ENERGY SYSTEMS LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

Energy Efficiency and Renewable Energy Impacts on NOx Emission Reductions in Texas

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2021 TEXAS ENERGY SUMMIT
TEXAS ENERGY SUMMIT
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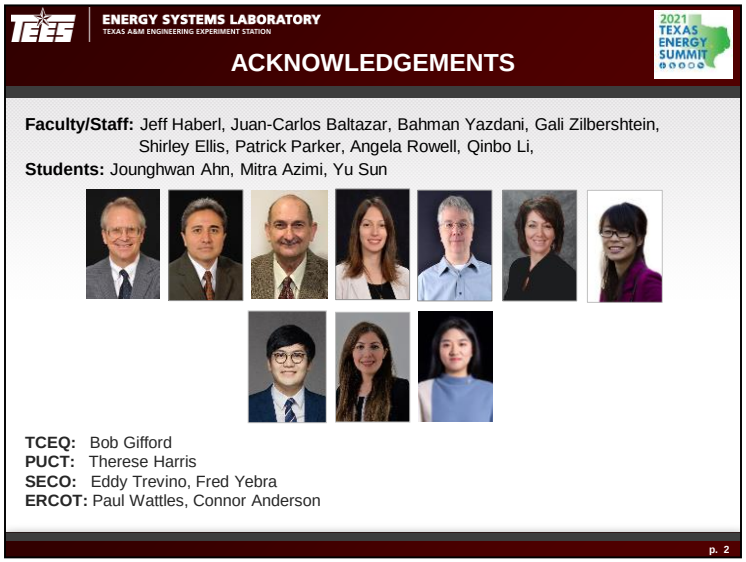
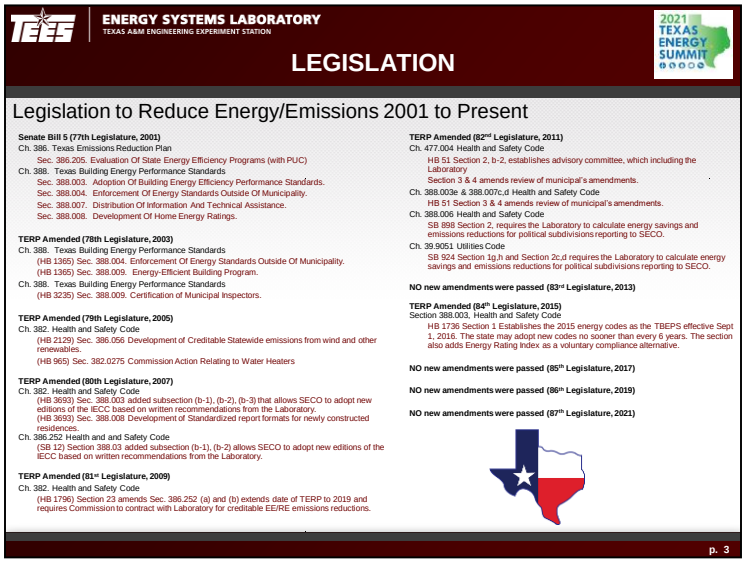


This work is the team effort of Texas Emissions Reductions Program (TERP) at the Energy Systems Laboratory at Texas A&M, which includes (left to right):

Jeff Haberl, Juan-Carlos Baltazar, Bahman Yazdani, Gali Zilbershtein, Shirley Ellis, Patrick Parker, Angela Rowell, Qinbo Li, and graduate students Jounghwan Ahn. Mitra Azimi and Yu Sun.

This effort would not be possible without the effort of numerous individuals at other Texas State Agencies, including: Mr. Bob Gifford at the TCEQ; Ms. Therese Harris at the PUC

Texas; Mr. Eddy Trevino and Mr. Fred Yebra at SECO, and Mr. Paul Wattles and Connor Anderson at ERCOT.



Texas has had Legislation since 2001 to reduce air pollution, which includes Energy Efficiency and Renewable Energy (EE/RE).

These begin with the original legislation in the 77th Legislature in 2001 – Senate Bill 5.

This was followed by amendments in the 78th Legislature in 2003;

Amendments in the 79th Legislature in 2005;

Amendments in the 80th Legislature in 2007;

Amendments in the 81st Legislature in 2009;

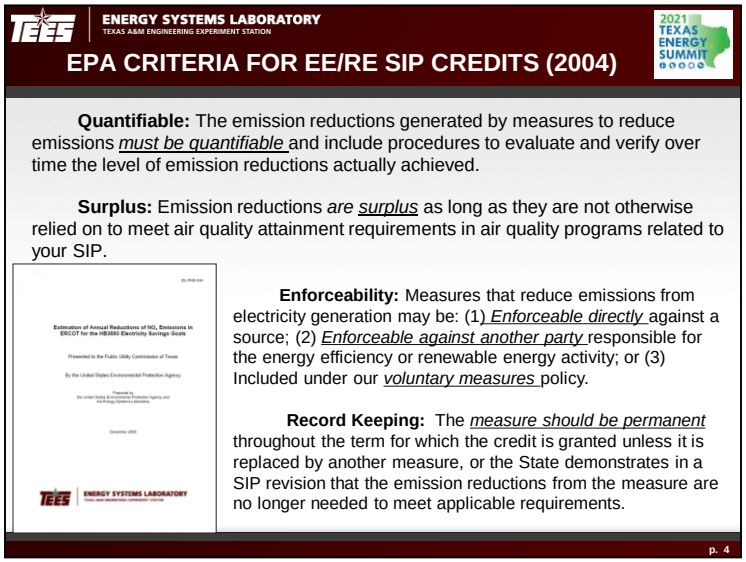
Amendments in the 82nd Legislature in 2011;

Amendments in the 83rd Legislature in 2013; and

Amendments in the 84th Legislature in 2015.

No new amendments were passed in the 85th Legislature (2017), the 86th Legislature (2019) and the 87th

Legislature (2020).



Currently, the State of Texas follows the Criteria set forth by the U.S.E.P.A. in 2004 for determining State Implementation Credits (SIP).

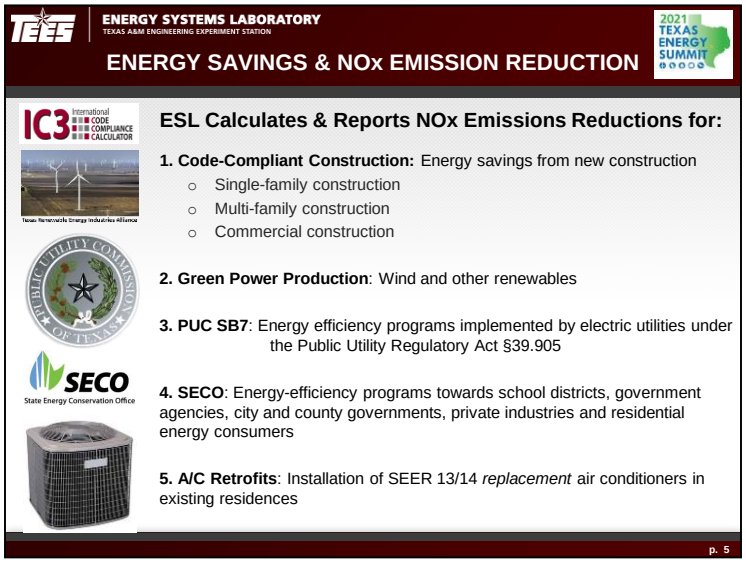
These credits certify that the emissions reductions are Quantifiable, Surplus, Enforceable and that proper Record Keeping is performed.

