Renewable & Appropriate Energy Laboratory

RAEL

Clean Energy Markets in the Wake of COVID-19

Daniel Kammen

Energy and Resources Group (Chair)

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

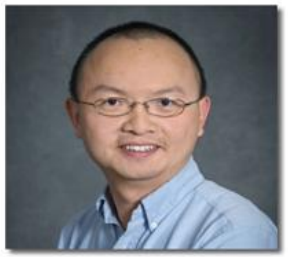
Selection from PhD Students (50)

Dr. **Rick Duke**, Special Advisor to Pres. Obama on Climate Change

Assoc. Prof **Tracey Osborne**, Geography, U of Arizona

Asst. Prof. **Dan Sanchez**, Extension, ESPM, UC Berkeley

Prof **Charles Kirubi**, Environmental Studies, Kenyatta University



Asst Prof. **Gang He**, Dept. Tech. & Society Stony Brook University

Assoc. Prof. **Donna Green**, UNSW

Dr. **Rebekah Shirley**, Dir. Power for All, Strathmore University, Nairobi, Kenya

Energy Extension, **Christian Casillas**, U of New Mexico

Asst. Prof **Derek Lemoine**, Economics, U. of Arizona

Prof. **Katie Purvis** Environmental Chemistry, The Claremont Colleges

Prof **Tonio Buonosissi**, Mechanical Eng., Dir. Solar Materials Lab, MIT

Assoc. Prof. **Joanna Lewis**, Georgetown U

Prof **Arne Jacobsen** Director, Schatz Energy Lab Humboldt State U

Prof **Tracey Holloway**, Atmospheric Science, U Wisc. Founder, Env. Science Women's Network

Dr. **Carla Peterman** Commissioner, California Public Commission

Prof **Majid Ezzati**, Dir. Global Env. Health Imperial College, London & Harvard School of Public Health

Asst Prof, **Deborah Sunter**, Mechanical Engineering, Tufts U. & UC Berkeley Institute of Data Sciences Fellow

Assoc. Prof. **Greg Nemet**, U. Wisconsin, LaFollette School of Public Affairs & Nelson Instiute

The Impact of COVID-19 on Energy Use and Emissions

Coal use **- 10 %** **globally since January**

Gas use **- 4 %** **globally since January**

Green energy + 3 % **globally since January**

COVID-19 causes record decline in global CO2 emissions

Zhu Liu[1*], Zhu Deng[1], Philippe Ciais[2], Ruixue Lei[3], Steven J. Davis[4], Sha Feng[4], Bo Zheng[2], Duo Cui[1], Xinyu Dou[1], Pan He[1], Biqing Zhu[1], Chenxi Lu[1], Piyu Ke[1], Taochun Sun[1], Yuan Wang[5,6], Xu Yue[7], Yilong Wang[2], Yadong Lei[8], Hao Zhou[8], Zhaonan Cai[9], Yuhui Wu[10], Runtao Guo[11], Tingxuan Han[12], Jinjun Xue[13, 14, 15], Olivier Boucher[16], Frederic Chevallier[2], Eulalie Boucher[2], Yimin Wei[17], Qiang Zhang[1], Dabo Guan[1], Peng Gong[1], Daniel M. Kammen[18], Kebin He[10], Hans Joachim Schellnhuber[19]

