# The Relative Air Quality Impacts of DGs and CGs in the South Coast Air Basin

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- Motivation
- Technical Approach
- Evaluation of AERMOD
- Results
- Conclusions

# Motivation

- Increase in distribution generation (DG) leading to small power plants in urban areas
- Will DGs have a larger impact on air quality than CGs producing the same power?

# Past Work

- Allison and Lents(2002)
  - DG increases emissions even when heating emissions are offset
- Rodriguez et al. (2006)
  - Realistic scenarios lead to small increases in ozone and PM
- Heath et al.(2006), Heath and Nazaroff (2007)
  - DG exposure is about 10 times CG expressed in terms of inhalation factor – Exposure/Emission
    - » No plume rise or emissions

# Approach

- Construct emission scenarios for DGs and CGs in the South Coast Air Basin
- Run a model, such as AERMOD, to estimate the relative impact of these scanarios
- Compare results

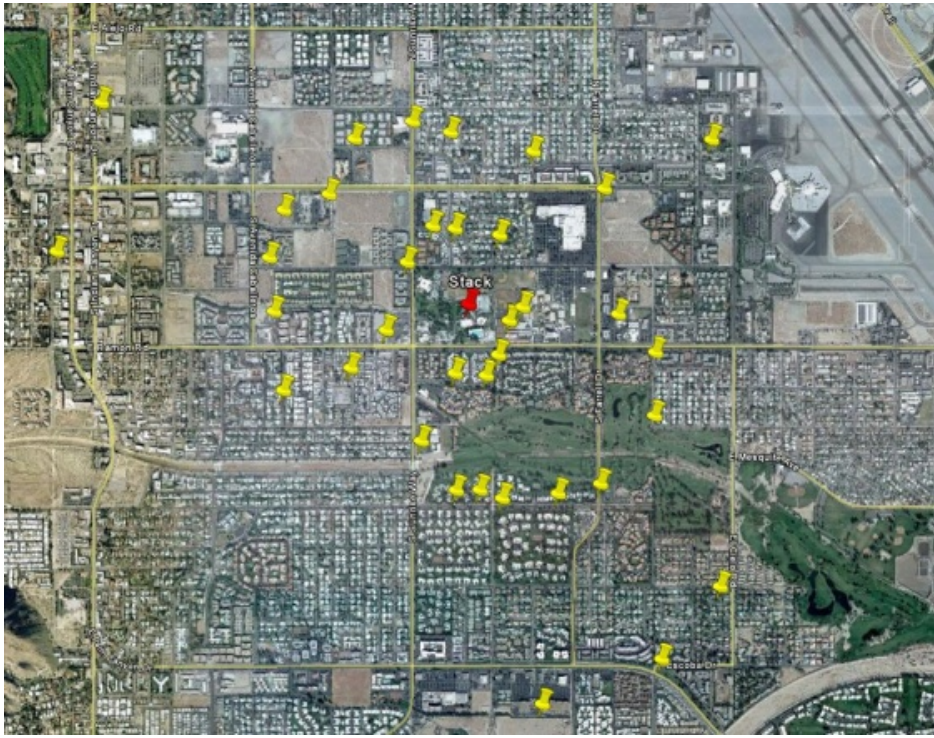
Models not evaluated for low level buoyant sources

# Dispersion of Buoyant Releases in Urban Areas

- Plume rise is critical under low wind speeds
- Dispersion and plume rise occur in the lower PBL where wind speed and turbulence levels change with height
- Buildings affect flow and turbulence

Conducted field study and water channel experiments to understand some of these effects

