Impacts of Natural Gas Composition on Air Quality – An Assessment Using TEMPLES Model

Provided to the California Air Resources Board

by

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Glossary

ARB: Air Resources Board

BTU: British Thermal Unit, unit of energy equivalent to 1055.06 Joules

CMAQ: Community Multiscale Air Quality Modeling System

CNG: Compressed natural gas

CUC: California Unified Cycle (driving cycle)

Emission Sensitivity Factor: emissions change in a NG combustion device due to an increase in Wobbie Index (WI)

FTP: Federal Test Procedure (driving cycle)

G_S: Specific gravity

HHV: Higher heating value

LNG: Liquefied natural gas

MN: Methane number

NEI: National Emissions Inventory

NG: Natural gas

NMHCs: Non-methane hydrocarbons

NO_X: Nitrogen oxides

$PM_{2.5}$: Particulate matter with diameter smaller than 2.5 micrometers

SCC: Standard Classification Code

scf: Standard cubic feet

SMOKE: Sparse Matrix Operator Kernel Emissions

SoCalGas: Southern California Gas Company

TEMPLES: Tool for Emissions Processing of LNG Expansion Scenarios

tpd: Short tons per day

USEPA:	United States Environmental Protection Agency
VERDI:	Visualization Environment for Rich Data Interpretation
WI:	Wobbe Index, in BTU/scf
WRF-ARW:	Advanced Research Weather Research and Forecasting Model
ΔWI:	Change in Wobbe Index, in BTU/scf

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Executive Summary

This report describes and demonstrates the use of an updated version of the Tool for Emissions Processing of LNG Expansion Scenarios (TEMPLES) to analyze how natural gas composition relates to air pollutant emissions and statewide air quality.

TEMPLES comprises of an emissions model (Sparse-Matrix Operator Kernel Emissions (SMOKE) model) and an air quality model (Community Multiscale Air Quality (CMAQ) model) to simulate air pollutant emissions and atmospheric transport and transformation of pollutants in the entire state of California. The modeling region extends to the entire state of California, with a model resolution in the horizontal plane of 4 km 4 km, and a vertical height of up to 10,000 meters above ground, with 15 layers of variable height based on pressure distribution. The emissions model uses the California Air Resources Board emissions inventory data for 2012 as a baseline inventory, which includes all anthropogenic and biogenic sources of emissions. TEMPLES processes information on natural gas (NG) composition and emission factors from NG installations to determine perturbation in the emissions associated with NG combustion. Emission sources that are considered to be affected by natural gas composition and that are included in TEMPLES are residential, commercial and industrial natural gas combustion for space and water heating, cooking, electric power generation, industrial processes and transportation.

This version of TEMPLES includes:

(1) An update of baseline emission inventory with ARB's 2012 emission inventory

(2) Meteorological conditions that are consistent with 2012 emissions and that represent two episodes of two weeks: one in January and one in July.

(3) Fugitive emissions from natural gas transmission infrastructure

(4) Inventory of CNG vehicles

These updates in TEMPLES should provide a more accurate model for predicting the effects of changing natural gas properties on air pollutant emissions.

The simulated pollutant emissions and air quality impacts from changing natural gas composition depend on the assumed emission factor sensitivity for the technologies considered here. The incremental change in natural gas quality is defined by the Wobbe Index, which is used in experimental studies as an indicator for NG quality. Values for emission changes per change in Wobbe Index are obtained from experimental studies of residential appliances for cooking, and water and space heating, commercial and industrial boilers, and light-duty and heavy-duty compressed natural gas (CNG) vehicles. The

pollutant emissions included in the analyses depend on the source type, based on the data available from experimental studies. For residential sources, nitrogen oxide (NO_X) and CO emissions were reported, whereas for industrial and commercial installations only NO_X emissions were available. For mobile sources, NO_X and $PM_{2.5}$ are included in the analyses of CNG vehicles.

Two base cases and seven scenarios, summarized in Table ES1, were developed to illustrate the capabilities of TEMPLES to determine the impacts of natural gas composition on emissions and air quality.

Table ES1 Simulation scenarios

Scenarios	**Description**
Base Cases	
Summer Baseline	Baseline emissions from ARB 2012 Emissions Inventory for two weeks in July
Winter Baseline	Baseline emissions from ARB 2012 Emissions Inventory for two weeks in January
Study Cases	
Case A	Natural gas quality shift of ΔWI = +50 BTU/scf, with respect to Baseline cases
Case B	Natural gas quality shift of ΔWI = +50 BTU/scf with maximum burner sensitivity, with respect to Baseline cases
Case C	Impact of natural gas quality shift of ΔWI = +50 BTU/scf on large electricity generation point sources only, with respect to Baseline
Case D	Natural gas quality shift of ΔWI = +50 BTU/scf for CNG vehicles only, with respect to Baseline
Case E	Impact of natural gas quality shift of ΔWI = +50 BTU/scf in Southern California only, with respect to Baseline
Case F	Impact of natural gas quality shift of ΔWI = +50 BTU/scf in Northern California only, with respect to Baseline
Case G	Effect of NG fugitive emissions with respect to Baseline

The three largest contributors to total NO_X emissions from NG combustion in the summer are industrial natural gas combustion from boilers and engines and commercial sector natural gas combustion. These sources are assumed to use low-NO_X burners which are very sensitive to changes in Wobbe Index, and as a result, industrial and commercial sources are the main contributor to NO_X emission increases in all cases where stationary sources are perturbed: Cases A-E.

Cases A and B produce the maximum increases in NO_X emissions for summer episodes, with increases of 32 and 30 tons per day, respectively. The difference between Case A and B is due to differences in emission sensitivity factors for residential appliances. The same cases in winter cause increases in NO_X emissions of 41 and 34 tons per day, respectively. These emission increases correspond to less than 2% of total statewide NO_X emissions in the year 2012. The emissions increase in the summer cases A and B causes 8-hour average ozone concentrations to increase by 0.8 ppb in sensitive areas like the San Joaquin and Sacramento Valleys. Concentrations of $PM_{2.5}$ increase by up to 0.1 $\mu g/m^3$ in the Central Valley and the South Coast Air Basin. The applicability of TEMPLES to analyze specific sources and geographical differences is demonstrated with cases C, E and F.

The effect of Wobbe Index in mobile sources is evaluated with Case D. Based on new emission testing results, light-duty vehicles are assumed to be insensitive to changes in natural gas composition, whereas heavy-duty vehicles tend to decrease in NO_X emissions. As a result, the impact of NG composition on the emissions from CNG vehicles and their effect on air quality is small.

These results demonstrate the applicability of TEMPLES in determining the effect of changing natural gas composition on pollutant emissions and air pollutant concentrations in California. Overall, air quality impacts evaluated using this new version of TEMPLES are smaller than the ones predicted with the previous version of TEMPLES. The main factor is the substantial reduction in NO_X emissions from natural gas combustion from the 2005 emissions inventory used in the original TEMPLES to the 2012 emissions inventory used in this updated version. Addition of fugitive emissions did not affect ozone and $PM_{2.5}$ concentrations substantially. Finally, the addition of a detailed inventory of county-specific CNG vehicles helps refine the potential impacts of these vehicles on emissions and air quality.

I Introduction

Owing to changes in natural gas (NG) sources, the composition of NG used in California is changing, potentially increasing combustion emissions from NG equipment and engines. NG supplies can differ in composition (e.g., lower fraction of methane, higher fraction of ethane and other non-methane hydrocarbons) and properties (e.g., higher heating value and Wobbe index). Wobbe Index (WI) is particularly relevant as it is a measure of energy delivery to devices that control gas flow with a fixed orifice, and it is an indicator of interchangeability of fuel gases. It is defined by:

$$WI = \frac{HHV}{\sqrt{G_S}} \quad (1)$$

where HHV and G_S are the higher heating value and the specific gravity of the gas, respectively. Typical WI values in the NG system are around 1335 BTU/scf (British thermal unit per standard cubic foot of natural gas) and the maximum set by the California Public Utility Commission (CPUC) is 1385 BTU/scf.

Previous experimental results showed sensitivity in the emissions of nitrogen oxides (NO_X) and other pollutants from NG combustion applications due to changes in WI (SoCalGas, 2006a-c; Singer *et al*. 2009; Crawford and Lyons, 2009; Crawford and Lyons 2010). Changes in NO_X emissions affect ozone and particulate matter formation and could impact efforts of air pollution control strategies to attain ozone standards in California. Between 6% and 9% of NO_X emissions in California are produced by NG combustion in the residential, commercial, industrial, and utilities sectors (California Air Resources Board, 2009b), but the contribution from NG combustion to total emissions could change due to changes in NG composition.

This project developed a predictive model to analyze how natural gas composition relates to pollutant emissions and air quality, and provides the California Air Resources Board (ARB) with a tool to help assess the cost effectiveness of emissions reduction options. The model was originally devised to assess emissions impacts from changes in natural gas (NG) quality due to importing liquefied natural gas (LNG) into California. Because of the initial focus on LNG, the model was named Tool for Emissions Processing of LNG Expansion Scenarios (TEMPLES). Recent changes in the US NG market have nearly eliminated LNG imports into California. However, other sources of NG, such as domestic shale gas and biogas, may affect the quality and composition of natural gas, and can be studied by the TEMPLES model.

TEMPLES is developed with the objective of analyzing potential emission perturbations in the emissions from NG combustions. This report documents the model components, structure, and input requirements for TEMPLES, and includes demonstrations of TEMPLES in a series of scenarios that illustrate the model capabilities.

II Model Description

The TEMPLES model comprises three main modules: (1) an emissions model, (2) an air quality model and (3) a visualization package. The emissions model is based on the Sparse Matrix Operator Kernel Emissions (SMOKE) model. SMOKE is integrated in a custom-made program that receives input parameters related to natural gas composition and calculates the resulting emissions due to changes in gas composition. The air quality model module uses the community-developed Community Multiscale Air Quality (CMAQ) model and the post-processing tool to visualize results is the Visualization Environment for Rich Data Interpretation (VERDI) package, which are both publicly available. Figure 1 illustrates the main components of the modeling framework. TEMPLES refers to the three modules – Emissions Modeling, Air Quality Modeling, and Visualization Tools – and the inputs required to run the modules: Baseline Emissions Inventory and NG Distribution Scenarios parameters.

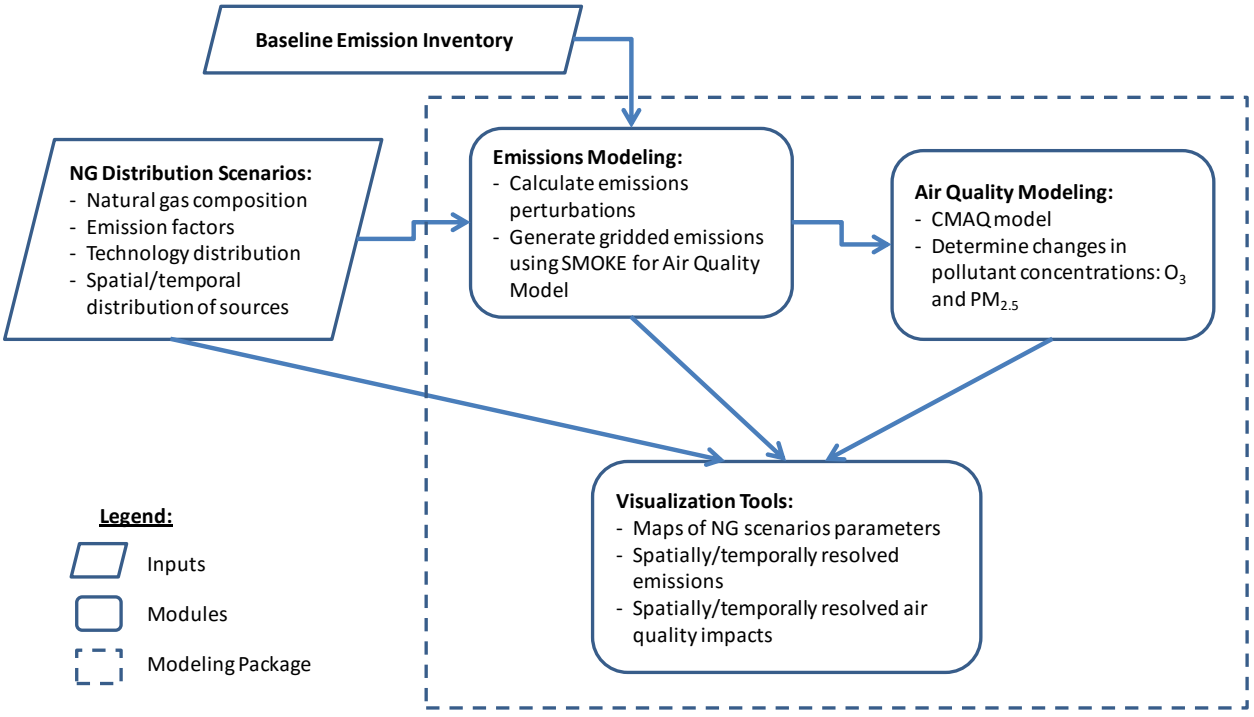


Figure 1 Components for the TEMPLES modeling framework.

Figure 2 illustrates the workflow and transfer of information within the TEMPLES modeling framework. In summary, the parameters input by the user (**Natural Gas δ, Impact Scenario**) are processed using the **Custom Pre-Processor** to apply emission perturbations to the **Base Inventory**. The resulting emissions (**Emissions***) are then input to the **Air Quality Model (CMAQ)**, which uses other inputs provided with TEMPLES (grey boxes). The results from the Air Quality Model (**Case Outcomes**), which are hourly and spatially-resolved concentration fields of pollutants, can be processed with the **Post-Processor (VERDI)** to obtain air pollution maps.

User interaction with TEMPLES is limited to two main tasks (shown in yellow boxes):

1) Input parameters that define a Test Case: changes in natural gas quality (defined by ΔWI), emission factors and emission sensitivity factors, and technology distribution factors.
2) Run the Post-Processor tool VERDI using the outputs generated by the air quality model (Case Outcomes)

In the following sections, the general concepts of the two modeling parts – emissions modeling and air quality modeling – along with the description of inputs parameters are explained in more detail. The primary purpose of TEMPLES is to evaluate the air quality and emissions impacts of changing natural gas quality. In a typical simulation, some input data (shown in grey boxes in Figure 2) will not be modified by the user so that natural gas quality can be isolated as the only changing variable. Therefore, users are provided with pre-loaded data relevant to California geography, atmospheric chemistry, and meteorology. Thus, these components are not discussed in detail; the user can visit the Community Modeling and Analysis Center website (CMAS; http://www.cmascenter.org) for more details on these components. Appendix A includes a user's manual for TEMPLES.

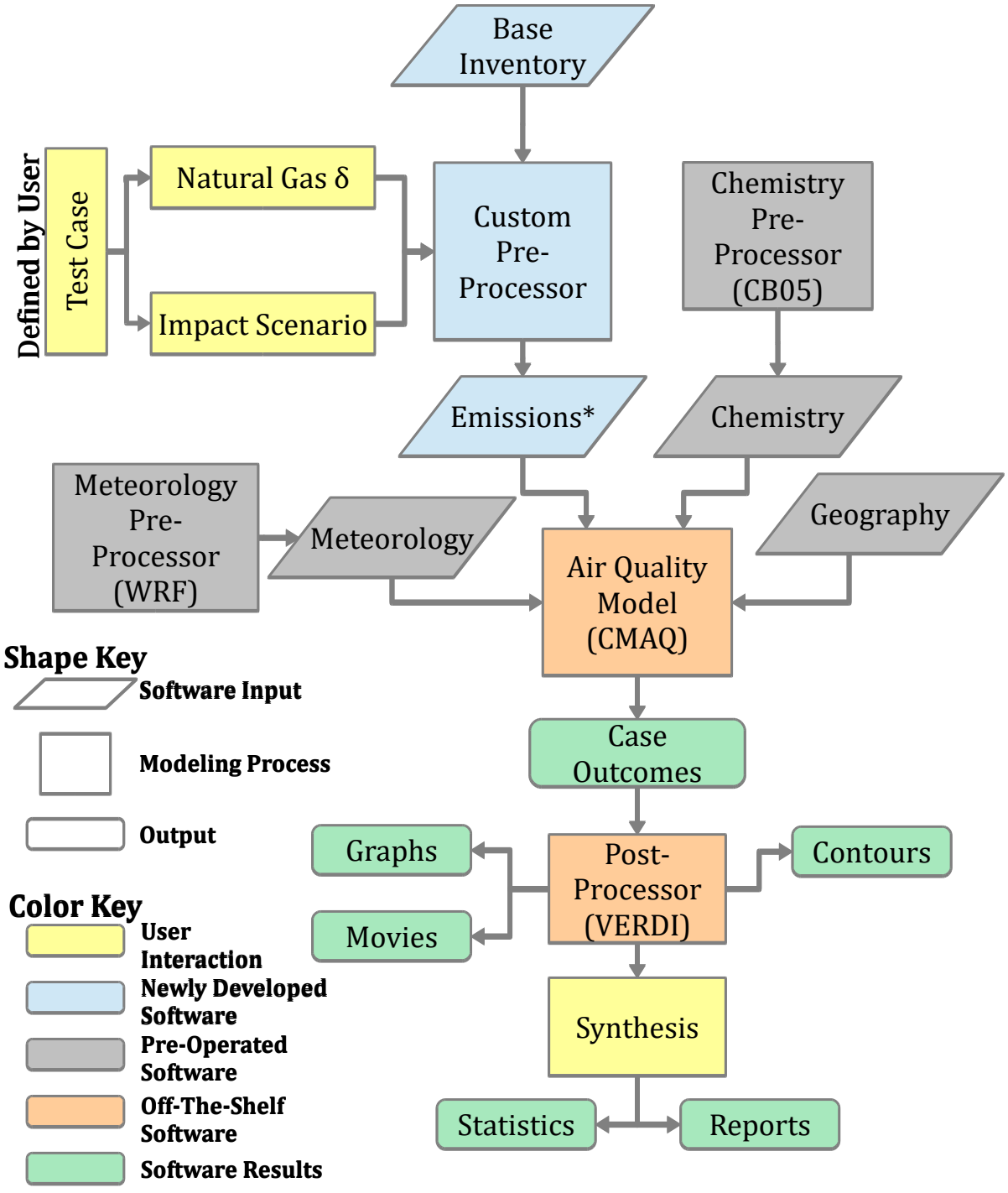


Figure 2 Detailed TEMPLES air quality model flowchart..

II.A Emissions Modeling

The emissions modeling part – executed by the Custom Pre-Processor – consists in processing of a set of input parameters that define a Test Case, to produce a perturbation in a Base Inventory of emissions due to natural gas composition changes, and generating the temporally-resolved gridded emissions that are required by the Air Quality Model (CMAQ). The Base Inventory is supplied with the natural gas tool and does not require direct user manipulation; it is based on the California Air Resources Board inventory for 2012.

