ENERGY SYSTEMS LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

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

Jeff Haberl, Ph.D.
Juan-Carlos Baltazar, Ph.D., P.E.
Bahman Yazdani, P.E.

ACKNOWLEDGEMENTS

Faculty/Staff: Jeff Haberl, Juan-Carlos Baltazar, Bahman Yazdani, Gali Zilbershtein, Shirley Ellis, Patrick Parker, Angela Rowell

Students: Sungkyun Jung, Farshad Kheiri, Qinbo Li, Chul Kim











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PUCT: Katie Rich, Therese Harris
SECO: Dub Taylor, Stephen Ross
ERCOT: Paul Wattles, Connor Anderson

LEGISLATION

Legislation to Reduce Energy/Emissions 2001 to Present

Senate Bill 5 (77th Legislature, 2001)
Ch. 386. Texas Emissions Reduction Plan
- Sec. 386.205. Evaluation Of State Energy Efficiency Programs (with PUC)

Ch. 388. Texas Building Energy Performance Standards
- Sec. 388.003. Adoption Of Building Energy Efficiency Performance Standards.
- Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.
- Sec. 388.007. Distribution Of Information And Technical Assistance.
- Sec. 388.008. Development Of Home Energy Ratings.

TERP Amended (78th Legislature, 2003)
Ch. 388. Texas Building Energy Performance Standards
- (HB 1365) Sec. 388.004. Enforcement Of Energy Standards Outside Of Municipality.
- (HB 1365) Sec. 388.009. Energy-Efficient Building Program.

Ch. 388. Texas Building Energy Performance Standards
- (HB 3235) Sec. 388.009. Certification of Municipal Inspectors.

TERP Amended (79th Legislature, 2005)
Ch. 382. Health and Safety Code
- (HB 2129) Sec. 386.056 Development of Creditable Statewide emissions from wind and other renewables.
- (HB 965) Sec. 382.0275 Commission Action Relating to Water Heaters

TERP Amended (80th Legislature, 2007)
Ch. 382. Health and Safety Code
- (HB 3693) Sec. 388.003 added subsection (b-1), (b-2), (b-3) that allows SECO to adopt new editions of the IECC based on written recommendations from the Laboratory.
- (HB 3693) Sec. 388.008 Development of Standardized report formats for newly constructed residences.

Ch. 386.252 Health and and Safety Code
- (SB 12) Section 388.03 added subsection (b-1), (b-2) allows SECO to adopt new editions of the IECC based on written recommendations from the Laboratory.

TERP Amended (81st Legislature, 2009)
Ch. 382. Health and Safety Code
- (HB 1796) Section 23 amends Sec. 386.252 (a) and (b) extends date of TERP to 2019 and requires Commission to contract with Laboratory for creditable EE/RE emissions reductions.

TERP Amended (82nd Legislature, 2011)
Ch. 477.004 Health and Safety Code
- HB 51 Section 2, b-2, establishes advisory committee, which including the Laboratory
- Section 3 & 4 amends review of municipal's amendments.

Ch. 388.003e & 388.007c,d Health and Safety Code
- HB 51 Section 3 & 4 amends review of municipal's amendments.

Ch. 388.006 Health and Safety Code
- SB 898 Section 2, requires the Laboratory to calculate energy savings and emissions reductions for political subdivisions reporting to SECO.

Ch. 39.9051 Utilities Code
- SB 924 Section 1g,h and Section 2c,d requires the Laboratory to calculate energy savings and emissions reductions for political subdivisions reporting to SECO.

NO new amendments were passed (83rd Legislature, 2013)

TERP Amended (84th Legislature, 2015)
Section 388.003, Health and Safety Code
- HB 1736 Section 1 Establishes the 2015 energy codes as the TBEPS effective Sept 1, 2016. The state may adopt new codes no sooner than every 6 years. The section also adds Energy Rating Index as a voluntary compliance alternative.

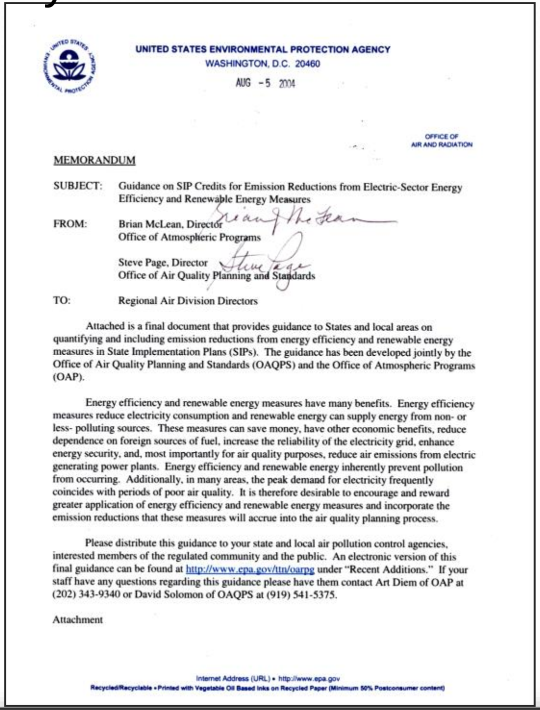
NO new amendments were passed (85th Legislature, 2017)

NO new amendments were passed (86th Legislature, 2019)

EPA CRITERIA FOR SIP CREDITS (2004)

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.


UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

AUG -5 2004

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Guidance on SIP Credits for Emission Reductions from Electric-Sector Energy Efficiency and Renewable Energy Measures

FROM: Brian McLean, Director
Office of Atmospheric Programs

Steve Page, Director
Office of Air Quality Planning and Standards

TO: Regional Air Division Directors

Attached is a final document that provides guidance to States and local areas on quantifying and including emission reductions from energy efficiency and renewable energy measures in State Implementation Plans (SIPs). The guidance has been developed jointly by the Office of Air Quality Planning and Standards (OAQPS) and the Office of Atmospheric Programs (OAP).

Energy efficiency and renewable energy measures have many benefits. Energy efficiency measures reduce electricity consumption and renewable energy can supply energy from non- or less- polluting sources. These measures can save money, have other economic benefits, reduce dependence on foreign sources of fuel, increase the reliability of the electricity grid, enhance energy security, and, most importantly for air quality purposes, reduce air emissions from electric generating power plants. Energy efficiency and renewable energy inherently prevent pollution from occurring. Additionally, in many areas, the peak demand for electricity frequently coincides with periods of poor air quality. It is therefore desirable to encourage and reward greater application of energy efficiency and renewable energy measures and incorporate the emission reductions that these measures will accrue into the air quality planning process.

Please distribute this guidance to your state and local air pollution control agencies, interested members of the regulated community and the public. An electronic version of this final guidance can be found at http://www.epa.gov/ttn/oarpg under "Recent Additions." If your staff have any questions regarding this guidance please have them contact Art Diem of OAP at (202) 343-9340 or David Solomon of OAQPS at (919) 541-5375.

Attachment

Internet Address (URL) • http://www.epa.gov
Recycled/Recyclable • Printed with Vegetable Oil Based Inks on Recycled Paper (Minimum 50% Postconsumer content)

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.

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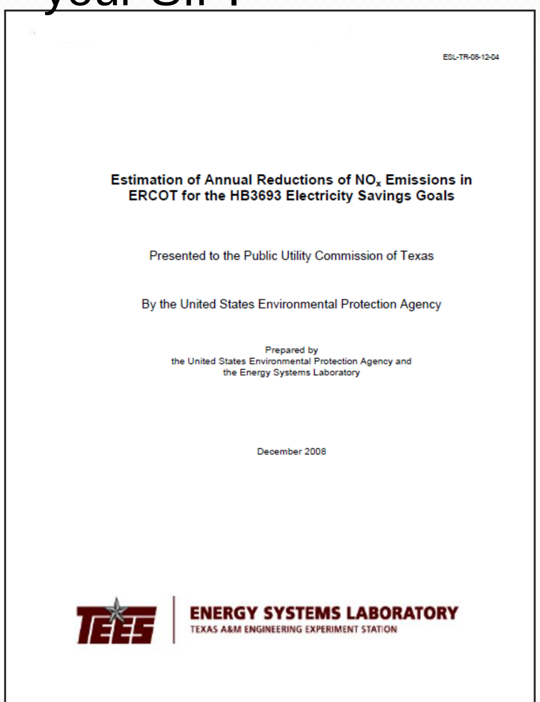
ESL-TR-08-12-04

Estimation of Annual Reductions of NO_x Emissions in ERCOT for the HB3693 Electricity Savings Goals

Presented to the Public Utility Commission of Texas

By the United States Environmental Protection Agency

Prepared by
the United States Environmental Protection Agency and
the Energy Systems Laboratory

December 2008

ENERGY SYSTEMS LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

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ENERGY SAVINGS & NOx EMISSION REDUCTION

