

# 21st Century Energy Transition



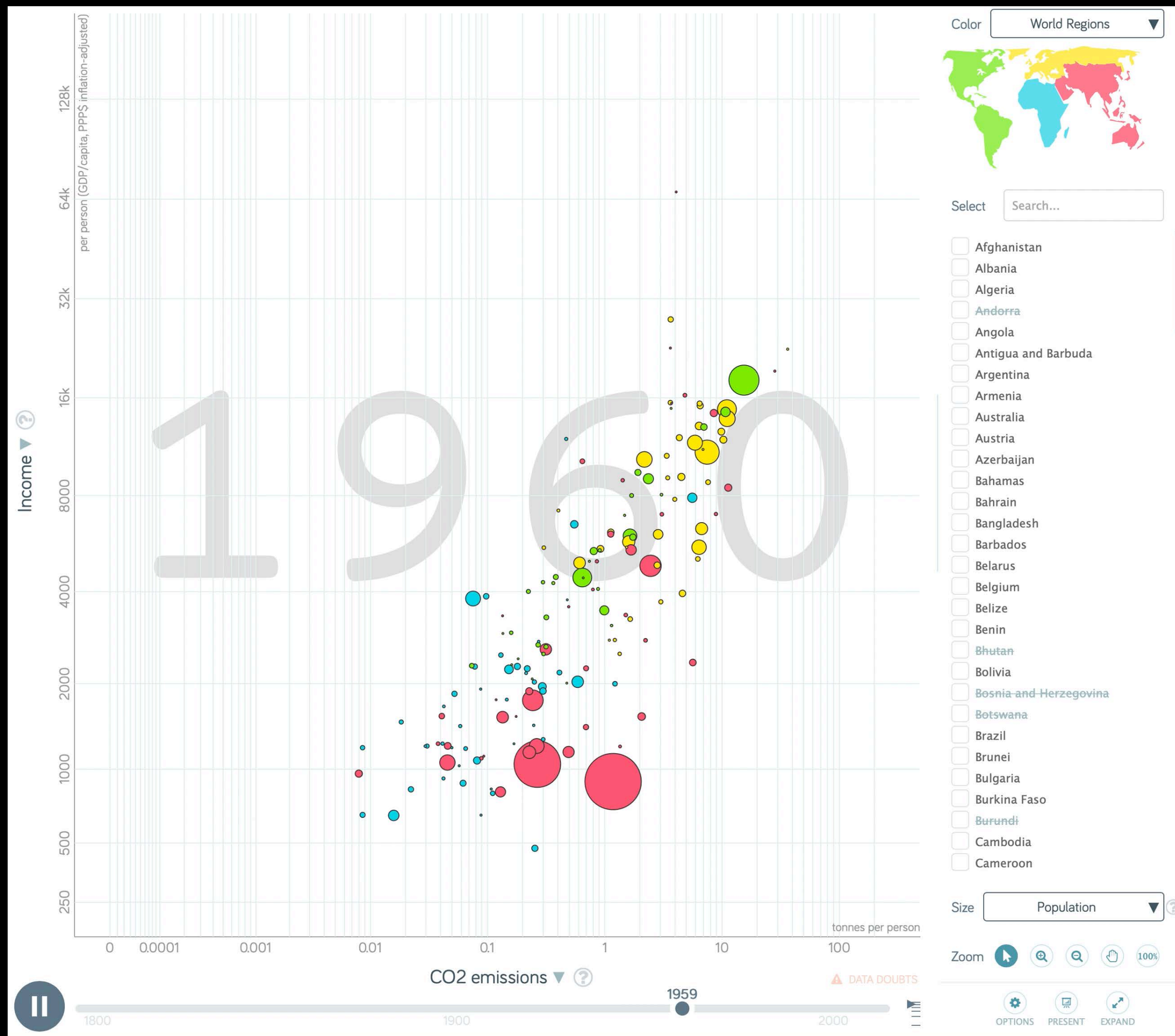
*Chesapecten jeffersonius*

Peter de Menocal  
Columbia University

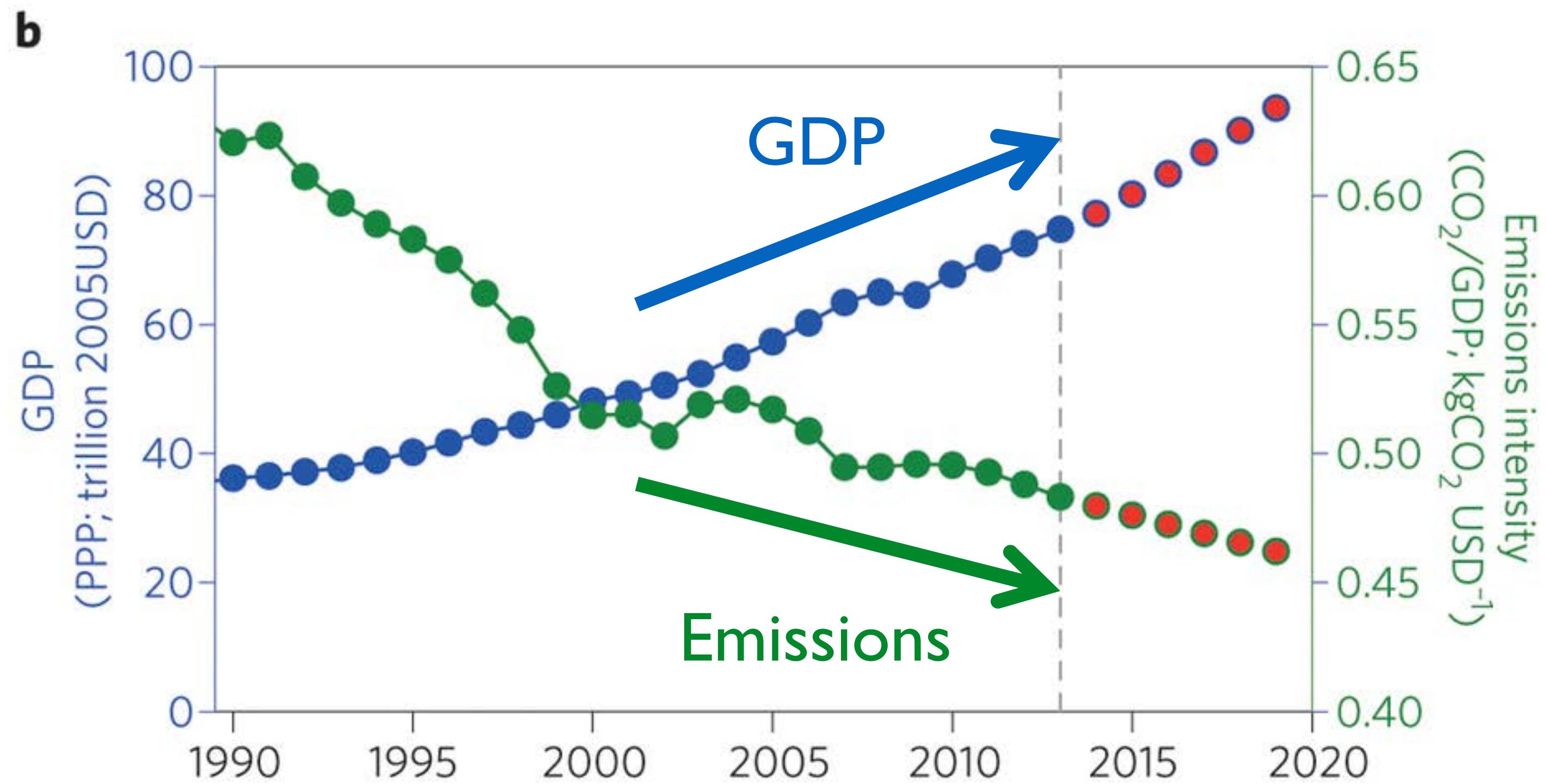


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# The ethical case for fossil fuels

