
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



Biomass use impacts:

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

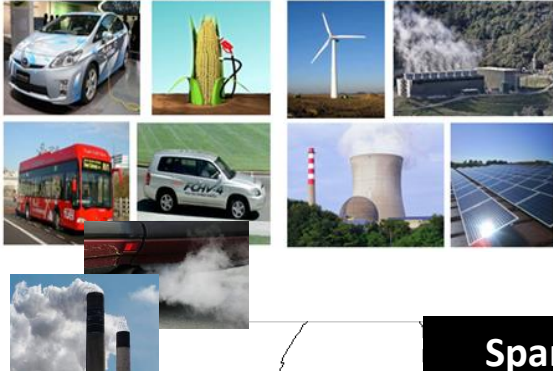


Methodology

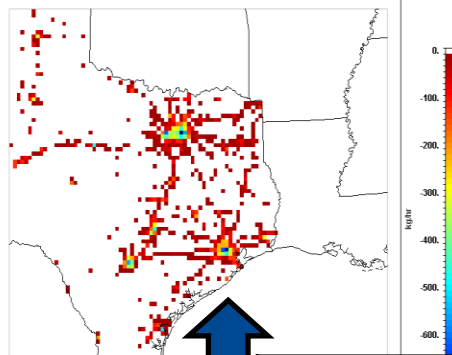
Technology Scenarios

Transportation

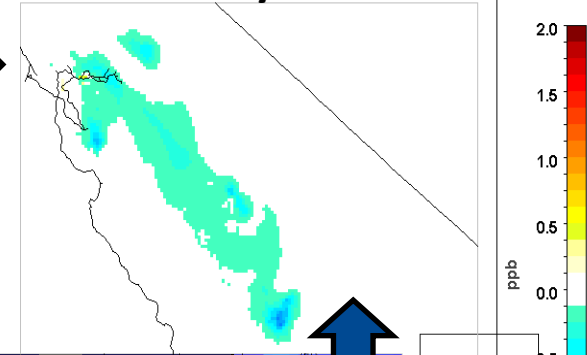
Power Generation



Pollutant Emissions



Air Quality Simulations



Baseline Emissions

NEI, ARB

Sparse Matrix Operator Kernel Emissions (SMOKE) Model

Spatial Surrogates

Activity Profiles

Community Multi-scale Air Quality (CMAQ) Model

- Dilution, transport and mixing
- Photochemical transformation

Meteorological Fields

Chemical Mechanism

Emissions of NO_x over a 24 h period in 2005

PM_{2.5} concentration over a 24 h period in 2005

Project Overview

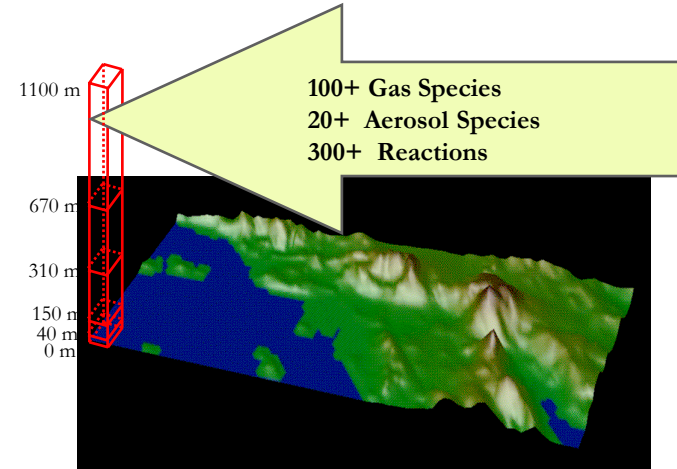
Biomass scenarios



Determine
spatial/temporal
emissions



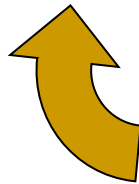
3-D air quality model



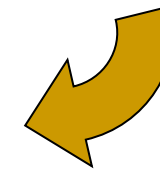
Air quality impacts



Determine GHG
co-benefits



Determine
spatial/temporal
AQ impacts



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**

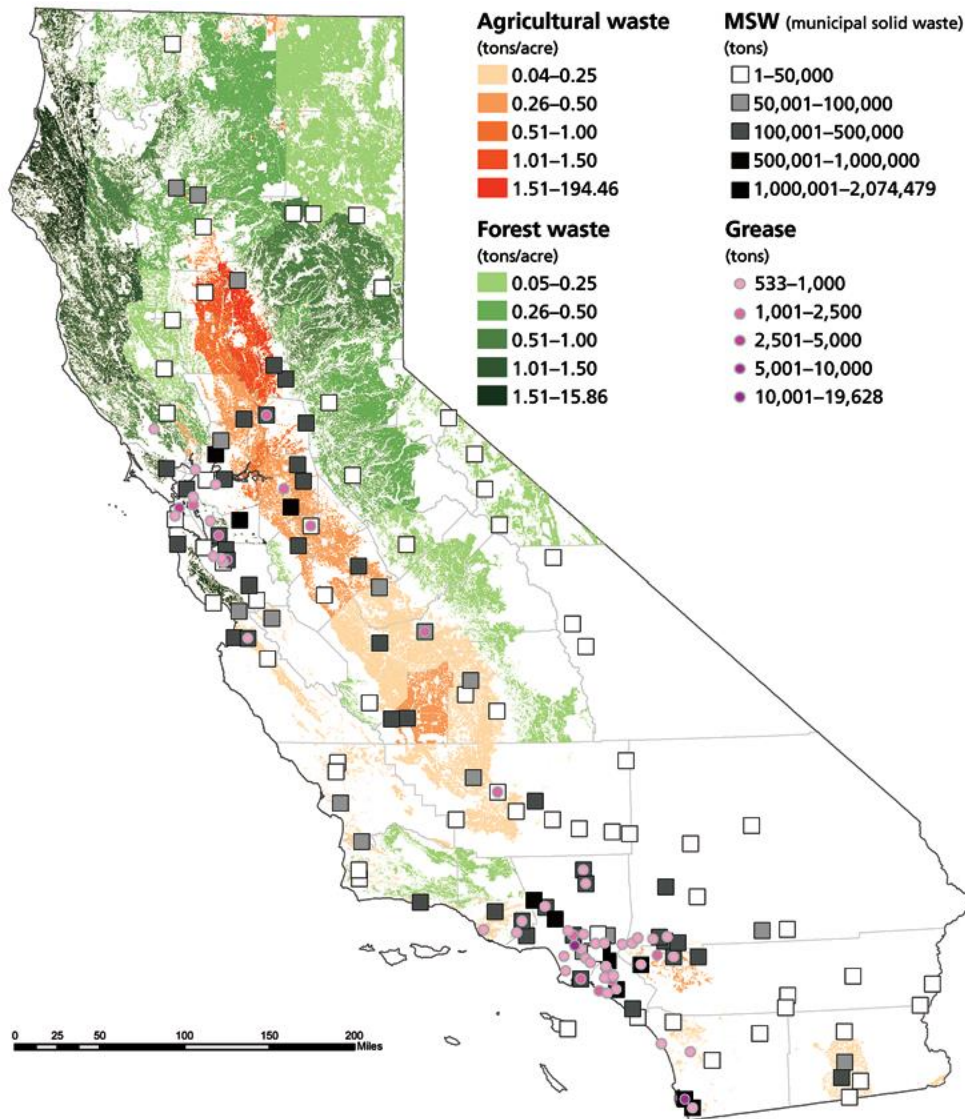
Policy Drivers for Research

- **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

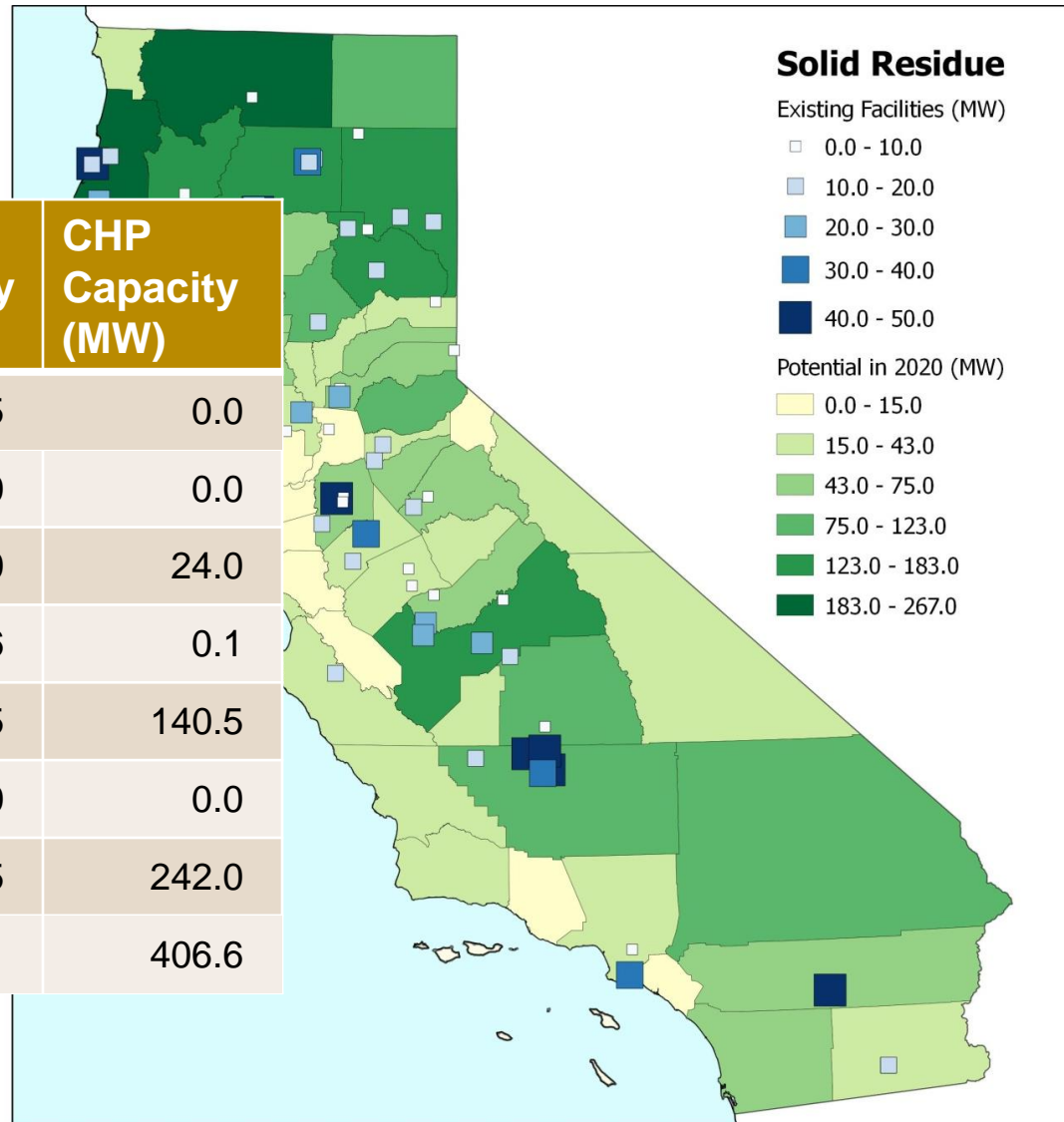


California great biomass resources (CBC, 2011):

