"Climate Change is one of the most destabilizing forces of our time, exacerbating other national security concerns and posing serious readiness challenges."

Honorable Carlos Del Toro, Secretary of the Navy

O re.

https://www.youtube.com/watch?app=desktop&v=kXSy3t51e8M

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Special Thanks

My Students

Venkatesh Pulletikurthi

Walter Gutierrez

Clarice Nelson

Jossy O'Donniel

Purdue President

Mung Chiang

Past President

Mitch Daniels

ONR

Tom Fu

Sponsor of BIP Consortium

OUTLINE

#1. **ONR-Blue Integrated Partnerships (BIP)**

- **Consortium for Minority Serving Institutions**

#2. Key Challenges along the US/Mexico border & other regions

- Socio-economic

#3. The Caribbean & USA-Mexico Corridors

- Solar and Wind
- Water: Droughts & Applications
- *The Water 4 Energy: The Quiet Crisis in the Making!*

#4. Wind Energy for Carbon Capture

#5. **Conclusions & Hope ☺!**

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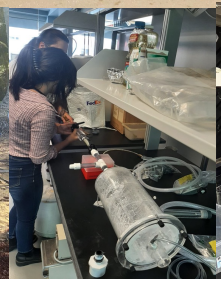
Blue Integrated Partnerships- Solving Grand Challenges While Building the USA STEM Workforce

Summer Institute on Sustainability & Climate Change



USA/Mexico Border

Water Insecurity

Strategic Partnerships & Key Focus Areas:

Renewable Energy & Coastal Resiliency: PR100 by 2050!

Resilient power grid for the island and using the **island as a living laboratory** for coastal resiliency: Caribbean, USA-Mexico Border

Integrating aerodynamics of renewable energy and **extreme events** such as hurricanes

New R&D activities to support **DoE** and **DHS-FEMA**

Big Data generation for AI based models towards energy and disaster management in the **form of IPs and Invest.**

Cluster #1: Coastal Resiliency & Sustainability

#1A. Energy-Food-Water
#1B. Carbon Capture & Storage
#1C. Climate Change & Mass Migration

Cluster #2: Precision Medicine-The Brain

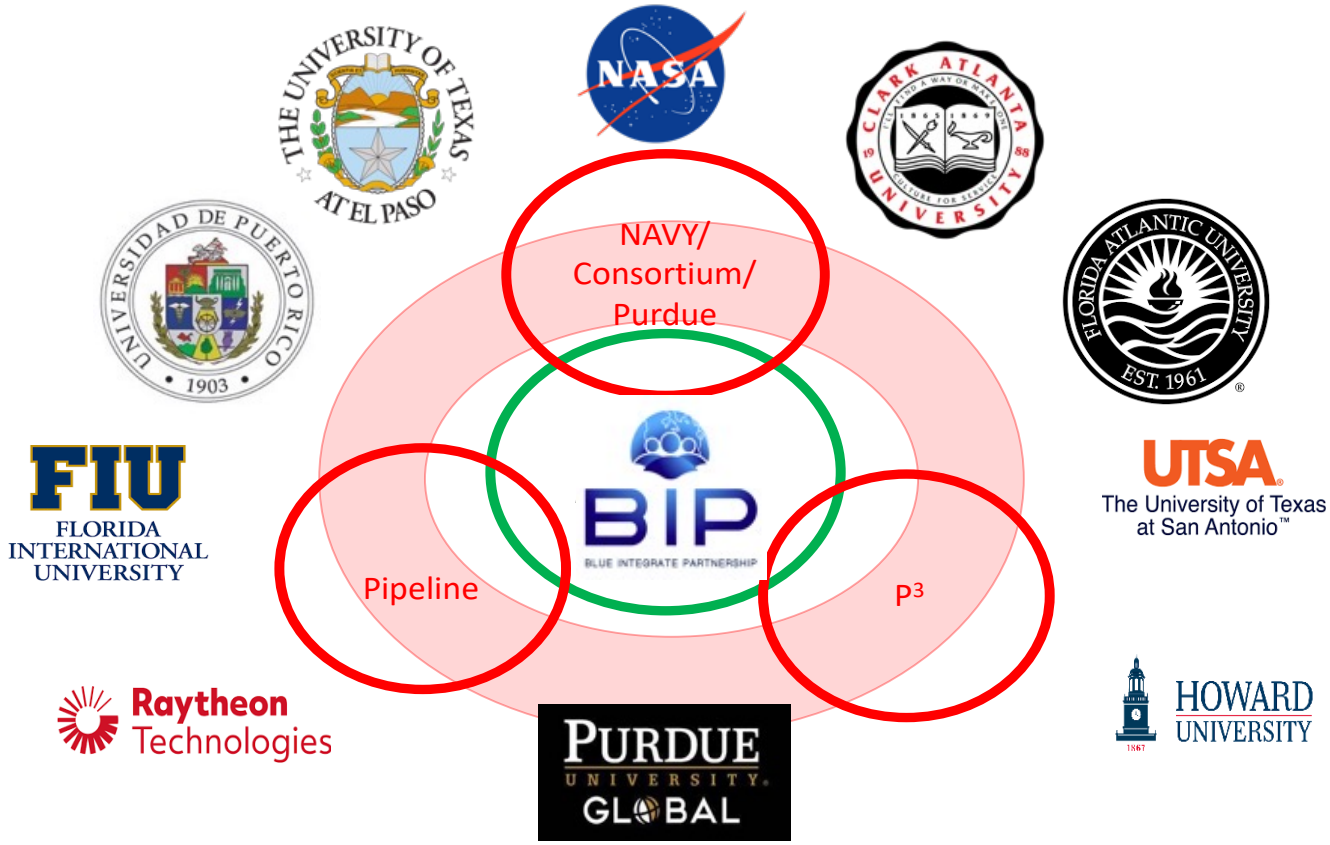
#2A. Engineering & Mental Health
#2B. Brain Injury & Big Data
#2C. Human Performance & Brain

Cluster #3: Security:

#3A. Bio-inspired surface & hypersonic
#3B. Advanced materials & manufacturing.
#3C. Noiseless hypersonic misile

The Key Partnerships- Blue Integrated Partnerships (BIP)

Enhance HBCU/HSI Research Capabilities & Federal Contracting



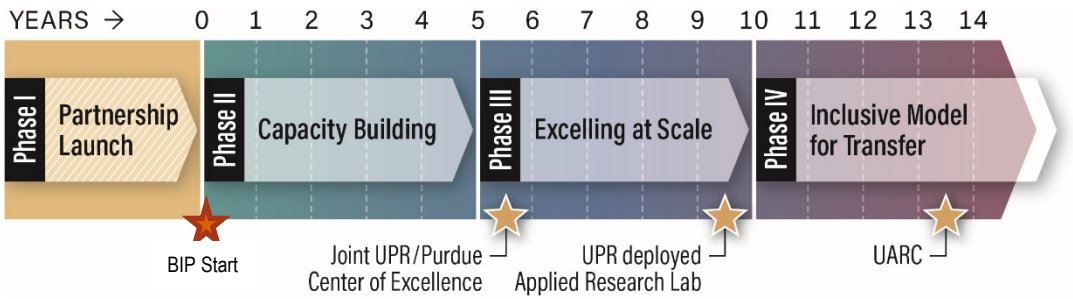
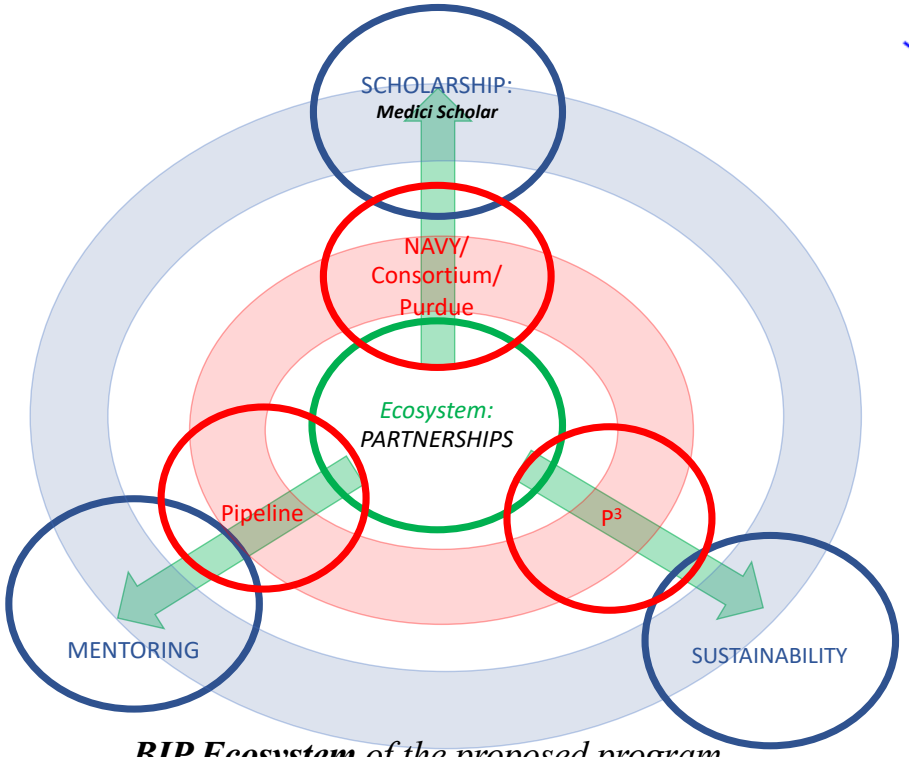
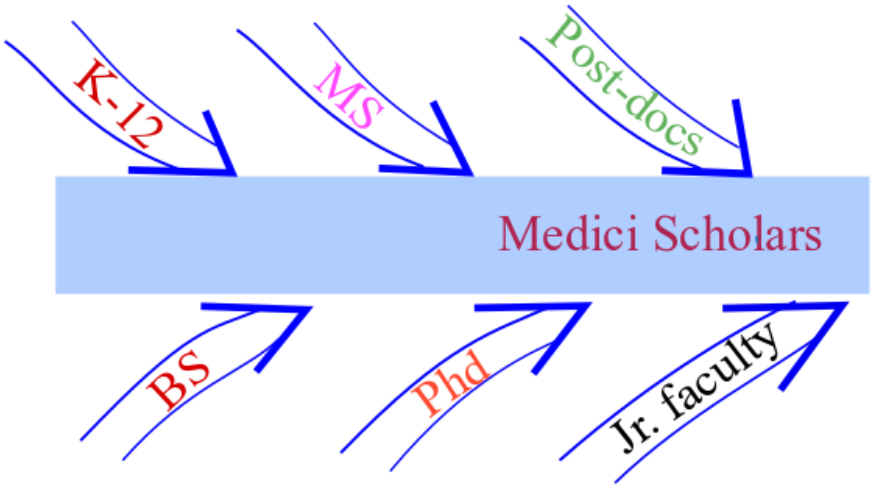


Figure 3. Strategic Phases for BIP 2.0 Transformative Impact with Phase II capacity building now moving to excellence at scale and enabling a joint Center of Excellence and UPR-deployed Applied Research Lab.

BIP Building The Workforce of Tomorrow



BIP Ecosystem *of the proposed program centered around Partnerships to train the Medici Scholars who will solve tomorrow's big challenges*



Super-pipeline for attracting, mentoring, and training the Medici Scholars.

