Comments on Innovation and Infrastructure

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US DOE Summit Energy Innovation and Storage – January 25, 2023

To access the materials presented today:

http://rael.berkeley.edu

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Opportunities to integrate energy innovation & social justice

The New York Times

Opinion

Why Housing Policy Is Climate Policy

In California, where home prices are pushing people farther from their jobs, rising traffic is creating more pollution.

By Scott Wiener and Daniel Kammen

Senator Wiener is the chairman of the California Senate's Housing Committee. Dr. Kammen is a professor of energy at the University of California, Berkeley.

March 25, 2019

https://www.nytimes.com/2019/03/25/opinion/california-home-prices-climate.html

San Francisco Chronicle

WILDFIRES VIRUS LOCAL FOOD ELECTION SPORTING GREEN BIZ+TECH CULTURE DATEB

OPINION

How electric vehicles can help advance social justice

By Daniel Kammen | June 21, 2020 | Updated: June 22, 2020 6:21 p.m.

https://www.sfchronicle.com/opinion/article/How-electric-vehicles-can-help-advance-social-15351293.php

Mapping Resource Footprints (coolclimate.Berkeley.edu)

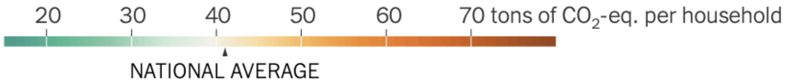
The New York Times

The Climate Impact of Your Neighborhood, Mapped

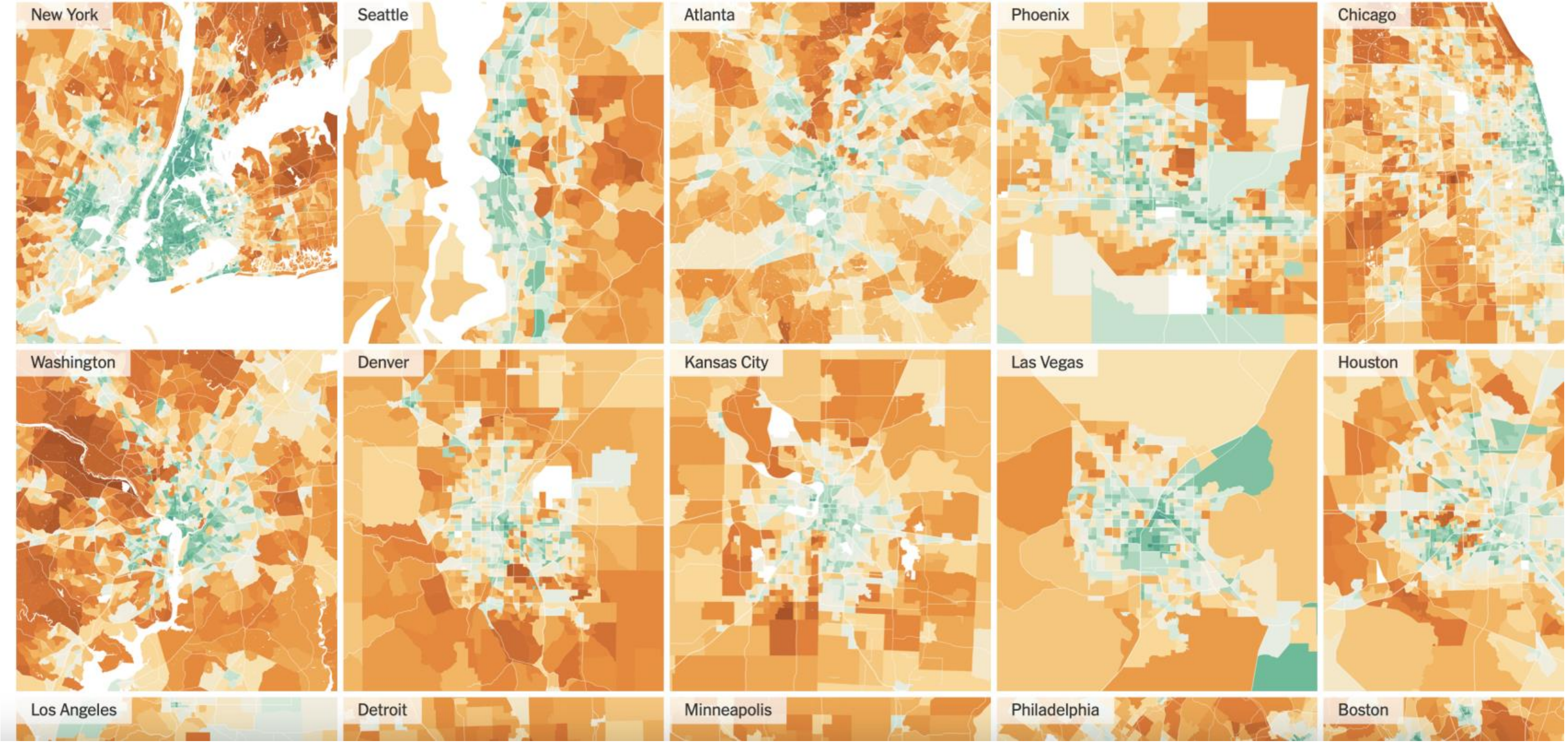
By Nadja Popovich, Mira Rojanasakul and Brad Plumer Dec. 13, 2022

New data shared with The New York Times reveals stark disparities in how different U.S. households contribute to climate change. Looking at America's cities, a pattern emerges.

Emissions Footprint of the Average Household



Mapping Resource Footprints (coolclimate.Berkeley.edu)



COP27 Transition Agenda

CLEAN POWER already the least cost option for new construction in many settings.

Zero emissions **ROAD TRANSPORT** the new normal – accessible, affordable and sustainable in all regions by 2030.

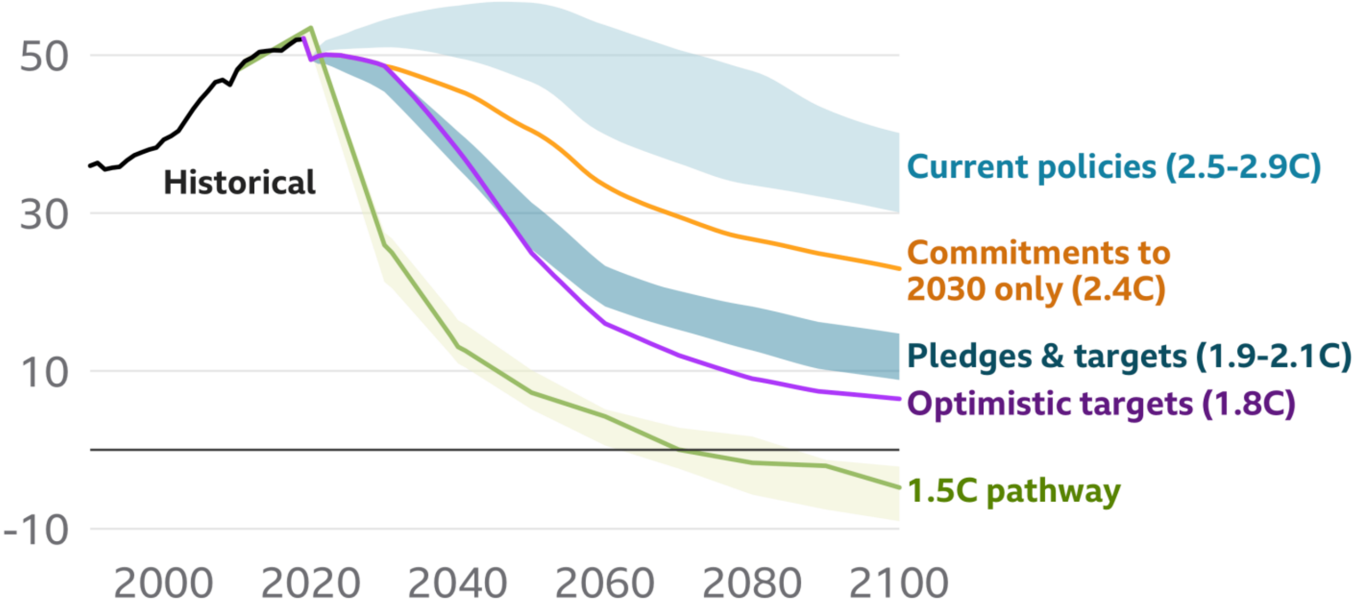
Near zero **STEEL** the preferred choice in global markets, with efficient use and near-zero emission steel production established and growing in every region by 2030.