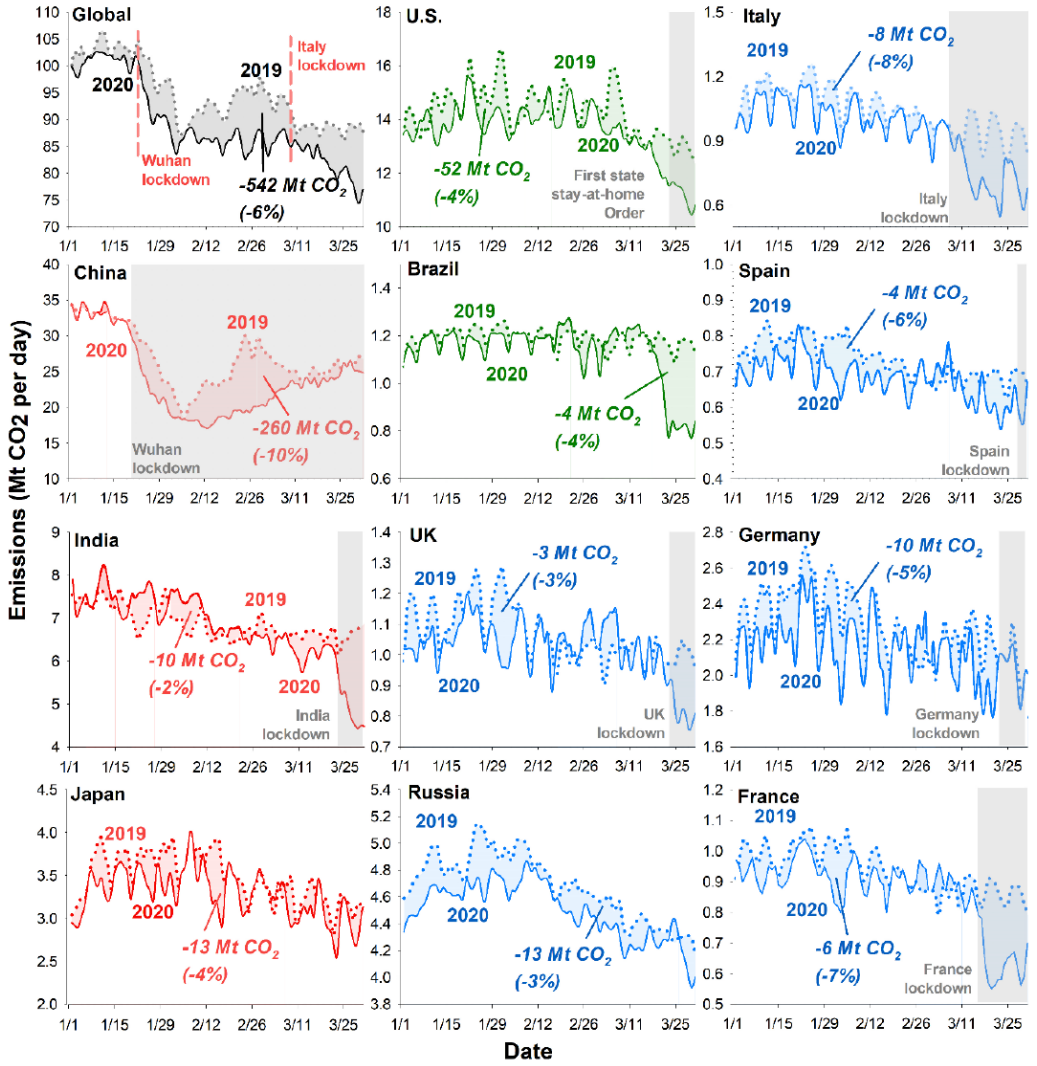


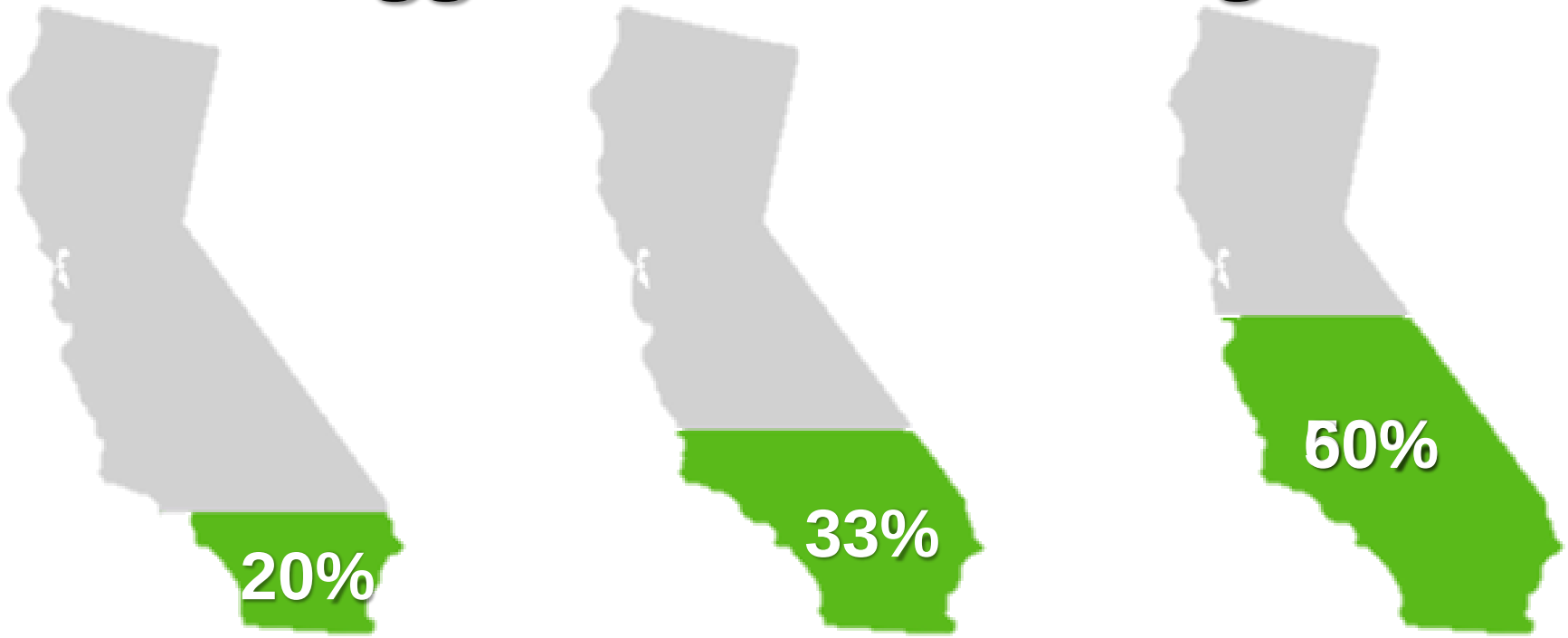
Figure 1

Daily CO_2 emissions Q1 of 2019 (dotted line) and 2020 (Solid Line)

Nature Communications

https://www.nature.com/articles/s41467-020-18922-7

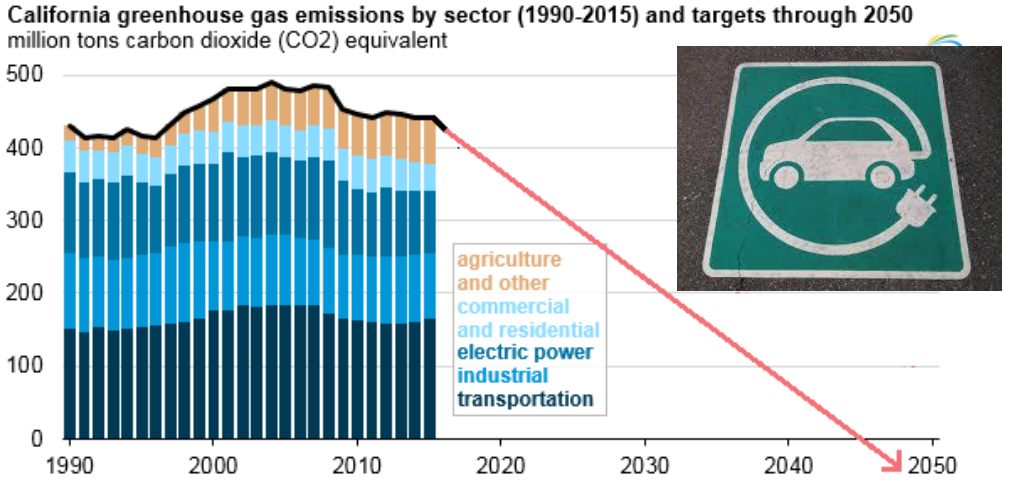
California Energy Goals: Aggressive & Evolving

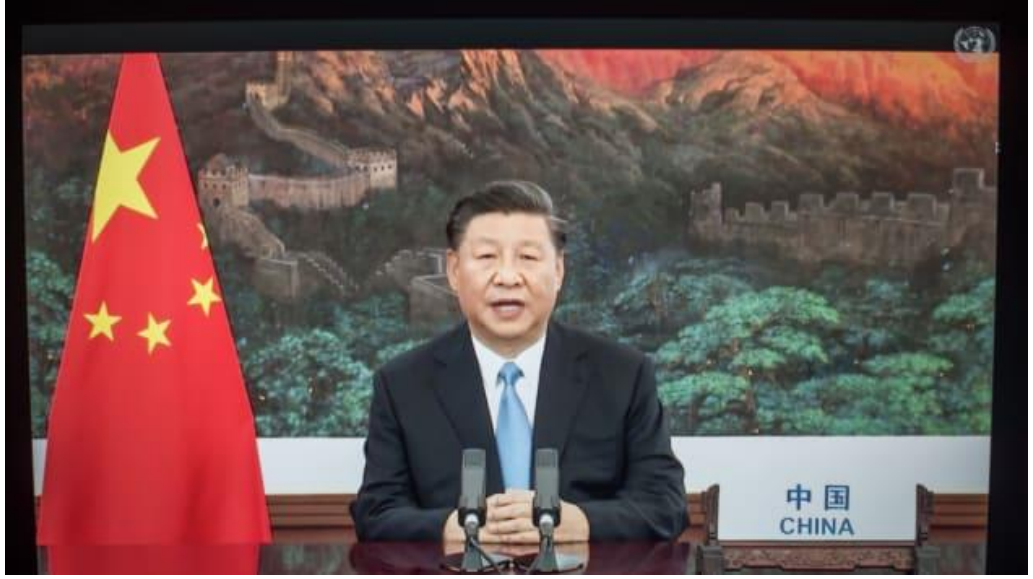


2013 **2020** **2030**

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

9.22.2020 - California has peaked emissions, & will now end internal combustion sales by 2035





9.23.2020 - China to peak emissions by 2030, carbon neutral by 2060

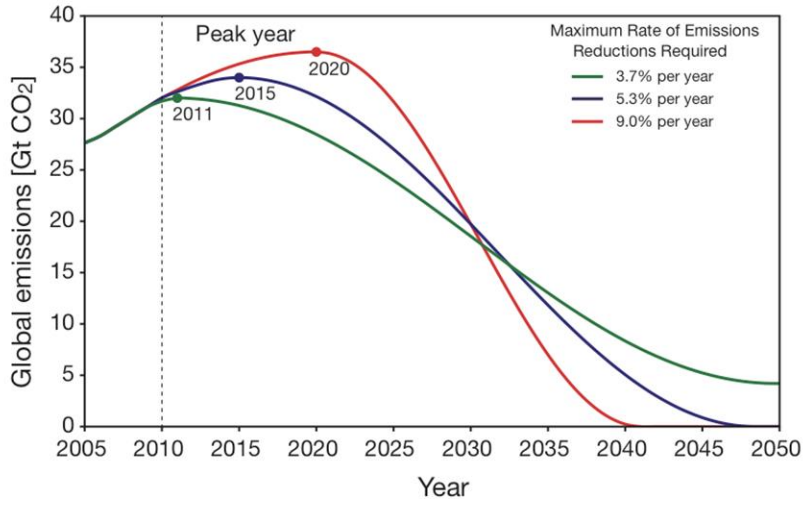
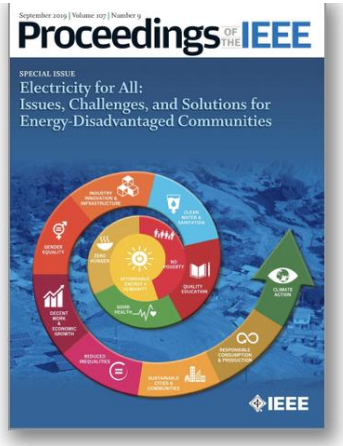


Figure 22: Emissions pathways to give 75% chance of limiting global warming to 2ºC

The Copenhagen Diagnosis
Updating the World on the Latest Climate Science
http://www.copenhagendiagnosis.com/

Renewable & Appropriate Energy Laboratory
RAEL

Berkeley
UNIVERSITY OF CALIFORNIA



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

More solar jobs in California than fossil fuel jobs

More solar jobs in California than utility jobs.

