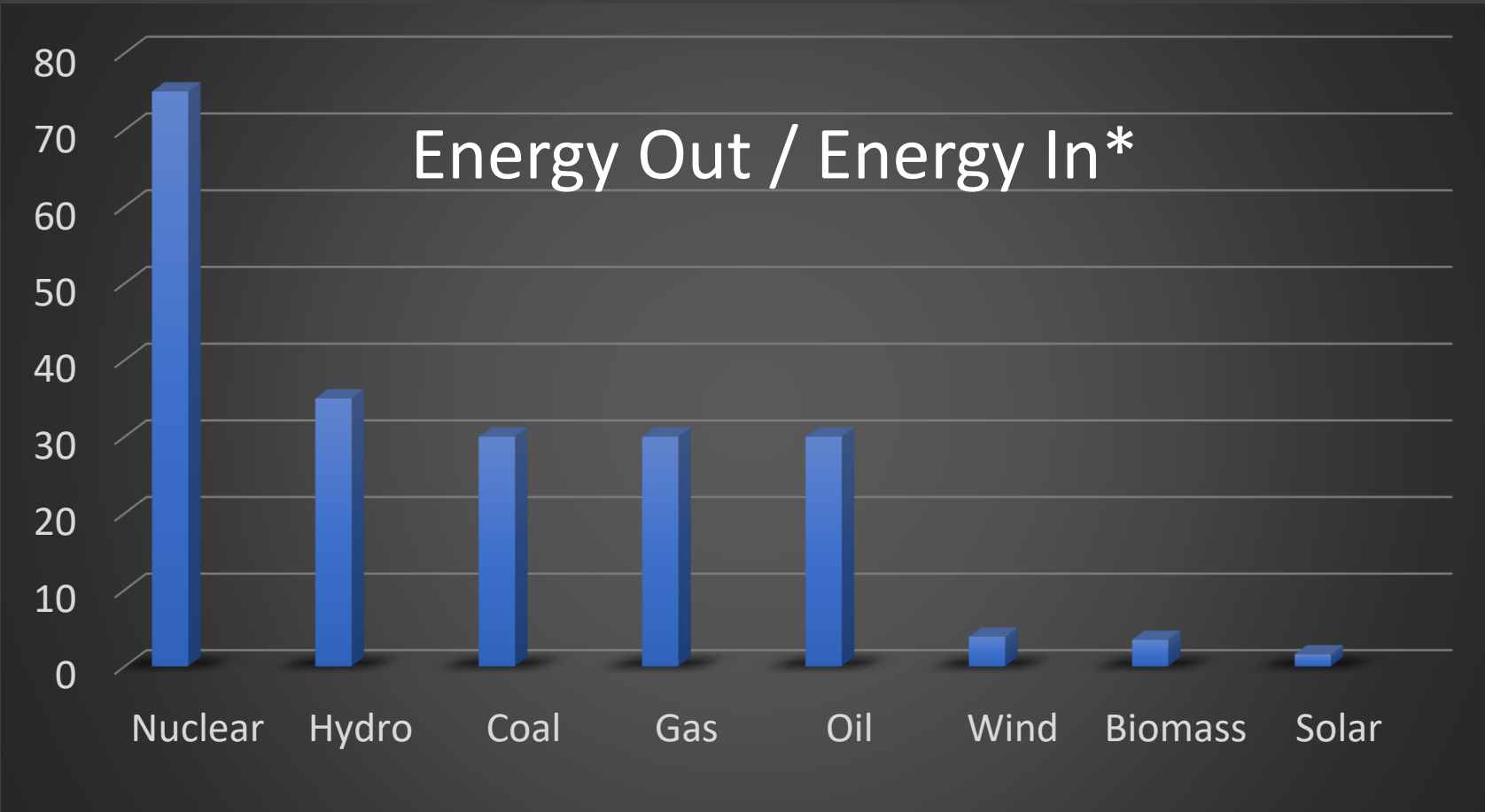


60kWh



- 1 -15,000 miles/yr, 200 mile range, 90% efficiency, 11000 kWh average residential load
2. US Energy Information Agency, 2018 Commercial Buildings Energy Consumption Survey
3. US Energy Information Agency, 2015 Residential Energy Consumption Survey

