RESEARCH ON TAP

Climate Change and Clean Energy

Thursday, December 5 | 4-6 pm

bu.edu/research/events

Boston University Office of Research

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Agenda

Opening Remarks

Thomas Bifano
Vice President and Associate Provost ad interim for Research

Presentations

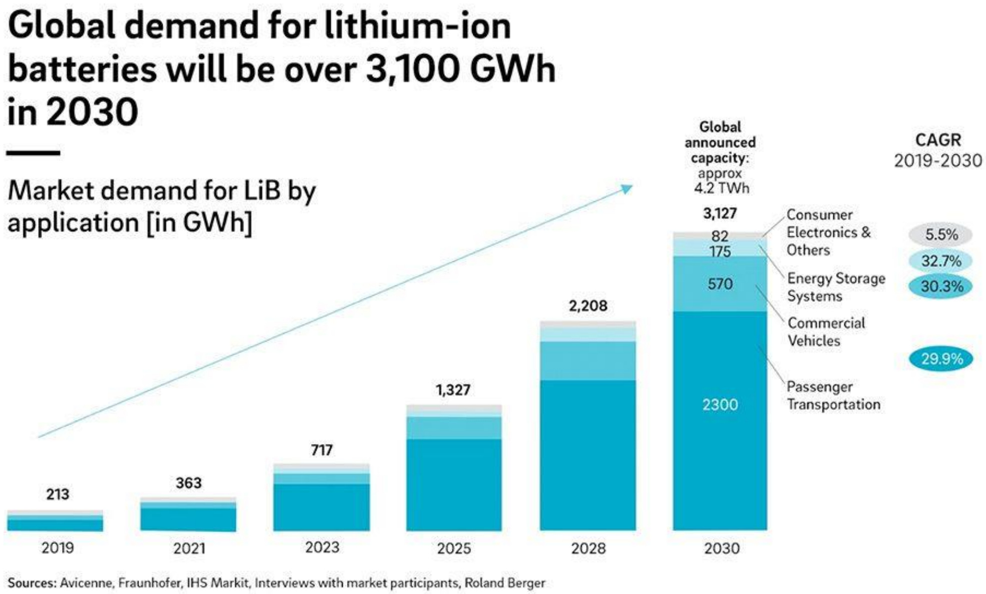
Emily Ryan
Ian Sue Wing
Eric Cueny
Kevin Gallagher
Patricia Fabian
Dan Li
Emiliano Dall'Anese
Mary Willis
Benjamin Sovacool
Srikanth Gopalan
Ayse Coskun
Cutler Cleveland

Interface Stability for Next Generation Batteries

Emily Ryan

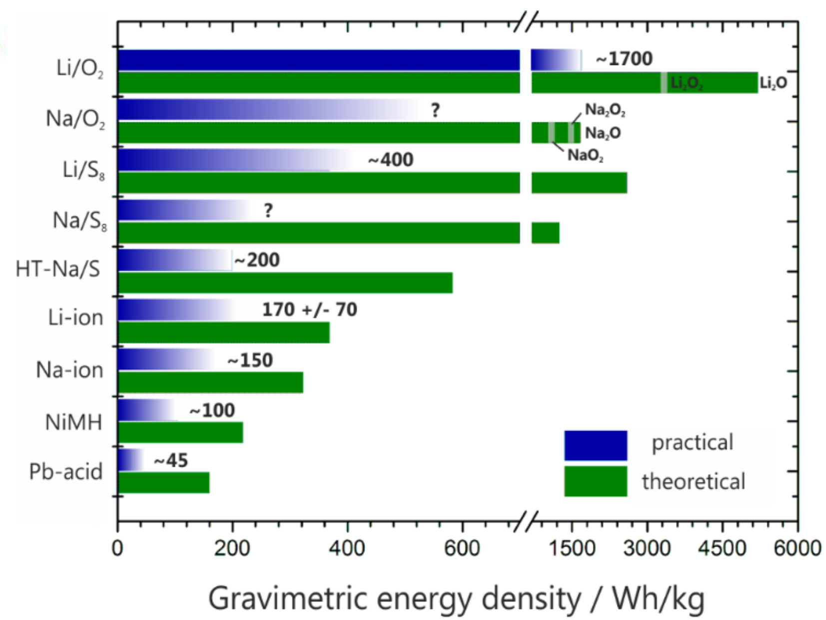
Associate Professor
Mechanical Engineering, College of Engineering
Associate Director
Institute for Global Sustainability

Need for higher energy density batteries



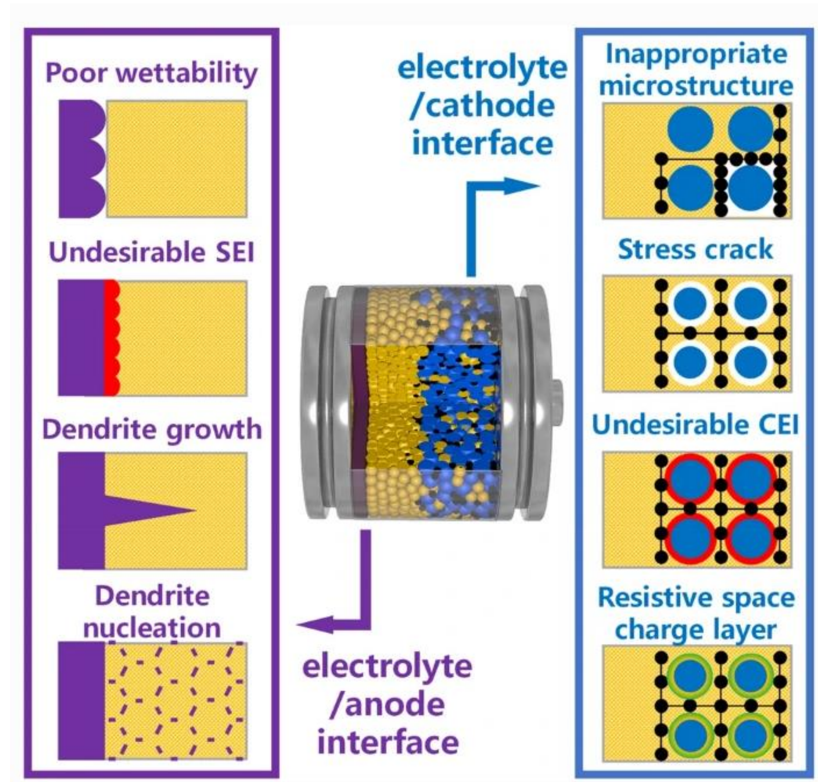
Growing demand for energy storage

Li ion limited in increasing energy density



Challenges of High Energy Density Lithium Batteries

- Lithium plating
  - Decreases performance over time
  - Safety issues with thermal runaway



Interfacial challenges in solid state Li batteries
Pang et al 2021

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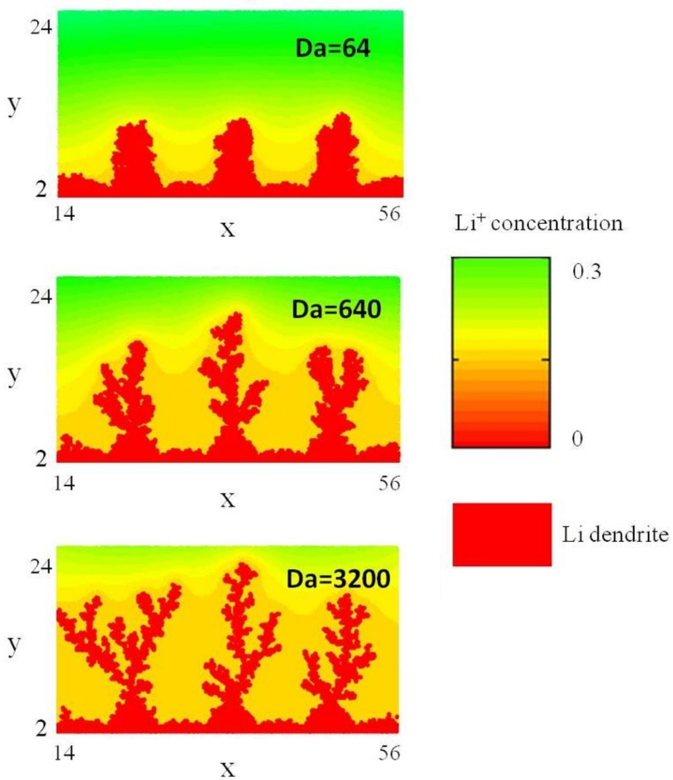
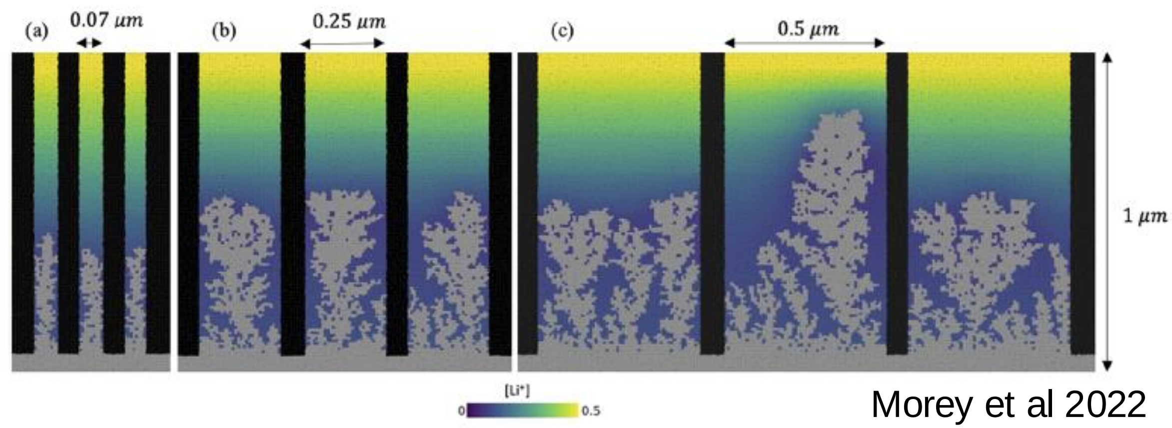
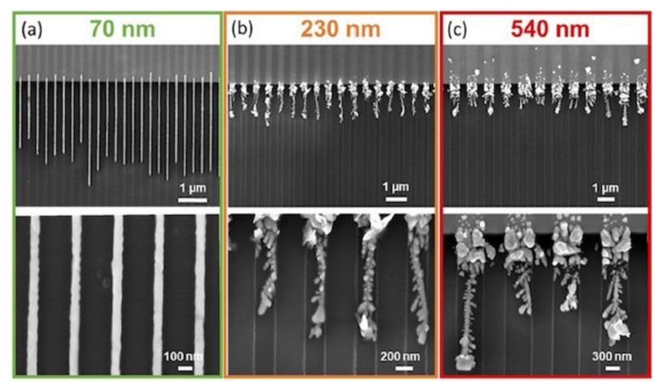
Computational Modeling of Dendrite Growth at the Electrode-Electrolyte Interface

- Lagrangian particle based model of dendrite growth
  - Reactive transport: diffusion, advection, electrochemistry, surface reactions



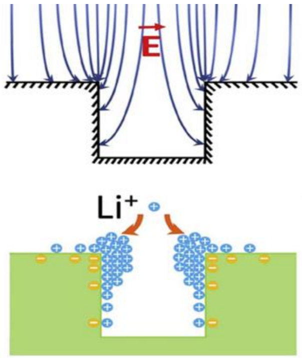


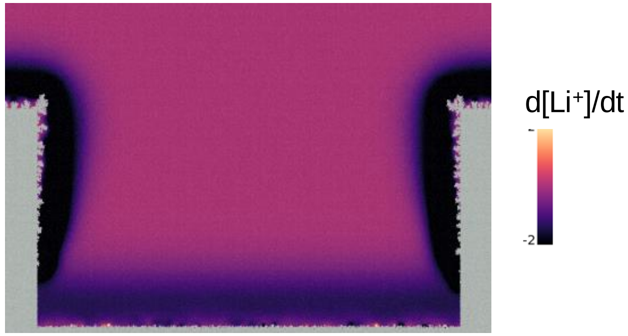
Morey et al 2022



Sharon et al 2020

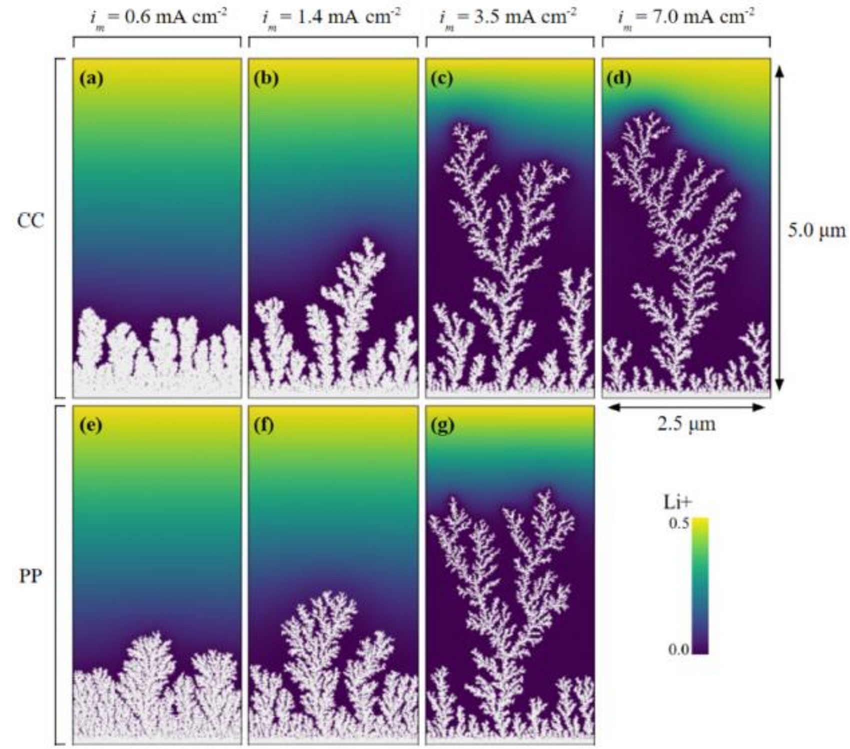
Interfacial Geometry



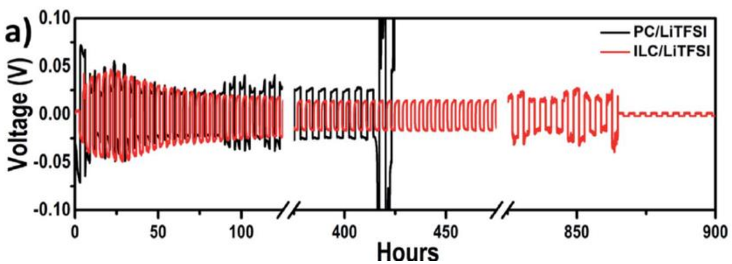


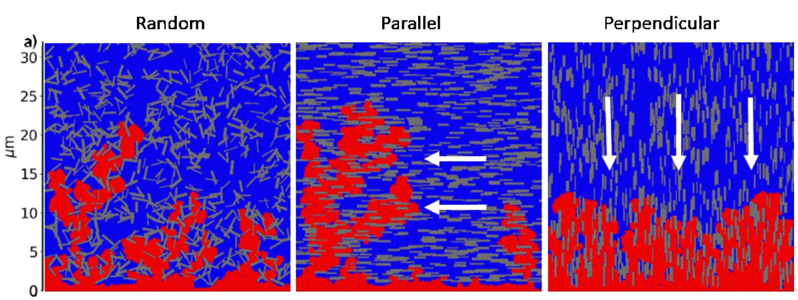
Li, Q. *et al. (2018)*

Charging Protocol



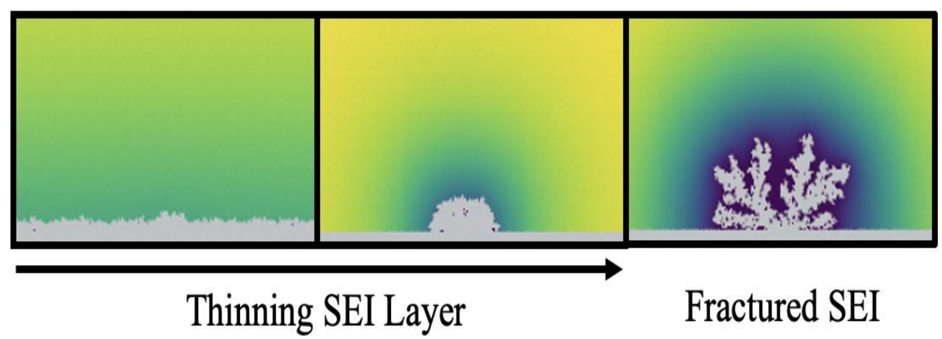
Membranes and Separators





Gopalakrishnan et al, 2021

SEI Formation



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Inequalities in global residential cooling energy use to 2050

Ian Sue Wing

Professor

CAS Earth & Environment

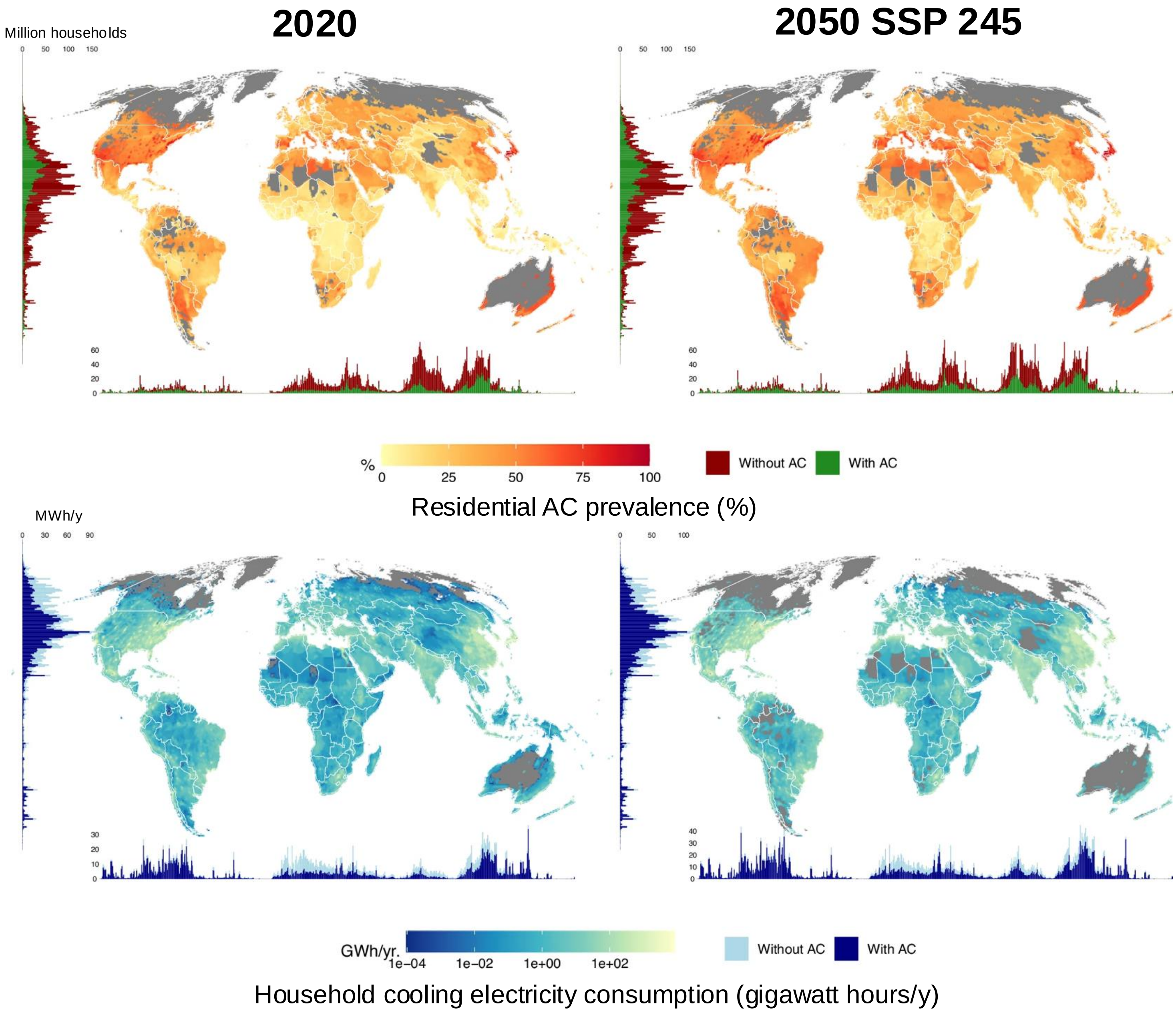
As the climate warms, households will increase adoption and utilization of residential air conditioning (AC)

