Renewable & Appropriate Energy Laboratory

RAEL

The Clean Energy Revolution

For audio & video for this talk, watch:

https://drive.google.com/file/d/0B1bnfGXKHqpcOVdQWWtJNEtUX0U/view

Daniel Kammen

Energy and Resources Group, Goldman School of Public Policy
& Department of Nuclear Engineering
Director, Renewable and Appropriate Energy Laboratory
University of California, Berkeley

Science Envoy for the U. S. State Department

International Renewable Energy Academy, 2017

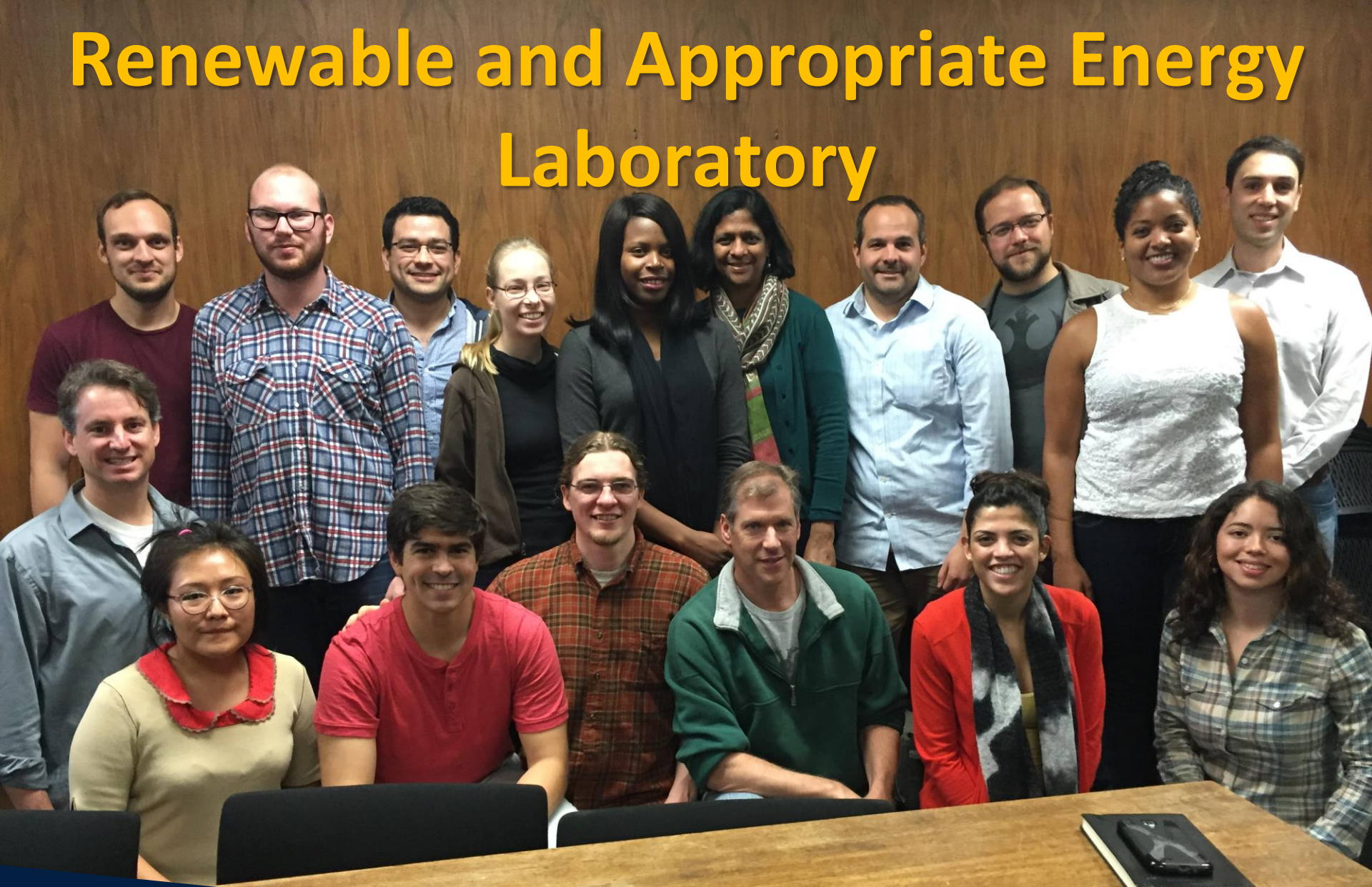
Resources:

Watch & listen at
https://drive.google.com/file/d/0B1bnfGXKHqpcOVdQWWtJNEtUX0U/view

Website: http://rael.berkeley.edu

Twitter: @dan_kammen

Renewable and Appropriate Energy Laboratory



Renewable & Appropriate Energy Laboratory
RAEL

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UNIVERSITY OF CALIFORNIA

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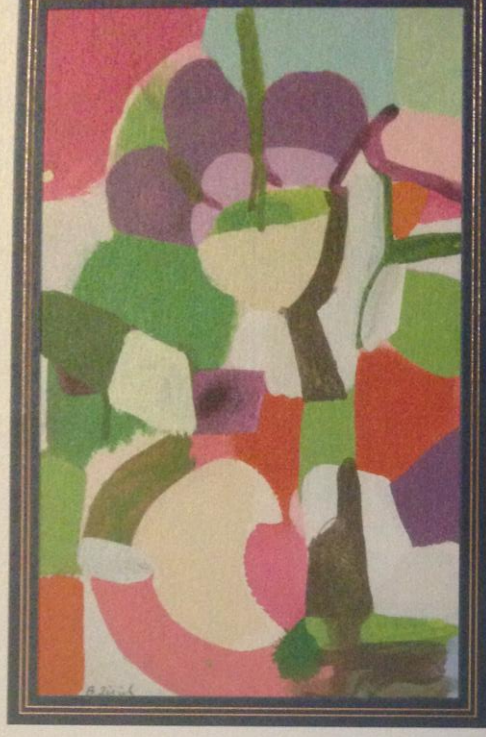


Den Norske Nobelkomite
har overensstemmende med
reglene i det av
ALFRED NOBEL
den 27. november 1895
opprettede testamente tildelt
Intergovernmental Panel on
Climate Change
Nobels Fredspris
for 2007
Oslo, 10. desember 2007

