# Science & Policy Innovations for Electricity Quality & Justice

**Daniel Kammen**

James and Katherine Lau Distinguished Professor of Sustainability
Energy and Resources Group
Goldman School of Public Policy
Department of Nuclear Engineering
Director, Renewable and Appropriate Energy Laboratory
University of California, Berkeley

Former Science Envoy, United States Department of State

August 3, 2023, Brisbane, Australia

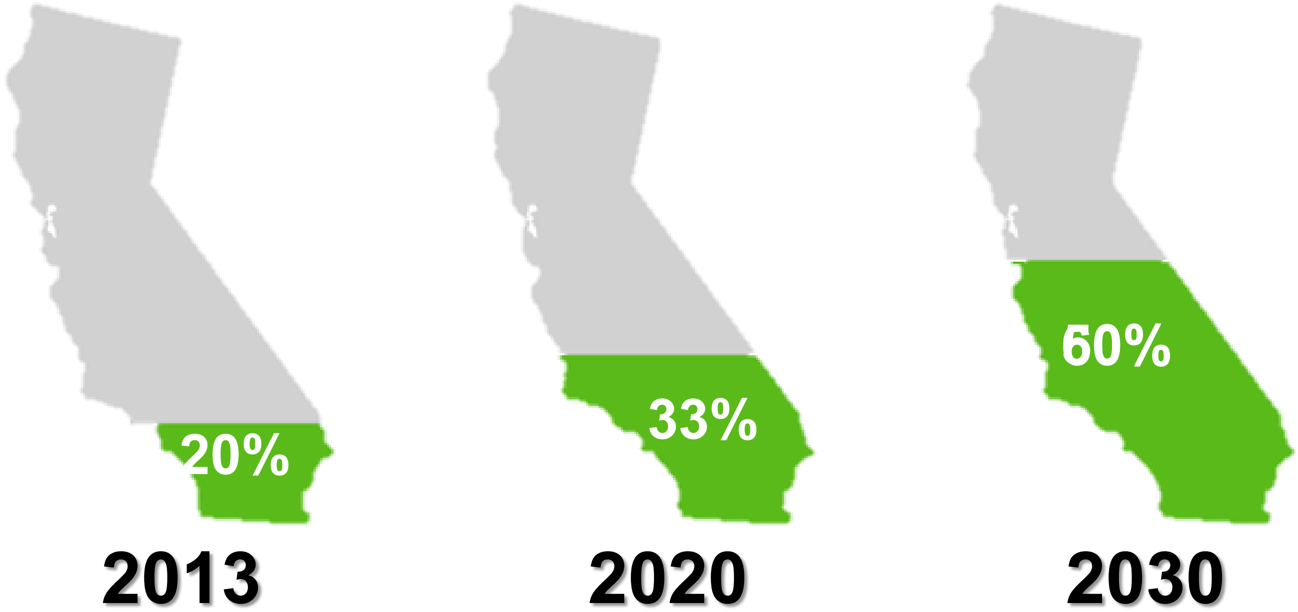
# To follow our work in the Renewable and Appropriate Energy Laboratory

**http://rael.berkeley.edu**

**Twitter: @dan_kammen**

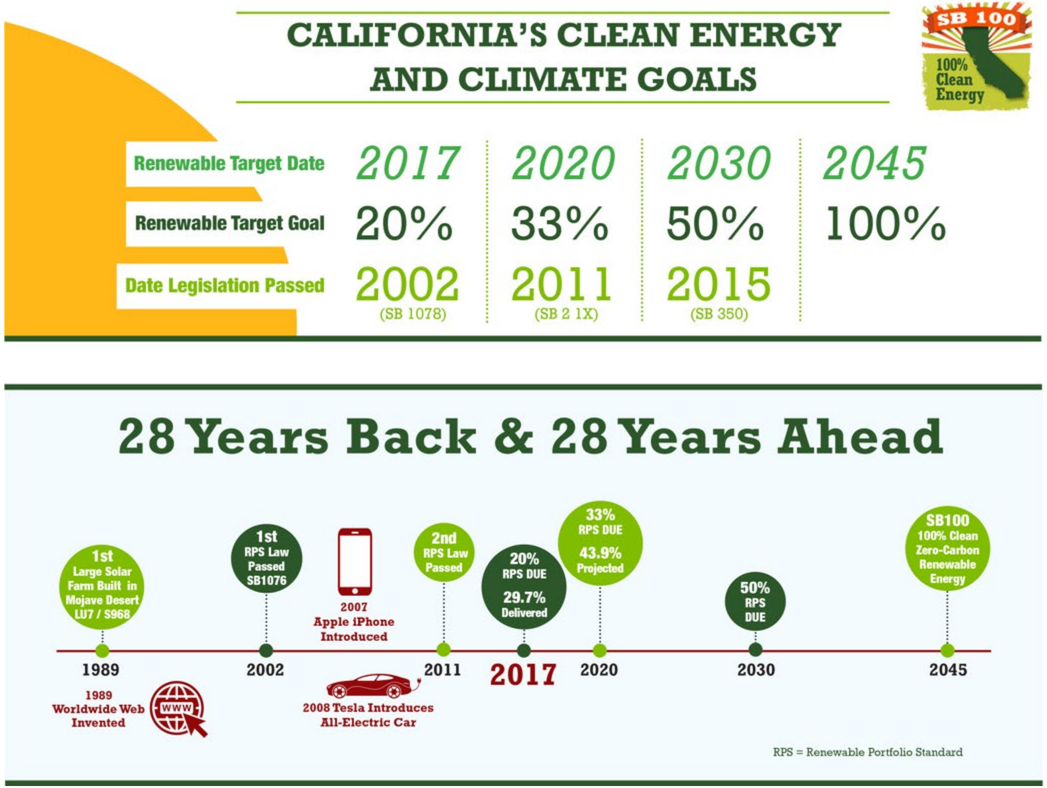
# California Energy & Environmental Justice Path

## 35%+ of Carbon Cap & Trade Funds for Under-Served Communities




California Senate Bill 100: 100% clean energy by 2045 and 2030 standard now 60% (without nuclear or large hydro)

# The California Clean Energy Trajectory




https://focus.senate.ca.gov/sb100

**2035 is now under discussion for 100% RE**

# From the analysis of biofuels to low-carbon mobility



CORRECTED 23 JUNE 2006; SEE LAST PAGE

## Ethanol Can Contribute to Energy and Environmental Goals

Alexander E. Farrell,[1]* Richard J. Plevin,[1] Brian T. Turner,[1,2] Andrew D. Jones,[1] Michael O'Hare,[2] Daniel M. Kammen[1,2,3]

To study the potential effects of increased biofuel use, we evaluated six representative analyses of fuel ethanol. Studies that reported negative net energy incorrectly ignored coproducts and used some obsolete data. All studies indicated that current corn ethanol technologies are much less petroleum-intensive than gasoline but have greenhouse gas emissions similar to those of gasoline. However, many important environmental effects of biofuel production are poorly understood. New metrics that measure specific resource inputs are developed, but further research into environmental metrics is needed. Nonetheless, it is already clear that large-scale use of ethanol for fuel will almost certainly require cellulosic technology.

Energy security and climate change imperatives require large-scale substitution of petroleum-based fuels as well as improved vehicle efficiency (*1*, *2*). Although biofuels offer a diverse range of promising alternatives, ethanol constitutes 99% of all biofuels in the United States. The 3.4 billion gallons of ethanol blended into gasoline in 2004 amounted to about 2% of all gasoline sold by volume and 1.3% ($2.5 \times 10^{17}$ J) of its energy content (*3*). Greater quantities of ethanol are expected to be used as a motor fuel in the future because of two federal policies: a $0.51 tax credit per gallon of ethanol used as motor fuel and a new mandate for up to 7.5 billion gallons of "renewable fuel" to be used in gasoline by 2012, which was included in the recently passed Energy Policy Act (EPACT 2005) (*4*, *5*).

Thus, the energy and environmental implications of ethanol production are more important than ever. Much of the analysis and public debate about ethanol has focused on the sign of the net energy of ethanol: whether manufacturing ethanol takes more nonrenewable energy than the resulting fuel provides (*6*, *7*). It has long been recognized that calculations of net energy are highly sensitive to assumptions about both system boundaries and key parameter values (*8*). In addition, net energy calculations ignore vast differences between different types of fossil energy (*9*). Moreover, net energy ratios are extremely sensitive to specification and assumptions and can produce uninterpretable values in some important cases (*10*). However, comparing across published studies to evaluate how these assumptions affect outcomes is difficult owing to the use of different units and system boundaries across studies. Finding intuitive and meaningful replacements for net energy as a performance metric would be an advance in our ability to evaluate and set energy policy in this important arena.