- Biopower current capacity: 1200 MW
- Potential additional capacity: > 4,000 MW

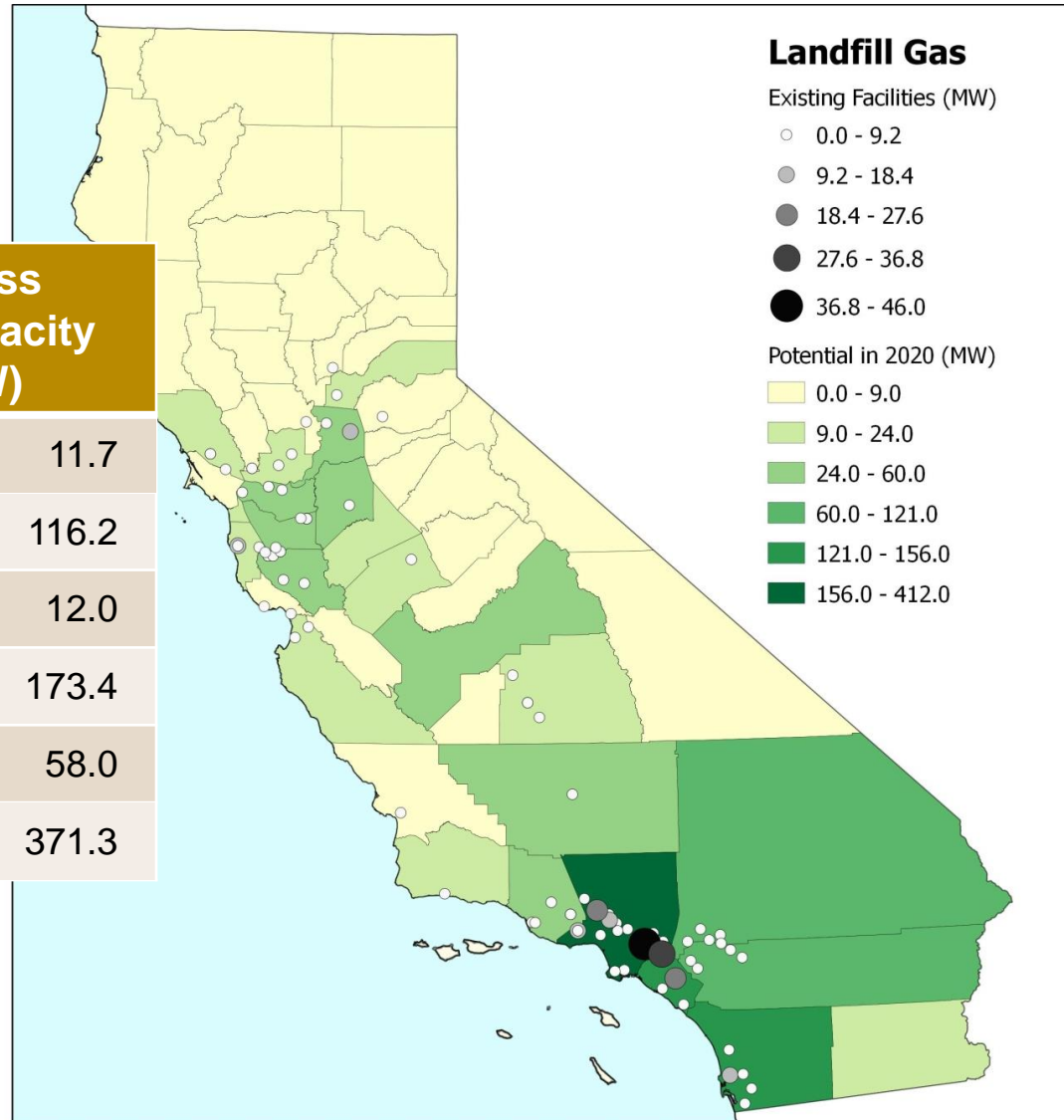
Solid Residue Potential Location

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

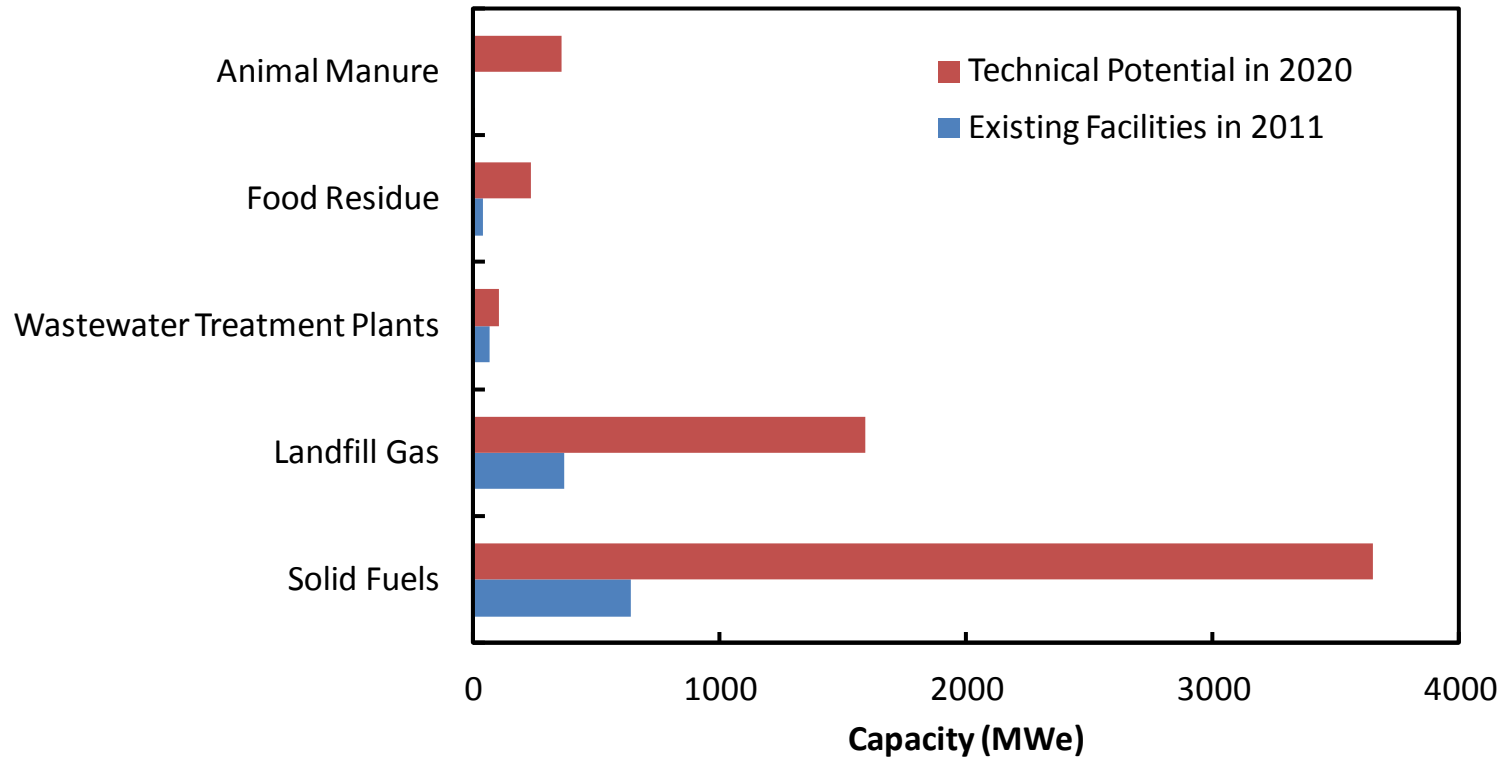


Landfill Gas Potential Location

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



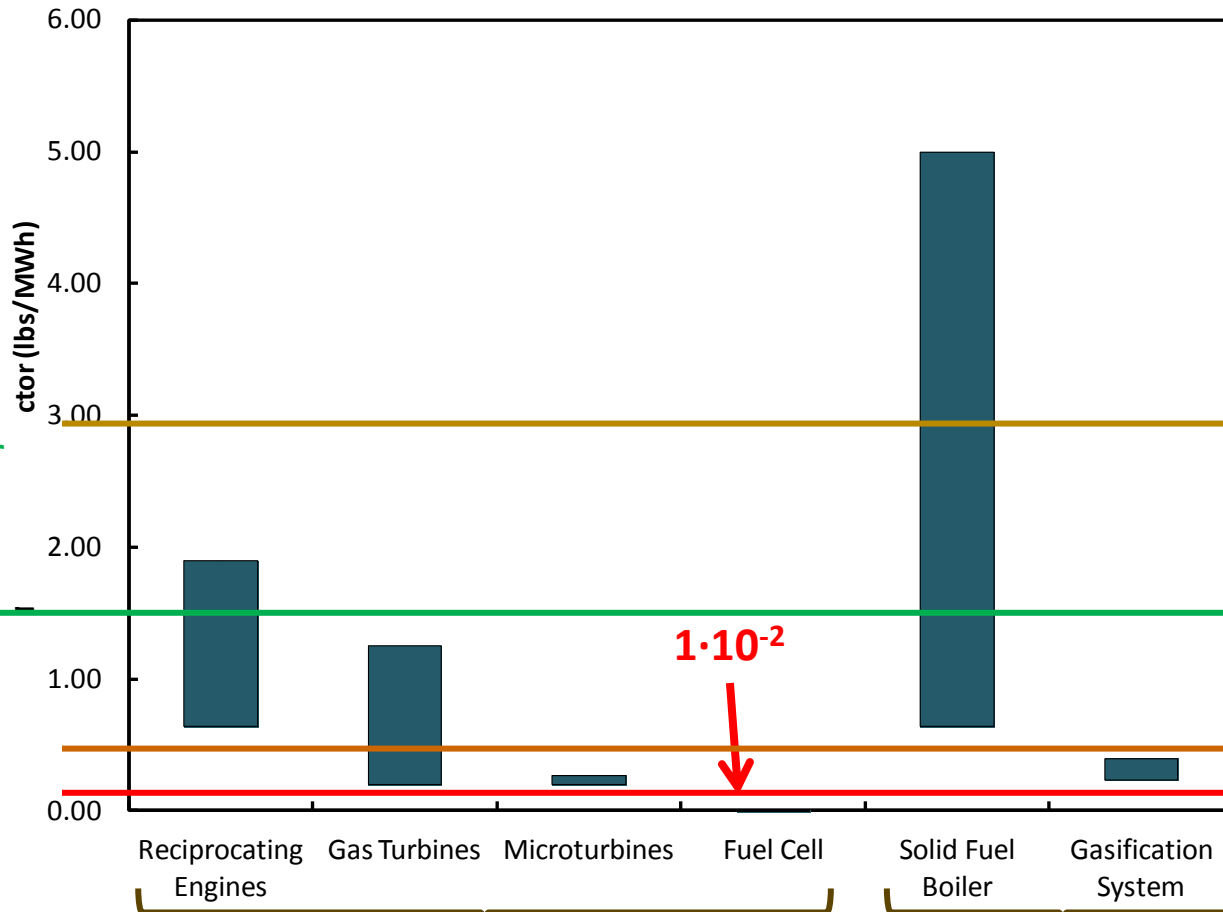
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Emission Factors



