Quantification of NO_x Emissions Reductions for SIP Credits from Energy Efficiency and Renewable Energy Projects in Texas

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ABSTRACT

This paper provides a detailed discussion of the procedures that have been developed and used to calculate the electricity savings and resultant NO_x reductions from energy efficiency and renewable energy projects in non-attainment and affected counties using the United States Environmental Protection Agency (US EPA) and Texas Commission on Environmental Quality (TCEQ) guidance and the US EPA's eGrid national data base of power plant emissions. This new methodology provides, for the first time, full emissions offsets from energy efficiency and renewable energy programs using creditable engineering analysis and verifiable data to help demonstrate compliance with the Federal Clean Air Act. Since four large metropolitan areas in Texas have been designated by the United States Environmental Protection Agency as non-attainment areas because ozone levels exceed the National Ambient Air Quality Standard (NAAQS) maximum allowable limits, this work is significant because these areas face severe sanctions if attainment is not reached by 2009.

Background

In 1970, the Federal Clean Air Act directed the United States Environmental Protection Agency to establish the maximum allowable concentrations of pollutants that are known to endanger human health, harm the environment or cause property damage. In response to this act, the EPA established NAAQS,[1] which describe the allowable maximum limits of six primary air pollutants.[2] In Texas, the Texas Commission on Environmental Quality (TCEQ) has the responsibility of measuring and reporting these emissions, including ozone, to the EPA. Nationally, areas that exceed safe levels of ozone are closely monitored by the EPA. Ozone is a poison formed when oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and oxygen (O_2) combine in the presence of strong sunlight. Hence, controlling NO_x emissions is fast becoming a critical priority for many areas of the United States. Furthermore, the US EPA is very interested in developing procedures for calculating creditable NO_x emissions reductions from energy efficiency/renewable (EE/RE) programs, since many of the traditional enforcement programs have reached either their effective limits or are becoming very expensive and politically unacceptable.[3]

[1] National Ambient Air Quality Standards (NAAQS).
[2] These pollutants currently are: carbon monoxide (CO -- 9 ppm, 8 hour average.), lead (Pb -- 1.5 ppm, maximum quarterly average), oxides of nitrogen (NO2 -- 53 ppb annual average), Ozone (O3 -- 120 ppb, 1 hour average.), particulate matter (PM10-- 50 micrograms/m3 annual average), and sulfur dioxide (SO2 -- 30 ppb annual average).
[3] In Texas, the US EPA relies primarily on mandatory measures to produce large changes in air pollution. These measures include limits on VOC emissions, and limits on NOx emissions from point sources (i.e., power plants),

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NO_x by sources that are currently not regulated by the state, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.).[4] An important part of this legislation is the evaluation of the State's new energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, renewable energy programs, and mandatory implementation of the International Energy Conservation Code[5] (IECC 2000; 2001). In 2001, 38 counties in Texas were designated by the EPA as either non-attainment or affected areas. In 2003, three additional counties were classified as affected counties, bringing the total to 41 counties (16 non-attainment and 25 affected counties). Figure 1 shows the location of these counties in the state, with the largest concentration of counties in the three metro areas of Dallas-Ft. Worth in the northeastern portion of the state, the Houston-Galveston-Beaumont-Port Arthur area in the southeast corner along the Gulf coast, and the Austin-San Antonio area in central Texas.[6] This paper provides a detailed discussion of the procedures that have been used to calculate the weather-normalized electricity savings and NO_x reductions from more efficient residential and commercial construction in non-attainment and affected counties, energy efficiency projects from utility programs, and emissions reductions from green power purchases.

Significance of the Work

Federal, state, and local governments are interested in quantifying the air quality benefits of EE/RE policies, programs and projects. Unfortunately, there is a considerable gap in available tools to assist federal and state agencies in estimating the environmental benefits of energy efficiency and renewable energy applications. In the US, methodologies are largely developed on a case-by-case basis for different purposes, and often contain poorly documented calculations and data sources, or are prohibitively expensive to apply to a state or region to achieve adequate rigor. Furthermore, the complexity of electricity production and inter-connection, and grid delivery are also a major barrier in estimating air emission reductions from electric sector EE/RE technologies.

In August 2004, the US EPA issued guidance on quantifying the air emission benefits from electric sector EE/RE projects. However, this was not a "cook book," but rather it provided a flexible framework of requirements under which quantification methodologies could be designed so states could incorporate the reductions into their State Implementation Plans (SIPs) for achieving or maintaining the NAAQS. Only in Texas has a comprehensive engineering toolkit and database been developed that satisfies all aspects of the EPA's 2004 guidance. The presence of this toolkit has also provided Texas with the ability to evaluate EE/RE technologies,

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reductions in NOx emissions from mobile sources (automobiles and trucks), and mandatory NOx emissions levels for new large boilers, furnaces, etc.