Business Plan & Big Idea Competition:

The United Nation's Sustainable Development Goals

Critical access to clean energy

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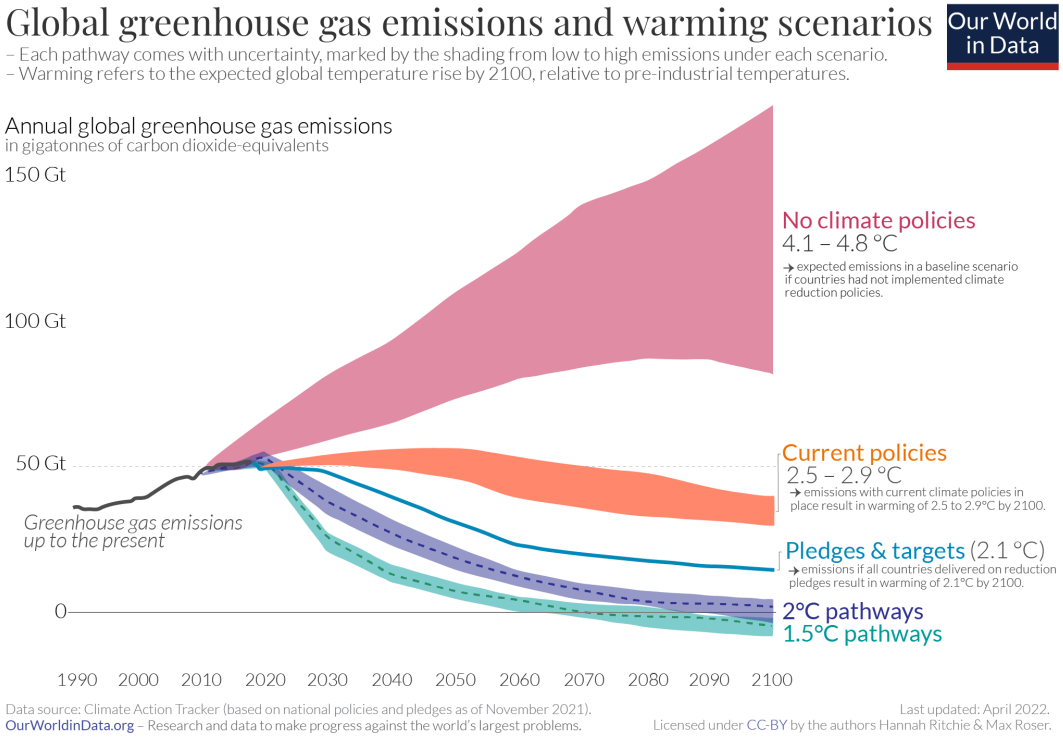
The Root of the Problem: Climate Change & Mass Migration

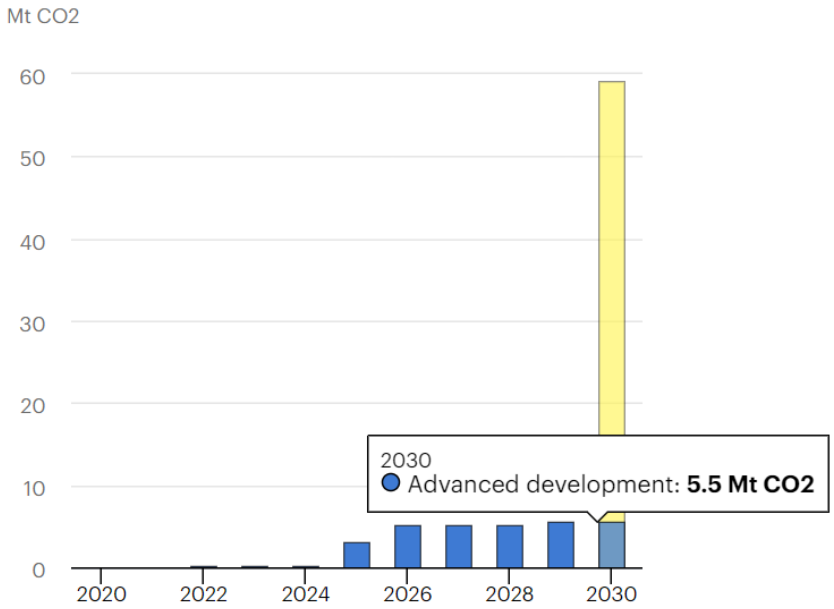


20 -660 Gton CO_2

removal to maintain 1.5°C through 2100 [IPCC, 2022]

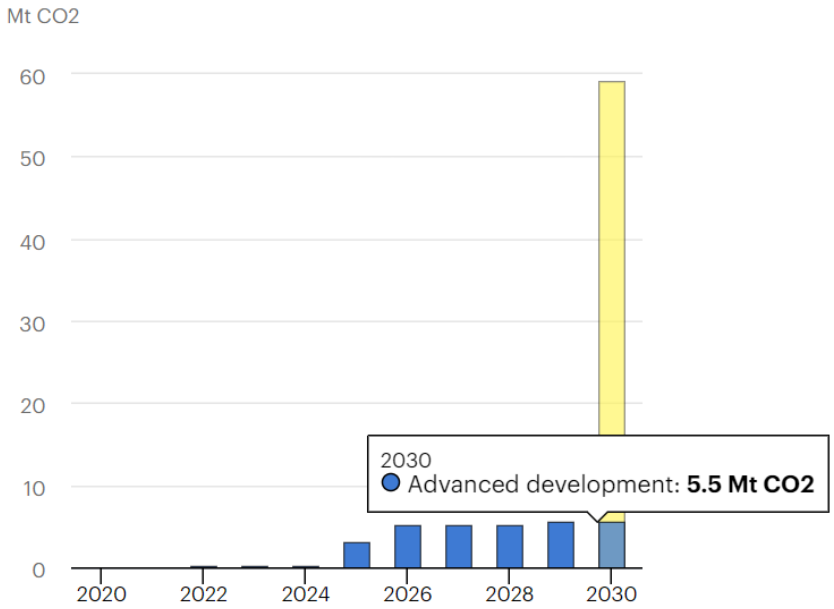
Source Dispersion Inhibits Decarbonization

CO_2 capture by direct air capture, planned projects and in the Net Zero Scenario (2050), 2020-2030



[IEA., 2022]

DAC is not Currently Economically Viable



[IEA., 2022]

Capture cost:

$100 – 600 / ton-$CO_2$ [McQueen et al., 2021]

vs.

Market value:

as low as

$3 / ton-$CO_2$ [Keith et al., 2018]

Tax credit (2022):

as low as

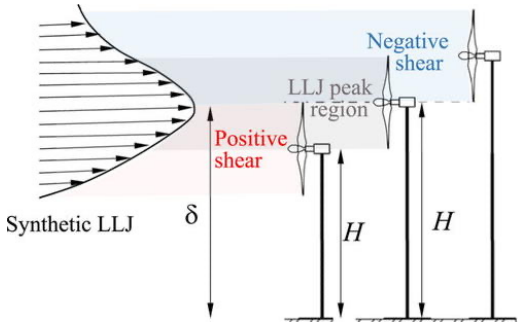
$50-85/ ton-$CO_2$

[Reuters., 2021]

Research Question

Can we extrapolate the velocity recovery mechanism found in the kinetic energy entrainment?

$$-U(y)\overline{u'v'}(y)$$



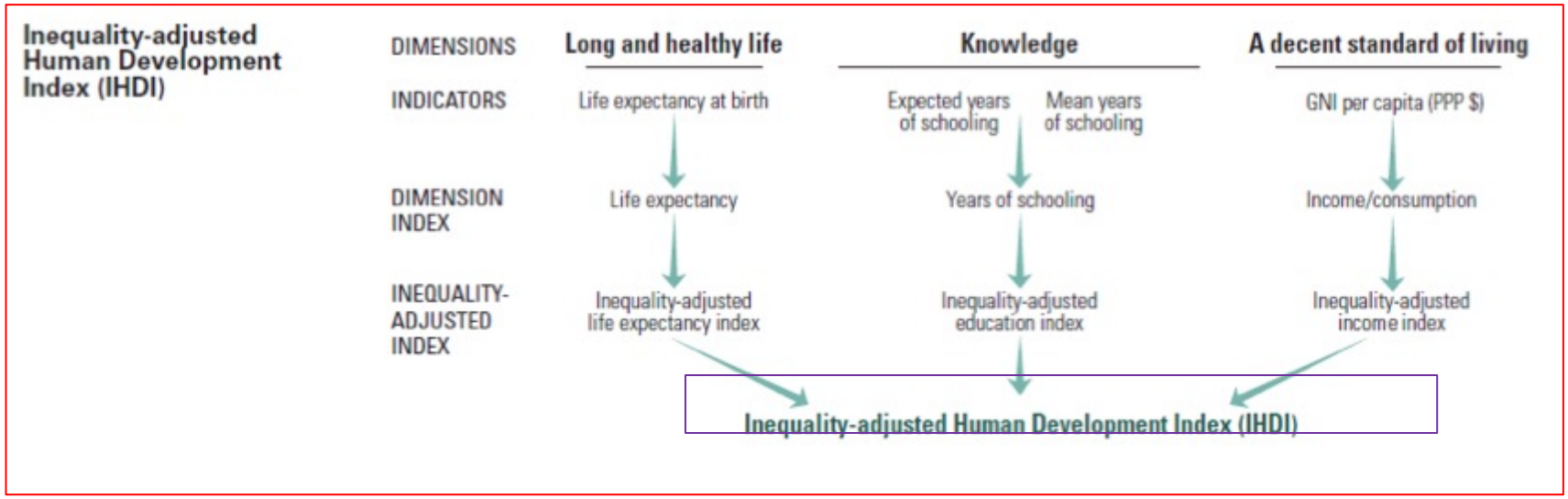
[Doosttalab et al., 2020]