Average CA solid fuel facilities

ARB BACT for biogas engines

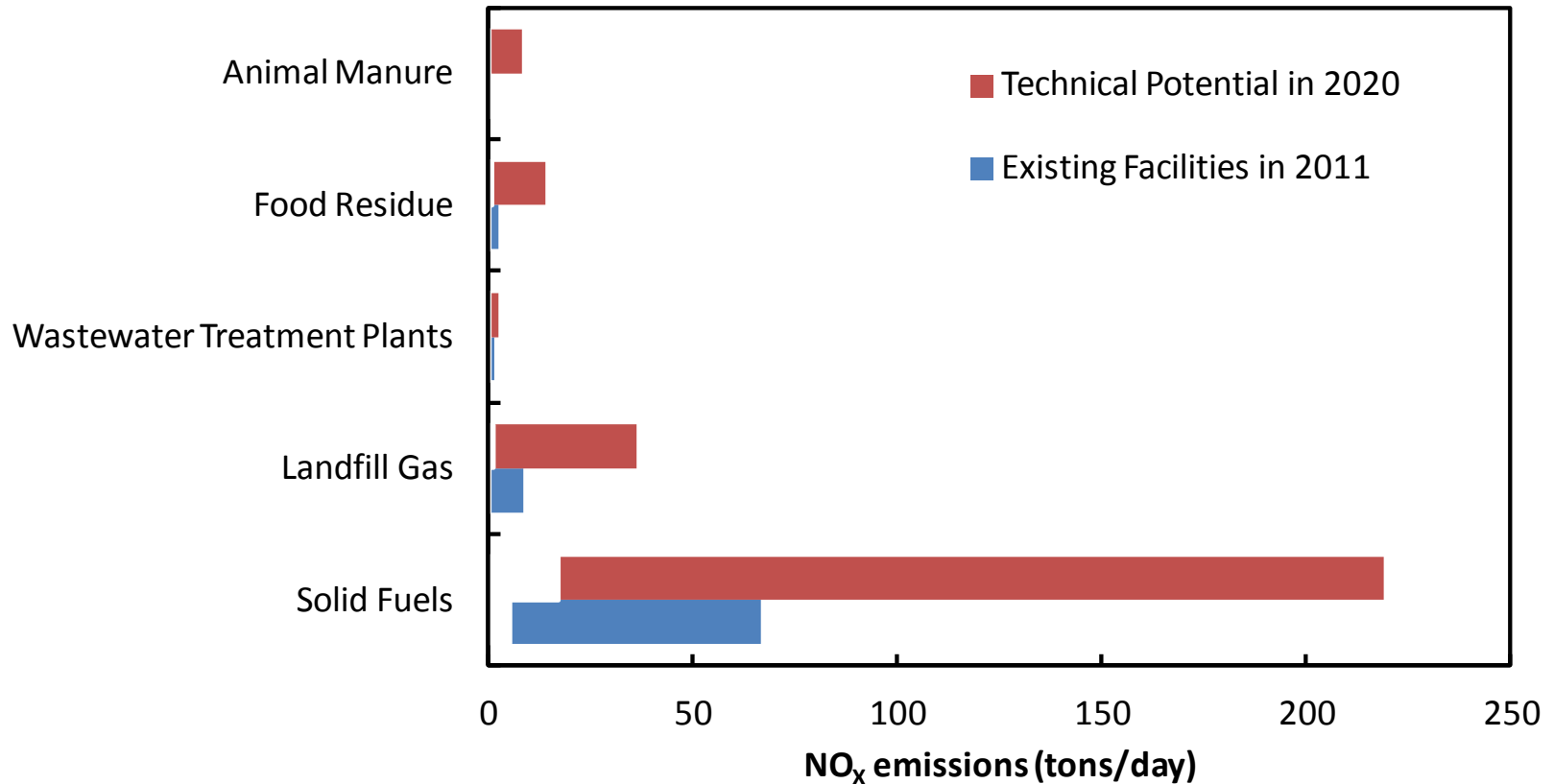
2008 ARB limits for DG

2013 ARB limits for DG

Biogas from wastewater treatment plants, landfill gas, and animal manure

Forest and other solid fuels

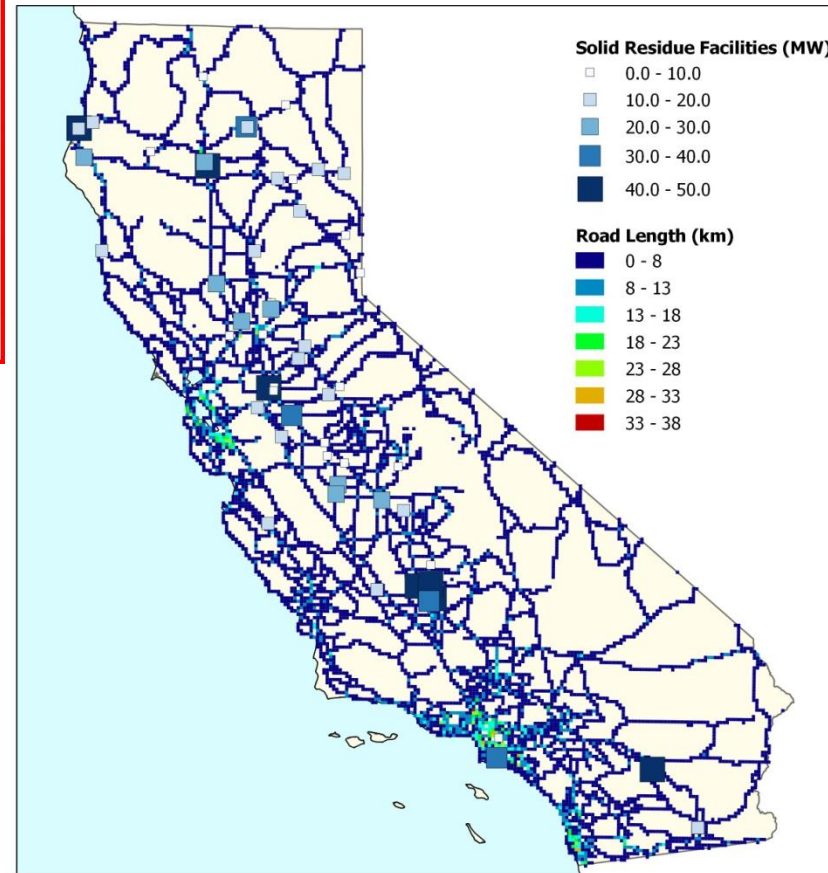
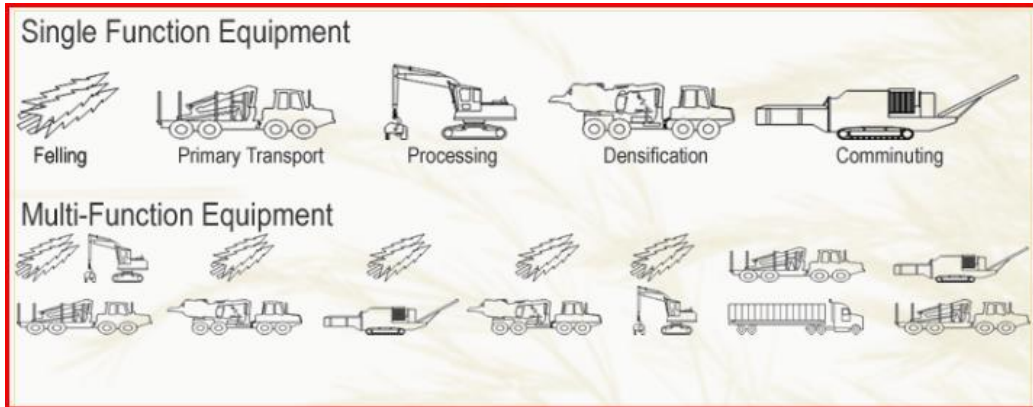
Potential Emissions in CA



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

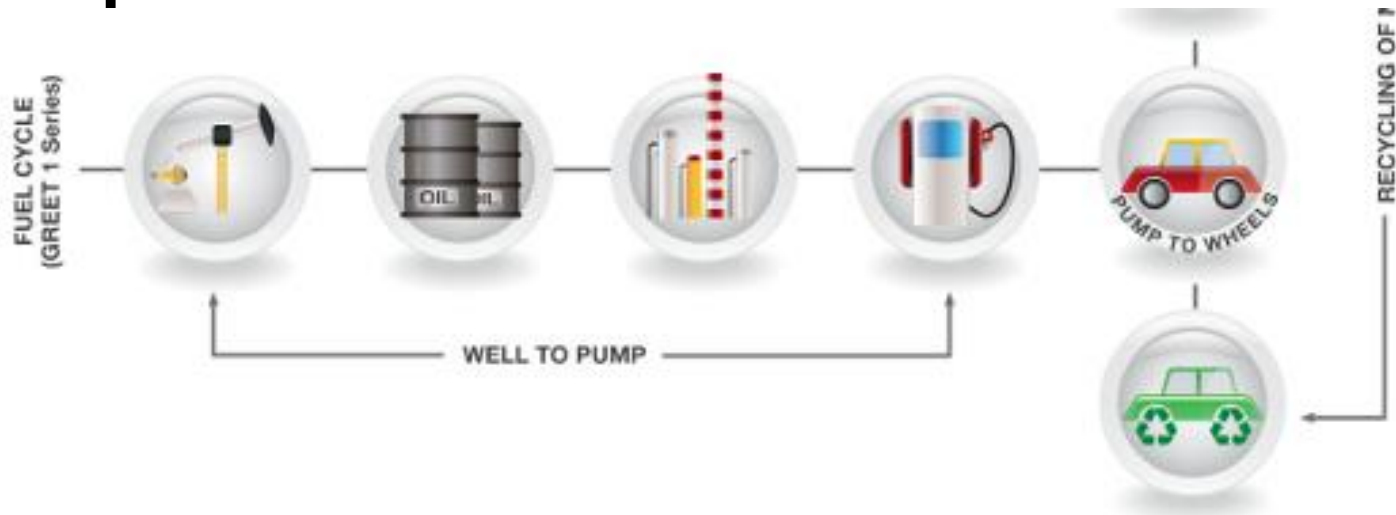
Total NO_x emissions in CA in 2012 = 2105 tons/day (ARB)

