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3rd of 3 filed documents.

Additional submitted attachment is included below.

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Near-Zero Emission (NOx) Natural Gas Truck Opportunities in the South Coast Air Basin

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1 Introduction, Background, Purpose

This is a companion to the evaluation of near-zero nitrogen oxide (NOx) emission ("NZE") natural gas ("NG") trucks, also referred to as advanced NG trucks. ENVIRON has been evaluating the effectiveness of trucking sector financial incentives on the adoption rate of advanced natural gas engine technologies that can achieve a NOx emission rate of 0.02 g/bhphr, which is 90% lower than the current, most stringent on-road truck emission standards. The geographic boundary of this analysis is the South Coast Air Basin("Basin"). These results are a part of a larger effort to examine near-zero NOx natural gas opportunities in the entire mobile source inventory.

The US Environmental Protection Agency ("USEPA") requires the Basin to meet the 80 ppb ozone National Ambient Air Quality Standard (NAAQS) by 2023, which requires NOx emissions to be reduced below 115 tons/day. Current air quality regulations are predicted to bring NOx emissions down to just under 330 tons/day in that timeframe; thus, NOx emissions must be reduced approximately 65% beyond current regulations. Furthermore, EPA adoption of the more stringent 75 ppb ozone NAAQS requires that the Basin bring NOx emissions below 80 tons/day by 2032, or 75% beyond 2023 levels given current regulations. Seventy-eight percent of NOx emissions in the Basin are mobile sources of which 21% are heavy-duty trucks.

This analysis is based upon a pure economic justification for the adoption of natural gas technologies in the heavy-duty trucking sector through the use of the Future of Transportation Fuels economic decision model published by the National Petroleum Council in 2012 ("FTF Model"). The analysis segments heavy-duty (HD) trucks by gross vehicle weight rating categories (Light HD (14,000 – 26,000lbs), Medium HD (26,000lbs – 33,000 lbs) and Heavy HD (>33,000 lbs)). Two scenarios were modeled, "SoCalGasRef," a reference case that predicts the likely, natural, adoption of natural gas as a fuel in this sector, and "SoCalGasHigh," a maximum case which predicts the most aggressive adoption rate of natural gas technologies. Differences between these scenarios are described in the next section.

Finally, financial incentives are applied to each of the modeling cases. Incentives are applied in two tiers. The first tier incentives are designed to boost the adoption rate of conventional natural gas technologies, which from a regulatory perspective, have the same emissions as conventional diesel technologies. Second-tier financial incentives are designed to change the purchase of a conventional natural gas technology truck to an advanced, NZE natural gas truck. The first tier incentives and second-tier incentives were applied together in both the SoCalGasRef and the SoCalGasHigh incentive cases.

The analysis results presented include the truck fleet population impacts, NOx emission benefits, total financial incentive program cost and programmatic cost-effectiveness.

2 Economic Modeling

The Heavy-Duty Truck component of the FTF Model predicts the rate at which various fuel technologies will be adopted by the trucking industry between now and 2050. The model predicts the percentage of conventional truck sales (diesel/gasoline) vs. the alternative fuel (natural gas in this case) on an annual basis. These percentage sales values are then applied to vehicle populations predicted by the California Air Resources Board's (CARB) motor vehicle emission model, EMFAC 2011. Basic assumptions of the modeling runs include the following:

- The model assumes NG truck sales begin in 2007 and run through 2050;
- The approximate incremental cost of an NG truck over diesel starts at $65k in 2015 and drops to $47k in 2023;
- Three market adoption curves choices are, "conservative," "moderate" and "aggressive," which are based on an American Trucking Association (ATA) owner survey regarding tolerance to payback for investment. The aggressive curve is closely aligned with the actual ATA survey respondent preferences on payback;
- The consumer begins with a preference towards diesel, but by 2050 is indifferent between diesel and natural gas (preference factor); and
- Fuel prices are based on EIA Annual Energy Outlook 2010 Reference case x 150%; the FTF Model relies on the EIA Annual Energy Outlook, without adjustment.

