Renewable & Appropriate Energy Laboratory
RAEL

The Clean Energy Revolution is (Finally) Here

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

Kleinman Center for Energy Policy, U of Pennsylvania- February 26, 2020

Resources:

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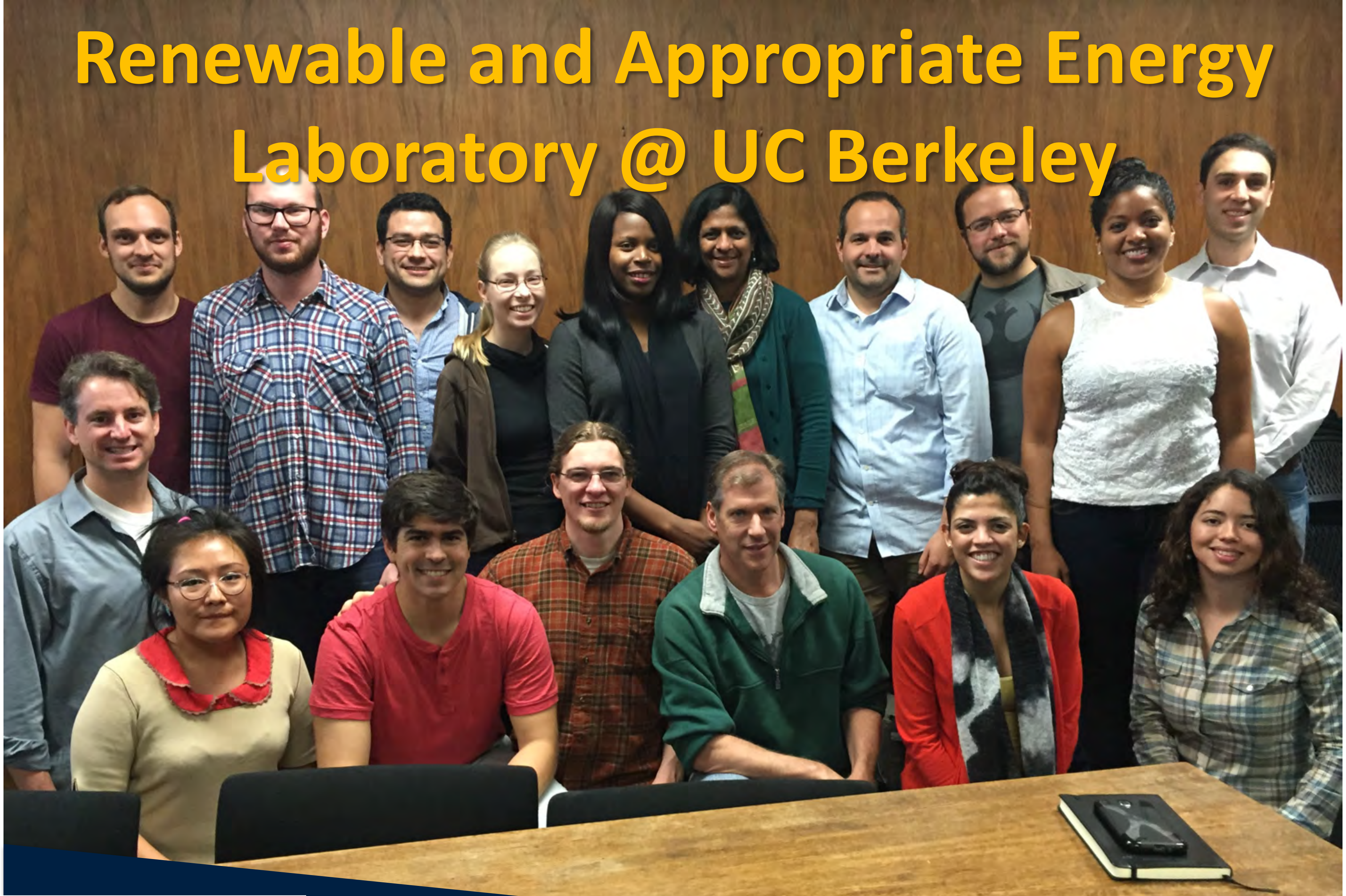
Renewable and Appropriate Energy Laboratory @ UC Berkeley



Renewable & Appropriate Energy Laboratory
RAEL

Berkeley
UNIVERSITY OF CALIFORNIA

http://rael.berkeley.edu

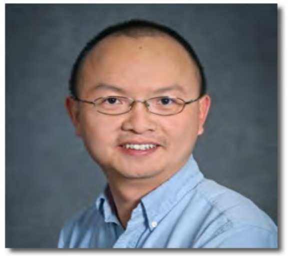
RAEL: 50 PhD graduates and counting

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

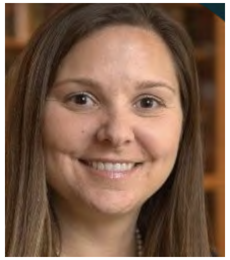
Rebekah Shirley, Dir. Power for All, Strathmore University, Nairobi, Kenya

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

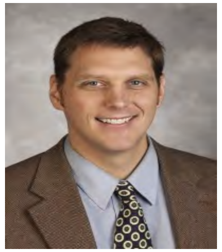
Prof **Arne Jacobsen** Director, Schatz Energy Lab Humboldt State U

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

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

Overview

- The climate crisis is now an (urgent) opportunity
- Infrastructure for the green energy economy
- The power the Just Transition / Green New Deal

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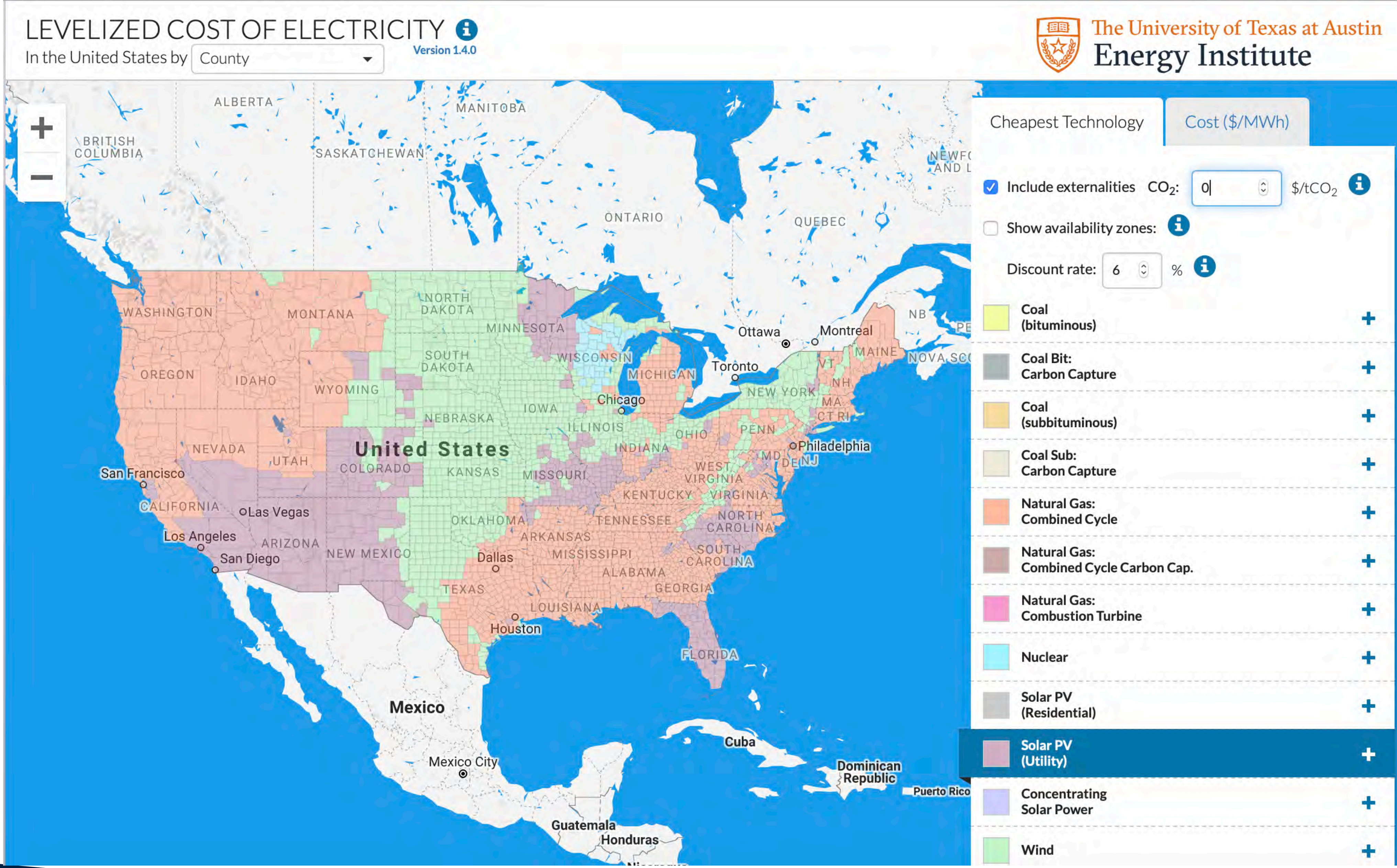
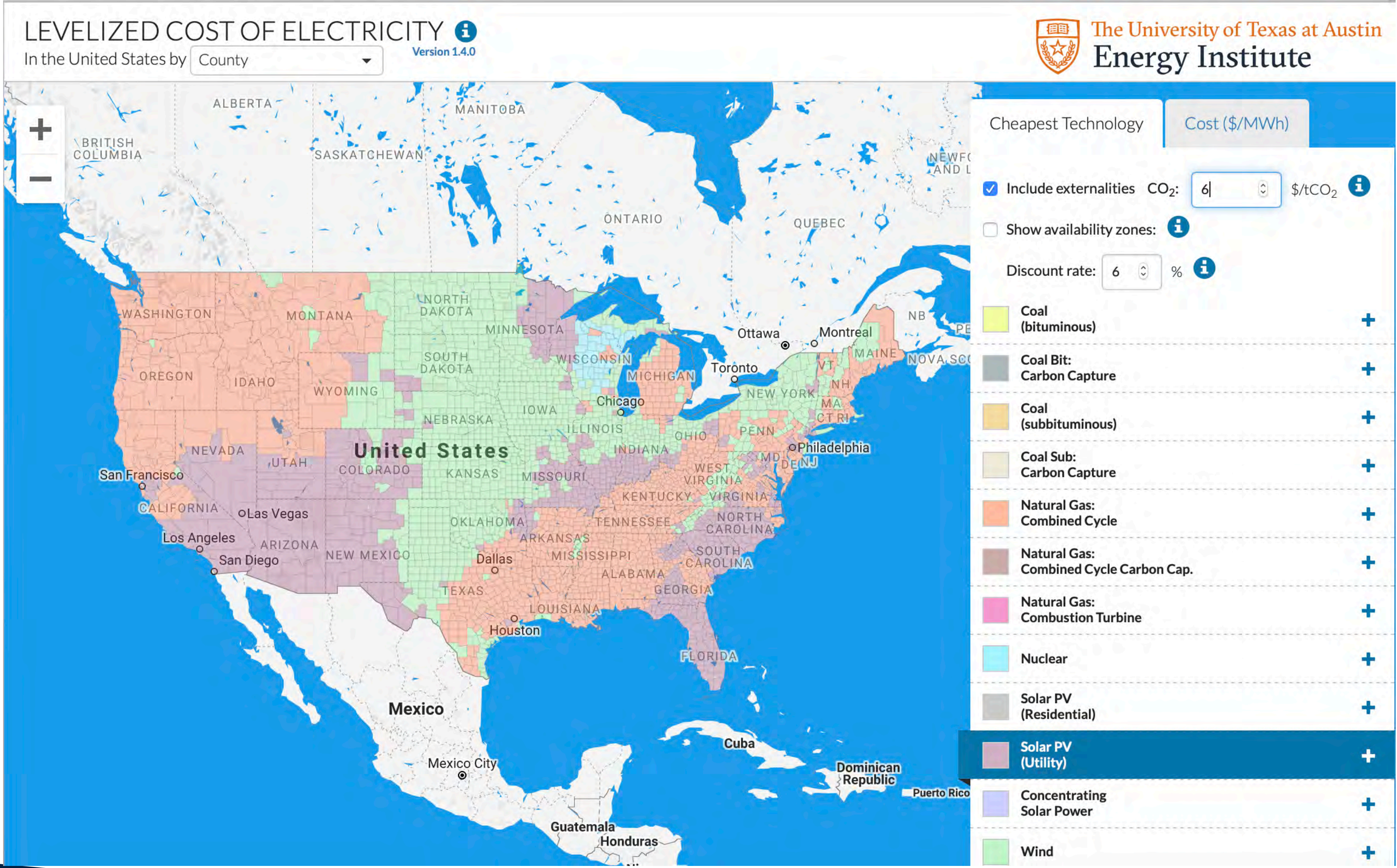
Energy costs (current)



http://calculators.energy.utexas.edu/lcoe_map/#/county/tech

UT Austin - Levelized Cost of Electricity

Regional Greenhouse Gas Initiative

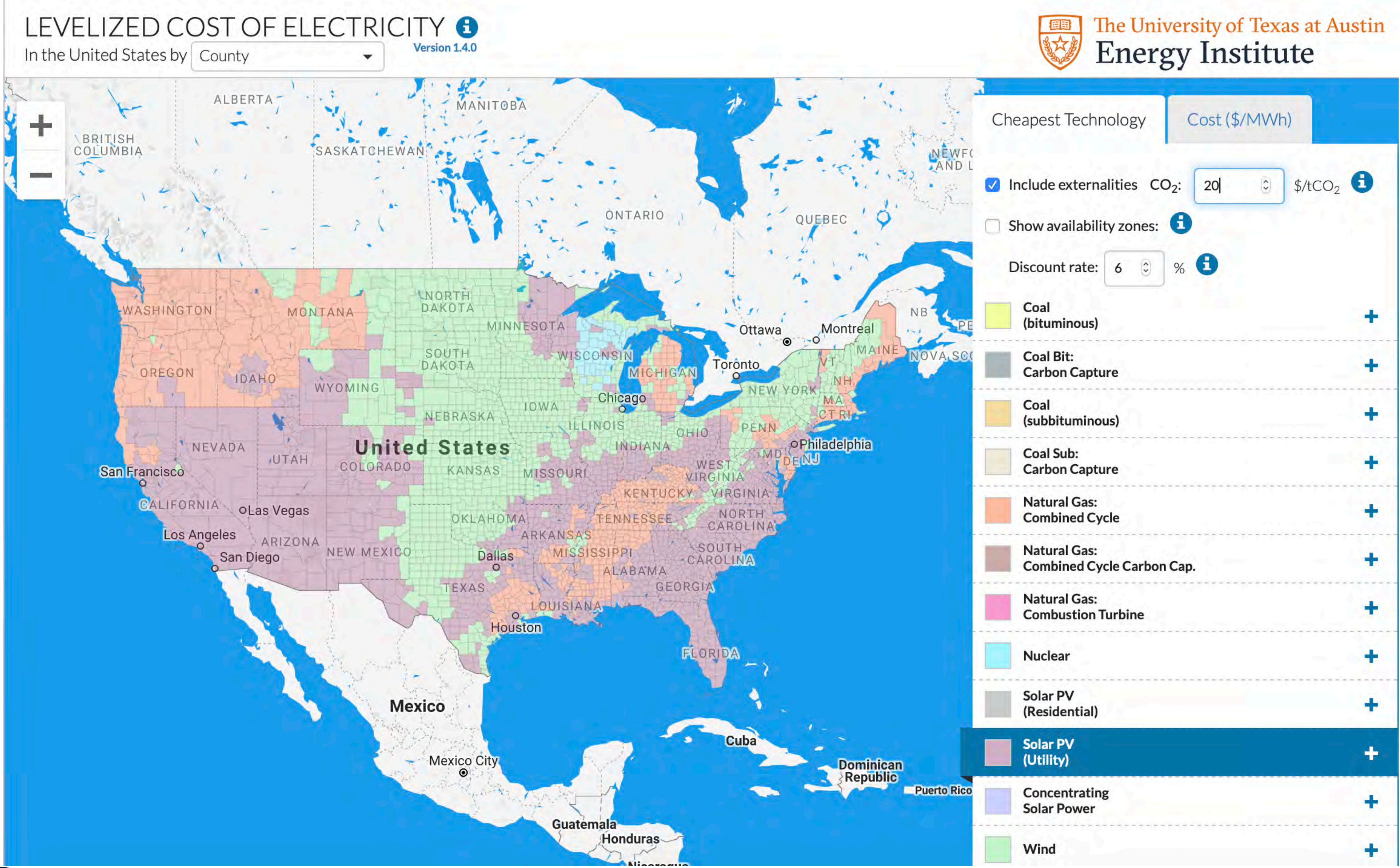


http://calculators.energy.utexas.edu/lcoe_map/#/county/tech

UT Austin - Levelized Cost of Electricity

Renewable & Appropriate Energy Laboratory

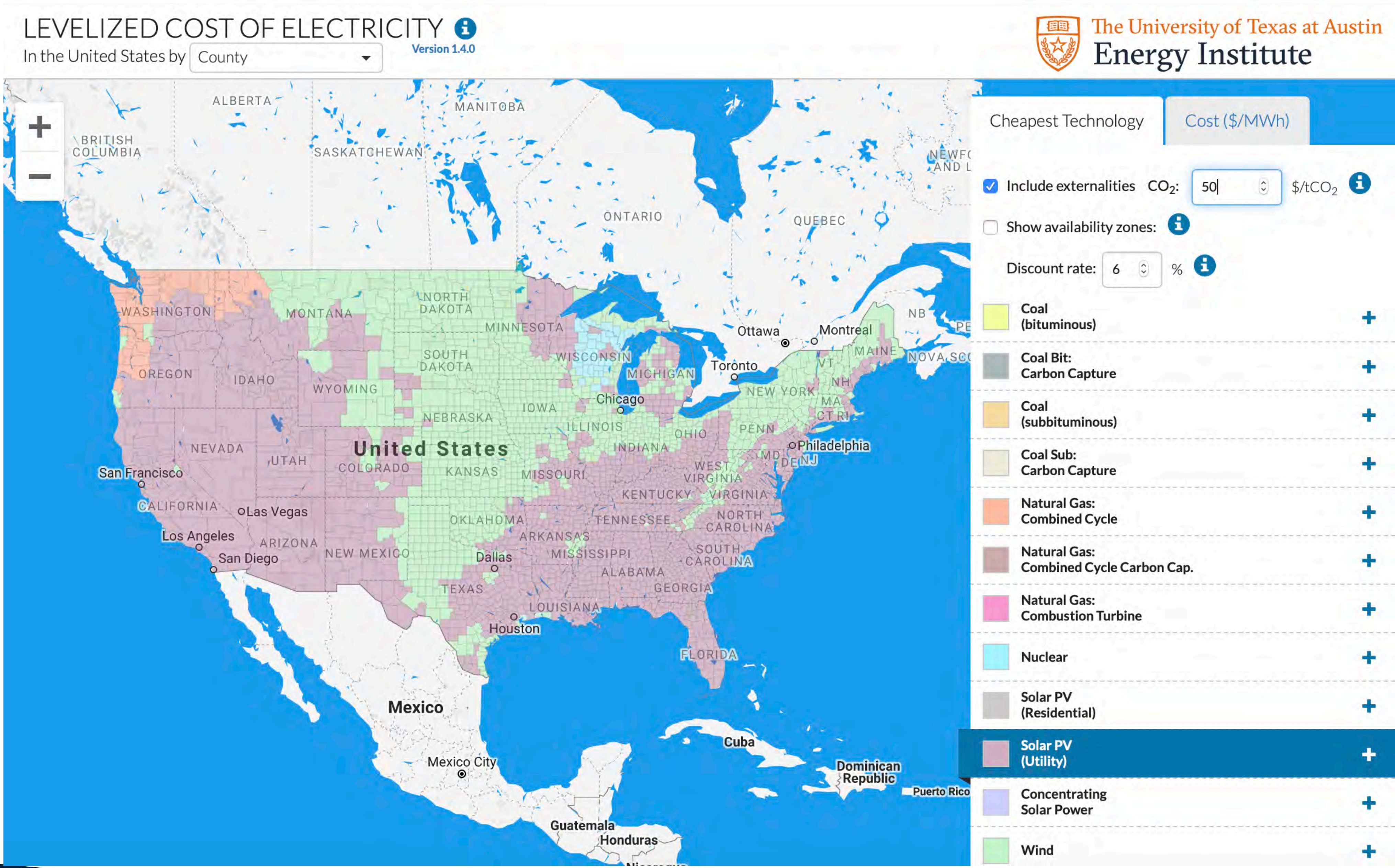
CA & Quebec



http://calculators.energy.utexas.edu/lcoe_map/#/county/tech

UT Austin - Levelized Cost of Electricity

Social Cost of Carbon ($50)

