# Assessment of the Emissions and Energy Impacts of Biomass and Biogas Use in California


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*ARB Research Seminars*

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# Outline

- **Overview**
- **Biomass Resources**
- **Emissions Impacts of Biomass Use**
- **Air Quality Impacts of Biomass Use**
- **Conclusions and Future Work**

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# Use of Biomass

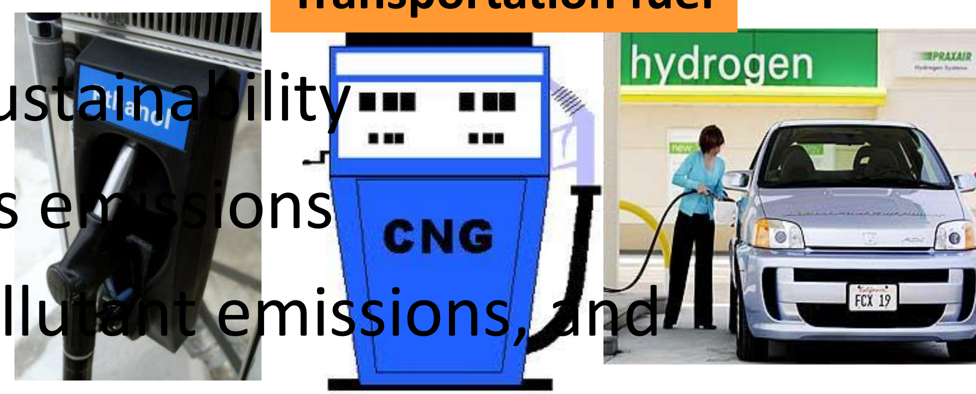
- **What are the biomass resources?**
  - Types of biomass available
  - Co-location of biomass installations with power and fuel infrastructure
- **How are biomass resources used?**
  - Biopower production
  - Biofuel production:  bio CNG, Ethanol
- **What are the potential air quality and greenhouse gas impacts?**

# Biomass Uses

Biomass

Biopower

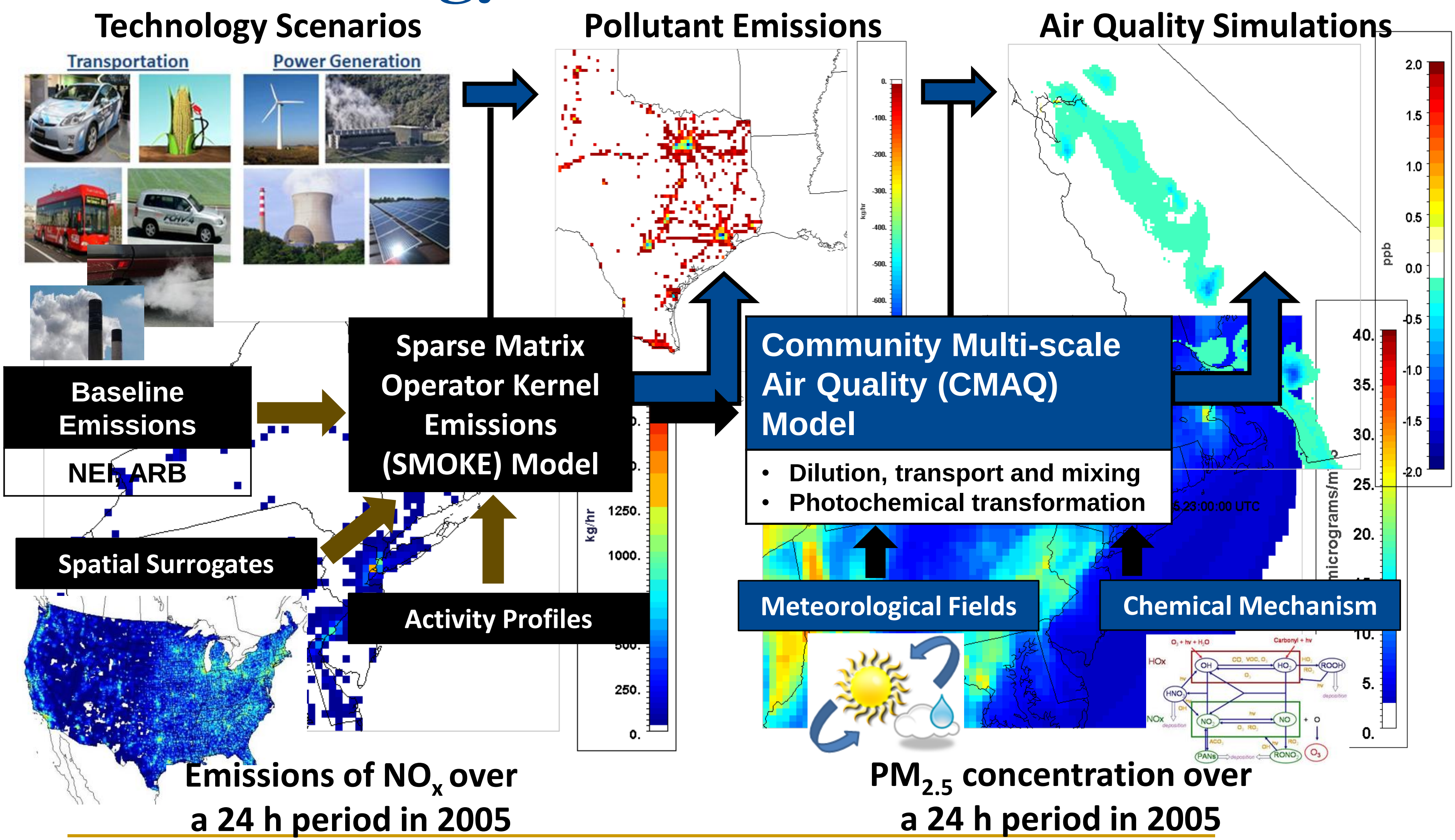
Transportation fuel




Biomass use impacts:

- Contributes to energy sustainability
- Reduces greenhouse gas emissions
- Contributes to direct pollutant emissions, and secondary air pollutants

# Methodology

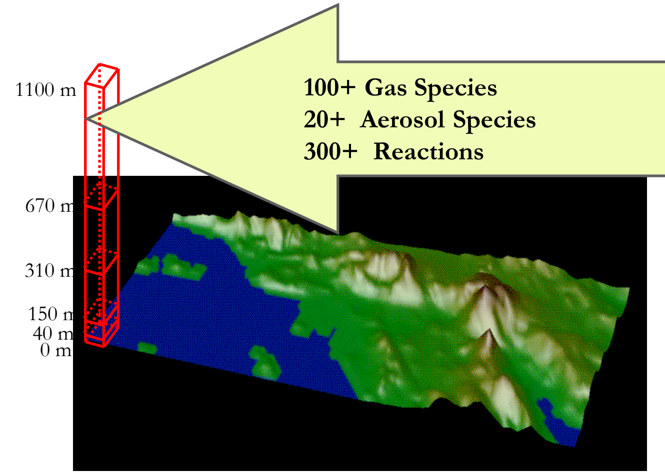


# Project Overview

**Biomass scenarios**

**Determine spatial/temporal emissions**

**3-D air quality model**




**Determine spatial/temporal AQ impacts**

**Air quality impacts**


**Determine GHG co-benefits**

# Policy Drivers for Research

- **Laws and Regulations**
  - **AB 32: Global Warming Solutions Act**
  - **SB X1-2: Renewable Portfolio Standard**
  - **AB 1900: Renewable Energy Resources: Biomethane**
  - **AB 118: California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act**
  - **AB 341: Mandatory Commercial Recycling**

# Policy Drivers for Research

- Policies/Plans
  - Governor Brown's Clean Energy Jobs Plans
  - Low Carbon Fuel Standard
  - Integrated Energy Policy Report
  - Sustainable Freight Transport Initiative

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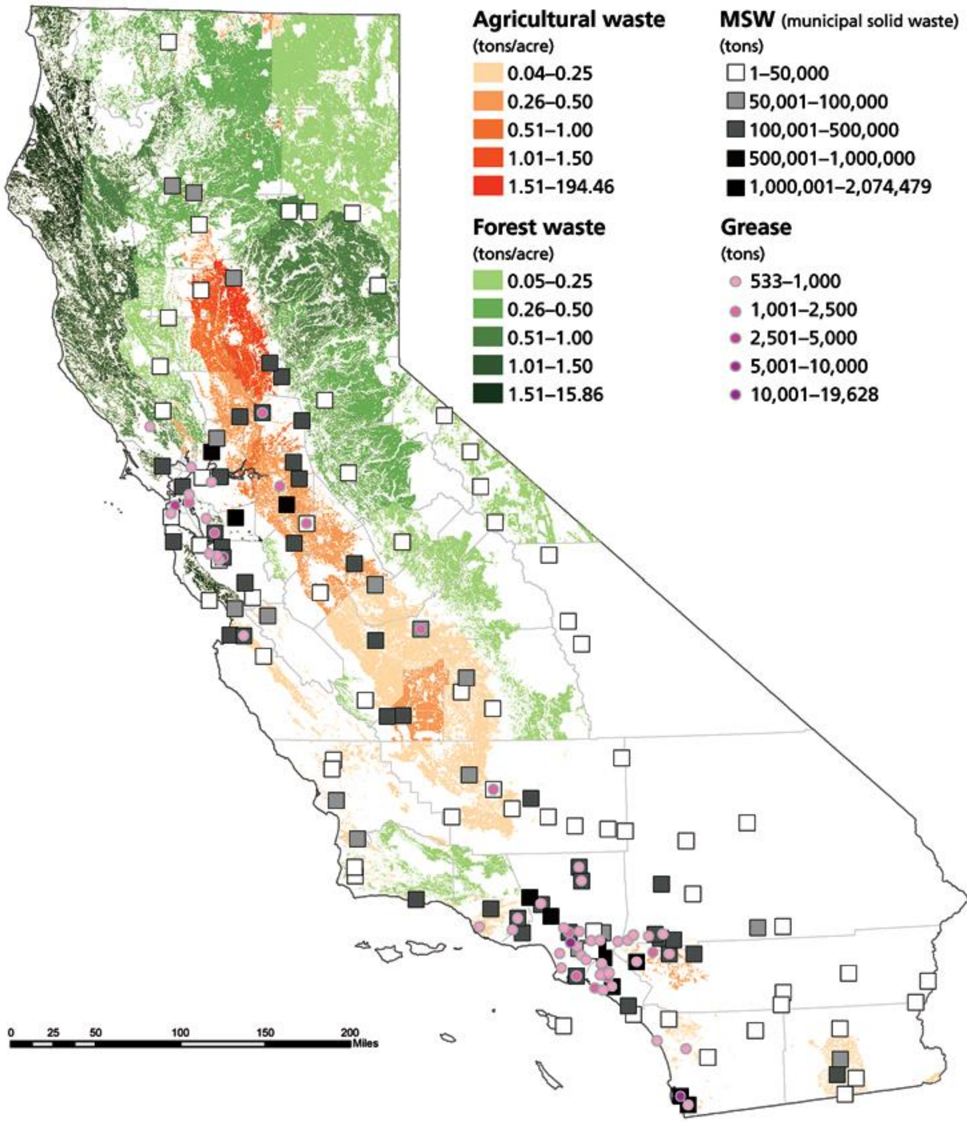
# Overview of California Biomass Resources