To define the test case, the user must be familiar with the type of emission sources considered in the inventory and the input data needed to define the case completely. The Custom Pre-Processor is built upon the SMOKE model (www.smoke-model.org), which accounts for all anthropogenic and biogenic emission sources. The types of sources that are relevant to the analysis of emissions from natural gas combustion are the following:

Point Sources: Point sources are large pollutant sources that are emitted from a single point, such as a stack at a factory. Emissions from these sources are reported to local air districts. Examples of point sources are electricity plants, refineries, and factories. In addition to latitude and longitude, the location of a point source includes elevation, and stack height and vertical plume rise are considered when determining the elevation of a point source.

Area Sources: Area sources are small pollutant sources that are spread over a geographical area and do not emit from any single location. These sources are individually much smaller than the industrial sources categorized as point sources, but the large number of area sources. Examples include residential cooking and small commercial and industrial processes. Data for area source emissions are aggregated for a region such as a city, county, or district. The resolution of the aggregation area often depends on the activity density within the region and the availability of monitoring station data within the area. Emissions reported as area sources are the aggregate of all emissions sources within the specified area. Vehicles have a separate source designation and are not included in area sources.

On-Road Mobile Sources: This source type includes all vehicles traveling on highways, streets and roads. The base emissions inventory includes the estimated vehicle fleet size and the total vehicle miles traveled within the state of California.

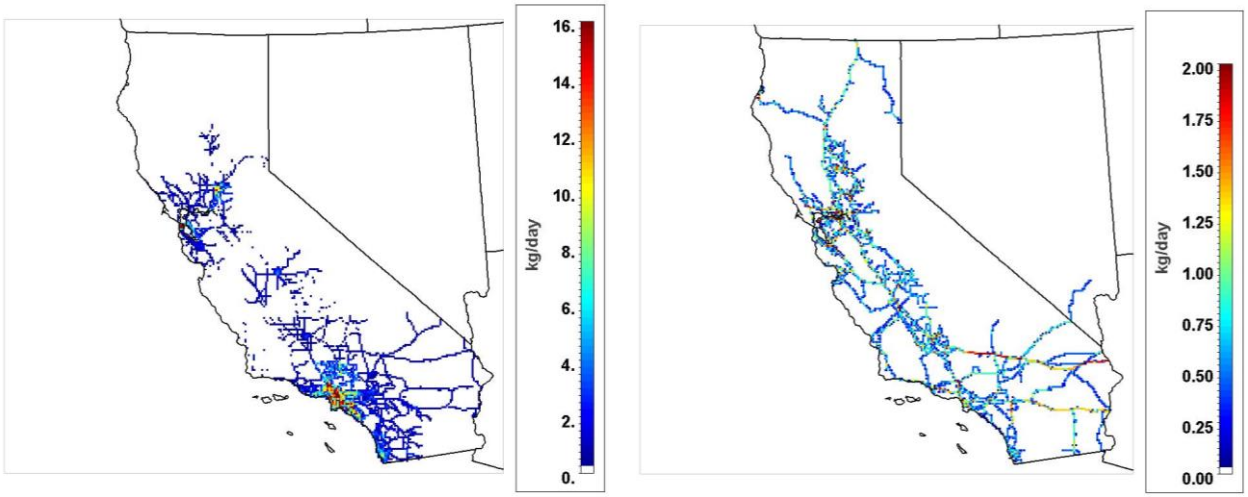
The Custom Pre-Processor is designed to apply emission sensitivity factors obtained from emission testing to the relevant emission source types described above. Emission testing is performed on specific NG applications (e.g. oven burner, premix power surface burner boiler, CNG Honda Civic), whereas emission sources included in the inventory are more generic (e.g. residential NG combustion, commercial space heating, light-duty vehicles). Consequently, the Custom Pre-Processor requires additional inputs that define technology distribution factors to link emission testing emission sensitivity factors with the emission sources present in the inventory. Section II.A.1 describes the emission sensitivity factors used in this study, and section II.A.2 presents the methodology to apply emission sensitivity factors to emissions in the inventory.

This new version of TEMPLES includes a detailed inventory of CNG vehicles that exist in the state. The inventory includes number of vehicles per county. The CNG vehicle population in California in 2012 is presented in Table 1. Spatially-resolved emissions from CNG vehicles are shown in Figure 3a.

Table 1 CNG vehicle population in California in 2012

Vehicle Type	Population
Passenger Cars	16,434
Light-Duty Trucks	258
Medium-Duty Trucks	5,100
Light Heavy-Duty Trucks	3,242
Medium Heavy-Duty Trucks	867
Heavy Heavy-Duty Trucks	433
Waste Collection Vehicles	1,003
Transit Buses	5,303
School Buses	1,841

Fugitive Emissions from NG Transmission: This new version of TEMPLES includes fugitive emissions from the transmission of NG throughout the state. Based on data provided by the California Energy Commission there are nearly 12,700 miles of transmission lines throughout the state. Assuming an average loss of 3.7 kilograms of NG a year, per meter of transmission line (Picard, 1999), and that approximately 5% of Natural Gas is comprised of non-methane hydrocarbons (short-chain alkanes), potential emissions of short-chain alkanes from NG transmission lines are 11.4 tons per day on average. Spatially-resolved emissions from NG transmission lines are shown in Figure 3b.



(a) CNG vehicles NO_X (b) VOC from NG Transmission Lines

Figure 3 Emissions from CNG vehicles and NG transmission lines

II.A.1 Emission Factors from Combustion of Natural Gas and Sensitivity to Natural Gas Composition Changes

The impacts of natural gas composition changes determined by TEMPLES depend on the assumed emission factor sensitivity for the technologies considered. These values are obtained from experimental studies conducted to determine emission changes due to changes in gas composition or WI.

The changes in emissions per change in WI are categorized for three different source types: residential sources, commercial and industrial sources, and mobile sources.

1) Residential Sources

The emission factors and perturbations due to changes in WI for residential sources are based on extensive emission testing conducted by the Lawrence Berkeley National Laboratory, LBNL (Singer *et al*. 2009). Various residential appliances were tested to determine changes in criteria pollutant emissions due to changes in WI. A thorough statistical analysis to determine emission factors and uncertainty bounds for those residential appliances is presented in Appendix B. Based on the statistical analysis of all measurements conducted by LBNL, two sets of emission sensitivity factors were calculated based on experimental probability distribution and interval of confidence. Table 2 presents the baseline emission factors for CO and NO_x and the two sets of emission sensitivity factors, the Best Engineering Estimate values and the Maximum Likely Increase values. For details on the statistical analysis, refer to Appendix B.

Table 2 Baseline emissions factors ($ef_{i,j,l}$) and emission sensitivity factors ($\Delta ef_{i,j,l}$) for residential burners.

	Baseline Emission Factor (ng/J)		Emission Sensitivity Factor: Best Engineering Estimate (ng/J per 50 BTU/scf increase in WI)		Emission Sensitivity Factor: Maximum Likely Increase (ng/J per 50 BTU/scf increase in WI)	
	CO	**NO_X**	**CO**	**NO_X**	**CO**	**NO_X**
Furnaces	12.9	29.2	-1.50	1.20	3.26	3.06
Storage Water heaters	0.1	25.6	0.38	0.24	1.98	1.26
Tankless Water Heaters	129.3	20.4	7.88	3.48	76.28	10.50
Cooktops	118.0	34.7	22.16	0.78	66.40	1.64
Ovens	117.4	34.5	25.10	-0.36	52.04	1.00
Broilers	97.0	29.3	12.34	0.66	34.10	3.08

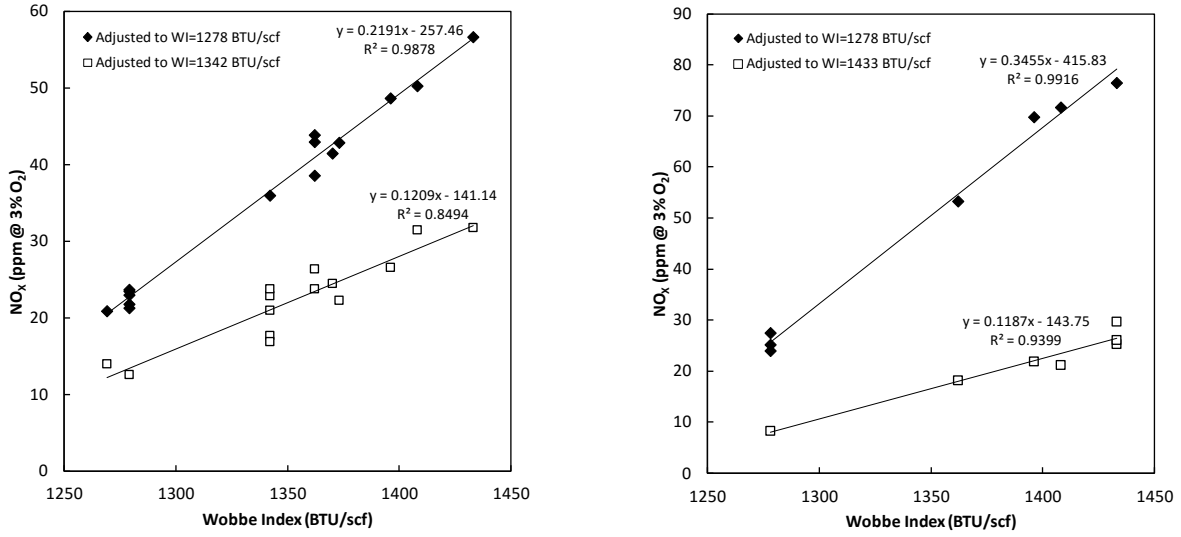
2) Commercial and Industrial Sources

In contrast to residential appliances, data on the effect of gas composition in commercial and industrial sources is limited. Emission tests were performed on low-NO_X (SoCalGas, 2006a, 2006b) and ultra-low-NO_X burners (SoCalGas, 2006c). In the experiments with low-NO_X burners, two types of steam boilers were used: (1) a 645,000 BTU/hr boiler, with a premix power surface burner type, which is the most common burner type in the SoCalGas service territory, and (2) a 397,000 BTU/hr boiler with premixed gun-type power burner, which industry experts claimed might be sensitive to rich gases. The emission testing included tuning the boilers to the baseline gas so that they met emission standards, and then measuring emissions when combusting two gases with WI values different from the baseline gas. For example, for the power surface burner, equipment was tuned to meet the emission specifications for NG with WI values of 1278 and 1342 BTU/scf, and then the burner was operated on NG with different WI values (SoCalGas, 2006a). Figure 4a presents the NO_X emission results of these experiments. Similar tests were conducted for the

premixed gun-type power burner, with the boiler tuned to NG with WI values of 1278 and 1434 BTU/scf, and those results are presented Figure 4b (SoCalGas, 2006b). Interpolation of this data for low-NO_X burners shows that NO_X emissions increase by up to 40% for a WI increase from 1335 to 1385 BTU/scf.

A boiler with a 645,000 BTU/hr surface premix power burner was used in experimental emission testing of ultra-low-NO_X burners (SoCalGas, 2004). Emission controls for this ultra-low NO_X burner are more sophisticated and complex than the controls in the low-NO_X burners in order to meet more stringent emission specifications. This more advanced technology could make the equipment more sensitive to changes in natural gas composition. The experimental data for the ultra-low NO_X burner is presented in Figure 5; the measurements showed an increase in NO_X emissions of 15% for a WI increase from 1335 to 1385 BTU/scf. Table 3 summarizes the emission sensitivity factors ($\Delta ef_{i,j,l}$) for commercial and industrial burners that are used in this study.

Based on an internal equipment survey conducted by the South Coast Air Quality Management District (Baez, 2010), commercial and industrial area sources are typically smaller units with low-NO_X burner technology, and commercial and industrial point sources are usually large equipment with ultra-low NO_X technologies.



(a) (b)

Figure 4 Measured NO_X emissions versus WI for commercial and industrial burners: (a) steam boiler with premixed gun-type power burner (SoCalGas, 2006a), (b) low-NO_X steam boiler (SoCalGas, 2006b).

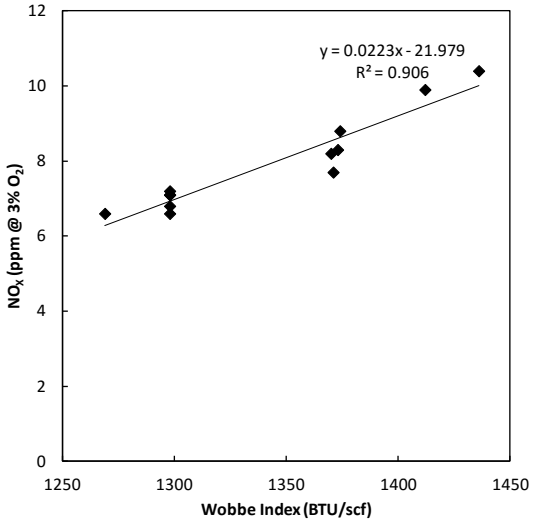


Figure 5 Measured NO_X emissions versus WI for an industrial ultra-low NO_X steam boiler (SoCalGas, 2004).

Table 3 Emission sensitivity factors ($\Delta ef_{i,j,l}$) for commercial and industrial burners.

Burner Type	NO_X Emission Sensitivity Factor (% per 50 BTU/scf increase in WI)
Low-NO_X burner	40%
Ultralow-NO_X burner	15%

Additional information on emissions from industrial and commercial applications is found in reports conducted by the Gas Technology Institute (Tickel *et al*. 2009; Tickel and Wagner, 2009). These reports show that emissions from industrial burners tuned at Wobbe index of 1332 BTU/scf are insensitive to changes in Wobbe index in the range 1335-1385 BTU/scf. Hence, the NO_X emission sensitivity factors shown in Table 3 may represent an overestimation of the potential effects of changes in Wobbe Index.

All the data presented above for industrial sources is related to boilers and burners. There is very limited information on the sensitivity of gas turbines and other stationary internal

combustion engines. Only one source shows qualitatively the sensitivity of gas turbines to NG quality (GE, 2005). For the present study, large boilers from the utility and industrial sectors are assumed to employ ultra-low NO_X burner technology. Because experimental data are unavailable, gas turbines are assumed to have the same emission sensitivity factor as low-NO_X burners. This is a gross assumption that introduces high uncertainty in the results. Experimental emission testing of gas turbines and engines would reduce this uncertainty.

3) Mobile Sources

Experimental data on emissions from compressed natural gas (CNG) vehicles are limited to a few studies. Crawford and Lyons (2009) studied emission changes in a light-duty CNG vehicle (Honda Civic GX) under two driving cycles. For heavy-duty trucks, Crawford and Lyons (2010) tested several models with varying natural gas WI and Methane Number (MN) for heavy-duty trucks. More recently, Durbin et al. (2015) analyzed different engines used in refuse haulers.

Results obtained by Crawford and Lyons (2009) showed little sensitivity in NO_X emissions for two driving cycles: Federal Test Procedure (FTP) and California Unified Cycle (CUC). For the FTP cycle, NO_X emissions decreased slightly with departures in fuel composition from CARB specifications for CNG. Emissions of NO_X were insensitive to changes in fuel composition under the CUC driving cycle. Thus, based on the results obtained in that study, light-duty CNG vehicles are assumed to be insensitive to changes in natural gas composition.

Crawford and Lyons (2010) showed that NO_X emissions would decrease with increasing Methane Number (MN), and would increase with decreasing MN and increasing WI. Maximum increases in NO_X compared to a CARB-certified CNG (WI=1333 BTU/scf and MN=89) were 29%, for a fuel with WI=1385 and MN=75. More recently, Durbin et al. (2015) tested newer engines for a similar mix of fuels as in Crawford and Lyons (2010). In general, Durbin et al. (2015) report considerably lower emissions of NO_X compared to previous studies. In addition, results show opposite sensitivity to changes in gas composition. Namely, results suggest that NO_X emissions decrease with increasing WI and decreasing MN. This is attributed to richer combustion in the engines evaluated, which promotes greater reduction of NO_X emissions in the three-way catalysts. Maximum decrease in NO_X during a transport cycle for the diesel engine was 21%.

Table 4 summarizes the emission sensitivity factors ($\Delta ef_{i,j,l}$) for light-duty and heavy-duty CNG vehicles used in this study.

Table 4 NO_X emission sensitivity factors ($\Delta ef_{i,j,l}$) for CNG vehicles.

Vehicle Type	Emission Sensitivity Factor (% per 50 BTU/scf increase in WI)
Light-duty CNG	0%
Heavy-duty CNG	-21%

A statistical analysis of CNG mobile source emissions tests, similar to that conducted for residential sources, would provide more reliable estimates of natural gas composition impacts on vehicle emissions, but the current data are too limited to allow such an analysis. Using maximum emission changes can demonstrate the use of TEMPLES for simulating natural gas composition effects on emissions from mobile sources and establishes maximum likely bounds on these impacts.

II.A.2 Natural Gas Tool Methodology

The overall process executed by the Custom Pre-Processor is to apply a multiplication factor to the baseline inventory (Base Emissions) to obtain the emissions for a particular NG case (Eq. 2). The multiplication factor depends on the natural gas composition (parameterized by a change in WI), emission sensitivity factors obtained from emission testing, and information on technology distribution to relate technologies tested with emission sources in the inventory.

NG Case Emissions = Base Emissions ×

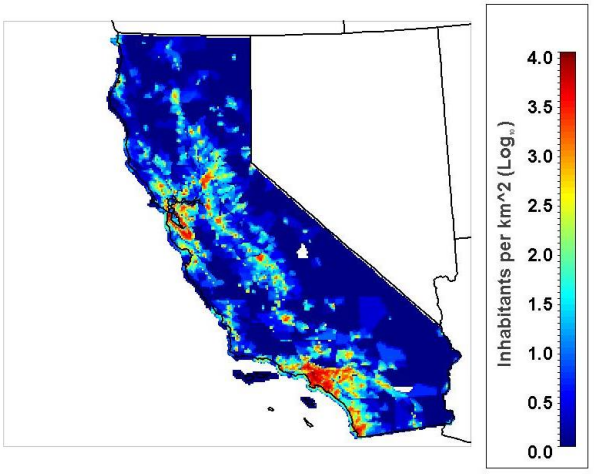
$$\text{Factor } (\Delta WI, \text{ emission testing , tech distribution}) \qquad (2)$$

The baseline emissions inventory is based on CARB inventory for 2012. The CARB inventory contains area, on-road and off-road mobile, and point sources. CARB emission sources are categorized using the Emissions Inventory Codes (EIC) system, whereas TEMPLES, which follows the same convention as SMOKE, uses categories of emissions based on the Standard Classification Codes (SCC) system. Area and mobile sources are

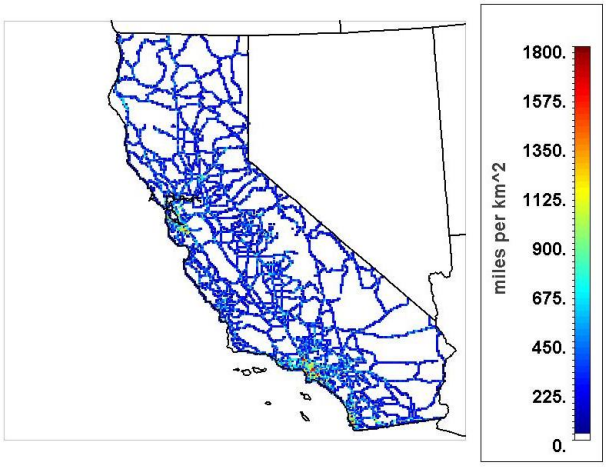
reported by EIC at a county level. Emissions by EIC are translated into SCC categories and are spatially allocated at the necessary grid resolution using appropriate spatial surrogates. SCCs for area and mobile sources have ten digits that denote four levels of characterization in the format AA-BB-CCC-DDD. For area sources, level one (AA) denotes a process; level two (BB) is the major activity sector; level three (CCC) describes fuel use; and level four (DDD) denotes technology. For mobile sources, AA denotes mobile sources, BB denotes fuel, CCC denotes vehicle class and DDD denotes road type. SCCs for point sources have eight digits with four levels of characterization in the format A-BB-CCC-DD. For point sources, level one (A) denotes a type of process, level two (BB) denotes major activity sector, level three (CCC) denotes fuel use; and level four (DD) denotes technology.