… towards a scalar entrainment in the turbine wake…. $-U(z)\overline{w'c'}(z)$

and could benefit efficient capture of CO_2

Energy Poverty Countries: On Inequality & Access to Energy

Toward Social Equality: Energy versus IHDI



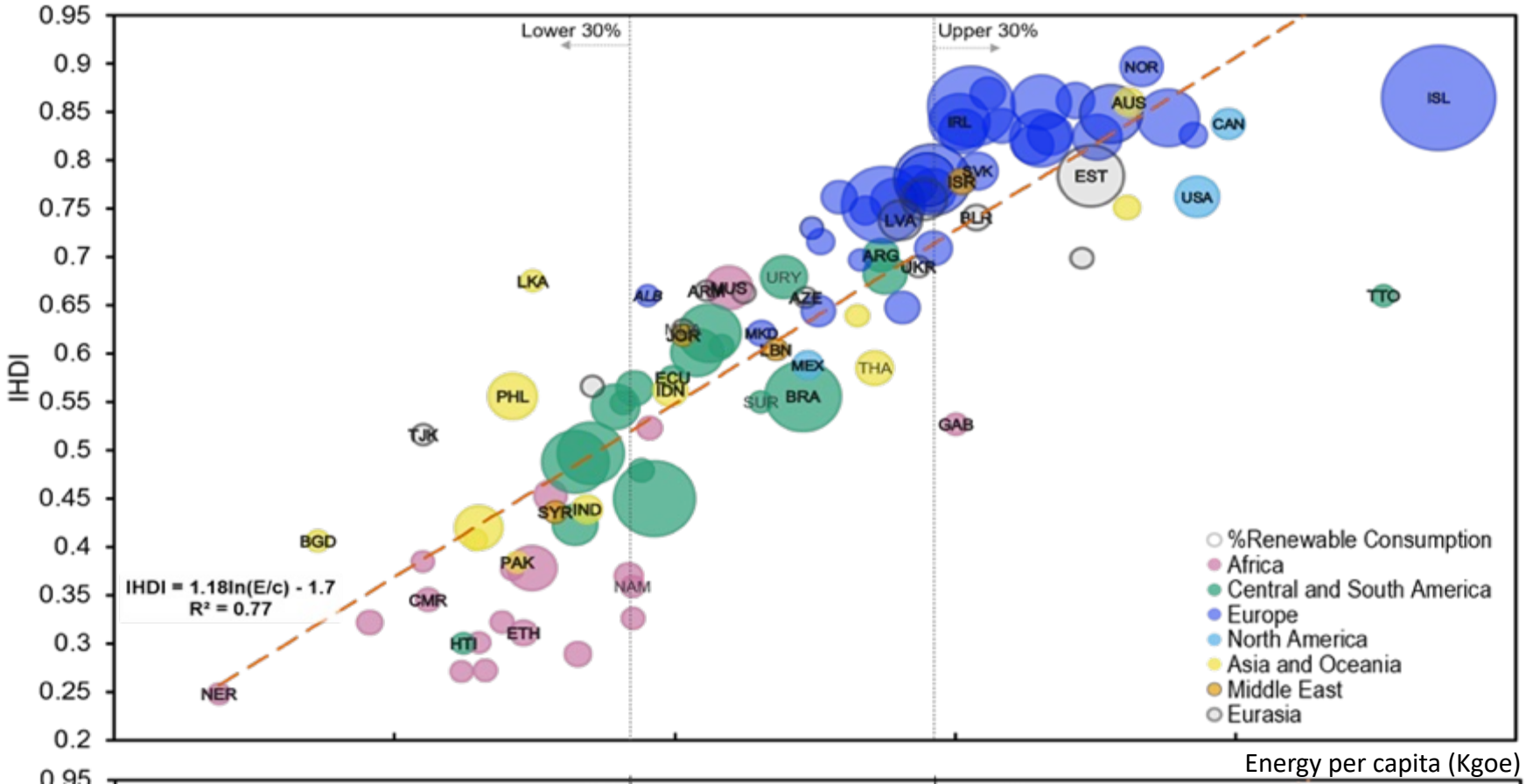
Work at the Kenninger Summer Institute:
Mellissa Hege, Jossy O'Donniel & Maulin Shah

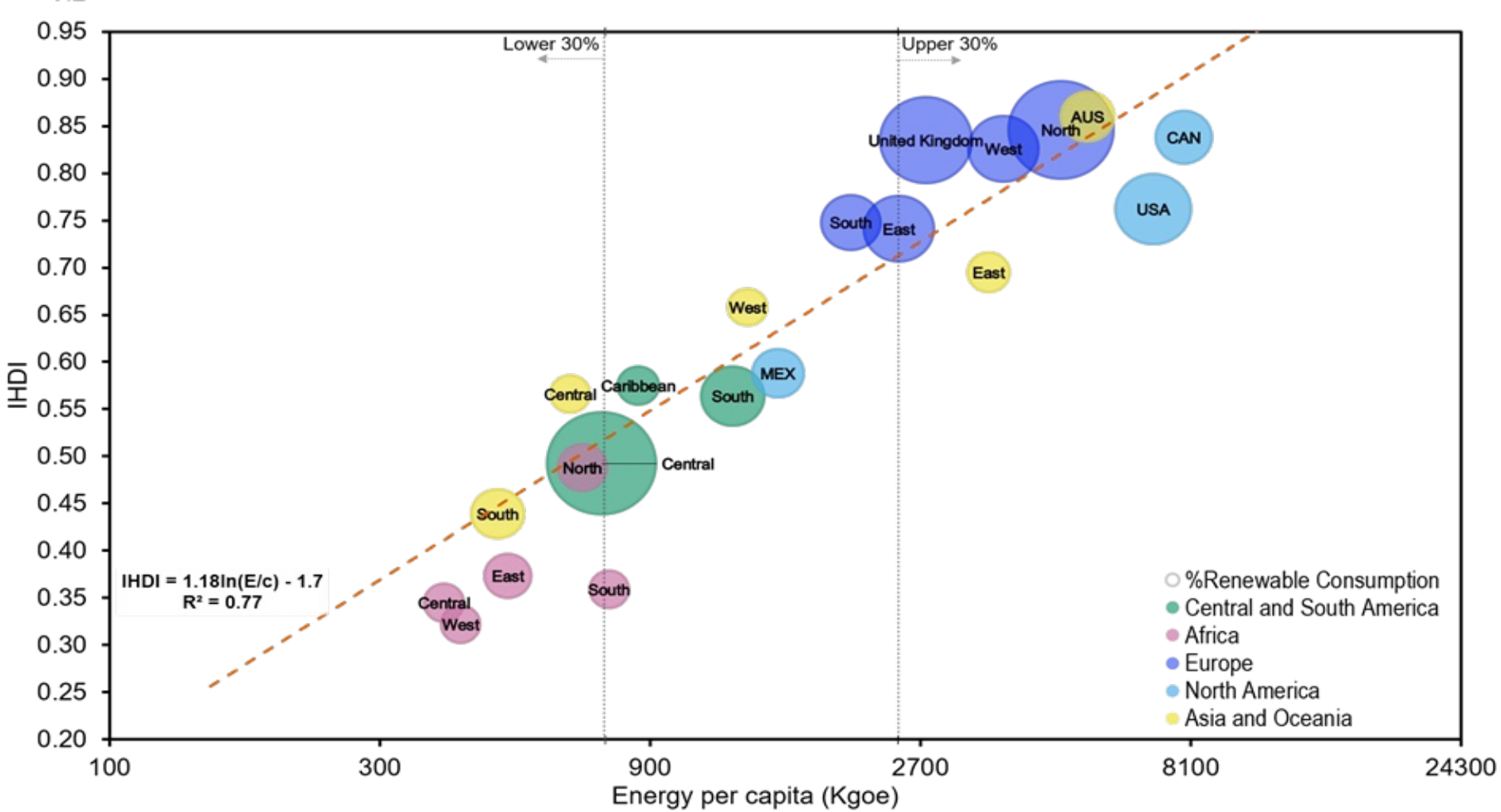
UNITED NATIONS DEVELOPMENT PROGRAMME

IHDI Versus Energy per capital

Inequality Human Development Index

Gutierrez, et al. to be submitted Energy Policy (2023).





Gutierrez, et al. to be submitted Energy Policy (2023).

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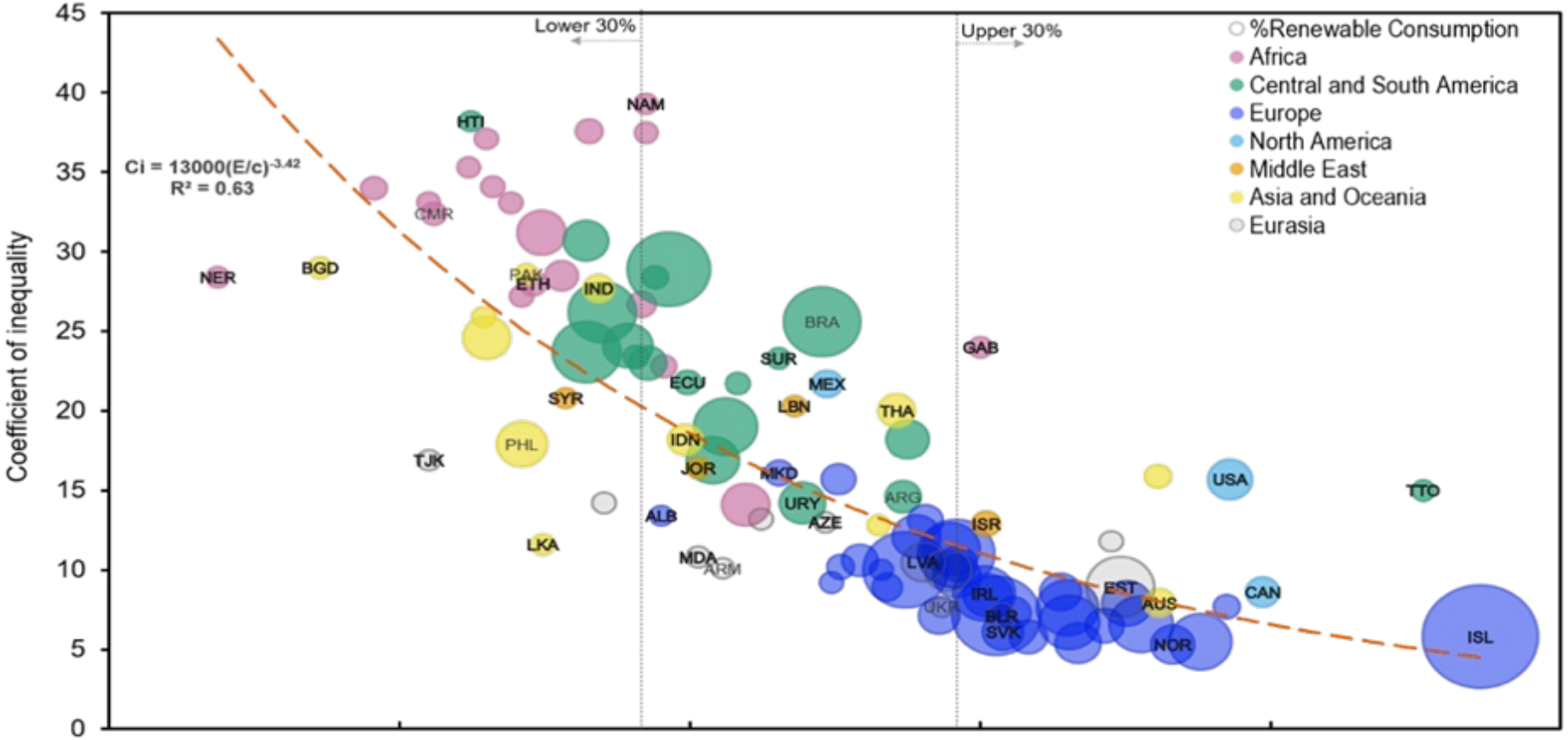
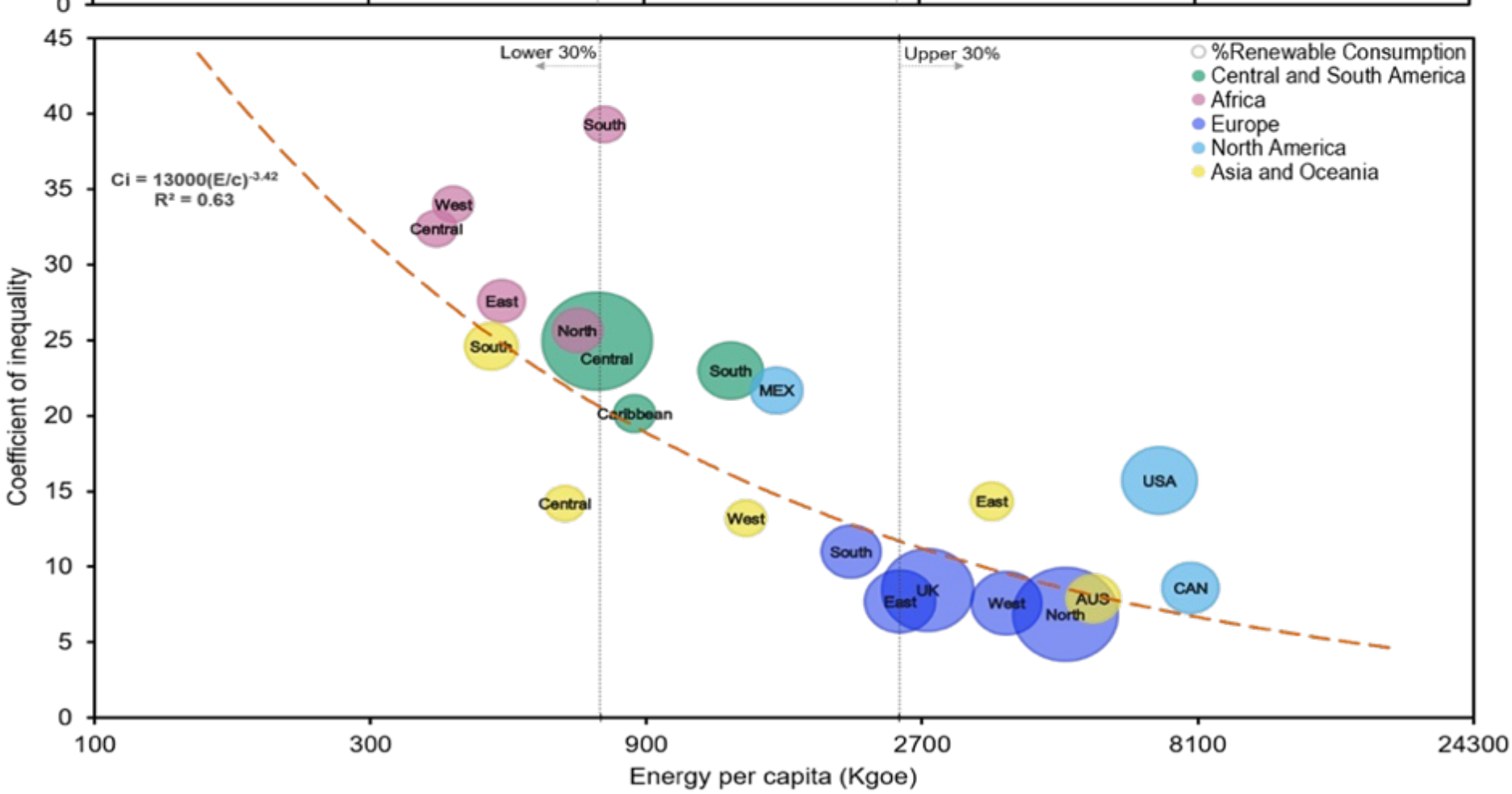
Inequality (Health, Education, Economic)
vs.
Energy per capita