A positive feedback loop

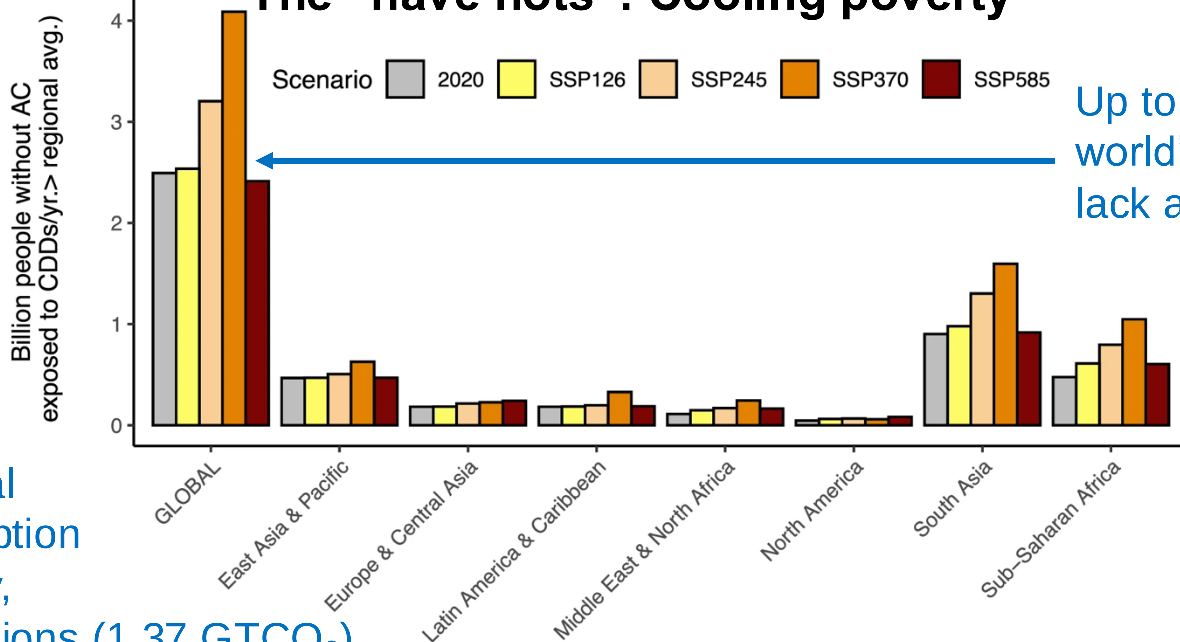
- AC is a widely available and effective technology to adapt to high ambient temperatures, but it is expensive and consumes electricity
- Higher long-run average temperatures will boost demand for cooling, inducing more households to purchase and operate AC units
- Higher transitory temperatures incentivize increased utilization of AC, and demand for electricity to provide cooling
- If higher electricity demand is satisfied by additional fossil fuel generation, CO_2 emissions, amplification of warming could result!

How worried should we be about this? [Answer: <u>very</u>!]

- How much additional AC capacity will be added in response to rising temperatures?
- Conditional on adoption of AC, how much additional electricity will households use?
- Given scenarios of future population, economic growth and warming, how will the future benefits of cooling be distributed across the world?
- How much additional CO_2 will we need to avoid emitting?

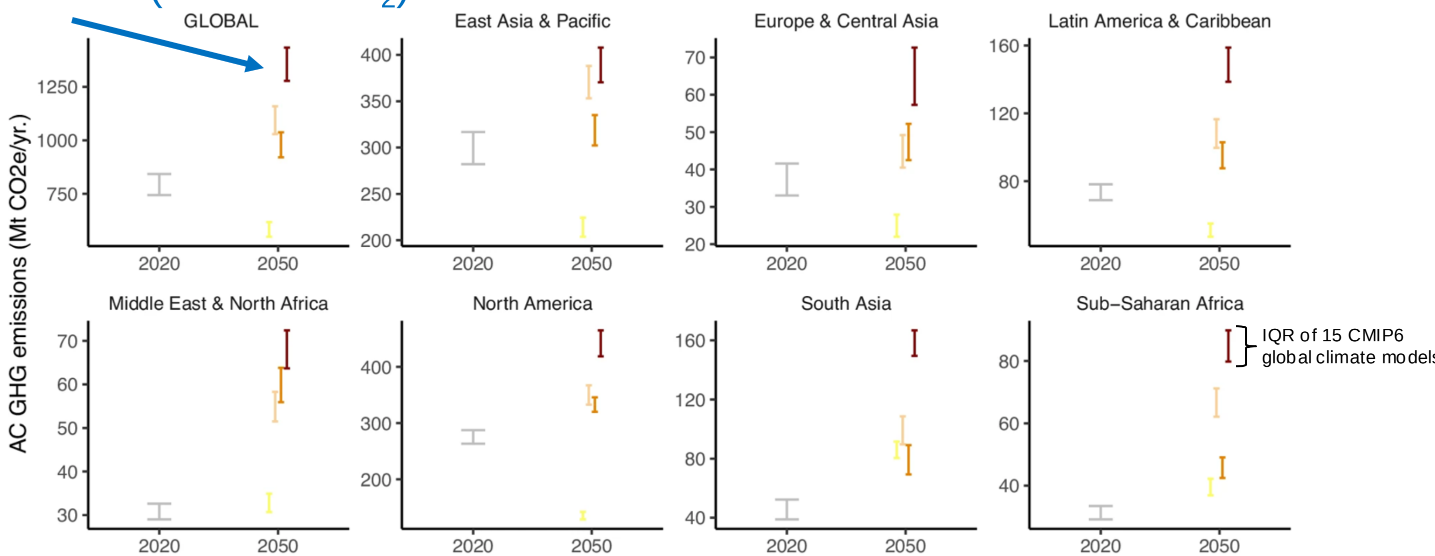

2020
2050 SSP 245
Million households
0 50 100 150
60
40
20
0
%
0 25 50 75 100
Without AC
With AC
Residential AC prevalence (%)
MWh/y
0 30 60 90
0 50 100
30
20
10
40
GWh/yr.
1e−04 1e−02 1e+00 1e+02
Without AC
With AC
Household cooling electricity consumption (gigawatt hours/y)

The "have nots": Cooling poverty



Up to 41% of the world's population could lack access to cooling

Up to 2x residential electricity consumption for cooling globally, 1.5% higher emissions (1.37 $GTCO_2$)



How much more CO_2 will we emit?

nature communications

Article

https://doi.org/10.1038/s41467-024-52028-8

Inequalities in global residential cooling energy use to 2050

Received: 22 October 2023

Accepted: 22 August 2024

Published online: 16 September 2024

Check for updates

Giacomo Falchetta [1,2,3], Enrica De Cian [1,3,4], Filippo Pavanello[1,3,5] & Ian Sue Wing [6]

Intersecting socio-demographic transformations and warming climates portend increasing worldwide heat exposures and health sequelae. Cooling adaptation via air conditioning (AC) is effective, but energy-intensive and constrained by household-level differences in income and adaptive capacity. Using statistical models trained on a large multi-country household survey dataset ($n = 673{,}215$), we project AC adoption and energy use to mid-century at fine spatial resolution worldwide. Globally, the share of households with residential AC could grow from 27% to 41% (range of scenarios assessed: 33-48%), implying up to a doubling of residential cooling electricity consumption, from 1220 to 1940 (scenarios range: 1590-2377) terawatt-hours yr.$^{-1}$, emitting between 590 and 1,365 million tons of carbon dioxide equivalent ($MtCO_2e$). AC access and utilization will remain highly unequal within and across countries and income groups, with significant regressive impacts. Up to 4 billion people may lack air-conditioning in 2050. Our global gridded projections facilitate incorporation of AC's vulnerability, health, and decarbonization effects into integrated assessments of climate change.

Paper: https://doi.org/10.1038/s41467-024-52028-8
Data: https://zenodo.org/records/12697821

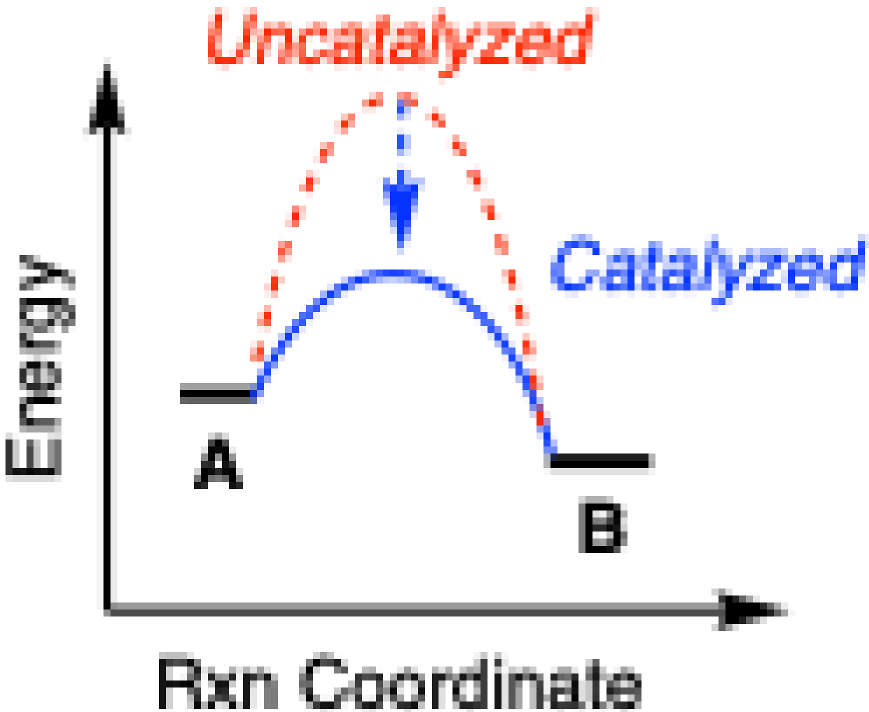
Understanding Reactive Intermediate Exchange Reactions: How to Achieve More Efficient Catalysis

Eric S Cueny

Assistant Professor
Chemistry, College of Arts and Sciences

Catalysis: A Global Impact

Catalysis contributes up to ~ 35% of GDP



Catalyzed pathway lowers the energy required for chemical transformations!

Important Catalytic Reactions

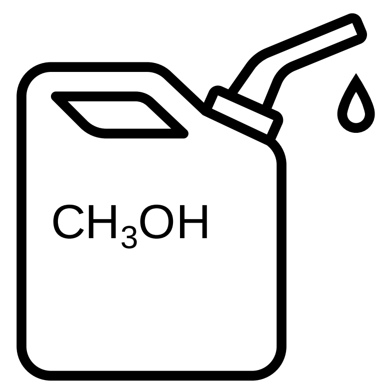
N_2 → NH_3

Fertilizer Production

183 million metric tonnes / yr

~ 1 – 2 % of global CO_2

CO_2 → CH_3OH



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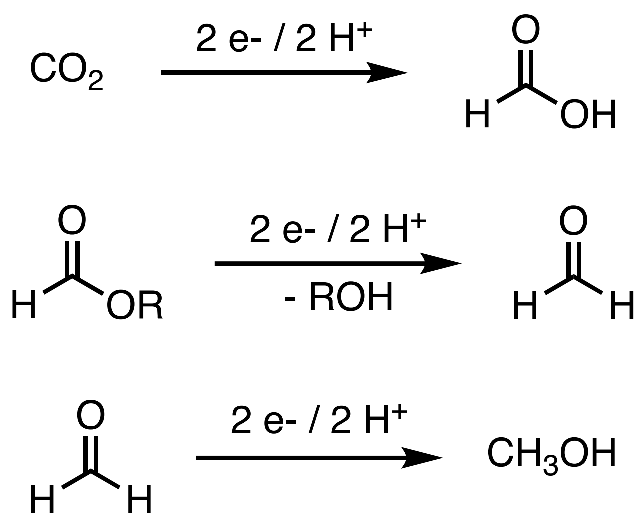
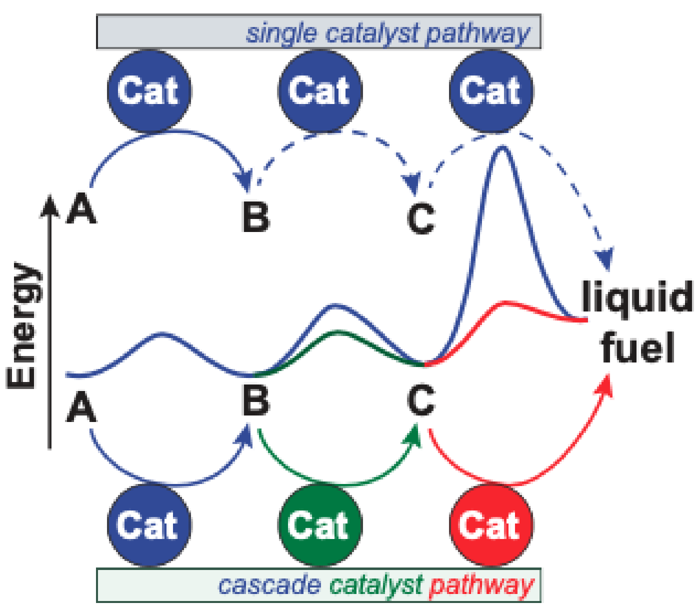
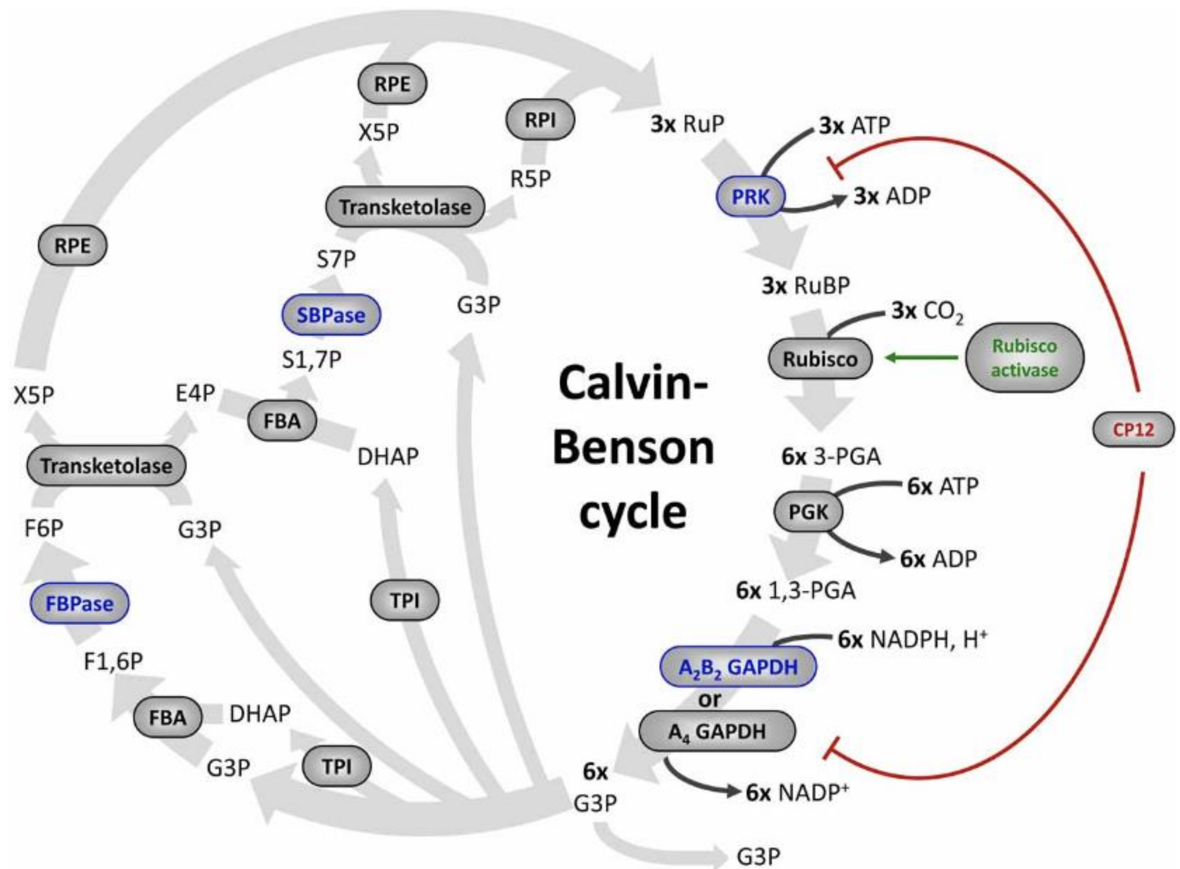
Topics in Catalysis **2023**, *66*, 338–374

Reduction of CO_2 to Fuels and/or Sugars





Sugars from CO_2



Frontiers in Plant Science **2013**, *4*, DOI: 10.3389/fpls.2013.00470

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CHASE
Center for Hybrid Approaches in Solar Energy to Liquid Fuels