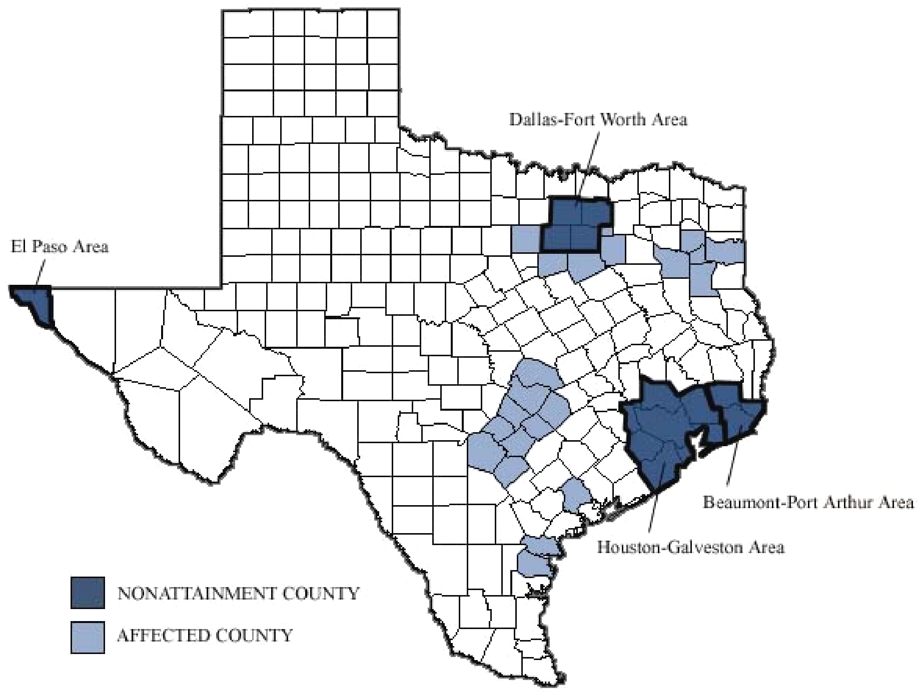
[4] In 2003, the 78th Legislature modified the Texas Emissions Reduction Plan (TERP) with House bill 3235 and House bill 1365. This new legislation strengthened the previous legislation, but did not reduce the stringency of the building code or the reporting of the emissions reduction. In the 2005 79th Legislature, the TERP was further modified to include the development of creditable emissions calculations from wind and renewables, and to investigate emissions reduction from area sources such as natural gas-fired, domestic water heaters.

[5] The code adopted by the State of Texas is the 2000 IECC (IECC 2000), as modified by the 2001 Supplement (IECC 2001).

[6] The El Paso area was designated a non-attainment area due high particulate concentrations.

which differ from traditional control techniques that are expensive and have no "payback" to the customer like EE/RE technologies. The success of this effort has also attracted the attention of the US EPA who is considering the application of the procedures developed in Texas for potential use by other states.

Figure 1. EPA Non-Attainment (Blue) and Affected Counties (Light Blue)



Quantification Methodology

The TCEQ is currently working with the EPA, through the Texas Emissions Reduction Plan (TERP), to determine how State Implementation Plan emissions reduction credits can be obtained from the reductions in electricity use from energy efficiency and renewable energy projects, with an emphasis on peak summertime electric demand,[7] that are attributable to the adoption of the International Energy Conservation Code (IECC 2000) in non-attainment and affected counties. In order for the TCEQ to accomplish this, county-wide reductions in electricity use must be calculated by the Energy Systems Laboratory (ESL) and presented to the TCEQ in a suitable format for calculating emissions reductions using the EPA's Emissions and Generation Resource Integrated Database (eGRID).[8] This methodology is composed of several procedures

[7] Currently, the peak day is the Ozone Season Day (OSD), which is the average daily use during a period from July 15 to Sept. 15 of the base year. For the current analysis this base year is 1999. Future analysis will include 2000 and 2002 base years.

[8] The use of the eGRID database, which includes a simplified utility grid model based on annual sales of electricity data, was proposed by the TCEQ for use in calculating the emissions reduction from energy efficiency and renewable energy projects in 2001. Although more sophisticated electricity dispatch models provide higher accuracy, eGRID is acceptable to the EPA because it is based on public domain data and uses procedures that were developed and maintained for this purpose by the EPA. This database, eGRID, can be found at www.epa.gov/airmarkets/egrid/. The Texas eGRID database was specially compiled by Art Diem at the USEPA for the TCEQ.

that calculate and verify energy savings and emissions reductions from EE/RE projects using different sources of information, including:

1. The calculation of electricity and natural gas savings and peak-day electricity and natural gas use reductions from the implementation of the IECC 2000 in new single-family and multi-family residences in non-attainment and affected counties as compared against 1999 single-family and multi-family housing characteristics using a code-traceable, calibrated DOE-2 simulation.
2. The calculation of electricity and natural gas savings and peak-day electricity and natural gas use reductions from the implementation of ASHRAE Standard 90.1-1999 in new commercial buildings in non-attainment and affected counties as compared against 1999 building characteristics using a code-traceable, calibrated DOE-2 simulation.
3. A cross-check of electricity and natural gas savings using a utility bill analysis method.
4. A cross-check of pre-code and post-code construction data using on-site visits.

In 2005, TCEQ expanded the TERP to include the development of integrated emissions reduction reporting across all state agencies participating in the TERP, which includes new code-compliant construction, utility programs, municipal projects, and green power purchases. Many of these procedures were also incorporated into a web-based EE/RE emissions calculator for use by planners. Additional detailed information about the methodologies described in this paper can be found in Haberl et al. (2002, 2003a, 2003b, 2004a, 2004b) and Im (2003).

