Regional Air Quality Impacts of Distributed Generation – Importance of CHP

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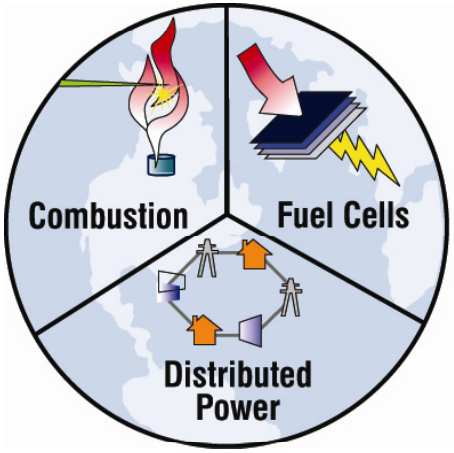

ADVANCED POWER & ENERGY PROGRAM
UNIVERSITY of CALIFORNIA · IRVINE

Jack Brouwer, Donald Dabdub, G. Scott Samuelsen

Marc Carreras, Satish Vutukuru

Advanced Power and Energy Program
Computational Environmental Sciences Laboratory
University of California, Irvine

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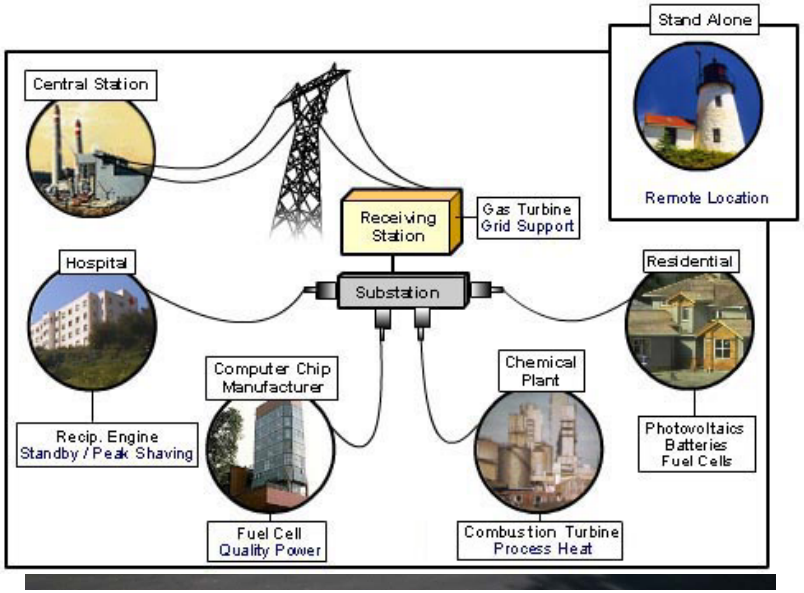
Outline

- Overview of Methodology and Tools
- Regional Air Quality Impacts of Advanced Generation Technologies
- Summary

Overview of the Methodology

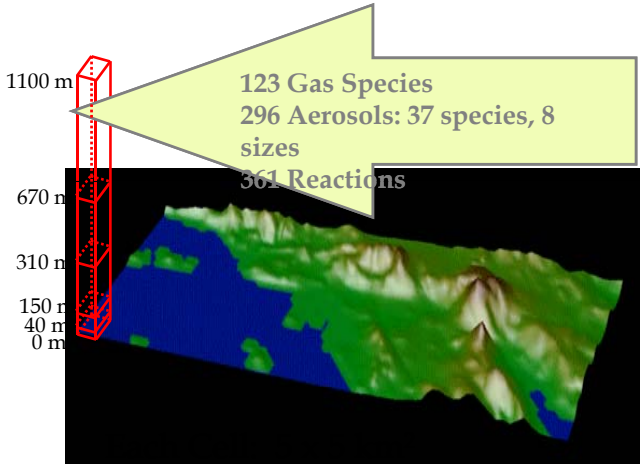
Determine impacts of Future Energy Technologies on air quality

Future Technology Assessment



Introduce new spatially & temporally resolved emissions

3-D Air Quality Model



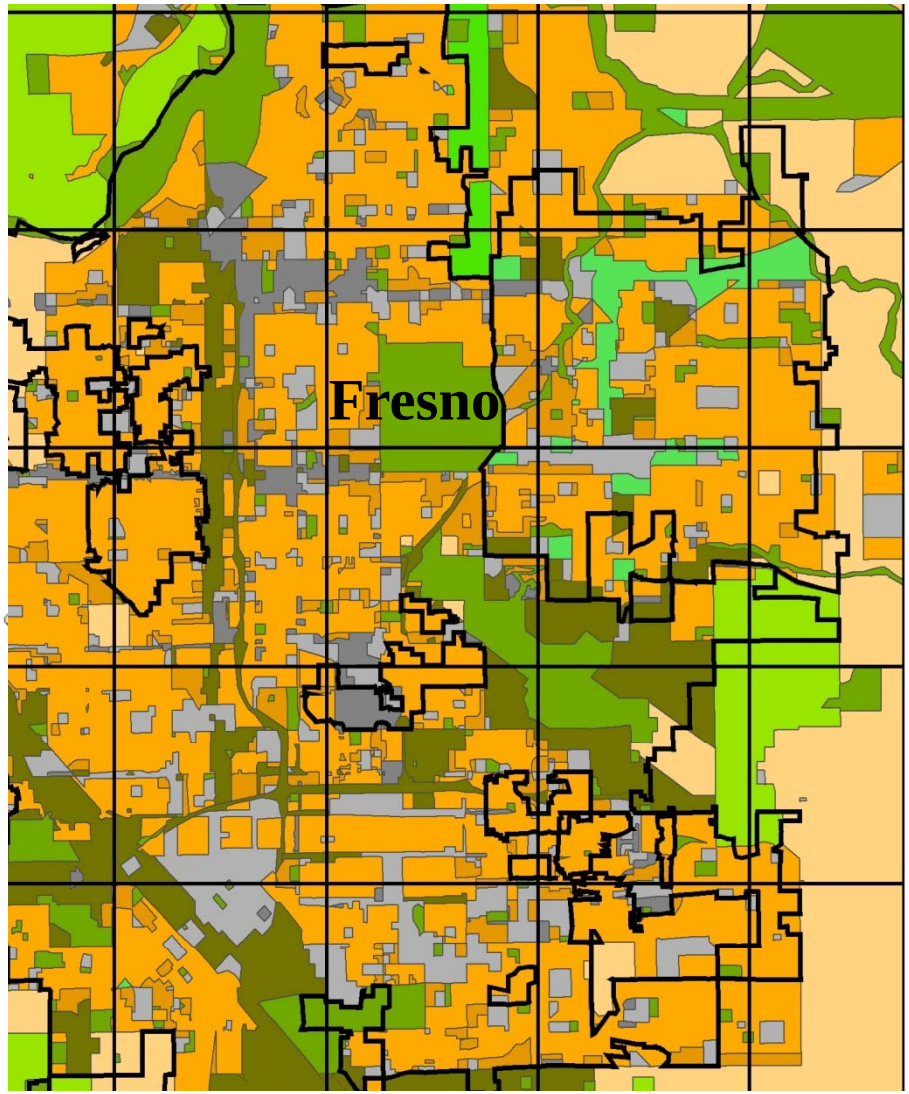
Air Quality (AQ) Impacts

Determine spatial & temporal AQ impacts

Feedback to Scientific Community Regulatory Bodies, General Public, etc.

How do we spatially allocate future technology?

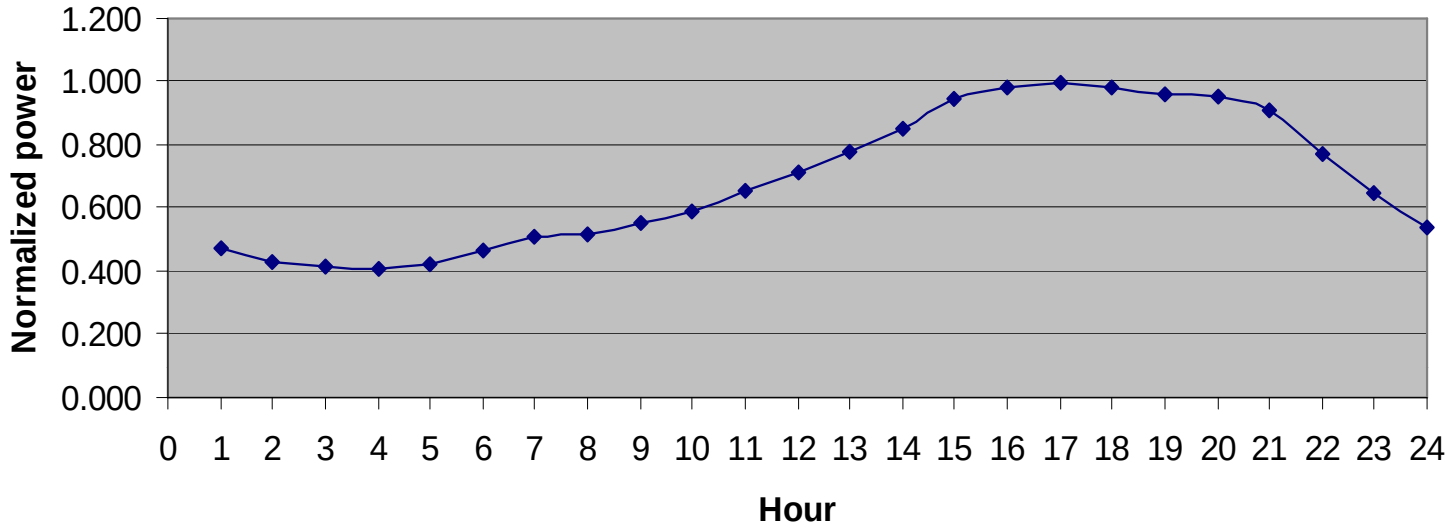
GIS Land-Use Data (e.g., Long Beach & Fresno Areas)