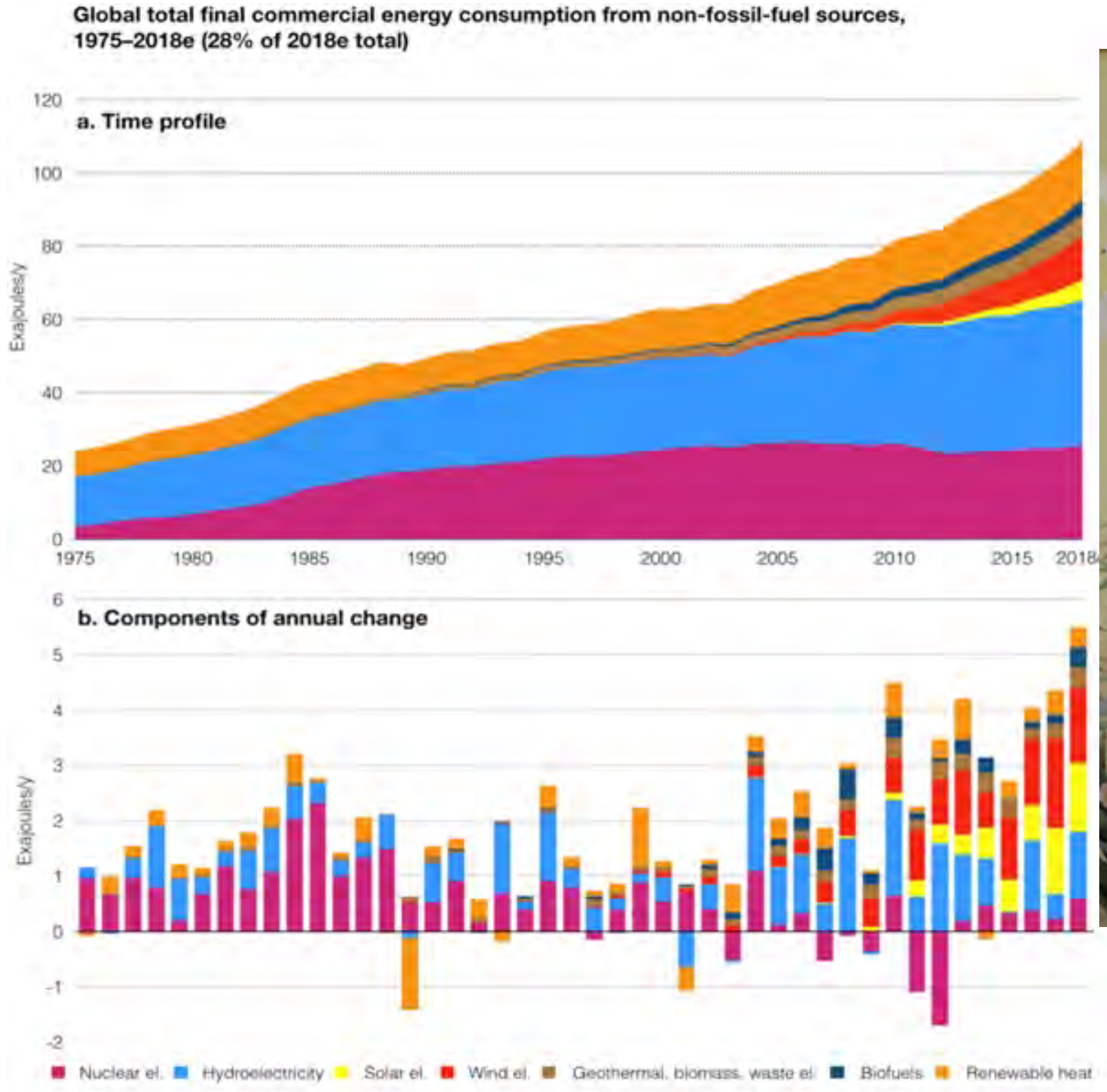


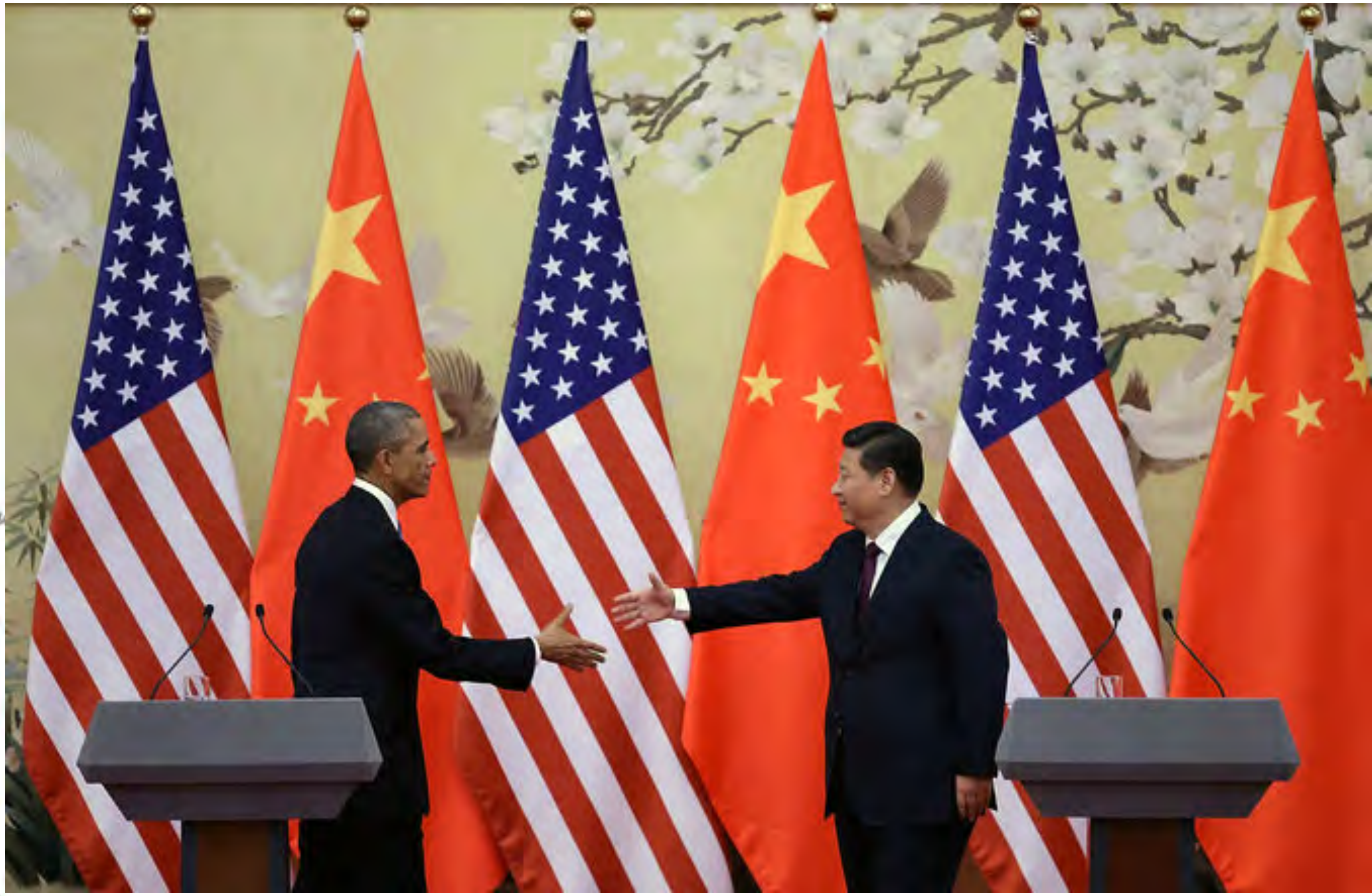
Renewable & Appropriate Energy Laboratory RAEL

Berkeley UNIVERSITY OF CALIFORNIA

http://calculators.energy.utexas.edu/lcoe_map/#/county/tech

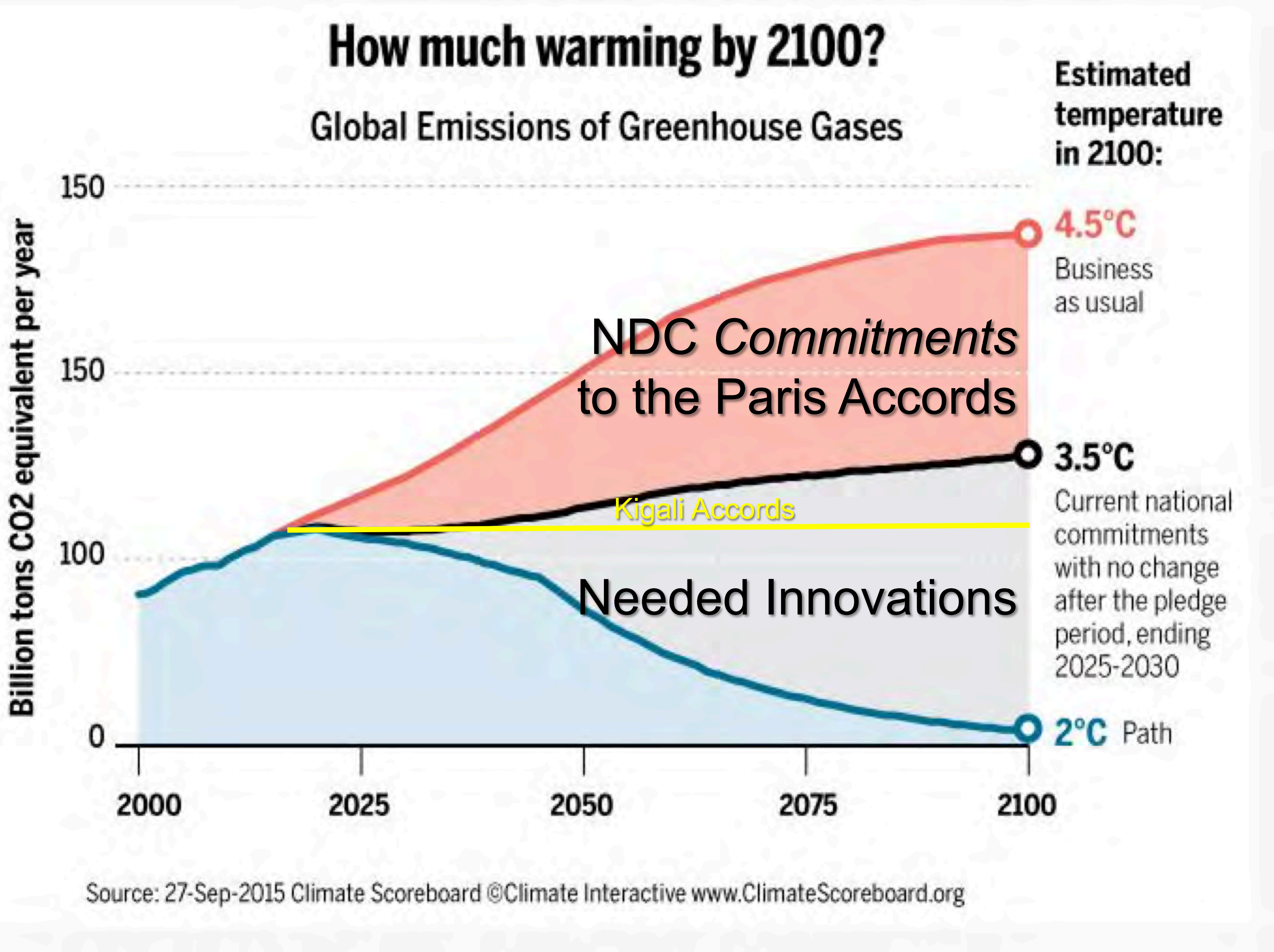
UT Austin - Levelized Cost of Electricity





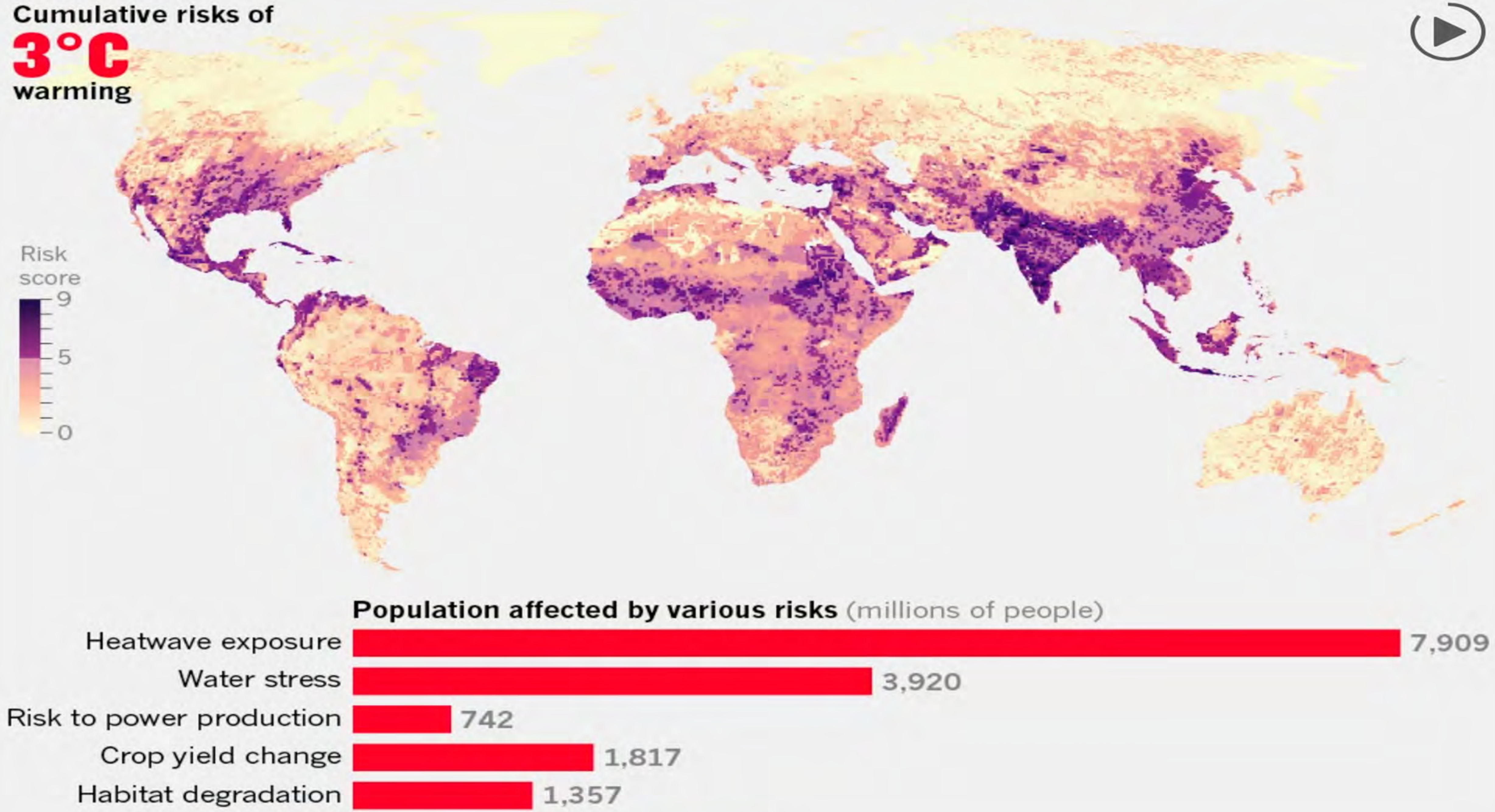
2014 APEC Summit

Lovins, Kammen, *et al* (2019) *Environmental Research Letters*
https://iopscience.iop.org/article/10.1088/1748-9326/ab55ab



Paris, 2015: 2 degree objective

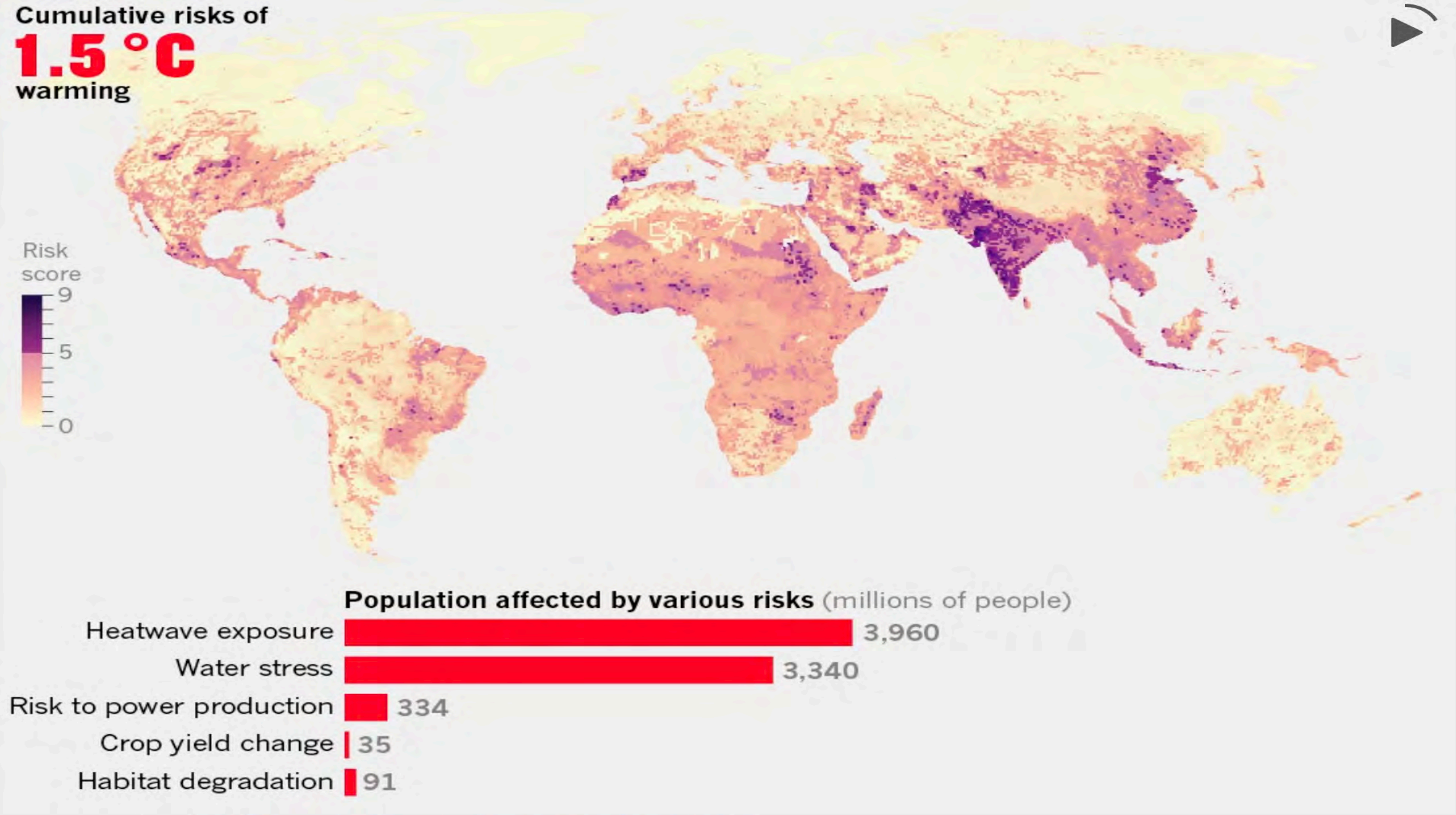
IPCC, 2018: 1.5 degree objective



Source: IPCC/E. Byers et al. Environ. Res. Lett. 13, 055012 (2018).