International CODE COMPLIANCE CALCULATOR

Texas Renewable Energy Industries Alliance

SECO
State Energy Conservation Office

ESL Calculates & Reports NOx Emissions Reductions for:

1. Code-Compliant Construction: Energy savings from new construction

- ESL Single-family construction
- ESL Multi-family construction
- ESL 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

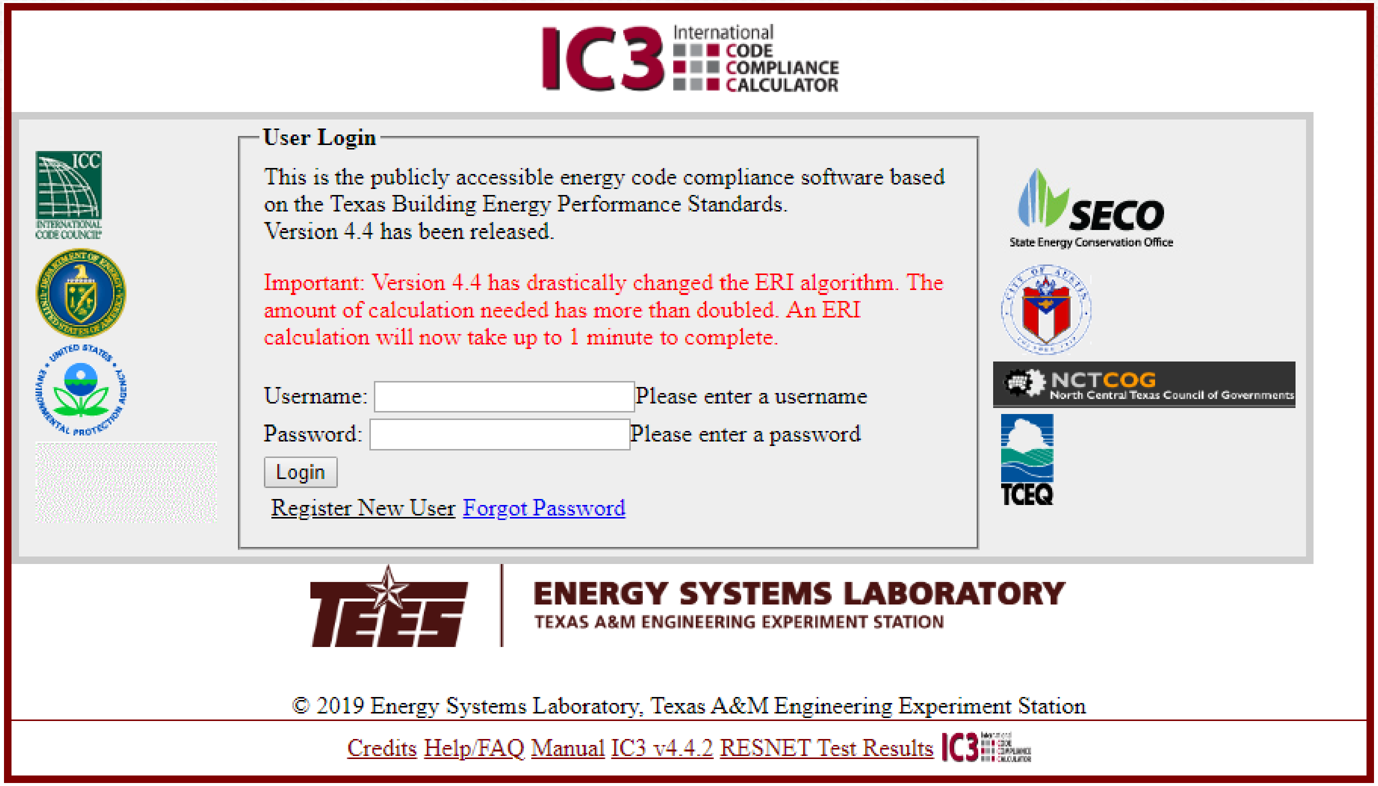
4. SECO: Energy-efficiency programs towards school districts, government agencies, city and county governments, private industries and residential energy consumers

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

ENERGY SAVINGS & NOx EMISSION REDUCTION

ESL Calculates & Reports NOx Emissions Reductions for:

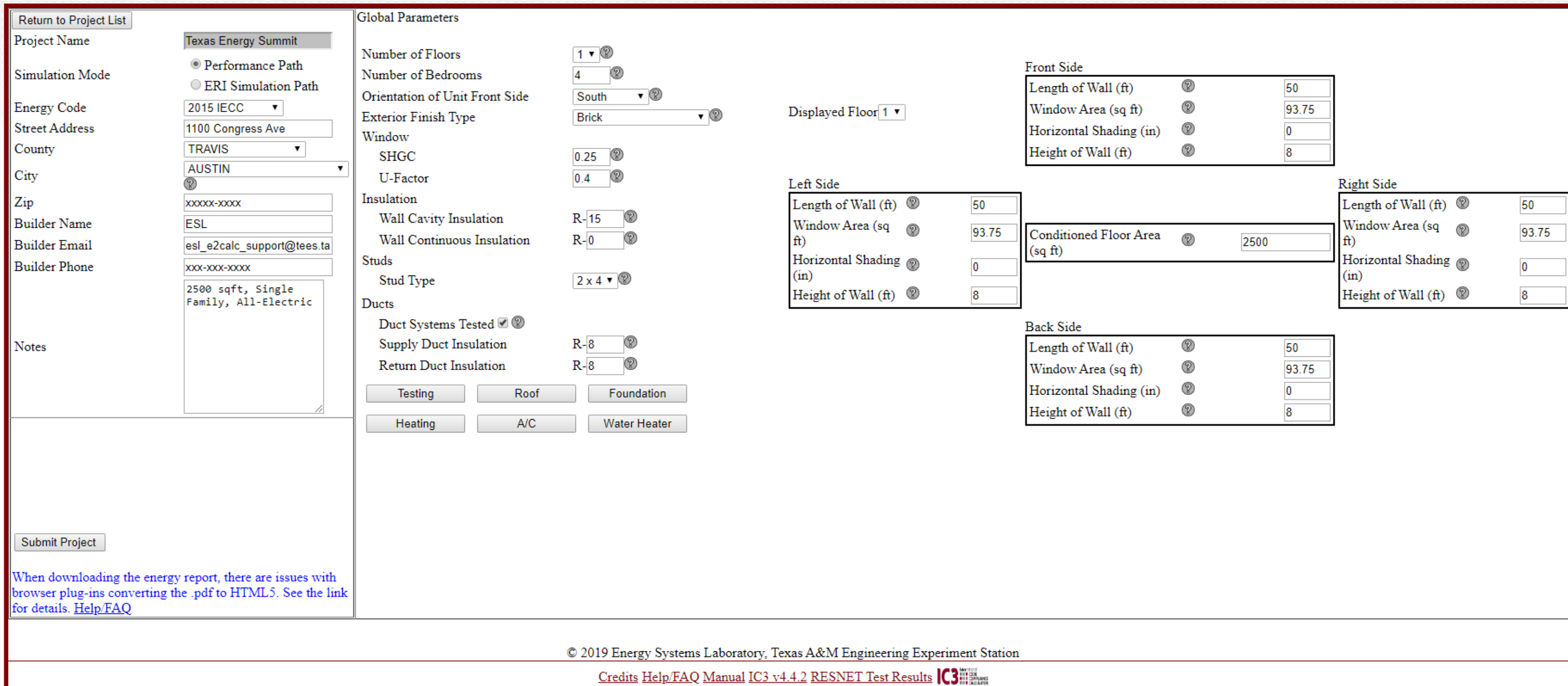
Code-Compliant Construction: Energy savings from new construction



Login Screen

ESL Calculates & Reports NOx Emissions Reductions for:

Code-Compliant Construction: Energy savings from new construction



Main Page

ENERGY SAVINGS & NOx EMISSION REDUCTION

International CODE COMPLIANCE CALCULATOR (IC3)

ESL Calculates & Reports NOx Emissions Reductions for:

Code-Compliant Construction: Energy savings from new construction

Residential Energy Efficiency Certificate

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TEXAS A&M ENGINEERING EXPERIMENT STATION

Window U-Value	U- 0.4	Duct Tightness (in CFM25)	100
Window SHGC	0.25	Cooling Efficiency	SEER 14
Wall Cavity Insulation	R - 15	Heating Efficiency	8.2 HSPF
Roof/Ceiling Insulation	R - 32	Water Heater Efficiency	Electric EF 0.904
Floor/Foundation Insulation	R - 0	Builder Email	xxxxx@tamu.edu
Supply Duct Insulation	R - 8	Builder Phone	xxx-xxx-xxxx
Return Duct Insulation	R - 8	Date Issued	10/2/2019
Blower Door (in ACH50)	5	Certificate Number	1,138,738

