Urban Heat Island Effects on Energy Use, Climate, Air Pollution, and Greenhouse Gases

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Bay Area Air Quality Management District • San Francisco • 11 March 2015
1. The Urban Heat Island
Hot town—summer in the city

a summer urban heat island
What makes cities warm?

Sacramento, California (≈ 1 km²)

One reason:
many dark surfaces.

- Pavements: 39%
- Vegetation: 29%
- Roofs: 19%
- Other: 14%
Cool strategies include roofs, pavements, trees—and soon walls.
2. Identifying Urban Heat Islands
The U.S. Department of Agriculture's National Agriculture Imagery Program collects high-resolution images in blue, green, red, and near-infrared.

How reflective are California's roofs?
the images

their bands

the solar spectrum
lab-tested roofing products
remote measurements

roof albedo?

\[ S = 0.17b - 0.13g + 0.33r + 0.54i \]
verifying roof albedo with a pyranometer
Average roof albedo

- San Francisco: 0.18
- San Jose: 0.18
- Bakersfield: 0.20
- Los Angeles: 0.17
- Long Beach: 0.18
Let's go to the Oscars with AlbedoMap.LBL.gov
Mesoscale climate models predict air temperature reductions of up to 1 °C

Change in air temperature at 2 m AGL at 11:00 PDT on 27 July 2000

Corresponding change in ozone with year-2000 emissions

Study increased
roof albedo by 0.25 – 0.55
pavement albedo by 0.22 – 0.27


Upcoming LBNL-Altostratus-USC study will measure UHI in Los Angeles Basin

First guess of monitoring region (red oval). At bottom-right, the top 5 percent areas (census tracts) in CalEnviroScreen are highlighted. Top-right figure shows prevailing wind direction for June, July, and August in Los Angeles based on 30 years of data.

Conceptual framework for weather station siting. Shaded boxes represent possible heights of sensors for detection of (1) wide-area urban heat island effect (UHIE) (about 10 meters above ground level) and (2) local UHIE (about 2 meters above ground level). Diagram not to scale.

1: Vertical sensor location for detection of wide-area UHIE
2: Vertical sensor location for detection of local UHIE
3. Cool roof requirements and incentives
2013 Title 24 prescribes cool roofs for all nonres buildings, some res buildings

<table>
<thead>
<tr>
<th>Climate Zone (CZ)</th>
<th>Min aged SR</th>
<th>Min aged TE</th>
<th>Min aged SRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonres or high-rise res, low slope, all CZ</td>
<td>0.63</td>
<td>0.75</td>
<td>75</td>
</tr>
<tr>
<td>Nonres or high-rise res, high slope, all CZ</td>
<td>0.20</td>
<td>0.75</td>
<td>16</td>
</tr>
<tr>
<td>Res, low slope, CZs 13 &amp; 15</td>
<td>0.63</td>
<td>0.75</td>
<td>75</td>
</tr>
<tr>
<td>Res, high slope, CZ 10 - 15</td>
<td>0.20</td>
<td>0.75</td>
<td>16</td>
</tr>
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</table>

SR = solar reflectance (fraction of incident sunlight reflected, 0 - 1)
TE = thermal emittance (efficiency emitting thermal radiation, 0 - 1)
SRI = solar reflectance index (0 = reference black, 100 = reference white)
PG&E formerly offered rebates for exceeding T24 cool roof requirements

### Pacific Gas & Electric (PG&E) Multifamily Residential Energy Efficiency Rebate Program

<table>
<thead>
<tr>
<th>Roof Slope</th>
<th>Rebate level</th>
<th>Min aged SR</th>
<th>Min aged TE</th>
<th>Rebate ($/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (≤2:12), excluding CZ 13</td>
<td>N/A</td>
<td>0.55</td>
<td>0.75</td>
<td>0.20</td>
</tr>
<tr>
<td>High (&gt;2:12)</td>
<td>Level 1</td>
<td>0.35</td>
<td>0.75</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Level 2</td>
<td>0.25</td>
<td>0.75</td>
<td>0.10</td>
</tr>
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</table>

- Installation address must be in qualifying California climate zones (2, 4, 11, 12, or 13). Only steep-slope roofs qualify in climate zone 13. To find your climate zone, visit PG&E's climate zones page.
- Qualifying products: Cool Roof Rating Council rated products.
- Customer must purchase and install qualifying product before December 31, 2014.
4. Cool materials development
Fluorescent cool dark pigments reflect NIR light and re-emit absorbed visible light as NIR.
Ruby-pigmented coatings offer high Effective Solar Reflectance (ESR) in non-white colors.