*Tittmann et al. 2008*

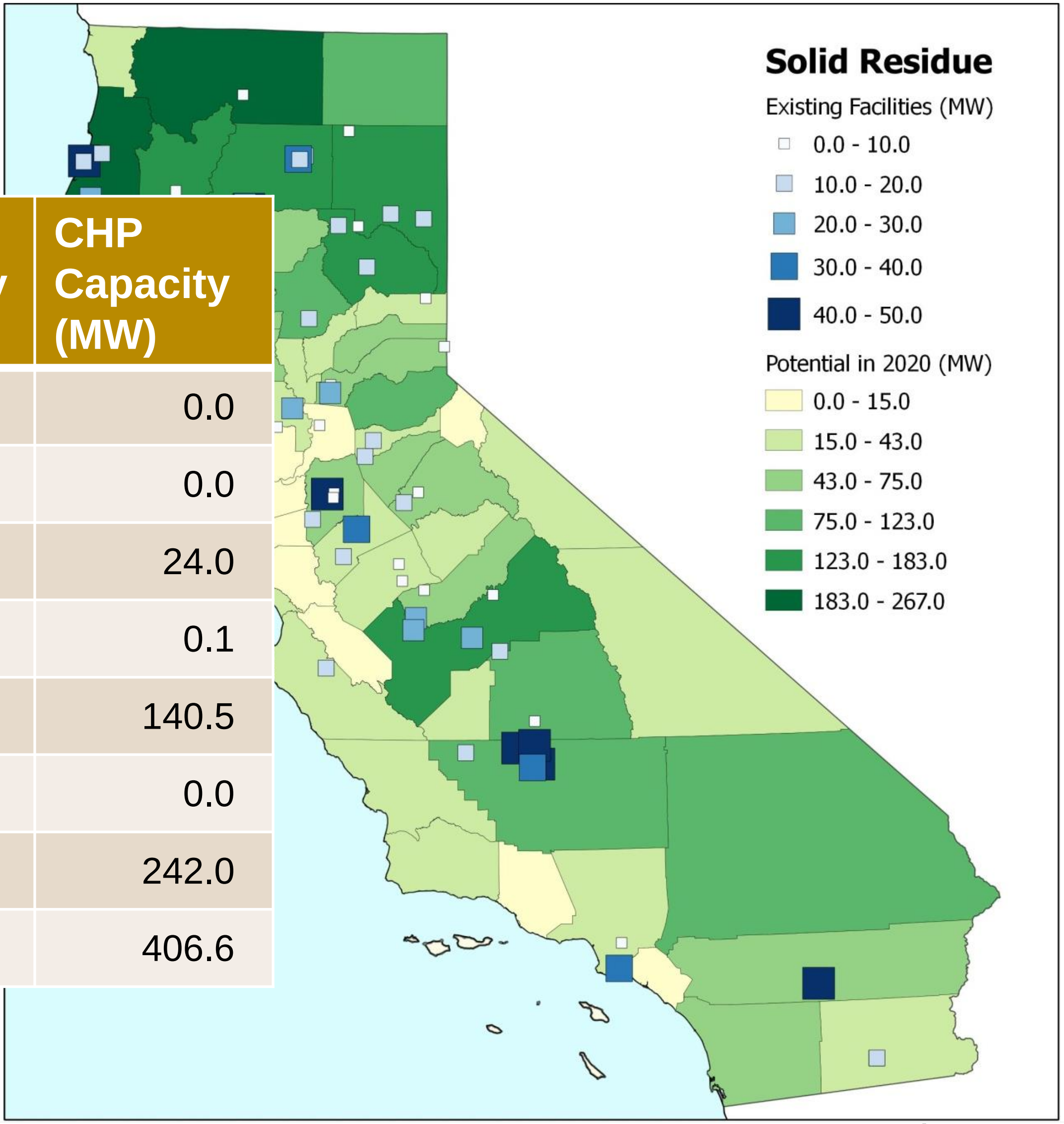
**California great biomass resources (CBC, 2011):**

– Biopower current capacity: 1200 MW

– Potential additional capacity: > 4,000 MW

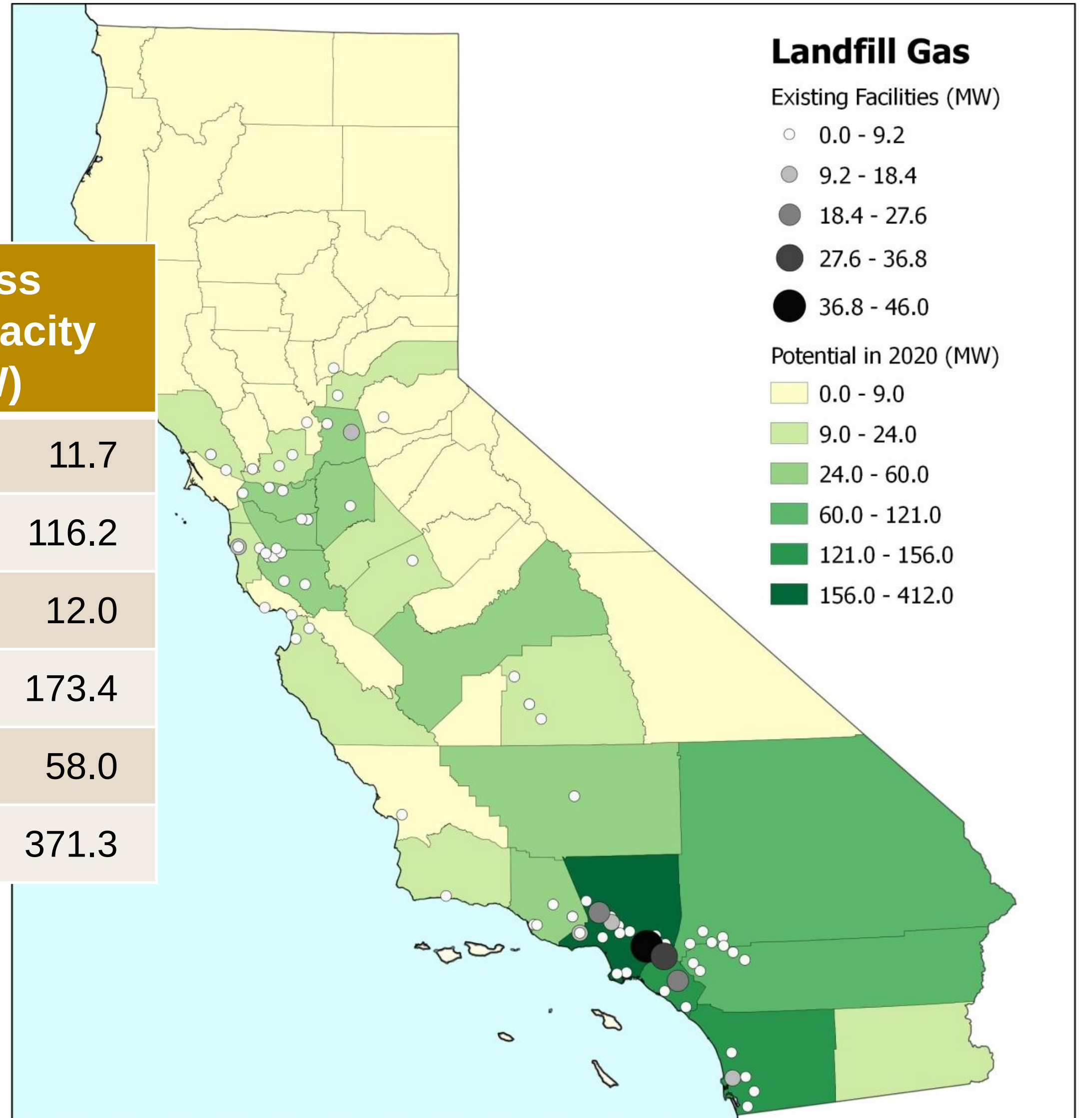
# Solid Residue Potential Location

| Technology | Net Capacity (MW) | CHP Capacity (MW) |
|---|---|---|
| Bubbling Fluidized Bed | 125.5 | 0.0 |
| Circulating Fluidized Bed | 147.0 | 0.0 |
| Combustion Steam Cycle | 24.0 | 24.0 |
| Downdraft Gasifier | 0.6 | 0.1 |
| Stoker - Grate | 370.5 | 140.5 |
| Suspension Fired Boiler | 25.0 | 0.0 |
| Other | 419.5 | 242.0 |
| Total | 1112.1 | 406.6 |

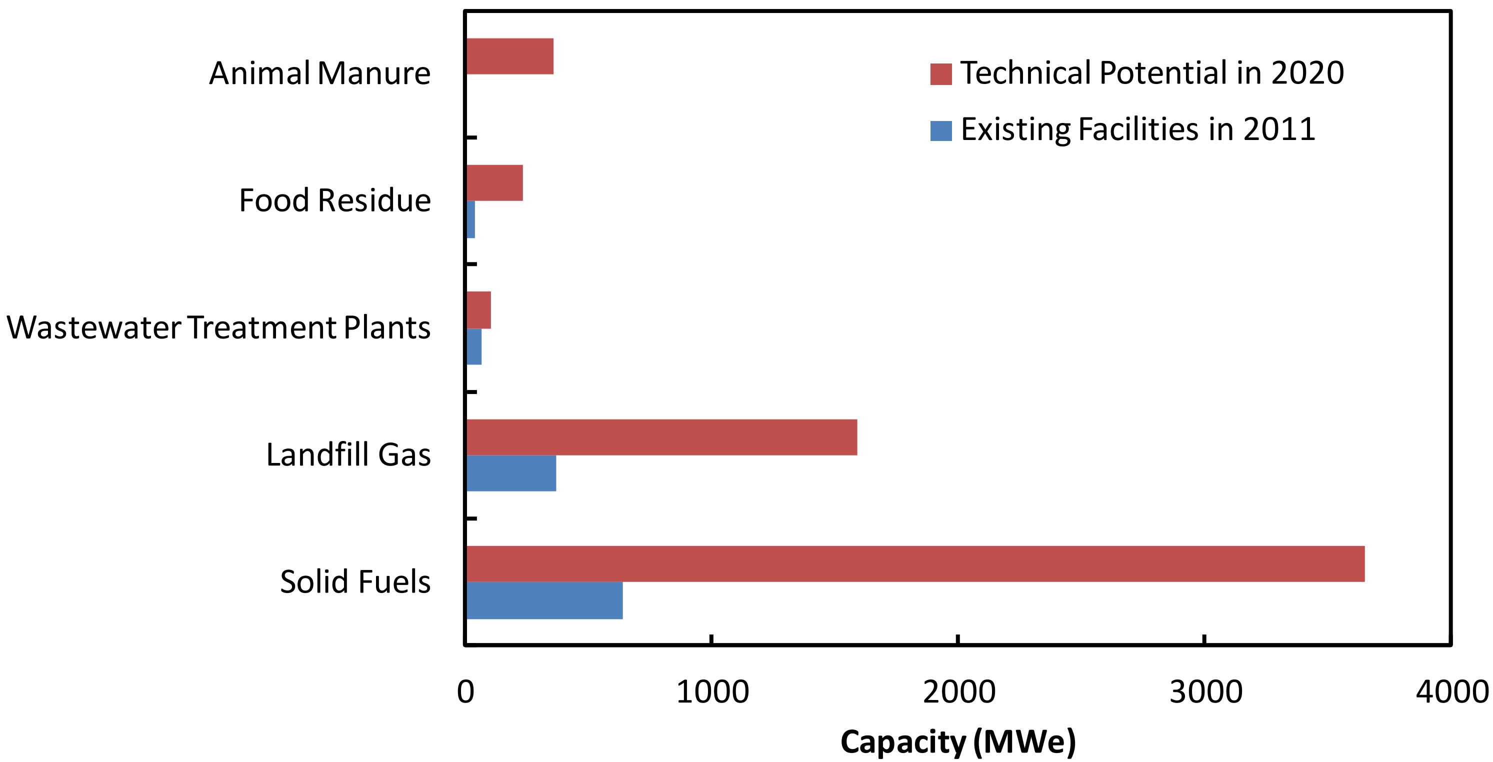


# Landfill Gas Potential Location

| Technology - Power | Gross Capacity (MW) |
|---|---|
| Gas and Steam Turbines | 11.7 |
| Gas Turbine | 116.2 |
| Microturbine | 12.0 |
| Reciprocating Engine | 173.4 |
| Steam Turbine | 58.0 |
| Total | 371.3 |



