Data Science to Inform Sustainability

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Advancing scientific discovery through collaboration across research domains

Big wisdom, making sense and innovating from big data
Takeaway *information rich* messages:

1. The ‘2 degree pathway’ is still achievable

2. Scientific and technical transformations are critical to enabling a sustainable energy system, but it is social and policy innovation that provides the ‘killer app’ for innovation and change

This is true on-grid and off-grid in both industrialized and industrializing nations
A revolution in climate politics

U.S.-China Joint Announcement on Climate Change, 2014
How much warming by 2100?

Global Emissions of Greenhouse Gases

- INDC Commitments in the Paris Accords
- Innovations not yet envisioned
- Estimated temperature in 2100:
  - 4.5°C Business as usual
  - 3.5°C Current national commitments with no change after the pledge period, ending 2025-2030
  - 2°C Path

Billion tons CO2 equivalent per year

Source: 27-Sep-2015 Climate Scoreboard ©Climate Interactive www.ClimateScoreboard.org
What we need to do:
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.
A pathway to sustainability

Four Actions to Reduce Emissions

1. Efficiency
2. Electrification

Summary

1. “Low-Carb” Fuels + Electricity

http://rael.berkeley.edu
Summary

“Low-Carb” Fuels + Electricity

Electrification

GHG Intensity

2050 Target Emissions (80 MtCO₂e)

Fuels

Electricity

Efficiency

Demand

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

WECC (Western North America) 5/2012

Chile 4/2014

Nicaragua: 6/2014

Kosovo 3/2013

China, 4/2016

Malaysia, 1/2013

East African Power Pool (EAPP):
2. (Selection underway)

India, Planned: 10/2017

East Asian

Kosovo
Solar cost decreases 10% per year

Cumulative production GigaWp

- **1978**
  - Single crystal, evaporated contacts
  - Screen printed metal
  - Wire saws
  - Textured mono
  - Aluminum BSF
  - Cast multi
  - Point contact mono
  - Passivating SN
  - Iso-texture multi

7% Global Generation from PV

Retail Natural Gas Electricity

Grid Parity

Wholesale Coal Electricity

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.
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
Predictions after 2015

- historical prices Li+
- economies of scale Li+
- two-factor model Li+
- experience curve Li+
- wind price ($/MWh) 100% = 140 $/MWh
- solar price ($/W) 100% = 7.5 $/W
Dispatch in 2050: Flexibility and variable renewables dominate

- Storage almost exclusively moves solar to the night
- Geothermal only remaining substantial baseload
Pathways for Western North America
In China even aggressive wind, solar and storage learning alone is not enough to phase out coal. [http://rael.berkeley.edu/project/SWITCH](http://rael.berkeley.edu/project/SWITCH)


**Diagram:**
- **Business as Usual**
- **BAU with Carbon cap**
- **Current aggressive solar and wind continued**
- **IPCC 2050 (80% cut in carbon)**
SWITCH-China: A Systems Approach to Decarbonizing China’s Power System

Gang He, Anne-Perrine Avrin, James H. Nelson, Josiah Johnston, Ana Mileva, Jianwei Tian, and Daniel M. Kammen

Figure 4. Generation, transmission, and storage capacity needed to achieve an 80% carbon reduction in 2050. All represented lines are new transmission expansion. Inner Mongolia emerges as a major center of clean energy generation thanks to the combination of its location (a few hundred kilometers from major demand centers) and high-quality renewable energy resources.
Case Study: Photovoltaics to Satisfy Urban Transportation Needs
Urban Transport Electrification

87 Global Cities Considered

GoogleMaps: UITP Millenium Cities
Photovoltaic Coverage Needs

\[ u_{\text{transport}} = \frac{e_{\text{transport}}}{\rho_{\text{urban}}} \]

\[ u_{\text{solar}} = \eta_{PV} \frac{G}{\rho} \]

% PV Coverage Required

\[ = \frac{u_{\text{transport}}}{u_{\text{solar}}} \]

Private Passenger Vehicle Use Predicts Feasibility of PV-Powered Transportation

Oakland EcoBlock - ZNE and Zero Carbon Retrofit Pilot Project

Community Solar PV Micro Grid

Waste Water Capture/Reuse

California Energy Commission Grant

http://rael.berkeley.edu/project/the-eco-block-project
Example: the impact of Natural Gas Leakage on carbon budgets

Base: Carbon budget

Carbon emissions, Mt-CO2eq/yr

NG Leakage Rate as % of delivered fuel

Technology
- Methane leaks
- Gas CT + storage
- Gas CT
- Gas CCGT
- Coal

Johnstone and Kammen, 2017 in press
Off-grid Electricity Enabled by Storage and Efficient Lights, but ...

Impossible without secure mobile money
Information Technology Enables Transformative Energy Access Technologies

All SHS with data (n=1025) marked on a map with satellite-derived estimates of solar potential during operations period.

Mean Solar Ob: kWh/m²/day

Expected progression

Accumulated payments (Ksh)

Days after registration

TRUE

FALSE

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http://coolclimate.berkeley.edu/maps
Carbon Dioxide Emissions by ZCTA

Jones and Kammen, 2014
http://coolclimate.berkeley.edu/maps
Takeaway message:

Scientific and technical transformations are critical to enabling a sustainable energy system, but it is the energy-information nexus that provides the ‘killer app’ for change.
Resources:

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