IC3 International CODE COMPLIANCE CALCULATOR

Builder or Registered Design Professional ______________________

This certificate was generated by IC3 in compliance with 2015 IECC

Prints Certificate for Electrical Panel

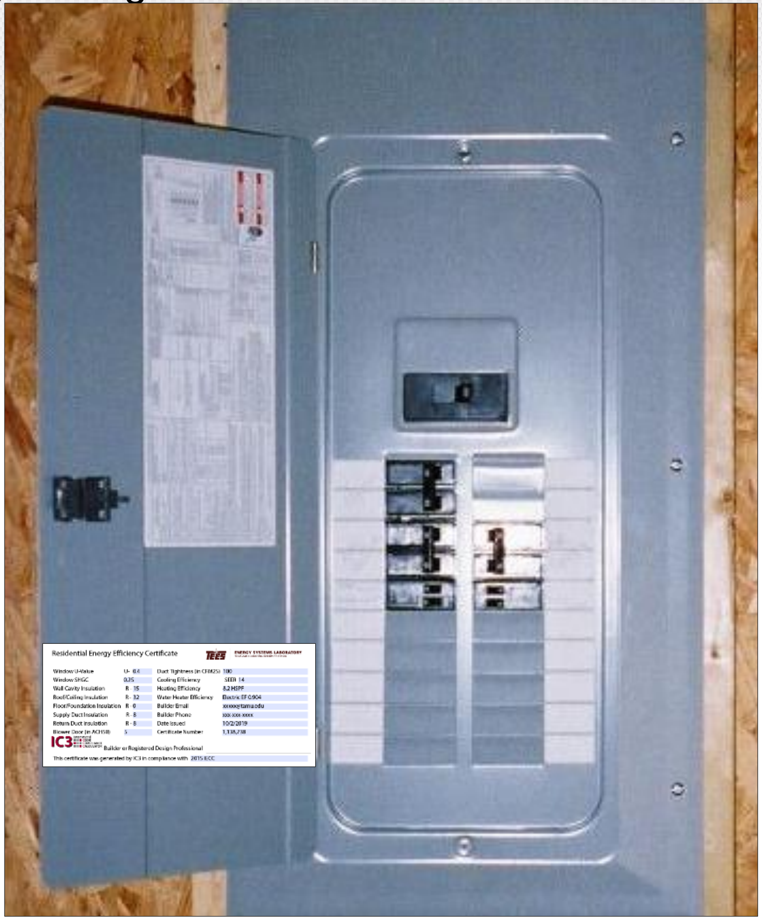
ENERGY SAVINGS & NOx EMISSION REDUCTION

International CODE COMPLIANCE CALCULATOR

ESL Calculates & Reports NOx Emissions Reductions for:

Code-Compliant Construction: Energy savings from new construction

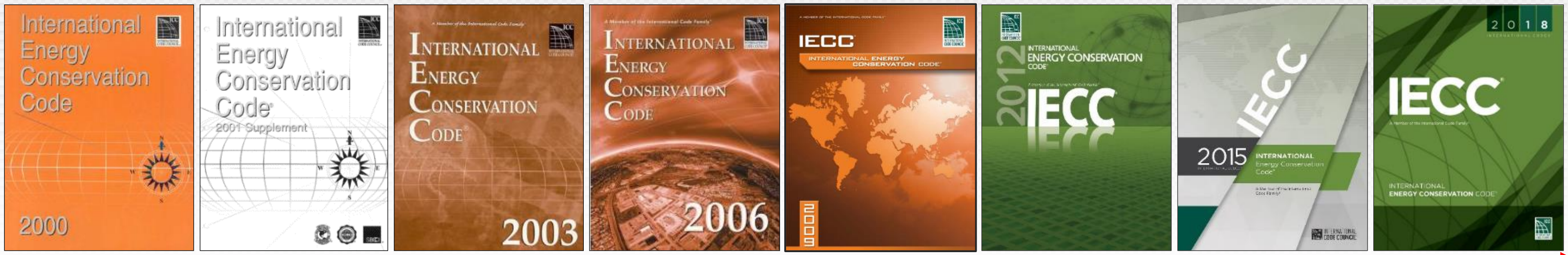
- IC3 Prints Certificate for Posting on Electrical Panel
- Records Certificate in IC3 Registry



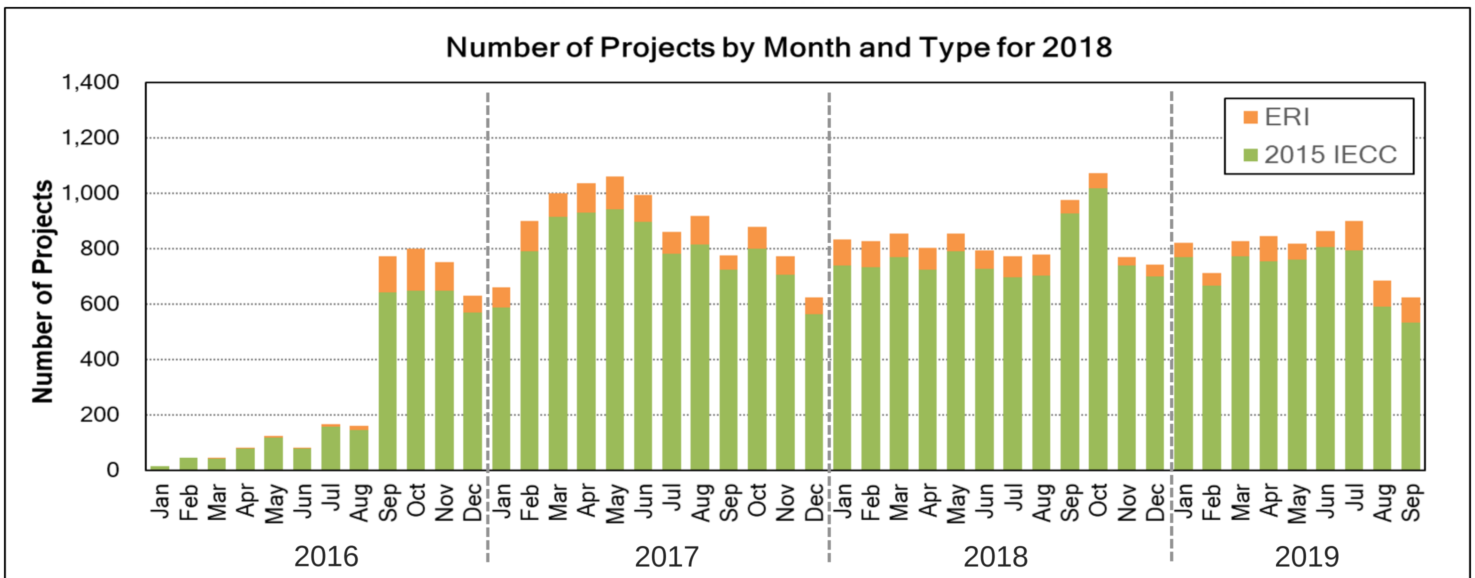
Prints Certificate for Electrical Panel

STATEWIDE SAVINGS FROM CODE COMPLIANCE

How much electricity has been saved from residential code compliance for all single-family housing 2000-2019?