# Existing vs Technical Potential





Source: California Biomass Collaborative, 2011

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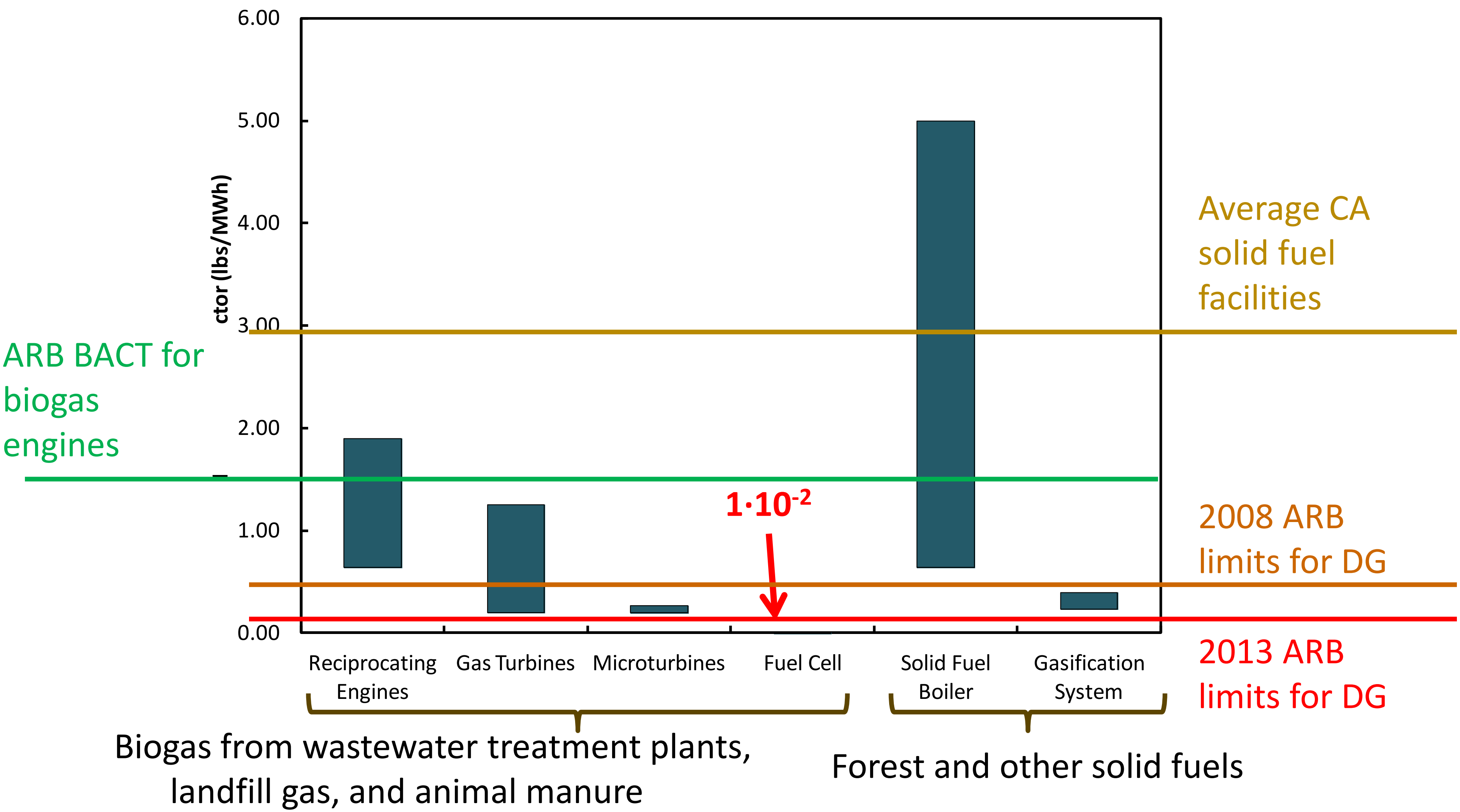
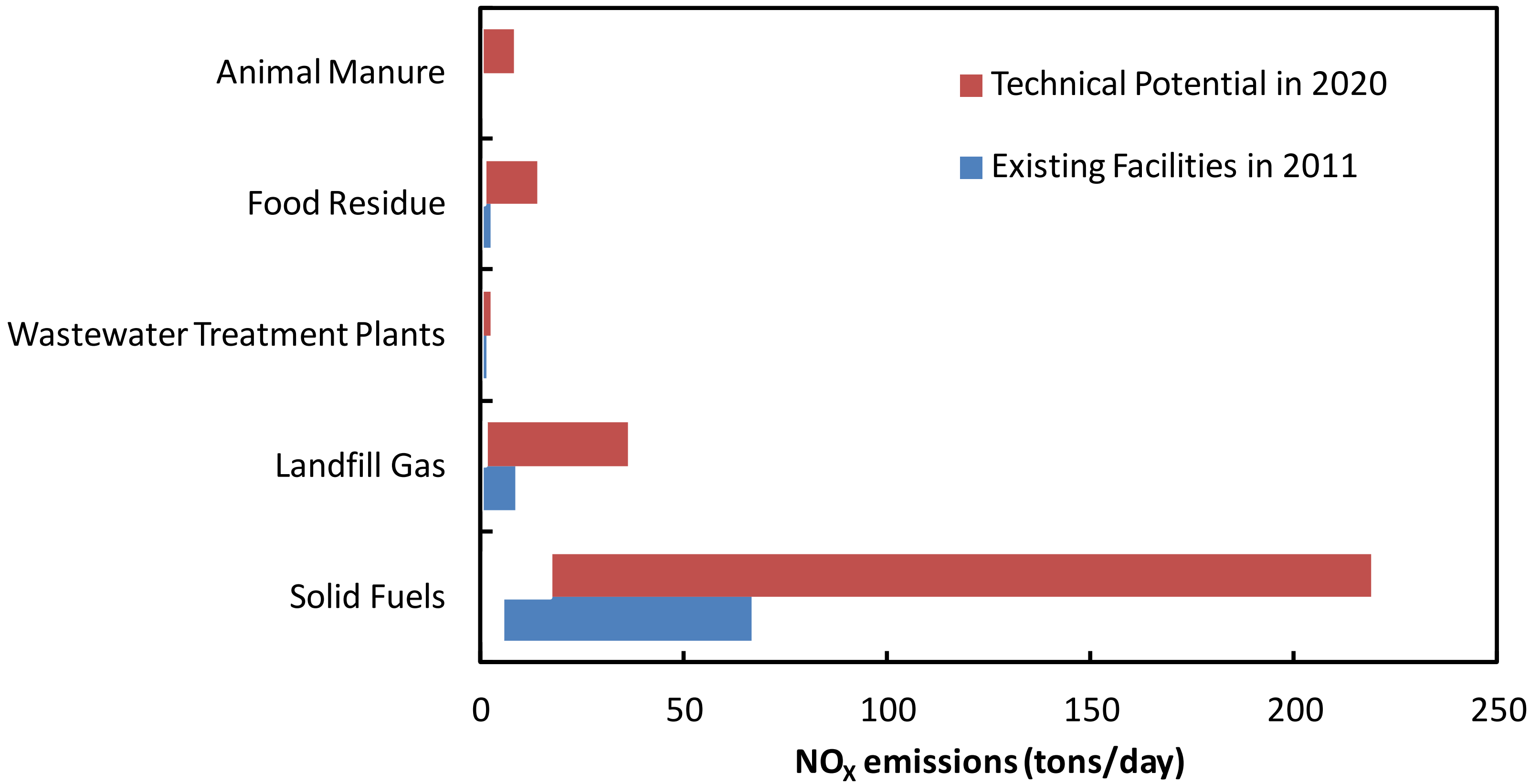
# Emission Factors



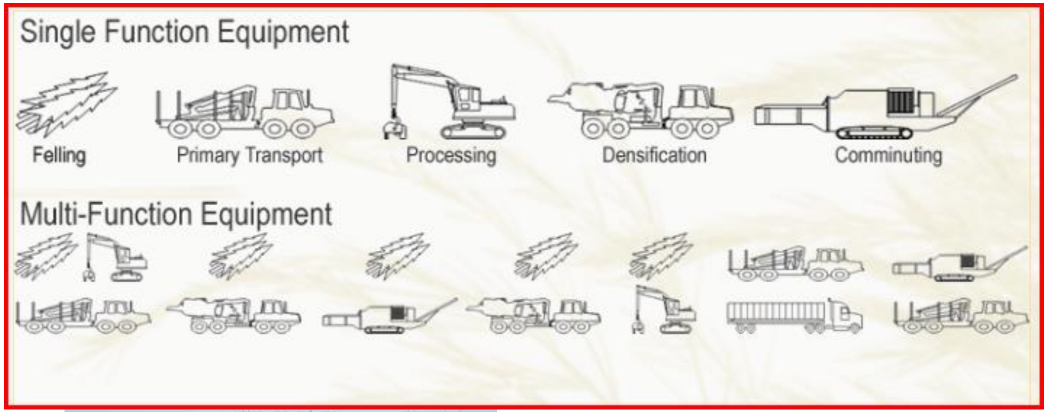
# Potential Emissions in CA

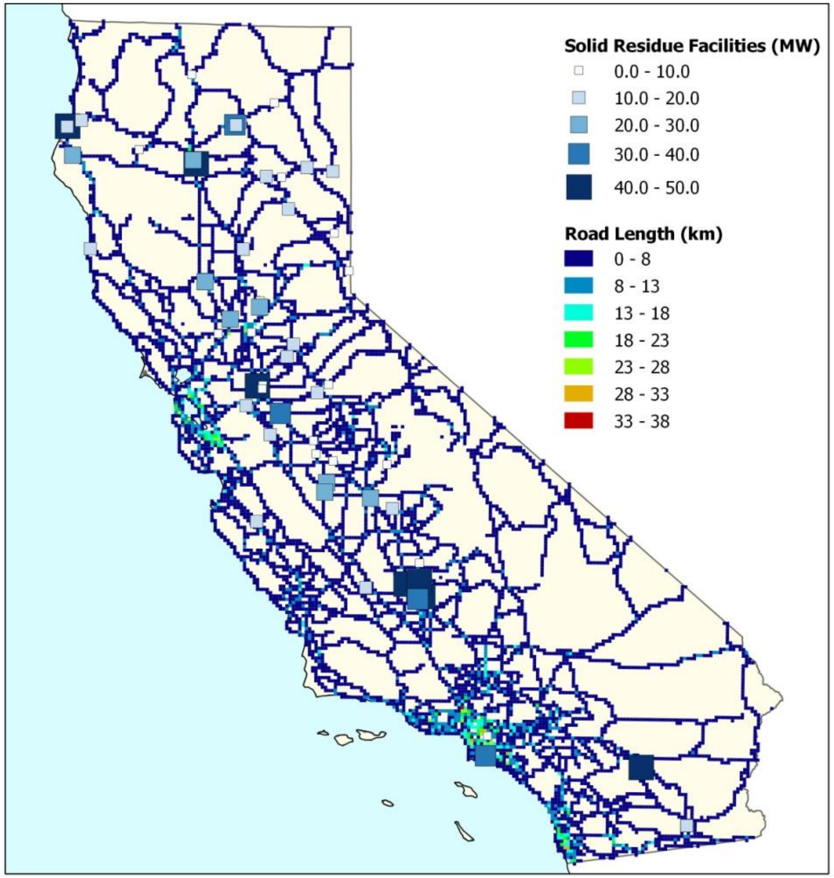



Biopower total $NO_X$ emissions from in CA in 2011 = 10 tons/day (EPA)

Total $NO_X$ emissions in CA in 2012 = 2105 tons/day (ARB)

