


Optimal Renewable Energy Portfolio for Electricity in 2050 ~ U.S. Lowest Carbon Emissions



Rahim Khoie, Ph.D.

**Professor of Electrical and Computer Engineering
University of the Pacific**




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Washington DC, May 21, 2024**


 **Thanks!**

 **To SOLAR 2024 Organizers!**

 **To You!**



➤ **Meet**
C³FMC³
Team !

School of Engineering and Computer Science ~ \$77,000

- R. Khoie, **D. Mueller**, **M.K. Camarillo**, “Preliminary Work Toward Creation of Carbon Capture Center for Mitigating Climate Change

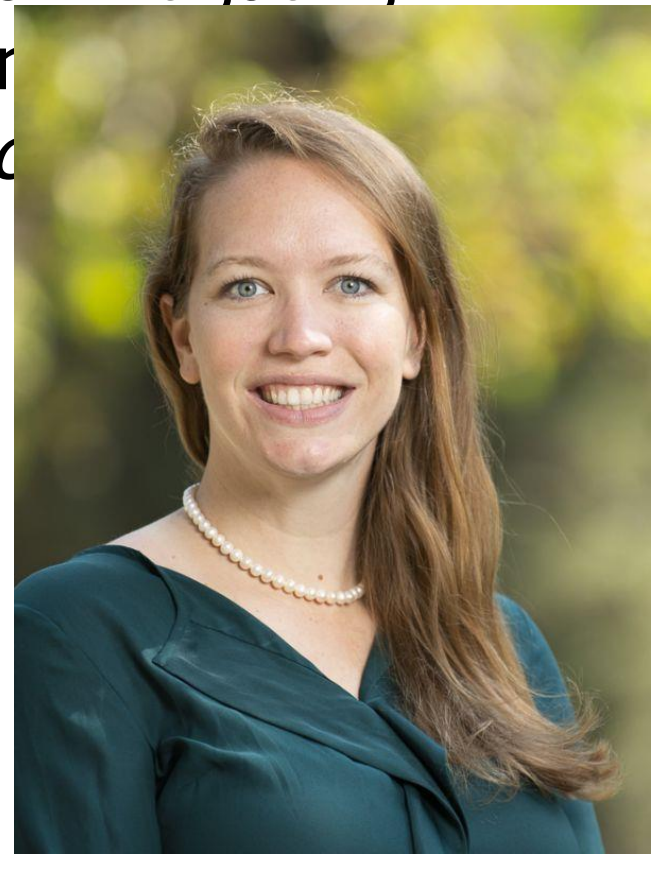


Pacific's Interdisciplinary Research Program ~ \$27,000

- R. Khoie, D. Mueller, M.K. Camarillo, **S. Carlson,**
S. Kunwar, "Carbon Capture for Mitigating



Interdisciplinary
University of the Pacific
view.



Our Work



Among Solutions

Renewables Emissions !
Renewables Optimization !

Our Starting Point: NOAA 2018 Report **Warning:**

The U.S. National Oceanic and Atmospheric Administration (NOAA) in its 2018 and updated 2022 reports indicated that

- while **emission reduction strategies** are required in all energy sectors,
- there is a growing interest in **removing greenhouse** gases already in the atmosphere. NOAA (2022).

<https://www.noaa.gov/news-release/carbon-dioxide-removal-as-tool-to-mitigate-climate-change>
<https://sciencecouncil.noaa.gov/cdr-strategy/>

Emissions?



➤ **Solar and**

➤ **Wind ?**

Emissions of Solar

1

- R. Khoie and D. Mueller, “A Study of Carbon Emissions and Energy Consumption of Solar Power Generation in Phoenix, Arizona,” Accepted for Poster Presentation at **SOLAR 2024, American Solar Energy Society 53st National Solar Conference and Summit, Washington, DC, May 20-23, 2024.**
- R. Khoie and D. Mueller, “A Comprehensive Study of Carbon Footprint of Solar Power Generation from Raw Materials to Operation and Maintenance in Various Locations in the United States,” To be submitted to *Clean Technology and Environmental Policy*, May 2024.

Emissions of Wind

2

- R. Khoie, A. Bose, and J. Saltsman, “A study of carbon emissions and energy consumption of wind power generation in the Panhandle of Texas”, *Clean Technologies and Environmental Policy*, Vol. 23, pp. 653-667, 2021.