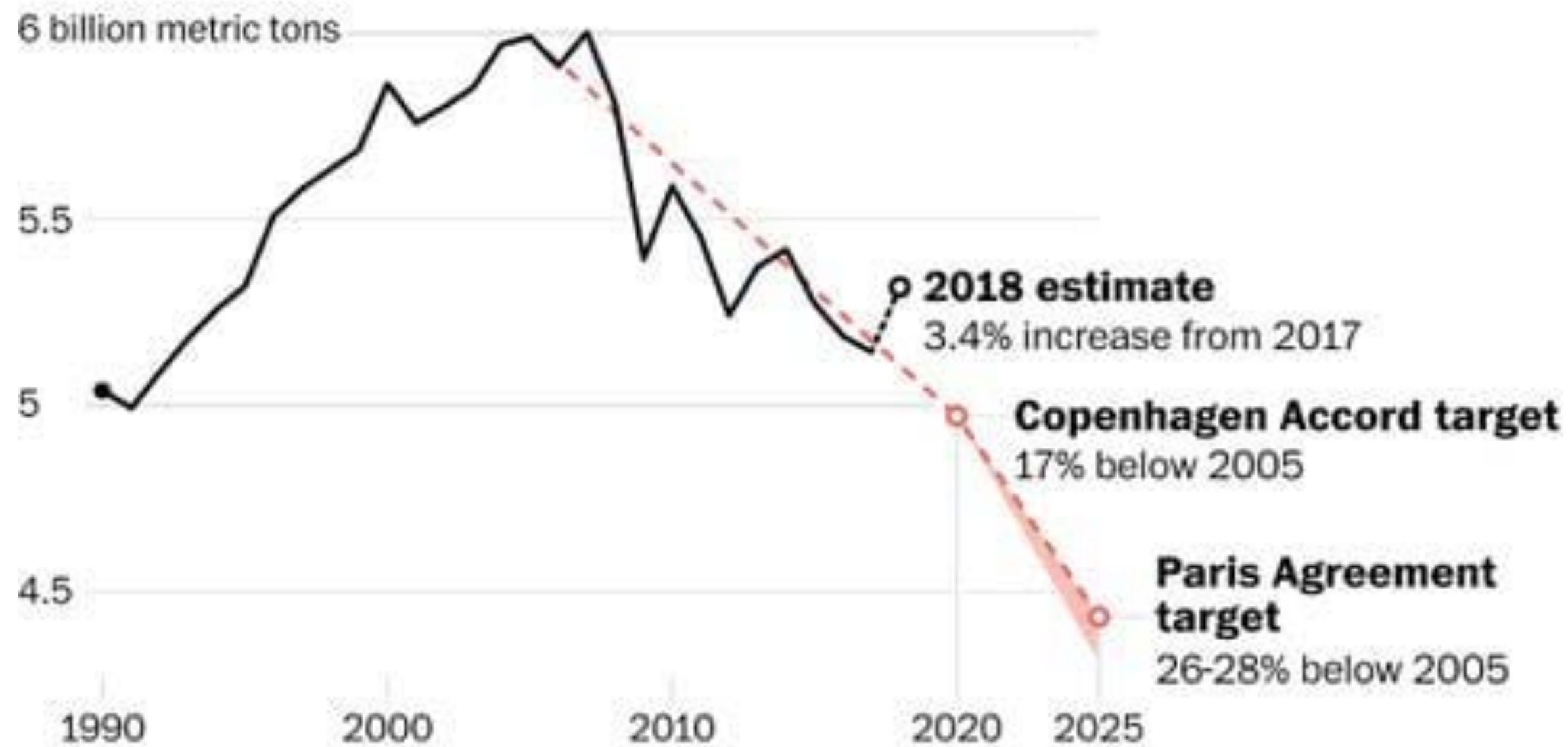


# Emissions are decoupling from wealth



# US (sort of) on target for Paris

Energy-related CO<sub>2</sub> emissions are estimated to have increased in 2018