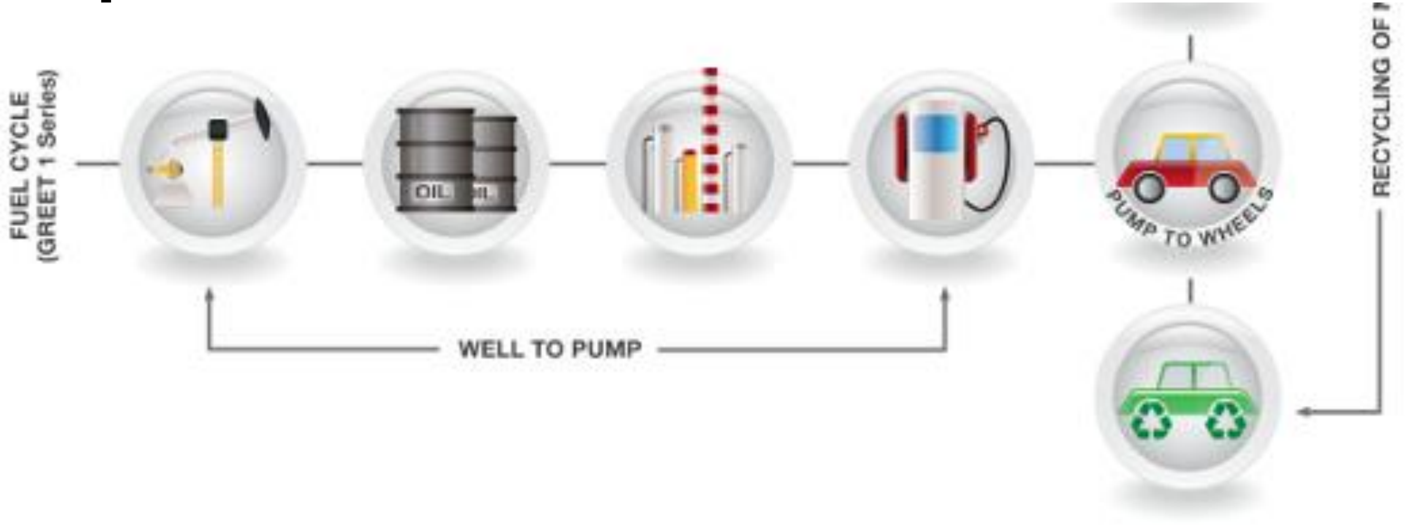
# Collection and Transport



# Analysis of Full Cycle Emissions

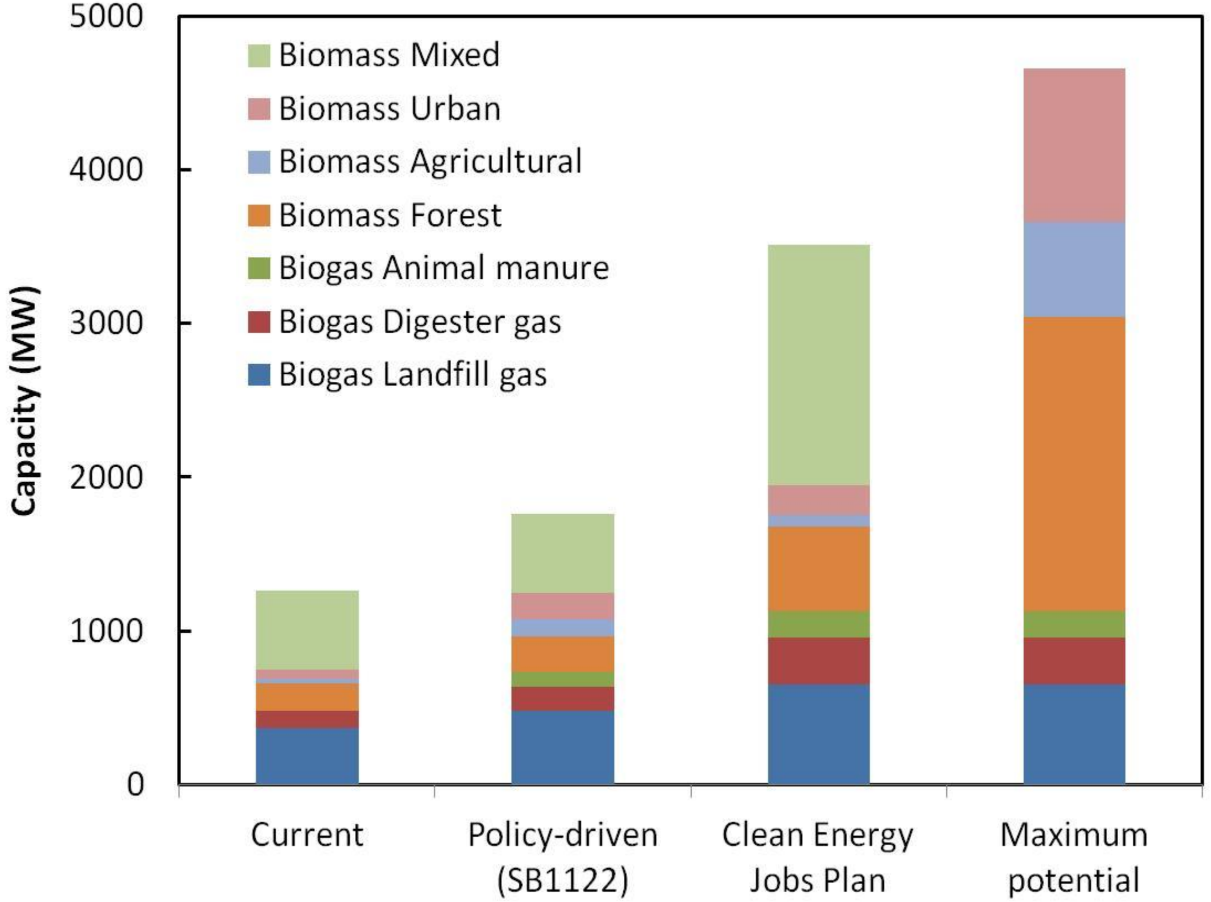
- **Following ARB's Low Carbon Fuel Standards Pathways**
- **Using CA-GREET model emissions for well-to-tank processes**



# Scenarios

- **Increasing Capacity with Conventional Technology**
  - **Current Capacity**
  - **Policy-Driven with SB1122**
  - **Governor Brown's Clean Energy Jobs Plan**
  - **Maximum Technical Potential**
- **Technology Upgrade for Efficiency and Emissions**
- **Shift End Use from Electricity to Fuel**
  - **CNG for fuel**
  - **CNG for pipeline**
  - **Ethanol**

# Increasing Capacity with Conventional Technology



# Technology Upgrade for Efficiency and Emissions

- **Solid Biomass:**
  - **Boiler → Next Gen Gasification**

    **$NO_X$: +97% ↓**

    **PM: +88% ↓**

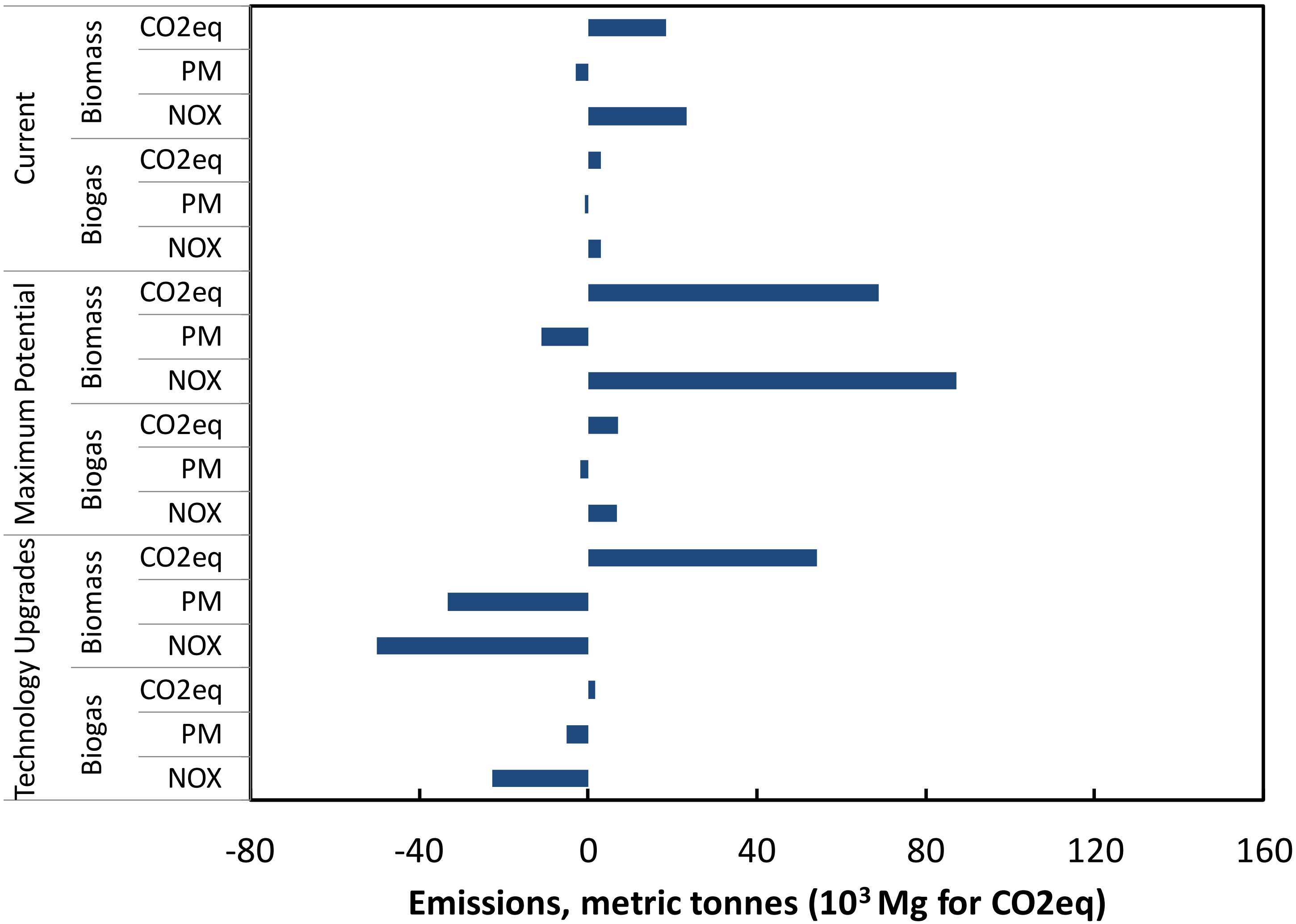
    **$CO_2$: +28% ↓**
- **Biogas:**
  - **IC Engine → Fuel Cell**