Cumulative risks of **2°C** warming

Source: IPCC/E. Byers et al. Environ. Res. Lett. 13, 055012 (2018).

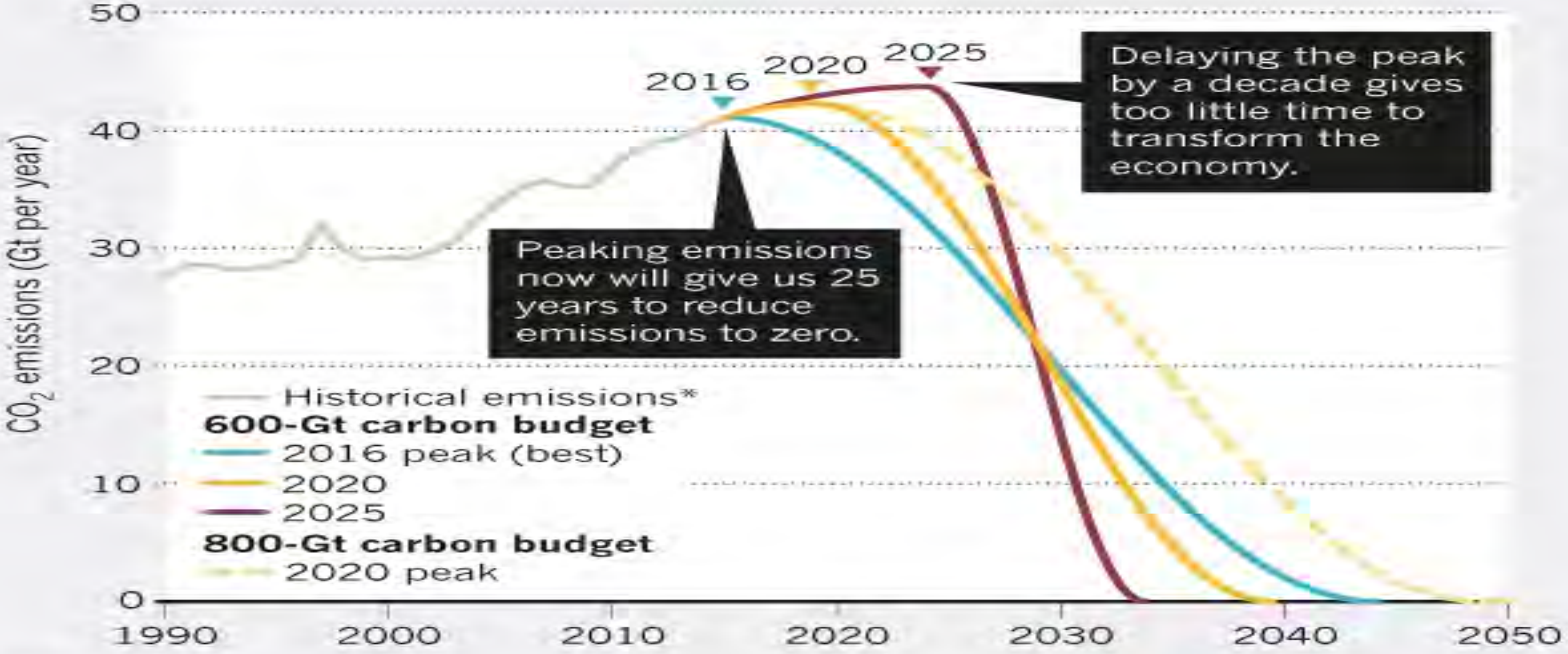


Source: IPCC/E. Byers et al. Environ. Res. Lett. 13, 055012 (2018).

C. Figueres, et al, 2017, *Nature*

CARBON CRUNCH

There is a mean budget of around 600 gigatonnes (Gt) of carbon dioxide left to emit before the planet warms dangerously, by more than 1.5–2°C. Stretching the budget to 800 Gt buys another 10 years, but at a greater risk of exceeding the temperature limit.



*Data from The Global Carbon Project.

Supplementary information to:
Three years to safeguard our climate (Comment in *Nature* 546, 593–595; 2017)

doi:10.1038/546593a

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The Green Energy Economy

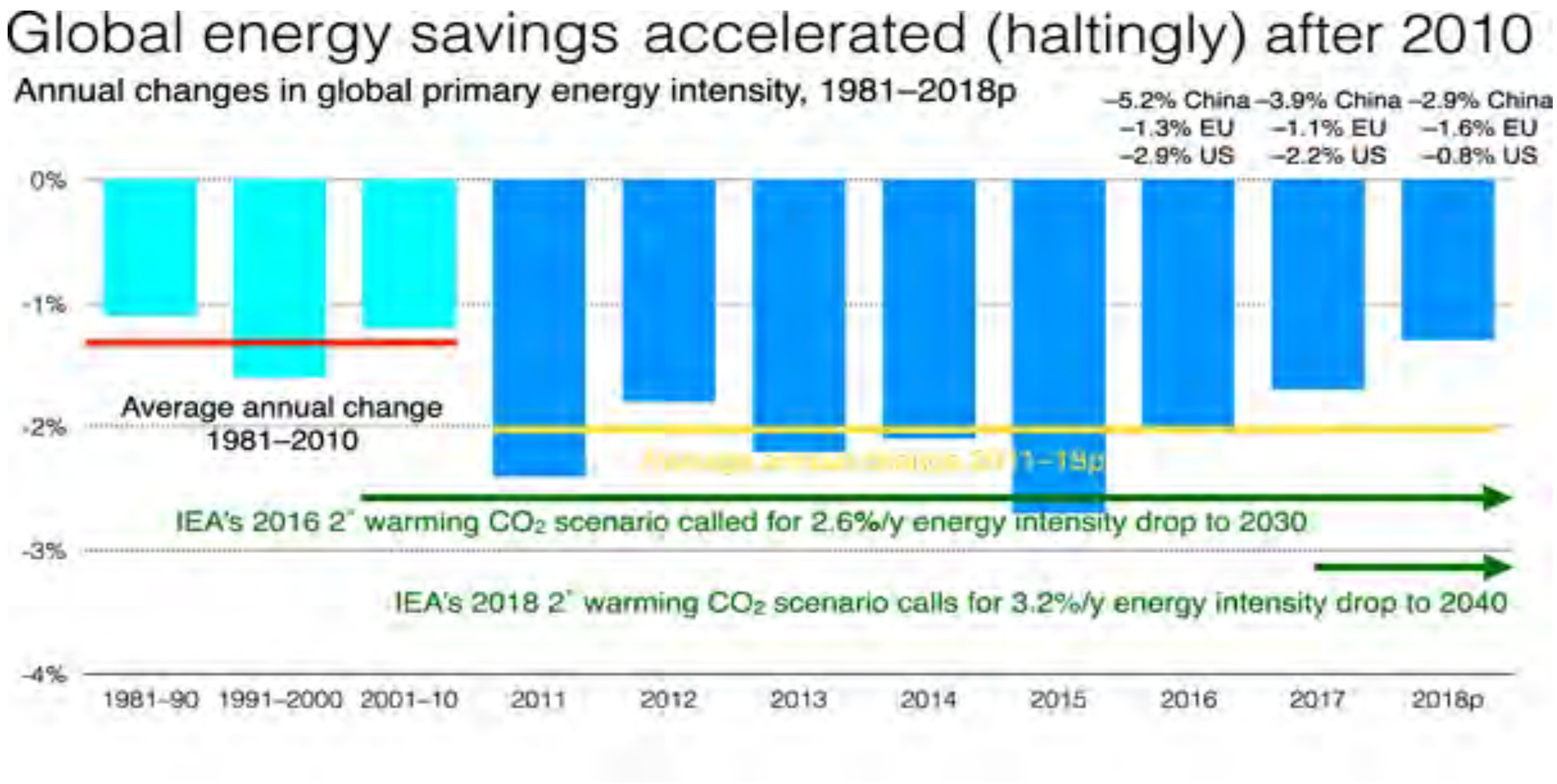
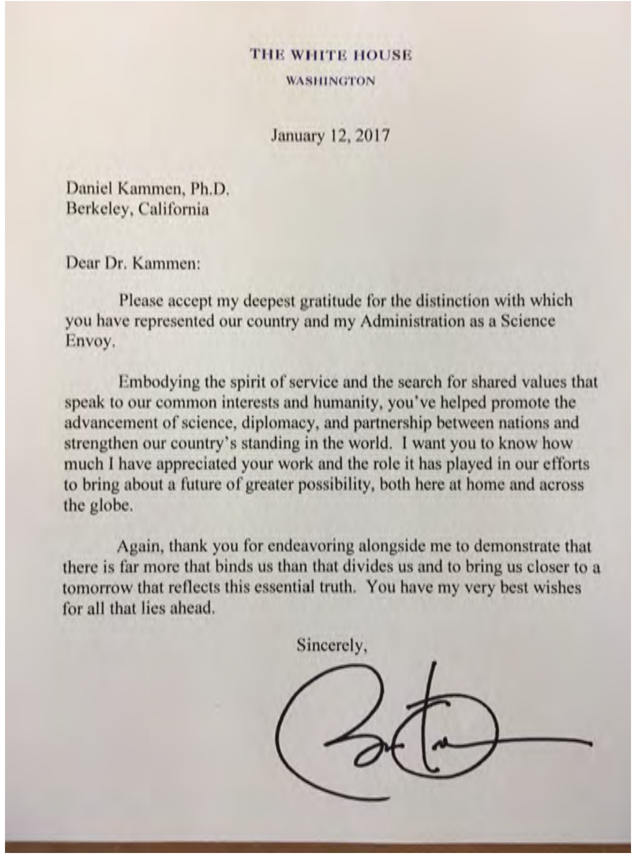


Figure 2 from "Recalibrating climate prospects"

Lovins, Ürge-Vorsatz, Mundaca, Kammen & Glassman

***Environ. Res. Lett.* 14, 120201 (2019)**
doi:10.1088/1748-9326/ab55ab


THE WHITE HOUSE
WASHINGTON

January 12, 2017

Daniel Kammen, Ph.D.
Berkeley, California

Dear Dr. Kammen:

Please accept my deepest gratitude for the distinction with which you have represented our country and my Administration as a Science Envoy.

Embodying the spirit of service and the search for shared values that speak to our common interests and humanity, you've helped promote the advancement of science, diplomacy, and partnership between nations and strengthen our country's standing in the world. I want you to know how much I have appreciated your work and the role it has played in our efforts to bring about a future of greater possibility, both here at home and across the globe.

Again, thank you for endeavoring alongside me to demonstrate that there is far more that binds us than that divides us and to bring us closer to a tomorrow that reflects this essential truth. You have my very best wishes for all that lies ahead.

Sincerely,

Director, Renewable and Appropriate Energy Lab (RAEL)
Berkeley, CA 94720-3050
URL: *http://rael.berkeley.edu*
Twitter: @dan_Kammen

Daniel M. Kammen
Professor and Chair, Energy and Resources Group
Professor of Public Policy in the Goldman School
Professor of Nuclear Engineering

August 23, 2017

Mr. President,

I am resigning from my position as Science Envoy for the Department of State of the United States. Since 1996, I have served the Departments of Energy, the US Environmental Protection Agency, and the State Department in a number of roles. Working closely with the talented teams at State Department Headquarters and at U. S. embassies abroad, we have built significant partnerships in North and East Africa, and in the Middle East, around shared visions of national security, job creation in the U. S. and sustainable energy.

My decision to resign is in response to your attacks on core values of the United States. Your failure to condemn white supremacists and neo-Nazis has domestic and international ramifications. On this issue, I stand with the unequivocal and authoritative statements of Charlottesville Mayor Mike Signer, Virginia Governor Terry McAuliffe, Ohio Governor John Kasich, Senator John McCain, Congresswoman Ileana Ros-Lehtinen, Governor Arnold Schwarzenegger, Presidents George H. W. Bush and George W. Bush, Dr. Cornel West, Linda Sarsour, the Palestinian-American activist and one of the organizers of the Women's March, and many others.

Particularly troubling to me is how your response to Charlottesville is consistent with a broader pattern of behavior that enables sexism and racism, and disregards the welfare of all Americans, the global community and the planet.

Examples of this destructive pattern have consequences on my duties as Science Envoy. Your decision to abdicate the leadership opportunities and the job creation benefits of the Paris Climate Accord, and to undermine energy and environmental research are not acceptable to me.

Acts and words matter. To continue in my role under your administration would be inconsistent with the principles of the United States Oath of Allegiance to which I adhere.

Character is vital in leadership. I find particularly wise the admonition of President Dwight D. Eisenhower, who cautioned that, "A people [or person] that values its privileges above principles soon loses both."

Herein, with regret, I resign. I deeply respect and value the work of the many fine people I have encountered in our federal agencies and will miss the opportunity to work with and support them. Your actions to date have, sadly, harmed the quality of life in the United States, our standing abroad, and the sustainability of the planet.

Sincerely,

Professor Daniel M. Kammen
Science Envoy, U. S. State Department (former)

J.K. Rowling @jk_rowling Aug 23

I wonder whether there's anyone left in America who doesn't know what an acrostic is.

> **Daniel M Kammen** @dan_kammen
>
> Mr. President, I am resigning as Science Envoy. Your response to Charlottesville enables racism, sexism, & harms our country and planet. pic.twitter.com/eWzDc5Yw6t

4,271 20K

Daniel M Kammen @dan_kammen Aug 23

Mr. President, I am resigning as Science Envoy. Your response to Charlottesville enables racism, sexism, & harms our country and planet.

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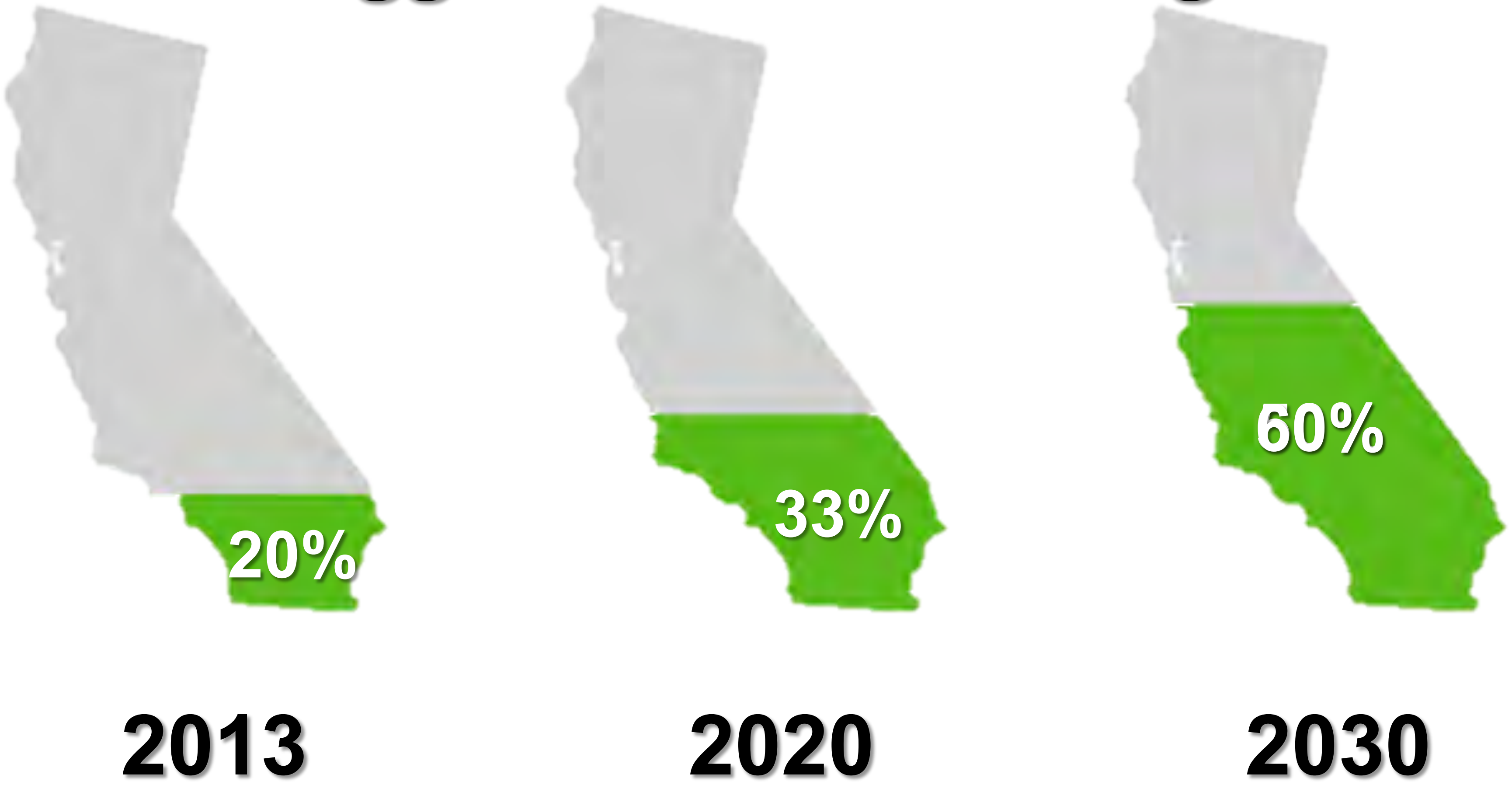
45K 125K

Overview

- The climate crisis is now an (urgent) opportunity
- **Infrastructure for the green energy economy**
- The power the Just Transition / Green New Deal

California Energy Goals: Aggressive & Evolving



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

California Climate Laws

E6 Insight | San Francisco Chronicle and SFChronicle.com | Sunday, August 19, 2018

NATION

CLIMATE ACTION

Growth in green energy is gold for California, U.S.

By Daniel M. Kammen

I am a physicist, and an energy and sustainability science researcher, and I live in California because of its penchant for not just setting but actually achieving big goals and adopting bold visions others may consider too ambitious. What California proposes, we research, debate and then accomplish. In fact, we often exceed the goals skeptics have deemed unmeetable. This is why I believe that California should — and ultimately will — pass into law the "100 Percent Clean Energy Act" (Senate Bill 100), which would establish a bold goal of 100 percent clean, zero-carbon electricity by 2045.

