Science and Policy Innovations for a Low-Carbon Economy

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http://rael.berkeley.edu
UCLA IoE Oppenheim Lecture, Los Angeles, CA March 31, 2010
Switch: Transmission, Storage & End-Use
Low-Carbon energy analysis and planning

Energy & development
- science
- technology
- economics
- health
- policies

TSRC: Transportation options, planning and systems science: EV/PHEV, biofuels, LCA

Renewable and Appropriate Energy Laboratory
UC Berkeley

transportation
sustainability
research center
The battle of tipping points

- The climate crisis - constant reminders

- Developing innovative technical and social ‘tipping points’ is vital

- Carbon pricing is needed in as many settings as possible - ahead of adoption via the COP process

- Energy ‘Systems Thinking’ is critically needed
Annual worldwide CO$_2$ emissions have grown faster than any of the IPCC 2001 scenarios.

Observed 2000-2006 3.3%
California Global Warming Solutions Act: ~25% cut in emissions by 2020
The Cascade of Commitment: IPCC Science, CA and US targets

- Historic U. S. emissions
- Business as usual (EIA)
- Administration intensity target
- Kyoto protocol
- EU Copenhagen plan (2020 = 1990 less 25 - 40%

IPCC Assessment: Climate Stabilization Zone

Kammen, “September 27, 2006 – A day to remember”, San Francisco Chronicle, September 27,
Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?

by

Daniel M. Kammen
Kamal Kapadia
Matthias Fripp

of the
Energy and Resources Group &
the Goldman School of Public Policy

APRIL 13, 2004
Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2006 to 2008 are forecast data)
Residential New Construction

• All new residential construction in California will be zero net energy by 2020.
Technological Innovation: solar
Actual PV Growth vs. Historic Forecasts

European Commission Directorate-Generale for Energy "Photovoltaics in 2010"

Made in 1994
Projected 26.6 MWp
too low (21%) for 1997

Actual market development

Annual shipments in MWp

Year

Grid-Connect, small scale
Military/ signalling
Solar Home Systems
Grid-Connect, medium-large scale
Remote houses
Water Pumping
Communic.
Camping Boating Leisure
Village Power
Cathodic protection
Consumer Indoor
Other remote
Information Technology Integrated with Solar Technology: Performance Monitoring
Micro-inverters versus traditional designs: A household and building electronics strategy

Energy Advantage: 10.24%
- SMA SB6000US (95.5%) - Blue
- Enphase – Red
- Location: Petaluma, CA
- Date: November 2007

Energy Advantage: 33.63%
- Xantrex GT3 (94.5%) - Blue
- Enphase – Red
- Location: Grass Valley, CA
- Date: December 2007
Market Innovation: Financial tools
Clean Energy Municipal Financing
(PACE: Property Assessed Clean Energy)
see Fuller, Portis and Kammen (2009) Environment, 51 (1), 22 - 32,
and http://rael.berkeley.edu/financing

- Creates financing district & approval process
- Provides upfront capital
- Attaches repayment obligation to the building

- Identifies work & chooses contractor
- Repays financing as a line item on the property tax bill
- Repayment obligation transfers with ownership
- Builds clean energy equity
Property Assessed Clean Energy (PACE): State Actions

PACE financing has now been adopted by the White House for support and appears in the US House Climate Bill (Waxman-Markey)

<table>
<thead>
<tr>
<th>State</th>
<th>Bill Numbers</th>
<th>Status</th>
</tr>
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<tbody>
<tr>
<td>Arizona</td>
<td>HB 2335</td>
<td>Passed House-In Senate (6/16/09)</td>
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<tr>
<td>Colorado</td>
<td>HB 08-1350</td>
<td>Signed into law (5/08)</td>
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<tr>
<td>Florida</td>
<td>pre-existing authority</td>
<td>Pre-existing Authority</td>
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<tr>
<td>Hawaii</td>
<td>existing authority</td>
<td>Existing county legal authority</td>
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<tr>
<td>Illinois</td>
<td>SB 582</td>
<td>Passed both houses 5/19/09</td>
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<tr>
<td>Louisiana</td>
<td>SB 224</td>
<td>Pending House Final Passage (6/15/09)</td>
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<tr>
<td>Maryland</td>
<td>HB 1562</td>
<td>Signed into law (4/09)</td>
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<td>Nevada</td>
<td>SB 358</td>
<td>Approved by Governor (5/28/09)</td>
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<td>New Mexico</td>
<td>HB 572 SB 647</td>
<td>Signed into law (4/9/09)</td>
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<td>New York</td>
<td>A 7611; A 2672</td>
<td>A 7611 referred to ways and means as of 6/16/09 A 2672 no action since intro on 1/29/09</td>
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<tr>
<td>Oregon</td>
<td>HB 2181</td>
<td>In committee – Subcommittee on Natural Resources (5/18/09)</td>
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<td>Texas</td>
<td>HB 1391</td>
<td>Pending Governor’s signature (5/11/09)</td>
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<td>Utah</td>
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<td>May have pre-existing authority</td>
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<td>Virginia</td>
<td>SB 1212</td>
<td>Signed into law (3/30/09)</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>AB 255</td>
<td>Enacted 5/15/09</td>
</tr>
</tbody>
</table>
Technological & market Innovation: biofuels
Carbon Intensity of Fuels