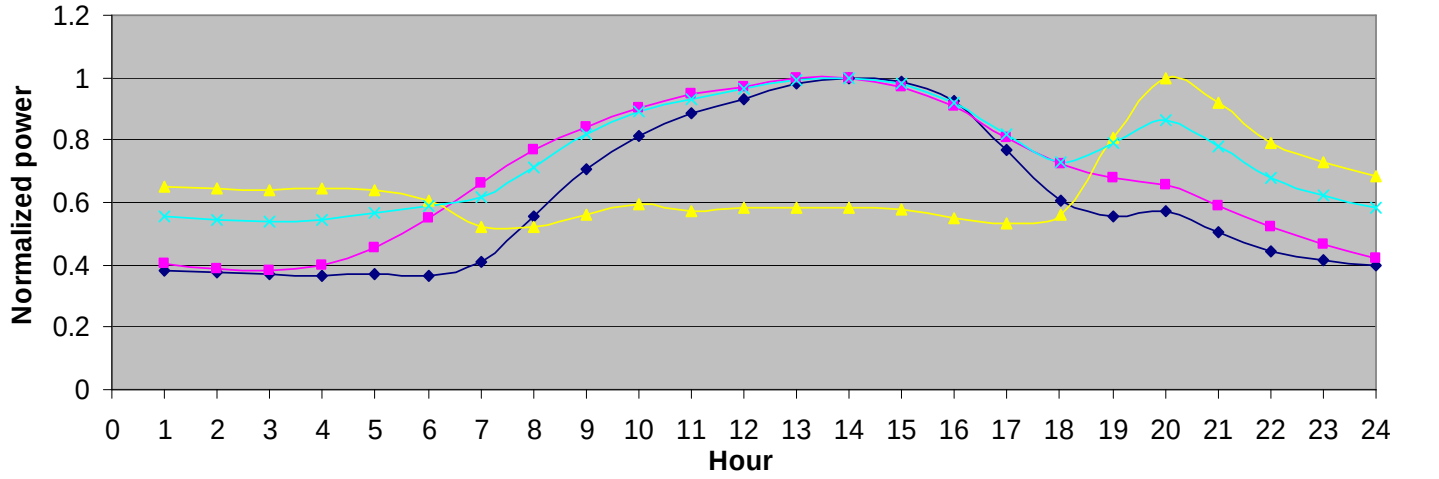
- Agricultural
- High density commercial
- High density residential
- Industrial
- Low density commercial
- Low density residential
- Medium density residential
- Mixed use of resid. and comm.
- Open space and public lands
- Planned development
- Urban reserve
- Very low density residential
- Water

How do we temporally allocate future technology?

Normalized hourly electric profiles for SCE residential sector



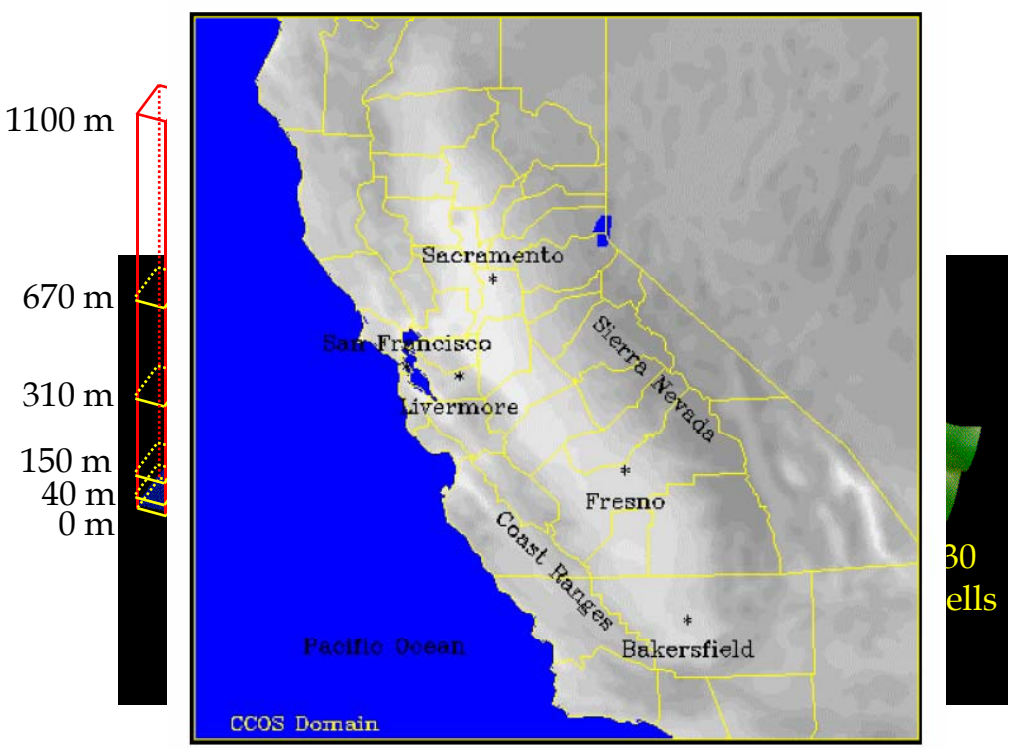
Normalized hourly electric profiles for SCE commercial sector



The Air Quality Model: UCI-CIT Airshed

Governing Dynamic Equation:

$$\frac{\partial Q_m^k}{\partial t} + \nabla \cdot \left(u Q_m^k \right) = \nabla \cdot \left(K \nabla Q_m^k \right) + \left(\frac{\partial Q_m^k}{\partial t} \right)_{\substack{sources/\\ sinks}} + \left(\frac{\partial Q_m^k}{\partial t} \right)_{aerosol} + \left(\frac{\partial Q_m^k}{\partial t} \right)_{chemistry}$$



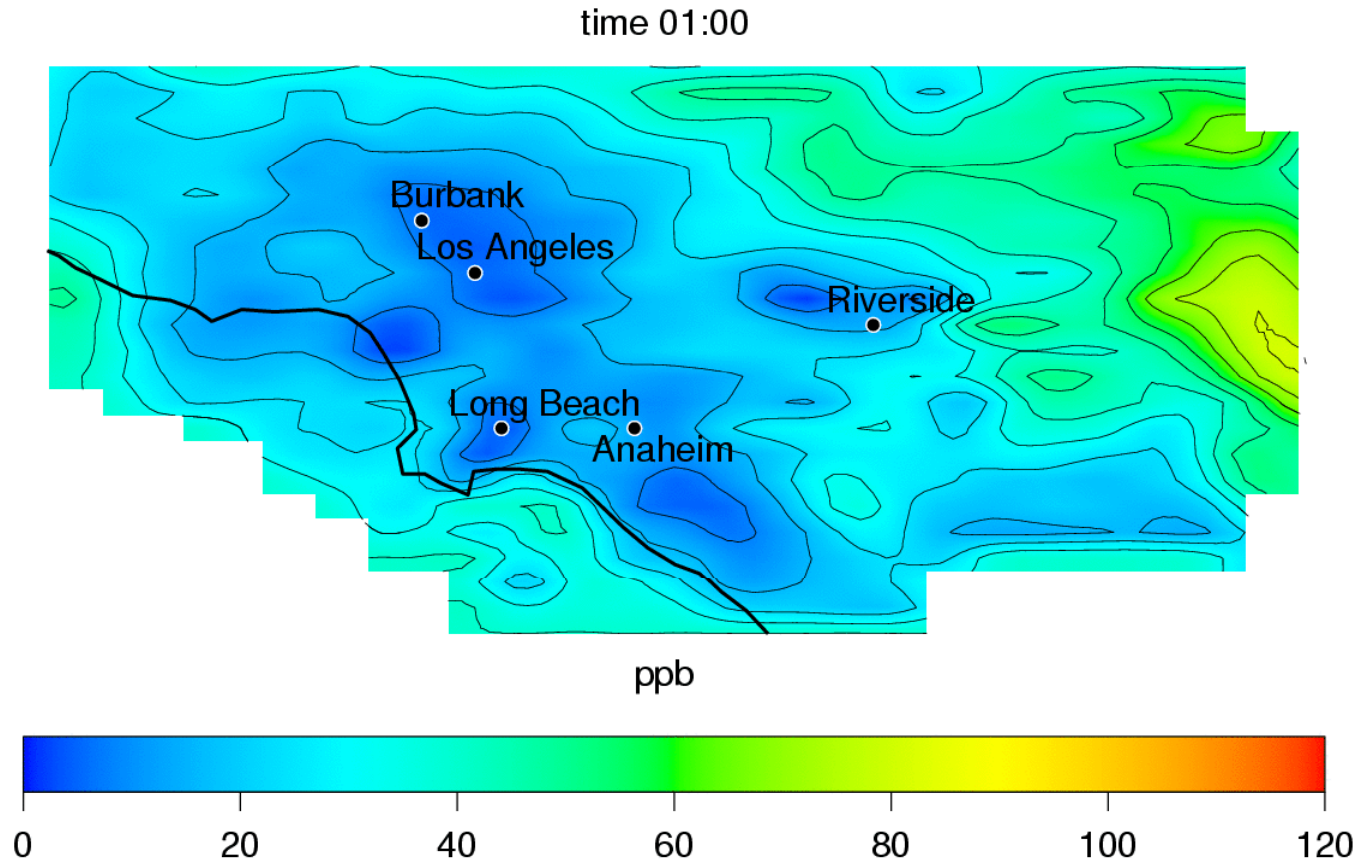
Measured Meteorology:

- Southern California Air Quality Study (SCAQS), Sept. 27-29, 1987
- Central California Ozone Study (CCOS), summer 2000
- California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS), Dec. 1999 – Feb. 2001
- High Ozone and PM concentration episodes

Air Quality Baseline

South Coast Air Basin Baseline Results in 2023:

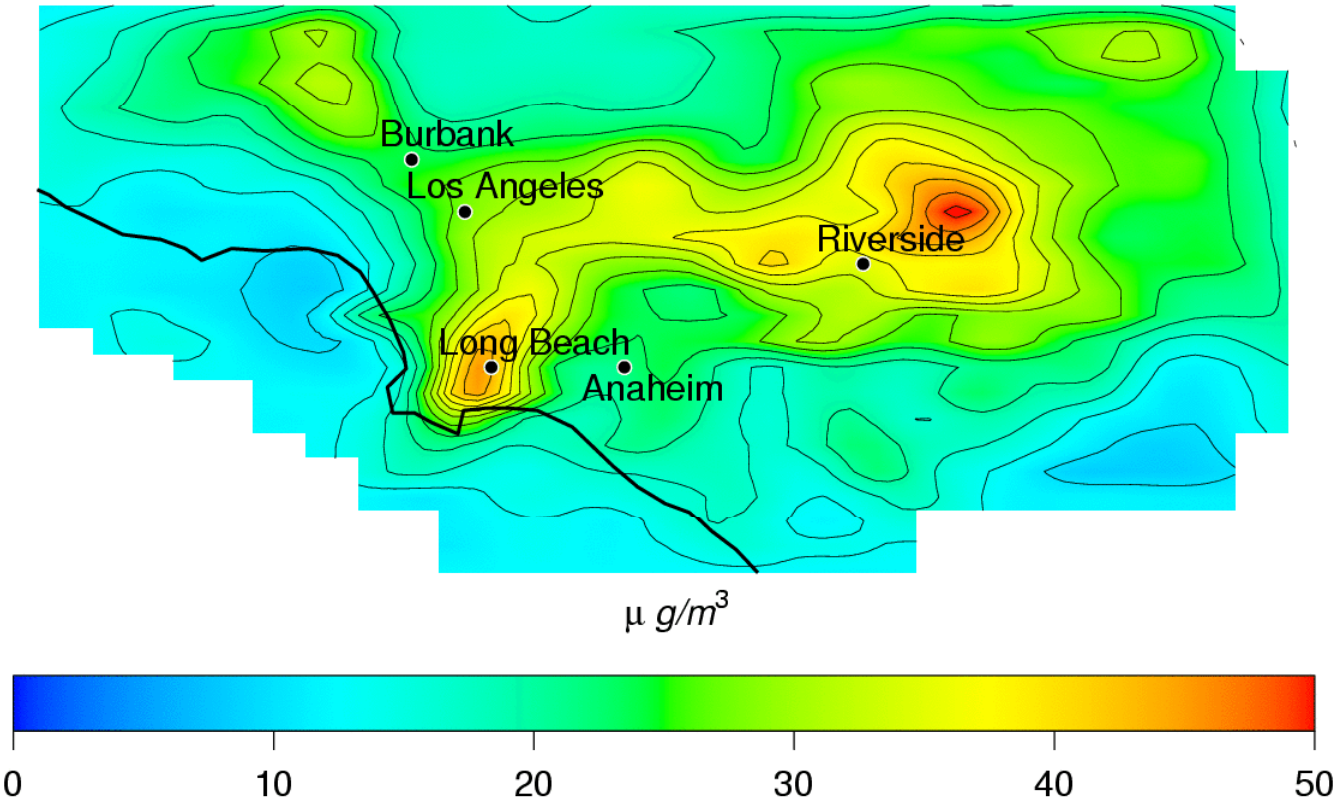
- **Hourly ozone concentration:**



Air Quality Baseline

South Coast Air Basin Baseline Results in 2023:

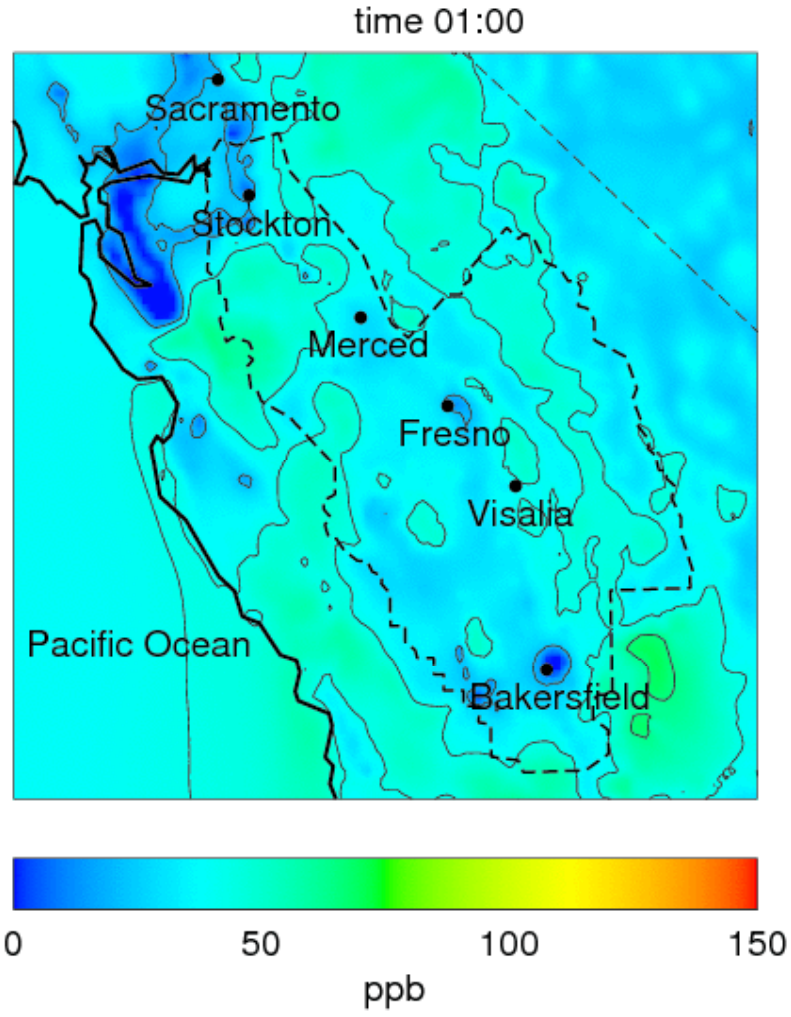
- 24-hour average of $PM_{2.5}$ concentration:



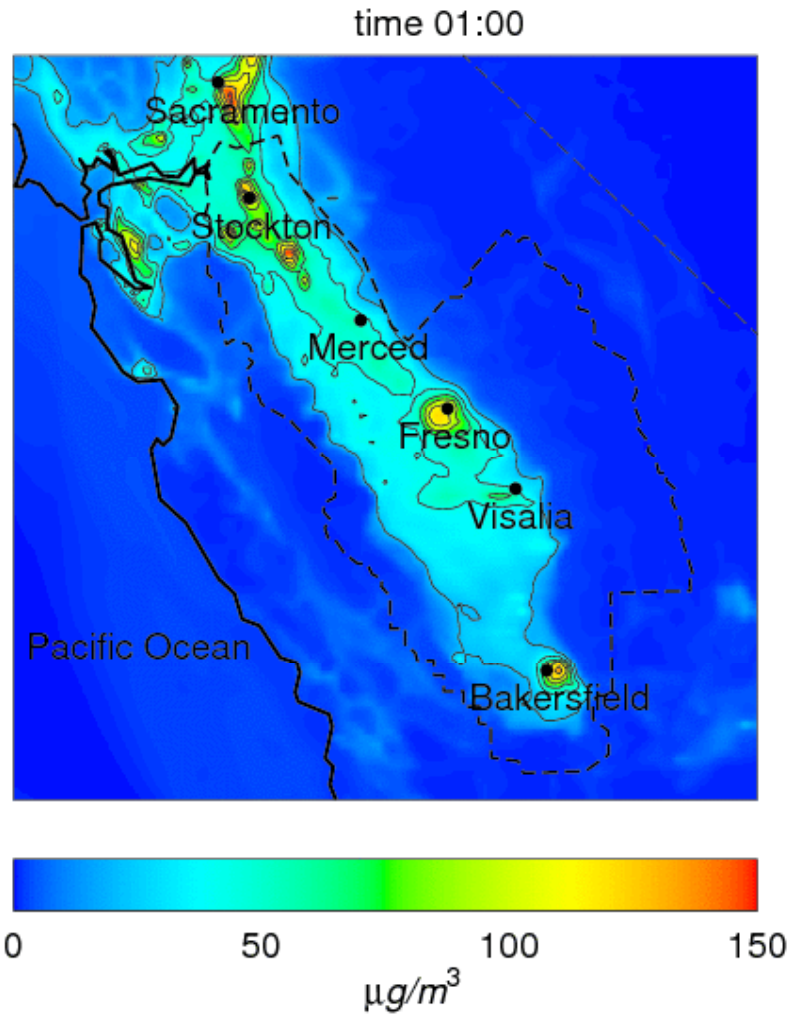
Air Quality Baseline

San Joaquin Valley Baseline Results in 2023

One-hour average ozone



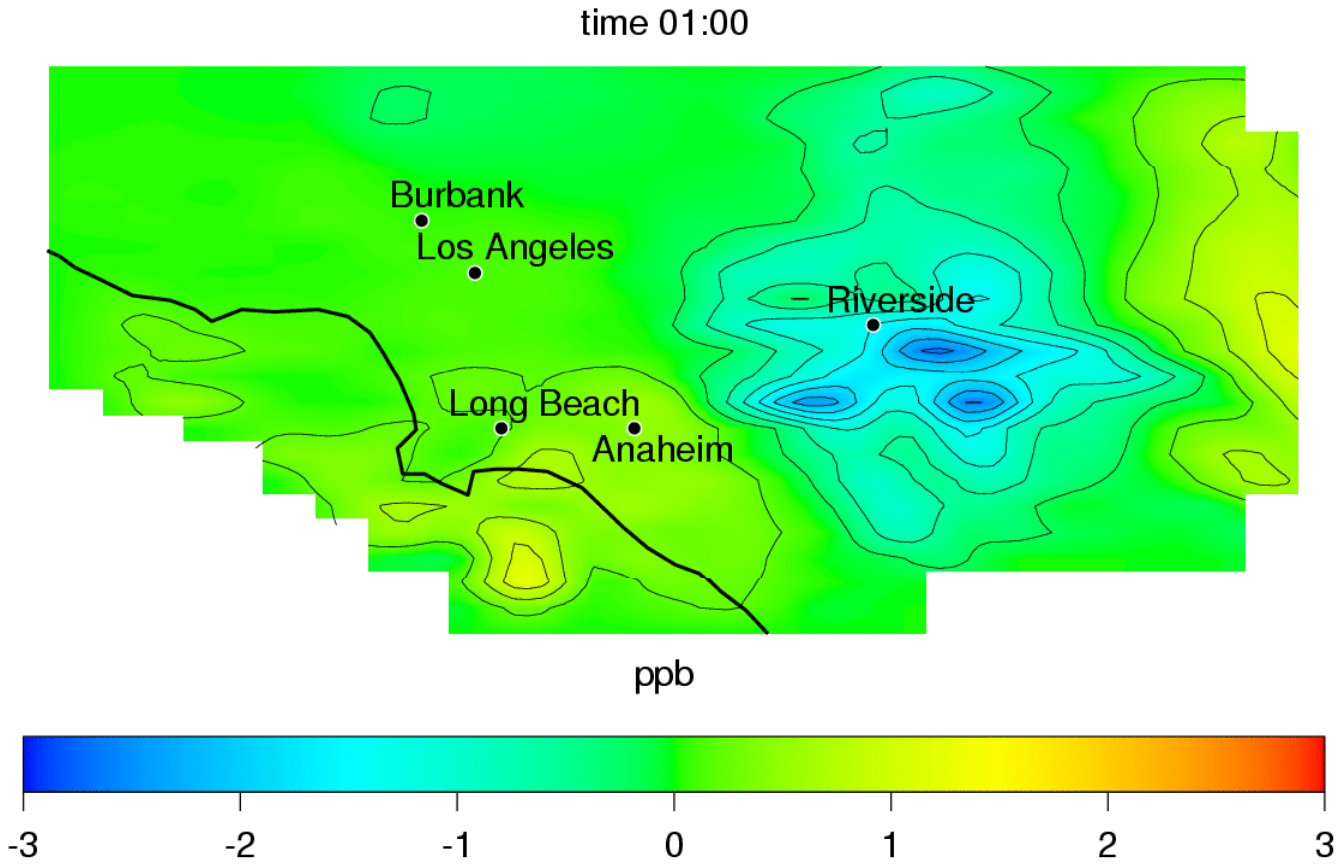
One-hour average $PM_{2.5}$



Air Quality Difference Plots

Difference plots used to show significance of impacts:

- **Example showing peak ozone concentrations that are displaced towards the east**



Outline

- Overview of Methodology and Tools
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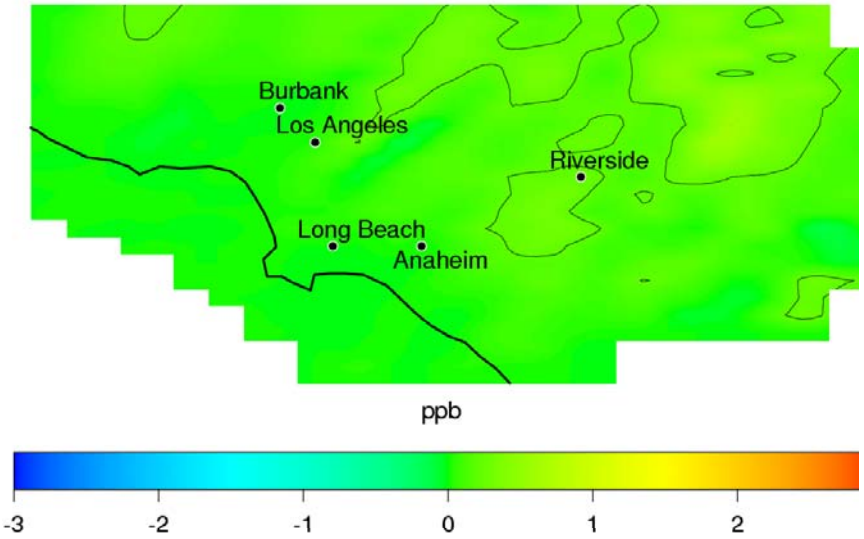
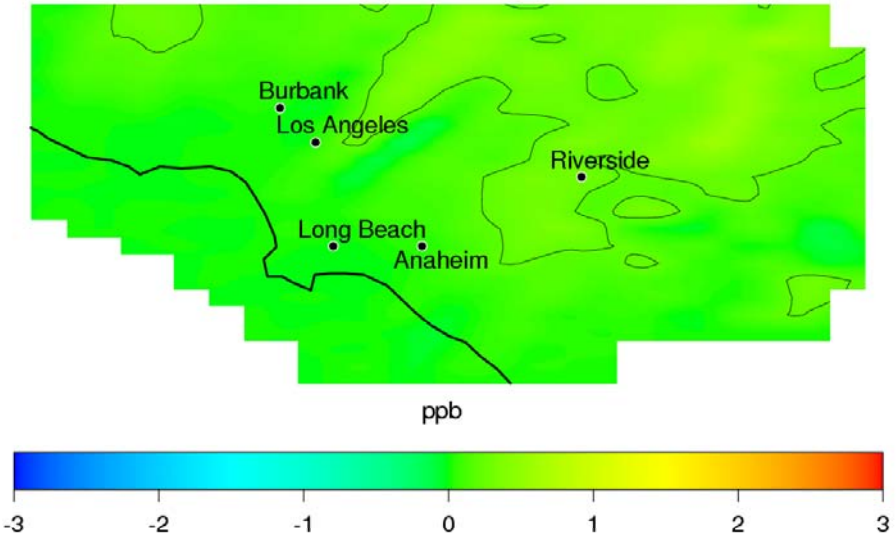
Effects of DG Technology / Emissions Rates