Assembly of Measured Weather Data for 1999 through 2005

As a first step in the development of weather-normalized energy savings and peak demand reductions, measured weather data needed to be assembled for Texas as shown in Figure 2. To be consistent with long-term weather files, the emphasis was placed on those active stations nearest to the TMY2 stations as shown in Figure 2 (NREL 1995). Counties were then classified according to the nearest TMY2 station and corresponding IECC weather zone. Temperature, humidity, and wind measurements were obtained from NOAA (NOAA 1993). Solar data were assembled from the NREL measured solar data base, which was supplemented with TCEQ's solar data base in those areas where the NREL solar data had been discontinued. Solar thermal and PV weather files used the weather designations provided by the F-CHART and PV F-CHART programs (Klein and Beckman 1983; 1985).

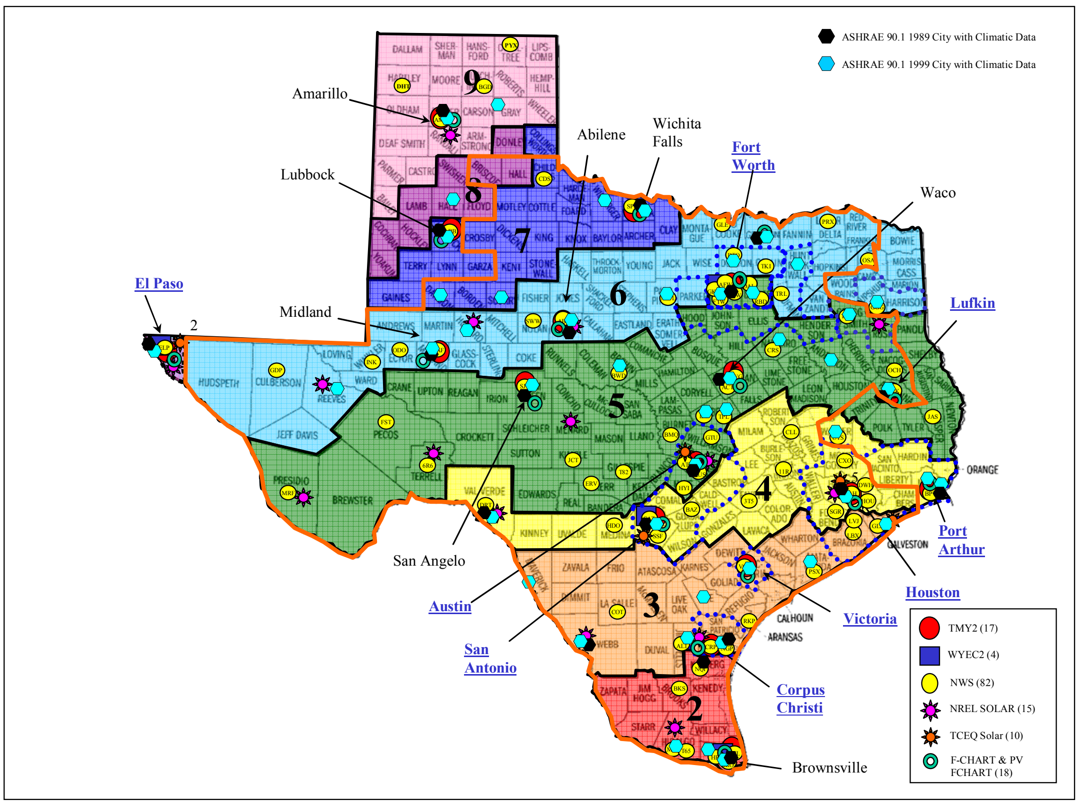
Determination of Code Compliant Residential Construction

To calculate the energy savings and NO_x emissions reductions from the implementation of the building codes in new construction, simulation models were created for single-family and multi-family residential buildings (Ahmed et al. 2005a; Malhotra 2005; Mukhopadhyay 2005). These simulation models were then modified to accommodate the different scenarios of construction and HVAC equipment typically used in the residential sector. The simulation models, created with the DOE-2.1e simulation program (LBNL 1993a; 1993b), were then linked to a web-based graphic user interface and the US EPA's eGRID to automatically convert the energy savings to NO_x emissions reduction.[9] In Figure 3, an outline of the overall analysis is

[9] This web-based calculator can be viewed at "ecalc.tamu.edu".

provided. In this analysis, prototypical buildings were created. For each building type, simulations were performed for code and pre-code conditions using measured weather data assigned to each location. Savings were then multiplied by the number of new[10] buildings in each county to yield the total county-wide savings. The electricity savings for each county were then converted to NO_x reductions using eGRID.[11] Natural gas savings were converted using the EPA's conversion factors for the specific appliance/system.[12] In the case of single-family residences, this included one-story, two-story, and slab-on-grade or crawlspace. Heating/cooling system types included electric resistance, heat pump or natural gas heating; electric or natural gas domestic water heating, and air-conditioning. The percentages of house/system types were determined by the National Association of Home Builders (NAHB) builder's survey form (NAHB 2005).

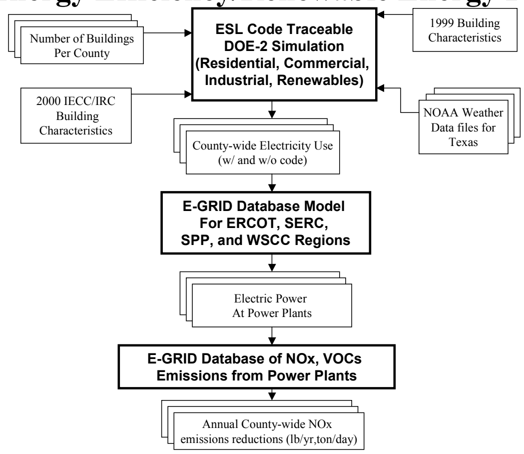
Figure 2. Available Weather Data Sources and Climate Zones for Texas



In multi-family housing, the building types include 1 to 3 story units, which contain 2 to 12 residential units. In a similar fashion as single-family residential, heating/cooling system types included electric resistance, heat pump or natural gas heating; electric or natural gas domestic water heating, and air-conditioning. The percentages of house/system types were also determined by the NAHB builder's survey form.