Spatial surrogates are spatially-gridded weighting factors based on geographical and/or socio-economic factors to disaggregate emissions data with coarse resolution to a resolution that matches the emissions and air quality models. For example, residential, commercial and industrial sector sources of emissions are weighted using population density, commercial and industrial sector area distribution as respective surrogates. Emissions from mobile sources are allocated using the distribution of road miles as surrogate. Figure 6 presents the spatial distribution of population density, road distribution and commercial and industrial area distribution in California. Point sources are reported by SCC and by specific spatial coordinates, so spatial surrogates are not needed to allocate point source emissions. Figure 7 presents the spatially resolved emissions from various types of emission sources. Table 5 through Table 7 present the sources by SCC that are related to natural gas combustion in the baseline inventory. Non-road mobile sources were not included in the analyses presented in this report due to lack of emission sensitivity data.

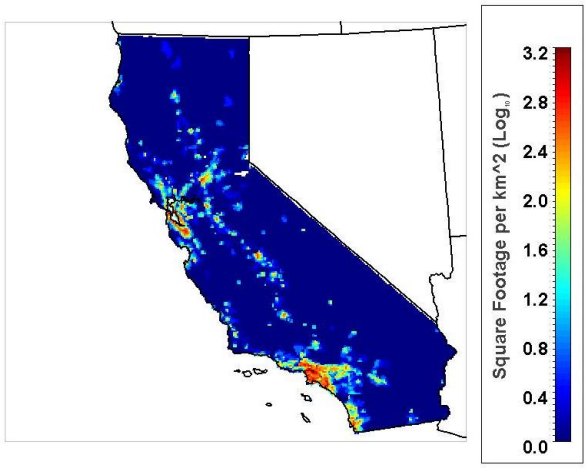
Emissions from CNG vehicles were estimated by ARB and are incorporated in the inventory. However, there are no specific SCC codes for CNG vehicles. Thus, this work established new artificial SCC codes for CNG vehicles, so that their emissions could be manipulated separately from gasoline and diesel vehicles. Spatial and temporal surrogates for CNG vehicles are assumed to be the same as their gasoline and diesel counterparts.



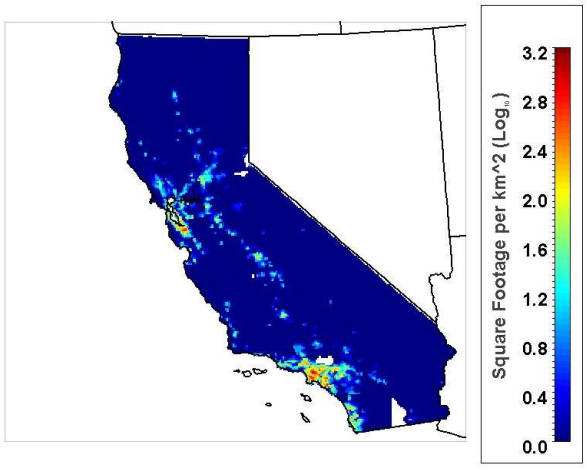
(a) Population



(b) Roads

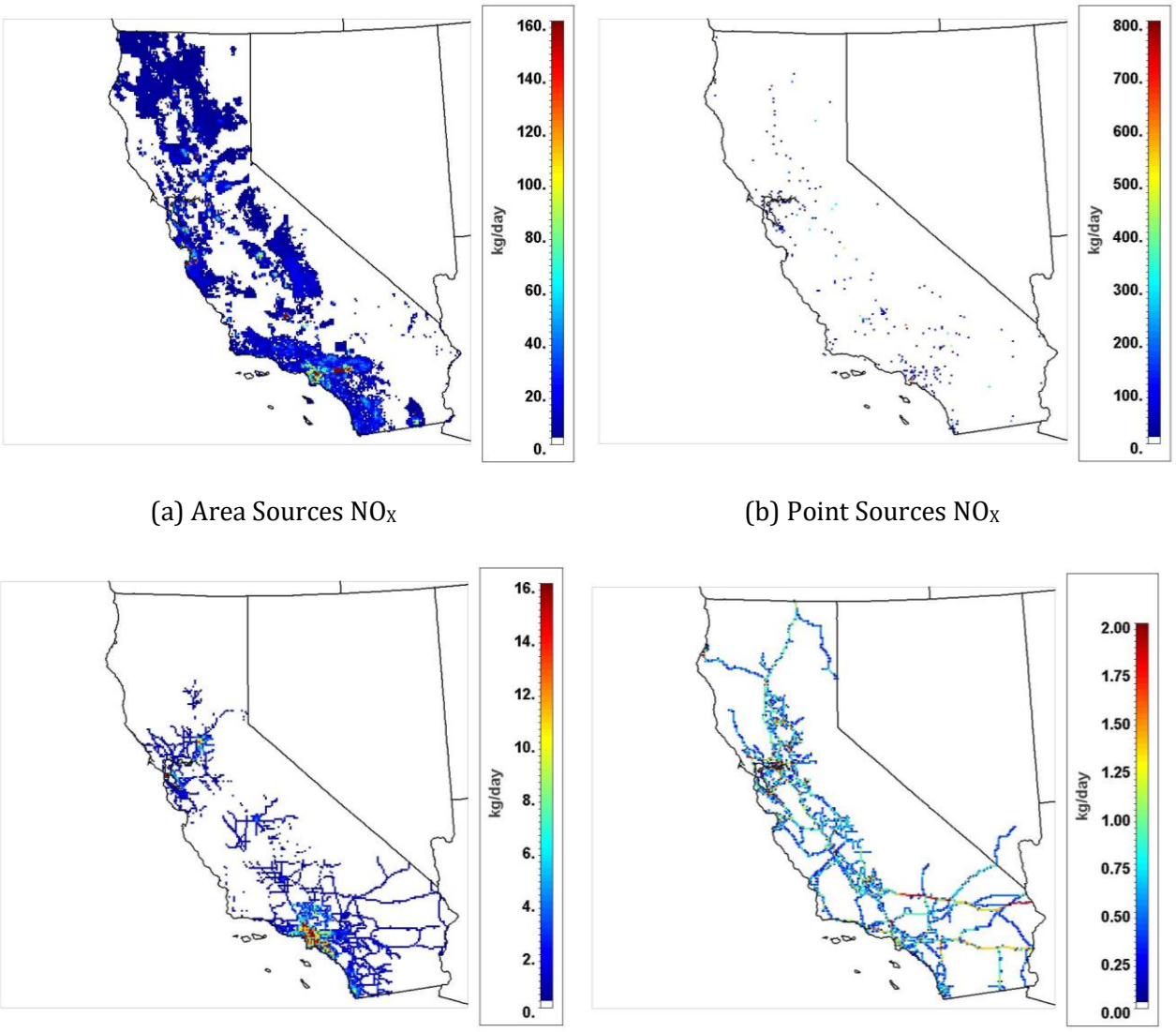


(c) Commercial Sector



(d) Industrial Sector

Figure 6 Examples of spatial surrogates for the entire State of California to allocate area emissions



(a) Area Sources NO_X (b) Point Sources NO_X

(c) CNG vehicles NO_X (d) VOC from NG Transmission Lines

Figure 7 Emissions from various sources: (a) NO_X from area sources, (b) NO_X from point sources, (c) NO_X from CNG vehicles, and (d) VOC from NG transmission lines.

Table 5 SCC descriptions for area sources.

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four
2101006000	Stationary Source Fuel Combustion	Electric Utility	Natural Gas	Total: Boilers and IC Engines
2102006000	Stationary Source Fuel Combustion	Industrial	Natural Gas	Total: Boilers and IC Engines
2102006002	Stationary Source Fuel Combustion	Industrial	Natural Gas	All IC Engine Types
2103006000	Stationary Source Fuel Combustion	Commercial/Institutional	Natural Gas	Total: Boilers and IC Engines
2104006000	Stationary Source Fuel Combustion	Residential	Natural Gas	Total: All Combustor Types
2104006010	Stationary Source Fuel Combustion	Residential	Natural Gas	Residential Furnaces
2310020000	Industrial Processes	Oil and Gas Exploration and Production	Natural Gas	Total: All Processes

Table 6 SCC descriptions for on-road CNG vehicles.

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four
2266610000	Mobile Sources	Highway Vehicles – CNG	Passenger Cars	All types
2266620000	Mobile Sources	Highway Vehicles – CNG	Light-Duty Trucks	All types
2266630000	Mobile Sources	Highway Vehicles – CNG	Medium-Duty Vehicles	All types
2266640000	Mobile Sources	Highway Vehicles – CNG	Light Heavy-Duty Trucks	All types
2266650000	Mobile Sources	Highway Vehicles – CNG	Medium Heavy-Duty Trucks	All types
2266660000	Mobile Sources	Highway Vehicles – CNG	Heavy Heavy-Duty Trucks	All types
2266670000	Mobile Sources	Highway Vehicles – CNG	Waste Collection Vehicles	All types
2266680000	Mobile Sources	Highway Vehicles – CNG	Transit Buses	All types
2266690000	Mobile Sources	Highway Vehicles – CNG	School Buses	All types

Table 7 SCC descriptions for point sources.

SCC	SCC Level One	SCC Level Two	SCC Level Three	SCC Level Four
10100601	External Combustion Boilers	Electric Generation	Natural Gas	Boilers : 100 Million Btu/hr except Tangential
10100602	External Combustion Boilers	Electric Generation	Natural Gas	Boilers < 100 Million Btu/hr except Tangential
10100604	External Combustion Boilers	Electric Generation	Natural Gas	Tangentially Fired Units
10200601	External Combustion Boilers	Industrial	Natural Gas	> 100 Million Btu/hr
10200602	External Combustion Boilers	Industrial	Natural Gas	10-100 Million Btu/hr
10200603	External Combustion Boilers	Industrial	Natural Gas	< 10 Million Btu/hr
10200604	External Combustion Boilers	Industrial	Natural Gas	Cogeneration
10300601	External Combustion Boilers	Commercial/Institutional	Natural Gas	> 100 Million Btu/hr
10300602	External Combustion Boilers	Commercial/Institutional	Natural Gas	10-100 Million Btu/hr
10300603	External Combustion Boilers	Commercial/Institutional	Natural Gas	< 10 Million Btu/hr
20100201	Internal Combustion Engines	Electric Generation	Natural Gas	Turbine
20100202	Internal Combustion Engines	Electric Generation	Natural Gas	Reciprocating
20100205	Internal Combustion Engines	Electric Generation	Natural Gas	Reciprocating: Crankcase Blowby
20200201	Internal Combustion Engines	Industrial	Natural Gas	Turbine
20200202	Internal Combustion Engines	Industrial	Natural Gas	Reciprocating
20200203	Internal Combustion Engines	Industrial	Natural Gas	Turbine: Cogeneration
20200204	Internal Combustion Engines	Industrial	Natural Gas	Reciprocating: Cogeneration
20200205	Internal Combustion Engines	Industrial	Natural Gas	Reciprocating: Crankcase Blowby
20200252	Internal Combustion Engines	Industrial	Natural Gas	2-cycle Lean Burn
20200253	Internal Combustion Engines	Industrial	Natural Gas	4-cycle Rich Burn
20200254	Internal Combustion Engines	Industrial	Natural Gas	4-cycle Lean Burn
20300201	Internal Combustion Engines	Commercial/Institutional	Natural Gas	Reciprocating
20300202	Internal Combustion Engines	Commercial/Institutional	Natural Gas	Turbine
20300203	Internal Combustion Engines	Commercial/Institutional	Natural Gas	Turbine: Cogeneration
20300204	Internal Combustion Engines	Commercial/Institutional	Natural Gas	Reciprocating: Cogeneration
39000602	Industrial Processes	In-process Fuel Use	Natural Gas	Cement Kiln/Dryer
39000603	Industrial Processes	In-process Fuel Use	Natural Gas	Lime Kiln
39000699	Industrial Processes	In-process Fuel Use	Natural Gas	General

For the calculation of the multiplication factor, changes in WI are based on the assumption that California's average NG has a WI of 1335 BTU/scf, and are defined at a county level. Using WI to describe a new fuel source is a simplification of what is likely to be a much more complex variation in fuel properties. However, WI is a commonly used metric for relating emission factors in natural gas burners to natural gas quality and is therefore a natural fit for this model (Martinez *et al*., 2013; Southern California Gas, 2004, 2006a, 2006b)). The methodology to determine the multiplication factor uses the emission testing data presented in section II.A.1 and technology distribution factors that establish a relation between NG specific technologies and SCC codes is presented below in four steps. Terms used in the methodology are defined as follows:

Symbol	Definition	Units
i	Appliance/technology evaluated experimentally	-*
j	Type of source: area, mobile, point	-
k	Standard Classification Code	-
l	Pollutant emitted: NO_x, CO, SO_x, VOC, PM	-
m	Location (i.e., county)	-
$ef_{i,j,l}$	Baseline emission factor for technology *i*, in source category *j*, for pollutant *l*	ng/J or -**
$\Delta ef_{i,j,l}$	Emission sensitivity factor by technology *i* due to 50 BTU/scf increase in WI	ng/J or %**
$EF_{j,k,l}$	Baseline emission factor for SCC *k*, in source category *j*, for pollutant *l*	ng/J or -**
$\Delta EF_{j,k,l}$	Increase in emission factor by SCC *k* due to 50 BTU/scf increase in WI	ng/J or %**
$f_{i,j,k}$	Technology distribution factor between technology *i*, and SCC *k*, by source type *j*	-
ΔWI_m	Increment in WI from baseline at location *m*	BTU/scf
$I_{j,k,l,m}$	Impact in emissions – multiplication factor – per source category *j*, SCC *k*, pollutant *l* and at location *m*	-
$E_{j,k,l,m}$	Baseline emissions per source category *j*, SCC *k*, pollutant *l* and at location *m*	tpd
$uE_{j,k,l,m}$	Updated emissions per source category *j*, SCC *k*, pollutant *l* and at location *m*	tpd
X_{NG}	Fraction of vehicles converted to NG	-
$\left({EF_{NG}}/{EF_{CV}}\right)$	NG to conventional vehicle ratio of emission factors for pollutant *l*	-

*- represents dimensionless

**For commercial, industrial and mobile sources emission sensitivity factors are expressed as % relative to baseline factors, and baseline factors are not needed for calculations

STEP 1: Calculate values of $EF_{j,k,l}$. the baseline emission factors for each SCC and type of source.

Prior to calculating the increment in emissions due to changes in WI, baseline emission factors, $EF_{j,k,l}$, for each type of source j, SCC code k, and pollutant l, need to be estimated using Equation 3. Each activity sector k denoted by an SCC may include a variety of technologies and/or appliances i. For instance, SCC 2104006000 corresponds to residential natural gas combustion, which can include cooking and water heating. For cooking, emissions from several types of burners have been measured, and all of them contribute to the total emissions for that SCC. Hence, there is the need for technology distribution factors, $f_{i,j,k}$, to define the distribution of technology i, in each source type j and within each SCC code k. The $f_{i,j,k}$, values used in this study for area and on-road mobile sources are presented in Table 8, and those for point sources are given in Table 9. There are some technology surveys that report the technology mix in use for some appliances (KEMA, 2010; Klug et al. 2011), but data are generally scarce and assumptions are required to complete the entire matrix of $f_{i,j,k}$ values. The baseline emission factors, $ef_{i,j,l}$, for residential appliances are presented in Table 2. The baseline emission factors for the commercial, industrial and mobile sources are assumed to be 1, because the emission sensitivity factors, $\Delta ef_{i,j,l}$, are expressed in relative terms with respect to $ef_{i,j,l}$.

$$EF_{j,k,l} = \sum_i f_{i,j,k} \cdot ef_{i,j,l} \tag{3}$$

STEP2: Calculate values of $\Delta EF_{j,k,l}$. incremental emission factors for each SCC and type of source.

Incremental emission factors, $\Delta EF_{j,k,l}$, for each type of source j, SCC code k, and pollutant l, and for a 50 BTU/scf increase in WI are calculated by Equation 4, using the same technology distribution factors $f_{i,j,k}$ that define a technology mix in a particular SCC and the emission sensitivity factors from reported experimental measurements, $\Delta ef_{i,j,l}$ (presented in Table 2-Table 4).

$$\Delta EF_{j,k,l} = \sum_i f_{i,j,k} \cdot \Delta ef_{i,j,l} \tag{4}$$

STEP3: Calculate values of $I_{j,k,l,m}$. the spatially resolved relative increase in emissions due to changes in WI.

The multiplication factors, $I_{j,k,l,m}$, which is applied to each source category *j*, SCC code *k*, pollutant *l* and at location *m*, are calculated using Equation 5. The change in emissions due to a change in WI is assumed linear over the expected WI range for each technology type. Because $\Delta ef_{i,j,l}$ and $\Delta EF_{j,k,l}$ values are expressed as a change in emissions per 50 BTU/scf increment in WI, the increase in emissions is proportional to the WI change, ΔWI_m, that occurs in location *m* (county), divided by 50 BTU/scf.

$$I_{j,k,l,m} = 1 + \frac{\Delta WI_m}{50} \cdot \frac{\Delta EF_{j,k,l}}{EF_{j,k,l}} \tag{5}$$

STEP4: Calculate values of $uE_{j,k,l,m}$. the spatially resolved updated emissions for the defined scenario.

The updated emissions for a particular NG Case are calculated using Equation 6. The baseline emissions are multiplied by the $I_{j,k,l,m}$ values to perturb baseline emissions and obtain the emissions for a particular scenario for type of source *j*, SCC code *k*, pollutant *l* and location *m*.

$$uE_{j,k,l,m} = I_{j,k,l,m} \cdot E_{j,k,l,m} \tag{6}$$

For vehicle scenarios, the model assumes that only a fraction of vehicles, X_{NG}, is converted to NG vehicles. Hence, the multiplication factors $I_{j,k,l,m}$ are applied only to the fraction of NG vehicles. In addition, baseline emissions from NG vehicles differ from baseline emissions from conventional vehicles. Hence, a correction factor must be applied to the fraction X_{NG} of vehicles, $\left({EF_{NG}}/{EF_{CV}}\right)_l$. The remaining (1- X_{NG}) fraction of vehicles is not altered by the multiplication factors, $I_{j,k,l,m}$. As a result, the vehicle emissions are calculated using Equation 7.

$$uE_{j,k,l,m} = (1 - X_{NG}) \cdot E_{j,k,l,m} + X_{NG} \cdot \left({EF_{NG}}/{EF_{CV}}\right)_l \cdot I_{j,k,l,m} \cdot E_{j,k,l,m} \tag{7}$$

Table 8: Technology distribution factors ($f_{i,j,l}$) for area and on-road mobile sources.