Ole Danbolt Mjøs

WMO

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

UNEP

PRESENTED TO

DANIEL M. KAMMEN

FOR CONTRIBUTING TO THE AWARD OF THE

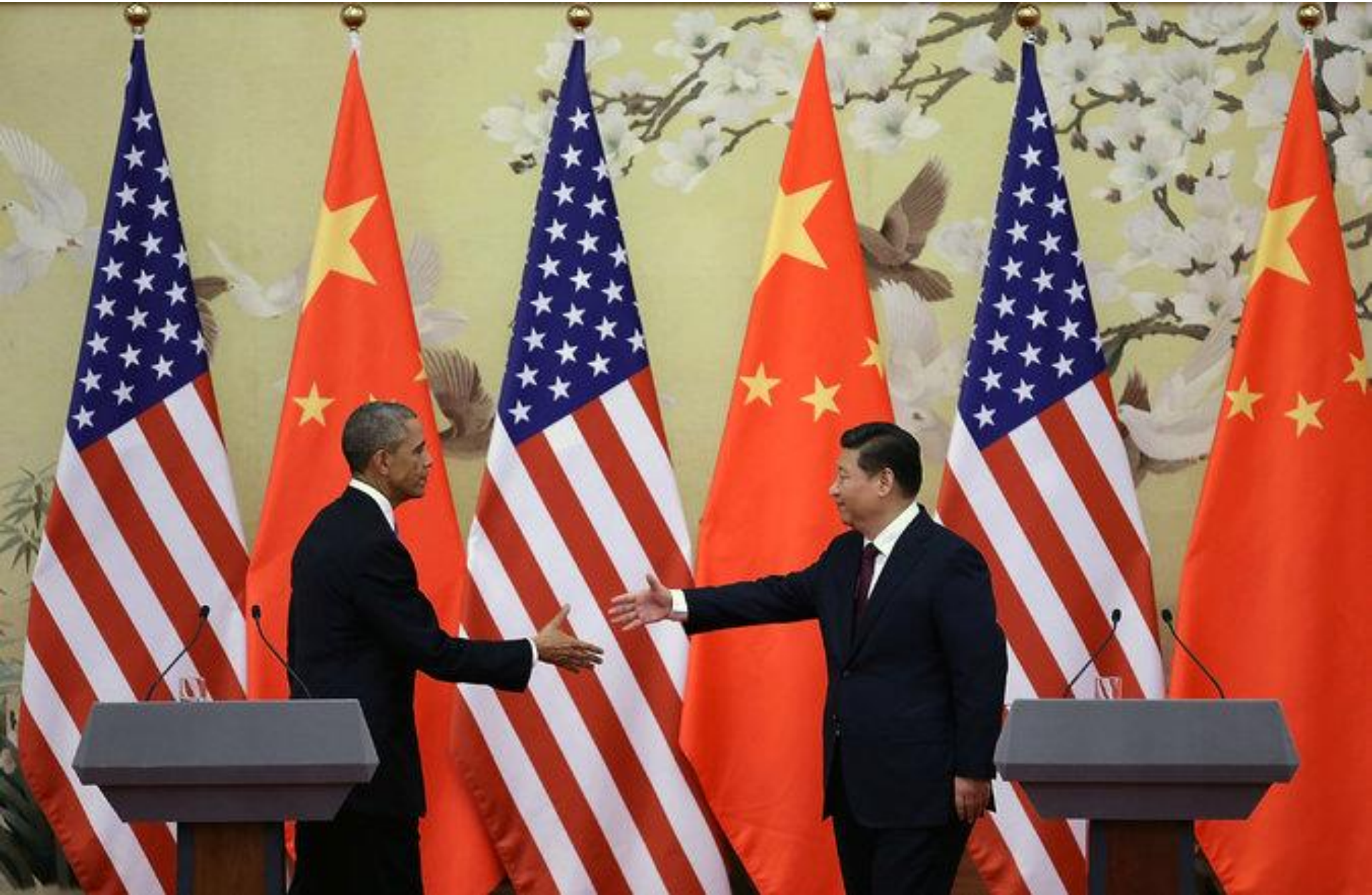
NOBEL PEACE PRIZE

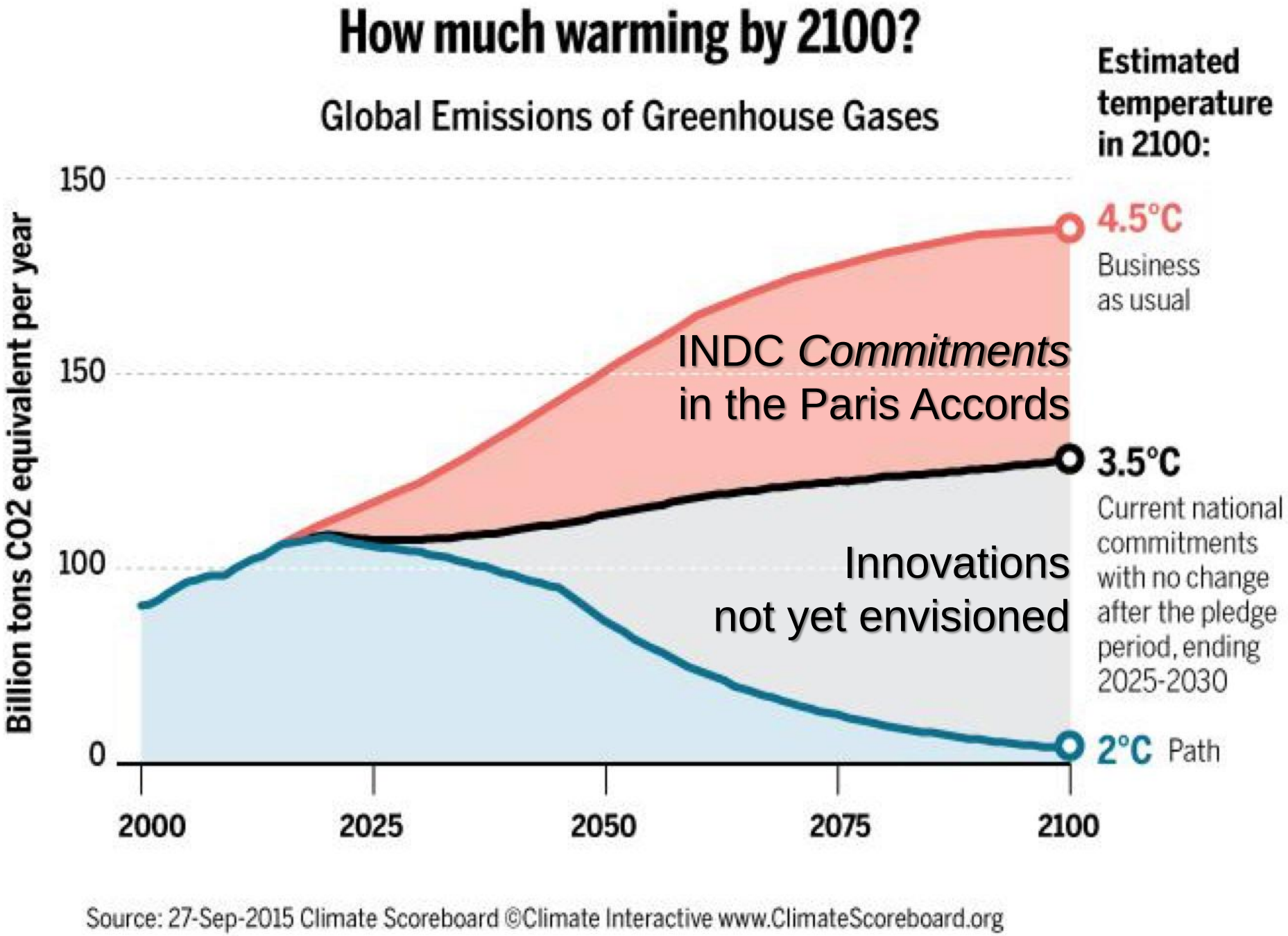
FOR 2007 TO THE IPCC

R. K. Pachauri
IPCC Chairman

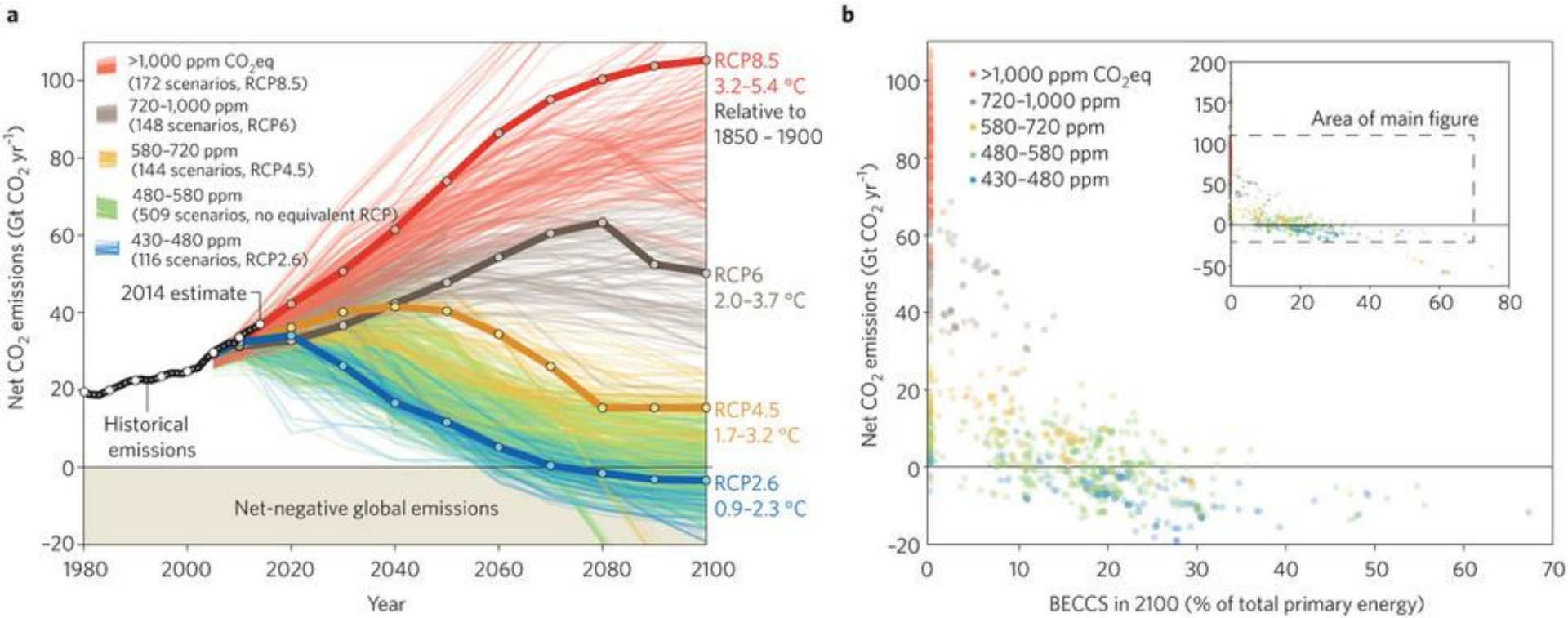
R. Christ
IPCC Secretary

A revolution in climate politics
U.S.- China Joint Announcement on Climate Change, 2014




How much warming by 2100?
Global Emissions of Greenhouse Gases
Estimated temperature in 2100:
Billion tons CO2 equivalent per year
150
150
100
0
2000
2025
2050
2075
2100
4.5°C
Business as usual
INDC *Commitments* in the Paris Accords
3.5°C
Current national commitments with no change after the pledge period, ending 2025-2030
Innovations not yet envisioned
2°C Path
Source: 27-Sep-2015 Climate Scoreboard ©Climate Interactive www.ClimateScoreboard.org

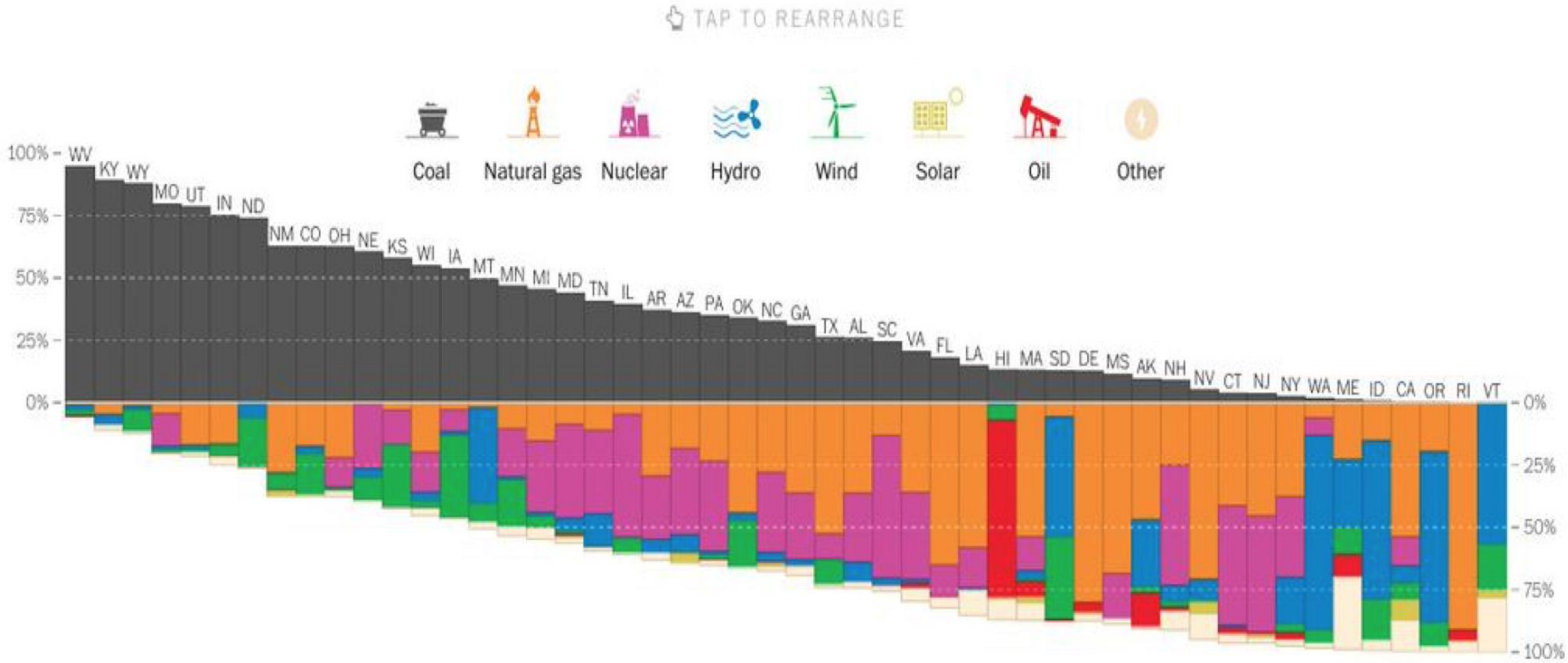
What we need to do:



