NERA
ECONOMIC CONSULTING

Economic Impacts of a Proposed 65 ppb National Ambient Air Quality Standard for Ozone on the State of Texas

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Texas Commission on Environmental Quality

Final Report

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EXECUTIVE SUMMARY

The Texas Commission on Environmental Quality (TCEQ) engaged NERA Economic Consulting (NERA) to evaluate on an *ex ante* basis the potential costs and economic impacts on the state of Texas associated with a proposed National Ambient Air Quality Standard (NAAQS) for ozone of 65 parts per billion (ppb).

To perform this analysis, NERA estimated the total tons of NO_X reductions that would be required to bring all Texas monitors into attainment with a 65 ppb standard. We then estimated the costs of the required reductions. Our analysis took as a starting point EPA's cost analysis reported in its Regulatory Impact Analysis (EPA, 2014a), but we made several refinements we concluded would result in more realistic cost estimates:[1]

- **We incorporated additional Texas-specific information**: We worked with TCEQ staff to identify additional controls potentially available in East Texas, where the projected nonattainment areas are located. We also refined the projected locations of emissions reductions that EPA's analysis indicates would be required for East Texas to achieve attainment.
- **We used a more evidence-based approach for estimating costs of *all* the needed tons of reduction**: After exhausting the list of standard control measures that it had initially identified as available to reduce ozone, EPA's analysis was left with a very large share of the reductions needed for attainment completely unidentified. Rather than attempting to use its emissions inventory data to determine what types of sources and controls would be needed for those remaining reductions, EPA assumed a flat average dollar-per-ton cost for all of them, regardless of the depth of the remaining emissions cuts. We inspected EPA's inventory data and determined that most of those remaining emissions reductions would have to come from vehicles and other relatively small, area-type sources. We used available information to develop more refined estimates of their cost per ton, which increase with the depth of the required cut into these remaining emissions.
- **We excluded reductions associated with the proposed Clean Power Plan (CPP) that EPA assumed would occur costlessly in attaining a tighter ozone NAAQS**: By assuming reductions before 2025 due to the proposed CPP reductions in its Baseline scenario, EPA's analysis lowered the projected reduction needs associated with compliance with a 65 ppb standard by 2025.

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[1] The emission controls that NERA assumes for this *ex ante* cost estimation study are based on approximate, presently-available information. Controls that will actually be included in any future TCEQ state implementation plan may differ because TCEQ will first use detailed air quality modeling to more accurately determine each measure's effectiveness (*i.e.*, how much each control will reduce ozone levels in nonattainment areas during times when 8-hour ozone values are at their highest). In addition, the analysis in this study has been based on standard nonattainment classifications and their schedules for achieving attainment; thus, this study's results do not apply to other potential classifications that might occur.

- **We applied emissions reduction timing consistent with EPA's specified attainment schedule**: Texas's nonattainment areas are expected to be classified as either Marginal or Moderate, meaning that attainment would be required by 2023 (not 2025 like EPA assumed).

Based on these refinements, we developed independent estimates of emissions-reduction costs by sector by year for sources in Texas. We then evaluated the economic impacts associated with these costs using our integrated energy-economic model called N_{ew}ERA. Key findings of our analysis are summarized below.

- The estimated reductions of NO_X emissions needed to comply with a proposed 65 ppb ozone standard in Texas are quite large – a 67% reduction in East Texas and a 46% reduction in West Texas (averaging 60% statewide).
    - These are the incremental reductions needed after first making the cuts necessary to attain the current ozone standard.
- Achieving such deep cuts entails heavy reliance on non-standard control options that can only be generally characterized at this time, but are known to be costly and difficult to implement.
    - Our entire list of clearly-identifiable potential control measures provides only 34% of all the tons of reduction projected to be needed in East Texas. It also provides only 65% of the projected reduction need in West Texas.
- The total annualized emission reduction costs for Texas are estimated to be $51 billion per year (in 2011$), with the majority of those costs ($47 billion) being in East Texas.
    - For comparison purposes, our estimated annualized costs for Texas are approximately 9 to 14 times higher than EPA's analysis implies.
    - We estimate that costs for Texas exceed 30% of all U.S. costs.
- The impact on the Texas economy of this amount of emissions reduction spending is estimated to reduce Texas's gross state product (GSP) relative to its baseline levels by 1.4%, or about $30 billion per year (in 2014$). Spending by Texas households is projected to be reduced by an average of $1,690 per household per year (in 2014$).
    - These impact estimates are the *net* effects after accounting for the positive as well as the negative effects of the spending. Although there may be many individual winners, at the level of sector and state aggregation in this analysis, natural gas is the only sector projected to experience a net gain.

- This economic impact analysis addresses only spending to reduce emissions. Areas of the state that are designated nonattainment will face an array of additional compliance requirements (such as transportation conformity planning and nonattainment new source review permitting requirements) that may hinder those areas' economic growth too.

I. INTRODUCTION

On December 17, 2014, the *Federal Register* published a proposal by the United States Environmental Protection Agency (EPA) to revise the National Ambient Air Quality Standard (NAAQS) for ozone. The current ozone standard is 75 parts per billion (ppb), established by EPA in 2008. EPA has proposed to tighten that standard to a level in the range of 65 to 70 ppb, and indicated it would accept comments on a 60 ppb alternative and on the option to retain the current standard at 75 ppb. In its Regulatory Impact Analysis (RIA) for the proposed ozone NAAQS (EPA, 2014a), EPA presented its analysis estimating the potential costs associated with reducing ozone precursor emissions to levels that would allow national attainment with tighter standards of 60, 65, and 70 ppb. EPA estimated that the cost of the incremental emissions reductions needed in the year 2025 to attain the 65 ppb alternative NAAQS would be $15 billion per year (2011$) nationally.[2] EPA did not disaggregate its cost estimate to individual states. EPA also did not perform any analysis of how its estimated emissions reduction costs would impact the U.S. economy.

In previous studies for the National Association of Manufacturers (NAM), NERA Economic Consulting (NERA) had critiqued each element of EPA's analysis for reasonableness in light of available evidence and facts, finding indications that EPA's analysis likely understated the true emissions reduction cost (NERA, 2015b). Making modifications to several of EPA's assumptions that NERA's research suggested would provide greater realism, NERA developed an estimate of the potential national cost of a 65 ppb standard that was about ten times larger than EPA's national estimate (NERA, 2015a).

The Texas Commission on Environmental Quality (TCEQ) engaged NERA to take a more focused look at the costs and impacts of a 65 ppb ozone NAAQS to the State of Texas specifically. In this study, NERA applied a more detailed analysis of ozone compliance needs projected for Texas, evaluated the realism of EPA's emissions control options data for Texas, and reviewed data used in Texas's current ozone state implementation plan (SIP) and otherwise available to TCEQ air quality staff to try to expand the list of potential control options available in Texas. Using these additional data, NERA made a refined estimate of the emissions reduction spending that Texas would likely face under a 65 ppb ozone standard. NERA also estimated the economic impacts to Texas of these emissions reduction costs.

All costs in this study are stated as the incremental spending that is projected to be needed after all states have first attained the current ozone NAAQS of 75 ppb. The on-going efforts to attain the current standard are effectively treated as costless in this report, as they are incorporated into the baseline from which incremental costs and economic impacts are estimated. Also, the economic impact analysis in this study reflects only the impacts of financial spending to make

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[2] This estimate does not include any attainment costs for California because EPA concluded that California would face a much later attainment deadline than 2025, and thus did not assign it any incremental emissions reductions in 2025.

the emissions reductions necessary to achieve attainment. Areas of the state that are designated nonattainment will face an array of additional compliance requirements (such as transportation conformity planning and nonattainment new source review permitting requirements) that may hinder those areas' economic growth too.

Section II provides background on EPA's analysis of the costs of the proposed rule, which is the starting point for NERA's own estimates. Section III summarizes ways in which NERA concluded that EPA's cost calculations should be modified to provide a more realistic, evidence-based estimate of the costs of reducing emissions to attain the 65 ppb NAAQS. Section IV then details NERA's cost estimates for Texas. Section V presents estimates of the macroeconomic and energy market impacts of NERA's emissions reduction cost estimates. These results were produced using NERA's N_{ew}ERA model, which is described in detail in Appendix A. Appendix B provides information on background ozone and the locations of monitors that EPA excluded from its analysis.

II. OVERVIEW OF EPA'S COST ESTIMATION APPROACH

This section describes the steps and key assumptions that EPA used in its cost analysis in the ozone RIA (EPA, 2014a) because that report provides the analytic and data foundation from which NERA started for its assessment. Section III identifies the elements and assumptions in EPA's analysis that NERA has concluded should be refined, and summarizes the modifications NERA made for its analysis for TCEQ.

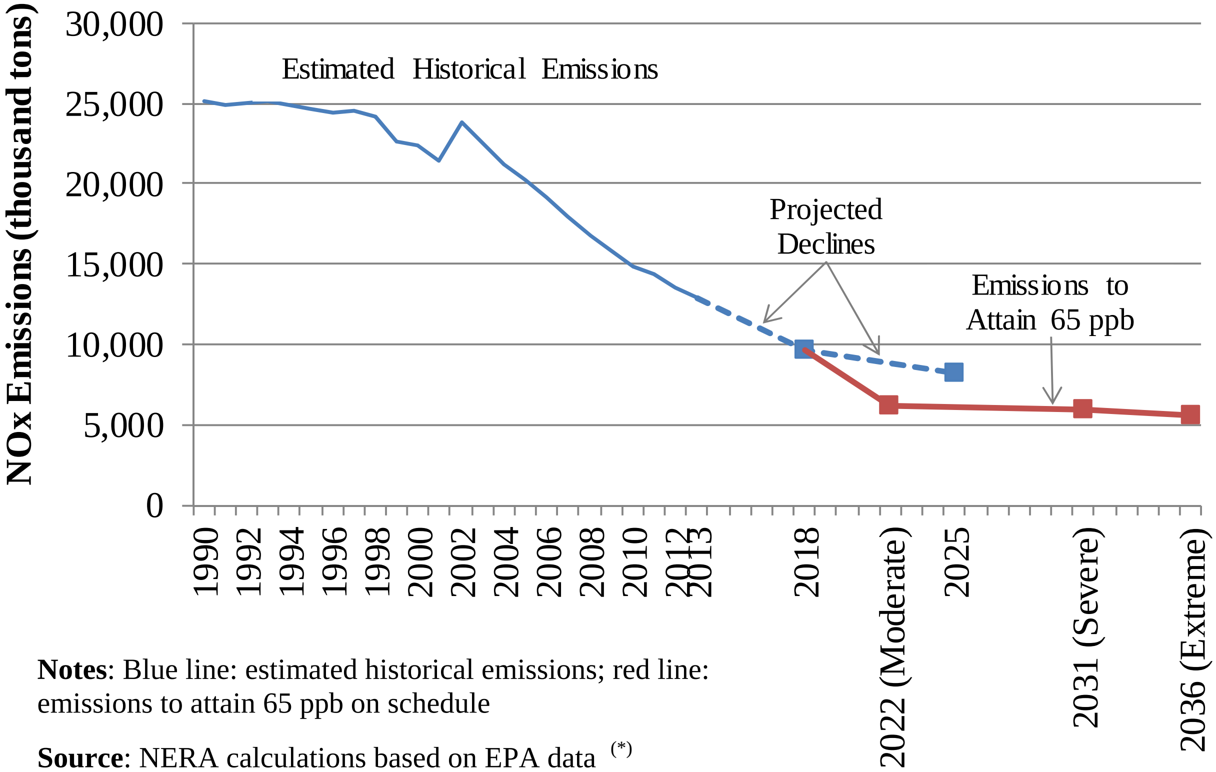
After a NAAQS has been promulgated, each state must review data from its ambient monitoring networks and identify areas that are not attaining the new NAAQS. States make recommendations to the EPA for nonattainment area designations, but the final determination on which areas are designated nonattainment as well as the classification for those areas is ultimately made by the EPA. After the EPA issues final designations, states with nonattainment areas must then develop SIPs that identify what sources of emissions will be reduced, and when, to achieve attainment on the regulatory schedule. For ozone, attainment will require reductions in both NO_X and many types of volatile organic compounds (VOCs). In most of the U.S., NO_X reductions are presently more effective for reducing ozone formation than VOC reductions, and as a result both EPA's analysis and NERA's analysis focus on NO_X reductions.

Since 1990, the U.S. has made great progress in reducing NO_X emissions (and hence ozone), as shown by the solid blue line in Figure 1, and yet more large percentage reductions are expected between now and 2025. However, these reductions are not sufficient to attain a 65 ppb NAAQS.

EPA's process for developing the incremental costs of attaining a tightened ozone NAAQS begins with estimating the ozone precursor emissions in the absence of that tightened standard in the required future attainment year. This future year emissions projection is called the cost analysis's "Baseline." For its cost analysis, EPA used 2025 as its Baseline year. The red line in Figure 1 shows NERA's calculation of what EPA estimates national NO_X emissions will have to be to attain a 65 ppb NAAQS by 2025, which we call "compliance emissions" in this report. Estimates of the quantity of emissions *reductions* necessary to achieve attainment are based on the difference between estimated Baseline emissions and estimated compliance emissions.

While this figure shows emissions on an aggregated national scale, emission reduction needs are actually calculated at a state/regional level, as the reductions will need to be concentrated around the specific areas of the U.S. that are designated as not attaining the NAAQS, which are not uniformly situated over the U.S. Texas is a state with several areas that are projected to fail to attain a 65 ppb NAAQS under 2025 Baseline emissions. In the rest of this section, as we describe the EPA cost estimation steps in more detail, we provide only the Texas-specific values from EPA's analysis, as those are the most relevant for this study for TCEQ.

Figure 1: Historical and Projected Baseline NO$_x$ Emissions



Notes: Blue line: estimated historical emissions; red line: emissions to attain 65 ppb on schedule

Source: NERA calculations based on EPA data (*)

(*) Historical data are from EPA (http://www.epa.gov/ttn/chief/trends/trends06/national_tier1_caps.xlsx). Projections are based on trends interpolated from EPA Baseline emissions in 2018 and 2025 from EPA (ftp://ftp.epa.gov/EmisInventory/2011v6/ozone_naaqs). Emissions after compliance are presumed to remain constant, and match the baseline before compliance. In California and Utah, where baseline emission information did not exist after 2025, emissions were assumed to remain at 2025 baseline emissions until compliance.

A. EPA's Base Case and Baseline Calculations

As noted, the starting point from which EPA determined the incremental emissions reductions that would be needed to attain each alternative ozone NAAQS is called the “Baseline.” EPA calculated its Baseline emissions in two steps. In the first step, EPA developed a projection of “Base Case” NO$_X$ emissions by county for each U.S. state for future years of 2018 and 2025. The Base Case reflects what future emissions levels are expected to be after implementation of all existing emissions-related regulations, and accounting for economic growth in certain sectors. Figure 2 summarizes EPA's Base Case NO$_X$ emissions estimates in Texas, by the categories of sources in its emissions inventory.

Figure 2: Actual and Projected Base Case NO_x Emissions for Texas (tons)

	2011	2018	2025
Commercial marine and railroad	70,783	58,372	45,141
Ocean going vessels	9,698	9,309	6,996
Other nonroad mobile source equipment	132,681	81,010	59,602
Onroad mobile sources plus refueling	468,480	215,016	122,909
Nonpoint oil and gas sources	190,561	222,820	230,861
Other nonpoint sources	34,328	38,889	42,727
Point oil and gas sources	2,950	3,564	3,734
Non-peaking electric generators	141,394	140,440	140,020
Peaking electric generators	4,767	3,969	3,539
Other point sources	192,452	209,970	232,855
Residential wood combustion	768	815	866
Grand Total	1,248,861	984,175	889,251

Note: Grand Total may not equal sum of rows due to rounding.

Ozone levels projected under these Base Case emissions do not attain the current standard of 75 ppb in Texas, which is the desired starting point, or “Baseline,” for an analysis of the *incremental* costs of a tighter NAAQS. It is a standard procedure in estimating costs of revisions to NAAQS to first assume a sufficient quantity of control measures will be adopted to establish an emissions Baseline that exactly attains the existing NAAQS. These controls are usually assumed to come from the lowest-cost measures on the list of potential controls known to still be available that is to be used in the cost analysis. These adjustments to the Base Case are treated as costless from the perspective of meeting a tighter alternative NAAQS, but they leave a shorter list of remaining control options for meeting that tightened standard that are also relatively more costly. In this case, however, before making this adjustment to create the emissions Baseline, EPA chose to first remove from the Base Case NO_X emission reductions that were projected to occur in EPA’s analysis of the then-proposed Clean Power Plan (CPP) – a regulation intended to address greenhouse gas emissions from existing electricity generating units (EGUs). Only from this reduced emissions level did EPA perform the standard adjustment of “costlessly” adopting a sufficient quantity of the available list of low-cost emissions controls to just attain the existing ozone standard of 75 ppb in Texas.

EPA’s adjustment of the Base Case to include emissions reductions from the proposed CPP is unorthodox in regulatory cost estimation practice. Because the CPP’s objectives are unrelated to any ozone standard or ozone precursor reduction regulation, its coincidental reductions of Base Case ozone-precursor emissions cannot be expected to be selectively using up the least-cost of the remaining available ozone precursor reduction measures; this has the effect of reducing EPA’s estimated cost to attain a tighter ozone NAAQS, even though it does not change the level of the ozone NAAQS’s emissions Baseline. If the CPP analysis that EPA incorporated had been a final rule, this point would be less relevant.[3] However, EPA made this adjustment using a proposed rule that still was subject to potentially significant changes; this adjustment was particularly lacking in credibility given the highly uncertain nature of the timing, stringency, and compliance formulas of the final CPP compared to those in the proposed CPP. The extent to which the CPP was likely to *actually* reduce the incremental cost of attaining a tighter ozone NAAQS was thus likely overstated.[4] We further discuss the implications of this unorthodox creation of the Baseline later. Figure 3 provides EPA's 2025 Base Case and Baseline emissions for Texas, detailing the sources of additional reductions EPA projects will be needed just to comply with the 75 ppb standard.

Figure 3: NO_x Emissions Reductions from EPA 2025 Base Case to EPA 2025 Baseline (tons)

Source of Emissions/Emissions Reductions	Amount of Emissions/ Emissions Reductions (tons)
EPA 2025 Base Case NO_x Emissions in Texas	889,251
Clean Power Plan Reductions	80,484
Compliance with 75 ppb Ozone Standard	
Point Source Reductions	*18,148*
Non-Point Source Reductions	*26,282*
Non-Road Reductions	*825*
Total CPP and 75 ppb Reductions	125,739
EPA 2025 Baseline NO_x Emissions in Texas	763,512

B. Estimating Compliance Emissions

We use the term "compliance emissions" to refer to the maximum levels of ozone precursor emissions that are estimated to be consistent with attainment of a particular ozone NAAQS. Air quality models are used to estimate compliance emissions. EPA used the Comprehensive Air Quality Model with Extensions (CAMx) model,[5] which combines assumptions regarding hourly emissions by location with detailed meteorological data and air chemistry information to

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[3] Furthermore, if the CPP had been a promulgated rule, it would have been included in the projected Base Case itself.