SCC	Furnace	Storage Water Heater	Tank-less Water Heater	Cook-top	Oven Burner	Broiler Burner	Low-NO_X Burner	Ultralow-NO_X Burner	Light Duty CNG	Heavy-Duty CNG
2101006000							1			
2102006000							1			
2102006002							1			
2103006000	0.3	0.3					0.4			
2104006000		0.35	0.15	0.4	0.08	0.02				
2104006010	1									
2310020000							1			
2101006000							1			
2201001000									1	
2201020000									1	
2201040000									1	
2201070000										1
2230060000										1
2230070000										1

Table 9 Technology distribution factors ($f_{i,j,l}$) for point sources.

SCC	Low-NO_X Burner	Ultralow-NO_X Burner
10100601		1
10200601		1
10300601	1	
20100201	1	
20200201	1	
20300201	1	
39000602	1	

II.B Air Quality Modeling

Tropospheric ozone is a product of photochemistry between NO_X and volatile organic compounds (VOCs) in the ambient atmosphere in the presence of sunlight. In California, NO_X and VOCs are mostly emitted from anthropogenic sources such as on-road and off-road vehicles, power plants and industrial operations, although there are significant biogenic sources of VOCs (CARB, 2009b). Ozone concentrations depend on spatial and temporal profiles of precursor emissions, meteorological conditions, transport of precursors and reaction products , and removal processes such as deposition and chemical reaction. Comprehensive models that incorporate all these physical and chemical processes in detail are widely used to understand and characterize ozone formation on regional scales. These air quality models numerically solve a series of atmospheric chemistry, diffusion, and advection equations in order to determine ambient concentrations of pollutants within control volumes over a given geographic region.

Most models employ an Eulerian representation (i.e., one that considers changes as they occur at a fixed location in the fluid, usually called a cell or control volume) of physical quantities on a three-dimensional computational grid. The atmospheric advective diffusion equation for species *m* in a given control volume is:

$$\frac{\partial Q_m^k}{\partial t} = -\nabla \cdot \left(u Q_m^k\right) + \nabla \cdot \left(K \nabla Q_m^k\right) + \left(\frac{Q_m^k}{\partial t}\right)_{sources/sinks} + \left(\frac{Q_m^k}{\partial t}\right)_{aerosol} + \left(\frac{Q_m^k}{\partial t}\right)_{chemistry} \quad (8)$$

where *t* is time, *k* is phase – gas or aerosol, u is wind velocity and *K* is the coefficient of eddy diffusivity tensor that parameterizes turbulent diffusion.

The above equation is numerically integrated in time to obtain the concentration, *Q,* of each species *m* in phase *k* (gas phase or aerosol phase), over a series of discrete time steps in each of the spatially distributed discrete cells of the air quality model. Each term on the right side of the advective diffusion equation represents a major process in the atmosphere. From left to right these are: (1) advective transport due to wind, (2) turbulent diffusion due to atmospheric stability/instability, (3) emission (sources) and deposition (sinks), (4) mass transfer between gas and aerosol phases, and (5) chemical reaction.

The outputs from air quality models are spatially and temporally resolved concentrations of pollutant species within control volumes over a geographic region. To minimize the effects of initial conditions, air quality simulations are performed over multiple days and results from the first few days are not included in the analysis.

The CMAQ model (Byun and Ching, 1999) is a comprehensive air quality modeling system developed by the United States Environmental Protection Agency (US EPA) and is used in many regulatory air quality applications such as studying tropospheric ozone, particulate matter, acid deposition and visibility (Appel *et al*. 2008, 2010; Foley *et al*. 2010). The chemical mechanism used in CMAQ is the CB05 (Sarwar *et al*., 2008), and includes the photochemical formation of ozone, oxidation of volatile organic compounds and formation of organic aerosol precursors. The advection model in CMAQ is based on the Yamartino-Blackman Cubic Scheme (Yamartino, 1993) and vertical turbulent mixing is based on K-theory (Chang *et al*., 1987, and Hass *et al*., 1991). For the simulations presented in this report, the spatial resolution of control volumes is 4km × 4km over the entire state, and a vertical height of 10,000 meters above ground, with 30 layers of variable height based on pressure distribution. Meteorological input data for CMAQ was obtained from the Advanced Research Weather Research and Forecasting Model, WRF-ARW (Skamarock *et al*. 2005). The National Centers for Environmental Prediction (NCEP) Final Operational Global Analysis 1° × 1° grid data (NCEP, 2005) were used for WRF-ARW initial and boundary conditions.

III Simulated Scenarios

This report demonstrates some modeling capabilities of the TEMPLES/CMAQ software developed at UC Irvine to address questions about the impacts of changing natural gas quality on emissions from natural gas equipment and engines. Seven sample cases are simulated to provide an overview of the TEMPLES/CMAQ capabilities and to illustrate likely impacts of changing natural gas quality on statewide emissions and air quality. In addition, certain cases demonstrate the model's sensitivity to the input parameters. These cases were developed to simulate real world and to provide ARB with useful preliminary results for evaluating the impacts of natural gas compositions on air quality. The cases are listed in Table 10.

Table 10 Simulation scenarios.

Scenarios	Description
Base Cases	
Summer Baseline	Baseline emissions from ARB 2012 Emissions Inventory for two weeks in July
Winter Baseline	Baseline emissions from ARB 2012 Emissions Inventory for two weeks in January
Study Cases	
Case A	Natural gas quality shift of ΔWI = +50 BTU/scf, with respect to Baseline cases
Case B	Natural gas quality shift of ΔWI = +50 BTU/scf with maximum burner sensitivity, with respect to Baseline cases
Case C	Impact of natural gas quality shift of ΔWI = +50 BTU/scf on large electricity generation point sources only, with respect to Baseline
Case D	Natural gas quality shift of ΔWI = +50 BTU/scf for CNG vehicles only, with respect to Baseline
Case E	Impact of natural gas quality shift of ΔWI = +50 BTU/scf in Southern California only, with respect to Baseline
Case F	Impact of natural gas quality shift of ΔWI = +50 BTU/scf in Northern California only, with respect to Baseline
Case G	Effect of NG fugitive emissions with respect to Baseline

Base Cases

The Baseline is the 2012 Emissions inventory developed by the California Air Resources Board. For this case, the WI for all of the NG used in the state is 1335 BTU/scf. This case assumes no changes in natural gas composition and is the reference emission inventory for a summer episode. Temporal profiles for some NG combustion sources, such as space heating, vary throughout the year because of seasonal variability in usage. The SMOKE model incorporates typical temporal profiles for all emission sources so that those seasonal variations are reflected in the spatially-resolved emissions.

Two typical episodes are evaluated: (1) 2-week summer episode in July 8-21, 2012, and (2) 2-week winter episode in January 1-14, 2012.

Study Cases

Case A – Best Engineering Guess: Summer-Time Natural Gas Quality Shift of ΔWI = +50 BTU/scf:

This case applies an increase in WI from 1335 to 1385 BTU/scf for natural gas used throughout the state. All natural gas combustion emission sources burn the higher WI fuel. For all technologies, a median or best estimate value for the changes in emission rates for all species and burner technologies are assumed. Thus, for residential burners, the **Best Engineering Estimates** for emission sensitivity factors from Table 2 are used. For commercial and industrial sources, emission sensitivity factors from Table 3 are used.

Case B – Maximum Likely Increase: Summer-Time Natural Gas Quality Shift of ΔWI = +50 BTU/scf with Maximum Burner Sensitivity

Similarly to Case A, this case assumes a WI increase from 1335 to 1385 BTU/scf for natural gas used throughout the state. The only difference with Case A is the emission factor assumed for residential appliances; the **Maximum Likely Increase** from Table 2 is used here as opposed to the Best Engineering Estimate used for Case A. All stationary natural gas combustion emission sources are assumed to burn the higher WI fuel.

Case C – Point Sources Only: Impact of Natural Gas Quality Shift of ΔWI = +50 BTU/scf on Large Emitters in Point Sources

This case evaluates the impacts of increasing Wobbe Index on emissions from large emitters in the point source category. For example, emissions from electric power generation contribute 2% of total statewide NO_x emissions, and those emissions are point sources released from stacks. Based on the state emissions inventory for 2005, 61% of the point source NO_X emissions from natural gas combustion for power generation are from

large gas turbines, 32% are from large boilers, and the remaining 7% are from small boilers and engines. Nearly 5% of the installed capacity in state consists of peaker plants, which are typically single cycle gas turbines that accommodate rapid fluctuations in power demand. Emissions of peaker plants are typically higher than base-load plants, and changes in the gas composition could impact emissions from these turbines. This case assumes that only large power generators experience NG with a higher WI, which is not a realistic scenario because power generators combust the same natural gas as other users. This hypothetical scenario illustrates the contribution to emission changes from large emitters alone should natural gas composition change, and it demonstrates the ability of TEMPLES to evaluate isolated impacts from specific emission sectors, and the potential benefits of controlling specific sources.

Case D – Contribution of CNG Vehicles

This case evaluates the impacts of increasing Wobbe Index on emissions from current CNG vehicles in California. Comparing this case with the Baseline provides information on the contribution of CNG vehicle to ozone and particulate matter formation

Case E - SoCal Only Max Likely Increase: Liquefied Natural Gas Importation to Southern California

This case evaluates the emissions and air quality impacts in Southern California Counties (up to Kern, and Santa Barbara Counties), when a portion of the natural gas supply is imported liquefied natural gas (LNG) from Mexico. The Energy Costa Azul (ECA) liquefied natural gas (LNG) terminal in Baja California, Mexico has the capacity to import approximately one billion cubic feet per day of gasified LNG from overseas, and a portion of this can be transmitted into California. Such imports to California have occurred briefly in the past, but due to the widespread extraction of shale gas in the US, no LNG is currently imported into California. While that is the current reality, energy markets regularly shift, and future LNG imports to California remain a possibility.

Case F - NorCal Only Max Likely Increase: Liquefied Natural Gas Importation to Southern California

This case evaluates the emissions and air quality impacts in Northern California Counties. This case illustrates the different sensitivity that different regions have with respect to changes in natural gas composition.

Case G – Contribution of Fugitive Emissions

This case evaluates the contribution to air pollution from NG fugitive emissions by removing emissions from the NG transmission system from the inventory. Fugitive emissions release short chain alkanes that can react to form ozone. Comparing this case with the Baseline provides information on the contribution of fugitive emissions to ozone and particulate matter formation.

IV Impacts of Gas Composition on Emissions

This section presents tables of absolute emissions for the Base Cases and the Study Cases. Pollutant emissions for all scenarios are disaggregated by the Source Classification Codes (SCC), which indicate specific emission. Table 5, Table 6 and Table 7 present SCCs and their corresponding description for area, mobile and point sources considered in the modeling scenarios. Discussion of the impacts of changing NG composition is centered on the analysis of NO_X emissions because NO_X affects ozone formation. Sensitivity factors for CO were also available and included in the simulations, but CO has low reactivity and little effect on ozone formation.

Table 11 presents the total natural gas-related emissions from stationary and mobile sources for the Baseline and the cases described above for summer. The largest contributors to total NO_X emissions in the Baseline inventory are industrial natural gas combustion from boilers and engines (SCC 2102006000) with NO_X emissions of 31.52 tpd, commercial sector natural gas combustion (2103006000), with NO_X emissions of 12.19 tpd, and residential NG combustion for water heating and cooking (2104006000) with NO_X emissions of 25.84 tpd. It is important to note that commercial and industrial sources are assumed to use low-NO_X burners which are very sensitive to changes in WI. Other large sources of NO_X emissions include gas turbines (20100201) for electricity production with 8.51 tpd, industrial and commercial engines (20200202 and 20300201) with 5.06 tpd and 5.47 tpd, and transit buses (2266680000) with 5.30 tpd.

Table 12 presents the total natural gas-related emissions from stationary and mobile sources for the winter Baseline inventory. The largest differences in emissions between summer and winter are due to the higher emissions from residential and commercial combustion for water and space heating during wintertime, and higher emissions from electricity generation from gas turbines in the summer (highlighted in the table). NO_X emissions from commercial and institutional boilers and engines (2103006000) and from residential NG combustion (2104006000) increase by 16 and 55 tpd, respectively, from summer Baseline to winter Baseline. Emissions from natural gas turbines for electricity generation (20100201) decrease 2.34 tpd from summer Baseline to winter Baseline. As a result, total NO_X emissions from natural gas combustion in the winter add up to 191 tpd, 69 tpd more than in the summer baseline.

Table 11 2012 statewide natural gas combustion emissions for various scenarios (tpd) by SCC for summer

SCC	Baseline	Best	Max	Point Only	CNGV Only	SoCal Only	NorCal Only
2101006000	1.32	1.85	1.85	1.32	1.32	1.36	1.82
2102006000	31.52	44.12	44.12	31.52	31.52	36.84	38.80
2102006002	2.09	2.92	2.92	2.09	2.09	2.63	2.38
2103006000	12.19	14.32	14.70	12.19	12.19	13.31	13.57
2104006000	1.49	1.55	1.67	1.49	1.49	1.59	1.57
2104006010	25.84	26.90	28.55	25.84	25.84	27.09	27.29
2266610000	0.10	0.10	0.10	0.10	0.10	0.10	0.10
2266630000	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2266640000	0.07	0.06	0.06	0.07	0.06	0.06	0.06
2266650000	0.26	0.22	0.22	0.26	0.22	0.24	0.24
2266660000	2.04	1.73	1.73	2.04	1.73	1.82	1.95
2266670000	0.94	0.79	0.79	0.94	0.79	0.83	0.90
2266680000	5.30	4.51	4.51	5.30	4.51	4.62	5.19
2266690000	0.54	0.46	0.46	0.54	0.46	0.49	0.51
10100601	1.71	1.96	1.96	1.96	1.71	1.95	1.71
10100602	0.11	0.12	0.12	0.12	0.11	0.11	0.12
10200601	0.61	0.71	0.71	0.71	0.61	0.66	0.66
10200602	1.12	1.29	1.29	1.29	1.12	1.20	1.21
10200603	0.68	0.78	0.78	0.78	0.68	0.73	0.74
10200604	0.10	0.11	0.11	0.11	0.10	0.11	0.10
10300601	0.30	0.43	0.43	0.43	0.30	0.40	0.33
10300602	1.35	1.88	1.88	1.88	1.35	1.75	1.49
10300603	1.30	1.82	1.82	1.82	1.30	1.70	1.43
20100201	8.51	11.92	11.92	11.92	8.51	10.77	9.66
20100202	0.60	0.83	0.83	0.83	0.60	0.72	0.70
20200201	3.00	4.21	4.21	4.21	3.00	3.62	3.59
20200202	5.06	7.08	7.08	7.08	5.06	6.87	5.27
20200203	3.17	4.43	4.43	4.43	3.17	4.21	3.39
20200204	0.08	0.11	0.11	0.11	0.08	0.10	0.08
20200252	0.41	0.57	0.57	0.57	0.41	0.41	0.57
20200253	0.21	0.30	0.30	0.30	0.21	0.21	0.30
20300201	5.47	7.66	7.66	7.66	5.47	7.51	5.62
20300202	0.50	0.70	0.70	0.70	0.50	0.53	0.67
20300203	2.54	3.56	3.56	3.56	2.54	2.54	3.56
20300204	0.37	0.52	0.52	0.52	0.37	0.39	0.51
39000602	0.15	0.22	0.22	0.22	0.15	0.20	0.17
39000603	0.06	0.08	0.08	0.08	0.06	0.06	0.08
39000699	0.62	0.86	0.86	0.86	0.62	0.65	0.83
Total NG (tpd)	122	152	154	136	120	138	137
Total CA (tpd)	2051	2081	2083	2065	2050	2068	2066
Increase (tpd)		30	32	14	-1	17	15
Increase (%)		1.4%	1.5%	0.7%	-0.1%	0.8%	0.7%

Table 12 2012 statewide natural gas combustion emissions for various scenarios (tpd) by SCC for winter

SCC	Baseline	Best	Max	Only Point	Only CNGV	SoCal Only	NorCal Only
2101006000	1.32	1.85	1.85	1.32	1.32	1.36	1.82
2102006000	31.52	44.12	44.12	31.52	31.52	36.84	38.80
2102006002	2.09	2.92	2.92	2.09	2.09	2.63	2.38
2103006000	28.52	33.51	34.40	28.52	28.52	31.16	31.75
2104006000	56.64	58.76	63.31	56.64	56.64	60.47	59.47
2104006010	25.84	26.90	28.55	25.84	25.84	27.09	27.29
2266610000	0.10	0.10	0.10	0.10	0.10	0.10	0.10
2266630000	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2266640000	0.07	0.06	0.06	0.07	0.06	0.06	0.06
2266650000	0.26	0.22	0.22	0.26	0.22	0.24	0.24
2266660000	2.04	1.73	1.73	2.04	1.73	1.82	1.95
2266670000	0.94	0.79	0.79	0.94	0.79	0.83	0.90
2266680000	5.30	4.51	4.51	5.30	4.51	4.62	5.19
2266690000	0.54	0.46	0.46	0.54	0.46	0.49	0.51
10100601	1.15	1.33	1.33	1.33	1.15	1.32	1.16
10100602	0.12	0.13	0.13	0.13	0.12	0.12	0.13
10200601	0.61	0.70	0.70	0.70	0.61	0.65	0.65
10200602	1.15	1.32	1.32	1.32	1.15	1.23	1.24
10200603	0.79	0.91	0.91	0.91	0.79	0.85	0.86
10200604	0.10	0.11	0.11	0.11	0.10	0.11	0.10
10300601	0.31	0.44	0.44	0.44	0.31	0.41	0.34
10300602	1.72	2.41	2.41	2.41	1.72	2.23	1.90
10300603	1.48	2.07	2.07	2.07	1.48	1.93	1.63
20100201	6.17	8.64	8.64	8.64	6.17	7.81	7.00
20100202	0.60	0.83	0.83	0.83	0.60	0.72	0.70
20200201	2.97	4.16	4.16	4.16	2.97	3.58	3.54
20200202	5.18	7.25	7.25	7.25	5.18	7.04	5.40
20200203	2.75	3.85	3.85	3.85	2.75	3.66	2.95
20200204	0.08	0.11	0.11	0.11	0.08	0.11	0.08
20200252	0.41	0.57	0.57	0.57	0.41	0.41	0.57
20200253	0.21	0.30	0.30	0.30	0.21	0.21	0.30
20300201	5.21	7.30	7.30	7.30	5.21	7.16	5.36
20300202	0.53	0.74	0.74	0.74	0.53	0.56	0.70
20300203	2.54	3.56	3.56	3.56	2.54	2.54	3.56
20300204	0.37	0.52	0.52	0.52	0.37	0.39	0.51
39000602	0.15	0.22	0.22	0.22	0.15	0.20	0.17
39000603	0.06	0.08	0.08	0.08	0.06	0.06	0.08
39000699	0.62	0.86	0.86	0.86	0.62	0.65	0.83
Total NG (tpd)	191	224	232	204	189	212	210
Total CA (tpd)	2102	2136	2143	2115	2101	2123	2122
Increase (tpd)		34	41	13	-1	21	20
Increase (%)		1.6%	1.9%	0.6%	-0.1%	1.0%	0.9%

Table 13 presents the emissions increases for the modeling cases in summer. Emissions increases are with respect to the Baseline case and expressed in tons per day. Negative values represent a decrease in emissions from Baseline. The Maximum Likely Increase (Case B) and the Best Engineering Guess (Case A) cases have the highest increases in emissions. The only difference between Cases A and B is the emissions sensitivity factor assumed in the residential sector. However, since the emissions increases are dominated by area sources in the industrial sector (SCCs 2102006000), the NO_X emissions increase for Cases A and B with respect to Summer Baseline are very similar: Case A increased by 30 tpd and Case B increased by 32 tpd. The difference between using the "Best Engineering Estimate" and "Maximum Likely Increase" emission sensitivity factor for residential sources generates a difference that totals 2 tpd in NO_X emissions over the entire state of California. Total 2012 statewide NO_X emissions were approximately 2,051 tpd, so the 30-32 tpd increase for Cases A and B reflect a 1.5%-1.6% increase compared to the Summer Baseline.

