ENERGY SYSTEMS LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

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

**** December 2022 Update ****

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TEXAS ENERGY SUMMIT

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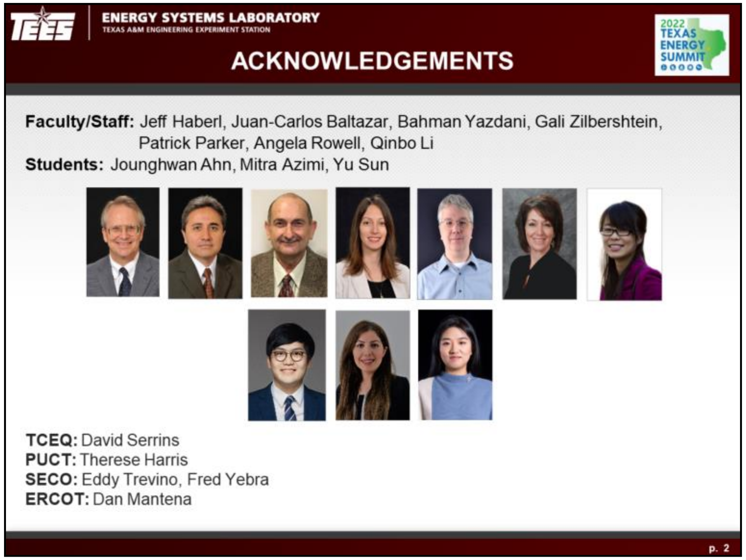
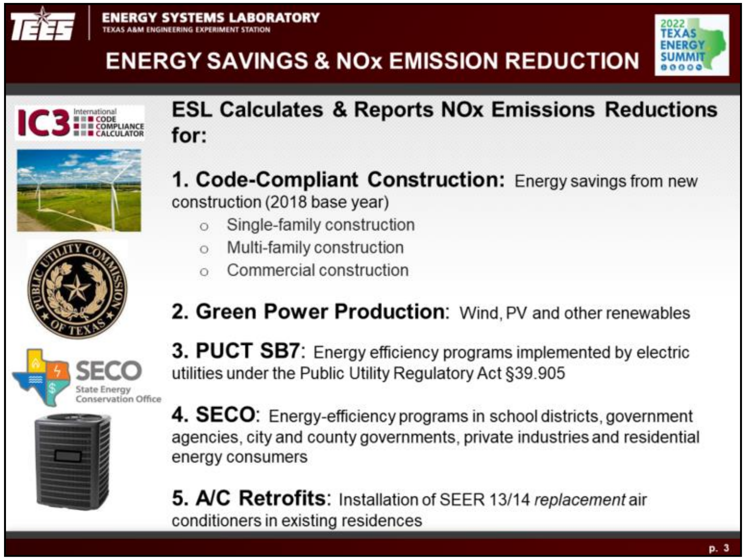


This work is the team effort of Texas Emissions Reductions Program (TERP) at the Energy Systems Laboratory at Texas A&M University, which includes (left to right): Jeff Haberl, Juan-Carlos Baltazar, Bahman Yazdani, Gali Zilbershtein, Patrick Parker, Angela Rowell, Qinbo Li, and graduate students Jounghwan Ahn, Mitra Azimi and Yu Sun.

This effort would not be possible without numerous individuals at other Texas State Agencies, including: Mr. David Serrins at the TCEQ; Ms. Therese Harris at the PUC Texas; Mr. Eddy Trevino and Mr. Fred Yebra at SECO, and Mr. Dan Mantena at ERCOT.



A quick review of the ESL's TERP duties:

Currently, the ESL calculates statewide Energy Savings and NOx Emissions Reduction From Energy Efficiency and Renewable Energy from five areas:

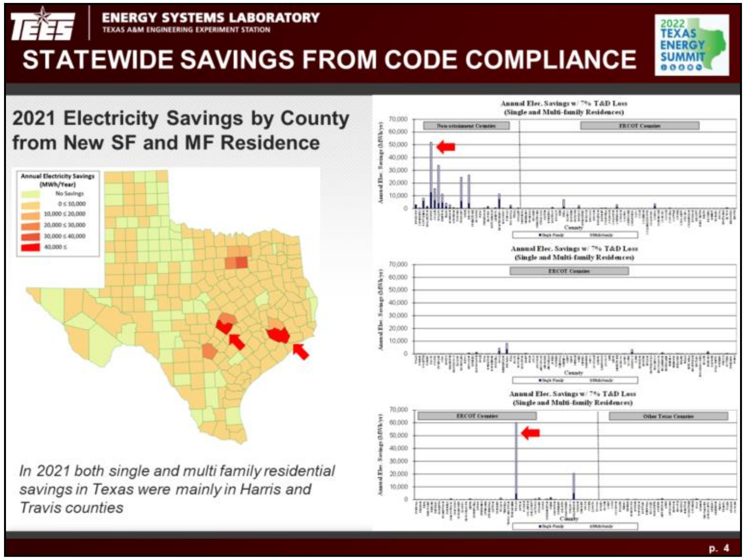
1. Code-Compliant Construction: Energy savings from new construction: Single-family construction, Multi-family construction, Commercial construction