Ozone Difference Plots without CHP

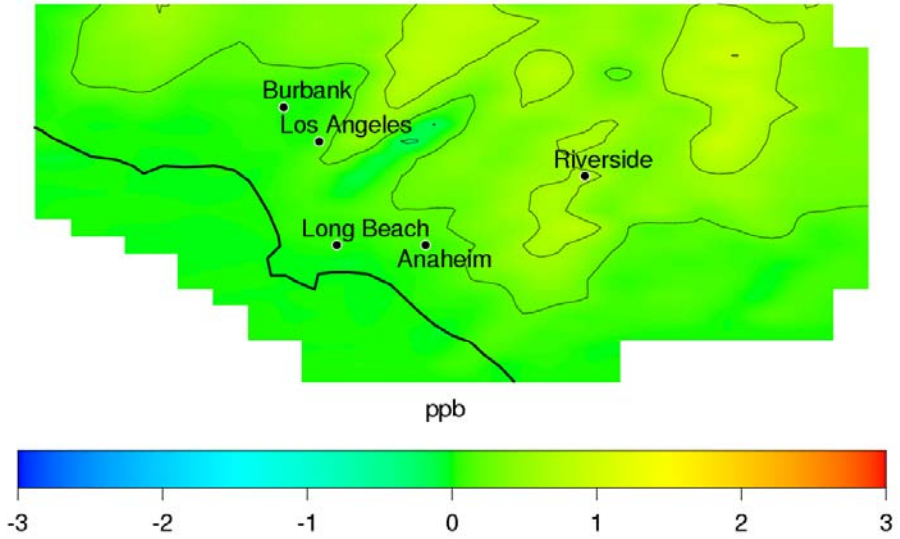
All Fuel Cell Case - Baseline



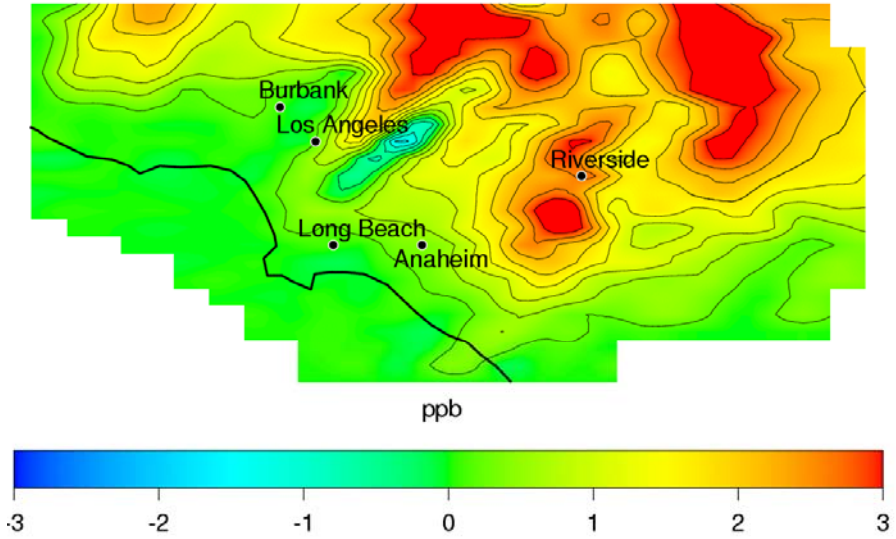
CARB Standard Case - Baseline



45% Market DG Mix - Baseline



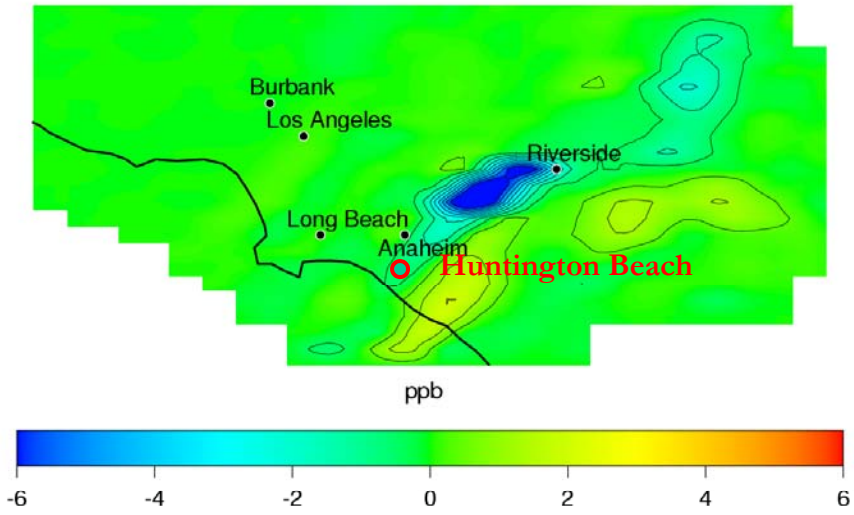
All ICE (BACT) Case - Baseline



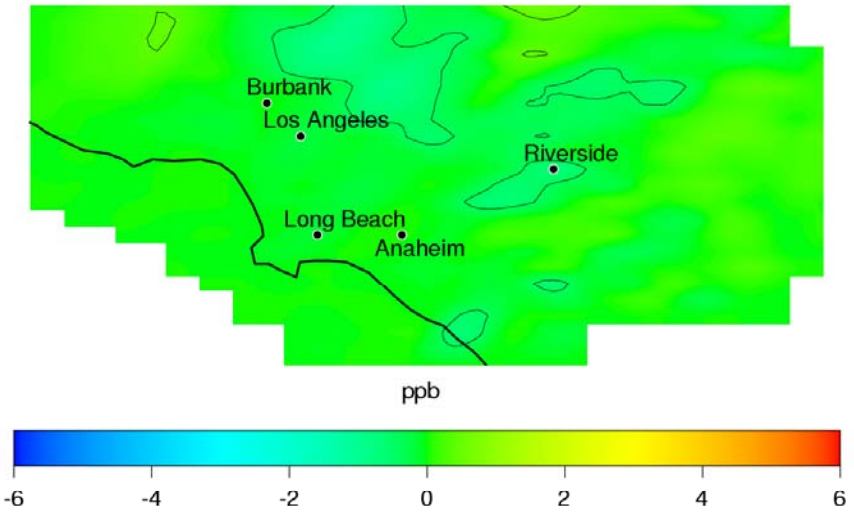
Central Generation vs. DG: Air Quality

- **Both scenarios introduce 1200 MW of new generation**

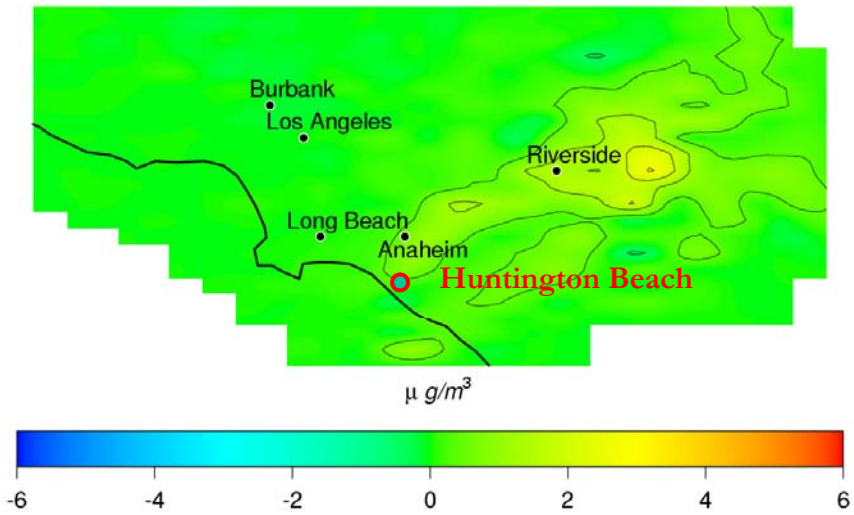
Peak O_3: Normal CG – Base



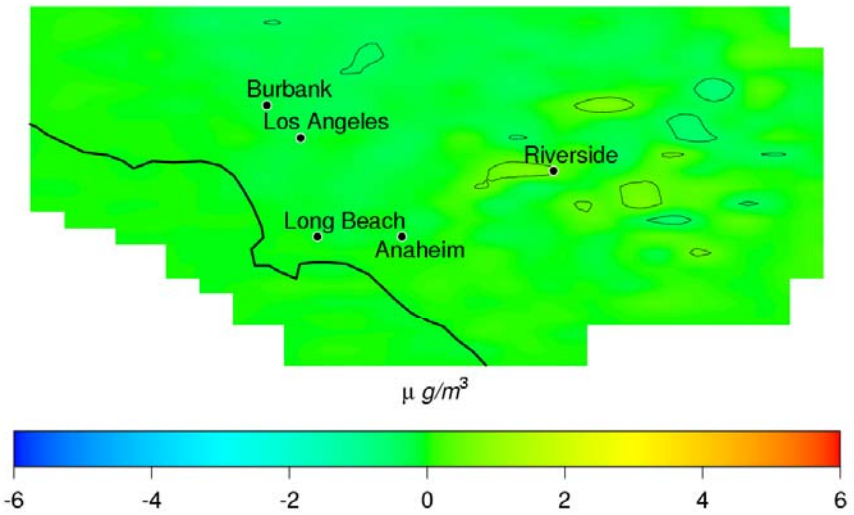
Peak O_3: DG – Base



24h $PM_{2.5}$: Normal CG – Base



24h $PM_{2.5}$: DG – Base



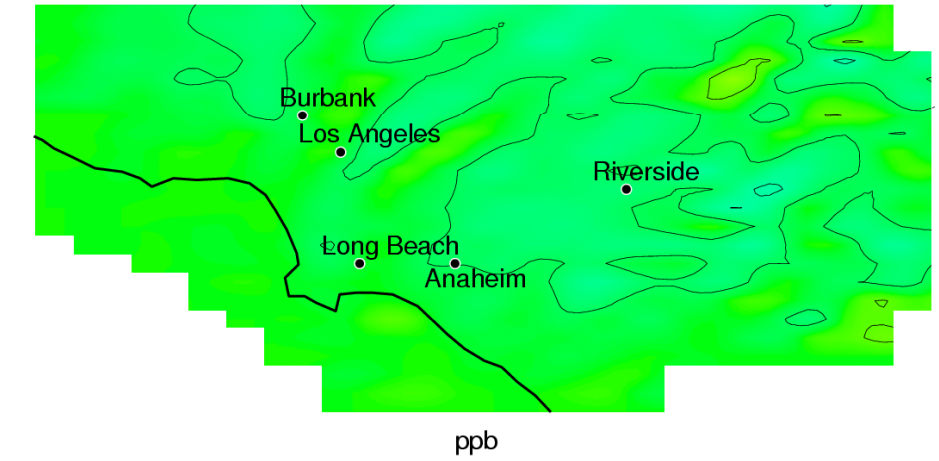
Effects of CHP on Ozone

Comparison of Realistic Scenarios with More or Less CHP:

- **DG meets 18% of increased power demand from 2007 to 2023**
- **DG Mix (~53% GT, ~33% ICE, ~4% FC, ~10% PV)**