[10] The number of new residences in each county was determined from the Real Estate Center (RECenter 2005), and consisted of 1-story or 2-story, slab-on-grade, or crawlspace statistical distributions.
[11] This used a specially-created version of eGRID for all utilities in ERCOT projected to the year 2007, which was created by Art Diem at the USEPA for the TCEQ. eGRID can be found at www.epa.gov/airmarkets/egrid/.
[12] EPA AP42 Project, 2003, www.epa.gov/ttn/chief/ap42/ap42supp.html.

Figure 3. Overall Analysis Method for Calculating Energy and Emissions Savings from Energy Efficiency/Renewable Energy Projects



In commercial buildings, the procedure used is shown in **Figure 4**. In this procedure it was assumed that buildings built prior to September 2001[13] were built to be compliant with ASHRAE Standard 90.1-1989. After September 2001, buildings were assumed to be compliant with ASHRAE Standard 90.1-1999. New construction for commercial buildings was determined by merging information from three data sources. First, new construction activity by county was obtained from the Dodge MarkeTrack database (Dodge 2005), which provides the square footage of 12 building types by county. Energy savings from the adoption of ASHRAE Standard 90.1-1999 over 90.1-1989 was determined from the USDOE's 2004 report on ASHRAE Standard 90.1-1999 (USDOE 2004), which included 7 building types. Next, as shown in **Figure 4**, the 12 Dodge building types were merged into the 7 USDOE building types, using information from CBECS (1995) to provide the annual energy savings by building type for each county. Then, using a DOE-2 code-compliant simulation for an office/retail building, annual/OSD ratios were created for the electricity and natural gas savings (Ahmed 2005b). The electricity savings for each county were then converted to NO_x reductions using eGRID. Natural gas savings were converted using the EPA's conversion factors for the specific appliance/system.

Using these procedures, the estimated electricity savings for code-compliant residential and commercial construction[14] in 2005 were determined to be 347,938 MWh/year, which included single-family (SF) savings of 263,656 MWh/year (180 tons-NO_x/year), multi-family (MF) savings of 9,210 MWh/year (6 tons-NO_x/year), and commercial (CO) savings of 75,072 MWh/year (49 tons-NO_x/year). Natural gas savings (SF, MF and CO) were 699,737 MBtu/year (32 tons-NO_x/year). Total NO_x emissions reductions (electricity and natural gas) were 267 tons-NO_x/year.

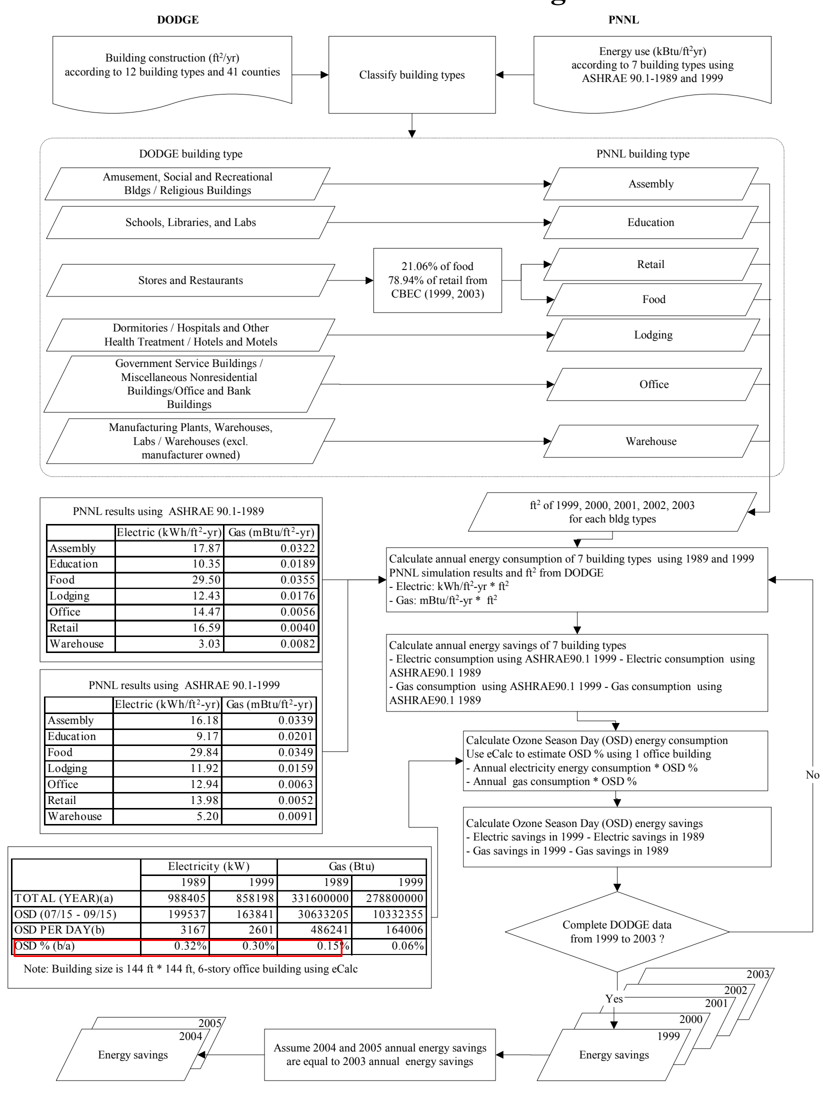
On an ozone season day (OSD) the 2005 estimated electricity savings for code-compliant residential and commercial construction were determined to be 1,795 MWh/OSD, which included single-family (SF) savings of 1,298 MWh/OSD (0.88 tons-NO_x/OSD), multi-family