# Low Density Energy Sources Increase Costs



	Wind & Solar	Price \$/kWh
U.S. Avg	12%	\$0.15
California	26%	\$0.30

\*Michael Schellenberger, Apocalypse Never



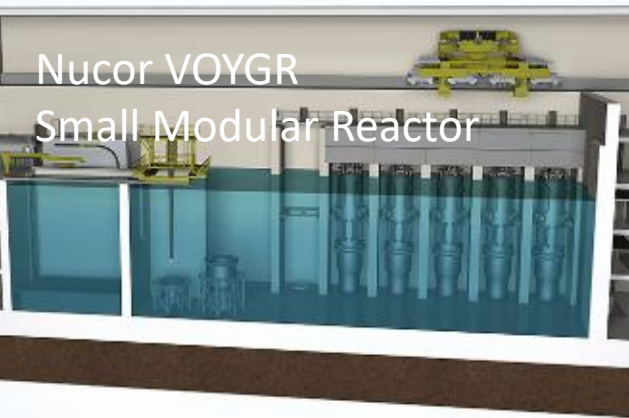
# Electric Batteries

Designed for Small Electric Vehicles, not Utility Scale Storage

Fast charge/discharge

2 – 4 hour run time

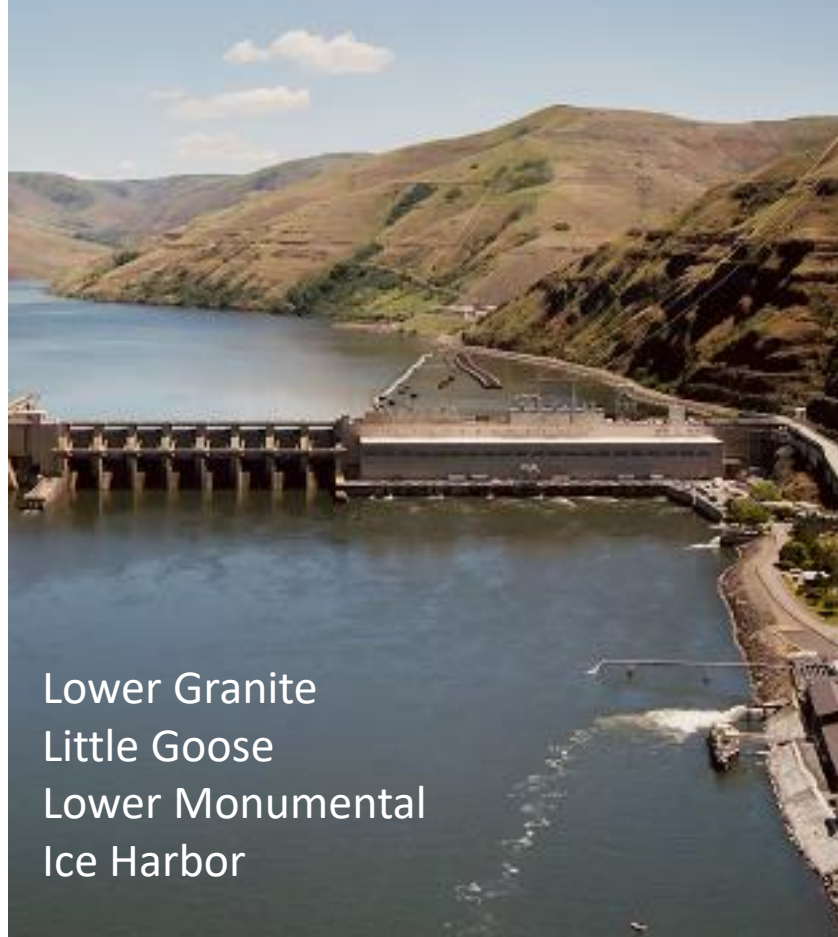
5:1 energy cost premium



Nucor VOYGR  
Small Modular Reactor



Siemens SST/SGT6  
Combined Cycle Gas



Lower Granite  
Little Goose  
Lower Monumental  
Ice Harbor

## Snake River Hydroelectric Replacement Options

- 900 MW average power  
(Power for 600,000 population)
- 2,300 MW firm peaking power