Collection and Transport



Analysis of Full Cycle Emissions

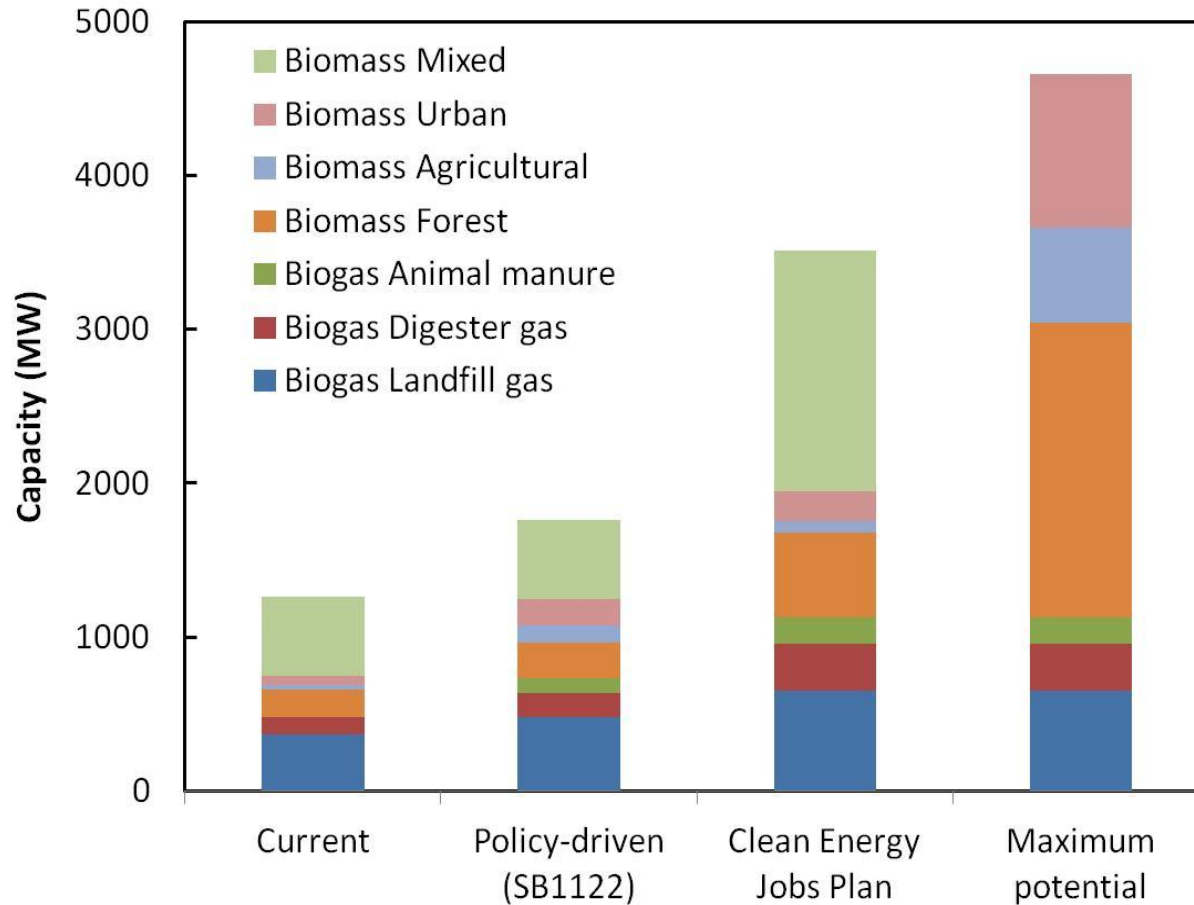
- Following ARB's Low Carbon Fuel Standards Pathways
- Using CA-GREET model emissions for well-to-tank processes