Zero and very low carbon **HYDROGEN** globally available by 2030.

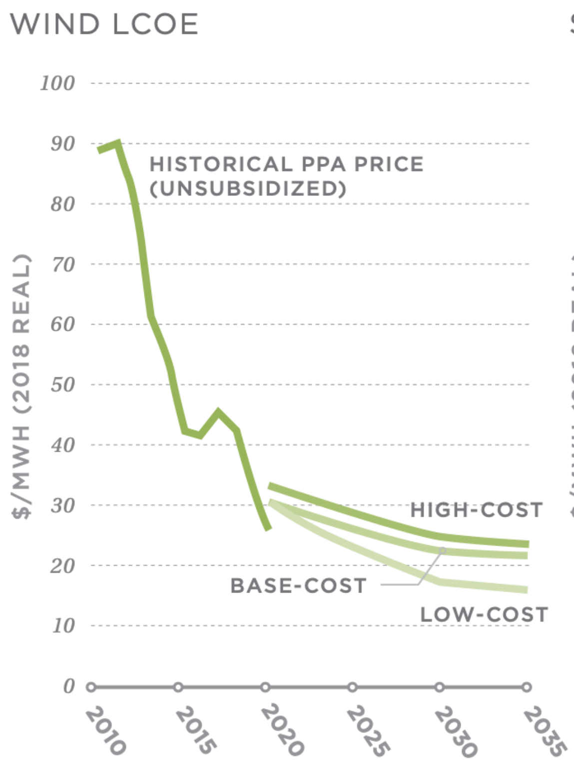
Climate-resilient, sustainable **AGRICULTURE** the most attractive and widely adopted option for farmers everywhere by 2030.

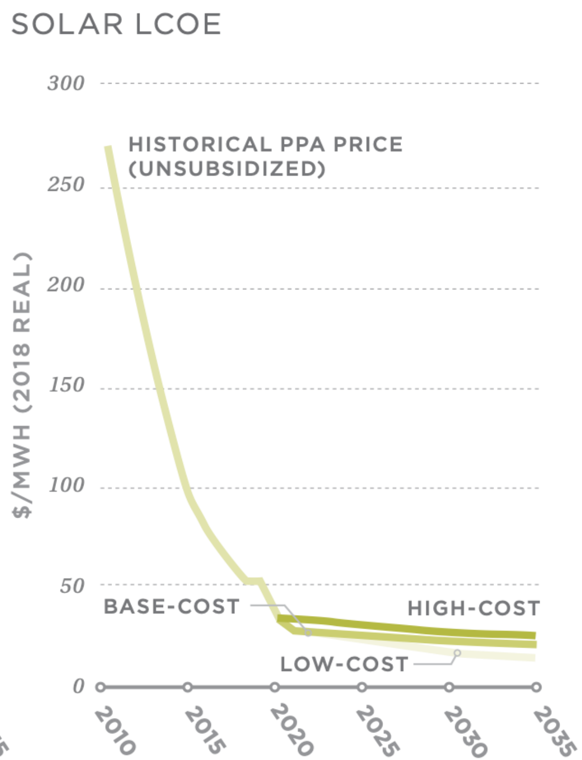
Projected trends in emissions and warming

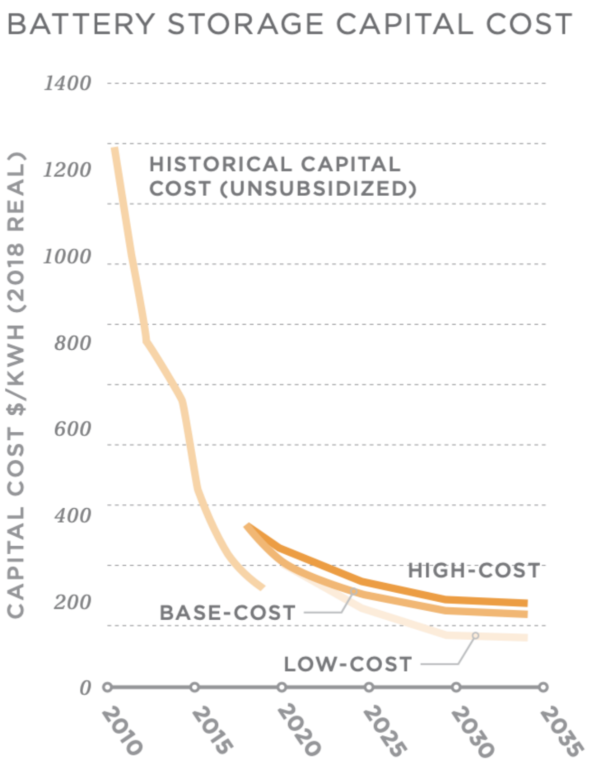
Global greenhouse gas emissions in gigatonnes of carbon dioxide equivalent