[4] In August 2015, after NERA had completed the analysis phase of this study, EPA released its final CPP rule. It is indeed significantly different from the proposed CPP in many respects. EPA assumed approximately 80,000 tons of NO_X reductions in Texas based on the proposed CPP, whereas for its final CPP, EPA estimates NO_X reductions of only 27,000 tons in Texas. This validates the concerns that we raised in our review of EPA's ozone NAAQS cost estimation process.

[5] CAMx is an air quality model, and it is used to project design values in the future. There are many uncertainties with any model, but particularly with such a complex model and a complex issue. There are many uncertainties associated with inputs as well, such as weather (used 2011 meteorological data) and 2025 emissions projections.

simulate the complex atmospheric reactions that produce ambient ground level ozone. CAMx results are then combined with existing monitored ambient ozone observations to project design values at monitors located throughout the U.S.[6]

With the exception of California, EPA's estimate of compliance emissions was made for the year 2025. EPA's cited three reasons for focusing on 2025: (1) data and resource limitations, (2) 2025 would reflect the "remaining air quality concerns" for nonattainment areas with moderate classifications, and (3) 2025 would provide a near-comprehensive picture of costs since most areas will likely be required to comply with a new ozone standard by 2025.

Starting with its 2025 Base Case emissions forecast, EPA performed national scale air quality modeling using CAMx. EPA also did air quality modeling of 12 "sensitivity cases" (one of which was the Baseline) to develop ozone sensitivity factors based on the modeled response of monitors to specific amounts of change in emissions. These sensitivity factors were used to estimate the quantity of reductions necessary for attainment.

Based on the estimated 2025 design values from its air quality modeling of Baseline emissions, EPA determined areas that were likely to be in nonattainment with a proposed 65 ppb standard. EPA then used its sensitivity factors to estimate the required NO_X emission reductions and the general location for such reductions to bring all monitors throughout the U.S. into attainment.[7] EPA's sensitivity factor estimation was done on a broad regional scale, so the location for estimated reduction needs was also regional. EPA's analysis is thus silent on *where* within each broad region those reductions are most likely to be imposed when actual SIPs are prepared. For some of the reductions needed to attain a 65 ppb NAAQS in Texas, Texas was modeled as part of a seven-state "Central Region" that also contains Missouri, Kansas, Oklahoma, Arkansas, Louisiana, and Mississippi.

Nationally, EPA projected nine counties outside of California to have 2025 Baseline design values above 70 ppb and an additional 59 counties to exceed 65 ppb. Several of these areas are in Texas, as shown in Figure 4. Within Texas, all of the counties above 70 ppb in the Baseline (colored in red) are in East Texas and a majority of the counties exceeding 65 ppb (those colored in green, in addition to those colored in red) are also in East Texas. The only West Texas counties with monitors projected to have design values above 65 ppb are El Paso, Brewster, and Randall counties. For its cost analysis, EPA chose to exclude these West Texas counties when identifying nonattainment areas that would be assigned emissions reduction needs. EPA argued that these areas appear to have special ozone-formation conditions that would probably enable them to obtain compliance exemptions. Appendix B explains this in more detail, but the primary

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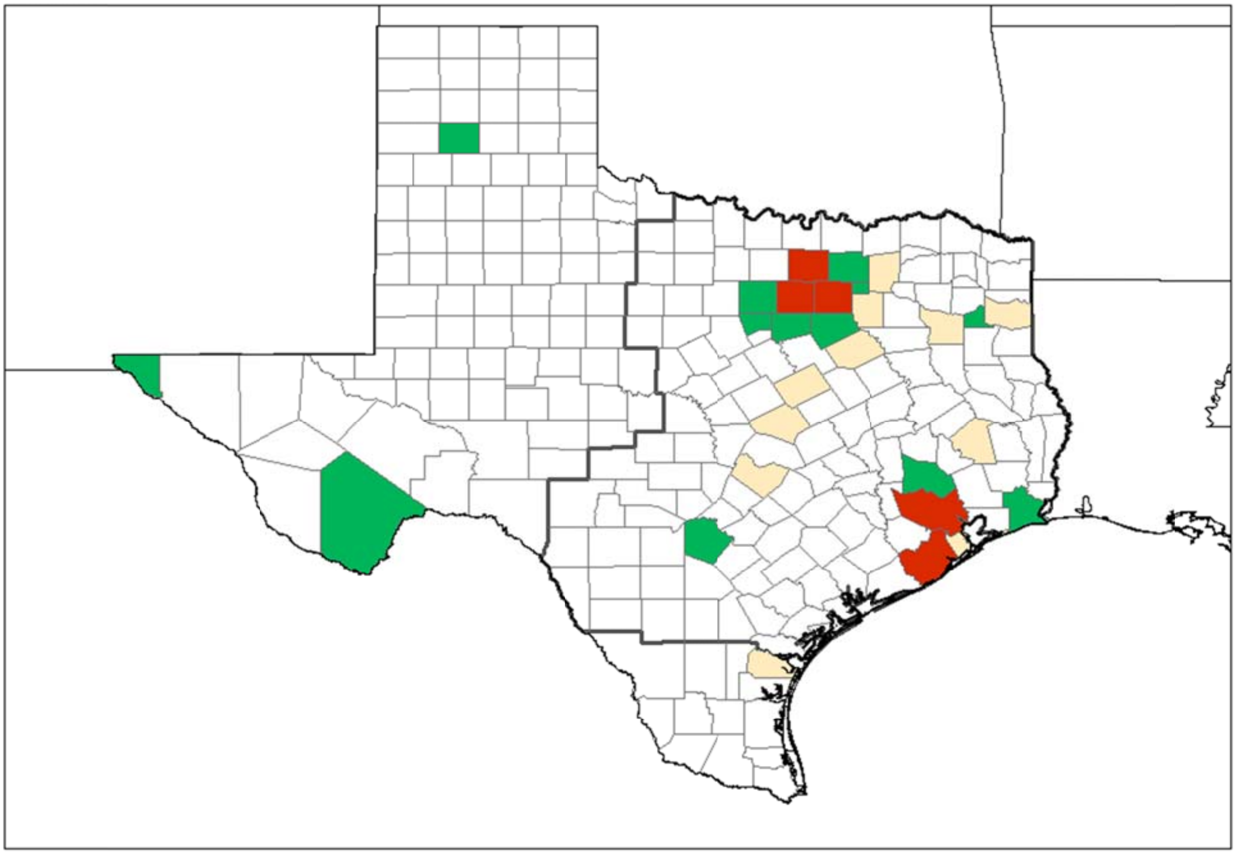
[6] A "design value" reflects the particular air concentration metric used to determine whether ambient levels of a pollutant at a monitor attain its respective NAAQS.

[7] California was excluded from the 2025-based analyses because its attainment date would be much later. In the rest of this discussion of how EPA estimated compliance emissions and costs for the year 2025, California should be assumed to be excluded.

point for this study is that EPA's cost analysis assumes nonattainment in Texas will exist only in its eastern portions.

Figure 4: Map of EPA 2025 Baseline Design Values in Texas
(Key: red: design value > 70 ppb; green: design value > 65 ppb; tan: design value > 60 ppb)
(Source: NERA re-creation of Figure ES-2, EPA Ozone RIA)



C. EPA's Identification of "Known" and "Unknown" Controls

Once EPA determined the quantity of NO_X emissions reductions that would be required for compliance with 65 ppb in 2025, it could attempt to identify the controls that would be used to make those reductions. EPA started by relying on an inventory of what it has termed "Known Controls." (We will continue to use this term in the rest of this report to reflect measures that are clearly identified by type and location in our analysis.) EPA's Known Controls inventory contains primarily "end-of-pipe" control technologies that were identified using the EPA's Control Strategy Tool (CoST), Integrated Planning Model (IPM Model), and NONROAD Model. For the ozone RIA, EPA identified Known Controls in the following sectors: electric generation, non-electric point sources, area sources, and nonroad mobile sources. EPA did not include any Known Controls for the onroad sector because its Baseline already includes the recent Tier 3 rule that is projected to result in significant NO_X reductions in the onroad sector. EPA eliminated any controls it estimated would cost more than $15,000/ton of NO_X.[8]

Within each of EPA's broad regions that it projected would have at least one nonattainment area for an alternative NAAQS, EPA's cost analysis for that alternative NAAQS level assumed Known Controls would be adopted in cost-effectiveness order throughout that region until regional emissions would be reduced to the estimated compliance level. However, for many of its regions, there were not enough Known Controls in EPA's dataset to achieve all the needed reductions. As a result, *all* Known Controls would be necessary to adopt in those regions, and more forms of controls would still be needed. Lack of sufficient Known Controls affected EPA's assessment of Texas's compliance needs for every alternative NAAQS level.

Rather than identify what those additional forms of control would be, EPA adopted a concept it calls "Unknown Controls" to account for the additional reductions that it projected to be necessary for attainment.[9] Figure 5 shows the resulting estimates of NO_X emissions reductions in Texas that EPA has assumed for the 65 ppb alternative standard. EPA identified approximately 172,000 tons of reductions from Known Controls in Texas, with an additional 211,000 tons of reductions coming from Unknown Controls.[10] Thus, NERA finds that 45% of the NO_X reductions EPA estimated to be needed in Texas to attain a 65 ppb NAAQS in 2025 are achieved with its Known Controls, and the remaining 55% are met from the category it called Unknown Controls.

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[8] EPA (2014a), p. 3-12.

[9] In this study, we use emissions inventory data to more clearly characterize what types of measures fall into this group, but we do not identify each one *individually*; we will continue to use the term Unknown Controls to refer to the measures that are not individually-identified in our analysis.

[10] 180,000 tons of Unknown Controls are clearly from within Texas in EPA's analysis, as they are specifically in an all-Texas zone that EPA calls the "Within TX Buffer" zone. EPA's analysis then estimates 170,000 tons of Unknown Controls throughout the remainder of a multi-state "Central Region" that Texas is part of. EPA does not identify in *which* state these additional Unknown Controls would be. NERA has made state-specific estimates based on each state's share of Base Case emissions in 2025, which indicated another 31,000 tons of Unknown Controls occurring in Texas. Because East Texas's nonattaining monitors are the controlling factor determining the total Central Region Unknown Control tons, this is likely an underestimate.

Figure 5: EPA's Estimates of 2025 NO_X Emissions Reductions Needed in Texas for Attainment of a 65 ppb Ozone NAAQS.

Source of Emissions/Emissions Reductions	Amount of Emissions/ Emissions Reductions (tons)
EPA 2025 Baseline NO_x Emissions in Texas	763,512
Reductions from Known Controls for 65 ppb	
Electric Generating Units (EGUs)	*20,178*
Non-EGU Point	*63,694*
Non-Point	*86,590*
Non-Road	*1,276*
Total Known Control Reductions	171,738
Reductions from Unknown Controls for 65 ppb	
"Within TX Buffer"	*180,496*
Other Texas (*)	*30,608*
Total Unknown Control Reductions	211,104
EPA 2025 NO_x Compliance Emissions for Texas	380,670

(*) EPA did not identify Central Region Unknown Controls at a state-specific level. The value stated in this table for Unknown Controls in "Other Texas" is a NERA estimated based on allocating EPA's Unknown Controls for the entire Central region to states/areas based on their respective levels of 2025 EPA Base Case NO_X emissions. Because East Texas's nonattaining monitors are the controlling factor determining the total Central Region Unknown Control tons, this estimate is likely low (the upper bound for this estimate would be nearly 170,000 tons).

D. EPA's Estimated Emission Reduction Costs for Texas

EPA estimated annualized compliance costs in 2025 based on estimates of the cost per ton for both Known and Unknown Controls.[11]

Known Control Costs. For each Known Control, EPA had a specified annualized cost per ton and that is multiplied by the number of tons reduced to calculate the total annualized cost from Known Controls. EPA provided details, including the costs and tons removed, for each Known Control in a file that was provided in the ozone docket.[12] Because EPA chose not to include as

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[11] Annualized costs represent the equivalent to a present valued cost estimate if all the costs were to be spread over an asset's lifetime in equal amounts per year. The present value of a stream of annualized costs over the number of years used in the annualization calculation is equal to the total present value of a stream of costs that vary from year to year, when using the same discount rate in both calculations. EPA used a 3% discount rate, and equipment life is typically 20 years.

[12] Available at: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0169-0015.

Known Controls any measures that exceeded $14,000/ton, the vast majority of these controls are below $14,000/ton.[13]

Unknown Control Costs. The EPA did not provide any analysis of what types of sources would likely be subject to control for any of their Unknown Controls, and they assumed that all Unknown Controls would have an average cost of $15,000 per ton. EPA provided several justifications for this assumption, including:

- Of all of EPA's Known Controls, 96% cost less than $14,000/ton and the average cost in their dataset was $3,400/ton (EPA, 2014a, p. 7-29);
- Known Controls focus on a "limited set of emissions inventory sectors" while Unknown Controls could include currently-available controls in other sectors (EPA, 2014a, p. 7-11);
- Historically, EPA has sometimes overestimated the cost of Unknown Controls (EPA, 2014a, pp. 7-39 to 7-40);
- The cost per ton for other NO_X rules had costs between $2,200 and $11,300/ton (EPA, 2014a, p. 7-15);
- Annualized NO_X offset prices in several areas in nonattainment with the current ozone NAAQS (75 ppb) are still less than $15,000 per ton (EPA, 2014a, pp. 7-22 to 7-25);
- Costs could be lower because of technological innovation and diffusion (EPA, 2014a, pp. 7-18 to 7-20);
- Environmental policy can create incentives for technological change (EPA, 2014a, p. 7-28); and
- Cost changes from technological change will be available nationally, so a single cost per ton is used across all the regions (EPA, 2014a, p. 7-30).

Note that none of the above reasons make any reference to the types of emissions sources that remain after the Known Controls have been applied, or to actual estimates of costs of possible controls that might be available for the remaining types of sources. NERA (2015b) provides a point-by-point reason why each of the above-listed reasons is not a sound reason for the Unknown Controls cost to average as low as $15,000/ton.[14] Also, NERA (2014 and 2015a) developed a more evidence-based approach for making a cost estimate for reductions of the types of emission sources remaining after application of all the Known Controls. This same approach, tailored specifically to Texas's data, is adopted in this study, as described in Section III. As will

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[13] NERA found a few measures in EPA's list of Known Controls with cost per ton exceeding the purported maximum of $14,000/ton. For example, one measure producing 11 tons of reduction in East Texas and two measures in West Texas totaling 68 tons of reduction cost more than $14,000/ton, the highest being $27,712/ton. Given how few these exceptions are, one might infer they were unintentionally missed when EPA was eliminating options costing more than $14,000/ton.

[14] EPA did not actually assume any variation in the cost of Unknown Controls – they assumed all Unknown Controls had a cost of $15,000/ton.

be shown, NERA finds that $15,000/ton cannot be justified for the degree of reduction and the sources of reduction that are needed in Texas after all Known Controls have been exhausted.

Based on EPA's approach summarized above, EPA estimated national costs of attaining the 65 ppb NAAQS would be $15 billion per year (in 2011$) in 2025 (excluding California, which EPA assumes does not incur any incremental emissions reductions costs until the next decade). EPA did not provide any state-specific cost estimates. However, using a range of allocations of Central Region Unknown Controls to Texas, NERA estimates that Texas's share of these costs would be between 24% and 38% of the national 2025 cost estimate. This range suggests that an estimate of Texas's cost based entirely on EPA assumptions (as described above) would be between $3.6 billion and $5.7 billion per year.

Figure 6 provides NERA's assessment of the breakdown of EPA's costs by type of control. As the next section will show, NERA finds this cost estimate to be very substantially understated, even when assuming use of new technologies and a least-cost approach for attaining the standard.

Figure 6: NERA Estimation of EPA's Annualized Compliance Costs for Texas, with Average Cost per Ton in Parentheses (2011$)

Source of Costs	**Annualized Costs (Average Cost per Ton)**
Costs of Known Controls for 65 ppb	$475 Million ($2,800/ton)
EGUs	*$270 Million ($13,000/ton)*
Non-EGU Point	*$151 Million ($2,400/ton)*
Non-Point	*$48 Million ($560/ton)*
Non-Road	*$5.9 Million ($4,600/ton)*
Costs of Unknown Controls for 65 ppb	$3.2 Billion to $5.3 Billion ($15,000/ton)
EPA 2025 Compliance Costs for Texas	$3.6 Billion to $5.7 Billion ($9,500/ton to $11,000/ton)

III. NERA'S ADJUSTMENTS TO EPA'S COST ASSUMPTIONS

In the previous section we detailed EPA's approach to estimating the compliance costs associated with Texas's compliance with a proposed 65 ppb standard. In this section, we present the refinements that NERA has made, and our reasons why we conclude that they provide a more accurate representation of the compliance approach that will be faced by Texas. Section IV then summarizes the cost estimate for Texas that results from these alternative cost analysis assumptions.

A. Changes to EPA's Calculations of Emissions Reduction Needs for Attainment of a 65 ppb Ozone NAAQS

There are two broad elements to an estimate of the cost of attaining a 65 ppb ozone NAAQS. One element is estimating the tons of reduction and the other is the cost per ton for each of those tons. In this part, we discuss estimating the tons of reduction that will be needed, which has three dimensions: their location, total quantity needed, and the timing of the reduction activities.

1. Location of Reductions

The regional approach that EPA adopted when using its air quality model to estimate emissions that need to be controlled to achieve attainment is inconsistent with the actual process states undertake in SIP preparation. For example, in the case of reductions to meet Texas's attainment needs, there are only two zones for NO_X emissions reduction: (1) anywhere in Texas within 200 km of any Texas monitor projected to exceed the 70 ppb NAAQS under 2025 Base Case emissions,[15] and (2) anywhere beyond that area but within EPA's Central Region (which includes Texas, Oklahoma, Kansas, Missouri, Arkansas, Louisiana, and Mississippi). EPA's analysis does account for the different effectiveness in reducing NO_x in those two zones on reduction in nonattainment area ozone, and it does assume a greater concentration of emissions reductions will occur in the first zone. However, besides that rough division, any ton reduced within one of those large zones is considered equally effective as any other ton in that zone at reducing ozone in Texas's nonattainment areas. As a result, EPA's analysis assumes a substantial number of tons of reduction in areas that are unlikely to be required to make such reductions under an actual SIP that addresses the projected Texas nonattainment areas.