2. Green Power Production: Wind, PV and other renewables

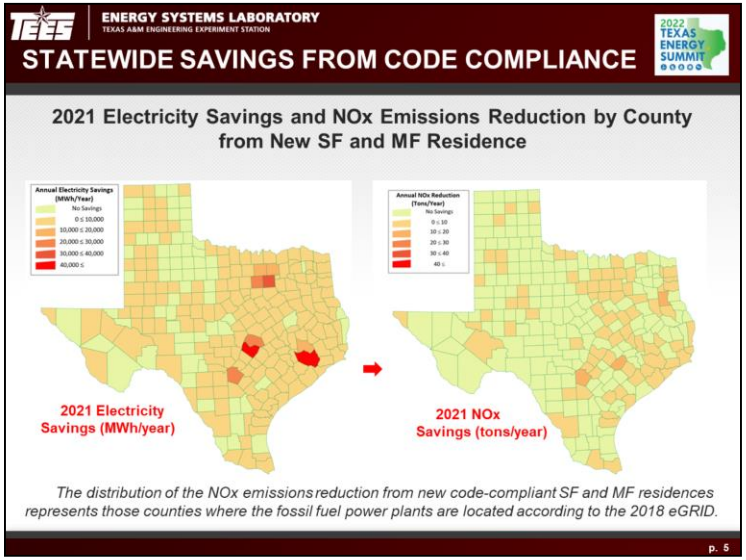
3. PUCT SB7: Energy efficiency programs implemented by electric utilities under the Public Utility Regulatory Act §39.905

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

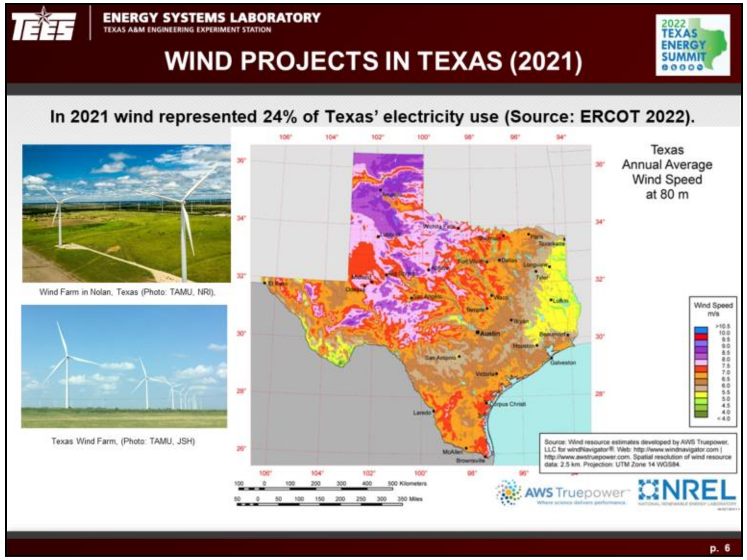
5. A/C Retrofits: Installation of SEER 13/14 replacement air conditioners in existing residences



The calculated electricity savings from new, code-compliant SF and MF construction is shown in this map using building permit data provided by the Texas A&M Real Estate Center.
(click)
As you would expect, the largest amount of single-family residential construction took place near Austin (Harris county) and in Houston (Travis county), both of which are in ozone non-attainment areas.



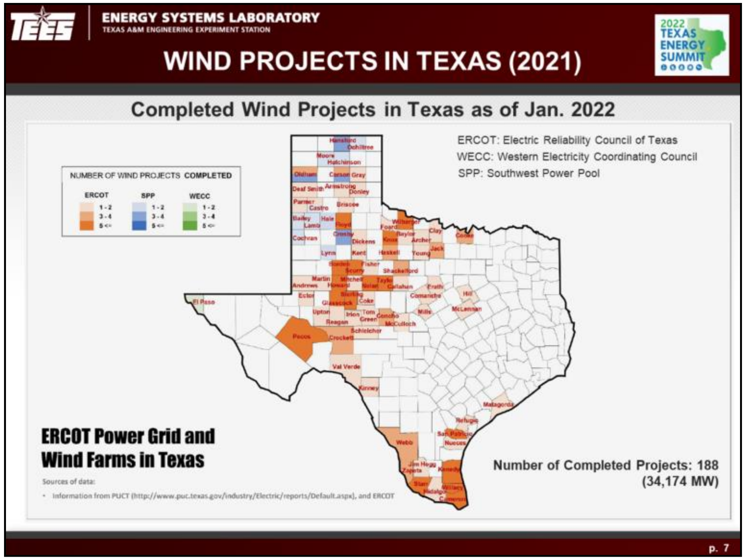
To determine the 2021 NOx emissions reduction from residential SF and MF code compliant construction we use the 2018 USEPA eGRID to determine which electric power plants are effected.
(click)
The distribution of the NOx emissions reduction from electricity savings from new, code-compliant SF and MF residences represents those counties where the fossil fuel power plants are located according to the 2018 eGRID.



NOx emissions reductions from the electricity produced by wind farms has become increasingly significant in recent years.

Large portions of Texas have significant wind resources, especially in the panhandle and the McCamey region (purple).