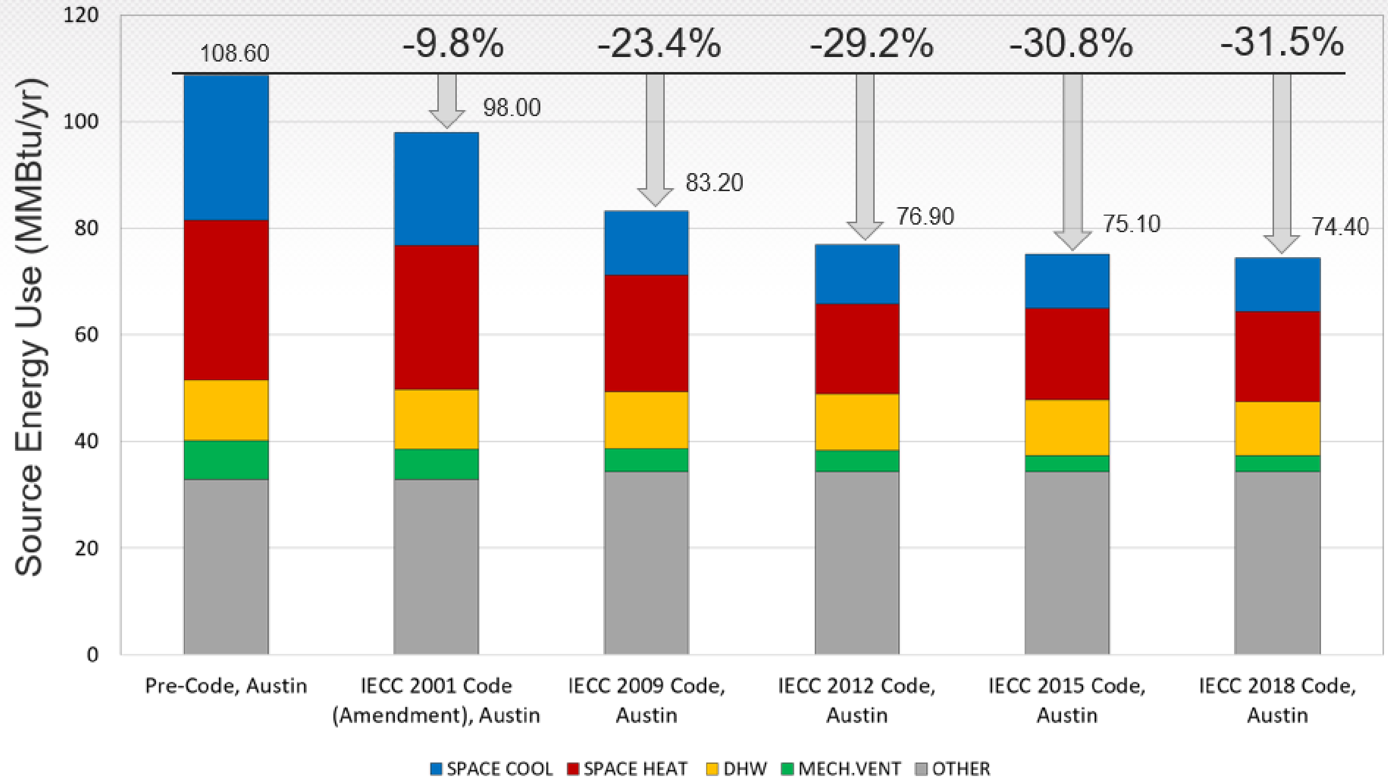
Projects/Certificates in IC3 Registry



How much residential code compliances have saved in Austin, TX (Climate Zone 2A) from 1999 to 2019?

2,500 ft2 SF House

Wall: ***R-11 to R13***
Roof: ***R-26 to R-38***
Win Uval: ***1.11 to 0.40***
Win SHGC: ***0.71 to 0.25***
SEER: ***10 to 14***
AFUE: ***0.80 to 0.82***
HSPF: ***6.8 to 8.2***
DHW EF: ***0.86 to 0.95***



STATEWIDE SAVINGS FROM CODE COMPLIANCE 2000 – 2018 (ESTIMATED)

Savings (2002 to 2017)

Total: **$6,737 million**

Savings (2002 to 2018)

Electricity (Envelope): $2,352 million (+10.0%)
Electricity (HVAC Systems): $2,247 million (+19.5%)
Demand: $3,078 million (+13.2%)
Total: **$7,677 million (+14.0%)**

Increased Costs (2002 to 2018)

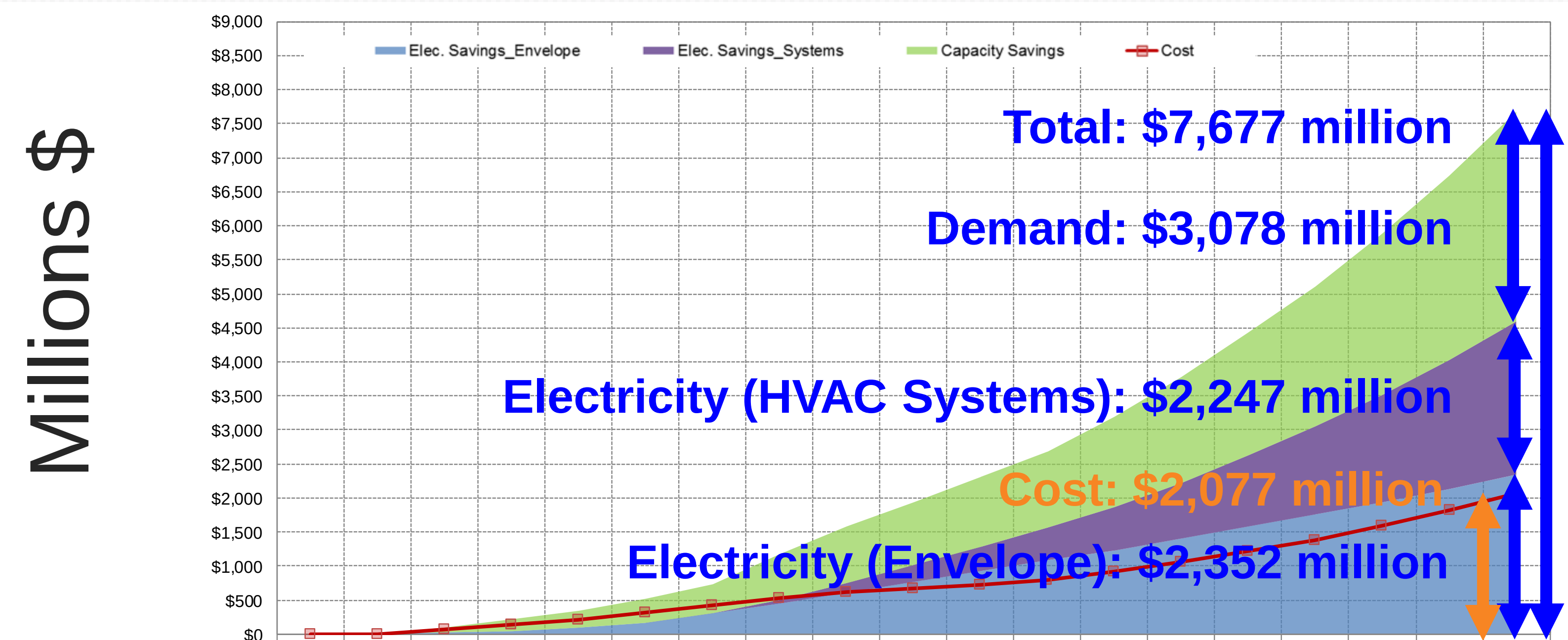
Costs: $ 2,077 million

NOx Emissions Reduction (2008 to 2018)

82.21 tons NOx / year

Emissions Reduction in 2018

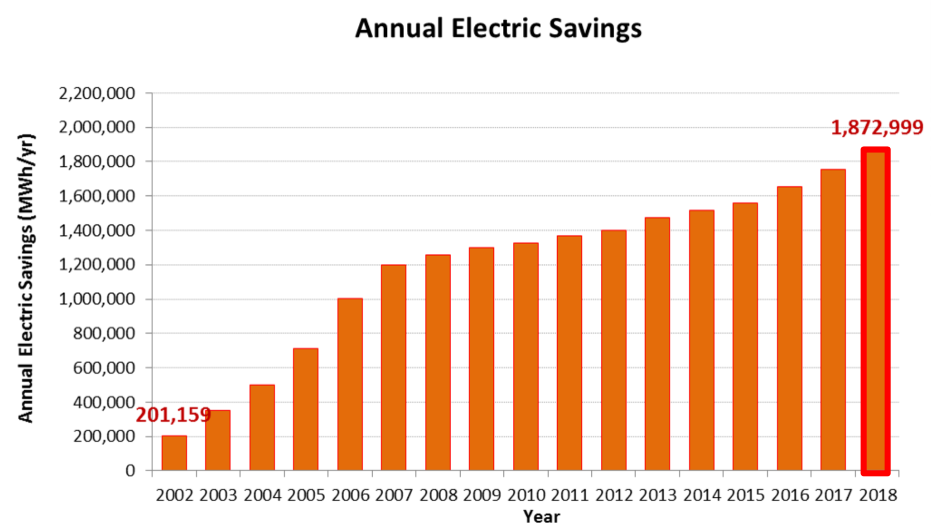
(Equivalent to about 62,500 cars)

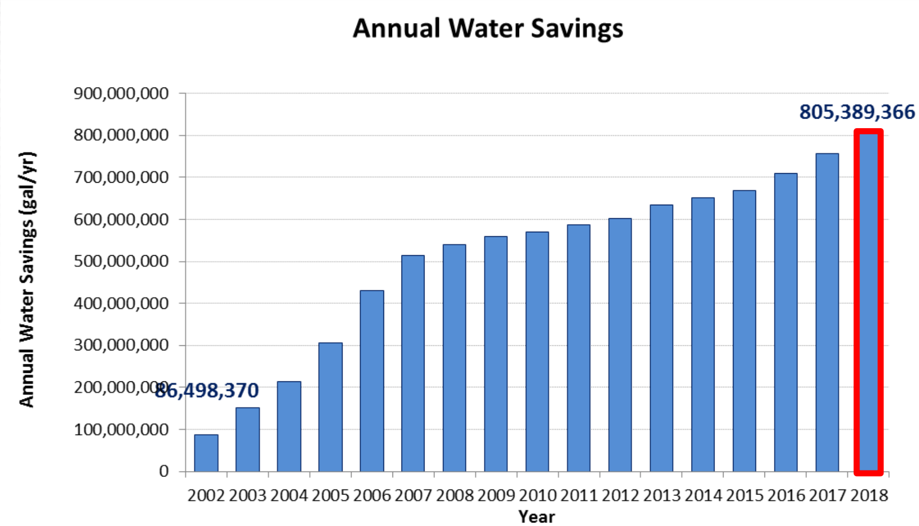


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Capacity Savings	-	-	$79	$163	$251	$345	$430	$678	$822	$929	$1,028	$1,118	$1,327	$1,563	$1,814	$2,057	$2,377	$2,718	$3,078
Elec. Savings_Systems			$0	$0	$0	$0	$0	$55	$138	$240	$351	$476	$624	$813	$1,039	$1,286	$1,563	$1,881	$2,247
Elec. Savings_Envelope	-	-	$16	$48	$97	$175	$304	$451	$615	$776	$930	$1,082	$1,236	$1,403	$1,583	$1,763	$1,945	$2,138	$2,352
Cost	-	-	$64	$136	$218	$321	$422	$536	$610	$669	$729	$788	$914	$1,060	$1,220	$1,386	$1,595	$1,825	$2,077