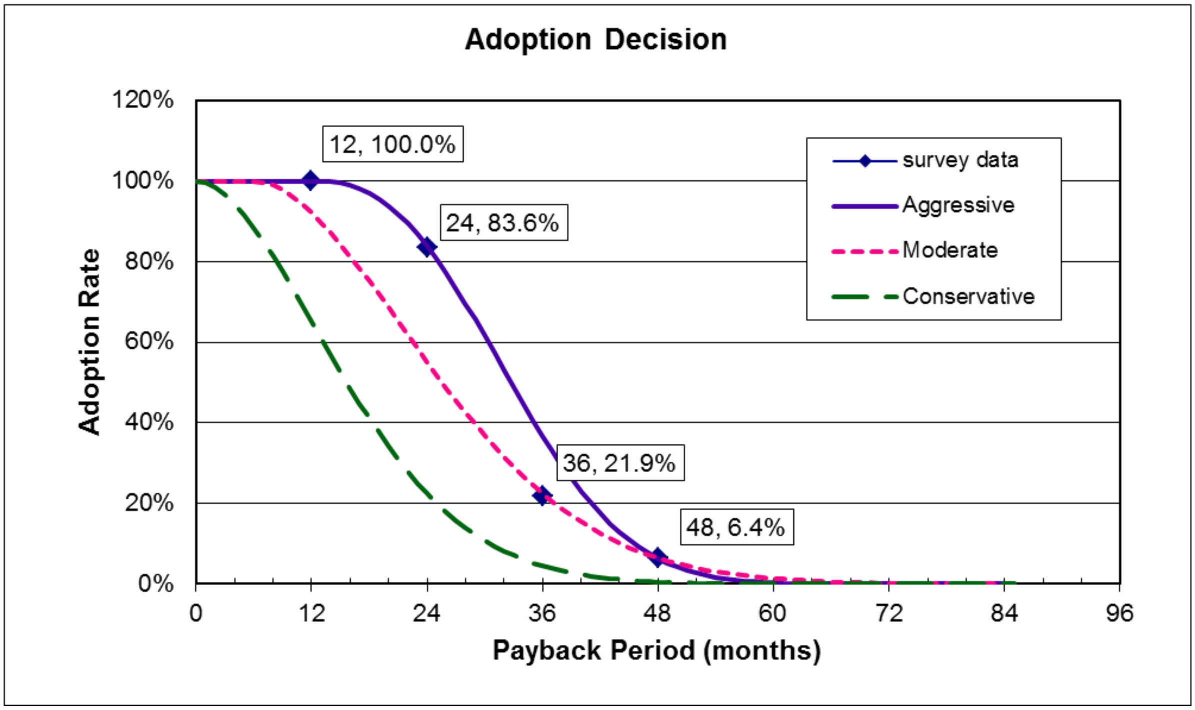
The incremental cost of alternative fuel technologies is one of the most influential factors on the model results. The vehicle price assumptions used in this analysis are presented in Table 1.

Table 1. SoCalGas FTF Model runs technology pricing assumptions, diesel base cost & incremental natural gas truck incremental price above diesel.

Truck Group	2023 Base Diesel Vehicle Cost	NG Incremental Price in 2023	
		SoCalGas Reference	SoCalGas High
Heavy HD Combination	$144,953	$47,355	$30,028
Heavy HD Single	$ 190,399	$18,906	$7,463
Drayage	$144,953	$34,604	$18,399
Refuse	$190,399	$18,906	$7,463
Light & Medium HD	$61,529	$21,165	$15,682

Another variable that was adjusted to develop the SoCalGasRef and SoCalGasHigh penetration curves is the NGV Adoption Curve. The technology adoption curves make up the core of the FTF Model and are based on surveys of American Trucking Association (ATA) members regarding their purchasing behaviors and various economic scenarios including fuel pricing and expected return on investment in these alternative fuel technologies. The survey results were then compiled into adoption curves that indicate the rate at which alternative fuel technologies compete with diesel and gasoline. The FTF Model has three settings for these, "aggressive," "moderate" and "conservative."[1] Note that the aggressive curve is based on the actual ATA survey results, therefore the Moderate and Conservative curves are somewhat more conservative than the actual ATA survey responses. The SoCalGasHigh case is based on the Aggressive NGV adoption curve (the real world survey results of the trucking industry), therefore the SoCalGasRef case, based on the Moderate Adoption Curve, is more conservative than the real world survey results of the trucking industry.

Figure 1: Incentives Modeling NGV Technology Adoption Curves– Payback Period.



The model also has a "Preference Factor" variable that is indicative of the market's preference for conventional fuels (diesel/gasoline) against the alternative fuel, in this case, natural gas. The scenarios modeled in this exercise assume that truck purchasers are initially wholly biased towards conventional fuels (i.e., 100% bias to conventional, 0% bias to natural gas), but by the end year of the scenario (2050), are indifferent to conventional fuels over natural gas (i.e., 50% bias to conventional fuel, 50% bias to natural gas). These settings allow 100% penetration of natural gas truck sales into the market under the proper conditions. This differs from the FTF Model default settings, which artificially limit the maximum market penetration of natural gas to

[1] The "aggressive" setting is indicative of a fleet consumer that has a higher tolerance to longer payback (50% of respondents indicated that they would accept a 33 month payback of the additional cost of the Natural Gas fueled truck due to fuel cost savings). The "moderate" setting consumer would accept a shorter payback period than the aggressive setting (28 months) and the "conservative" setting consumer would expect a still shorter payback period (16 months).-

50% of new sales by setting the "preference factor" such that there is always a bias against NG Trucks.

Specific to fuel pricing, both the SoCalGasRef and SoCalGasHigh modeling scenarios assume that natural gas fuel pricing is 1.5x the Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2010 natural gas pricing. Natural gas fuel price forecasts are scaled due to the relatively low NG pump price assumed in AEO2010 and are an effort to provide pump prices that are more representative of current (2013) average pricing. The FTF Model default fuel price projection is based directly on AEO2010 data, which are likely based on fueling information for a fleet that involved a greater percentage of transit bus, refuse, and other large, time-fill station applications. As more fleets adopt natural gas, it is predicted that more fuel will be dispensed through smaller stations, fast-fill stations, and/or in a retail setting, contributing to a higher dispensed price than the AEO2010 projections.

2.1 NOx NZE Natural Gas Engine Technologies

This analysis is predicated on the assumption that natural gas engine technologies capable of achieving NOx emission rates at a 0.02 g NOx/bhphr certification level in the 8.9L and 15L sizes are commercially available in 2018. This is based on feedback from the natural gas engine manufacturer, Cummins Westport.