COMMENT

A microhydro turbine on the Nam Ou River in Laos generates electricity for nearby villages.

Deploy diverse renewables to save tropical rivers

A strategic mix of solar, wind and storage technologies around river basins would be safer and cheaper than building large dams, argue **Rafael J. P. Schmitt, Noah Kittner** and colleagues.

Demand for clean energy is soaring across developing nations in Africa, South America and southeast Asia. Governments from Myanmar to Brazil face hard decisions. Should they invest billions of dollars in tried-and-tested hydropower, damming yet more rivers to generate electricity? Or should they spend on emerging solar, wind and energy-storage technologies, the costs of which have plummeted in the past decade?

Many emerging economies are planning to increase their hydropower generation. For example, Cambodia is considering spending US$5 billion — almost one-quarter of its gross domestic product — on building the Sambor dam on the Mekong River. Should it go ahead, the dam could generate 11,000 gigawatt hours (GWh) of electricity each year, a big jump from the 7,000 GWh the country generated in 2017.

But a surge of dam development across the tropics threatens to interrupt the planet's last free-flowing rivers[1] — including the Mekong, Congo, Amazon and Irrawaddy. The lives of millions of people and many species depend on these rivers[2]. The projects address important energy needs, but advocates often overestimate economic benefits and underestimate the far-reaching effects on biodiversity and important fisheries. Powerful analytical tools and high-resolution environmental data can clarify trade-offs between engineering and environmental goals, and can enable governments and funding institutions to compare many alternative scenarios for dam building and expansion of renewable energy.

The proposed Sambor dam, for example, would prevent fish from migrating, threatening fisheries worth billions of dollars[3]. It would further cut the supply of sediment to

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

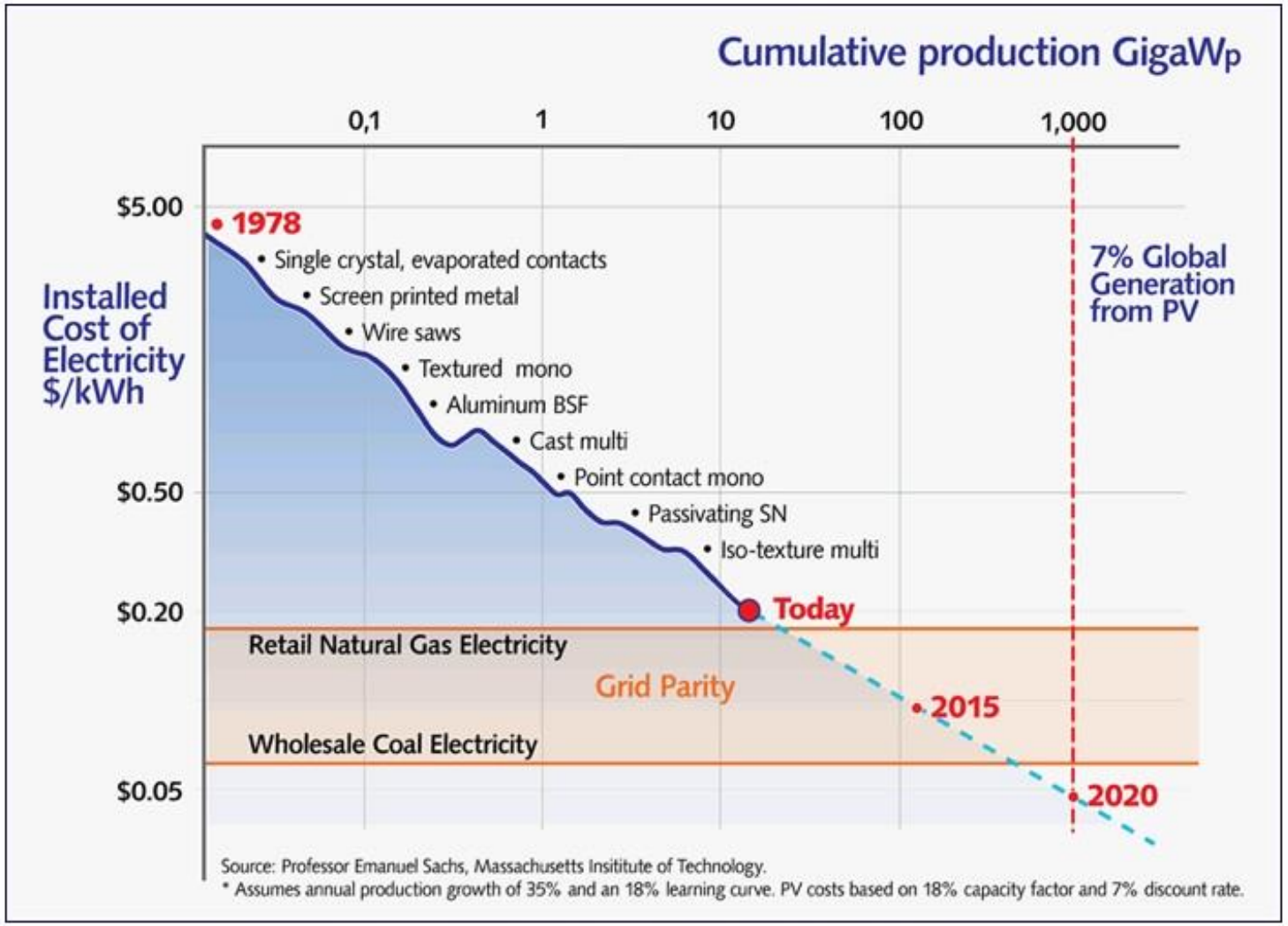
Renewable & Appropriate Energy Laboratory
RAEL
Berkeley
UNIVERSITY OF CALIFORNIA