Quantifiable: The emission reductions generated by measures to reduce emissions *must be quantifiable* and include procedures to evaluate and verify over time the level of emission reductions actually achieved.

Surplus: Emission reductions *are surplus* as long as they are not otherwise relied on to meet air quality attainment requirements in air quality programs related to your SIP.

Enforceability: Measures that reduce emissions from electricity generation may be: (1) *Enforceable directly* against a source; (2) *Enforceable against another party* responsible for the energy efficiency or renewable energy activity; or (3) Included under our *voluntary measures* policy.

Record Keeping: The *measure should be permanent* throughout the term for which the credit is granted unless it is replaced by another measure or the State demonstrates in a SIP revision that the emission reductions from the measure are no longer needed to meet applicable requirements.



The Energy Savings and NOx Emissions Reduction From Energy Efficiency and Renewable Energy are calculated from five areas:

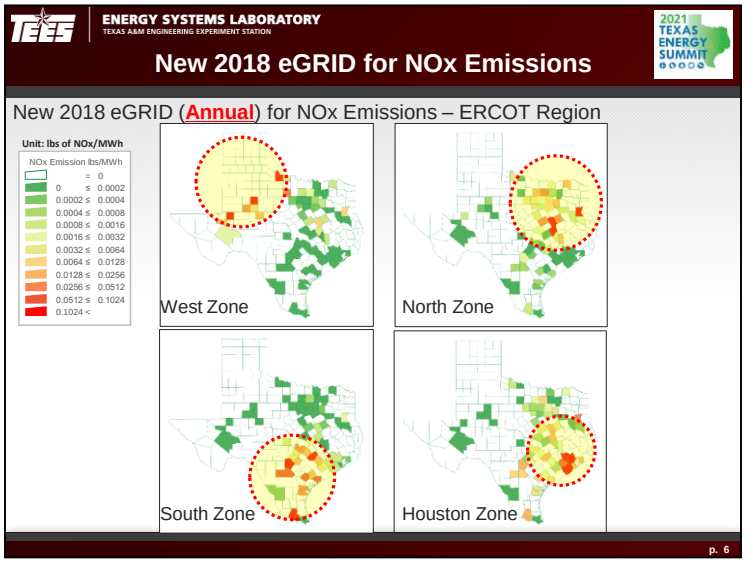
1. Code-Compliant Construction: Energy savings from new construction: Single-family construction, Multi-family construction, Commercial construction

2. Green Power Production: Wind and other renewables

3. PUC SB7: Energy efficiency programs implemented by electric utilities under the Public Utility Regulatory Act § 39.905

4. SECO: Energy-efficiency programs towards school districts, government agencies, city and county governments, private industries and residential energy consumers

5. A/C Retrofits: Installation of SEER 13/14 *replacement* air conditioners in existing residences



To calculate the NOx emissions reductions in 2020, we used the 2018 version of the USEPA's Emissions & Generation Resource Integrated Database (eGRID).

eGRID 2018 is the national database of air pollution or emissions data from electric power plants, which includes:, the lbs/MWh for NOx, SOx, CO2 and other pollutants for 2018, which is the version of eGRID chosen by the Texas Commission on Environmental Quality (TCEQ).

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This slide shows the 2018 eGRID Annual NOx emissions by the West, North, South and Houston ERCOT load zones. In the map the red or orange counties represent those counties with a large concentration of NOx emissions (lbs/MWh) from electric power production facilities in that county.

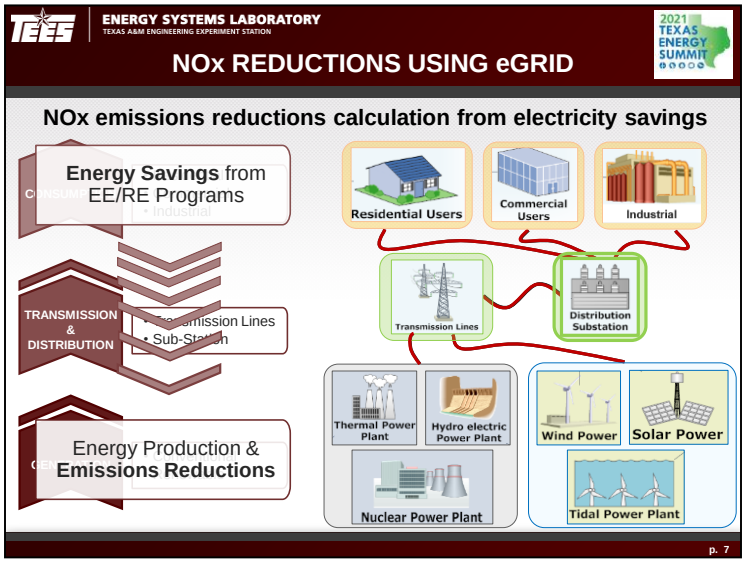
Non-ERCOT zones (not shown) are

WECC = Western Electric Coordinating Council,

SPP = Southwest Power Pool and

MISO = Midcontinent Independent System Operator

A similar map of the NOx emissions (lbs/MWh) during the Ozone Season Period (OSP) is also maintained for all ERCOT loads zones.

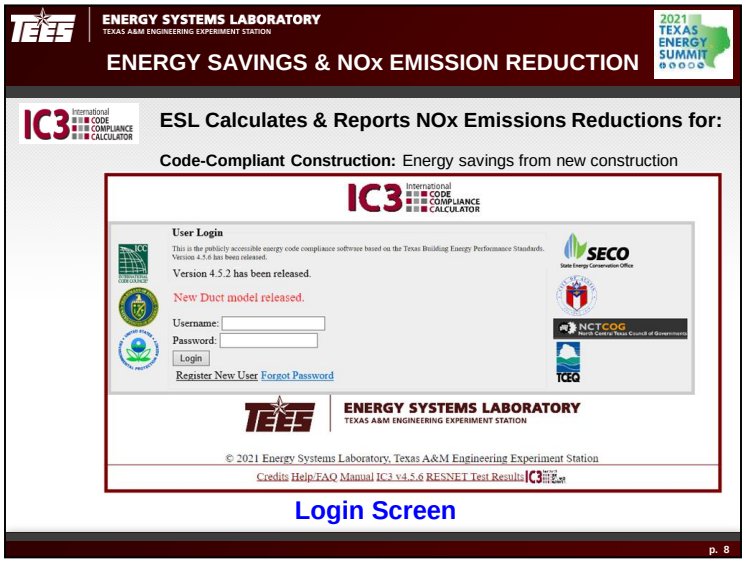


The total NOx emission reductions from energy efficiency and renewable energy is calculated using a process called displaced emissions.

