Moving the Clean Energy Agenda Forward in Developing Countries

Daniel Kammen

Class of 1935 Distinguished Professor of Energy
Energy and Resources Group | Goldman School of Public Policy
Director, Renewable and Appropriate Energy Laboratory
University of California, Berkeley

GCEP 10th Annual Research Symposium, Moving the Clean Energy Agenda Forward
October 14, 2014
The Global Energy Access and Carbon Challenge

- A transition to sustainable energy is needed now

- Low-cost fossil fuel versus high cost clean energy (is a false dichotomy) [quote: ‘don’t research on the development dollar’]

- Developing countries are technology takers (wrong: in fact they are innovators that need added facilitation)

- On-grid and off-grid strategies must be coordinated, and largely today are not.

- Financing is available, but too often on the sidelines

- Carbon and resource accounting are critically valuable in both industrialized and developing nations
The Fulbright NEXUS Program links early or mid-career academics, applied researchers and public policy professionals across the Western Hemisphere. Program participants will engage in collaborative thinking, analysis, problem-solving and multi-disciplinary research in five areas:

- Social and Behavioral Adaptation to Climate Change
- Measuring Climate Change and its Impact
- Renewable Energy
- Climate Change and Biodiversity
- Climate Change and Food and Water Security

The 2014 Fulbright NEXUS Distinguished Lead Scholars will provide the overall leadership and facilitation of the Fulbright NEXUS Program.

Dr. Daniel M. Kammen
Professor of Energy
University of California, Berkeley

Daniel M. Kammen is Professor in the Energy and Resources Group (ERG), Professor of Public Policy in the Goldman School of Public Policy and Professor of Nuclear Engineering. He is the founding Director of the Renewable and Appropriate Energy Laboratory.

Dr. Sergio Pacca
Associate Professor
University of São Paulo

Sergio Pacca is Associate Professor at the School of Arts, Sciences and Humanities (EACH). He is the Director of the Research Group on Carbon Emissions Policy and Regulation, and member of the International Society for Industrial Ecology (ISIE).

Eligibility
- Participants should be early or mid-career academics, applied researchers and/or professionals with research experience in the public, non-profit or private sector.
- A Ph.D. or equivalent professional/terminal degree is preferred, but is not required. Candidates with a master’s degree are required to have a minimum of five years research experience.

Program Activities
- Between June 2014 and May 2016, twenty program participants from the United States, Canada, the Caribbean and Latin America will:
  - Engage in multidisciplinary group research;
  - Participate in three seminar meetings across the region;

For more information, visit www.cies.org/nexus
US State Department Initiative on international cooperation through energy exchange and collaboration
IPCC AR5 (2014): Climate Projections and Associated Risks

All of these risks are more severe in developing nations.
IPCC Science, state and national targets

![Graph showing U.S. GHG emissions (GT C eq.) from 1990 to 2050.]

- Historic U.S. emissions
- Business as usual (EIA)
- Intensity Target: President Bush (2004) and China (current)
- Kyoto protocol
- EU Copenhagen plan
- IPCC Assessment: Climate Stabilization Zone

Kammen, “September 27, 2006 – A day to remember”, San Francisco Chronicle, September 27,
World Bank Transition: The Meaning of 4°C Warming


• Internal and partner carbon accounting as a business requirement

• Household energy unit

• Innovation and outreach ‘do-tanks’

• Moratorium on lending for coal
California Global Warming Solutions Act: ~25% cut in emissions by 2020 to 1990 baseline, **and then reduce by 80%**

% Change from 1990 levels

- CEC Data
- Business as Usual
- AB 32 Scenario

![Graph showing % change from 1990 levels over years 1990 to 2020.](image-url)
FAR - 1st IPCC Assessment (1990): unequivocal detection of human impact not likely for a decade


TAR - 3rd (2001): most of the warming in the last 50 years is likely (>66%) due to human activities

AR4 - 4th (2007): most of the warming very likely (>90%) due to human activity; warming will most strongly and quickly impact the global poor

SRREN (2011): 80% clean by 2050 possible, if ...