The Point Source-only case (Case C) models the impacts of WI changes on the emissions from point sources alone. Point sources are generally large emitters whose location is known and which have more specific controls to limit emissions. Point source SCC codes starting by 1 correspond to large boilers and SCC codes starting by 2 correspond to engines and turbines. Boilers were assumed to have ultra-low NO_X burners, whereas turbines and engines were assumed to use low-NO_X burners (see discussion in Section II.A.1). Results for this scenario show an increase of 14 tpd (0.7%) in NO_X emissions with respect to the Summer Baseline. The biggest increases in NO_X emissions are caused by turbines for electricity generation (20100201), and industrial and commercial engines (20200202, 20300201). Case C was modeled assuming that all large turbines/engines use low NO_X technology, which experience a 40% increase in NO_X emissions over the 50 Btu/scf WI change under consideration. However, large turbines typically include dynamic emission controls that compensate for changes in gas composition. As a result, the emission increases for Case C are likely to represent a worst-case emissions scenario for large turbines responding to a change in gas composition.

The CNGV-only case (Case D) illustrates the potential impacts of changing CNG specifications on emissions. Based on the latest emission testing, NO_X emissions decrease with departures in specifications from the CARB certified CNG in heavy-duty vehicles. Light-duty vehicles are unaffected by changes in NG composition. As a result, Case D causes a total decrease of 1 tpd in all California. This corresponds to a decrease of 0.1% in total statewide emissions.

The SoCal-only (Case E) and NorCal-only (Case F) cases illustrate the geographical differences in terms of natural gas combustion emissions. While NO_X emission increases in both SoCal and NorCal are very similar (17 tpd and 15 tpd, respectively), Southern California has higher emissions in the point sources and lower emissions in the area sources, compared to the sources in Northern California.

Table 14 presents the emissions increases for the modeling cases in winter. The main differences between the winter and the summer cases is that in winter emissions from residential and commercial natural gas combustion are higher than in summer. As a result, residential and commercial natural gas combustion emissions become more sensitive to changes in NG WI. For example, the Maximum Likely Increase case (Case B) for winter causes an increase in NO_X emissions of 41 tpd, 9 tpd higher than in the summer case. This increase in emissions corresponds to a total statewide increase in NO_X emissions of 1.9%.

Table 13 Increase in emissions from natural gas combustion with respect to summer baseline emissions, for various scenarios (tpd) by SCC

SCC	Best	Max	Only EGU	Only CNGV	SoCal Only	NorCal Only
2101006000	0.53	0.53			0.03	0.49
2102006000	12.61	12.61			5.32	7.29
2102006002	0.83	0.83			0.54	0.29
2103006000	2.13	2.51			1.13	1.38
2104006000	0.06	0.18			0.10	0.07
2104006010	1.06	2.71			1.25	1.45
2266610000						
2266630000						
2266640000	-0.01	-0.01		-0.01	-0.01	0.00
2266650000	-0.04	-0.04		-0.04	-0.02	-0.02
2266660000	-0.31	-0.31		-0.31	-0.22	-0.09
2266670000	-0.14	-0.14		-0.14	-0.10	-0.04
2266680000	-0.80	-0.80		-0.80	-0.68	-0.12
2266690000	-0.08	-0.08		-0.08	-0.05	-0.03
10100601	0.26	0.26	0.26		0.25	0.01
10100602	0.02	0.02	0.02		0.01	0.01
10200601	0.09	0.09	0.09		0.05	0.04
10200602	0.17	0.17	0.17		0.08	0.09
10200603	0.10	0.10	0.10		0.05	0.06
10200604	0.01	0.01	0.01		0.01	0.00
10300601	0.12	0.12	0.12		0.10	0.03
10300602	0.54	0.54	0.54		0.40	0.14
10300603	0.52	0.52	0.52		0.39	0.13
20100201	3.41	3.41	3.41		2.26	1.14
20100202	0.24	0.24	0.24		0.13	0.11
20200201	1.20	1.20	1.20		0.62	0.58
20200202	2.02	2.02	2.02		1.81	0.21
20200203	1.27	1.27	1.27		1.04	0.22
20200204	0.03	0.03	0.03		0.03	0.00
20200252	0.16	0.16	0.16		0.00	0.16
20200253	0.08	0.08	0.08		0.00	0.08
20300201	2.19	2.19	2.19		2.04	0.15
20300202	0.20	0.20	0.20		0.03	0.17
20300203	1.02	1.02	1.02		0.00	1.02
20300204	0.15	0.15	0.15		0.01	0.14
39000602	0.06	0.06	0.06		0.05	0.01
39000603	0.02	0.02	0.02		0.00	0.02
39000699	0.25	0.25	0.25		0.03	0.21
Total NG (tpd)	30	32	14	-1	17	15
Total CA (tpd)	2081	2083	2065	2050	2068	2066
Increase (%)	1.5%	1.6%	0.7%	-0.1%	0.8%	0.8%

Table 14 Increase in emissions from natural gas combustion with respect to winter baseline emissions, for various scenarios (tpd) by SCC

SCC	Best	Max	Only EGU	Only CNGV	SoCal Only	NorCal Only
2101006000	0.53	0.53			0.03	0.49
2102006000	12.61	12.61			5.32	7.29
2102006002	0.83	0.83			0.54	0.29
2103006000	4.99	5.88			2.64	3.24
2104006000	2.12	6.67			3.83	2.84
2104006010	1.06	2.71			1.25	1.45
2266610000						
2266630000						
2266640000	-0.01	-0.01		-0.01	-0.01	0.00
2266650000	-0.04	-0.04		-0.04	-0.02	-0.02
2266660000	-0.31	-0.31		-0.31	-0.22	-0.09
2266670000	-0.14	-0.14		-0.14	-0.10	-0.04
2266680000	-0.80	-0.80		-0.80	-0.68	-0.12
2266690000	-0.08	-0.08		-0.08	-0.05	-0.03
10100601	0.17	0.17	0.17		0.17	0.01
10100602	0.02	0.02	0.02		0.01	0.01
10200601	0.09	0.09	0.09		0.05	0.04
10200602	0.17	0.17	0.17		0.08	0.09
10200603	0.12	0.12	0.12		0.05	0.07
10200604	0.01	0.01	0.01		0.01	0.00
10300601	0.12	0.12	0.12		0.10	0.03
10300602	0.69	0.69	0.69		0.51	0.18
10300603	0.59	0.59	0.59		0.45	0.15
20100201	2.47	2.47	2.47		1.64	0.83
20100202	0.24	0.24	0.24		0.13	0.11
20200201	1.19	1.19	1.19		0.61	0.58
20200202	2.07	2.07	2.07		1.86	0.21
20200203	1.10	1.10	1.10		0.91	0.19
20200204	0.03	0.03	0.03		0.03	0.00
20200252	0.16	0.16	0.16		0.00	0.16
20200253	0.08	0.08	0.08		0.00	0.08
20300201	2.09	2.09	2.09		1.94	0.14
20300202	0.21	0.21	0.21		0.03	0.18
20300203	1.02	1.02	1.02		0.00	1.02
20300204	0.15	0.15	0.15		0.01	0.14
39000602	0.06	0.06	0.06		0.05	0.01
39000603	0.02	0.02	0.02		0.00	0.02
39000699	0.25	0.25	0.25		0.03	0.21
Total NG (tpd)	34	41	13	-1	21	20
Total CA (tpd)	2136	2143	2115	2101	2123	2122
Increase (%)	1.6%	2.0%	0.6%	-0.1%	1.0%	0.9%

Table 15 and Table 16 summarize NO_X emissions and emission increments for each county in California for the summer cases. Table 17 and Table 18 summarize NO_X emissions and emission increments for each county in California for the winter cases.

Table 15 NO_X emissions from NG combustion by county (tpd) for various scenarios in the summer

	Baseline	Best	Max	EGU	CNGV	SoCal	NorCal
Total	121.79	151.77	153.92	135.92	120.42	138.48	137.23
Los Angeles	24.10	28.57	29.06	25.71	23.52	29.06	24.10
San Bernardino	11.63	15.39	15.47	14.75	11.55	15.47	11.63
Monterey	7.59	10.35	10.39	7.84	7.59	7.59	10.39
Kern	7.51	10.03	10.08	9.64	7.48	10.08	7.51
Contra Costa	6.14	7.93	8.03	7.26	6.14	6.14	8.03
Imperial	5.72	7.79	7.80	5.89	5.72	7.80	5.72
Orange	4.81	5.29	5.43	5.18	4.65	5.43	4.81
Santa Clara	4.59	5.54	5.68	5.20	4.58	4.59	5.68
San Diego	3.64	4.27	4.33	4.25	3.53	4.33	3.64
Riverside	3.31	3.84	3.93	3.71	3.23	3.93	3.31
Sacramento	3.29	3.69	3.79	3.45	3.20	3.29	3.79
San Joaquin	3.11	4.08	4.12	3.23	3.11	3.11	4.12
Fresno	3.00	3.72	3.77	3.48	2.96	3.00	3.77
Alameda	2.94	3.26	3.38	3.06	2.91	2.94	3.38
Santa Barbara	2.70	3.51	3.54	3.42	2.70	3.54	2.70
Solano	2.50	3.23	3.26	3.09	2.48	2.50	3.26
Santa Cruz	2.10	2.80	2.82	2.12	2.10	2.10	2.82
Shasta	1.80	2.33	2.35	1.92	1.80	1.80	2.35
San Francisco	1.80	1.93	2.01	1.84	1.76	1.80	2.01
San Mateo	1.54	1.73	1.80	1.57	1.53	1.54	1.80
Amador	1.36	1.87	1.88	1.40	1.36	1.36	1.88
Placer	1.35	1.59	1.63	1.38	1.34	1.35	1.63
Humboldt	1.24	1.65	1.66	1.27	1.24	1.24	1.66
Ventura	1.24	1.51	1.53	1.50	1.21	1.53	1.24
Yolo	1.22	1.52	1.54	1.26	1.21	1.22	1.54
Stanislaus	1.16	1.42	1.45	1.25	1.16	1.16	1.45
Sutter	1.00	1.36	1.36	1.25	1.00	1.00	1.36
San Luis Obispo	0.96	1.12	1.14	0.98	0.95	1.14	0.96
Tulare	0.87	1.04	1.06	0.91	0.86	0.87	1.06
Sonoma	0.84	0.92	0.96	0.85	0.83	0.84	0.96
Colusa	0.77	0.95	0.96	0.87	0.77	0.77	0.96
Madera	0.71	0.95	0.95	0.72	0.70	0.71	0.95
Plumas	0.68	0.95	0.95	0.68	0.68	0.68	0.95
Glenn	0.64	0.88	0.88	0.85	0.64	0.64	0.88
Butte	0.61	0.72	0.74	0.62	0.61	0.61	0.74
San Benito	0.60	0.81	0.81	0.61	0.60	0.60	0.81
Marin	0.56	0.62	0.65	0.58	0.56	0.56	0.65
Merced	0.53	0.67	0.68	0.55	0.53	0.53	0.68
Tehama	0.46	0.62	0.62	0.55	0.46	0.46	0.62
Kings	0.32	0.39	0.39	0.38	0.32	0.32	0.39
Napa	0.29	0.33	0.34	0.32	0.29	0.29	0.34
Mendocino	0.20	0.25	0.25	0.20	0.20	0.20	0.25
Yuba	0.11	0.13	0.13	0.12	0.11	0.11	0.13
Nevada	0.11	0.11	0.12	0.11	0.11	0.11	0.12
El Dorado	0.09	0.10	0.10	0.09	0.09	0.09	0.10
Calaveras	0.02	0.03	0.03	0.02	0.02	0.02	0.03
Modoc	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lassen	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 16 Increases in natural gas-related NO_X emissions by county for various scenarios (tpd) in the summer

	Best	Max	EGU	CNGV	SoCal	NorCal
Total	29.98	32.13	14.13	-1.37	16.69	15.44
Los Angeles	4.47	4.95	1.61	-0.58	4.95	
San Bernardino	3.76	3.84	3.11	-0.08	3.84	
Monterey	2.76	2.80	0.25	0.00		2.80
Kern	2.52	2.57	2.12	-0.03	2.57	
Contra Costa	1.79	1.90	1.12	0.00		1.90
Imperial	2.07	2.08	0.17	0.00	2.08	
Orange	0.48	0.62	0.37	-0.16	0.62	
Santa Clara	0.95	1.09	0.61	-0.01		1.09
San Diego	0.63	0.69	0.60	-0.12	0.69	
Riverside	0.53	0.62	0.40	-0.08	0.62	
Sacramento	0.40	0.50	0.17	-0.08		0.50
San Joaquin	0.97	1.01	0.12	-0.01		1.01
Fresno	0.72	0.77	0.48	-0.04		0.77
Alameda	0.32	0.44	0.12	-0.03		0.44
Santa Barbara	0.80	0.84	0.72	-0.01	0.84	
Solano	0.73	0.77	0.60	-0.01		0.77
Santa Cruz	0.69	0.72	0.02	0.00		0.72
Shasta	0.53	0.56	0.12	0.00		0.56
San Francisco	0.13	0.21	0.05	-0.03		0.21
San Mateo	0.19	0.26	0.03	0.00		0.26
Amador	0.52	0.52	0.04	0.00		0.52
Placer	0.24	0.28	0.03	0.00		0.28
Humboldt	0.41	0.42	0.03	0.00		0.42
Ventura	0.27	0.29	0.26	-0.03	0.29	
Yolo	0.30	0.32	0.04	-0.01		0.32
Stanislaus	0.26	0.29	0.09	0.00		0.29
Sutter	0.35	0.36	0.25	0.00		0.36
San Luis Obispo	0.16	0.19	0.03	0.00	0.19	
Tulare	0.17	0.19	0.04	-0.01		0.19
Sonoma	0.08	0.12	0.01	-0.01		0.12
Colusa	0.18	0.19	0.10	0.00		0.19
Madera	0.24	0.24	0.01	0.00		0.24
Plumas	0.27	0.27		0.00		0.27
Glenn	0.24	0.24	0.21			0.24
Butte	0.11	0.13	0.00	0.00		0.13
San Benito	0.21	0.21	0.01	0.00		0.21
Marin	0.06	0.09	0.02	0.00		0.09
Merced	0.13	0.14	0.02	0.00		0.14
Tehama	0.16	0.16	0.08	0.00		0.16
Kings	0.07	0.08	0.06	0.00		0.08
Napa	0.04	0.05	0.03	0.00		0.05
Mendocino	0.05	0.05	0.00	0.00		0.05
Yuba	0.01	0.02	0.00	0.00		0.02
Nevada	0.01	0.01	0.00	0.00		0.01
El Dorado	0.01	0.02		0.00		0.02
Calaveras	0.01	0.01		0.00		0.01
Modoc	0.00	0.00	0.00	0.00		0.00
Lassen	0.00	0.00		0.00		0.00

Table 17 NO_X emissions from NG combustion by county for various scenarios (tpd) in the winter

	Baseline	Best	Max	EGU	CNGV	SoCal	NorCal
Total	190.52	224.44	231.52	203.66	189.15	211.74	210.30
Los Angeles	40.55	46.05	47.71	42.10	39.98	47.71	40.55
San Bernardino	14.47	18.19	18.54	17.40	14.39	18.54	14.47
Orange	9.63	10.38	10.89	10.01	9.48	10.89	9.63
Monterey	8.96	11.81	11.94	9.14	8.96	8.96	11.94
Kern	8.65	11.03	11.20	10.49	8.62	11.20	8.65
Contra Costa	8.51	10.45	10.72	9.57	8.51	8.51	10.72
Santa Clara	7.52	8.60	8.97	8.09	7.51	7.52	8.97
San Diego	6.67	7.35	7.66	7.18	6.55	7.66	6.67
Riverside	6.32	7.01	7.32	6.69	6.24	7.32	6.32
Sacramento	6.31	6.89	7.20	6.44	6.22	6.31	7.20
Imperial	6.23	8.36	8.40	6.35	6.23	8.40	6.23
Alameda	5.50	5.95	6.26	5.62	5.46	5.50	6.26
Fresno	4.94	5.76	5.95	5.38	4.90	4.94	5.95
San Joaquin	4.68	5.75	5.90	4.80	4.68	4.68	5.90
Santa Barbara	4.18	5.12	5.25	4.92	4.18	5.25	4.18
Ventura	3.60	3.94	4.15	3.81	3.58	4.15	3.60
Solano	3.38	4.17	4.26	3.97	3.37	3.38	4.26
San Francisco	3.37	3.58	3.78	3.42	3.34	3.37	3.78
Placer	3.19	3.66	3.79	3.22	3.19	3.19	3.79
San Mateo	3.00	3.27	3.45	3.04	3.00	3.00	3.45
Santa Cruz	2.91	3.68	3.75	2.93	2.91	2.91	3.75
Shasta	2.89	3.58	3.65	3.01	2.89	2.89	3.65
San Luis Obispo	2.27	2.58	2.68	2.30	2.27	2.68	2.27
Stanislaus	2.26	2.57	2.68	2.33	2.25	2.26	2.68
Yolo	2.06	2.46	2.52	2.10	2.05	2.06	2.52
Humboldt	1.71	2.16	2.20	1.74	1.71	1.71	2.20
Tulare	1.70	1.92	2.00	1.74	1.69	1.70	2.00
Sonoma	1.68	1.80	1.90	1.69	1.66	1.68	1.90
Amador	1.53	2.07	2.08	1.57	1.53	1.53	2.08
Butte	1.32	1.49	1.55	1.32	1.31	1.32	1.55
Colusa	1.28	1.54	1.57	1.37	1.28	1.28	1.57
Sutter	1.16	1.48	1.51	1.36	1.16	1.16	1.51
Marin	1.13	1.22	1.29	1.16	1.13	1.13	1.29
Merced	0.98	1.14	1.18	1.00	0.98	0.98	1.18
Madera	0.88	1.13	1.14	0.89	0.87	0.88	1.14
San Benito	0.74	0.95	0.96	0.75	0.74	0.74	0.96
Glenn	0.69	0.94	0.95	0.91	0.69	0.69	0.95
Plumas	0.68	0.95	0.95	0.68	0.68	0.68	0.95
Tehama	0.62	0.80	0.81	0.71	0.62	0.62	0.81
Kings	0.59	0.67	0.69	0.64	0.58	0.59	0.69
Napa	0.52	0.57	0.59	0.55	0.51	0.52	0.59
Mendocino	0.37	0.44	0.45	0.38	0.37	0.37	0.45
Nevada	0.34	0.36	0.39	0.34	0.34	0.34	0.39
Yuba	0.30	0.32	0.34	0.30	0.30	0.30	0.34
El Dorado	0.20	0.23	0.24	0.20	0.20	0.20	0.24
Calaveras	0.04	0.04	0.05	0.04	0.04	0.04	0.05
Modoc	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lassen	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Table 18 Increases in natural gas-related NO_X emissions by county for various scenarios (tpd) in the winter