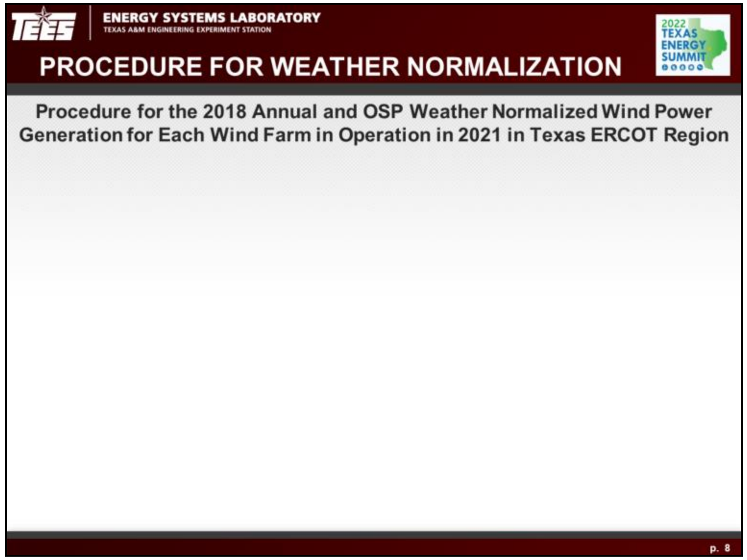
In 2021 wind represented 24% of Texas' electricity use (Source: ERCOT 2022)



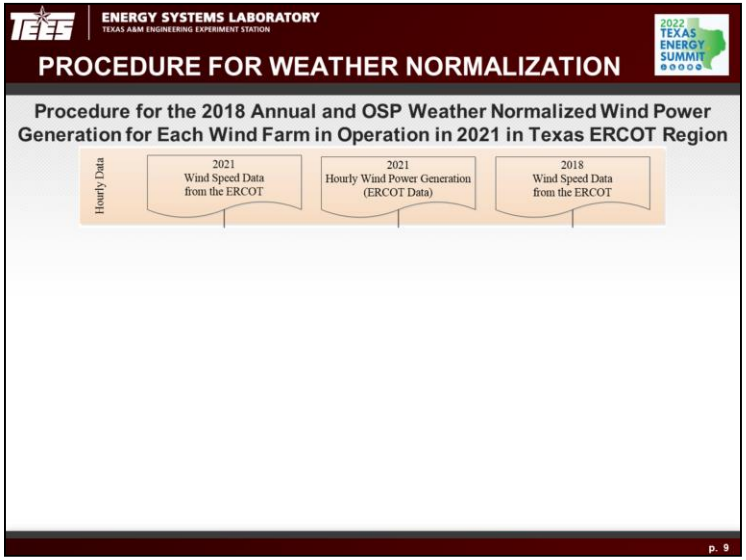
To calculate the NOx emissions reductions from the electricity generated by wind in 2021 we used the 15-minute electricity data recorded and archived at ERCOT for the wind farms across Texas.

In 2021 there were 188 completed projects (34,174 MW-max) statewide with most of the new projects in ERCOT (orange colored counties), followed by wind farms in the Southwest Power Pool (SPP) (blue) and finally wind farms in the Western Electricity Coordinating Council (WECC) (green – El Paso).

In the ESL's calculations of the NOx emissions reduction calculations a "normalized" model for each wind farm is created, which is needed to normalize the electricity production for the USEPA's 2018 base-year calculations.

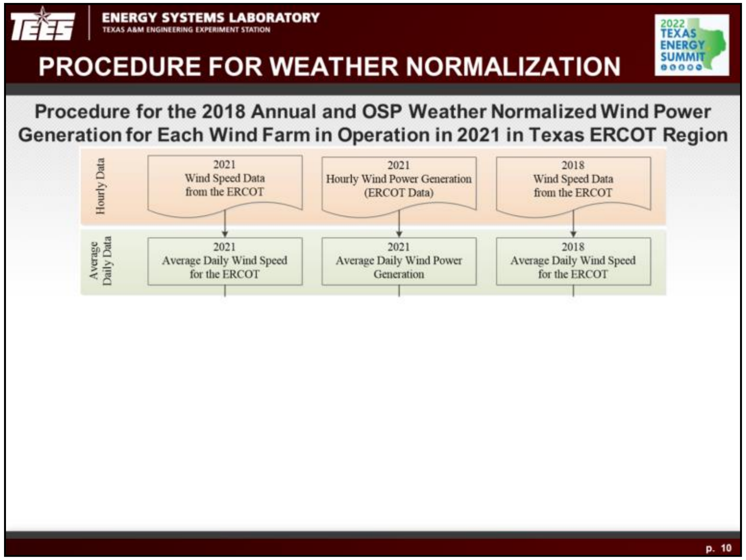


To determine the NOx emissions reductions the ESL developed a weather normalization method that predicts the electricity and NOx emissions reductions in the USEPA baseyear.