- **More CHP: 60% of units; Less CHP: 10% of units (50% recovery)**

Difference in peak O_3 concentration

More CHP – Base Case



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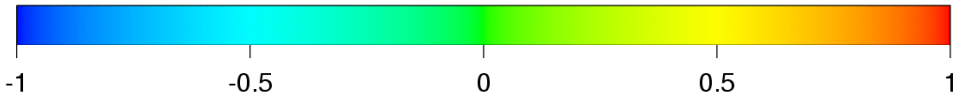
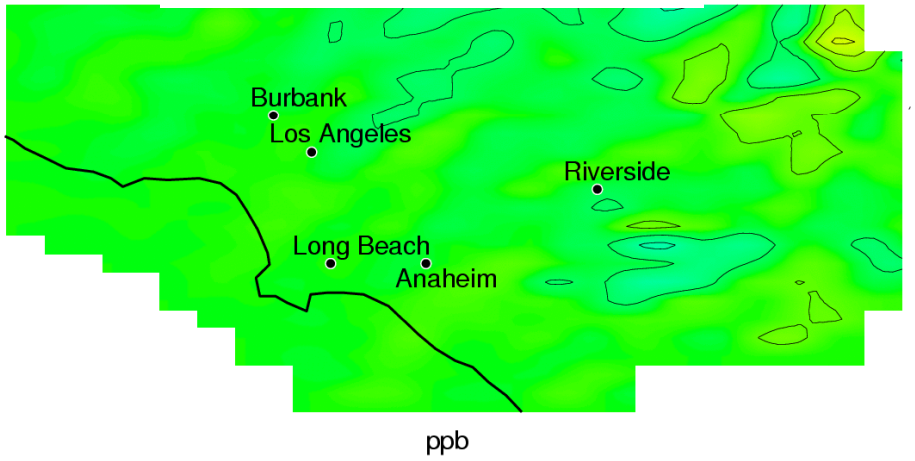


Less CHP – Base Case



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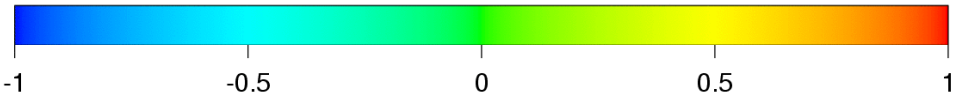


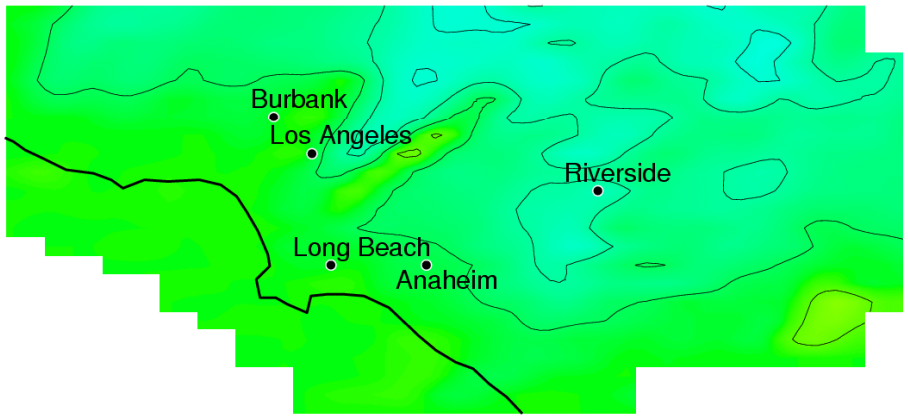
Effects of CHP on Ozone

Comparison of Land-Use Distributed Generation w/ & w/o CHP:

- **DG meets 18% of power demand increase from 2007 to 2030**
- **All CHP case: all units include CHP (50% recovery)**
- **No CHP case: no units include CHP**

Difference in peak O_3 concentration

All CHP – Base Case



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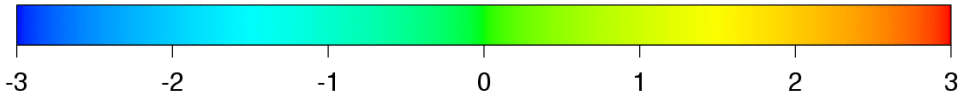
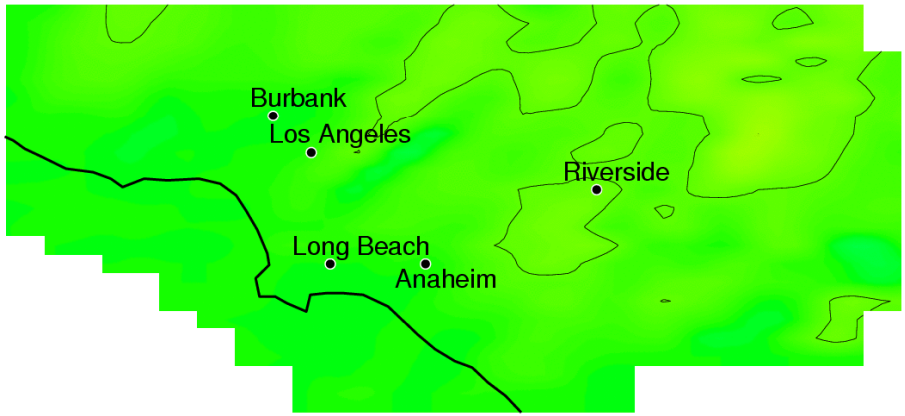