2.2 NOx & Greenhouse Gas (GHG) Emission Modeling

The FTF model output of percent new vehicle sales based on model year and fuel type are apportioned to the CARB EMFAC 2011 emission model fleet population. Information on vehicles miles travelled (VMT) by truck type (e.g., light-, medium-, and heavy-heavy duty truck) and truck usage (e.g., drayage, construction, refuse collection, utility service, etc.) is included in EMFAC 2011. Those sectors/truck types with the highest VMT per truck would maximize potential NOx emission reductions per truck using advanced technology NZE engines, increasing the effectiveness of financial incentives for such trucks/trucking sectors.

This analysis makes a blanket assumption that conventional natural gas engines certified to a 0.2 g/bhphr NOx standard will be commercially available in 2015, and starting in 2018, NZE natural gas engines certified to a 0.02 g/bhphr NOx emission standard are made commercially available. Emissions are quantified by vehicle size and type and then summed to provide a total Basin NOx impact. The difference between the default EMFAC emission prediction and SoCalGasRef and SoCalGasHigh NZE natural gas scenarios represent the modeled NOx reductions.

GHG emissions are modeled by application of CARB's GHG natural gas potency factor to the predicted volume of natural gas consumed. Natural gas fuel consumption is calculated from the volume of gasoline and diesel fuel displaced and application of an efficiency loss factor.

3 Financial Incentives Scenarios

The two scenarios modeled are SoCalGas Reference and SoCalGas High.

- SoCalGas Reference assumes: (1) a high price differential between NGV and Diesel Trucks; and (2) uses the conservative NGV adoption curve;
- SoCalGas High assumes: (1) a low price differential between NGV and Diesel Trucks; and (2) uses the aggressive NGV adoption curve

Each of these two scenarios are presented as a base case ("Base Case"), representing the modeled, natural adoption rate of NG technologies given the economic market conditions assumed, and a financial incentive scenario case ("Incentive Case") where incentive funding is offered to encourage the adoption of NZE natural gas technologies. For the Incentive Case runs, financial incentives are applied in two levels; Incentive 1 encourages additional natural gas technology adoption by depressing the cost of natural gas technology engine and Incentive 2 is applied to convert all conventional natural gas truck sales to near zero natural gas technology, which is defined as 0.02 g NOx/bhp-hr.

- Financial Incentive 1 to accelerate conventional NG truck adoption[2]
  - $25,000 for Class 8 Truck Tractors and Class 8 Drayage Trucks
  - $15,000 for Class 4 through 8 Straight and Solid Waste Collection Trucks ($7,500 in the high penetration rate case)
- Financial Incentives 2 to influence NZE natural gas technology adoption (0.02 g/bhp-hr NZE NG truck technology vs. 0.2 g/bhp-hr conventional NG truck technology)[3]
  - $10,000 for Class 8 Tractors
  - $8,000 for Class 4 – 8 Straight Trucks

The financial incentives are assumed to be direct grants to qualifying vehicle purchasers. More sophisticated forms of incentives that have been used in the past were not investigated. It is likely that other incentive programs can be used which will result in equal or greater penetration, at lower total costs. A partnership among appropriate government agencies and others with more experience in these types of programs is recommended for vetting these issues.

3.1 SoCalGas Reference Scenario Results

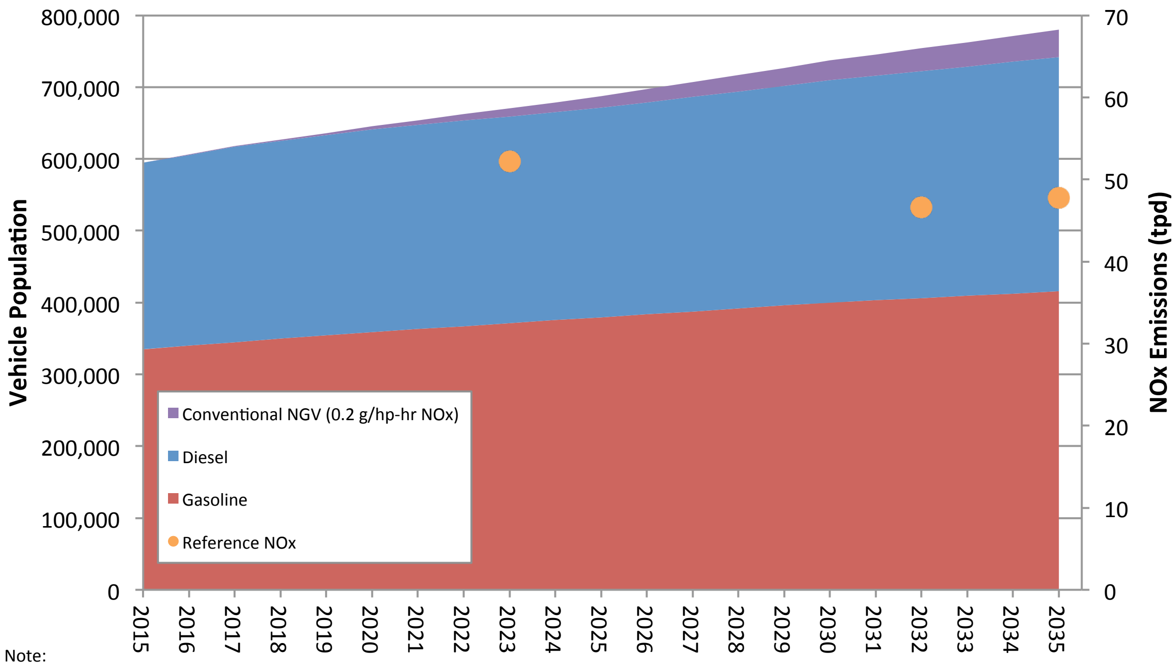
The results of the SoCalGas Reference scenario runs are presented in Figures 2, 3, and 4. Figure 2 is the SoCalGas Reference Base Case. The area chart is a representation of the total

[2] The $25,000 and $15,000 incentives were based on estimated 2015 price differentials discussed in Section 2. For example, the larger trucks have a $65k price differential in 2015. Program incentives can be refined based on updated price information for vehicles and the incentive program objectives.