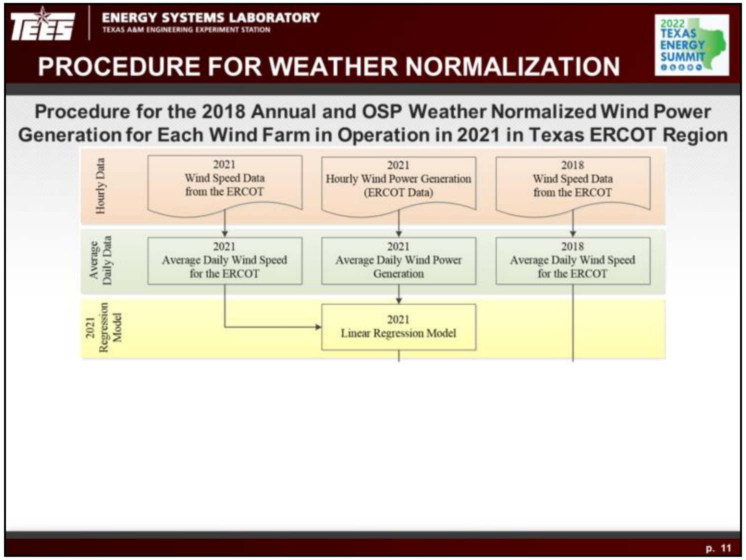
The procedure for "normalizing" the electricity power production from a wind farm is shown here. This "normalization" is required to "back-cast" the measured 2021 wind electricity production data to the USEPA-required base year, which is 2018.

The procedure begins by collecting the hourly 2021 NOAA wind speed near the wind farms (1.7 million records) and the electricity generated by the wind farms every 15-minutes in 2021 (6.7 million records for 188 wind farms).

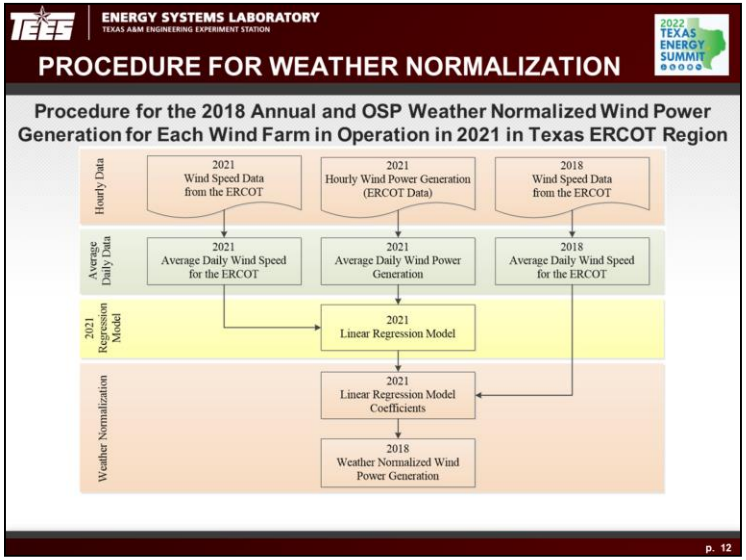


In the next step the 2021 hourly wind speed is converted to average daily wind speed and the 15-minute electricity production from wind farms across the state in 2021 is converted to daily electricity production.

In addition, the hourly wind speed associated with each wind farm in 2021 and the hourly wind speed from the same NOAA station in 2018 are converted to average daily wind speed.

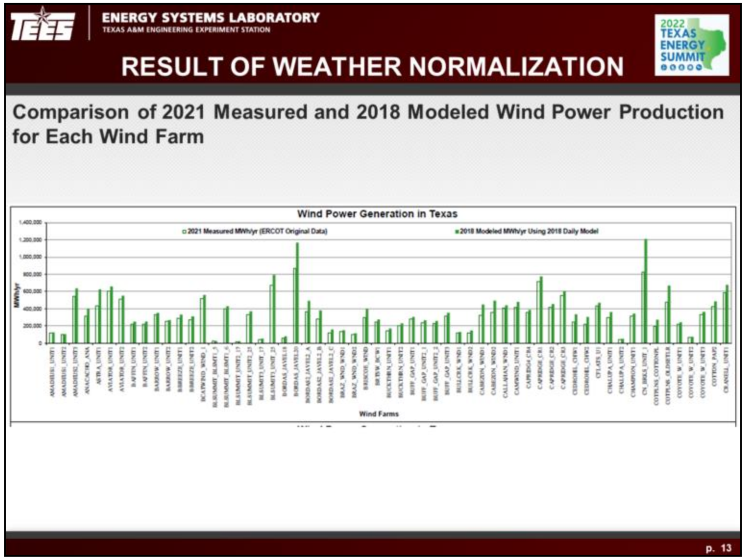


Next, a change-point linear regression model is created of the daily total electricity production versus average daily wind speed for each wind farm using the 2021 data.



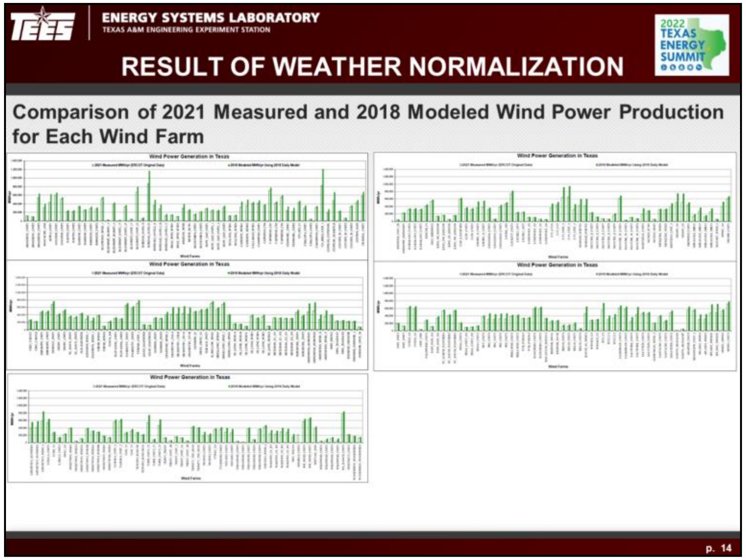
The coefficients from the regression model of the electricity production in 2021 are then used to calculate the predicted average daily electricity production that would have been produced in 2018 from the wind turbines that existed in 2021, which yields the “2018 normalized electricity production” for this wind farm.