To explain this point in more detail we refer to Figure 7 (which presents a cropped portion of Figure 3-2 in EPA's RIA). The orange and blue-shaded counties in the figure comprise the 200 km zone noted above.[16] We will call this zone "East Texas," and (for simplicity of

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[15] EPA used 70 ppb to define a buffer because they did analyses for both 65 ppb and 70 ppb, and set the buffer zone only once, using the 70 ppb nonattainment projection.

[16] The blue-shaded counties are those projected to exceed a 70 ppb NAAQS under Base Case 2025 emissions. There are eight more counties in East Texas that EPA projects would be in nonattainment for a 65 ppb NAAQS, as can be seen in Figure 4.

terminology) call all the unshaded counties in the figure "West Texas."[17] Under EPA's regional approach, EPA ends up assuming reductions in West Texas. TCEQ air quality modeling, however, indicates that those emissions are highly unlikely to be found to have any significant effect on any nonattainment area projected in Texas. Second, TCEQ information indicates that reductions in the outer parts of the "East Texas" area, particularly to the west, also may not be found to have any significant effect. That would have the effect of requiring reductions EPA has assumed across the entire East Texas zone to be more concentrated around the actual nonattainment areas — which would eliminate a large number of the Known Controls that EPA has assumed will be available in East Texas.

Figure 7: Split of Texas between "East Texas" and "West Texas" for NERA's Cost Estimation
(Source: EPA Ozone RIA, Figure 3-2, cropped to focus on Texas)

Additionally, under EPA's regional approach, EPA ends up assuming reductions in seven states (*i.e.*, in EPA's "Central Region" zone), a disproportionate share of which EPA's modeling and nonattainment projections indicate could only be needed to reduce ozone in the Texas

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[17] EPA calls the zone we adopt as "East Texas" the "Within TX buffer." Counties in this East Texas zone are: Anderson, Angelina, Aransas, Archer, Atascosa, Austin, Bandera, Bastrop, Baylor, Bee, Bell, Bexar, Blanco, Bosque, Bowie, Brazoria, Brazos, Brown, Burleson, Burnet, Caldwell, Calhoun, Callahan, Camp, Cass, Chambers, Cherokee, Clay, Collin, Colorado, Comal, Comanche, Cooke, Coryell, Dallas, DeWitt, Delta, Denton, Dimmit, Eastland, Edwards, Ellis, Erath, Falls, Fannin, Fayette, Fort Bend, Franklin, Freestone, Frio, Galveston, Gillespie, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Hamilton, Hardin, Harris, Harrison, Hays, Henderson, Hill, Hood, Hopkins, Houston, Hunt, Jack, Jackson, Jasper, Jefferson, Johnson, Karnes, Kaufman, Kendall, Kerr, Kimble, Kinney, La Salle, Lamar, Lampasas, Lavaca, Lee, Leon, Liberty, Limestone, Live Oak, Llano, Madison, Marion, Mason, Matagorda, Maverick, McLennan, McMullen, Medina, Milam, Mills, Montague, Montgomery, Morris, Nacogdoches, Navarro, Newton, Orange, Palo Pinto, Panola, Parker, Polk, Rains, Real, Red River, Refugio, Robertson, Rockwall, Rusk, Sabine, San Augustine, San Jacinto, San Patricio, San Saba, Shackelford, Shelby, Smith, Somervell, Stephens, Tarrant, Throckmorton, Titus, Travis, Trinity, Tyler, Upshur, Uvalde, Van Zandt, Victoria, Walker, Waller, Washington, Wharton, Wichita, Williamson, Wilson, Wise, Wood, Young, and Zavala.

nonattainment areas.[18] Although some controls needed only by Texas may be undertaken by upwind states under a "Good Neighbor Provision" in the Clean Air Act, the primary responsibility for developing a SIP that will bring a nonattainment area into attainment falls on the state where that nonattainment area is located. For this reason too, it would be reasonable to expect that the actual SIP process will result in a greater concentration of emissions reductions in East Texas than EPA's regional analysis approach might suggest, if one assumes its estimates of Central Region reductions would be evenly distributed across all the states of the region.

Lacking modeling information to better assess the actual locations of reductions under a Texas SIP for a 65 ppb NAAQS, NERA made only a modest adjustment in EPA's locational assumptions about NO_X reductions that would be required of Texas under a 65 ppb ozone NAAQS. For purposes of estimating the costs of the emissions reductions, we calculate the cost per ton for Unknown Controls separately for the areas we call East Texas and West Texas; however, we have not moved any of the tons of reductions that EPA assumed would occur in West Texas into East Texas, even though we see little reason why the West Texas controls would be required under any actual SIP process, given the locations of the projected nonattainment areas.[19] We also continued to assume all the Known Controls EPA assumed in East Texas, regardless of their distance from the nonattainment areas.

The one refinement we made was to attribute to East Texas a small share of EPA's estimates of Central Region Unknown Controls. Based on EPA's analysis, all of the monitors in the Central Region that just reached attainment (*i.e.*, had a 2025 design value of 65 ppb) were located in East Texas, implying that these were the monitors that were determining the total quantity of Unknown Controls that were required for all monitors in the Central Region to reach attainment. We also found that two of the Central Region states, Arkansas and Mississippi, have no projected in-state nonattainment, yet are treated as if they will bear an equal share of Central Region control needs. For example, EPA's analysis applies 31,814 tons of Known Controls in these two states.[20] Section 110(a)(2)(D)(i)(I) of the Clean Air Act, known as its "Good Neighbor" provision, requires that attaining states make available cost-effective reductions in their own emissions if they are found to be making a significant contribution to the ambient concentrations in a nonattainment area in another state. Noting that EPA has concluded that

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[18] Central Region reductions were increased until all Central Region monitors were estimated to get into attainment. Given that monitors in Texas are the last of all the Central Region monitors to reach attainment, and thus control the total number of tons of reduction needed from the Central Region, at least a portion of those reductions are occurring solely for Texas's needs and not for needs in other states in the Central Region.

[19] In addition to the set of Known Controls EPA identified in West Texas, we assumed that the West Texas region would undertake a share of the Unknown Controls that EPA determined would be needed from across the Central Region. The share was based on NO_X 2025 Base Case emissions in West Texas as a fraction total NO_X from all other parts of the Central Region except East Texas (which EPA had already assigned a specific number of tons from Unknown Controls).

[20] Source: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0169-0015.

these states contribute significantly to nonattainment with the current ozone standard in Texas,[21] it might be reasonable to expect a similar finding for those states' Baseline emissions in 2025 with respect to a standard of 65 ppb. For this reason, we did *not* alter EPA's assumed set of Known Controls in these two attaining states. However, it is less clear what to assume about the location of the hundreds of thousands of tons of highly costly Unknown Controls that EPA estimated for the entire Central Region to attain a 65 ppb NAAQS.

To address this question, we first assumed that emissions reductions from retirement of electricity generating units that would cost less than $30,000 per ton would be among the first of the additional control actions in all these states to fill the need EPA called Unknown Controls. This produced electric sector controls in all the Central Region states (including 32,498 tons of reduction of NO_X from coal-fired generators in Arkansas and Mississippi) that helped diminish the number of Central Region (excluding East Texas) Unknown Control reductions down to 169,610 tons. If we were to assign the remaining Unknown Controls reductions to each state based on its *pro rata* share of the region's Base Case NO_X emissions, 45,011 of those tons could be "attributed" to the two attaining states, Arkansas and Mississippi. We decided to assume that the two attaining states' *pro rata* share of those remaining Central Region Unknown Controls would be left as a compliance burden for Texas. (We assumed that all other states in the Central Region, each with at least one nonattainment area of its own, would account for the other 124,599 tons of Unknown Controls). This decision can be viewed as an assumption that controls under the "Good Neighbor" provision in attaining states will be required, but not in excess of a cost of about $30,000/ton.

2. Quantity of Reductions

In this study for TCEQ, we also made two modest adjustments to the total *quantity* of reductions that EPA estimated as needed in its RIA. The first adjustment was related to the movement of Unknown Controls from two other Central Region states into the East Texas zone (noted above). The other was due to our decision to not include the proposed CPP when determining the emissions Baseline.[22]

Arkansas and Mississippi Reductions. For the reasons described above, we assumed that 45,011 tons of the 170,000 tons of Unknown Controls that EPA's analysis ascribed to the Central

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[21] As part of the 2008 Ozone NAAQS, EPA found that both Arkansas and Mississippi had ozone contributions between 1% and 1.5% to 2018 nonattainment receptors in Texas (Houston and Dallas areas). See EPA Memorandum, "Information on the Interstate Transport "Good Neighbor" Provision for the 2008 Ozone National Ambient Air Quality Standards (NAAQS) under Clean Air Act (CAA) Section 110(a)(2)(D)(i)(I)," January 22, 2015. Available at: http://www.epa.gov/airtransport/GoodNeighborProvision2008NAAQS.pdf.

[22] The final CPP was released after the analysis phase of this study was completed, making it impossible to incorporate it. However, we note that the final CPP is much different from the proposed CPP, validating our decision to have excluded the proposed version of the rule from our Baseline.

Region (excluding those EPA specifically assigned to East Texas) would be the burden of Texas, and particularly would need to be found in East Texas.[23] We did not simply impose that many more tons of reduction need in East Texas, however. A smaller number of tons would be needed if more selectively located in East Texas. To determine an equivalently effective number of tons of reductions if located in East Texas, we evaluated the relative design value responsiveness of those East Texas monitors of tons emitted in the Central Region versus in East Texas.[24] Based on this, we determined that if 45,011 tons of reduction that EPA assumed in the Central Region were to actually occur in East Texas, then the equivalent incremental reduction need in East Texas would be 40,703 tons.

Clean Power Plan Reductions. At the time of our analysis, the CPP was a proposed policy. (The final rule was released in August 2015). The final CPP reflects many significant changes from the proposed CPP, particularly with a delay in the phase-in of its emissions limits. This difference alone gives reason to expect that EPA's use of the proposed CPP rule in its Baseline adjustments resulted in understatement of its estimate of ozone NAAQS costs, as discussed in the previous section. EPA's final CPP compliance analysis also shows that EPA overstated the rule's coincidental reductions in NO_X in Texas by incorporating the highly uncertain proposed CPP into its Baseline. It would be a dubious proposition even to include the final CPP in an analysis of the ozone NAAQS costs (if that could even have been done given the timing of its release relative to the timing of our analysis). Now that the CPP has been finalized, it faces an uncertain future based on expected litigation from selected states and business groups. The outcome of this litigation also could result in modifications that delay or change its implementation. Clearly, however, the proposed CPP's coincidental NO_X reductions did not belong in the Baseline. For this reason, we removed from the Texas Baseline the 80,484 tons of NO_X reductions from EGU system changes that EPA projected would occur in Texas to comply with the proposed CPP prior to 2025.

This did not alter the possibility in our analysis that those EGU NO_X emissions could be reduced as part of our estimated 65 ppb ozone attainment strategy for Texas, to the extent we would find them to be cost-effective for that purpose. Our analysis of cost-effective NO_X reductions in the East Texas region is described below, and does indeed include a similar quantity of EGU NO_X reductions. However, the reductions we include in the Texas attainment strategy are not necessarily from the same electricity system changes as those assumed by EPA to result from the proposed CPP. (We also ascribe an incremental cost to these reductions, whereas EPA's method of placing them in the Baseline effectively treats them as having no cost in the ozone cost analysis.)

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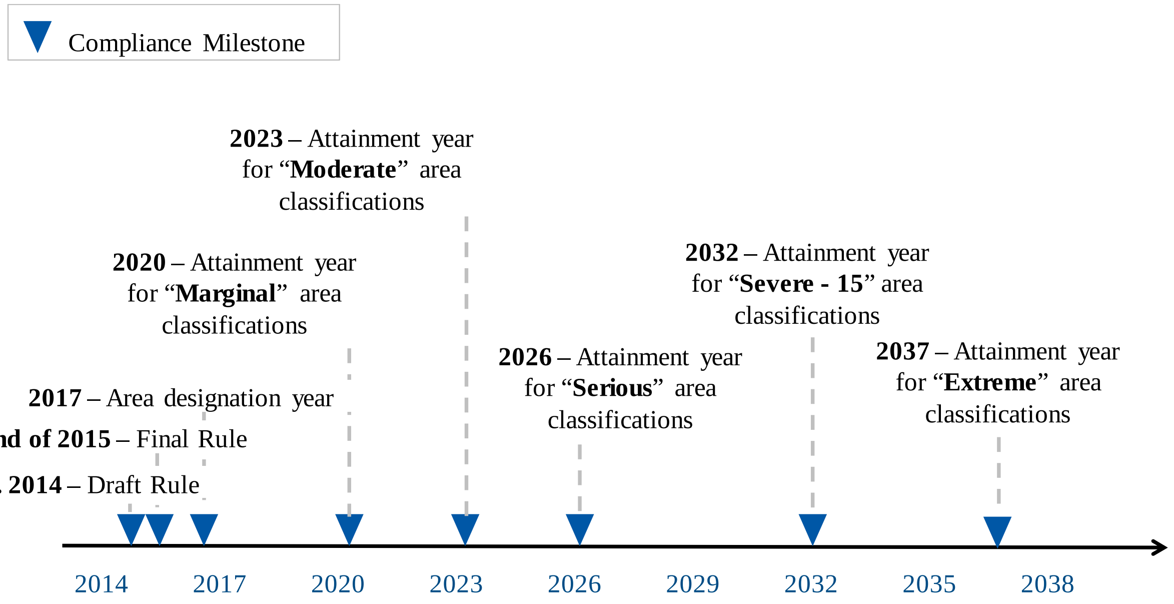
[23] This could be viewed as a low estimate, because a portion of the Unknown Controls that are still attributed to other states in the Central Region is also likely being required as a result of the attainment needs in East Texas. If we ascribed all of the non-Texas Unknown Controls to Texas (as we did when estimating an upper bound for Figure 6), the East Texas reduction need would be much larger still.

[24] This information comes from EPA's air quality modeling sensitivity cases, specifically sensitivity case 7 (controls only in East Texas) and sensitivity case 8 (controls throughout the Central Region).

3. Timing of Reductions

A final adjustment made to EPA's assumptions in this study relates to the timing of the reductions. We find that EPA's assumption that the incremental reductions will not be needed until 2025 is inconsistent with the requirements of a revised ozone NAAQS. Figure 8 shows the estimated compliance timing based on our understanding of the Clean Air Act, and corroborated by statements in EPA's RIA. Areas classified as Moderate will be required to demonstrate attainment in late 2023, not 2025.[25] This means that each Texas monitor's 4th highest 8-hour maximum daily ozone level would have to be at or below 65 ppb based on ozone levels monitored during 2022, and hence all reductions would have to be in full effect by 2022.[26]

Figure 8: Estimated Ozone Attainment Timing



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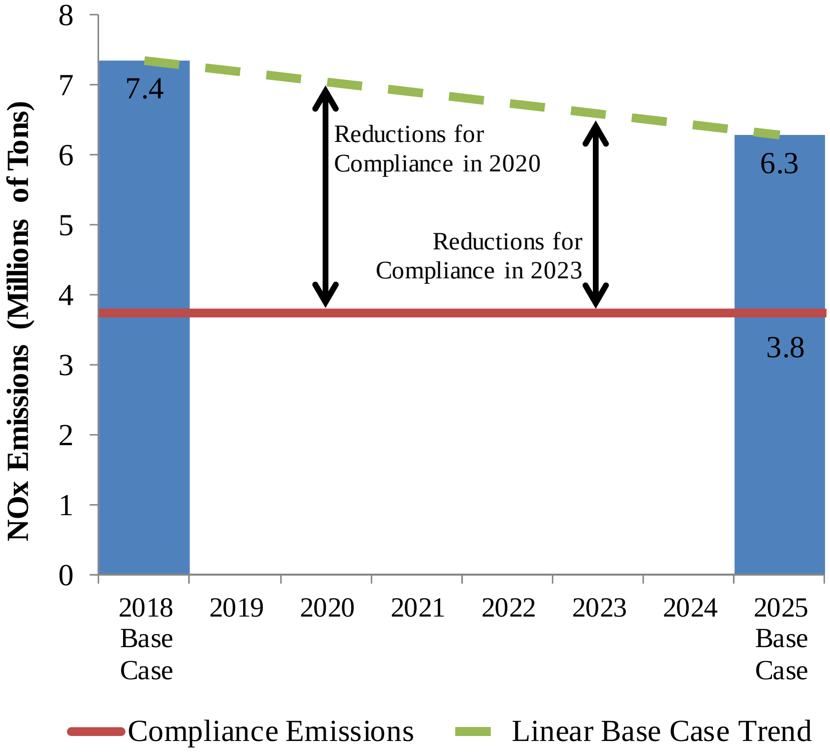
[25] EPA requires that controls for attainment need to be in place no later than the beginning of a full ozone season before the attainment date. The beginning of the ozone season within Texas depends on the part of the state - for the Houston-Galveston-Brazoria area the ozone season begins on January 1; for the Dallas-Fort Worth area it begins March 1. If EPA makes the designations such that the attainment date is December 31, 2023, then control would have to be in place at the beginning of ozone season in 2023. If the attainment date is in the middle of the ozone season in 2023, then controls are supposed to be in place at the beginning of the ozone season in 2022. Also, Reasonably Available Control Technology (RACT) controls are sometimes required to be in place even earlier. Even before the attainment date court decision, EPA required RACT controls for the 2008 ozone NAAQS to be implemented by January 1, 2017.

[26] Literal attainment by 2023 would imply that those monitored ozone values would need to be at or below 65 ppb for all three years before 2023, which would mean that all needed reductions would be fully in effect by 2020. However, if the 2022 monitor value is found to be at or below 65 ppb, the state can qualify for two one-year extensions to show literal attainment without the greater compliance burden of being assigned to a higher classification.

Having all of the reductions in place by the end 2022 is not just a matter of earlier spending. The interaction between a more correct (earlier) timing and the projected rapid decline in Baseline emissions between now and 2025 results in a larger number of incremental tons to be reduced. This adjustment is not insignificant. Figure 9 demonstrates this point at a national level. EPA provided forecasted NO_X emissions for 2018 and 2025. Using a linear interpolation of reductions between 2018 and 2025, we find that the incremental reductions that would be needed in 2022, as compared to EPA's calculations of reduction needs based on 2025, are about 22,000 tons for East Texas and 16,000 tons for West Texas (based on our estimate of the higher quantity of NO_X emissions in 2022 compared to in 2025).

Figure 9: Emissions in States Requiring Reductions in EPA's Analysis (Excluding California)



B. Revisions to EPA's Estimates of Cost per Ton Removed

1. Costs of EPA's List of Known Controls

Working with TCEQ staff, we performed a high-level review of EPA's list of Known Controls to ensure that they did not reflect any actions that had already been undertaken (and thus would be double-counting). We identified a few instances where facilities already had controls that EPA proposed as Known Controls.[27] However, we ultimately decided to accept all of EPA's Known

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[27] Examples include the Longhorn Glass furnace in the Houston/Galveston/Brazoria area and one of the glass furnaces at the Works No 4 plant in Wichita County, which already have oxy-firing, which EPA proposed as

Controls for our analysis, and also adopted EPA's estimates of their cost per ton; this was done simply to avoid making adjustments that would be too minor to have any detectable effect on our final cost and economic impact results.