    **$NO_X$: +99% ↓**

    **PM: +99% ↓**

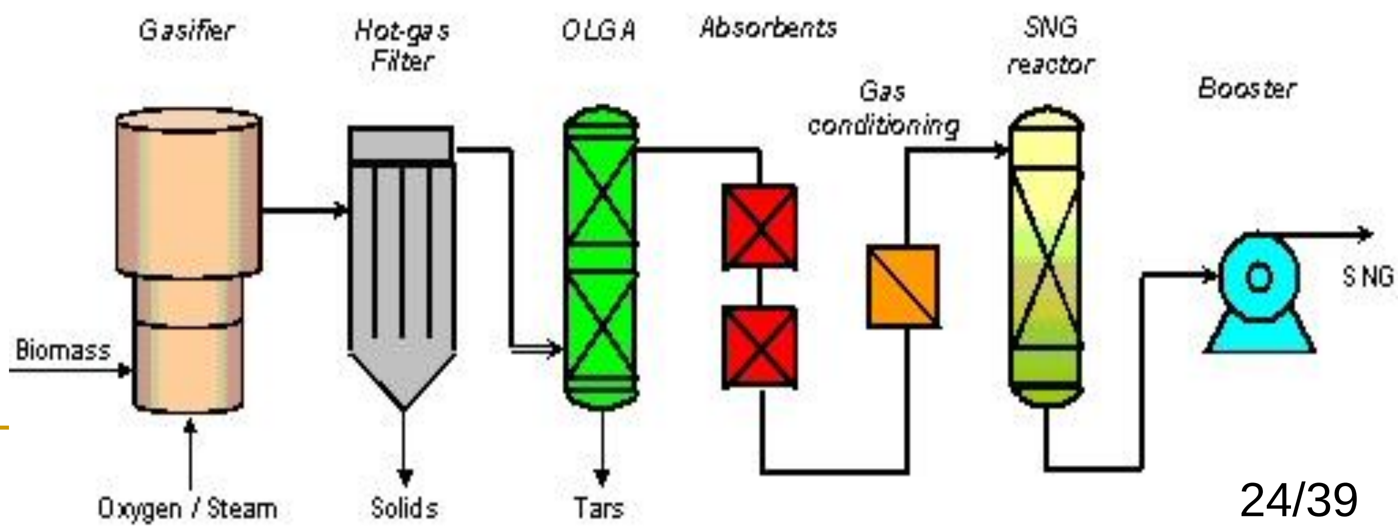
    **$CO_2$: +35% ↓**

# Emissions from Biomass for Biopower



# Shift End Use from Electricity to Fuel

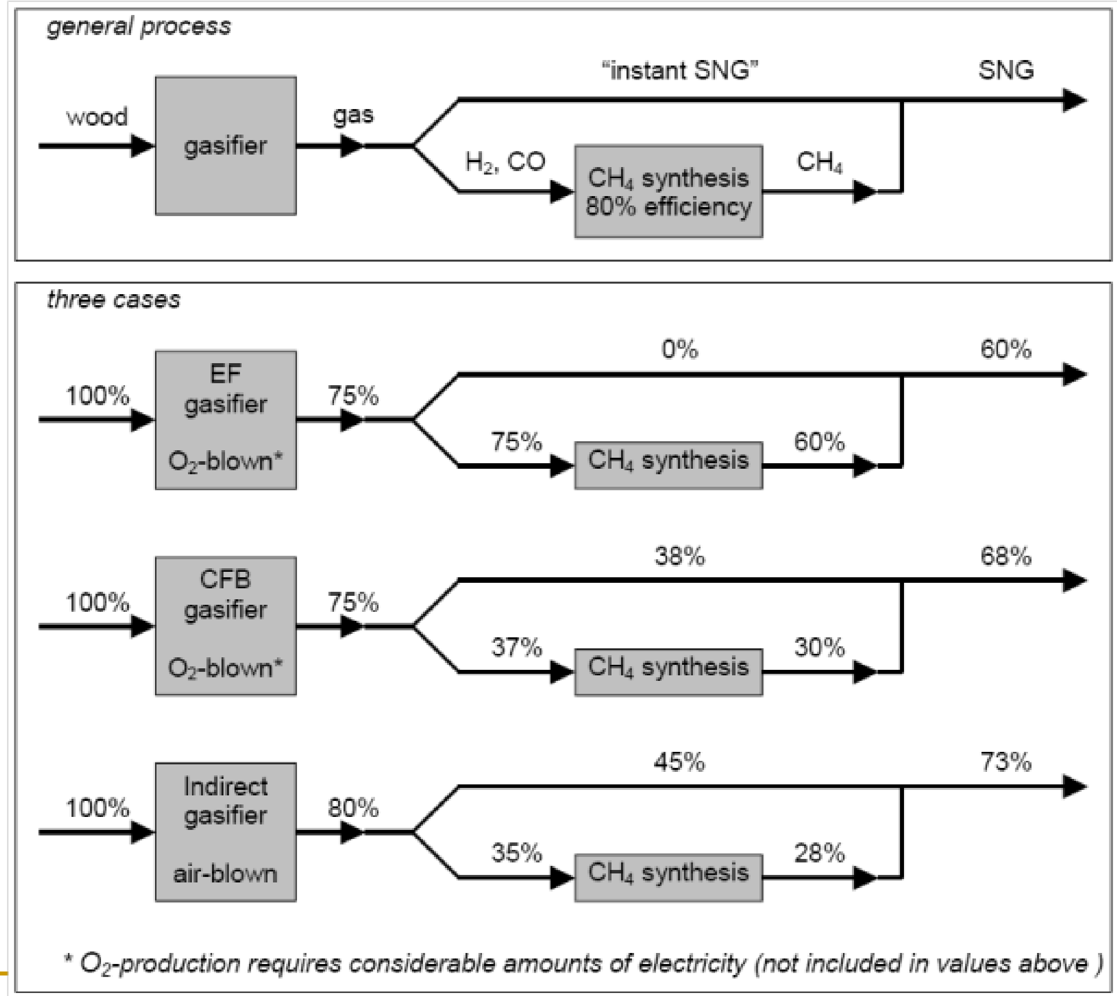
- **Biogas:**
  - **Clean-up, upgrade and compression to produce CNG**
  - **Potential: 2.4 million gasoline gallon equivalent (GGE)**
- **Biomass:**
  - **Renewable synthetic natural gas production (RSNG)**
  - **Potential: 6.5 million GGE of CNG or 3.4 million gallons of ethanol**



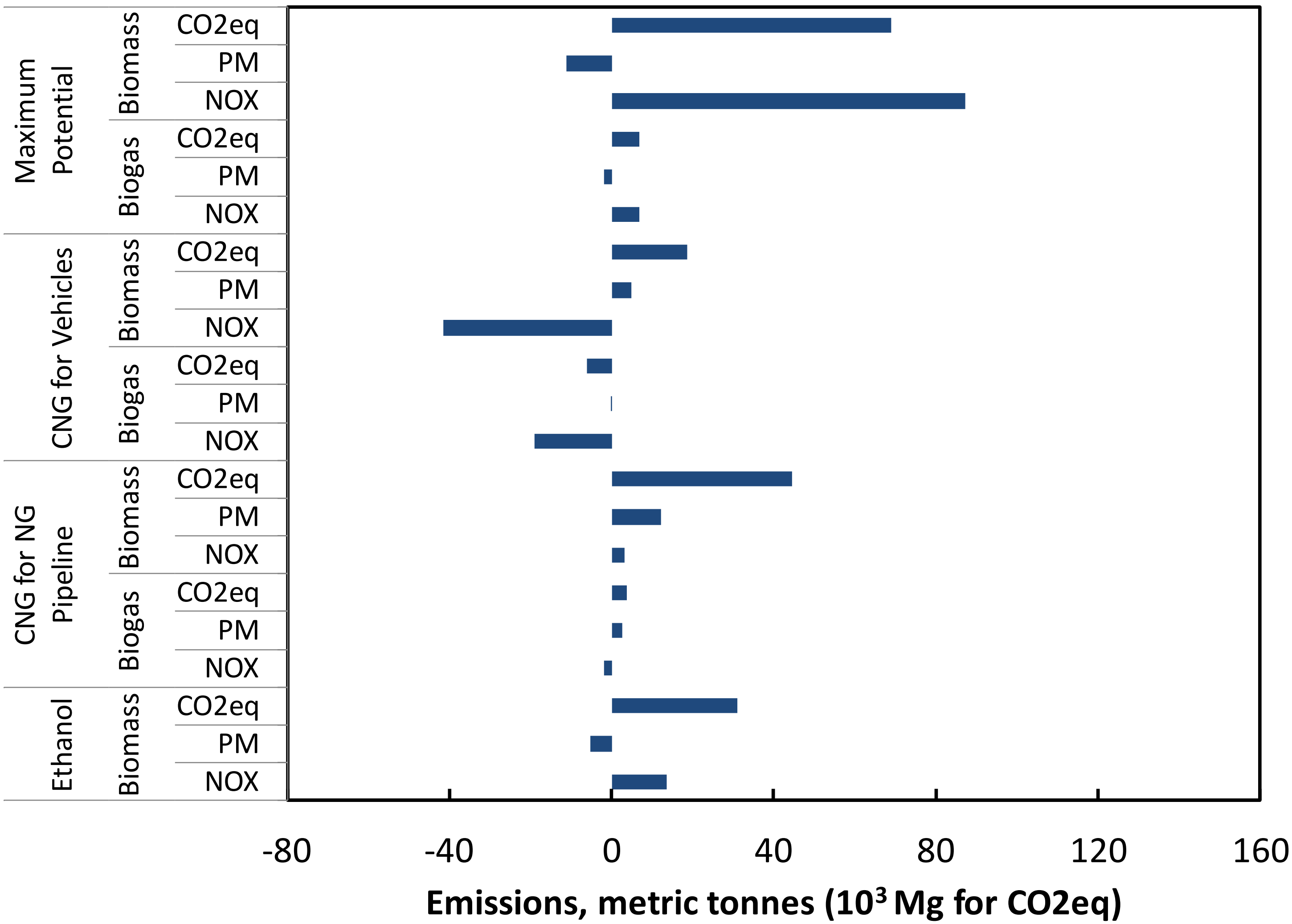
# RSNG Production

| Waste Type | Carbon content |
|---|---|
| Forest residue | |
| Beech wood[1] | 48.7% |
| Grass[1] | 43.7% |
| Conifers[2] | 50.0% |
| Angiosperms[2] | 48.0% |
| MSW[3] | 30.0% |