This process is required by the USEPA to determine the normalized NOx emissions reductions in the “2018 base year”, which means it needs to be completed for each of the 188 wind farms in Texas.

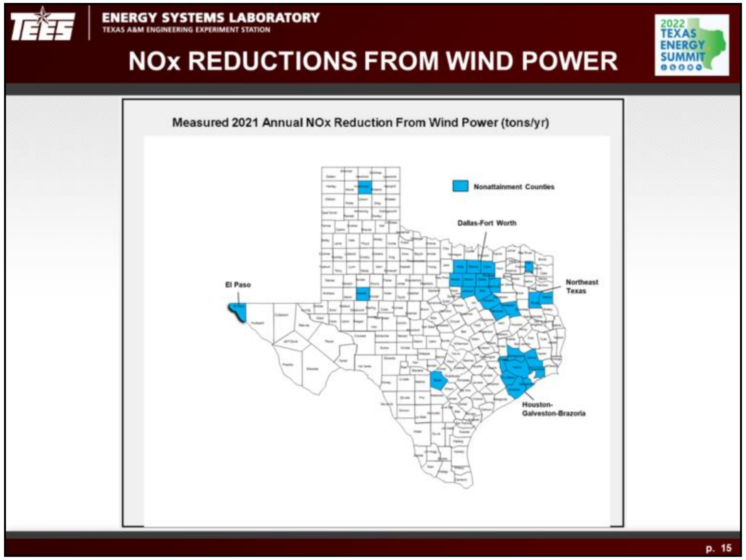


Here is an example of the results for a portion of the wind farms across the state. Graphs like these are produced for the 188 wind farms in 2021. In the graphs, for each wind site, values are shown for 2021 and for the 2018 normalized year.

In general, the 2018 base year (green lines) was windier than 2021 (white lines). However, this was not uniform across all the wind farms.



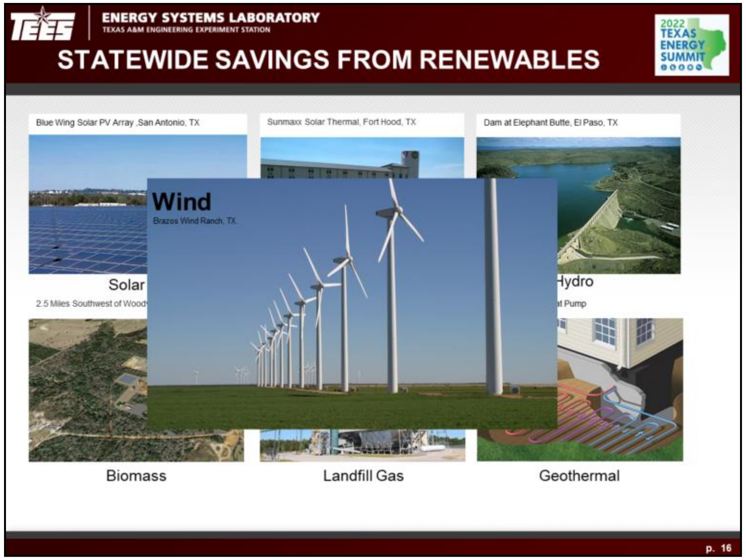
These are graphs of the results for all the 188 wind farms in 2021.



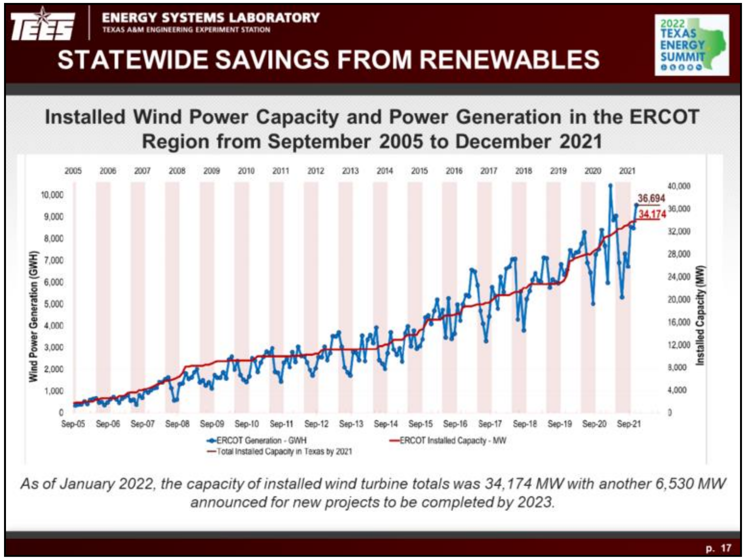
In the next step the NOx emissions from the electricity produced by the fossil fuel burning electricity plants that was displaced by the wind-generated electricity in 2021 is determined for each power plant using the USEPA's eGRID database for Texas (red = highest reduction, green = least).

The NOx emissions reduction for each county can then be compared to the location of the non-attainment to estimate the effectiveness of the NOx reduction in the non-attainment.