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% ↓

- CO₂: +28% ↓

- **Biogas:**

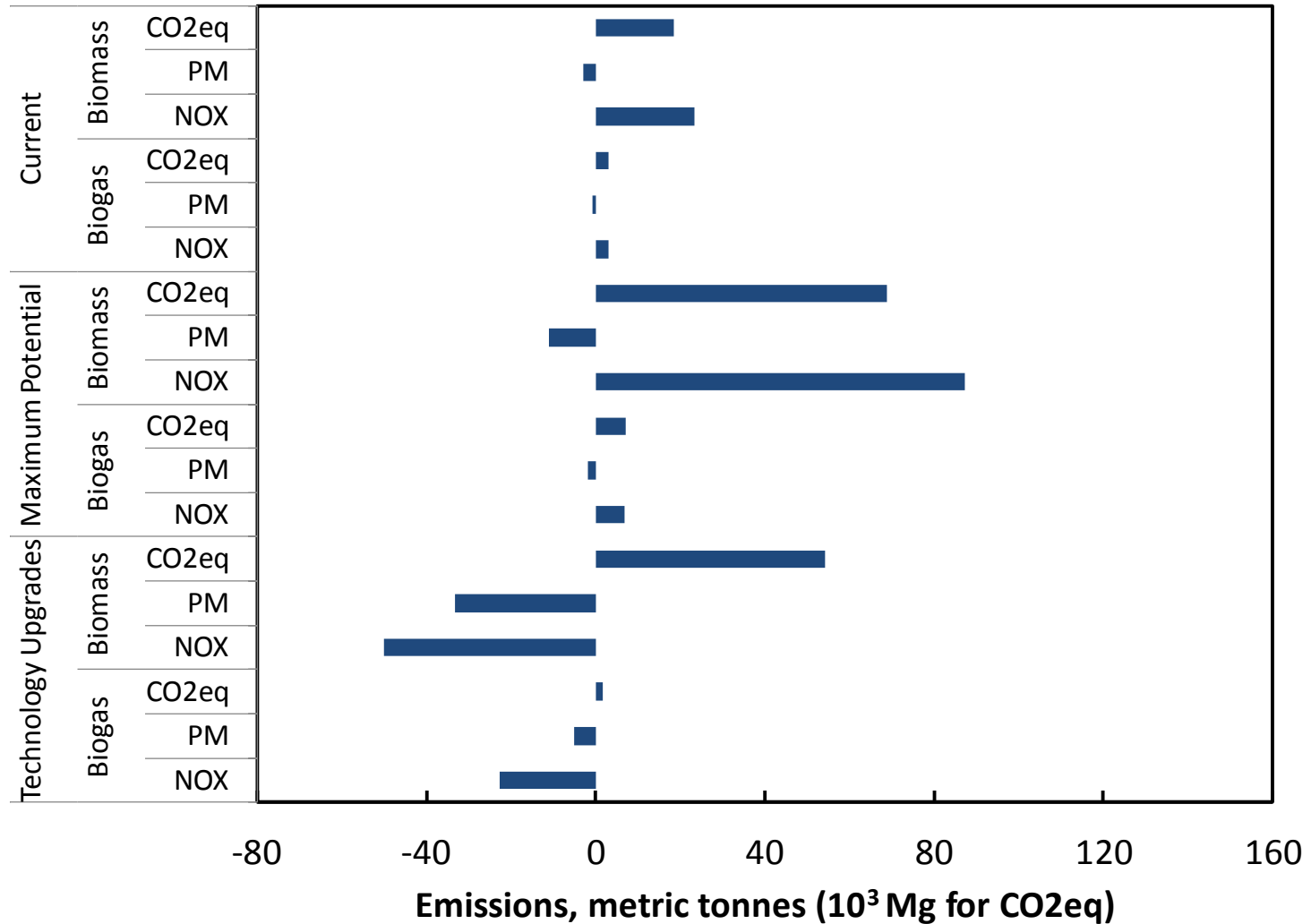
- **IC Engine → Fuel Cell**

- NO_x: +99% ↓

- PM: +99% ↓

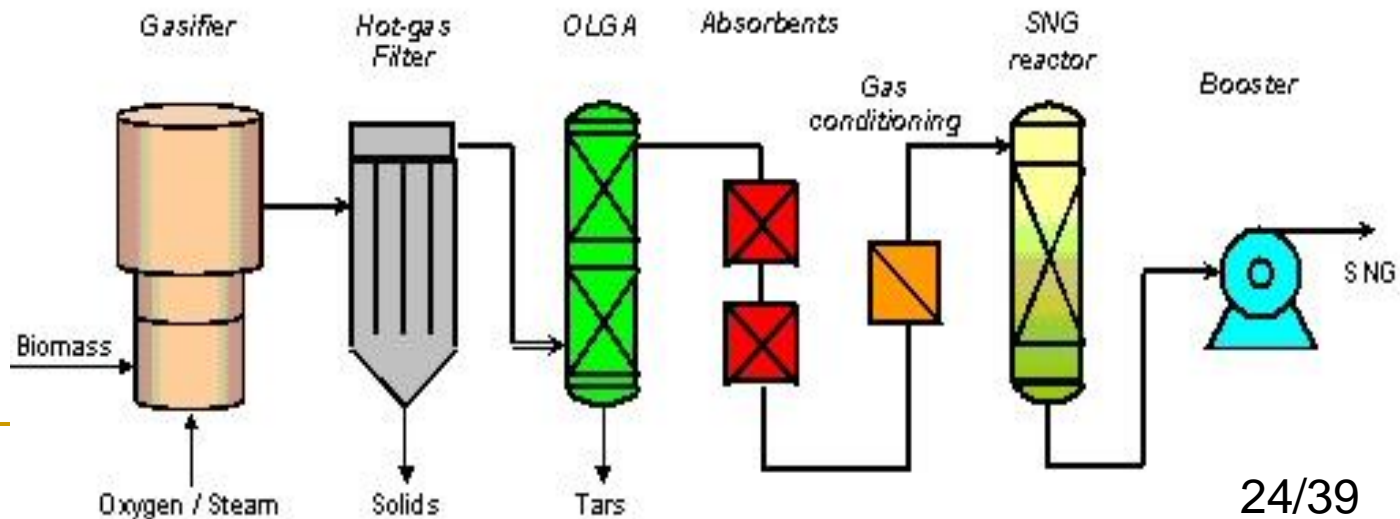
- CO₂: +35% ↓

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



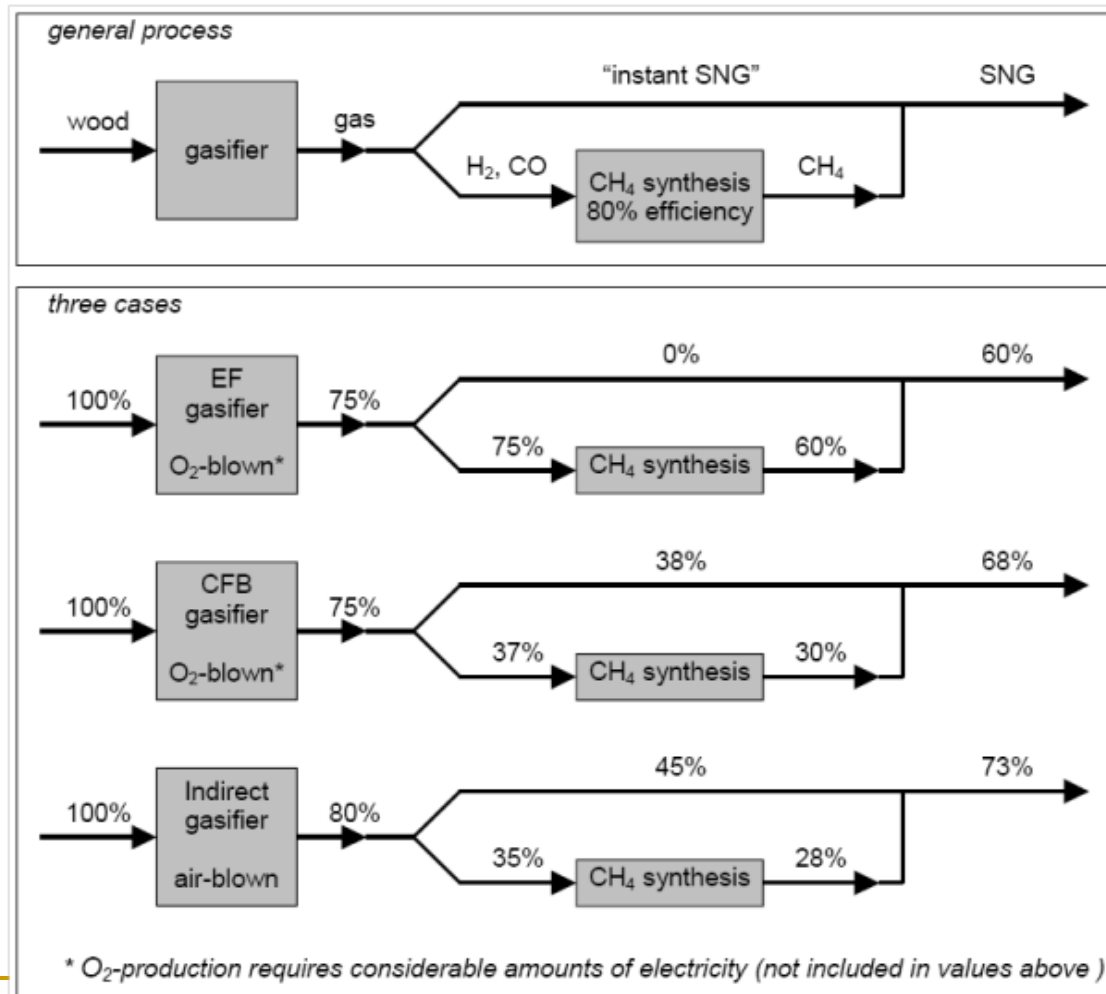
RSNG Production

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%

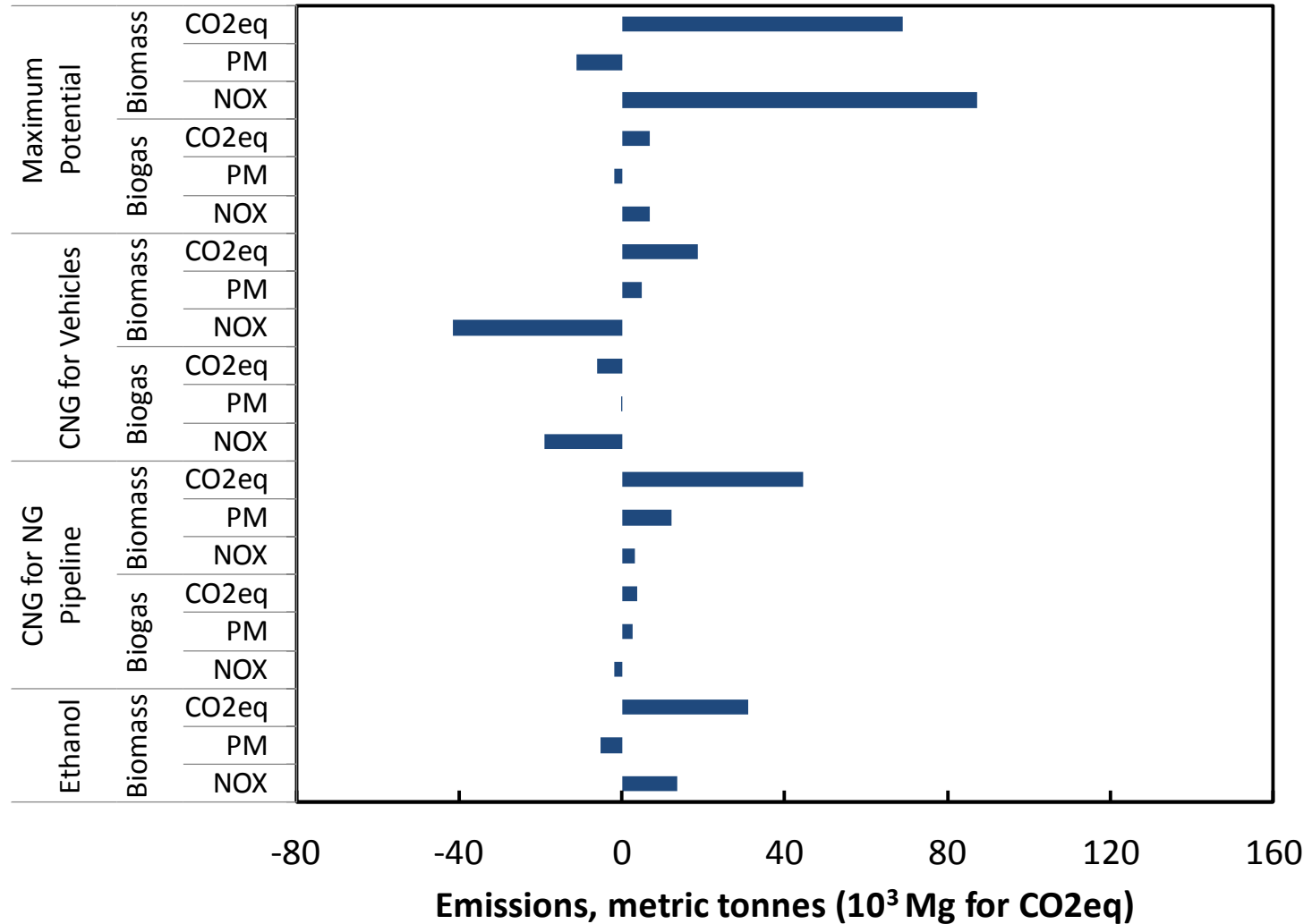
¹Zwart et al., 2006

²Thomas and Martin, 2012

³Bahor et al., 2008



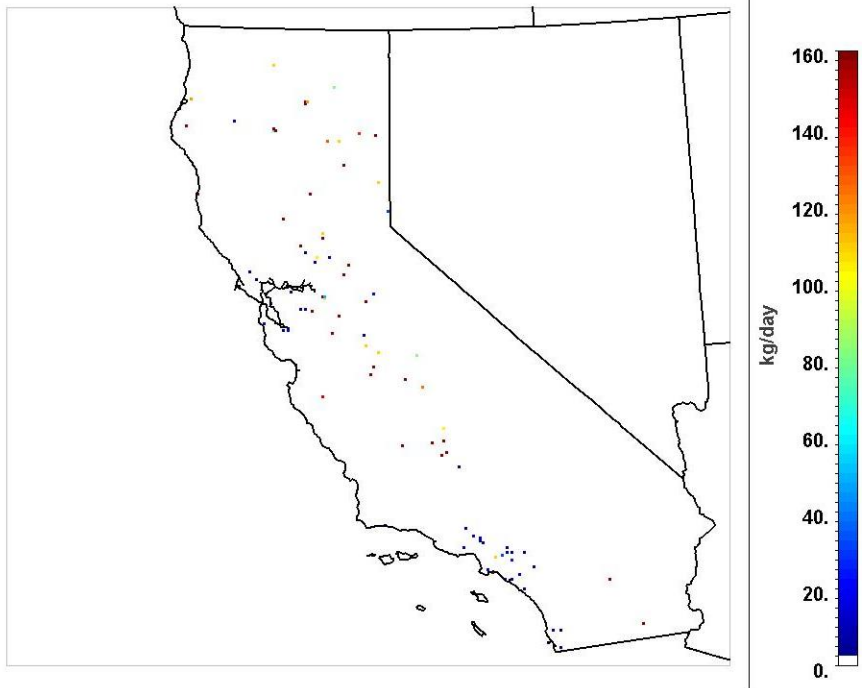
Emissions from Biomass for Fuel



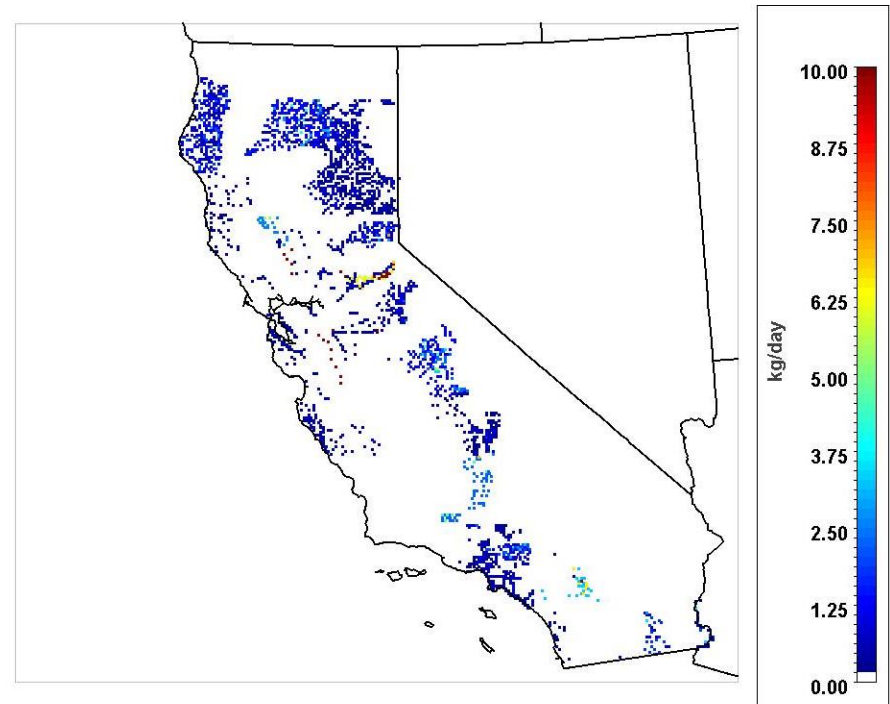
Spatial Allocation of Emissions