The Learning Curve

Swanson's Law

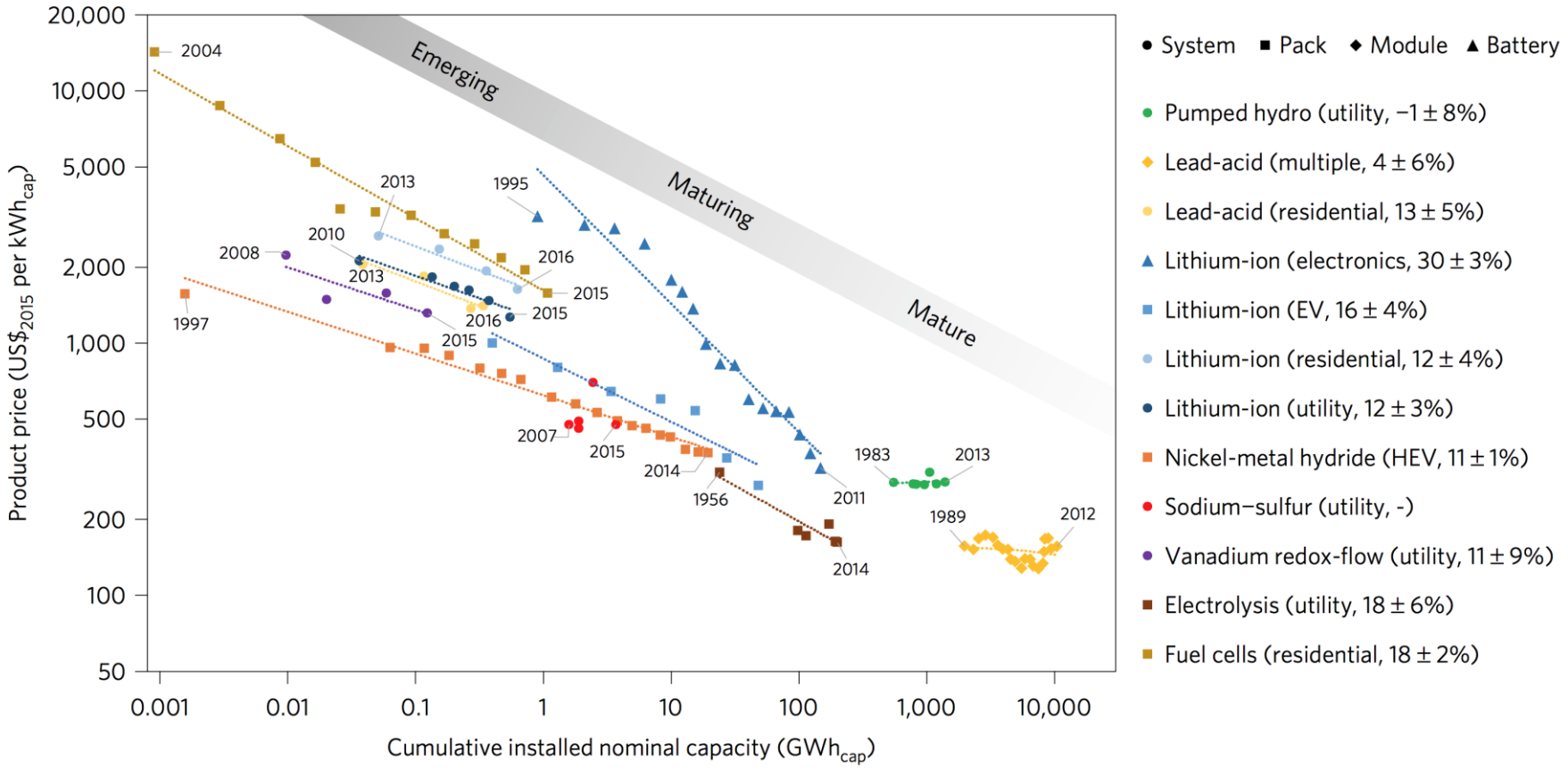
"Moore's Law"

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



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

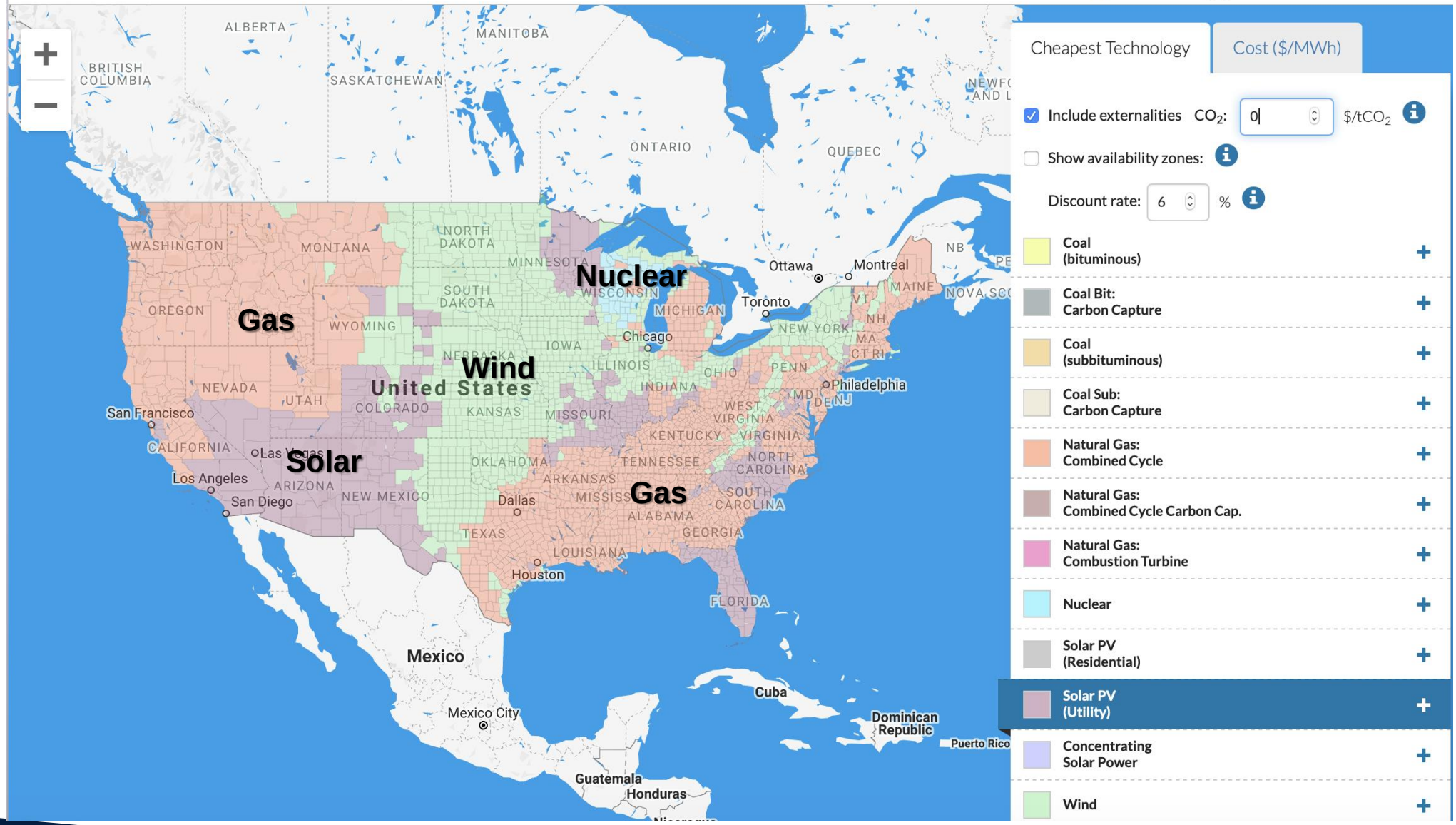
Materials Science for Storage Innovation



Data from: Schmidt, O., Hawkes, A., Gambhir, A., & Staffell, I. (2017). The future cost of electrical energy storage based on experience rates. *Nature Energy, 2,* 2017110. Qiu, Y., & Anadon, L. D. (2012). The price of wind power in China during its expansion: Technology adoption, learning-by-doing, economies of scale, and manufacturing localization. *Energy Economics*, *34*(3), 772-785. ;