**Today’s Biofuels**
- Gasoline - CaRFG + 10% Corn Ethanol (Ave)
- Ethanol (Midwest Corn, Ave)
- Sugarcane Ethanol (Brazil)
- California Ethanol (Dry Mill, Wet DGS)
- Cellulosic Ethanol (Farmed Poplar)
- Cellulosic Ethanol (Waste)
- Electricity (California Marginal)
- Hydrogen (SB1505)

**Future Low-Carbon Fuels**
- 2020 Target

**Baseline**

**Fuel Type**
- Indirect
- Direct
Energy Biosciences Institute
University of California, Berkeley
Lawrence Berkeley National Laboratory
University of Illinois at Urbana-Champaign

Ethanol Can Contribute to Energy and Environmental Goals

Alexander E. Farrell, Richard J. Plevin, Brian T. Turner, Andrew D. Jones, Michael O’Hare, Daniel M. Kammen

To study the potential effects of increased biofuel use, we evaluated six representative analyses of fuel ethanol. Studies that reported negative net energy incorrectly ignored coproducts and used some obsolete data. All studies indicated that current corn ethanol technologies are much less petroleum-intensive than gasoline but have greenhouse gas emissions similar to those of gasoline. However, many important environmental effects of biofuel production are poorly understood. New metrics that measure specific resource inputs are developed, but further research into environmental metrics is needed. Nonetheless, it is already clear that large-scale use of ethanol for fuel will almost certainly require cellulosic technology.

27 JANUARY 2006   VOL 311   SCIENCE   www.sciencemag.org

CLIMATE CHANGE

Fixing a Critical Climate Accounting Error


Rules for applying the Kyoto Protocol and national cap-and-trade laws contain a major, but fixable, carbon accounting flaw in assessing bioenergy.

www.sciencemag.org   SCIENCE   VOL 326   23 OCTOBER 2009

A $500 million biofuel development grant from BP
LCA GHG emissions from tar sands: 10 to 30% greater emissions relative to conventional gasoline and diesel

- A number of studies have been conducted based on both current operations or future operations with most studies estimating between 10 to 30% increased emissions on a well-to-wheel basis (specific value dependent on the bitumen extraction, upgrading, and refining process (e.g. mining versus in-situ)).
- Loss of soil and biogenic carbon can be significant and have not been generally included

![Graph showing increase in lifecycle GHG emissions vs U.S. 2005 average gasoline]
Clean vehicles, low carbon fuels, and Smart Growth are all needed

- California’s 2020 goal requires about 25% reduction from Business-as-Usual.
- California’s 2050 goal is 80% reduction from 1990 levels.

![Graph showing GHG emissions projections for various categories.](image-url)
Plug-in Hybrids: Can they move rapidly to scale?
Research & Action Flow on Low-Carbon Transportation

**Report Timeline**


**Action Timeline**

March 2010: IPCC and Roundtable on Sustainable Biofuels develop protocols for carbon accounting

October 2009: US-China Electric Vehicle Summit

June 2008: CA adopts PHEV/EV metrics in Low-Carbon Fuel Standard (& WA, OR)

January 2007 (CA Ex Order S-7-01) Adopts Low-Carbon Fuel Standard
How does it work?
As simple as your navigator

VEV logs your real world driving behavior, and translates it into virtual performance for a variety of electrified vehicles.

1. Turn on Smart Phone app or telemetry device.
2. Sign up on VEV Co. website
3. Drive. Your device sends VEV Co. your location and speed.
4. VEV Co. “translates” your data into performance for a variety of EVs.
5. Visit your page to explore your virtual plug-in day (more on next slide).

Virtual EV uses well-established modeling practices to model the performance of a variety of electrified vehicles.

VEV will validate and calibrate its models using relationships with OEMs, advanced vehicle simulator software, as well as testing real electrified vehicles.

Figure: Model output (battery state of charge) for a pilot drivers in a virtual EREV 40 based on the Chevy Volt.
The education happens at our web interface: consumers to explore their Virtual EV day

User can visualize different EV options.

Line colors designate which fuel powered the car at each moment in time.

Actual miles driven and MPG for each day. Most Americans do not know these two facts about their driving.