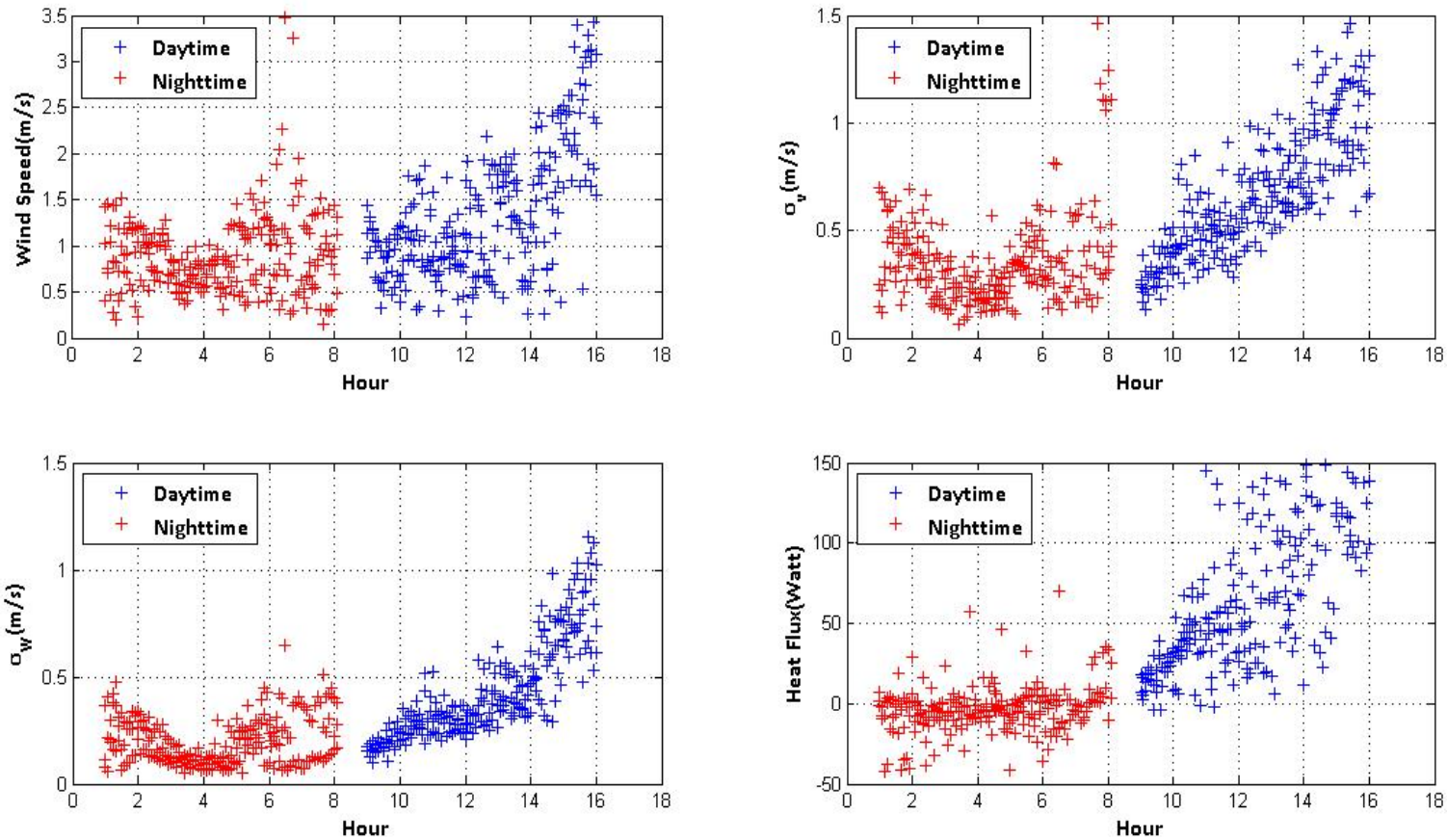
# Palm Springs Field Study



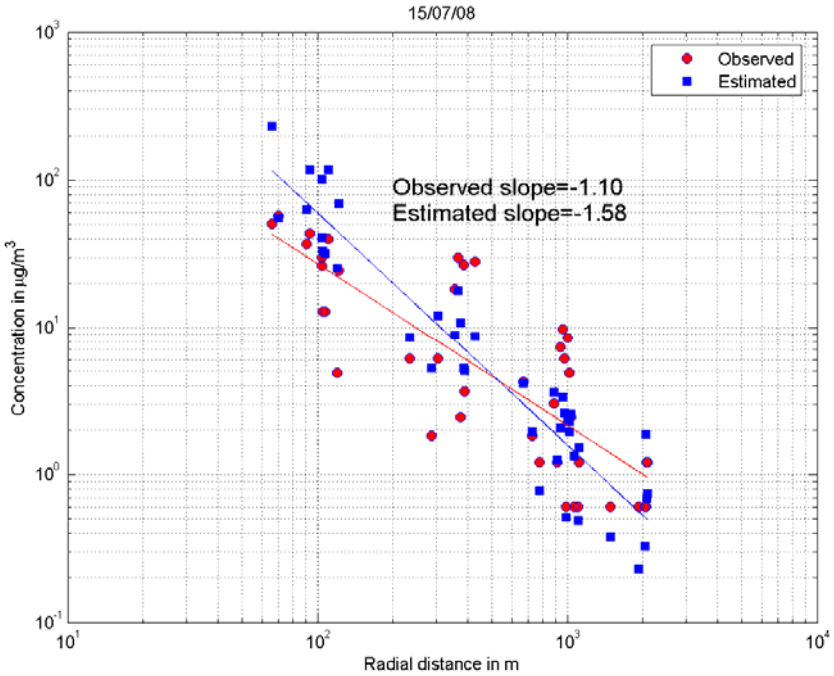

Tracer study conducted in July 15-21, 2008 around 650 kW plant. 3 daytime, and 4 nighttime releases

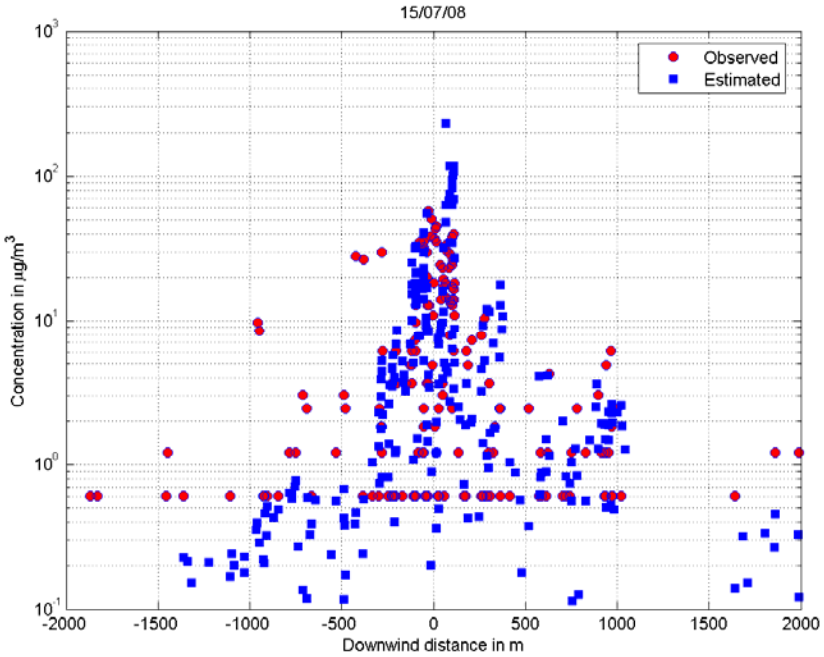
# Palm Springs Field Study

# Meteorology

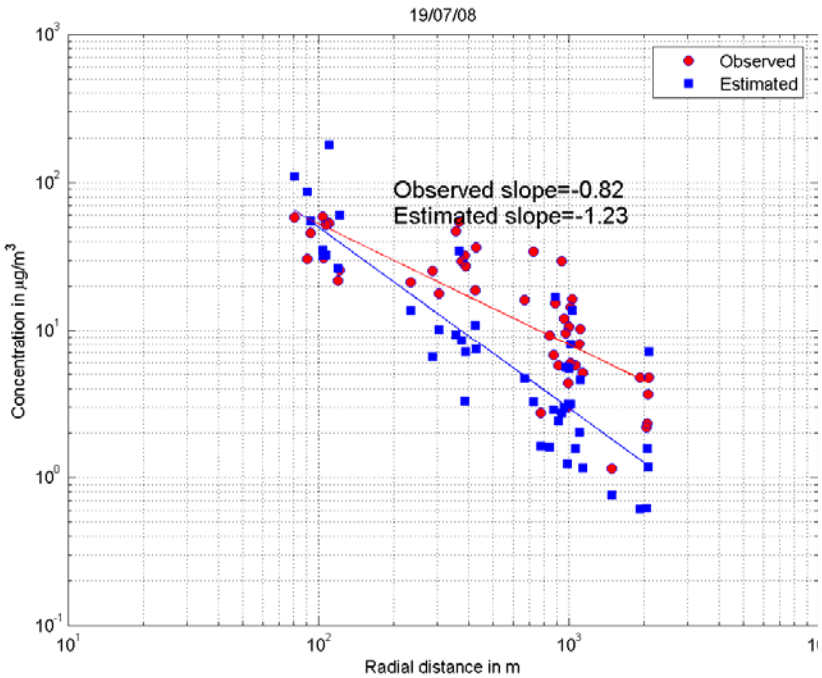


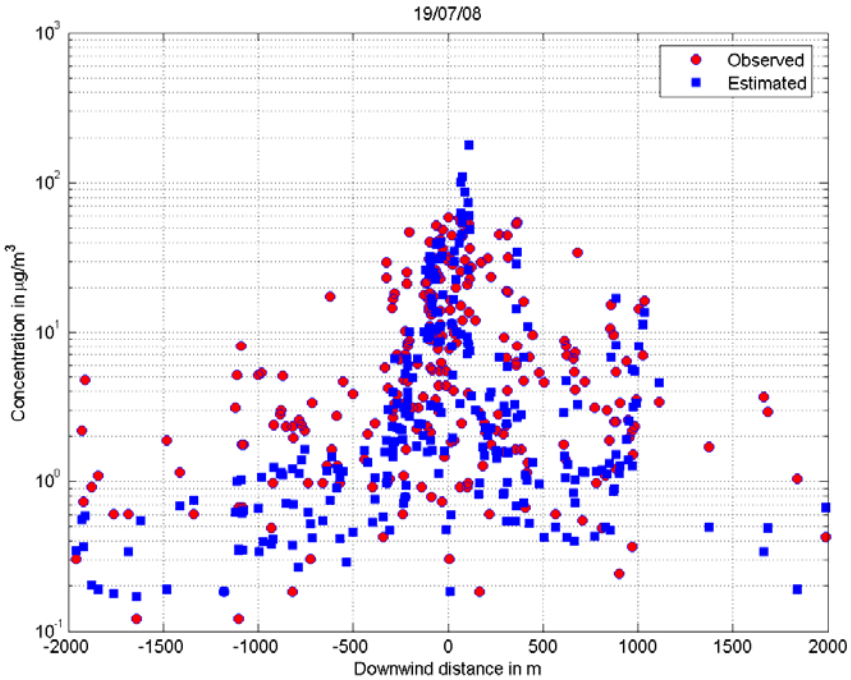
# Concentrations Daytime



# Concentrations Nighttime



# Modeling Implications

- Plume rise modeling is important
  - Interaction with top of boundary layer
- Meandering and upwind dispersion required under low wind, high turbulence conditions
- Need model for urban boundary layer
  - Nighttime boundary layer model is important
  - Need models to infer urban variables from rural measurements