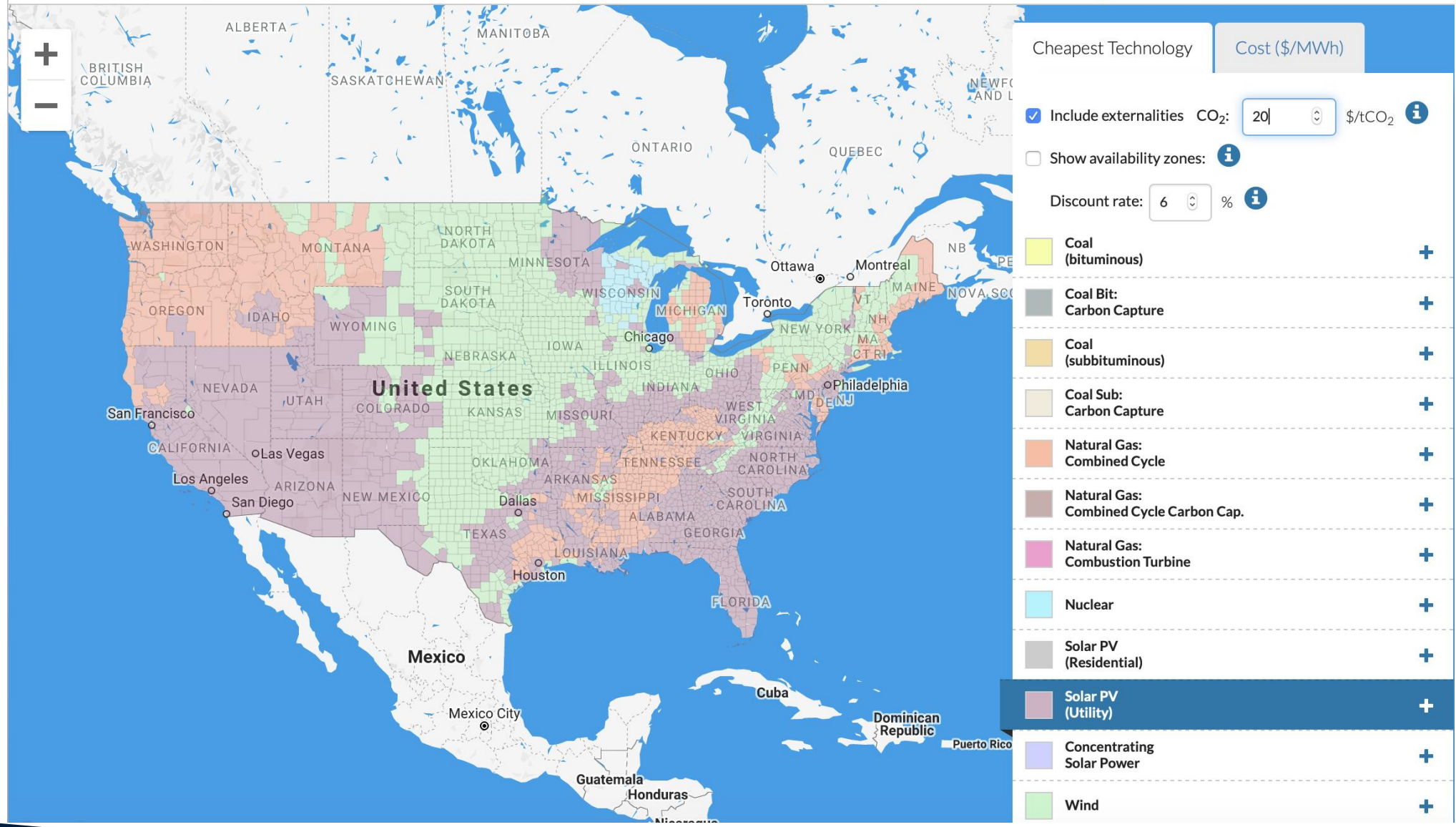
Overnight Energy costs:

$0/tCO$_2$



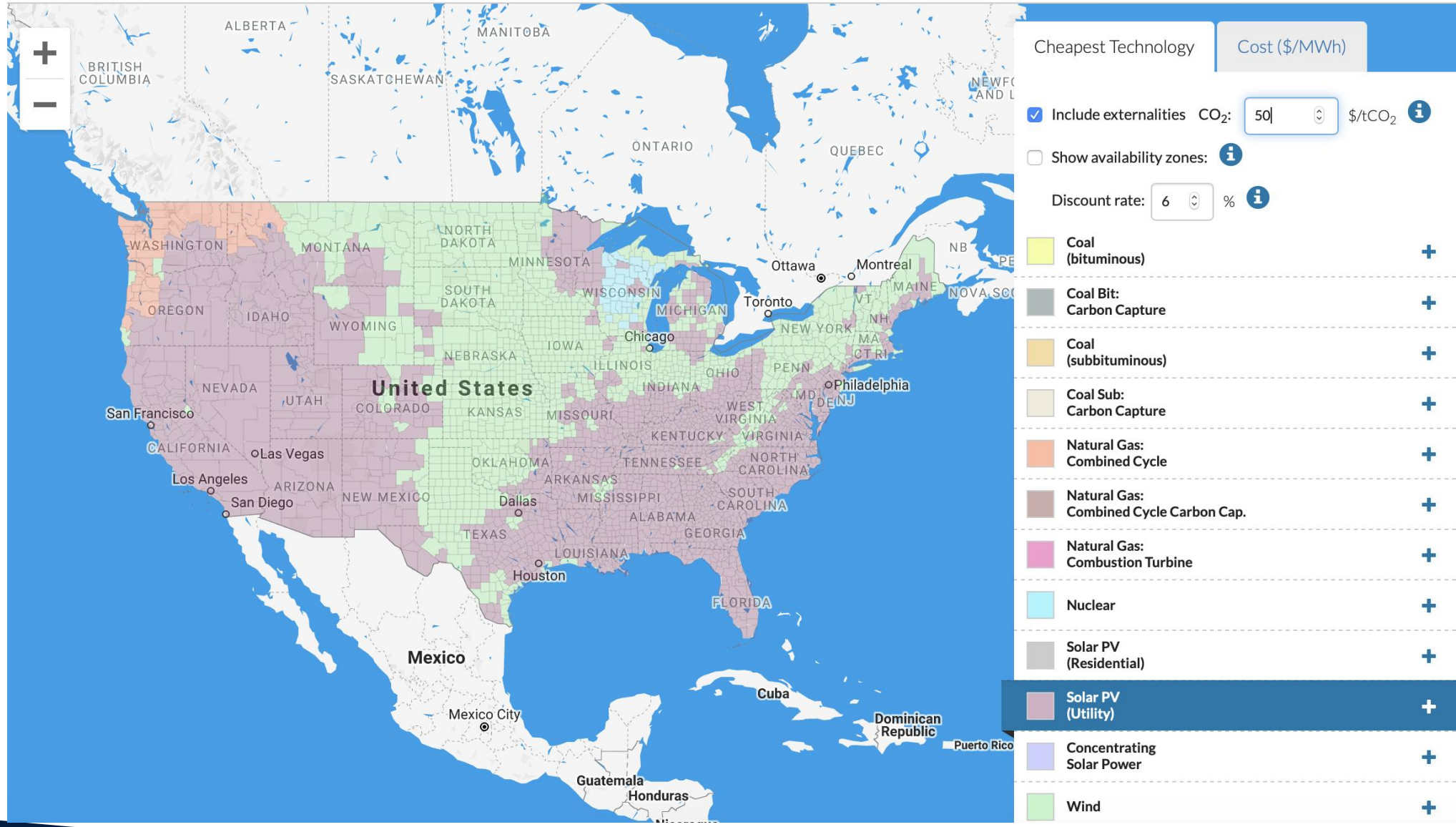
California & Quebec:

$20/tCO$_2$



Social Cost of Carbon:

$50/tCO$_2$



Renewable & Appropriate Energy Laboratory
RAEL

Berkeley
UNIVERSITY OF CALIFORNIA

http://rael.berkeley.edu

Under the Radar, but Over the Moon

BRIEF

CPUC proposes optimal 2030 system portfolio tripling battery storage, more than doubling solar

Fotolia

BRIEF

FERC has legal authority to implement a carbon price, experts tell commissioners

Elizabeth Regan, Industry Dive

BUSINESS // ENERGY

FERC clears states to move ahead on carbon pricing

James Osborne | Oct. 15, 2020 | Updated: Oct. 15, 2020 10:02 p.m.