Mass Migration & Inequality?





Gutierrez, et al. to be submitted Energy Policy (2023).

Mass Migration from Energy Poor Countries

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The Caribbean & USA Mexico Corridor


over 1,000,000
over 200,000
other main city
National Capital
CARIBBEAN SEA
0 km 110 220 330 km
© 2011 GEOATLAS.com
UNITED STATES (Florida)
Miami
Fort Lauderdale
West Palm Beach
Freeport
Nassau
GULF OF MEXICO
TROPIC OF CANCER
La Habana (Havana)
235km/146mi
BAHAMAS
NORTH ATLANTIC OCEAN
Mérida
Cancún
210km/130mi
CUBA
Camagüey
Santiago de Cuba
78km/48mi
Cap-Haïtien
Santiago
DOMINICAN REPUBLIC
HAITI
Port-au-Prince
Puerto Rico Trench
314km/195mi
San Juan
Santo Domingo
131km/81mi
Kingston
JAMAICA
MEXICO
BELIZE
GREATER ANTILLES
ANTIGUA AND BARBUDA
SAINT KITTS AND NEVIS
104km/65mi
Basseterre
Basse-Terre
Pointe-Pitre
DOMINICA
78km/48mi
Fort-de-France
Martinique (France)
HONDURAS
Tegucigalpa
San Pedro Sula
CARIBBEAN SEA
SAINT LUCIA
BARBADOS
98km/60mi
SAINT VINCENT AND THE GRENADINES
GRENADA
182km/114mi
NICARAGUA
Managua
LESSER ANTILLES
602km/375mi
Santa Marta
Barranquilla
Cartagena
Maracaibo
Caracas
Barquisimeto
Valencia
TRINIDAD AND TOBAGO
Port of Spain
COSTA RICA
San José
PANAMA
Panama Canal
Panama
COLOMBIA
VENEZUELA
Cúcuta
NORTH PACIFIC OCEAN

USA-Mexico Corridor

https://www.youtube.com/watch?app=desktop&v=kXSy3t51e8M

The Atlantic

Science

The Engineers' Plan for Creating Border Security With Clean Energy

A proposal imagines how building solar panels and wind turbines along the U.S.-Mexico border could unite calls for a Green New Deal and a border wall.

Amal Ahmed May 7, 2019

SCIENTIFIC AMERICAN.

Bold Plan? Replace the Border Wall with an Energy–Water Corridor

Building solar, wind, natural gas and water infrastructure all along the U.S.–Mexico border would create economic opportunity rather than antagonism

By Mark Fischetti on February 14, 2019

The Washington Post

Democracy Dies in Darkness

Opinions

A genuine Big Idea that could fix the border problem

U.S Main Foreign Trade Partners (Imports + Exports)

2020

Data source: U.S. Census Bureau, 2020

Key Question

Can we develop an energy-water corridor along the USA-Mexico border as a solution for existing border proposals?

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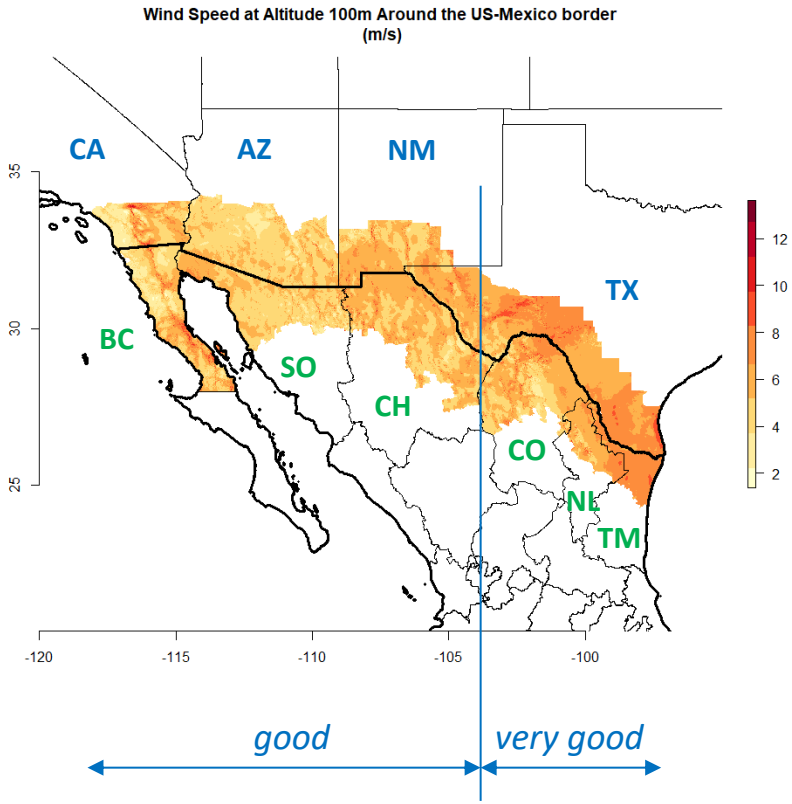
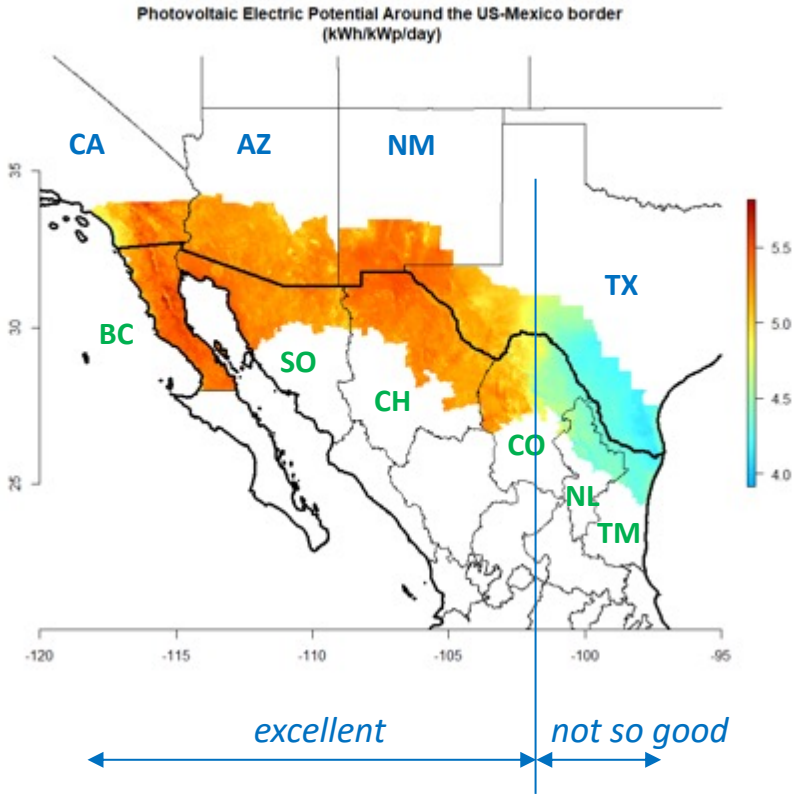
Renewable resources at both sides of the US-Mexico border

Wind

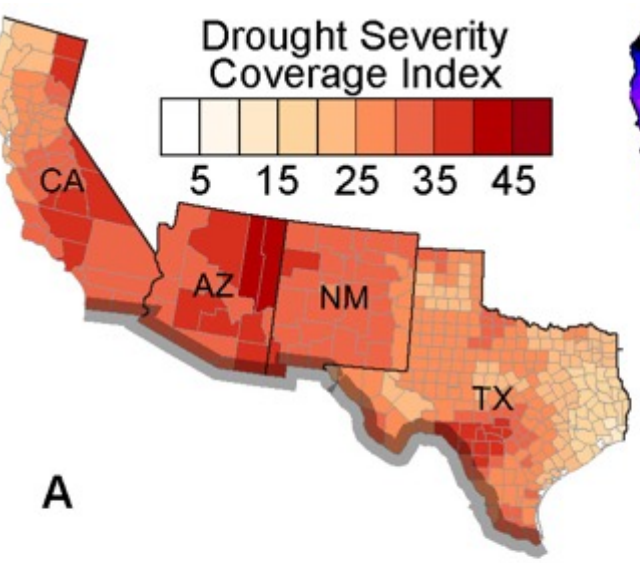


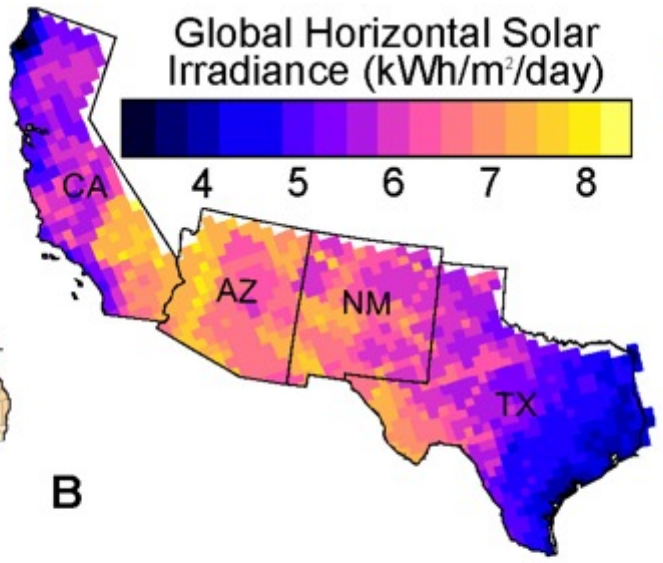
Solar

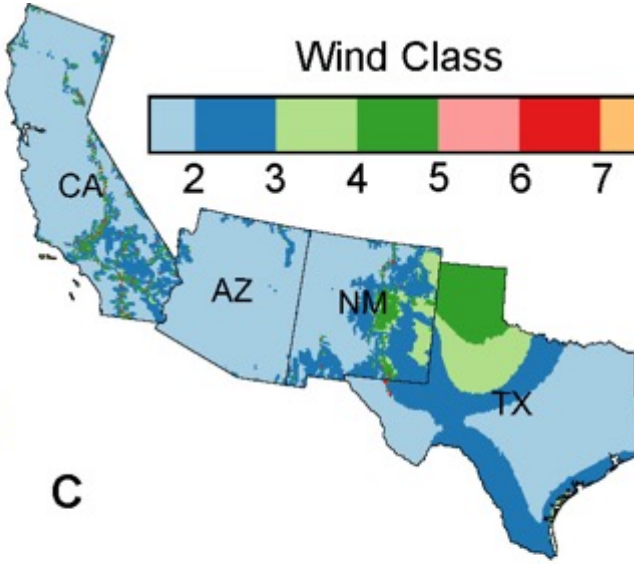


The Largest Technology Park of the World

How about evaluation of Droughts along the border?