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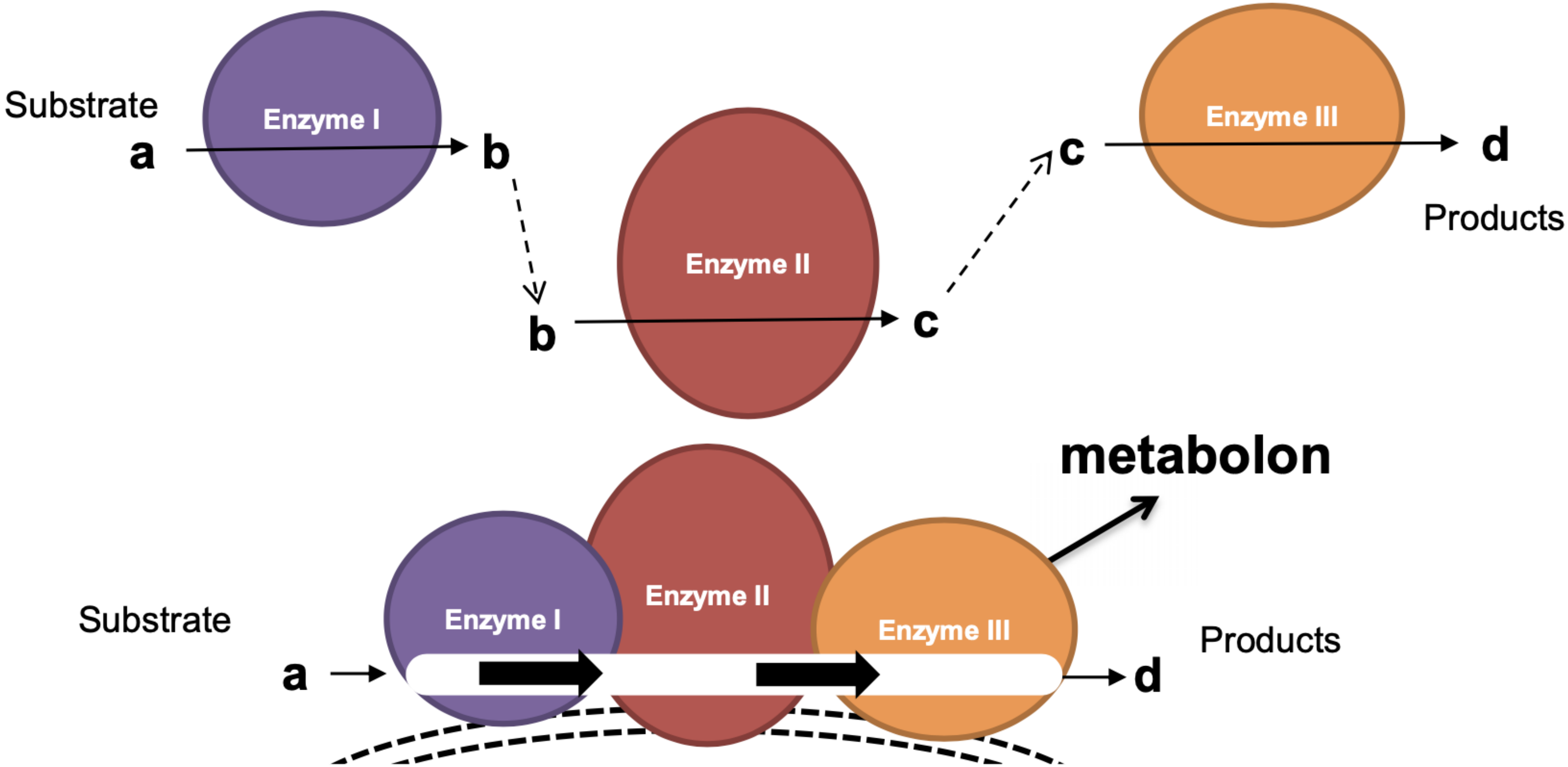
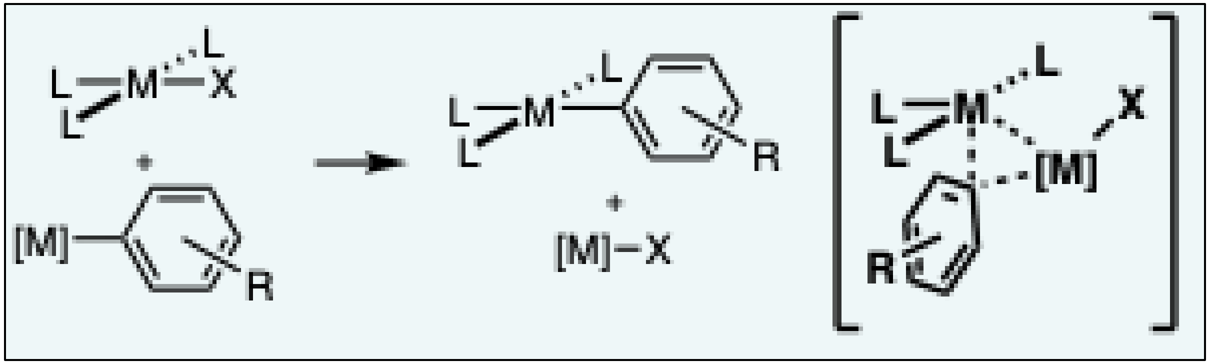
Cascade Catalysis vs Cooperative Strategy

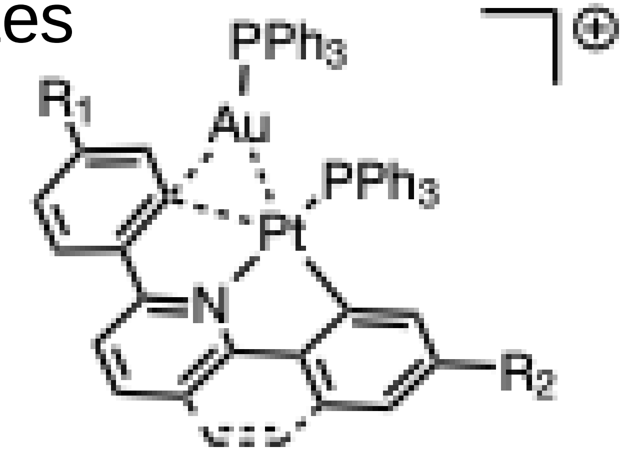


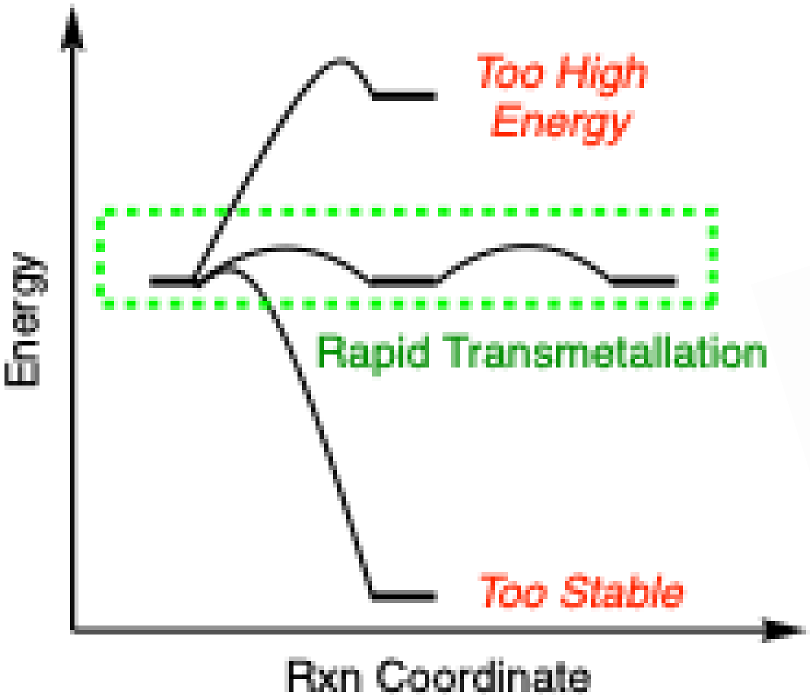
Use the Same Strategy with Organometallic Complexes?

Plant Communications **2021**, *2*, 100081

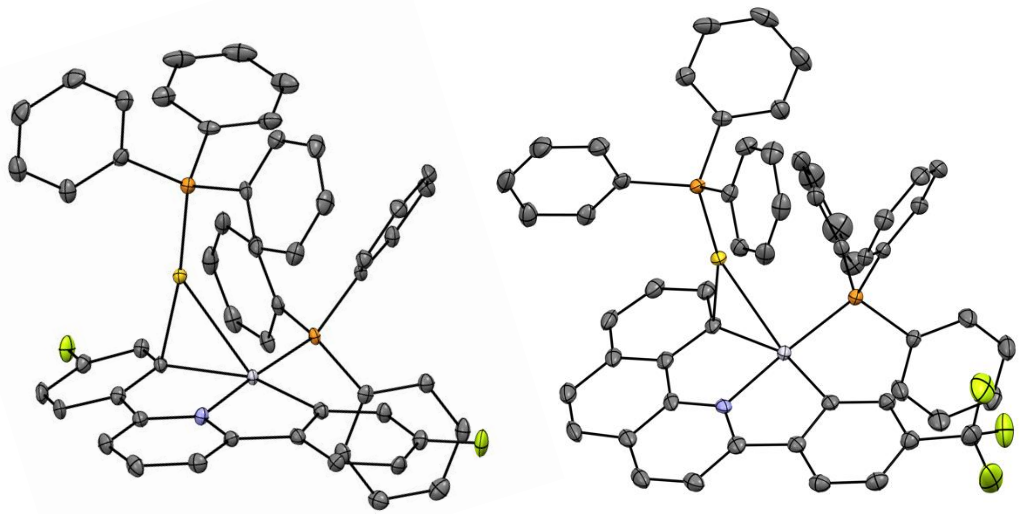
Cueny Lab Research: Understanding Transmetallation Through Structural Mimics of Intermediates







Structural Mimic of Transmetallation



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Marghalani, R.; Cueny, E. S. *Dalton Trans.* **2024**, DOI: 10.1039/D4DT01828A

Climate Change, Climate Policy, and Development

Kevin P. Gallagher

Professor of Global Development Policy, Pardee School
Director, BU Global Development Policy Center

Macro-critical aspects of climate and climate policy

DIRECT IMPACTS

PHYSICAL RISK
Temperature
Precipitation
Agricultural Productivity
Sea Levels

Capital stock destruction
Shifts in prices from supply shock

TRANSITION RISK
Policy & Regulation
Technology Development
Consumer Preferences

Shifts in prices from structural changes
Carbon stranded assets

SPILLOVER TRANSITION RISK
Foreign Carbon Tax

Lower fossil fuel import
Shock on balance of payment

INDIRECT IMPACTS

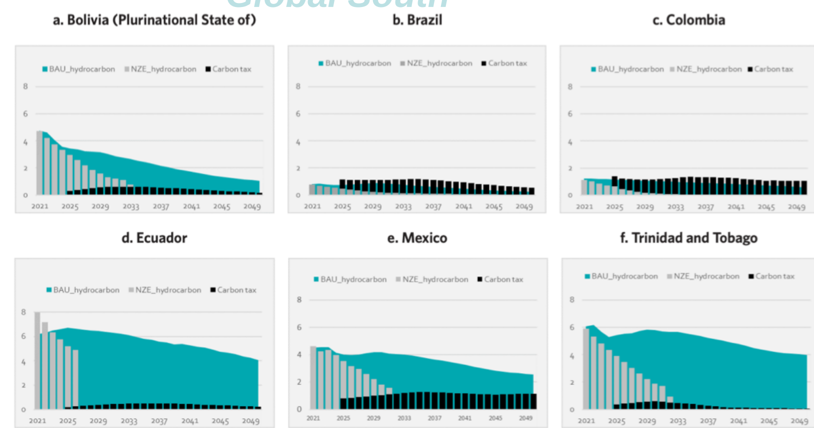
BUSINESS
- Property damage and business disruption from severe weather
- Stranded assets and new capital expenditure due to transition
- Changing demand and costs
- Legal liability

HOUSEHOLD
- Loss of income
- Property damage and restrictions
- Increasing costs and affecting valuations

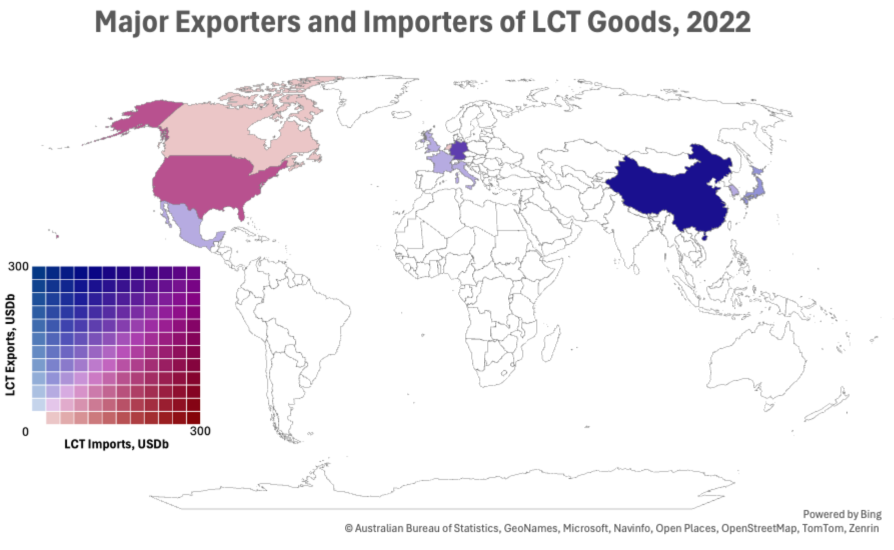
MACRO
- Capital depreciation
- Productivity changes
- Labor market frictions
- Socioeconomic changes
- Impacts on international trade, sovereign debt, government revenues, fiscal revenue, sovereign bond spread

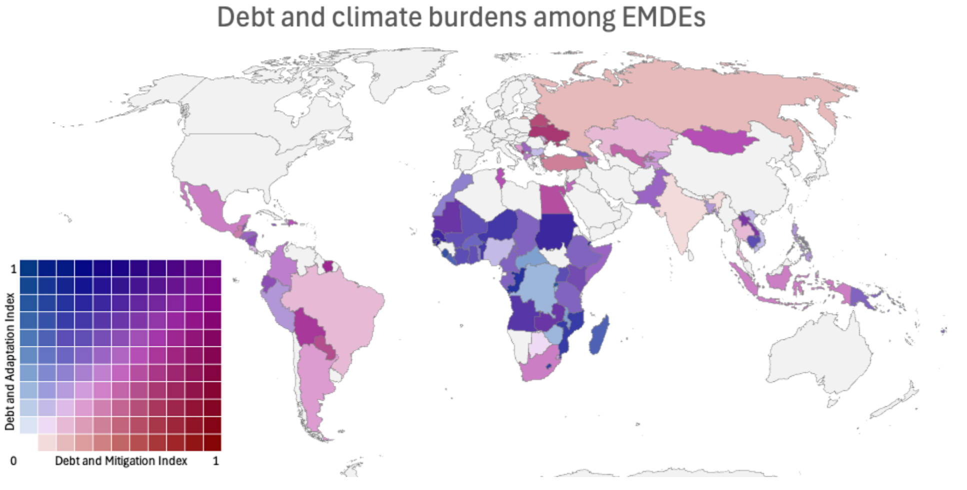
Climate Vulnerability Causes BOP Crises

Climate Policies in Global North Could Cause BOP/Debt Crises in Global South



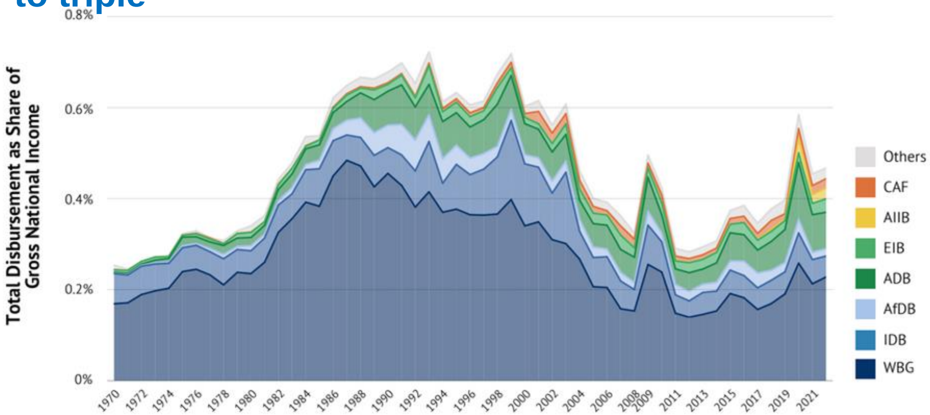
Developing Countries Locked out of New Climate Economy Trade





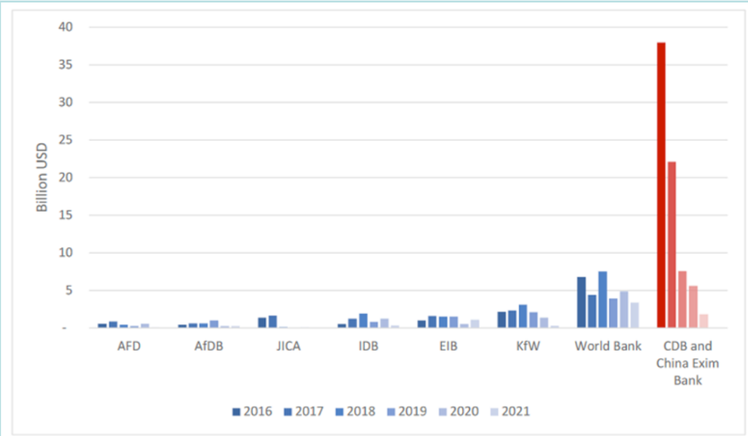
Development Finance and Climate Change

MDB Lending levels at lowest level since 1970s, need to triple



China adds a 'World Bank' to the Global South

China finances more energy than everyone else combined



RESEARCH THAT MATTERS: IMPACTS

TASK FORCE ON CLIMATE, DEVELOPMENT AND THE IMF

- Resilience and Sustainability Trust; Incorporating Climate in Models for Debt Sustainability Analysis