Neil Chatterjee, chairman of U.S. Federal Energy Regulatory Commission (FERC), speaks during the 2019 CERAWeek by IHS Markit conference in Houston, Texas, U.S., on Thursday, March 14, 2019.
Photo: F. Carter Smith / Bloomberg

California Energy Efficiency Strategies: Policy Drives Innovation

Residential New Construction

Took 10 years to implement

- All new residential construction in California will be zero net energy by 2020.

California Energy Efficiency & Solar Policy Drives Innovation

Residential Construction

Zero net energy after January 1, 2020

Big Bold EE Strategies

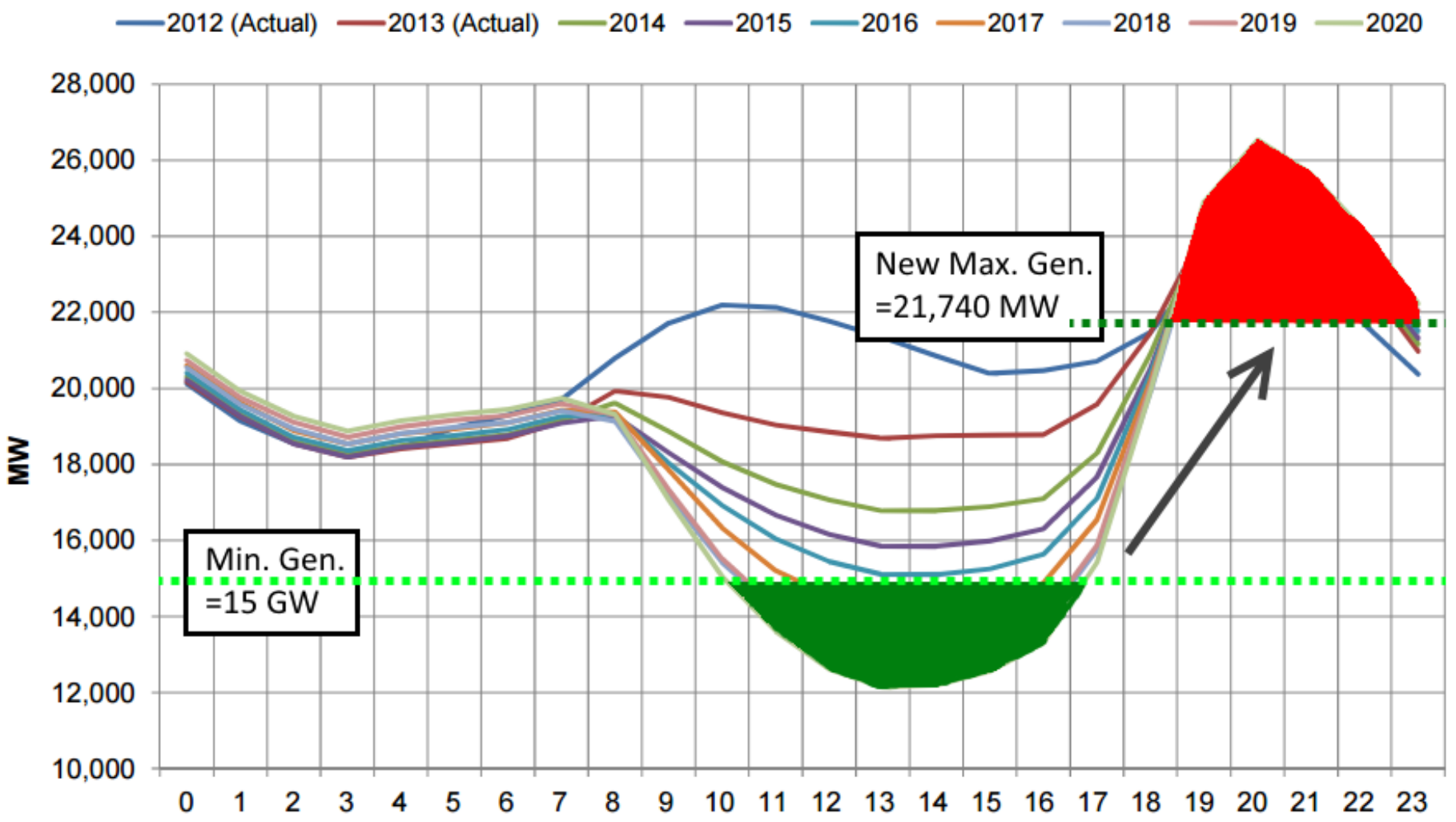
Commercial New Construction

- All new commercial construction in California will be zero net energy by 2030.
- Leverage opportunities from emerging technologies initiatives, incentive programs, and local initiatives targeting commercial building/ property developers.

The World's Largest Iron-Chromium Flow Battery

EnerVault Iron-Chromium Technology
1 MW-hr capacity at 250 kW (4 hour duration)
Turlock, CA

California Advancing Energy Efficiency




实时充电功率 (kW)
76425
今日充电电量 (kWh)
1155509
今日充电次数 (次)
35840
累计充电电量 (kWh)
全国充电网络
充电桩类型分布
65018个
7549个
57469个
1544个
189041个
77735个
21925个
17551个
13128个
10414个
2862个
1049个
44377个
各国电动汽车与充电桩数量
车 233.5 万辆
桩 27.9 万个
车 92.2 万辆
桩 4 万个
车 140.8 万辆
桩 10.6 万个
车 34.8 万辆
桩 2.2 万个
故障信息
近12月故障数量（个）
近12月故障及时消缺率（%）
运营商分布 2018年8月
合计电量 37384 万KWh
社会电量 31296 万KWh
公司电量 6088 万KWh
年度充电量和充换电次数
充电量
充换电次数
月度充电量 (万kWh)
2016
2017
2018

Dr Cheng Zheng, CEO, Aspiring Citizens Cleantech (ACC) & Gordon Bauer (ERG, UC Berkeley)

Target: 100% EV taxi fleet in Shenzhen, China (28,000+ vehicles)
96% of the taxi fleet