703 Accesses. 6 Citations.

<https://link.springer.com/article/10.1007/s10098-020-01994-w>

Models



Raw Materials

Manufacturing

Transportation

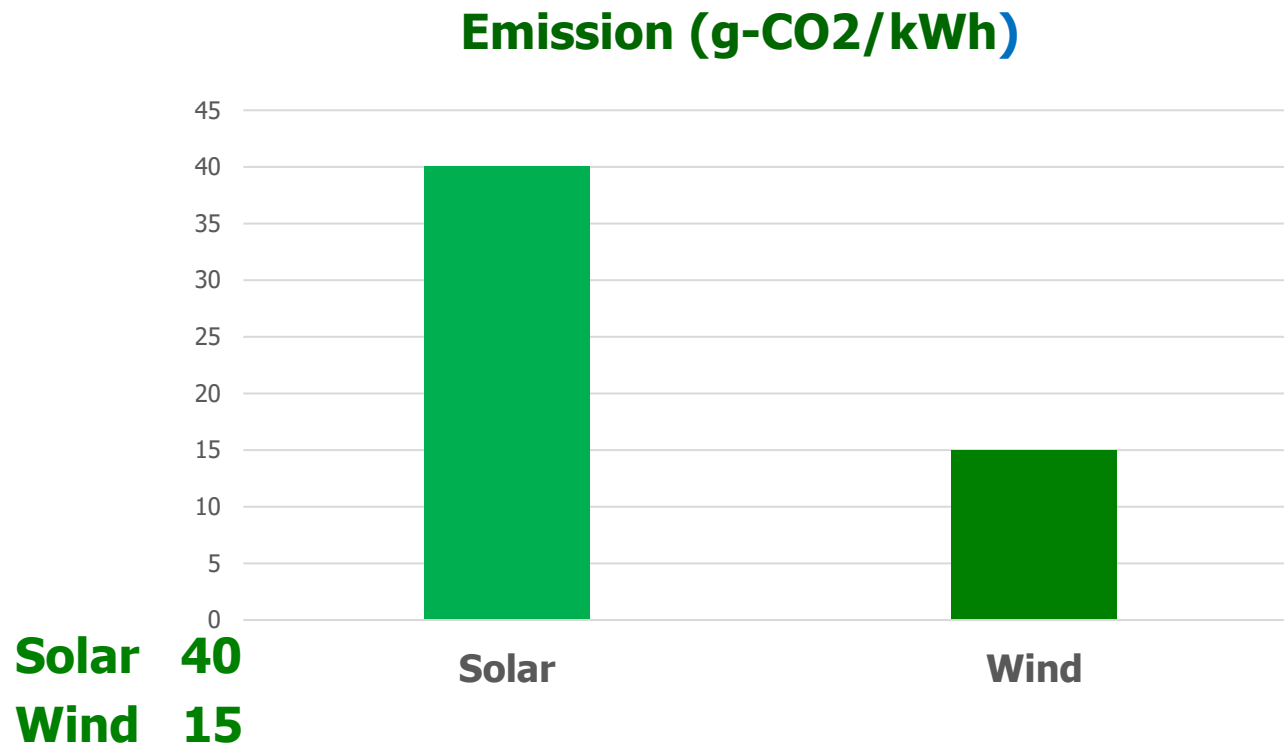
**Construction
Installation**

**Operation
Maintenance**

**Decommision
Disposal**

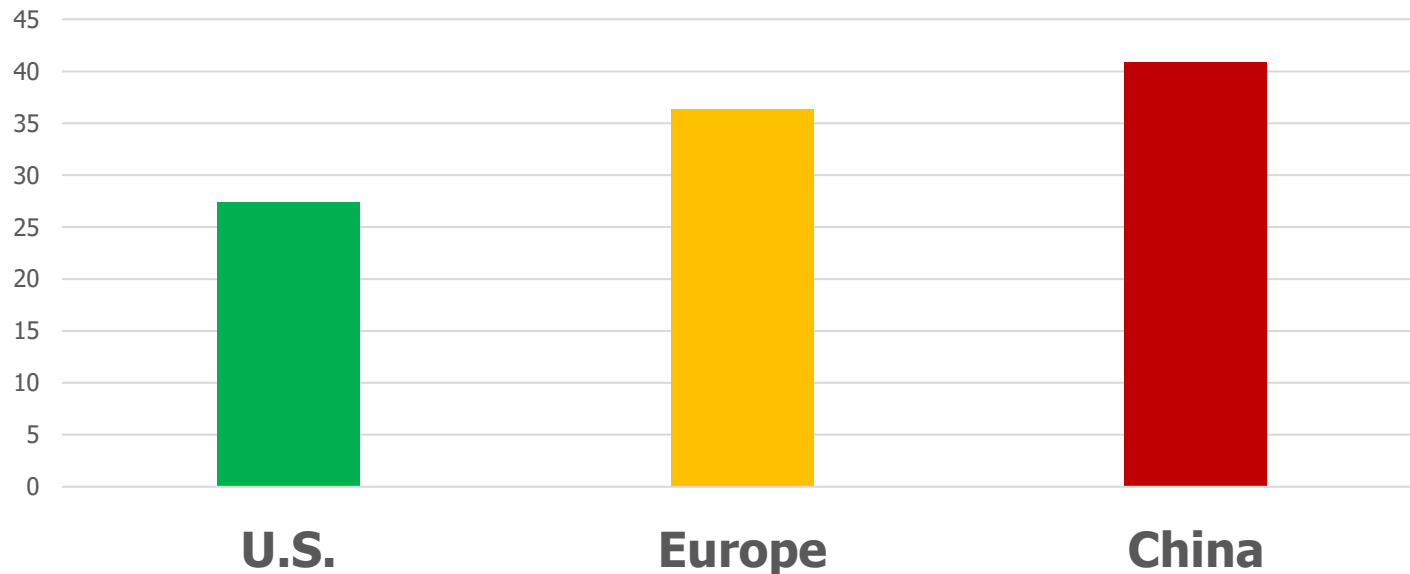
Conclusions:

Emissions of Solar and Wind



However, Solar Panels Made in China?

Emissions of Solar Panels Made in (g-CO₂/kWh)