# Impact Metrics

- Maximum concentrations

$$C_{max} \sim \frac{Q}{h_e^2}$$

- Concentrations averaged over 5 km

$$E \sim \frac{Q}{r z_i U}$$

# Generating Stations

| Name | Capacity (MW) | NOx emission factor (g/MWh) | h (m) | $D_s$[1] (m) | $v_s$[2] (m/s) | $T_s$[3] (K) | Ratio of energy out of stack to capacity | $F_B$[4] ($m^4/s^3$) | $F_M$[5] ($m^4/s^2$) | $C_{av}$[6] (ppt) |
|---|---|---|---|---|---|---|---|---|---|---|
| PS DG | 0.650 | -- | 9.3 | 0.3 | 11.0 | 460 | 15% | 1 | 3 | -- |
| Small DG | 0.625 | 120 | 9.3 | 1.5 | 3.0/3.3* | 450/773* | 100%/200%* | 6/11* | 5/6* | 3/2 |
| Medium DG | 2.5 | 120 | 10.3 | 1.8 | 8.2/9.1 | 450/773 | 100%/200% | 22/45 | 55/66 | 5/4 |
| Large DG | 12.5 | 101 | 11.3 | 2.6 | 19.6/21.9 | 450/773 | 100%/200% | 111/223 | 653/789 | 10/9 |

| Name | Total capacity (MW) | Capacity factor | $NO_x$ emission factor (g/MWh) | h (m) | $D_s$[1] (m) | $D_{se}$[2] (m) | $v_s$[3] (m/s) | $T_s$[4] (K) | Ratio of energy out of stack to capacity | $F_B$[5] ($m^4/s^3$) | $F_M$[6] ($m^4/s^2$) | $C_{av}$[7] (ppb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alamitos | 1970 | 0.0779 | 236 | 61 | 4.4 | 10.8 | 24.7 | 401 | 10% | 1812 | 17780 | 2 |
| El Segundo | 1020 | 0.1109 | 114 | 61 | 4.0 | 7.9 | 24.2 | 401 | 11% | 961 | 9239 | 0.5 |
| Harbor | 597 | 0.0734 | 206 | 53 | 4.8 | 6.7 | 23.0 | 454 | 17% | 881 | 5986 | 0.6 |
| Haynes | 1724 | 0.2380 | 61 | 73 | 7.0 | 17.3 | 13.9 | 386 | 15% | 2314 | 14444 | 0.5 |
| Huntington Beach 1 | 507 | 0.1998 | 46 | 62 | 5.2 | 7.4 | 26.2 | 401 | 20% | 904 | 9405 | 0.1 |
| Huntington Beach 2 | 507 | 0.1998 | 69 | 62 | 5.2 | 7.4 | 26.2 | 401 | 20% | 904 | 9406 | 0.2 |
| Mountainview | 1054 | 0.0153 | 49 | 40 | 3.0 | 7.5 | 9.9 | 392 | 3% | 323 | 1355 | 0.3 |
| Placerita | 120 | 0.0165 | 437 | 26 | 3.8 | 6.6 | 23.0 | 412 | 65% | 683 | 5780 | 0.1 |
| Redondo Beach | 1343 | 0.0372 | 583 | 61 | 5.1 | 10.4 | 15.2 | 416 | 10% | 1139 | 6216 | 4 |
| Scattergood | 803 | 0.1464 | 32 | 99 | 6.9 | 12.0 | 12.7 | 408 | 17% | 1201 | 5765 | 0.1 |

# Meteorology and Emission factors

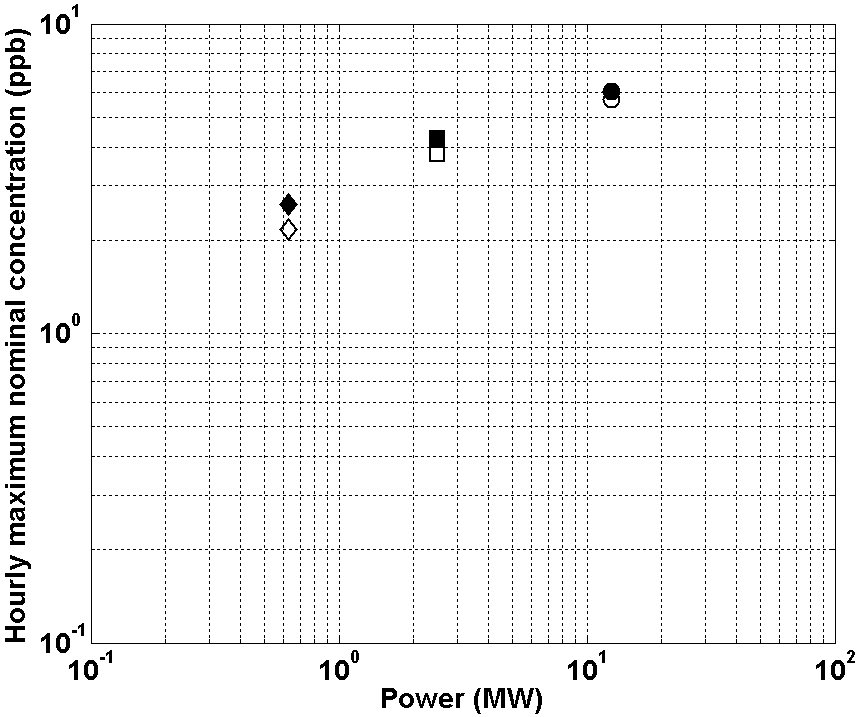
- **Two sets of meteorological data** (AQMD, 2009)

| Meteorology station | Wind speed (m/s) | | |
|---|---|---|---|
| | Maximum | 95th percentile | Median |
| Pomona | 4.4 | 2.9 | 0.6 |
| Fontana | 15 | 6.8 | 1.9 |

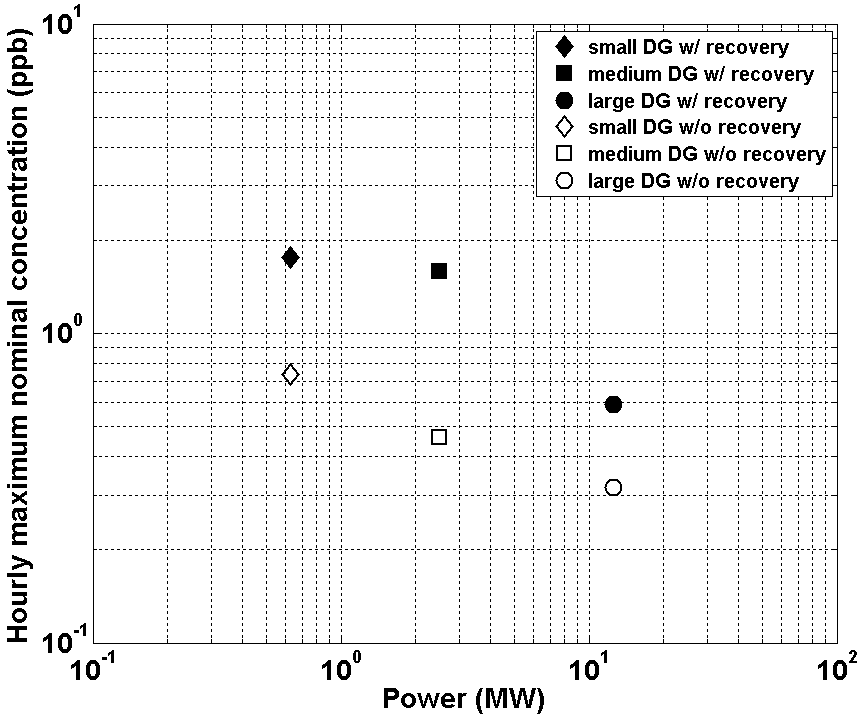
- **Emission factor for $NO_x$**
  - 32 g/MWh, the CA emission standard for new generators