https://racetozero.unfccc.int/system/breakthrough-agenda/



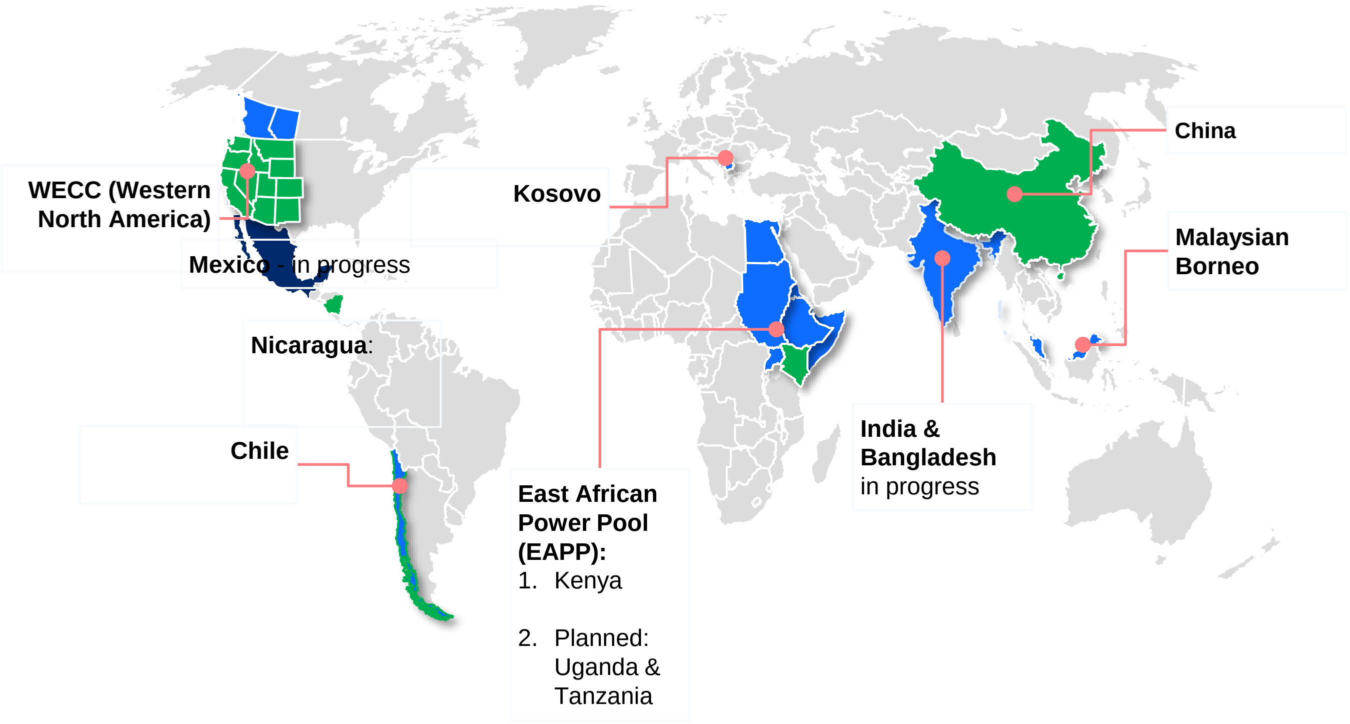




According to Bloomberg New Energy, it is now cheaper to *build renewables* than to *operate fossil fuel power plants in most locations*[1].

[1] https://www.bloomberg.com/news/articles/2021-06-23/building-new-renewables-cheaper-than-running-fossil-fuel-plants

RAEL's "SWITCH" Power System Models to Plan the Clean Energy Transition



http://rael.berkeley/edu/project/SWITCH

The SWITCH Modeling Framework

http://rael.Berkeley.edu/project/SWITCH

$$\min_{(c_i)} . NPV \sum_{i,k=1}^{n,m} TC_k\ (c_i)$$

$$Total\ Cost\ TC_k = Capital\ Cost_i * Capacity\ (c_i) + [Variable\ Cost_i * Capacity\ (c_i) *\ CF_i *\ 8760]$$

$$\sum_{i=1}^{n} Capacity\ (c_i) * Peak\ Contribution_i \quad \geq Annual\ Peak\ Demand * [1 + Reserve\ Margin]$$

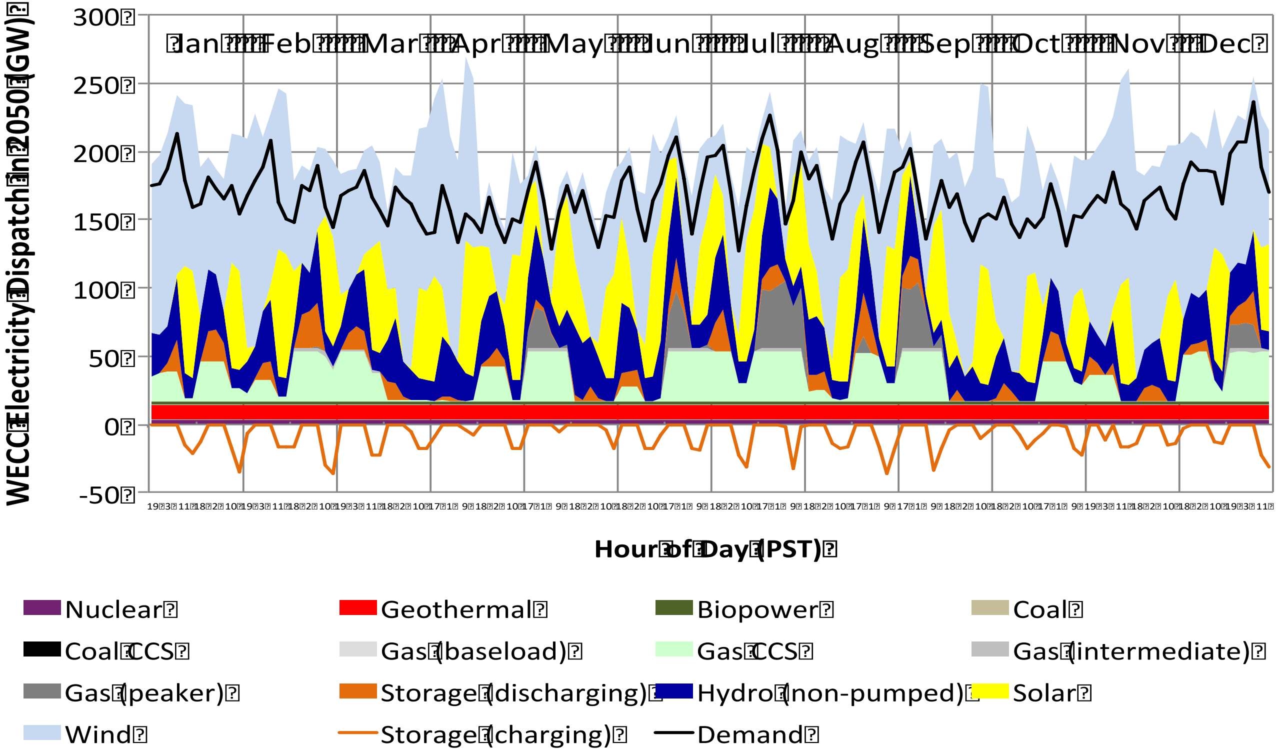
$$\sum_{i=1}^{n} [Capacity\ (c_i) *\ CF_i *\ 8760]\ \geq\ Annual\ Load$$

$$Annual\ Load *\ Spill\ Factor\ \geq \sum_{i=1}^{n}\ [Capacity\ (c_i) *\ \ CF_i *\ 8760]$$

$$Total\ Resource\ Potental_i\ \geq \sum_{k=1}^{m}\ Capacity\ (c_i)$$

Dispatch in 2050:
Flexibility and variable renewables dominate

Storage almost exclusively moves solar to the night
Geothermal only remaining substantial baseload