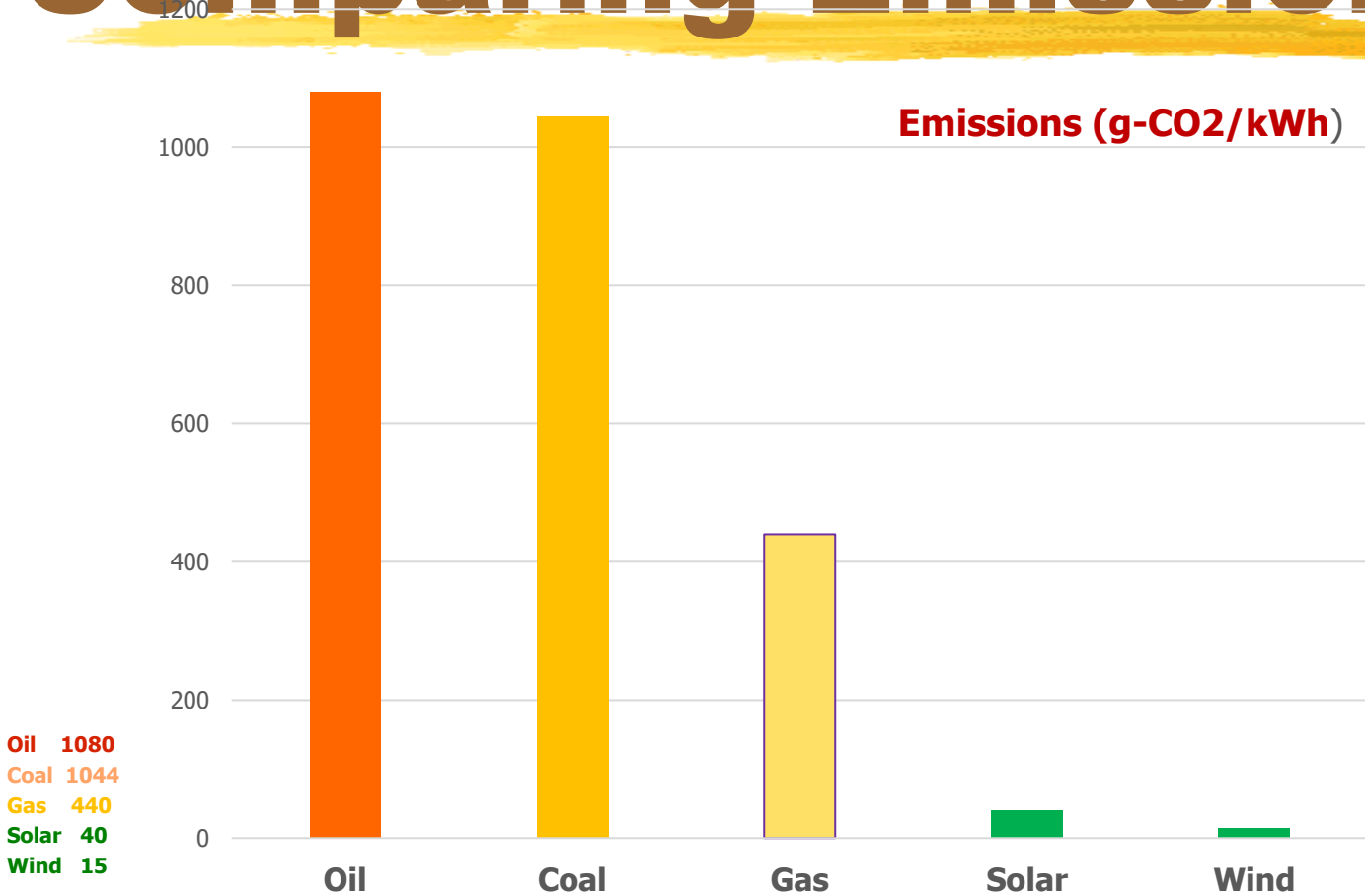
U.S.	27.41
Europe	36.37
China	40.88

Made in China? versus Made in the U.S.?

U.S.	27.41
China	40.88

- $E_{Solar\ in\ 2050} = 50,000\ TWh$
- $C_{China} = 50\ Terra\ kWh * 40.88\ g-CO_2/kWh$
 $= 2.04\ Billion\ Tons$