AR5 (2013) - warming is human caused (95% confidence)
The California Strategy to reduce emissions

GHG Intensity-Demand Diagram

2050 BAU Emissions (830 MtCO₂e)

http://rael.berkeley.edu
to 2020 and 2050

“Low-Carb” Fuels + Electricity

Electrification

GHG Intensity

2050 Target Emissions (80 MtCO$_2$e)

Fuels

Electricity

Efficiency

Demand

http://rael.berkeley.edu
California’s ‘Dense network’ of technical, market and policy innovations

- **2010**: 20% RPS, 20% energy with 20% biomass
- **2020**: 3000 MW Distr. PV, 500 MW rooftop PV, 20% RPS
- **2030**: 33% RPS, 20% biomass target, 80–85% GHG reduction
- **2040**: 100% zero-net energy commercial construction & New RPS (in progress)
- **2050**: 100% zero-net energy residential construction, 100,000 miles of pipeline; 20 million smart meters; $10B CapEx/year

- **SB1368 & AB1270**: Power emission and low-carbon fuel standards
- **SB17**: Smart Grid plans
- **Mandates**: 1 million solar roofs, 1 million EVs
- **Forecast demand**: -10%
- **500 MW rooftop PV**
- **3000 MW Distr. PV**
- **+4000 MW Combined Heat & Power**
- **100% zero-net energy residential construction**
- **Carbon cap and trade market (includes vehicles in 2015)**
- **Once-through cooling (proposed)**
- **100% zero-net energy commercial construction & New RPS (in progress)**
- **100,000 miles of pipeline; 20 million smart meters; $10B CapEx/year**
Kenya’s ‘Dense network’ of technical, market and policy innovations

- **National feed-in tariff**
- **Lake Turkana windfarm**: largest in Africa
- **Largest off-grid lighting program per capita in the world**
- **Off-grid program evolving to rival on-grid clean energy plan**
- **Prime Minister: deep decarbonization target**
- **Prime Minister**: deep decarbonization target
- **Safaricom -> MPESA**: most active mobile money program in the world
- **5000 MW in 40 month plan**: Discussion with Ethiopia over harmonized FIT
- **Geothermal to replace hydropower as majority baseload**
- **MPESA electronic banking forecast to be dominated by off-grid energy**
- **$50 million for Scale Up Renewable Energy (SREP) program**: 2012 - 2020

As in California, oil and gas (shale) discoveries complicate the landscape
Energy Access, Economic Opportunity and Quality of Life

Alstone, Gerhenson, and Kammen, Nature Climate Change, in press
Fuel Based Lighting
Expensive, Unhealthy, and Inefficient

Kerosene for Lighting is a $10+ billion per year industry in Africa
Modern Off-Grid Lighting

1) Market opportunity is large & IT systems are radically changing education, monitoring and support options

2) Potential customers are very price sensitive…

3) … but, once they are familiar with good quality off-grid lighting products, many do recognize their value

4) Danger of market spoiling is real (already happening)

5) Effective quality assurance mechanisms are needed (and we are working on them – initial framework is in place)
Flames v. LED
(opens a business and development opportunity)

Flame

Light Emitting Diode

One lux is equal to one lumen per m²:
1 lux = 1 lm/m² = 1 cd·sr·m⁻².

Flame: 0.1 lumens/watt • 1-10 lux

LED: 50 lumens/watt • 100-500 lux

Street vendor (Dar es Salaam)
Unelectrified People (and fuel based lighting users) in Asia is Even Higher than in Africa

Africa: ~600 million

Americas: ~30 million

Asia: ~800 million

Source: IEA, 2010 World Energy Outlook
Historical View of the Energy Transition

1882: First Electric Utility
Pearl St., New York

1947: First Transistor
Bell Labs

2010: Low cost solar
photovoltaics (~$2/W)

2010 - 2030 Development
of pico-power market

[A] Tech. Timeline

1850 1900 1950 2000

[B] Electricity
Access

People (billions)

Tot. Population

On-grid Population

2030 Forecasts

UN Population

IEA Grid Expansion

[C] Electricity
Deprivation

People (billions)

Unelectrified Population

IEA Grid Expansion
(New Policies
scenario covers
population growth
and additional persons)

Mini-grids

Household Systems

[D] ICT
Access

(100 people)⁻¹

Telegraphs
(messages/year)