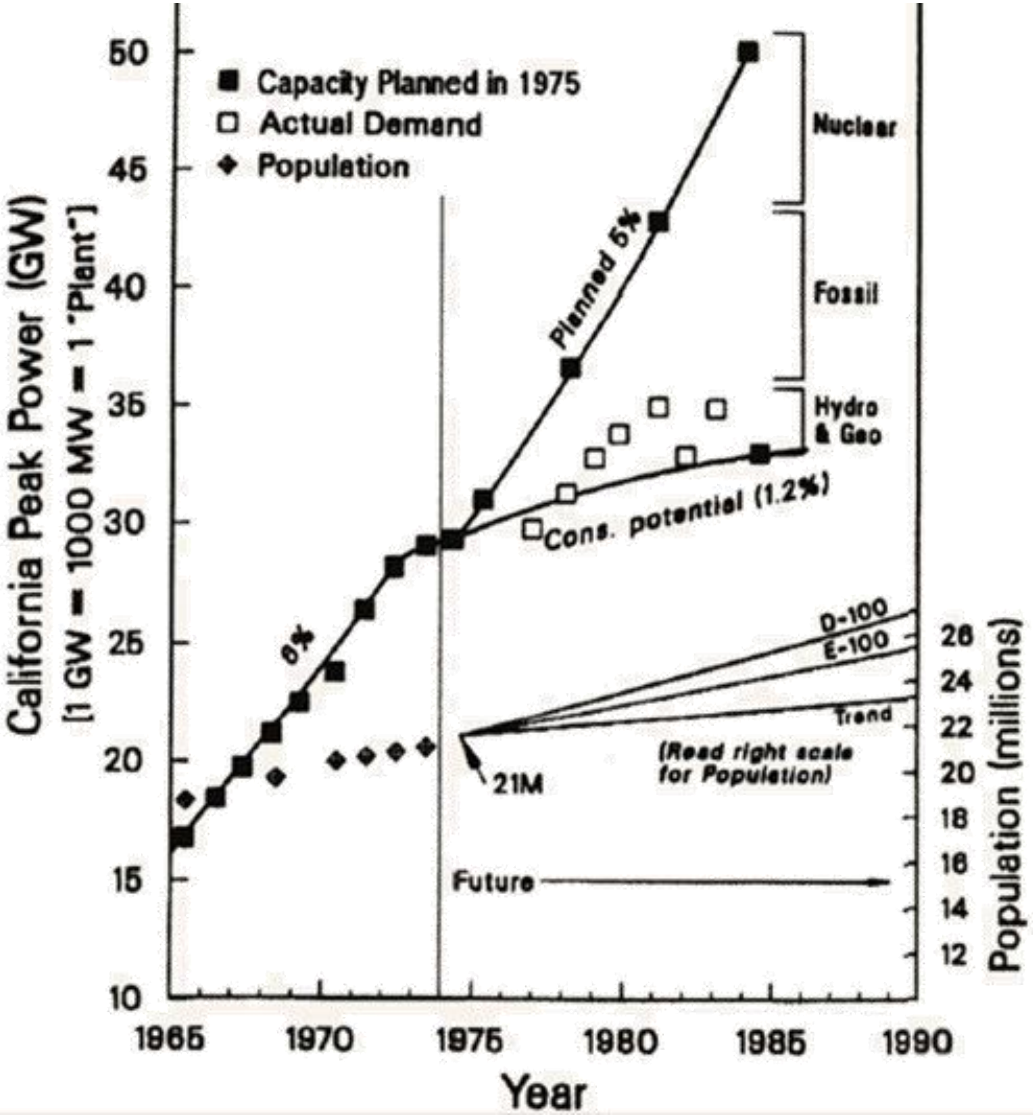
Fuss et al. (2014)

Electricity generation by power source, January to May 2015

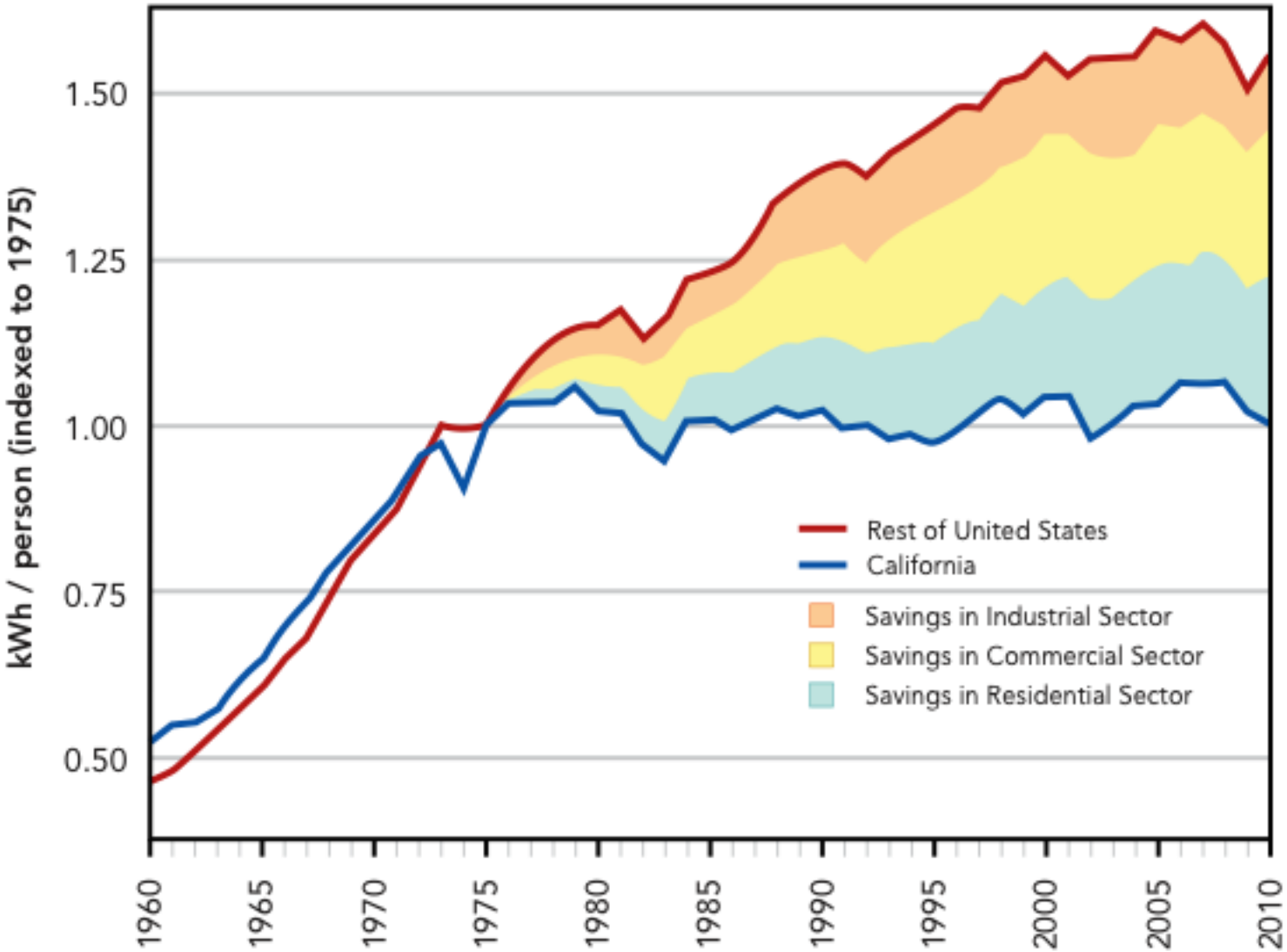
Local electric utilities take advantage of the power sources most accessible to them: coal mines, dammed rivers, new supplies of natural gas or nuclear plants to generate the bulk of the nation's electricity. This shows the source of electricity generation in each state in 2015.



CA Peak Power: Testimony by Goldstein and Rosenfeld (Dec. 1974)