- Fluorescence (at ~700 nm) contributes up to 0.16 to ESR.
- Reflectance is high up to 3% doping.
- **550 nm curve** shows visual brightness.
- Performance of commercial coatings will not be as high.
Cool colored synthetic limestone granules can capture CO$_2$, raise asphalt shingle albedo

conventional (gray granules + non-cool pigmented coating)

ρ = 0.14  ρ = 0.07  ρ = 0.05  ρ = 0.03

cool (CaCO$_3$ granules, integrally colored w/cool pigment)

ρ = 0.39  ρ = 0.35  ρ = 0.31  ρ = 0.31

Prototype shingles by Blue Planet + CertainTeed + LBNL
CaCO$_3$ granules by Blue Planet (blueplanet-ltd.com)
White sponge roofing provides high albedo, evaporative cooling, storm water mitigation

- Reflective porous TPO over cross-linked polymer water absorber
- Provides evaporative cooling & high albedo at cost comparable to conventional TPO
- Mitigates storm water issues originating from roof surfaces, absorbing up to 3 cm water

\[ T_{\text{surface}} - T_{\text{air}} \ (^\circ\text{C}) \]

- Black dry: -1.7
- Black wet: -5.4
- White dry: 25.2
- White wet: 3.1

Weather

\[ T_{\text{air}} = 33.2 \ ^\circ\text{C} \]

RH = 62%
wind = 9.4 m/s
Subsurface sponge expands by 2.5 cm when wet

CLOSE UP OF POROUS TPO TOP SURFACE

For more information:
Joe D. Byles
Turquoise Roofing Concepts
Corpus Christi, Texas
+1-830-305-2299
bylesj@msn.com
How can we speed the development of cool roofs?

- Soiled white roof: 
  - Albedo ≈ 0.8

- New white roof: 
  - Albedo ≈ 0.5

+15 °C [+27 °F]
exposure rack

3 years!

3 sites

HOT & DRY (Phoenix, Arizona)

TEMPERATE & POLLUTED (Cleveland, Ohio)

HOT & HUMID (Miami, Florida)
STEP 1: conditioning (24 hours)

STEP 2: soiling (10 minutes)

STEP 3: weathering (24 hours)

Done!
LBNL laboratory aging method quickly predicts 3-year-aged roof albedo, thermal emittance

- Match?

- Approved by U.S. Cool Roof Rating Council in Sept. 2014

- ASTM standard in progress

5. Some benefits of UHI countermeasures
A cool tile roof in Fresno, CA saved both cooling and heating energy in a single-family home.

Cool concrete tile roof, albedo 0.51

Dark asphalt shingle roof, albedo 0.07

**Roof footprint**: 188 m² (2020 ft²)

**Annual energy cost savings**: US$167

**Annual power-plant emission savings**: 307 kg CO₂, 117 g NOₓ, 8.69 g SO₂

California's schools are growing cooler with reflective roofs and schoolyards

Cool Schoolyards pilot in Los Angeles Unified School District

Before

AFTER

Los Angeles Unified School District will soon build two more pilot cool schoolyards

Cool roof retrofits in Sacramento City Unified School District

Cool roof retrofits on 450,000 m² of roof area in Sacramento schools will save ~US$670K/y
6. Roles of state and local agencies
Cities, state are acting to cool California

Berkeley is developing a plan to incorporate cool pavements into practice

Mandatory cool roof ordinance in Los Angeles for all residences

Chula Vista raises cool roof requirements beyond state building code

The State passed cool pavement legislation (AB 296)

The State passed stricter cool roof requirements in recent building code update
7. Resources
LBNL has created new cool community resources for local governments in California

Presentations & courses

Online resources

Demonstrations

Existing & model code language

Cool Communities address issues all urban environments experience: heat island effect, air pollution, energy demand, and more. Check out the topics below to learn more about what your city can do to make a cool community in your area.

CoolRoofs  CoolPavements  UrbanVegetation

CoolCalifornia.org
Global Cool Cities Alliance offers new UHI resources for officials, experts, and the public

- Science, costs, and benefits of cool surfaces
- Global best practices for program and policy implementation
- Sample materials and relevant organizations.
- A comprehensive “knowledge base”
- Networking Forum
Visit the LBNL Heat Island Group website

HeatIsland.LBL.gov
Exploring Bay Area Energy Future as Part of Climate Protection Strategy

2014 Efforts of Advisory Council

Prepared for the Board of Directors 2015
Topics and Speakers

Bay Area Energy Future

- **Mark Jacobsen**, Professor, Stanford (100% wind, water, solar pathway)
- **Jim Williams**, PhD, E3 (all available measures pathway)
- **Jane C.S. Long**, PhD, LLNL/EDF (action plan, feasibility, all available measures pathway)
- **Emilio Camacho**, Esq., CA Energy Commission (innovation)
- **Daniel Kammen**, Professor, UC Berkeley (Bay Area energy and climate opportunities)
- **Haresh Kamath**, PhD, EPRI (energy storage and integrated smart grid)
Energy Future: Big Picture

• **Efficiency**
  – Especially uses that cannot be easily electrified

• **Electrification**
  – All feasible fossil-fuel combustion uses

• **Decarbonization**
  – Electricity supply (e.g., renewables) and fossil fuels
Where We Are

CA In-State Electricity Generation in 2012

Natural Gas 62%
Renewables 17%
Large Hydro 12%
Nuclear 9%

Sources: California Energy Commission, QFER and SB 1305 Reporting Requirements. In-state generation is reported generation from units 1 MW and larger.