# Wind and solar are cheap - getting cheaper

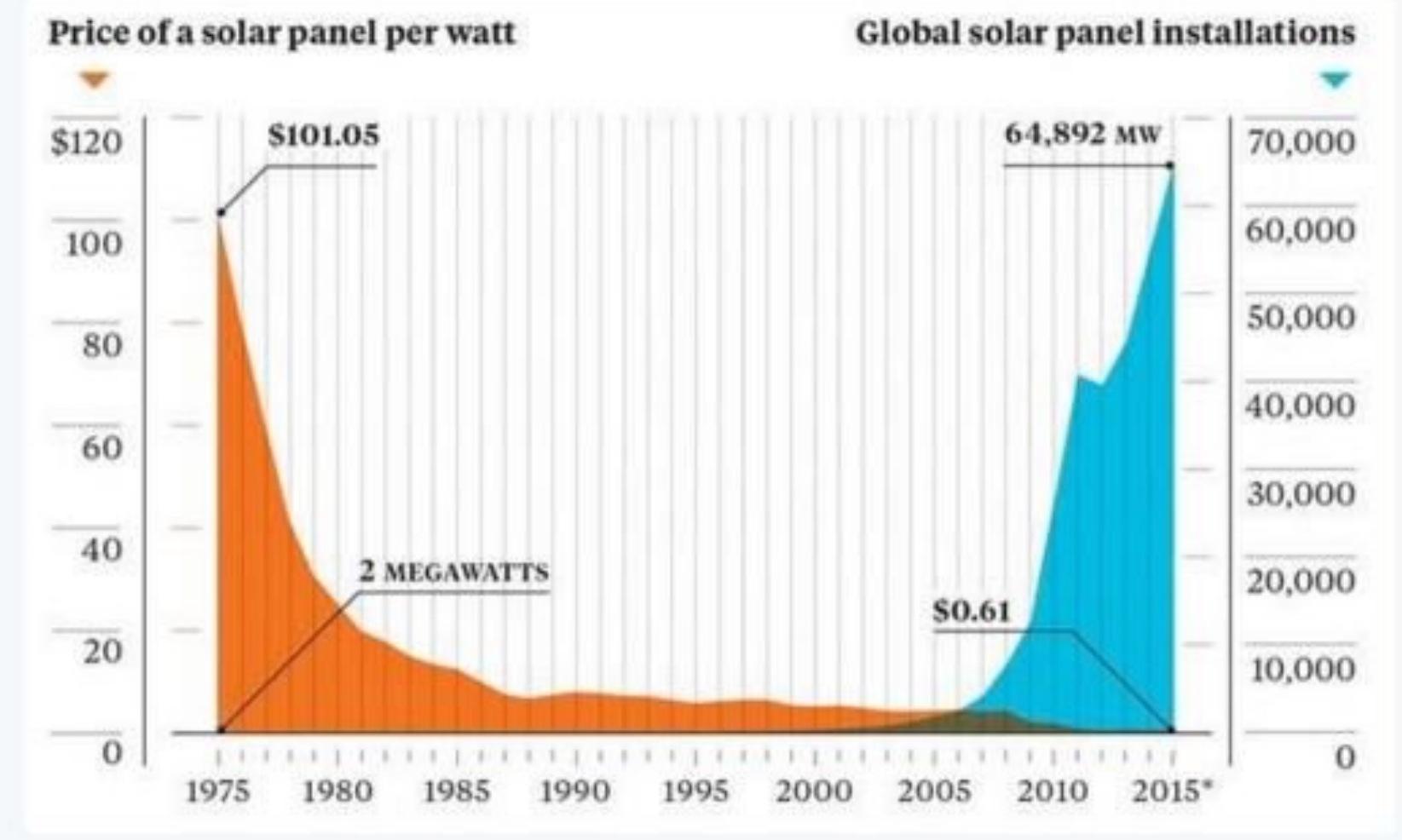


1. LAND-BASED WIND POWER



cost

capacity

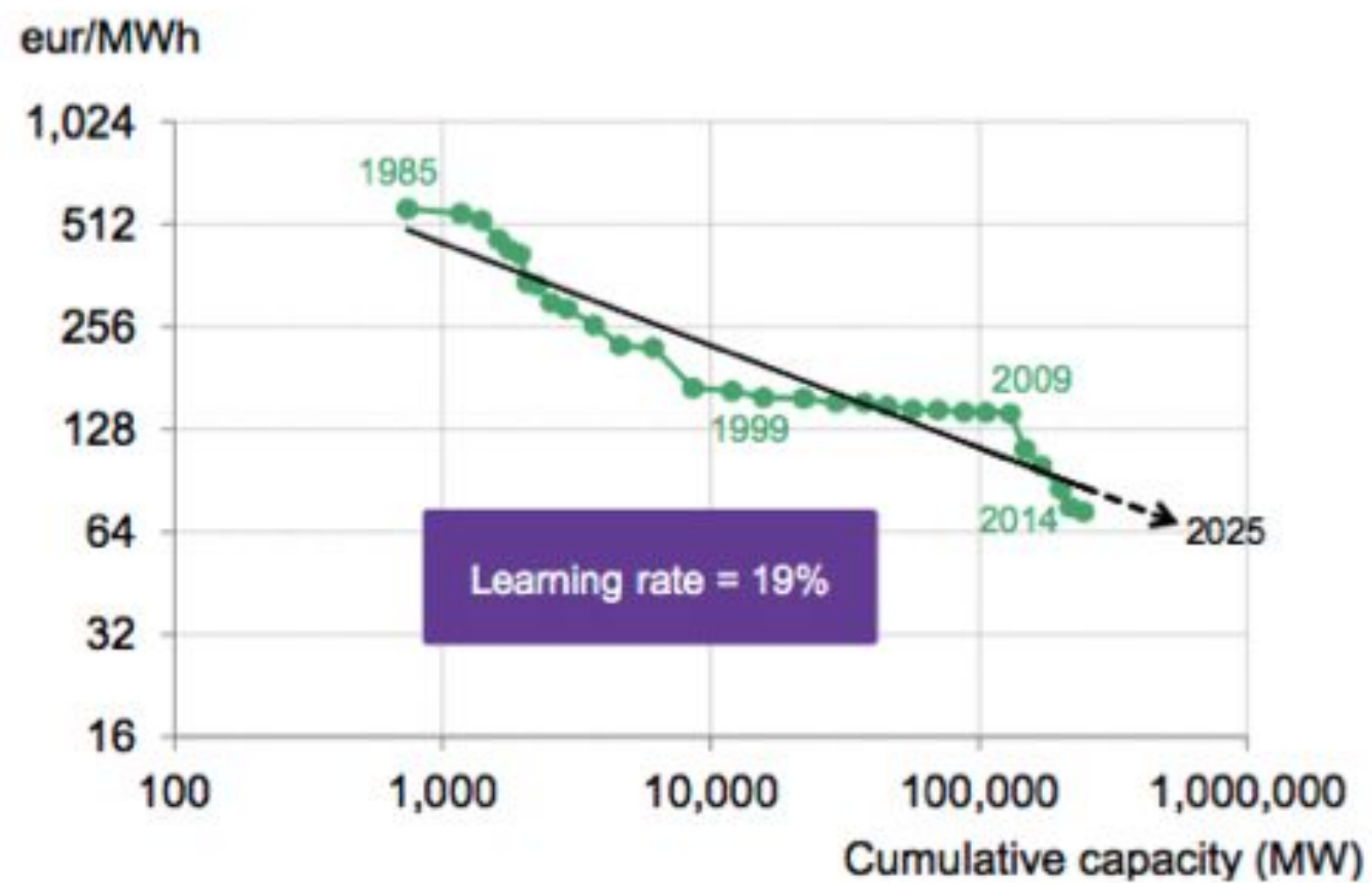


cost

capacity

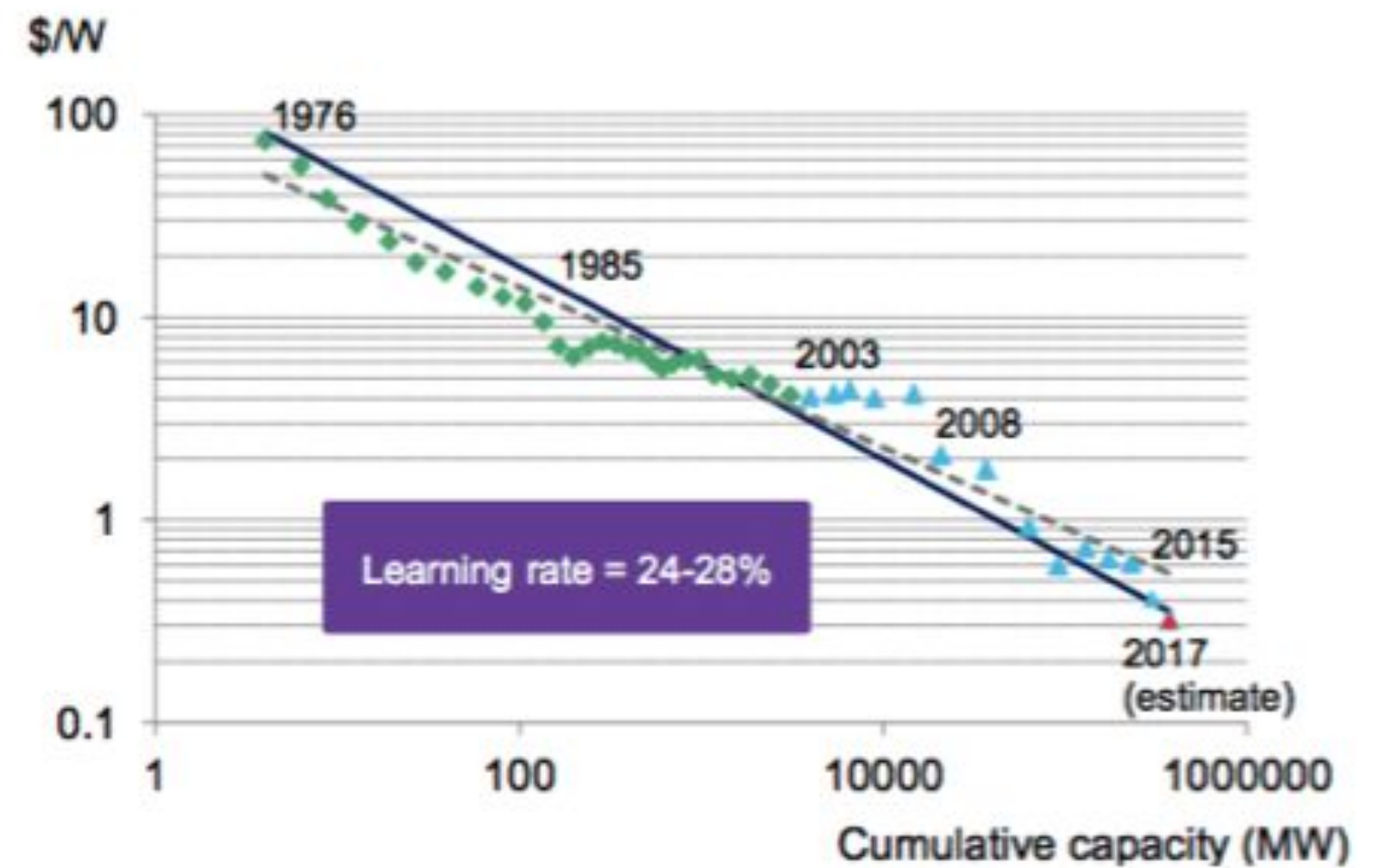
# Why? Technology “learning rates”