In addition, we explored with TCEQ whether, based on publicly-available analyses previously performed by TCEQ, we could identify any other specific sources of emissions reductions that might supplement EPA's list of Known Controls. As a result of this effort, we decided to assume an additional 8,000 tons of potential additional reduction (*i.e.*, beyond the quantity assumed available by EPA) from boilers and engines in counties east and northeast of the Houston-Galveston-Brazoria ozone nonattainment area.[28] These reductions are incorporated into the Known Controls for East Texas.[29]

We also considered assuming a tightening of the Houston Mass Emissions Cap and Trade (MECT) cap that TCEQ considered in the 2010 Houston RACM analysis. TCEQ's analysis identified the potential to reduce the MECT cap by 53 tons/day (19,345 tons/year). EPA's Known Controls included 27,182 tons of reductions in the counties subject to the MECT cap, more than the potential tightening considered by TCEQ. Thus, it appeared that EPA's Known Controls have effectively already accounted for all the likely potential under an MECT cap, and so we did not expand the Known Controls in this regard.

Another potential area to supplement the EPA-specified controls was in the electricity sector, which has a large number of tons in the Baseline. EPA included some NO_X reductions from the electricity sector in its Known Controls in the form of retrofits of units with technology such as selective catalytic reduction (SCR). For this study, we considered the cost-effectiveness of more aggressive approaches to reducing NO_X emissions from the electric sector in Texas. Using our

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Known Controls. The Sandy Creek Energy Station coal-fired power plant (which is misidentified in EPA's Known Controls spreadsheet as a non-EGU unit) is identified as installing low NOx burners and over fire air. Sandy Creek Energy Station is a new electric generator with selective catalytic reduction (SCR) achieving a NO_X rate of 0.046 lbs/MMBtu. It is unlikely that low NOx burners and optimized combustion would have any impact on its NO_X emissions.

[28] TCEQ's 2010 Houston Reasonably Available Control Measures (RACM) analysis identified the potential to reduce an additional 32 tons/day (11,680 tons/year) at a capital cost of approximately $142 million from counties east and northeast of the Houston-Galveston-Brazoria ozone nonattainment area to reduce transport into the area (these reductions were ruled out because the benefits to the HGB area did not justify the costs, and this could still be the case). The reductions would be achieved from stationary rich-burn gas-fired engines down to 50 horsepower in Hardin, Jefferson, Jasper, Newton, Orange, Sabine, San Augustine, and Tyler Counties, and from industrial, commercial, and institutional boilers in Hardin, Jefferson, and Orange Counties. To avoid potential double counting, we netted out some EPA Known Controls in the relevant counties related to rich and lean burn compressor engines down to 50 horsepower.

[29] While this measure was included in this *ex ante* analysis, the TCEQ's ultimate decision to implement this or any other measure will depend on a number of other factors, such as the potential ozone reduction benefit in the nonattainment areas, which are not considered in this report. Its inclusion in this analysis should *not* be taken as an indication that TCEQ has determined, or will ever determine, that this specific measure will become part of its ultimate SIP for a 65 ppb ozone NAAQS. (This caveat applies equally well to *all* of the list of Known Controls, most of which are taken from an EPA list that is similarly unvetted by any actual SIP development process, and to the EGU sector reductions discussed next.)

full-scale electricity sector planning model (a component of $N_{ew}ERA$, described in Appendix A), we estimated the cost per ton of SCR retrofits on and retirements of East Texas coal-fired generating units. This analysis found that for each one of the existing coal-fired generators in East Texas without maximal NOx control technology, the cost per ton of controlling its NO_X would be much cheaper than assuming additional controls from the Unknown Controls category; however, our analysis also found that it would be more cost-effective to retire those units rather than to retrofit SCRs on them.[30]

As a result of these analyses, we assumed that 11 GW of East Texas coal units would be retired before 2023 as part of the emissions reductions to meet a 65 ppb NAAQS. The assumed retirement of these units results in 56,000 tons of NO_X reduction in East Texas. The prospect of retiring all these units sounds extreme and is very unlikely as part of a Texas SIP. However, we decided to incorporate this into our cost analysis based on the relative costs of the different options, the total tons that could be reduced, and the cost for reductions outside of the electricity sector. Not doing so would force our total emissions reduction cost estimates even higher, because even more costly (and more extreme-seeming) types of emissions reduction measures would have to be found in East Texas instead. We do not present this as a *likely* projection of the contents of a Texas SIP for a 65 ppb NAAQS, but only an assumption that, if applied, helps minimize our estimate of the total cost of meeting Texas's emissions reduction need for that potential NAAQS.[31]

Despite our efforts to identify more options for controls in East Texas, many tons of reduction remained in the category EPA called Unknown. The inventory data on remaining emissions indicates that most of these sources of emissions are relatively small, and many are not owned by large industrial entities that are relatively easy to regulate. Costs per ton for reducing such small sources can be very high, and ultimately our total cost estimate differed most strongly from EPA's due to our assessment of what would have to be done to achieve a large number of tons of reductions from those Unknown Controls, as we discuss next.

2. Assessing Sources of Remaining Tons and Estimating Costs of Reductions from Such Remaining Sources

As explained in Section III, EPA has assumed an average cost of $15,000/ton for all of the reduction needs after EPA's list of Known Controls is exhausted. This average allows for one to assume that some controls would cost less than $15,000/ton and some more. However, one flaw immediately apparent in this approach is that EPA's method assumes the same average cost

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[30] For the retirement simulations, we let our electricity sector model determine how to replace their generation in the least-cost manner from existing and new low-NO_X generating resources available in the region.

[31] If we limit our cost per ton calculations to model estimates that do not account for transitional costs, a cost-minimizing case can also be made to retire even the coal-fired units that already have maximal NO_X controls in place. Recognizing that closure of all East Texas coal-fired capacity by 2022 would put too much strain on the regional electricity system, and the excessive unrealism of such a SIP, we chose not to assume these additional retirements for our analysis.

whether the remaining Unknown Controls require additional percentage cuts of 1% or 99%. More logically, one would expect that the average cost per ton would increase with deeper required cuts into a region's remaining emissions.[32]

To determine the range for the costs per ton as a function of the depth of the remaining cuts, one needs to have more understanding of what types of emissions sources remain that could provide further reductions. With additional information of that sort, one can also start to assess the potential methods for reducing emissions from those sources, and develop at least a ballpark estimate of their cost. To demonstrate how this could be done, NERA developed an evidence-based approach for estimating the costs for Unknown Controls, first described in NERA (2014).

To do this, we first determined the sources of the NO_X emissions that would remain after the adoption of all Known Controls and controls on electric generators. At this point, coal plants are either maximally controlled or closed. Large point sources (manufacturing and industrial) have already been subject to significant control. Trucking, freight rail, and other sources like construction equipment and marine vessels are very hard to regulate at the state level.[33] Lastly, commercial and residential sources are numerous and difficult to regulate. Based on these facts, it is difficult to reject the view that the remaining emissions controls will have to come largely from mobile and small sources.

Using the approach first described in NERA (2014), we developed a supply curve for reductions across a set of mobile sources of differing vintages. That is, we estimated the cost per ton for replacing older (Tier 1) vehicles of different vintages projected to still be in use in our Baseline year of 2022 (but for the ozone NAAQS) with much lower-emitting Tier 3 vehicles that will be available for purchase by that year.[34,35] The oldest of the remaining Tier 1 vehicles offer the lowest cost per ton if replaced earlier than otherwise projected, but they also offer only a limited

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[32] EPA's single fixed price for Unknown Controls is inconsistent with its prior RIA cost approaches. In 2008 and 2010, EPA included estimates of Unknown Control costs using a "hybrid" approach that had an upward-sloping cost per ton, such that areas needing a higher share of their total emission reductions to come from Unknown Controls faced higher average costs per ton, as one would expect. The earlier approaches still lacked a foundation in actual evidence about what types of sources would be providing those reductions, but at least EPA's prior approach had a cost per ton that increased with the depth of the incremental cuts.

[33] It is our understanding that states may not be able to regulate some emissions. For example, states' authority to regulate nonroad engines is restricted to some degree by the Clean Air Act, 40 CFR Part 89.

[34] Tier1, Tier 2, and Tier 3 refer to EPA standards that apply to both tailpipe emission standards and fuel standards. Tier 2 standards were phased in beginning in 2004; Tier 3 standards are to be phased in beginning in 2017.

[35] We note that TCEQ cannot require vehicle owners to turn over their vehicles more rapidly than they otherwise would. Such vehicle turnover decisions would have to be made voluntarily by vehicle owners based on individual assessments of their vehicle's current value, the cost of new vehicles, and any financial incentives that could be offered for vehicle retirements. Thus, if Texas decides (as we have assumed here for purposes of *ex ante* cost estimation) that early retirements of various mobile sources will be needed for a future potential SIP to attain a 65 ppb standard, our analysis presumes that this will be achieved by the offering of sufficient financial incentive in the form of rebates to equipment owners. We assume these rebates would be funded though vehicle registration or other fees applied to all owners and not just to those who choose to take advantage of the incentive.

number of tons of emissions reduction. As deeper and deeper reductions are needed from the fleet, the cost per ton increases as increasingly less old Tier 1 vehicles are replaced early.

For this analysis we used an updated supply curve based on our estimate that up to a 40% reduction in 2022 onroad vehicle NO_X emissions could be achieved by replacing all Tier 1 passenger cars and light duty trucks projected by EPA to still be in operation in 2022. Using EPA information on vehicle emissions rates by vehicle type, and on the cost of future new technology vehicles, we estimated the marginal cost per ton to remove the first 10% of those vehicles' NO_X emissions at about $50,000. We estimated the cost per ton to replace the last such vehicle (*i.e.*, to get to a 40% reduction) at $235,000 per ton.[36] This provides us with an evidence base for an upward sloping supply curve based on more rapid turnover of onroad vehicles. However, these onroad vehicles account for only about one-tenth of the remaining tons of emissions that must provide the Unknown Controls. As noted, most of the other emissions in this category are also from mobile sources and other equipment that comprise area, commercial, and residential sources. Recognizing that it is a major approximation, we assumed that these other sources would follow a similarly rising cost curve. That is, we assumed that for every ton of vehicle emission reduction achievable at a given cost-per-ton level, we could find nine tons from the other types of emitting equipment at the same cost-per-ton level.

Thus, the cost curve for Unknown Controls that we have used in this analysis begins at $30,000 per ton, reaches $50,000 per ton when all remaining emissions have been reduced by 10%, and continues upwards to $235,000 per ton when 40% cuts are made. The percent cut in emission that is actually taken off this rising marginal cost curve (and hence the average cost per ton for Unknown Controls) is region-specific and is determined by the compliance emissions level estimated in a region, and the emissions projected to remain once all the region's Known Controls (including EPA's and those that our analysis has also identified) have been applied.

Figure 10 provides a highly conceptual illustration of the way this Unknown Control cost curve is used in our cost analysis. First, all Known Controls from EPA's list are adopted, as these are certainly the least costly (on a $/ton basis) of all the options. However, they are usually insufficient for a region's attainment reduction need, as illustrated in this figure. (The reduction need is illustrated in the figure by the solid vertical line). Another category of controls that NERA considers to be among its Known Controls is controls on the region's coal-fired electricity generating units (labelled "EGU controls" in this figure). For most regions, we find that retirement of many of the coal-fired EGUs is less costly than $30,000/ton, and these are adopted before starting to assume any controls from the rising marginal cost curve. If the region still needs more reduction after all the cost-effective EGU controls have been adopted, then we assume that those remaining reductions will be taken from the rising marginal cost curve, always taking them in their lowest-cost order, until the region's full emission reduction need is met.

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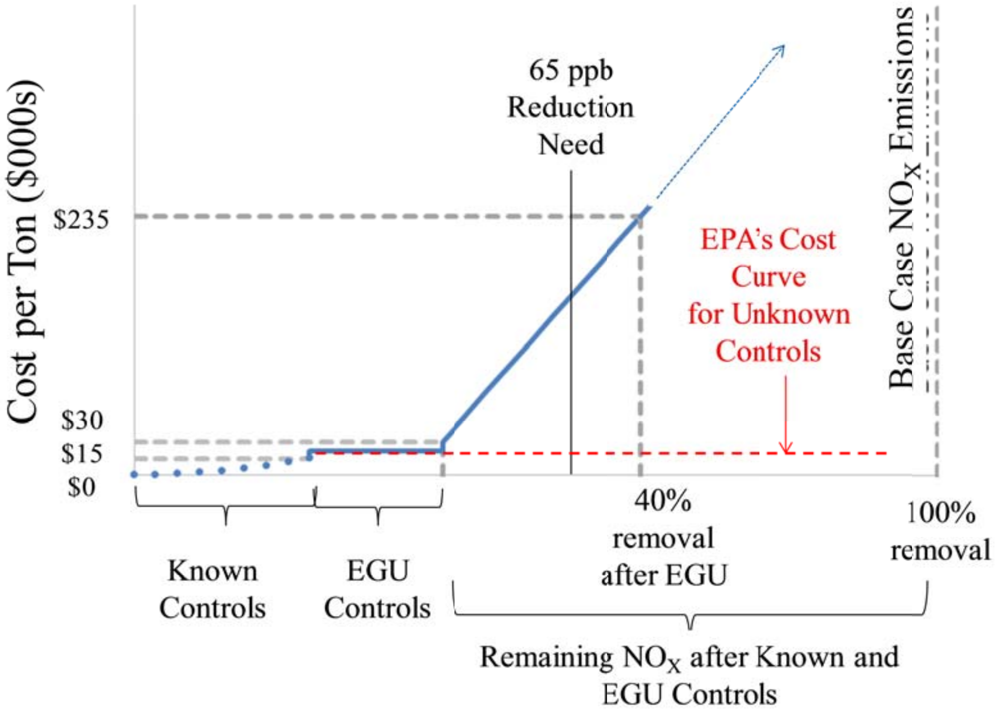
[36] A detailed explanation of these types of calculations is provided in NERA (2014), pp. C-10 to C-11, and is based on a methodology first described in Knittel (2009). The calculations remain the same as in NERA (2014) but were updated here to reflect a different compliance year than was assumed in that report.

Figure 10: Cost Curve for Emissions Controls for an Illustrative Cost Region



The total cost for attainment is calculated as the area under this supply curve from 0 tons over to "65 ppb reduction need." If only a few percent of emissions reductions from the Unknown category is needed to get to that point, the cost per ton reduced will not reach the very high levels of $100,000/ton or more. However, for regions needing very deep cuts into the Unknown Category, some (but by no means all) of the reductions may be that costly. While control costs in excess of $100,000 per ton may seem high, control actions with those costs have previously been undertaken for NAAQS compliance: "For example, recent regulatory control measures adopted in the San Joaquin Valley for some stationary sources have cost in excess of $100,000 per ton of NOx reduced. The cost of developing and ultimately deploying new transformative technologies required for attainment will be substantially greater than today's costs based on existing technologies."[37]

The dotted red line in Figure 10 shows what EPA's Unknown Controls cost assumption would look like as a cost curve. Clearly the area under the red dotted line from 0 tons to the "65 ppb reduction need" mark is much smaller, and this explains much of the difference between cost estimates using NERA's more evidence-based approach and those that come from EPA's unsubstantiated assumption about those Unknown Control costs per ton.

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[37] San Joaquin Valley Air Pollution Control District (2015), p. 4.

For this study, we developed separate Unknown Control cost curves for East Texas and West Texas. We provide the specific cost results based on this approach for those two regions in Section IV.

IV. NERA'S ESTIMATES OF TEXAS'S EMISSIONS REDUCTION COSTS

This section provides the quantitative emissions and emissions control cost estimates that were derived for Texas when applying the more SIP-like and evidence-based approach described in the previous section. Part A summarizes 2022 Baseline emissions estimates and the associated estimates of the required reductions to attain a 65 ppb standard at all monitored locations within Texas.[38] Part B summarizes the costs associated with those reductions and provides some information on the geographical distribution of those costs.

A. Estimated Attainment Emissions and Reductions

As explained in the prior section, 2022 is the latest year by which emissions reductions need to be in place. Figure 11 starts at the top with NERA's 2022 Baseline NO_X emissions and associated reduction needs for East Texas, West Texas, and Texas as a whole. The Baseline emissions are taken from EPA's 2025 Baseline, but with the proposed Clean Power Plan reductions removed, adjusting for emissions in 2022 rather than 2025 (by the method described in Section III), and removing emissions reductions needed to attain the current standard of 75 ppb.[39] Figure 11's bottom line is the compliance emissions for East and West Texas implied by EPA's analysis (adjusting for the assumption that East Texas would bear a small portion of the Unknown Controls in the Central Region that might otherwise be ascribed to two attaining states in the region).

The gap between Baseline emissions and compliance emissions in Figure 11 is the total emission reduction need. Figure 11 summarizes our analysis's estimates of how that total reduction need would be met, disaggregated into various categories of sources reduction.

The first category, called Known Controls, primarily reflects controls that EPA identified in Texas using its control options data bases, with the refinements we described above. As explained in Section III, we adopted all of EPA's Known Controls, including those located in West Texas. We consider it unlikely those West Texas controls would be required under an actual SIP to achieve attainment in any of Texas's projected East Texas nonattainment areas. However, we decided to leave those control measures in our analysis as well, as a proxy for the

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[38] Technically, not all Texas monitors are projected to achieve 65 ppb because EPA excluded several monitors in West Texas when estimating compliance emissions, as discussed in Section III and again later in this section.

[39] We also do not rely on EPA's Base Case NO_X projections for the electric sector. Our N_{ew}ERA model includes a detailed representation of the electric sector of its own, and since we use our model to assess the cost-effectiveness of controlling NO_X from EGU sources, it is more consistent to use that model's electric sector Baseline emissions too. This adjustment is less significant, but results in lower Base Case emissions than EPA estimated in Texas. Our 2022 Baseline NO_X emissions for the electric sector in Texas were 112,665 tons (with 91,908 tons in East Texas). EPA's 2025 Base Case NO_X emissions in Texas were higher: 143,559 tons. (After EPA subtracted out the approximate 80,000 tons due to the proposed CPP, EPA's 2025 Baseline emissions were approximately 63,000 tons).

possibility that there would be at least some emissions reductions required in the West Texas area of the state. Retaining the West Texas Known Controls in our analysis also reduces our total cost estimate because it reduces the amount of additional, very costly reductions that would otherwise have to be assumed to occur in East Texas.