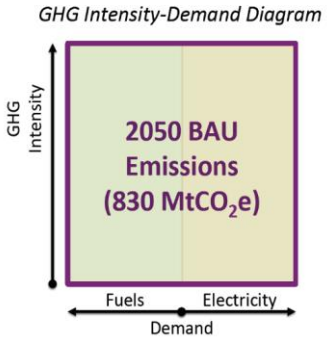


California Advancing Energy Efficiency

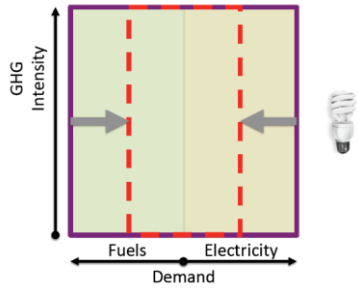


A pathway to sustainability

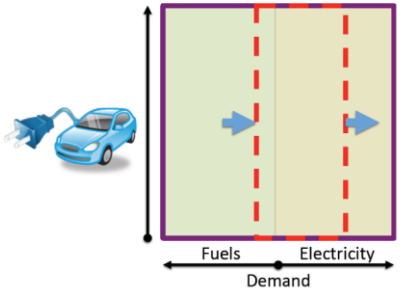
Four Actions to Reduce Emissions



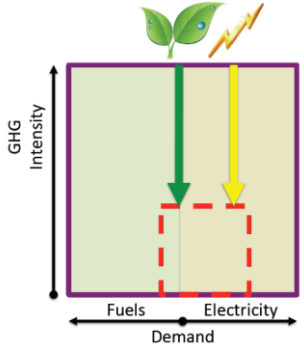
1. Efficiency



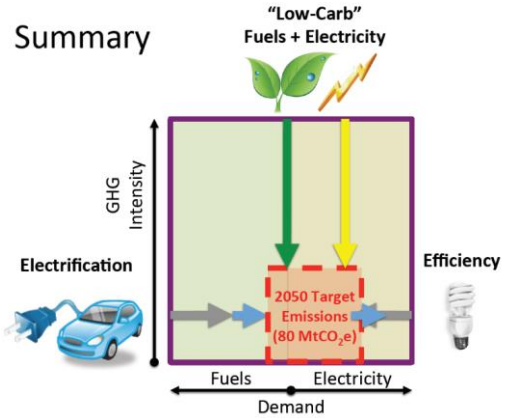
2. Electrification



3. "Low-Carb" Fuels + Electricity

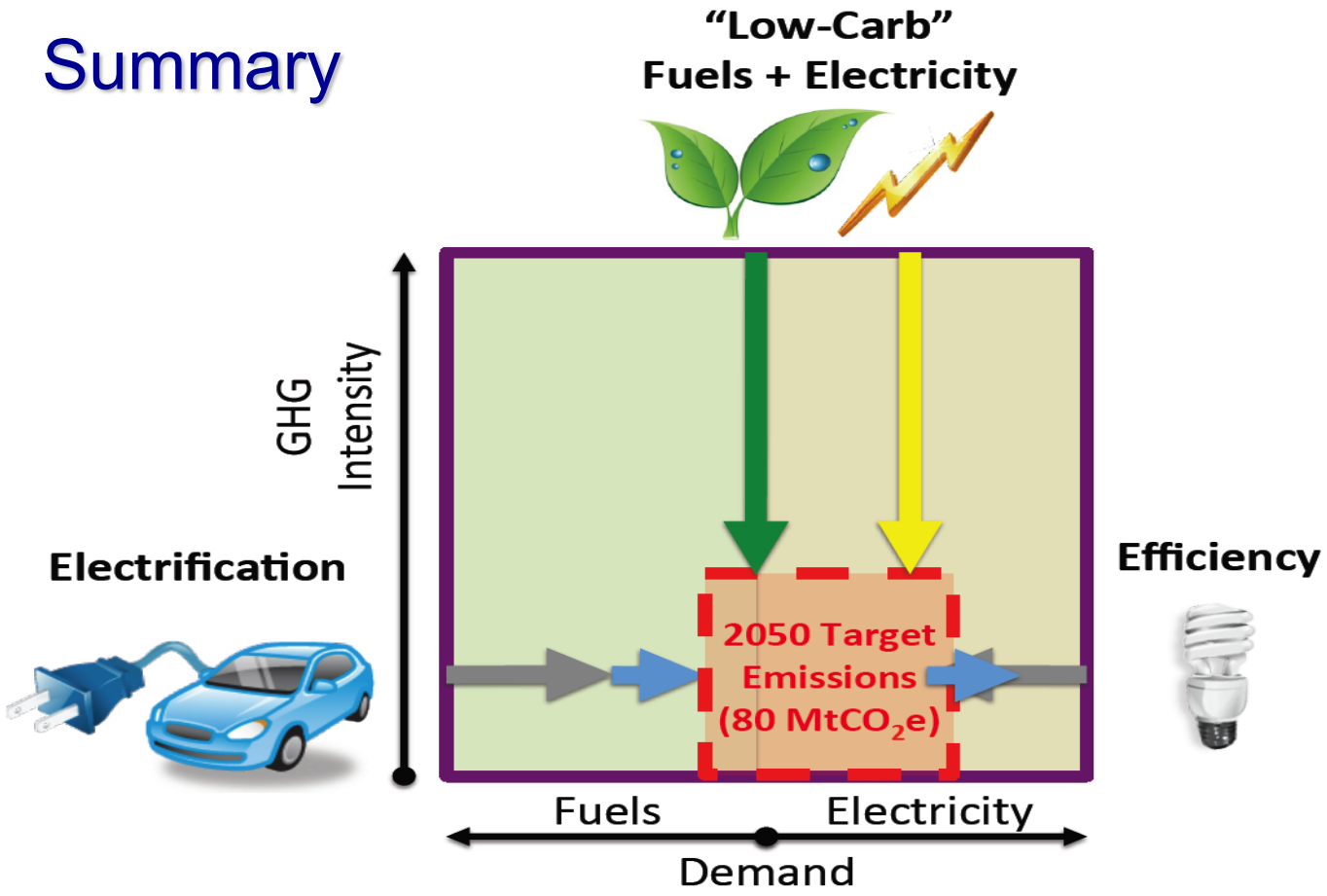


Summary

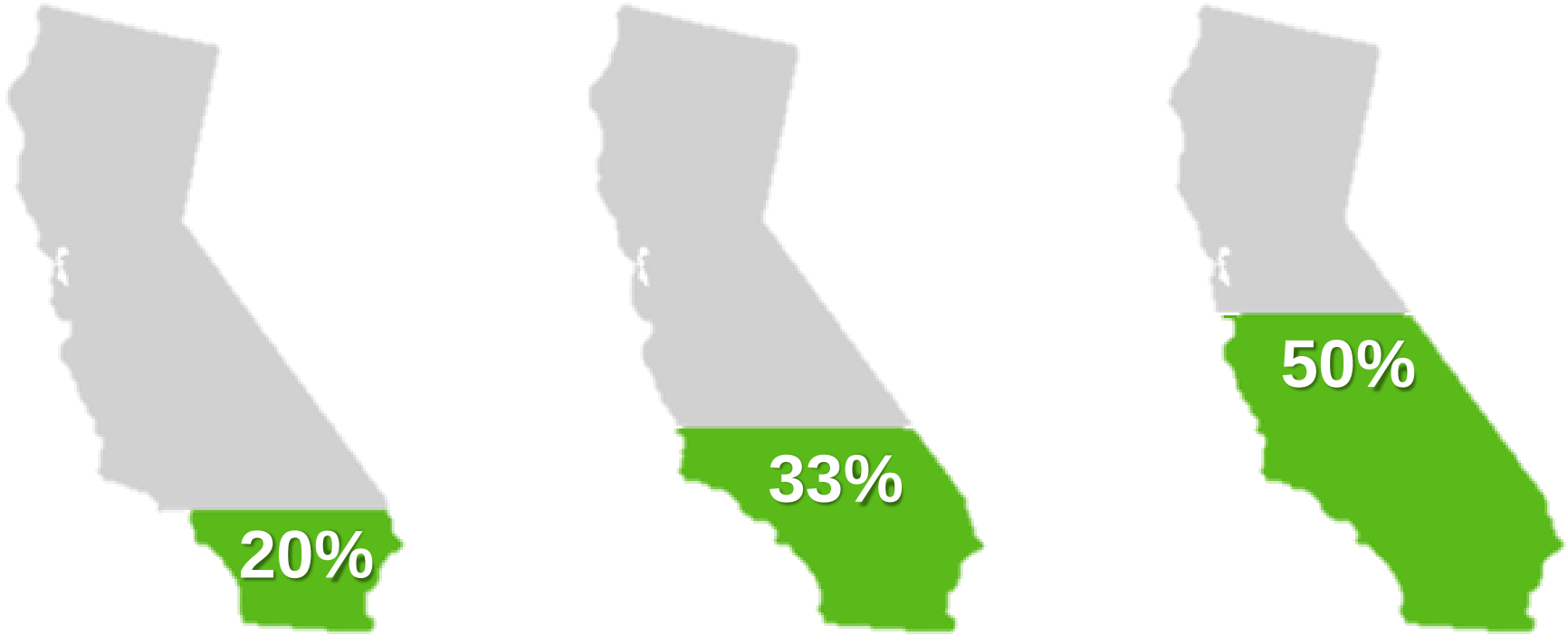


http://rael.berkeley.edu

Summary


"Low-Carb"
Fuels + Electricity
GHG
Intensity
Electrification
Efficiency
2050 Target
Emissions
(80 MtCO2e)
Fuels
Electricity
Demand

The Challenge is Big…

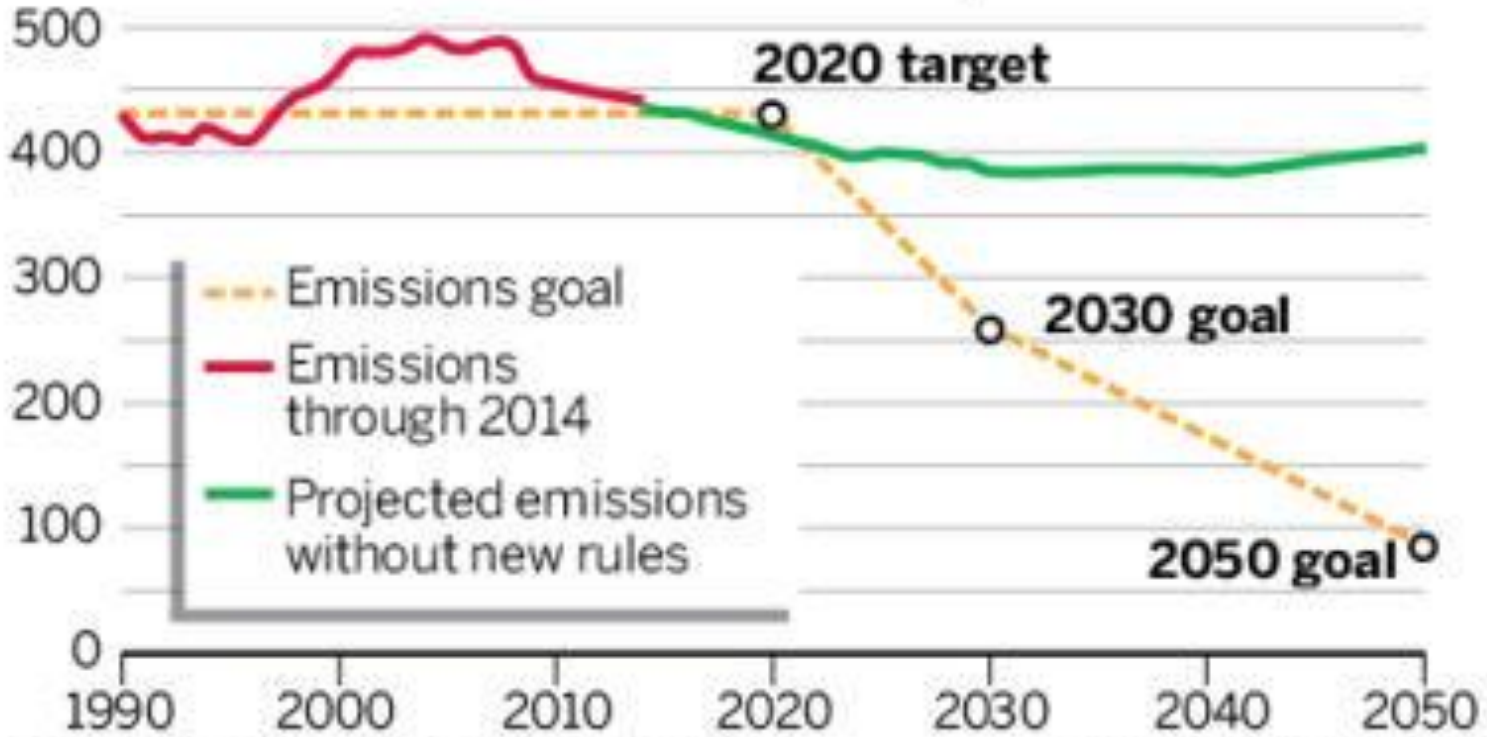


2013 **2020** **2030**

CALIFORNIA GREENHOUSE GAS EMISSIONS

California is on track to meet its goal for greenhouse gas emissions by 2020, but will need to do far more to reach targets for 2030 and 2050.