## Wind



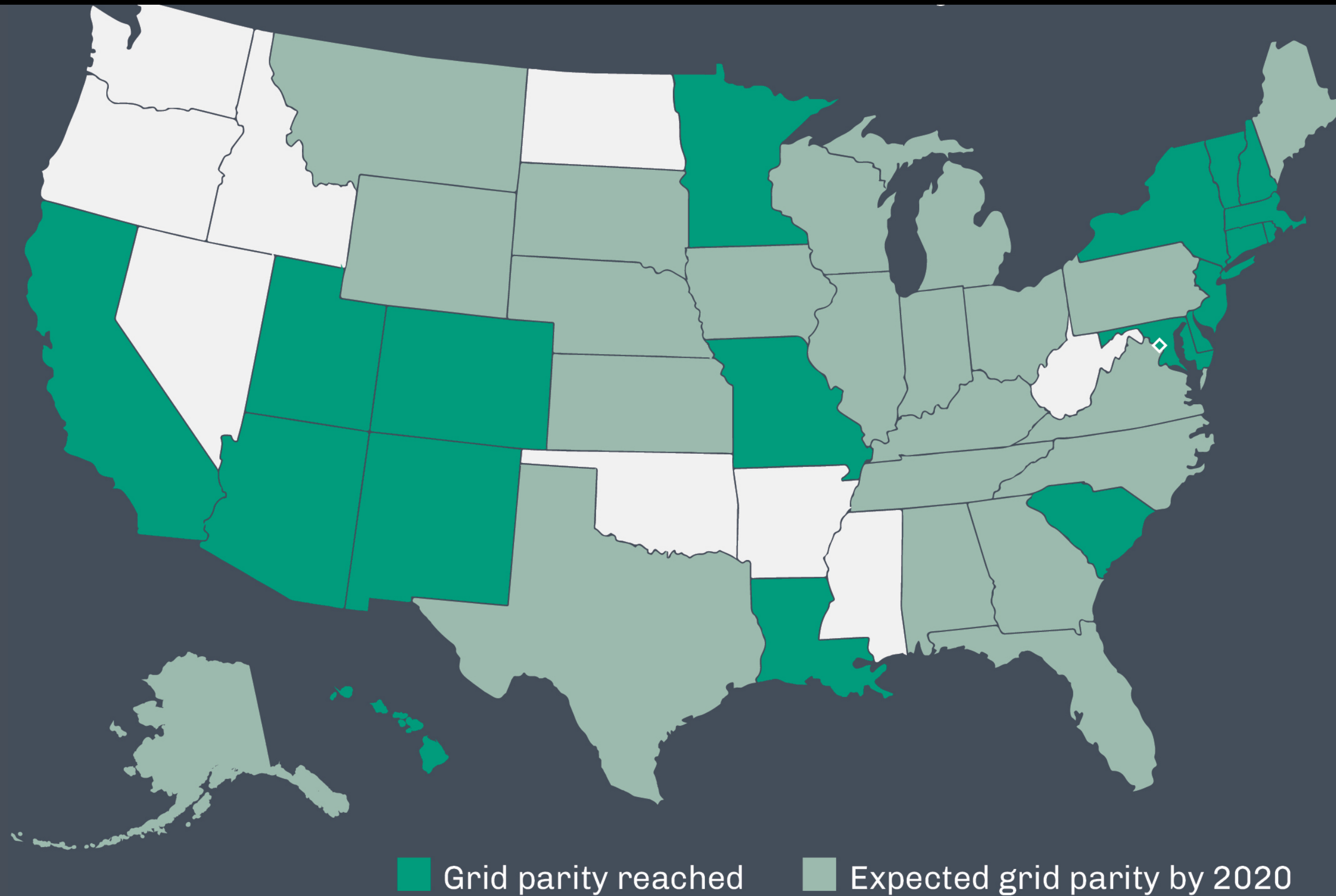
Source: Bloomberg New Energy Finance

## Solar



Source: Bloomberg New Energy Finance

# Grid Parity

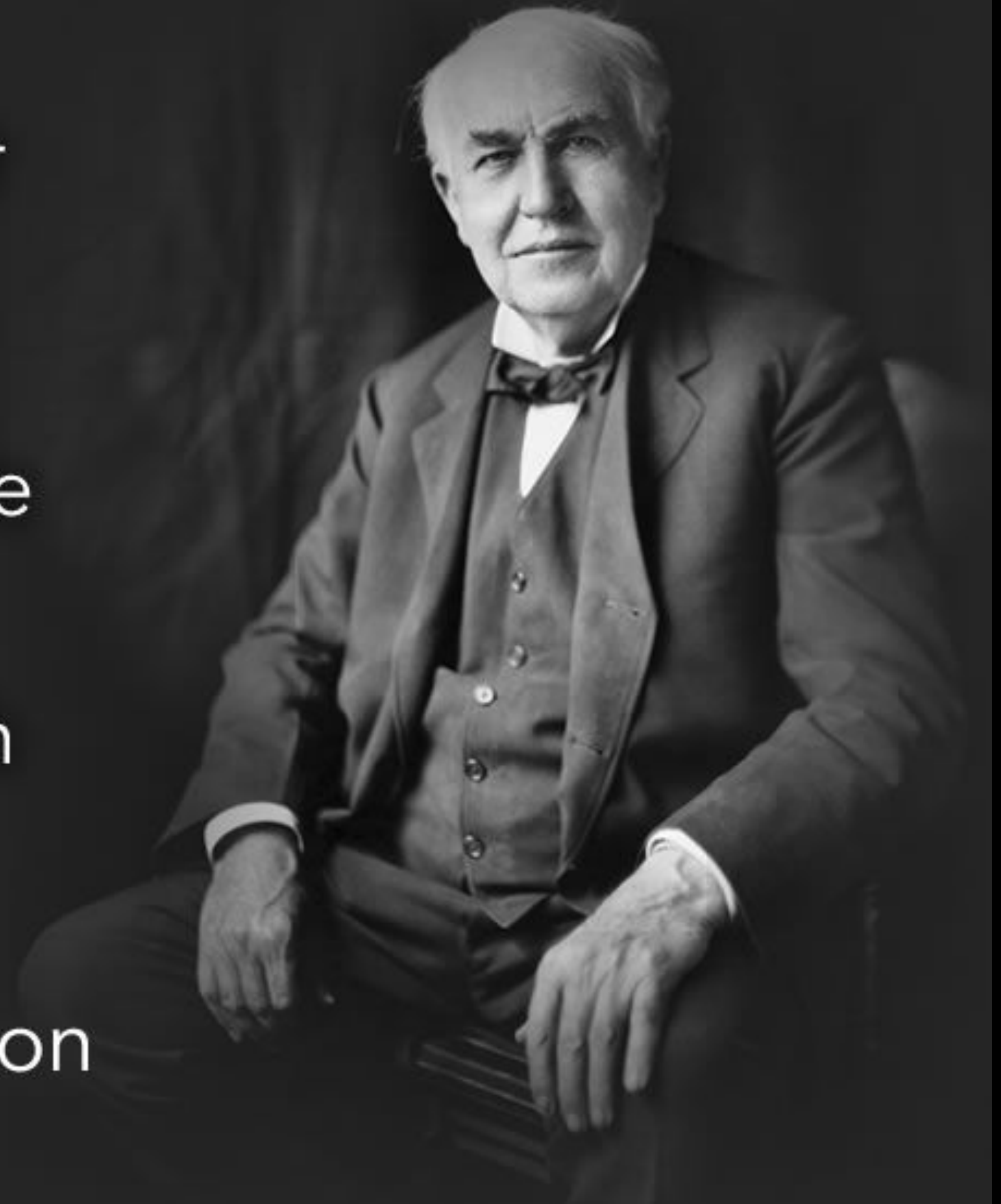


Source: GTM Research, 2016

“I’d put my money on the sun and solar energy. What a source of power!

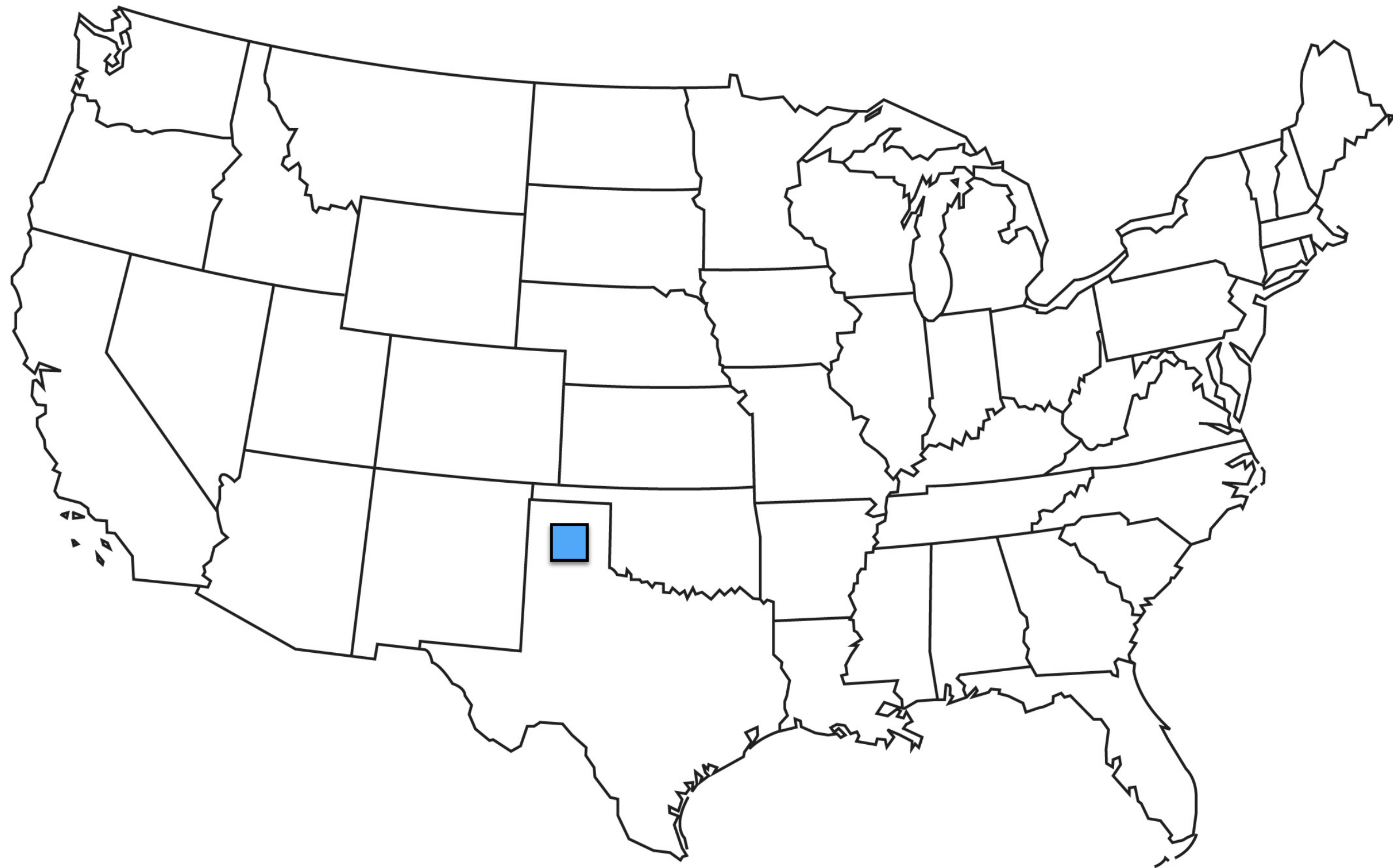
I hope we don’t have to wait until oil and coal run out before we tackle that. I wish I had more years left.”