[1]Zwart et al., 2006
[2]Thomas and Martin, 2012
[3]Bahor et al., 2008



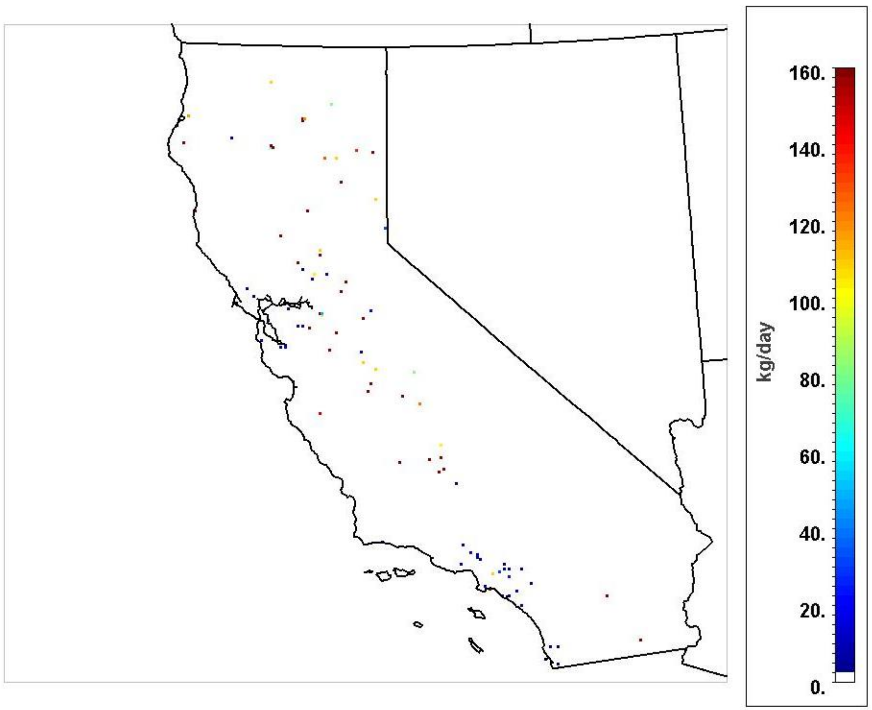
# Emissions from Biomass for Fuel



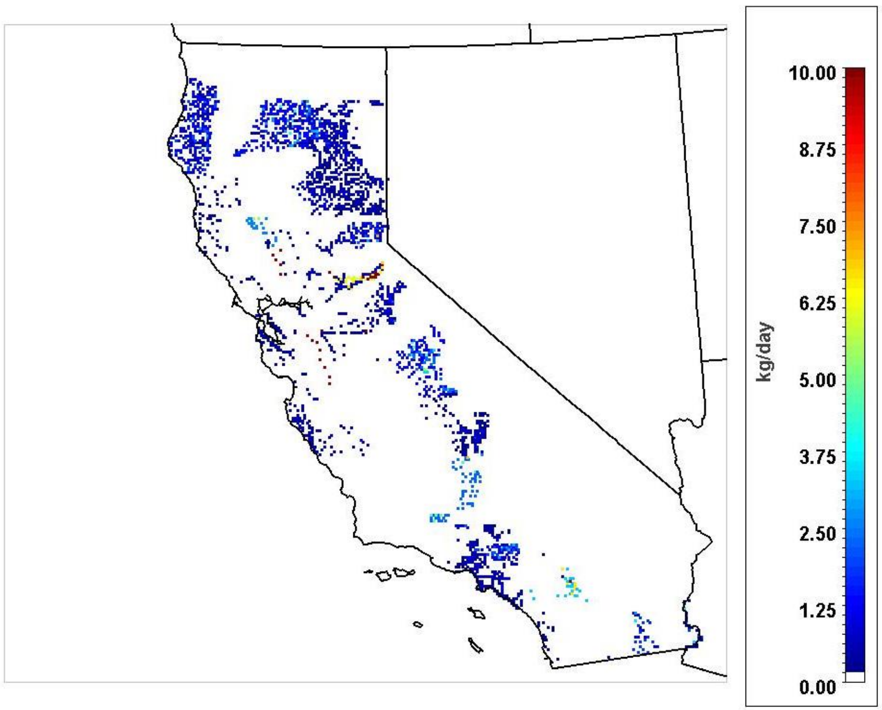
# Spatial Allocation of Emissions

## 2020 Technical Potential: $NO_X$ Emissions

**Facilities**

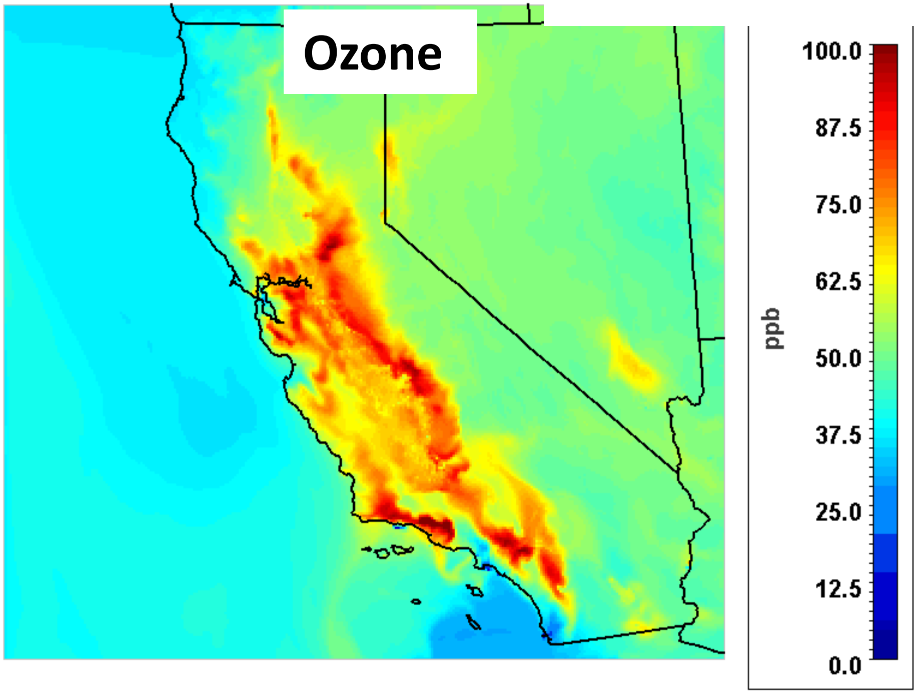


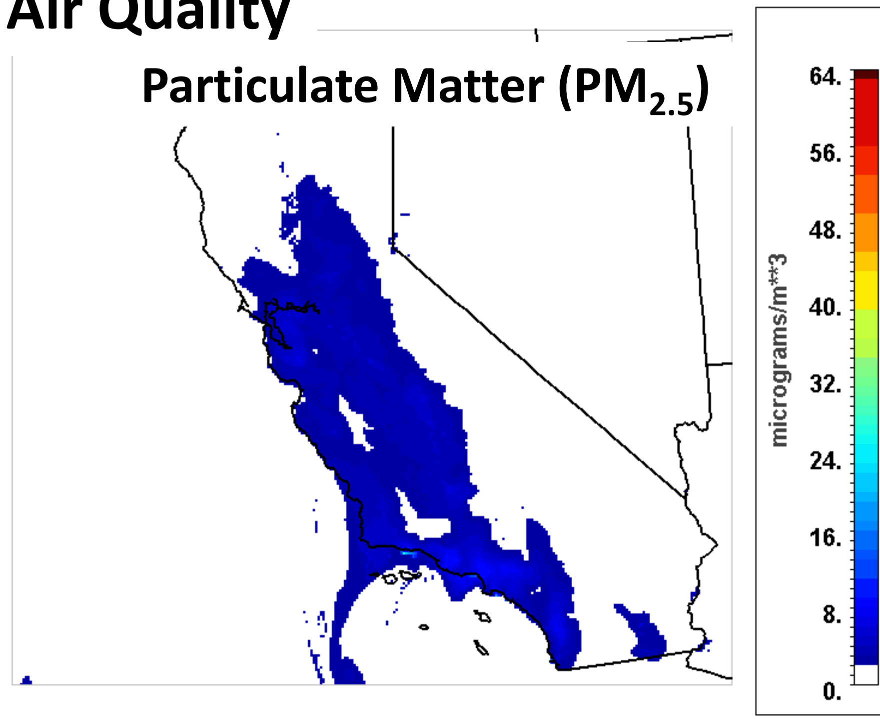

**Collection and Transport**



# Typical Episodic Air Quality Simulation

**2020 Baseline Air Quality**




**Air quality model:** Community Multiscale Air Quality (CMAQ) model, v. 4.7.1

**Baseline Emissions:** EPA's 2005 National Emissions Inventory projected to 2020 based California Air Resources Board estimates

**Meteorological fields:** Weather Research Forecast (WRF) model, for July and December, 2005

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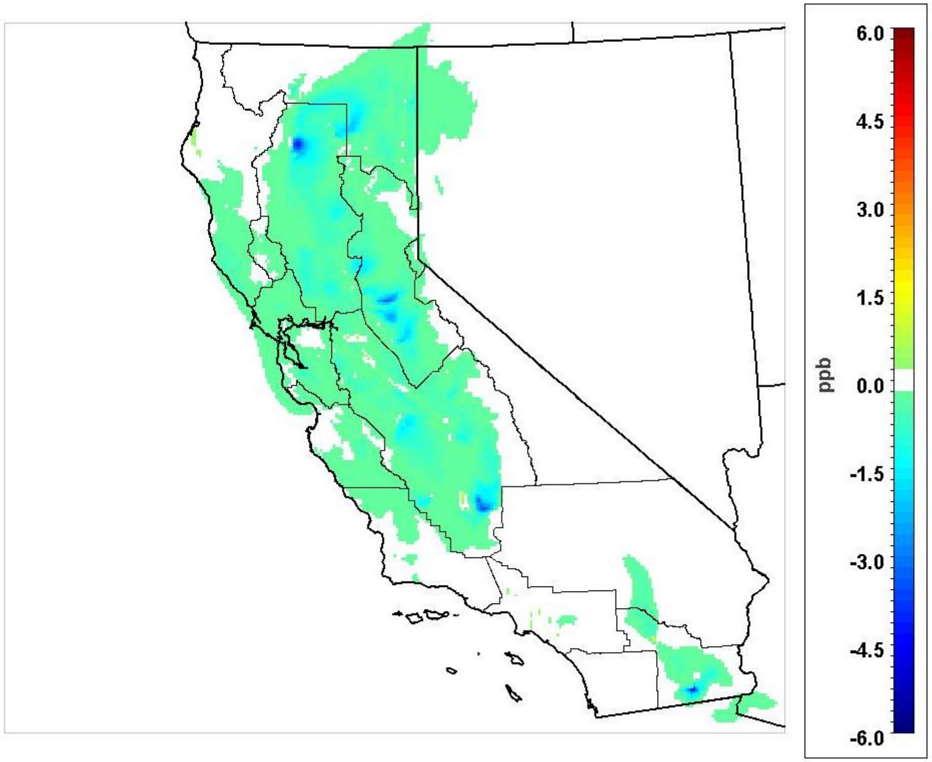
# Effect of Current Biopower