DRAFT
Where We Are Going

Business as usual projection

85% from Fuel Combustion

2020 Goal under AB32

2050 Goal

Executive order

DRAFT
How We Can Get There

[Graph showing GHG emissions with categories including BAU, + Efficiency, + Electrification, + Low-Carb Elec, and + Low-Carb Fuels. The graph illustrates sequential addition of actions to reduce emissions. The 2050 target is highlighted, indicating a reduction from current BAU levels to 150 MtCO₂e per year.]
Energy Future: Two Different Paths

1. 100% Wind, Water, and Solar
   – All renewables including energy conservation and efficiency gains
   – Maximizes air quality and climate benefits with no air emissions

   **Issues:** Technical challenges, large number, permitting, variability, grid reliability

2. All Available Measures Includes above strategy +
   – All possibilities, including biofuels, carbon capture, storage, and nuclear
   – 60% reduction in carbon doable with known technologies; remaining 20% reduction challenging

   **Issues:** Technical challenges, negative side effects, use of fossil fuels for back up power with associated emissions, public acceptance

Bay Area Air Quality Management District
Energy Future: Major Challenges

• Technical challenges
  – Not yet available, some technologies maybe decades away
• Carbon pricing
  – Needed for market-based solutions
• Energy storage
  – Critical to renewables success, pumped storage most readily available now, batteries, hydrogen, and compressed air not ready yet
• Grid reliability & load balancing
  – Integrated “smart” grid, demand management
• Environmental & social equity
  – Economic, feasibility, air quality/climate tradeoffs
• Political leadership
  – Many difficult decisions, cost, reliability, public acceptance
## Recommendations

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<tr>
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</thead>
<tbody>
<tr>
<td>Integration into District Planning</td>
</tr>
<tr>
<td>Coordination with Other Agencies</td>
</tr>
<tr>
<td>Public Education and Outreach</td>
</tr>
<tr>
<td>Grants</td>
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Recommendations: Integration into District Planning

- Given mission to achieve clean air and climate protection, identify District’s most appropriate role vis-à-vis Bay Area energy future

- Conduct emission inventory-based study to project how Bay Area future energy trends may impact or complement District’s clean air plans

- Integrate implications of future energy trends into District’s clean air and climate plans, modifying those plans if necessary

- Integrate into new District’s permitting rules while reviewing past rules for consistency
Recommendations: Planning

Adhere to multi-pollutant approach to reduce GHG emissions while limiting unintended consequences and negative effects from other airborne pollutants.
Recommendations: Coordination with Other Agencies

• **Consult and coordinate** with relevant agencies and other stakeholders involved in energy-related planning
  
  – State and federal agencies
    ▪ ARB, CEC, CPUC, EPA, DOE
  
  – Regional and local agencies:
    ▪ MTC, ABAG
  
  – Private sector
    ▪ EPRI, PG&E, refineries, other
Recommendations: Regional Leadership

Collaborate with state, regional, and local agencies to develop regional GHG action plan
Recommendations: Reduce Emissions from Small Sources

Explore ways to reduce GHG emissions from large numbers of small stationary sources of CO₂:
- backup generators (understand significant growth in number and look for opportunities to use energy storage devices instead)
- furnaces
- water heaters
- boilers
Recommendations: Public Education and Outreach

• **Integrate latest information on energy** behavior-oriented recommendations into District’s public education and outreach efforts

• **Concepts** could include:
  – Greater efficiency for appliances, cost savings
  – Energy audits/upgrades to residences, offices
  – Electric vehicles
  – Public transit
Recommendation: Education

Build public support for GHG policies through education, including:

– Energy efficiency (e.g., codes, financing, retrofits)
– Electrification
– Energy use (e.g., choice of supply, rates, reliability)
– Energy generation (e.g., distributed energy, on-site renewable, CCS)
– Planning (e.g., zoning, density, infill)
– Transit and goods movement
– Climate change adaptation
– Carbon sequestration
Recommendations: Grants

- **Integrate future energy-related criteria** into grant proposal evaluation and selection
- **Expand incentives** to encourage/support more desirable energy sources and behavior
Recommendations: Grants

Identify new funding sources to expand grant program to stationary sources. Prioritize the following:

- Electrification and related infrastructure
- Low-Carbon clean-energy backup emergency power systems
- Energy efficiency in buildings, appliances, and processes
- Further VMT reductions through ‘smarter” vehicles and technologies that optimize operations
Thank You!

- We appreciate your time and interest
- Questions or comments?