~Thomas Edison



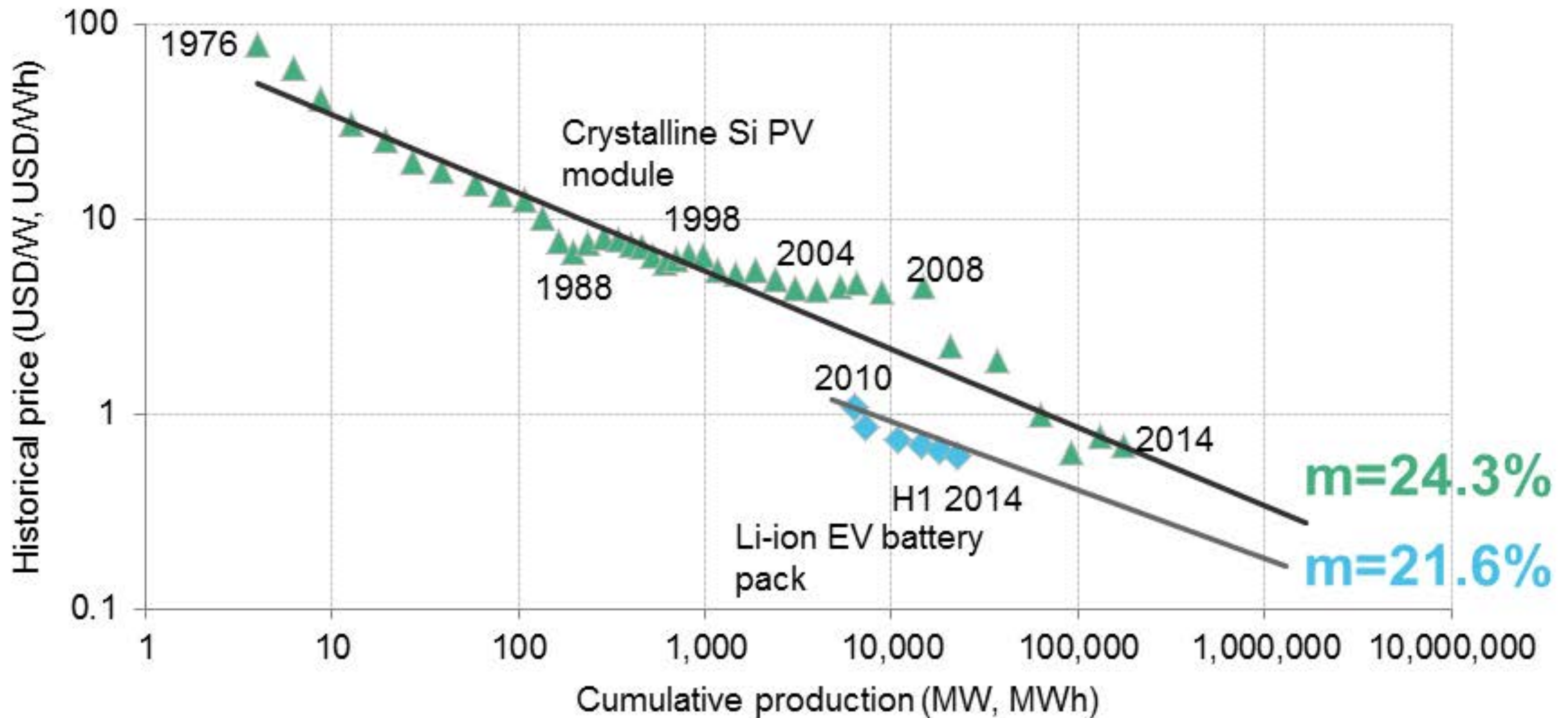


# Solar area needed to supply US electricity



US NREL

# Batteries getting cheaper, too

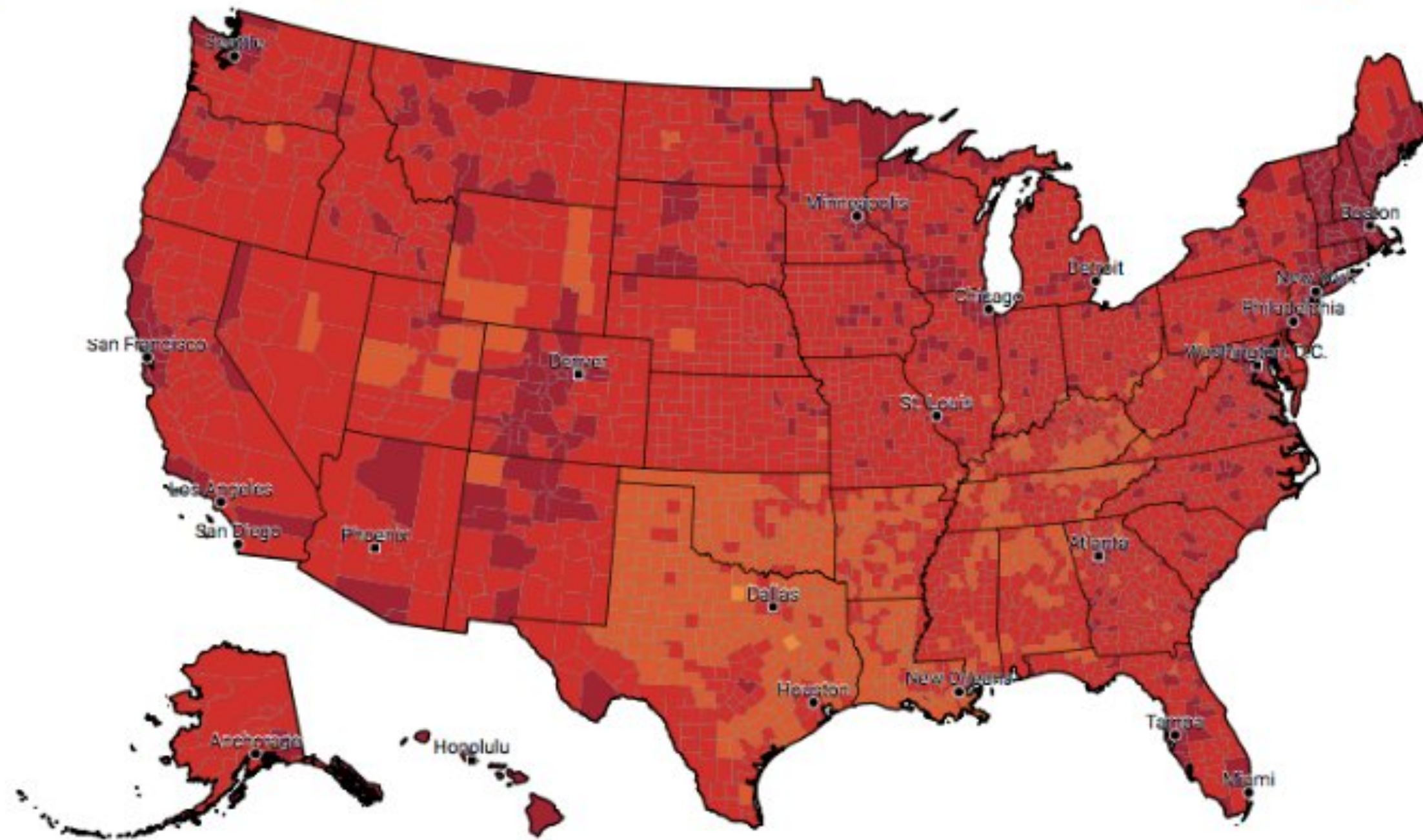


Note: Prices are in real (2014) USD.