STATEWIDE WATER SAVINGS AT POWER PLANTS 2000 – 2018

Electricity/Water Savings from SF (Code Compliance)





Seaholm Power Plant, Austin

2018 Total Electricity Savings (MWh/yr)
1,872,999

2018 Total Water Savings	
(gal/yr)	(acre-ft/yr)
805,389,366	2,472

Conversion Factors: 430 *gal/MWh*
325,851 *gal/acre-ft*

SAVINGS FROM RENEWABLES

Blue Wing Solar PV Array, San Antonio, TX

Solar PV

Sunmaxx Solar Thermal, Fort Hood, TX

Solar Thermal

Dam at Elephant Butte, El Paso, TX

Hydro

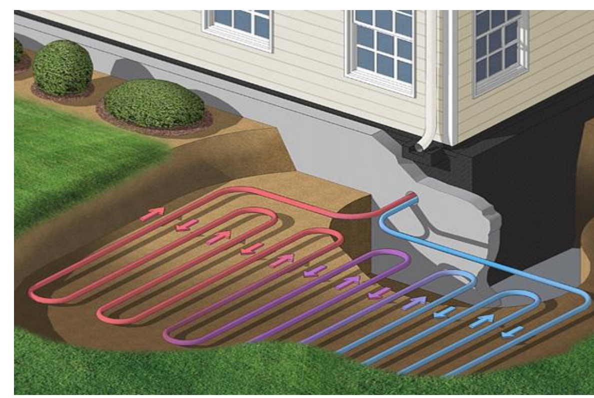
2.5 Miles Southwest of Woodville, TX

Biomass

Aspen Power plant in Lufkin, TX

Landfill Gas

Ground Source Heat Pump



Geothermal

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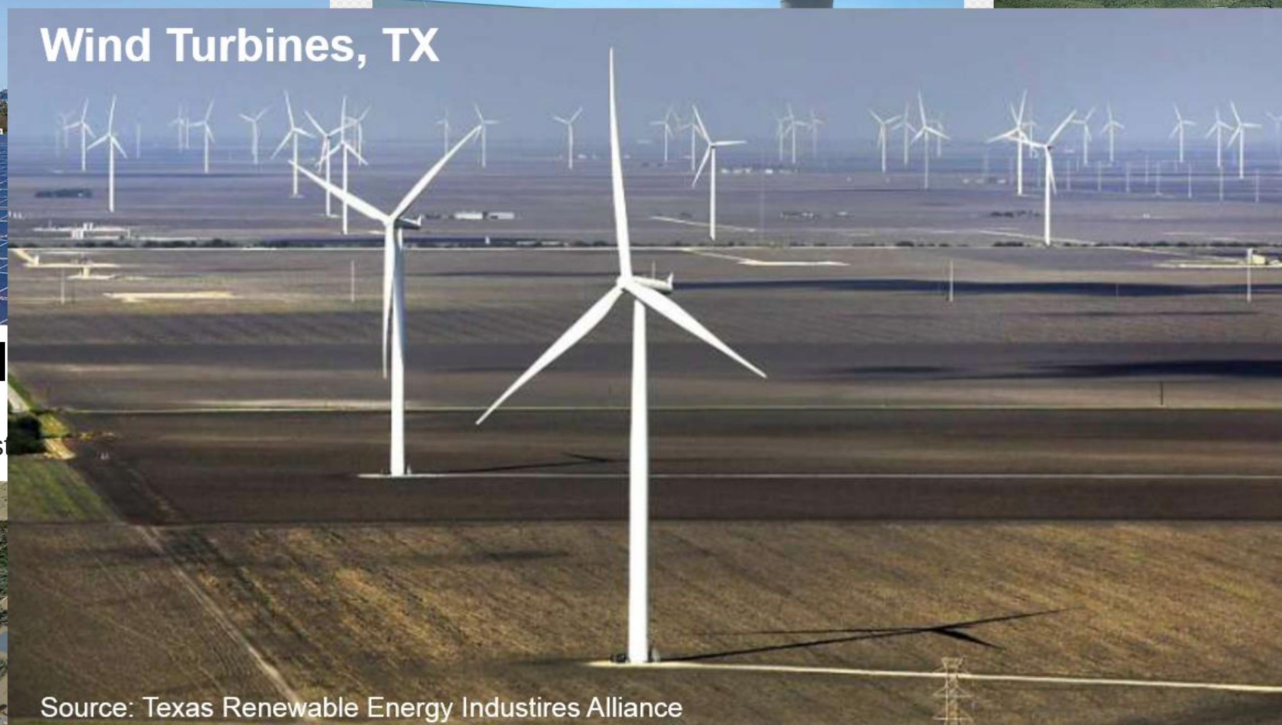
Dam at Elephant Butte, El Paso, TX



