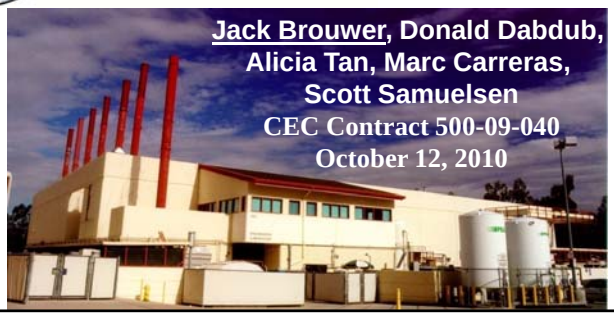
Air Quality and GHG Impacts of Renewable Power in CA

ADVANCED POWER & ENERGY PROGRAM
UNIVERSITY of CALIFORNIA · IRVINE

Energy & Air Quality Seminar
California Energy Commission



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Outline

- Problem Statement
- Goal and Objectives
- Approach
- Initial Work
- Summary

Problem Statement

- The air quality and greenhouse gas (GHG) emissions impacts of meeting RPS goals in California are uncertain.
- Power system and wholesale market must remain stable and viable, which requires consideration of:
  - Transmission & distribution constraints
  - Complementary energy storage, demand response, dispatchable generation, smart grid, and other technologies
- Determining air quality and GHG impacts requires realistic implementation scenarios for renewable power & complementary technologies
  - Spatial and temporal resolution
  - Simulation of atmospheric chemistry and transport
- To-date no in-depth study that includes all of these considerations has been conducted to assess air quality and GHG impacts of meeting RPS goals in California

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Goal and Objectives

Goal:

- **Identify and analyze renewable power implementation scenarios with enabling technologies & demand response strategies that can maintain system reliability and optimize the impact on air quality and greenhouse gas emissions in California.**

Objectives (6 total):

1. **Review existing relevant literature and previous studies**
2. **Organize and conduct stakeholder interviews and a workshop focused on coordination with current and previous efforts including at the California Energy Commission , *ARB, CAISO, WECC* and NREL**

Goal and Objectives

Objectives (continued):

3. **Develop future more renewable grid implementation scenarios (detailed electric sector modeling)**
4. **Spatially and temporally allocate emissions from each scenario**
5. **Simulate air quality impacts of each scenario with a detailed atmospheric chemistry and transport model**
6. **Develop life cycle GHG emissions inventories for each scenario**

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Approach

Task 2 – Literature Review and Previous Studies

Goal: review relevant literature and previous studies

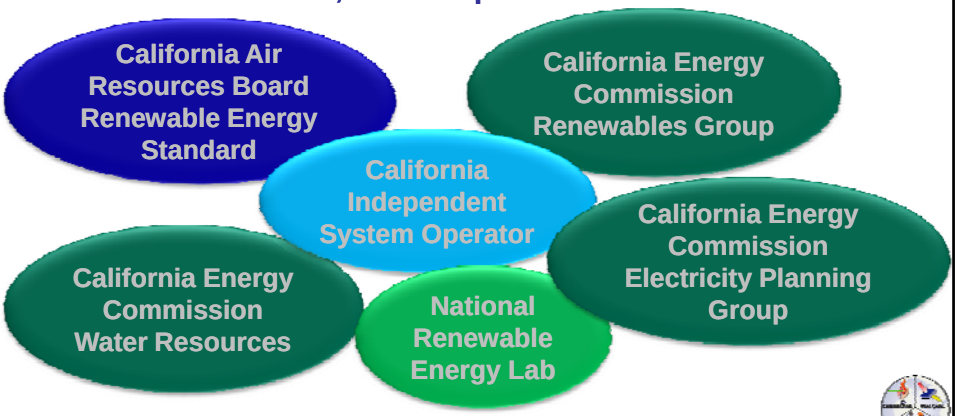
- **current grid infrastructure and technologies, future grid infrastructure and technologies, renewable energy technology deployment, complementary energy storage, distributed generation (DG), and other power plant deployment, electric vehicle deployment, and smart grid technologies.**