To fully appreciate the multifaceted benefits of SB100 for California and the country, a bit of history is needed.

Thanks to a law California passed in 2002 (the Renewables Portfolio Standard), the state has nearly tripled its use of electricity produced from renewable resources. Today, solar, wind, biomass, and geothermal power (the "renewables") meet more than a third of the state's electricity demand — up from 12 percent in only a decade.

Just last month, the California Air Resources Board announced that the state has met its goal of reducing greenhouse gas emissions below 1990 levels in 2016 — a full four years ahead of its 2020 deadline. Our system of renewable electricity generation is a key driver of that success.

In fact, the state Public Utilities Commission has estimated that California will probably meet its goal of producing 50 percent of electricity from renewable resources well ahead of the 2030 deadline. California and New York state have emerged as national leaders in energy efficiency and in setting and meeting clean energy targets that together have kept utility rates low. Financial benefits follow directly: The majority of all U.S. "clean tech" investment has come through these two states.

This transition has been a net job generator: California now has more people employed in the solar energy industry than in traditional utilities. For 15 years, I have been tracking job creation in the clean energy sector, where today we find two to four times more jobs in solar, wind, sustainable biomass, efficiency and energy storage than in any fossil-fuel sector. The price of wind- and solar-generated energy has dropped faster than expected and is cost-competitive or cheaper than the cost of building new fossil-fuel-powered plants. The fact that the best solar and wind energy projects are actually *cheaper* than natural gas has been an enormous surprise to many not following the sector closely.

Next up is for California to establish the bold new goal to power our state with 100 percent zero-carbon energy by 2045. SB100 would mandate that 60 percent of our electricity demand be met with renewable sources, and allows flexibility for how the other 40 percent might be met via additional renewables, existing large hydropower, or other clean energy sources — including new technologies. Some critics note that SB100 does not explicitly prohibit carbon emissions if we also capture the carbon. This is less useful — and more expensive — in my analysis than a mixture of zero carbon sources and energy storage, but permitting the flexibility is a broader, more inclusive mandate that does not try to pick specific winners and losers.

More synergies between clean energy and jobs for Californians exist here, too. The same wave of innovation we saw in solar energy — where California played key research and deployment roles — we now are seeing in the energy storage industry. California is leading this charge, too, and stands to profit in revenue and more jobs.

Big transformational goals are proven drivers of innovation. In 2005, the Legislature passed legislation that set a target of 1 million solar rooftops by 2020. At the time, the typical response was that it was too ambitious, and more details were needed. Today, California has close to 700,000 solar rooftops, well on the way to the goal. Each rooftop saves the homeowner money, too, as solar power costs pencil out at under 5 cents per kilowatt-hour, while utility-generated power retails at more than four times that cost. Despite some legal and regulatory battles, residential rooftop solar saves utilities money, too, as rooftops are generating power during the day — i.e., during the time of the peak of power demand. Any extra generation can be put into storage.

Since 1999 I have served as a coordinating lead author for the Intergovernmental Panel on Climate Change, where scientists have recognized that clean and renewable energy sources must become the dominant source of electricity powering buildings, industry and transportation if we are to avoid the worst climate change effects that threaten California. As the world's fifth-largest economy, California will gain economically as we develop new technologies and services that others will need as they work toward global climate goals. Current political troubles aside, this is where the United States must go.

As the world will see at the Global Climate Action Summit that California will host Sept. 12-14 in San Francisco, we have demonstrated the capacity and leadership needed to achieve big goals. SB100 sets a new goal for a clean, healthy and profitable energy system. With the global clean energy market growing far faster that the fossil-fuel sector, what California is doing is a good business decision for the state and the nation.

Daniel M. Kammen is the founding director of the Renewable and Appropriate Energy Laboratory and director of the Center for Environmental Public Policy at UC Berkeley. Kammen has served as the chief technical specialist for renewable energy at the World Bank, and science envoy for the U.S. State Department. Twitter: @dan_kammen To comment, submit your letter to the editor at SFChronicle.com/letters.

Michael Macor / The Chronicle 2015

The state Legislature's goal of having 1 million solar rooftops in the state was once seen as too ambitious, but now there are close to 700,000 installed.

Senate Bill 100:

100% green energy in 2045

Senate Bill 32:

Cap & Trade carbon market

Senate Bill 375:

Vehicle miles must be offset

Solar Mandate:

1 million solar roofs by 2020

EV Mandate:

1 million EVs by 2020

California Energy Efficiency Policy Drives Innovation

Residential New Construction

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

Community Groups

blueEnergy

PARC NATIONAL DES VIRUNGA
République Démocratique du Congo

Energy Peace Partners

WWF

GRID ALTERNATIVES

givepower

SAVE Rivers

Businesses

dissigno

NATEL ENERGY

HumanNeeds PROJECT

VIRUNGA POWER

Google

KUBE ENERGY

INYENYERI

Nations

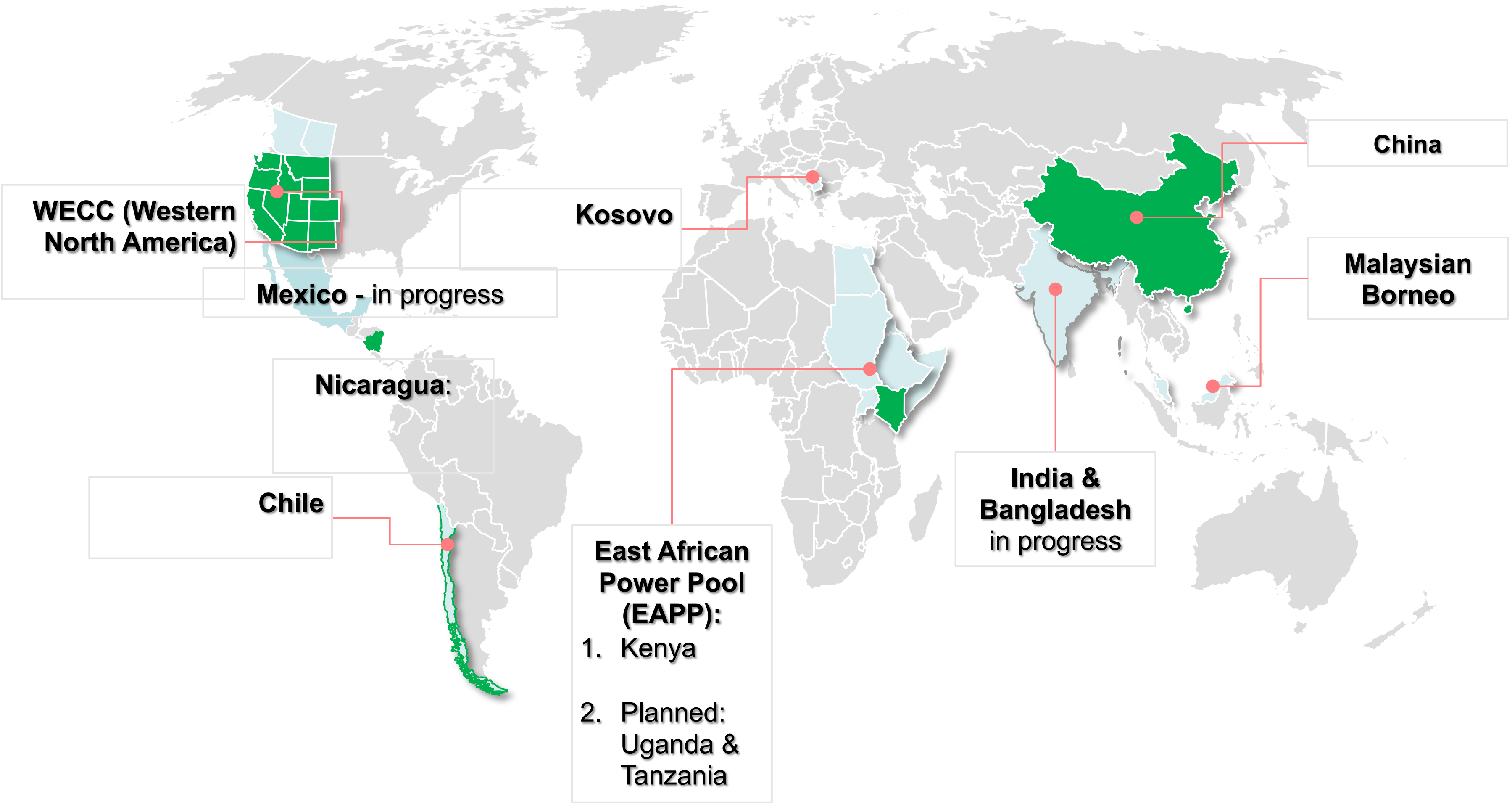
CALIFORNIA REPUBLIC

Institutions

POWER AFRICA

SUSTAINABLE ENERGY FOR ALL

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

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

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

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

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

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

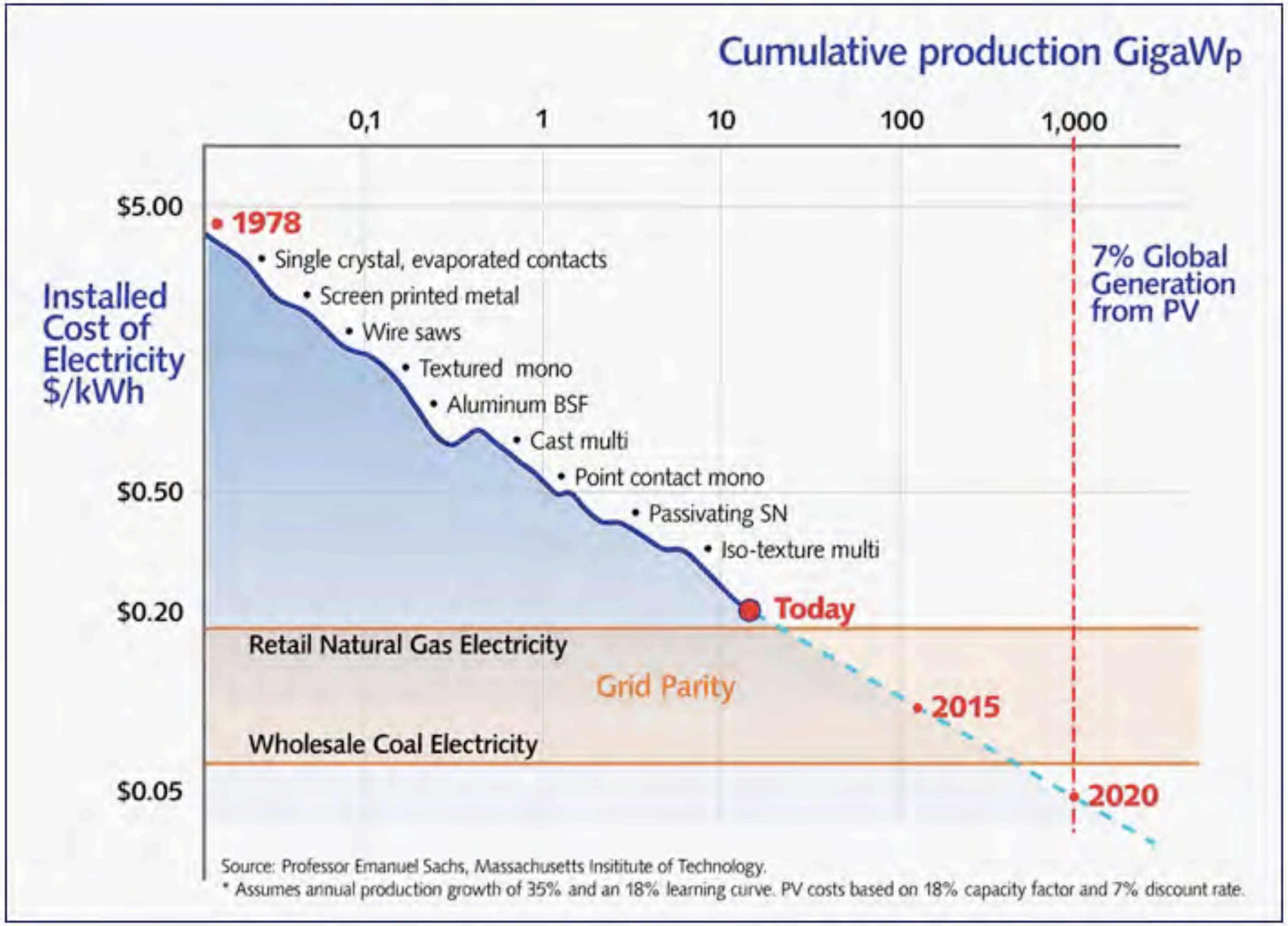
$$Total\ Resource\ Potental_i \geq \sum_{k=1}^{m} Capacity\ (c_i)$$

Renewable & Appropriate Energy Laboratory RAEL

Berkeley UNIVERSITY OF CALIFORNIA

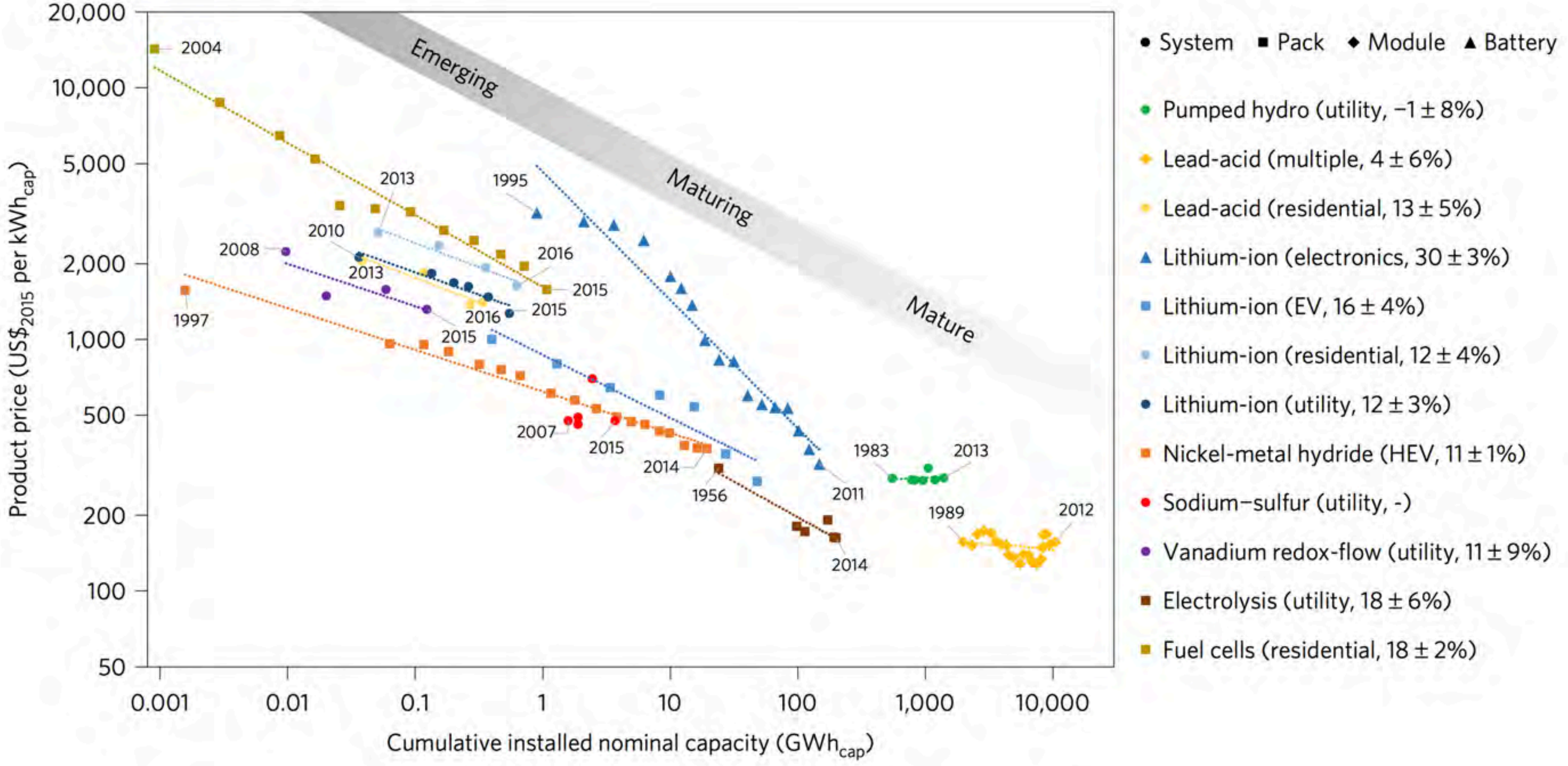
$$\frac{C_2}{C_1} = \left(\frac{V_2}{V_1}\right)^{-b}$$

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 for Storage Innovation



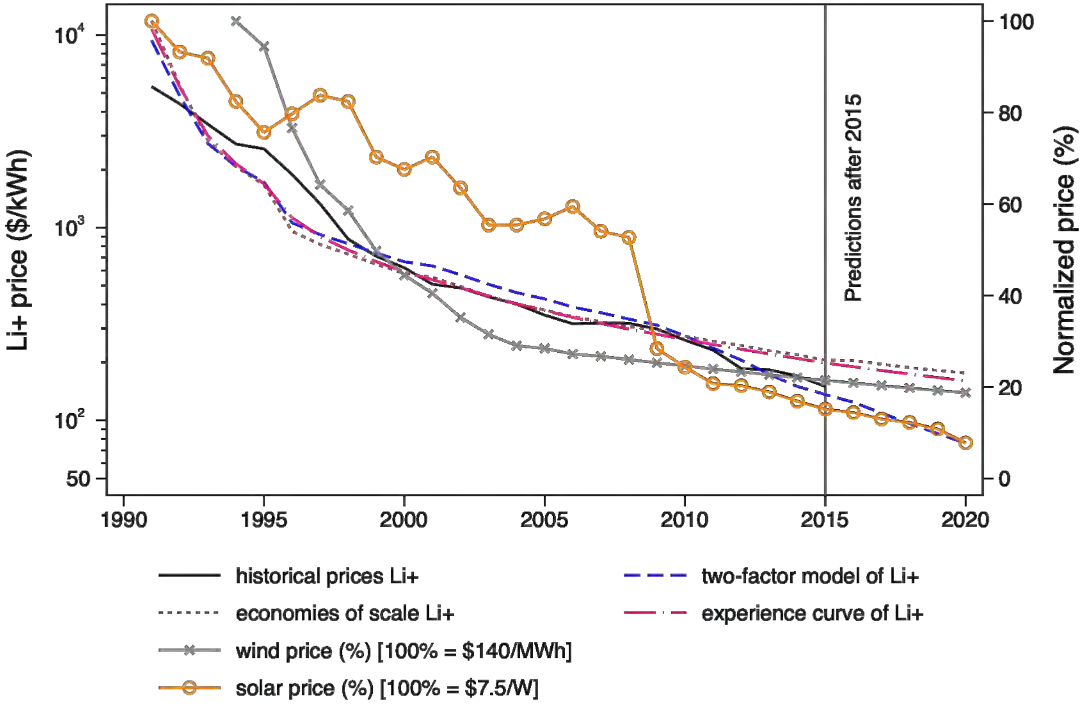
Data from: Schmidt, O., Hawkes, A., Gambhir, A., & Staffell, I. (2017). The future cost of electrical energy storage based on experience rates. *Nature Energy, 2,* 2017110. Qiu, Y., & Anadon, L. D. (2012). The price of wind power in China during its expansion: Technology adoption, learning-by-doing,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