Fixed-line Telephone
(accounts)

Mobile Phone
(accounts)

1850 1900 1950 2000

[E] Light
Source
Performance

Efficacy (lm/W)

Incandescent

Fluorescent

LED

Year
1. Energy access for all by 2030
2. Double the rate of energy efficiency deployment
3. Double the global share of renewable energy

UN Assembly, September 24, 2012
Addressing Market Failure through Quality Assurance

Quality Assurance Principles

• Seek an appropriate balance between product quality and affordability
• Effectively communicate product performance info so buyers can make informed purchasing decisions
• Use rigorous tests that can be carried out using low cost instruments
• Maintain stable and transparent QA policies so companies know what to expect

Buyer oriented quality assurance framework
Solar PV + LED + battery
(+color TV, refrigeration....)

These devices have become vibrant platforms for innovation
Historical and projected LED package efficacy and price.

PRICE-EFFICACY TRADEOFF FOR LED PACKAGES AT 35 A/CM² AND 25 °C

Total effect of higher lumen efficacy & lower prices since 2010 is 300+% gain
The Energy-Poverty-Climate Nexus

Christian E. Casillas and Daniel M. Kammen

Close to two-thirds of the world’s poorest people live in rural areas (1). Eradication of rural poverty depends on increased access to goods, services, and information, targets detailed in the United Nations Millennium Development Goals. However, alleviating poverty is hindered by two interlinked phenomena: lack of access to improved energy services and worsening environmental shocks due to climate change. Mitigating climate change, increasing energy access, and alleviating rural poverty can all be complementary, their overlap defining an energy-poverty-climate nexus. We describe interventions in a rural Nicaraguan community to show that energy services can be provided in cost-effective manners, offering the potential to address aspects of rural poverty while also transitioning away from fossil fuel dependence.

The Energy-Poverty-Climate Nexus

Increased access to energy services alone will not eradicate poverty, but it can have immediate effects (2, 5). More than 1.5 billion people live without access to electricity, another billion only have access to unreliable electricity, and close to half the global population depends on traditional biomass fuels for cooking and heating (4). Energy poverty results from unmet basic needs and depressed economic and educational opportunities that are particularly pervasive among women, children, and minorities (3, 6). Electricity catalyzes rural economic activity (7–10) and increases the quality of services available to meet basic business and domestic needs through improved lighting, labor-saving devices, and access to information through TV, radio, and cellular telephones (11). Provision of high-quality public lighting can increase security and improve delivery of health and education services (7, 11).

Environmental shocks related to climate change will first and most severely affect vulnerable, poor populations, many living in rural areas (1, 12). Improving delivery of affordable, reliable energy services to rural communities is critical for helping them develop human and economic capacity to adapt in the face of a changing climate.

Greenhouse gas emissions in industrialized countries are dominated by electricity generation and transportation, whereas the majority of emissions from the world’s poorest countries come from agriculture and changes in land use (1). However, with 1.5 billion people without access to electricity, combustion-related emissions from the rural power sector are expected to grow. Because of low capital costs and a large network of suppliers, diesel generators are often the technology of choice in rural areas, without sufficient consideration of the volatility of fuel prices, resulting in expensive generation costs (9, 13).

Given the relationships outlined above, every dollar spent on the transition to more efficient low-carbon energy systems in rural areas has the potential to produce greater human development, savings, and carbon mitigation returns than in more industrialized areas (if economies of scale do not dominate). However, debates about climate change and vulnerability have been slow to highlight the energy-poverty-climate nexus. This has been due, in part, to the lack of meaningful metrics needed to stimulate social, economic, and technical innovation in this sector.

Marginal Abatement Cost Curves

A marginal abatement cost (MAC) curve typically shows the annual carbon abatement potential for an intervention, and the cost per unit of carbon emissions abated relative to the emissions costs for a baseline case (14, 15). A community-level MAC curve derived from ongoing research on the Atlantic coast of Nicaragua demonstrates that low-cost rural energy services can be delivered at a cost savings in cases where communities use diesel-powered generation, isolated from the national grid (microgrids).