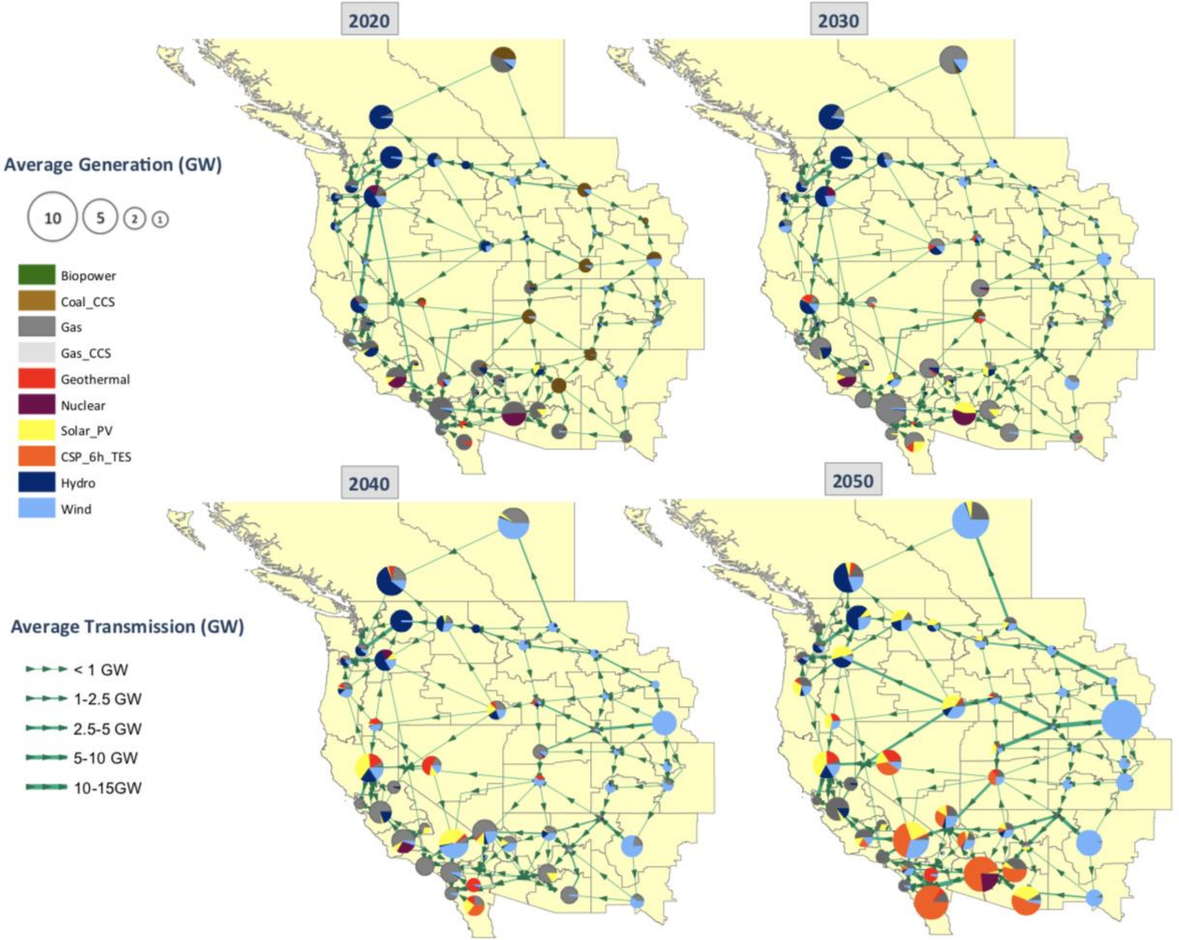
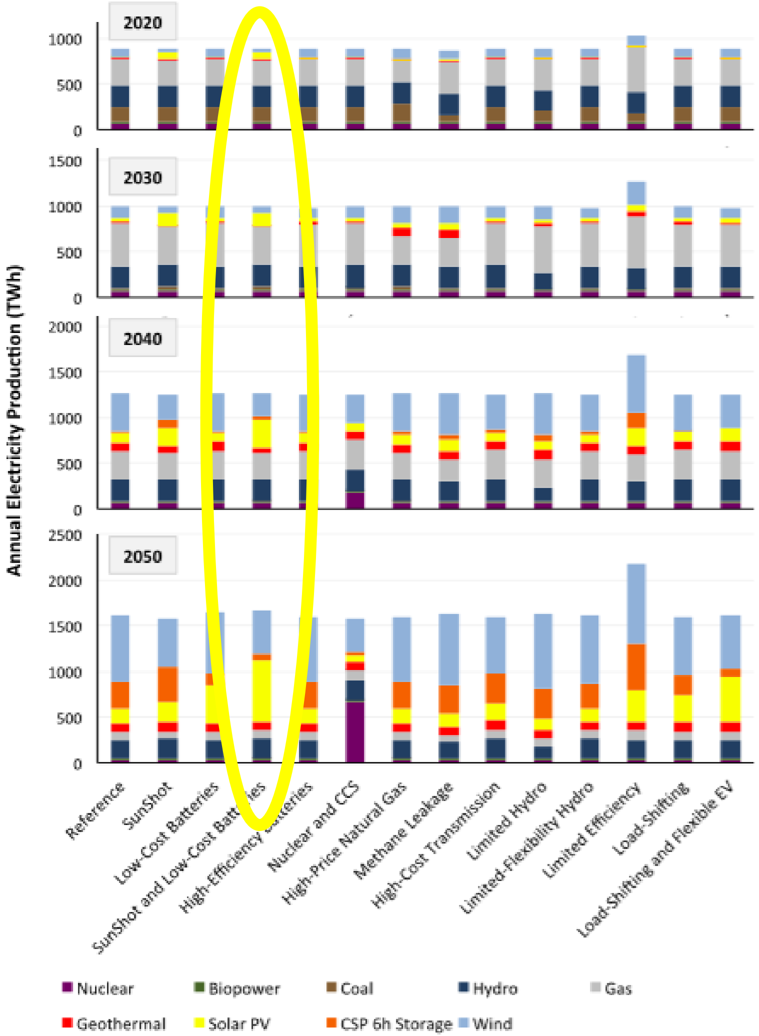
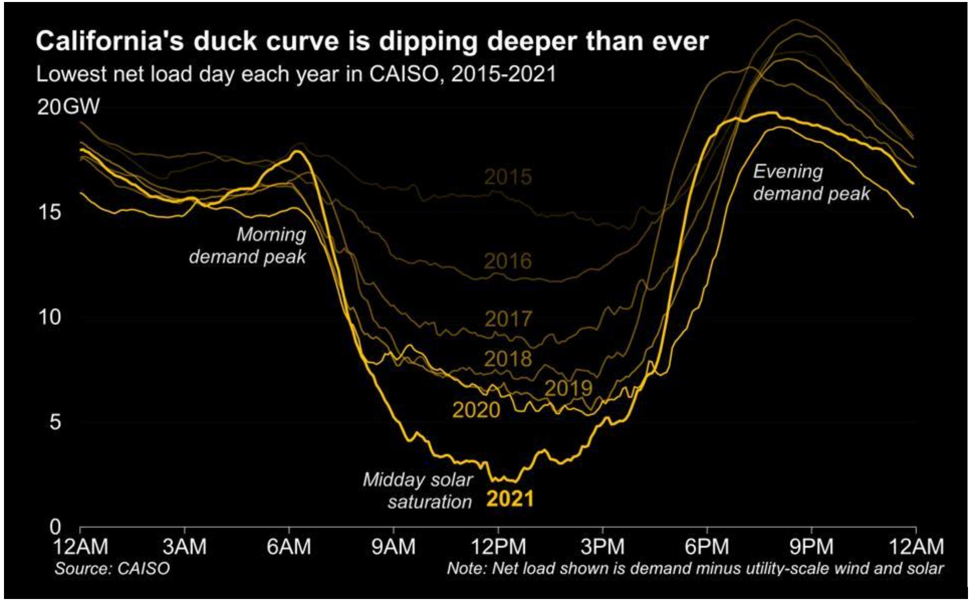