[3] The $8,000 - $10,000 price estimates for "financial incentive 2" were based on the original cost indicated by a natural gas engine manufacturer however the same manufacturer revised this cost estimate to $4,000 - $5,000 in more recent, subsequent discussions. These more recent updated values for financial incentive 2 were not modeled.

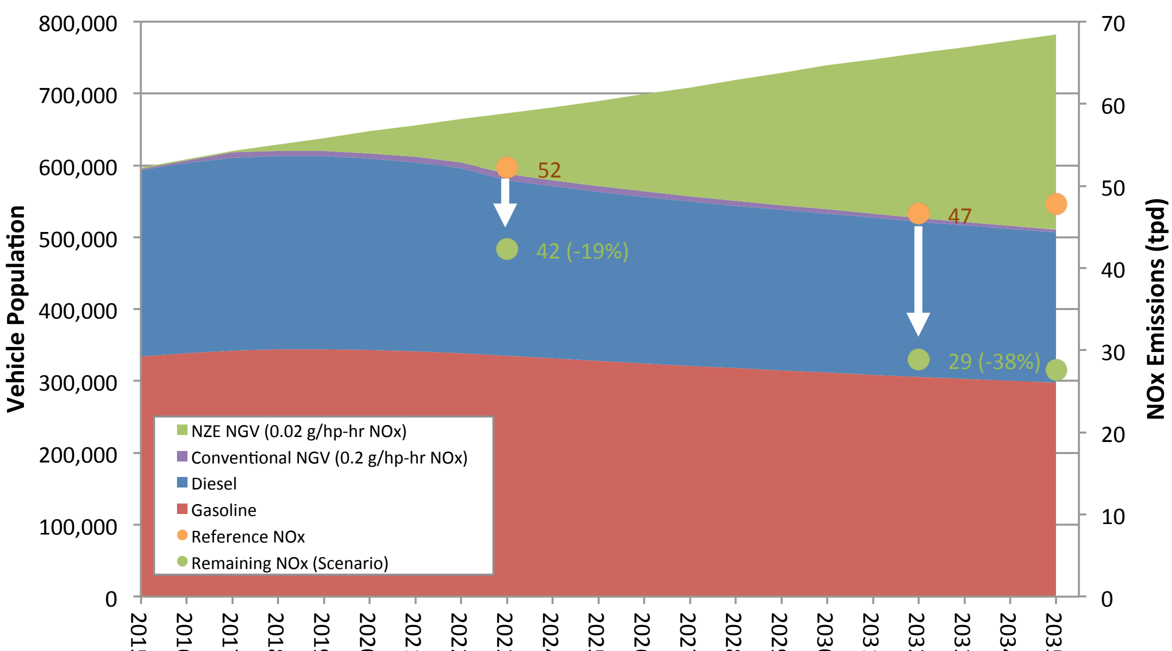
population of heavy-duty trucks registered in the South Coast Air Basin, predicted in the years 2015 – 2035, stratified by fuel type (gasoline-red, diesel-blue and natural gas-purple) and is

Figure 2: SoCalGas Reference- Base Case Scenario.



Note:
1. Analysis includes T7 Drayage, T7 Single, T7 Solid Waste Collection Vehicle, T7 Tractor, T7 Tractor Construction, T7 Agriculture, T7 Single Construction, T7 Public, T7 Utility, T7 IS, T6 Instate Heavy, T6 Instate Small, T6 Utility, T6 Public, T6 TS, T6 Agriculture, T6 Instate Construction Heavy, T6 Instate Construction Small, LHDDT, and LHDGT.
2. Vehicle population is based on the EMFAC2011 data for the South Coast Air Basin.
3. Reference NOx emissions were obtained from the 2012 Air Quality Management Plan (AQMP) from the SCAQMD.

Figure 3: SoCalGas Reference Incentive Case.



Notes:
1. Analysis includes T7 Drayage, T7 Single, T7 Solid Waste Collection Vehicle, T7 Tractor, T7 Tractor Construction, T7 Agriculture, T7 Single Construction, T7 Public, T7 Utility, T7 IS, T6 Instate Heavy, T6 Instate Small, T6 Utility, T6 Public, T6 TS, T6 Agriculture, T6 Instate Construction Heavy, T6 Instate Construction Small, LHDDT, and LHDGT.
2. Maximum incentives range from $23,000 - $35,000/Truck depending on the vehicle type and engine size.
3. Assumed penetration rates after the incentive period ends remain at the 2023 level due to some mechanism.

associated with the primary y-axis (to the left). No incentive is applied in Figure 2. The three orange dots represent daily NOx emissions associated with the fleet population in the year indicated (2023, 2032 and 2035) and are associated with the second y-axis (to the right). These NOx emission values are the reference against which all scenarios are compared.