Two-factor learning curves: manufacturing and R&D

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

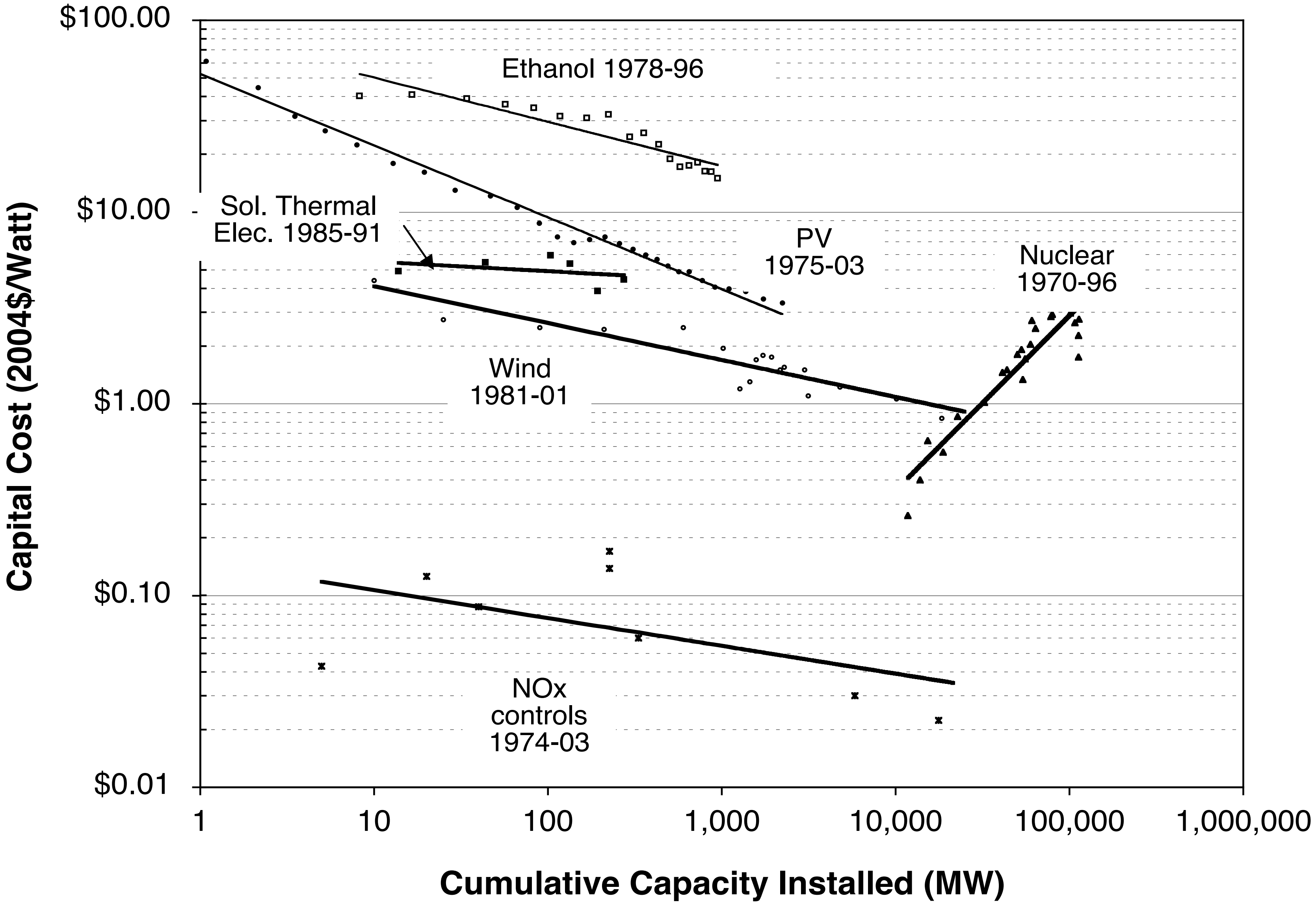
$$\frac{C_2}{C_1} = \left(\frac{V_2}{V_1}\right)^{-b}$$

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



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

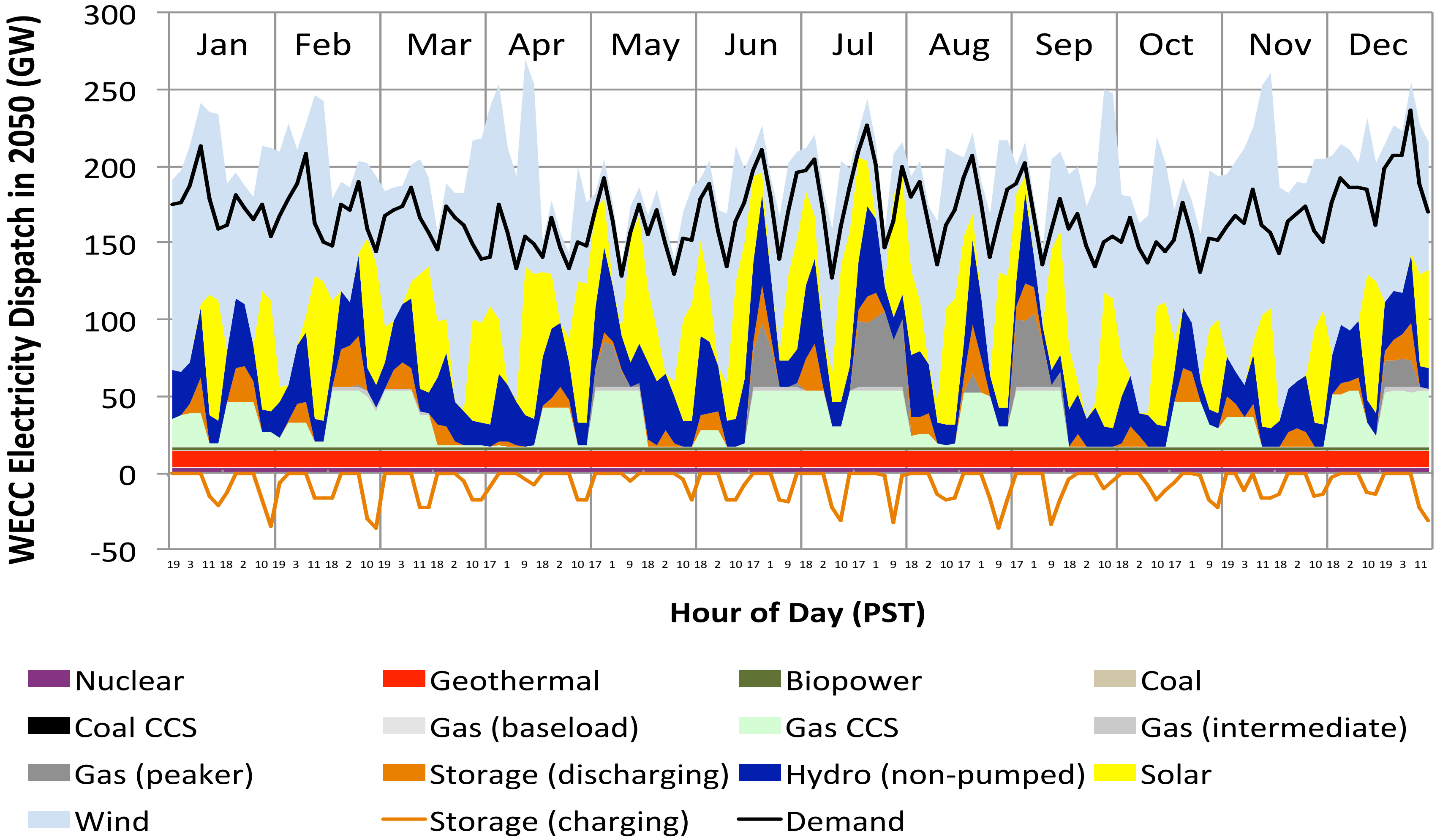
Well …



$100.00
$10.00
$1.00
$0.10
$0.01
Capital Cost (2004$/Watt)
Ethanol 1978-96
Sol. Thermal Elec. 1985-91
PV 1975-03
Nuclear 1970-96
Wind 1981-01
NOx controls 1974-03
1
10
100
1,000
10,000
100,000
1,000,000
Cumulative Capacity Installed (MW)

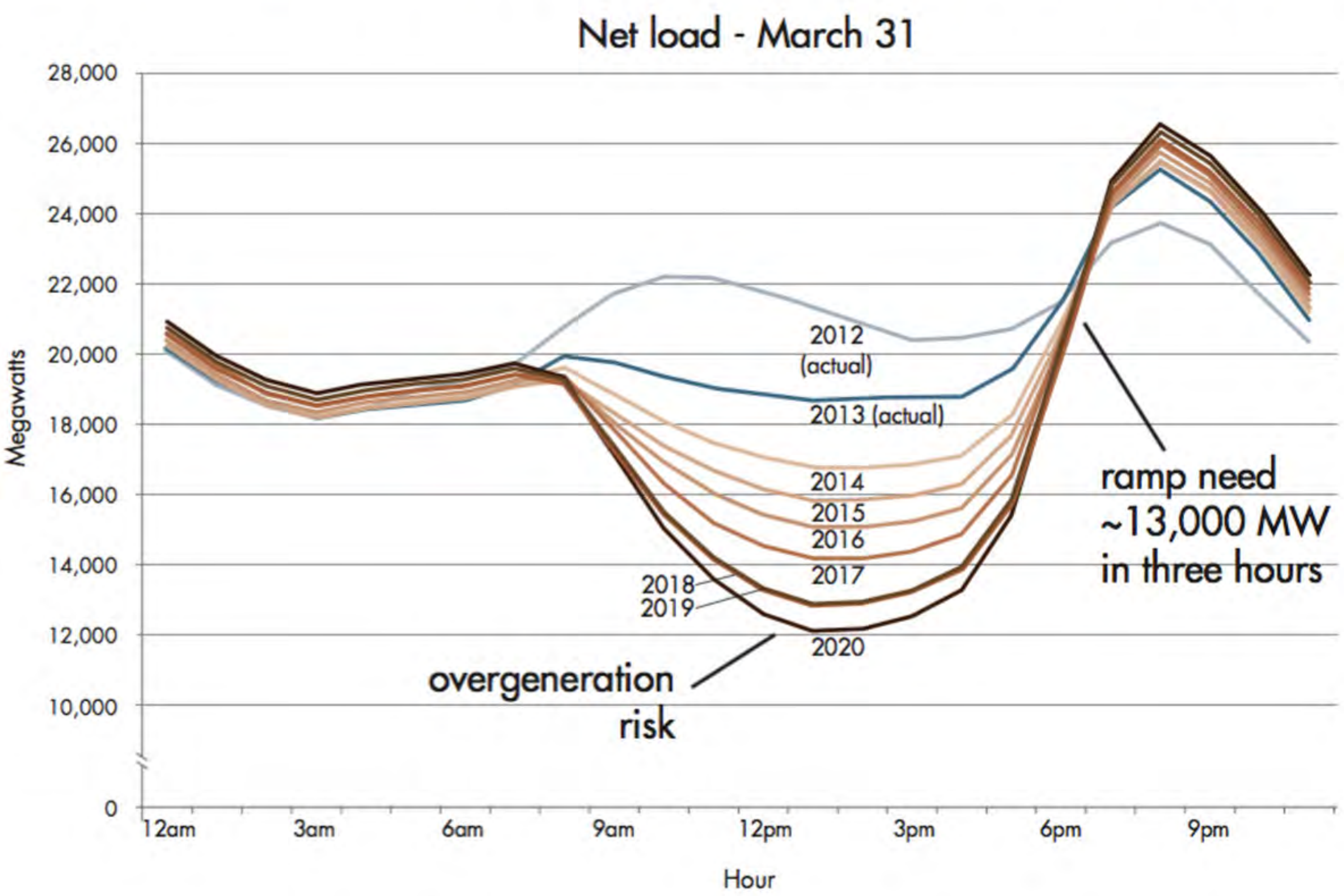
Dispatch in 2050:
Flexibility and variable renewables dominate

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

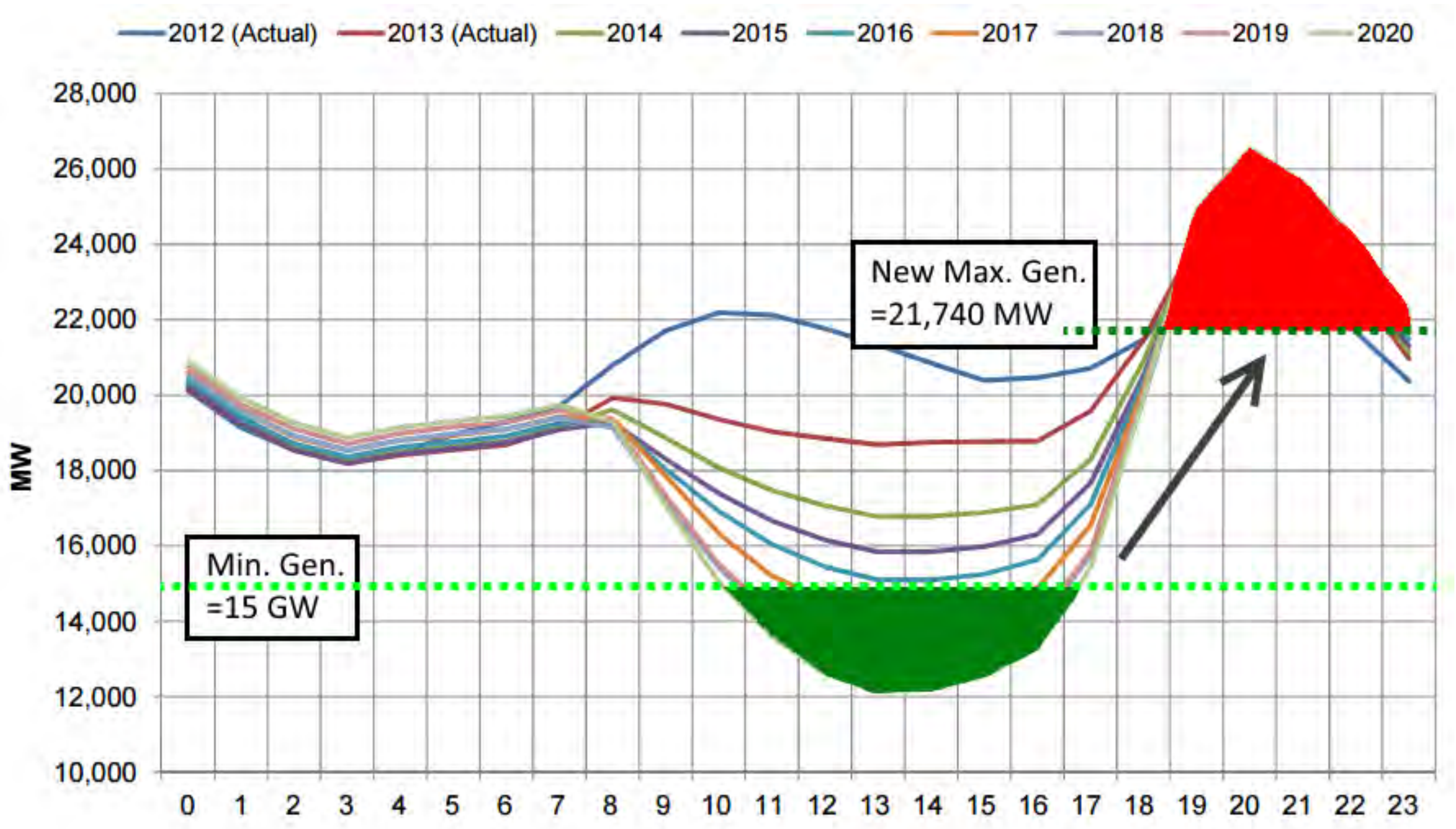


California Advancing Energy Efficiency

Figure 2: The duck curve shows steep ramping needs and overgeneration risk



California Advancing Energy Efficiency



From the SWITCH Model to Implementation

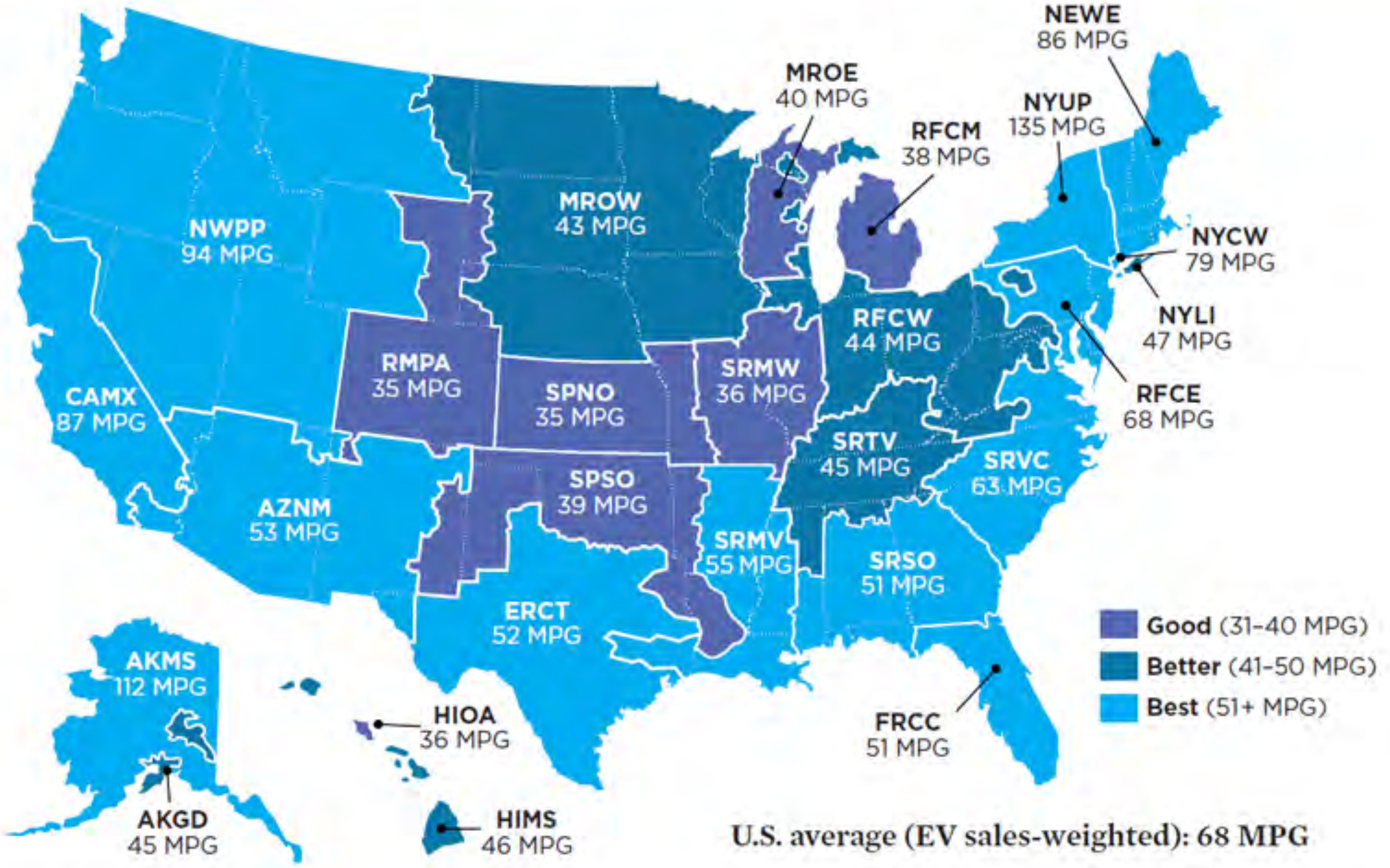
California's (2020) 2% Peak Demand Storage Requirement