The second category in the table, the electric sector reductions, reflects the result of NERA's assessment of which NO_X emissions in the Texas electricity sector would be cost-effective to eliminate, when compared to other options available to meet the total reduction needs in the East Texas region. As explained in Section III, our analysis assumes retirements of 11 GW of coal-fired generating units in East Texas, for a reduction of 56,000 tons before 2023. As noted, this is a very unlikely actual outcome of a Texas SIP process for a 65 ppb NAAQS, but we use it for our cost analysis because any alternative assumption would only result in a much higher estimate of the cost of attaining the 65 ppb NAAQS in Texas.[40]

Figure 11: NERA's 2022 Summary NO_X Emissions and Reductions for East Texas and West Texas Compliance with 65 ppb in 2022 (tons)

	East Texas	West Texas	Total Texas
NERA Baseline	562,034	291,384	853,418
Known Controls (*)	71,574	87,941	159,515
EGU Net Reductions	55,509	0	55,509
Unknown Controls	252,076	46,353	298,429
Total Reductions	379,159	134,294	513,453
Estimated Compliance Emissions (for 65 ppb)	182,875	157,090	339,965

(*) The tons of Known Controls on this row exclude 45,256 tons of reductions in East Texas to reach 75 ppb, which have already been removed from the NERA Baseline on the row above. These tons have zero cost in our analysis.[41]

Thus, despite our efforts to scour additional TCEQ data sources, our analysis is left with a large number of tons of reduction that must come from a wide array of small sources that EPA chose to simply call Unknown: about 252,000 tons of such remaining controls would be needed in East Texas and about 46,000 in West Texas. The estimated required reductions are quite large in terms of incremental percentage reduction from 2022 baseline emissions – a 60% reduction relative to the Baseline for Texas with a 67% reduction in East Texas (incremental to the reductions needed first to attain the current standard) and a 46% reduction in West Texas.

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[40] Our calculations used the most cost-effective mix of replacement power, including from existing but underutilized low-NO_X capacity, and/or new capacity. This was calculated by our electricity sector optimization model (called N_{ew}ERA) which minimizes cost of meeting electricity loads by region.

[41] When removing the 80,484 tons of proposed CPP reductions from the Baseline calculation, they should have been replaced with an additional roughly-equivalent number of Known Controls, so that the Baseline emissions would still be consistent with attainment of the 75 ppb ozone standard. Our analysis, however, continued to attribute those tons of reduction to incremental compliance with the 65 ppb standard. If we were to render an additional 80,484 tons of the Known Controls in our analysis as "costless" with respect to meeting the 65 ppb compliance our estimate of the cost for Texas to meet the 65 ppb standard (discussed next) would be approximately 0.15% lower.

The estimated reductions show a heavy reliance on controls that EPA has made no effort to identify or even characterize the source categories that would be most affected. Although our analysis makes effort to characterize the types of controls that would have to be employed in this category, and to develop evidence-based estimates of their costs, we continue to label them Unknown Controls. Note that 58% of all reductions in Texas are from Unknown Controls with a higher percentage in East Texas (66%) and a lower percentage in West Texas (35%).

Our estimated reductions in West Texas may be overstated, because EPA did not project any nonattainment areas in West Texas. Thus, it is unclear if counties in West Texas would be subject to any required reductions like those that EPA's analysis has assumed. If TCEQ were to determine that the reductions in West Texas are not necessary for SIPs addressing the East Texas attainment needs (*e.g.*, because these sources of emissions do not significantly contribute to the ozone levels in the East Texas nonattainment areas), then the West Texas reductions are probably overstated, but then even more tons of reductions may be needed in East Texas. This would not be a one-for-one shift of reduction tons from West to East because if the reductions were to be placed in the East, fewer tons of reduction would likely be needed because of the greater effectiveness of making such reductions closer to the areas of nonattainment. Nevertheless, the *cost* of those reductions could actually rise, because finding ways to make those incremental reductions in the East would be more difficult compared to the relatively low-cost Known Controls that are presently assumed to be made in the West.

There is some reason, however, to believe that reductions assumed in the West are not overstated. When assessing areas with nonattainment and needs for emissions reductions to meet the 65 ppb NAAQS, EPA excluded several monitors with projected design values above 65 ppb that are in West Texas. Its reason was that these monitors' design values are not responsive to even very deep anthropogenic emissions reductions, and are thought to be strongly affected by background ozone levels. EPA discusses some possible options for relief for such areas, such as excluding data associated with exceptional events, designation as rural transport areas under Federal Clean Air Act Section 182(h), and Federal Clean Air Act Section 179B demonstrations regarding international emissions. Whether or not emission reduction controls in West Texas would be necessary for nonattainment areas located in West Texas will depending heavily on actual designations and these other factors. Even under some of these options, some controls may still be needed. For example, a Section 179B demonstration does not relieve a moderate nonattainment area of the requirement to implement RACT. Appendix B provides more information on background ozone and the locations of these monitors.

This project was limited to assessing Texas's emissions reduction costs and economic impacts. However, the relative stringency of the policy is high for Texas compared to other states. Our estimate of a 60% average reduction needed in Texas compares to a national average reduction need of 43% estimated in NERA (2015a) and NERA (2015c). Since costs per ton escalate as emissions cuts go deeper towards zero emissions, these estimates indicate that Texas's costs to attain a 65 ppb ozone standard will be a relatively greater burden than in most other parts of the

U.S., including other states that face nonattainment of their own. Texas cost estimates are summarized next.

B. Estimated Direct Costs

Figure 12 presents the breakdown of our cost estimate by type of reduction, for East Texas and West Texas separately. The costs for the Non-EGU point, non-point, and non-road reductions are all sourced from EPA, with a few refinements we have described above. The EGU costs are from our N$_{ew}$ERA model, and reflect the aggregate cost of retiring the 11 GW of East Texas coal plants and replacing them with the least-cost mix of new capacity and increased generation from existing generators.

The costs for Unknown Controls are from NERA's evidence-based approach, as described in Section III. This cost category accounts for the largest variance from EPA's cost estimates for its Unknown Control category. The primary reason is because EPA assumed all such reductions could be achieved at an average cost of $15,000/ton, no matter how deeply all remaining emissions would have to be cut, and no matter what types of sources comprise the remaining emissions. Recognizing that Baseline emissions in 2022 would need to be cut by 67% across all of the East Texas region, and that 66% of those tons of reduction would be coming from small sources such as mobile sources and commercial equipment rather than relatively large industrial point sources, we find it more realistic that a majority of the reductions in this category will actually cost far more than $15,000/ton.[42]

Figure 12: NERA's Estimate of Annualized Compliance Costs for Texas (2011$)

Source of Costs	**East Texas**	**West Texas**	**Total Texas**
Costs of Known Controls for 65 ppb			
EGUs	$1.5 Billion	-	$1.5 Billion
Non-EGU Point	$92 Million	$60 Million	$151 Million
Non-Point	$38 Million	$26 Million	$64 Million
Nonroad	$2.6 Million	$3.2 Million	$5.9 Million
Total Known Control Costs	$1.6 Billion	$89 Million	$1.7 Billion
Costs of All Other Controls Needed for 65 ppb	$45 Billion	$4 Billion	$49 Billion
NERA Compliance Costs for Texas	$47 Billion	$4 Billion	$51 Billion

The total annualized compliance costs for Texas are thus estimated to be approximately $51 billion per year, with the majority of those costs ($47 billion) being incurred in East Texas.

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[42] As noted in Section III, even replacing the highest-emitting old cars still on the road in 2022 with clean, future technology cars (*i.e.*, Tier 3 cars or all-electric vehicles) would reach a marginal cost of $50,000/ton by the time 10% of vehicle emissions would be eliminated.

EPA did not provide cost estimates for individual states such as Texas, but our calculations indicate that this cost is 9 to 14 times higher than an equivalent estimate using EPA's approach. For the reasons explained above, we consider our cost estimate to be more consistent with the evidence on emissions sources and control alternatives available at the time that attainment must be achieved, and with the actual SIP-based approached to developing attainment strategies.

Figure 13 summarizes the average cost per ton of NO_X removed for each category of reductions. The average cost per ton of NO_X removed across all reductions in Texas is $90,000. In East Texas, the average cost is $110,000 while in West Texas the average cost is $30,000. The primary reason for this large difference in cost per ton is the much deeper cuts in total emissions that must be achieved in East Texas compared to West Texas, which means having to move farther up the East Texas curve of marginal costs per ton reduced. The analysis is fully consistent with an assumption that the SIP (and Texas's affected businesses) will take actions to minimize the costs of compliance. The higher costs for steeper emissions cuts reflect the unavoidable economic reality that some control options are going to be more costly per ton than others, and our presumption that the lower cost measures are adopted before higher cost measures (*i.e.*, that the State and individual companies and consumer comply in a cost-minimizing manner). Once relatively low cost measures have been adopted, if yet-deeper cuts are needed, some of the relatively high cost measures will have to be adopted too.

Figure 13: NERA Estimated Compliance Costs for Texas ($2011 per Ton)

Source of Costs	**East Texas**	**West Texas**	**Total Texas**
Costs of Known Controls for 65 ppb(*)			
EGUs	$27,000	-	$27,000
Non-EGU Point	$4,000	$1,500	$2,400
Non-Point	$800	$570	$680
Non-Road	$4,700	$4,700	$4,700
Costs of Unknown Controls for 65 ppb	$180,000	$90,000	$160,000
NERA Compliance Costs for Texas	$120,000	$30,000	$100,000

(*) In calculating the cost per ton by category that we have excluded the tons of Known Controls necessary for compliance with 75 ppb, whose costs would not be attributable to compliance with 65 ppb.

Differences in the relative severity of the cuts required in different parts of Texas can be seen in Figure 14 through 16. Figure 14 maps projected 2022 Baseline NO_X emissions (excluding EGUs) by county. It shows that Baseline emissions density in 2022 varies across the state, with concentrations occurring in the west as well as the east. However, our analysis and EPA's find that the projected emissions reduction requirements will be imposed mostly in the region we have called East Texas. Figure 15 maps our estimates of annualized emission reduction costs by county (with allocations of Unknown Controls based on emission shares). These are, of course, more heavily concentrated in the eastern counties of the state than are the emissions, with the highest total costs occurring in the eastern counties with the highest emissions density. Figure 16 maps the same costs, but now stated as costs per ton of NO_X removed. This more clearly shows that all counties in the East Texas zone are bearing similar costs *per ton*, consistent with a least-cost approach to achieving controls over an entire geographic region.

Figure 14: NERA 2022 Baseline NOx by County in Texas (Excluding Electric Generators)

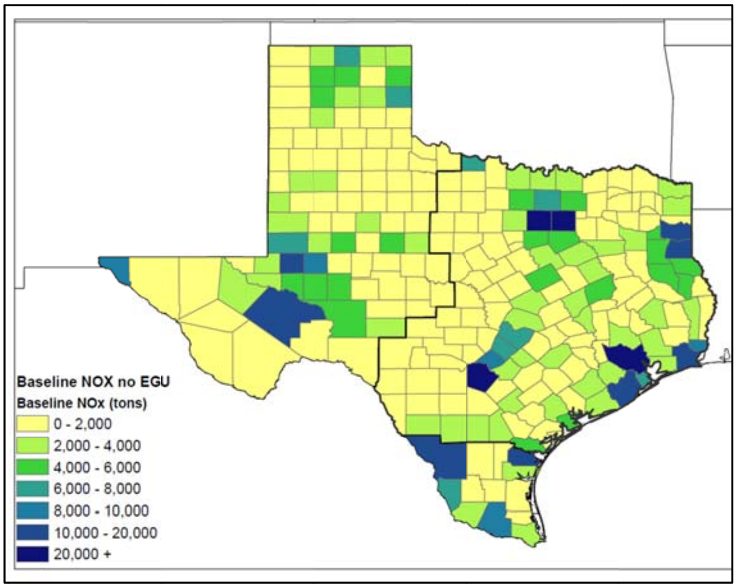


Figure 15: Annualized Emission Control Costs by County in Texas (excluding power sector costs)

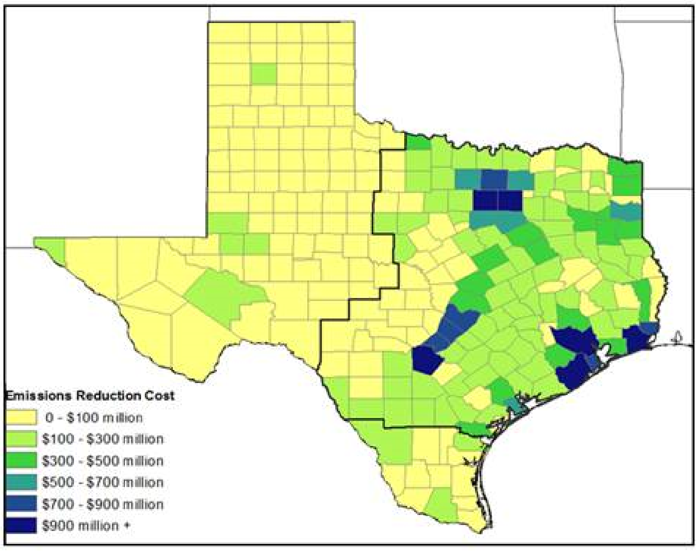
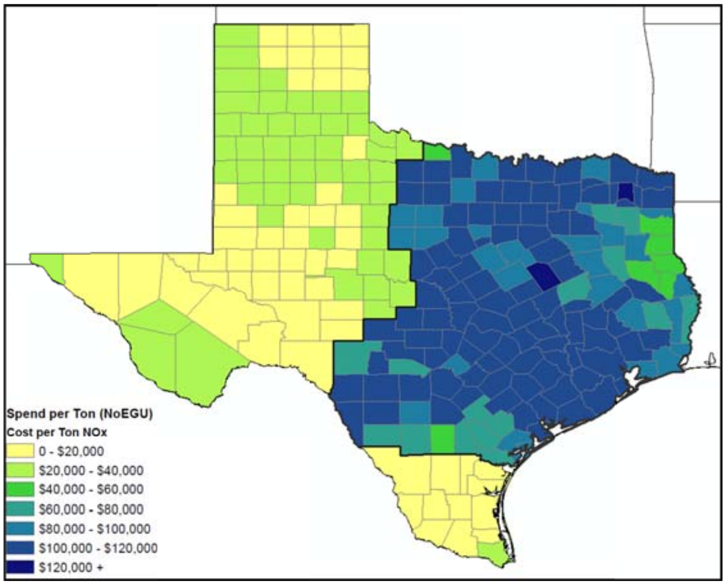


Figure 16: Annualized Emission Control Costs per Ton NO_x Removed by County in Texas (excluding power sector costs)



In NERA (2015a), total non-EGU emissions reduction cost to attain a 65 ppb NAAQS in all U.S. states was estimated using a methodology comparable to that which we have applied here for Texas alone. Stated in terms of the present value of emissions reduction costs (as opposed to annualized emission reduction costs), the U.S. cost estimate is $1.1 trillion. Noting that this is equivalent to an annualized cost estimate of approximately $160 billion, our current estimate of $51 billion for Texas's non-EGU emissions control costs to attain a 65 ppb NAAQS exceeds 30% of an estimate of total U.S. compliance costs based on the same general approach and cost assumptions.

V. NERA'S ESTIMATES OF ECONOMIC IMPACTS TO TEXAS FROM ITS EMISSION REDUCTION SPENDING

In this study, after estimating the likely spending necessary to reduce Texas's Baseline emissions to levels that would attain a 65 ppb NAAQS, we performed a macroeconomic simulation to assess the economic impacts of such costs on the Texas economy. This part of the study required use of a macroeconomic model that could take the spending estimates as inputs. We used NERA's N_{ew}ERA model to perform the macroeconomic impact assessment, the results of which are summarized in this section.

A. Overview of the Modeling Approach and Model Used

NewERA is an economy-wide integrated energy and economic model that includes a bottom-up, unit-specific representation of the electric sector, as well as a representation of all other sectors of the economy and households. It assesses, on an integrated basis, the effects of major policies on individual sectors as well as the overall economy. It has substantial detail for all of the energy sources used by the economy, with separate sectors for coal production, crude oil extraction, electricity generation, refined petroleum products, and natural gas production. Appendix A of this report provides a detailed description of the NewERA model.

Direct costs flow throughout the economy, resulting in higher costs for goods and services. The increased investments in pollution controls also displace other investments with higher returns. It is these impacts that the N_{ew}ERA energy-economic model traces for a given set of direct cost inputs, while accounting for interregional competitiveness and trade effects. In this analysis, Texas was modeled as an individual economic region within the U.S., while spending on ozone NAAQS compliance in the rest of the U.S. was included to properly represent the relative market impacts of Texas's spending.[43]

To be used as an input to the N_{ew}ERA model, the estimates of direct costs for all sectors except the electricity sector must be separated into their capital and operating cost components.[44] We have assumed that 50% of the costs will be related to capital spending (investments in retrofits or replacement of older with newer technologies) and 50% would be incremental costs to operate the new control equipment and/or technologies. The capital costs are spent prior to when the controls can be considered operational, while the operating costs begin once the controls are in place and continue throughout the model horizon. The costs are assigned to specific source

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[43] To properly assess the inter-regional competitiveness effects of the added production costs in Texas, our model also accounted for compliance costs in all other U.S. states. The costs for other states were obtained from an earlier analysis that assessed costs of the 65 ppb ozone NAAQS compliance nationally (NERA, 2015a).

[44] For the electricity sector controls, the specific control requirements are input as constraints on that part of the model optimization. (In this case, they were imposed as forced retirements of specific units, but force retrofits of SCRs could also have been the constraint.) The model itself then endogenously computes the least-cost way to adjust electricity supply to meet demand given those constraints.

sectors of the economy, consistent with which sectors are responsible for the emissions being reduced.[45]

On the national scale, the capital costs associated with compliance spending were assumed to be incurred from 2017 until 2036 (the last projected compliance date, for extreme areas), while each state's estimated operating and maintenance (O&M) costs are incurred for all years after the state's attainment date. For Texas (assumed to be classified as Moderate nonattainment) the capital spending occurs between 2017 and 2022, and the operating costs are incurred from 2023 through the end of the model simulation, which was 2040 in this analysis.

The macroeconomic analysis also requires an economic baseline that projects market outcomes in the absence of the incremental spending to attain the tighter ozone NAAQS. For this study, N_{ew}ERA's economic baseline conditions were calibrated to reflect projections developed by Federal government agencies, notably the Energy Information Administration (EIA) as defined in its *Annual Energy Outlook 2014* (*AEO 2014*) Reference case. This economic baseline includes the effects of environmental regulations that have already been promulgated as well as other factors that lead to changes over time in the U.S. economy and the various sectors. Our baseline does not include the effects of proposed regulations, such as the CPP, although we do include power sector closures as an available way to attain the ozone NAAQS, to the extent that we find such closures to be cost-effective elements of each state's control strategy.[46]

B. Macroeconomic Results

The direct costs for Texas are projected to be quite significant and these costs are projected to have a substantial impact on the Texas and U.S. economies and households as shown in Figure 17.