The rural communities of Orinoeco and Marshall Point share a diesel microgrid serving 172 households. In partnership with the Nicaraguan government and a local nongovernmental organization (NGO), these communities are transitioning away from diesel generation and toward distributed generation, solar energy, and microgrids. This transition may be characterized as a “green” rural electrification, as it reduces both energy costs and carbon emissions generated by traditional fuels. The average cost of the transition, based on a community-level MAC curve, was $200/Mt CO2.

Sustainable Development Opportunities at the Climate, Land, Energy, and Water Nexus in Nicaragua

Sharon Goudji, Matthias Craig, Rebekah Shirley, Diego Ponce de León Barido, et al.

February 2014 / Paper No. 33
Lessons disseminated to new micro-grid developers

Microgrids for Rural Electrification:
A critical review of best practices based on seven case studies

http://energyaccess.org/images/content/files/MicrogridsReportFINAL_high.pdf
Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2006 to 2008 are forecast data)

United States

California

Denmark

Per Capita Income in Constant 2000 $

<table>
<thead>
<tr>
<th></th>
<th>1975</th>
<th>2005</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>US GDP/capita</td>
<td>16,241</td>
<td>31,442</td>
<td>94%</td>
</tr>
<tr>
<td>Cal GSP/capita</td>
<td>18,760</td>
<td>33,536</td>
<td>79%</td>
</tr>
</tbody>
</table>
Almost 80% of the California RPS is Projected to Be Met by Solar & Wind by 2020

Source: CPUC RPS Report
http://rael.berkeley.edu
California Pathways: Responding to New Challenges
Ivanpah Solar Thermal Project – 370 MW - San Bernardino County, CA
World’s Largest Thin Film Solar PV Project...
World’s Largest Wind Project

Alta Wind Energy Center – 1550 MW - Kern County
ALL-ELECTRIC Vehicles (EVs) Entering the Marketplace

- **Ford Focus**
  - 100 mi
  - Model S $56k+
  - 160-300mi

- **Nissan Leaf**
  - 100 mi
  - $32k

- **BMW Mini E**
  - Roadster $109k

- **Coda**
  - $20k

- **Smart**
  - $24k
The Evolving Solar Energy Economy
Kenya’s baseload energy development strategy is now dominate by the least cost option: geothermal power at large and small-scales
Africa’s Largest Windfarm Under Construction

Left: Ngong Hills Windfarm (Nairobi)

Right: Lake Turkana and site (background) of the Lake Turkana Windfarm
Carbon Intensity of Fuels

Today's Biofuels

Future Low-Carbon Fuels

**Baseline**

**2020 Target**

**Fuel Type**

- Gasoline - CaRFG + 10% Corn Ethanol
- Midwest Ethanol (Ave)
- Sugarcane Ethanol (Brazil)
- California Ethanol (Dry mill, Wet DGS)
- Cellulosic Ethanol (Farmed Poplar)
- Cellulosic Ethanol (Waste)
- Electricity (Ca Marginal)
- Hydrogen (SB1505)
Indirect Land Use Change: Methodologies

Choose increment in biofuels production
e.g., 40 to 60 billion L·yr⁻¹

a. Estimate global market impacts
   economic model estimates net crop area changes

b. Map economic results to physical hectares
   may be endogenous or based on historical data

c. Estimate emissions from land cover change
   some portion of above-ground and soil carbon is assumed lost

d. Associate emissions with quantity of biofuel
   may involve cycle modeling, amortization, discounting, etc.

The Electric Jeepney (eJeepney): Makati

Cleaner, fresher air in Makati
Ang Saya, ang Sarap sumakay sa Electric Jeepney!

Go to the nearest designated eJeepney stop
WEEKDAYS - 7AM TO 10AM
11AM TO 1PM - 4PM TO 6:30PM

THE EJEEPNEY MAKATI GREEN ROUTE

"GOING GREEN" STARTS WITH YOU
In 100 words or less, tell us how you, as an individual, can help make our cities and our environment Green & Eco-friendly and get a chance to win P10,000 Grand Prize & Other Prizes.
Entries should be sent at the following Binacen stores in Makati: Delta Rose Carpet 2, Sawa Build 7, Binacen Bldg. Salcedo, & Dona Ines

Name: 
E-Mail: 
Company name: 
Contact Number: 

Press release by: BMI
For OAM permit no. 999 series of 2019
SWITCH Model

• Blends capacity-expansion and unit-commitment models with customizable space-time resolution.