- $C_{US} = 50\ Terra\ kWh * 27.41\ g-CO_2/kWh$
 $= 1.37\ Billion\ Tons$
- $\Delta_C = 674\ Million\ Tons$

Comparing Emissions



U.S. 100% Renewable ? 1+2

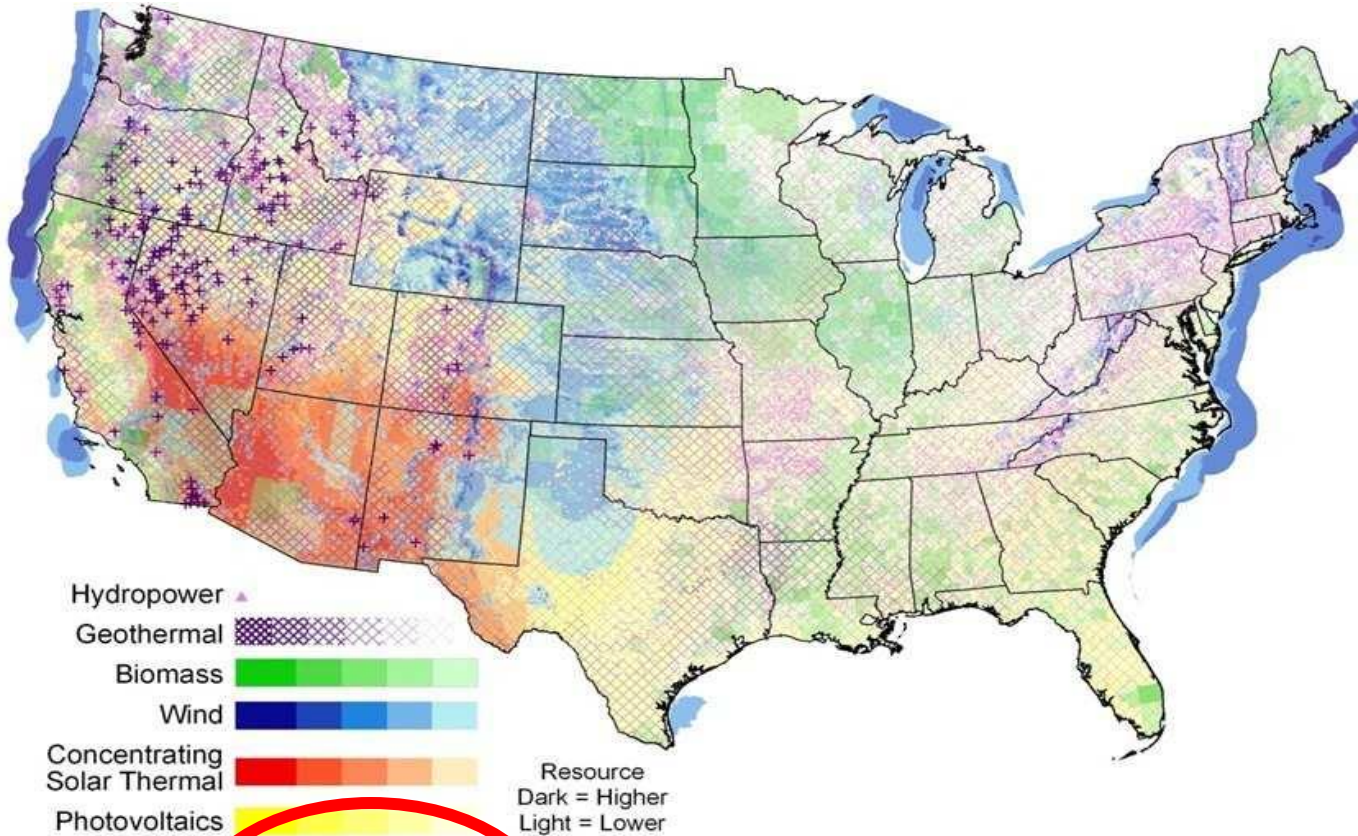
➤ Optimal Electricity Portfolio *?