Figure 17: Potential Impacts of 65 ppb Ozone Standard on Texas Gross State Product and Average Household Consumption (2017-2040, 2014$)

	Texas State Impact	As percent of Texas's Baseline
GSP Loss - Annualized (Relative to Baseline)	$30 Billion/year	1.4%
GSP Loss – Present Value (Relative to Baseline)	$350 Billion	1.4%
Consumption Loss per Household - Annualized	$1,690/year	1.2%

Notes: Present value is from 2017 through 2040, discounted at a 5% real discount rate. Consumption per Household is annualized value calculated using a 5% real discount rate.

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[45] NERA (2014) provides a detailed explanation of how we attributed costs to specific sector and years as macroeconomic model inputs.

[46] EPA's inclusion of the CPP in its baseline was inconsistent with its standard practice of only including promulgated regulations. This deviation from standard procedure seems particularly unjustified given the enormous uncertainty in what carbon limits may actually be applied and how states would comply, and hence what NO_X emission reductions might actually occur as a result of this carbon regulation.

Emissions reduction spending to attain the 65 ppb ozone standard is projected to reduce Texas's gross state product (GSP) from its projected baseline levels by $350 billion on a present value basis from 2017 through 2040 (as of 2014, stated in 2014$). Stated in annualized terms (*i.e.*, when spread evenly over the years 2017 through 2040 while retaining the same present value), this is a reduction from baseline levels of $30 billion per year.

Figure 18 presents the estimated potential impacts in Texas on employment from emissions reductions costs to attain a 65 ppb ozone standard. The figure focuses on several dimensions of projected impacts on income from labor ("worker income"). Relative to baseline levels, real wages in Texas are projected to be about 1.2% lower on average over the period and labor income in Texas is projected to be about 2.9% lower on average. Stated as an equivalent number of jobs, Texas's labor income loss is about 0.4 million job-equivalents.[47] A loss of one job-equivalent does not necessarily mean one less employed person—it may be manifested as a combination of fewer people working and less income per worker. However, this measure allows us to express employment-related impacts in terms of an equivalent number of employees earning the average prevailing wage.[48] These are the *net* effects on labor and include the positive benefits of increased labor demand in sectors providing pollution control equipment and technologies. In percentage terms, they are roughly twice the average impact that has been estimated for the U.S. as a whole (NERA, 2015a).

Figure 18: Potential Impacts of 65 ppb Ozone Standard on Texas Employment (Average 2017-2040)

	Texas State Impact
Real Wage Rate (% Change from Baseline)	-1.2%
Labor Income (% Change from Baseline)	-2.9%
Labor Income Change in Job-Equivalents	-0.4 million

Notes: Job-equivalents are defined as the change in labor income divided by the annual baseline income for the average job. Baseline annual job-equivalents in Texas are 12 million.

C. Energy Market Results

Emissions reduction costs of a 65 ppb ozone standard also are likely to have impacts on U.S. energy sectors, largely because the more stringent ozone standard is projected to lead to the premature retirement of many additional coal-fired power plants, and increased costs of oil and gas production and pipeline transport. Figure 19 shows average energy price projections under

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[47] Job-equivalents are defined as the change in labor income divided by the annual baseline income for the average job.

[48] The NewERA model, like many other similar economic models, does not develop projections of unemployment rates or layoffs associated with reductions in labor income. Modeling such largely transitional phenomena requires a different type of modeling methodology; our methodology considers only the long-run, equilibrium impact levels.

the baseline and the 65 ppb ozone standard for Texas. Residential electricity rates in Texas are projected to increase by an average of 2.6% over the period from 2017 through 2040 relative to what they could otherwise be in each year, which is projected to be rising even without a tighter ozone NAAQS. Henry Hub natural gas prices are projected to increase by an average of 2.1% in the same time period (again, relative to what they could otherwise be in each future year), while delivered residential natural gas prices in Texas are projected to increase by an average of 2.7%. Part of the increase in delivered natural gas prices reflects the increase in pipeline costs due to control costs for reductions in NO_X emissions in the pipeline system that would be recovered through tariff rates. Retail gasoline prices in Texas are also projected to increase by approximately 13% on average over the time period.

Figure 19: Potential Impacts of 65 ppb Ozone Standard on Texas Energy Prices (Average 2017-2040, 2014$)

	Texas State Impacts			
	Baseline	65 ppb	Change	% Change
Henry Hub Natural Gas Price ($/MMBtu)	$6.22	$6.36	$0.14	2.1%
Residential Delivered Natural Gas ($/MMBtu)	$14.10	$14.49	$0.39	2.7%
Industrial Delivered Natural Gas ($/MMBtu)	$6.47	$6.91	$0.44	6.8%
Retail Gasoline ($/gallon)	$3.68	$4.14	$0.46	13%
Residential Electricity Rates (¢/kWh)	15.2¢	15.6¢	0.4¢	2.6%
Industrial Electricity Rates (¢/kWh)	9.5¢	9.9¢	0.4¢	4.6%

All sectors of the economy would be affected by a 65 ppb ozone standard, both directly through increased emissions control costs and indirectly through impacts on affected entities' customers and/or suppliers. There are noticeable differences across sectors, however. Figure 20 shows the estimated changes in output for the non-energy and energy sectors of the economy due to the emissions reduction costs of a 65 ppb ozone standard.

- Coal sector output in Texas declines 23% on average from 2017 through 2040 as Texas coal units are forced to retire.
- Texas's natural gas sector output is projected to increase by 2.4% as coal-fired generators throughout the U.S. retire leading to increases in natural gas consumption nationally. As one of the largest natural gas-producing states, Texas's economy benefits from the increased demand in that particular sector.
- Other non-energy sectors in Texas, which typically use less energy, also have declines, and these declines are larger than the declines nationally because of the significant compliance costs borne directly by Texas companies.

Figure 20: Potential Percentage Impacts of 65 ppb Ozone Standard on Sectoral Output in Texas (Average 2017-2040)

	Texas State Impact
Non-Energy Sectors	
Agriculture	-8.7%
Commercial/Services	-1.5%
Manufacturing	-2.5%
Commercial Transportation	-2.1%
Commercial Trucking	-1.8%
Energy Sectors	
Coal	-23%
Natural Gas	2.4%
Crude Oil/Refining	-0.7%
Electricity	-3.5%

VI. DISCUSSION AND CONCLUSIONS

The analysis presented in this paper should make it clear that the costs to reduce ozone precursor emissions to levels that would attain a 65 ppb ozone NAAQS by the regulatory attainment deadlines could be substantially more challenging and costly than has been reported in EPA's RIA (EPA, 2014a). Considering both EPA's estimates and NERA's, it appears that Texas could bear over 30% of total U.S. attainment costs. When these emission reduction costs are incorporated into a macroeconomic model, they imply potentially large costs to households and businesses, and potentially large impacts on energy prices.

It is important to note that this is an <u>ex ante</u> assessment of costs that requires use of data and analyses that are far more limited than those that will ultimately inform the development of actual SIPs. The emission controls that NERA assumes for this ex ante cost estimation study are based on approximate presently-available information. Controls that will actually be included a future Texas SIP may differ because TCEQ will first use detailed air quality modeling to more accurately determine each measure's effectiveness (i.e., how much each control will reduce ozone levels in nonattainment areas during times when 8-hour ozone values are at their highest). In addition, the analysis in this study has been based on standard nonattainment classifications and their schedules for achieving attainment; thus, this study's results do not apply to other potential classifications that might occur.

We conclude by noting several other aspects of costs and economic impacts that have not been addressed in the estimates provided in this report.

A. Distributional Impacts

It can also be important when reviewing economic impacts to consider which segments of the population bear the largest burden. A common finding is that costs per household are larger as a percentage of income for lower income households than for higher income households (*i.e.*, impacts are "regressive"). The N$_{ew}$ERA model does not presently have representation of different income groups, and this study cannot report on distributional impacts by type of household. We note however that it is reasonable to expect that the economic impacts that we have identified would be regressive. The primary reasons for this are:

- Price increases are projected for electricity, natural gas, and gasoline — energy costs that tend to be a larger fraction of lower income household budgets; and

- More rapid turnover of older vehicles reduces the supply of low-cost vehicle alternatives that are more likely purchased by lower income people.

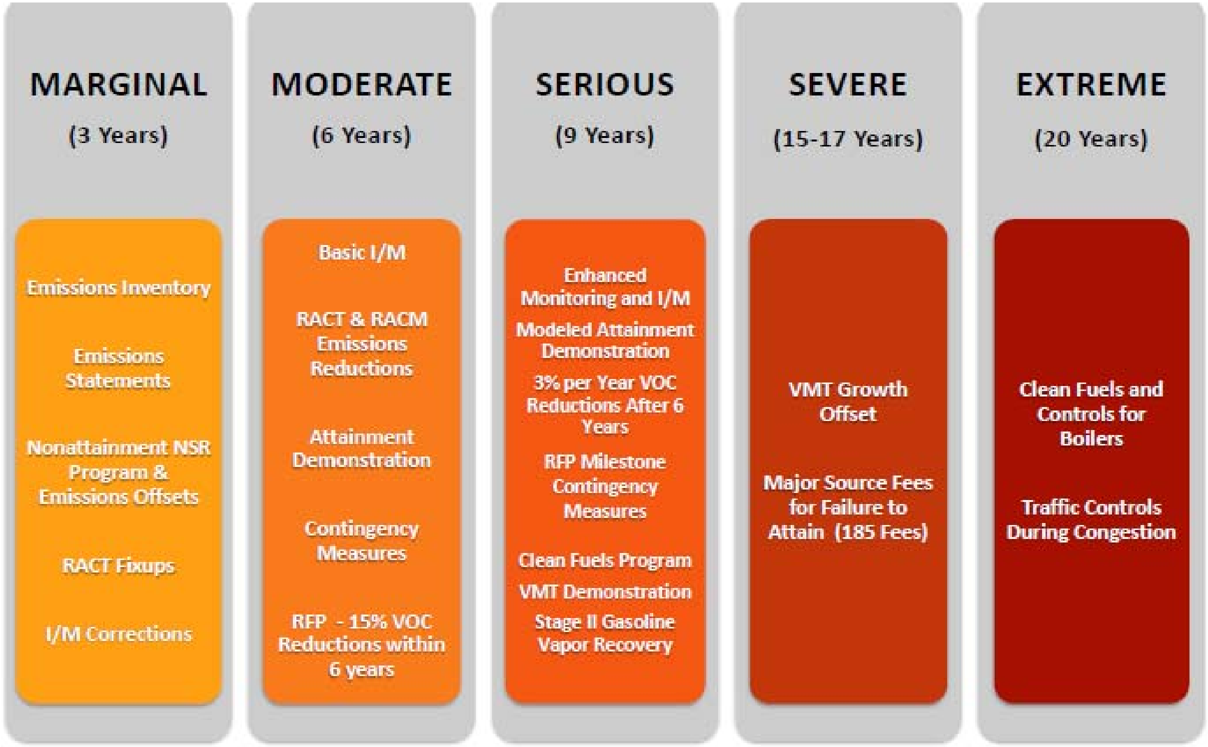
More analysis would be needed to provide better insight on the potential distributional impacts by household type.

B. Costs of Compliance Beyond Emissions Reduction Spending

Another missing element of this economic impact analysis is that it is limited to assessment of emissions reduction costs only. While these are very large in terms of direct dollar spending, there are other important ways that nonattainment status can affect the growth and vibrancy of a state's economy. The requirements of the Clean Air Act for states with nonattainment areas also impose administrative costs on the state and local governments to develop the required SIP documents. While not large in contrast to the billions of dollars per year that we estimated for actually reducing the emissions they nevertheless are not included in our cost estimates, nor in the economic impact assessment.

A more important missing element in our economic impact analysis is that it has not accounted for a range of constraints on new infrastructure development that are required by the Federal Clean Air Act when an area is designated as nonattainment. Figure 21 summarizes those types of constraints. (For a 65 ppb ozone standard, Texas is likely to fall into the Moderate classification shown in this figure.)

Figure 21: Federal Clean Air Act Requirements for Ozone Nonattainment Areas (Source: Jacobsen, 2014)[49]



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[49] Source: SIP 101, Kristin Jacobsen, TCEQ. Available at: https://www.tceq.texas.gov/assets/public/implementation/air/sip/miscdocs/2014_SIP101.pdf.

As a starting point, there are administrative costs that are borne by each state that must produce a SIP for each nonattainment area in its state. A more significant burden comes from restraints on potential growth that result from required nonattainment new source review (NNSR). Under NNSR, all new sources and modifications to existing sources require the following:

- Install controls to achieve the lowest achievable emission rate (LAER);
- Purchase emission offsets; and
- Allow for public involvement.

Each one of these factors increases the costs for economic growth and may lead potential new businesses to locate in areas that are not in nonattainment. For example, if a new manufacturing plant wanted to locate in a nonattainment area and the new plant was projected to have 100 tons of NO_X emissions per year, then that new plant would need to purchase offsets based on the NNSR ratio, which increases from 1.1 for Marginal areas to 1.5 for extreme areas. Thus, a new plant in a marginal area that was projected to emit 100 tons of NO_X per year would need to purchase 110 tons of offsets where the cost per ton of these offsets could be in the tens of thousands of dollars (or more).

With respect to transportation, there are also additional costs. Nonattainment areas classified as Moderate or worse must adopt vehicle inspection and maintenance programs, which have a direct cost on state/local governments (and those in the state who own vehicles). Also, transportation conformity is required for all nonattainment areas and requires state/local governments to demonstrate that any new transportation project will not add emissions. This delays states' ability to quickly undertake new transportation projects, and could limit an area's access to Federal highway funds.

Although there is minimal direct spending implication of most of these constraints, they hinder regional growth in nonattainment areas in a number of ways. Our economic impact analysis could not address the economic impacts of such constraints because these types of constraints apply only within the nonattainment areas of a state, and our model presently does not have a sub-state level of detail. Since nonattainment areas generally coincide with the areas of concentrated economic activity, they could have significant additional impacts on the economic outcomes that are omitted from our analysis.

C. Transitional Impacts

Another element of economic impact that is omitted from our analysis is transitional costs. The model used is a long-run equilibrium model and has minimal ability to determine the types of impacts that come from a major and sudden shift from one set of economic activities (such as coal-fired electricity generation) to an alternative, less-emitting set (such as natural gas or renewables generation). The model assumes shifts to a new, potentially very different set of market conditions occur instantaneously and without inefficient uses of resources during a transition. This understates lost productivity in the transitional period. It also means that our analysis cannot predict what amount of layoffs and other forms of involuntary unemployment may occur during the phase-in of the new policy.

D. Uncertainty

In closing, it is important to recognize that any cost estimate for such a major policy, particularly one that requires such steep reductions in emissions from sources that have not even been identified, is highly uncertain. Our cost estimates are substantially higher than EPA has projected. However, we have provided our reasons for why our approach is more consistent with the realities of SIPs, and with the evidence indicating increasingly higher cost-per-ton to squeeze out reductions that must come from ever smaller and more dispersed sources of ozone precursor emissions. While we believe that actual attainment on the legally-prescribed attainment schedule is more likely to have a cost (and hence economic impacts) in the range we have projected, there is still a range of uncertainty around our economic impact estimates in both the upward and downward direction. They may be higher due to the omitted aspects of nonattainment constraints noted above, due to omission of transitional frictions by our modeling methodology, and also due to the failure to account for potential nonattainment areas that may be designated in West Texas. They may be lower due to whatever shifts in human lifestyles or unanticipated innovations that could render existing emitting capital stock economically obsolete prior to 2022. Another way that costs could be lower is if the attainment schedules required of a NAAQS could be extended by several years without the simultaneous imposition of the growth-reducing burdens of more severe nonattainment classification. Nevertheless, we see no possibility that costs of attaining a 65 ppb NAAQS could be reduced to levels as low as EPA's cost estimates, which we find to be based on simplistic, low-cost assumptions that have no evidentiary foundation, and which we also find are contradicted by the available evidence that EPA did not review.

APPENDIX A. THE NEWERA MODEL

A. Introduction

NERA developed the NewERA model to forecast the impact of policy, regulatory, and economic factors on the energy sectors and the economy. When evaluating policies that have significant impacts on the entire economy, this model specification captures the effects as they ripple through all sectors of the economy and the associated feedback effects. The NewERA model combines a macroeconomic model with all sectors of the economy with a detailed electric sector model that represents electricity production. This combination allows for a complete understanding of the economic impacts of different policies on all sectors of the economy.

The macroeconomic model incorporates all production sectors except electricity and final demand of the economy. Policy consequences are transmitted throughout the economy as sectors respond until the economy reaches equilibrium. The production and consumption functions employed in the model enable gradual substitution of inputs in response to relative price changes, thus avoiding all-or-nothing solutions.

The main benefit of the integrated framework is that the electric sector can be modeled in great detail yet through integration the model captures the interactions and feedbacks between all sectors of the economy. Electric technologies can be well represented according to engineering specifications. The integrated modeling approach also provides consistent price responses since all sectors of the economy are modeled. In addition, under this framework we are able to model electricity demand response.

The electric sector model is a detailed model of the electric and coal sectors. Each of the more than 17,000 electric generating units in the United States is represented in the model. The model minimizes costs while meeting all specified constraints, such as demand, peak demand, emissions limits, and transmission limits. The model determines investments to undertake and unit dispatch. Because the NewERA model is an integrated model of the entire U.S. economy, electricity demand can respond to changes in prices and supplies. The NewERA model represents the domestic and international crude oil and refined petroleum markets.

The NewERA model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include gross regional product, consumption, investment, and changes in "job equivalents" based on labor wage income, as discussed below in the section on macroeconomic modeling.