No CHP – Base Case



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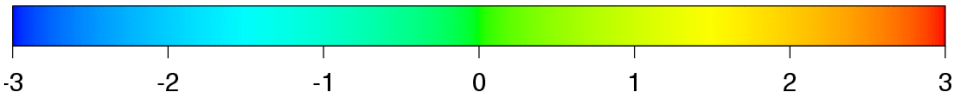
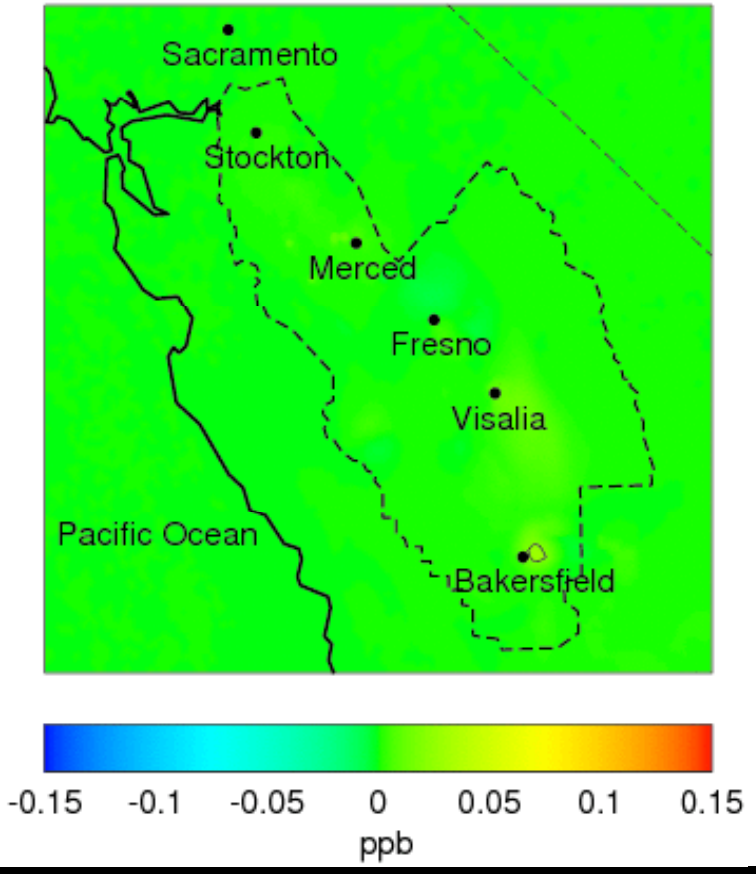


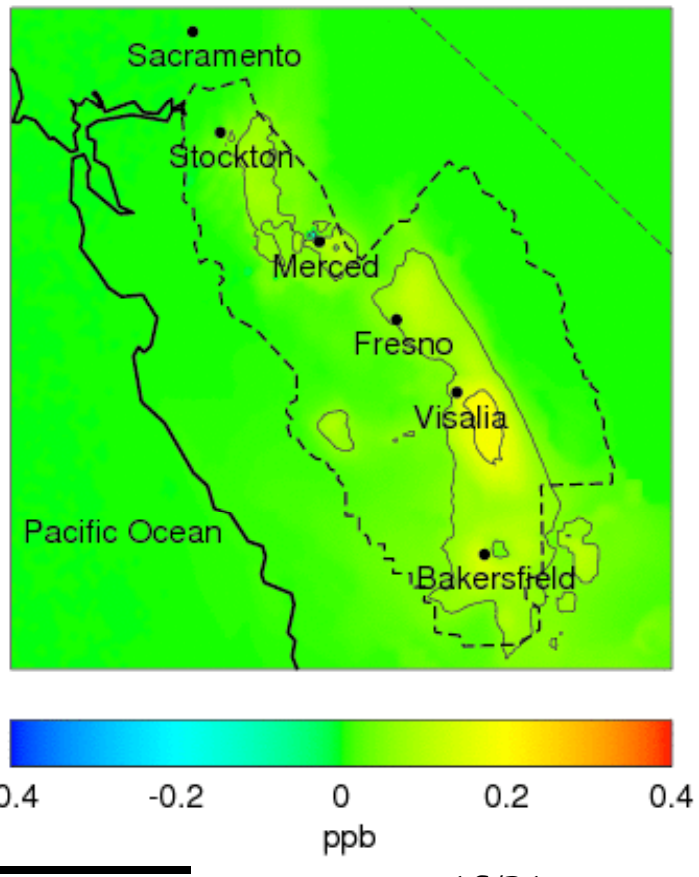
Effects of CHP on Ozone

NO CHP scenario predicts peak ozone impacts of 0.2 ppb

Increase in maximum one-hour ozone concentration for scenario R2 with CHP



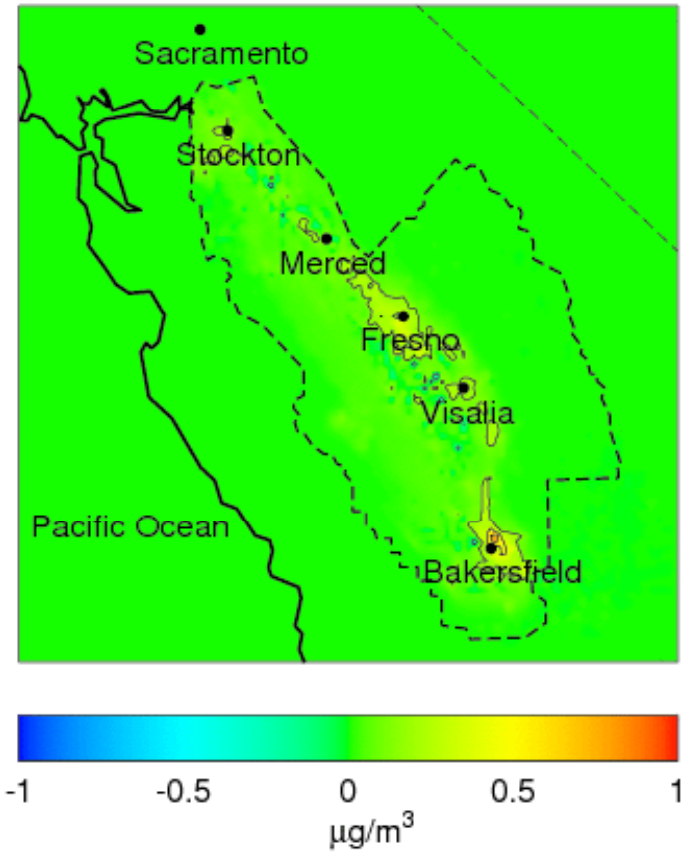
Increase in maximum one-hour ozone concentration for scenario NO CHP (same as R2, without CHP offset)