2020 Technical Potential: NO_x Emissions

Facilities

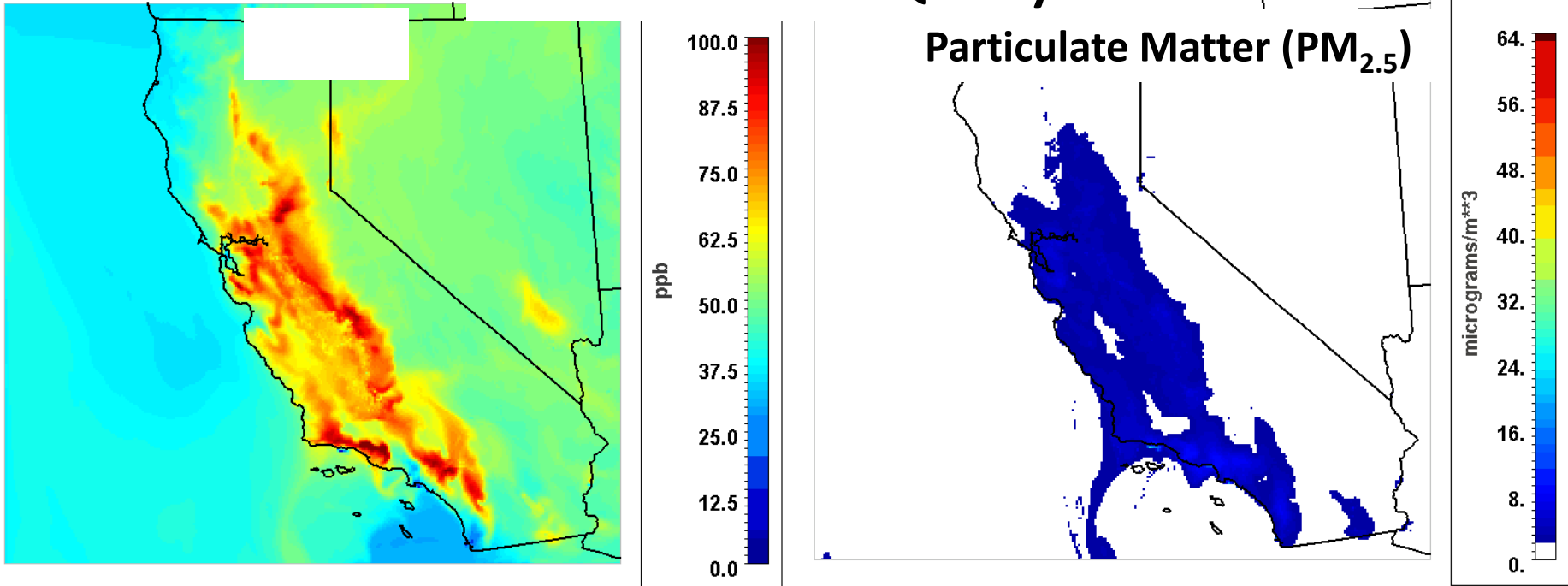


Collection and Transport



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

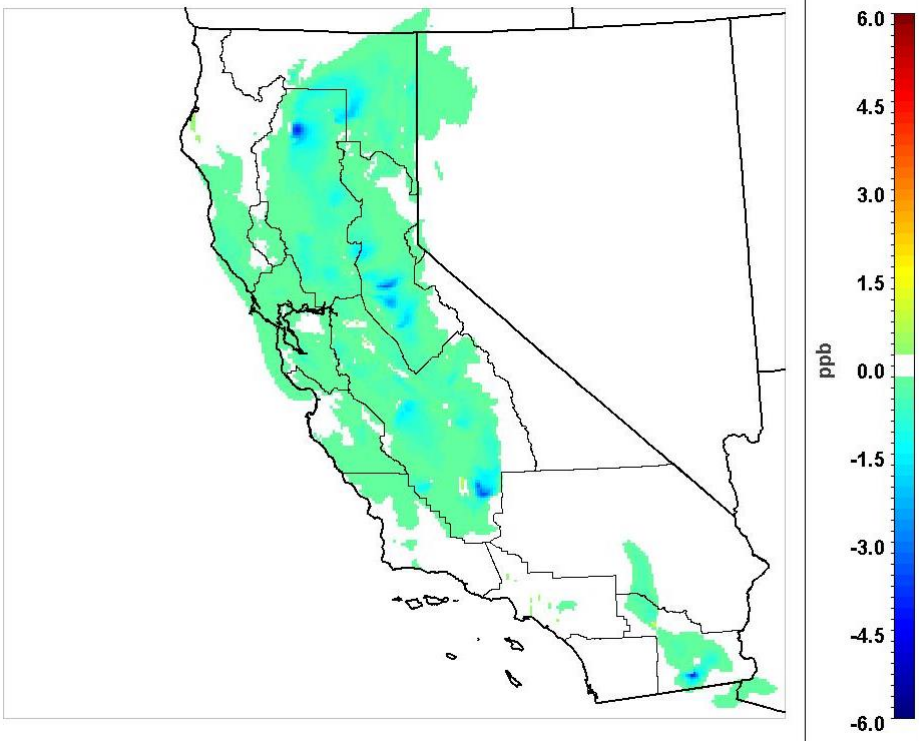
No Biopower vs Current Biopower

0 MW

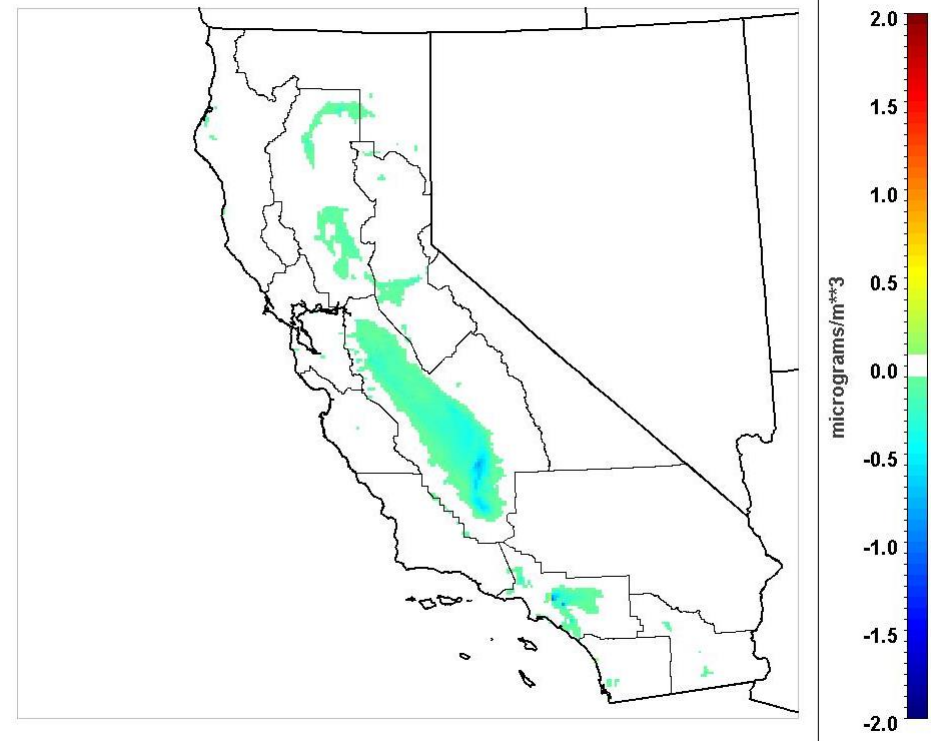
vs

1,264 MW

Difference in Max 1-hour Ozone



Difference in 24-hour average PM_{2.5}



Maximum Biopower Potential: Summer

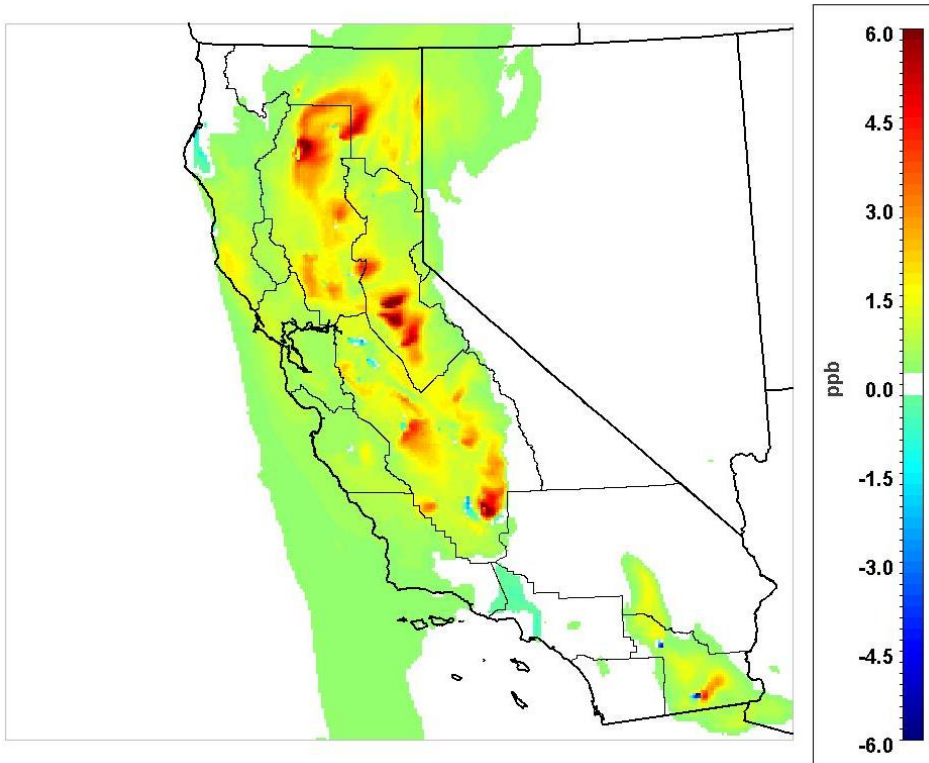
Maximum Biopower vs Current Biopower

4,660 MW

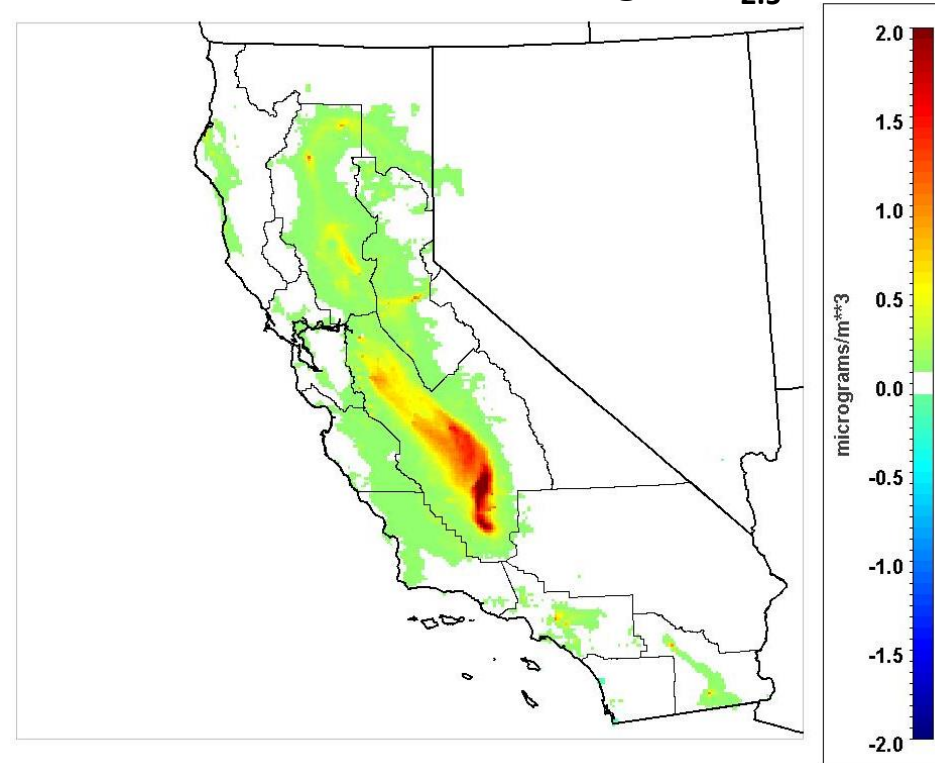
vs

1,264 MW

Difference in Max 1-hour Ozone



Difference in 24-hour average PM_{2.5}