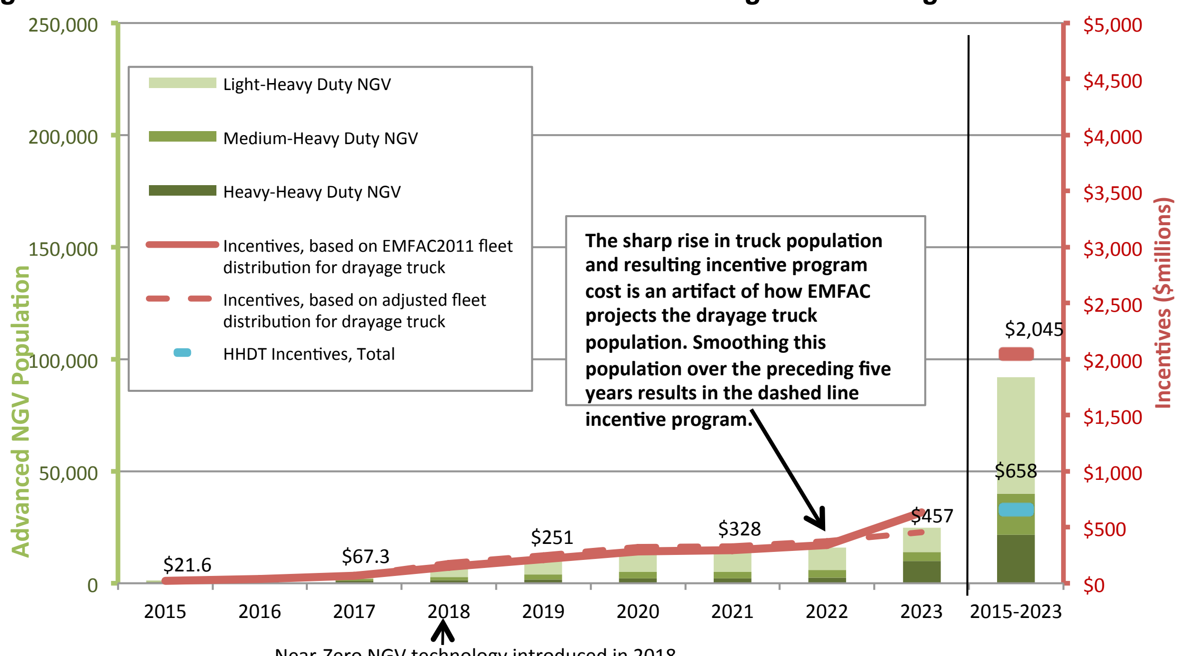
This case assumes three differences from the Reference Base Case:

1. A financial incentive for conventional (0.20 g NOx/bhp-hr) natural gas trucks is introduced in 2015 through 2023;
2. A financial incentive for the adoption of NZE NOx technology (0.02 g NOx/bhp-hr) is introduced starting in 2018 through 2023; and
3. A mechanism, yet to be defined, is introduced starting in 2023 to maintain the adoption rate of NZE NOx technology at 2023 levels.

The purple portion of the area chart represent the population of conventional natural gas vehicles introduced in period from 2015 – 2018. The green portion represents NZE natural gas vehicles introduced in the period from 2018 – 2035. The green dots represent the NOx emissions of the total fleet in the years indicated, and the orange dots represent the reference NOx emissions of the SoCalGas Reference Base Case (transcribed from Figure 2).

The incentive program yields daily NOx reductions of 19% and 38% in 2023 and 2032, respectively, at an incentive program cost of $2.05 billion. It is noted that a majority of these NOx reductions come from the heavy heavy-duty truck segment of the market at a cost of $660 million (Figure 4).

Figure 4: SoCalGas Reference Scenarios- Incentive Program Funding.



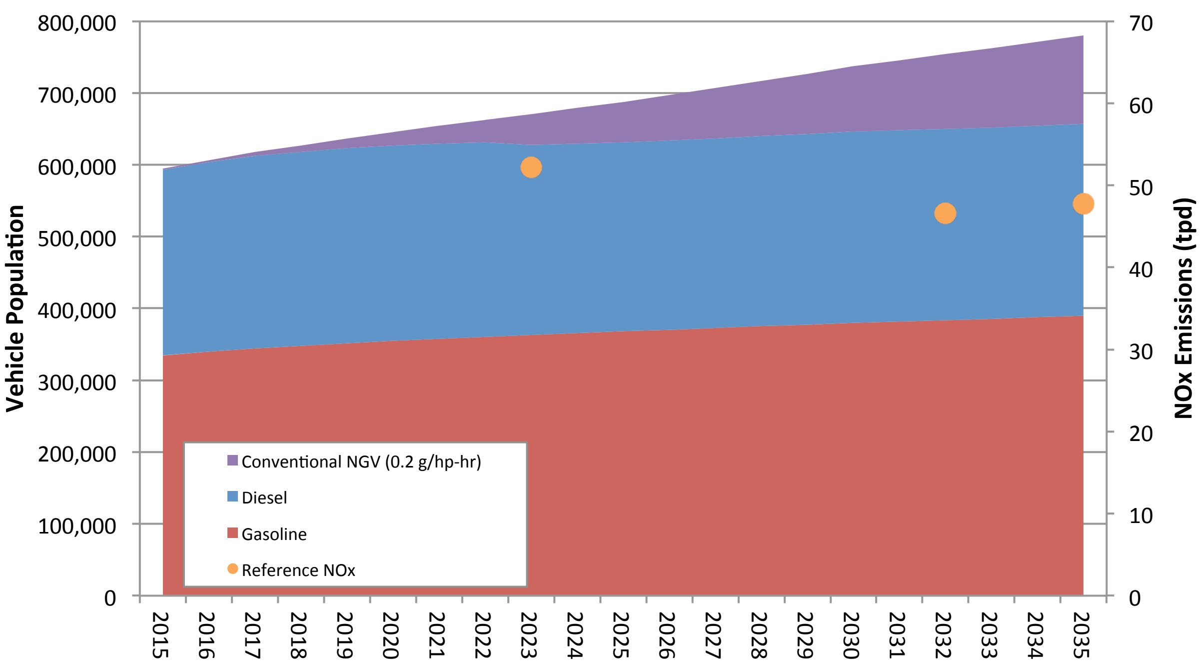
Notes:
1. Represents the funding needed to incentivize purchase of the new near-zero NG vehicle each year that would otherwise have been diesel if no incentives provided.
2. Analysis includes T7 Drayage, T7 Single, T7 Solid Waste Collection Vehicle, T7 Tractor, T7 Tractor Construction, T7 Agriculture, T7 Single Construction, T7 Public, T7 Utility, T7 IS, T6 Instate Heavy, T6 Instate Small, T6 Utility, T6 Public, T6 TS, T6 Agriculture, T6 Instate Construction Heavy, T6 Instate Construction Small, LHDDT, and LHDGT.
3. The last bars show the cumulative advanced NGV population and the total incentive dollars required during 2015 - 2023 under NPC high penetration scenario
4. The NGV new sales projection was derived from the NPC model based on the high adoption assumptions and the natural gas price at 1.5 times EIA 2010 forecast.