- **Conduct a thorough and systematic literature review**
- **Collect information on current & future grid focused upon renewables & complementary technologies**
- **Collect information on current grid emissions and expected future emissions**
- **Collect information for life cycle analysis of power generation including power plants & grid infrastructure**

Approach

Task 2 – Literature Review and Previous Studies

- Wealth of directly applicable previous studies [1-12] for "Scenario Development"
- Agreement of groups to work with us to develop and evaluate scenarios, for example:



Approach

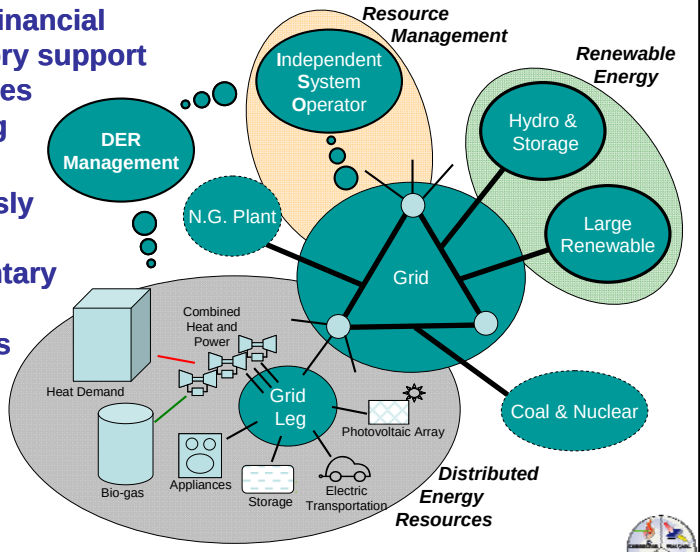
Task 3 – Project Advisory Committee (PAC) & Workshop

- Plan for and conduct biannual PAC meetings
- Work with the Energy Commission to plan for, organize and host a one-day workshop in *Sacramento*
  - Document contributions of stakeholders during the workshop
  - Address suggestions of stakeholders in the workshop
  - Use feedback from stakeholders to refine the project approach
- PAC members considered from, but not limited to:
- *State and local agencies* (e.g., CEC, CAISO, *CPUC,* CARB, SCAQMD, SJVAPCD, BAAQMD, SMAQMD, SDAPCD)
- *Industry* (e.g., SCE, PG&E, SDG&E, GE, GM, Ford, Toyota),
- *Environmental groups* (e.g., NRDC), and
- WECC
- DOE national labs, Others?

Approach

Task 4 – Renewable Implementation Scenario Development

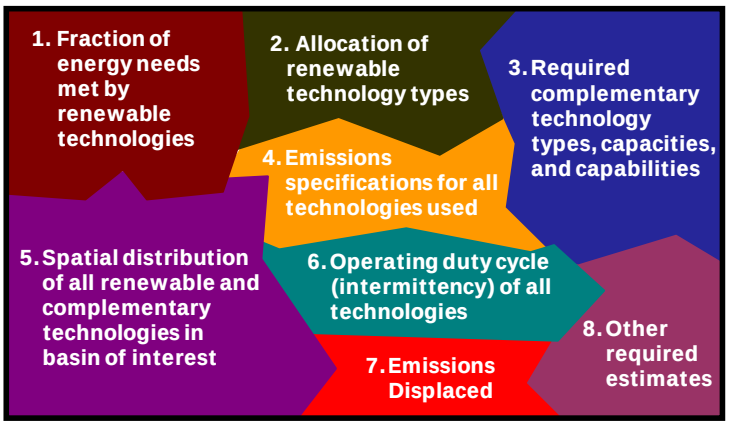
- RPS goals, financial and regulatory support for renewables are changing the grid
- Few rigorously consider "complementary technology" requirements
- Spatial & temporal resolution
- Evolution is complex