To better understand the energy and environmental implications of ethanol, we surveyed the published and gray literature and present a comparison of six studies illustrating the range of assumptions and data found for the case of corn-based (*Zea mays*, or maize) ethanol (*11*–*16*). To permit a direct and meaningful comparison of the data and assumptions across the studies, we developed the Energy and Resources Group (ERG) Biofuel Analysis Meta-Model (EBAMM) (*10*). For each study, we compared data sources and methods and parameterized EBAMM to replicate the published net energy results to within half a percent. In addition to net energy, we also calculated metrics for greenhouse gas (GHG) emissions and primary energy inputs (table S1 and Fig. 1).

Two of the studies stand out from the others because they report negative net energy values and imply relatively high GHG emissions and petroleum inputs (*11*, *12*). The close evaluation required to replicate the net energy results showed that these two studies also stand apart from the others by incorrectly assuming that ethanol coproducts (materials inevitably generated when ethanol is made, such as dried distiller grains with solubles, corn gluten feed, and corn oil) should not be credited with any of the input energy and by including some input data that are old and unrepresentative of current processes, or so poorly documented that their quality cannot be evaluated (tables S2 and S3).

Sensitivity analyses with EBAMM and elsewhere show that net energy calculations are most sensitive to assumptions about coproduct allocation (*17*). Coproducts of ethanol have positive economic value and displace competing products that require energy to make. Therefore, increases in corn ethanol production to meet the requirements of EPACT 2005 will lead to more coproducts that displace whole corn and soybean meal in animal feed, and the energy thereby saved will partly offset the energy required for ethanol production (*5*, *18*). The studies that correctly accounted for this displacement effect reported that ethanol and coproducts manufactured from corn yielded a positive net energy of about 4 MJ/l to 9 MJ/l. The study that ignored coproducts but used recent data found a slightly positive net energy for corn ethanol (*13*). However, comparisons of the reported data are somewhat misleading because of many incommensurate assumptions across the studies.

We used EBAMM to (i) add coproduct credit where needed, (ii) apply a consistent system boundary by adding missing parameters (e.g., effluent processing energy) and dropping extraneous ones (e.g., laborer food energy), (iii) account for different energy types, and (iv) calculate policy-relevant metrics (*19*). Figure 1 shows both published and commensurate values as well as equivalent values for the reference, conventional gasoline.

The published results, adjusted for commensurate system boundaries, indicate that with current production methods corn ethanol displaces petroleum use substantially; only 5 to 26% of the energy content is renewable. The rest is primarily natural gas and coal (Fig. 2). The impact of a switch from gasoline to ethanol has an ambiguous effect on GHG emissions, with the reported values ranging from a 20% increase to a decrease of 32%. These values have their bases in the same system boundaries, but some of them rely on data of dubious quality. Our best point estimate for average performance today is that corn ethanol reduces petroleum use by about 95% on an energetic basis and reduces GHG emissions only moderately, by about 13%. Uncertainty analysis suggests these results are robust (*10*). It is important to realize that actual performance will vary from place to place and that these values reflect an absence of incentives for GHG emission control. Given adequate policy incentives, the performance of corn ethanol in terms of GHG emissions can likely be improved (*20*). However, current data suggest that only cellulosic ethanol offers large reductions in GHG emissions.

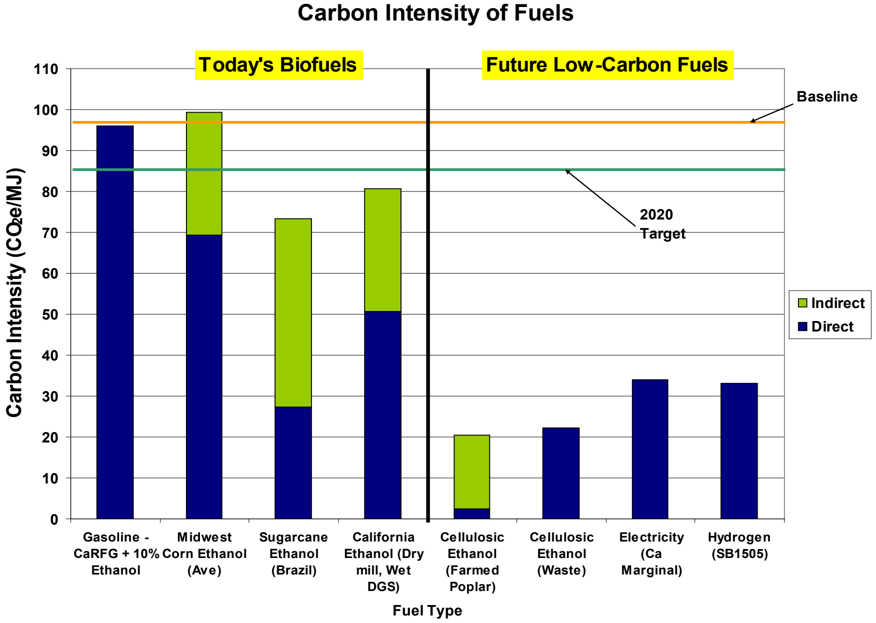
The remaining differences among the six studies are due to different input parameters, which are relatively easy to evaluate within the simple, transparent EBAMM framework. For instance, most of the difference between the highest and lowest values for GHG emissions in our data are due to differences in limestone ($CaCO_3$) application rate and energy embodied in farm machinery (table S1). The former is truly uncertain; data for lime application and for the resulting GHG emissions are poor (*15*). In contrast, the higher farm machinery energy values are unverifiable and more than an order of magnitude greater than values reported elsewhere and calculated here, suggesting that the lower values are more representative (*10*) (table S3).

This analysis illustrates the major contribution of agricultural practices to life-cycle GHG emissions (34% to 44%) and petroleum inputs (45% to 80%) to corn ethanol, suggest-

[1]Energy and Resources Group, [2]Goldman School of Public Policy, [3]Renewable and Appropriate Energy Laboratory, University of California, Berkeley, CA 94720–3050, USA.
*To whom correspondence should be addressed. E-mail: aef@berkeley.edu








The *Science* paper became the Low Carbon Fuel Standard
***That included indirect land use***

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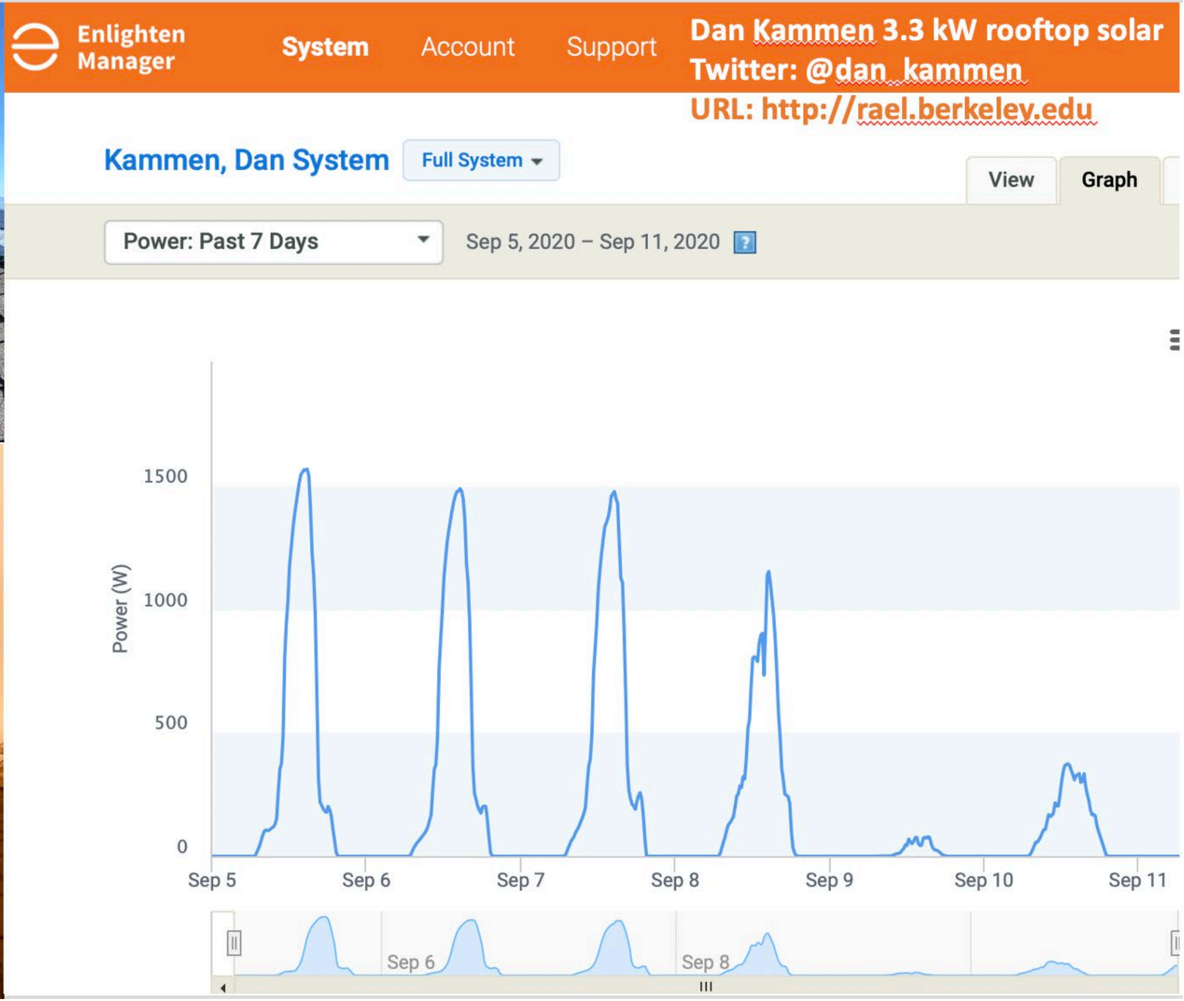
June 5, 2020