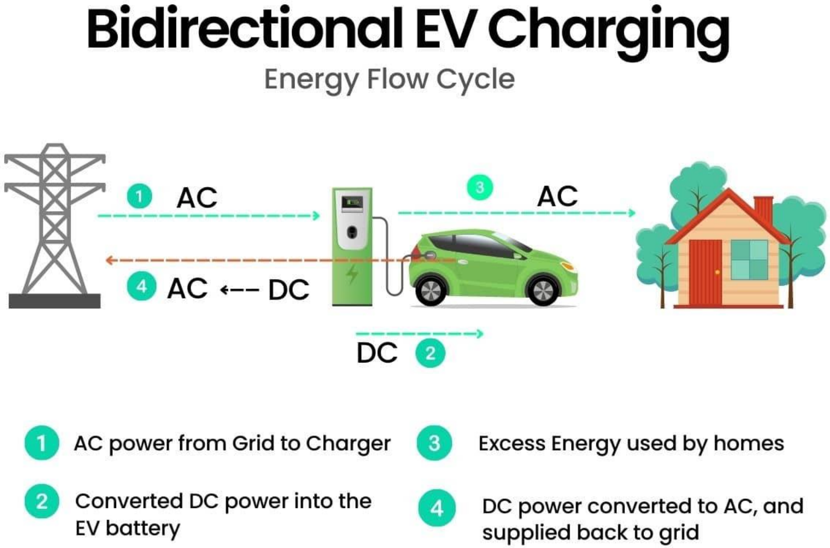
Figure 1. Maps of average transmission and generation in the Reference scenario in 2020, 2030, 2040, and 2050.

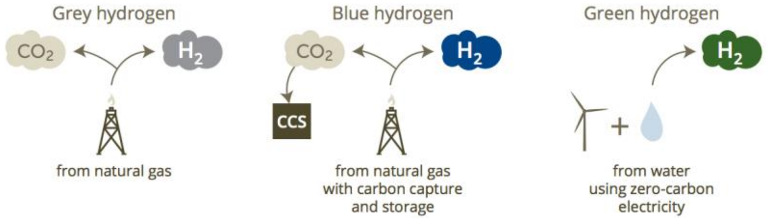
Pathways for Western North America



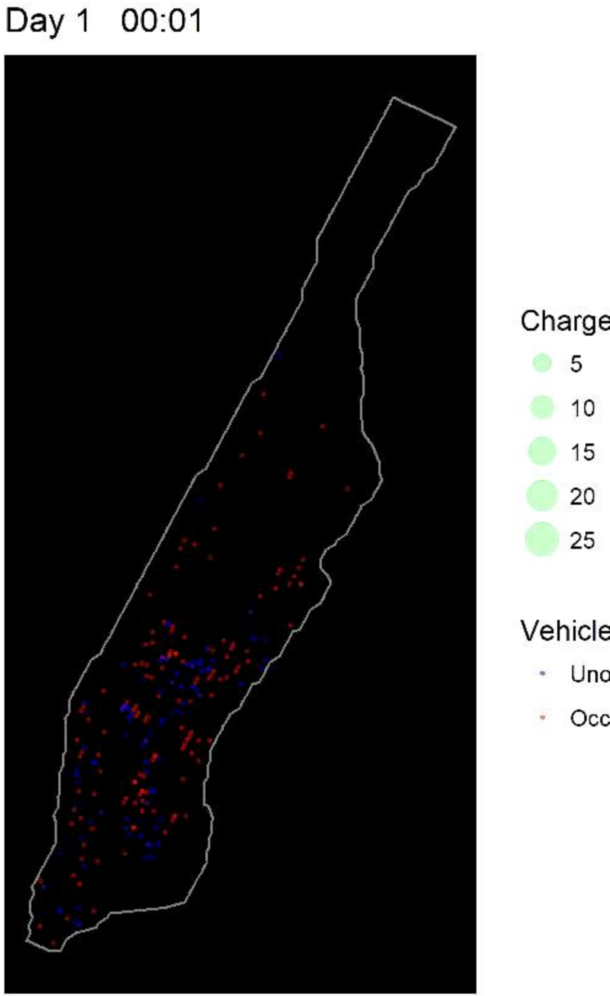
From (perceived) utility crisis to clean energy opportunity







Electric Vehicle Data Science: China and New York City

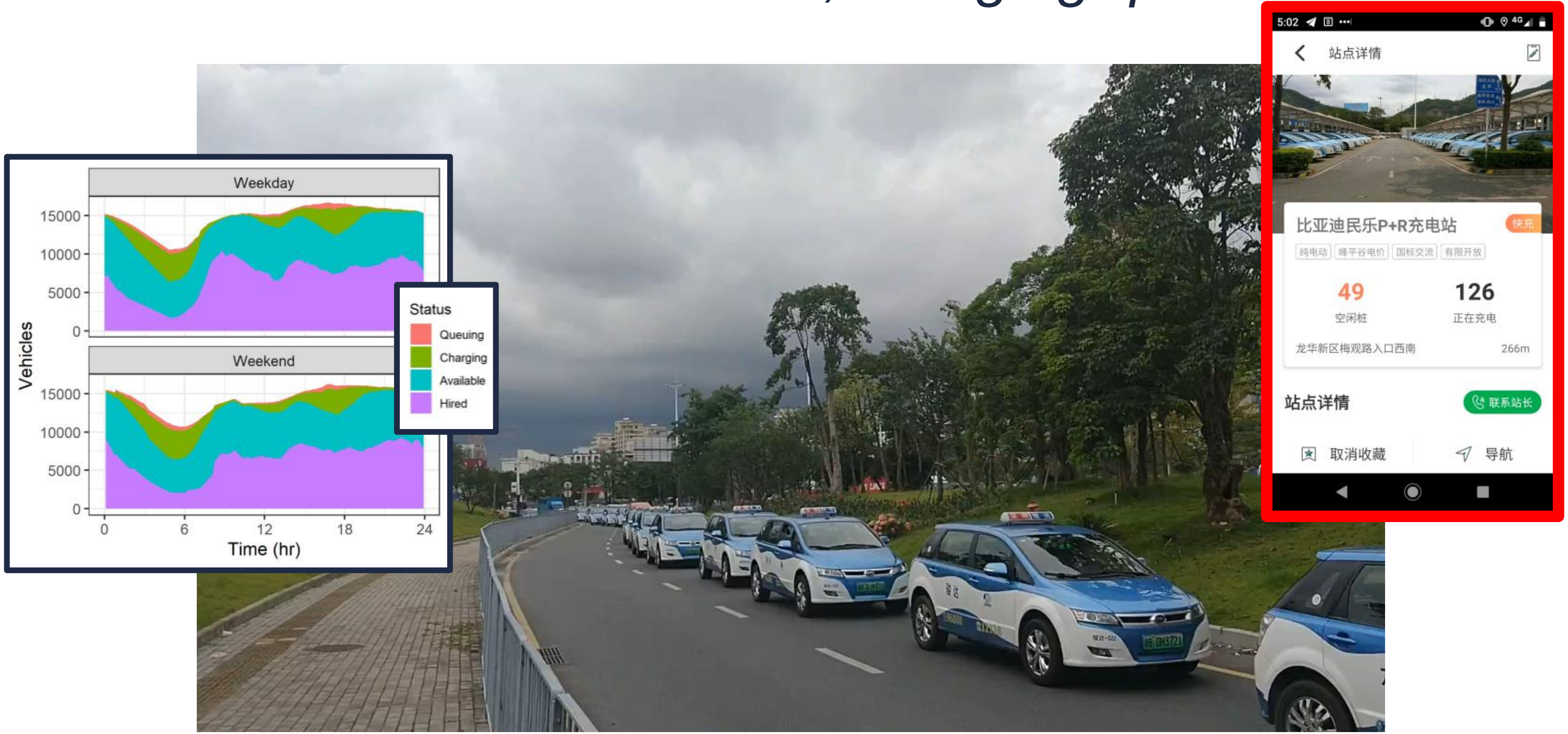


Example: Shenzhen Taxi Fleet Transformed in partnership with RAEL

As of 2021: 95% of the taxi fleet is EV in Shenzhen, China (31,000+ vehicles)