G20 BRASIL 2024 BUILDING A JUST WORLD AND A SUSTAINABLE PLANET

- Capital Needs reviews of MDBs for climate and debt sustainability

CLUB DE MADRID

- Lead Expert on International Financial Architecture Reform

CCICED

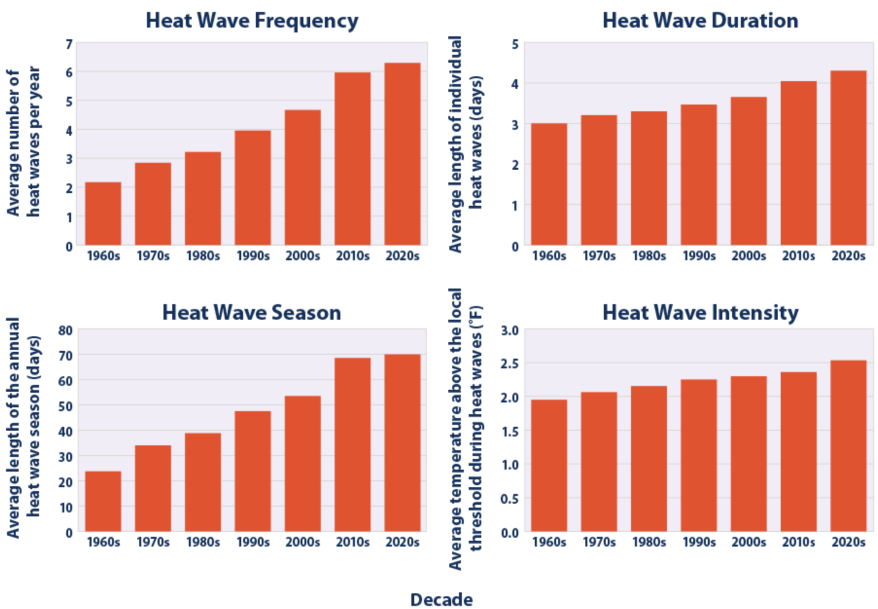
- Co-Chair Task Force on Green BRI---***GIFP and GAPFREE***

STRATEGIES TO BUILD URBAN HEAT RESILIENCE WHILE TRANSFORMING OUR ENERGY SYSTEM

M. Patricia Fabian

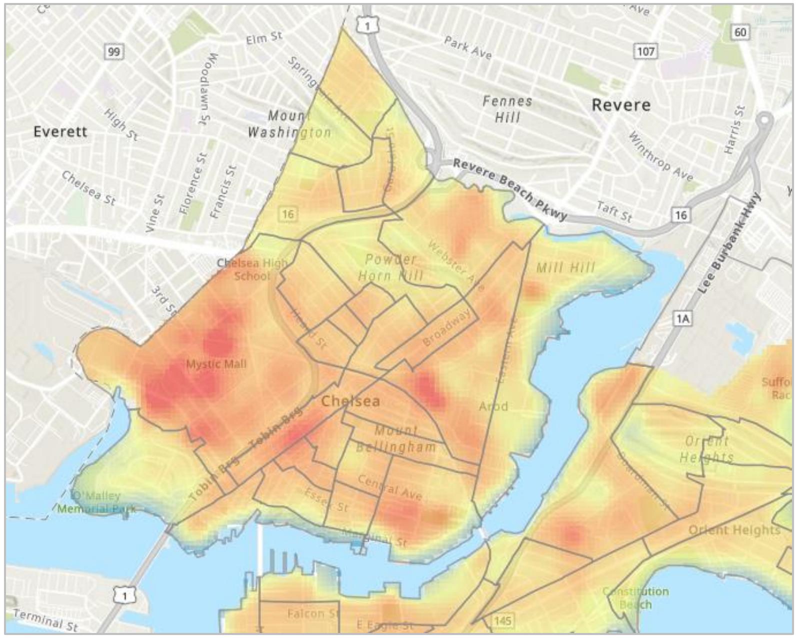
Associate Professor of Environmental Health, School of Public Health
Associate Director, Institute for Global Sustainability

Heat increasing in frequency, intensity and duration



https://www.epa.gov/climate-indicators/climate-change-indicators-heat-waves

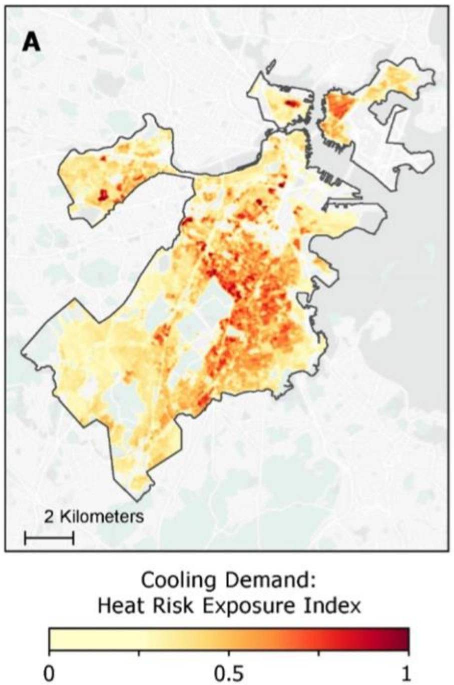
Living in urban heat islands (UHI) – some neighborhoods are hotter



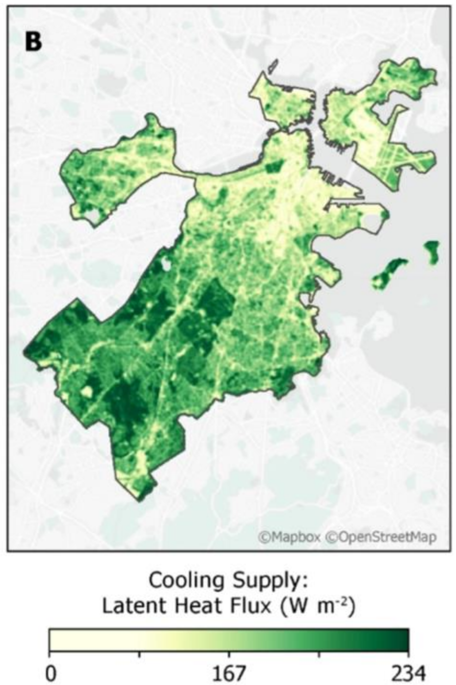
https://www.c-heatproject.org/datadashboard
Land surface temperature in Chelsea, MA from Landsat 8, Summer 2016

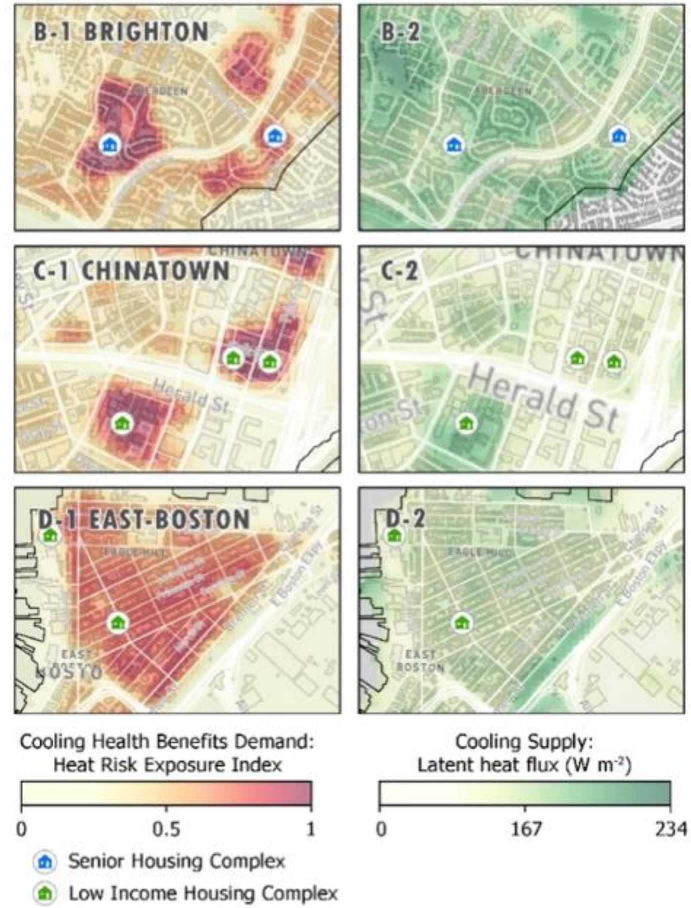
Where should we cool?

Cooling demand (people +UHI + vulnerability)



Cooling supply (trees)



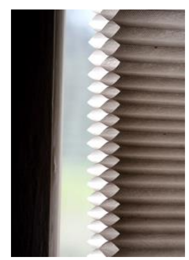


Tieskens et al, 2020 *STOTEN*

How can we cool? – Energy transition opportunities

- Neighborhood – reduce local heat islands

- Buildings – improve ability to cool in place at home, school, & work



- Individual – reduce vulnerability

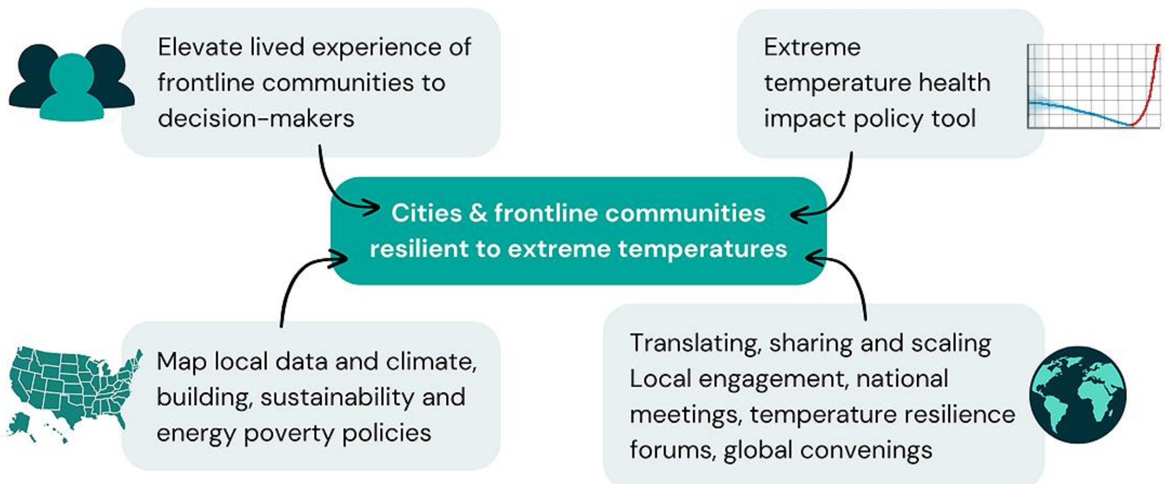
HEAT PROJECTS

Making extreme weather health impacts visible through household energy, climate, and sustainability policies in frontline communities

Chelsea and East Boston Heat Project
Barr Foundation

B-COOL
Boston COOL
The Boston Foundation

Climate Impact Award
Wellcome Trust Foundation



Dialogue Earth

nola gov

A BETTER CITY — IMAGINING A BRIGHT FUTURE. MAKING IT A REALITY.

I SEE CHANGE

City of Phoenix

CITY of BOSTON

BOSTON UNIVERSITY

Boston University Office of Research

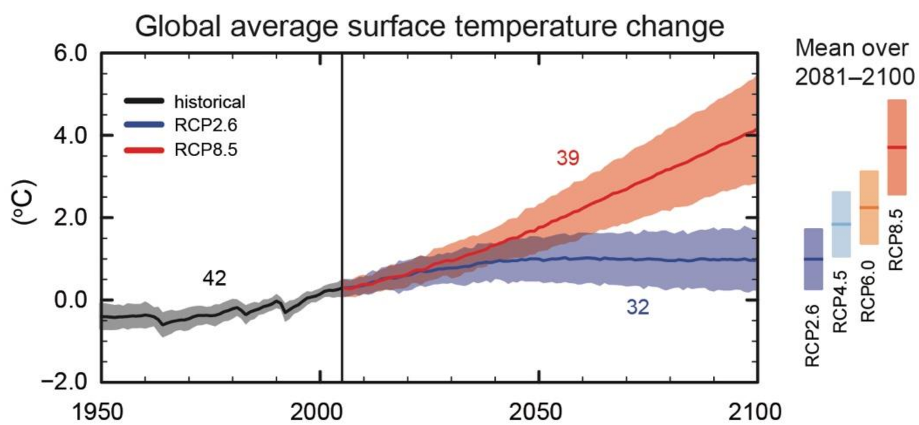
Interactions of climate change, urbanization, and building energy consumption: from global to local scales

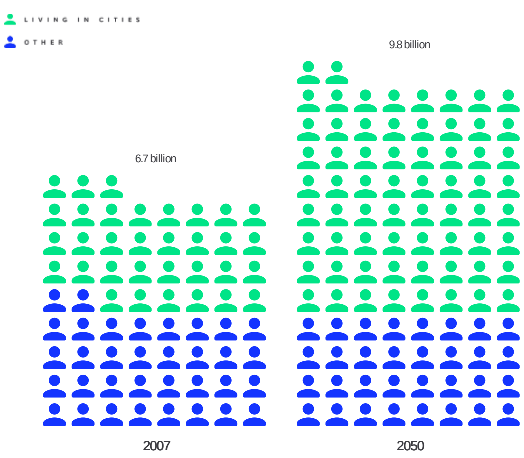
Dan Li

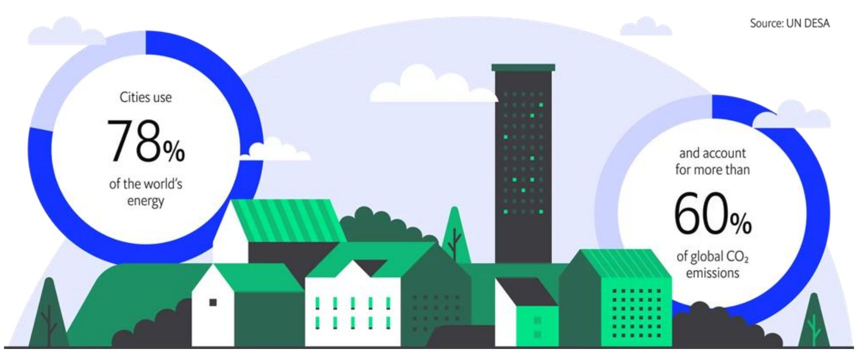
Associate Professor

Earth & Environment and Mechanical Engineering

Climate change, urbanization, building energy consumption

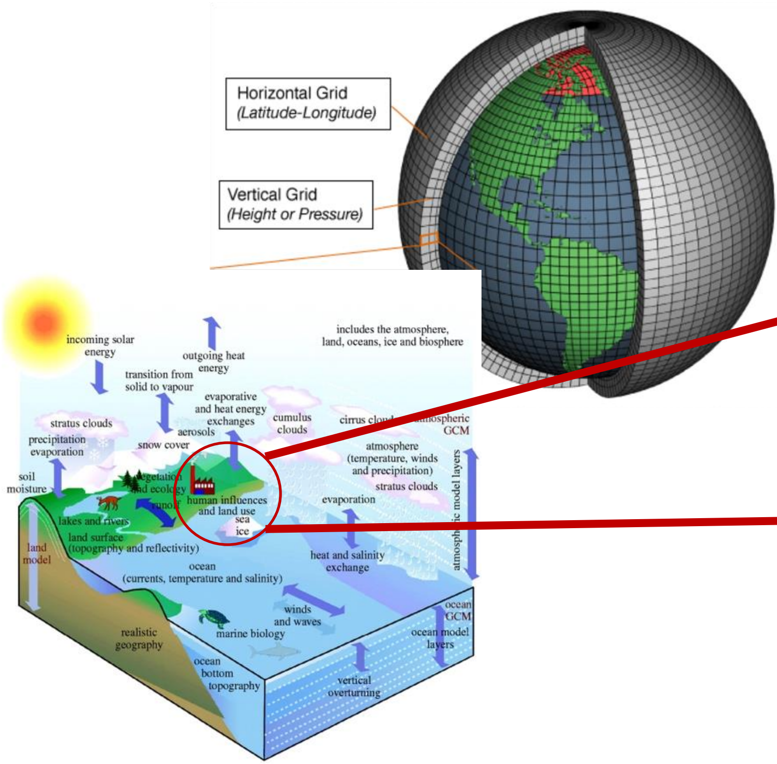


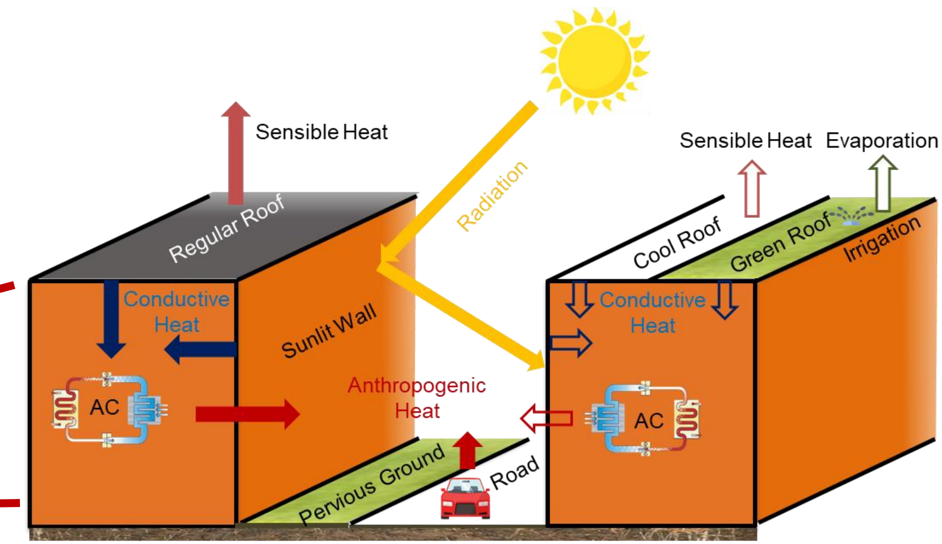




https://impact.economist.com/sustainability/net-zero-and-energy/cities-road-to-2050-lighting-the-way-to-sustainable-growth