3.2 SoCalGas High Scenario Results

The results of the SoCalGas High scenario runs are presented in Figures 5, 6 and 7. The High Base Case scenario, Figure 5, shows significantly higher adoption rates of natural gas truck technologies (purple) than the Reference Base Case (Figure 2). However predicted NOx emissions are identical to those of the Reference Base Case as conventional natural gas engines are certified to the same emission rate as a comparable diesel or gasoline engine.

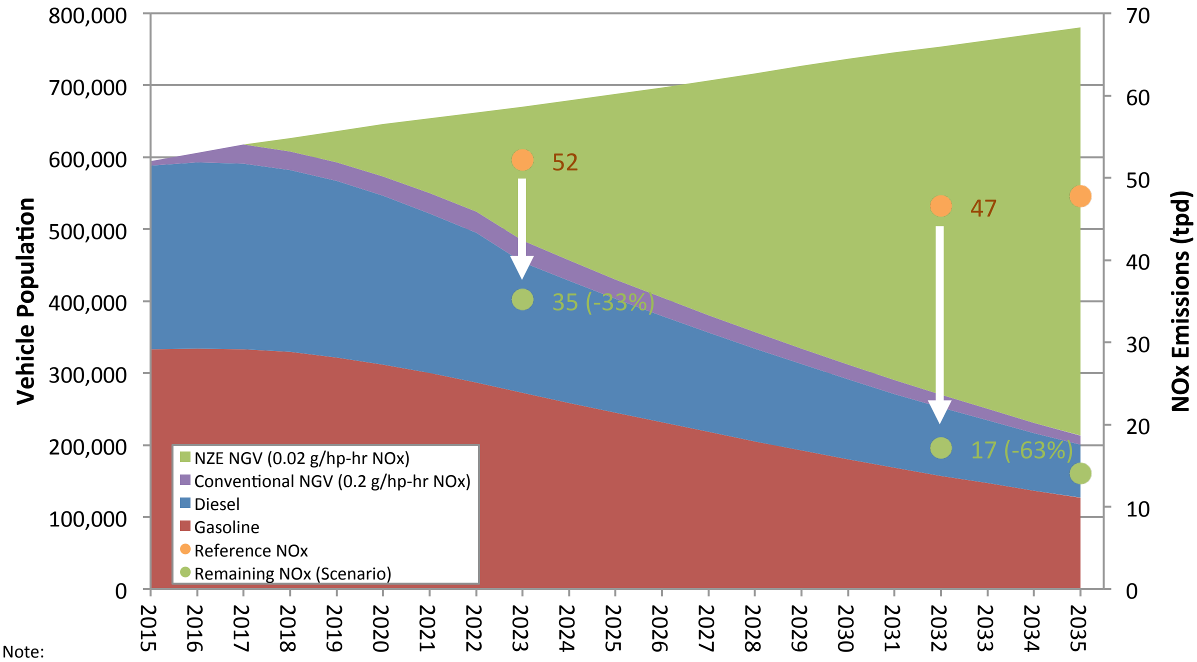
Figure 6 is the SoCalGas High Incentive Case. This case makes very similar financial incentive assumptions as the Reference Incentive Case, although the actual truck incentive funding amounts have been adjusted based on the higher underlying adoption rate of natural gas trucks. The purple portions of the area chart represent the population of conventional natural gas vehicles introduced in period from 2015 – 2018. The green portion represents NZE natural gas vehicles introduced in the period from 2018– 2035. The green dots represent the NOx emissions of the total fleet in the years indicated, and the orange dots represent the reference NOx emissions of the SoCalGas Reference Base Case (transcribed from Figure 5). The incentive program yields daily NOx reductions of 33% and 63% in 2023 and 2032, respectively, at an incentive program cost of $4.3 billion. It is noted that a majority of these NOx reductions (9.6 tpd out of 17 tpd) come from the heavy heavy-duty truck segment of the market at a cost of $885 million (Figure 7).