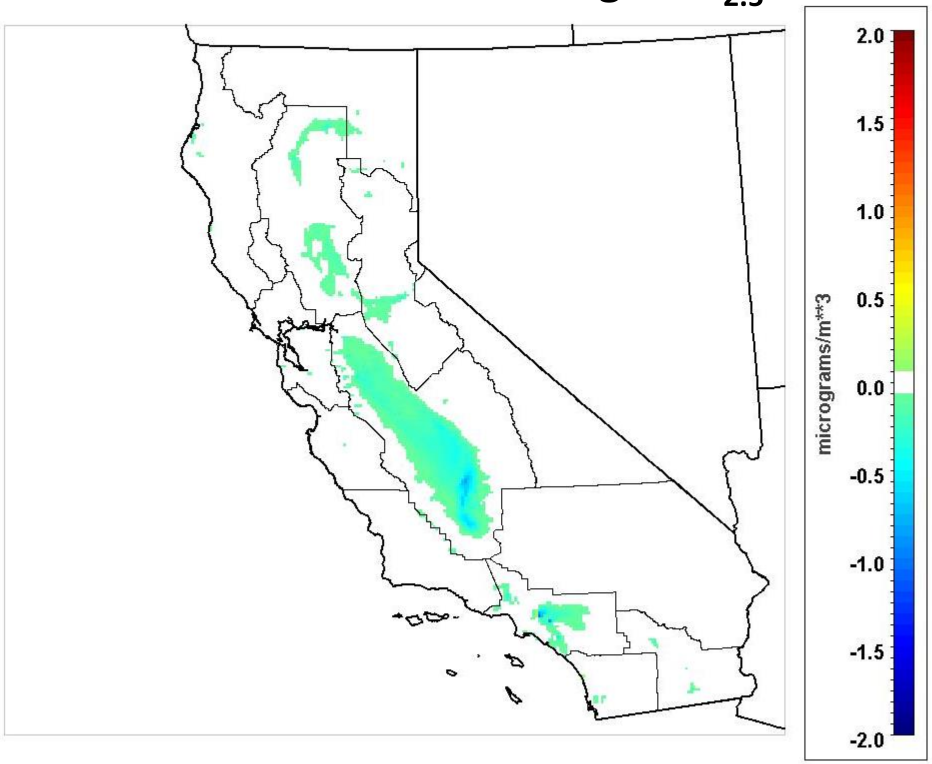
## No Biopower vs Current Biopower

**0 MW vs 1,264 MW**

**Difference in Max 1-hour Ozone**




**Difference in 24-hour average $PM_{2.5}$**

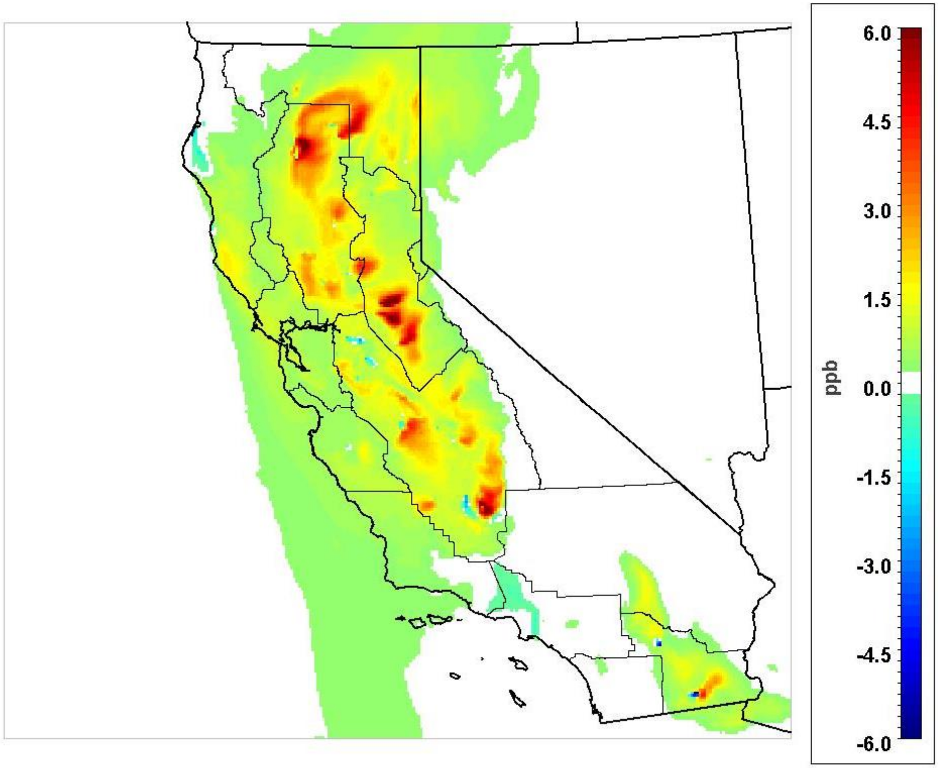


# Maximum Biopower Potential: Summer

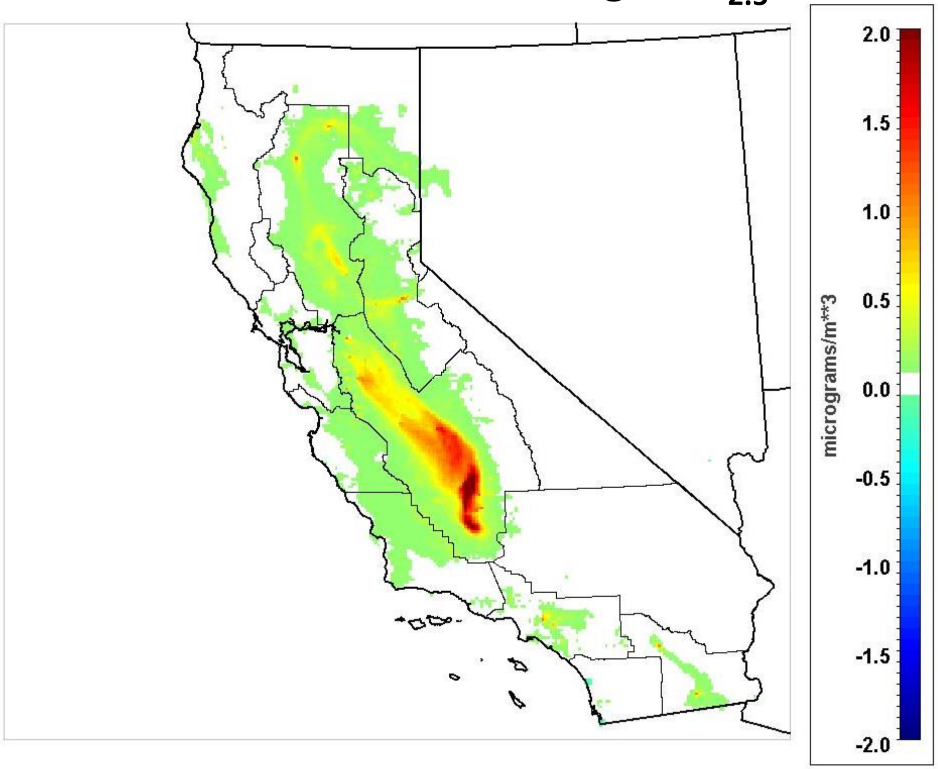
## Maximum Biopower vs Current Biopower

**4,660 MW vs 1,264 MW**

**Difference in Max 1-hour Ozone**




**Difference in 24-hour average $PM_{2.5}$**

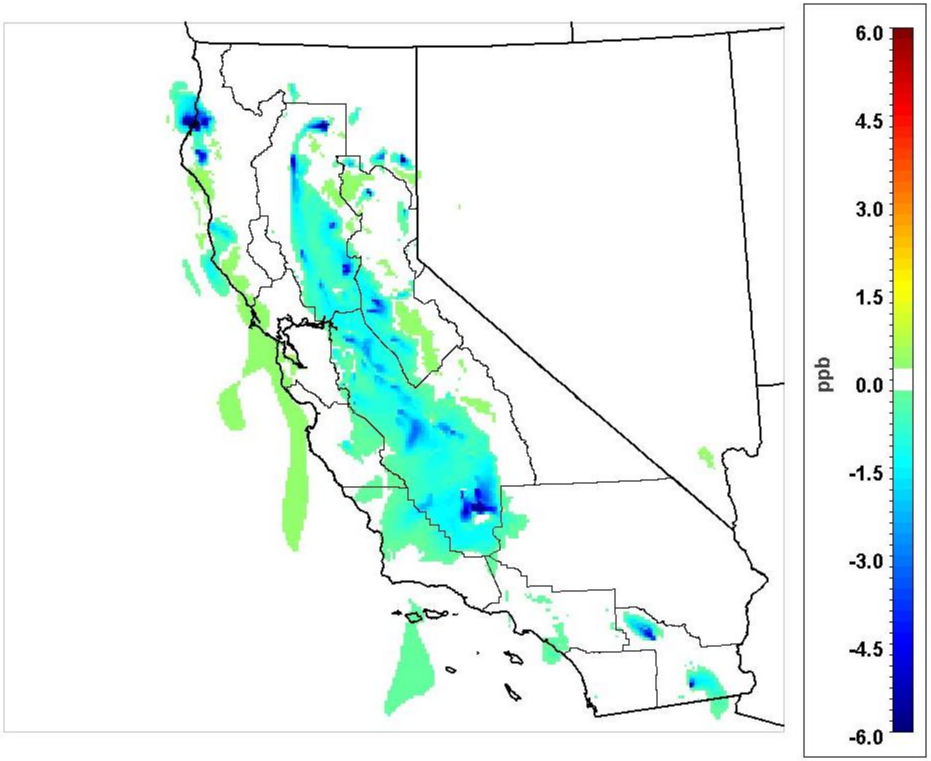


# Maximum Biopower Potential: Winter

## Maximum Biopower vs Current Biopower

**4,660 MW vs 1,264 MW**

**Difference in Max 1-hour Ozone**

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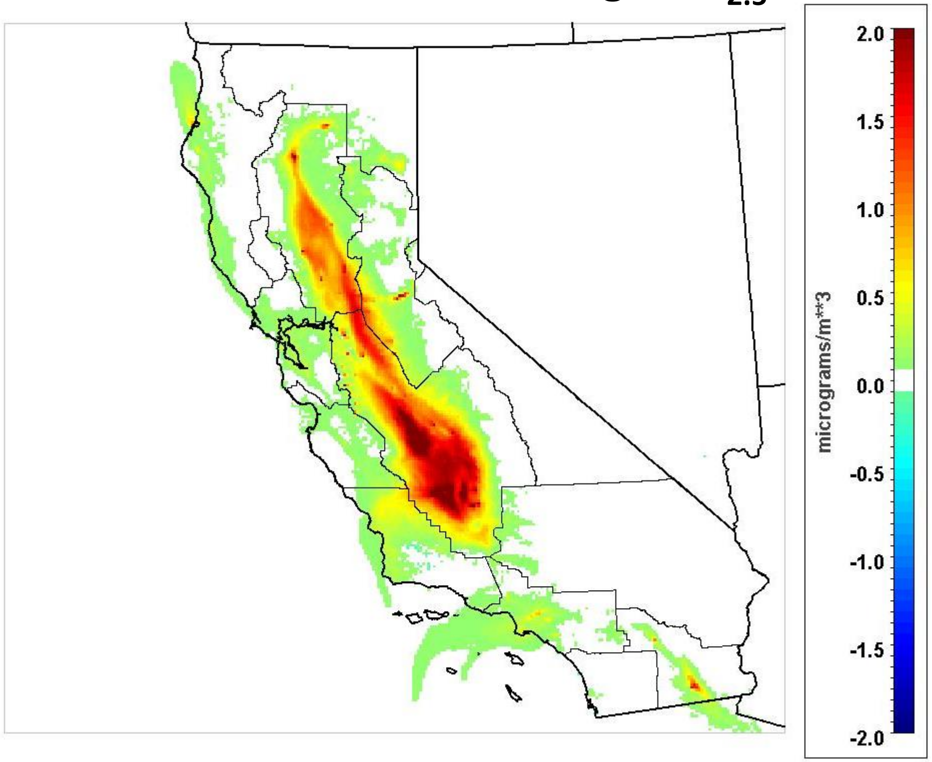
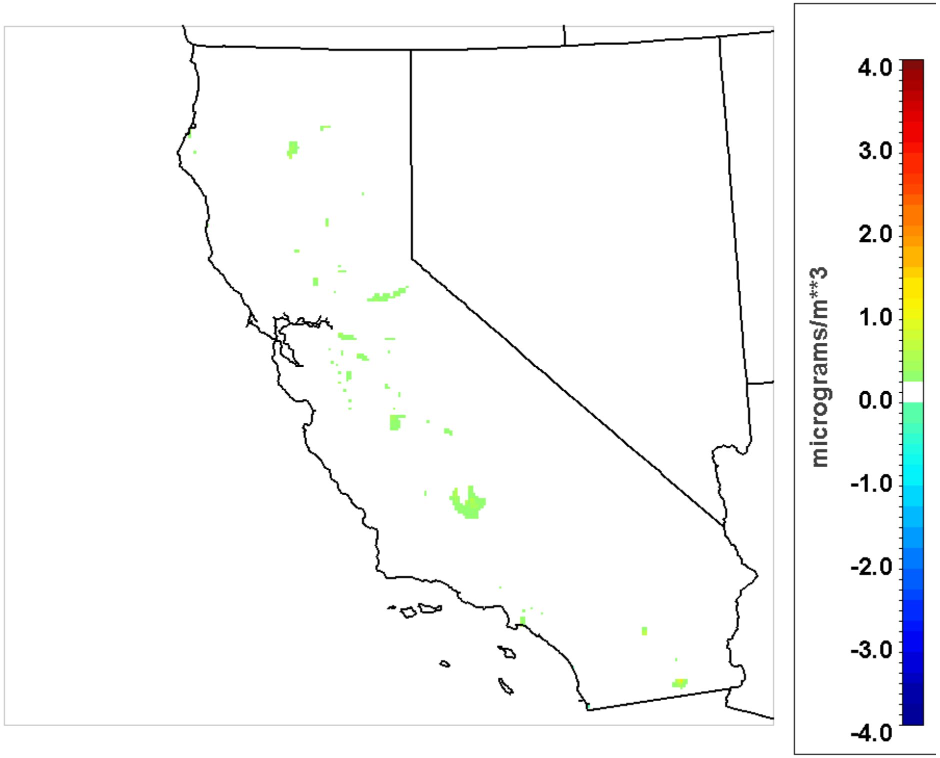