Shenzhen e-taxi fleet: long queues and lost revenue

Solutions through data analytics and optimization
20 % increase in driver revenue, charging queues reduced 80%



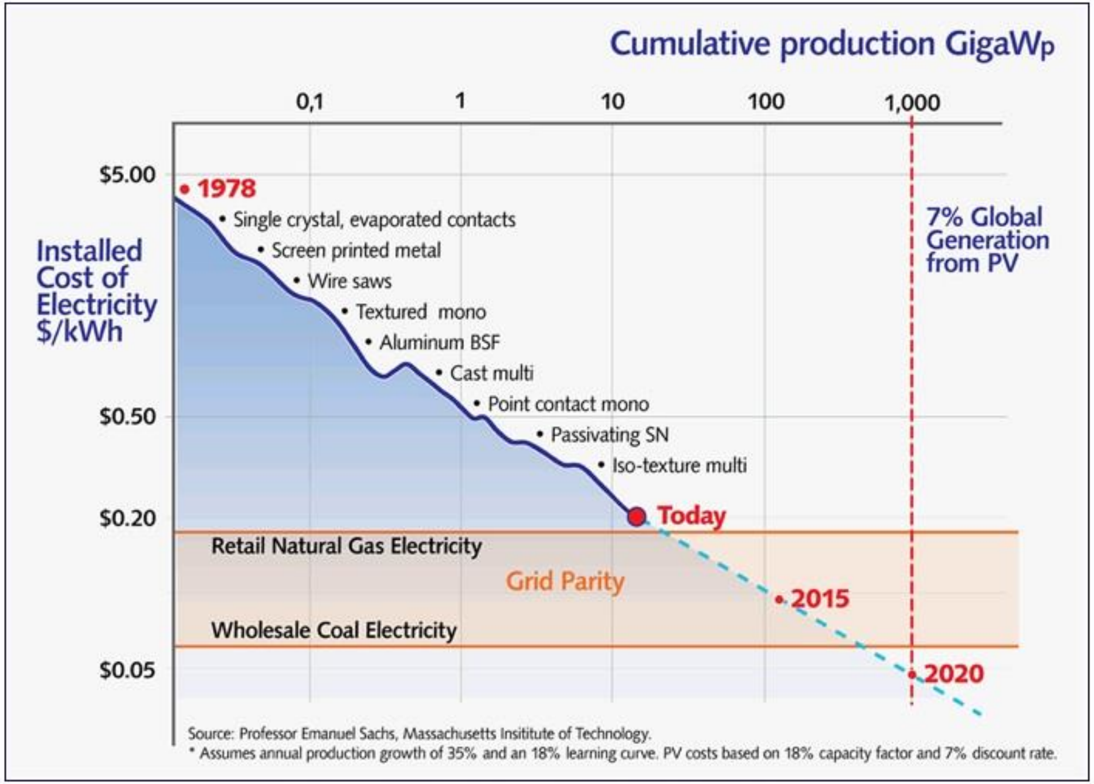
The Learning Curve

Swanson's Law

"Moore's Law"

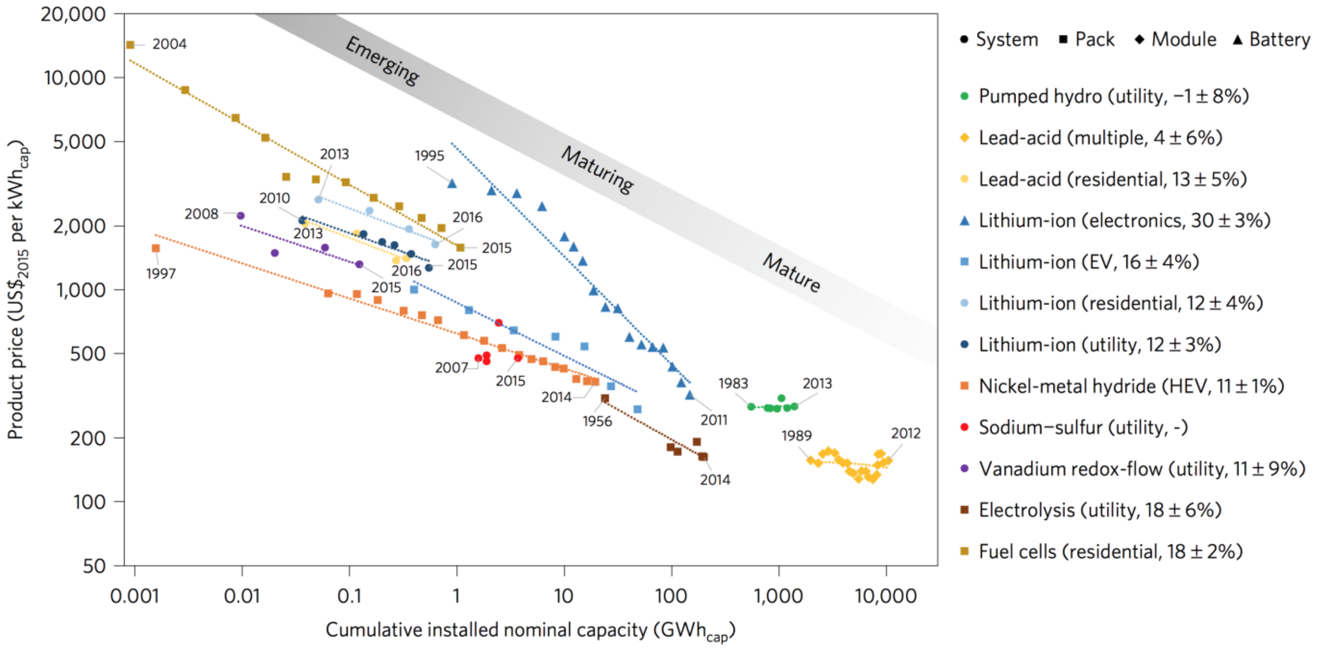
$$\frac{C_2}{C_1} = \left(\frac{V_2}{V_1}\right)^{-b}$$

Solar cost decreases 10% per year



Source: Professor Emanuel Sachs, Massachusetts Insititute of Technology.
*Assumes annual production growth of 35% and an 18% learning curve. PV costs based on 18% capacity factor and 7% discount rate.