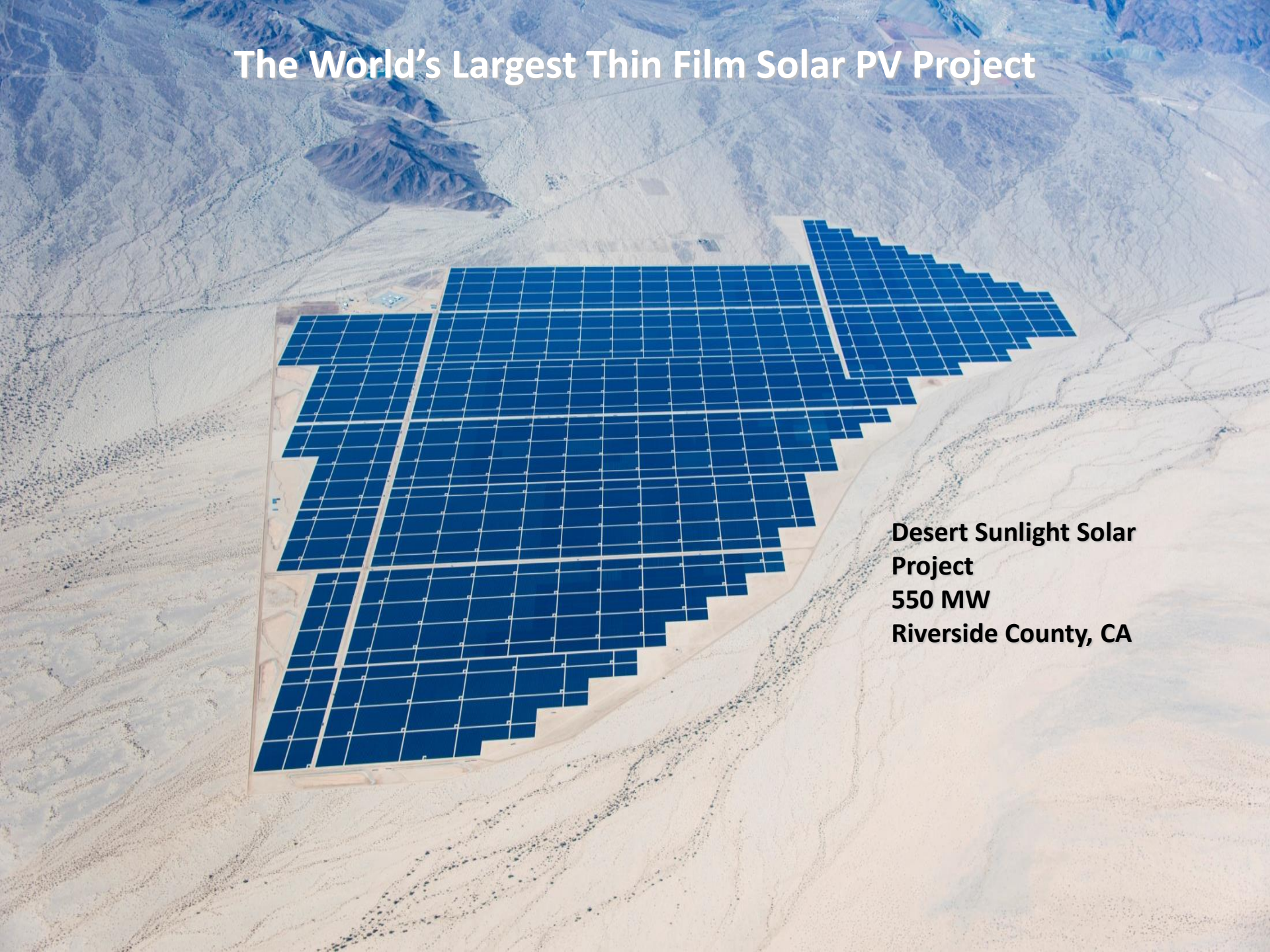
Million metric tons of carbon dioxide equivalent



Source: California Air Resources Board

BAY AREA NEWS GROUP

The World's Largest Thin Film Solar PV Project

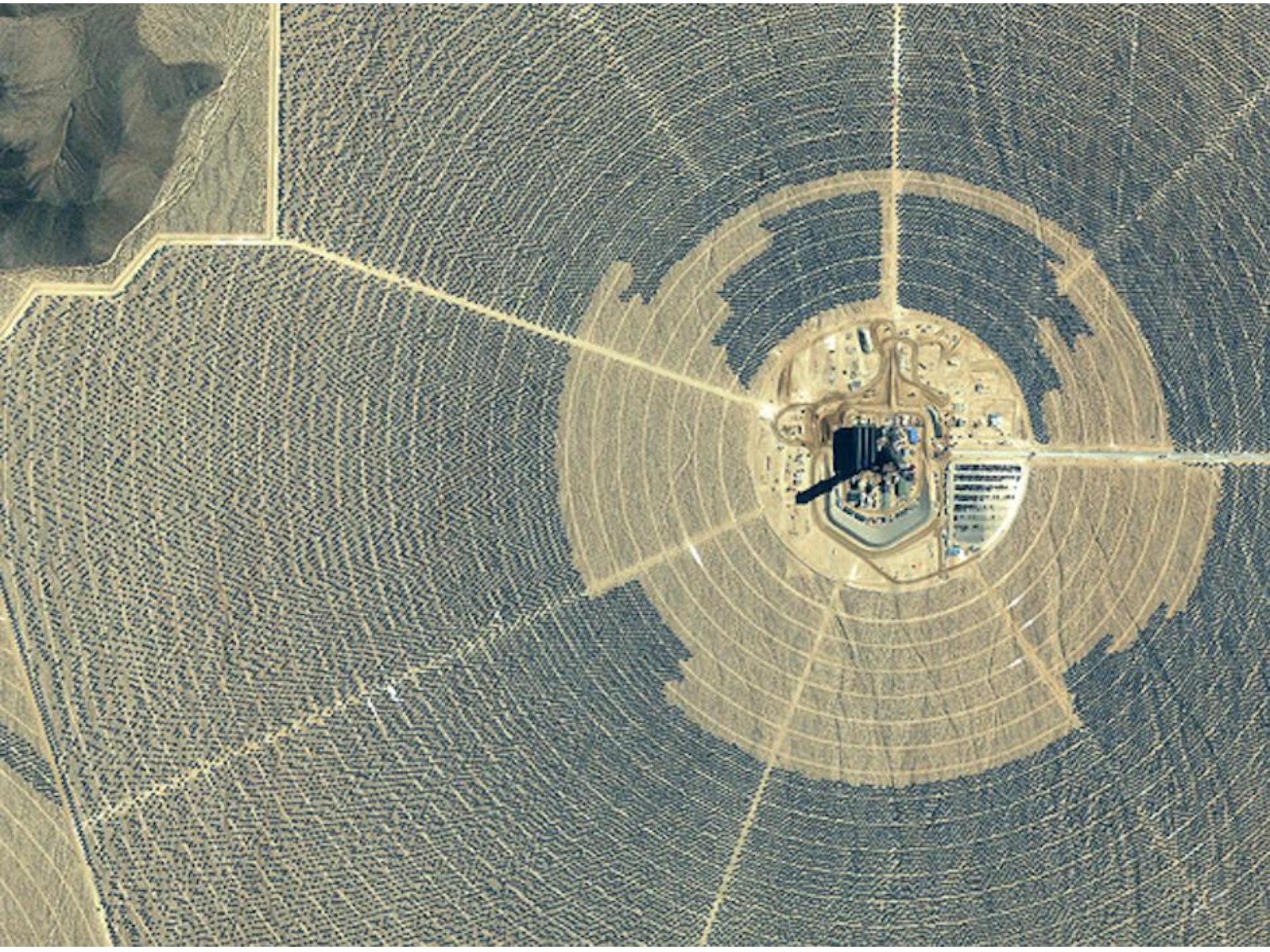


Desert Sunlight Solar Project
550 MW
Riverside County, CA

The World's Largest Silicon PV Project

The World's Largest Solar Thermal Power Plant (Tower)

Ivanpah Solar Thermal Project
393 MW
San Bernardino County, CA



The World's Largest Solar Thermal Power Plant (Trough)

Solar Energy Generating System (SEGS)
354 MW
San Bernardino County, CA

The World's Largest Geothermal Power Plant

Geysers Geothermal Power Plant
955 MW
Lake County, CA

The World's Largest Iron-Chromium Flow Battery

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

The World's Largest Wind Project

Alta Wind Energy Center
1550 MW
Kern County, CA

Largest Manufacturing Operation in CA is now Electric Vehicles

Automation is allowing "on-shoring" of manufacturing processes back from Asia

Tesla Factory - Fremont, CA

Over 3,000 workers now working at the Tesla Factory

Fastest production car ever: 0–60 in 2.5* sec.

The fine print: At $144,000 the Model S P100D with Ludicrous mode is the third fastest accelerating production car ever produced, with a 0-60 mph time of 2.5* seconds. However, both the LaFerrari and the Porsche 918 Spyder were limited $1 million dollar cars and cannot be bought new. Those cars are small two seaters with very little luggage space, the pure electric, all-wheel drive Model S P100D has four doors, seats 5.