# Hourly Maximum Nominal $NO_x$ Concentration from a Single DG

Fontana meteorological station
High wind speed



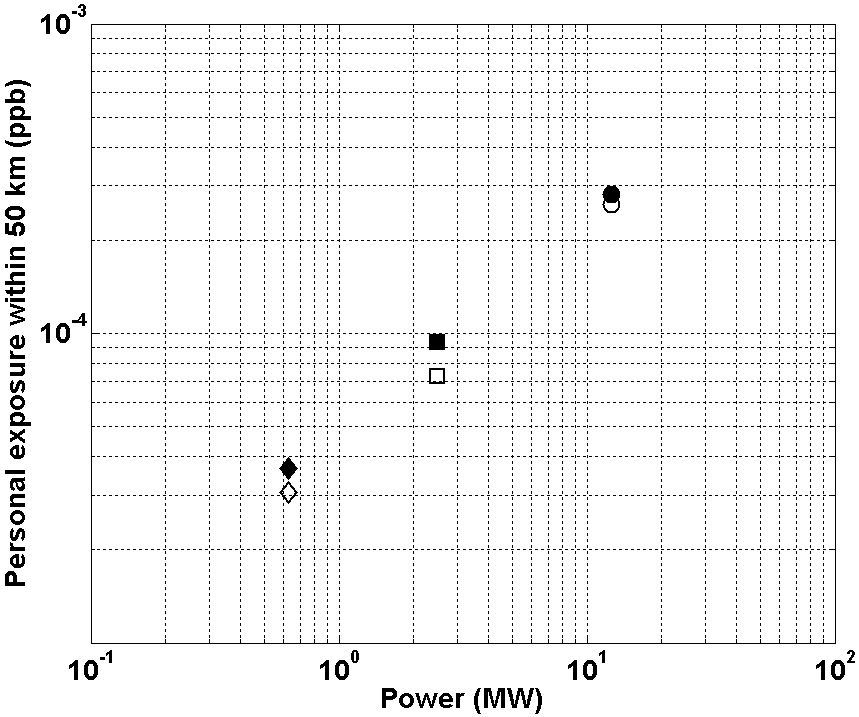

Pomona meteorological station
Low wind speed



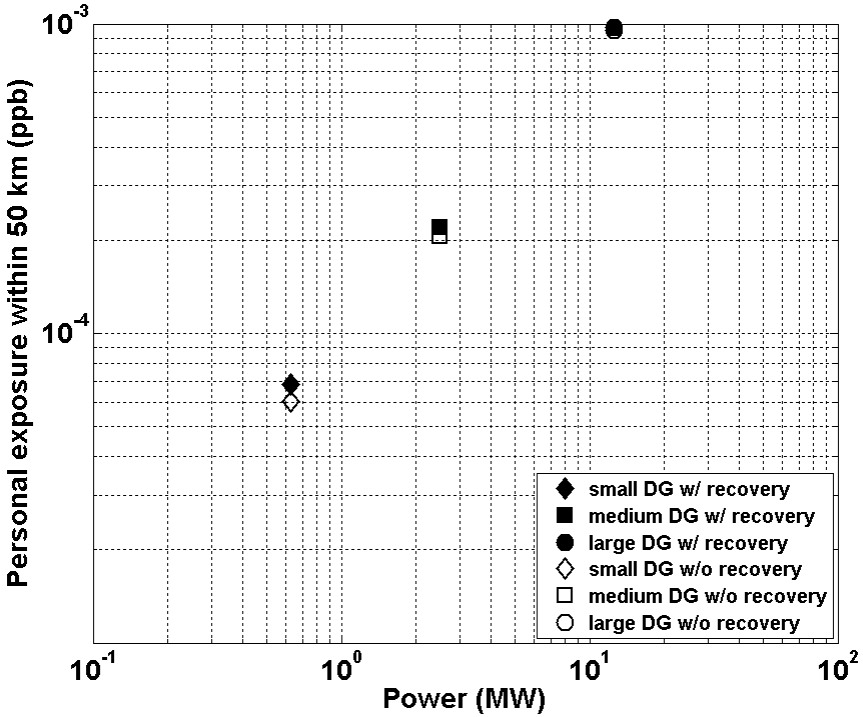

Effects of emission rate, plume rise, wind speed, heat recovery

# Personal Exposure to $NO_x$ from a Single DG

Fontana meteorological station
High wind speed



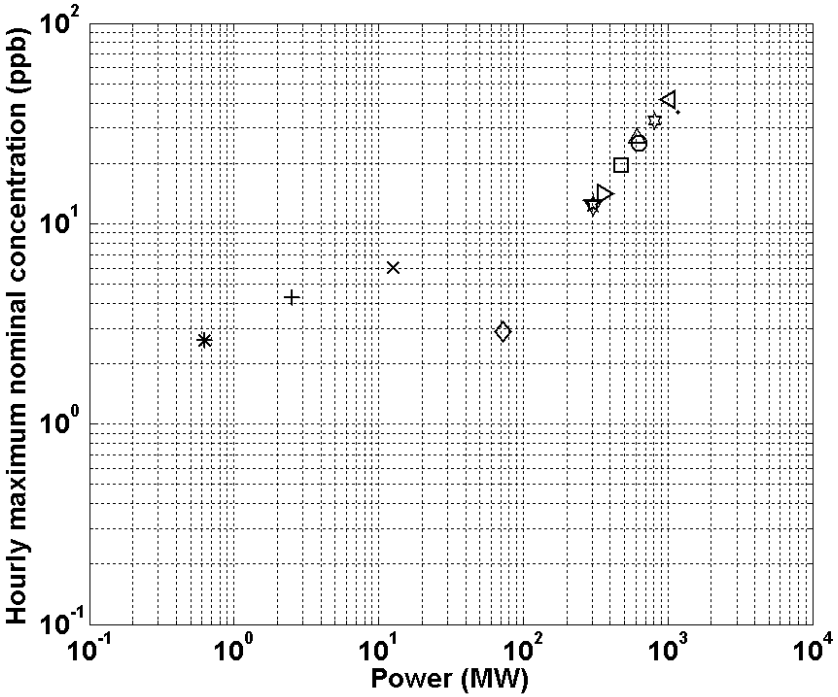

Pomona meteorological station
Low wind speed