VEV Co. picks the car with the lowest fuel costs for each day.

Graph compares fuel costs for all options. Users can see data at multiple levels.

Summary box makes a recommendation for the best EV match based on the entire test drive period, and offers links to more information and dealer websites.

Screen shot of VEV Co. website

Beyond EV education, our site tells users their basic driving stats (like daily fuel cost) and generate revenue through links to auto dealers.

Renewable and Appropriate Energy Laboratory - rael.berkeley.edu
Aggregated VEV Co. data helps answer important questions about recharging needs, grid preparation

By aggregating data, VEV offers a unique input to help answer questions like “where should the city invest in public charging stations” or “where can utilities expect to see lots of recharging, and at what times of day?”

Utilities, cities, and charge station providers will value this data.
The Electric Jeepney (eJeepney) in Makati
Charcoal Fuel and Improved Stove Value Chain in Tanzania (joint with the Blum Center on Poverty and Development)

Charcoal production for Dar-es-Salaam (Malimbwi and Zahabu, 2007)
Establishing Effective Cookstove Dissemination Strategies in Tanzania

A partnership with the:

Tanzanian Commission on Science and Technology

KUUTE Brochure

KUUTE Customers in Morogoro

Renewable and Appropriate Energy Laboratory - rael.berkeley.edu
Design and knowledge of improved stoves requires a flow of awareness and the re-design of market innovations.

Flow of awareness about the pipe stove benefits

Tanzanian Commission + Berkeley ↔ Artisans ↔ Vendors ↔ Consumers

Jiko la paipu liko wapi? Where is the “pipe stove”?
Information innovation: Policy and environmental accounting
Switch Summary
James Nelson, Josiah Johnston, Autum Petros-Good, Christian Blanco, Daniel Kammen, PI (UC Berkeley)
Generator Model
Objective: Minimize Total System Cost, Subject to GHG Constraints

Fixed Costs of all New Plants
\[ \sum_{p} \text{InstallGen. } MW_{p} \cdot \text{fixed.cost}_{p} \]

Variable Costs of New Dispatchable Plants
\[ + \sum_{p} \text{DispatchGen. } MW_{p} \cdot (\text{variable.cost}_{p} + \text{carbon.cost}_{p}) \]

Variable Costs of New Baseload Plants
\[ + \sum_{p} \text{InstallGen. } MW_{p} \cdot (\text{variable.cost}_{p} + \text{carbon.cost}_{p}) \cdot (1 - \text{forced.outage.rate}_{p}) \cdot (1 - \text{scheduled.outage.rate}_{p}) \]

Fixed Costs of Existing Plants (contingent on not mothballing)
\[ + \sum_{p} \text{operateInPeriod}_{p, \text{period}} \cdot \text{fixed.cost}_{p} \]

Variable Costs of Existing Baseload Plants (contingent on not mothballing)
\[ + \sum_{p} \text{operateInPeriod}_{p, \text{period}} \cdot \text{size.mw}_{p} \cdot (\text{variable.cost}_{p} + \text{carbon.cost}_{p}) \cdot (1 - \text{forced.outage.rate}_{p}) \cdot (1 - \text{scheduled.outage.rate}_{p}) \]

Variable Costs of Existing Dispatchable Plants
\[ + \sum_{p} \text{DispatchGen. } MW_{p} \cdot (\text{variable.cost}_{p} + \text{carbon.cost}_{p}) \]

Variable Costs of Existing Intermittent Plants
\[ + \sum_{p} \text{operateInPeriod}_{p, \text{period}} \cdot \text{variable.cost}_{p} \cdot \text{size.mw}_{p} \cdot \text{asp.factor}_{p} \cdot (1 - \text{forced.outage.rate}_{p}) \]

Cost of New Transmission
\[ + \sum_{s, t, d} \text{InstallTransmission. } MW_{s, t, d} \cdot \text{transmission.cost.per.mw}_{s, t, d} \]

Cost of New Distribution
\[ + \sum_{s, t} \text{InstallLocalDistribution. } MW_{s, t} \cdot \text{local.dist.cost.per.mw}_{s} \]

Sunk Costs (to obtain the correct price of power)
\[ + \sum_{p} \text{sunk.system.costs} \]
Electricity Supply in Western North American Forecast versus carbon price in 2024
Predicted transmission $50t/CO_2$ in 2024
Greenhouse gas and sustainability calculators:

http://coolclimate.berkeley.edu
&
http://www.coolcalifornia.org
1. Start with your home economic information

- Select U.S. State
- Select
- Nearest major U.S. city or region
- Select
- How many people live in your household?
- Select
- What is your gross annual household income?
- Select

- Click "Transportation" or other links at top to continue
- Then, either keep the "default" values or enter your own

How do you compare to the averages?

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