Approach

Task 4 – Renewable Implementation Scenario Development

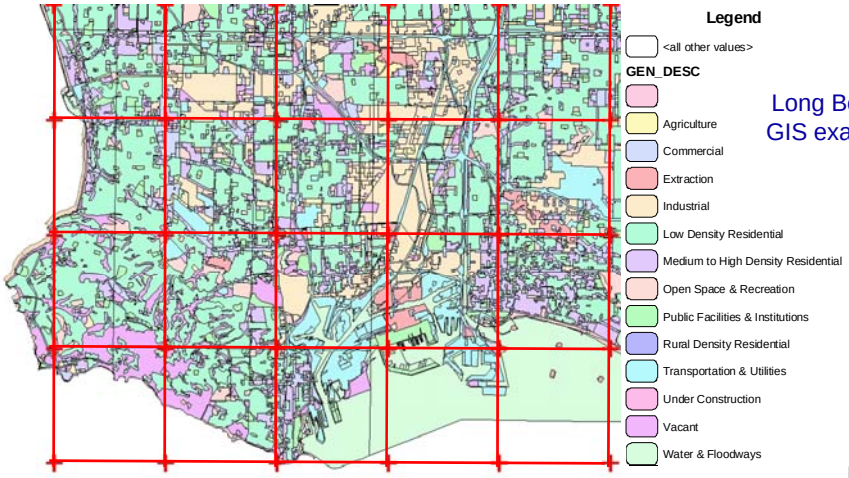
- Scenarios primarily based upon previous studies
- Consistent with workshop & PAC
- Minimum requirements for specification of a scenario



Approach

Task 5 – Spatial and Temporal Emissions Characterization

- **Methodology for *spatial and temporal resolution* previously developed [Medrano et al., 2008]**



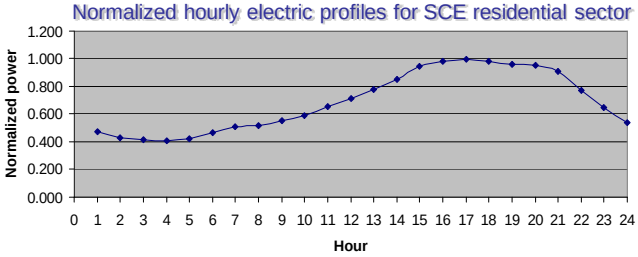
Long Beach GIS example

Approach

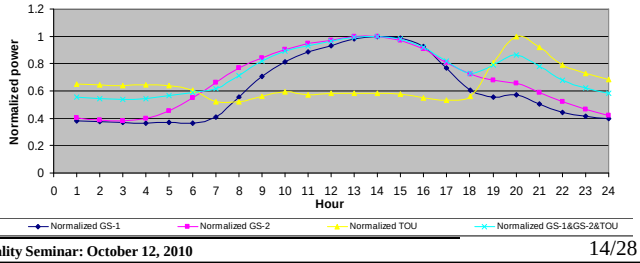
Task 5 – Spatial and Temporal Emissions Characterization

- **Sample temporal allocation, SCE residential & commercial**

Normalized hourly electric profiles for SCE residential sector



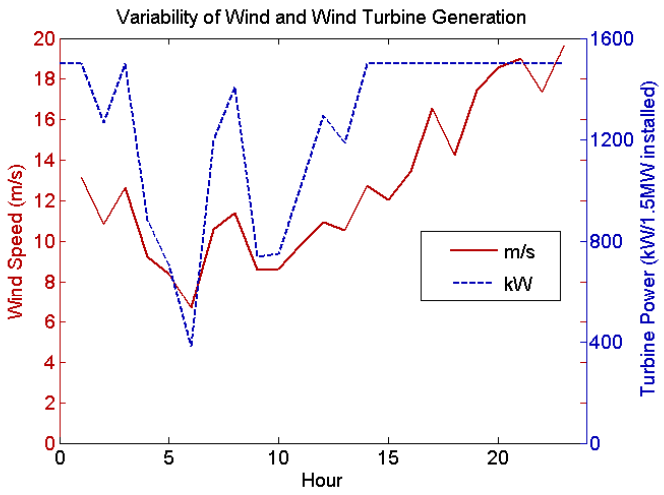
Normalized hourly electric profiles for SCE commercial sector