Sept 9, 2020

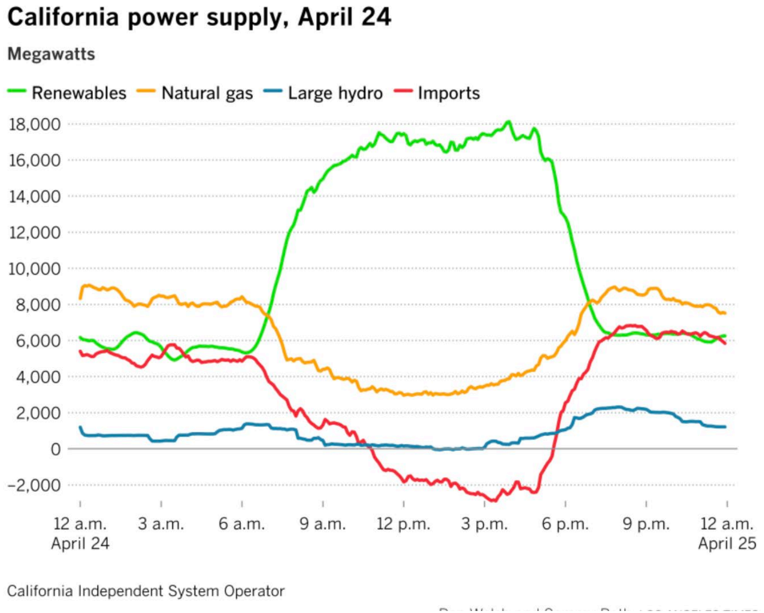

Enlighten Manager
System
Account
Support
Dan Kammen 3.3 kW rooftop solar
Twitter: @dan_kammen
URL: http://rael.berkeley.edu
Kammen, Dan System
Full System
View
Graph
Power: Past 7 Days
Sep 5, 2020 – Sep 11, 2020
Power (W)
1500
1000
500
0
Sep 5
Sep 6
Sep 7
Sep 8
Sep 9
Sep 10
Sep 11
Sep 6
Sep 8

# California sets new clean energy records:

## Update: 104% of demand met by clean energy, May 2022

**Los Angeles Times**

California just hit 95% renewable energy. Will other states come along for the ride?




California ISO

**Today's Outlook** AS OF 11:00 04/29/2021

| 22,507 MW | 29,026 MW | 15,257 MW | 68% |
|---|---|---|---|
| Current demand | Forecasted peak | Current renewables | Renewables serving load |

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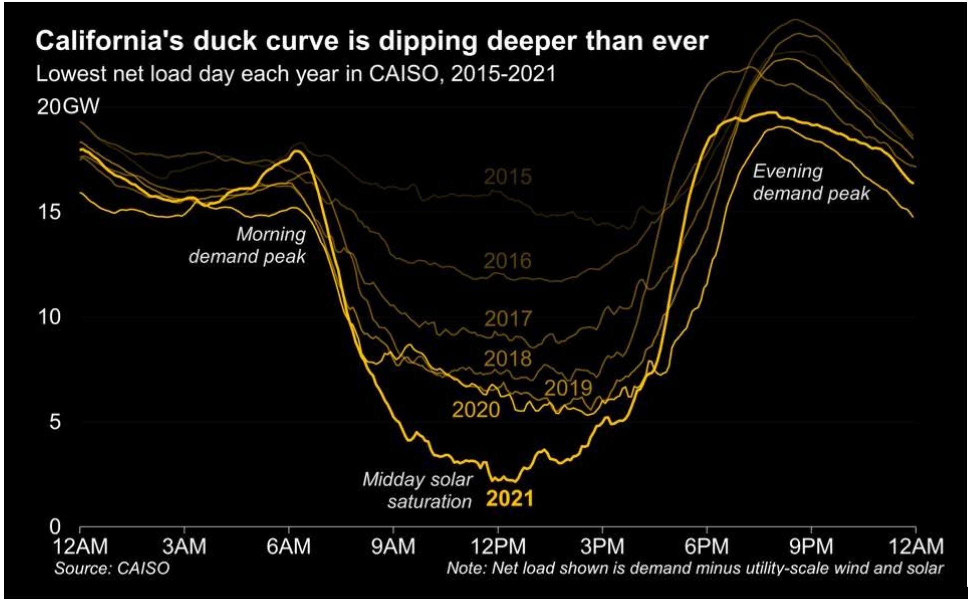
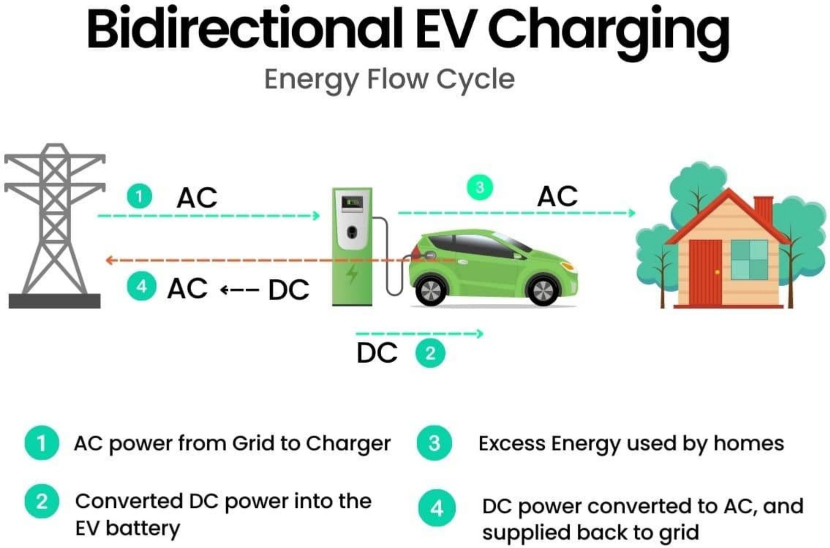
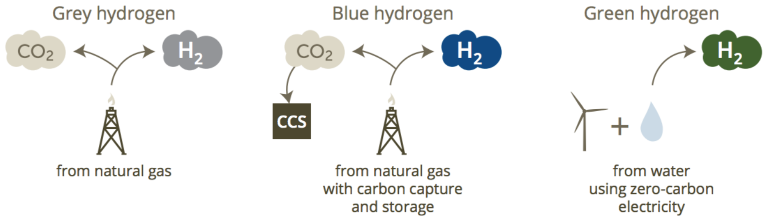
# From (perceived) utility crisis to clean energy opportunity



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FEATURE

# Is rooftop solar just a toy for the wealthy?

Nikkei ▲ 22297.58 1.30% | Hang Seng ▲ 28387.55 0.50% | U.S. 10 Yr ▼ -4/32 Yield 2.392% | Crude Oil ▲ 54.66 0.51% | Yen ▲ 113.91 0.24%

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THE EXPERTS

# Solar Subsidies Take Money From the Poor to Help the Rich

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# Is US residential solar just for the rich?