EnerVault Iron-Chromium Technology

1 MW-hr capacity at 250 kW (4 hour duration)

Turlock, CA

Electric Vehicle Global Warming Pollution Ratings and Gasoline Vehicle Emissions Equivalents by Region



U.S. average (EV sales-weighted): 68 MPG

The SWITCH Modeling Framework

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

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

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

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

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

Visiting Scholars Participating in RAEL-China Research Partnership

Professor Zechun Hu
2018

Professor Minyou Chen
2018, 2019

Ziming Ma, PhD Student
2018 - 2019

Bo Li, PhD Student
2019

Dongran Liu, PhD Student
2019 - 2020

Guangzhi Yin, PhD Student
2019 - 2020

Xiaoli Zhang, PhD Student
2019 - 2020

China’s Energy Future

SWITCH China model

- Capacity expansion deterministic linear program
- Minimizes total cost of the power system:
  - Generation investment and operation
  - Transmission investment and operation
  - New module: CO_2 emission cost

Geographic:
- 31 load areas

Temporal:
- 4 investment periods: 2016-2025 (“2020”); 2026-2035 (“2030”); 2036-2045 (“2040”); 2046-2055 (“2050”);
- 144 hours simulated for each period (516 hours in total)
  - Dispatch simulated simultaneously with investment decisions

Led by
Dr Cheng Zheng, CEO, Aspiring Citizens Cleantech (ACC), Chengdu, China
& Gordon Bauer & Daniel Kammen (ERG, UC Berkeley)

100% EV taxi fleet in Shenzhen, China (25,000+ vehicles)
24 month fleet conversion

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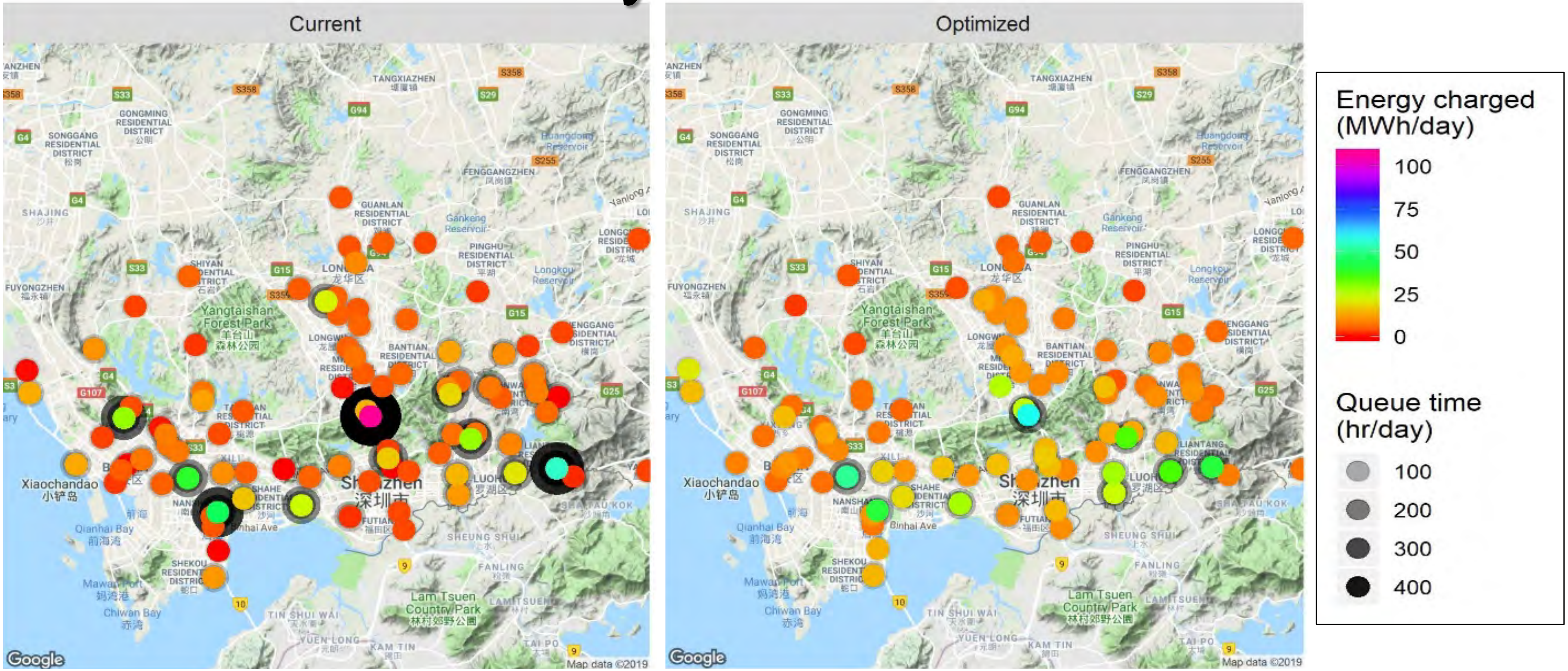
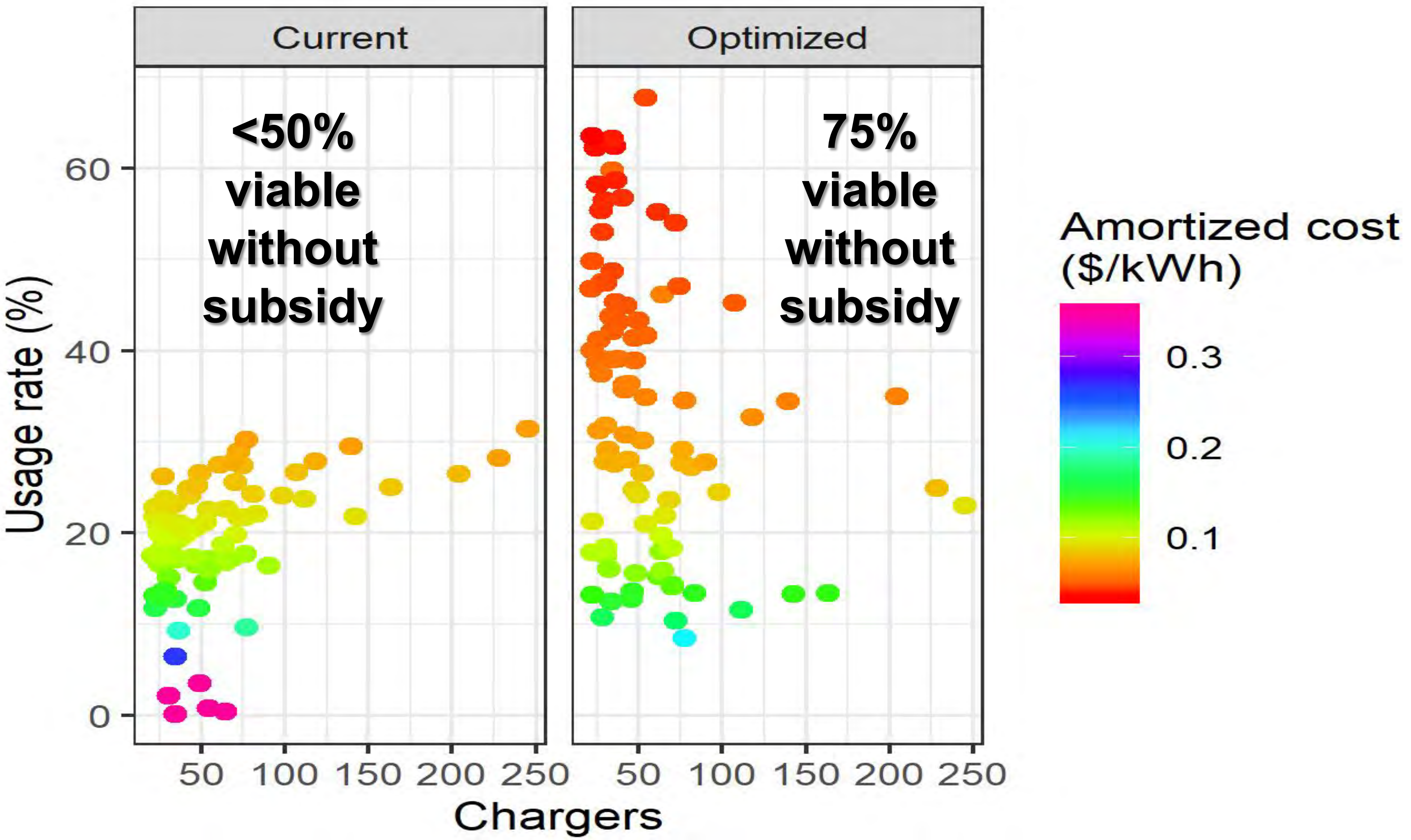
Optimized dispatch (with a simple app): 50% reduced delay time



Optimized dispatch improves charger economics

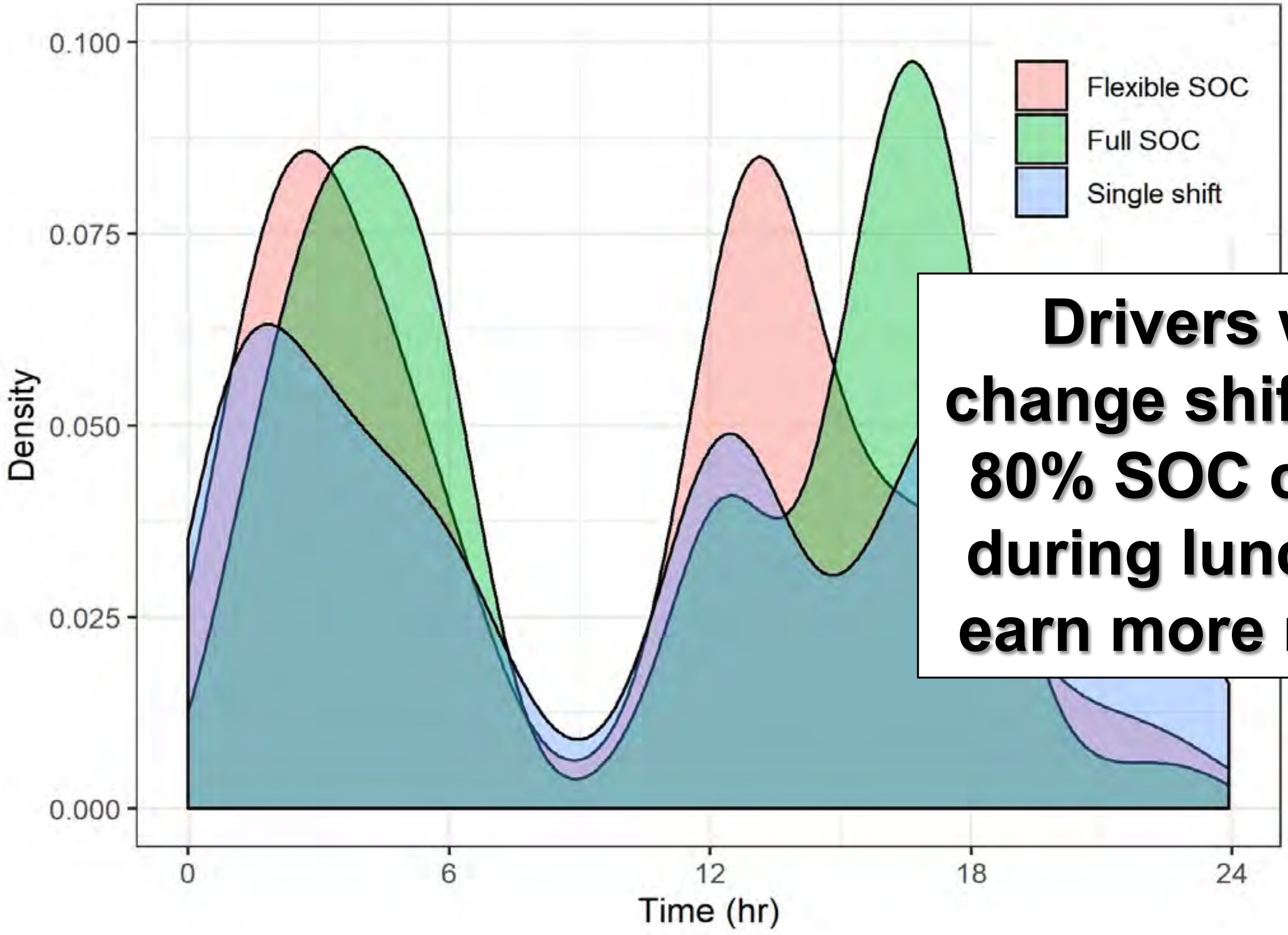


Optimized charging time: removing shift change constraint reduces charging burden by up to 90%

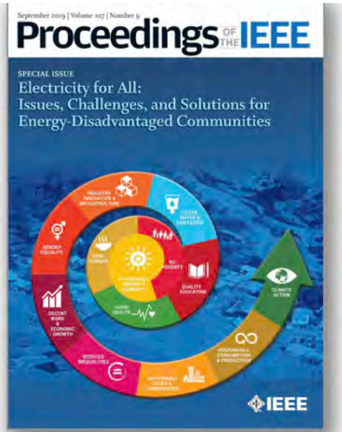
- Drivers prefer to change shift with full battery charge, creating inefficient charging behavior
- Peak charging occurs during peak demand, leading to lost revenue

Results:

- Enabling drivers to change shift at ~75% SOC reduces charging burden by almost **50%**
- If drivers also take advantage of break times to charge, they can reduce charging burden by **90%**



Drivers who change shift at 60-80% SOC charge during lunch and earn more money



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

Volume 107, Issue 9 | September 2019

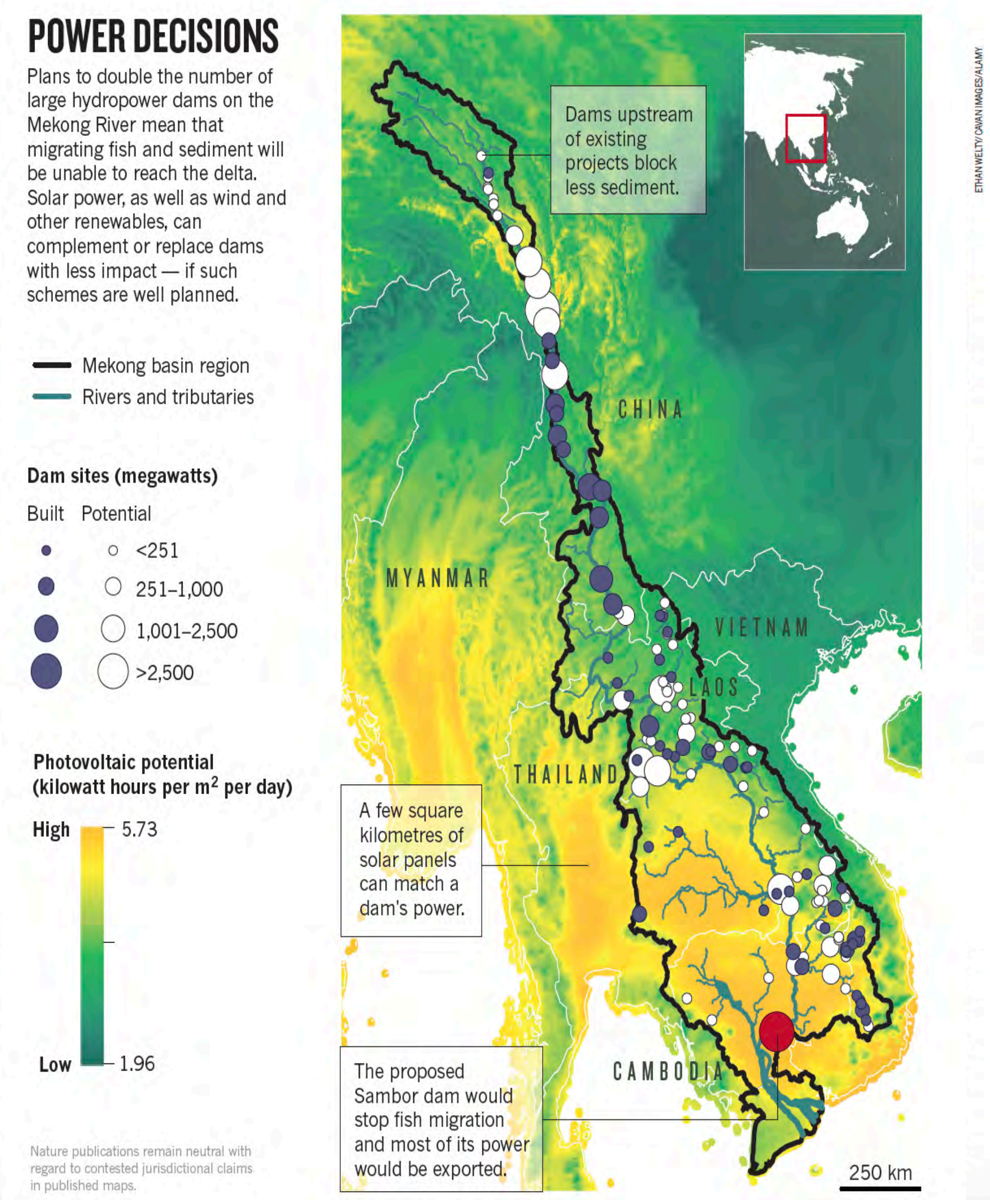
- Guest Editors
- Special Issue Papers

Guest Editors:

Claudio Cañizares

Jatin Nathwani

Daniel Kammen



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

Overview

- The climate crisis is now an (urgent) opportunity
- Infrastructure for the green energy economy
- The power the Just Transition / Green New Deal