Materials Science & Engineering for Storage Innovation

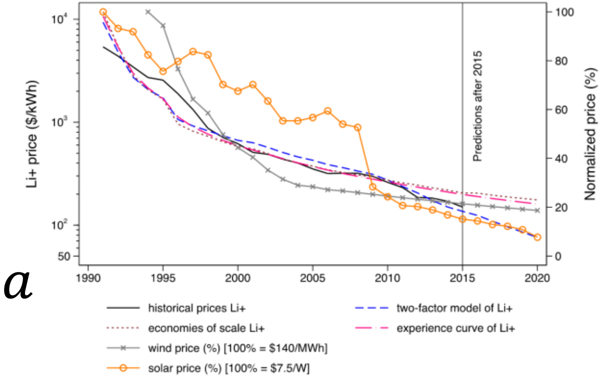


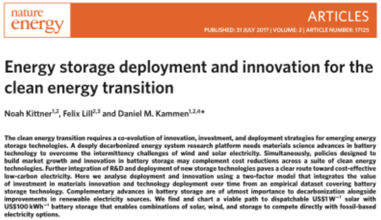
Schmidt, O., Hawkes, A., Gambhir, A., & Staffell, I. (2017) The future cost of electrical energy storage. *Nature Energy, 2,* 2017110.
Qiu, Y., & Anadon, L. D. (2012) The price of wind power in China during its expansion. *Energy Economics*, *34*(3), 772-785.
Kittner, Lil & Kammen (2017) Energy storage innovation. *Nature Energy,* ***2,*** 17125

Two-factor learning curves: engineering, manufacturing and R&D

Deployment as a function of cost *and* R&D … a significantly better fit

$$\frac{C_2}{C_1} = \left(\frac{V_2}{V_1}\right)^{-b} \left(\frac{[R\&D]_2}{[R\&D]_1}\right)^{-a}$$





nature energy

ARTICLES

PUBLISHED: 31 JULY 2017 | VOLUME: 2 | ARTICLE NUMBER: 17125

Energy storage deployment and innovation for the clean energy transition

Noah Kittner[1,2], Felix Lill[2,3] and Daniel M. Kammen[1,2,4]*

The clean energy transition requires a co-evolution of innovation, investment, and deployment strategies for emerging energy storage technologies. A deeply decarbonized energy system research platform needs materials science advances in battery technology to overcome the intermittency challenges of wind and solar electricity. Simultaneously, policies designed to build market growth and innovation in battery storage may complement cost reductions across a suite of clean energy technologies. Further integration of R&D and deployment of new storage technologies paves a clear route toward cost-effective low-carbon electricity. Here we analyse deployment and innovation using a two-factor model that integrates the value of investment in materials innovation and technology deployment over time from an empirical dataset covering battery storage technology. Complementary advances in battery storage are of utmost importance to decarbonization alongside improvements in renewable electricity sources. We find and chart a viable path to dispatchable US$1 W^{-1} solar with US$100 kWh^{-1} battery storage that enables combinations of solar, wind, and storage to compete directly with fossil-based electricity options.

Post IRA, Chips & Science Act, and Infrastructure Act, it is critical we collaborate to a accelerate investment in not only R&D, moving research to implementation

Kittner, N., Lill, F., Kammen, D.M. (2017). "Energy storage deployment and innovation for the clean energy transition." *Nature Energy* 2 17125.

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About Disciplines Resources News Blog

Block by Block:

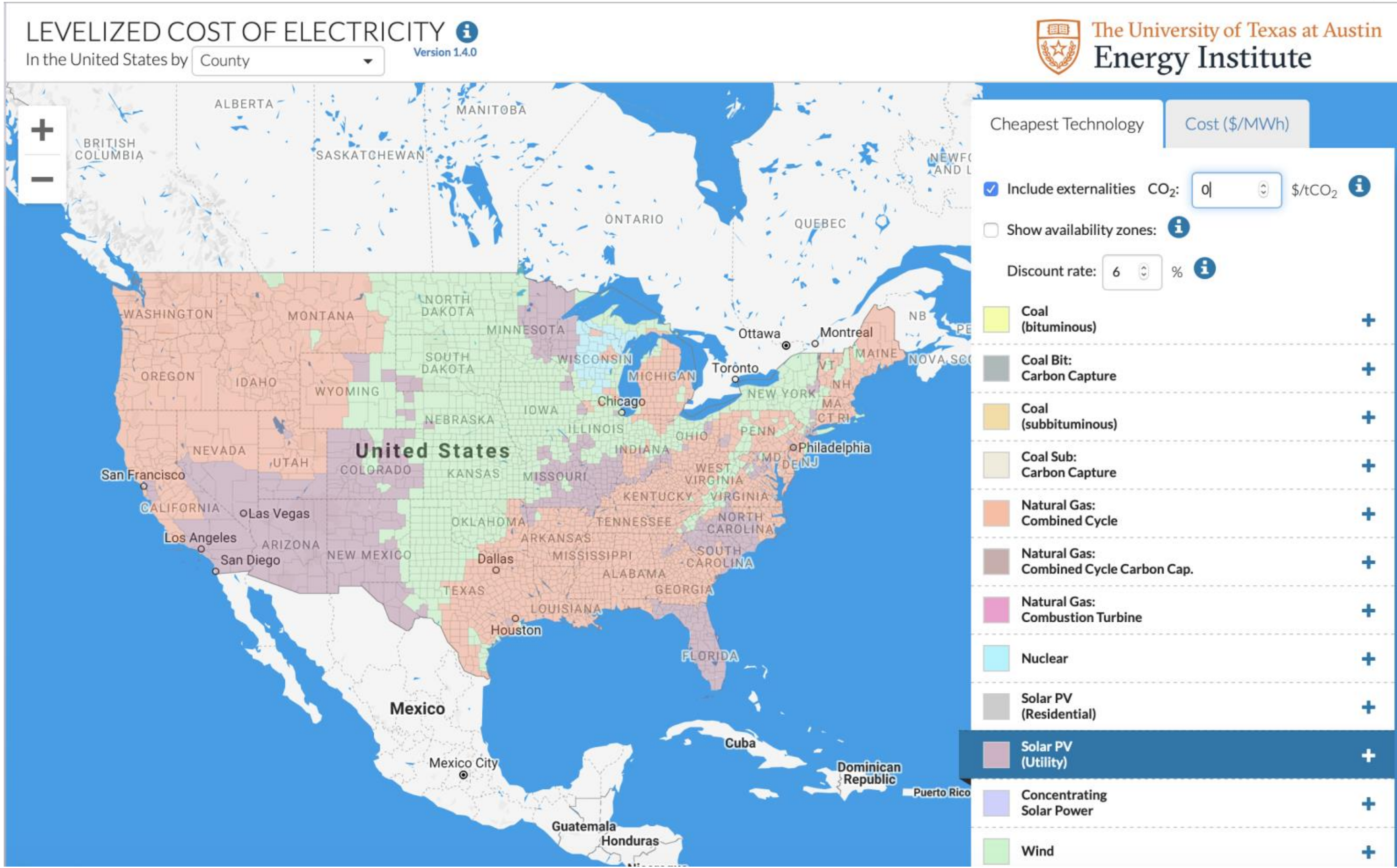
Transforming Cities for a Resilient and Carbon Neutral Future

ABOUT THE PROJECT

EcoBlock is a **radical retrofit** of existing residential homes to improve resilience, sustainability, and quality of life for all community members.