Sol

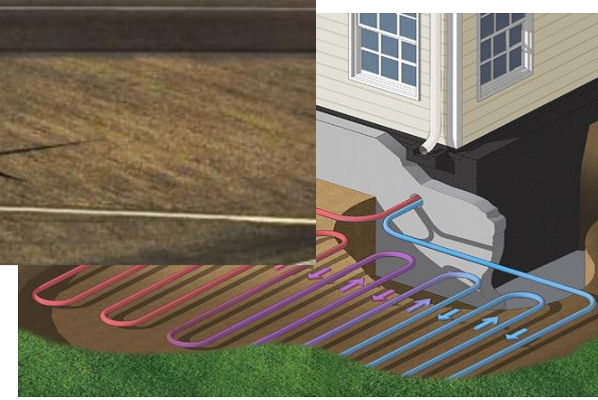
dro

2.5 Miles Southwest

ump

Biomass

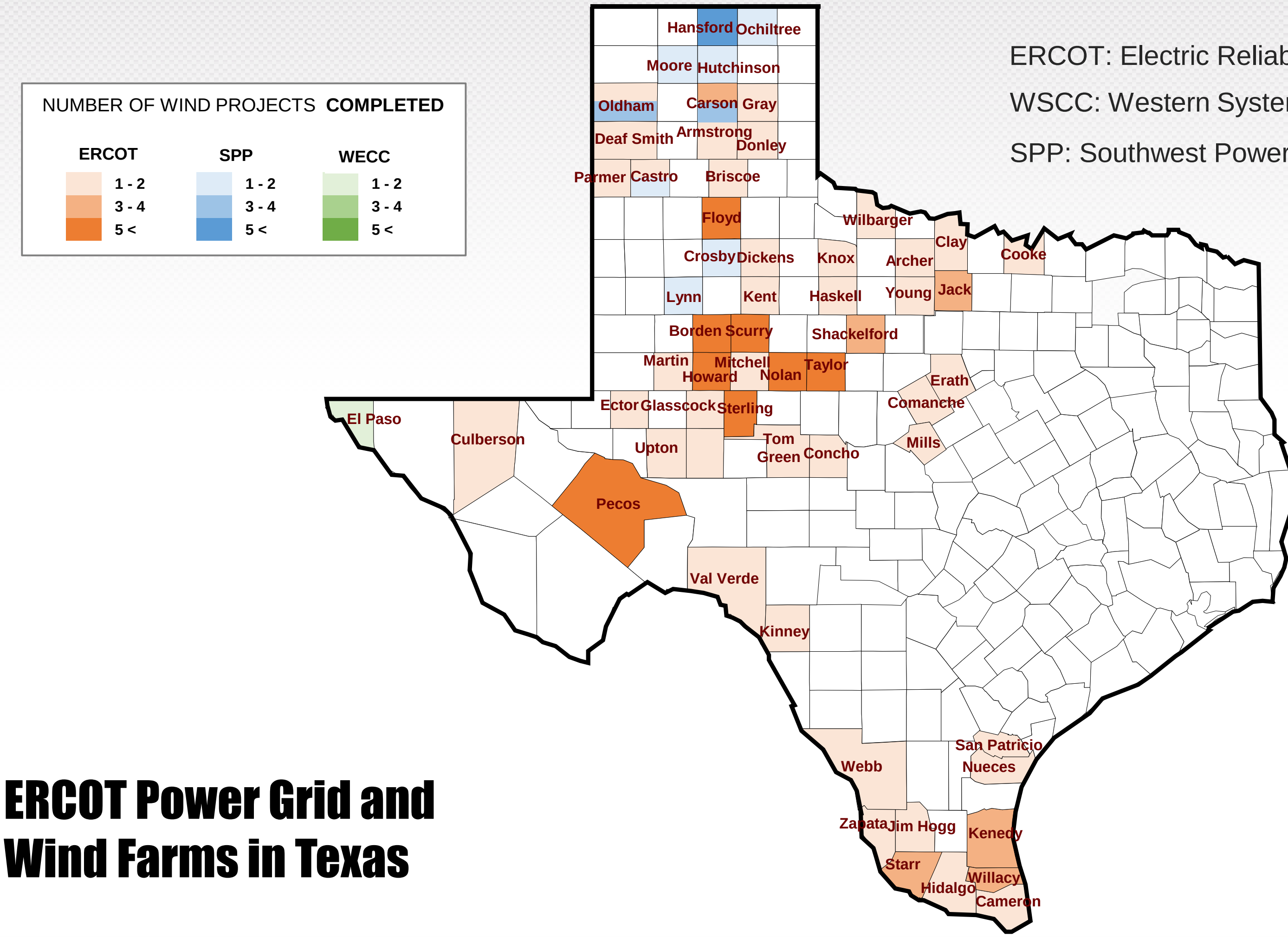
Landfill Gas



Geothermal

WIND PROJECTS IN TEXAS (2018)

Completed Wind Projects in Texas, as of Dec. 2018



ERCOT: Electric Reliability Council of Texas

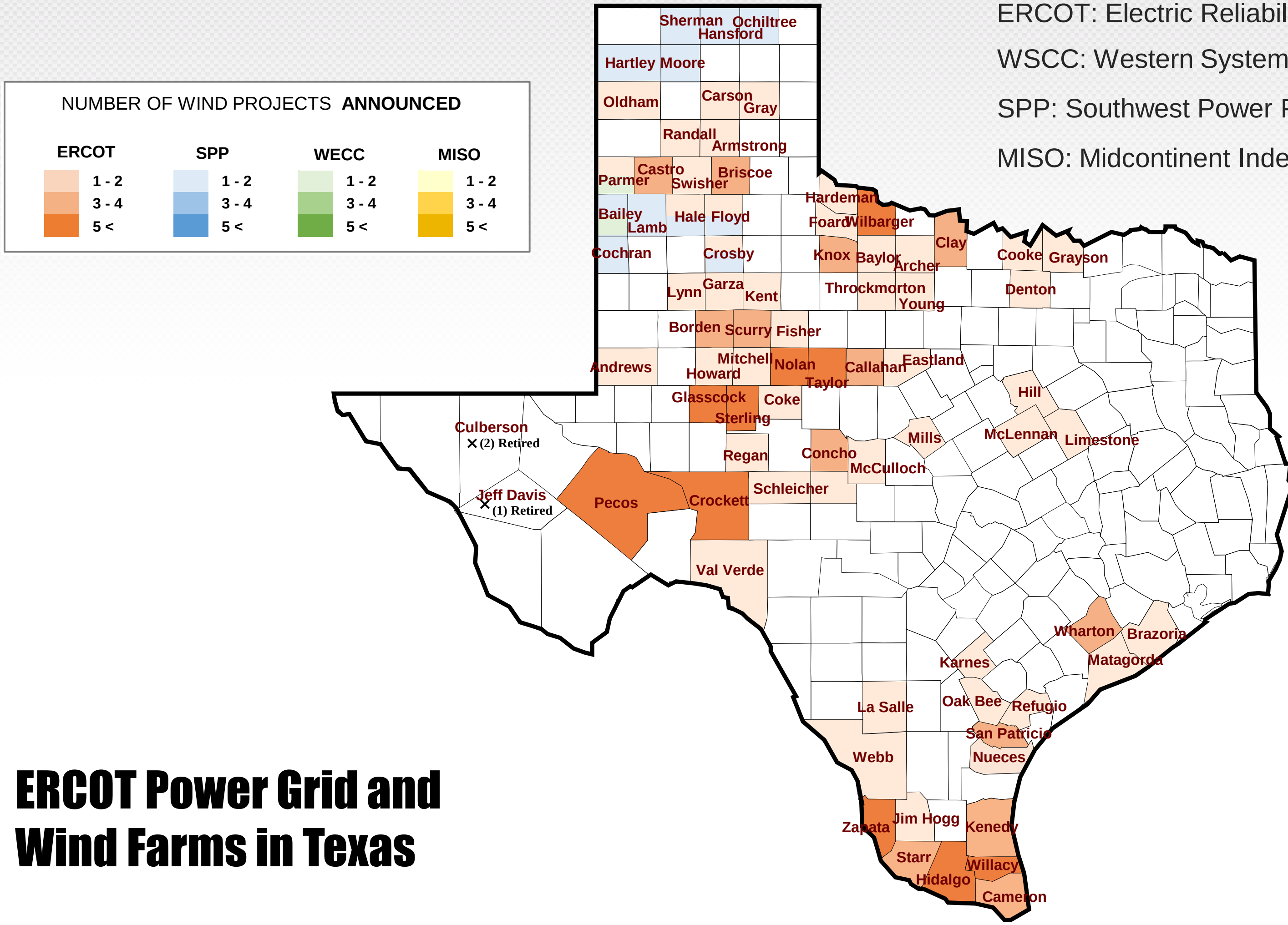
WSCC: Western Systems Coordinating Council

SPP: Southwest Power Pool

ERCOT Power Grid and Wind Farms in Texas

WIND PROJECTS IN TEXAS (2018)

Announced and Retired Wind Projects in Texas, as of Dec. 2018



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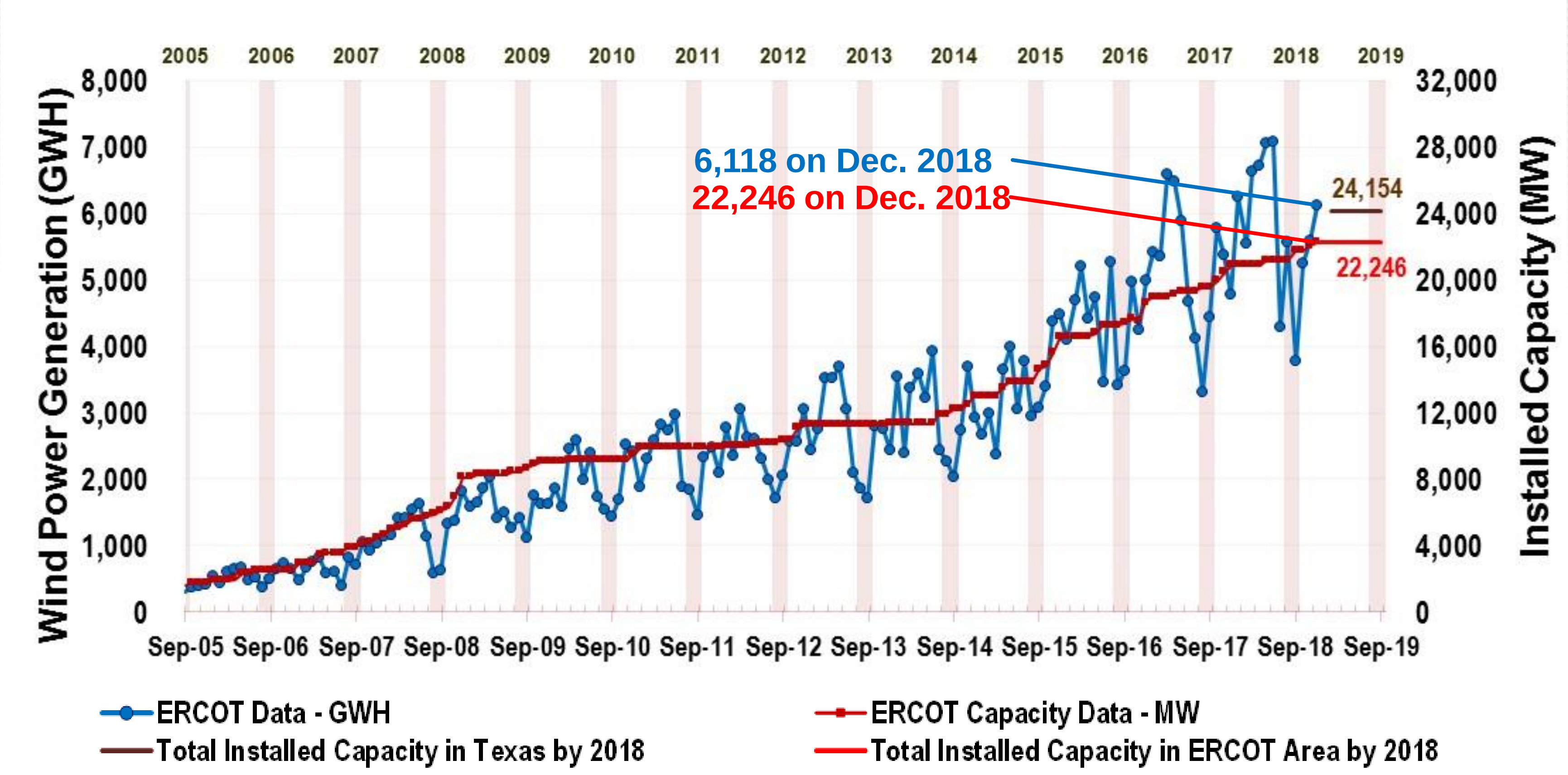
MISO: Midcontinent Independent System Operator