[13] September 2001 is the date that the 2001 Senate Bill 5 Legislation mandated code compliance. This assumption is based, in part, on the results of a survey conducted in 2004 of architects and engineers who design commercial buildings in Texas.

[14] In 2005, it is estimated that there were 128,804 single family residences; 29,972 multifamily residences, which totaled about 350 million ft2; and 122 million ft2 of commercial building construction. Additional details can be found in the Laboratory's 2005 report to the TCEQ (Haberl et al. 2006).

(MF) savings of 39 MWh/OSD (0.03 tons-NO_x/OSD), and commercial (CO) savings of 457 MWh/OSD (0.29 tons-NO_x/OSD). Natural gas savings (SF, MF and CO) were 1,209 MBtu/OSD (0.06 tons-NO_x/OSD). Total NO_x emissions reductions (electricity and natural gas) were 1.26 tons-NO_x/OSD). **Figure 5** shows the geographical distribution of the OSD electricity savings which corresponds to the most populated areas of the state (i.e., Harris, Tarrant, Collin and Dallas counties). Figure 6 shows the geographical distribution of the corresponding NO_x reductions calculated by eGRID for the electricity generation facilities expected to be in the state in 2007. Comparison of the location of the electricity savings (**Figure 5**) to the location of the pollution savings (Figure 6) emphasizes the importance of the use of county-wide NO_x distributions available in eGRID.[15]

Figure 4. Analysis Method for Calculating Energy and Emissions Savings from Commercial Buildings



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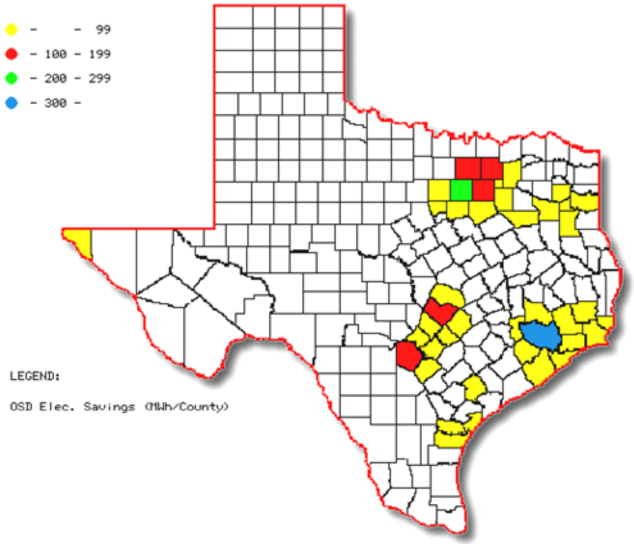
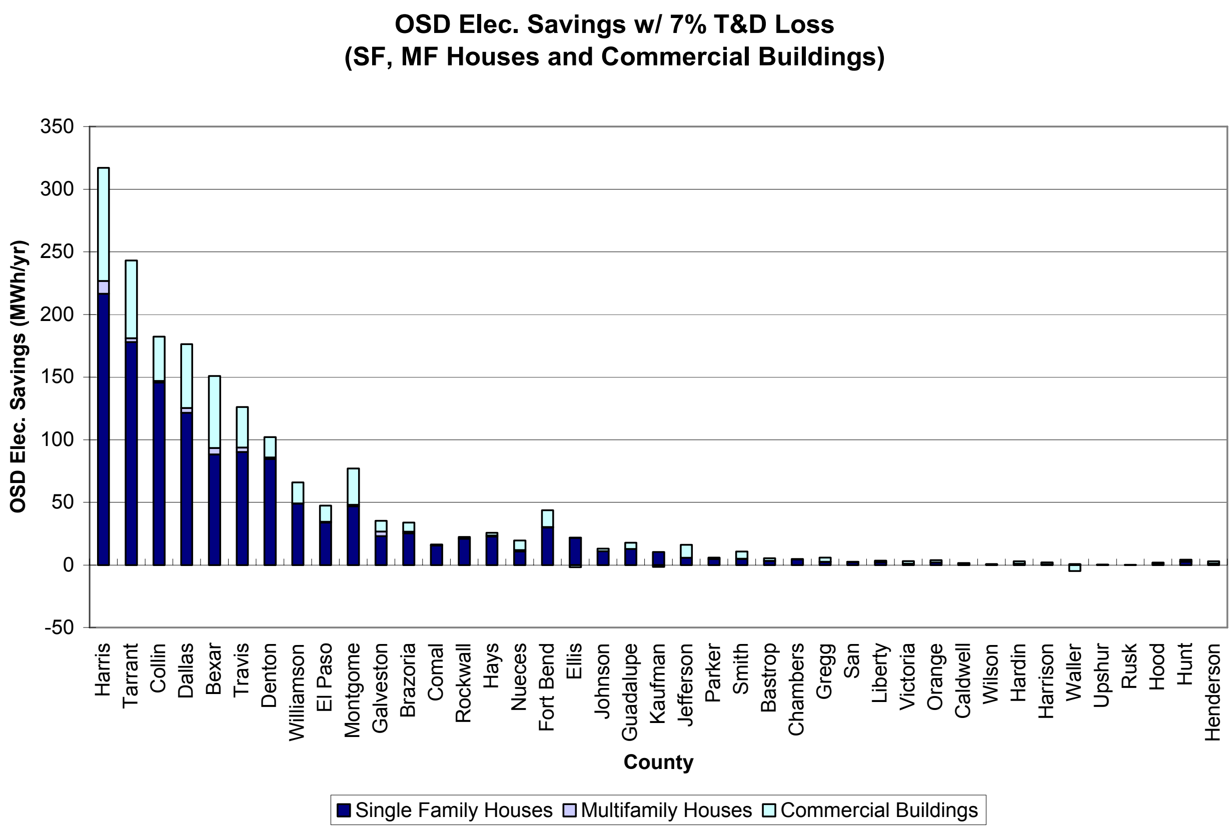
[15] In Figure 5, the bar graph shown compares with the left portion of the bar graph in Figure 6. The right side of eh bar graph in Figure 6 represents counties where the pollution is saved in counties outside the metropolitan area. In most instances, these represent rural counties where large power plants are located.