First, the conventional electricity generation (thermal, hydro, nuclear) is mapped onto the ERCOT transmission grid along with the renewables (wind, solar (PV & thermal power), as well as tidal power plants (future). This electricity is then traced down to the local distribution stations where it serves residential, commercial and industrial customers.

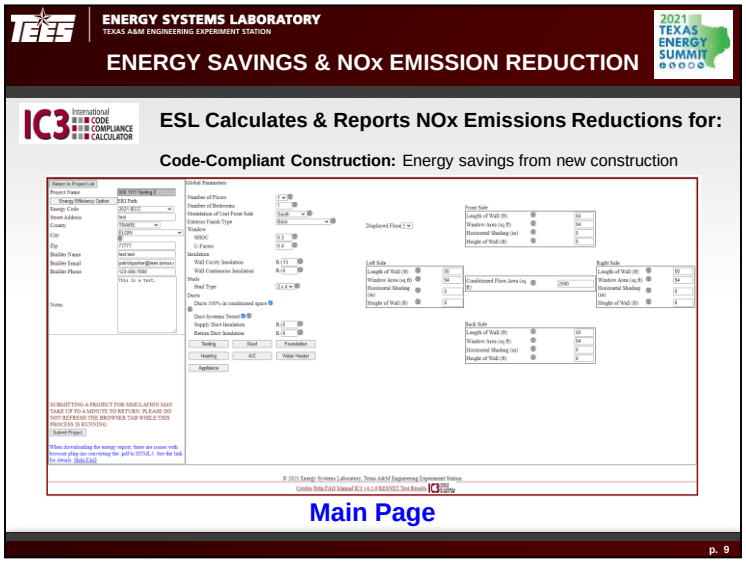
Then the electricity savings from code-compliance in residential, commercial and industrial utility customers AND the electricity generated from renewables sources is added together to displace the electricity that was not generated by the combustion of fossil fuels for the baseyear determined by TCEQ and EPA.

Sometimes it is easier to understand this process with a diagram like this.



The Energy Savings and NOx Emissions Reduction From Single-Family Residential New Construction is calculated with the assistance of the publically-available International Code Compliance Calculator (IC3), which was developed by the Energy Systems Laboratory.

This is the LOGIN screen for IC3.



This is the main data entry screen for IC3, which includes general information about the project (i.e., address, building name, phone number, etc.).

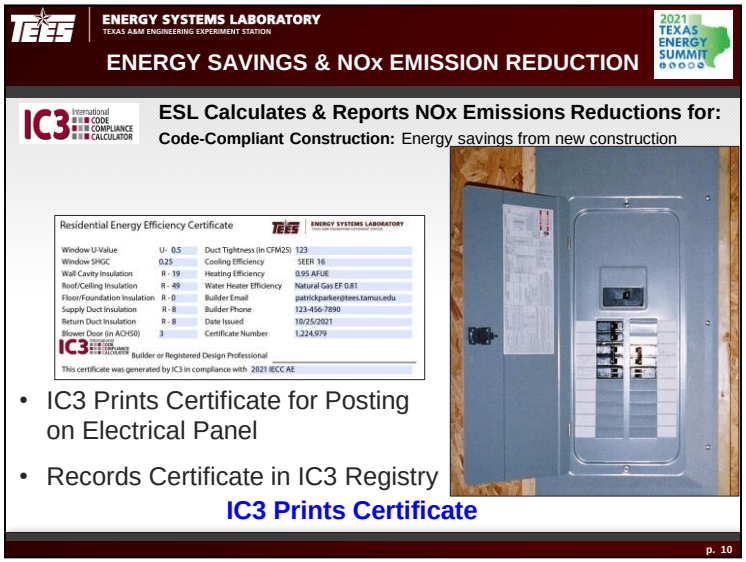
It also provides a choice as to whether the IC3 user chooses to follow the “performance path” or the “ERI Simulation Path” for code-compliance with the IECC.

On the right side of the screen are inputs that describe the house, including: number of floors, bedrooms, window information, details about the insulation levels, ductwork, and the dimensions of the house.

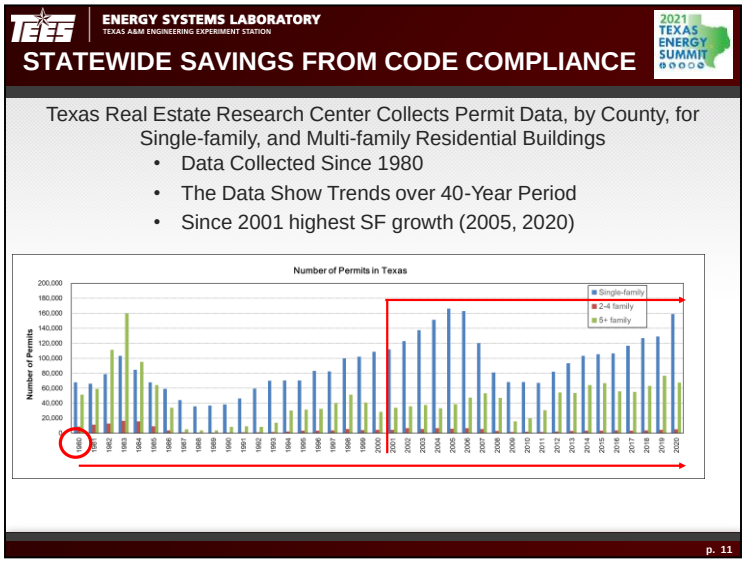
Six additional tabs are included so the user can enter information about: infiltration testing, roof, foundation, heating system, cooling system, and the domestic water heater.

Each of these inputs also have a “help” tab where the user can go to get help about what is being entered.

This screenshot is from IC3 in 2021.



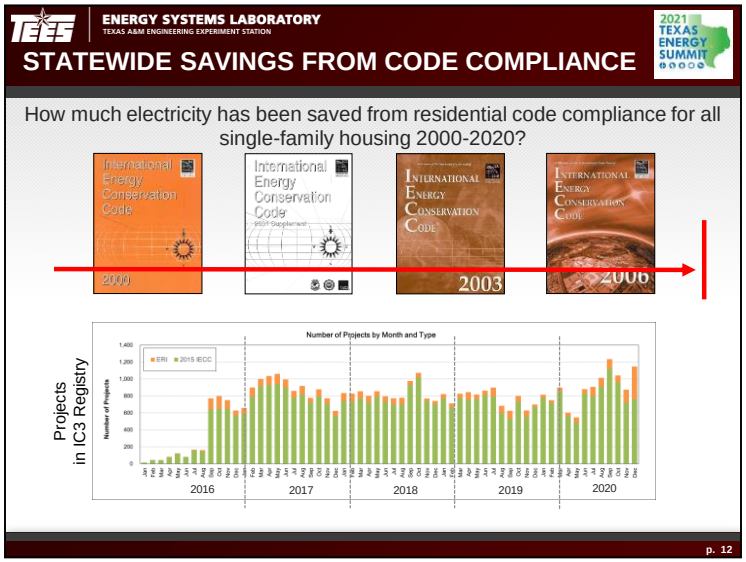
Once the information is entered, and the house complies with the IECC energy code a certificate is generated that can be posted on the electrical panel of the house. This certificate is then entered into the IC3 Registry that is maintained at the ESL.