• Co-optimizes capacity investment and hourly system dispatch.
  – Outputs include investment and cost streams for transmission, storage, generation, CO₂ emissions, operational insights for storage and demand response.

• Open source algorithms available and documentation at http://rael.berkeley.edu/switch
The SWITCH-WECC Model

Optimization and data framework of the western North American SWITCH model.

http://rael.berkeley.edu/switch
Renewable Generation

Conventional Generation

Carbon Capture and Sequestration

Pumped Hydro

Sodium Sulfur Battery

Compressed Air

Transmission
Energy System Modeling Efforts in the Renewable and Appropriate Energy Laboratory, UC Berkeley

WECC (Western North America) 5/2012

Chile 4/2014

Kosovo 3/2013

Nicaragua 6/2014


India, 9/2014

China, 8/2014

Malaysia, 1/2013

http://rael.berkeley.edu/switch
SWITCH-WECC Example Dispatch in 2050: Flexibility and variable renewables dominate

- Storage almost exclusively moves solar to the night
- Geothermal only remaining substantial baseload
Electricity Mix, 2020

- Coal, hydropower, and gas generation dominate the system
Electricity Mix, 2030

- Electricity production heavily dominated by natural gas
• The 2020 power system is dominated by coal, hydro, and gas generation
• Wind is the main source of renewable electricity
• Existing storage used regularly, charging at night and providing energy during the day
• By 2030, the share of renewables, both wind and solar, grows
• Combined-cycle gas generation replaces most baseload coal
• Storage is used less, especially in the spring and during the summer peak
System Unit-Commitment, Reference Scenario, 2050

- Large differences in how load is met across seasons
Electricity Mix, 2050

- Electricity production mix is much more dynamic by 2050
Large differences in how load is met across seasons
Clean Energy Options for Sabah
an analysis of resource availability and unit cost

Tyler McNish¹,²
Prof. Daniel M. Kammen¹,³,⁴,⁵
Benjamin Gutierrez⁵

March 2010

¹University of California, Berkeley Renewable and Appropriate Energy Laboratory
²University of California, Berkeley School of Law
³University of California, Berkeley Energy and Resources Group
⁴University of California, Berkeley Goldman School of Public Policy
⁵Harvard College

* Address correspondence to Professor Kammen, Director of RAEL, http://rael.berkeley.edu
Biomass can replace coal – Professor

By Sandra Sokial

KOTA KINABALU: Palm oil mill waste, or commonly known as biomass, can feasibly be used to replace coal as a source of energy in Sabah.

Dr. Daniel M. Kammen, a professor of energy at the University of California, Berkeley, disclosed this in his talk during a forum on Energy Options for Sabah here yesterday.

He said biomass presented an attractive electricity supply option and should continue to receive support from the government and utilities.

Kammen, who carried out a study on clean energy options for Sabah, said that biomass waste projects were cost competitive compared with coal, adding that it also solved two environmental problems at once.

"One is the problem of disposing of potentially hazardous mill waste in open ponds and landfills and the problem of supplying Sabah's energy demand," he said.

Several oil palm mills in Sabah have already adopted the project and a number of national incentives are aimed to stimulate further investments.

Kammen said based on the 2006 palm oil industry production statistics and conservative growth estimates, they calculated that 700MW of theoretical baseload capacity was economically feasible and logistically achievable via a four-project per-year ramp-up programme. "We recommend that Sabah support this project," he said.

During the study, Kammen, Tyler McNish and Benjamin Gutierrez also carried out a research on other energy options such as hydropower, solar, wind, geothermal and demand-side energy efficiency.

He also recommended phasing out fossil-fuel subsidies that distort energy markets and the 10MW limit on investment under the small renewable energy power programme be repealed.

"There should be continued research and outreach efforts targeted at increasing the quantity of grid-connected electricity available from palm oil mills besides recognising renewable energy status as a premium product."