Tesla Model 3: $35,000 in 2017

Designed to achieve
5-Star Safety Rating

Autopilot Hardware

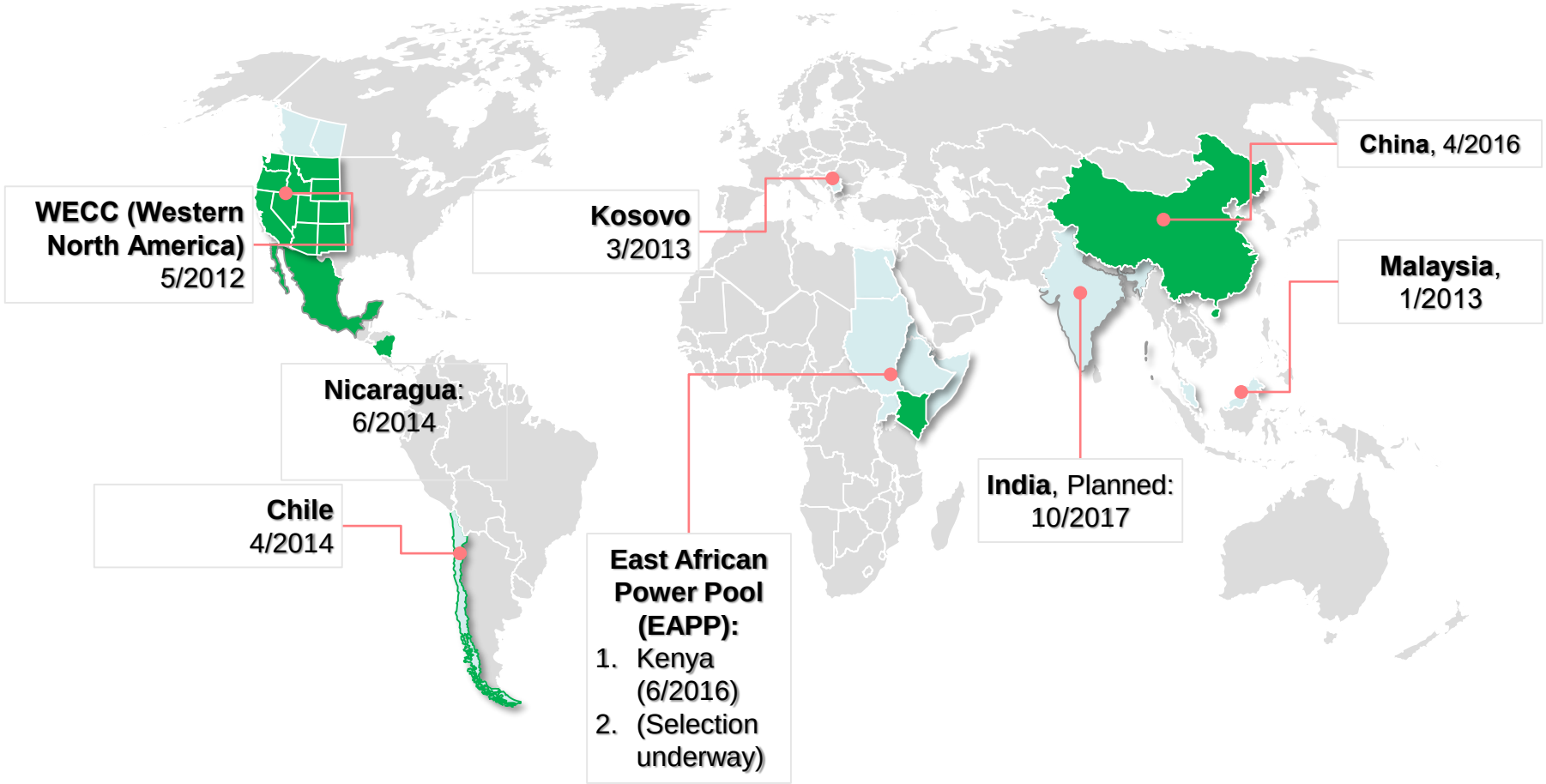
Supercharging

California Energy Efficiency Strategies: Policy Drives Innovation

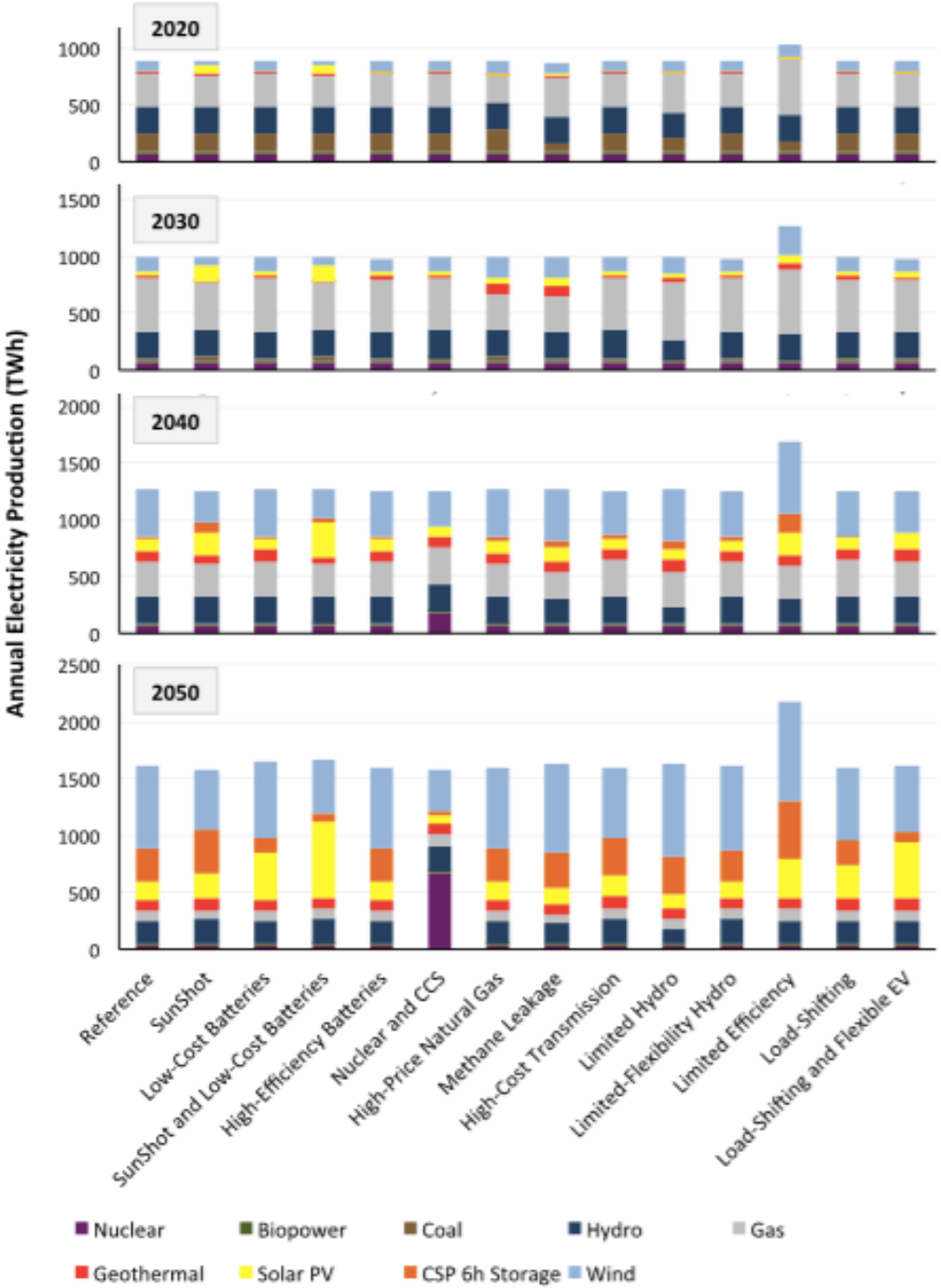
Residential New Construction

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

Power System Models
http://rael.berkeley/edu/project/SWITCH



Pathways for Western North America



Morocco

Les objectifs de la transition énergétique

La volonté du Royaume de porter la part des énergies renouvelables de 42% de puissance installée à 52%

Objectif fixé pour 2020

A l'horizon 2030

Investissement global dans le secteur énergétique entre 2016 et 2030

Près de 40 milliards de dollars dont

30 milliards Pour les projets de production d'électricité de sources renouvelables

Objectif Réduction de 32% des émissions de gaz à effets de serre (GES) à l'horizon 2030

Le Maroc aura à développer (entre 2016 et 2030)

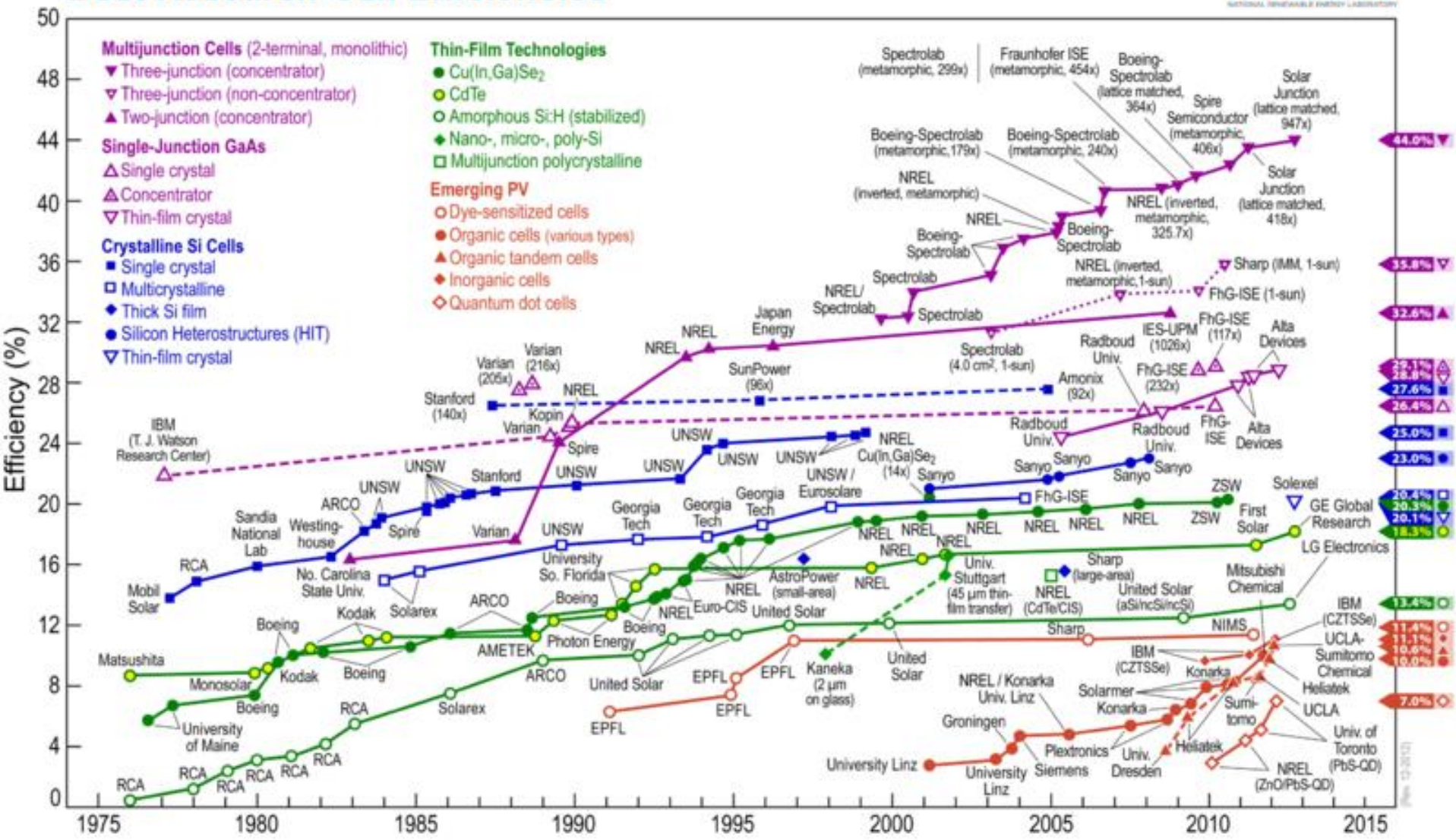
Une capacité additionnelle de production d'électricité de sources renouvelables d'environ