By Danielle Ola | Apr 21, 2017 11:15 AM BST | 0 | Share

Source: Flickr/Khirol Amir

nature sustainability

ANALYSIS

https://doi.org/10.1038/s41893-018-0204-z

# Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity

Deborah A. Sunter[1,2,3,4]*, Sergio Castellanos[3,4,5,6]* and Daniel M. Kammen[3,4,7]

**The rooftop solar industry in the United States has experienced dramatic growth—roughly 50% per year since 2012, along with steadily falling prices. Although the opportunities this affords for clean, reliable power are transformative, the benefits might not accrue to all individuals and communities. Combining the location of existing and potential sites for rooftop photovoltaics (PV) from Google's Project Sunroof and demographic information from the American Community Survey, the relative adoption of rooftop PV is compared across census tracts grouped by racial and ethnic majority. Black- and Hispanic-majority census tracts show on average significantly less rooftop PV installed. This disparity is often attributed to racial and ethnic differences in household income and home ownership. In this study, significant racial disparity remains even after we account for these differences. For the same median household income, black- and Hispanic-majority census tracts have installed less rooftop PV compared with no majority tracts by 69 and 30%, respectively, while white-majority census tracts have installed 21% more. When correcting for home ownership, black- and Hispanic-majority census tracts have installed less rooftop PV compared with no majority tracts by 61 and 45%, respectively, while white-majority census tracts have installed 37% more. The social dispersion effect is also considered. This Analysis reveals the racial and ethnic injustice in rooftop solar participation.**

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# The Oakland EcoBlock

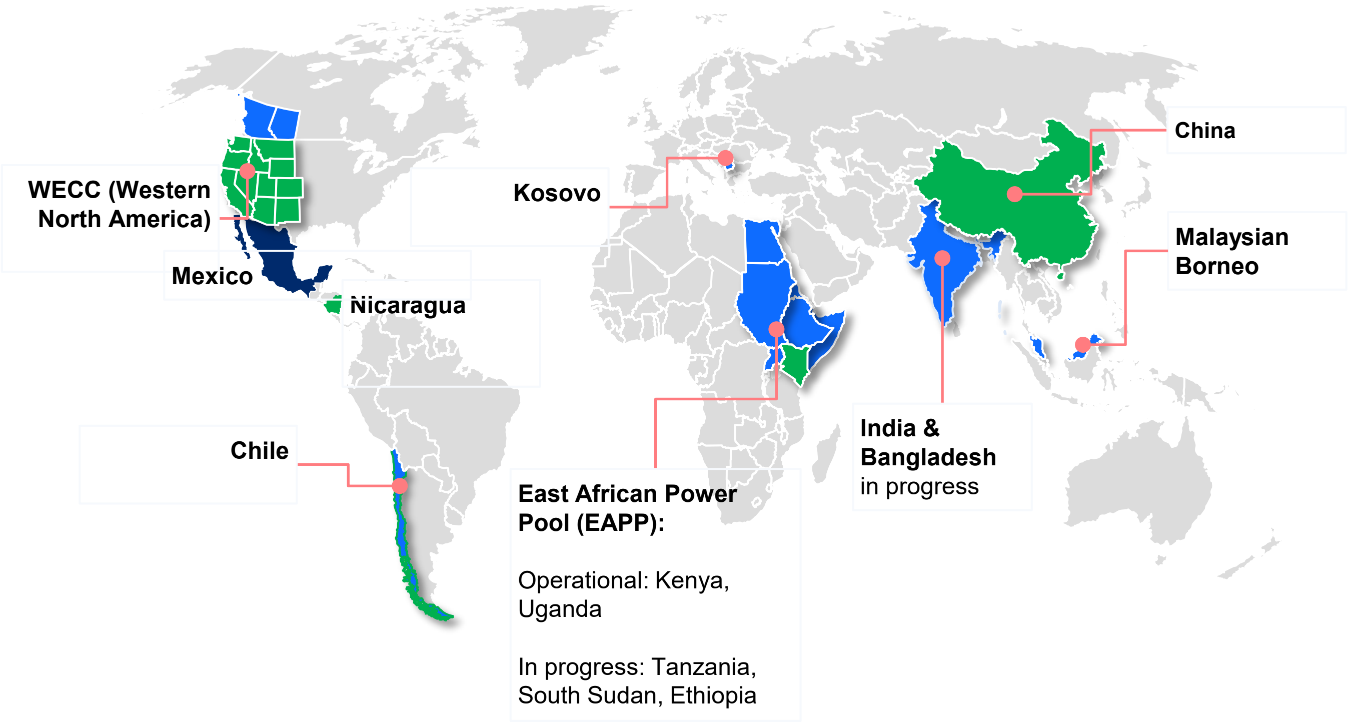
## Community Groups

## Businesses

## Nations

Institutions

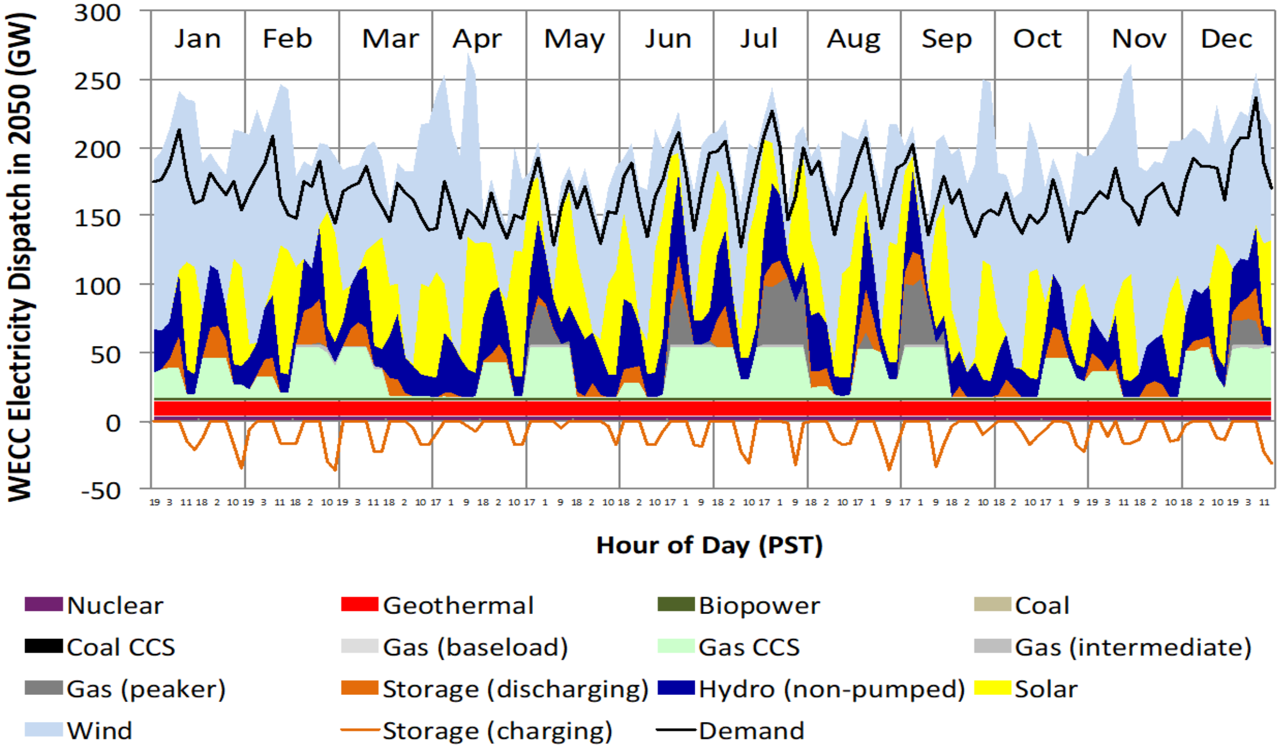
# RAEL's "SWITCH" Power System Models to Plan the Clean Energy Transition