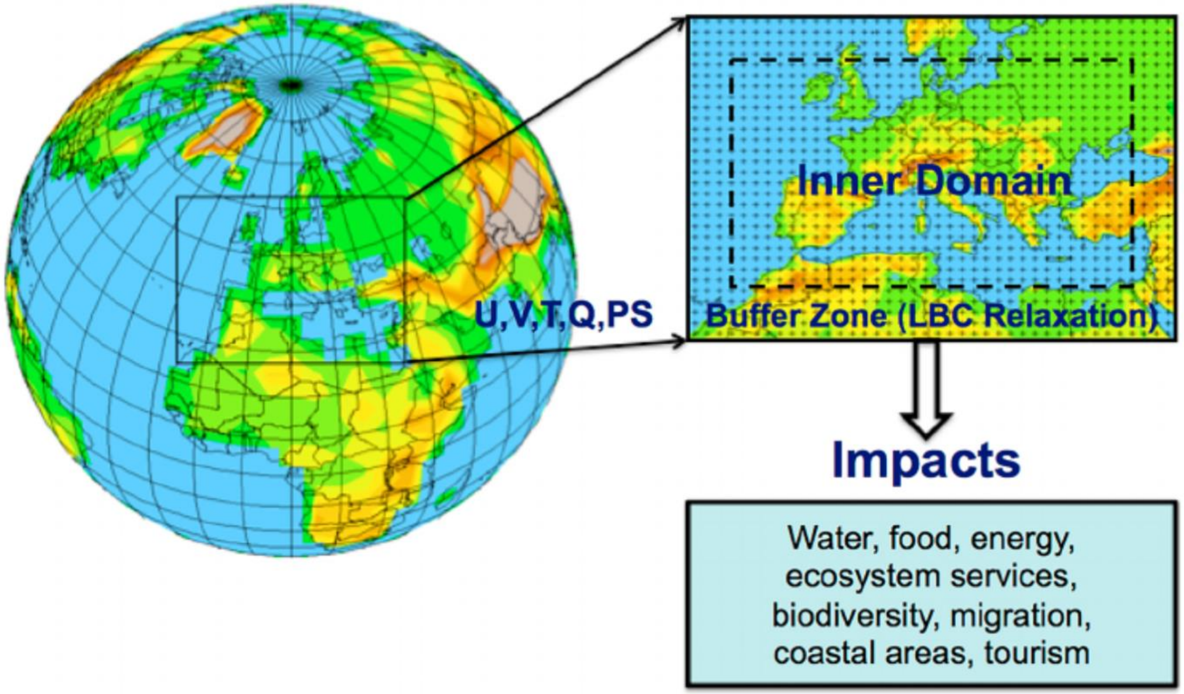
Urbanized global climate modeling





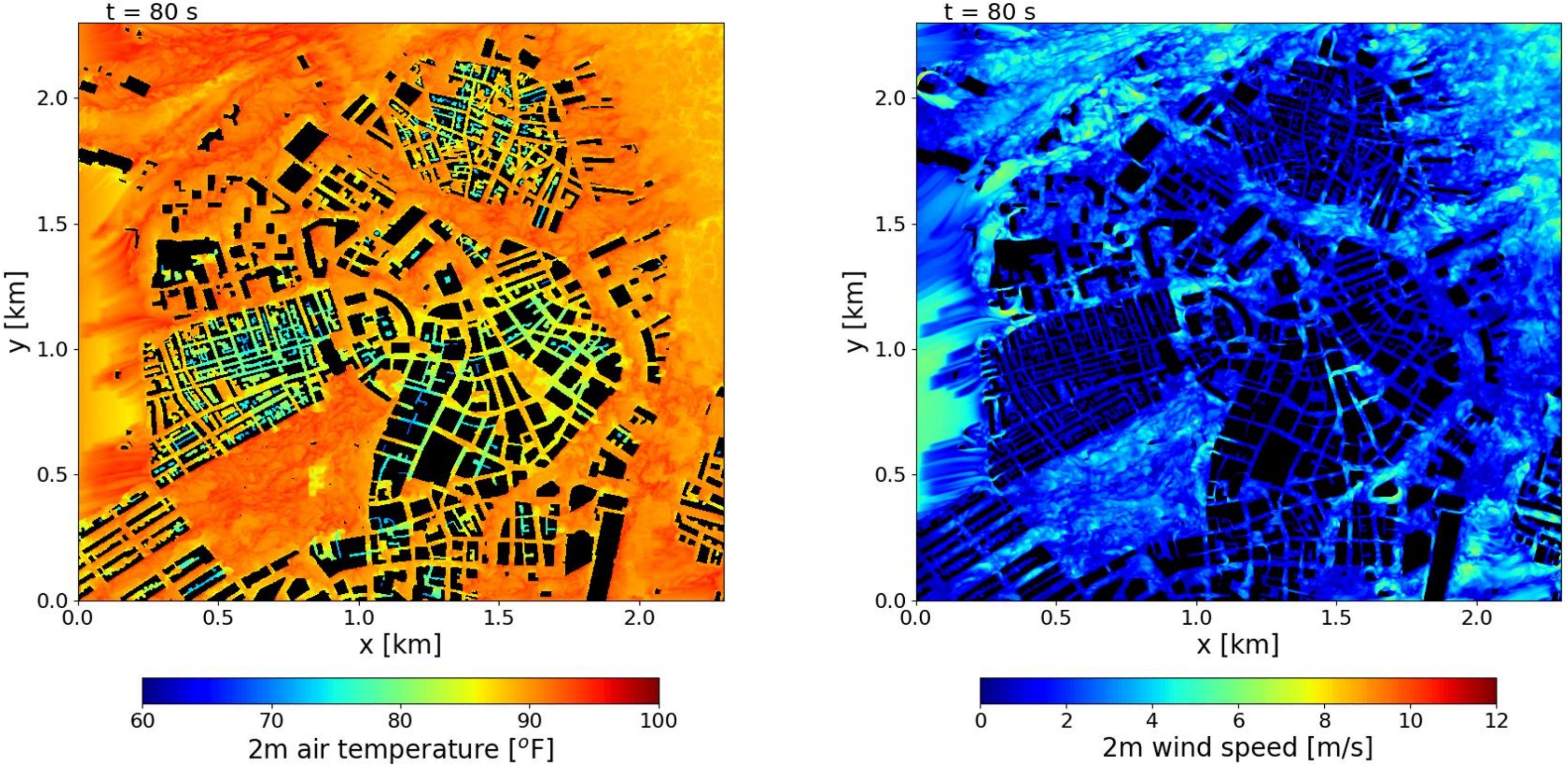
Wang et al. (2020) *Geophysical Research Letters*
Wang et al. (2021) *Environmental Research Letters*
Wang et al. (2023) *Environmental Research Letters*
Li et al. (2024) *Science Advances*

From global to local scales



Giorgi, F. (2019). *Journal of Geophysical Research: Atmospheres*

From global to local scales

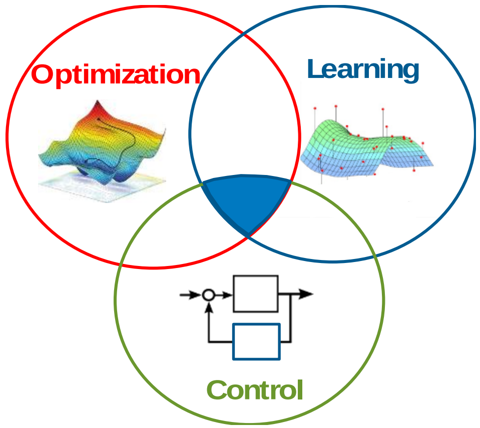


Advancing Optimization and Control of Sustainable Power and Energy Infrastructures

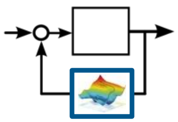
Emiliano Dall'Anese

Associate Professor
Department of Electrical and Computer Engineering
Division of Systems Engineering
College of Engineering

Research overview

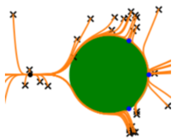


Online feedback optimization

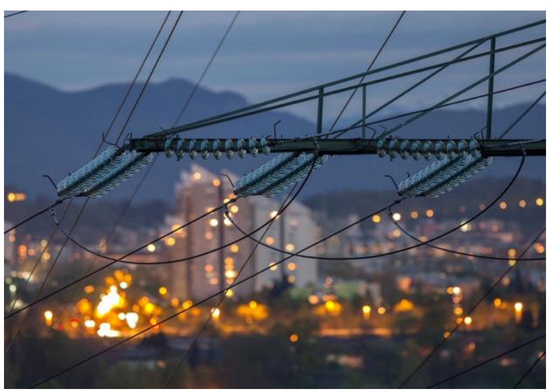


Optimization under uncertainty

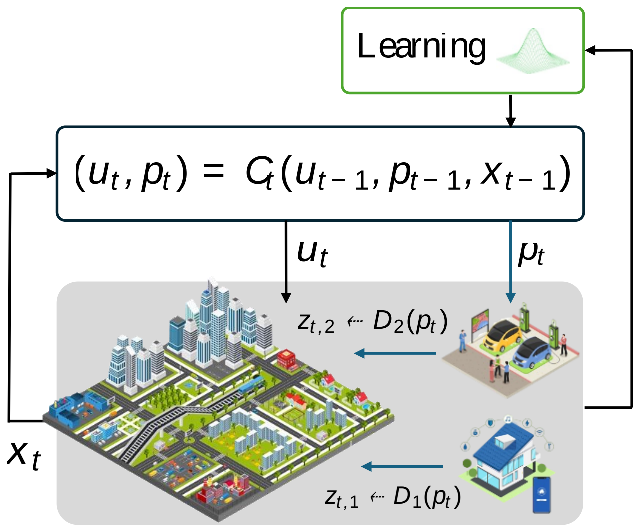
Safe optimization-based control



Main driver: Sustainable energy systems and infrastructures

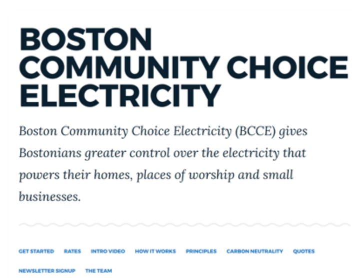


Designing control and optimization architectures



- Embed performance and reliability metrics
- Account for operational and reliability constraints
- Account for market and operational structures
- Learning of models and system behavior

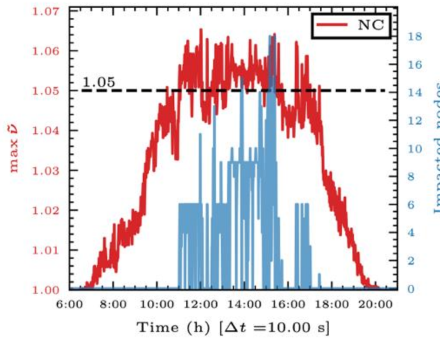
A new generation of control and AI for energy systems


BOSTON COMMUNITY CHOICE ELECTRICITY

Boston Community Choice Electricity (BCCE) gives Bostonians greater control over the electricity that powers their homes, places of worship and small businesses.

Example: DER integration distribution grids

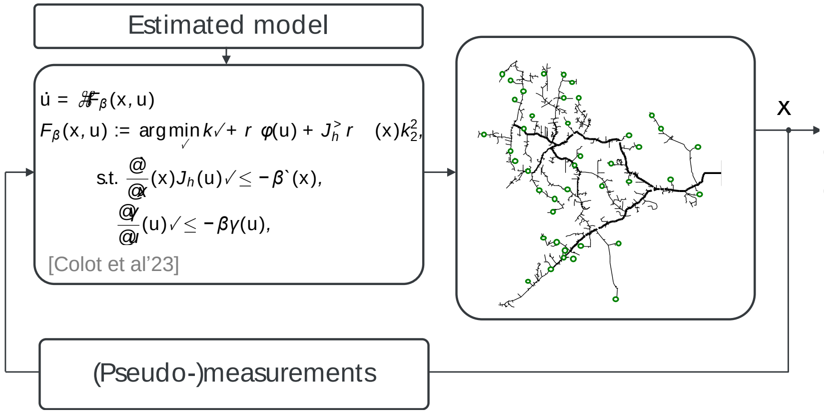
Over-voltages

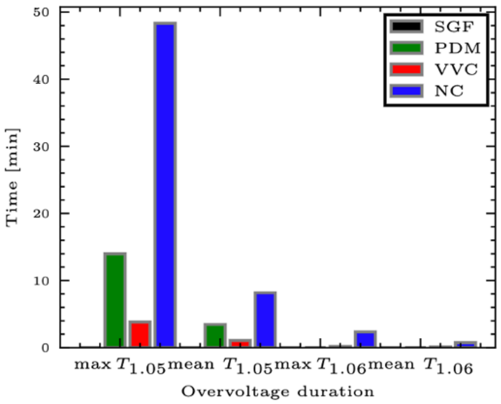


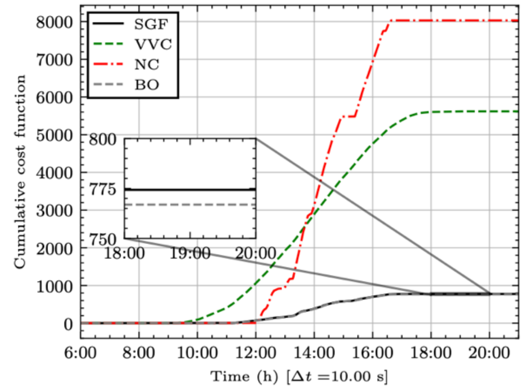
Overloading

Large & decentralized

Research: How to reliably integrate renewable energy systems and DERs in large scale?

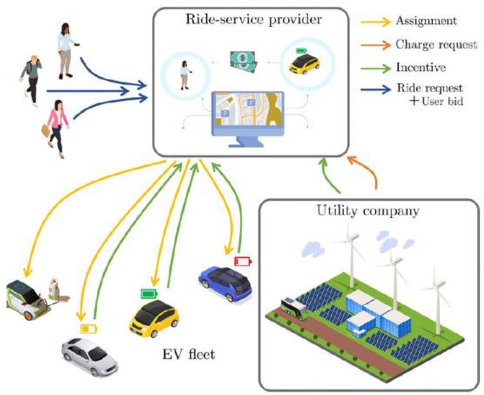


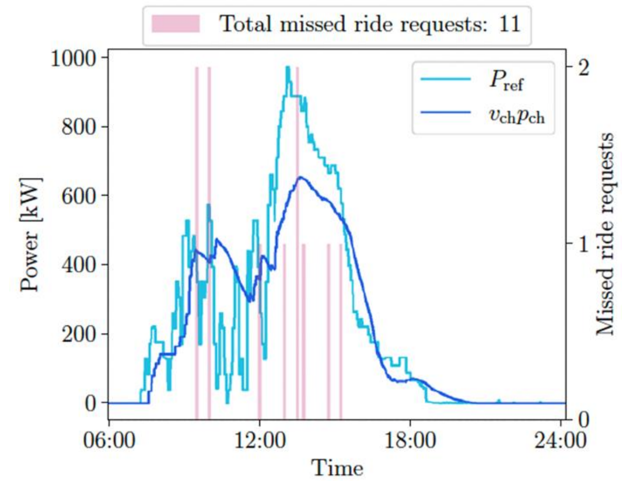




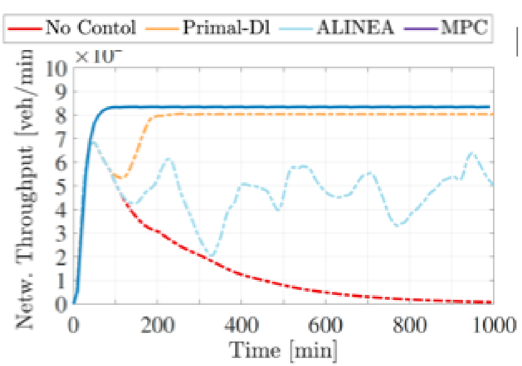
Example: sustainability of the transportation sector

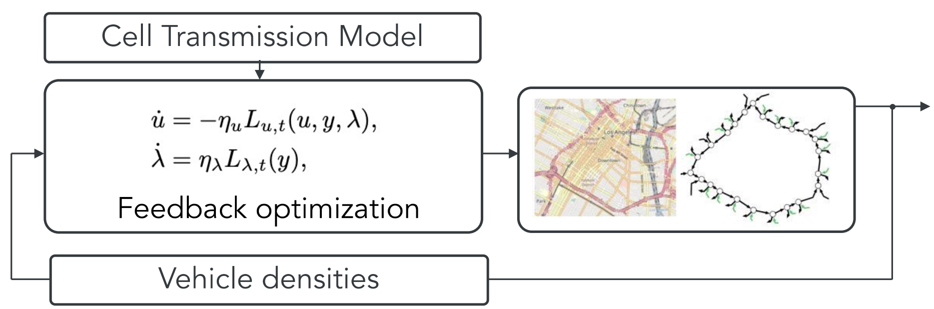
How can renewable-based EV charging be maximized without disrupting of services?





How can can we improve traffic congestion and enable electrification?





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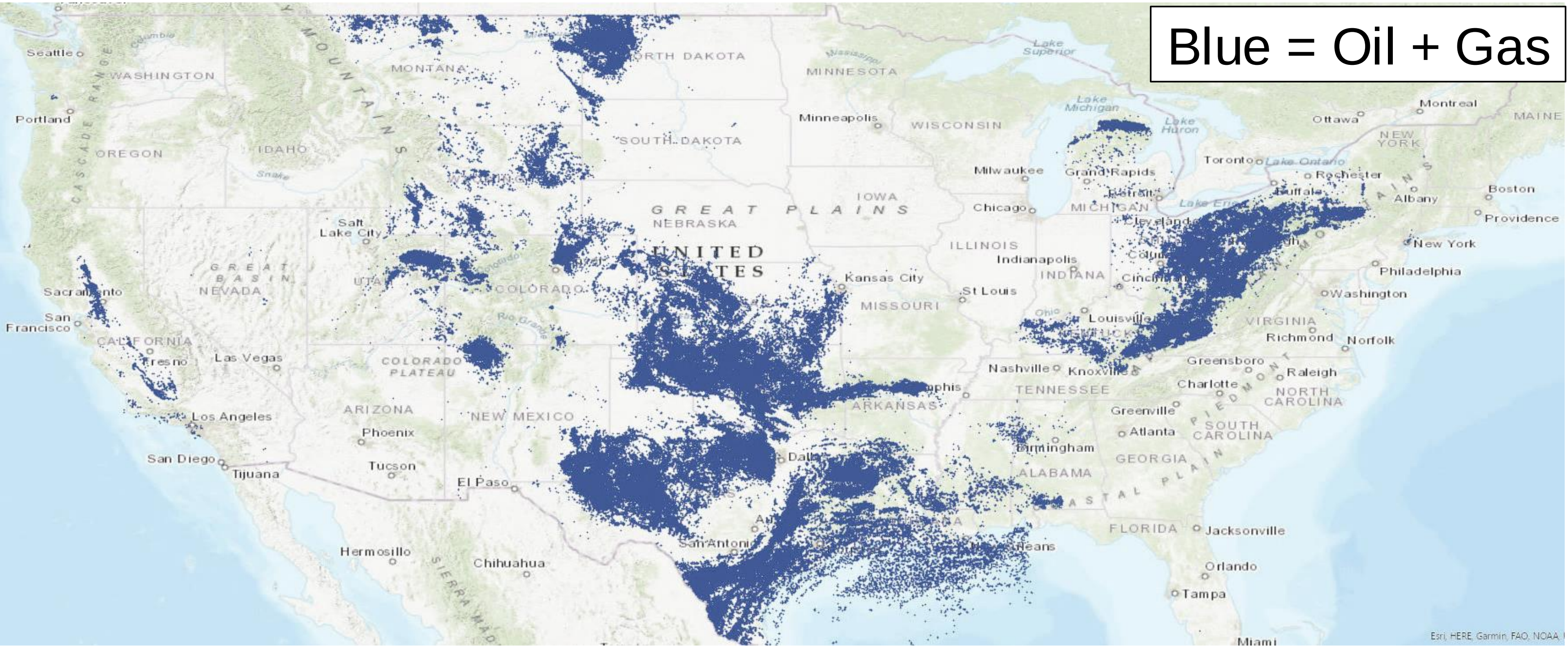
Oil & Gas Development and Population Health: An Environmental Hazard or Economic Threat?