Figure 5. 2005 OSD Electricity Reductions from IECC / IRC by PCA for Single-Family, Multi-Family Residences, and Commercial Buildings by County





Determination of Integrated NO_x Emissions across State Agencies

In 2005, the TCEQ initiated a program to develop estimates of cumulative NO_x emissions reduction across all the Texas state agencies participating in the EE/RE programs of the TERP for purposes of consideration in the SIP. To accomplish this, uniform accounting procedures needed to be applied to the reported energy savings that incorporated the EPA required degradation, discount, growth, and T&D losses.[16, 17] Figure 7 provides a flowchart of the overall process that was established for reporting energy savings and the conversion of savings into creditable annual and OSD NO_x values. For each agency, this required reporting the energy savings by county or utility provider. The 2007 eGRID values for annual and OSD were then applied for each utility to determine the NO_x emissions reduction by county, by agency and total emissions reductions. Figure 8 provides a summary graph of the cumulative electricity and NO_x emissions reductions for the OSD. In 2009, OSD savings are expected to be 15.42 tons-NO_x/OSD, which represents 4.47 tons-NO_x/OSD from new residential construction, 3.98 tons-NO_x/OSD from PUC SB5 and SB7 programs,[18] 1.29 tons-NO_x/OSD from SECO programs,[19] and 5.69 tons-NO_x/OSD from green power purchases[20] (i.e., wind).

Summary

This paper provides a discussion of the procedures that have been used to calculate the electricity savings and NO_x reductions from new code-compliant residential and commercial construction in non-attainment and affected counties, energy efficiency projects from utility programs, and emissions reductions from green power purchases in Texas. These procedures include weather-normalization of energy savings to allow for the calculation of NO_x emissions reductions during the base year and in future years using projections of new utility plants. This paper also discusses the efforts to develop integrated procedures across several state agencies that follow the US EPA's Guidance document for NO_x emissions reductions for State Implementation Plans for EE/RE programs.

In Texas, the promise of SIP credit for EE/RE projects has stimulated discussions among city planners and state officials about how to make buildings more efficient and how this efficiency can be translated in to creditable NOx emissions reductions – something that was only roughly estimated a few years ago. Also, the procedures discussed in this paper represent a first-of-a-kind effort by any state or national lab to develop creditable NOx emissions reductions from EE/RE projects. Previous efforts by other states have usually resulted in average emissions factors applied to statewide average assumptions. In Texas, emissions reductions been now been traced back to specific power plants, using county-level data from the EPA's eGRID database. The new methodology provides, for the first time, county-wide emissions offsets for specific EE/RE measures to help the state demonstrate compliance with the Federal Clean Air Act. These

[16] See the TCEQ Guide: Incorporating Energy Efficiency/Renewable Energy (EE/RE) Projects into the SIP: A Guide for Local Entities. (TCEQ 2004).

[17] Values used for TCEQ cumulative, integrated emissions calculations include: 5% annual degradation factor (ESL, SECO, PUC, Wind), 7% T&D losses (ESL, PUC, SECO), 0% T&D losses (wind), 20% discount factor (ESL), 25% discount factor (PUC, Wind), 60% discount factor (SECO). Growth rates used were 3.25% (ESL-MF), 1.54% (ESL-SF), 0% (PUC, SECO), 17% (Wind, approx. 3,700 MW, installed by 2009).

