Energy Efficiency
Lessons and Plans from California

Delhi & Mumbai
March 2009

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or just Google “Art Rosenfeld”
Does Anyone See A Problem With This Picture?
Two Energy Agencies in California

• The California Public Utilities Commission (CPUC) was formed in 1890 to regulate natural monopolies, like railroads, and later electric and gas utilities.
• The California Energy Commission (CEC) was formed in 1974 to regulate the environmental side of energy production and use.
• Now the two agencies work very closely, particularly to delay climate change.
• The Investor-Owned Utilities, under the guidance of the CPUC, spend “Public Goods Charge” money (rate-payer money) to do everything they can that is cost effective to beat existing standards.
• The Publicly-Owned utilities (20% of the power), under loose supervision by the CEC, do the same.
California Energy Commission Responsibilities

Both Regulation and R&D

- California Building and Appliance Standards
  - Started 1977
  - Updated every few years
- Siting Thermal Power Plants Larger than 50 MW
- Forecasting Supply and Demand (electricity and fuels)
- Research and Development
  - ~ $80 million per year
- CPUC & CEC are collaborating to introduce communicating electric meters and thermostats that are programmable to respond to time-dependent electric tariffs.
California’s Energy Action Plan

- California’s Energy Agencies first adopted an Energy Action Plan in 2003. Central to this is the State’s preferred “Loading Order” for resource expansion.

- 1. Energy efficiency and Demand Response
- 2. Renewable Generation,
- 3. Increased development of affordable & reliable conventional generation
- 4. Transmission expansion to support all of California’s energy goals.

- The Energy Action Plan has been updated since 2003 and provides overall policy direction to the various state agencies involved with the energy sectors
Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2006 to 2008 are forecast data)

United States

California

2005 Differences
= 5,300kWh/yr
= $165/capita

Per Capita Income in Constant 2000 $

1975 2005 % change

US GDP/capita 16,241 31,442 94%
Cal GSP/capita 18,760 33,536 79%
Annual Energy Savings from Efficiency Programs and Standards

- Utility Efficiency Programs at a cost of ~1% of electric bill
- Building Standards
- Appliance Standards

~15% of Annual Electricity Use in California in 2003
Per Capita Electricity Sales (not including self-generation)
(kWh/person)

- California w/out stds and programs
- United States
- California


KWh/person:
- 0
- 2,000
- 4,000
- 6,000
- 8,000
- 10,000
- 12,000
- 14,000
Impact of Standards on Efficiency of 3 Appliances

New United States Refrigerator Use v. Time
and Retail Prices

~ 100 gallons Gasoline/year
~ 1 Ton CO2/year

Refrigerator Size (cubic ft)

Energy Use per Refrigerator (kWh/Year)

Refrigerator Price in 1983 $

Source: David Goldstein
Annual Energy Saved vs. Several Sources of Supply

In the United States

- Nuclear energy
- Conventional hydro
- PV systems
- Renewables
- 100 Million 1 KW
- Energy Saved Refrigerator Stds
- = 80 power plants of 500 MW each
In the United States

Value of Energy to be Saved (at 8.5 cents/kWh, retail price) vs.
Several Sources of Supply in 2005 (at 3 cents/kWh, wholesale price)

- Refrigerator Stds
- 100 Million 1 KW PV systems
- Conventional hydro
- Renewables
- Nuclear energy

$ (US)/year in 2005

- Energy Saved Refrigerator Stds
- 100 Million 1 KW PV systems
- Conventional hydro
- Renewables
- Nuclear energy
Air Conditioning Energy Use in Single Family Homes in PG&E
The effect of AC Standards (SEER) and Title 24 standards

If only increases in house size -- no efficiency gains
Change due to SEER improvements
SEER plus Title 24
Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

三峡电量与电冰箱、空调能效对比

Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL
Annual Energy Savings from Efficiency Programs and Standards

- Utility Efficiency Programs at a cost of ~1% of electric bill
- Building Standards
- Appliance Standards

~15% of Annual Electricity Use in California in 2003
California IOU’s Investment in Energy Efficiency

Profits decoupled from sales
2% of 2004 IOU Electric Revenues
Performance Incentives
Market Restructuring
Crisis
Forecast

Public Goods Charges

Millions of $2002 per Year
White Roofs
Temperature Rise of Various Materials in Sunlight
White is ‘cool’ in Bermuda
and in Santorini, Greece
and in Hyderabad, India
Cool Roof Technologies

**Old**

- flat, white

**New**

- pitched, cool & colored

pitched, white
Cool Colors Reflect Invisible Near-Infrared Sunlight

**Solar Energy Distribution**

- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
White Roofs

• In California and a growing number of US states, white roofs are required for new buildings, and re-roofing to reduce air conditioning load and “smog” ($O_3$).

• But a new concept is that white roofs also cool the world directly.
Effect of Solar Reflective Roofs and Pavements in Cooling the Globe

(Source: Akbari, Menon, Rosenfeld. Climatic Change, 2008)

<table>
<thead>
<tr>
<th></th>
<th>Δ Solar Reflectivity</th>
<th>CO₂ Offset by 100 m²</th>
<th>CO₂ Offset Globally</th>
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<tbody>
<tr>
<td>White Roof</td>
<td>0.40</td>
<td>10 tons</td>
<td></td>
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<tr>
<td>Average Roof</td>
<td>0.25</td>
<td>6.3 tons</td>
<td>24 Gt</td>
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<tr>
<td>Cool Pavement</td>
<td>0.15</td>
<td>4 tons</td>
<td>20 Gt</td>
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<tr>
<td>Total Potential</td>
<td></td>
<td></td>
<td>44 Gt</td>
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</table>

Value of 44 Gt CO₂ at $25/t ~ $1 Trillion

* White Roof will be “diluted” by cool colored roofs of lower reflectivity, and roofs that can not be changed, because they are long-lived tile, or perhaps they are already white.