	Best	Max	EGU	CNGV	SoCal	NorCal
Total	33.91	40.99	13.14	-1.37	21.22	19.77
Los Angeles	5.49	7.16	1.55	-0.58	7.16	
San Bernardino	3.72	4.07	2.94	-0.08	4.07	
Orange	0.75	1.25	0.38	-0.16	1.25	
Monterey	2.85	2.98	0.18	0.00		2.98
Kern	2.37	2.54	1.84	-0.03	2.54	
Contra Costa	1.94	2.21	1.06	0.00		2.21
Santa Clara	1.07	1.44	0.57	-0.01		1.44
San Diego	0.69	0.99	0.51	-0.12	0.99	
Riverside	0.70	1.00	0.37	-0.08	1.00	
Sacramento	0.58	0.89	0.13	-0.08		0.89
Imperial	2.13	2.17	0.12	0.00	2.17	
Alameda	0.45	0.76	0.12	-0.03		0.76
Fresno	0.83	1.02	0.45	-0.04		1.02
San Joaquin	1.07	1.22	0.12	-0.01		1.22
Santa Barbara	0.94	1.07	0.74	-0.01	1.07	
Ventura	0.34	0.55	0.21	-0.03	0.55	
Solano	0.79	0.89	0.60	-0.01		0.89
San Francisco	0.21	0.41	0.05	-0.03		0.41
Placer	0.47	0.60	0.03	0.00		0.60
San Mateo	0.27	0.45	0.03	0.00		0.45
Santa Cruz	0.76	0.84	0.02	0.00		0.84
Shasta	0.69	0.76	0.12	0.00		0.76
San Luis Obispo	0.31	0.41	0.03	0.00	0.41	
Stanislaus	0.31	0.42	0.07	0.00		0.42
Yolo	0.40	0.47	0.04	-0.01		0.47
Humboldt	0.45	0.49	0.03	0.00		0.49
Tulare	0.21	0.30	0.04	-0.01		0.30
Sonoma	0.13	0.23	0.01	-0.01		0.23
Amador	0.54	0.55	0.04	0.00		0.55
Butte	0.17	0.23	0.00	0.00		0.23
Colusa	0.26	0.29	0.09	0.00		0.29
Sutter	0.32	0.35	0.20	0.00		0.35
Marin	0.09	0.16	0.03	0.00		0.16
Merced	0.16	0.20	0.02	0.00		0.20
Madera	0.25	0.27	0.01	0.00		0.27
San Benito	0.22	0.23	0.01	0.00		0.23
Glenn	0.25	0.25	0.22			0.25
Plumas	0.27	0.27		0.00		0.27
Tehama	0.18	0.19	0.08	0.00		0.19
Kings	0.08	0.11	0.05	0.00		0.11
Napa	0.05	0.08	0.03	0.00		0.08
Mendocino	0.07	0.08	0.00	0.00		0.08
Nevada	0.02	0.04	0.00	0.00		0.04
Yuba	0.03	0.05	0.00	0.00		0.05
El Dorado	0.03	0.04		0.00		0.04
Calaveras	0.01	0.01		0.00		0.01
Modoc	0.00	0.00	0.00	0.00		0.00
Lassen	0.00	0.00		0.00		0.00

V Impacts of Gas Compositions on Air Quality

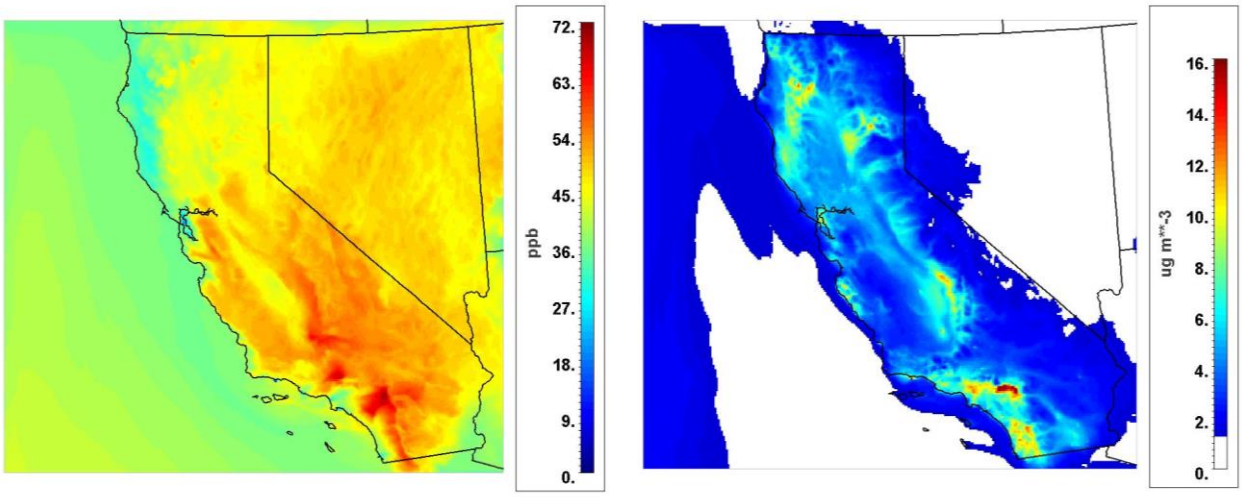
This section discusses air quality resulting from modeling the Summer Baseline and the Winter Baseline cases, and the air quality impacts resulting from the emissions increases in the six scenarios. Two meteorological episodes were simulated: July 8-21, 2012, a summer period with high observed ozone concentrations, and January 1-14, 2012, a winter period with high PM concentrations. Annual emissions were spatially and temporally disaggregated by SMOKE to approximate hourly emissions over the simulation domain. Figure 8 presents observed 8-hour average ozone concentrations and 24-hour average $PM_{2.5}$ concentrations for 4x4 kilometers grid cells over California for July 21, the summer base case. Simulated 8-hour average ozone concentrations were high, with many areas in the Central Valley, San Jose, and Riverside, above 80 ppb (Figure 8a). Concentrations of $PM_{2.5}$ on July 21 showed a spatial distribution typical for California, with peaks in the South Coast Air Basin and along the San Joaquin Valley (Figure 8b).

Figure 9 presents modeled hourly ozone concentrations together with observed ozone concentrations at four selected locations in California, and it shows that the model agrees well with observations for the period July 15 to July 21. Overall, model performance is determined by the Mean Normalized Bias (MNB) and Mean Normalized Gross Error (MNGE), using Equations 8 and 9. Hourly observations are obtained from ARB's monitoring data recorded in 175 stations (ARB, 2012). Both MNB and MNGE are calculated using concentrations that are higher than 40 ppb, which is the background level for ozone. These metrics are recommended by the USEPA for model evaluation (U.S. EPA, 2007), and have been used extensively in the literature (Russell and Dennis, 2000; Eder and You, 2006; Appel et al., 2008; Foley et al., 2010).

$$\mathrm{MNB} = \frac{1}{N}\sum_{i=1}^{N}\frac{C_M(x_i,t) - C_O(x_i,t)}{C_O(x_i,t)} \tag{9}$$

$$\mathrm{MNGE} = \frac{1}{N}\sum_{i=1}^{N}\frac{|C_M(x_i,t) - C_O(x_i,t)|}{C_O(x_i,t)}, \tag{10}$$

where N is the number of observations in the region of interest during the campaign, $C_O(x_i,t)$ is the concentration of the i^{th} observation, and $C_M(x_i,t)$ is the corresponding modeled concentration at the same position and time. MNB and MNGE for July 8-21, 2012 are -20.3% and 22.5%, respectively. These values are within acceptable model performance parameters (U.S. EPA, 2007).



(a) (b)

Figure 8 Ambient air concentrations for July 21, 2012: (a) 8-hour average ozone, (b) 24-hour average $PM_{2.5}$.

Figure 10 presents modeled and observed 24-hour average $PM_{2.5}$ concentrations at all monitoring stations that reported data for the period July 15–July 21, 2012. Model MNB and MNGE, calculated with no cut-off value for 24-hour average concentrations of $PM_{2.5}$, are -39.8% and 49.3%, respectively.

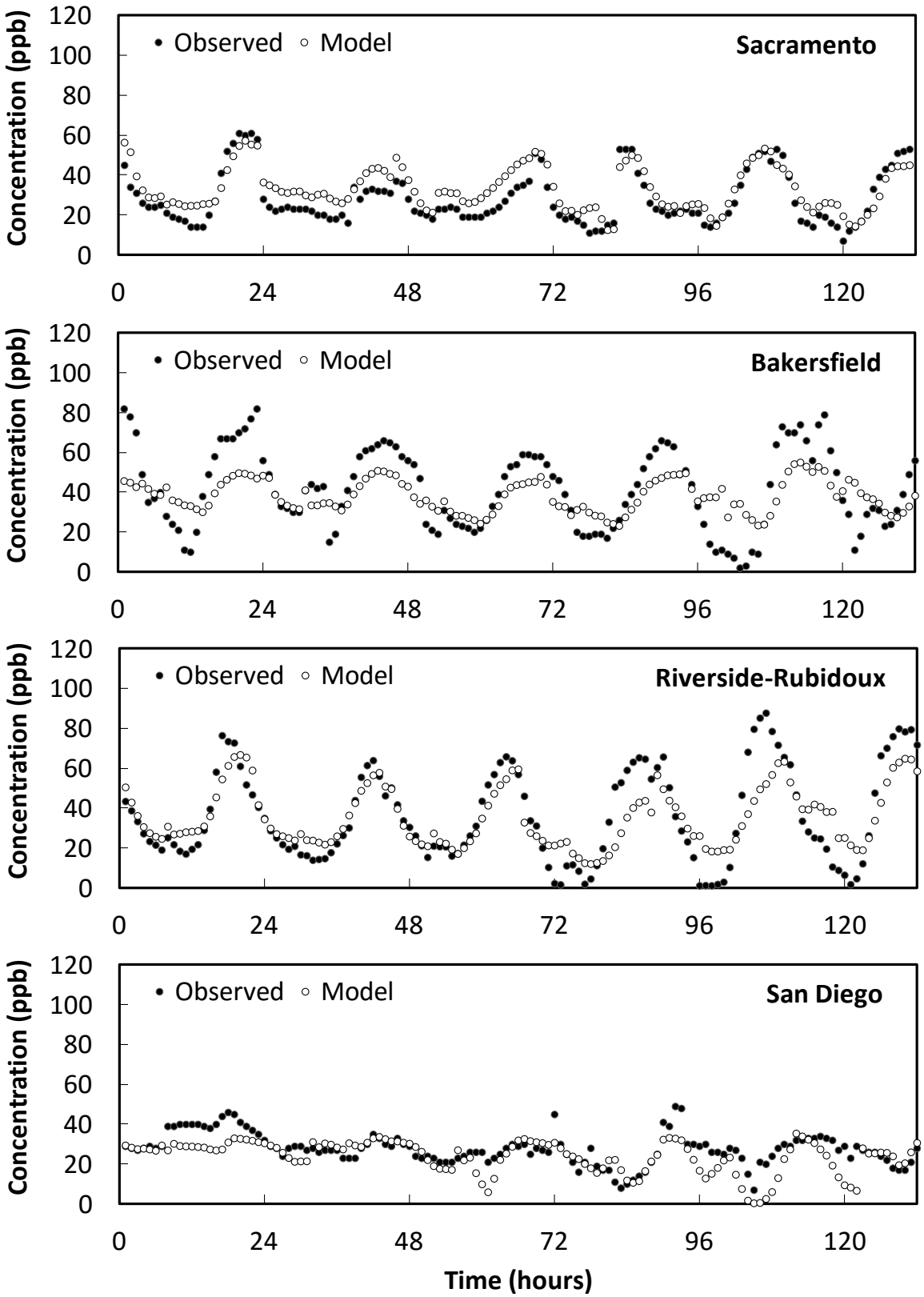


Figure 9 Modeled and observed hourly ozone concentrations for July 14-20, 2012 at selected locations

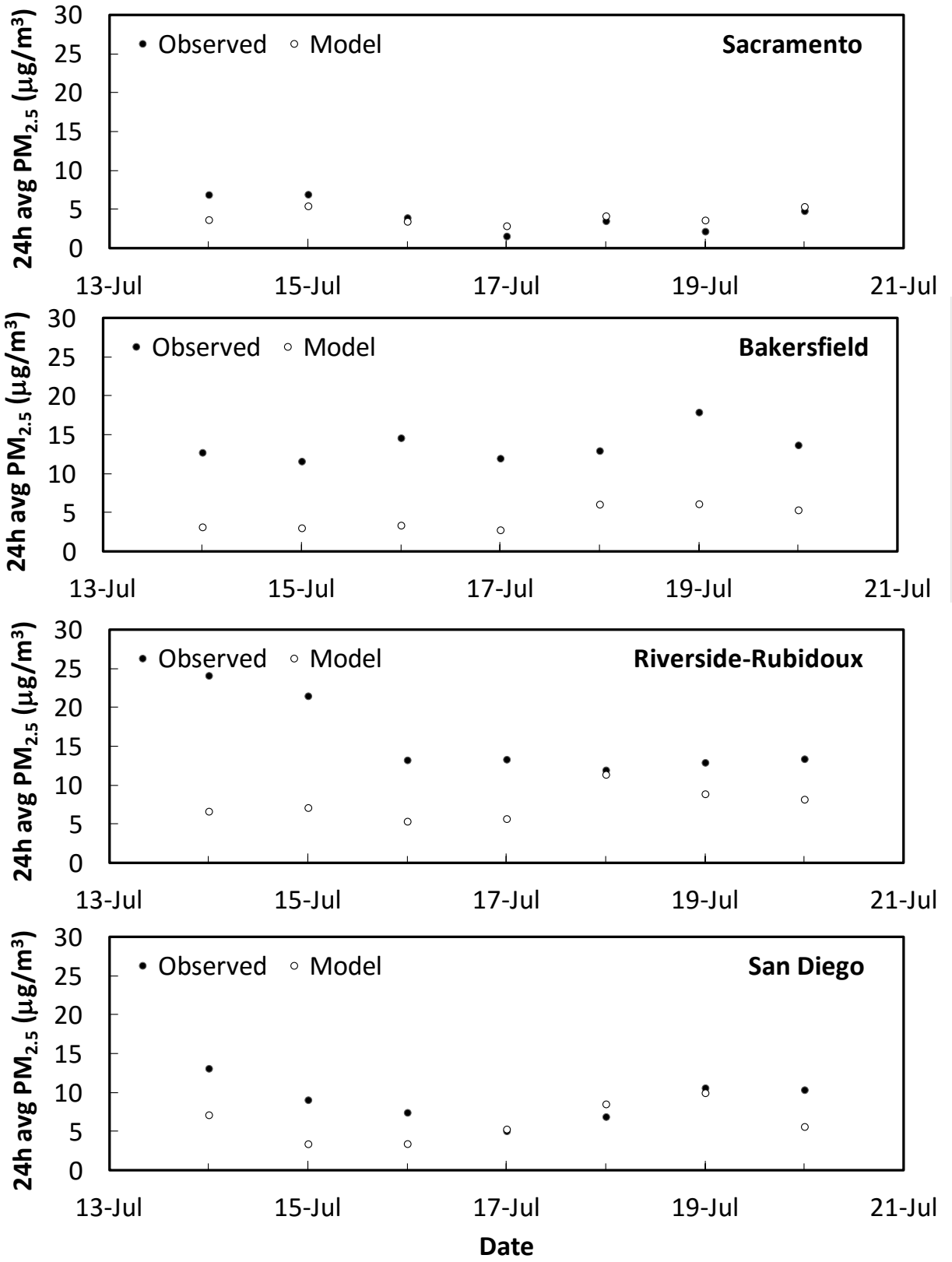
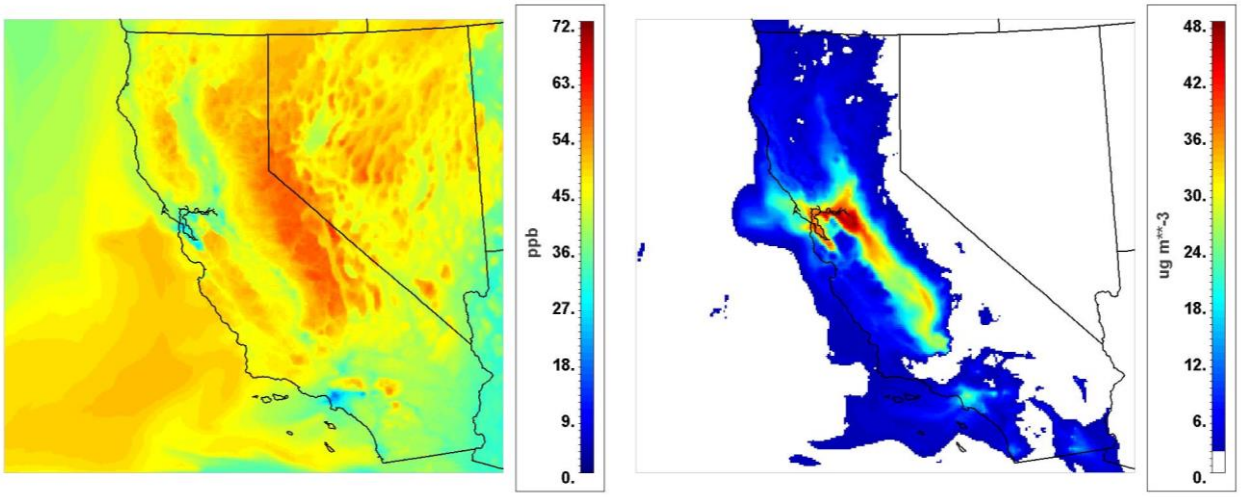


Figure 10 Modeled and observed 24-hour average $PM_{2.5}$ concentrations for July 14-20, 2012 at selected locations

Figure 11 shows simulated 8-hour ozone concentrations and 24-hour $PM_{2.5}$ concentrations for 4x4 km grid cells over California for the period December 1 to December 14, 2012, the Winter Baseline case. Simulated 8-hour ozone concentrations are low and below the state standard of 75ppb, which is typical for winter. MNB and MNGE for ozone in the winter period are -2.4% and 11.7%, respectively. These values are within acceptable model performance parameters (U.S. EPA, 2007).