Approach

Task 5 – Spatial and Temporal Emissions Characterization

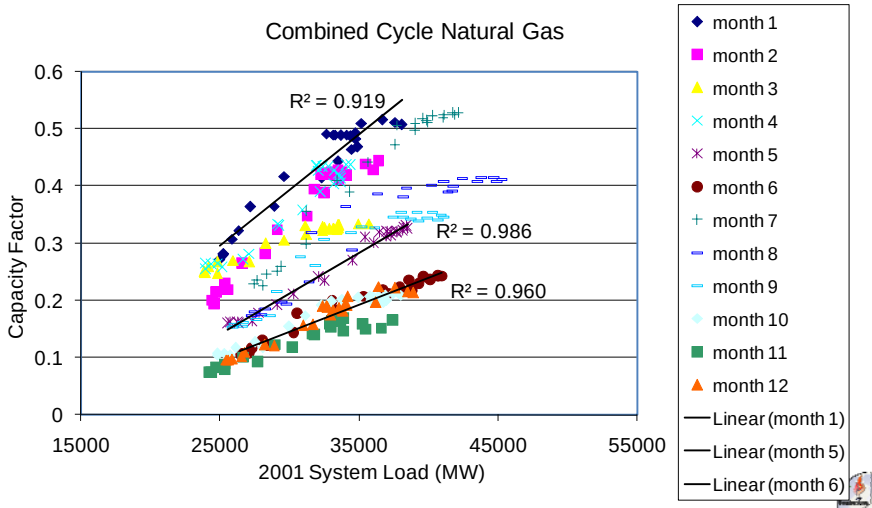
- **Example wind power dynamics – UCI Monte Carlo model**



Approach

Task 5 – Spatial and Temporal Emissions Characterization

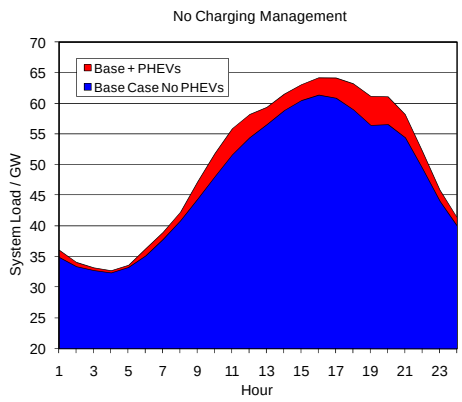
- **Example Gas Turbine Dispatch – UCI GT dispatch model**