nature sustainability

ANALYSIS

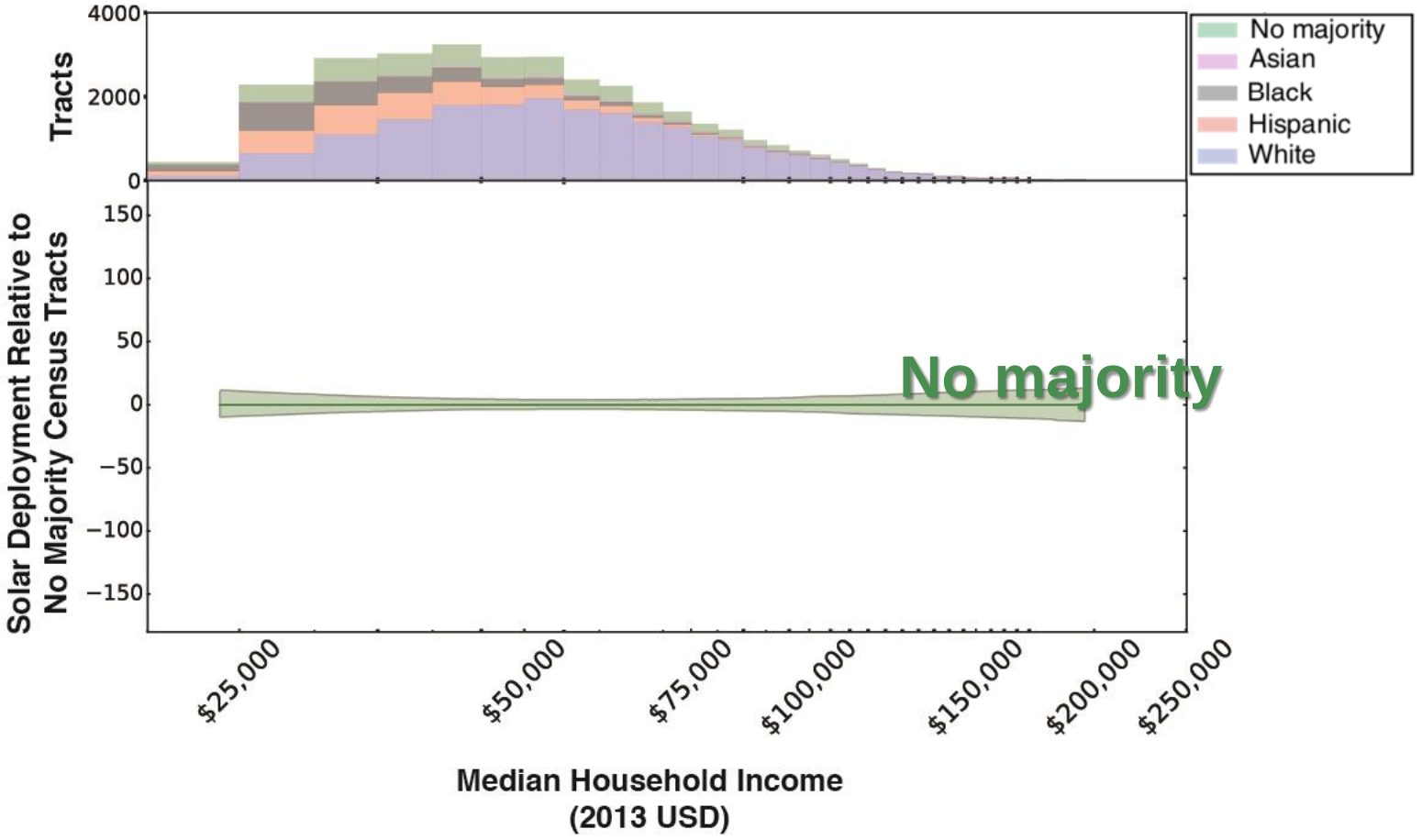
https://doi.org/10.1038/s41893-018-0204-z

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

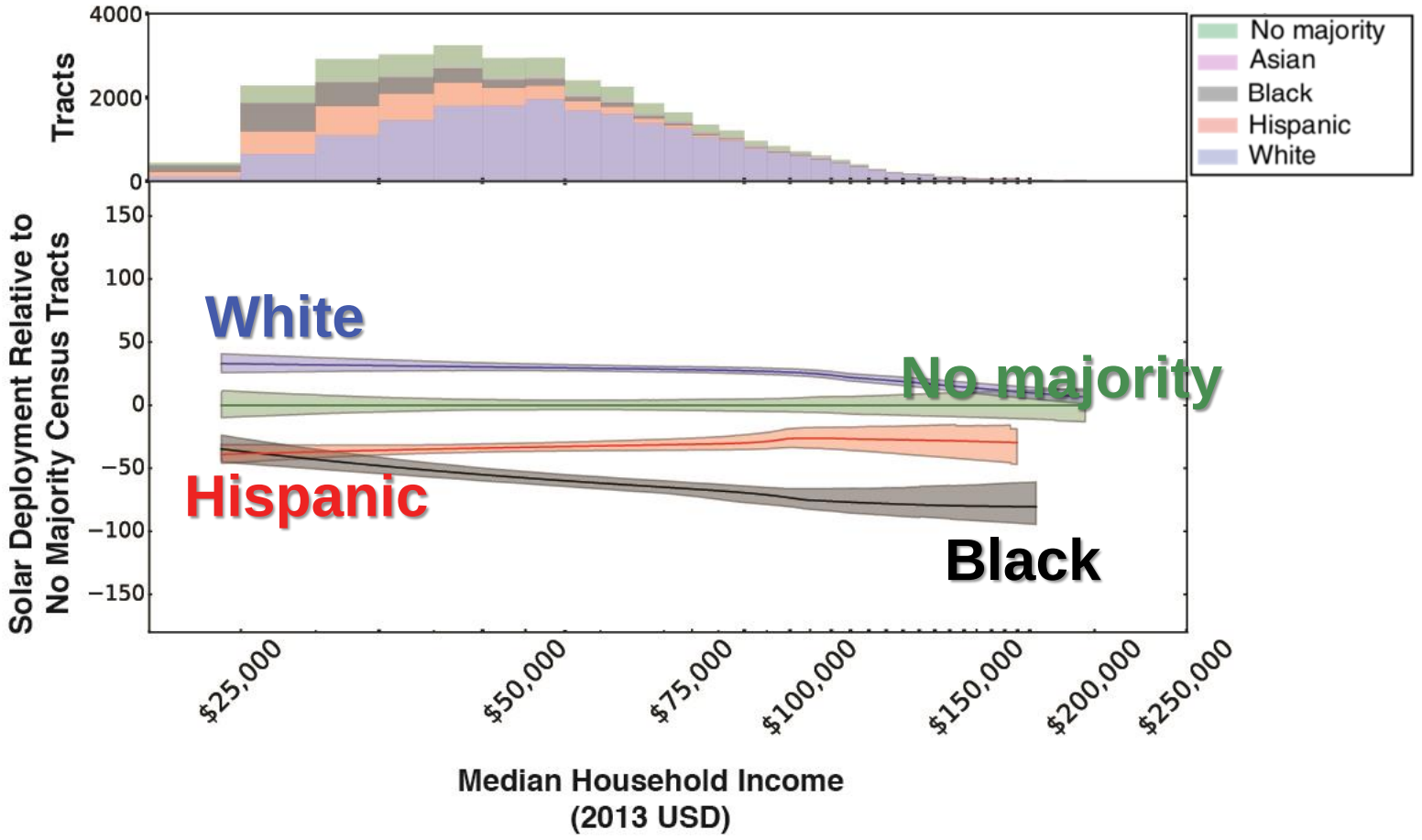
Deborah A. Sunter[1,2,3,4*], Sergio Castellanos[3,4,5,6*] and Daniel M. Kammen[3,4,7]

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.

Racial disparity is observed – even at same income



Racial disparity is observed – even at same income



OPINION

How electric vehicles can help advance social justice

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

San Francisco Chronicle

Learn from our Mistakes: The need for Environmental Justice

- **Lack of solar power and electric vehicle access where the health benefits are highest**
- **California Green New Deal: Dedicated seed fund of $3.5 billion/yr for disadvantaged areas**
- **One California proposal (not yet passed): affordable housing at transit hubs.**