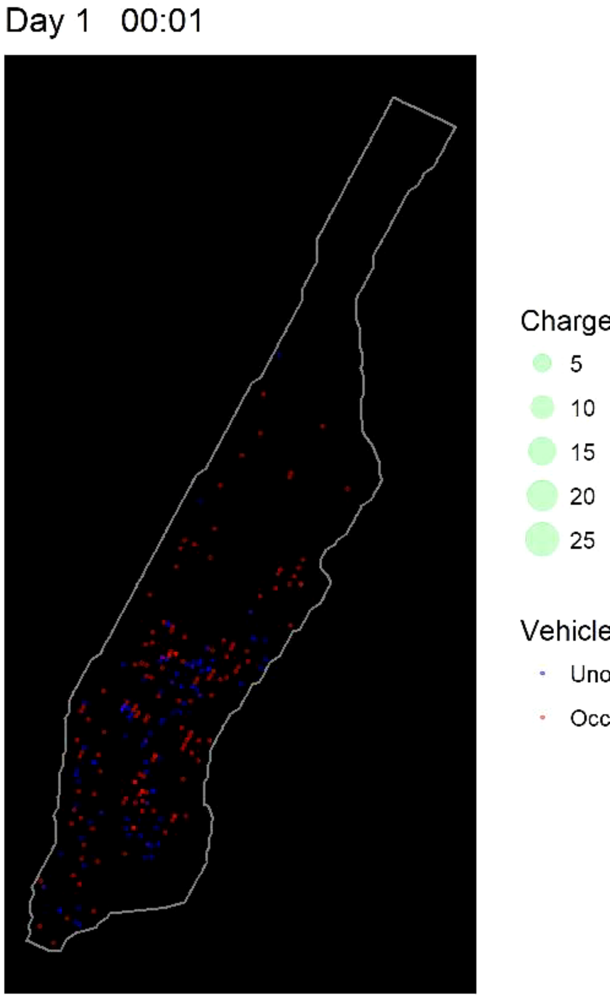

http://rael.berkeley/edu/project/SWITCH

# Dispatch in 2050 (SWITCH-WECC, Western North America): Flexibility and variable renewables dominate

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



# Electric Vehicle Data Science: China and New York City

派尔城市
PAIR CITY

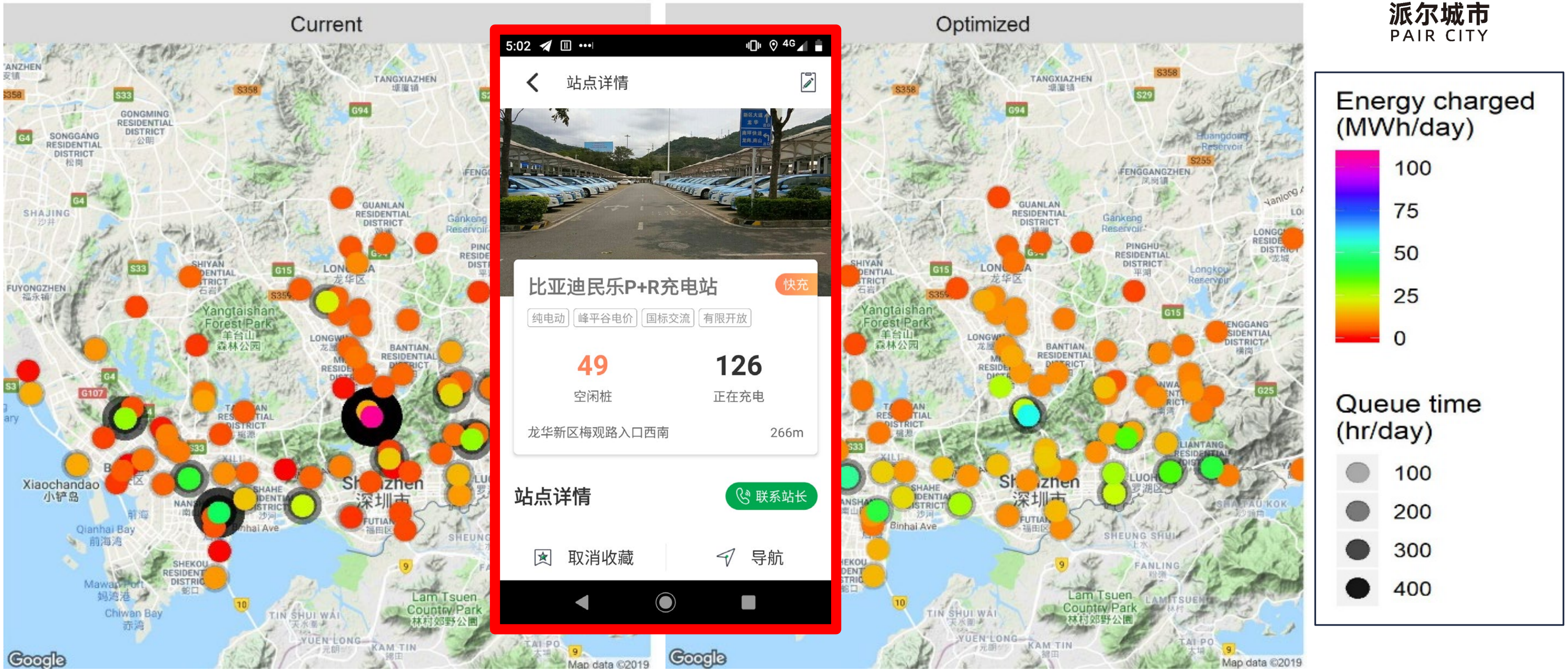
# Big Data Application | Solving long wait time outside EV taxi charging stations

Lines of EV taxis waiting
to enter the charging station

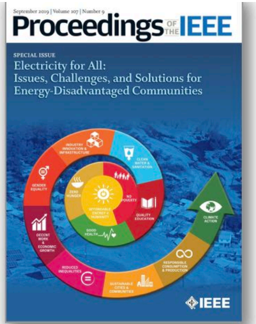
Rows of faster chargers (total 637)
inside China's largest EV charging station

# Data Science for Optimized dispatch:
# 20% reduced delay time; increased revenue

派尔城市
PAIR CITY



# PAIR MaaS Brain
# Integrated green mobility of subway, bus, bike & EV



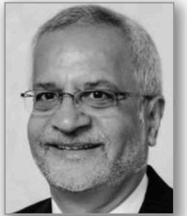

# Electricity for All: Issues, Challenges, and Solutions for Energy-Disadvantaged Communities

Volume 107, Issue 9 | September 2019

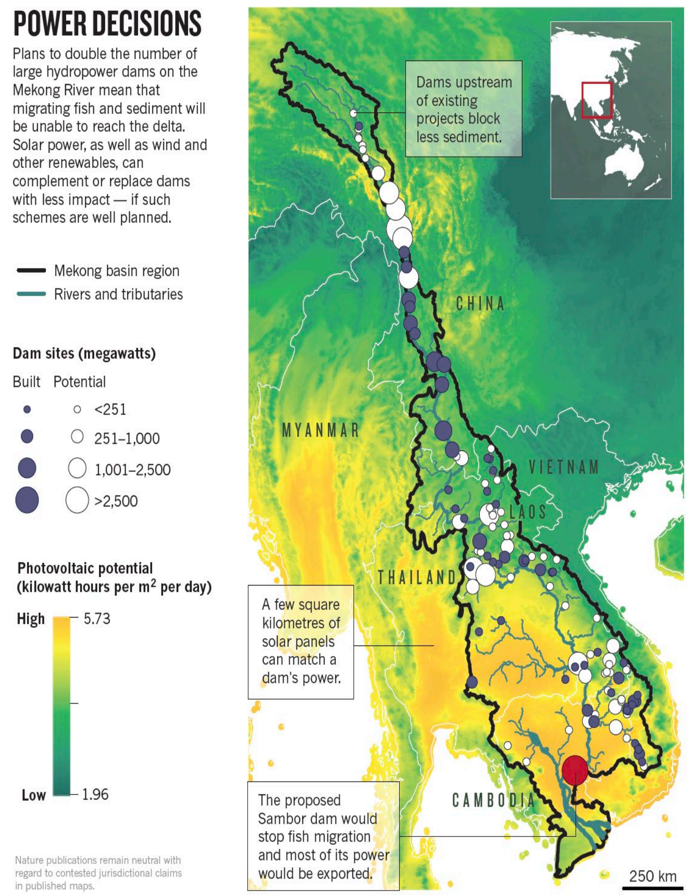
- Guest Editors
- Special Issue Papers

## Guest Editors:


Claudio Cañizares


Jatin Nathwani


Daniel Kammen




Schmitt, Kittner, Kondoff & Kammen (2019) *Nature*, **569**, 330-332

# ACCESS TO POWER SAVES LIVES

Approximately one in four public health facilities across sub-Saharan Africa do not have access to electricity