Overview

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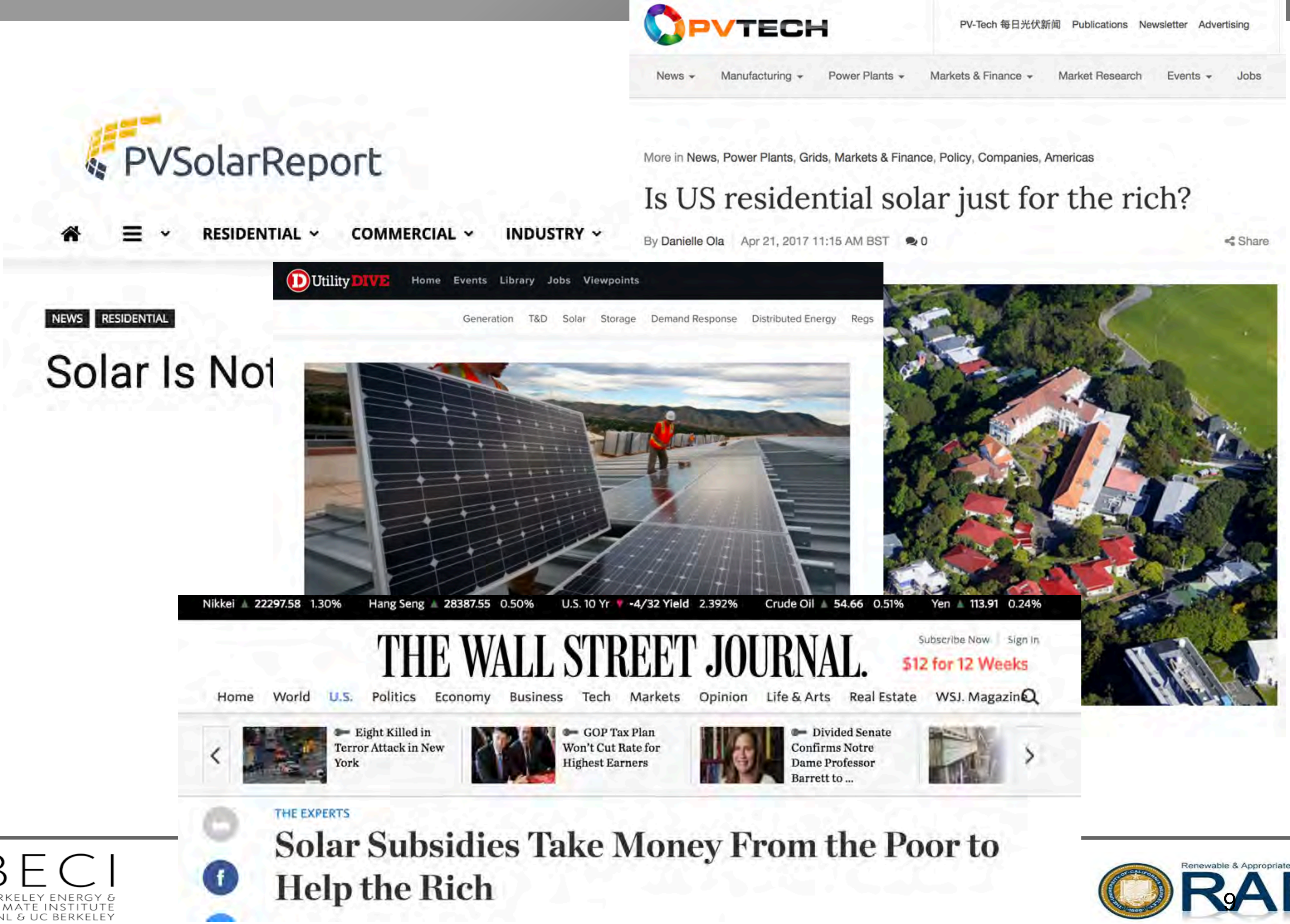
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Is US residential solar just for the rich?
By Danielle Ola Apr 21, 2017 11:15 AM BST 0
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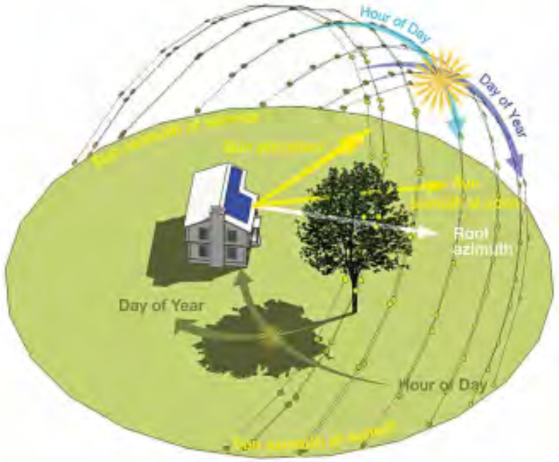
Divided Senate Confirms Notre Dame Professor Barrett to ...
THE EXPERTS
Solar Subsidies Take Money From the Poor to Help the Rich

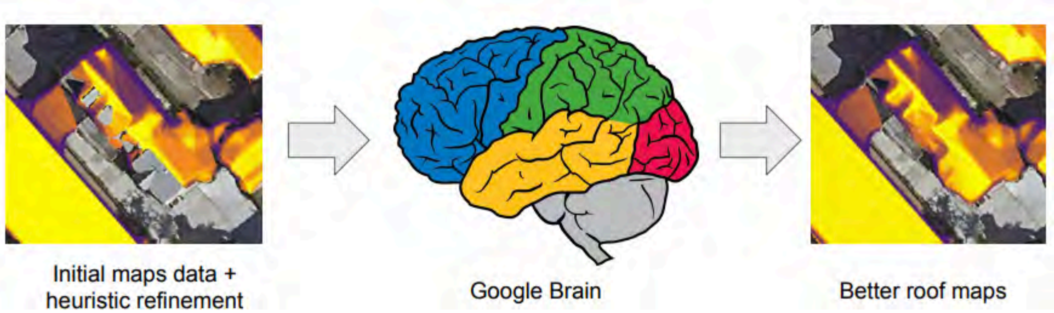
Sunroof Data

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

Sun location | Attenuate light

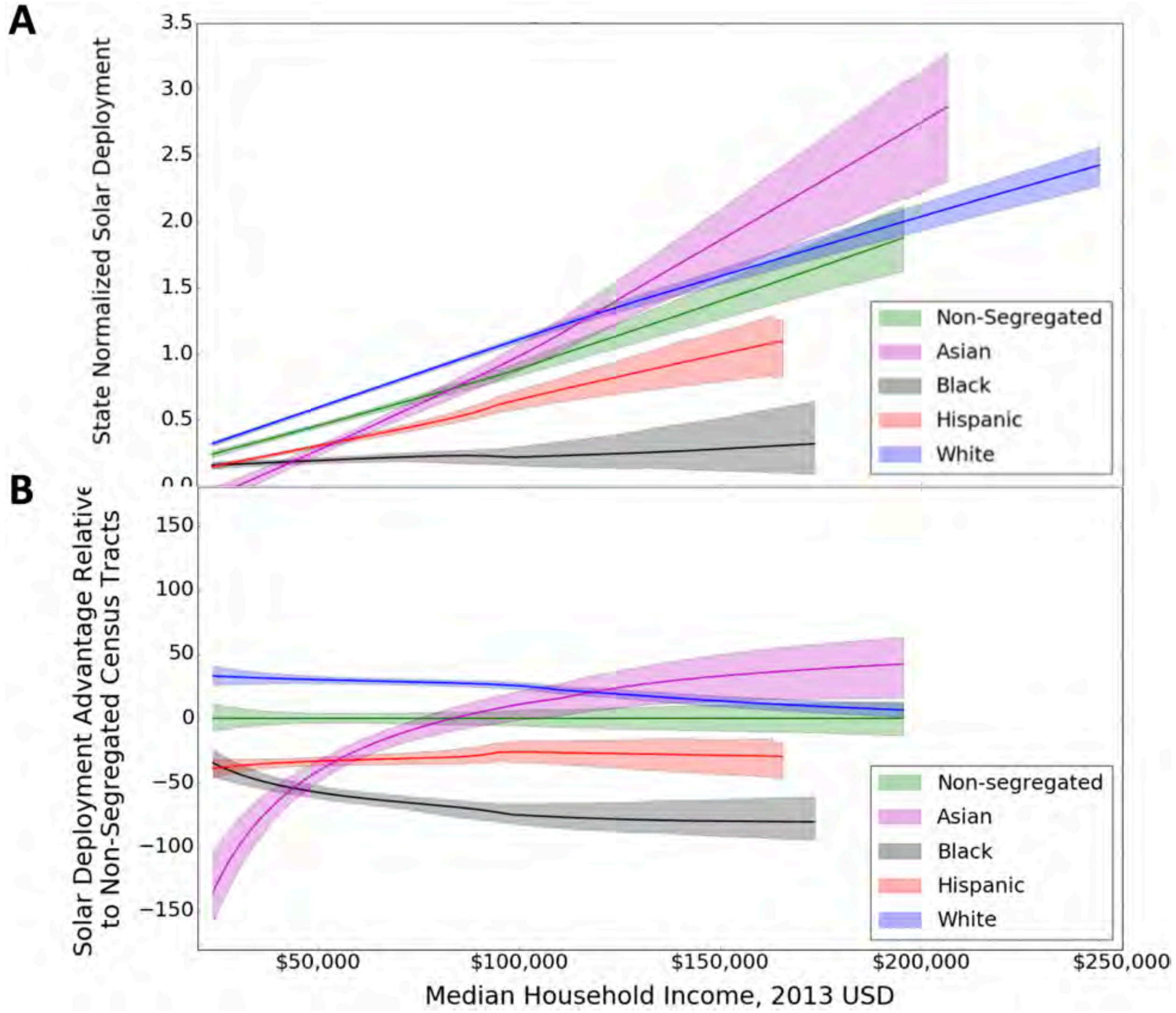
Blocked by tree? | Cloudy?





Deborah Sunter, Sergio Castellanos & Daniel M Kammen (2019) “Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity,“ *Nature Sustainability*, **2**, 71 – 76.

Large Racial disparity in solar – even at same income

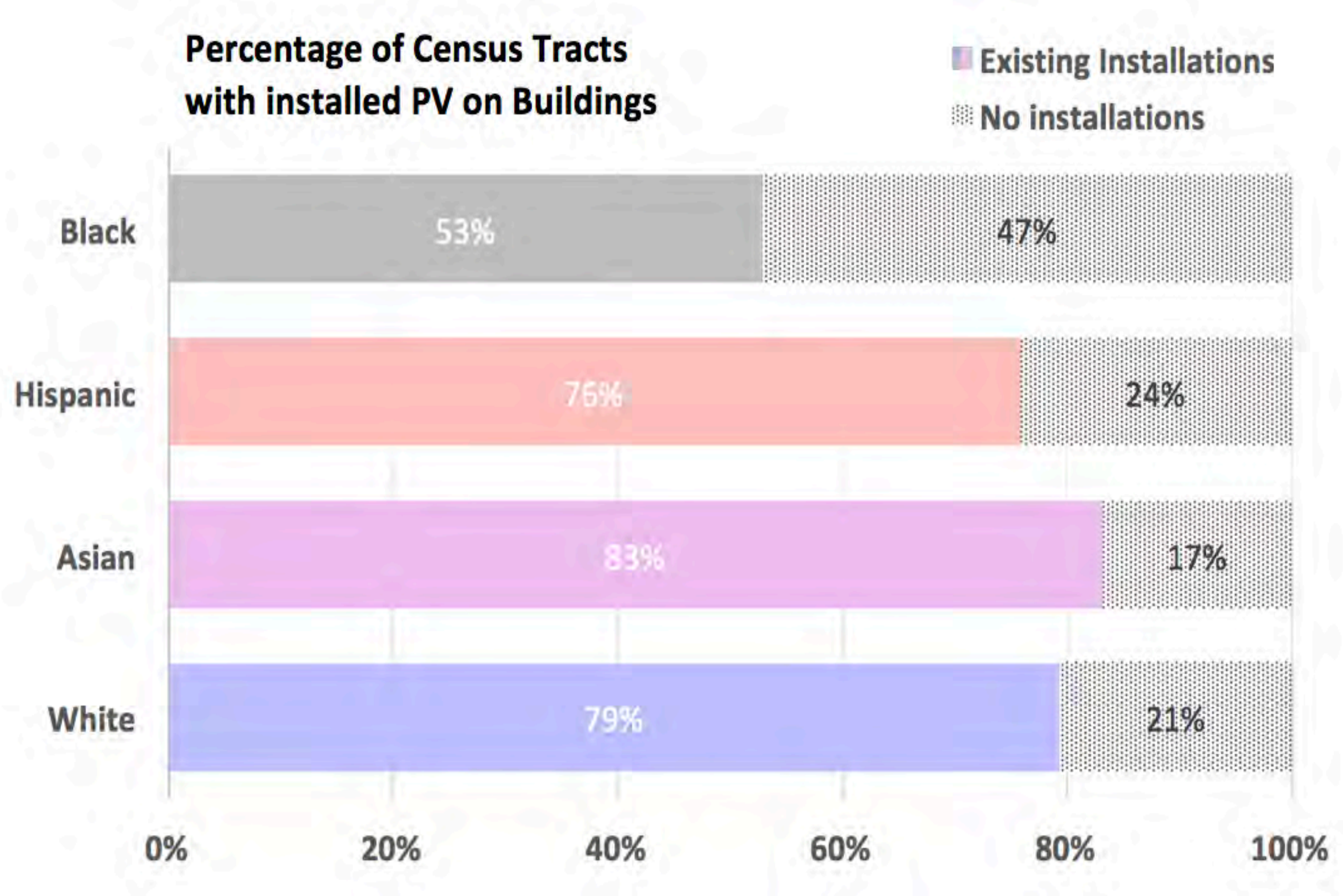


BECI BERKELEY ENERGY & CLIMATE INSTITUTE LBNL & UC BERKELEY

Renewable & Appropriate Energy Laboratory RAEL

Deborah Sunter, Sergio Castellanos & Daniel M Kammen (2019) "Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity," *Nature Sustainability*, **2**, 71 – 76.

Solar Installations by Racial Composition in Identified Tracts



Deborah Sunter, Sergio Castellanos & Daniel M Kammen (2019) "Disparities in rooftop photovoltaics deployment in the United States by race and ethnicity," *Nature Sustainability*, **2**, 71 – 76.

In one year a youth movement on climate went from

From this

To this

After the strike ended at noon, people marched through campus and took the BART station to San Francisco, where they met up with a larger UC Berkeley contingent to take a group photo. (UC Berkeley photo by Irene Yi)

Four million people
September 20 – 27: a week of action
Expectations locally to globally

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Environmental Justice

- Lack of EV access where the health benefits are highest
- CA Green New Deal: Dedicated seed fund of $3.5 billion/yr for disadvantaged areas
- CA SB50 (housing access at transit hubs): bill failed 2x

The New York Times

Opinion

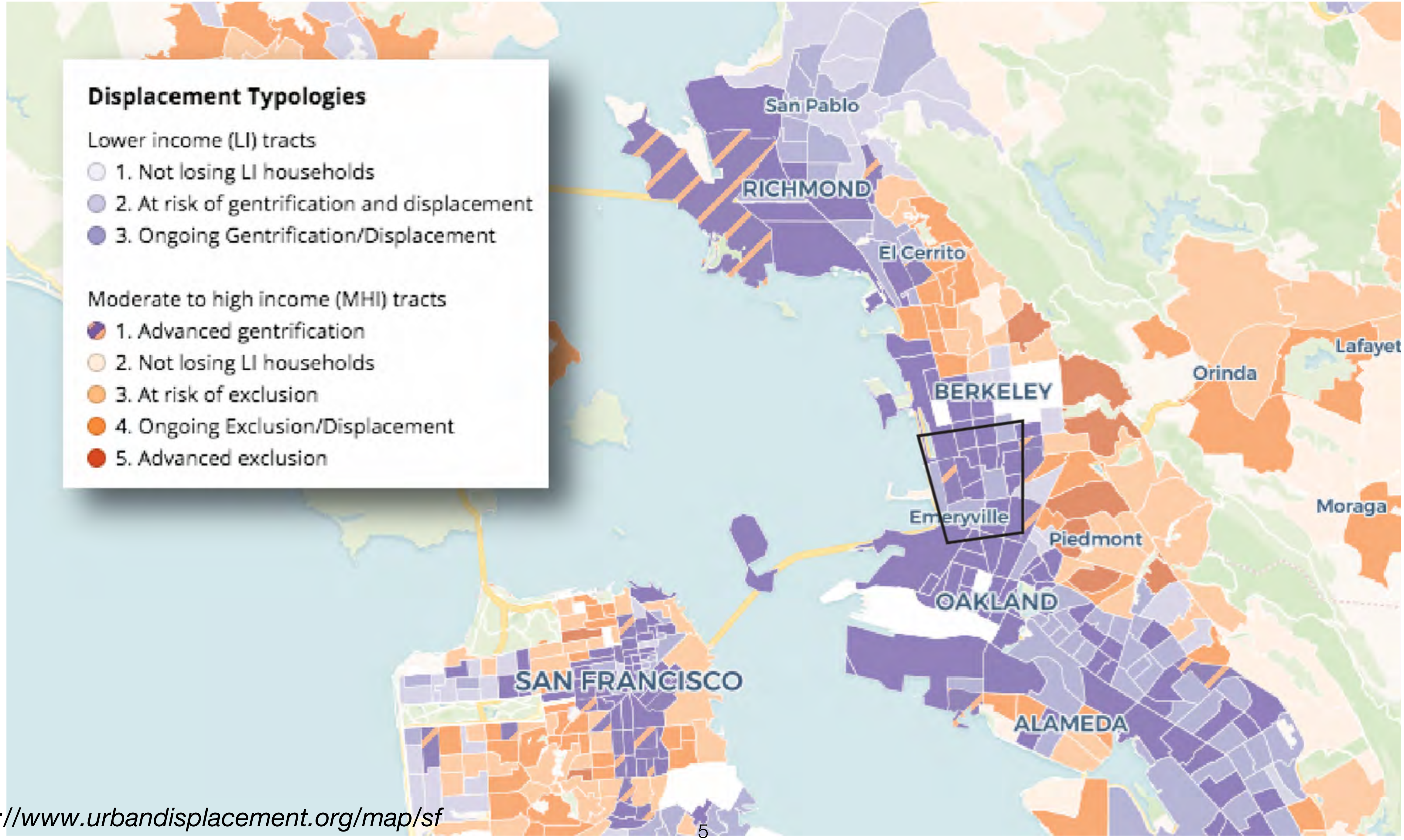
Why Housing Policy Is Climate Policy

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



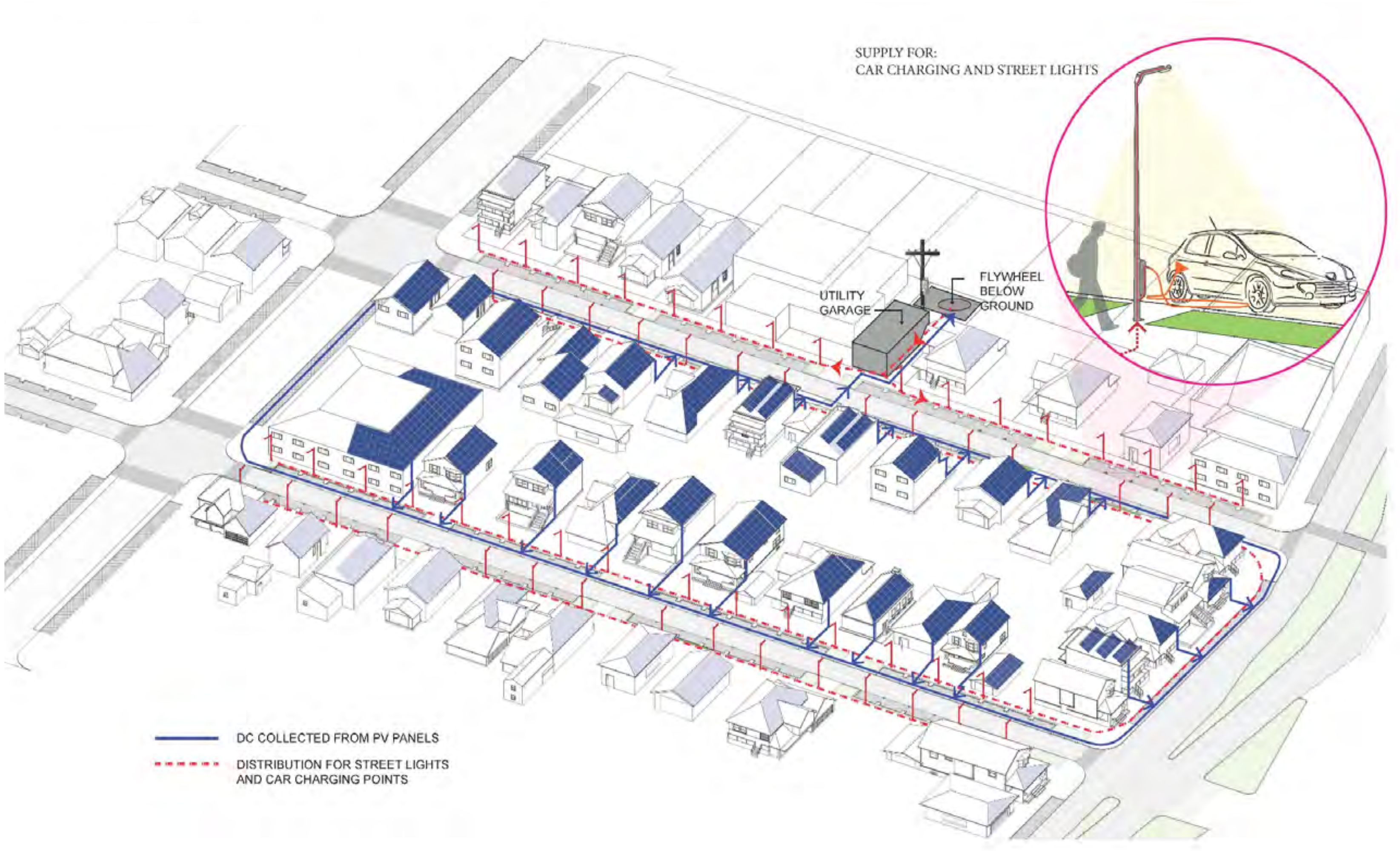
http://www.urbandisplacement.org/map/sf

EcoBlock Vision: A Multi-Customer Microgrid Solution

Electrical system combines DER

- Communal rooftop solar PV
- Communal energy storage system (flywheel and/or battery)
- Intelligent loads and electric demand response
- Shared Electric vehicle (EV) charging
- Smart controls in a direct-current (DC) microgrid infrastructure