Mary D. Willis

Assistant Professor

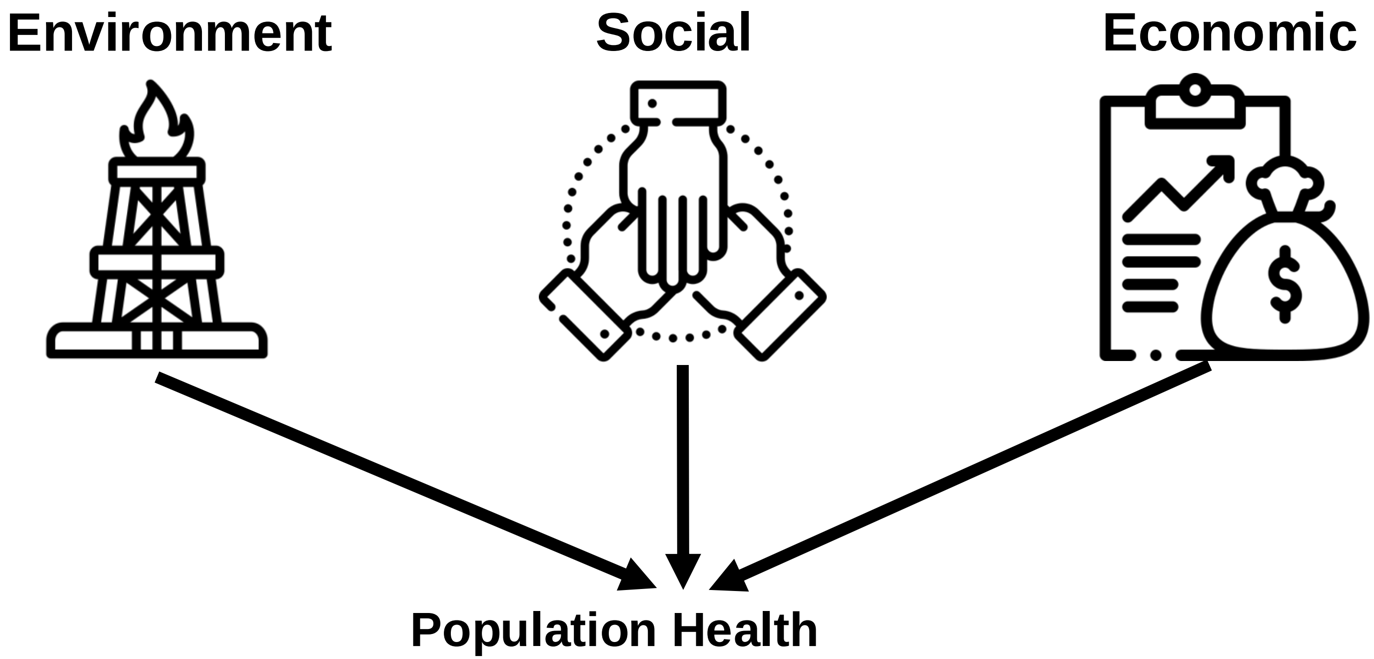
Department of Epidemiology, School of Public Health

Oil & Gas Development in the U.S.

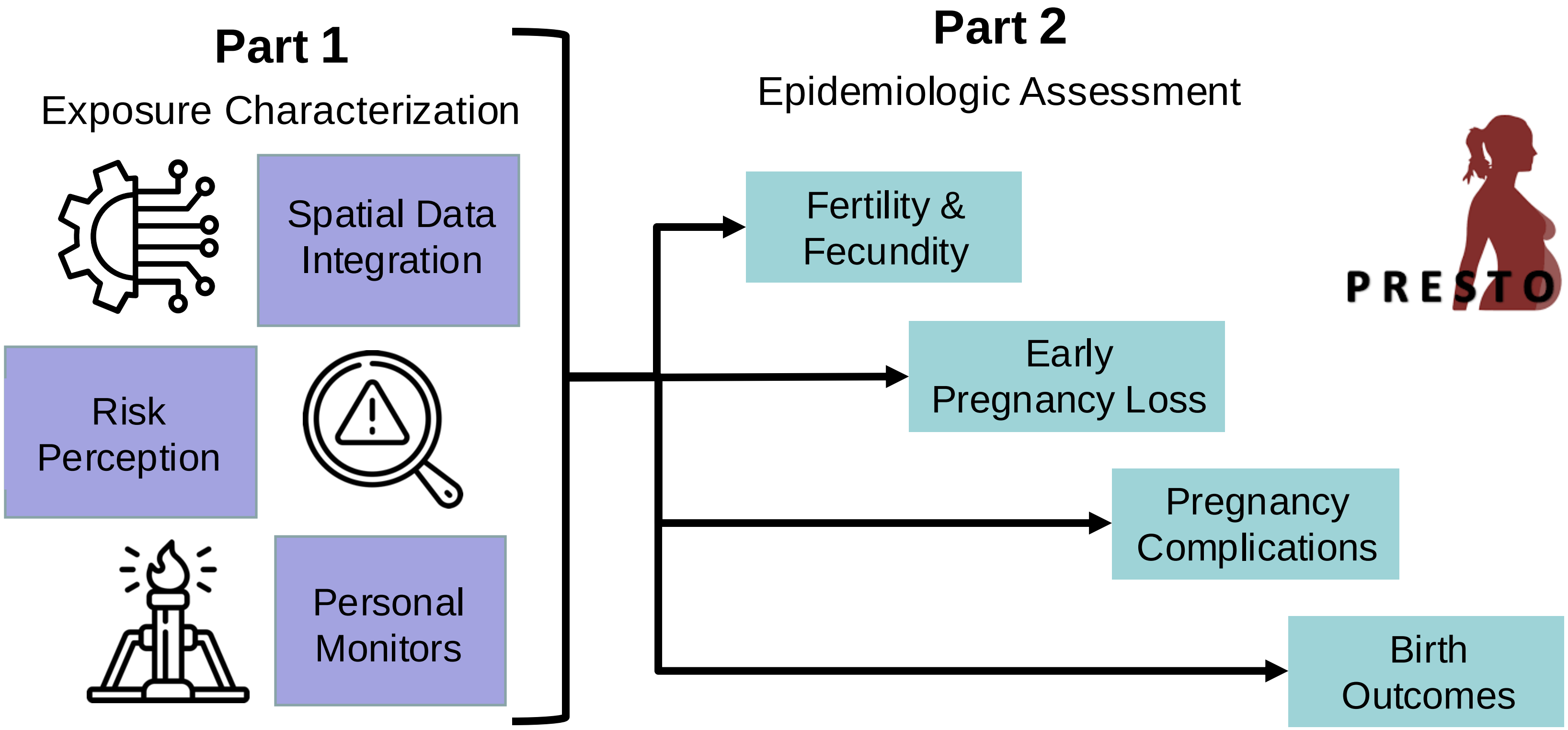


17.6 million Americans reside within 1.6 km (1 mile) of active oil or gas development

Multidimensional Community Impacts of Oil & Gas



Oil & Gas Development as an Environmental Hazard



This industry produces reproductive toxicants at levels that may harm fertility and pregnancy

Boston University Office of Research

Funded by NIH Office of the Director,
DP5-OD033415, PI: Willis

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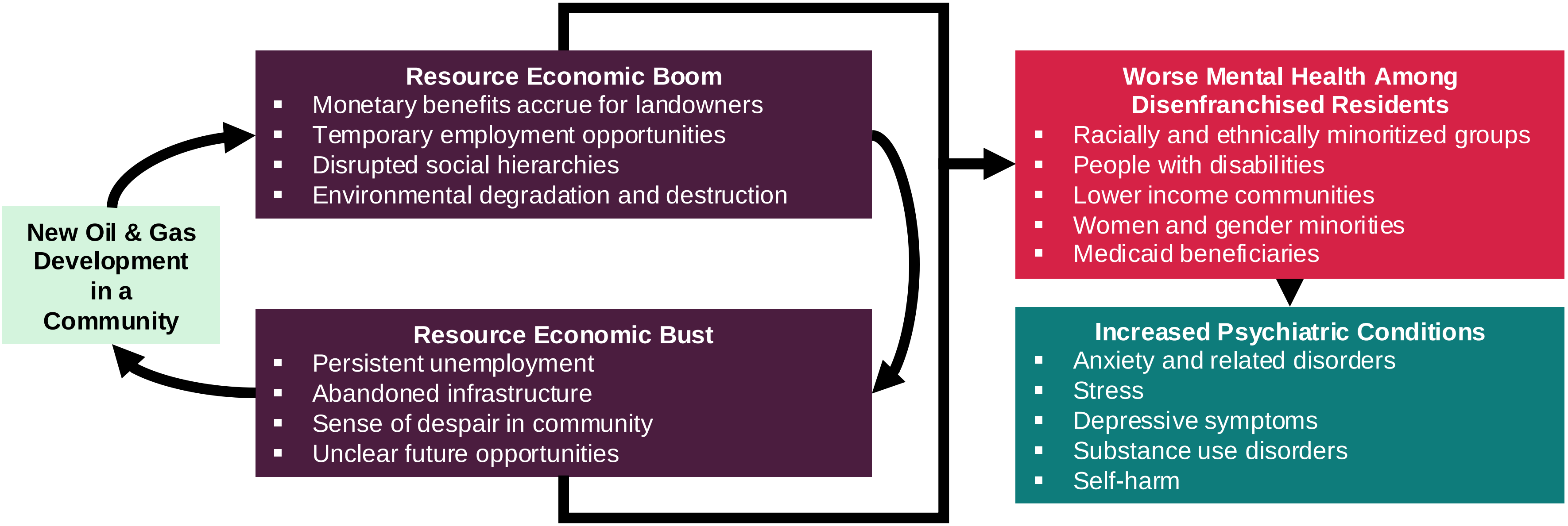
Oil & Gas Development as an Economic Threat



Cycles of boom-and-bust economies may threaten community mental health

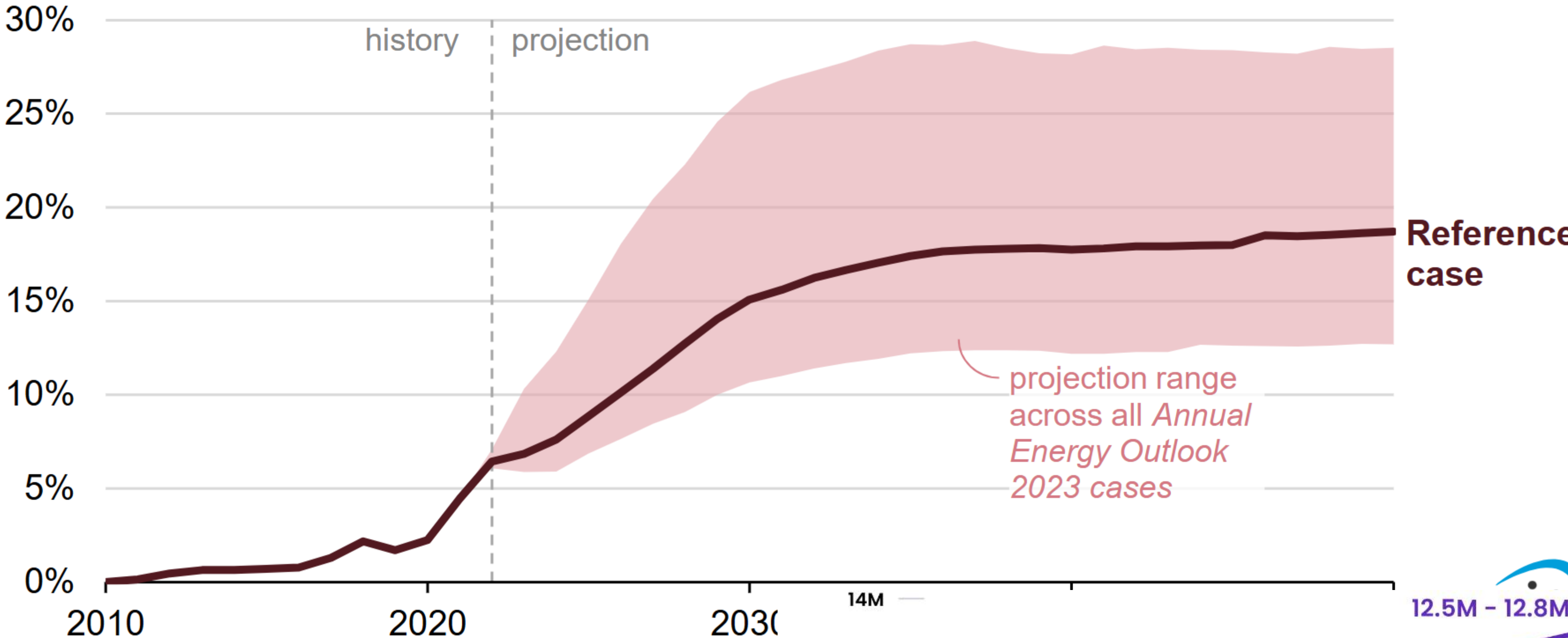
Equity, justice and racism in the electric mobility transition

Benjamin K. Sovacool

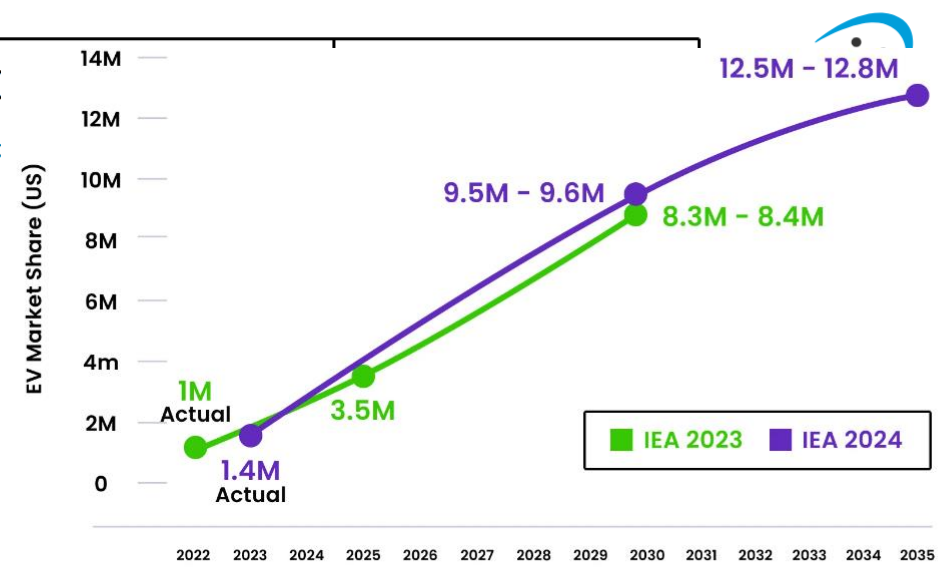
Professor of Earth & Environment
College of Arts & Sciences

We are amid a global electric vehicle ‘revolution’

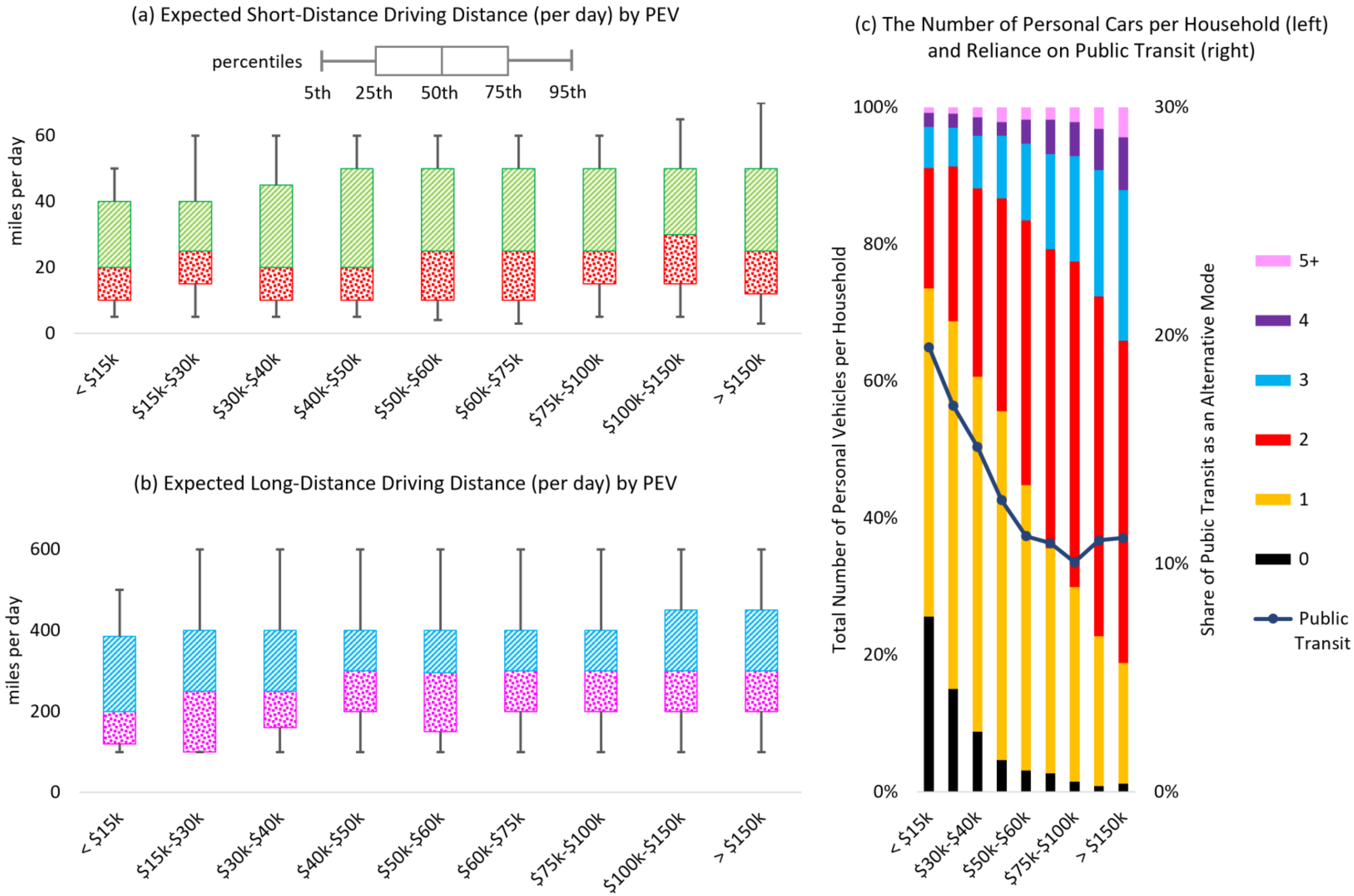
Market share of electric light-duty vehicles, United States (2010–2050)
percentage of sales



Data source: U.S. Energy Information Administration, *Annual Energy Outloc*



- Online public survey of 7,266 adults (18 or older)

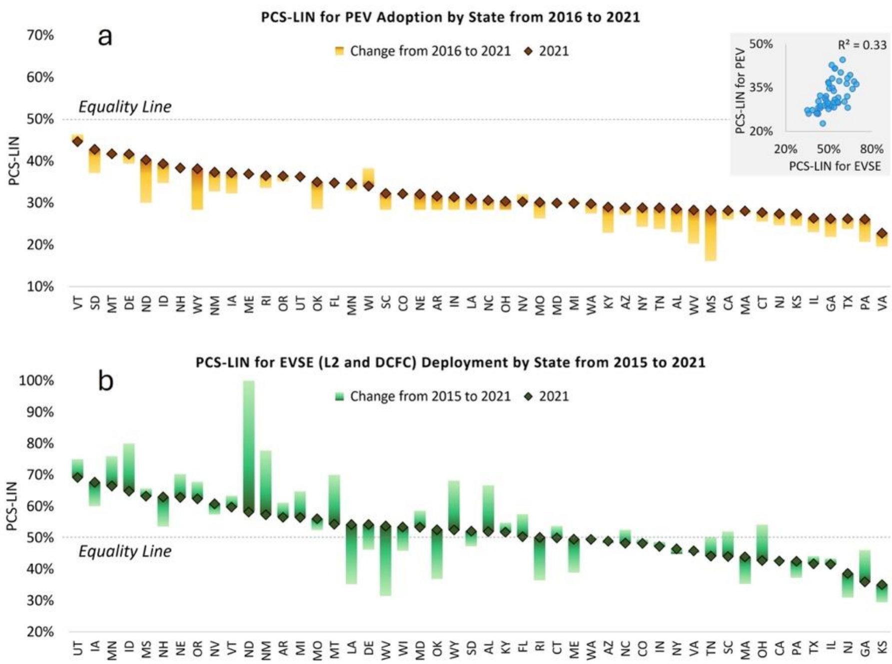


Lee, D-Y, MH McDermott, BK Sovacool, and R Isaac. "Toward Just and Equitable Mobility: Socioeconomic and Perceptual Barriers for Electric Vehicles and Charging Infrastructure in the United States," *Energy & Climate Change* 5 (December, 2024), 100146, pp. 1-19.