USAID FROM THE AMERICAN PEOPLE

POWER AFRICA A U.S. GOVERNMENT-LED PARTNERSHIP

- Up to 50% of vaccines are wasted to unreliable cold chain
- Low utilization of COVID-19 vaccine
- Significant patient record downtime
- Equipment failure
- Limited services
- Low staff retention

# The Toll of Being Unelectrified in Africa

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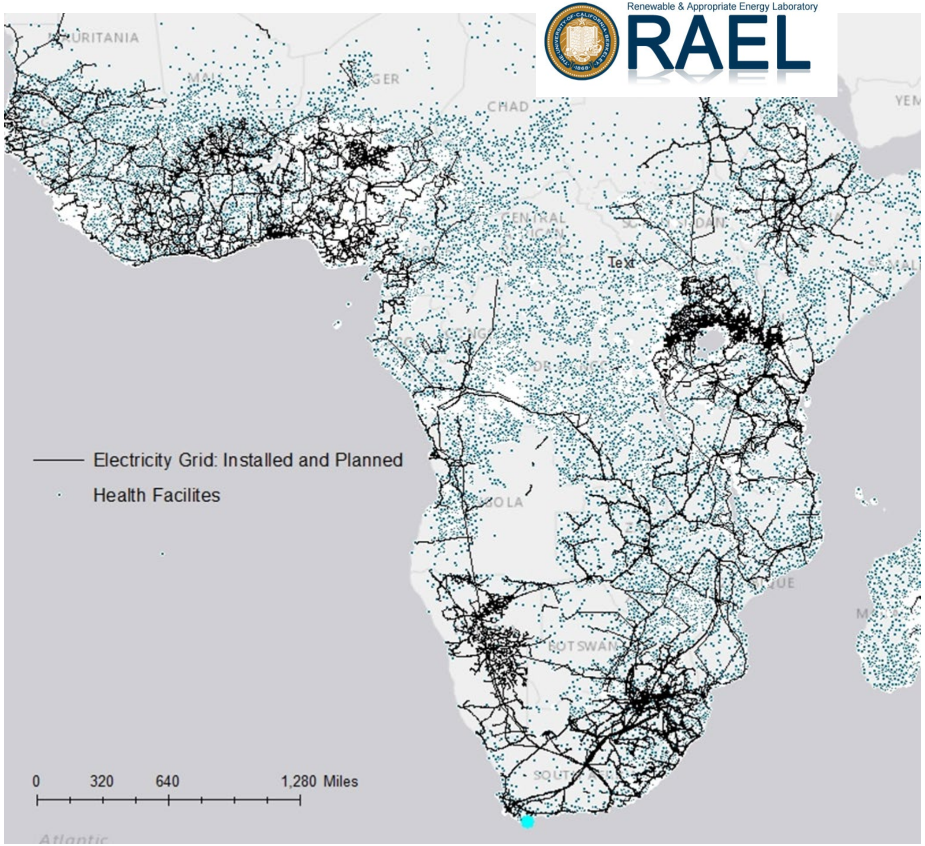
**67%** of public health facilities have intermittent access to electricity; **25%** with no access at all

**326,225**
preventable deaths of children ages 0-5 in 2019




Source: Kakoulaki, Georgia; Moner-Girona, Magda (2021); Miles & Kammen, (2022)