Tesla 400W



Vestas V90 3MW

# Snake River Energy: Land and Materials

900 Average MW

Generation Source	Snake River Hydro	Solar	Wind	Gas	Small Modular Reactor
Area (acres)	34,000	31,000	115,000	75	50
Weight (tons)	8,000,000 <sup>1</sup>	300,000 <sup>2</sup>	600,000 <sup>2</sup>	1,500 <sup>2</sup>	700 <sup>2</sup>

1. Freeingenergy.com, US average kg/MW

2. Manufacturer's specifications



# Snake River Zero Carbon Energy Options

900 Average MW plus 2,300 MW Firm Peaking Capacity

Generation Source	Snake River Hydro	Wind Solar	Wind Battery Gas	Wind Gas	Nuclear Gas
Construction Cost	--	\$77B	\$19.6B	\$12.4B	\$11B
Energy Cost \$/MWh	\$17	\$534	\$156	\$94	\$86

# EV's: 20% Emissions Reduction, 10X the Mining



ICE -> EV

## Carbon Emissions (tons)

	ICE	EV	ICE -> EV
IEA <sup>2</sup>	42	10 - 40	5% - 71%
Volkswagen <sup>3</sup>	28	23	18%
Volvo <sup>4</sup>	60	40 - 55	18% - 33%
Fuel Mined (lbs) <sup>1</sup>	50K	500K	10X

1. Mark Mills, Testimony to U.S. House Committee on Energy and Commerce, February 9, 2021  
 2. International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions," March 2022, 40kWh vehicle  
 3. Maciej Neugebauer, Adam Żebrowski, and Ogulcan Esmer, "Cumulative Emissions of CO2 for Electric and Combustion Cars: A Case Study on Specific Models," *Energies*, April 6, 2022  
 4. Elisabeth Evrard et al., "Carbon Footprint Report: Volvo C40 Recharge," VolvoCars.com, 2021