Wind Class	1	2	3	4	5	6	7
Wind Speed Interval (ms^{-1}) at 50 m	0	5.6	6.4	7.0	7.5	8.0	8.8	11.9

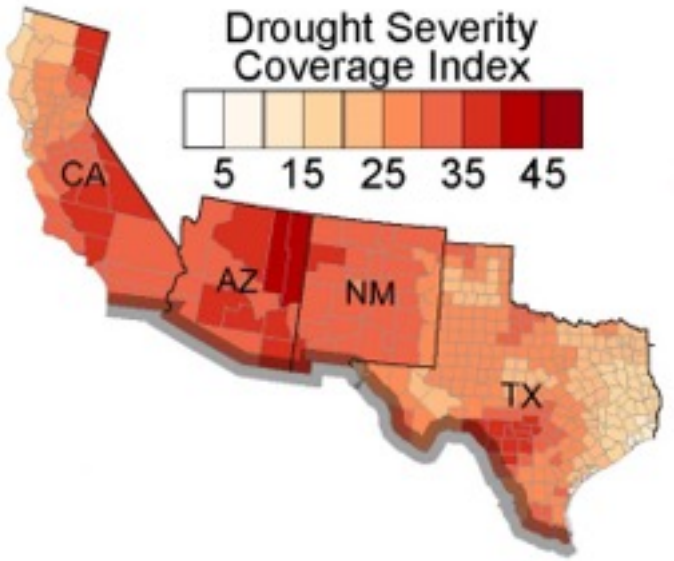
Droughts: Energy & Water

The Water Crisis Along the Border

- **Border states lack water**, but excellent solar & wind resources

- *Reliance on ground water* ("fossil water") for public needs for TX (**36%**), AZ (**43%**), NM (**87%**).

- USA withdraws **about 45% of our water for cooling of power plants** in production of electricity, Castillo et al., *Scientific American* (2018).



Droughts past 14 years:
Border states have high levels of droughts.

Data from U.S. Drought Monitor, NOA.
https://droughtmonitor.unl.edu

What about other borders?

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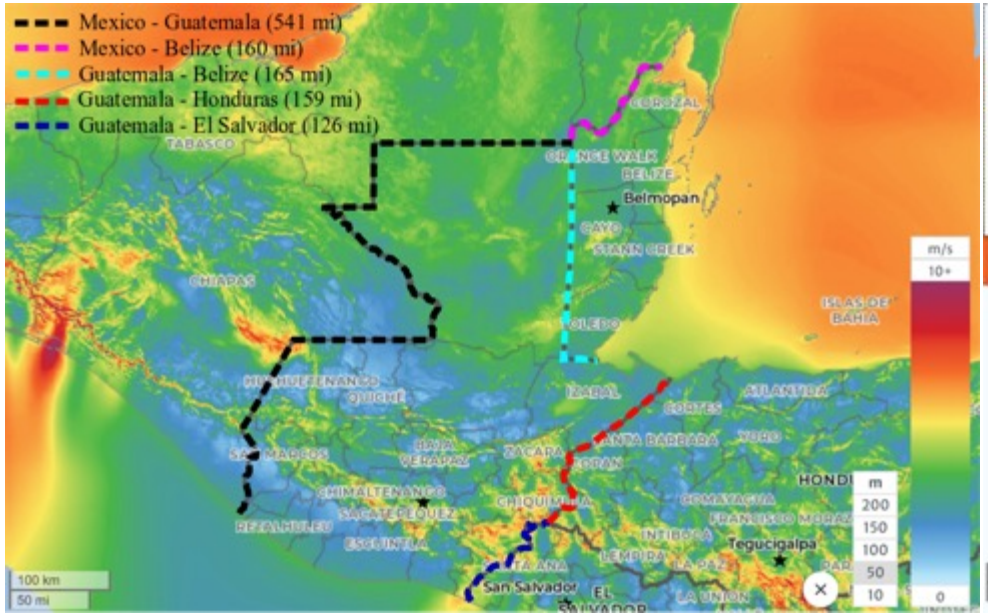
Wind and Solar Resources in Central America



Average wind speed at 50m above ground
https://globalwindatlas.info/

Global Solar irradiation (kWh/m2)
https://globalsolaratlas.info/map

Guatemala: Key Country in Solving USA/Mexico Border Challenges.

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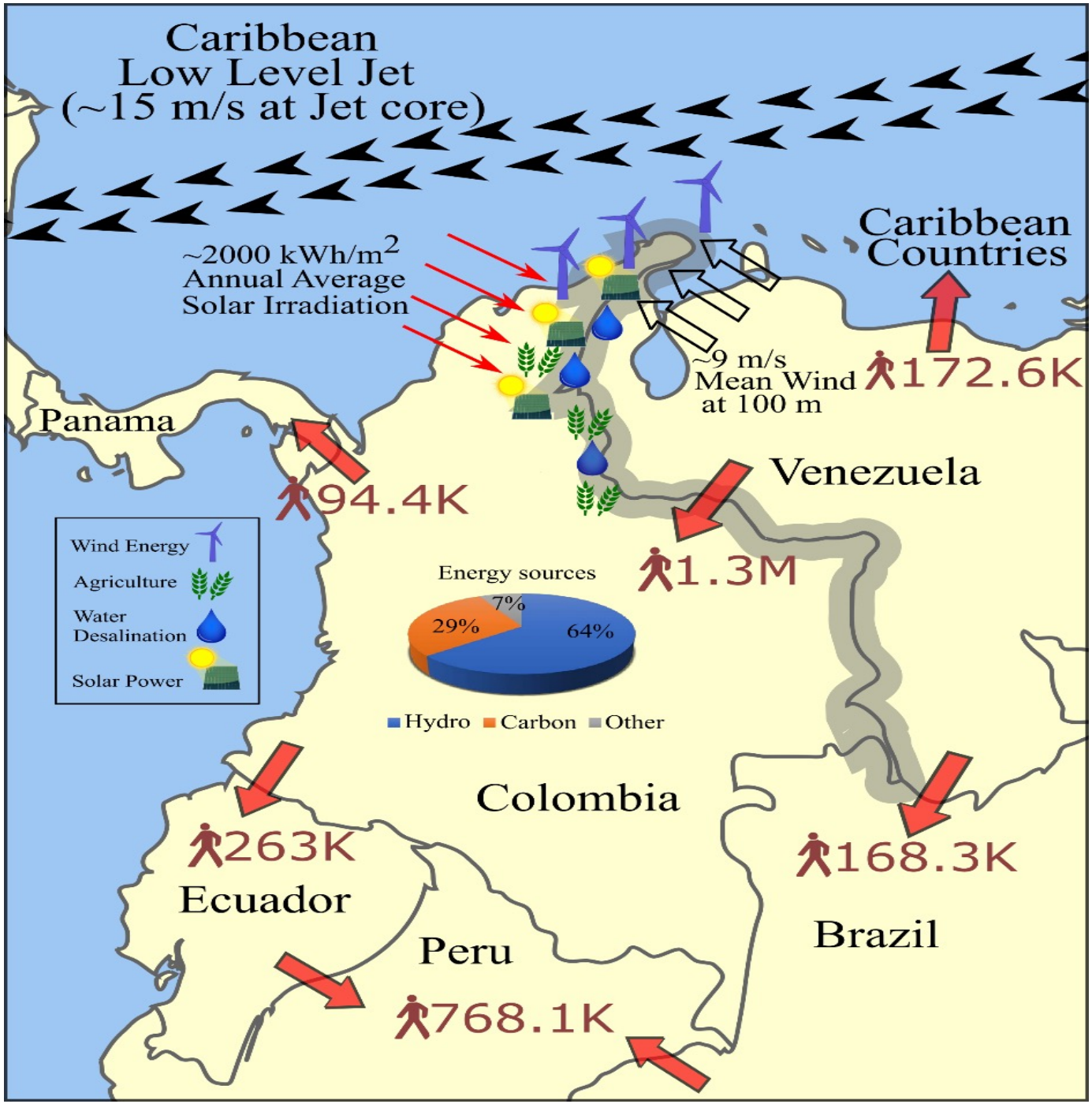

Inspired by President Mung Chiang

Mass Migration in Venezuela

Colombia could be 100% Renewable!

Castillo, **Scientific American** (2020)

The Water Insecurity & W4E Crisis

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Cape Town Water Crisis

The World Wildlife Fund estimates that **by 2025**, the problem faced on Cape Town today will be a crisis also for **2/3 of our world population**.