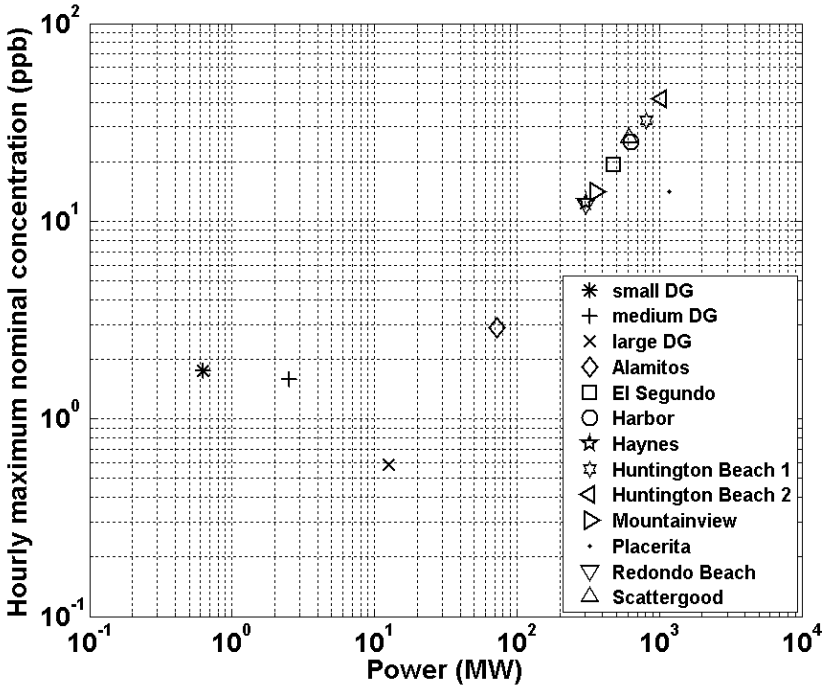

Effects of emission rate and wind speed

# Hourly Maximum Nominal $NO_x$ Concentrations from CGs

Fontana meteorological station
High wind speed



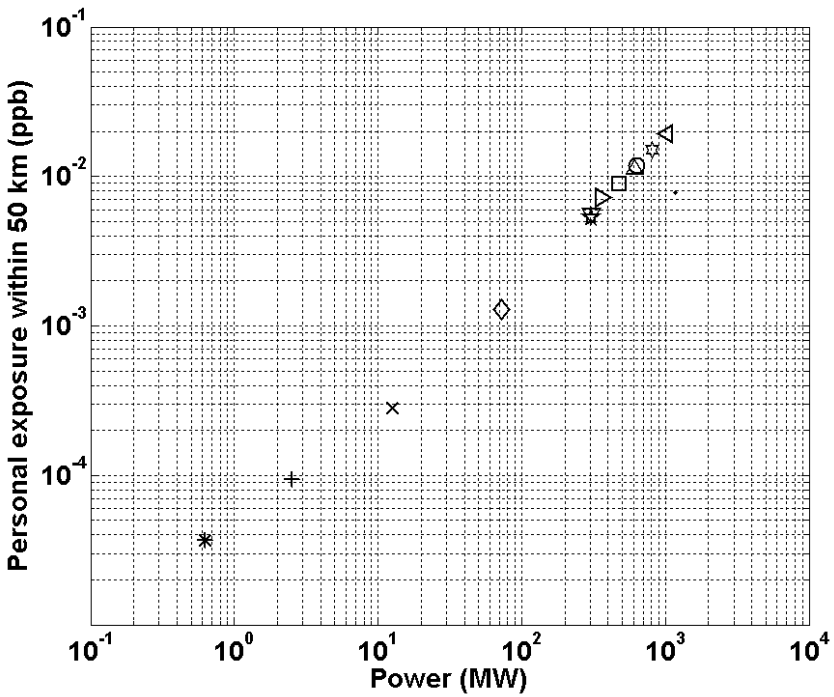

Pomona meteorological station
Low wind speed



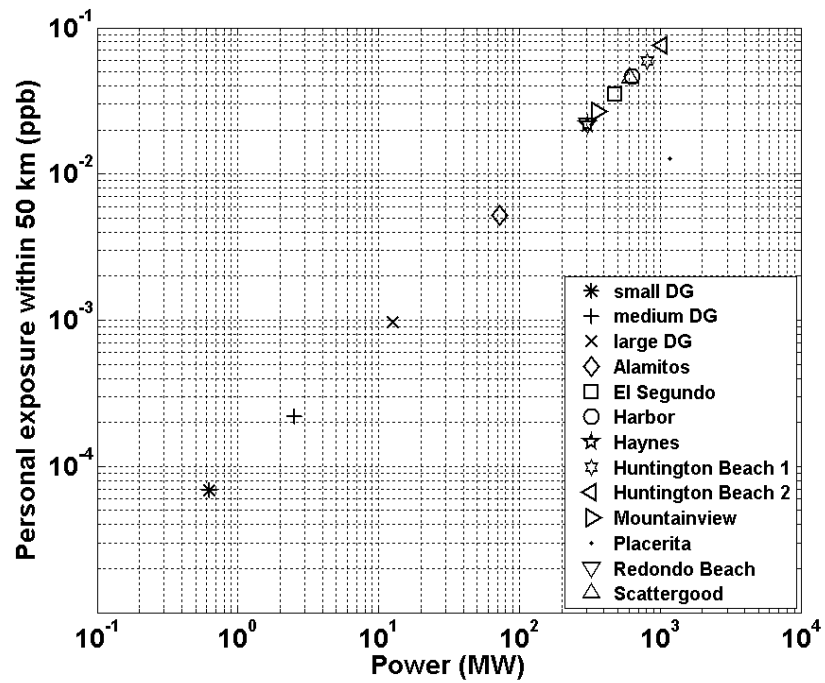

Emission rate dominates the $NO_x$ concentration from CGs

# Personal Exposure to $NO_x$ from Central Generators

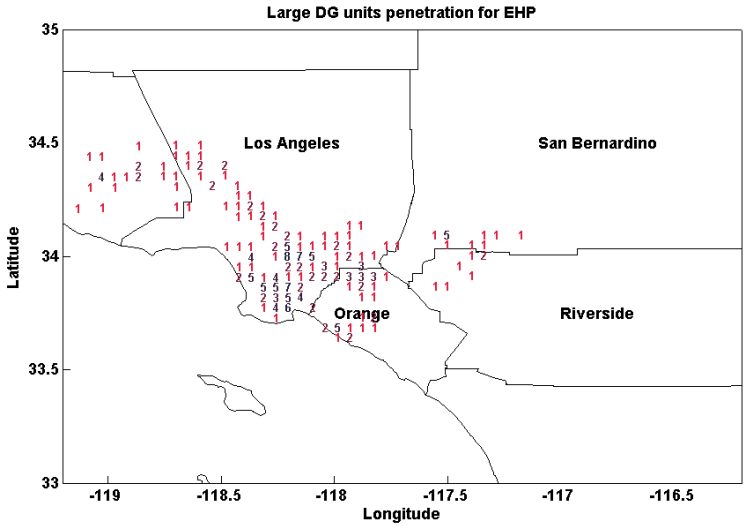
Fontana meteorological station
High wind speed