➤ *In Progress

Optimal Electricity Portfolio for U.S.

- R. Khoie, “Analyzing Optimal Renewable Energy Portfolio for Electricity Generation in Arizona and Texas with the Lowest Possible Carbon Emissions,” Accepted for Oral Presentation at **SOLAR 2024, American Solar Energy Society 53st National Solar Conference and Summit, Washington, DC, May 20-23, 2024.**
- R. Khoie, “Analyzing Optimal Renewable Energy Portfolio for Electricity Generation in the United States Through 2050 with the Lowest Possible Carbon Emissions,” To be submitted to *Clean Technology and Environmental Policy*, May 2024.

U.S. Renewables S+W > 220 TW



Resource	Solar PV/CSP	Wind	Geothermal	Water Power	Biopower
Theoretical Potential	206,000 GW (PV) 1,100GW (CSP)	8,000 GW (onshore) 2,200 GW (offshore to 50 nm)	39 GW (conventional) 520 GW (EGS) 4 GW (co-produced)	140 GW	78 GW



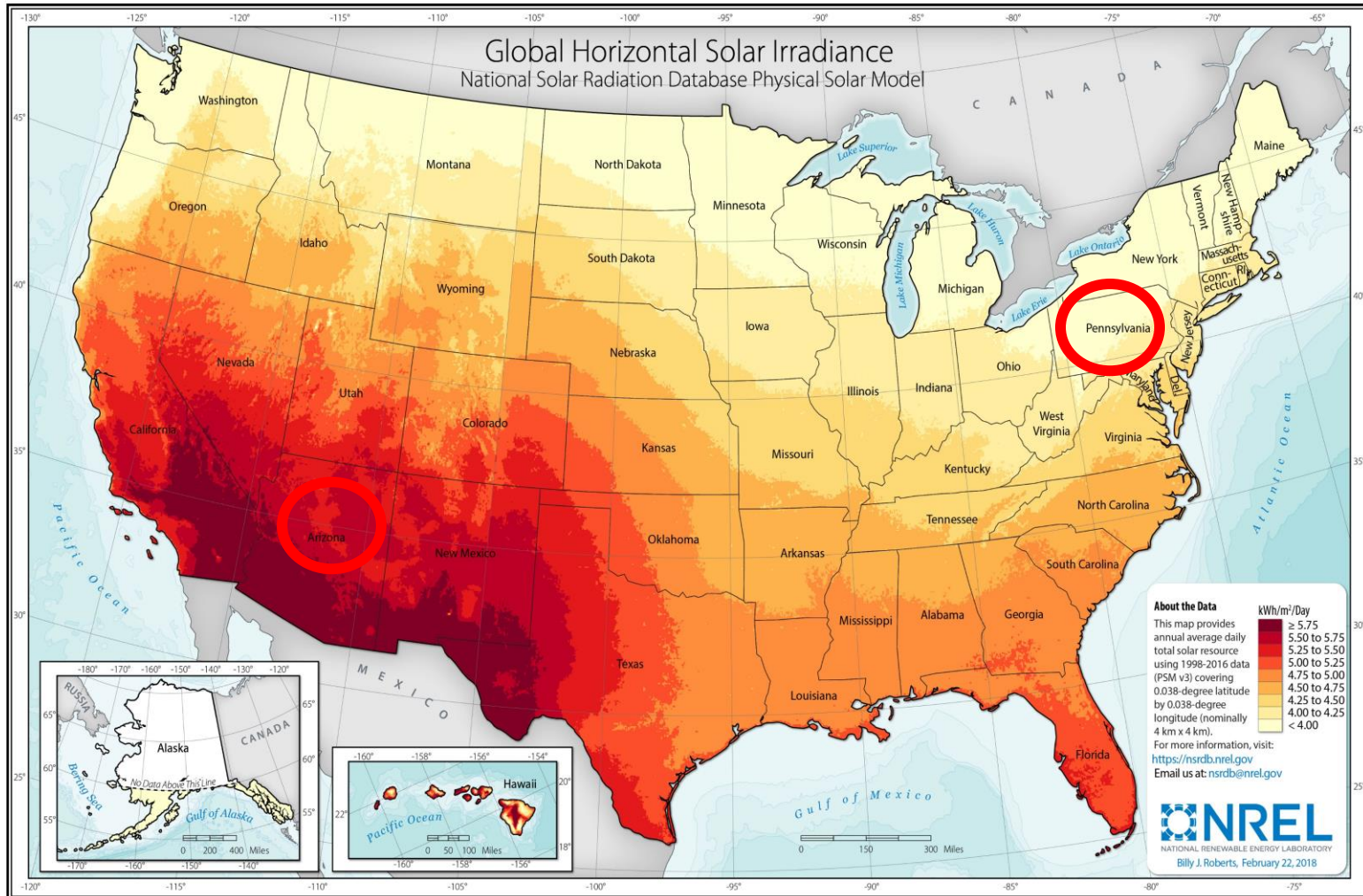
U.S. Wind:

Texas ~ 9 m/s to Georgia ~ 4.5 m/s



U.S. Solar

Pennsylvania ~ 4 kWh/m²/day to Arizona ~ 8 kWh/m²/day



Model



Get E_NEED in
2024
Run j ++ for 1, 25

Project
E_NEED in 2025 to
2050

Subtract NUC,
REN, HYDRO Get
E_SOL + E_WIND

Substitute FF with
E_SOL and
E_WIND Portfolio
k++ for 0 to 100%

Determine
Emissions
 $C = C_SOL + C_WIND$

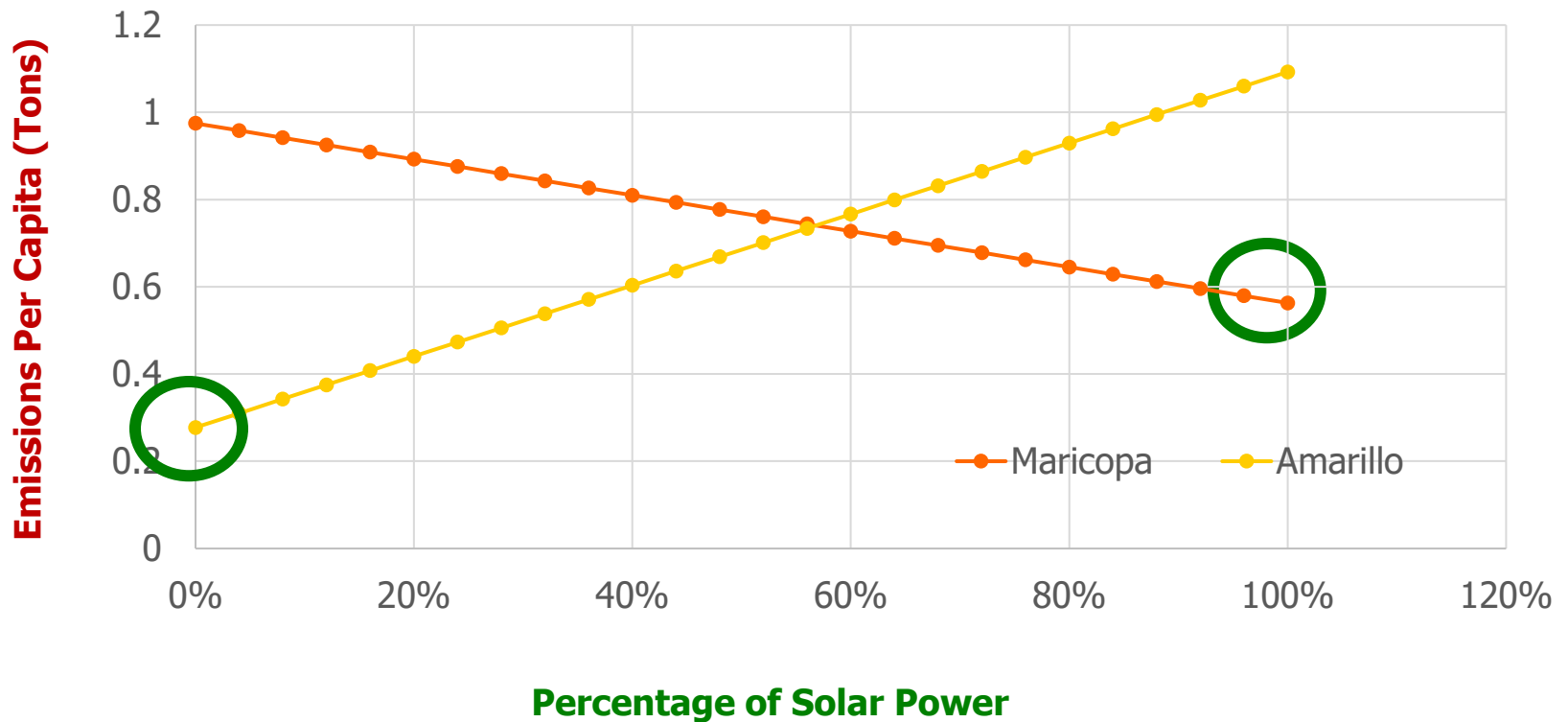
Find Optimal
Portfolio with
Minimum
Emission

Input Parameters

	Maricopa County, Arizona	Amarillo, Texas
Average Wind Speed (m/s)	5.6	9
Wind Emissions (g-CO2/kWh)	77.59	11.56
Average Solar Peak Hours (kWh/m ² /day)	6.5	5.8
U.S.-Made Solar Panel Emissions (g-CO2/kWh)	27.41	30.72
China-Made Solar Panel Emissions (g-CO2/kWh)	40.88	45.82
Nuclear Emissions (g-CO2/kWh)	12.0	12.0