"It is also important to continue studying the feasibility of renewable investments at known geothermal, wind and environmentally-sound micro hydro sites," he said.

In addition to this, Kammen said the continuation and extension of Malaysia's existing solar promotion programmes should be continued, and supplement these efforts by launching a state-level solar energy commission.

Another speaker, Adrian Lasimbang of the Pacos Trust, believes that Sabah should be a role model and spearhead the development of renewable energy (RE) in Malaysia.

"With such numbers, there is abundance of biomass waste which could be used for power supply thus reducing the electricity shortage faced by the people in the east coast of Sabah."

"We have initiated several projects in several villages to utilise agro-based waste as alternative to power supply. It helps to generate jobs for the villagers and other support services, such as transportation," he said.

About 400 people attended the forum which was organised by Green Surf.
Integrating these systems tools with civil society-industry dialog

Borneo Says No to Dirty Energy
By Jennifer Pinkowski Tuesday, Feb. 22, 2011

Daniel Kammen of the University of California, Berkeley, who directed an energy and environmental-impact study commissioned by a coalition of green groups, which was used widely in the discussions of Sabah's energy options. "It is a turning point that should bring deserved praise and partnerships to Malaysia at the upcoming climate conference in Durban, South Africa,"
Spatial representation: Chile

- Load areas are the minimal unit of analysis.
- Each area endowed with demand and generation

- Transmission is simplified as “corridors”
- New projects are individually connected
SWITCH-Chile Results

Energy produced per fuel type in 2030

- No Tx Builds
- BAU
- Cap 0tpc - Nuclear
- SIC-SING
- RPS 20% - Nuclear
- Cap 2tpc - Nuclear
- $50/ton Tax - Nuclear
- $20/ton Tax - Nuclear
- $50/ton Tax - Nuclear
- RPS 30% - 2030
- $20/ton Tax - Nuclear
- $50/ton Tax - Nuclear
- RPS 50% - 2030
- Cap 2tpc
- Cap 1tpc
- Cap 0tpc

Produced Power [TWh/yr]

NRET
Water
Hydrocarbon
Total Energy
SWITCH-Chile Results for 2030

Percentage of CO₂ emissions with respect to 1990

- BAU
- SIC-SING
- No Tx Builds
- Cap 2tpc
- Cap 2tpc - Nuclear
- $20/ton Tax
- $50/ton Tax
- $0/ton Tax - Nuclear
- $20/ton Tax - Nuclear
- $50/ton Tax - Nuclear
- RPS 20%-2030
- RPS 30%-2030
- Cap 0tpc
- Cap 0tpc - Nuclear
- Cap 1tpc
- RPS 50%-2030
SWITCH-China (2050)

R: reference | Low-cost renewable (current cost trends) | Carbon cap
The infrastructure, generation capacity and transmission, needed to achieve 80% carbon reduction by 2050. All lines are new transmission expansion corridors by 2050. Inner Mongolia emerges as a major center of clean energy generation due to a mixture of energy resources and location.
Annual emissions subject to existing carbon markets

$\text{CO}_2\text{e}$ reflects inclusion of non-$\text{CO}_2$ greenhouse gases converted to an equivalent amount of $\text{CO}_2$ based on radiative forcing.

TAKE ACTION TO KEEP THE PLANET COOL

WELCOME TO COOLCALIFORNIA.org, our goal is to provide resources to all Californians in order to reduce their environmental impact and take action to stop climate change. Realizing local governments, businesses, schools and individuals have different needs, we have customized pages for each audience. Click the tabs above to find:

- Money saving actions and best practices
- Financial incentives for actions and projects
- Carbon footprint and greenhouse gas emissions calculation tools
- Case studies and Success stories
- Educational resources

So, come on, be “cool” and check out the resources on CoolCalifornia.org today!