** Compare 10 tons with a family car, which emits ~4 tons/year.
CO$_2$ Equivalency of Cool Roofs World-wide (Tropics+Temperate)

- Cool Roofs alone offset 24 Gt CO2
- Worth > €600 Billion
- To Convert 24 Gt CO2 one time into a rate
- Assume 20 Year Program, thus 1.2 Gt CO2/year
- Average World Car Emits 4 tCO2/year, equivalent to 300 Million Cars off the Road for 20 years.
100 m² of a white roof, replacing a dark roof, offset the emission of 10 tons of CO₂
To be published in Climatic Change 2008.

Global Cooling: Increasing World-wide Urban Albedos to Offset CO2

July 28, 2008

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A First Step In Geo-Engineering Which Saves Money and Has Known Positive Environmental Impacts
Conservation Supply Curves and Carbon Abatement Curves
PG&E Electric Supply Curve
Summary of Previous Slide

- 200 Projects costing at or below 12 cents /kWh average retail price
- Total Potential Savings of 18,000 GWh for these projects
- This represents about 20% of total electric sales for PG&E in 2008
<table>
<thead>
<tr>
<th>Technology</th>
<th>Sector</th>
<th>Levelized Supply Cost</th>
<th>Levelized Supply Cost with Programs</th>
<th>Technical GWH 2016</th>
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<td>Fans_ASD_(6-100_hp)</td>
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<td>0.022</td>
<td>0.027</td>
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</table>
Electricity Conservation Supply Curve 220 Measures
California in 2011 -- Levelized Cost and kWh saved

Electricity Conservation Supply Curve 220 Mesures
translated to Carbon Dioxide Reduction curve
California in 2011 -- (1 kwh reduction saves 1 pound of CO2)
Reducing U.S. Greenhouse Gas Emissions: 
How Much at What Cost?

US Greenhouse Gas Abatement Mapping Initiative
December 12, 2007
Abatement cost <$50/ton

U.S. mid-range abatement curve – 2030

Source: McKinsey analysis
Possible Strategies to Reduce Electricity Sector Carbon Emissions in California, ignoring ramp up times and other implementation issues -- The ELECTRICITY Perspective

Source: Pat McAuliffe, pmcaulif@energy.state.ca.us
Possible Strategies to Reduce Electricity Sector Carbon Emissions in California, ignoring ramp up times and other implementation issues -- The CARBON Perspective

Source: Pat McAuliffe, pmcaulif@energy.state.ca.us
Backup Slides on Cool Colored Roofs, Pavements and Cars
Solar Reflective Surfaces Also Cool the Globe

Source: IPCC
Methodology: Energy and Air-Quality Analysis

Strategies

- Cooler Roofs
- Shade Trees
- Cooler Pavements
- All Vegetation

Processes

- Reduces A/C Use
- Reduces Demand at Power Plants
- Slows Reaction Rates
- Area Sources Emit Less

Results

- Less Energy Consumed
- Lower CO₂, NOₓ, and VOC Levels
- Lower Ozone Levels

Direct

Indirect
Cool and Standard Brown Metal Roofing Panels

- Solar reflectance ~ 0.2 higher
- Afternoon surface temperature ~ 10°C lower
Designing Cool Colored Roofing

- **cool concrete tile**
  - R \( \geq 0.40 \)

- **standard concrete tile**
  - (same color)
  - R \( \geq 0.04 \)

- **solar reflectance gain** = +0.37 +0.26 +0.23 +0.15 +0.29 +0.29

- **cool clay tile**
  - R \( \geq 0.40 \)
  - Courtesy MCA Clay Tile

- **cool metal**
  - R \( \geq 0.30 \)
  - Courtesy BASF Industrial Coatings

- **cool fiberglass asphalt shingle**
  - R \( \geq 0.25 \)
  - Courtesy Elk Corporation
Cool is Cool: From Cool Color Roofs to Cool Color Cars and Cool Jackets

Toyota experiment (surface temperature 10K cooler)
Ford is also working on the technology

Courtesy: BMW (http://www.ips-innovations.com/solar_reflective_clothing.htm)
Cool Paving Materials:

<table>
<thead>
<tr>
<th>Concrete</th>
<th>(a) Unexposed</th>
<th>(b) Weathered</th>
<th>(c) Weathered, wetted</th>
<th>(d) Sealed</th>
<th>(e) Abraded</th>
<th>(f) Formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1:81:R2 gray cement/riverbed sand/granite rock</td>
<td>p=0.44</td>
<td>p=0.34</td>
<td>p=0.14</td>
<td>p=0.43</td>
<td>p=0.24</td>
<td>p=0.25</td>
</tr>
</tbody>
</table>
Reflective Pavements are Cooler

- **Fresh asphalt**
  - Albedo: 0.05
  - Temperature: 123°F

- **Aged asphalt**
  - Albedo: 0.15
  - Temperature: 115°F

- **Prototype asphalt coating**
  - Albedo: 0.51
  - Temperature: 88°F
Temperature Effect on Rutting

Source: Dr. John Harvey, UC B Civil Engineering, Inst. Transpo. Studies
Simulated Meteorology and Air-quality Impacts in LA

Temperature Change

Ozone Concentration Change

Legend:
- °C
- Parts per billion
Potential Savings in LA

- **Savings for Los Angeles**
  - Direct, $100M/year
  - Indirect, $70M/year
  - Smog, $360M/year

- **Estimate of national savings**: $5B/year