Overnight Energy costs:

$0/tCO$_2$



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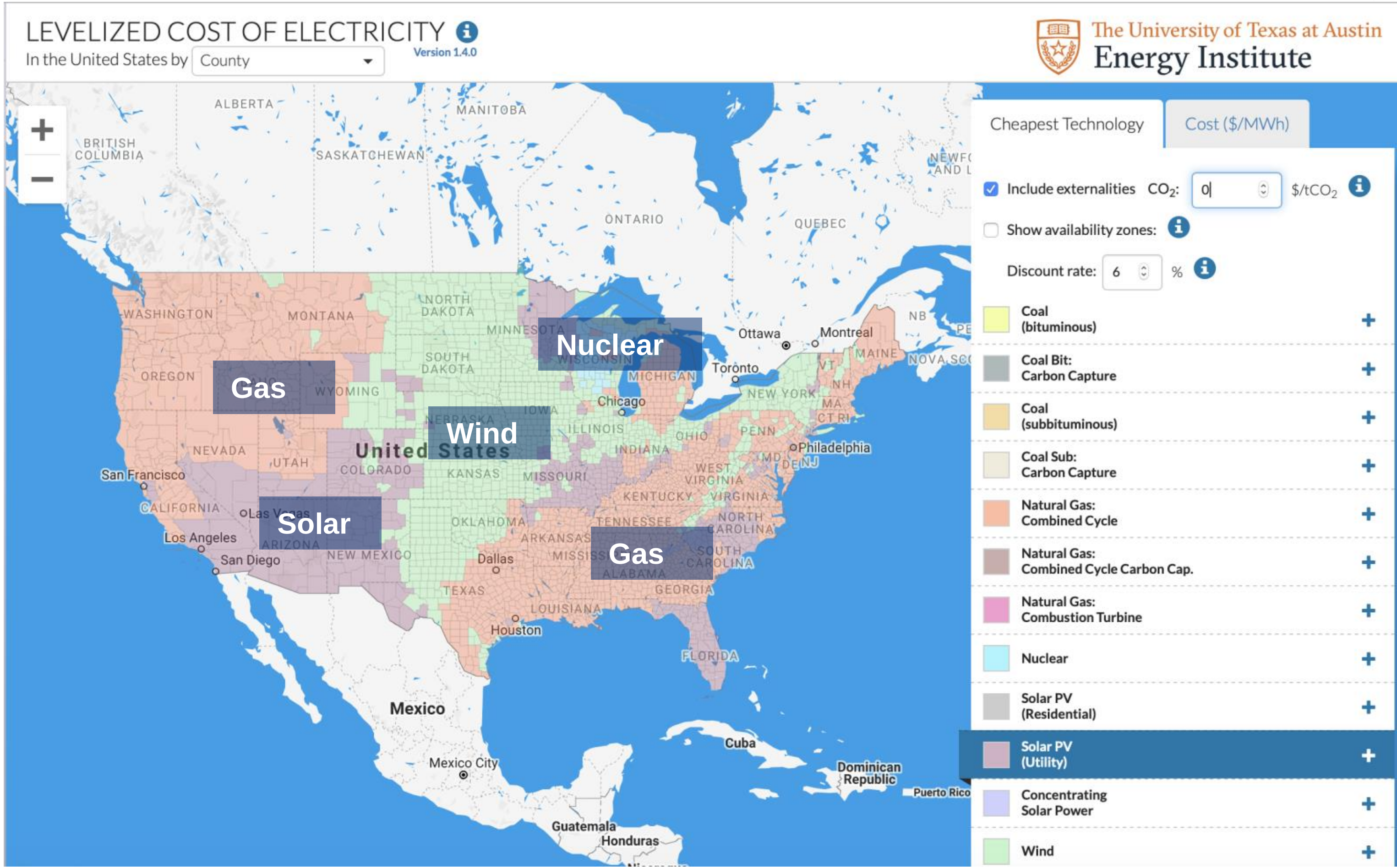
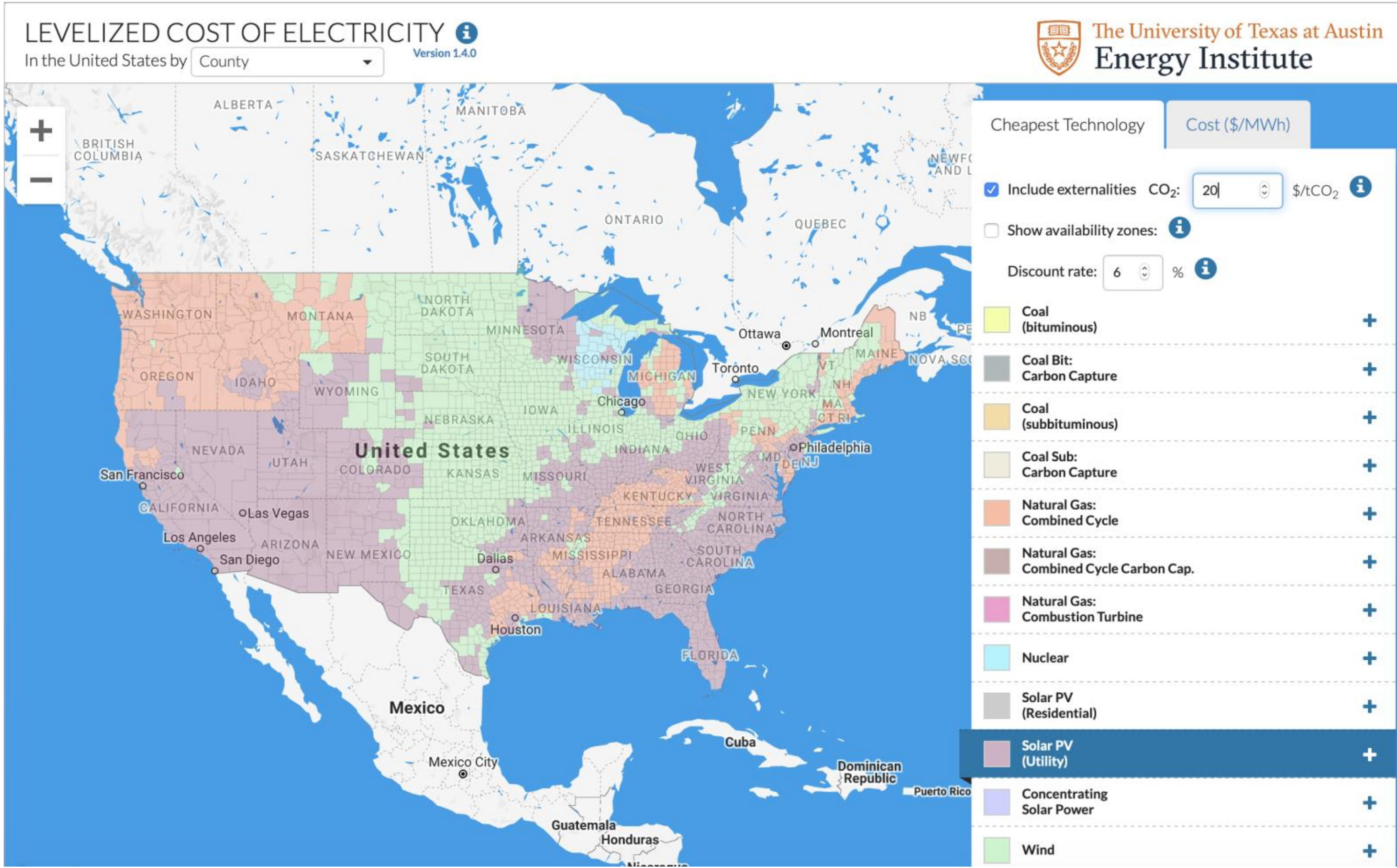


China & California's market price for carbon emissions

$20/tCO$_2$



A Social Cost of Carbon:

> $50/tCO_2$