10.100 MW

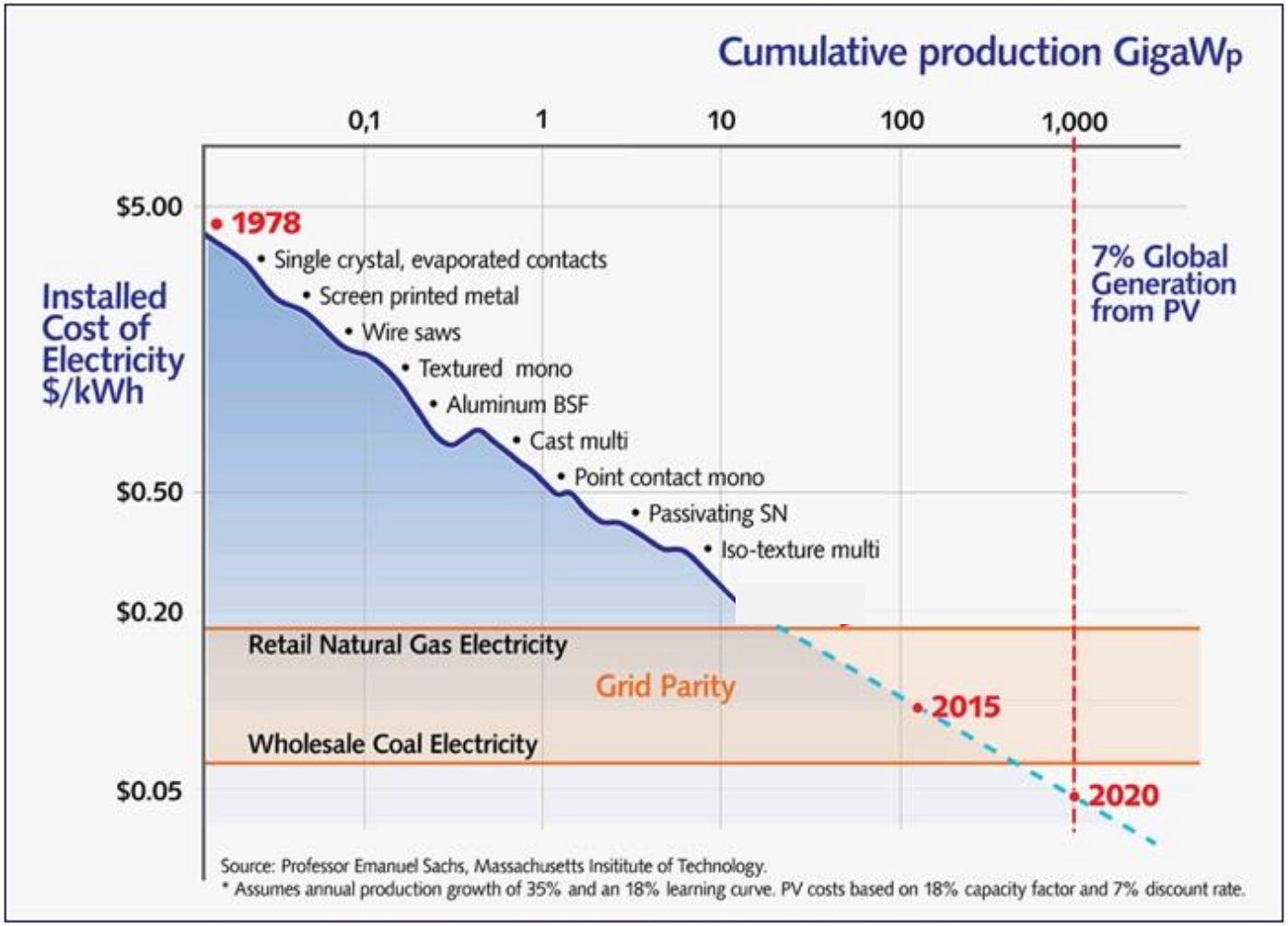
- 4.560 MW solaire
- 4.200 MW éolienne
- 1.330 MW hydro-électrique