- Online public survey of 7,266 adults (18 or older)

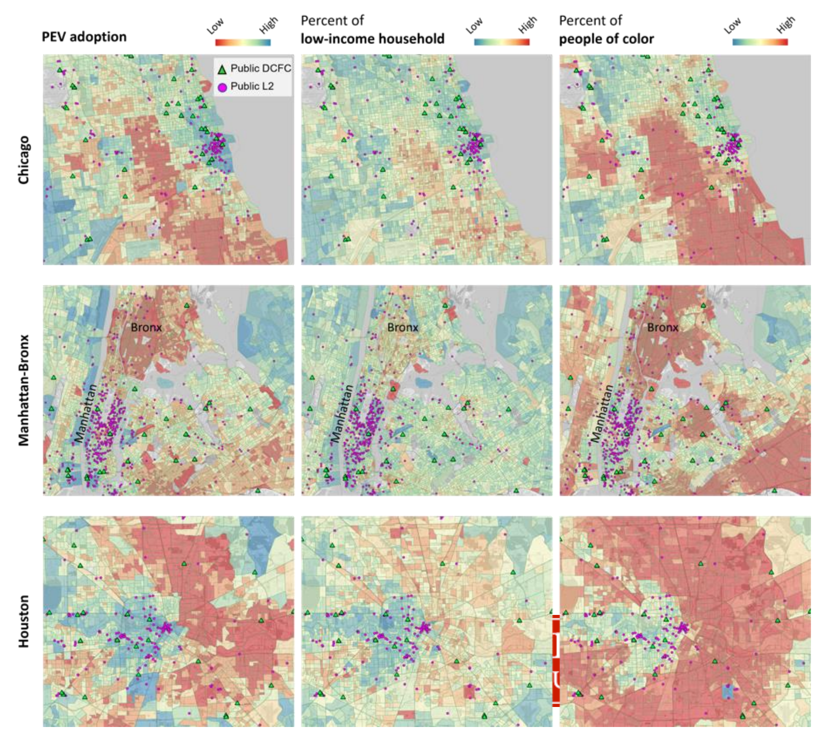
	Overall	18-29	30-39	40-49	50-69	70-79	80-89	90+
Cleaner air (no tailpipe emissions)	**19%**	18%	19%	19%	19%	20%	19%	18%
Generally, better for the environment	**17%**	17%	17%	18%	17%	18%	17%	15%
Cheaper fuel cost	**16%**	18%	19%	18%	15%	12%	12%	13%
Ability to refuel/charge at home	**14%**	14%	14%	14%	15%	14%	15%	16%
Noise reduction (car runs quietly)	**12%**	11%	11%	11%	13%	15%	15%	13%
Better driving efficiency (consumes less energy)	**11%**	12%	12%	11%	10%	9%	11%	9%
Better acceleration (than gasoline-powered cars)	**6%**	7%	6%	6%	5%	4%	5%	4%
I do not think there are benefits to electric vehicles over conventional gasoline cars	**4%**	2%	3%	3%	5%	9%	8%	13%

Lee, D-Y, MH McDermott, BK Sovacool, and R Isaac. "Toward Just and Equitable Mobility: Socioeconomic and Perceptual Barriers for Electric Vehicles and Charging Infrastructure in the United States," *Energy & Climate Change* 5 (December, 2024), 100146, pp. 1-19.



Geospatial modeling of EV registrations and driving patterns

[Lee, DY, A Wilson, MH McDermott, BK Sovacool, R Kaufmann, R Isaac, C Cleveland, M Smith, M Brown, and J Ward. "Does electric mobility display racial or income disparities? Quantifying inequality in the distribution of electric vehicle adoption and charging infrastructure in the United States," *Applied Energy* 378 (January, 2025), 124795, pp. 1-17.]



Geospatial modeling of adoption and charging infrastructure

[Lee, DY, A Wilson, MH McDermott, BK Sovacool, R Kaufmann, R Isaac, C Cleveland, M Smith, M Brown, and J Ward. "Does electric mobility display racial or income disparities? Quantifying inequality in the distribution of electric vehicle adoption and charging infrastructure in the United States," *Applied Energy* 378 (January, 2025), 124795, pp. 1-17.]

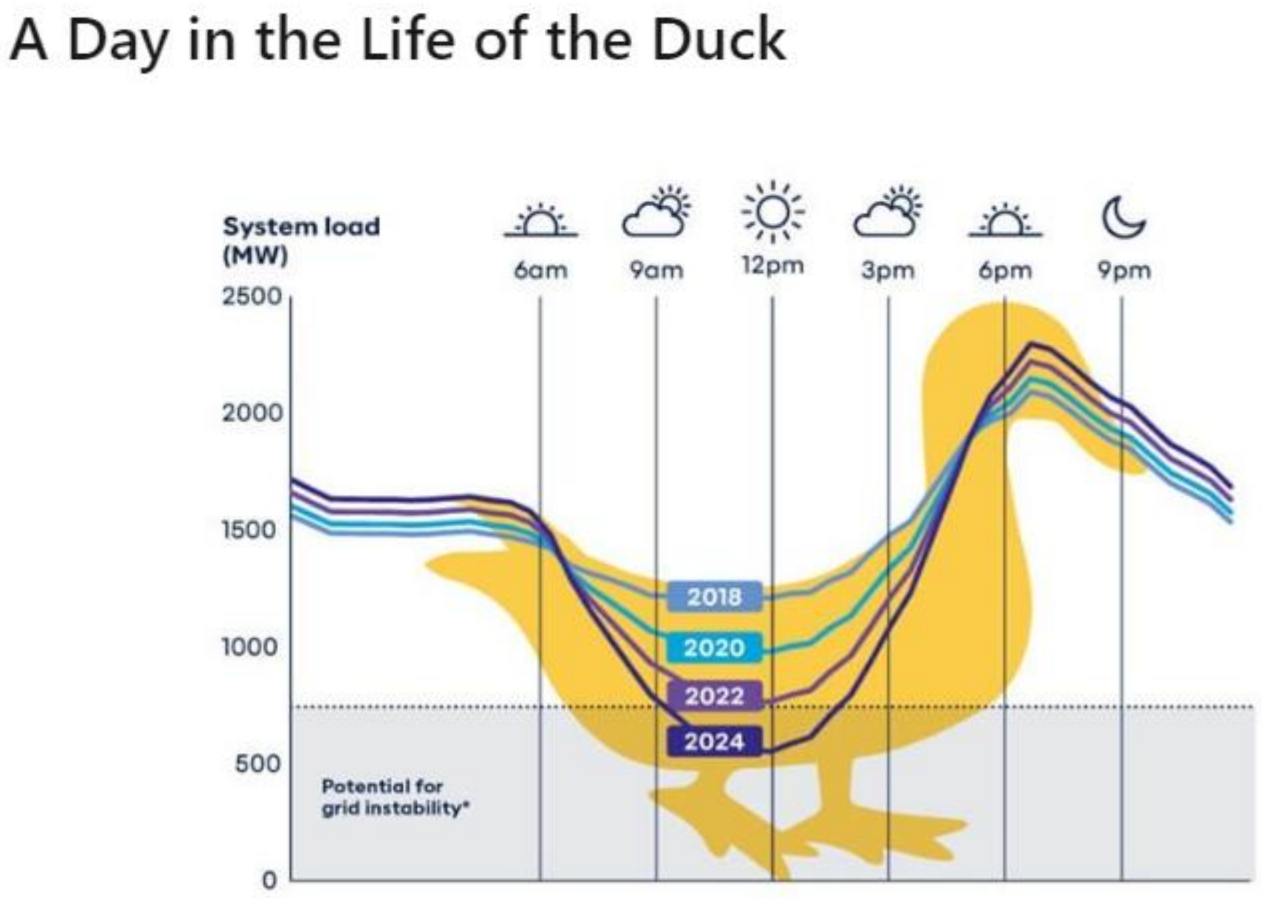
Grid Scale Renewable Energy Storage: Reversible Solid Oxide Cells

Srikanth Gopalan

Professor

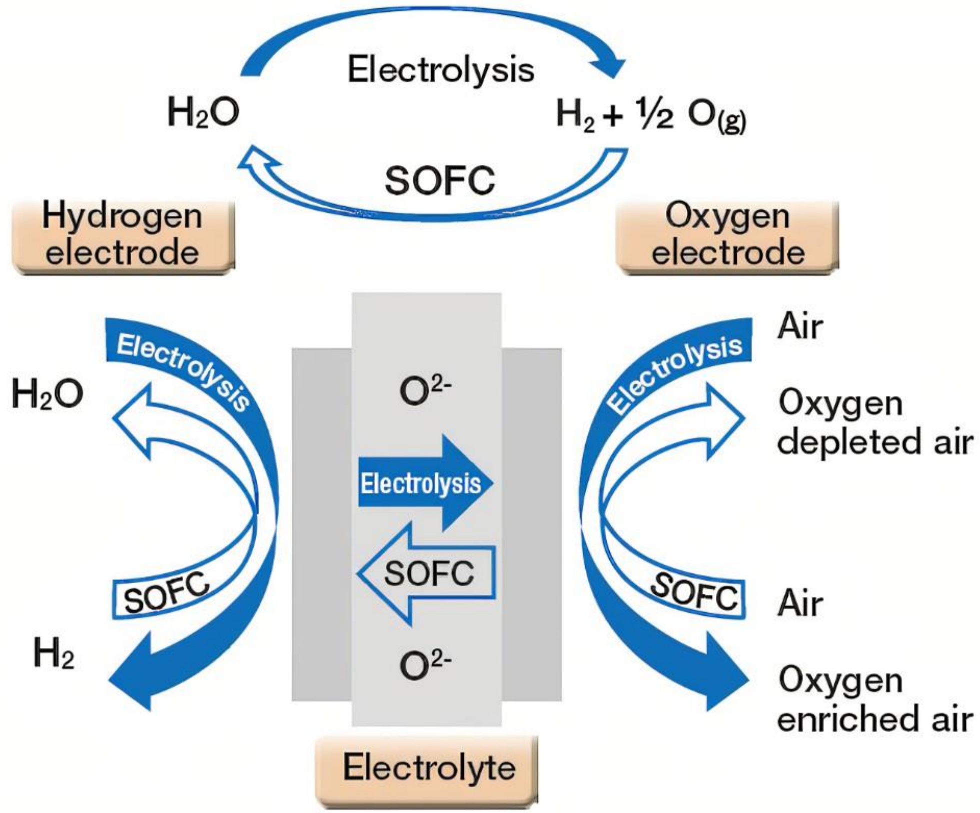
Mechanical Engineering & MSE, College of Engineering

A Day in the Life of the Duck



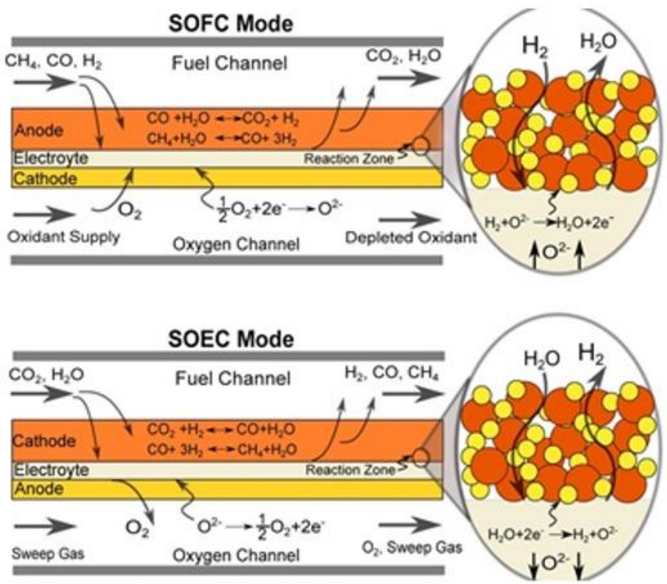
Credit: Stephen Osborne, Data Ranger

Solid Oxide Fuel Cells (SOFC) and Electrolysis Cells (SOECs)

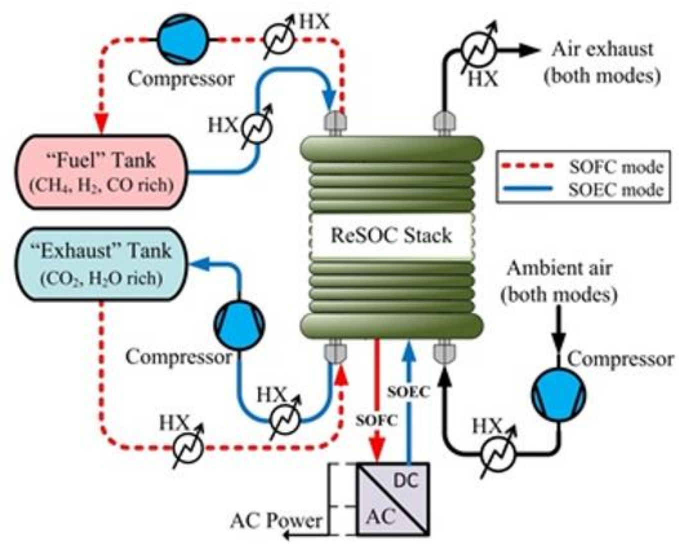


https://www.hitachi-hightech.com/global/en/sinews/si_report/080204/

Reversible Solid Oxide Cells (rSOCs)

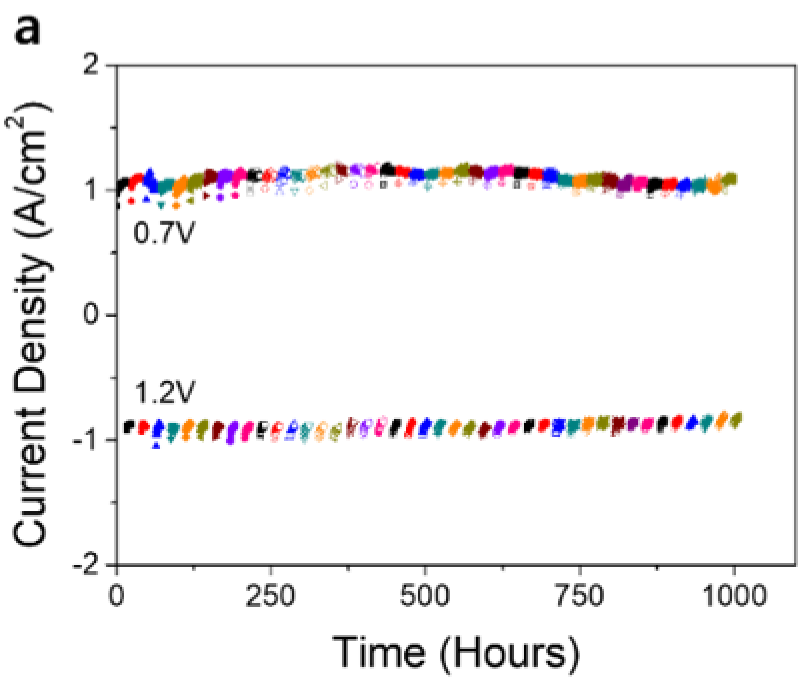


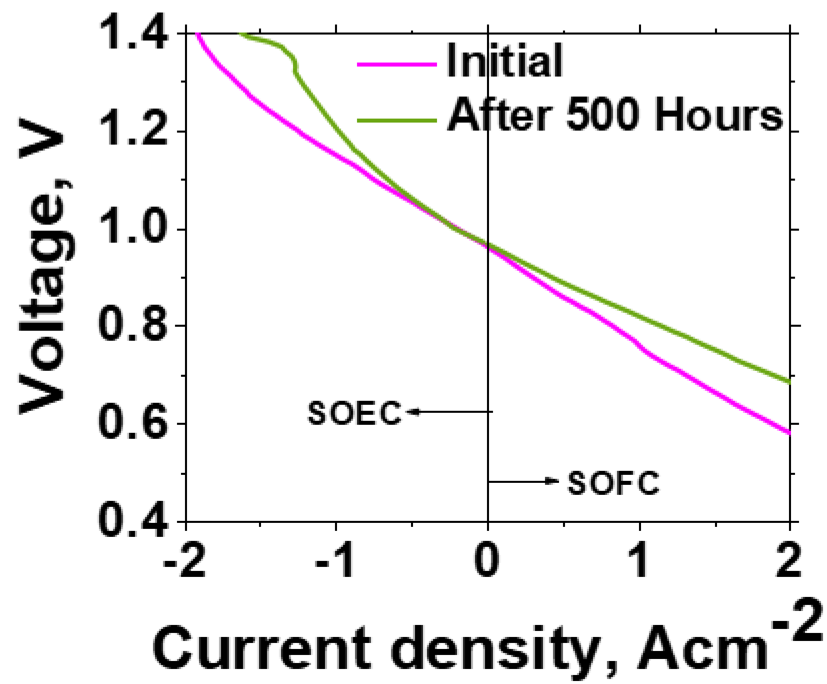
Reversible solid oxide cell operation



Simplified schematic of a ReSOC electrical energy storage system

Cycling from Storage to Generation





- Challenges: Addressing degradation – interfaces, interfaces, interfaces!