The 24-hour average $PM_{2.5}$ concentrations are higher for the Winter Baseline case than the Summer Baseline case, especially along the Sacramento and San Joaquin Valleys. Some regions in the Sacramento and San Joaquin Valleys experience 24-hour average $PM_{2.5}$ concentrations higher than the 35 $\mu g/m^3$ federal EPA standard. Figure 12 presents modeled and observed 24-hour average $PM_{2.5}$ concentrations at all monitoring stations that reported data for December 1 to December 14, 2012. Model MNB and MNGE, calculated with no cut-off value for 24-hour average concentrations of $PM_{2.5}$, are -26.8% and 47.6%, respectively.



(a) (b)

Figure 11 Modeled pollutant concentrations for December 14, 2012: (a) 8-hour average ozone, (b) 24-hour average $PM_{2.5}$.

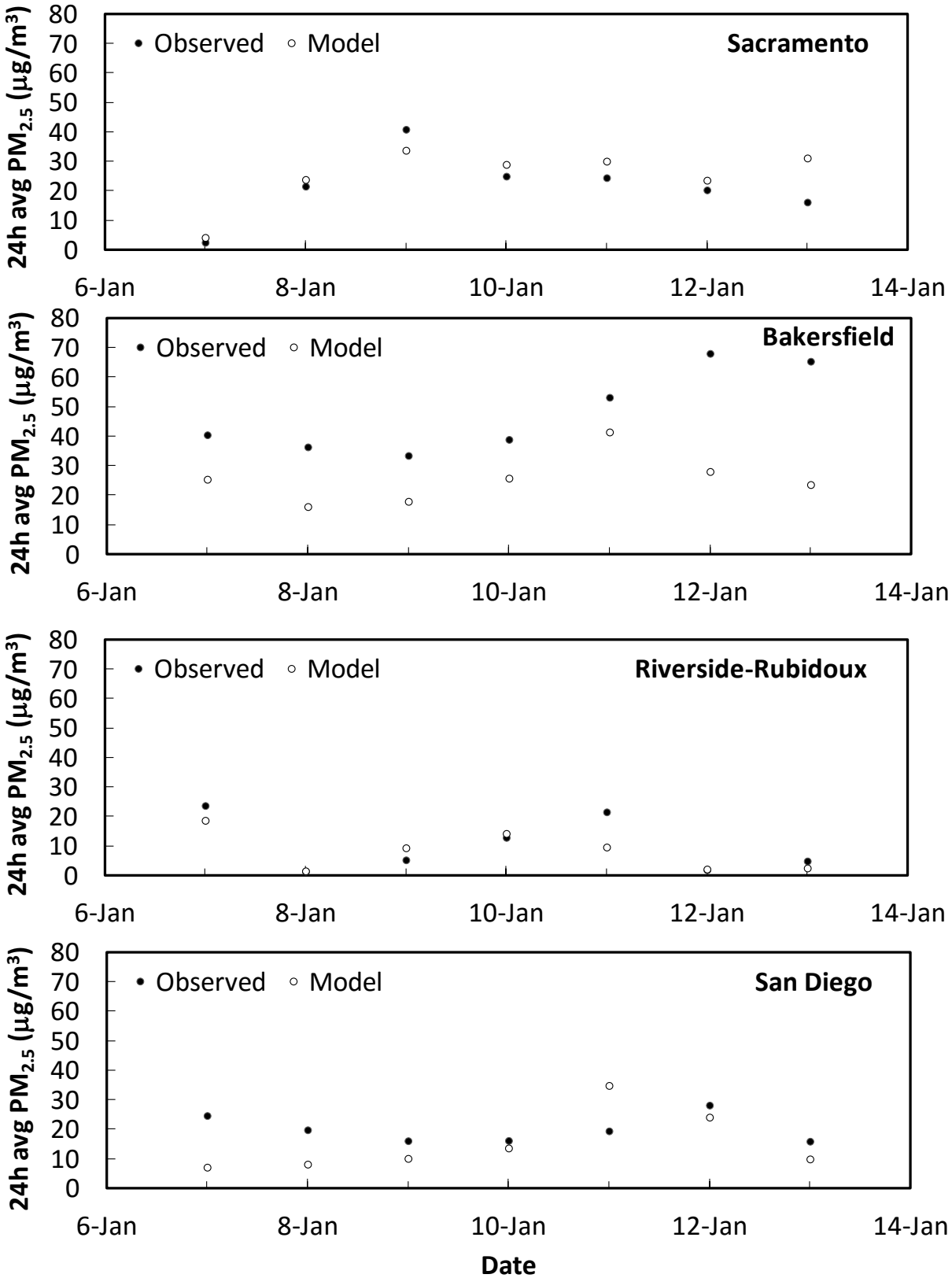


Figure 12 Modeled and observed 24-hour average $PM_{2.5}$ concentrations for December 7-13, 2012 at selected locations

V.A Summary of Atmospheric Processes for Ozone and Particulate Matter

Analysis of air quality impacts of natural combustion is focused on ozone and fine particulate matter ($PM_{2.5}$) formation. The overall atmospheric dynamics of ozone and $PM_{2.5}$ formation are briefly discussed here.

Ozone:

Ozone (O_3) is a secondary pollutant; it is not directly emitted, but rather is formed in the atmosphere through photochemical reactions of other pollutants. The formation of ozone is initiated by the photolysis of nitrogen dioxide (NO_2, a component of NO_X) in reaction R1:

$$NO_2 + h\nu \rightarrow NO + O \quad \text{(R1)}$$

$$O + O_2 \rightarrow O_3 \quad \text{(R2)}$$

$$NO + O_3 \rightarrow NO_2 + O_2 \quad \text{(R3)}$$

Photolysis of NO_2 produces a single atom of oxygen (O) that reacts readily with molecular oxygen (O_2) present in the atmosphere, producing ozone by reaction R2. In the absence of other components, ozone is consumed by its reaction with NO to produce NO_2 and O_2 again by reaction R3, the ozone titration reaction. During the day, ozone also produces hydroxyl radical via photolysis and water addition by reaction R4:

$$O_3 + H_2O + h\nu \rightarrow O_2 + 2\,OH \quad \text{(R4)}$$

VOC in the atmosphere can provide a catalyst to recycle NO back to NO_2 without undergoing ozone titration, hence contributing to the build-up of ozone. For example, an alkane VOC has a carbon-hydrogen bond (R-H) that can react with OH by reaction R5 to form H_2O and an alkyl radical R, which then reacts with NO to reform NO_2 by reaction R6.

$$R\text{-}H + OH \rightarrow R + H_2O \quad \text{(R5)}$$

$$R + NO + O_2 \rightarrow RO + NO_2 \quad \text{(R6)}$$

Finally, ozone production can also be terminated by reaction R7, the combination of NO_2 with OH to form nitric acid (HNO_3), which can deposit to surfaces, effectively removing NO_2 from the atmosphere (Jacob, 1999).

$$OH + NO_2 \rightarrow HNO_3 \quad \text{(R7)}$$

Ozone formation is not a linear process. Ozone concentrations depend on NO_X concentrations, but also on a complex system of reactions that compete to increase (reactions R1, R2 and R6) and decrease (reactions R3 and R7) ozone. In Los Angeles, emissions of NO_X are high enough that consumption reactions prevail over production of ozone. Under these conditions, referred as a VOC-limited regime, an increase in VOC emissions tends to increase ozone concentrations, but increases in NO_X emissions can lead to a decrease in ozone (Jacob, 1999). This phenomenon has been regularly observed in the South Coast Air Basin during weekends when emissions of NO_X are typically lower than on weekdays, but measured ozone concentrations are statistically higher than during weekdays (Qin *et al*. 2004). In other areas where NO_X emissions are more moderate than in Los Angeles, such as the San Joaquin Valley, conditions for ozone build-up prevail, and an increase in NO_X emissions generally produces an increase in ozone concentration.

Particulate Matter:

Unlike ozone, particulate matter (PM) is both emitted and formed in the atmosphere. Main sources of particulate matter emissions include combustion, suspension of material from natural processes and human activity, and from wear and tear of tires and brakes. Fine particles may be formed by the reaction of nitric and sulfuric acid with ammonia to form ammonium nitrates and ammonium sulfates. Because ammonia emissions from cattle and agricultural operations can be high, formation of ammonium nitrate and sulfates is an important PM source in the Central Valley and in Riverside and San Bernardino Counties where those activities are common. In general, increasing NO_X emissions leads to greater formation of atmospheric nitric acid and hence, an increase in secondary PM formation.

V.B Discussion of Scenarios

For each of the seven simulated scenarios, changes in 8-hour average ozone in the summer are presented in Figure 13 and Figure 14. Increments in 24-hour average $PM_{2.5}$ concentrations in the summer episode are presented in Figure 15 and Figure 16. All scenarios assume an overall increase in NO_X emissions with respect to their reference case except for the CNGV-only case.

Cases A and B simulate the effects of increasing WI by 50 BTU/scf on all NG combustion sources with the only difference being the emission sensitivity factor for residential appliances. These two cases present the highest simulated increases in emissions in the summer, with nearly 1.5%-1.6% increase in NO_X emissions with respect to the baseline. As discussed above, a moderate increase in NO_X emissions in an area with high baseline emissions, such as Los Angeles, can slightly reduce ozone concentration. In contrast, NO_X

emission increases in other areas of the state – such as the San Joaquin and Sacramento Valleys – lead to increases in 8-hour ozone concentrations of approximately 0.8 ppb.

Case C focused on changing emissions only from point sources, resulting in 0.7% increase in statewide NO_X emissions with respect to the Summer Baseline, approximately half the increase compared to Cases A and B. As a result, the impacts of large emitter point sources on ozone concentrations observed in Case C are slightly less widespread, although maximum increases in ozone are comparable to Case A and B.

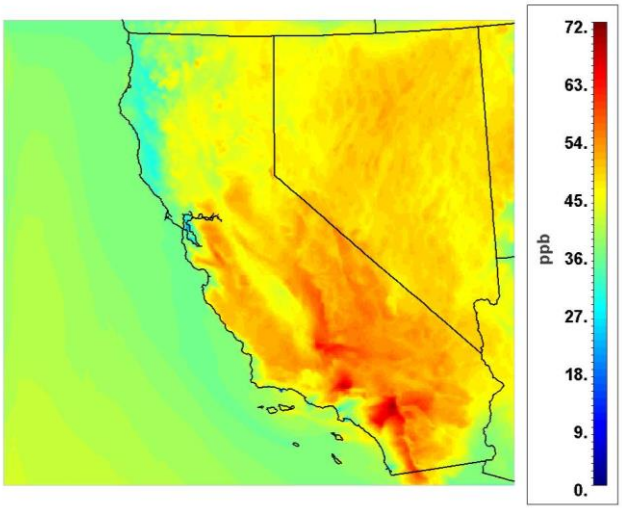
Case D is intended to evaluate the air quality impacts of changing emissions from CNG vehicles, and it is the only case that assumes a decrease in NO_X emissions. NO_X emissions from CNG vehicles decrease statewide NO_X emissions by 0.1%. The result of a small decrease in NO_X emissions is a slight increase in ozone concentration in Los Angeles.

Case E and Case F simulate the effects of increasing WI by 50 BTU/scf on all NG combustion sources in Southern and Northern California, respectively. As Figure 14b and Figure 14c show, there is a little ozone transport from Southern and Northern California, but overall, the effects of changing WI in Northern California in Case F are practically identical than in Case B. In general, ozone increases throughout Northern California, whereas in Southern California, ozone decreases in the metropolitan area of Los Angeles, due to the titration of ozone with increasing NO_X emissions.

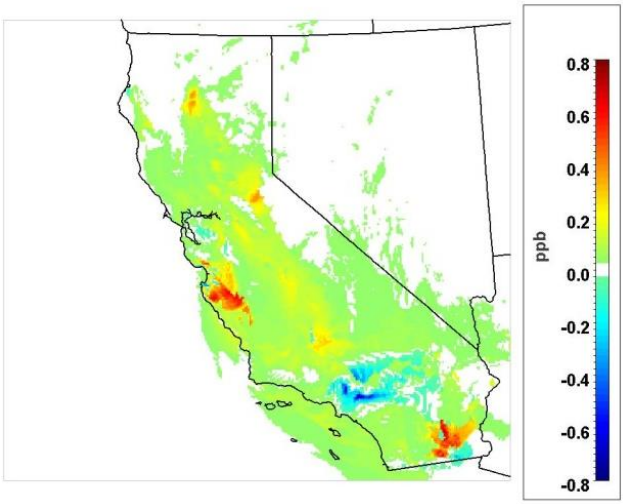
Case G assumes the removal of fugitive emissions from NG transmission lines. Assuming an average fraction of non-methane short-chain alkanes of 5%, total statewide emissions of alkanes are 11.4 tpd. Total VOC emissions in California in the year 2012 were 1,739 tpd, so fugitive emissions correspond to 0.65% of total VOC in the State. However, short chain alkanes have low reactivity with respect to ozone formation, and as a result, the contribution of VOC fugitive emissions to ozone formation is low, as shown in Figure 14d. The maximum increases in ozone concentration due to fugitive emissions are only 0.012 ppb.

Changes in direct emissions of $PM_{2.5}$ were not considered in any of the simulation scenarios, except for the CNGV-only case. Hence, the changes in 24-hour $PM_{2.5}$ concentrations presented in Figure 15 and Figure 16 are due to secondary formation of particles in the atmosphere. Nitric acid can be formed in the atmosphere by the oxidation of emitted NO_X. Fine particles form from the reaction of gas-phase nitric acid and ammonia. As for ozone, the cases with the greatest changes in $PM_{2.5}$ concentrations are Cases A, B and C, because these cases have the greatest increases in NO_X emissions. The largest increases in $PM_{2.5}$ concentrations occur along the San Joaquin Valley, where the increased NO_X emissions from combustion of higher WI natural gas form nitric acid, which then reacts with ammonia emitted from farming and cattle operations to create ammonium nitrate PM. In general, the impacts of changing natural gas combustion emissions on $PM_{2.5}$

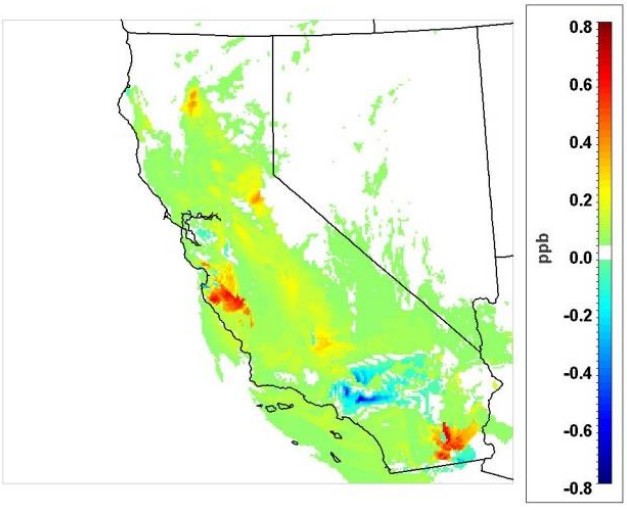
concentrations throughout the state is small, and the changes in 24-hour average concentrations are lower than 0.1 μg/m^3 for all modeling cases.



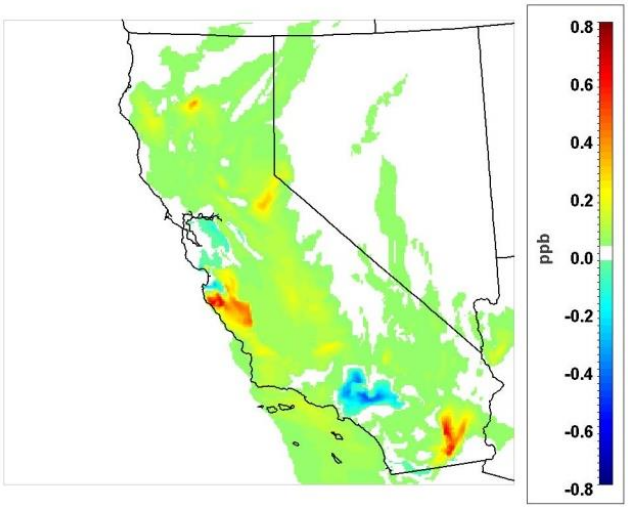
(a) Baseline



(b) Case A: Best Engineering Estimates - Baseline

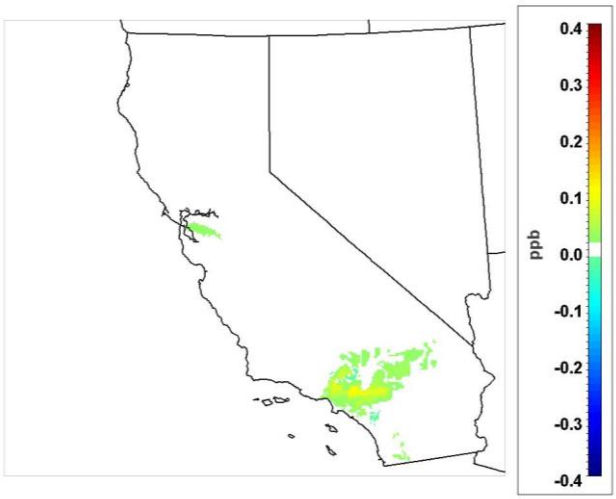


(c) Case B: Max Likely Increase - Baseline

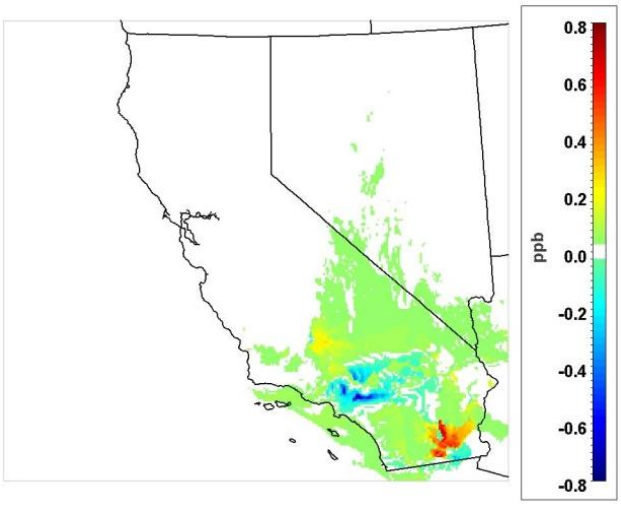


(d) Case C: Point Source Only - Baseline

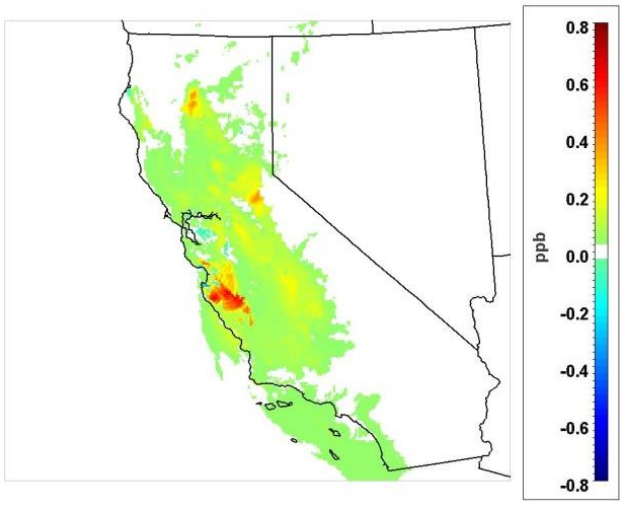
Figure 13: Air quality simulation results for different scenarios for July 21, 2012: (a) Baseline 8-hour peak ozone concentration and difference in peak ozone concentration with respect to Baseline for cases (b) Case A, Best Engineering Estimate, (c) Case B, Max Likely Increase, and (d) Case C, Point Source Only