This sort of analysis helps Texas air quality planners estimate the progress of reducing NOx emissions from those power plants located near to the ozone non-attainment counties (which also tends to be the area of the largest populations.



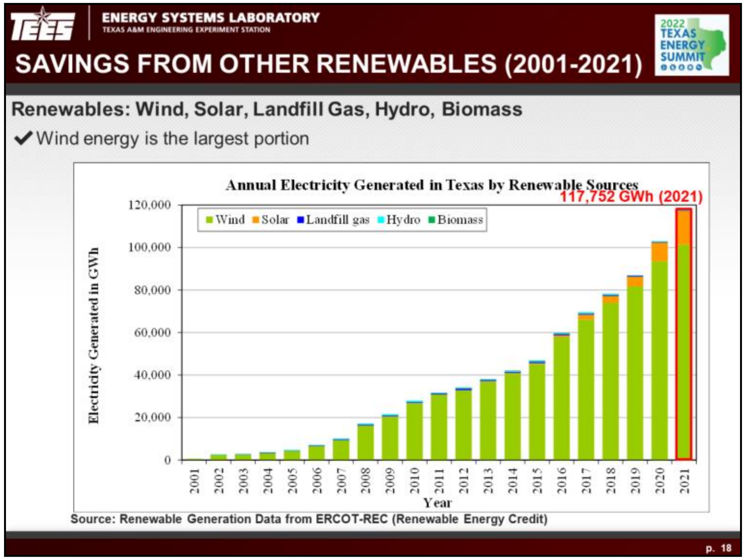
The ESL also calculates the electricity power production from renewable sources, including: Solar PV, hydroelectricity, biomass, landfill gas, and wind farms as well as the electricity savings from the use of solar thermal (DHW and space heating) and ground-coupled heat pump HVAC systems (geothermal).



For several years now, Texas has been the largest producer of wind energy in the United States.

As of January 2022, the installed capacity of wind turbines was 34,174 MW with another 6,530 MW announced for new projects to be completed by 2023.

These wind turbines produced 36,694 GWH/month in December of 2021.

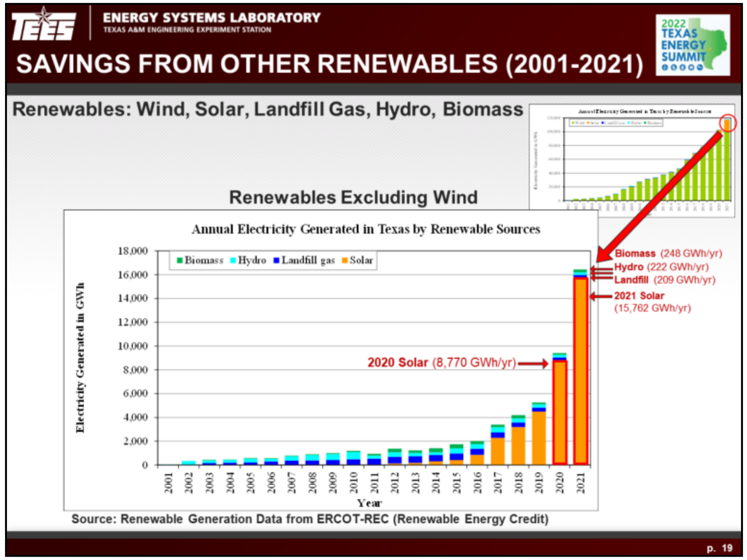


The ESL has been tracking the power produced by renewables in Texas since 2001.

This graph shows the growth of all renewables in Texas from 2001 (the beginning of the TERP) through 2021, resulting in 117,752 GWh (or 117.752 million MWh) of electricity generated in 2021.

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 PV, landfill gas, hydro and biomass renewable sources.

Problem with this graph is that it hides the significant growth in non-wind renewables.



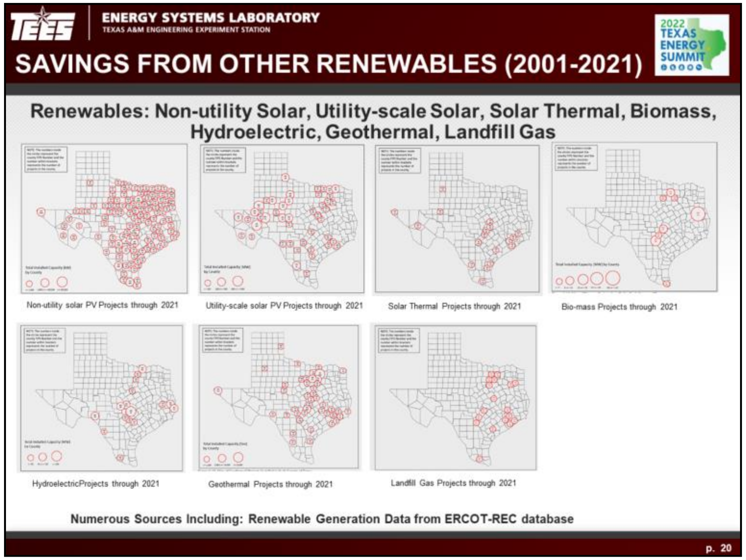
When we remove the wind energy electricity generation and rescale the graph, we can see the enormous increase in solar PV from 8,779 GWh/yr in 2020 to 15,762 GWh/yr in 2021 (179% increase).