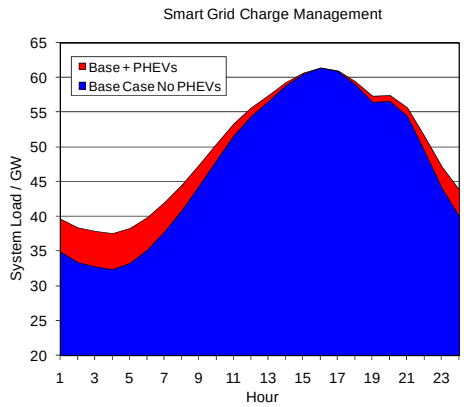


Approach

Task 5 – Spatial and Temporal Emissions Characterization

- **Example new complementary technology – PHEV**



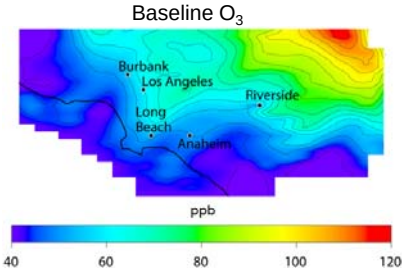


Approach

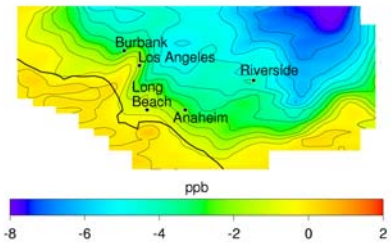
Task 6 – Air Quality Impacts Modeling

- **Examples from previous UCI-CIT model**

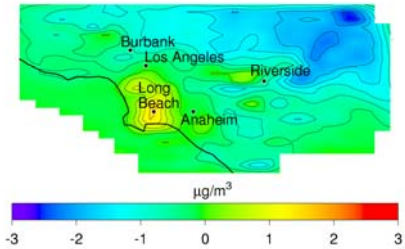
Baseline O_3



ΔO_3 (Scenario – Baseline)



$\Delta PM_{2.5}$ (Scenario – Baseline)



Approach

Task 7 – Greenhouse Gas Emissions Assessments

- Characterize grid technologies with respect to life cycle GHG emissions
  - Include carbon dioxide, methane, and nitrous oxide emissions factors for each component of the life cycle
- Compile & analyze data to assure a consistent basis
- Add grid technologies and established emission factors to the UCI Preferred Combination Assessment (PCA) model
- Use the PCA framework to allow for systematic parametric variation of the technologies affecting GHG emissions to produce life cycle GHG emissions for each scenario
- Compare the PCA GHG emissions results to those of the EPRI electric sector model, where applicable

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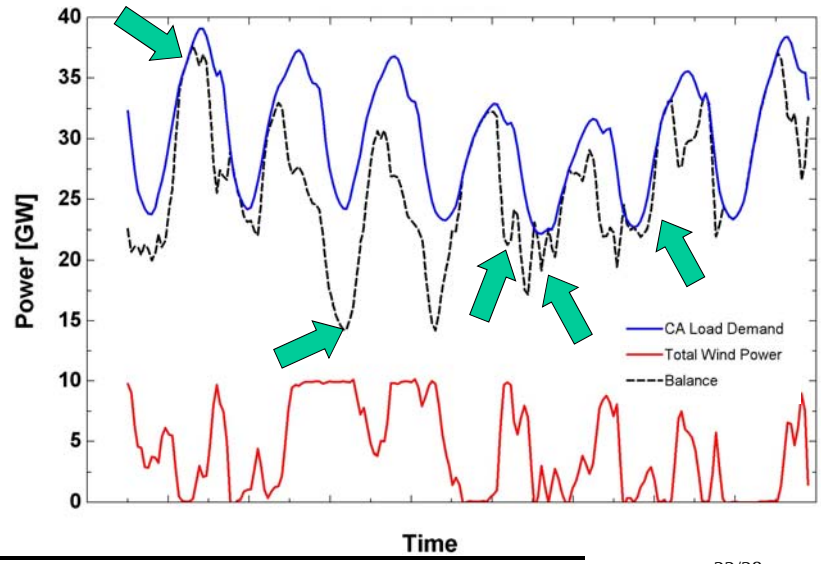
Initial Work

- **Task 2 – Literature and previous study review**
  - Renewable scenarios
  - Complementary technologies
  - Dynamics of renewable power technologies
  - Spatial and temporal emissions allocation methodology and tools
- **Task 3 – Project Advisory Committee (PAC) and workshop**
  - Identifying and contacting primary candidates
  - Looking for additional interest & candidates
  - Initial workshop ideas