Figure 5: SoCalGas High- Base Case Scenario.



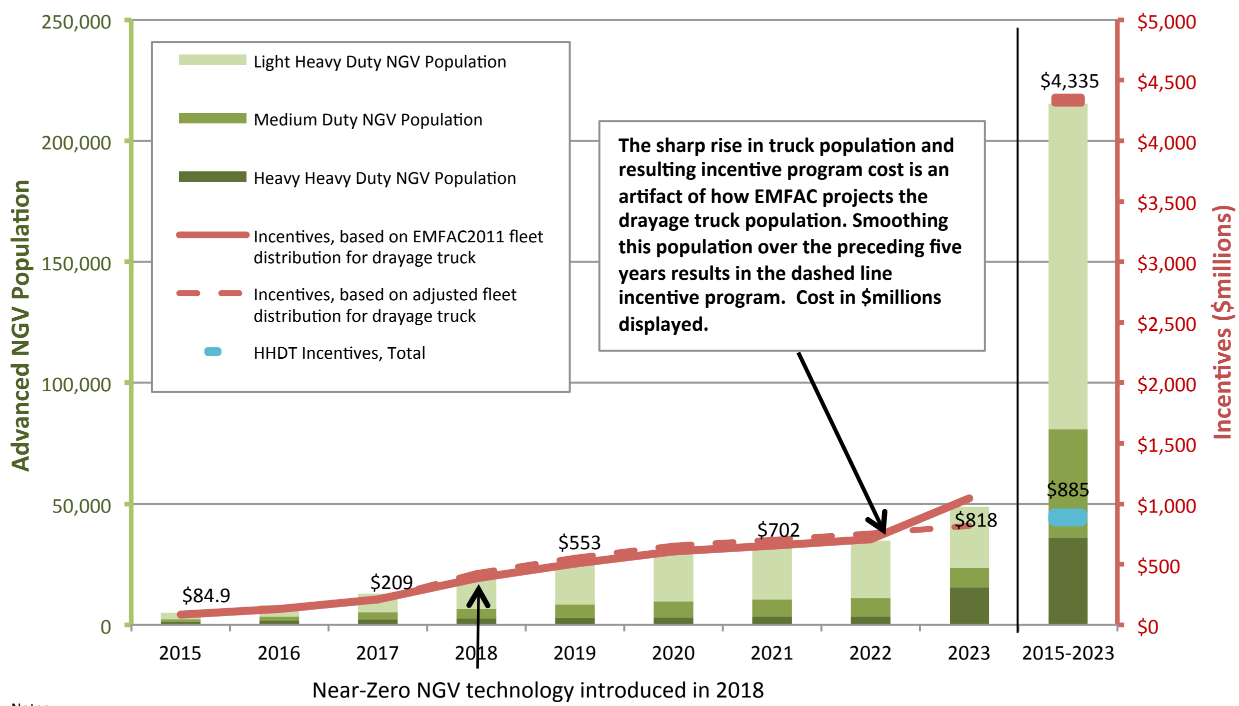
Notes:
1. Analysis includes T7 Drayage, T7 Single, T7 Solid Waste Collection Vehicle, T7 Tractor, T7 Tractor Construction, T7 Agriculture, T7 Single Construction, T7 Public, T7 Utility, T7 IS, T6 Instate Heavy, T6 Instate Small, T6 Utility, T6 Public, T6 TS, T6 Agriculture, T6 Instate Construction Heavy, T6 Instate Construction Small, LHDDT, and LHDGT.
2. Vehicle population is based on the EMFAC2011 data for the South Coast Air Basin.
3. Reference NOx emissions were obtained from the 2012 Air Quality Management Plan (AQMP) from the SCAQMD.

Figure 6: SoCalGas High- Incentive Case Scenario.



Note:
1. Analysis includes T7 Drayage, T7 Single, T7 Solid Waste Collection Vehicle, T7 Tractor, T7 Tractor Construction, T7 Agriculture, T7 Single Construction, T7 Public, T7 Utility, T7 IS, T6 Instate Heavy, T6 Instate Small, T6 Utility, T6 Public, T6 TS, T6 Agriculture, T6 Instate Construction Heavy, T6 Instate Construction Small, LHDDT, and LHDGT.
2. Maximum incentives range from $15,500 - $35,000/Truck depending on the vehicle type and engine size.
3. Assumed penetration rates after the incentive period ends remain at the 2023 level due to some mechanism.

Figure 7: SoCalGas High- Incentive Program Funding.



Notes:
1. Represents the funding needed to incentivize purchase of the new near-zero NG vehicle each year that would otherwise have been diesel or gas if no incentives provided.
2. Analysis includes T7 Drayage, T7 Single, T7 Solid Waste Collection Vehicle, T7 Tractor, T7 Tractor Construction, T7 Agriculture, T7 Single Construction, T7 Public, T7 Utility, T7 IS, T6 Instate Heavy, T6 Instate Small, T6 Utility, T6 Public, T6 TS, T6 Agriculture, T6 Instate Construction Heavy, T6 Instate Construction Small, LHDDT, and LHDGT.
3. The last bars show the cumulative advanced NGV population and the total incentive dollars required during 2015 - 2023 under NPC high penetration scenario
4. The NGV new sales projection was derived from the NPC model based on the high adoption assumptions and the natural gas price at 1.5 times EIA 2010 forecast.