To calculate the statewide energy savings from code-compliant housing the ESL relies on permit data published by the Real Estate Center (RECenter) at Texas A&M.

This graph shows the SF and MF housing starts from 1980 to 2020. Data from the RECenter is available for each county in Texas.

Since 2001 the SF permits have varied by 2:1 with the highest growth occurring in 2005 and 2020.

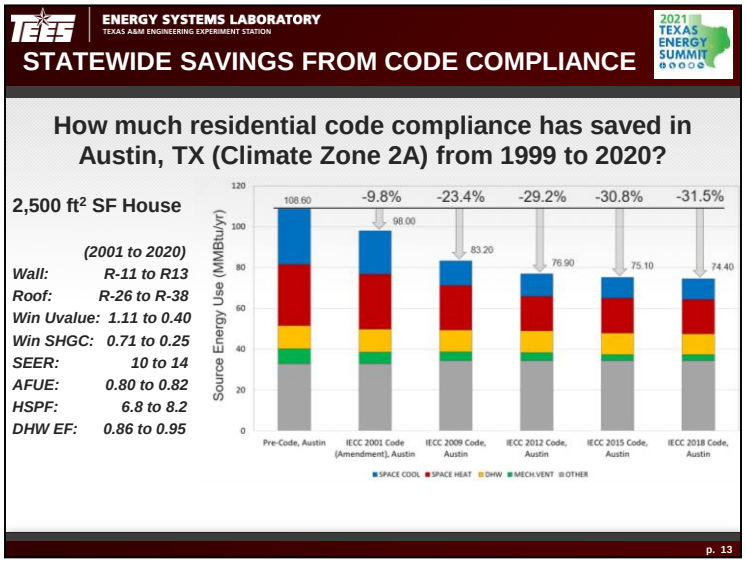


Since 2001 the IECC has been updated seven times, including: the 2001 Supplement, the 2003 IECC, 2006 IECC, 2009 IECC, 2012, 2015 IECC and most recently the 2018 IECC.

Since its inception, the ESL has been recording the certificates generated by IC3. This graph shows the number of certificates generated from the 2015 IECC onward, including those certificates that followed the performance path (green) and those certificates that followed the ERI path (orange).

The graph on this slide shows the number of projects (certificates+practice runs) through September of 2020, which includes a drop in usage by COVID-19 in April and May, which picked-up again in June and continued pretty much business as usual through September.

Depending on the month, there are usually about 800 to 1,000 IC3 certificates issued each month (about 26 to 33 per day, 7 days per week).



Since the 2000/2001 IECC was adopted by the state of Texas in 2001 there have been significant changes to the Residential Energy Building Code.

For example, in Austin, SOURCE energy use for a 2,400 ft2 single family residence, built to code has decreased by 31.5% (Pre-code to IECC 2018).

+ The Wall R-Value has gone from R-11 to R-13, the Roof insulation has gone from R-26 to R-38.

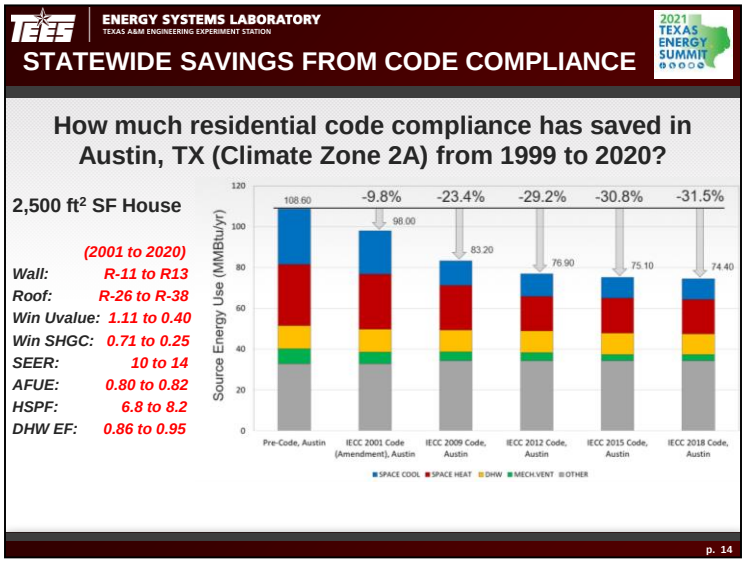
+ The Window U-factor has gone from 1.11 to 0.40, Window SHGC has gone from 0.71 to 0.25