Initial Work

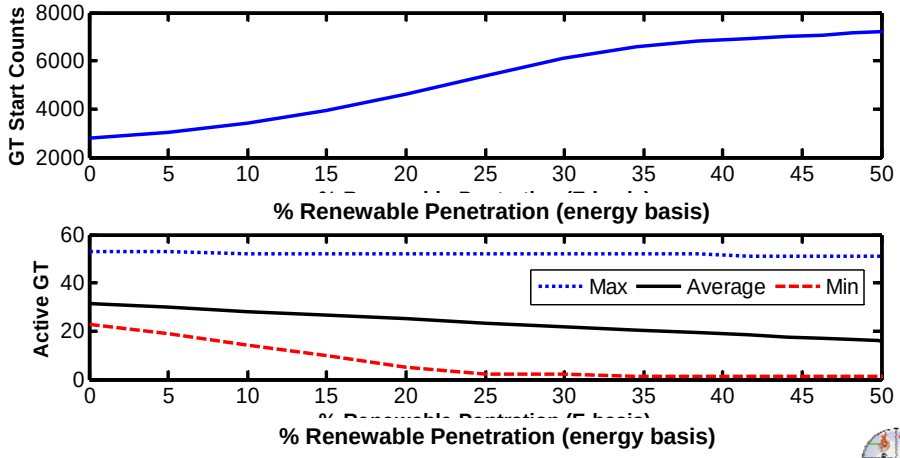
Task 4 – Energy Deployment Model - 33% Wind Penetration



Initial Work

Task 4 – Dynamic California Power Simulations (full year)

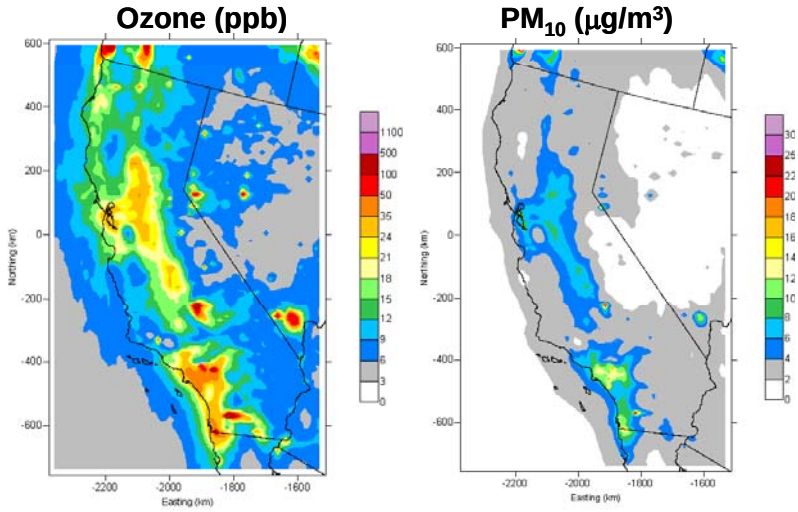
- **Effect of wind intermittency on complementary Gas Turbine operations**



Initial Work

Task 6 – Garnering Emissions, Meteorology, Tools (CARB)

- **Community Multiscale Air Quality model (CMAQ)**



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Summary

- **Outstanding team with energy conversion, spatial & temporal emissions allocation, and atmospheric chemistry and transport modeling expertise**

Initial work

- **Literature and previous studies review**
- **PAC and Workshop preparations**
- **Renewable & Complementary technology scenarios**
- **Tools for spatial and temporal allocation**
- **Data sets and tools for air quality modeling (CARB)**

References

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3) Western Wind and Solar Integration Study Update, National Renewable Energy Laboratory, Presentation at the WestConnect Planning Meeting [Lew, 2008]
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8) Intermittency Analysis Project: Summary of Final Results, under CEC contract 500-2007-081 [Porter et al. 2007]
9) Creating the Dataset for the Western Wind and Solar Integration Study (U.S.A.). 7th International Workshop on Large Scale Integration of Wind Power and on Transmission Networks for Offshore Wind Farms [Potter et al., 2008]

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12) Medrano, M., Brouwer, J., Carreras, M., Rodriguez, M.A., Dabdub, D., and Samuelsen, G.S., A Methodology for Developing Distributed Generation Scenarios in Urban Areas using Geographical Information Systems, International Journal of Energy Technology and Policy, Vol. 6, No. 4, pp. 413–434, 2008