Popular content
- Calculator
- Household Actions
- About Us
- Small Biz Actions
- Small Business Award Program

Recent Case Studies
- Diamond D General Engineering
- Heavy civil general engineering construction company...
- The Living Christmas Company
# Carbon Footprint Summary (tons CO₂e/year)

<table>
<thead>
<tr>
<th>Category</th>
<th>Footprint</th>
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<tbody>
<tr>
<td>Transportation</td>
<td>14</td>
</tr>
<tr>
<td>Housing</td>
<td>2</td>
</tr>
<tr>
<td>Food</td>
<td>6</td>
</tr>
<tr>
<td>Goods</td>
<td>7</td>
</tr>
<tr>
<td>Services</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
</tr>
</tbody>
</table>

### Climate Action Plan Summary

**My Current Footprint**: 41 tons 100%
- **Pledged reductions**: 5 tons 12%
- **Offsets**: 0 tons 0%

**My New Footprint**: 36 tons 88%
- **Financial savings per year**: $2223
- **10 year net savings**: $20321
- **Payback**: 0.9 years

1. **Click** view / hide 2. **Pledge** 3. **Save**  

<table>
<thead>
<tr>
<th>Assumptions</th>
<th>mt CO₂e/yr reduced</th>
<th>$/yr saved</th>
<th>10 year net savings</th>
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</thead>
<tbody>
<tr>
<td>Buy a More Efficient Vehicle</td>
<td>1.86</td>
<td>$500</td>
<td>$3000</td>
</tr>
<tr>
<td>Telecommute to Work</td>
<td>1.07</td>
<td>$528</td>
<td>$5280</td>
</tr>
<tr>
<td>Ride my Bike</td>
<td>0.58</td>
<td>$156</td>
<td>$1560</td>
</tr>
<tr>
<td>Take Public Transportation</td>
<td>0.47</td>
<td>$156</td>
<td>$1560</td>
</tr>
<tr>
<td>Practice Eco-Driving</td>
<td>0.93</td>
<td>$249</td>
<td>$2490</td>
</tr>
<tr>
<td>Maintain my Vehicles</td>
<td>0.71</td>
<td>$190</td>
<td>$1900</td>
</tr>
<tr>
<td>Reduce Air Travel</td>
<td>0.45</td>
<td>$100</td>
<td>$1000</td>
</tr>
<tr>
<td>Offset Remaining Transportation Footprint</td>
<td>13.07</td>
<td>-$261</td>
<td>-$2610</td>
</tr>
<tr>
<td>Switch to CFLs</td>
<td>0.18</td>
<td>$63</td>
<td>$721</td>
</tr>
<tr>
<td>Turn Down Thermostat in Winter</td>
<td>0.52</td>
<td>$95</td>
<td>$950</td>
</tr>
<tr>
<td>Turn up Thermostat in Summer</td>
<td>0.15</td>
<td>$54</td>
<td>$540</td>
</tr>
<tr>
<td>Choose an Energy Star Refrigerator</td>
<td>0.05</td>
<td>$17</td>
<td>$140</td>
</tr>
<tr>
<td>Dry your Clothes on the Line</td>
<td>0.22</td>
<td>$75</td>
<td>$750</td>
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<tr>
<td>Purchase Green Electricity</td>
<td>0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Effort Estimation Feedback</td>
<td>0.50</td>
<td>4.50</td>
<td>45.00</td>
</tr>
</tbody>
</table>

Christopher Jones*† and Daniel M. Kammen*,†‡§

†Energy and Resources Group, ‡Goldman School of Public Policy, and §Department of Nuclear Engineering, University of California, Berkeley, California 94720, United States

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

Housing

(Total household energy CO\textsubscript{2}e)
Household GHG emissions in four metro regions

New York

San Francisco

Bay Area

Chicago

Dallas
• Eight years old, ISI > 4.1
• Open Access
• No page fees for developing nations
• 90 days submission to print for successful articles
• Video abstracts / multiple languages
• Journal / web practitioner dialog

environmentalresearchweb.org
Addressing the Energy Access Gap

Investing $25B for five years could LightUp 250M households buying $200 “Pay-As-You-Go” systems.

$2+ Trillion US profits are “parked” overseas.

☑️ Apple $138B ☑️ Cisco $48B
☑️ GE $110B ☑️ Google $48B
☑️ Microsoft $93B ☑️ HP $38B
☑️ IBM $52B ☑️ Pepsi $34B
☑️ Johnson & Johnson $50B ☑️ Oracle $33B

For more see: BeyondCassandra.org (Felix Kramer) & (Daniel Kammen) rael.berkeley.edu