Source: Bloomberg New Energy Finance, Maycock, Battery University, MIT

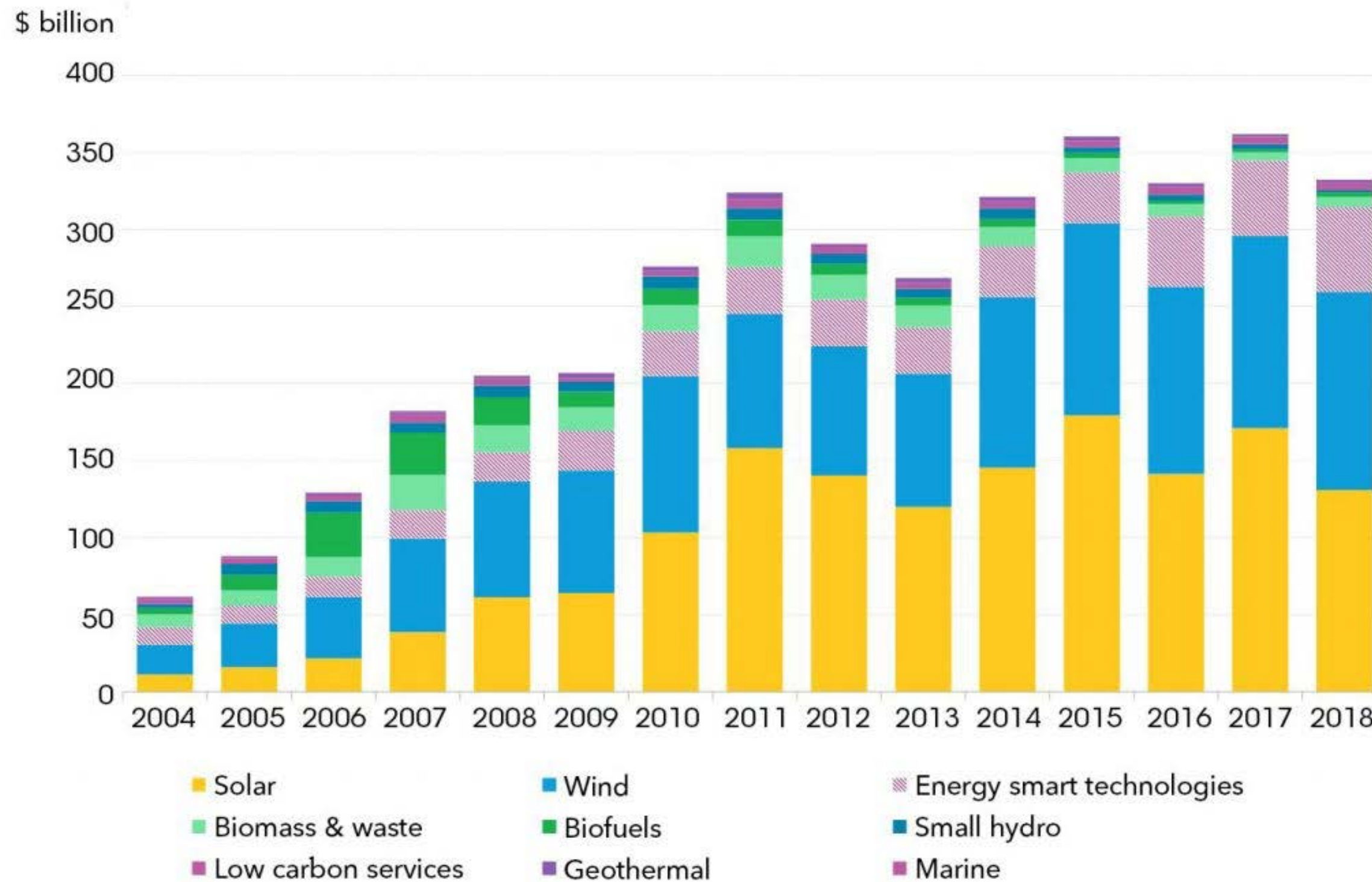
# Something we agree on

**85% of Americans**  
support funding research into renewable energy sources.



# Clean energy investment is growing

Global new investment in clean energy



\$300 billion/year

Source: BloombergNEF



# Jobs!

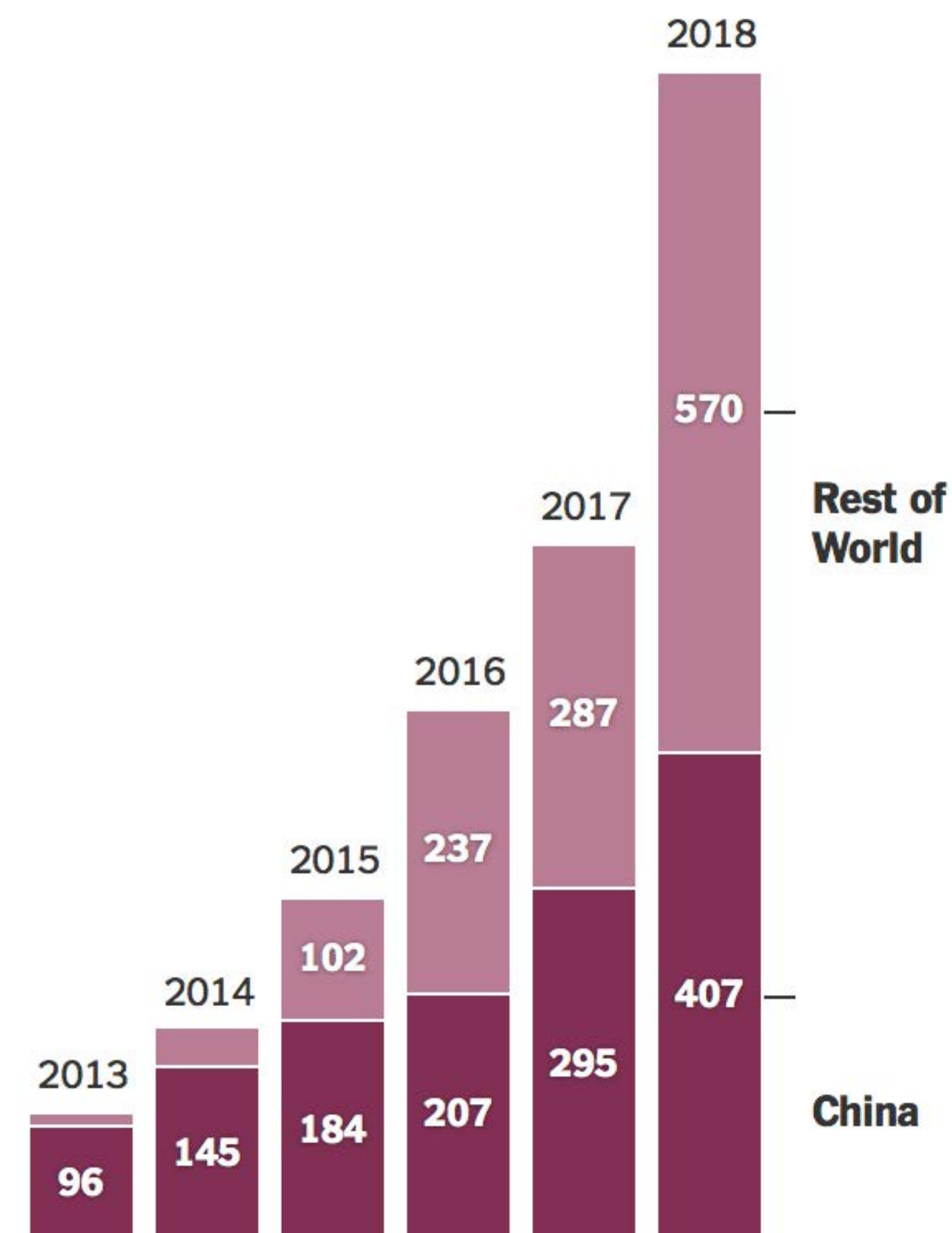
**3.3 million US jobs (2019)**

**Clean energy jobs outpace fossil fuel: 3:1**

# Electrifying transport

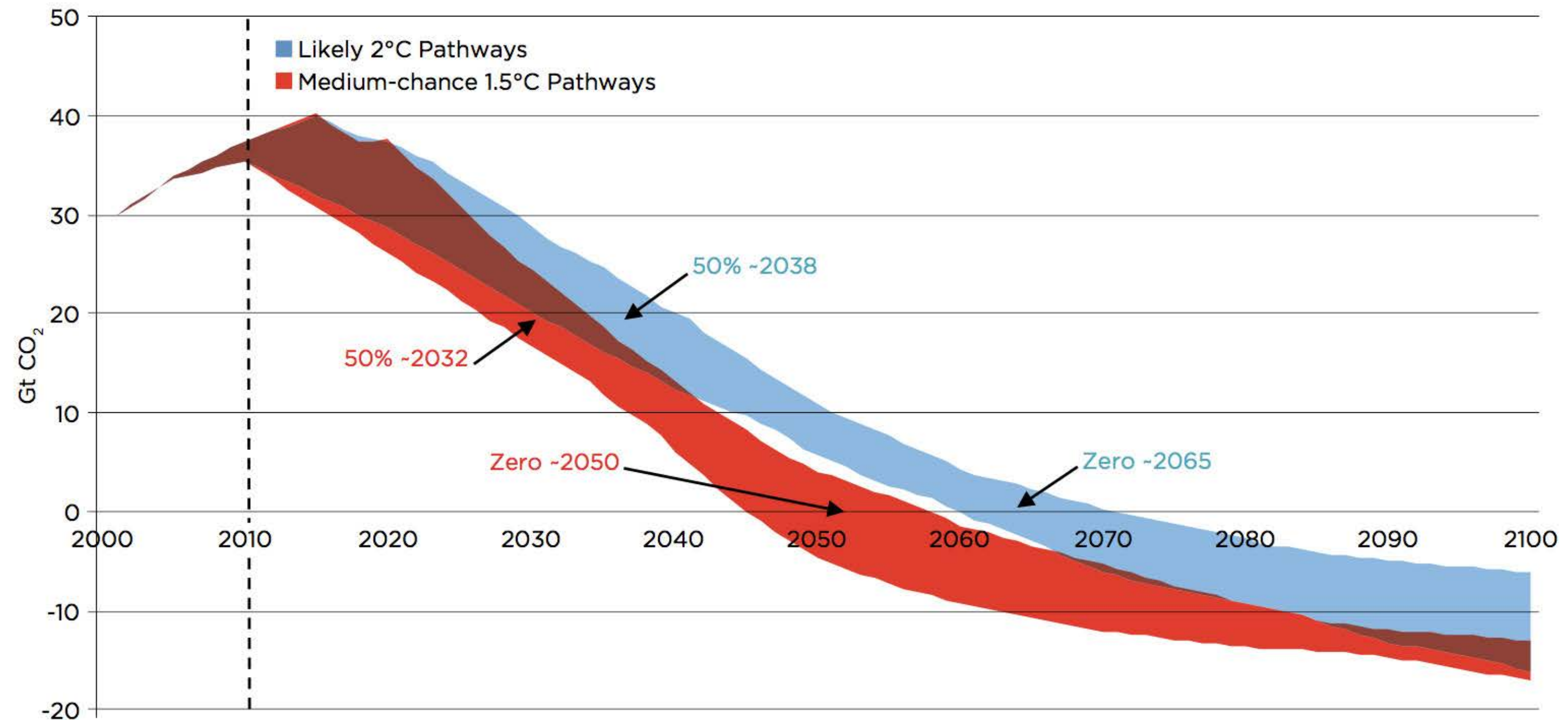