Co-PIs: Uday Pal (BU), Soumendra Basu (BU),
Yu Zhong (WPI), Olga Marina (PNNL),
John Pietras (Saint Gobain), Darren Hickey (Upstart Power)

Data Center Demand Response
(and How It Can Help with Clean Energy Transition)

Ayse K. Coskun

Professor

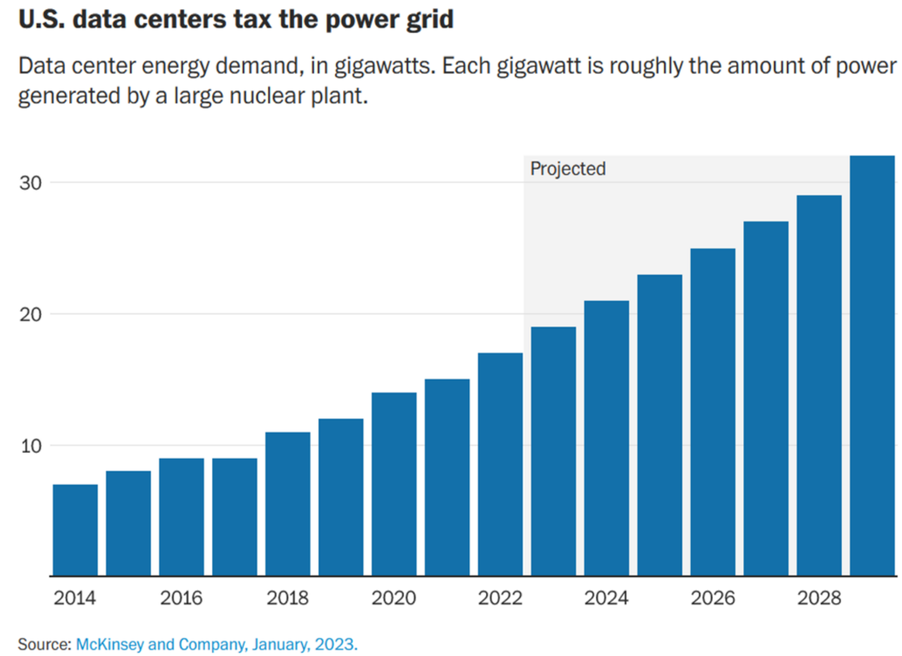
Electrical and Computer Engineering Department

College of Engineering

Data Center Energy Surge

- US: 73 TWh (LBL, 2020)
- Global: 460 TWh (IEA Report, 2022)

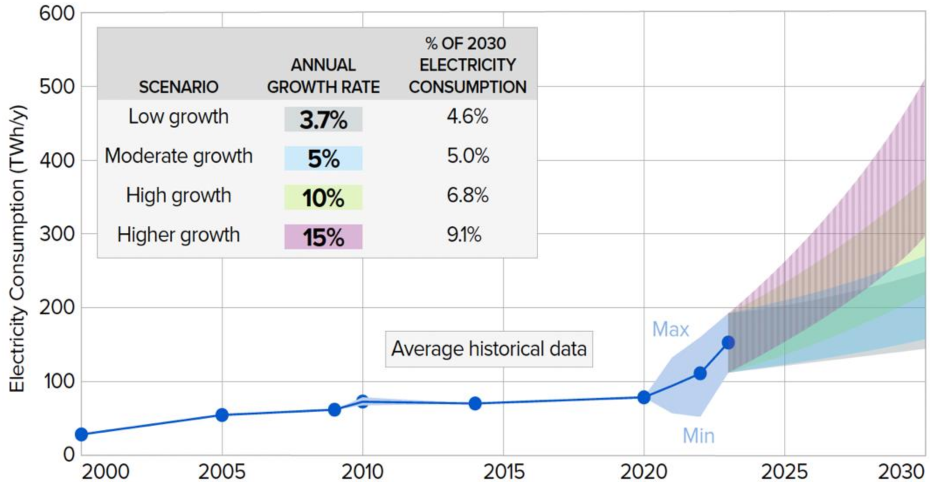
[Figure: baxtel.com/map]

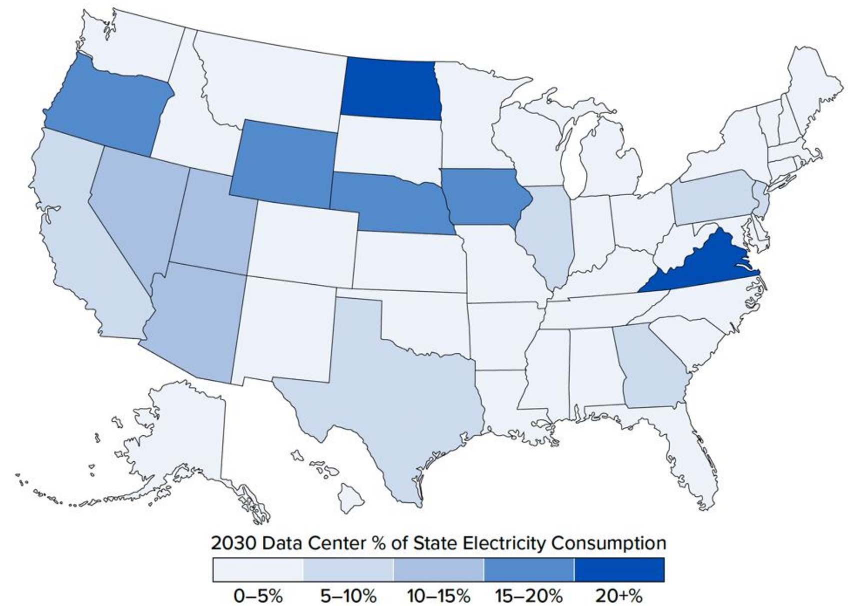


AI is driving the growth in data center infrastructure & power consumption.

Data Center Energy Growth in the US

EPRI Report, *"Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption",* 2024.





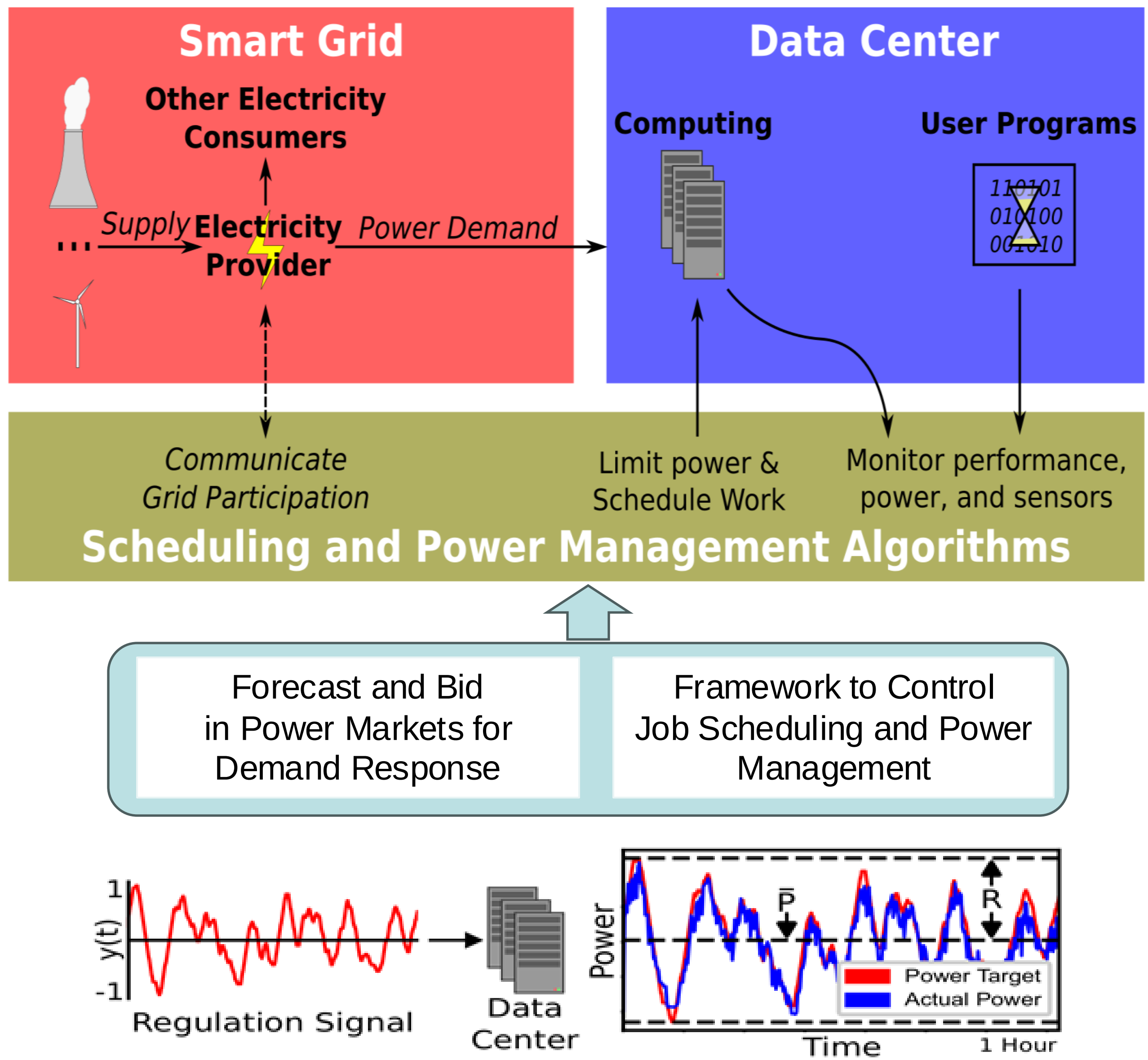
In 2023, about 4,178 billion kWh (or 4.18 trillion kWh) of electricity were generated at utility-scale electricity generation facilities in the US.

About **60% of this electricity generation was from fossil fuels**—coal, natural gas, petroleum, and other gases. About 19% was from nuclear energy, and about **21% was from renewable** energy sources. *(US Energy Information Administration)*

Demand Response
Helps Fix
Supply vs. Demand
Imbalance

More renewables

Better management of peak demand



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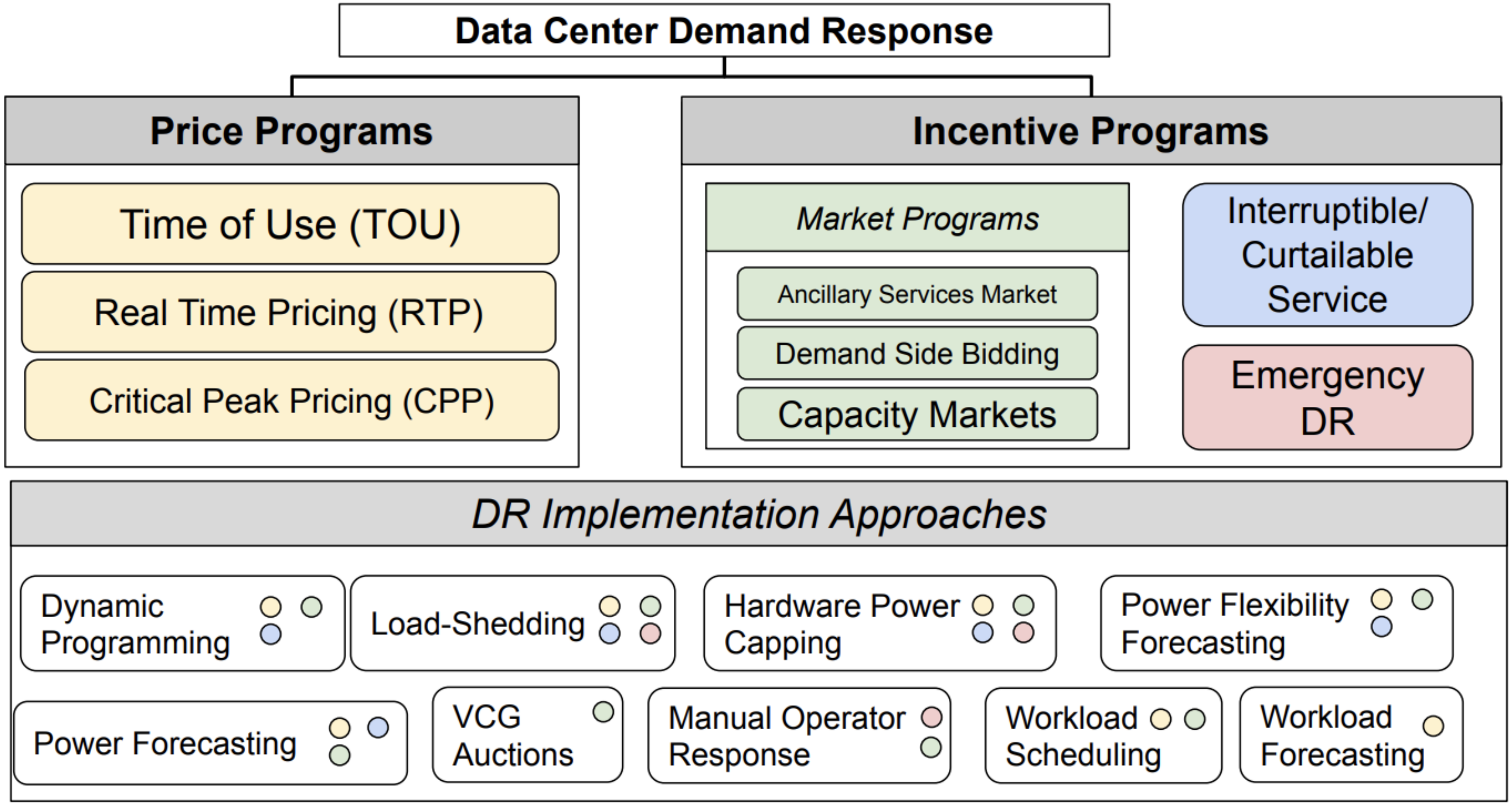
A Taxonomy of Data Center Demand Response



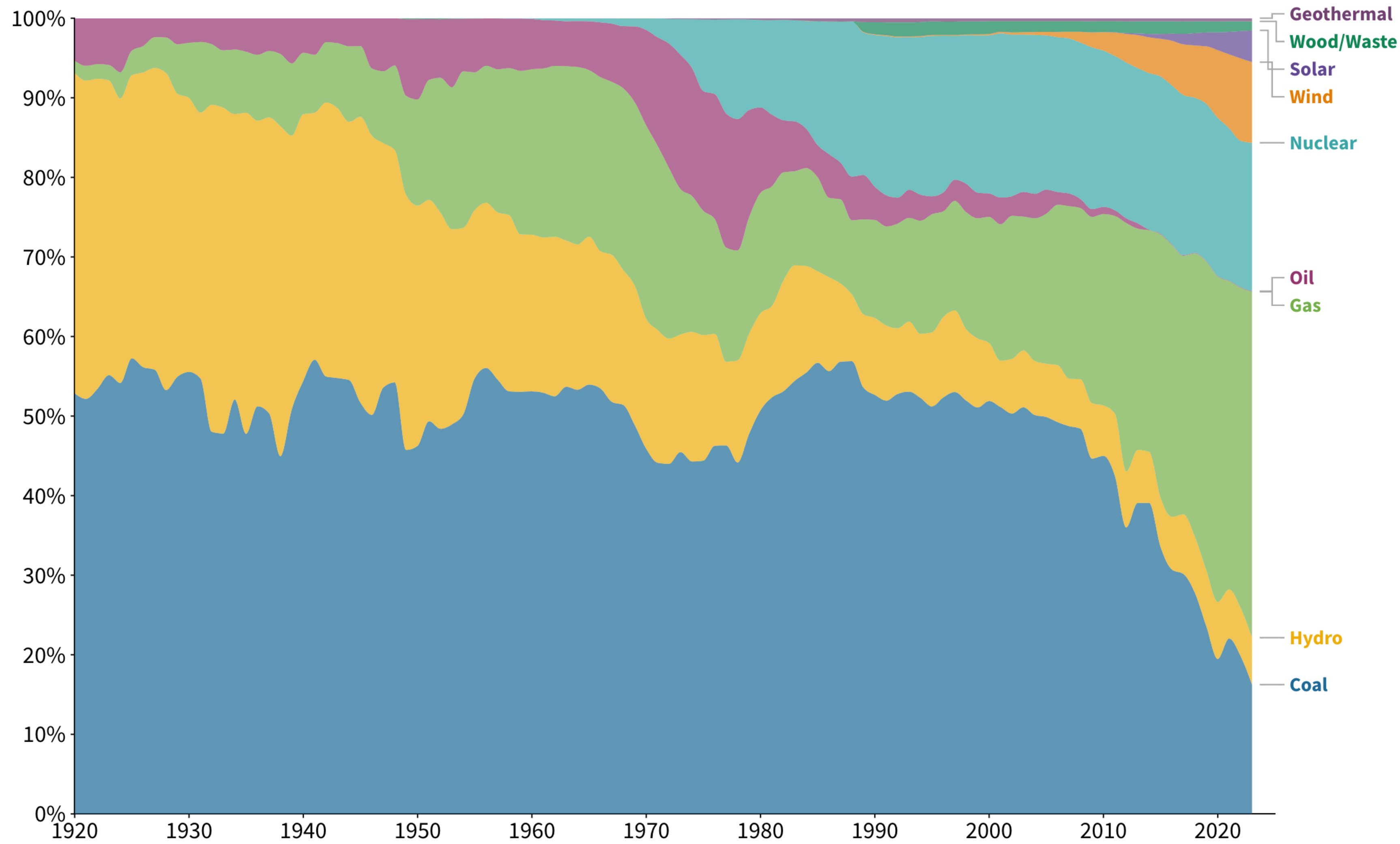
[Coskun, Design Automation and Test in Europe (DATE)'24]

U.S. Electricity in Transition

Cutler J. Cleveland

Professor, Department of Earth and Environment
Associate Director, Institute for Global Sustainability

Energy source shares in U.S. electricity generation, 1920-2023



Source: U.S. Energy information Administration; US Bureau of Census; author calculations
Boston University Institute for Global Sustainability | visualizingenergy.org | CC BY 4.0

visualizingEnergy

Boston University Office of Research

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Rapid Change is Possible

WHO Smallpox Eradication Program
(1966-1980)

Manhattan Project
(1942-1946)

The Green Revolution
(1940s - 1970s)

COVID-19 Vaccine (2020)

Thank you!

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