# Roadmap to 100,000+ electrified facilities

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**Market Based Solution**

Models created that support health electrification beyond donor investment

**Clinics electrified across SSA**

Since 2020 by USAID

**1,790**

**100,000**

**441**

**10,000**

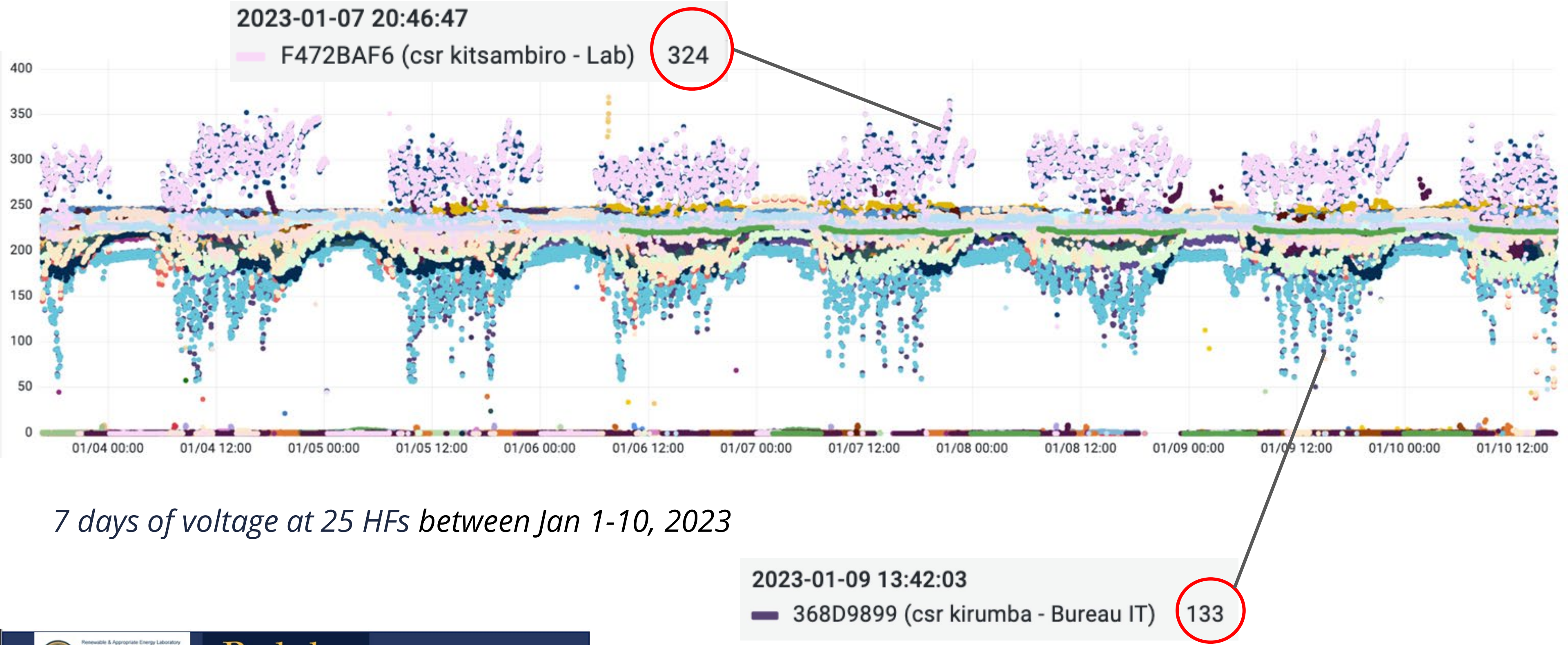
**25,000**

**Facilities electrified by Power Africa**


**HETA/ Multilateral HFE Compact**

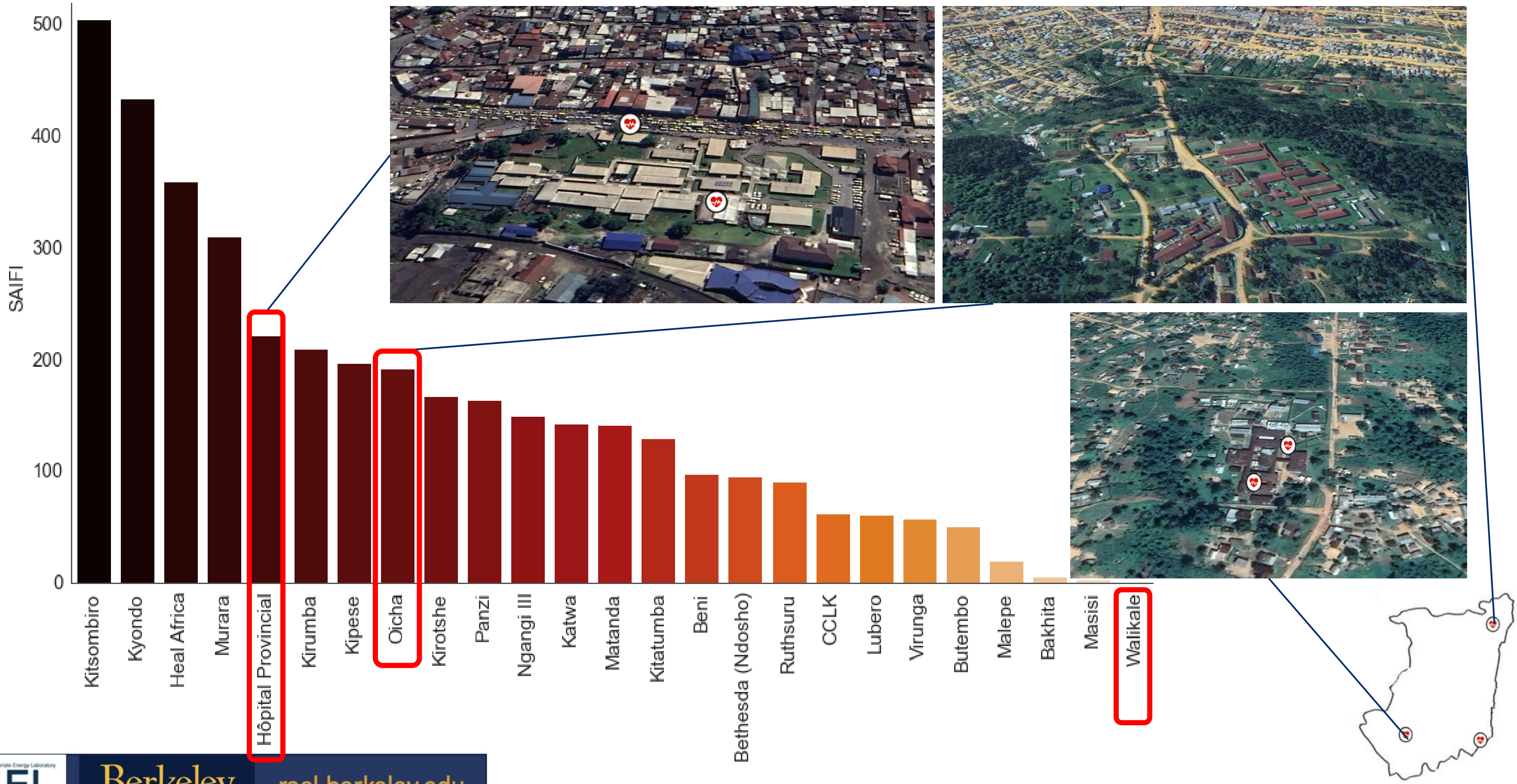
Power Africa committed to electrify 10,000 facilities under the Multilateral HFE Compact which aims to electricity 25,000 health facilities by 2025 through public-private partnerships

# Granular, live-view of outlet-level power quality




*7 days of voltage at 25 HFs between Jan 1-10, 2023*

# Reliability at three Hospitals in Goma & Kivu Provinces



# Thank you

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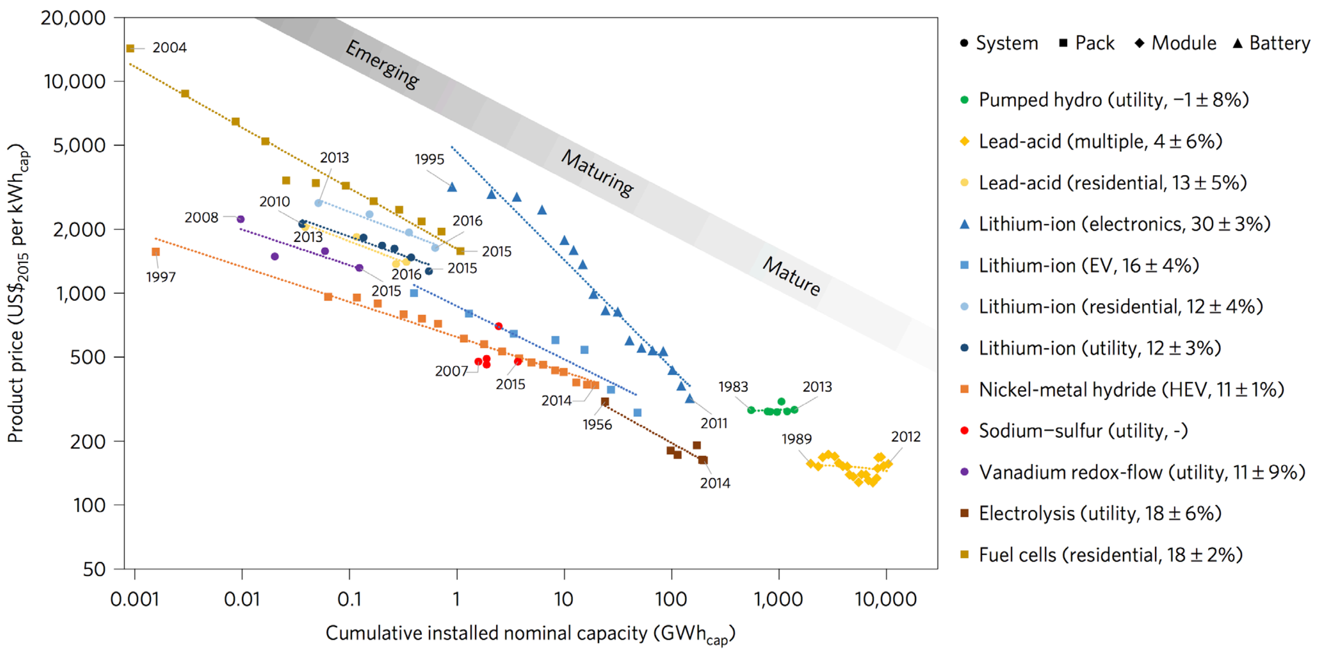
# Extra & Discussion Slides