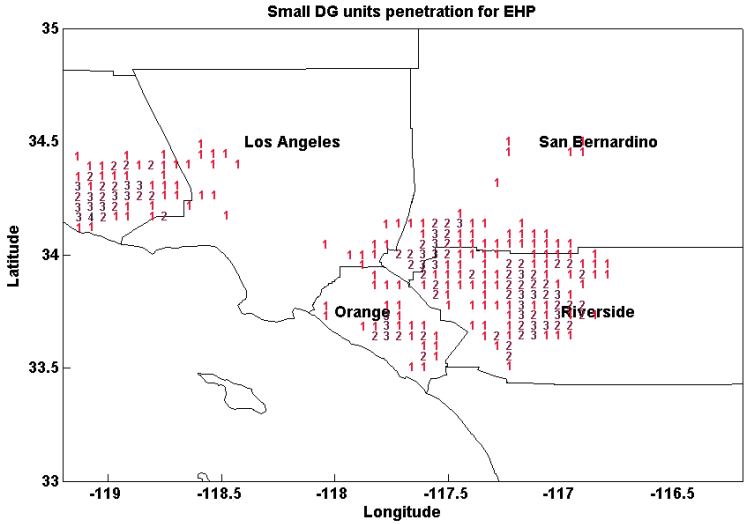


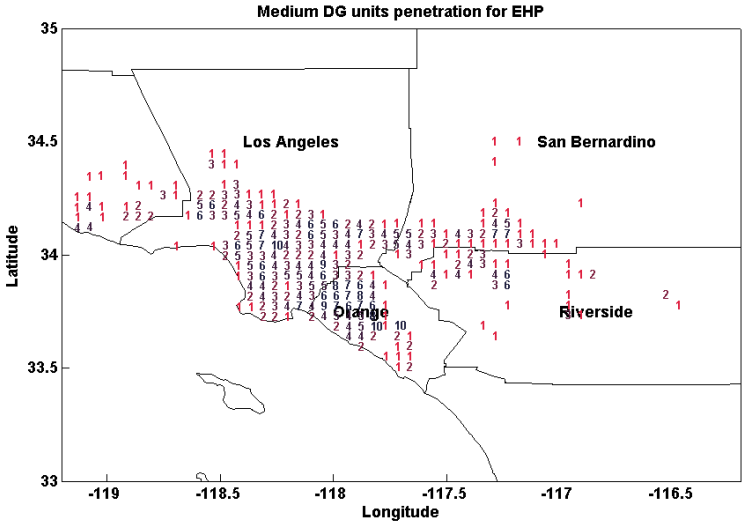

Pomona meteorological station
Low wind speed



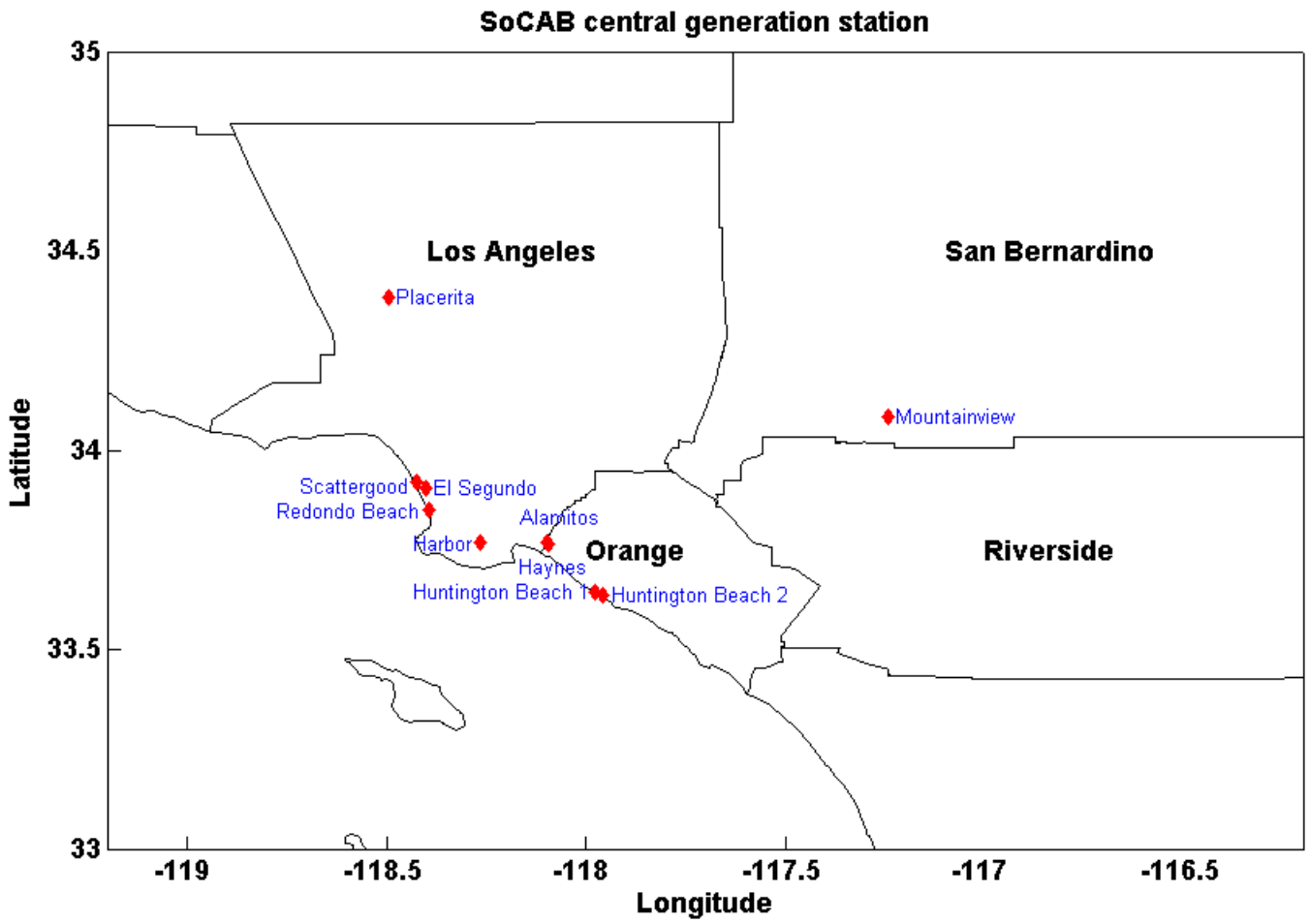
# DG Penetration in the South Coast Air Basin – Samuelsen et al. (2005)