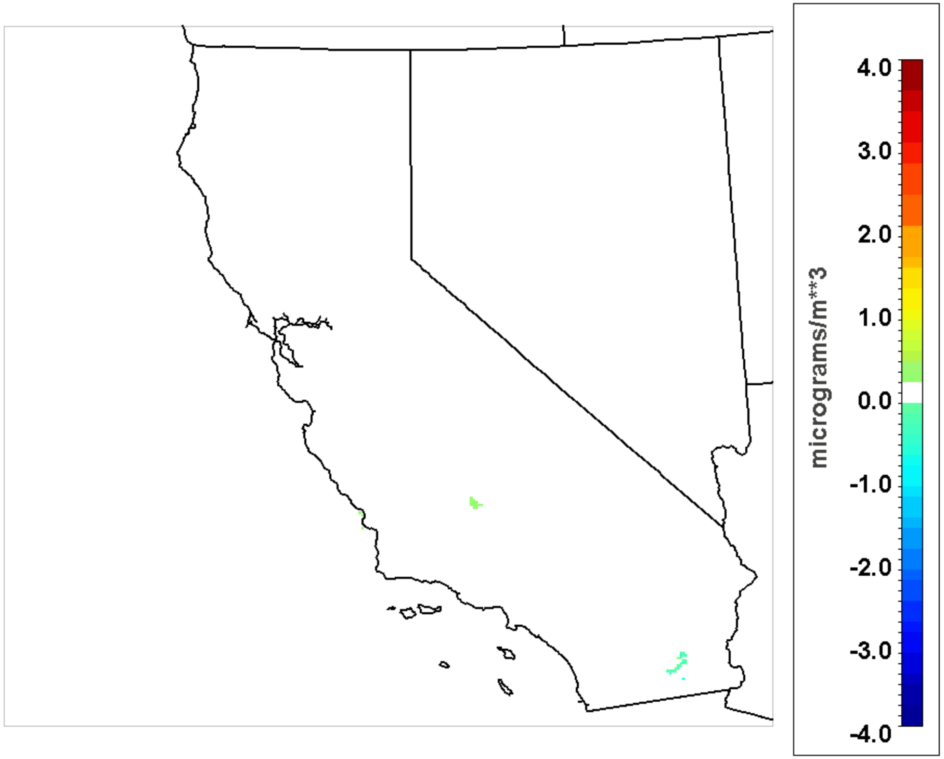
# Primary vs. Secondary PM – Summer

- **Primary $PM_{2.5}$: Contribution form collection and transport**
- **Secondary $PM_{2.5}$: Mostly ammonium nitrate**

**Primary $PM_{2.5}$**




**Secondary $PM_{2.5}$**

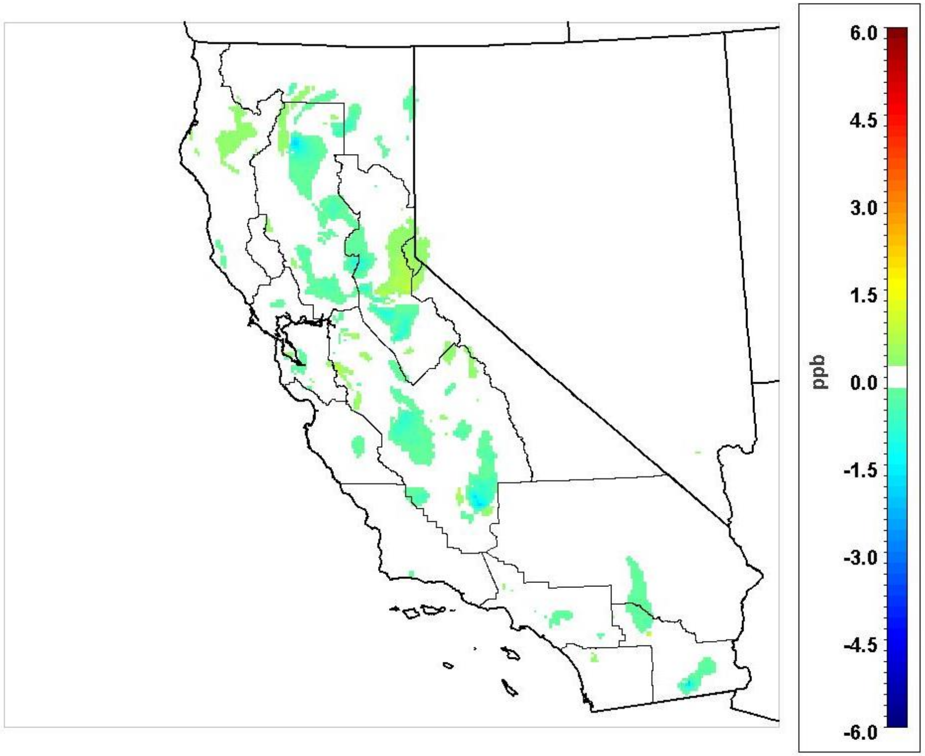


# Effect of Technology Upgrades

## Technology Upgrade vs Current Biopower

**4,660 MW vs 1,264 MW**

**Difference in Max 1-hour Ozone**

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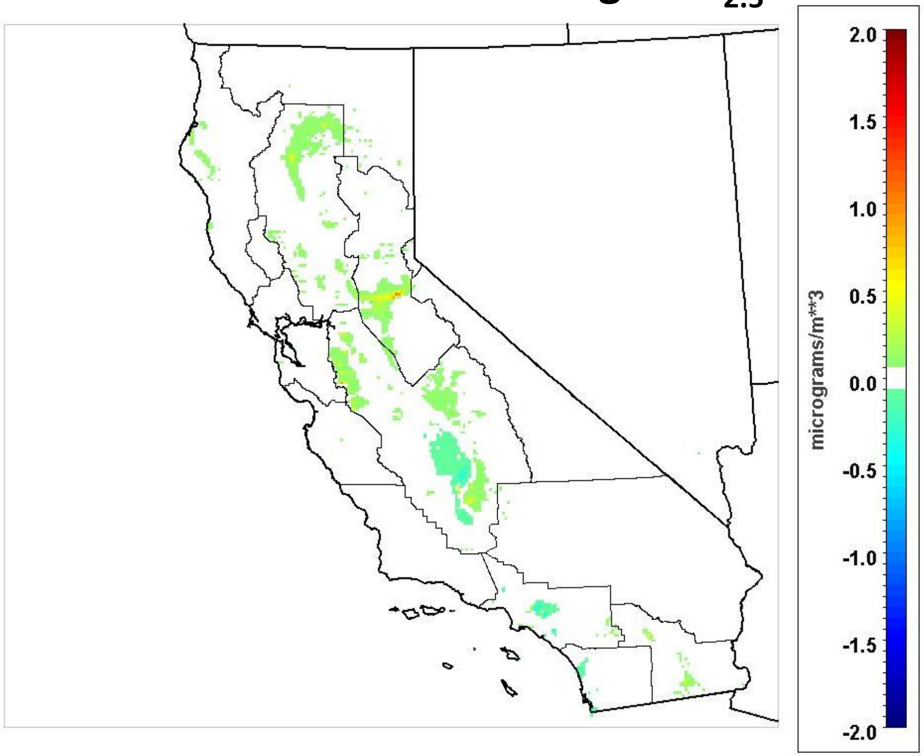
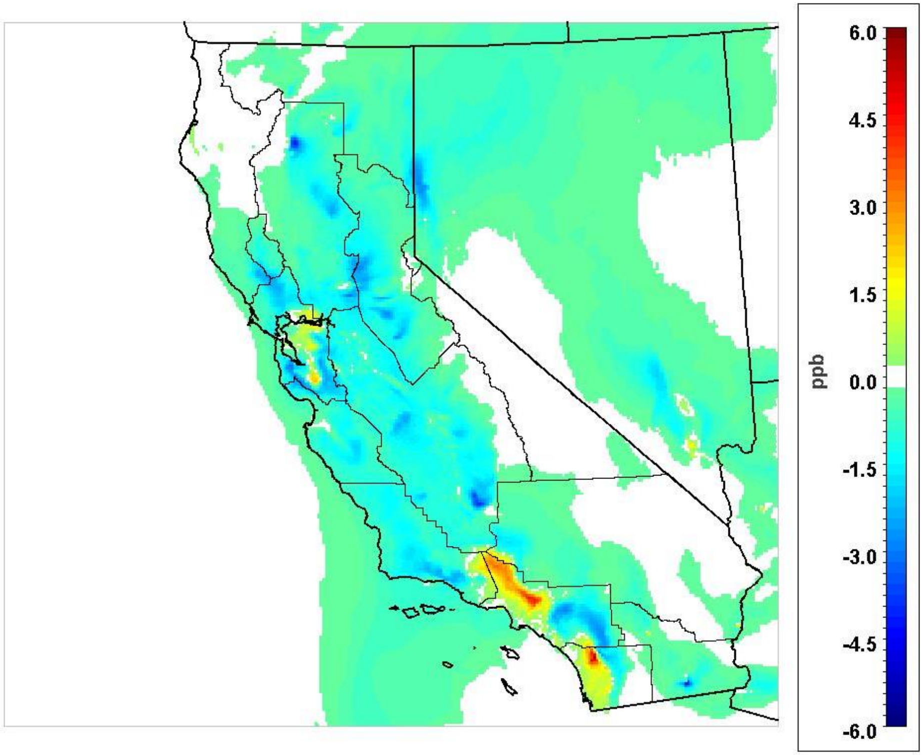


# Effect of CNG vehicles

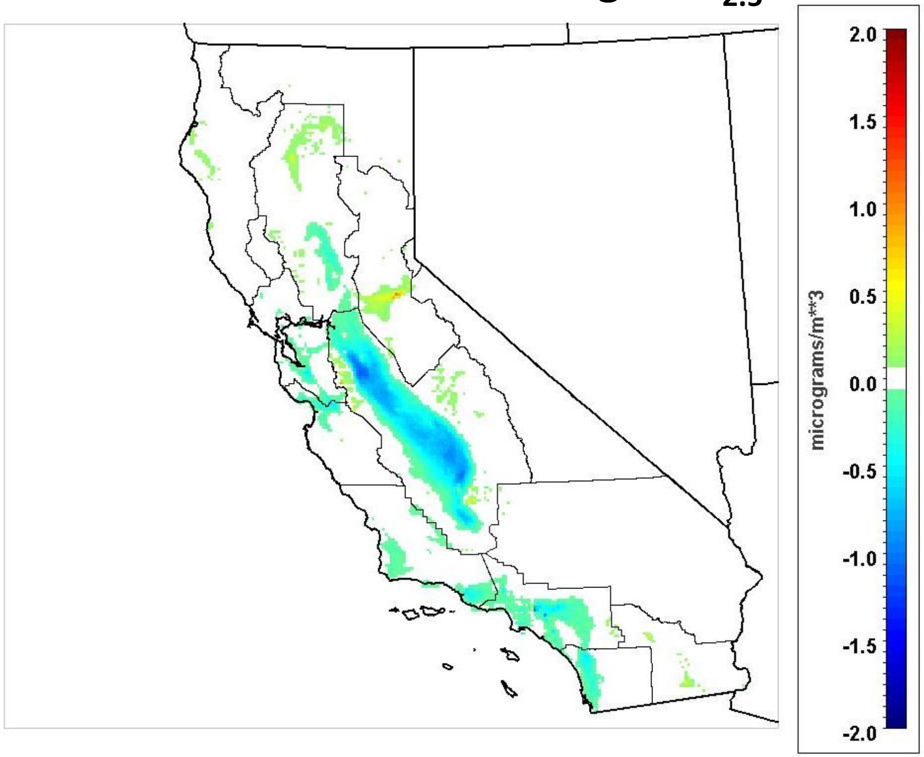
## Maximum CNG vs Current Biopower

**0 MW vs 1,264 MW**

**Difference in Max 1-hour Ozone**




**Difference in 24-hour average $PM_{2.5}$**



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# Summary and Conclusions

- **Technically recoverable biomass resources:**
  - **4.66 GW of biopower or 8.89 million GGE**
- **The impacts of biomass depend on:**
  - **Emission controls, technology, products**
- **Technology upgrades would obtain the lowest net emissions of <u>criteria pollutants</u>**
- **Conversion of biomass to CNG for vehicles would achieve the lowest <u>emissions of GHG</u>**
- **Conversion of biomass to CNG for vehicles achieved the overall lowest impacts on <u>air quality and GHG</u>**

# Future Work

- **Emissions and air quality assessment of ARB's LCFS scenarios for 2020**
- **Analysis of RNSG production from solid biomass**
- **Analysis of CNG alternatives:  hydrogen, bio-alcohols**
- **Analysis of Biofuels for Sustainable Freight Transport**
- **Analysis of management of solid waste to maximize recycling, and minimize disposal at landfills**

# Acknowledgments

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AIR RESOURCES BOARD