Maximum Biopower Potential: Winter

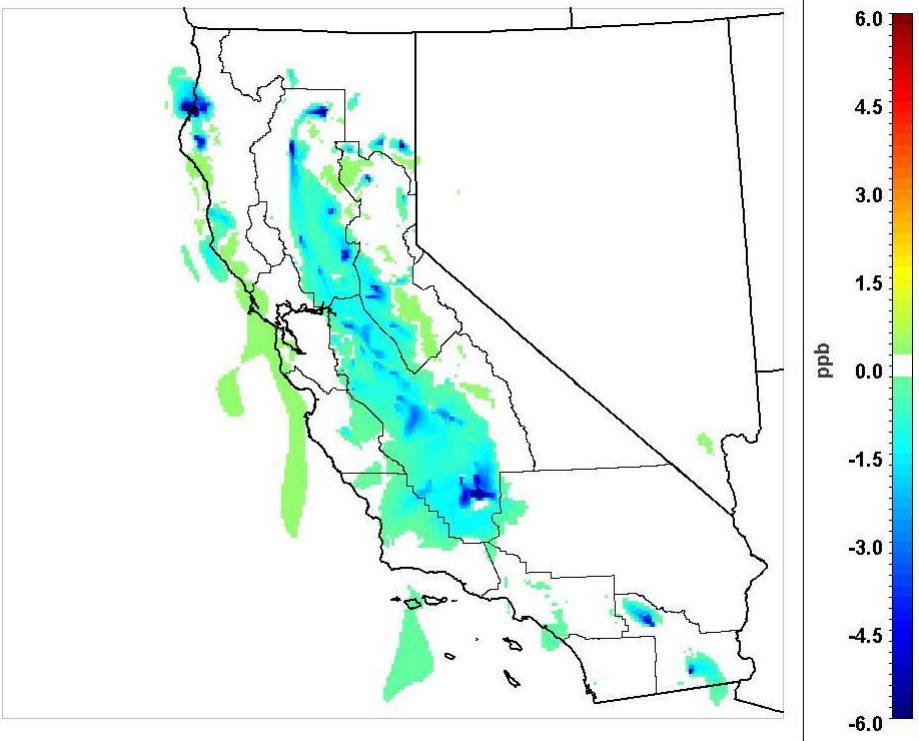
Maximum Biopower vs Current Biopower

4,660 MW

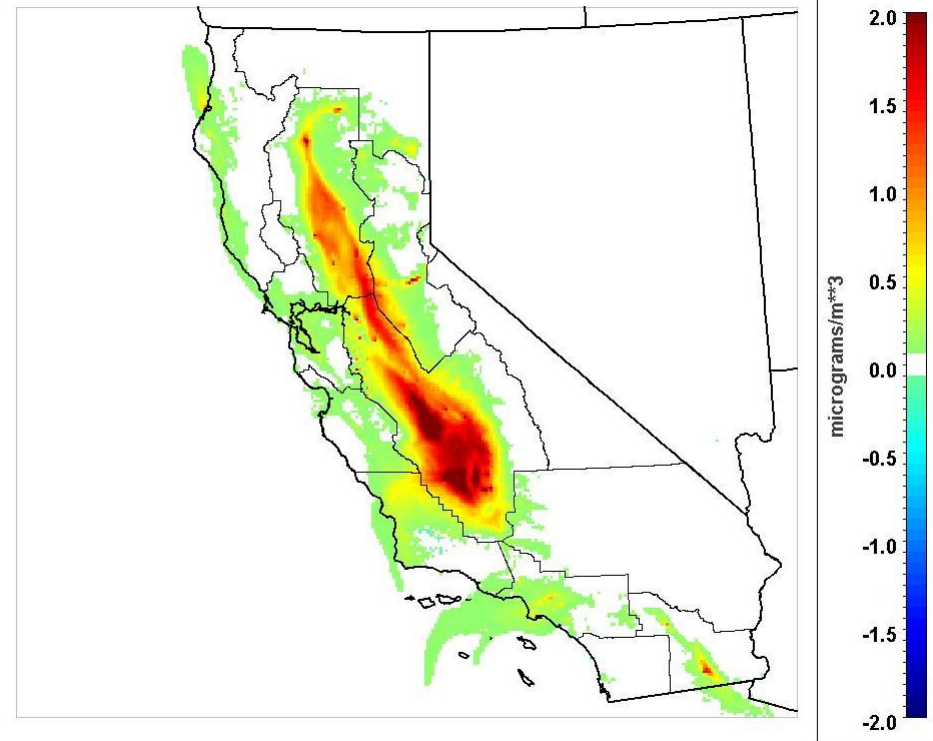
vs

1,264 MW

Difference in Max 1-hour Ozone



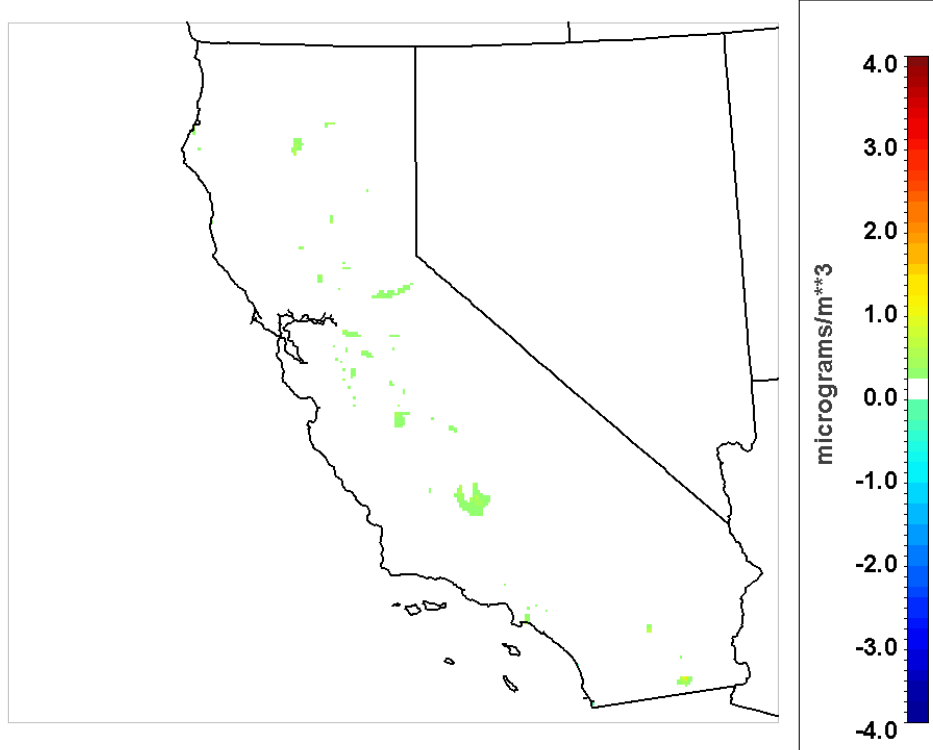
Difference in 24-hour average PM_{2.5}



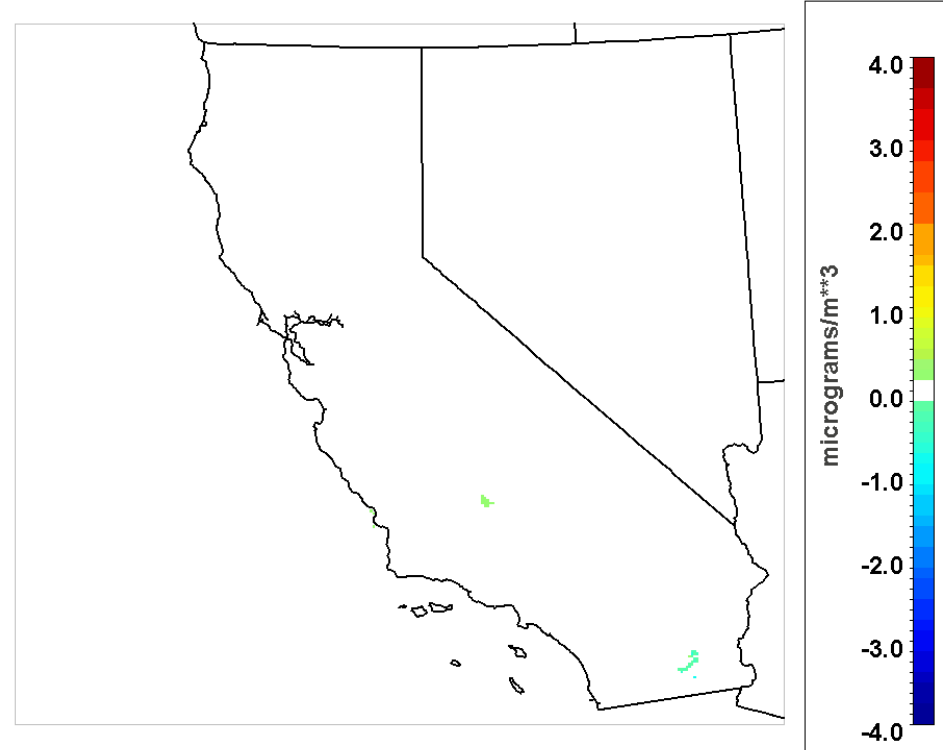
Primary vs. Secondary PM – Summer

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

Primary PM_{2.5}



Secondary PM_{2.5}



Effect of Technology Upgrades

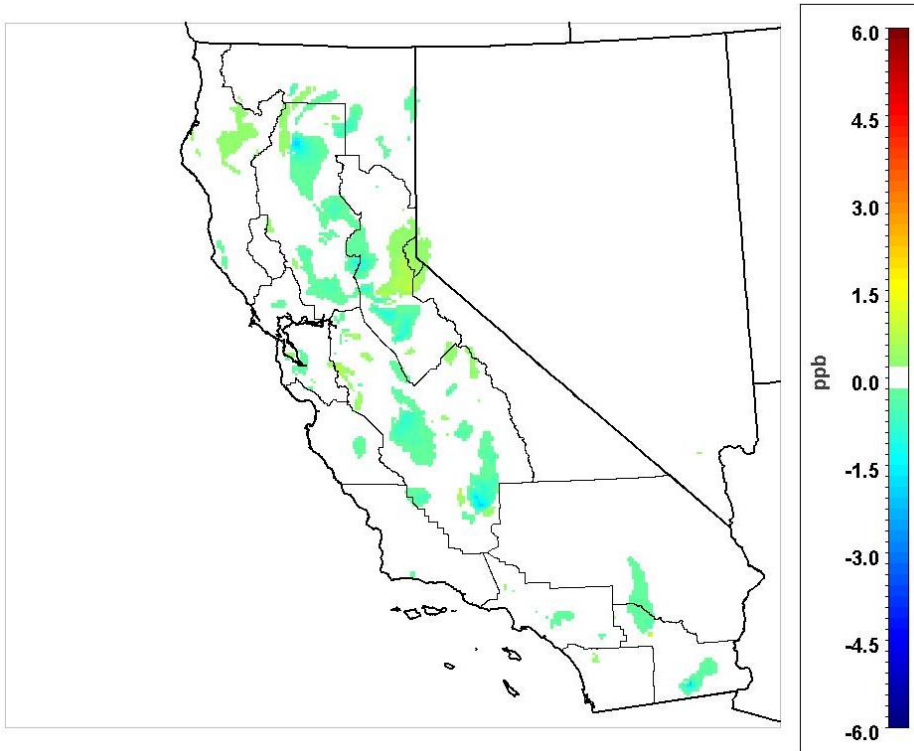
Technology Upgrade vs Current Biopower

4,660 MW

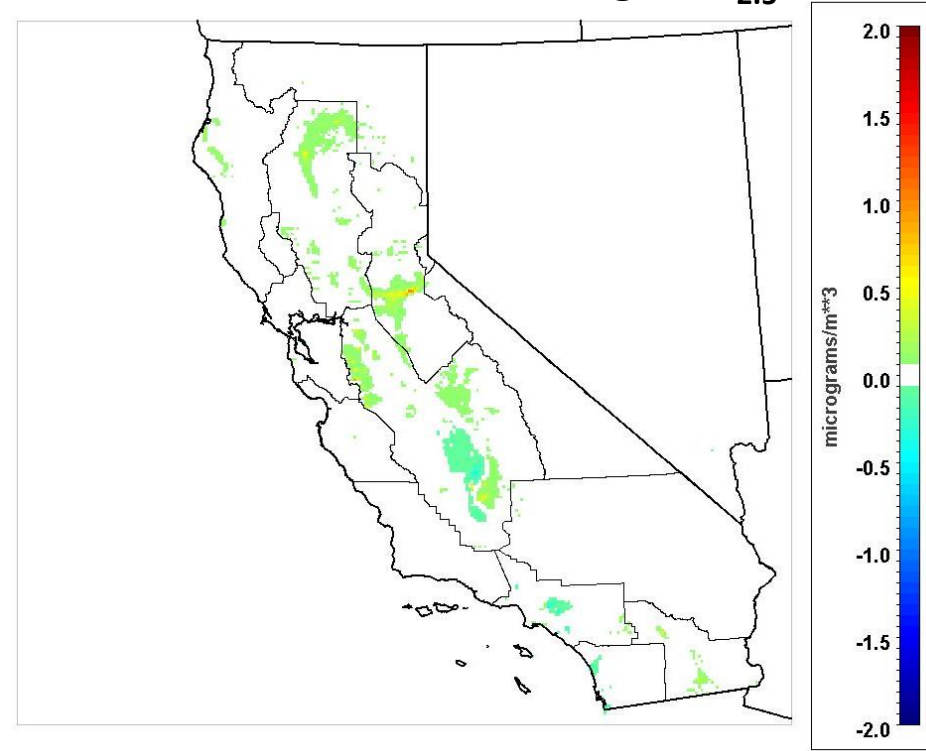
vs

1,264 MW

Difference in Max 1-hour Ozone