+ The SEER from 10 to 14,

+ AFUE from 0.8 to 0.82,

+ HSPF from 6.8 to 8.2,

+ DHW EF from 0.86 to 0.95



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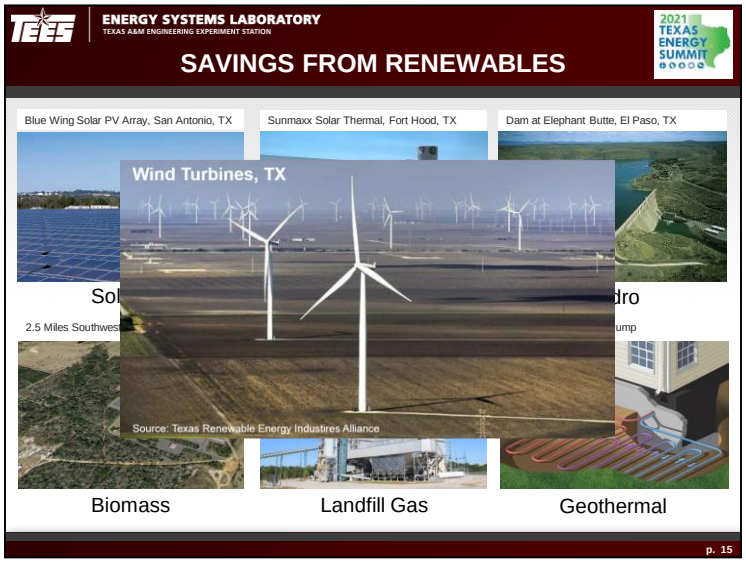
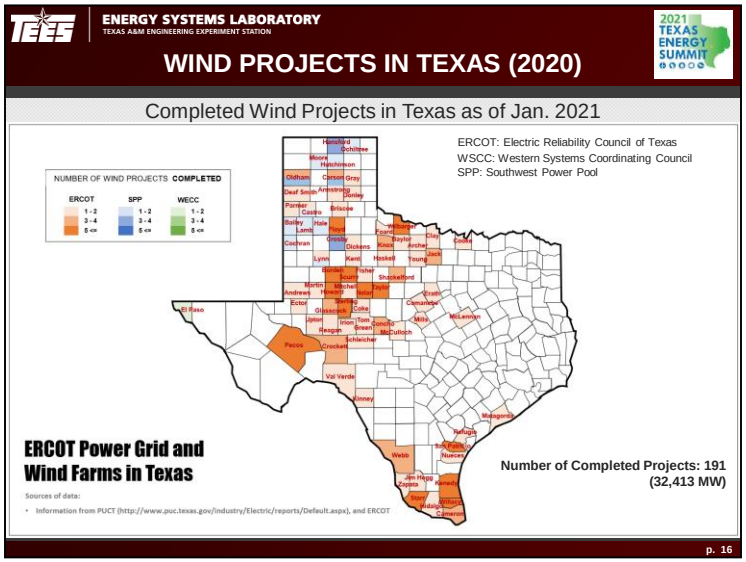
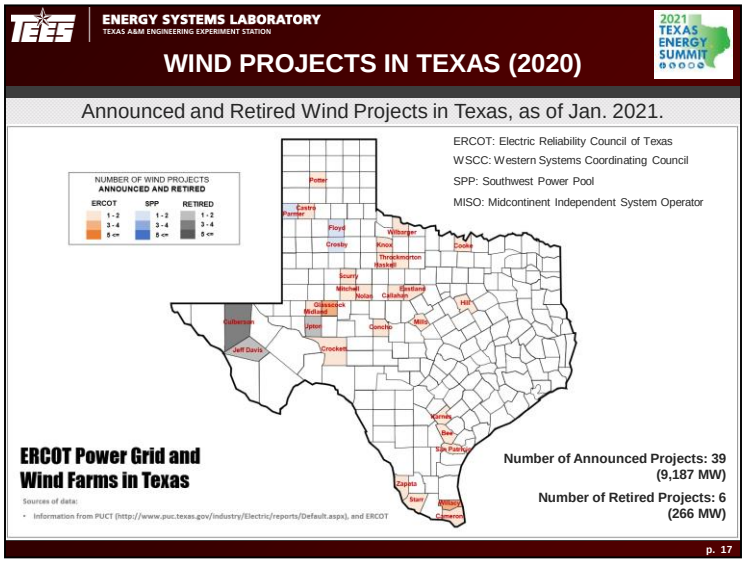


Texas has also had significant NOx emission reductions from the growing amount of renewable energy generated Statewide.

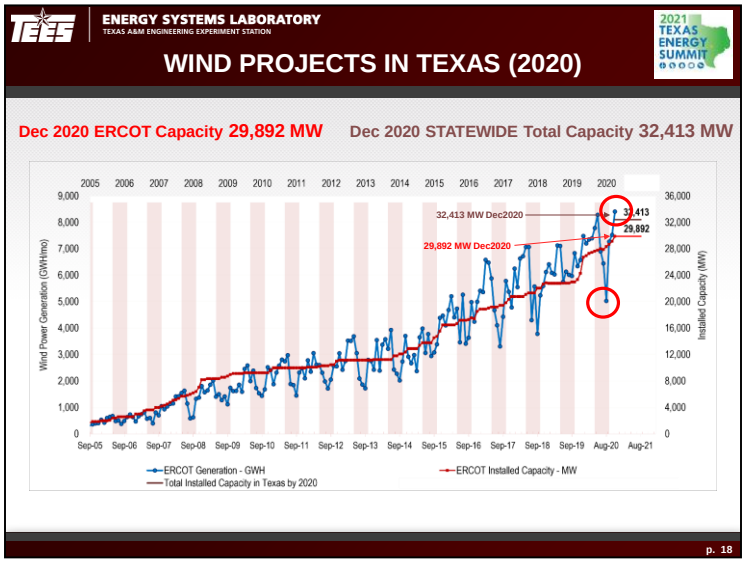
These include: solar PV, solar thermal, hydroelectric, biomass, landfill gas and geothermal sites.



In 2020 the number of completed projects equaled 191 (32,413 MW) Statewide with the majority of the projects in ERCOT and the Southwest Power Pool (SPP).



As of January 2021, the number of Announced Wind Projects equaled 136 (**9,187** MW). In addition, 6 projects (266 MW) were retired.



By December 2020 the total ERCOT installed capacity was 29,892 MW, and the total capacity Statewide was 32,413 MW.

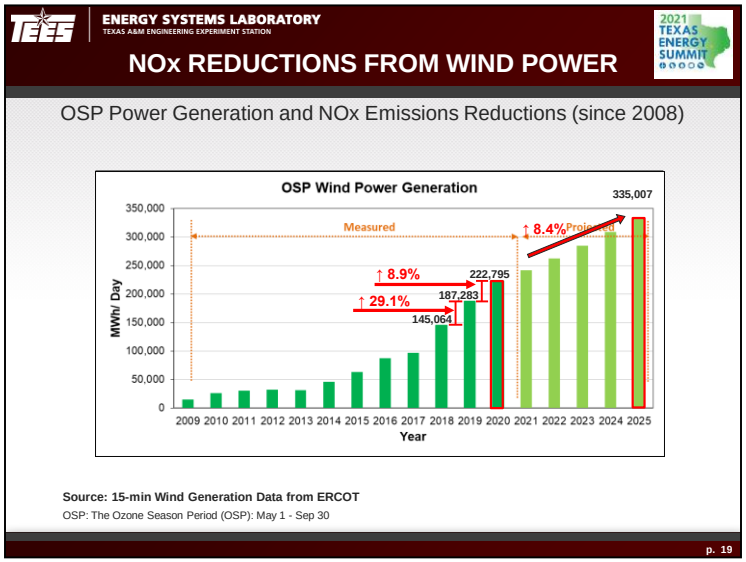
Total wind power generation exceeded 8,500 GWh/mo in 2020.

Wind power varied from apx. 5,000 GWh/mo to 8,500 GWh/mo in 2020.

NOTE: Texas consumed 365,100 GWh in 2020 (USDOE/EIA).

NOTE: Texas largest peak demand 74,820 MW (August 2019).