Results

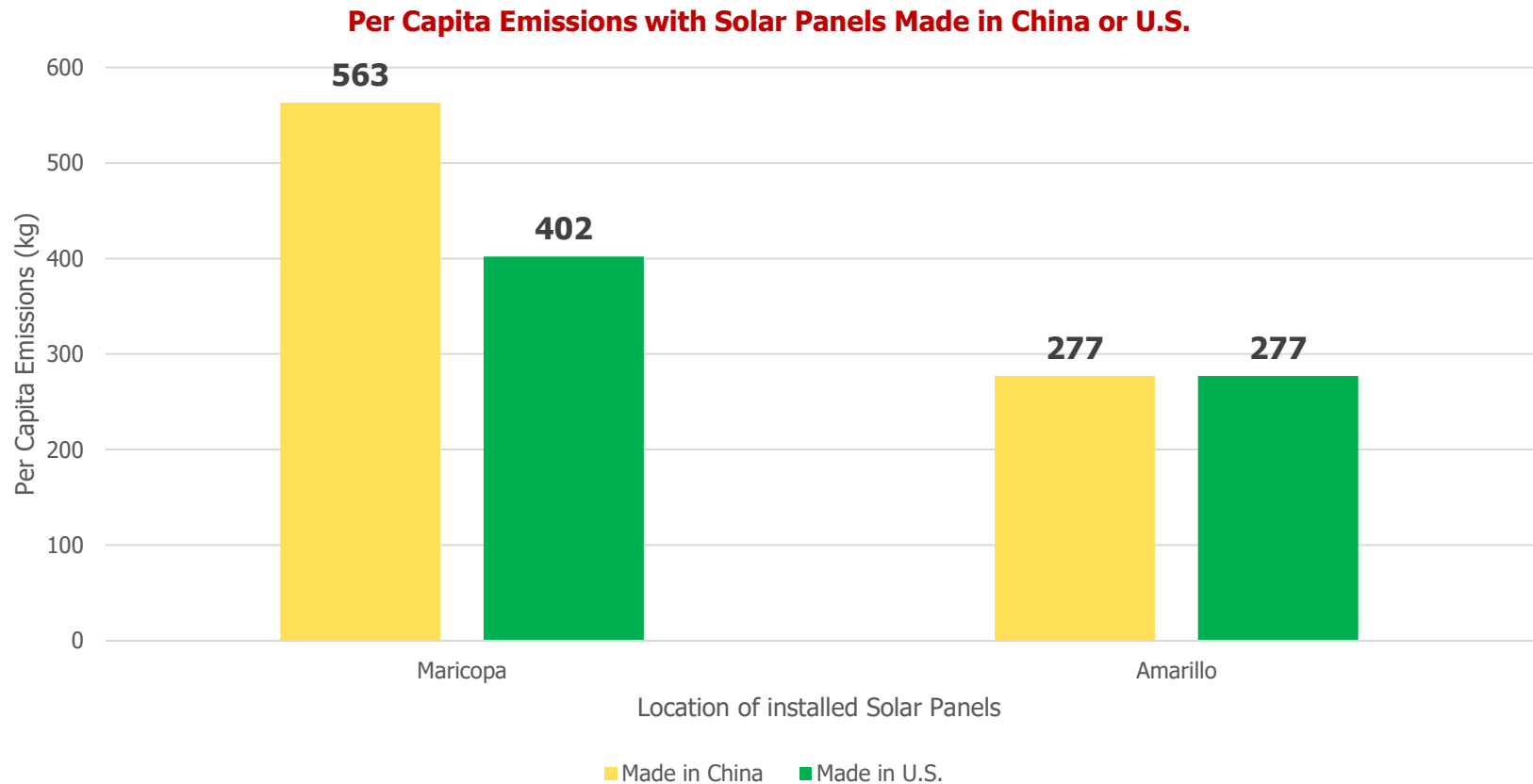
Emissions Per Capita (Tons)



Results

	Maricopa County in 2024	Maricopa County in 2050	Amarillo Texas in 2024	Amarillo Texas in 2050
Population (12% increase by 2050)	4,950,000	5,544,000	202,000	226,240
Total Generation (GWh) (1% annual increase thru 2050)	80,076	100,896	4,305	5,424
Total Generation from Fossil Fuels (GWh)	41,380	0	4,265	0
Total Emissions from Fossil Fuels (Tons)	18,220,000	0	3,984,560	0
Annual Generation from Nuclear (GWh)	34,510	34,510	0	0
Annual Generation from Wind (GWh)	0	0	40	5,424
Annual Generation from Solar (GWh)	3,900	66,100	0	0
Total Annual Generation from REN+N+W (GWh)	38,696	100,896	40	5,424
Total All Emissions (Tons)	18,796,984	3,119,710	3,985,022	62,705
Annual Emissions Per Capita (Tons/person)	3.80	0.563	19.73	0.277
% Reduction in Per Capita Emissions		85.2%		98.6%

Made in China? versus Made in the U.S.?





Conclusions



- Emissions with **Solar** ~ **402 kg/person** !
- Emissions with **Wind** ~ **277 kg/person** !
- **Depending on Location** !
- **Compare these to ~ 15,000 kg/person in 2024** !

➤ **Closing**



- **100% Renewable Electricity !
With Optimal Portfolio !**
- **Electric Vehicles with Renewable !
With Optimal Portfolio !**
- **Solutions to Two Major
Emissions Sources !**

Future Work in 2025



- R. Khoie, et. al., “When Electric Vehicles are Powered by Renewables; The Ultimate Solution to Emissions of Transportation.” 2025.
- R. Khoie, et. al., “When Solar Panels and Wind Turbines are Manufactured by Solar and Wind Energy: The Ultimate Solution to Emissions of Electricity Generation.” 2025.
- R. Khoie, et. al., “A Study of the Effects of Electrification of World-wide Transportation on the Emissions of Electricity Sector.” 2025.

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Thank You !



Comments ?

Critiques ?



Afterthought



- You have > 200 TW of RENEWABLE ENERGY
- You need ~ 1 TW ?
- Why **fossil fuels** ?
- Don't you have **scientists** ?
- We do. We just **don't listen** to them !
- That's **illogical** !