behind a single interconnection with PG&E



ecoblock

CEC Phase II Partners

CITY OF OAKLAND

INTEGRAL GROUP

SHERWOOD DESIGN ENGINEERS

Build It Green

REDHORSE CONSTRUCTORS

Morgan Lewis

DTA DAVID TAUSSIG & ASSOCIATES

Coblentz Patch Duffy & Bass LLP

SIEGEL & STRAIN Architects

Page/

AMERICAN JOBS PROJECT

EMerge™ ALLIANCE

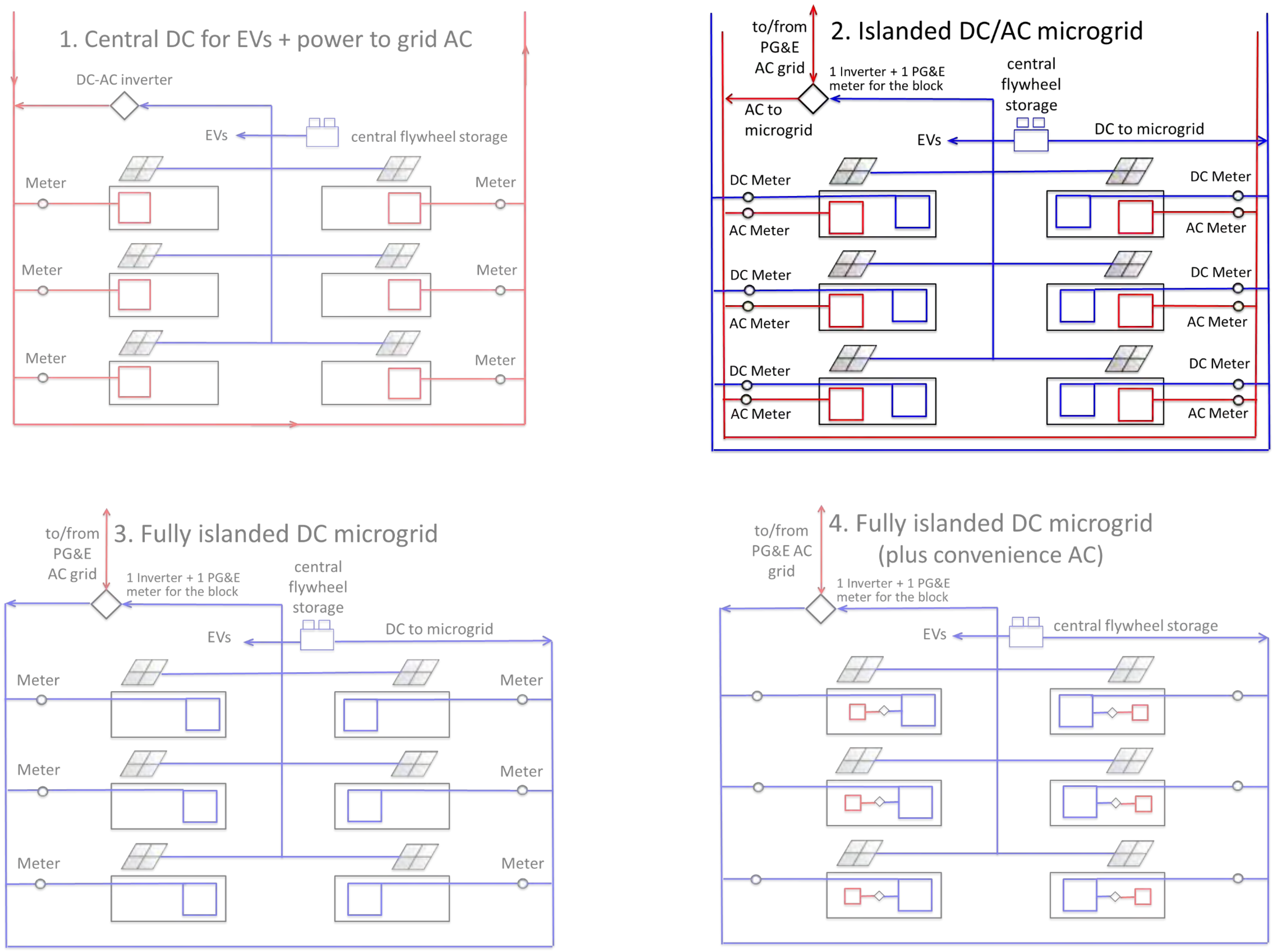
spie batignolles

ARDA™ power DC-connected energy

PLATT

AMBER KINETICS

EcoBlock Vision: Different possible topologies for AC and DC power sharing



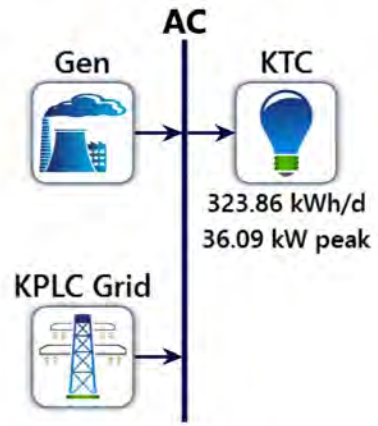
Project Team selected Option 2 as most appropriate for the first Pilot EcoBlock

Different topologies may fit different situations

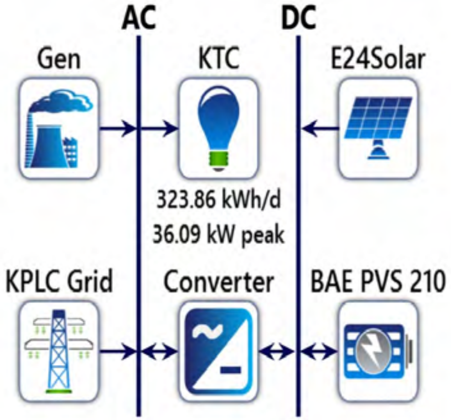
Electricity

- 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.

Kibera Town Women's Center, Nairobi:
Microgrid franchise model leverages community energy

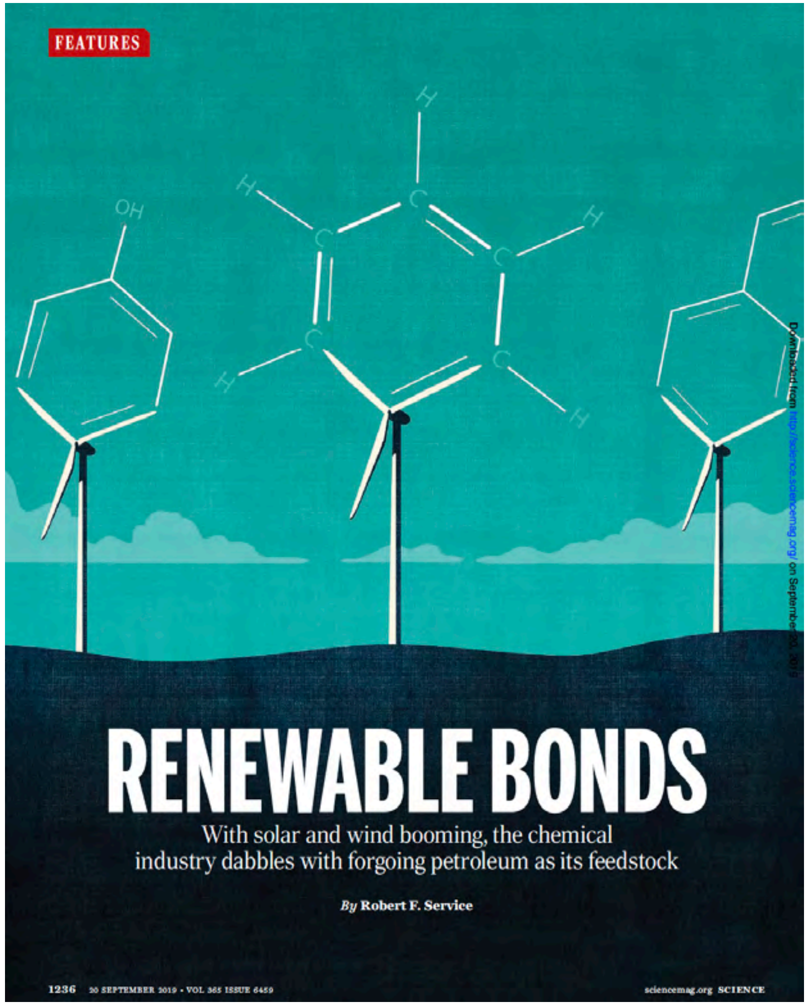


- Largest slum in Africa
- Minimal infrastructure
- Unmet energy demand
- Leverage Women's resource center (600 users/day)



- Women's resource center opens 2017
- Community training center
- Hub of franchise model for community micro-grid

The Green Energy Economy


FEATURES

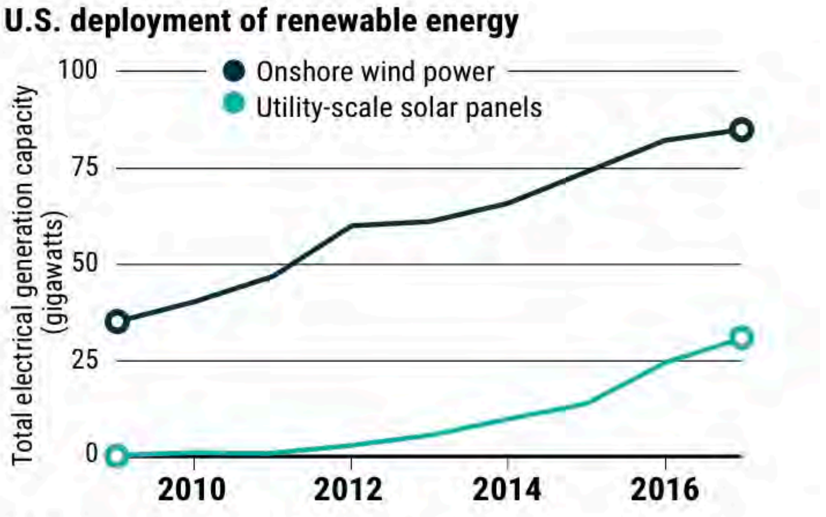
RENEWABLE BONDS

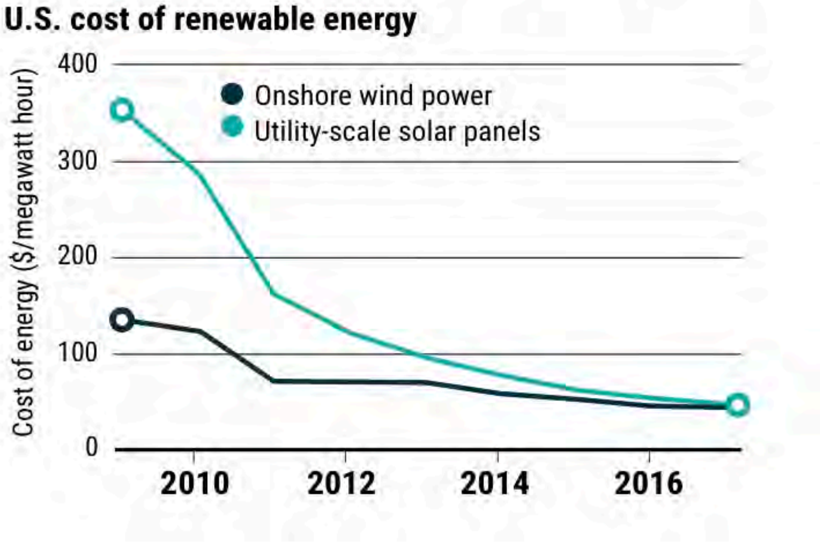
With solar and wind booming, the chemical industry dabbles with forgoing petroleum as its feedstock

By Robert F. Service

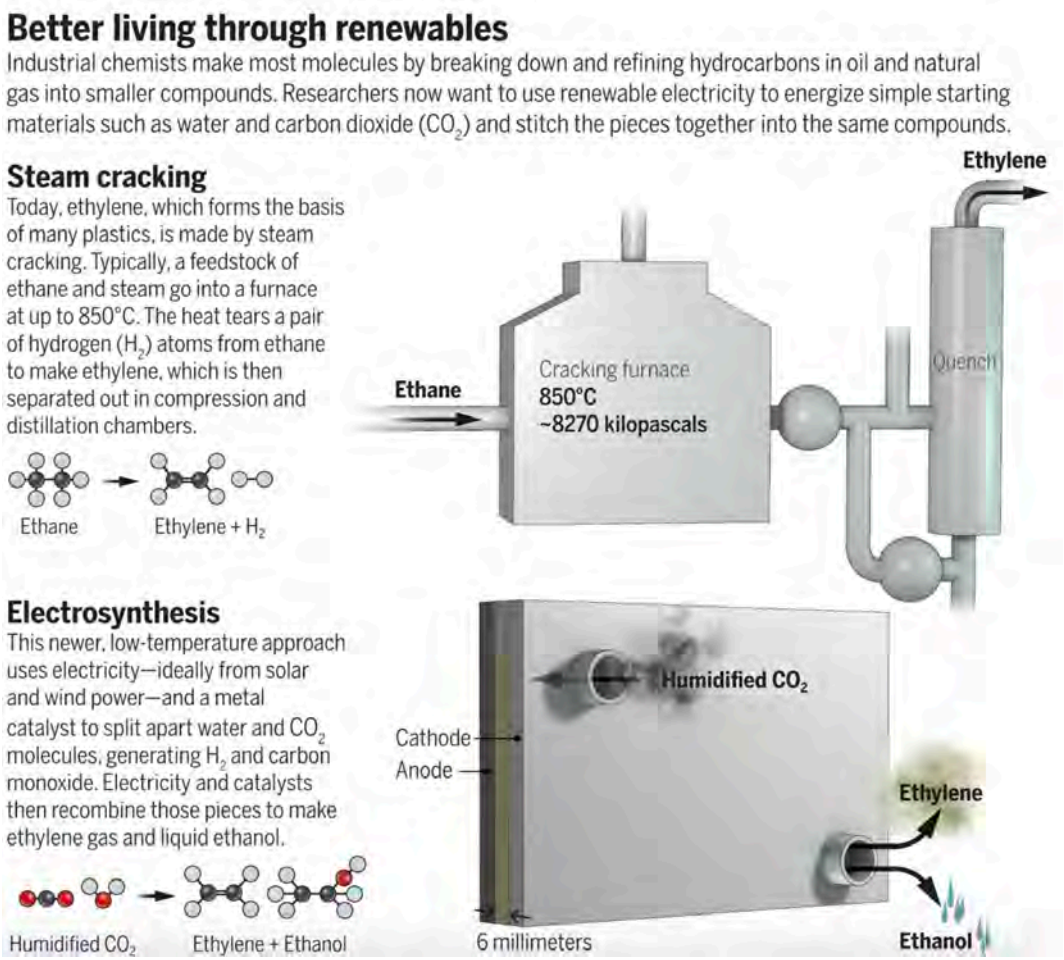
1236 20 SEPTEMBER 2019 • VOL 365 ISSUE 6459

sciencemag.org SCIENCE

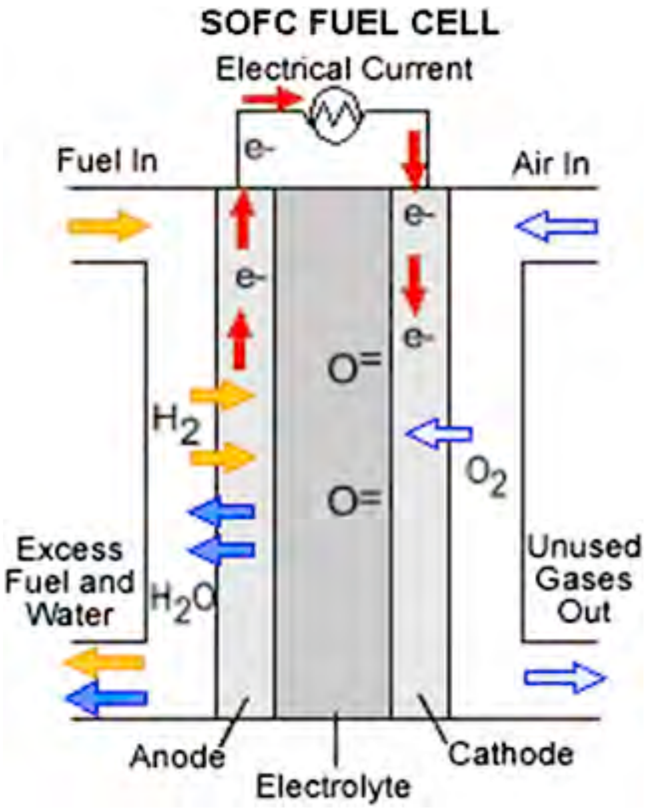


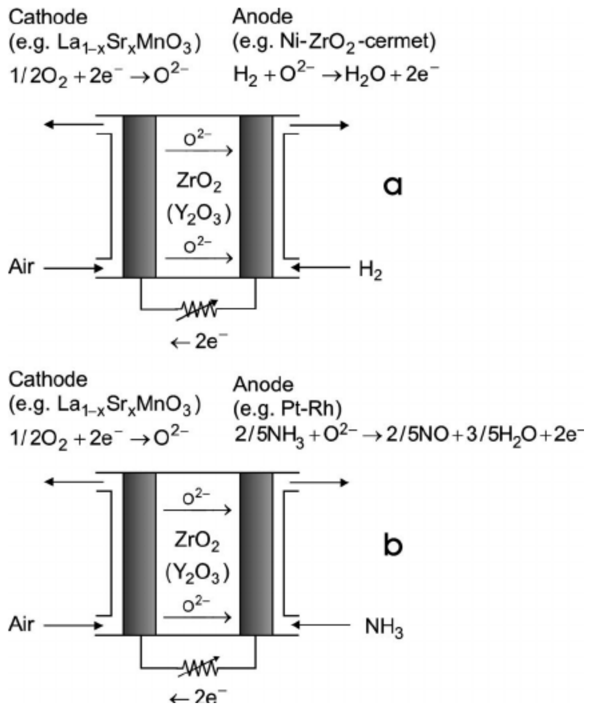


The Green Energy Economy



Low temperature (80 C+)





High temperature (400 C+)

Thank you

- Twitter: @dan_kammen
- http://rael.berkeley.edu