# U.S. Emissions Forecast

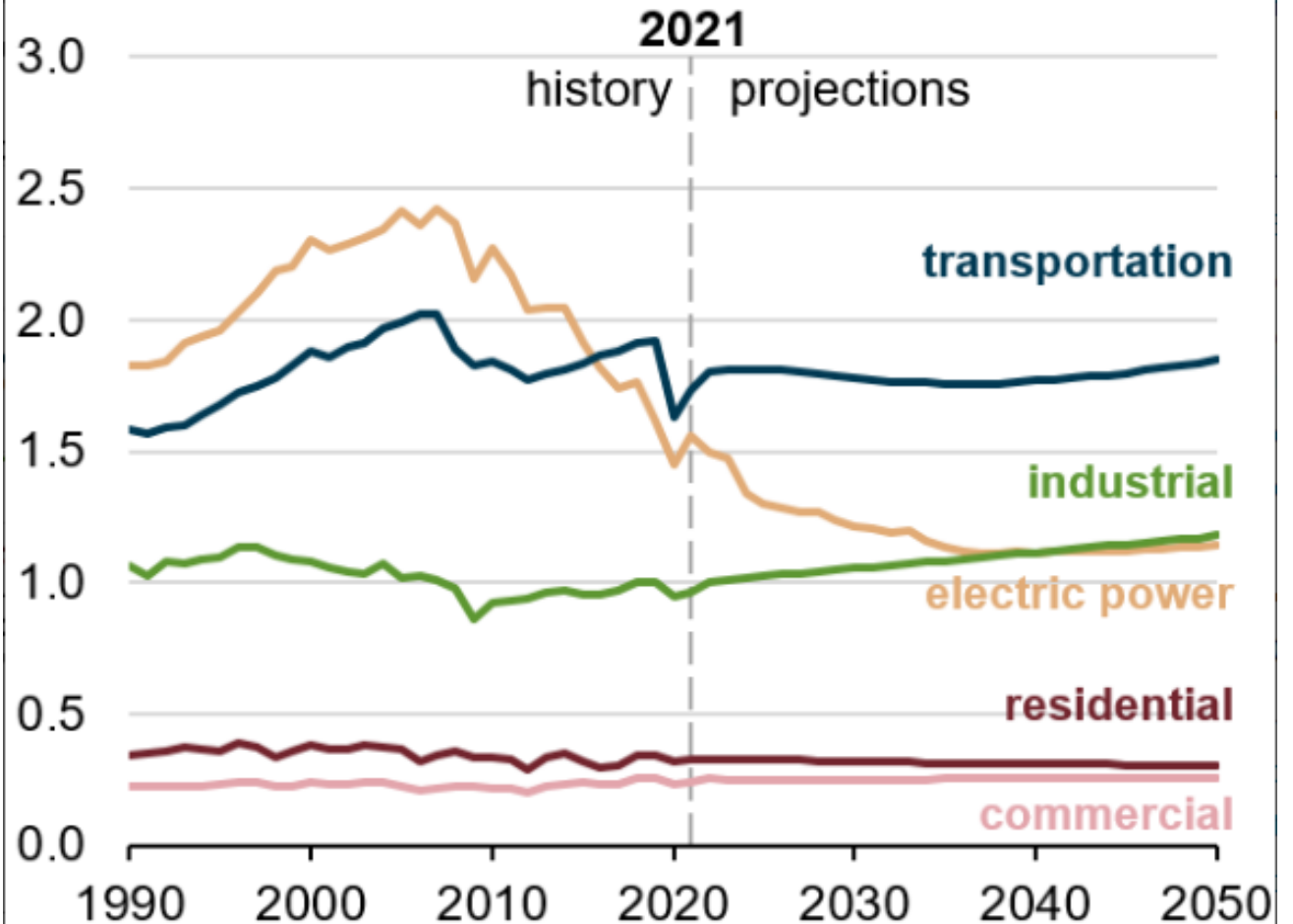
Electric Power Down  
All Others Flat or Up