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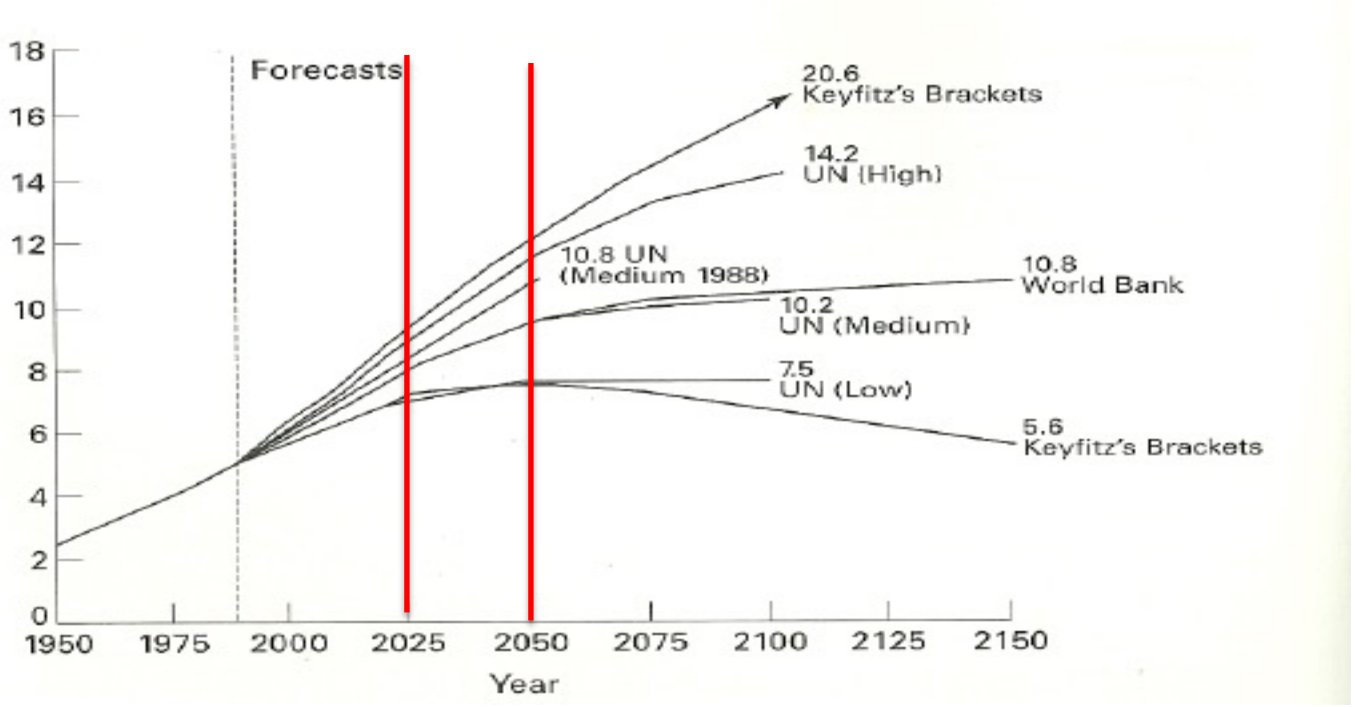
Population Growth & Energy Dependence



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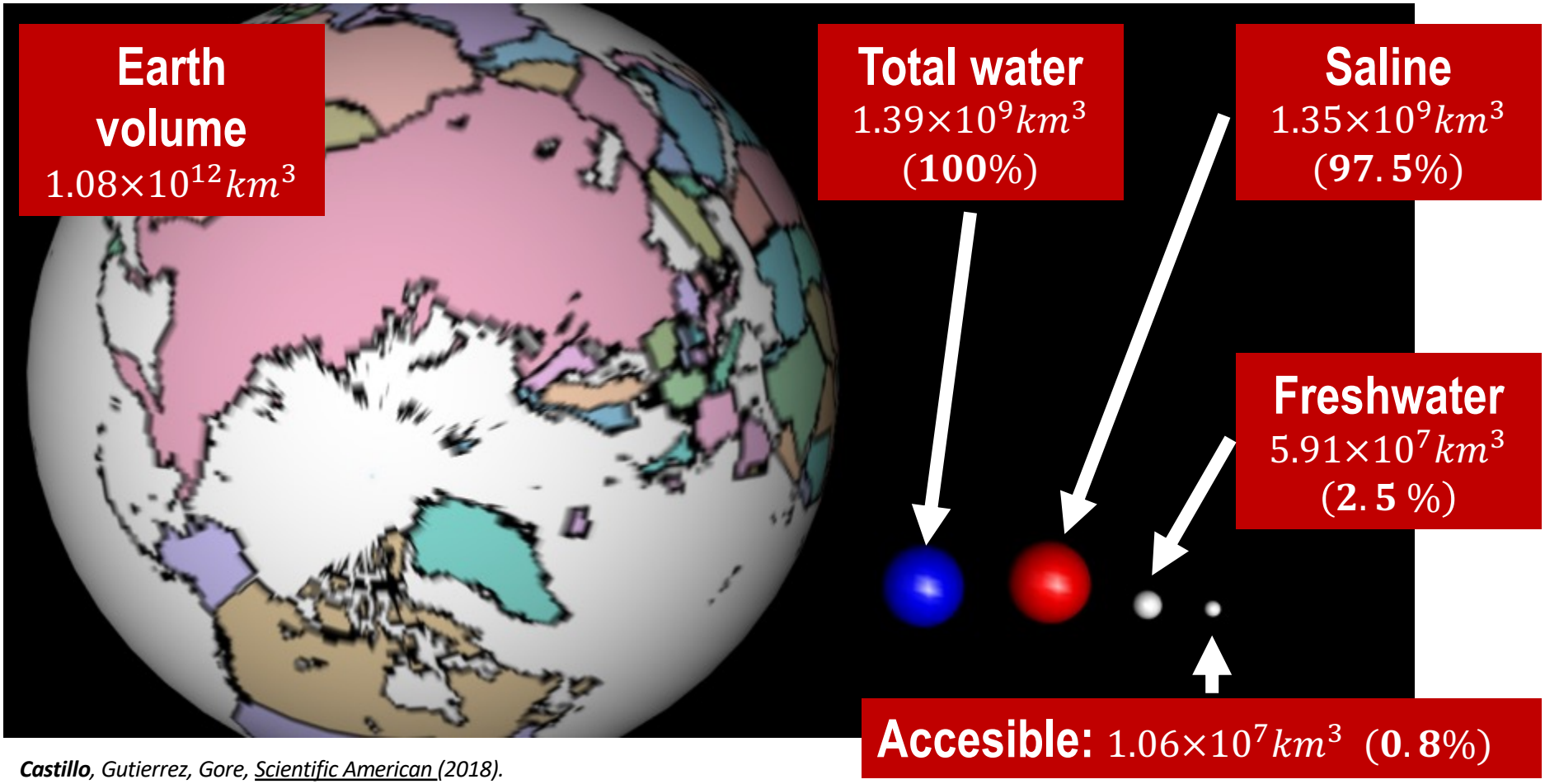
Earth's Water Reserves



***Castillo**, Gutierrez, Gore, Scientific American (2018).*

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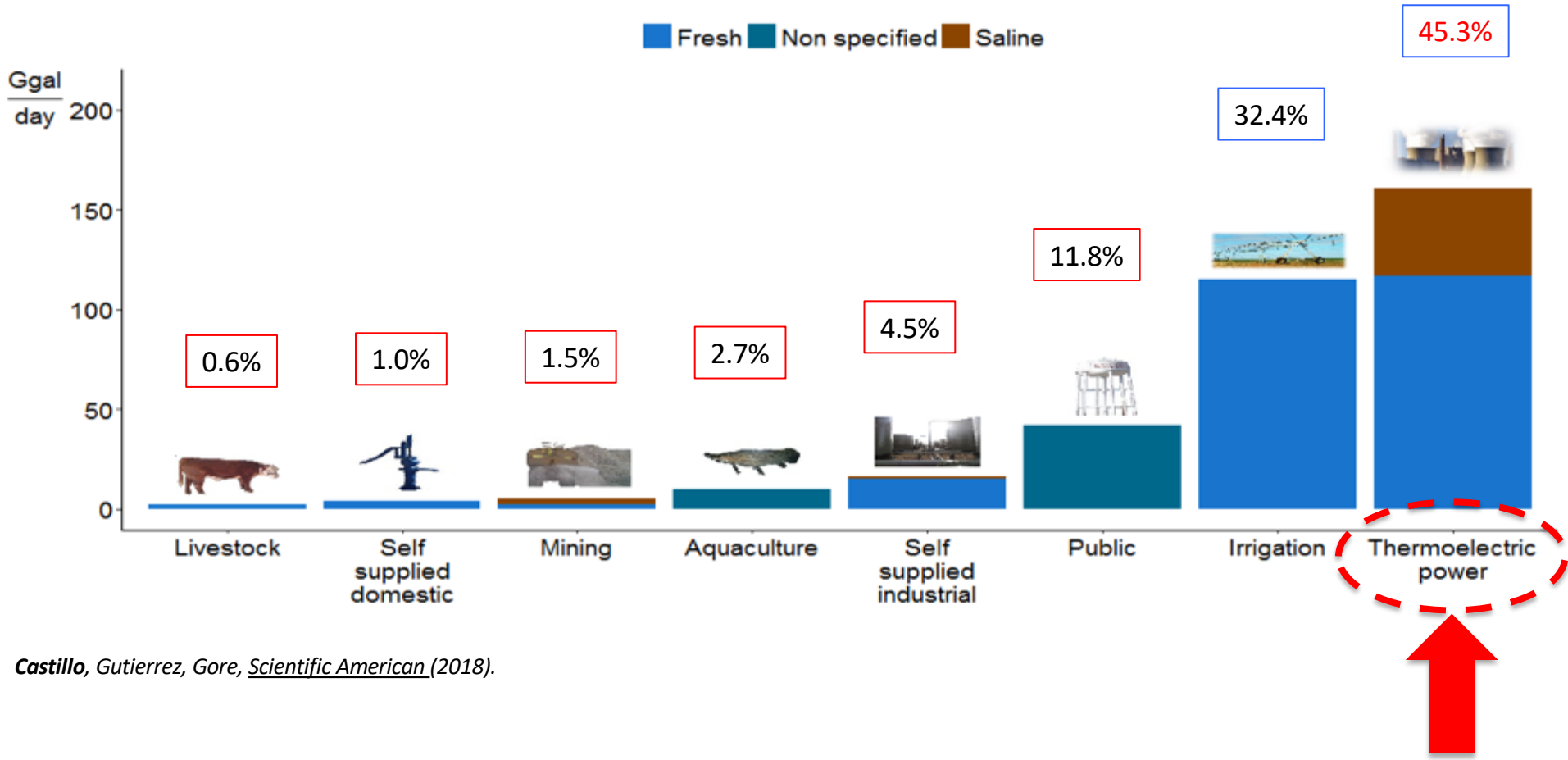
Water for Energy: The Quiet Crisis in the Making

What is wrong with this picture?



***Castillo**, Gutierrez, Gore, Scientific American (2018).*

WARNING: Our fresh water is used for cooling of power plants!