# Existing CGs

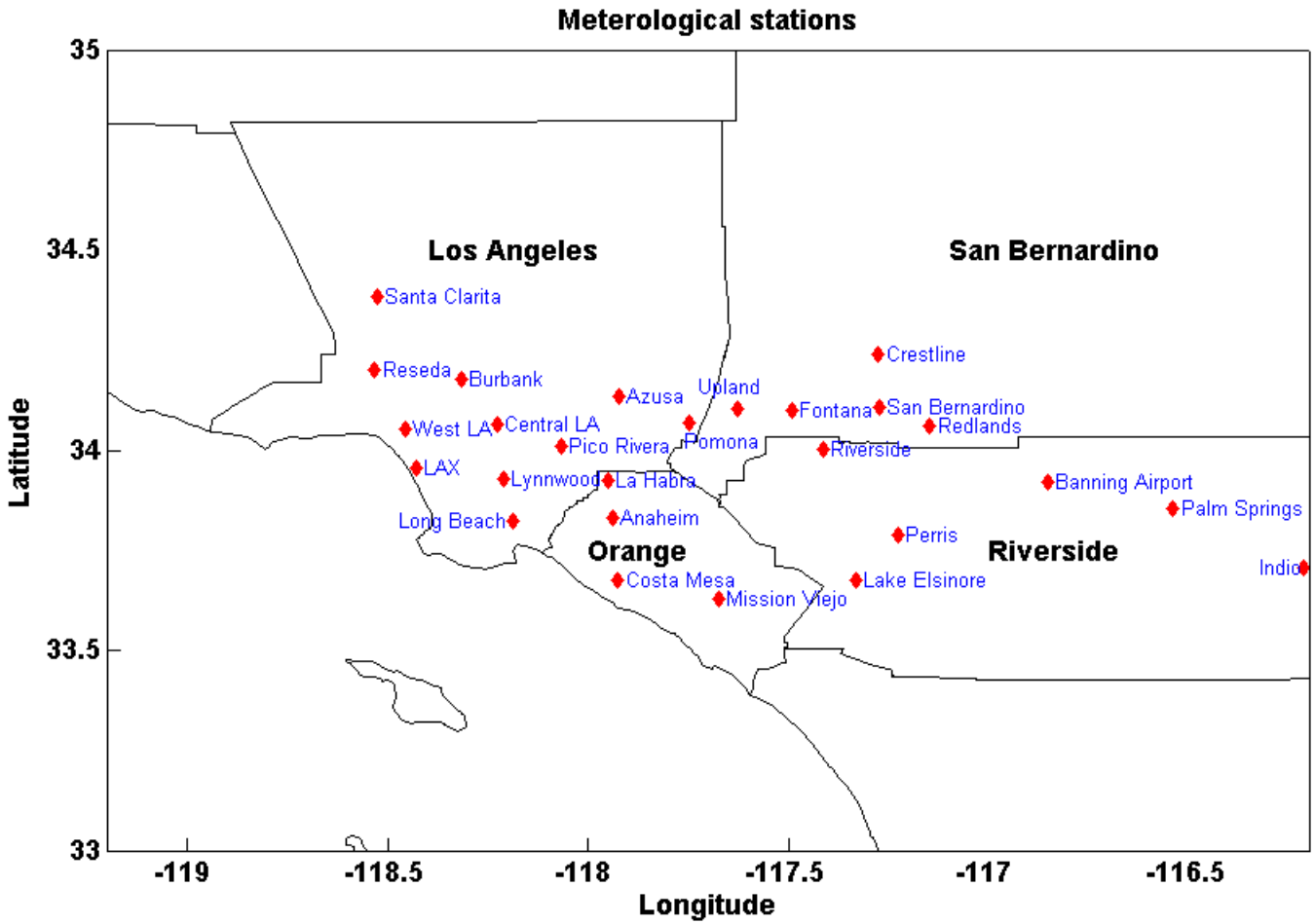


# Emission Scenarios

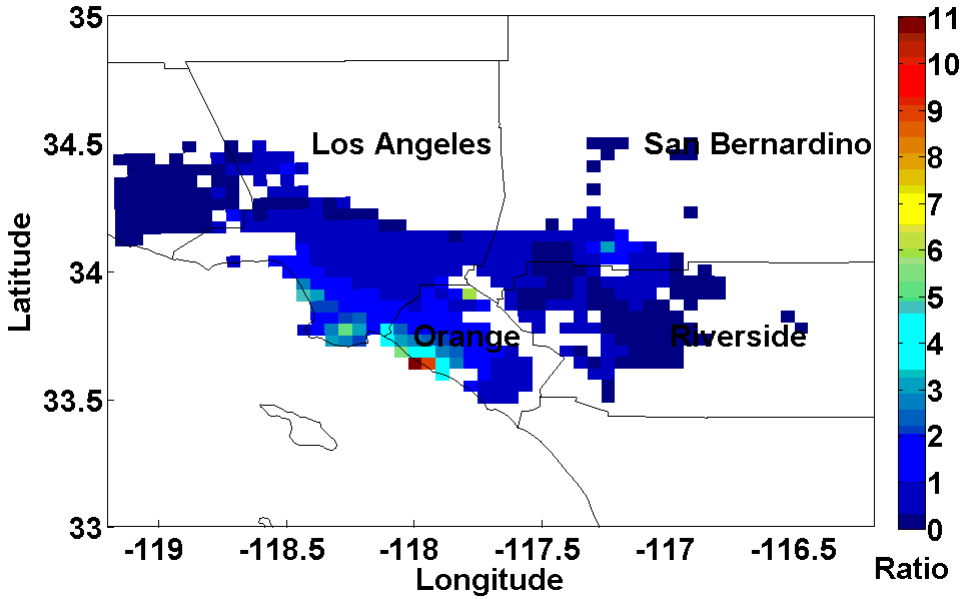
- Expand existing CGs to produce the extra power corresponding to the EHP scenario, 5781 MW
  - The increase in power at each CG is assumed to be inversely proportional to its current capacity
- Produce the extra power only through DGs

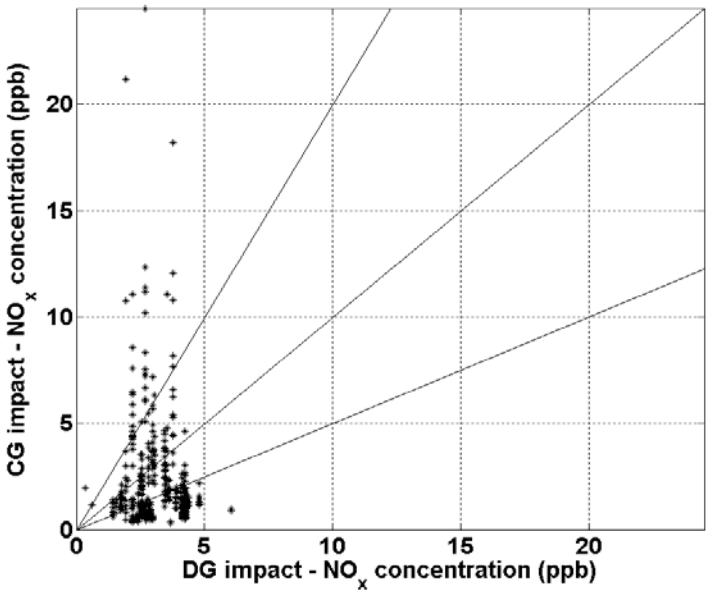
Emission factor for $NO_x$- 32 g/MWh, CA emission standard for new generators

# Meteorology, AQMD



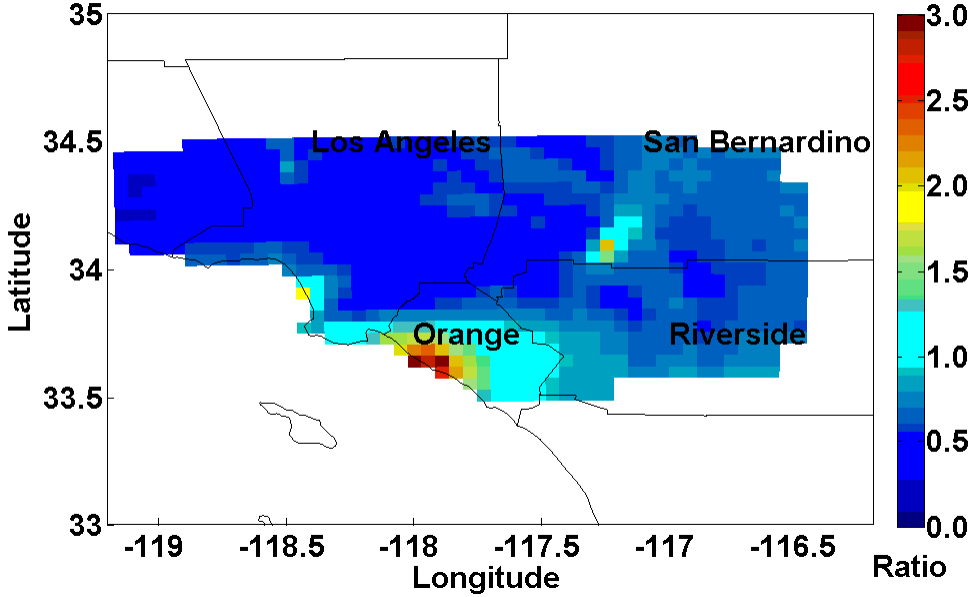
# Hourly Maximum Concentration-CG/DG Ratios

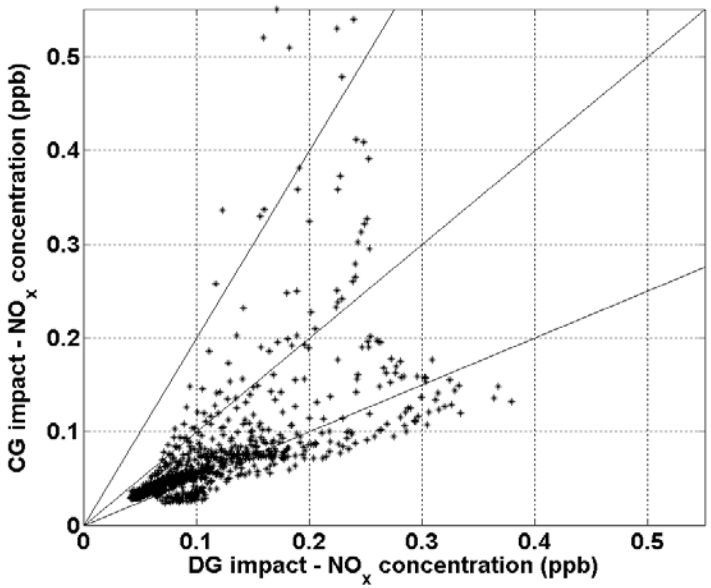



Peak hourly maximum concentration is reduced from 24.5 ppb to 6.0 ppb, if extra power is produced by DGs instead of CGs.