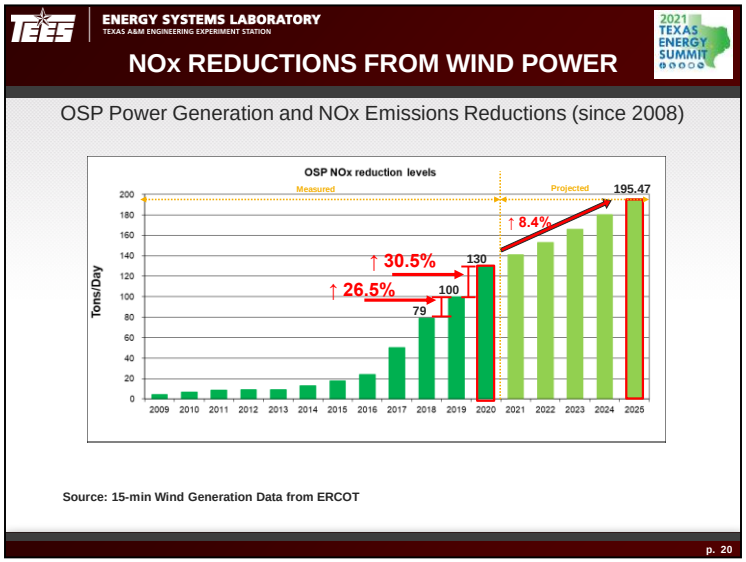
(Ref:https://www.eia.gov/electricity/data/state/Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)1→Final 2020 data re-released on October 8, 2021)



This slide shows the measured OSP electric power generation (MWh/OSD) for 2018, 2019 and 2020, with projections through 2025 that use an 8.4% per year growth rate. These electricity power generation calculations are weather-normalized to the 2008 base year (determined by TCEQ and EPA).

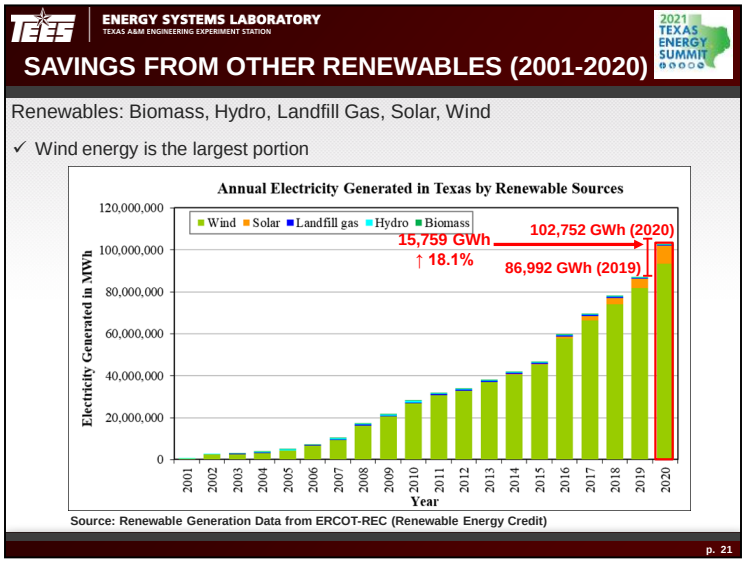
As shown on the graph there was a 29.1% increase from 2018 to 2019 resulting in 187,283 MWh/OSD, and an 8.4% increase from 2019 to 2020 resulting in 227,795 MWh/OSD.

By 2025 the electricity generated by wind is expected to grow to 335,007 MWh/OSD.



Using eGRID the MWh/OSD is translated into NOx emissions, which yields tons of NOx/day for all ERCOT, SPP, SERC and WECC load zones.

In 2018 this amounted to 79 tons of NOx/day, which grew to 100 tons of NOx/day in 2019 and 100 tons of NOx/day by 2020. This is expected to grow at 8.4% per year, which would amount to 195 tons/NOx/day by 2025.

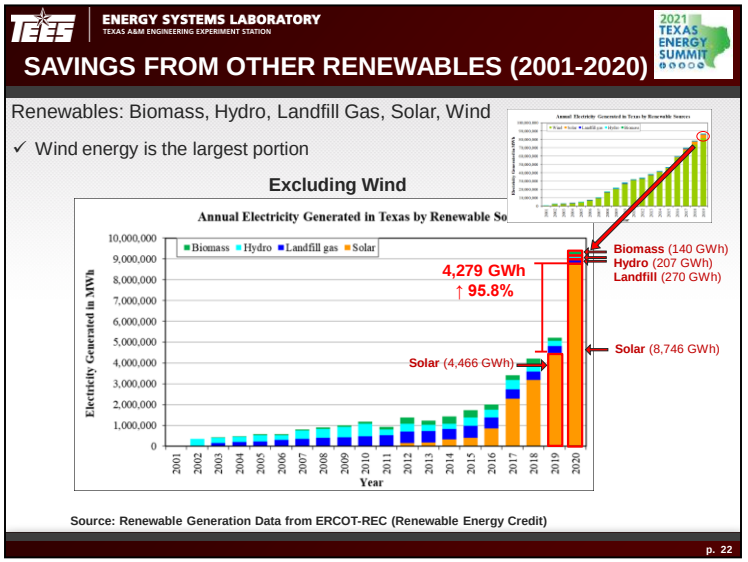


In this graph the total annual electricity generated by all renewables in Texas is shown from 2001 through 2019.

In 2020 102,752 GWh (or 102.75 million MWh) of electricity were generated, which represents a 18.1% increase (15,759 GWh) over the 86,992 GWh that were generated in 2019.

Of this total the largest amount was generated by wind (green portion of the graph), with smaller but growing amounts of electricity generated from solar, landfill gas, hydro and biomass renewable sources.

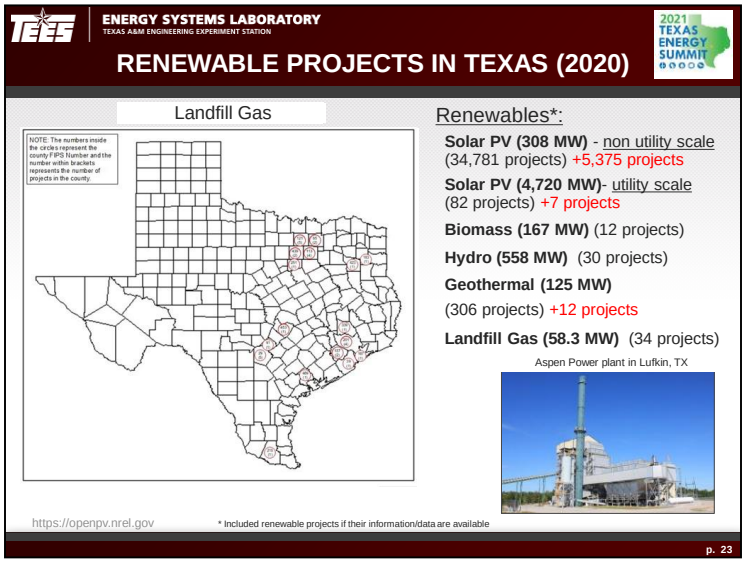
Problem with this graph is that it hides the substantial increase in the other renewables. We can see this more clearly if we look at these values only.



When we remove the wind energy generation and rescale the graph, we see that the enormous increase in solar PV which was 4,466 GWh/yr in 2019, an increase of 40.3% over the 3,183 GWh/year generated in 2018.

Electricity generated by other renewables includes: landfill gas 335 GWh/year, Hydro electric (249 GWh/yr), and biomass (154 GWh/yr).

(Ref: Table 7-2 Wind & other renewables report)



Unfortunately, tracking the energy generated by renewables requires merging data from different sources, including utility and non-utility scale installations. In 2019 there were:

29,406 non-utility scale projects (272 MW), which included 4,747 new projects.