The Water 4 Energy Quiet Crisis

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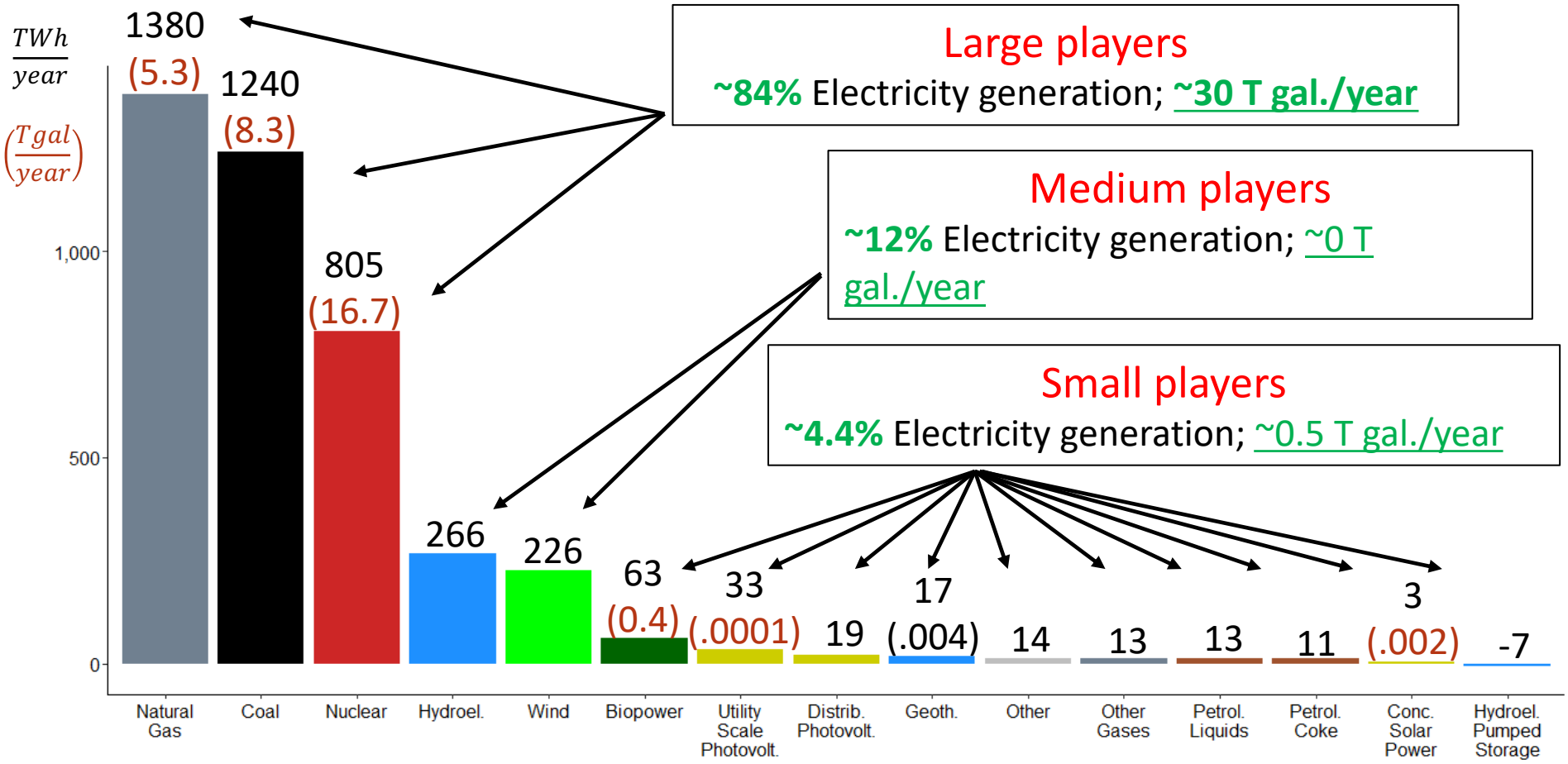
Water & Energy:

US Annual Electricity Production and Water Withdrawal (2016)



Large players
~84% Electricity generation; **~30 T gal./year**

Medium players
~12% Electricity generation; ~0 T gal./year

Small players
~4.4% Electricity generation; ~0.5 T gal./year

NOTE: Renewables the Cure for Water Insecurity!

***Castillo**, Gutierrez & Gore, Scientific American (2018).*

Castillo & Gutierrez, Axios(2018).

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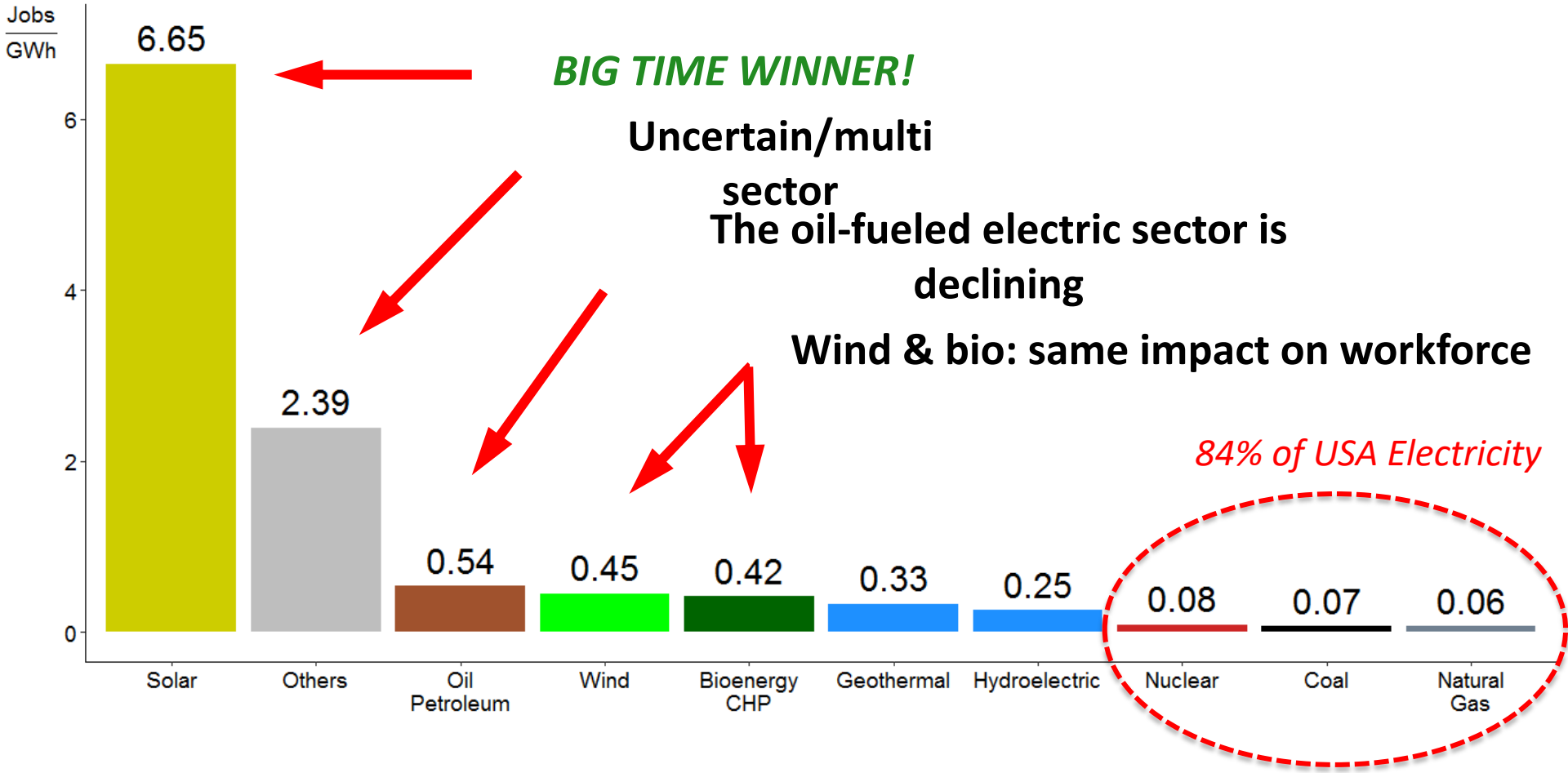
Jobs per GWh (electric)



***Castillo**, Gutierrez & Gore, Scientific American (2018).*

Data source: US Energy and Jobs Report, 2017.

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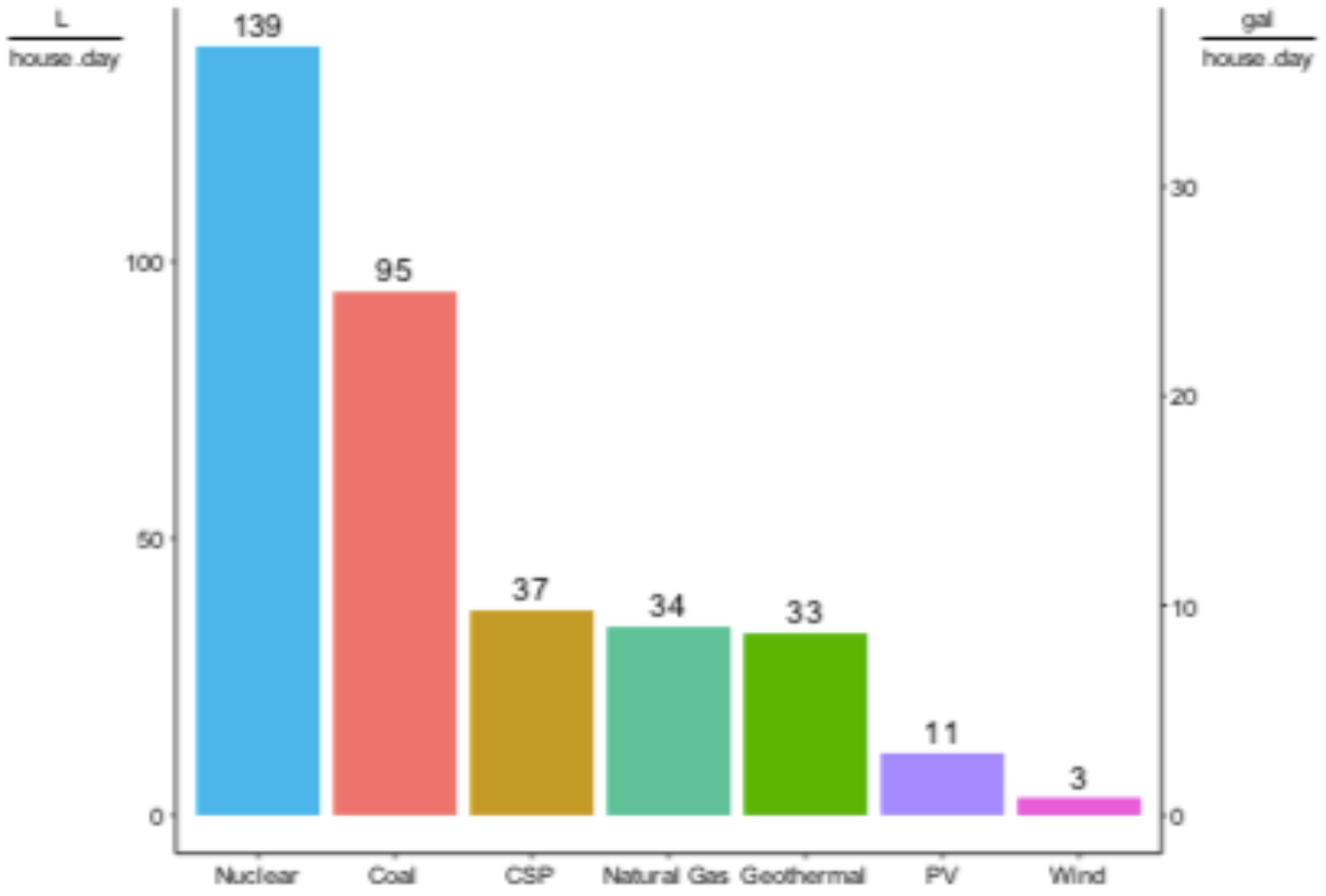
Water to Power House in 1-day



Gutierrez & Castillo, to be submitted Nature Energy (2023).

Can we use Wind Energy to Capture Co2 while producing electricity and saving water?

GOAL- Achieve Net-zero Co2 emissions by 2050!

"Climate Change is one of the most destabilizing forces of our time, exacerbating other national security concerns and posing serious readiness challenges."