Source: Ministère de l'Energie, des Mines, de l'Eau et de l'Environnement

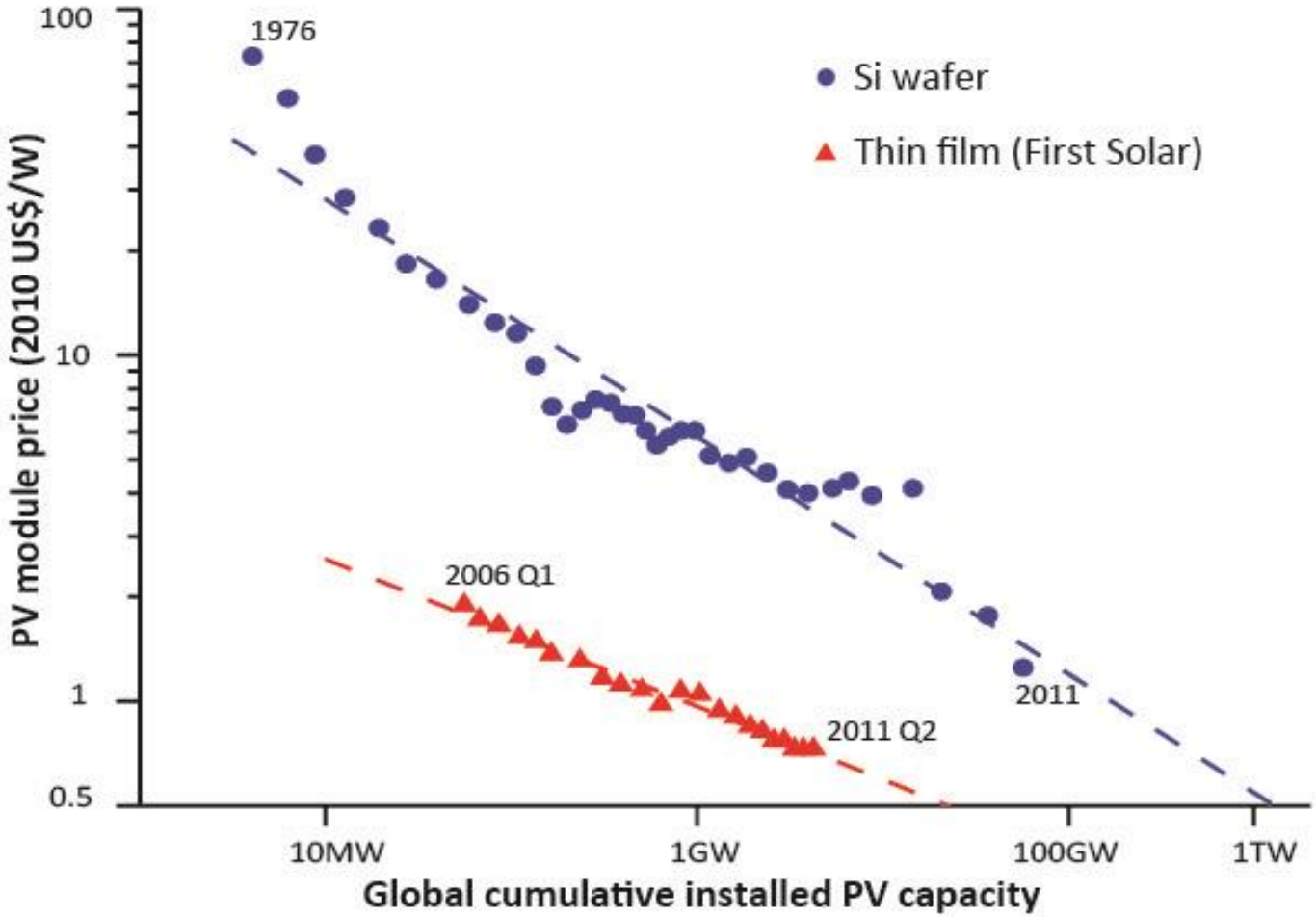
Best Research-Cell Efficiencies



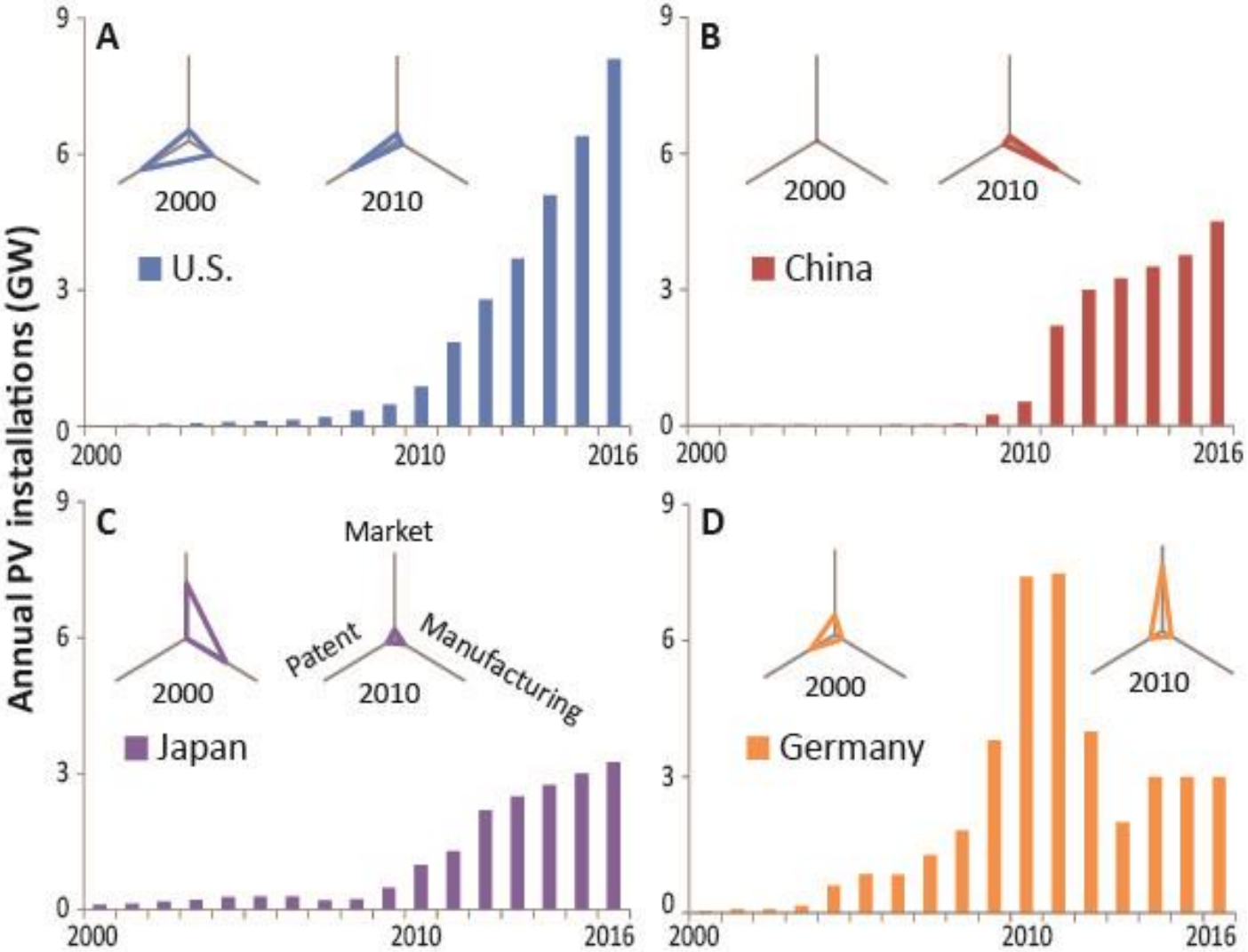
Solar cost decreases 10% per year



The Evolving Solar Energy Economy



The Solar Energy Industry is an International Partnership

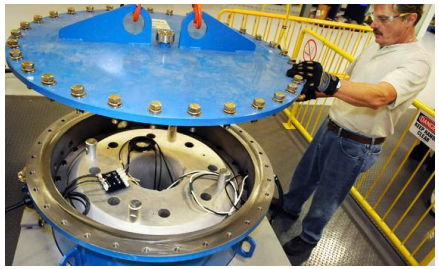


Energy Storage is Not Just Batteries

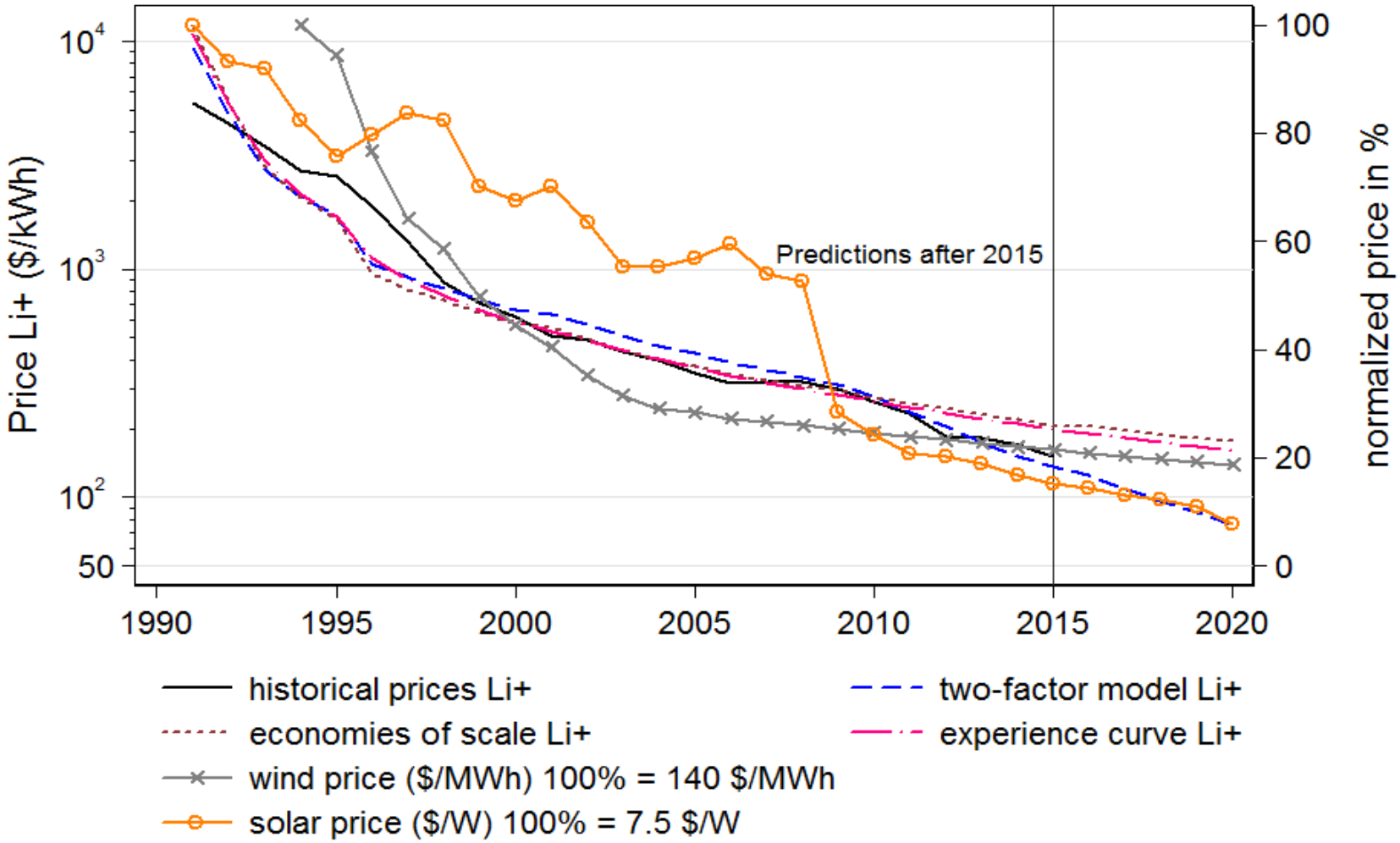
Natural gas (without or with storage)

Traditional and pumped hydropower

Flywheels



Flow batteries


Price Li+ ($/kWh)
10^4
10^3
10^2
50
normalized price in %
100
80
60
40
20
0
1990
1995
2000
2005
2010
2015
2020
Predictions after 2015
historical prices Li+
two-factor model Li+
economies of scale Li+
experience curve Li+
wind price ($/MWh) 100% = 140 $/MWh
solar price ($/W) 100% = 7.5 $/W

Energy access:

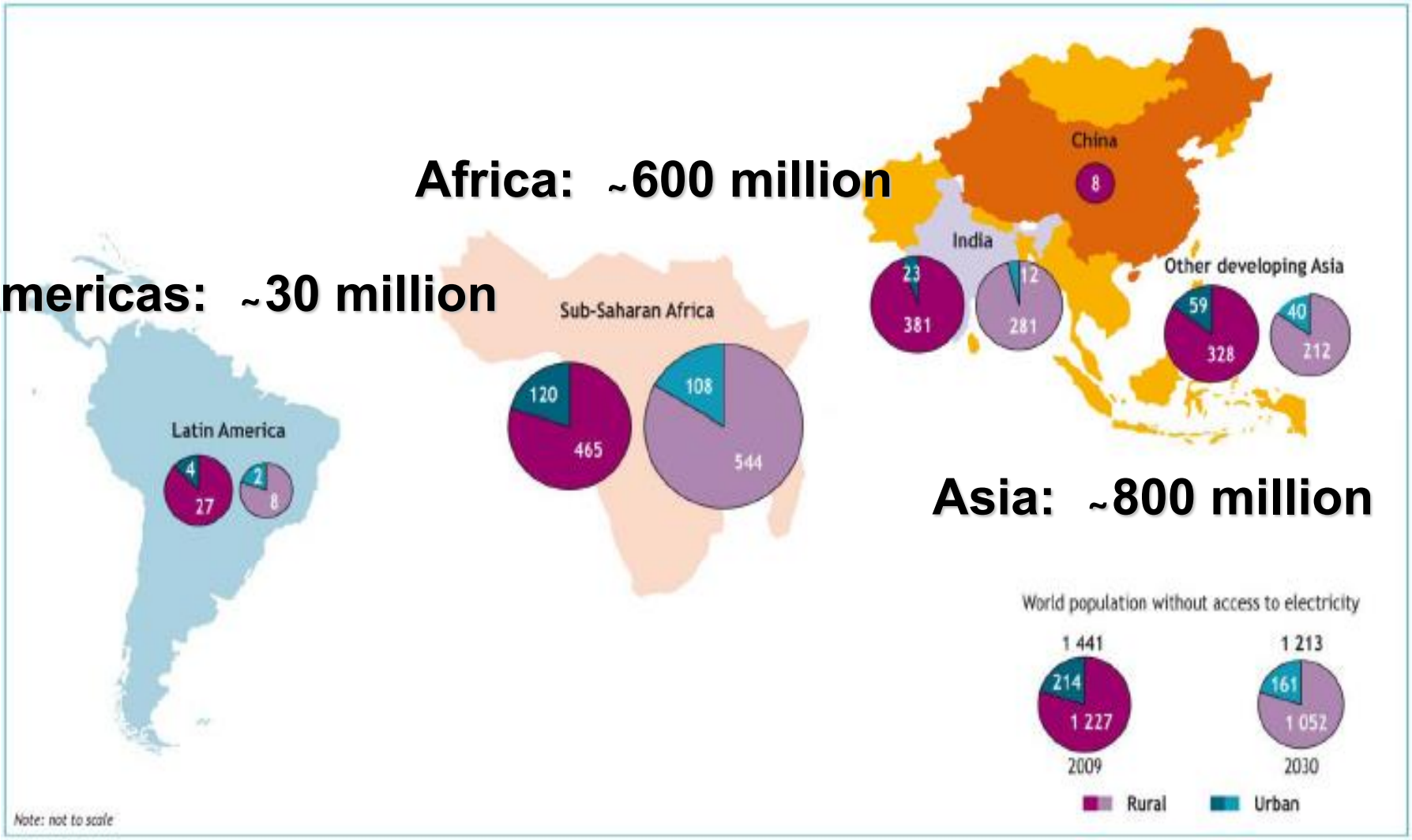
Reversal of Forest Degradation

Is a human rights and a development issue;

We must invest in sustainable land use by empowering the poor

Charcoal production from illegally harvested trees, Kenya

Unelectrified People (and fuel based lighting users) in Asia is Even Higher than in Africa



The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Source: IEA, 2010 World Energy Outlook

Off-grid Electricity Enabled by Storage and Efficient Lights, but …

Impossible without secure mobile money

Resources:

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Twitter: @dan_kammen