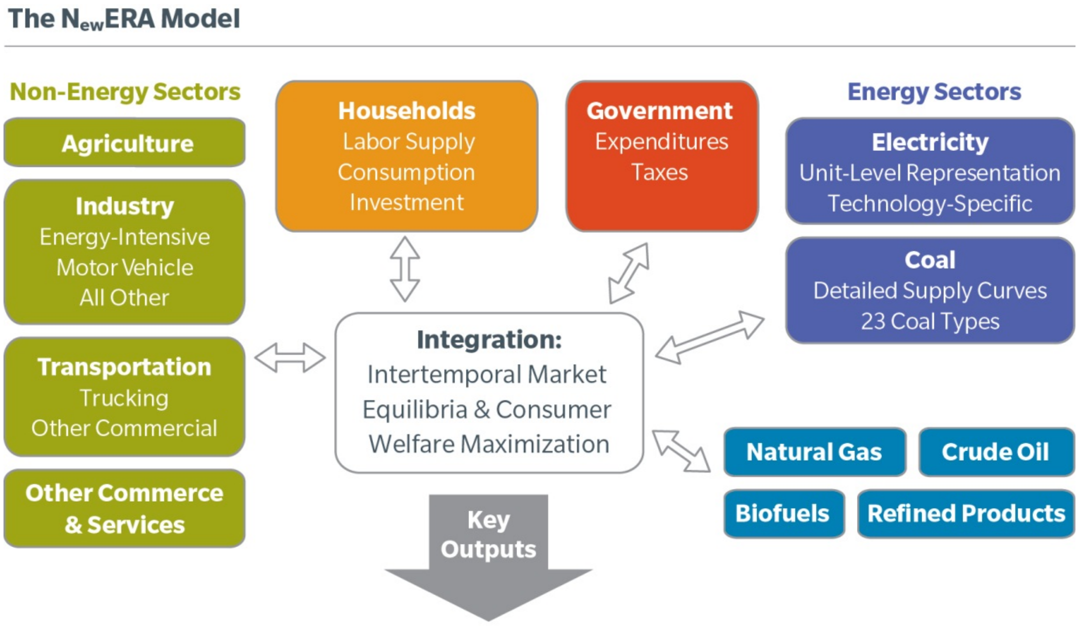
B. Overview

NERA's NewERA modeling system is an integrated energy and economic model that includes a bottom-up representation of the electricity sector, including all of the unit-level details that are required to accurately evaluate changes in the electric sector. N$_{ew}$ERA integrates the electricity sector model with a macroeconomic model that includes all other sectors of the economy (except for the electricity production) using a top-down representation. The model produces integrated forecasts for future years; the modeling for this study was for the period from 2014 through 2038 with modeling inputs and results for every third year in this period. The model produces a standard set of reports that includes the following information.

- *Unit-level investments in the electric sector* – retrofits in response to environmental policies, new builds (full range of new generation technologies represented), retirements based on economics.
- *Prices* – wholesale electricity prices for each of 34 U.S. regions, capacity prices for each U.S. region, delivered electricity prices by sector for each of 11 macroeconomic regions in N$_{ew}$ERA, Henry Hub natural gas prices and delivered natural gas prices to the electric sector for each U.S. region, minemouth coal prices for 24 different types of coal, delivered coal prices by coal unit, refined oil product prices (gasoline and diesel fuel), renewable energy credit (REC) prices for each state/regional renewable portfolio standard (RPS), and emissions prices for all regional and national programs with tradable credits.
- *Macroeconomic results* – gross domestic product (and gross regional product for each macroeconomic region), welfare, changes in disposable income, and changes in labor income and real wage rates (used to estimate labor market changes in terms of an equivalent number of jobs).

Figure 22 provides a simplified representation of the key elements of the N$_{ew}$ERA modeling system.

Figure 22: N$_{ew}$ERA Modeling System Representation



Macroeconomic (National/Regional)	**Primary Energy** (National/Regional)	**Electricity** (National/Regional/Generating Unit)
Welfare	Demand	Prices
GDP, consumption, investment	Prices	Builds, retrofits, retirements
Output by sector	Production	Load and Dispatch

C. Electric Sector Model

The electric sector model that is part of the N$_{ew}$ERA modeling system is a bottom-up model of the electric and coal sectors. Consistent with the macroeconomic model, the electric sector model is fully dynamic and includes perfect foresight (under the assumption that future conditions are known). Thus, all decisions within the model are based on minimizing the present value of costs over the entire time horizon of the model while meeting all specified constraints, including demand, peak demand, emissions limits, transmission limits, RPS regulations, fuel availability and costs, and new build limits. The model set-up is intended to mimic (as much as is possible within a model) the approach that electric sector investors use to make decisions. In determining the least-cost method of satisfying all these constraints, the model endogenously decides:

- What investments to undertake (*e.g.*, addition of retrofits, build new capacity, repower unit, add fuel switching capacity, or retire units);
- How to operate each modeled unit (*e.g.*, when and how much to operate units, which fuels to burn) and what is the optimal generation mix; and

- How demand will respond. The model thus assesses the trade-offs between the amount of demand-side management (DSM) to undertake and the level of electricity usage.

Each unit in the model has certain actions that it can undertake. For example, all units can retire, and many can undergo retrofits. Any publicly-announced actions, such as planned retirements, planned retrofits (for existing units), or new units under construction can be specified. Coal units have more potential actions than other types of units. These include retrofits to reduce emissions of SO_2, NO_X, mercury, and CO_2. The costs, timing, and necessity of retrofits may be specified as scenario inputs or left for the model to endogenously select. Coal units can also switch the type of coal that they burn (with practical unit-specific limitations). Finally, coal units may retire if none of the above actions will allow them to remain profitable, after accounting for their revenues from generation and capacity services.

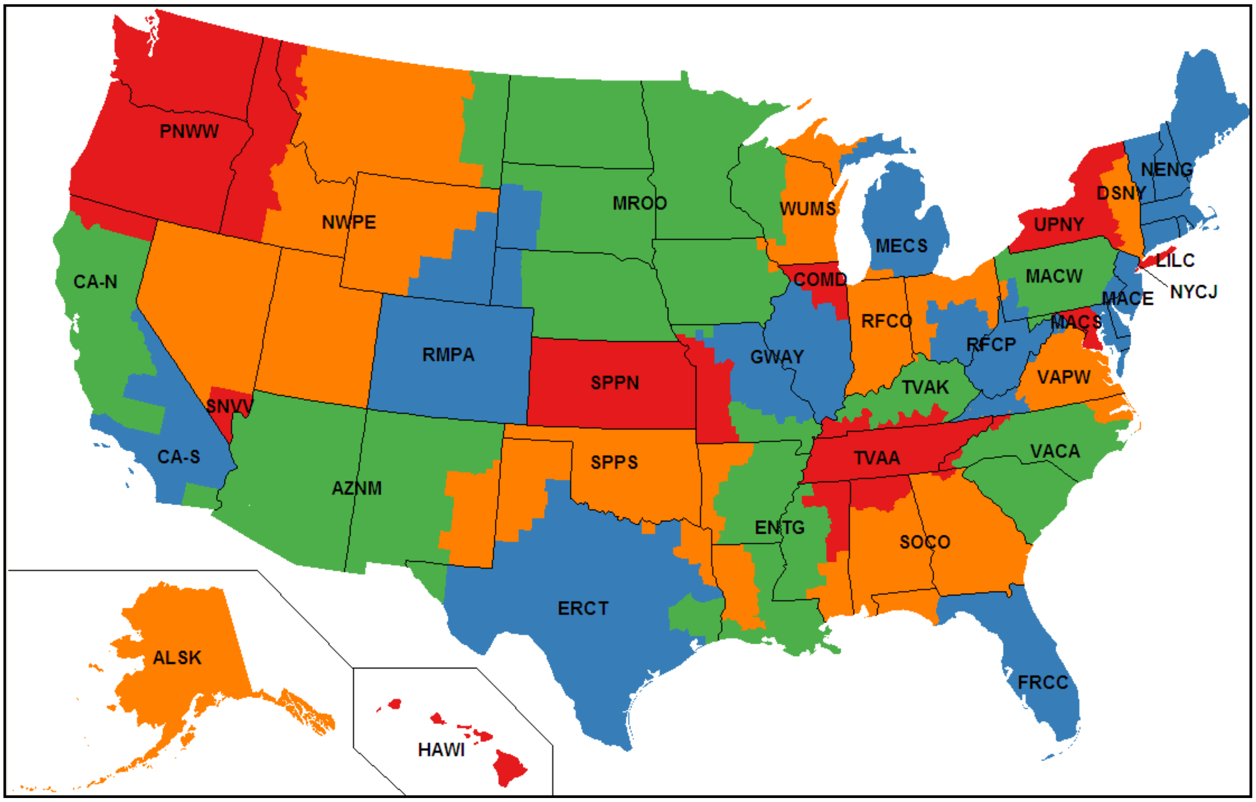
Most of the coal units' actions would be in response to environmental limits that can be added to the model. These include emission caps (for SO_2, NO_X, Hg, and CO_2) that can be applied at the national, regional, state or unit level. We can also specify allowance prices for emissions, emission rates (especially for toxics such as Hg) or heat rate levels that must be met. For this analysis, we have assumed that retirements of existing coal-fired generators in some states are part of the compliance actions of those states to achieve targeted NO_X reductions.

Just as with investment decisions, the operation of each unit in a given year depends on the policies in place (*e.g.*, unit-level standards), electricity demand, and operating costs, especially energy prices. The model accounts for all these conditions in deciding when and how much to operate each unit. The model also considers system-wide operational issues such as environmental regulations, limits on the share of generation from intermittent resources, transmission limits, and operational reserve margin requirements in addition to annual reserve margin constraints.

To meet increasing electricity demand and reserve margin requirements over time, the electric sector must build new generating capacity. Future environmental regulations and forecasted energy prices influence which technologies to build and where. For example, if a national RPS policy is to take effect, some share of new generating capacity will need to come from renewable power. On the other hand, if there is a policy to address emissions, it might elicit a response to retrofit existing fossil-fired units with pollution control technology or enhance existing coal-fired units to burn different types of coals, biomass, or natural gas. Policies calling for improved heat rates may lead to capital expenditure spent on repowering existing units. All of these policies will also likely affect retirement decisions. The N_{ew}ERA electric sector model endogenously captures all of these different types of decisions.

The model contains 34 U.S. electricity regions (and six Canadian electricity regions). Figure 23 shows the U.S. electricity regions.

Figure 23: N$_{ew}$ERA Electric Sector Model – U.S. Regions



The electric sector model is fully flexible in the model horizon and the years for which it solves. When used in an integrated manner with the macroeconomic model, and to analyze long-term effects, the model has the same time steps as in the macroeconomic model (2014 through 2038, modeling every third year).

D. Macroeconomic Model

1. Overview

The N$_{ew}$ERA macroeconomic model is a forward-looking dynamic computable general equilibrium (CGE) model of the United States. The model simulates all economic interactions in the U.S. economy, including those among industry, households, and the government. Additional background information on CGE models can be found in Burfisher (2011).

The N$_{ew}$ERA CGE framework uses the standard theoretical macroeconomic structure to capture the flow of goods and factors of production within the economy. A simplified version of these interdependent macroeconomic flows is shown in Figure 24. The model implicitly assumes "general equilibrium," which implies that all sectors in the economy are in balance and all economic flows are endogenously accounted for within the model. In this model, households supply factors of production, including labor and capital, to firms. Firms provide households with payments for the factors of production in return. Firm output is produced from a combination of productive factors and intermediate inputs of goods and services supplied by other firms. Individual firm final output can be consumed within the United States or exported. The model also accounts for imports into the United States. In addition to consuming goods and services, households can accumulate savings, which they provide to firms for investments in new capital. Government receives taxes from both households and firms, contributes to the production of goods and services, and also purchases goods and services. Although the model assumes equilibrium, a region in the model can run deficits or surpluses in current accounts and capital accounts. In aggregate, all markets clear, meaning that the sum of regional commodities and factors of production must equal their demands, and the income of each household must equal its factor endowments plus any net transfers received.

The model uses the standard CGE framework developed by Arrow and Debreu (1954). Behavior of households is represented by a nested Constant Elasticity of Substitution (CES) utility function. The model assumes that households seek to maximize their overall welfare, or utility, across time periods. Households have utility functions that reflect trade-offs between leisure (which reduces the amount of time available for earning income) and an aggregate consumption of goods and services. Households maximize their utility over all time periods subject to an intertemporal budget constraint based on their income from supplying labor, capital, and natural resource to firms. In each time period, household income is used to consume goods and services or to fund investment. Within consumption, households substitute between energy (including electricity, coal, natural gas, and petroleum), personal transportation, and goods and services based on the relative price of these inputs.

Figure 24 illustrates the utility function of the households.

Figure 24: Interdependent Economic Flows in N$_{ew}$ERA's Macroeconomic Model

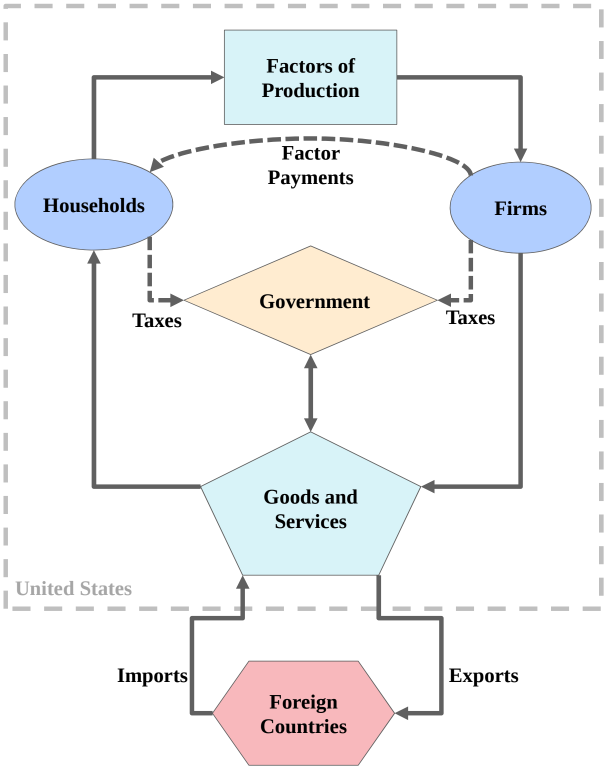
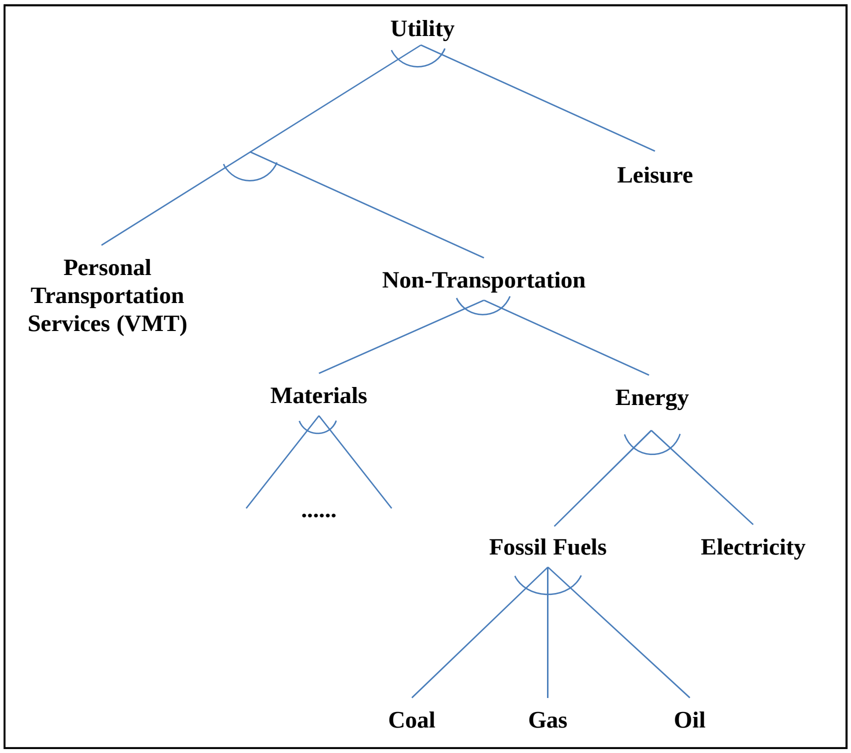


Figure 25: Household Consumption Structure in N$_{ew}$ERA's Macroeconomic Model



On the production side, Figure 26 shows the production structure of the commercial transportation and the trucking sector. Production structure for the rest of the industries is shown in Figure 27. The model assumes all industries maximize profits subject to technological constraints. The inputs to production are energy (including the same four types noted above for household consumption), capital, and labor. Production also uses inputs from intermediate products (*i.e.*, materials) provided by other firms. The N$_{ew}$ERA model allows producers to change the technology and the energy source they use to manufacture goods. If, for example, petroleum prices rise, an industry can shift to a cheaper energy source. It can also choose to use more capital or labor in place of petroleum, increasing energy efficiency and maximizing profits with respect to industry constraints.

Figure 26: Commercial Transportation and Trucking Sector Production Structure in N$_{ew}$ERA's Macroeconomic Model

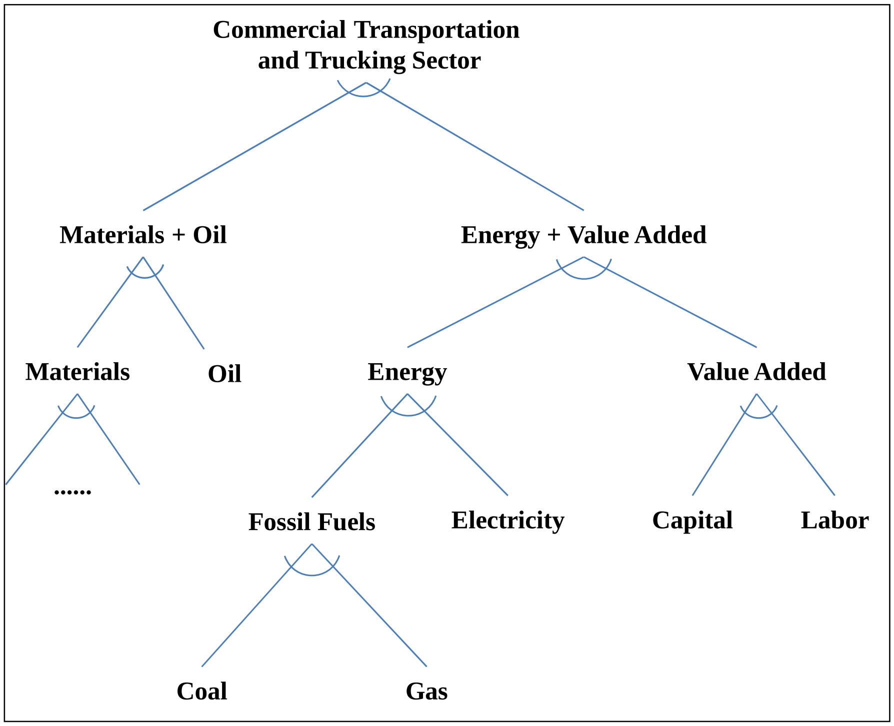
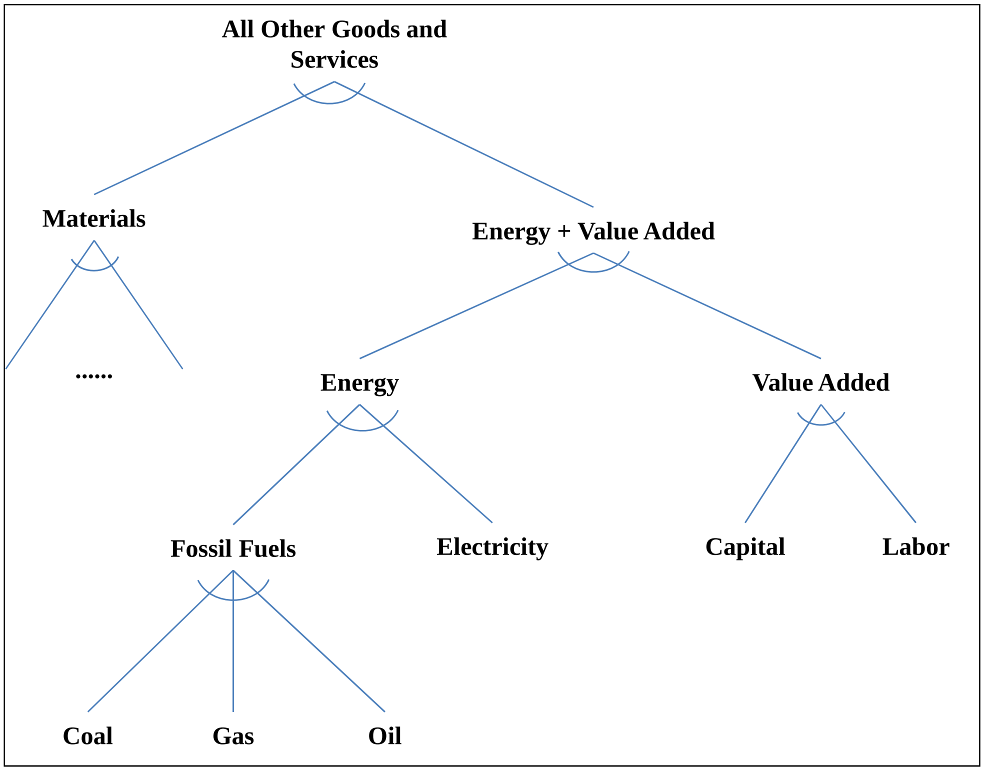


Figure 27: Production Structure for Other Sectors in N$_{ew}$ERA's Macroeconomic Model



All goods and services, except crude oil, are treated as Armington goods, which assume the domestic and foreign goods are differentiated and thus are imperfect substitutes (Armington 1969). The level of imports depends upon the elasticity of substitution between the imported and domestic goods. The Armington elasticity among imported goods is assumed to be twice as large as the elasticity between the domestic and imported goods, characterizing the greater substitutability among imported goods.