ERCOT Power Grid and Wind Farms in Texas

WIND PROJECTS IN TEXAS (2018)

ERCOT Capacity 22,246 MW **Total Capacity 24,154 MW** **Total Wind Power 69,898 GWh**



NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from electricity savings

CONSUMPTION

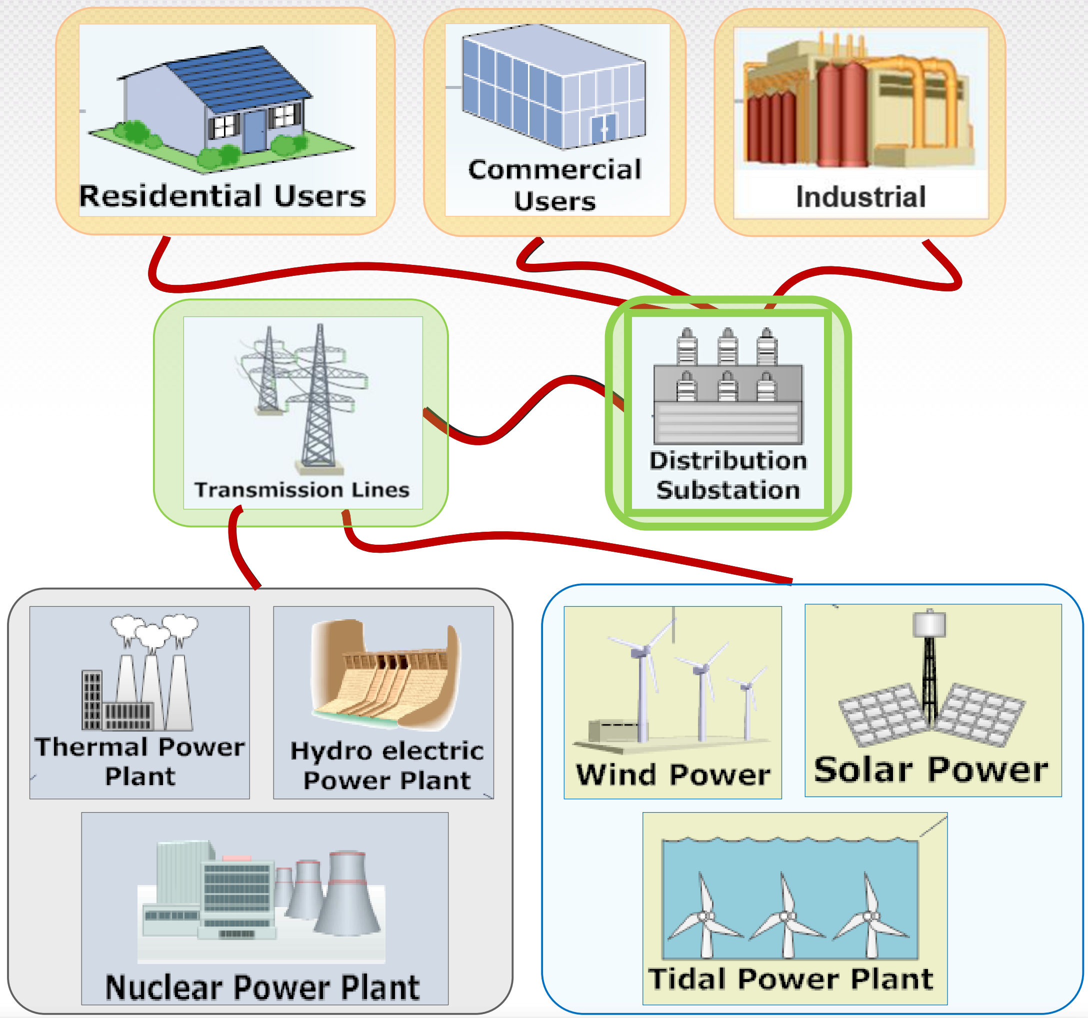
- Residential
- Commercial
- Industrial

TRANSMISSION & DISTRIBUTION

- Transmission Lines
- Sub-Station

GENERATION

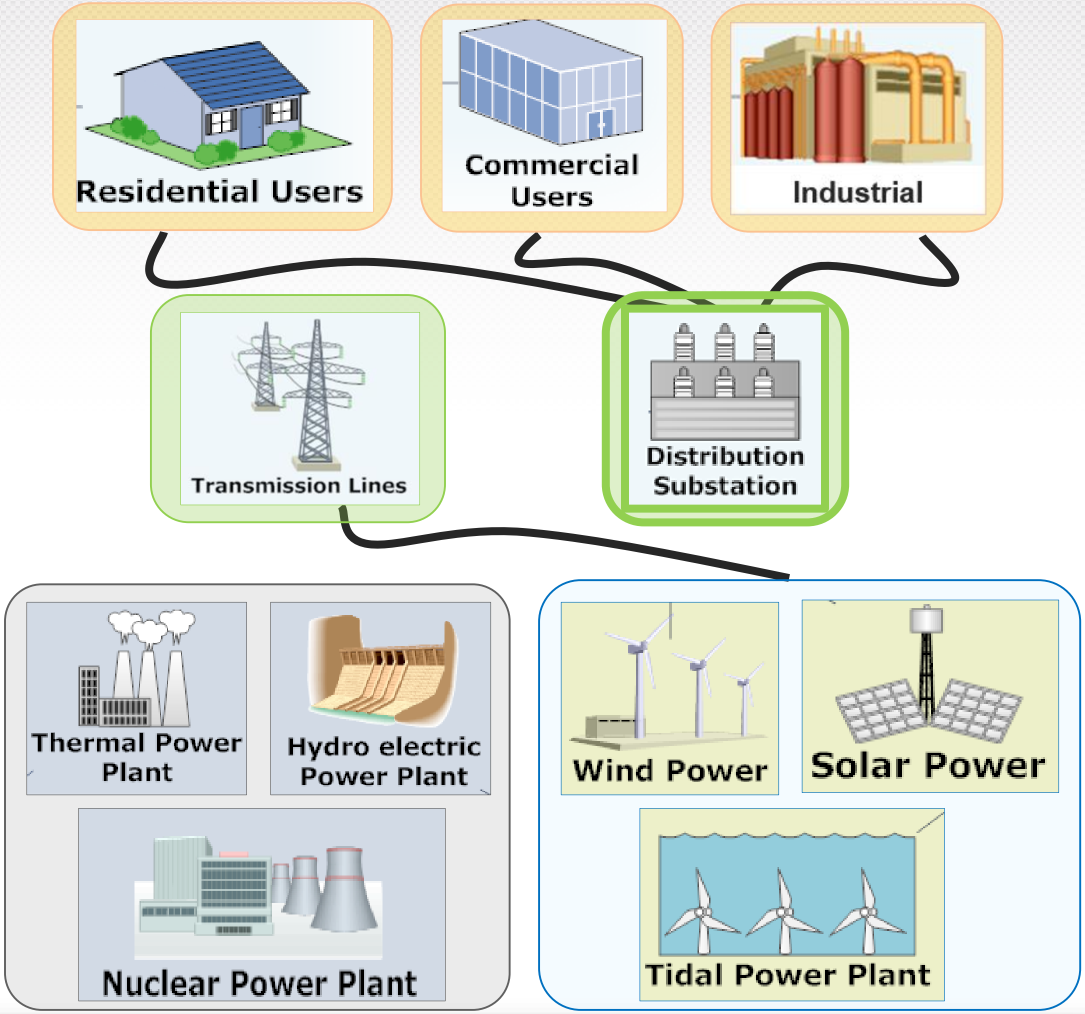
- Conventional
- Renewable



NOx REDUCTIONS USING eGRID

NOx emissions reductions calculation from electricity savings

Energy Savings from
EE/RE Programs



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NOx emissions reductions calculation from electricity savings