On this graph the electricity generated by other renewables includes:

Biomass (248 GWh/yr),

Hydro (222 GWh/year), and

Landfill (209 GWh/yr).



These “other” renewables are scattered around the state, which requires contacting numerous sources for information each year.

Non-utility Solar,

Utility-scale Solar,

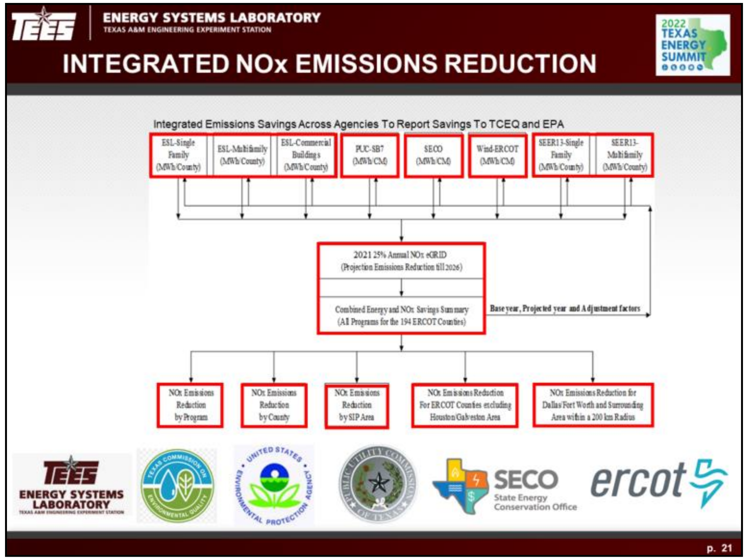
Solar Thermal,

Biomass,

Hydroelectric,

Geothermal,

Landfill Gas



So, in this way the integrated savings are calculated, each year, across state agencies, including:

TEES/ESL

PUC

SECO

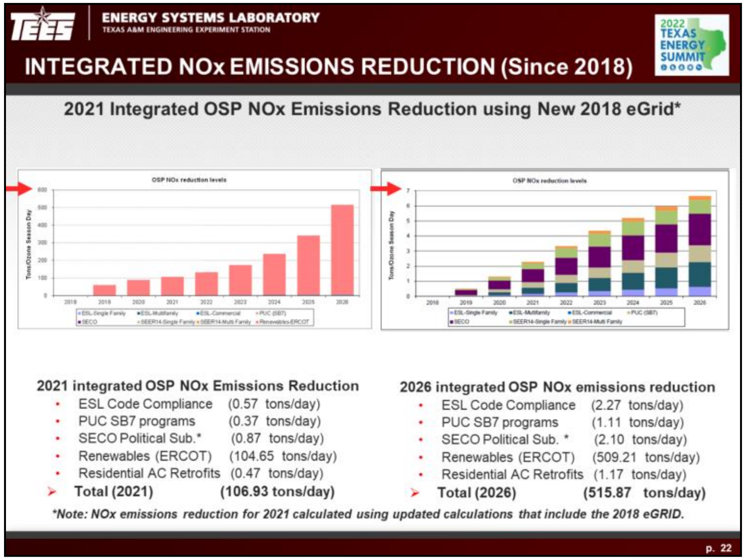
ERCOT/wind, solar and

SEER 13/14 replacement

The NOx emissions reductions are then determined by: program, county, SIP area, ERCOT-served counties, Cities and surrounding areas.

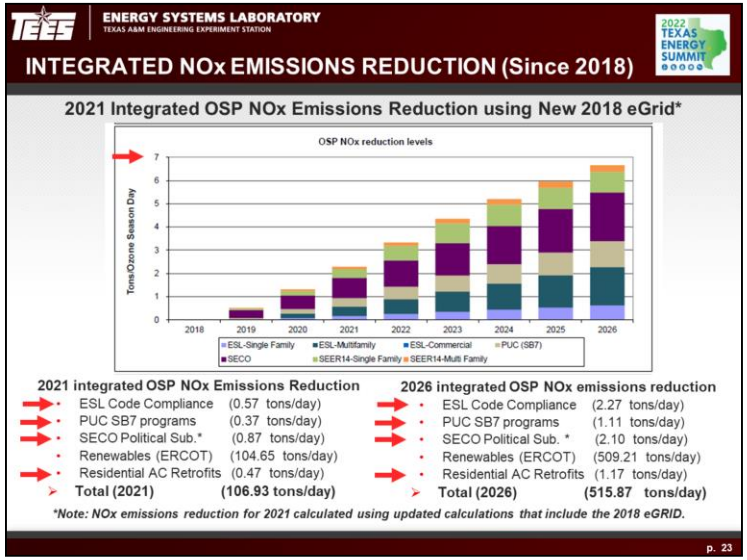
are then rolled-up into a total value for:

SF,



This brings us to the total results for 2021, which unfortunately don’t fit well on a standard linear graph because of the 100x difference in the magnitude of the savings.