# Annual Concentration-CG/DG Ratios

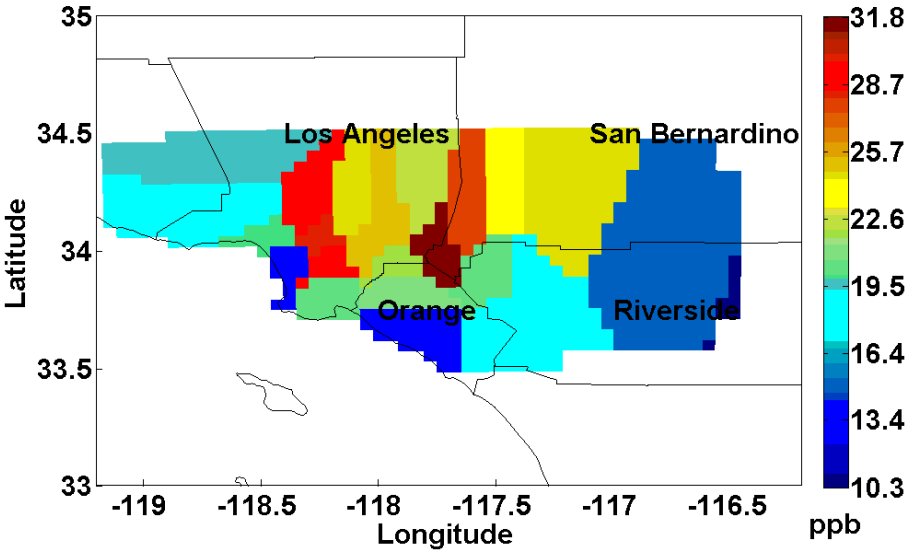


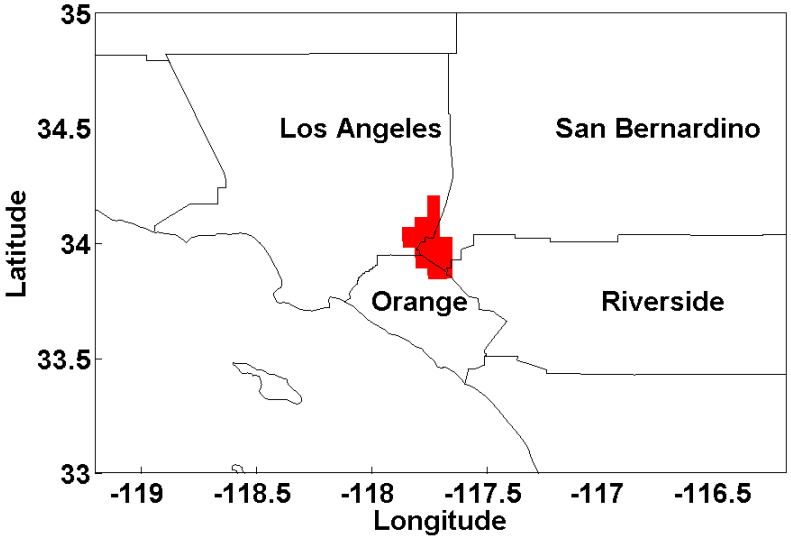

For about half of the basin, the air quality impact of the CG scenario is a factor of 0.5 smaller than that of the DG scenario

# 2007 annually averaged $NO_2$ concentration

2007 annually averaged $NO_2$ concentrations

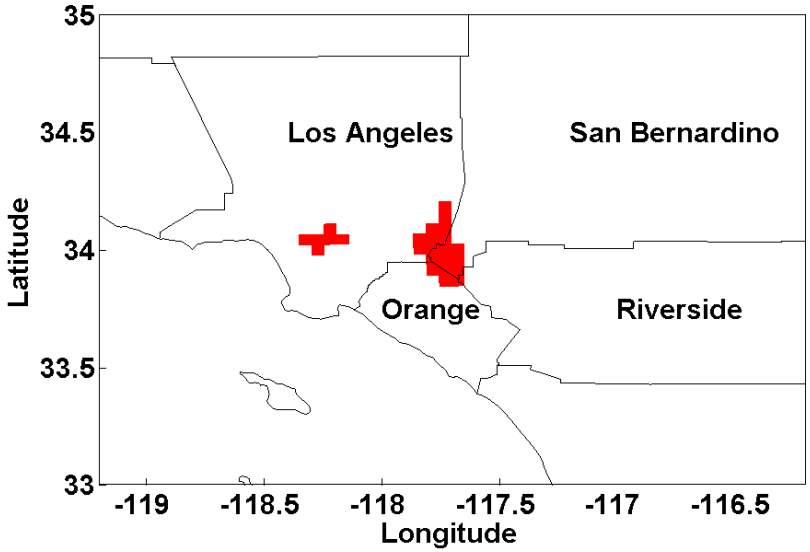



Locations which violated CA $NO_2$ standard (30 ppb)

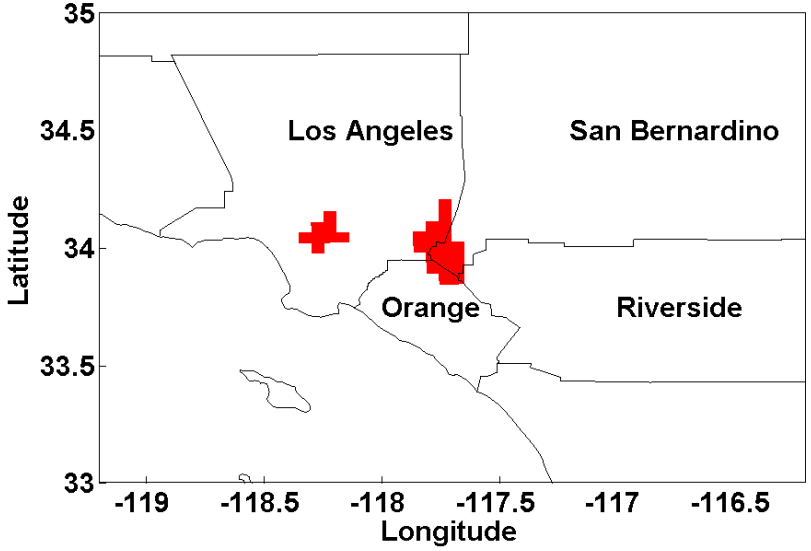


# Impacts on Air Quality of Emission Scenarios

Locations above CA $NO_2$ standard, CG scenario




Locations above CA $NO_2$ standard, DG scenario




Assuming all $NO_x$ is converted to $NO_2$

# Major conclusions

- Hourly maximum $NO_x$ nominal concentrations associated with most CGs are at least a factor of two higher than those of DGs because of the much higher emissions from CGs

- The maximum impact on hourly concentrations in the basin can be reduced from 24.5 ppb to 6.0 ppb if DGs rather than CGs are used to generate power

- The grid averaged annual concentrations are generally higher than those from the CG scenario over most of the basin

- Future DG penetration into the SoCAB will add an annual average of about 0.1 ppb to the existing level of about 20 ppb in the basin while expanding existing CGs will add about 0.05 ppb to the existing level. The impact of DG penetration is likely to be smaller if their emissions are offset by the decrease in boiler emissions if waste heat from the DGs is captured

# Secondary Conclusions

- The personal exposure due to both DGs and CGs is insensitive to the effective stack height. It increases with the increase of the power and the decrease of the mean wind speed. The personal exposure due to most individual CGs is at least a factor of twenty higher than that due to DGs because of much higher emissions from CGs

- Waste heat recovery is likely to increase the maximum ground-level concentrations in the vicinity of a DG especially when the average winds are low. This conclusion is relevant to locating DGs in urban areas where wind speeds are typically low because of sheltering by buildings

# Acknowledgements


- Undergraduate students who participated in the field study
- Marla Mueller and Nicole Davis for suggesting the comparison between CGs and DGs, and reviewing the results