77 utility-scale projects (3,838 MW), which included 21 new projects.

14 biomass projects (183 MW), with no new projects.

30 Hydroelectric projects (557 MW), with no new projects.

294 geothermal projects (125 MW), with 8 new projects.

33 landfill gas projects (58 MW), no new projects.

Sources for the data were:

Non-utility scale installations there were :

NREL data -> LBNL data

Solar PV – utility scale : ERCOT data

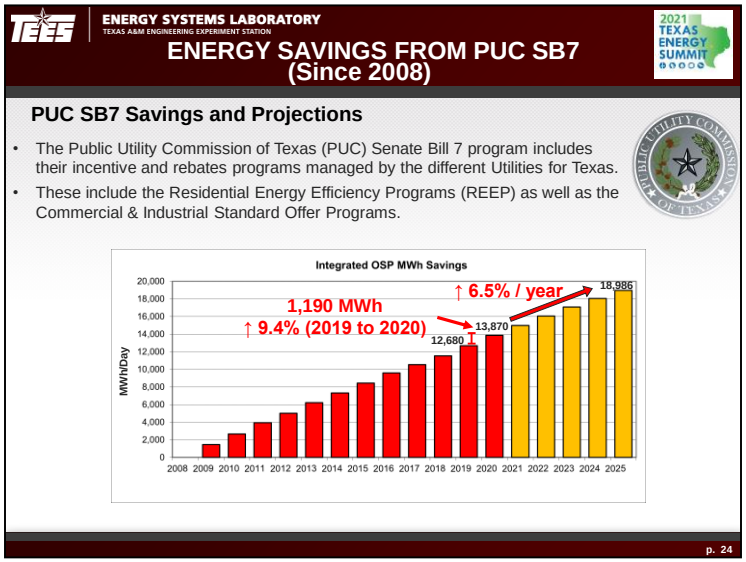
Biomass : ERCOT data

Hydro : ERCOT data

Landfill gas: EPA data

Geothermal : data from various websites (geothermal HVAC industry) (35,659 tons -> 125 MW), multiply the tonnage by 0.003516

*Solar Power is utility Scale

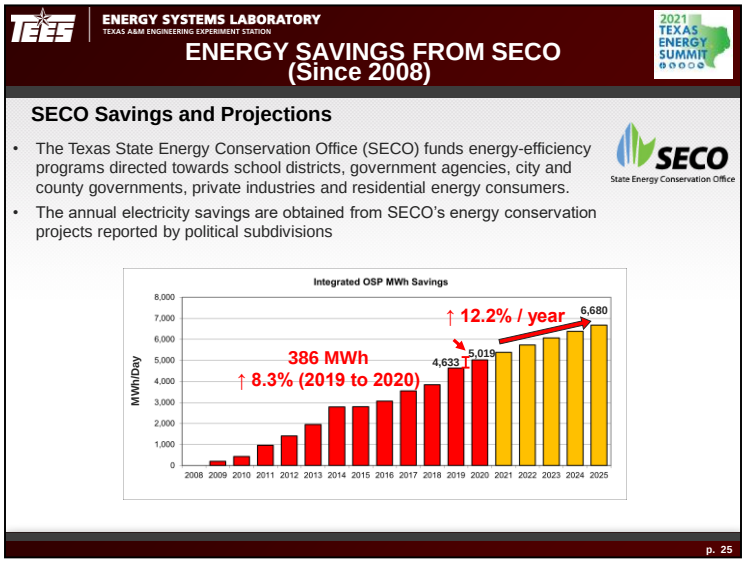


The electricity savings from the PUC Senate Bill 7 program includes

- The Public Utility Commission of Texas (PUC) Senate Bill 7 program that includes their incentive and rebates programs managed by the different Utilities for Texas.
- The Residential Energy Efficiency Programs (REEP) as well as the Commercial & Industrial Standard Offer Programs.

In 2019 12,680 MWh/year were reported, which is an increase of 1,148 MHh/year (10%) over the 2018 values reported by the PUCT

By 2024 this is expected to grow to 17,615 MWh/year (6.5% per year).

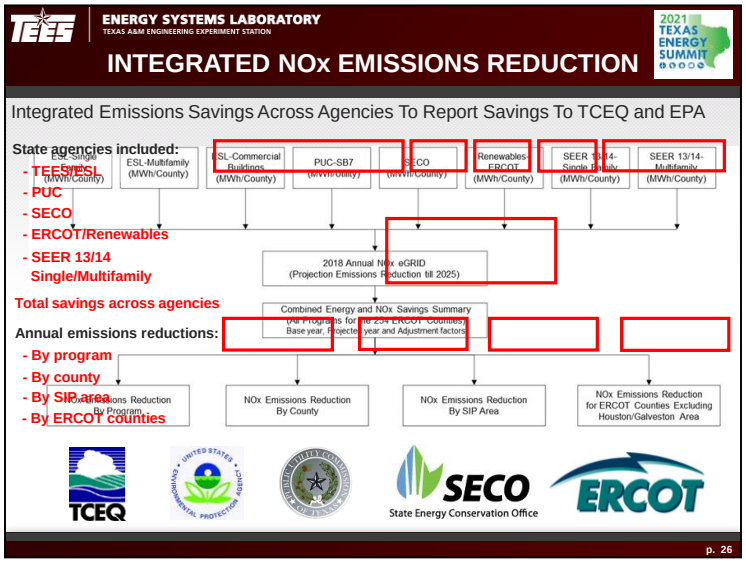


The Texas State Energy Conservation Office (SECO) reports electricity savings from their energy-efficiency programs that serve school districts, government agencies, city and county governments, private industries and residential energy consumers.

The annual electricity savings were obtained from SECO's energy conservation projects reported by political subdivisions.

In 2019 these savings were reported to be 4,633 MWh/year, which represents a 20.6% increase over 2018.

By 2024 these savings are expected to increase to 8,036 MWh/year (12.2% per year increase).



Finally, the NOx emissions savings across Texas State Agencies are then integrated into single value, which includes:

TEES/ESL – SF, MF, Commercial building energy code compliance.

PUC SB7 – the PUC Texas Senate Bill 7 reported program savings.

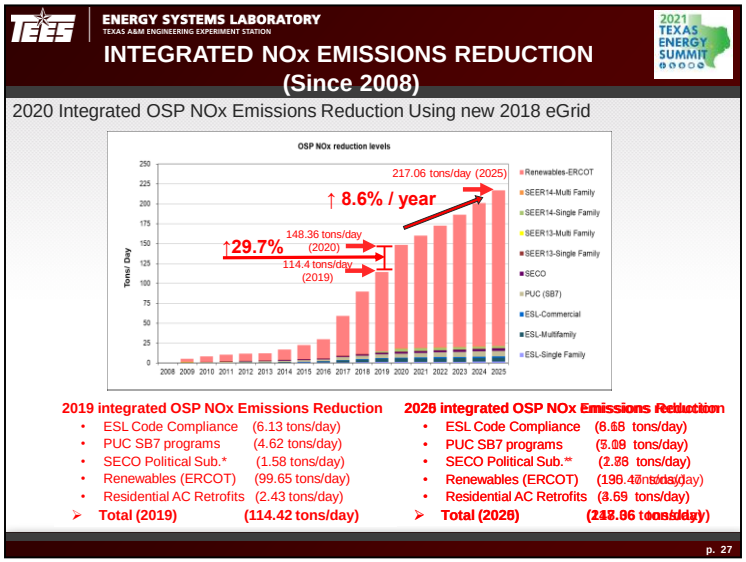
SECO – electricity savings reported for their energy efficiency programs.