Net: -5%

## Energy-related CO<sub>2</sub> emissions by sector AEO2022 Reference case



billion metric tons



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2022*, March 2022

# Worldwide Carbon Emissions Continue to Increase



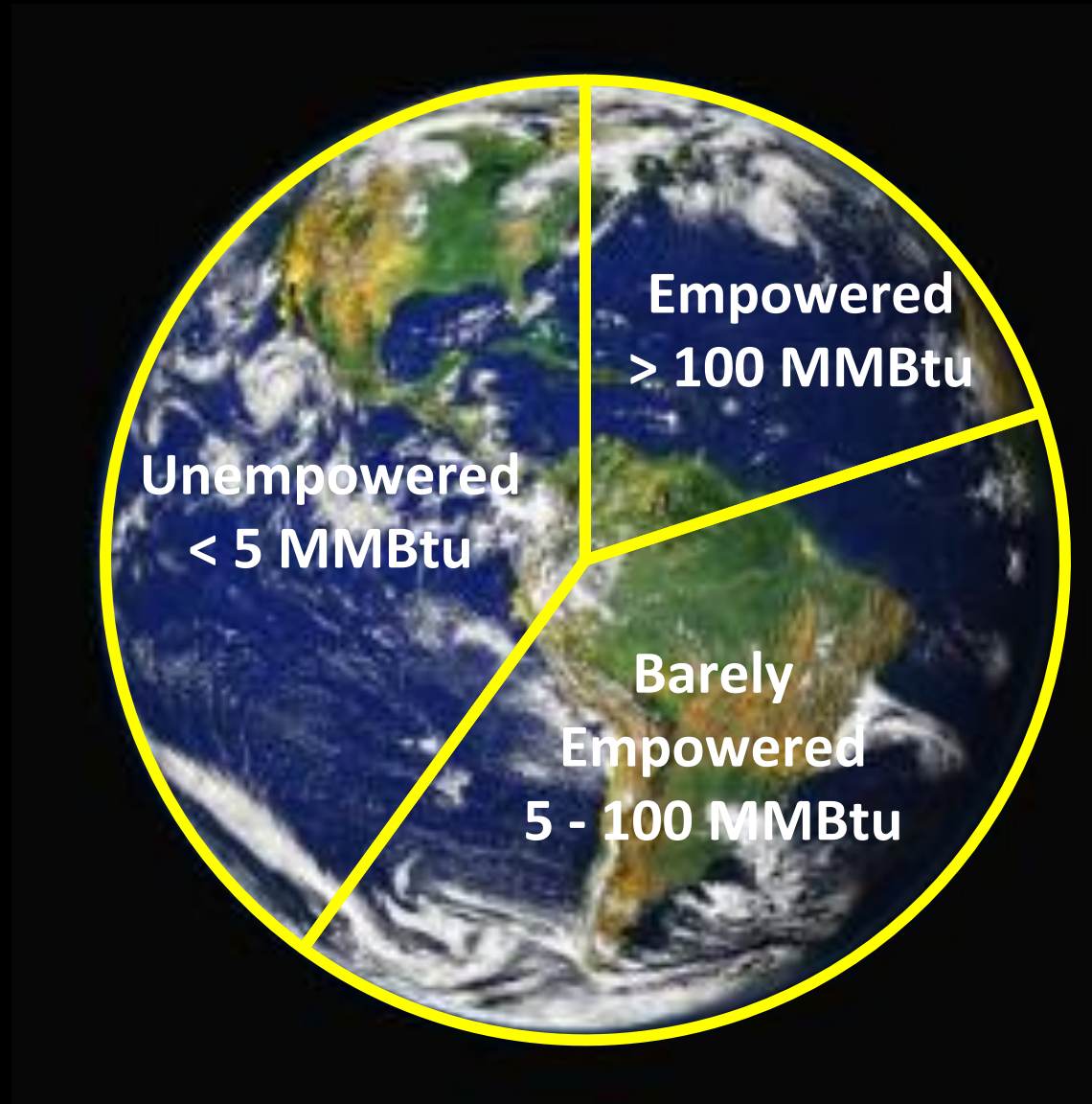
## Emissions Share and Trend

China	33%	↑
USA	13%	↓
Europe	7%	↓
India	7%	↑
Russia	5%	↑
Others	35%	↑

Crippa, et al., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2023, [doi:10.2760/953322](https://doi.org/10.2760/953322), JRC134504.

# Only 20% of Humanity Has Sufficient Energy

Per Capita Annual Energy Consumption



USA = 300 MMBtu

# Innovation and Creativity Will Drive Our Energy Evolution

- All forms of energy provide benefits and have negative environmental impacts
- Ideal energy sources are abundant, stored, and concentrated.





# Innovation and Creativity Will Drive Our Energy Evolution

- Power system stability will limit intermittent electric source penetration
- Intermittent low-density sources will supplement, but not replace, dense energy sources



# Innovation and Creativity Will Drive Our Energy Evolution

- The world will continue to increase fossil fuel use to improve living standards
- Innovation and creativity will improve energy access and minimize environmental impact



A scenic view of a town at the foot of snow-capped mountains. In the foreground, a tall, dark wooden tower with a ladder and a platform at the top stands prominently. The town below is densely packed with buildings and trees, some showing autumn colors. The mountains in the background are rugged and covered in snow, with a soft, golden light suggesting a sunrise or sunset. The sky is a mix of blue and orange.

Thank You