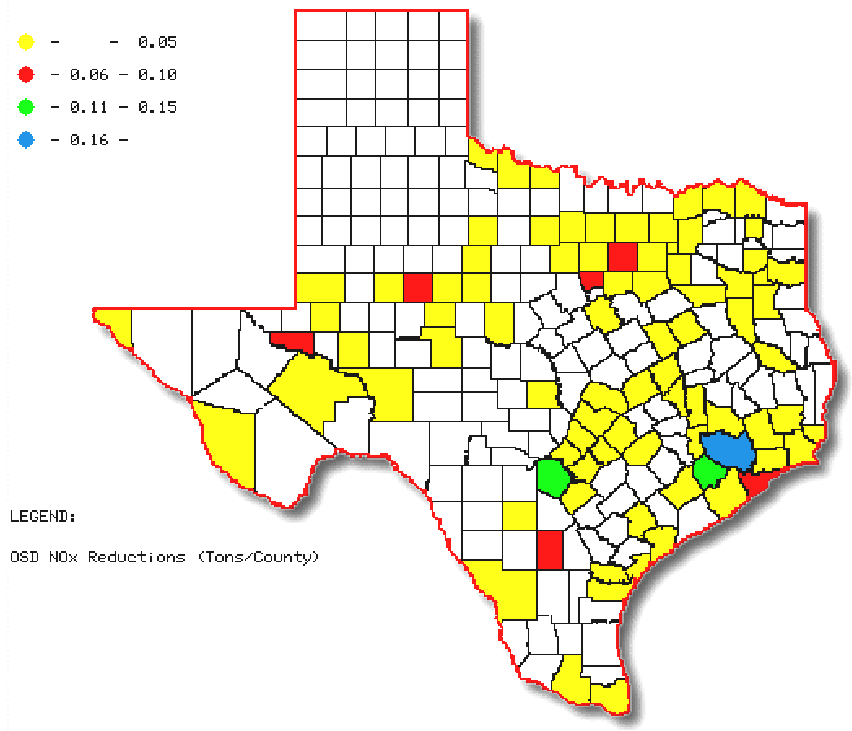
[18] The Public Utility Commission's SB5 and SB7 load reduction programs included savings from AEP, Centerpoint, TXU, TNMP, Entergy and Xcel Energy.

[19] In 2004 SECO reported energy savings from 154 municipal retrofit projects, which included primarily ESCO-funded projects. Some of the largest projects included the City of Dallas, the City of Ft. Worth, City of Gregg, City of Austin, City of Denton, City of Carrollton, and the City of Galveston.

[20] The installed green power sites included over 32 wind farms located in the state. These find farms generated power that offset power sold by TXU (106 TWh/yr = 106,000,000 MWh), Reliant (104 TWh/yr), Entergy (33 GWh), AEP (33 GWh), San Antonio Public Service (15 TWh), El Paso Electric (3 TWh), LCRA (12 TWh), TNMP (10 TWh), and Austin Energy (4 TWh).

county-level emissions reductions allow air modelers to calculate emissions reductions by region, by utility provider, or for the whole state.

Figure 6. 2005 OSD NO_x Reductions from Electricity and Natural Gas Savings Due to the IECC / IRC for Single-Family, Multi-Family Residences, and Commercial Buildings by County (Using 2007 eGRID)