ERCOT/Renewables – electricity savings reported by ERCOT, NREL and LBNL

SEER 13/14 – SF and MF air conditioner replacements Statewide.

Calculated using the 2016 eGRID for the 2008 baseyear and projected through 2024

Combined electricity and NOx savings reported: by program, by county, by SIP area, by ERCOT load zones.



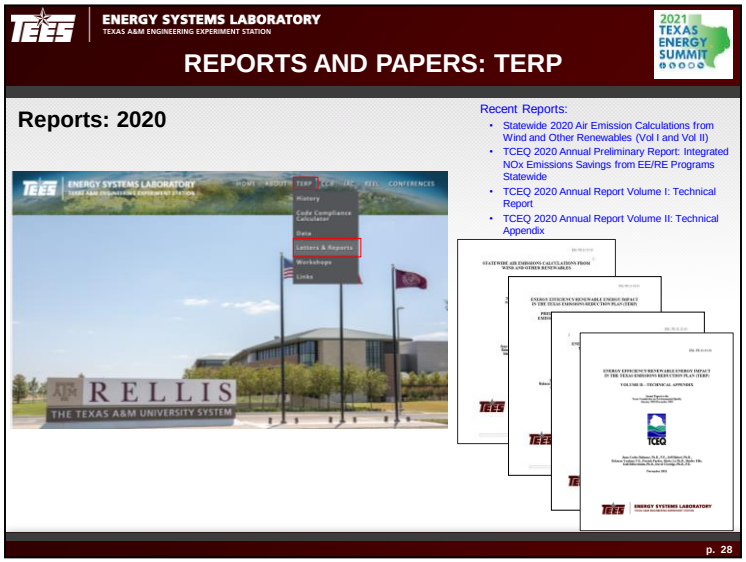
This graph shows the Statewide, integrated NOx Emissions Reduction (2008 baseyear).

In 2019 the NOx emissions were 114 tons/OSD, which is an increase of 27.3% over 2018.

By 2024 the NOx emissions are expected to grow to 173 tons/OSD (8.6% increase per year).

In 2019 the largest NOx emissions were from renewables (99.6 tons/OSD), followed by energy code-compliance (6.13 tons/OSD), PUC SB7 (4.62 tons/OSD), SEER 13/14 retrofits (2.43 tons/day), and SECO energy efficiency programs (1.58 tons/OSD).

Ref: Annual Report Vol 1



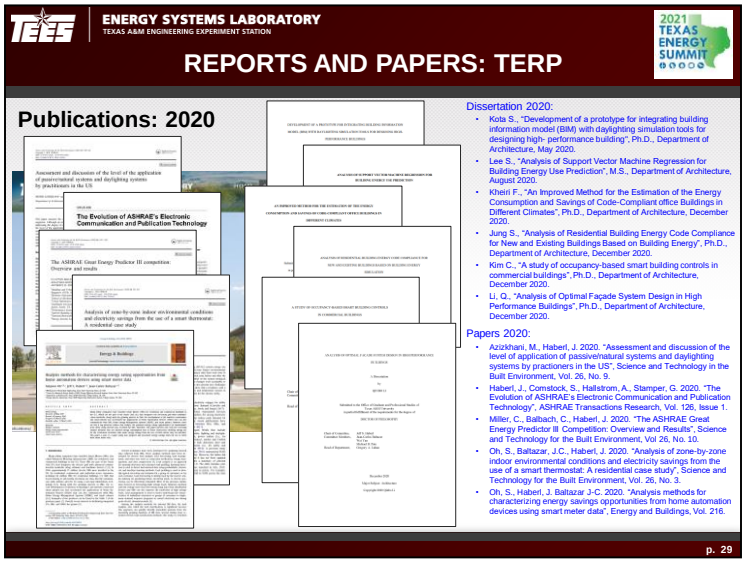
The technical details for the NOx emissions reductions are presented in the ESL's TERP report to the TCEQ (5 volumes):

Statewide 2020 Air Emission Calculations from Wind and Other Renewables (Vol I and Vol II)

TCEQ 2020 Annual Preliminary Report: Integrated NOx Emissions Savings from EE/RE Programs Statewide

TCEQ 2020 Annual Report Volume I: Technical Report

TCEQ 2020 Annual Report Volume II: Technical Appendix



In addition to the TERP reports, other related publications include:

Thesis 2020

Kota S., “Development of a prototype for integrating building information model (BIM) with daylighting simulation tools for designing high- performance building", Ph.D., Department of Architecture, May 2020.

Lee S., “Analysis of Support Vector Machine Regression for Building Energy Use Prediction”, M.S., Department of Architecture, August 2020.

Kheiri F., “An Improved Method for the Estimation of the Energy Consumption and Savings of Code-Compliant office Buildings in Different Climates”, Ph.D., Department of Architecture, December 2020.

Jung S., “Analysis of Residential Building Energy Code Compliance for New and Existing Buildings Based on Building Energy”, Ph.D., Department of Architecture, December 2020.

Kim C., “A study of occupancy-based smart building controls in commercial buildings”, Ph.D., Department of Architecture, December 2020.

Li, Q., “Analysis of Optimal Façade System Design in High Performance Buildings”, Ph.D., Department of Architecture, December 2020.

Papers 2020:

Azizkhani, M., Haberl, J. 2020. “Assessment and discussion of the level of application of passive/natural systems and daylighting systems by practioners in the US”, Science and Technology in the Built Environment, Vol. 26, No. 9.

Haberl, J., Comstock, S., Hallstrom, A., Stamper, G. 2020. “The Evolution of ASHRAE’s Electronic Communication and Publication Technology”, ASHRAE Transactions Research, Vol. 126, Issue 1.

Miller, C., Balbach, C., Haberl, J. 2020. “The ASHRAE Great Energy Predictor III Competition: Overview and Results”, Science and Technology for the Built Environment, Vol 26, No. 10.

Oh, S., Baltazar, J.C., Haberl, J. 2020. “Analysis of zone-by-zone indoor environmental conditions and electricity savings from the use of a smart thermostat: A residential case study”, Science and Technology for the Built Environment, Vol. 26, No. 3.

Oh, S., Haberl, J. Baltazar J-C. 2020. “Analysis methods for characterizing energy savings opportunities from home automation devices using smart meter data”, Energy and Buildings, Vol. 216.

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