Number of battery-electric cars sold, in thousands



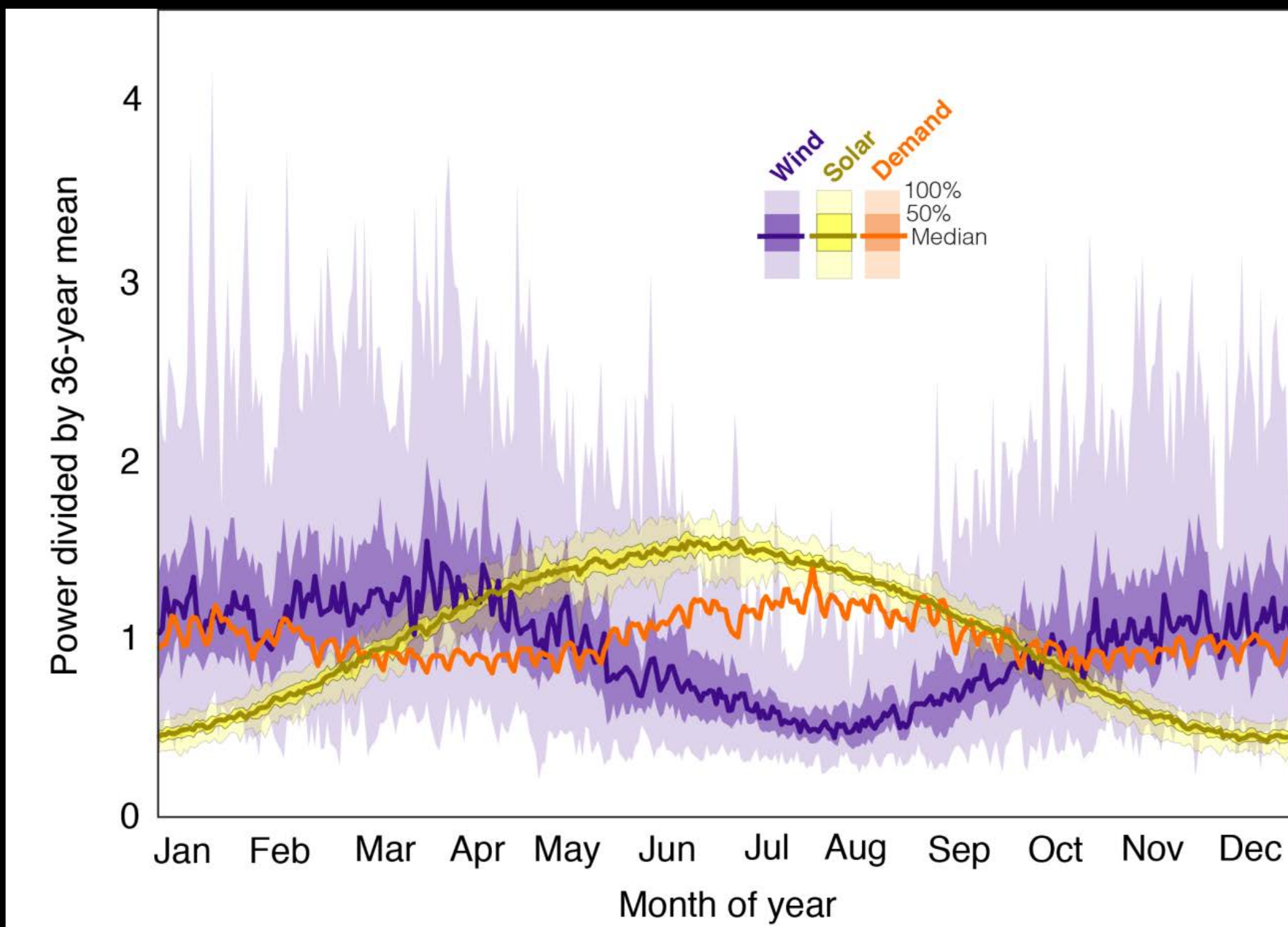
# Our deep carbon diet

Figure 1: Range of Global Emissions Pathways in Scenarios Consistent with Likely Chance of 2°C or Medium Chance of 1.5°C<sup>18</sup>



Sources: Joeri Rogelj et al

# U.S. Clean Energy Example



1.15 overbuild Solar + Wind  
Plus 12 hours storage

100% U.S. electricity demand

Shaner et al. (E&ES, 2018)