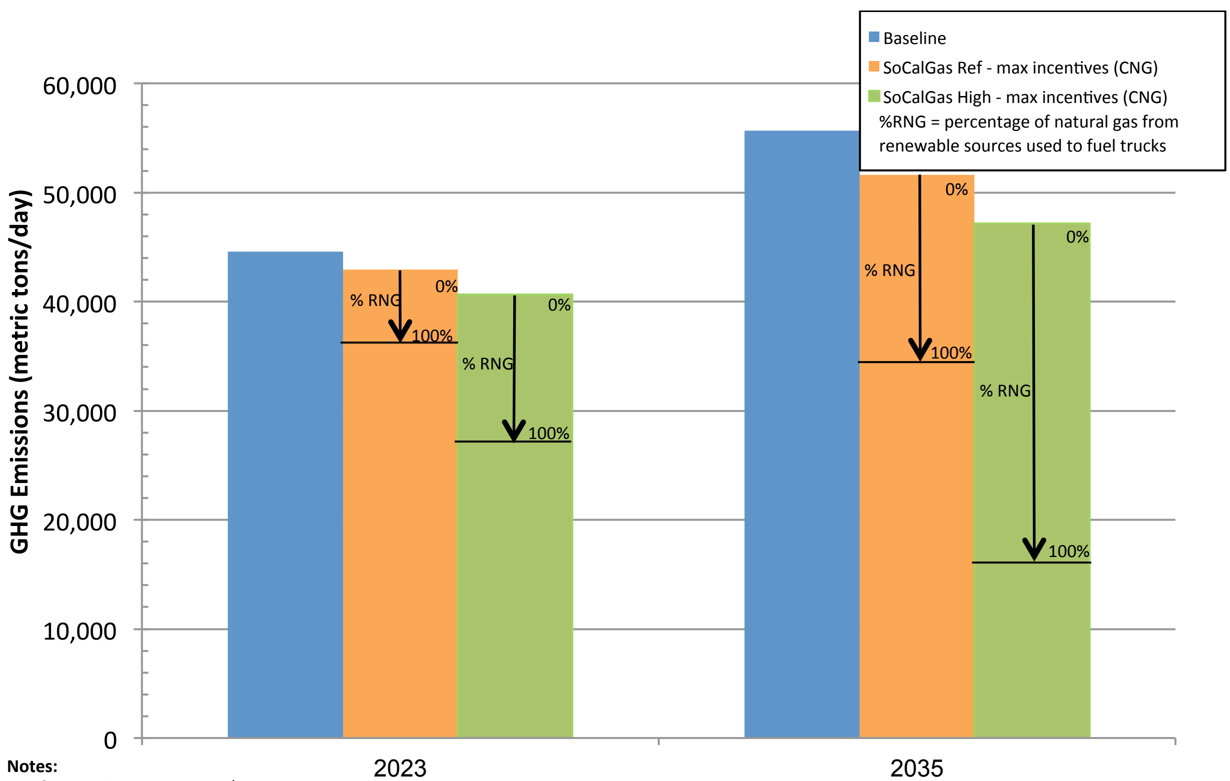
3.3 Cumulative Incentive Costs Compared to 2023 Emission Reductions

The cumulative cost of the incentives can be compared to the reductions that result from the incentives. The 2023 NOx reductions are compared to the cumulative cost of the incentives for each type of heavy-duty truck (light, medium, and heavy) for the SoCalGas High, maximum incentives scenario. The cumulative cost of the incentives for all heavy-duty trucks is $4,335M, resulting in a NOx reduction in 2023 of 17 tons/day. Over half of the 2023 NOx reductions (9.6 tons/day) result from only $885M (or 20%) of the cumulative cost of the incentives, for incentives given to heavy-heavy duty trucks only. Additional reductions can only be achieved at a much higher cumulative cost for incentives given to light- and medium-duty trucks per ton /day of NOx reduced (7.3 tons/day of NOx reductions in 2023 for a cumulative cost of $3,450M).

3.4 Greenhouse Gas Emissions Analysis

Lastly, the greenhouse gas (GHG) reductions for the maximum incentives scenario were analyzed. In Figure 9, the 2023 and 2035 GHG emission reductions are compared to the baseline emissions for each year. All SoCalGas maximum incentives scenarios show a decrease in GHG emissions compared to the current baseline of conventional diesel and gasoline in-state trucks. The results for each SoCalGas scenario include a range of GHG reductions that could further occur if natural gas from renewable sources (such as renewable natural gas from biomass or RNG) displaced fossil-fuel NG.

Figure 8: Greenhouse Gas Emission Reduction Analysis for In-State Trucks in the South Coast Air Basin (uses currently adopted climate intensity).



Notes:
1.CI for diesel is 98.03 gCO2e/MJ.
2.CI for gasoline is 98.83 gCO2e/MJ.
3.CI for renewable NG is 11.26 gCO2e/MJ based on landfill gas.
4.CI for CA pipleline CNG is 67.7 gCO2e/MJ.
5.Conventional natural gas assumes a fuel efficiency decrease of 10% when compared to diesel and equivalent fuel efficiency to gasoline.
6.Near zero natural gas assumes a fuel efficiency decrease of 15% when compared to diesel and a fuel efficiency decrease of 5% when compared to gasoline.