Business investment decisions are informed by future policies and outlook. The forward-looking characteristic of the model enables businesses and consumers to determine the optimal savings and investment levels while anticipating future policies with perfect foresight.

The benchmark year economic interactions are based on the IMPLAN 2008 database, which includes regional detail on economic interactions among 440 different economic sectors. The macroeconomic and energy forecasts that are used to project the benchmark year going forward are calibrated to EIA's *Annual Energy Outlook* (*AEO*) *2014* Reference case.

2. Interactions between Compliance Costs, Capital Investment, and Household Expenditures

Regulations cause producers in the affected industries to make capital expenditures that they would not make otherwise. In addition, regulations change consumption patterns for households. To model the macroeconomic impacts of regulations, N$_{ew}$ERA accounts for interactions between compliance costs, capital investments, and household expenditures based on the following three effects.

1. *Compliance costs for producers in the regulated industries*. Producers in the regulated industries have to make capital expenditures to comply with the regulation. These expenditures increase the costs of producing goods and services in the regulated industries. The higher costs lead to higher prices for the goods and services, which in turn lead to lower demand in the regulated industries. Thus, this effect reduces economic activity.

2. *Scarcity effect due to non-optimal capital allocation*. In N$_{ew}$ERA's modeling framework, the capital expenditures for regulatory compliance are assumed to be unproductive. The capital expenditures in the regulated industries make less capital available to produce goods and services throughout the economy. In other words, the unproductive capital expenditures in the regulated industries "crowd out" productive capital investment in the broader economy. This scarcity effect increases the opportunity cost of capital in the economy, which implies higher costs of capital. This in turn lowers investment in productive capital and slows economic growth.

3. *Household purchases of unproductive durable goods*. Regulations also cause households to change their consumption patterns, particularly in terms of durable goods. For example, households may need to purchase new automobiles, lawn mowers, or equipment for compliance with the regulation. These additional expenditures on unproductive durable goods are non-optimal from the standpoint of households, but they represent increased demand for the manufacturing sector. Thus, these additional household purchases increase economic activity.

The net macroeconomic impacts of regulations calculated by N$_{ew}$ERA reflect the combination of these three effects.

3. Regional Aggregation

The N$_{ew}$ERA macroeconomic model includes regions built up from economic data for the 50 U.S. states and the District of Columbia. For this analysis, the state of Texas was its own region. Other states were aggregated together to create additional regions. For the NAM analysis, more than 40 individual model runs were conducted such that there was a model run where each state was individually represented.

4. Sectoral Aggregation

The NewERA model includes a standard set of 10 economic sectors: five energy (coal, natural gas, crude oil, electricity, and refined petroleum products) and five non-energy sectors (services, manufacturing, agriculture, commercial transportation excluding trucking, and trucking). These sectors are aggregated up from the 440 IMPLAN sectors. The model has the flexibility to represent sectors at different levels of aggregation, when warranted, to better meet the needs of specific analyses.

5. Natural Gas and Crude Oil Markets

As with most commodity markets, there are uncertainties about how the U.S. natural gas market will evolve, and the NewERA modeling system is designed explicitly to address the key factors affecting future natural gas supply and prices. To account for natural gas supply uncertainty and the subsequent effect it could have on international markets, the NewERA modeling system has the ability to represent supply curves for conventional natural gas and shale gas for each region of the model. By including each type of natural gas, it is possible to incorporate expert judgments and sensitivity analyses on a variety of uncertainties, such as the extent of shale gas reserves, the cost of shale gas production, and the impacts of environmental regulations.

The NewERA model represents the domestic and international crude oil and refined petroleum markets. The international markets are represented by flat supply curves with exogenously specified prices. Because crude oil is treated as a homogeneous good, the international price for crude oil sets the U.S. price for crude oil.

For this study, we calibrated natural gas and crude oil production at the state level based on information from *AEO 2014*. While *AEO 2014* does not provide state-level information, they did provide us with basin-specific production forecasts that we translated into state-level production based on historical state-level production, other publicly-available forecasts by state, and our own expertise.

6. Macroeconomic Outputs

As with other CGE models, the NewERA macroeconomic model outputs include demand and supply of all goods and services, prices of all commodities, and terms of trade effects (including changes in imports and exports). The model outputs also include gross regional product, consumption, investment, cost of living or burden on consumers, and changes in “job equivalents” based on changes in labor wage income. All model outputs are calculated by time, sector, and region.

Impacts on workers are often considered an important output of policy evaluations. Impacts on workers are complicated to estimate and to explain because they can include several different impacts, including involuntary unemployment, reductions in wage rates for those who continue to work, and voluntary reductions in hours worked due to lower wage rates. No model addresses all of these potential impacts. The N_{ew}ERA model is a long-run equilibrium model based upon full employment, and thus its results relate to the longer-term effects on labor income and voluntary reductions in hours worked rather than involuntary unemployment impacts. It addresses long-run employment impacts, all of which are based on estimates of changes in labor income, also called the “wage bill” or “payments to labor.” Labor income impacts consist of two effects: (1) changes in real wage per hour worked; and (2) changes in labor market participation (hours worked) in response to changed real wage rates. The labor income change can also be expressed on a per-household basis, which represents one of the key components of disposal income per household. (The other key components of disposable income are returns on investments or “payments to capital,” and income from ownership of natural resources). The labor income change can also be stated in terms of job-equivalents, by dividing the labor income change by the annual income from the average job. A loss of one job-equivalent does not necessarily mean one less employed person—it may be manifested as a combination of fewer people working and less income per person who is working. However, this measure allows us to express employment-related impacts in terms of an equivalent number of employees earning the average prevailing wage.

For modeling the economic impacts of changes in energy prices, we assume that 50% of the wealth impacts would accrue to local residents in each energy production region (state), and the remaining 50% of wealth impacts would accrue to energy company shareholders based on national population percentages. We are not aware of any recent studies of the geographic distribution of potential energy sector gains, so we used an even division between state and national impacts given that some energy companies are in-state and some gains to national companies would accrue to local residents. A large fraction of energy production (particularly for natural gas shale developments that have become available through horizontal drilling techniques and hydraulic fracturing, or “fracking”) is on private land and generates payments to local residents (payments, severance taxes, renegotiated leases, etc.). The remaining wealth impacts from changes in energy prices would affect shareholders in large publicly-traded energy companies, who are spread throughout the country.

E. Integrated N_{ew}ERA Model

The N_{ew}ERA modeling framework fully integrates the macroeconomic model and the electric sector model so that the final solution is a consistent equilibrium for both models and thus for the entire U.S. economy.

To analyze any policy scenario, the system first solves for a consistent baseline solution; it then iterates between the two models to find the equilibrium solution for the scenario of interest. For the baseline, the electric sector model is solved first under initial economic assumptions and forecasts for electricity demand and energy prices. The equilibrium solution provides the baseline electricity prices, demand, and supply by region as well as the consumption of inputs—capital, labor, energy, and materials—by the electric sector. These solution values are passed to the macroeconomic model.

Using these outputs from the electric sector model, the macroeconomic model solves the baseline while constraining the electric sector to replicate the solution from the electric sector model and imposing the same energy price forecasts as those used to solve the electric sector baseline. In addition to the energy price forecasts, the macroeconomic model's non-electric energy sectors are calibrated to the desired exogenous forecast (EIA's *AEO 2014* forecast) for energy consumption, energy production, and macroeconomic growth. The macroeconomic model solves for equilibrium prices and quantities in all markets subject to meeting these exogenous forecasts.

After solving the baseline, the integrated N$_{ew}$ERA modeling system solves for the scenario. First the electric sector model reads in the scenario definition. The electric sector model then solves for the equilibrium level of electricity demand, electricity supply, and inputs used by the electric sector (*i.e.*, capital, labor, energy, emission permits). The electric sector model passes these equilibrium solution quantities to the macroeconomic model, which solves for the equilibrium prices and quantities in all markets. The macroeconomic model then passes to the electric sector model the following (solved for equilibrium prices):

- Electricity prices by region;
- Prices of non-coal fuels used by the electric sector (*e.g.*, natural gas and oil); and
- Prices of any permits that are tradable between the non-electric and electric sectors (*e.g.*, carbon permits under a nationwide greenhouse gas cap-and-trade program).

The electric sector model then solves for the new electric sector equilibrium, taking the prices from the macroeconomic model as exogenous inputs. The models iterate—prices being sent from the macroeconomic model to the electric sector model and quantities being sent from the electric sector model to the macroeconomic model—until the prices and quantities in the two models differ by less than a fraction of a percent.

This decomposition algorithm allows the N$_{ew}$ERA model to retain the information in the detailed electricity model, while at the same time accounting for interactions with the rest of the economy. The detailed information on the electricity sector enables the model to represent regulatory policies that are imposed on the electricity sector in terms of their impacts at a unit level.

F. References to the Appendix

Armington, P. 1969. "A Theory of Demand for Products Distinguished by Place of Production." *International Monetary Fund Staff Papers*, XVI: 159-78.

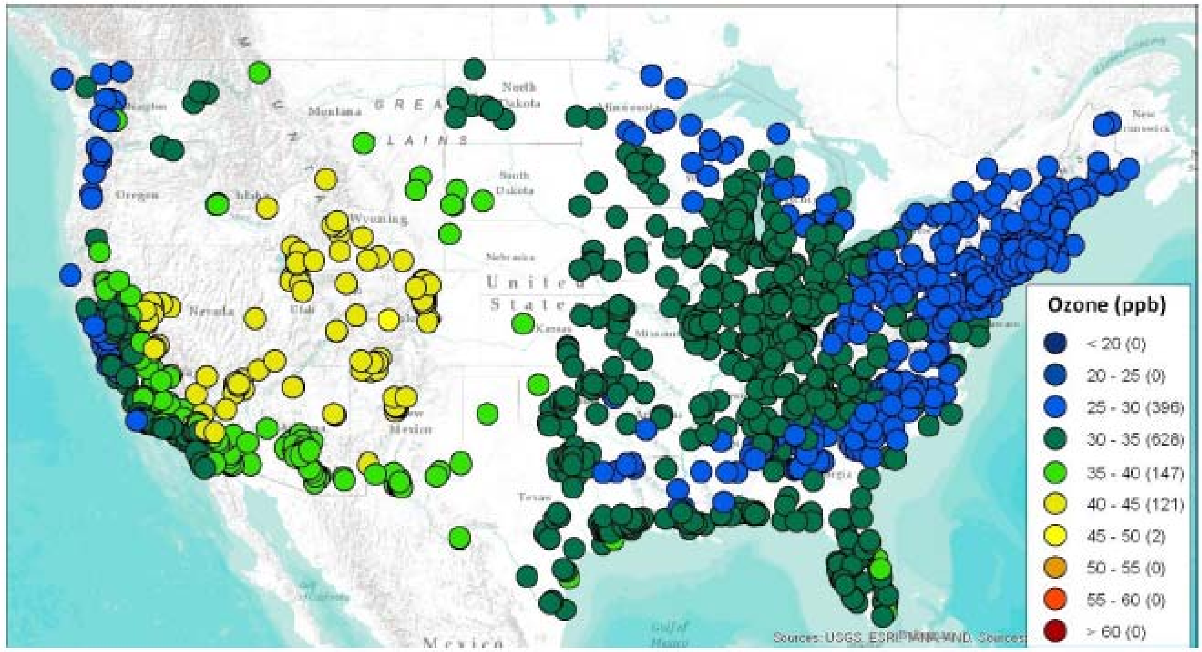
Arrow, K.J., and G. Debreu. 1954. "Existence of an Equilibrium for a Competitive Economy." *Econometrica* 22:265-290.

Burfisher, M.E. 2011. *Introduction to Computable General Equilibrium Models*. New York: Cambridge University Press.

APPENDIX B. BACKGROUND OZONE AND EPA'S EXCLUSION OF SOME MONITORS IN TEXAS FROM ANALYSIS

Background ozone levels[50] are a very important element of air quality modeling in terms of how it can influence emissions reduction targets and costs. Specifically, the higher the background ozone is, the lower the relative responsiveness to a reduction in NO_x or VOC emissions. In general, this leads to an implied need for more emissions reductions than for a similar area with lower background ozone, all else being equal. Background ozone is a relatively higher percentage of total ozone in the intermountain West area and along the U.S. coastlines and international borders, as shown in Figure 28.

Figure 28: 2007 Seasonal Mean of 8-Hour Daily Max Ozone from N. American Background (ppb)[51]



Some monitors in Texas were excluded from EPA's analysis because of high background ozone and low observed responsiveness to emissions reduction controls. Specifically, EPA excluded the following monitors (with additional information on EPA's specified ozone sources, historical design values, and projected baseline design values), as shown in Figure 29.

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[50] "The definition of background ozone can vary depending upon context, but it generally refers to ozone that is formed by sources or processes that cannot be influenced by actions within the jurisdiction of concern." (EPA Ozone RIA, p. 2-11)

[51] Source: EPA Ozone RIA, Figure 2-7 (based on zero-out modeling, CMAQ estimate).

Figure 29: EPA-Excluded Texas Monitors[52]

Monitor Name (Site ID)	County	Primary Ozone Sources	2009-2013 DV	Baseline DV
Big Bend NP (480430101)	Brewster	Mexican border	70	69
El Paso UTEP (481410037)	El Paso	Central region + Mexican border	71	67
Skyline Park (481410044)	El Paso	Central region + Mexican border	69	65
El Paso Chamizal (481410058)	El Paso	Central region + Mexican border	69	65
BLM Land/Carlsbad (483819991)	Randall	Central region + Mexican border + Other sources	73	66

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[52] Source: EPA Ozone RIA, p. 3A-56.

REFERENCES

79 *Federal Register* 75233. 2014 National Ambient Air Quality Standards for Ozone, A Proposed Rule by the Environmental Protection Agency. 75233 -75411. December 17.

Jacobsen, K. 2014. "SIP 101." Texas Commission on Environmental Quality. Available at: https://www.tceq.texas.gov/assets/public/implementation/air/sip/miscdocs/2014_SIP101.pdf.

Knittel, Christopher. 2009. "The Implied Cost of Carbon Dioxide under the Cash for Clunkers Program." Center for the Study of Energy Markets, UC Berkeley. Article available at: http://www.ucei.berkeley.edu/PDF/csemwp189.pdf. Spreadsheet available at: http://web.mit.edu/knittel/www/papers/CfC.xls.

NERA Economic Consulting (NERA). 2014. "Assessing Economic Impacts of a Stricter National Ambient Air Quality Standard for Ozone." July. Available at: http://www.nera.com/content/dam/nera/publications/2014/PUB_NERA_NAM_Ozone_Report_0714.pdf.

NERA Economic Consulting (NERA). 2015a. "Economic Impacts of a 65 ppb National Ambient Air Quality Standard for Ozone." February. Available at: http://www.nera.com/publications/archive/2015/economic-impacts-of-a-65-ppb-national-ambient-air-quality-standa.html.

NERA Economic Consulting (NERA). 2015b. "EPA Regulatory Impact Analysis of Proposed Federal Ozone Standard: Potential Concerns Related to EPA Compliance Cost Estimates." March. Available at: http://www.nera.com/content/dam/nera/publications/2015/EPA_Regulatory_Impact_0315.pdf.

San Joaquin Valley Air Pollution Control District. 2015. "RE: DocketNo.EPA-HQ-OAR-2008-0699 Comments on National Ambient Air Quality Standards for Ozone; Proposed Rule. March 17. http://www.csg.org/aapca_site/news/documents/SJVCommentsProposedOzoneNAAQS.pdf.

U.S. Environmental Protection Agency (EPA). 2014a. Regulatory Impact Analysis (RIA) of the Proposed Revisions to the National Ambient Air Quality Standards (NAAQS) for Ground-Level Ozone. http://www.epa.gov/ttnecas1/regdata/RIAs/20141125ria.pdf

U.S. Environmental Protection Agency (EPA). 2014b. 2011 and 2025 NO_X Emissions County Sector Comparison. ftp://ftp.epa.gov/EmisInventory/2011v6/ozone_naaqs/reports/2011ef_2025ef_county_sector_comparison_NOX.xlsx

U.S. Environmental Protection Agency (EPA). 2014c. 2011, 2018, and 2025 Emissions State Sector Comparison.

ftp://ftp.epa.gov/EmisInventory/2011v6/ozone_naaqs/reports/2011ef_2018ef_2025ef_state_sector_comparison.xlsx

U.S. Environmental Protection Agency (EPA). 2014d. O3 NAAQS RIA Control Strategy Results NOX Controls for 65ppb Analysis Incremental to Baseline. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0169-0015

U.S. Environmental Protection Agency (EPA). 2014e. Updated 2014 O3 NAAQS RIA NOx Control Strategy Results – 75 ppb. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0169-0035

U.S. Environmental Protection Agency (EPA). 2014f. Emission Reductions Beyond Known Controls. http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0169-0032

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