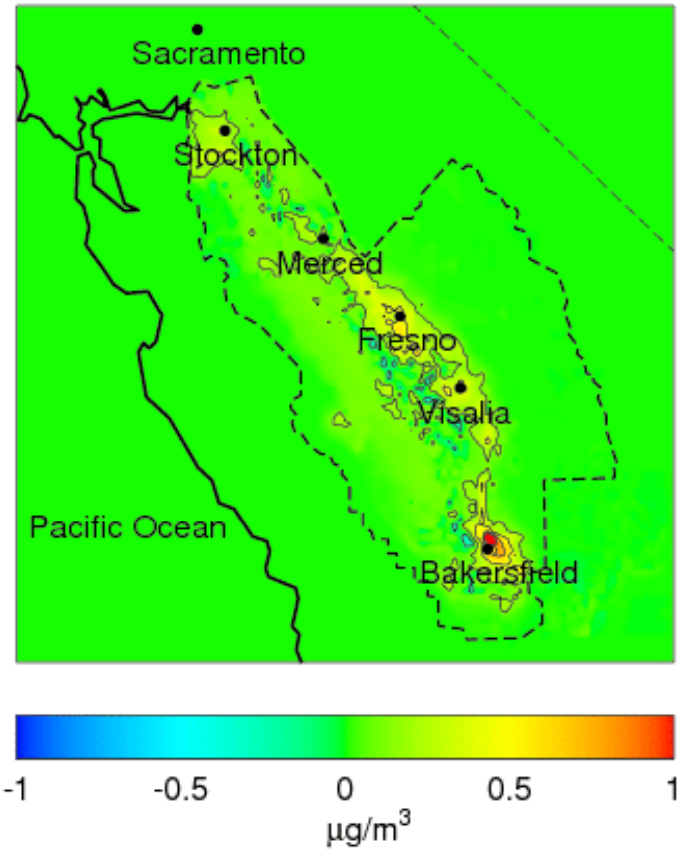
Effects of CHP on Particulate Matter

NO CHP scenario predicts peak impacts of 1.5 μg/m³

Increase in maximum 24-hour average PM2.5 concentration for scenario R2



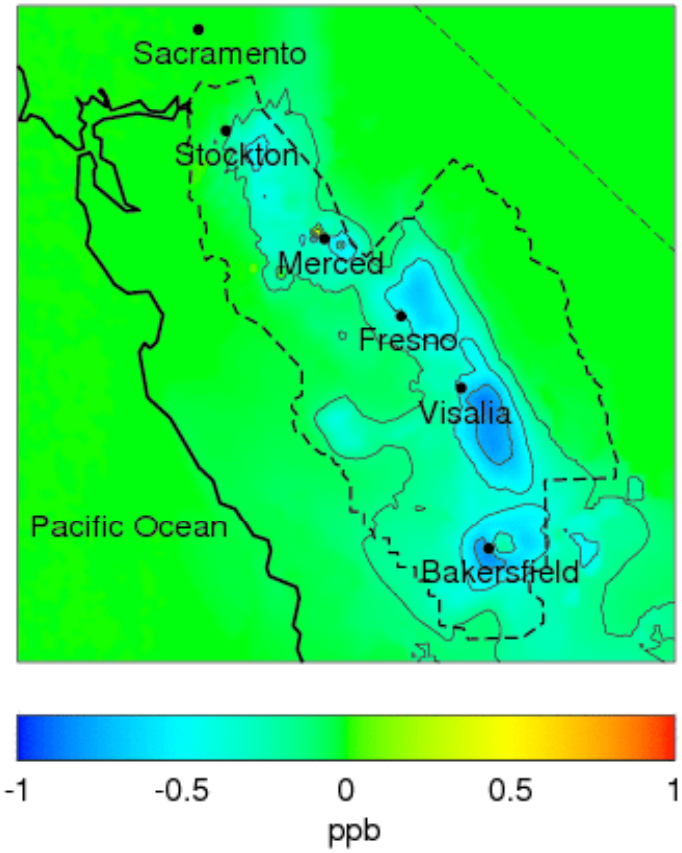
Increase in maximum 24-hour average PM2.5 concentration for scenario NO CHP (same as R2, without CHP offset)



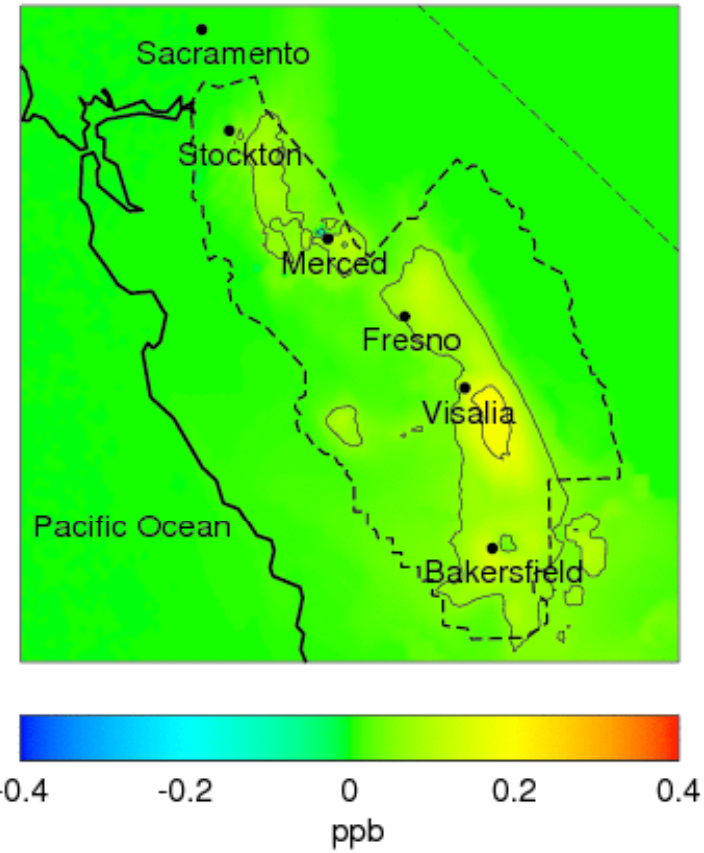
Effects of CHP on Ozone

ALL CHP scenario assumes 100% utilization of CHP and achieves decreases in ozone concentration

Increase in maximum one-hour ozone concentration for scenario ALL CHP (same as R2, 100% CHP offset)



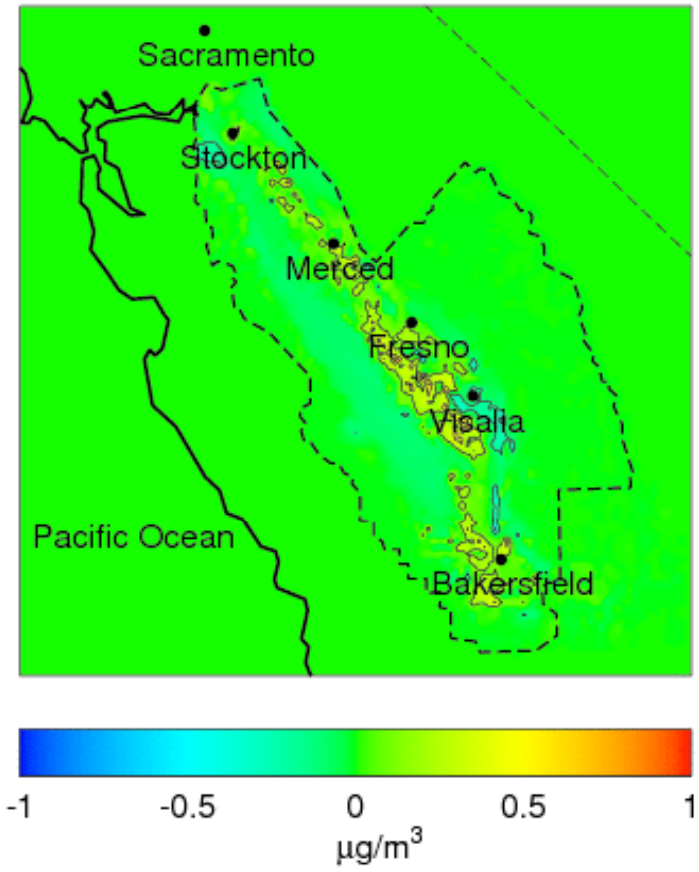
Increase in maximum one-hour ozone concentration for scenario NO CHP (same as R2, without CHP offset)



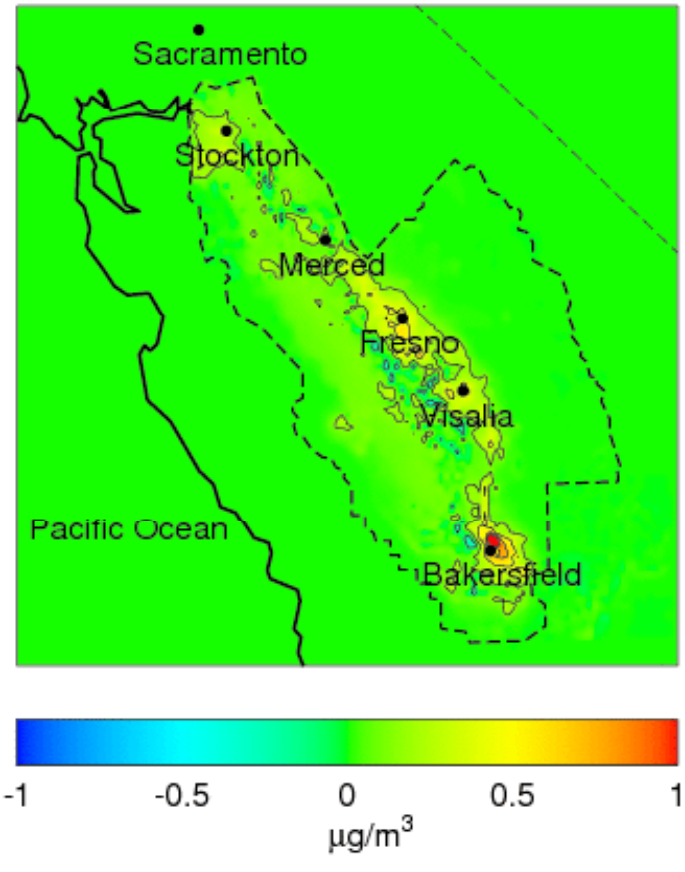
Effects of CHP on Particulate Matter

ALL CHP scenario assumes 100% utilization of CHP and has mixed impact on $PM_{2.5}$

Increase in maximum 24-hour average $PM_{2.5}$ concentration for scenario ALL CHP (same as R2, 100% CHP offset)



Increase in maximum 24-hour average $PM_{2.5}$ concentration for scenario NO CHP (same as R2, without CHP offset)



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Summary

- Energy Commission support has enabled UC Irvine to develop a unique methodology & toolset for rigorous spatially and temporally resolved analyses of energy and environmental impacts of future energy technologies
- The tools have been applied to understand air quality impacts of many future technologies (e.g., DG, PHEV)
- Low criteria pollutant emissions (e.g., those required by CARB and exhibited in fuel cell technology) are important to meeting air quality goals
- Combined cooling heating & power (CCHP) and combined heat & power (CHP) are known to significantly reduce GHG emissions
- Current rigorous analyses show that CHP also has significant air quality benefits in SoCAB and SJV