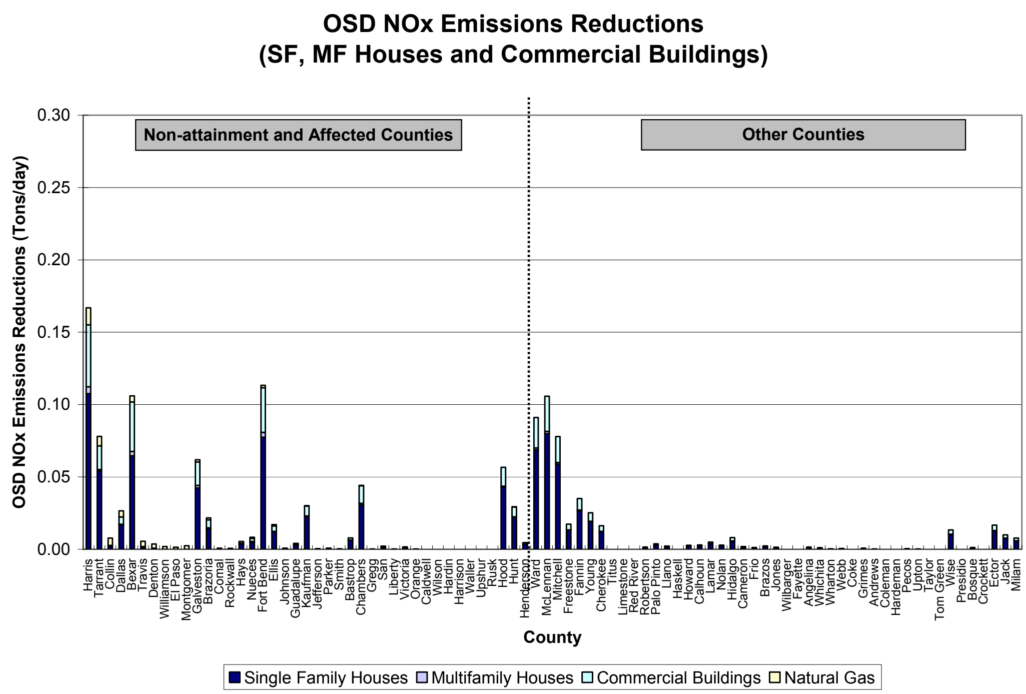


Figure 7. Process Flow Diagram of the NO_x Emissions Reduction Calculations

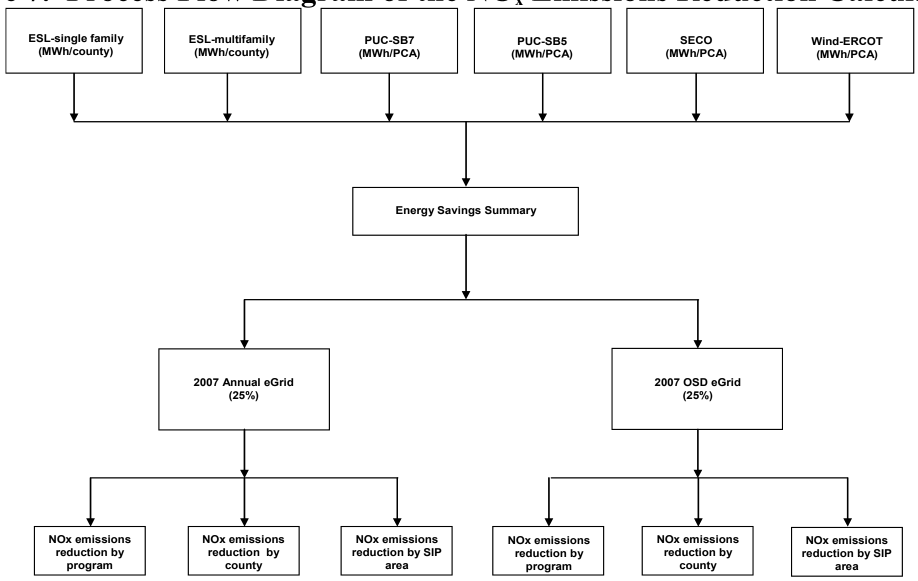
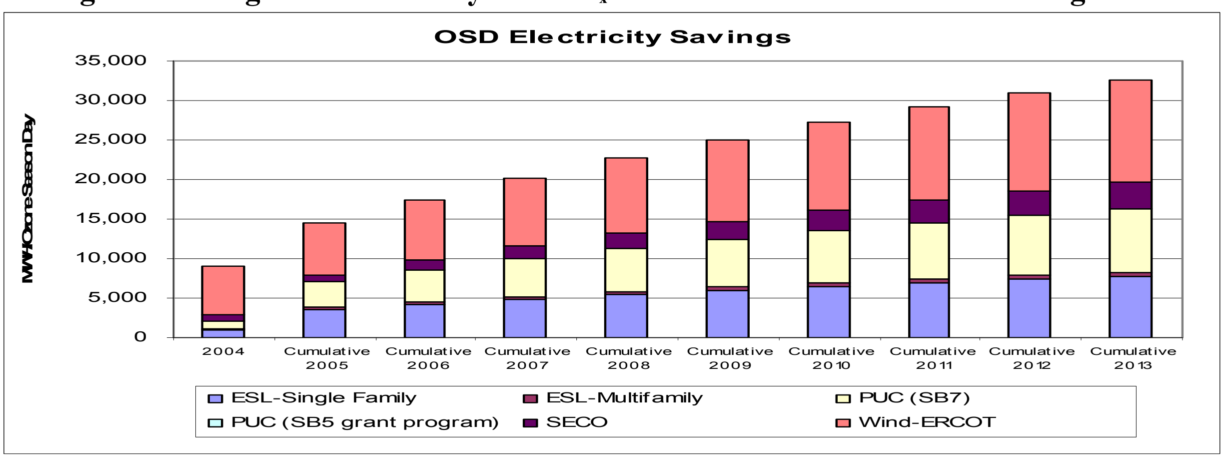
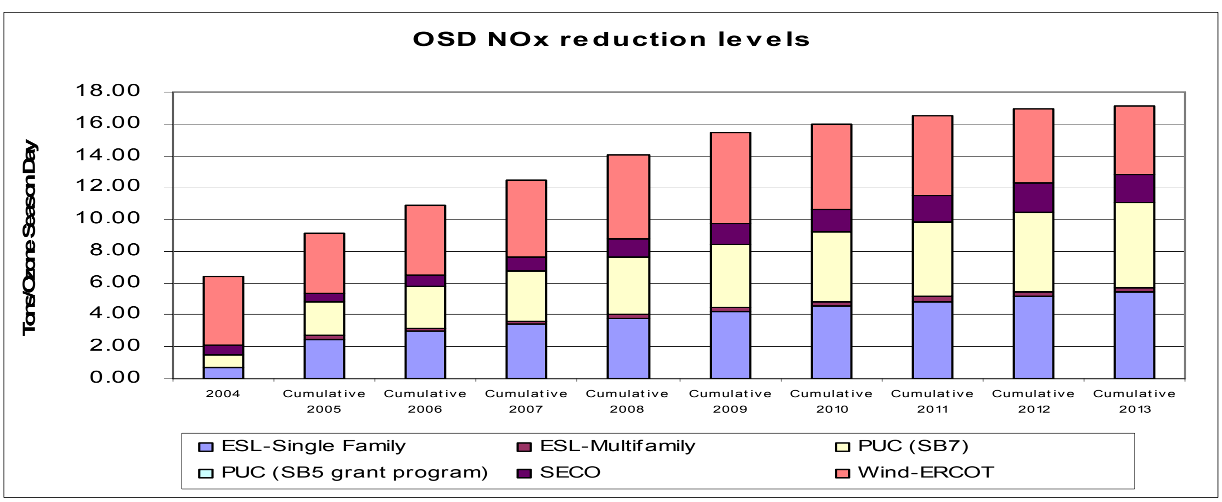


Figure 8. Integrated Electricity and NO_x Emissions Reductions 2004 through 2013





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