# 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

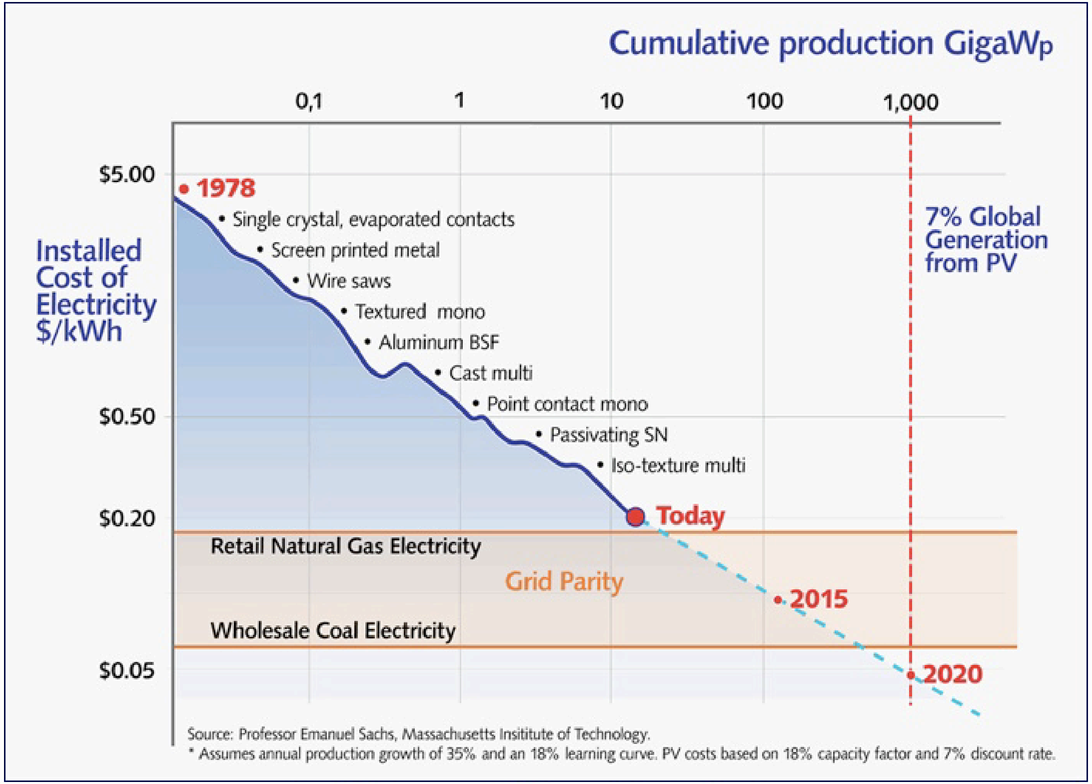
# The Learning Curve
# Swanson's Law

## "Moore's Law"

Cost (C) & Sales(V)
at times t1 and t2

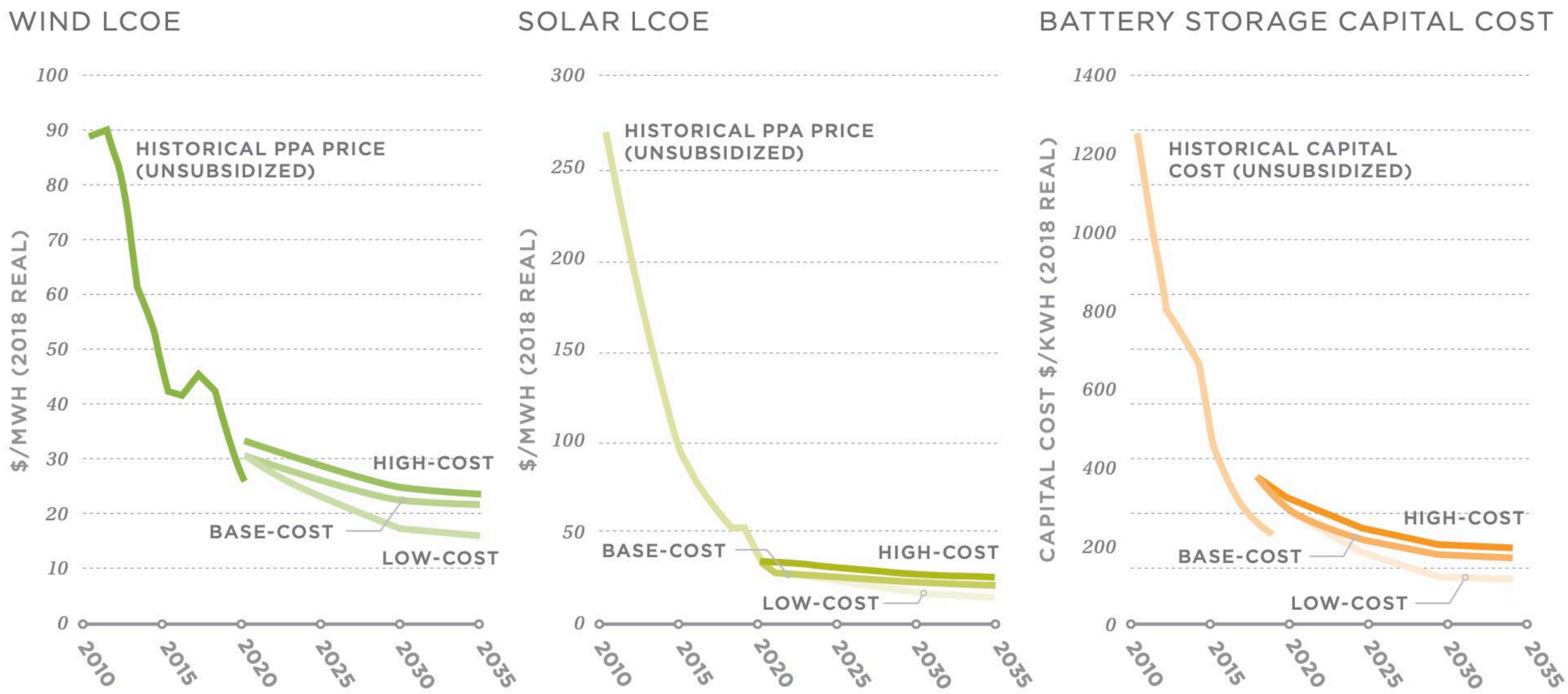
$$\frac{C_{t2}}{C_{t1}} = \left(\frac{V_{t2}}{V_{t1}}\right)^{-b}$$

**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.




**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

# Results dissemination and building partnerships

Development Engineering 7 (2022) 100101

ELSEVIER

Contents lists available at ScienceDirect

Development Engineering

journal homepage: www.elsevier.com/locate/deveng


Check for updates

## Productive uses of electricity at the energy-health nexus: Financial, technical and social insights from a containerized power system in Rwanda

Samuel B. Miles [a,*], Jessica Kersey [a], Emiliano Cecchini [b], Daniel M. Kammen [a,c]

[a] *Renewable and Appropriate Energy Laboratory, Energy and Resources Group, University of California, Berkeley, Berkeley, CA, USA*
[b] *OffGridBox, Inc., Cambridge, USA*
[c] *Renewable and Appropriate Energy Laboratory, Energy and Resources Group, Goldman School of Public Policy, University of California, Berkeley, Berkeley, CA, USA*

Article access: **https://doi.org/10.1016/j.deveng.2022.100101**

# Building Diverse Teams Drives Substantial, Positive Outcomes (n > 200 Silicon Valley startups, clean- fin-tech)

*Racial diversity boosts financial performance and market share*

**Top Quartile**
**in racial diversity**

+35%
financial outperformance

**For every**
10%
increase in senior team diversity

+1%
financial growth

*Companies with diverse leadership teams are*

45% likelier to grow market share

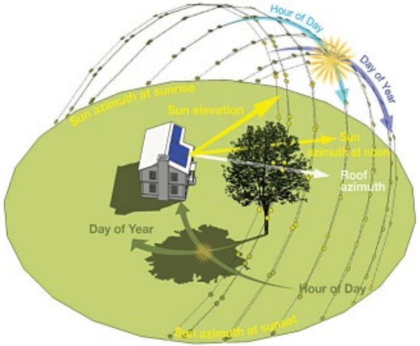
\+

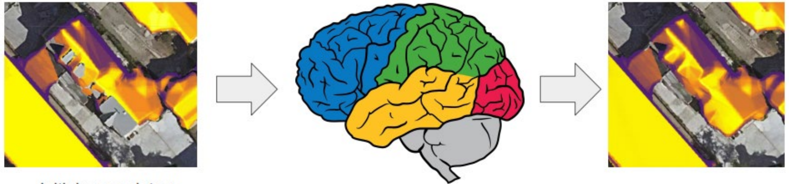
70% likelier to capture a new market

- Millions of oblique images acquired, processed, and refined.

Sun location | Attenuate light

Blocked by tree? | Cloudy?

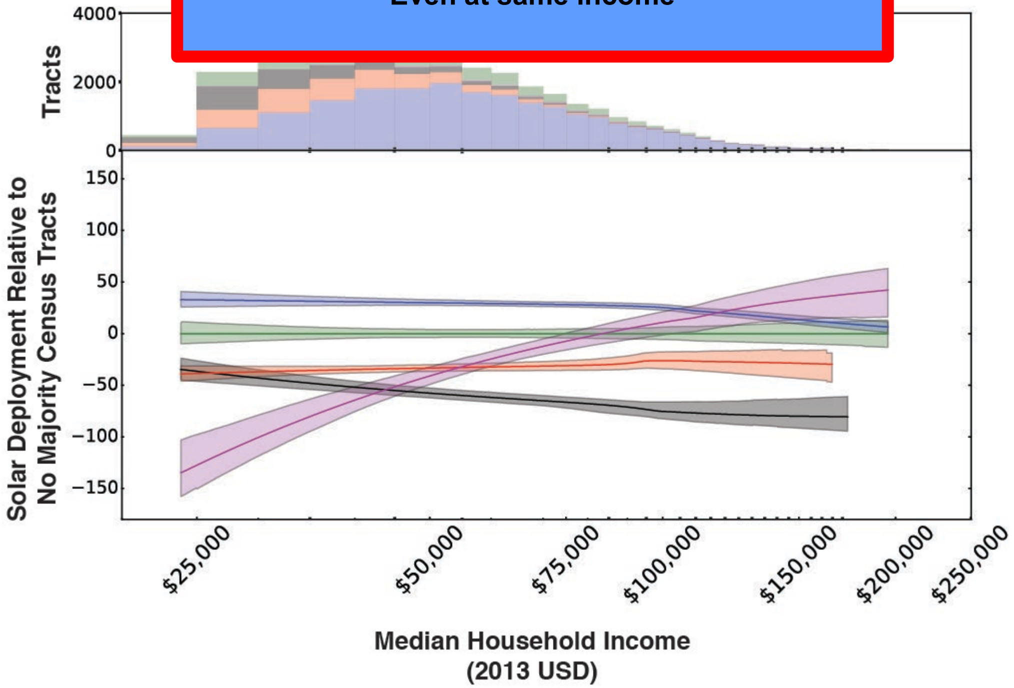


Initial maps data + heuristic refinement → Google Brain → Better roof maps

**White community ~+21%**
**Hispanic community ~–30%**
**Black community ~–69%**

**Even at same income**

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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)

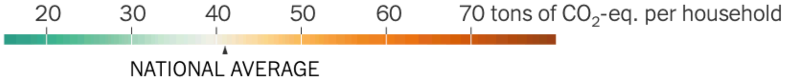
The New York Times

## 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)