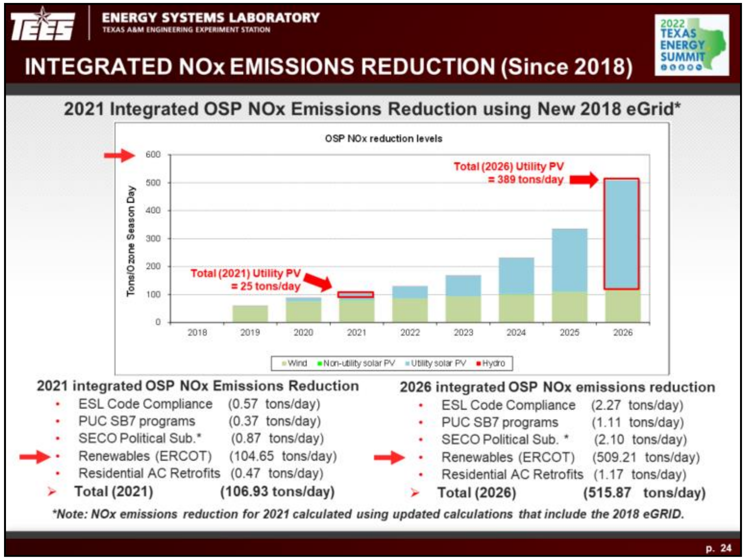
So, we’ll break this down into the non-renewable and energy efficiency programs.



First, we'll show:

ESL Code Compliance (0.57 tons/day)
PUC SB7 programs (0.37 tons/day)
SECO Political Sub.* (0.87 tons/day)
Residential AC Retrofits (0.47 tons/day)

Then project these through 2026 (5 years ahead).



Then, we show the renewables:

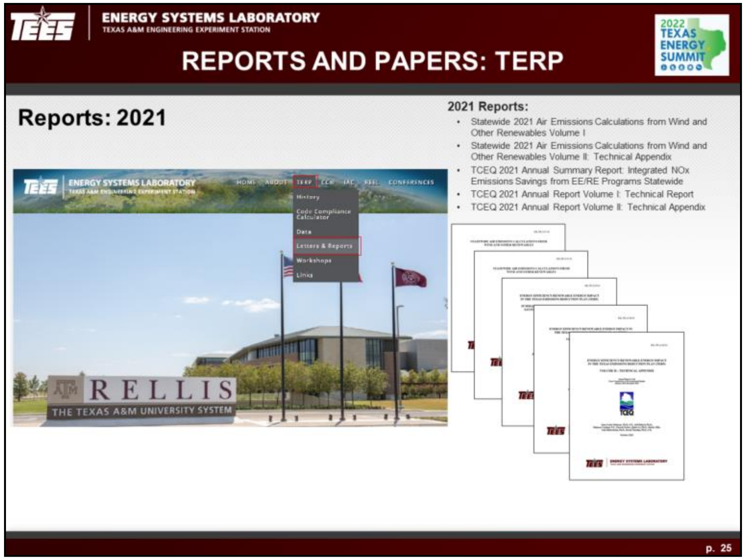
2021 Renewables (ERCOT) (104.65 tons/day)
(click)
(click)
(click)
2026 Renewables (ERCOT) (389 tons/day)

Which is a 37% per year increase.
(click)

We can also see that the largest portion of the increase is attributable to the growth in solar PV.

2021 = 25 tons/OSD

2026 = 389 tons/OSD



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

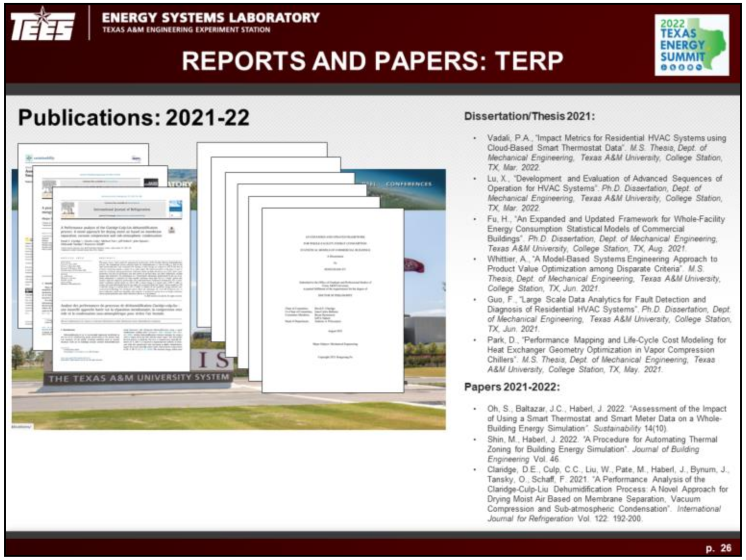
Statewide 2020 Air Emission Calculations from Wind and Other Renewables (Vol I and Vol II)

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

All reports are posted on-line at the ESL's TERP web site.



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

Dissertations/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 2020-21:

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.

Li, Q., Haberl, J. 2020. “Research Guidelines for Window Design Strategies in High Performance Office Buildings”, *SIMBUILD Building Performance Analysis Conference, joint-sponsored by IBPSA and ASHRAE*, Chicago, Ill, (August).

Claridge, D.E.,Culp, C.C., Liu, W., Pate, M., Haberl, J., Bynum, J., Tansky, O., Schaff, F. 2021. “A Performance Analysis of the Claridge-Culp-Liu Dehumidification Process: a Novel Approach for Drying Moist Air Based on Membrane Separation, Vacuum Compression and Sub-atmospheric Condensation”, International Journal for Refrigeration, accepted for publication (November).

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http://esl.tamu.edu/terp