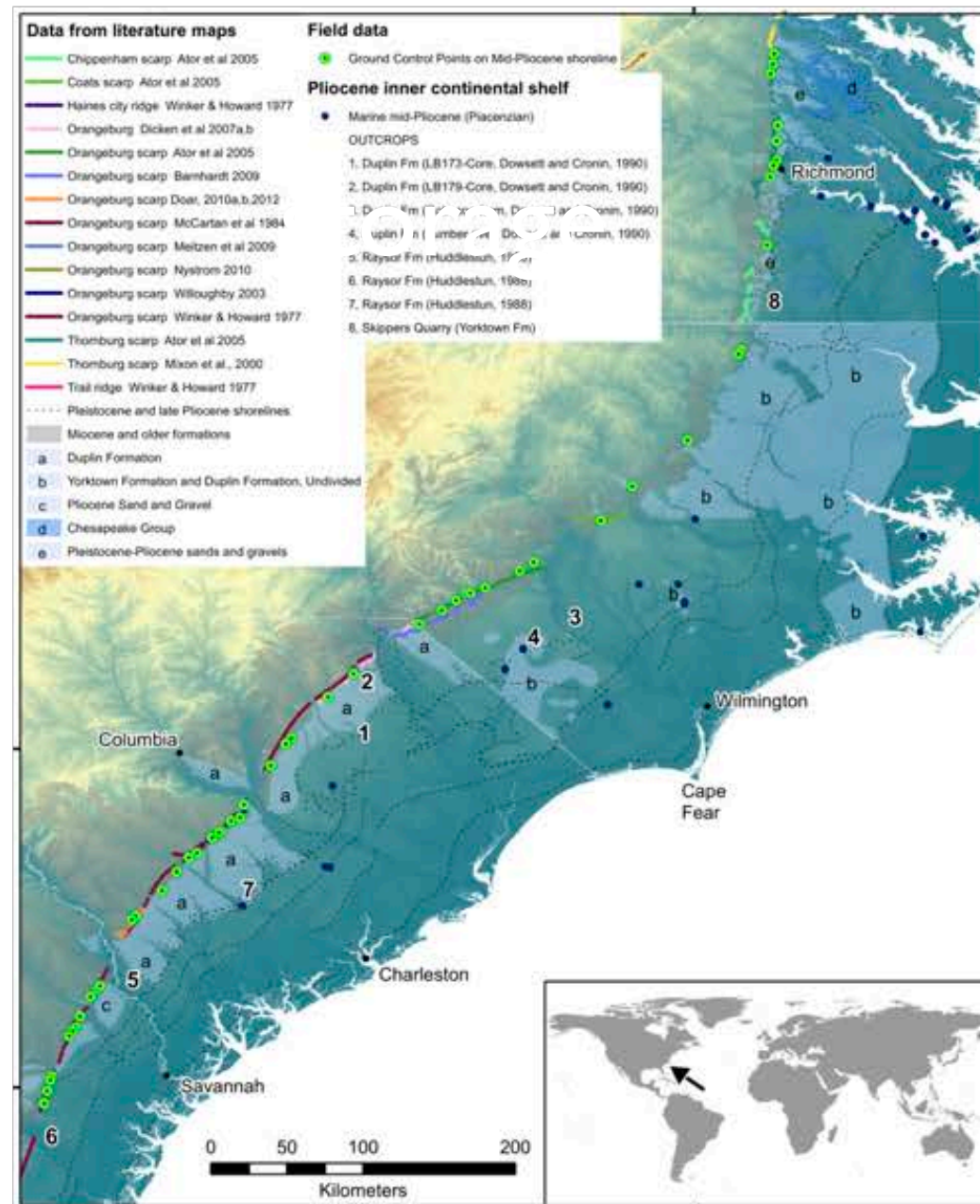
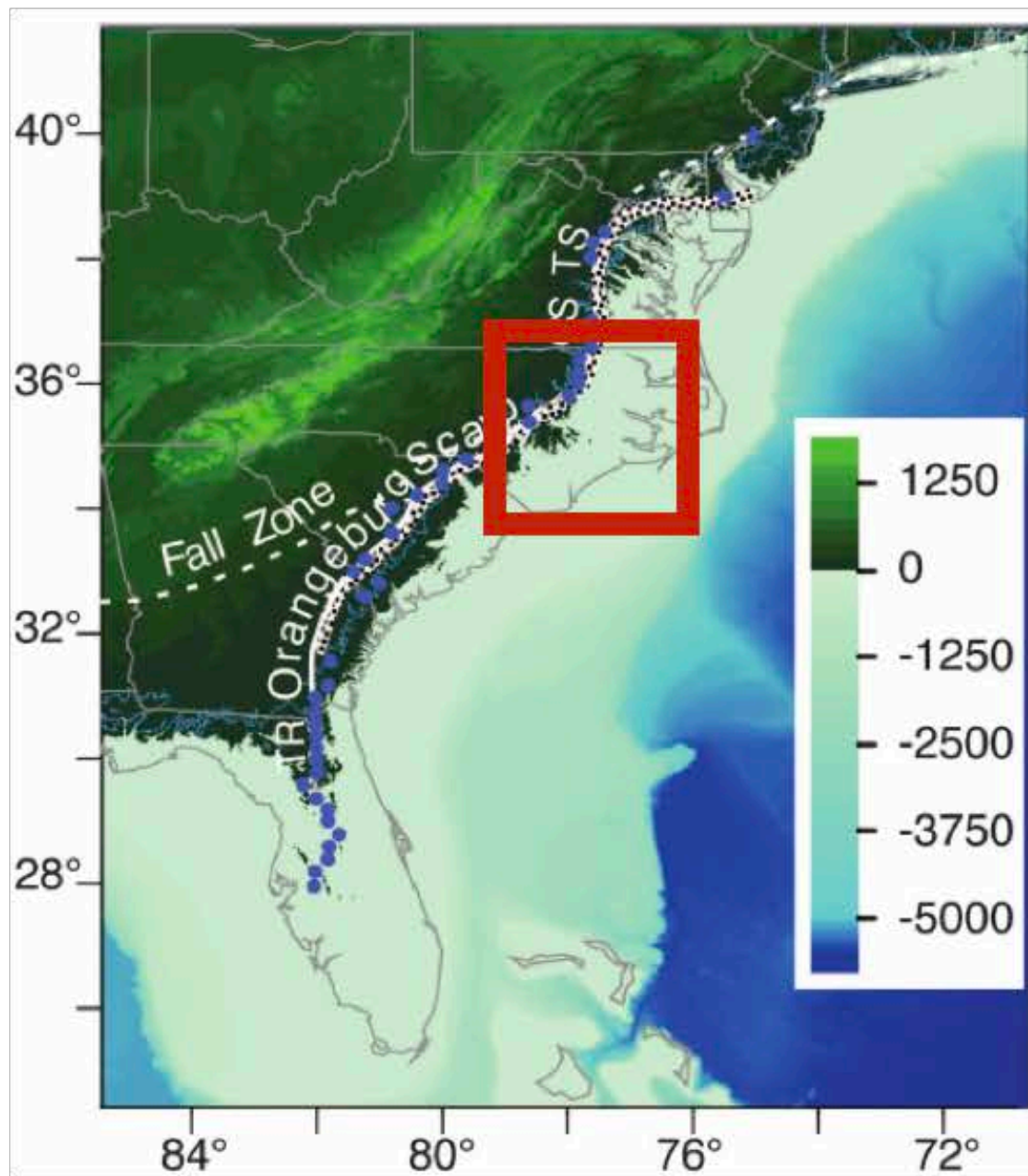


# Staying below +2.0°C

- Time is not our friend
- Radically increase renewables + storage
- Radically increase efficiency
- Electrify everything
- Negative emissions

# Why +2°C ?

Last time Earth was this warm: 3 million years ago  
Sea level was 75 feet higher.



# Solutions for Sustainability

Science, engineering, business, finance

# “Negative emissions” may be needed



Direct air CO<sub>2</sub> capture ...



...used to grow fruit & veggies

[Climeworks](https://www.climeworks.com)

# Carbon Storage: Turn CO<sub>2</sub> to mineral



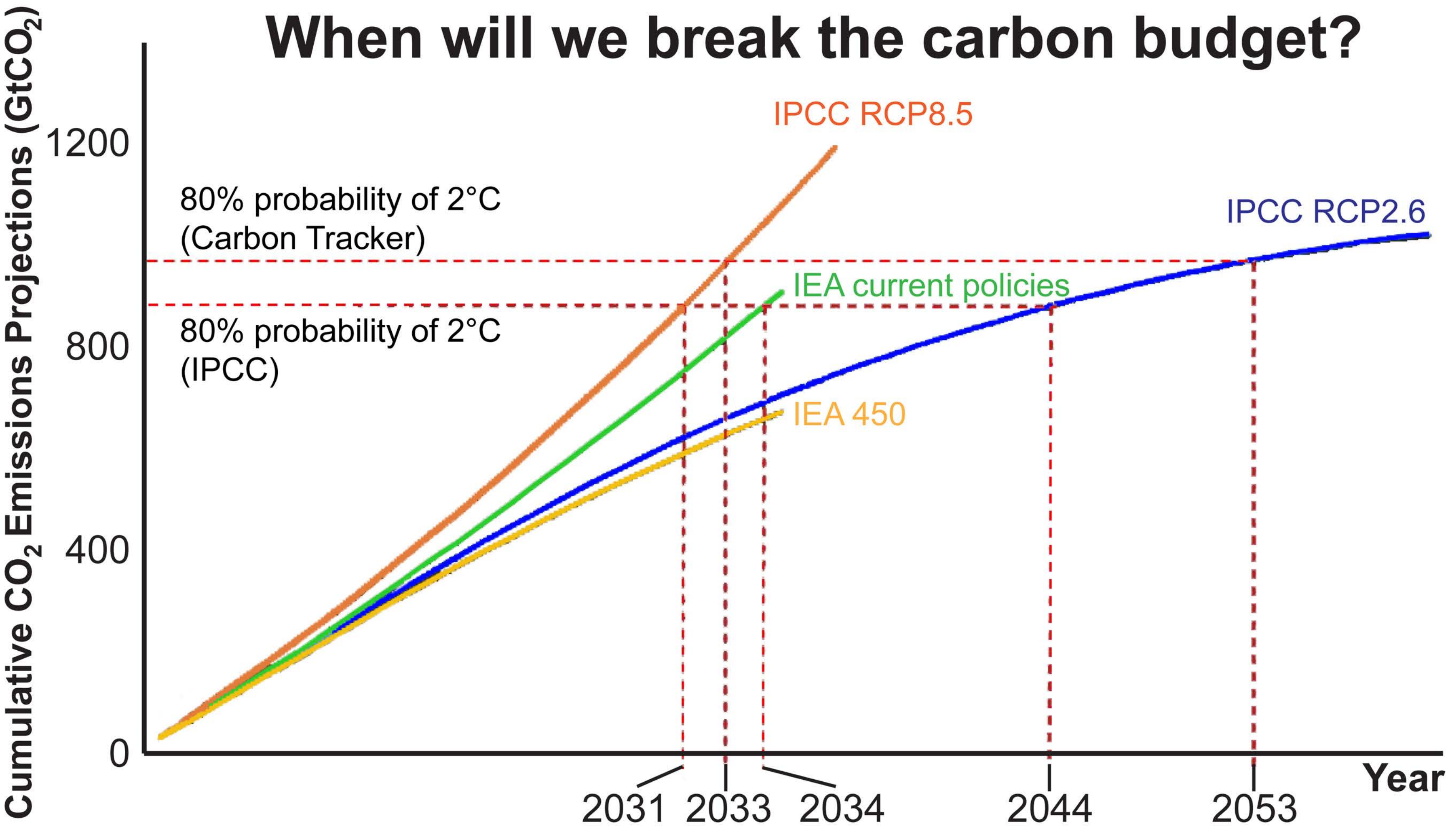
# Plan D: Geoengineering



# Staying below +2°C

- Time is not our friend
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- Radically increase efficiency
- Electrify everything
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# When will we break the carbon budget?



Sources: IEA World Energy Outlook 2012, IPCC AR5, Carbon Tracker 2013 Wasted Capital and Stranded Assets

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