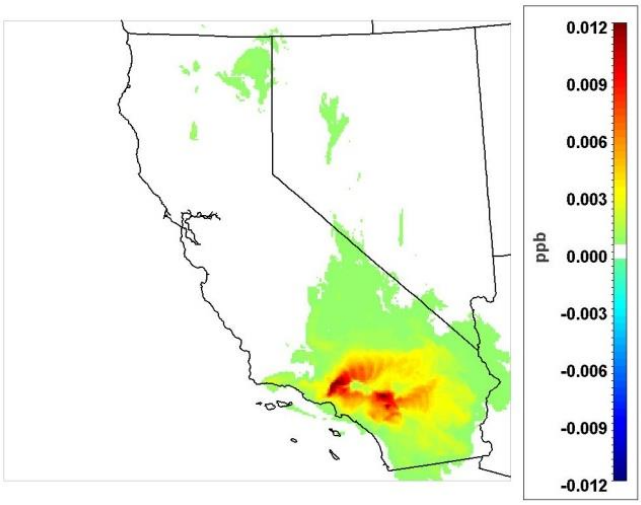
(a) Case D: CNG Vehicles Contribution



(b) Case E: SoCal Only Max Likely Increase - Baseline

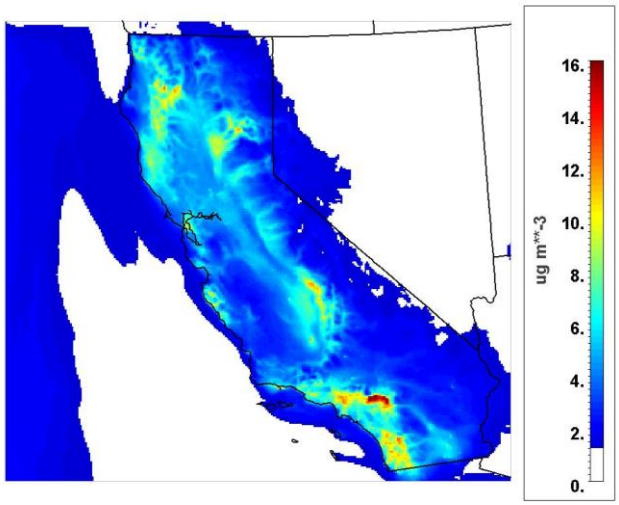


(c) Case F: NorCal Only Max Likely Increase - Baseline

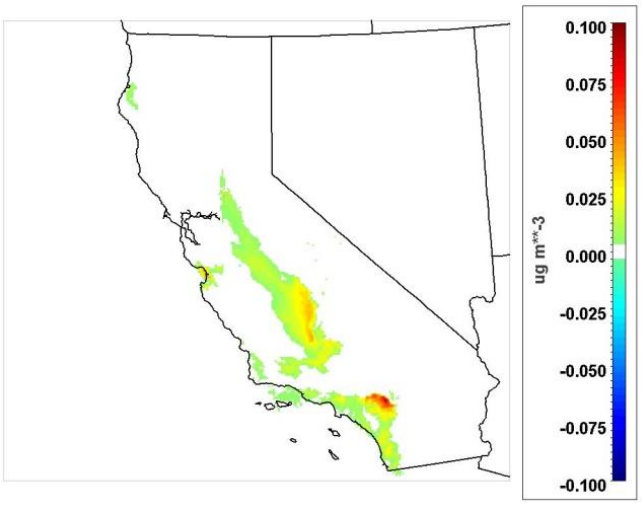


(d) Case G: Fugitive Emissions Contribution

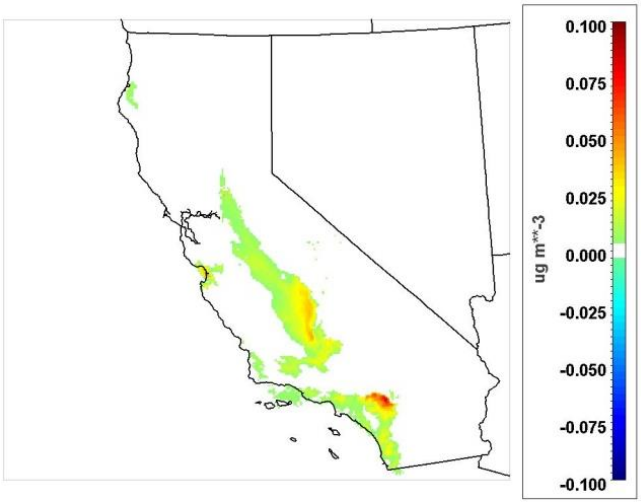
Figure 14: Air quality simulation results for different scenarios for July 21, 2012: difference in peak ozone concentration with respect to Baseline for cases (a) Case D, CNG vehicles contribution, (b) Case E, SoCal Only Max Likely Increase, (c) Case F, NorCal Only Max Likely Increase, and (d) Case G, fugitive emissions contribution



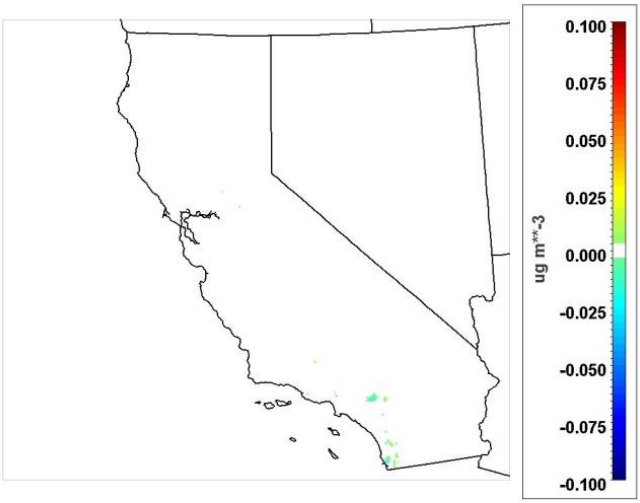
(a) Baseline



(b) Case A: Best Engineering Estimates - Baseline

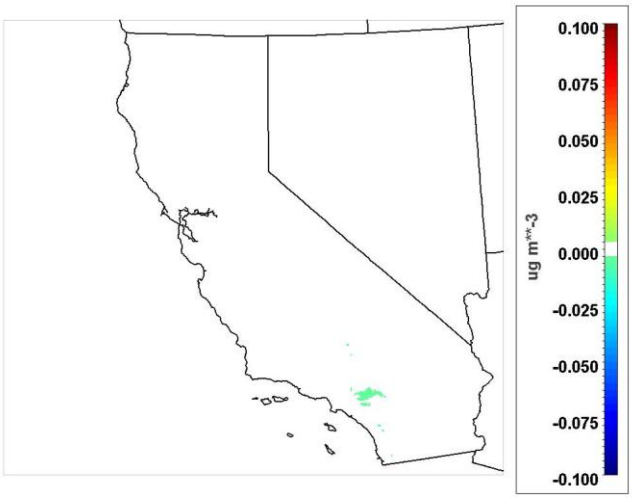


(c) Case B: Max Likely Increase - Baseline

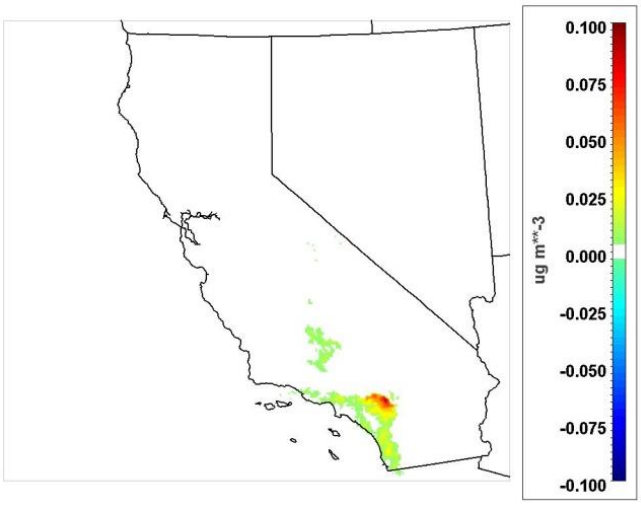


(d) Case C: Point Source Only - Baseline

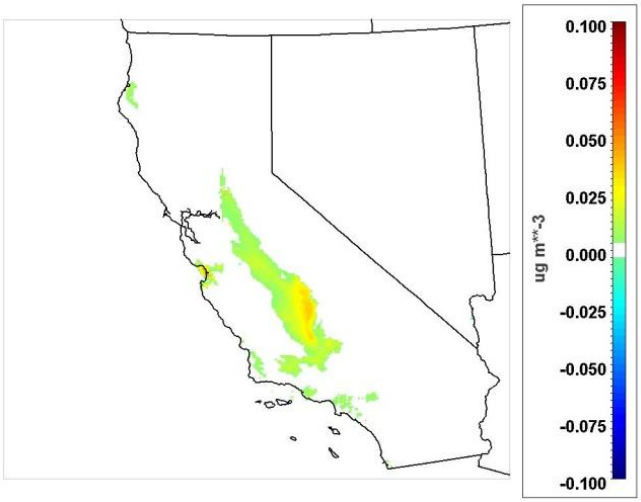
Figure 15: Air quality simulation results for different scenarios for July 21, 2012: (a) Baseline 24-hour average $PM_{2.5}$ concentration and difference in 24-hour average $PM_{2.5}$ concentration with respect to Baseline for cases (b) Case A, Best Engineering Estimate, (c) Case B, Max Likely Increase, and (d) Case C, Point Source Only



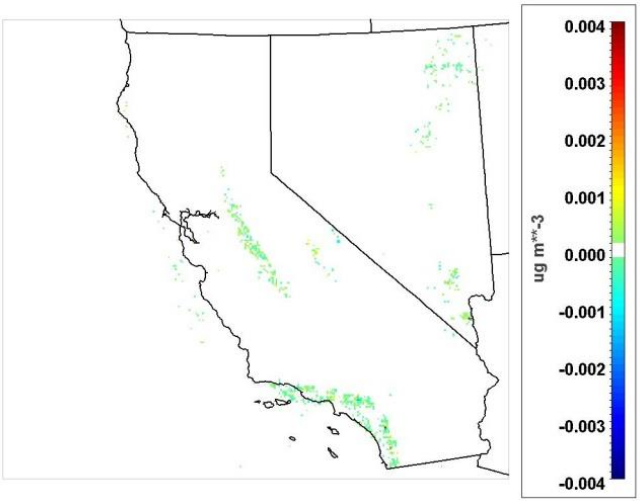
(a) Case D: CNG Vehicles Contribution - Baseline



(b) Case E: SoCal Only Max Likely Increase - Baseline



(c) Case F: NorCal Only Max Likely Increase - Baseline



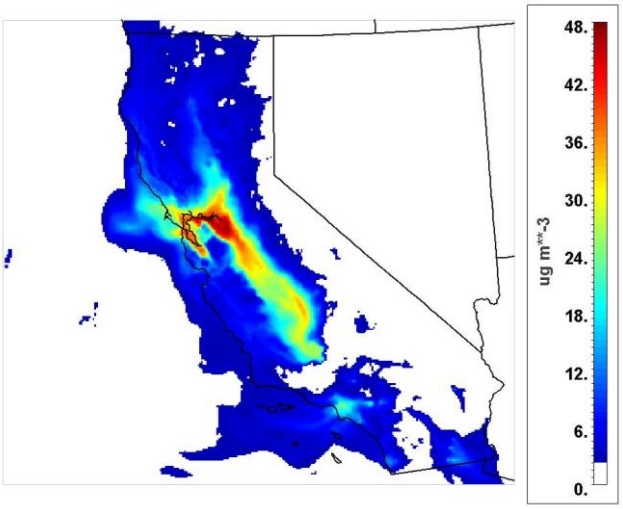
(d) Case G: Fugitive Emissions Contribution - Baseline

Figure 16: Air quality simulation results for different scenarios for July 21, 2012: difference in 24-hour average $PM_{2.5}$ concentration with respect to Baseline for cases (a) Case D, CNG vehicles contribution, (b) Case E, SoCal Only Max Likely Increase, (c) Case F, NorCal Only Max Likely Increase, and (d) Case G, fugitive emissions contribution

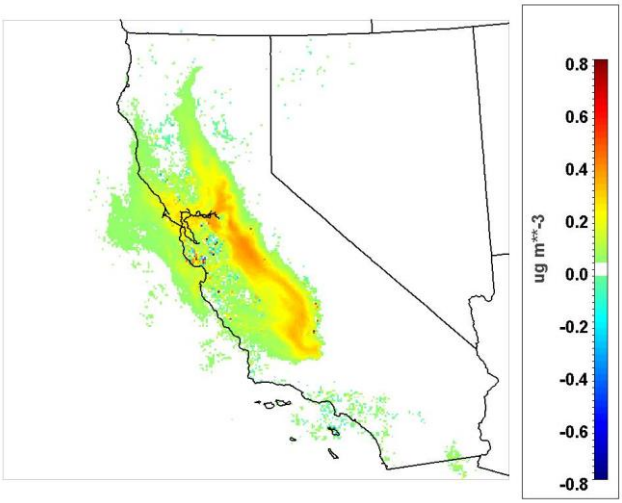
Typically, effects of natural gas combustion on $PM_{2.5}$ formation in the winter are stronger than in the summer. In the winter, NO_X emissions from natural gas combustion are higher than in the summer, and the increases in emissions due to changes in WI are also higher (as presented in Section IV). In addition, winter conditions with lower temperatures and stagnant conditions are conducive to higher concentrations of $PM_{2.5}$ than in summer. As a result, the impacts of the scenarios on $PM_{2.5}$ are more intense than in the summer.

Figure 17 presents the baseline $PM_{2.5}$ concentrations and the impacts of three selected scenarios. The Maximum Likely Increase case (Case B) causes increases in $PM_{2.5}$ of up to 0.8 $\mu g/m^3$, whereas the same case in the summer increases $PM_{2.5}$ concentrations by 0.1 $\mu g/m^3$ or less.

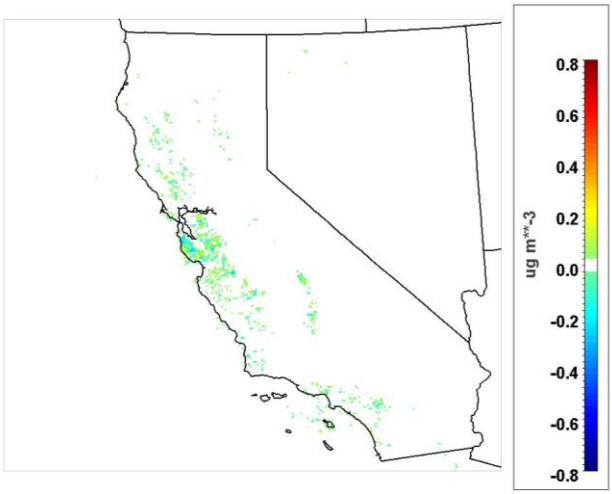
The impacts of point sources (Case C) and of CNGV (Case D) on $PM_{2.5}$ concentrations are also more noticeable than in the summer scenarios, although the overall impacts are less than 0.4 $\mu g/m^3$.



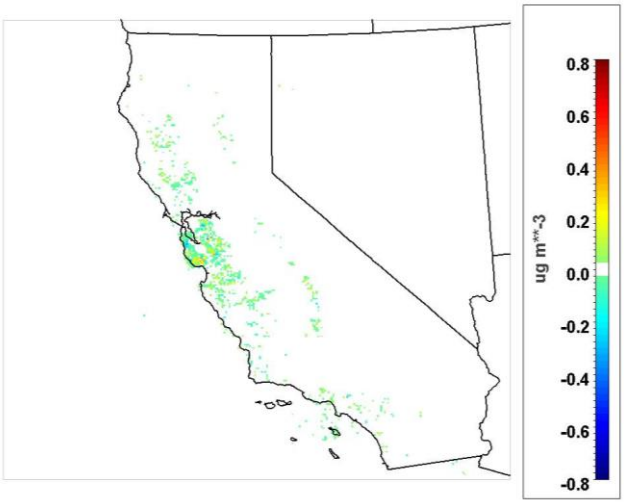
(a) Baseline



(b) Case B: Max Likely Increase - Baseline



(c) Case C: Point-Source Only - Baseline



(d) Case D: CNGV Only - Baseline

Figure 17: Air quality simulation results for different scenarios for January 14, 2012: (a) Baseline 24-hour average $PM_{2.5}$ concentration and difference in 24-hour average $PM_{2.5}$ concentration with respect to Baseline for cases (b) Case B: Max Likely Increase, (c) Case C, Point Source Only, and (d) Case D, CNGV Only

VI Summary

This report demonstrates the use of the TEMPLES model to determine potential impacts of changing natural gas composition on air pollutant emissions and air quality. Seven scenarios involving combustion emissions from residential, commercial, industrial, and transportation sectors were simulated. The results show industrial and commercial sectors are the main contributor to ozone changes. These changes are due to the high sensitivity of ultra-low NO_X burners with respect to changes in WI, based on experimental data (SoCalGas, 2004, 2006a, and 2006b). However, the data are scarce and are dated, nearly a decade old. More experimental data for small industrial burners, internal combustion engines and turbines are needed to improve the simulation results and to reduce the uncertainties.

This report includes new developments in TEMPLES that include:

(1) Update of baseline emission inventory with ARB's 2012 emission inventory

(2) Meteorological conditions that are consistent with 2012 emissions and that represent two episodes of two weeks: one in January and one in July.

(3) Fugitive emissions from natural gas transmission infrastructure

(4) Inventory of CNG vehicles

These updates in TEMPLES should provide a more accurate model for predicting the effects of changing natural gas properties on air pollutant emissions. Overall, air quality impacts evaluated using this new version of TEMPLES are smaller than the ones predicted with the previous version of TEMPLES. The main factor is the substantial reduction in NO_X emissions from natural gas combustion from the 2005 emissions inventory used in the original TEMPLES to the 2012 emissions inventory used in this updated version. Addition of fugitive emissions did not affect ozone and $PM_{2.5}$ concentrations substantially. Finally, the addition of a detailed inventory of county-specific CNG vehicles helps refine the potential impacts of these vehicles on emissions and air quality.

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