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

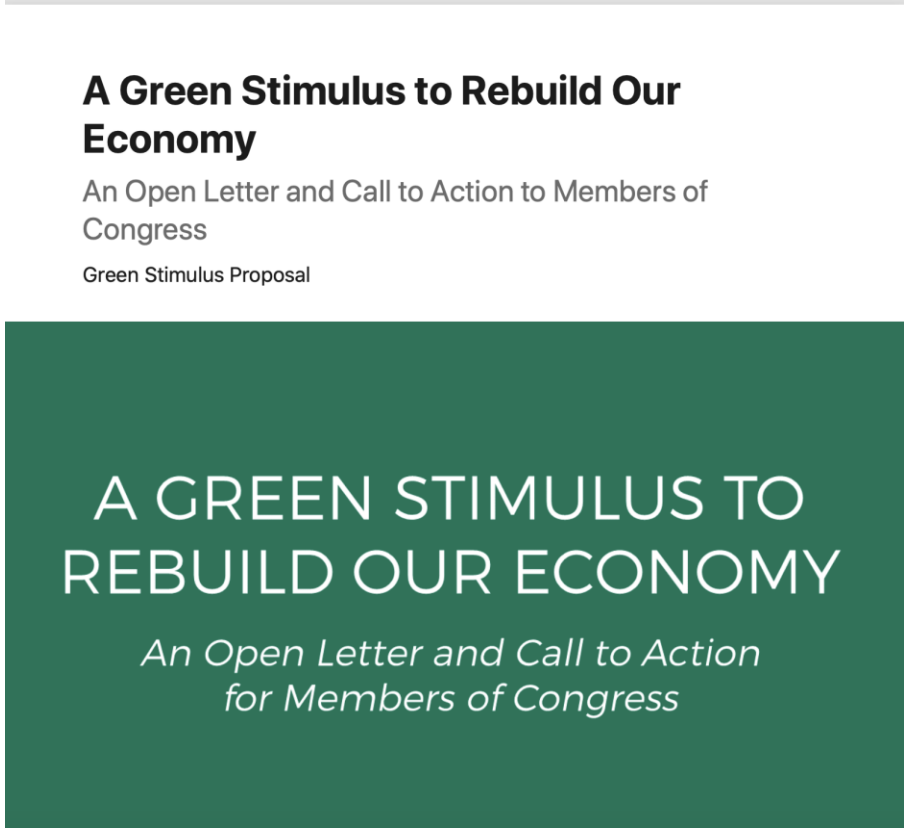
Electricity

- System Architecture
  - ~200 kW PV DC microgrid based on **utility backbone** with single inverter connection to the grid
  - Charging stations for shared EVs – or Individual charging stations
  - 10 x 25 kWh/10 kW flywheel storage
- Estimated ~250 to 300 MWh/year PV production.

RAEL partners with Shenzhen to use the Internet of Things (IOT) to reduce waiting times for EV recharging

Many Opportunities: The Green Stimulus

https://medium.com/@green_stimulus_now/a-green-stimulus-to-rebuild-our-economy-1e7030a1d9ee



Author team:
Johanna Bozuwa, J. Mijin Cha, Daniel Aldana Cohen, Billy Fleming, Jim Goodman, Ayana Elizabeth Johnson, Daniel M Kammen, Julian Brave NoiseCat, Mark Paul, Raj Patel, Thea Riofrancos (2020) "A Green Stimulus",

https://medium.com/@green_stimulus_now/a-green-stimulus-to-rebuild-our-economy-1e7030a1d9ee

Resources:

http://rael.berkeley.edu

@dan_kammen

FEEDBACKS AMONG ELECTRIC VEHICLE ADOPTION, CHARGING, AND THE COST AND INSTALLATION OF ROOFTOP SOLAR

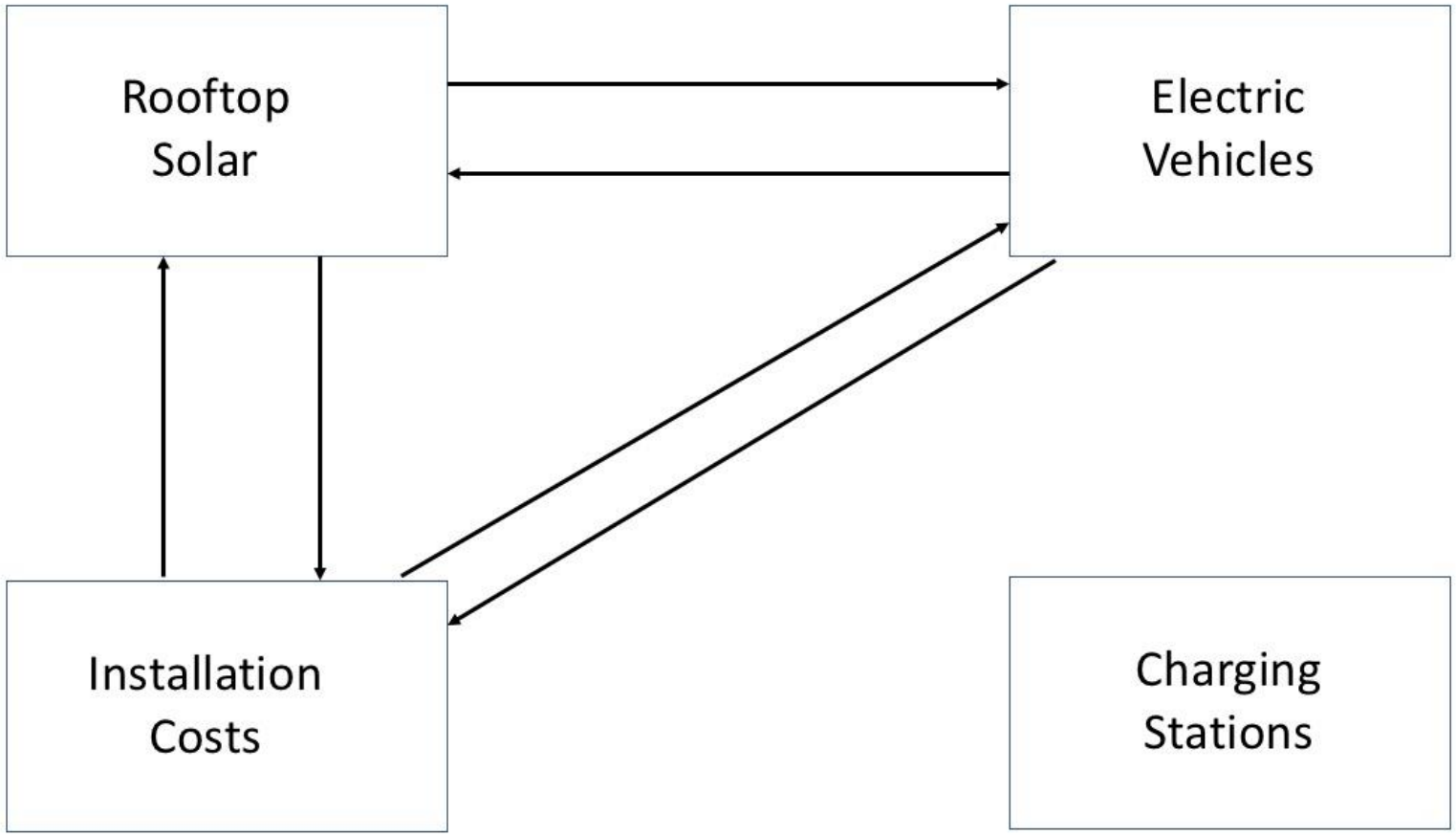
ROBERT K. KAUFMANN
DEREK NEWBERRY
XIN CHEN
SUCHARITA GOPAL

In Press *Nature Energy*

PANDEMIC DIMINISHES THE ROLE OF ECONOMICS

- Trust in science
- Home improvement
- Self-sufficiency

RELATIONS PV, COSTS, EV, & CHARGINING STATIONS



Rooftop Solar ↔ Electric Vehicles

- Environmental complementarity
- Visibility
- Social norms

Rooftop Solar ↔ Installation Costs

- Learning by doing
- Lower costs enhance installation

Electric Vehicles & Charging Stations

- No relation
- Range anxiety
- Housing type
- Charging equipment

Policy Implications

- Space Matters!
  - Trigger decision-making
  - EV subsidies by zip code
  - SREC conversion efficiencies by zip code
- Feedback Multiplier