Honorable Carlos Del Toro, Secretary of the Navy

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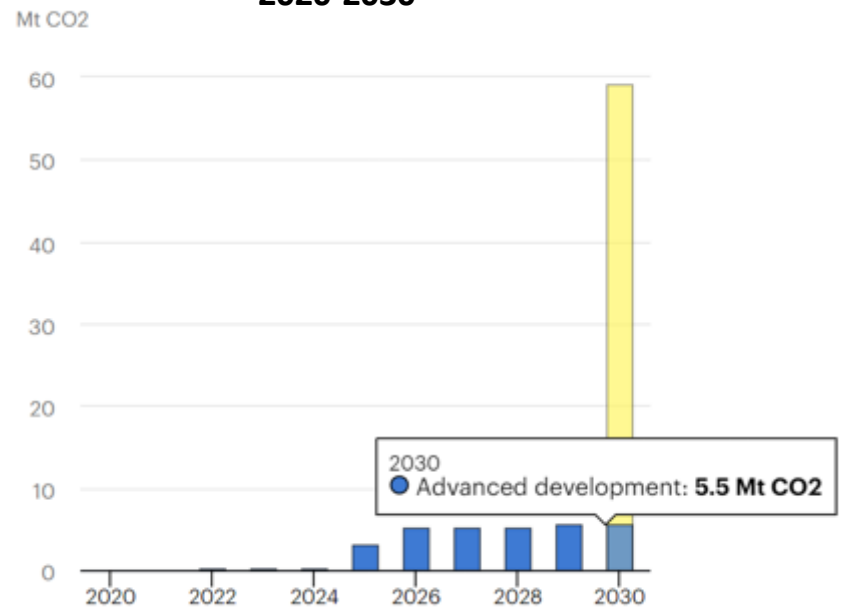
DAC IS NOT CURRENTLY ECONOMICALLY VIABLE

The Intergovernmental Panel on Climate Change (IPCC)

CO2 capture by direct air capture, planned projects and in the Net Zero Scenario (2050), 2020-2030



[IEA., 2022]

CAPTURE COST:

$$\$100 - 600_{/\text{ton-}CO_2}$$

vs

[McQueen et al., 2021]

[Keith et al., 2018]

MARKET VALUE:

as low as

$$\$3_{/\text{ton-}CO_2}$$

[Reuters., 2021]

TAX CREDIT (2022):

$$\$50\text{-}85_{/\text{ton-}CO_2}$$

[Reuters., 2021]

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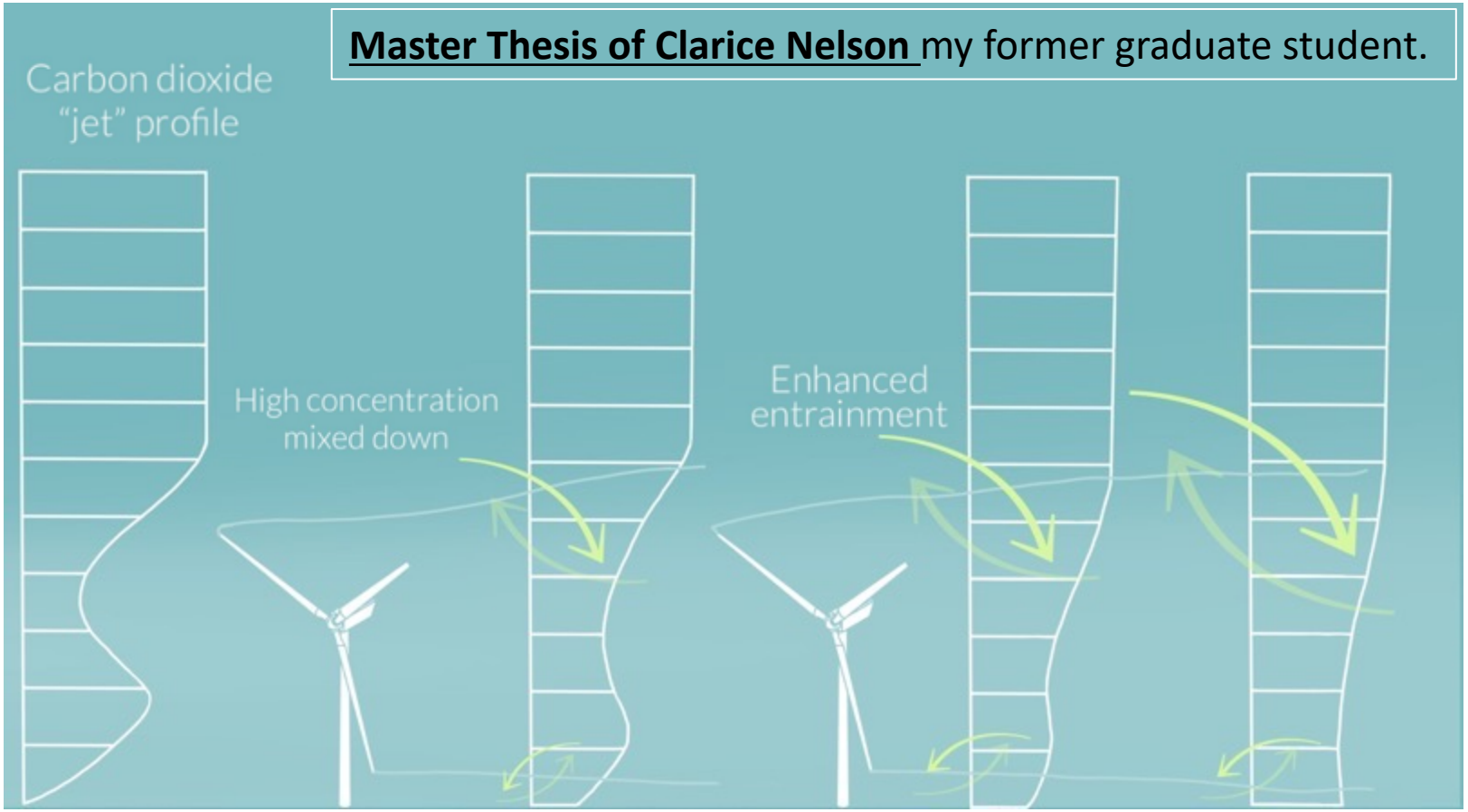
WIND ENERGY & DAC: A SYMBIOSIS



Potential to benefit the plant, at no additional cost!

Wind energy

- Near-zero carbon footprint [energy.gov, 2022]
- Low cost of energy [Lazard, 2019]
- Night Availability
- Velocity Deficit in Wake

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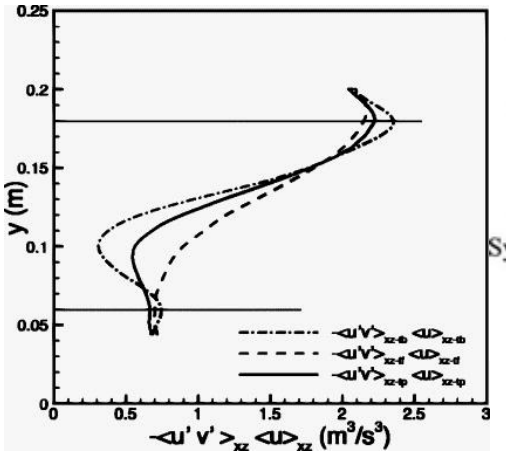
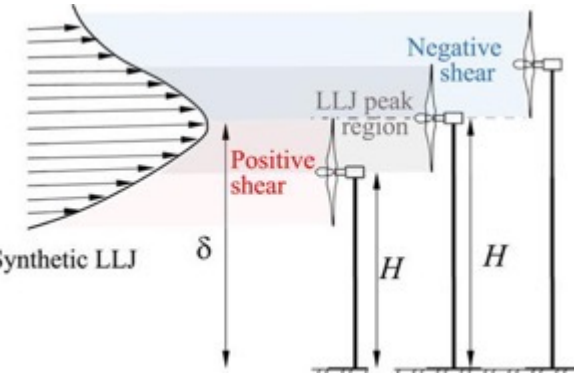
OUR RESEARCH QUESTION

Can we extrapolate the velocity recovery mechanism found in the kinetic energy entrainment: …

$$-\overline{U}(y)\overline{u'v'}(y)$$





[Doosttalab et al., 2020]

[Cal et al., 2010]

… towards a scalar entrainment in the turbine wake …

$$-\overline{U(z)}\,(\overline{w'c'})$$

and could an analogous jet benefit DAC?

Master Thesis of Clarice Nelson my former graduate student now at GE

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Low Dimensional: POD
Mean Kinetic Energy Equation

- Mean Kinetic Energy Equation:

$$\iiint E dV + \iint \left(\langle U_i \rangle E + \langle U_j \rangle \langle u'_i u'_j \rangle + \langle U_i \rangle \frac{\langle p \rangle}{\rho} - 2\nu \langle U_j \rangle S_{ij} \right) n_i dA - \iiint (P + \varepsilon)$$

- Following Cal *et. al*. (2009) we **examine the vertical flux of kinetic energy into the array**:

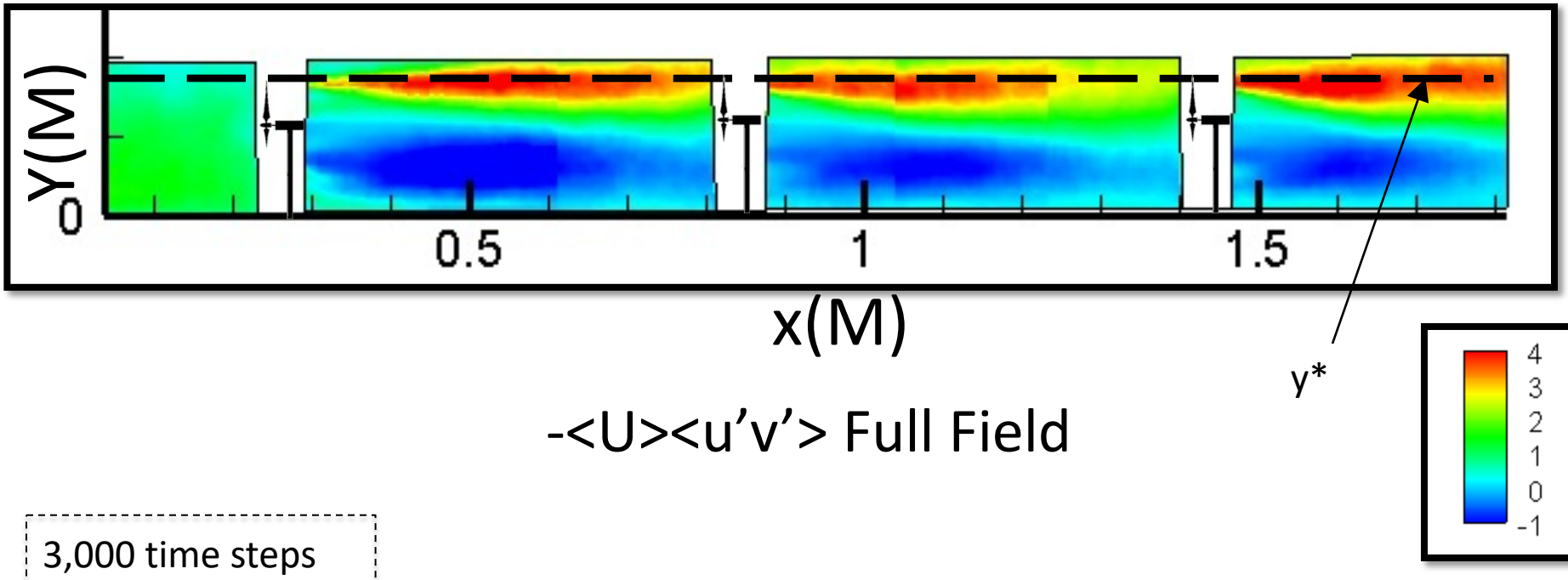
$$- \iint \langle U_1 \rangle \langle u'_1 u'_2 \rangle + \langle U_2 \rangle \langle u'_2 u'_2 \rangle dA$$

Second order term

Newman et al. J.Renewable Energy (2014)

Results: Full Field Energy Fluxes Entrainment (above/below)

- Flux contributions: integrate modes in the streamwise direction at the highest vertical point of a turbine blade tip, y*



-<U><u'v'> Full Field

3,000 time steps used in averaging

Newman, Drew, Castillo (2014, J. Renewable Energy)