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



Effect of CNG vehicles

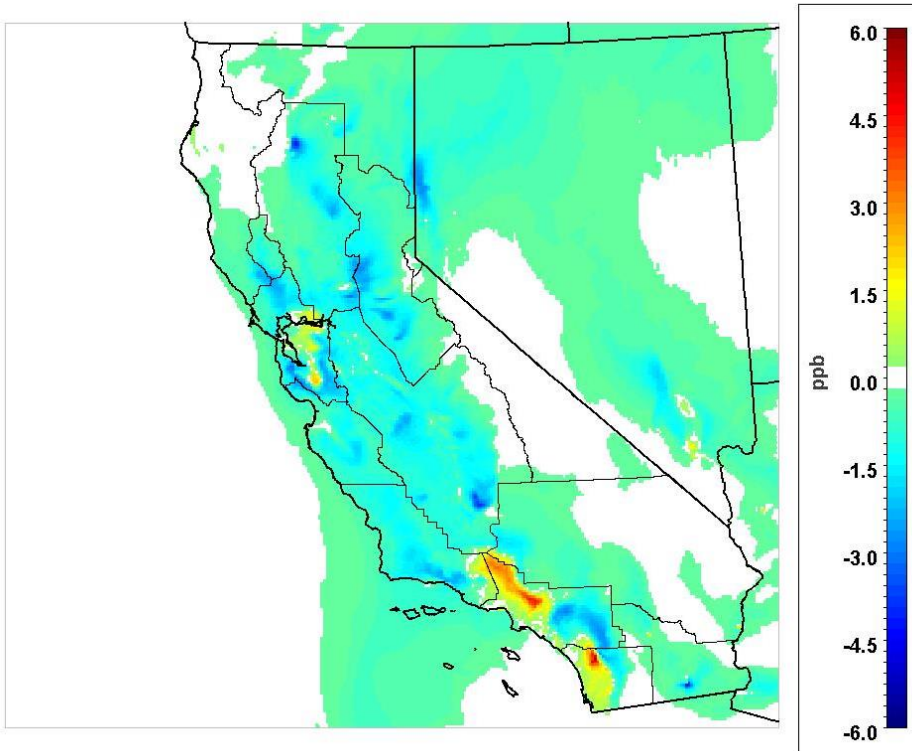
Maximum CNG vs Current Biopower

0 MW

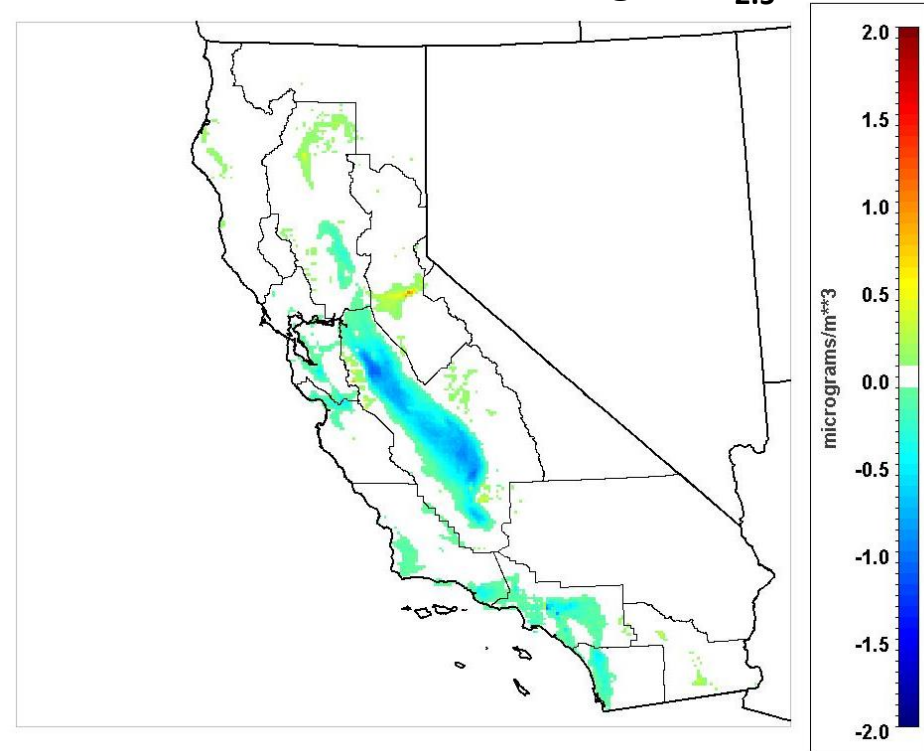
vs

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 criteria pollutants**
- **Conversion of biomass to CNG for vehicles would achieve the lowest emissions of GHG**
- **Conversion of biomass to CNG for vehicles achieved the overall lowest impacts on air quality and GHG**

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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California Environmental Protection Agency
AIR RESOURCES BOARD