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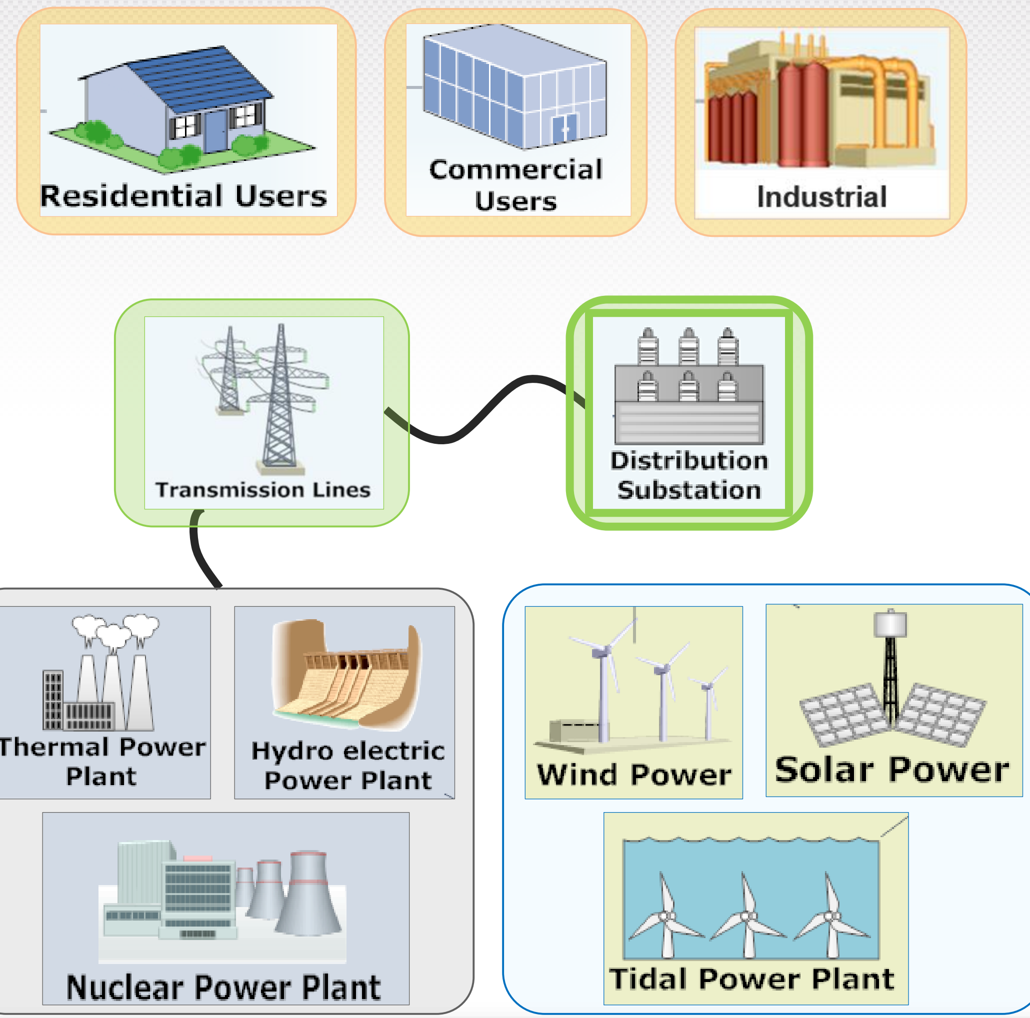
Energy Production & **Emissions Reductions**



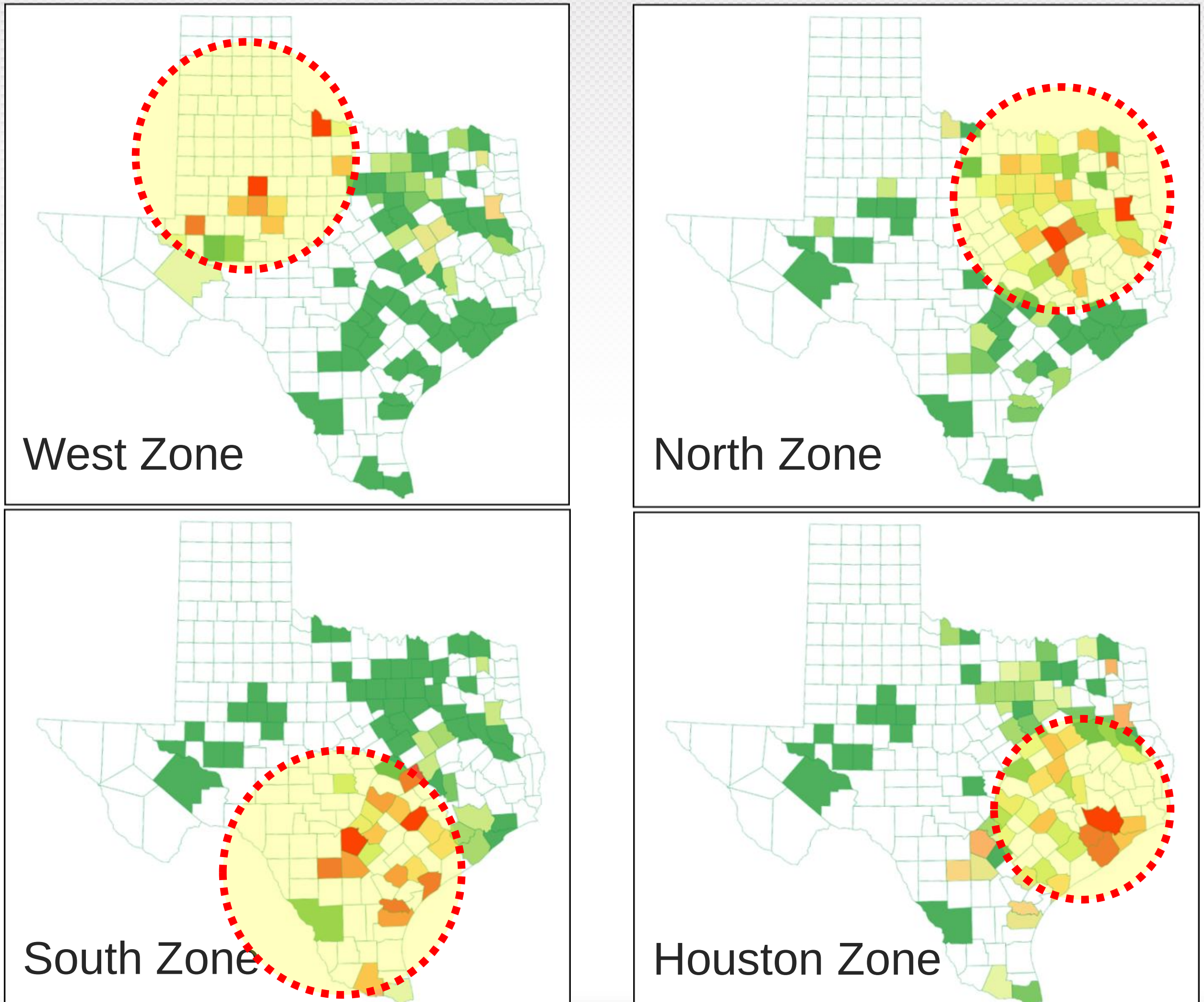
New 2016 eGRID for NOx Emissions

New 2016 eGRID (**Annual**) for NOx Emissions – ERCOT Region

Unit: lbs of NOx/MWh

NOx Emission lbs/MWh

= 0	
0 ≤	0.0002
0.0002 ≤	0.0004
0.0004 ≤	0.0008
0.0008 ≤	0.0016
0.0016 ≤	0.0032
0.0032 ≤	0.0064
0.0064 ≤	0.0128
0.0128 ≤	0.0256
0.0256 ≤	0.0512
0.0512 ≤	0.1024
0.1024 <	



New 2016 eGRID for NOx Emissions

New 2016 eGRID (**Annual**) for NOx Emissions - New Regions

Unit: lbs of NOx/MWh

NOx Emission lbs/MWh		
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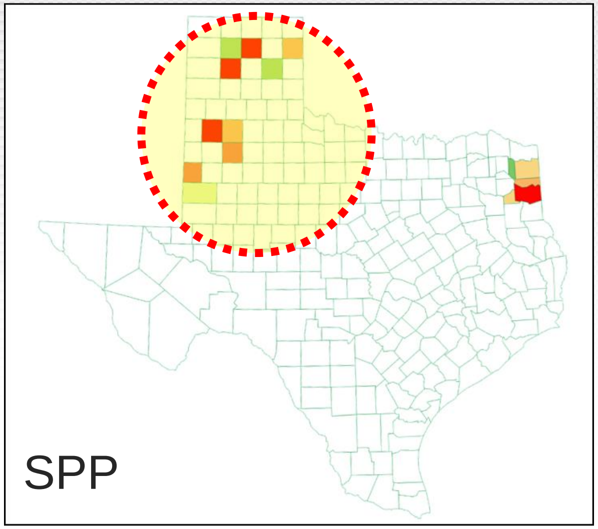
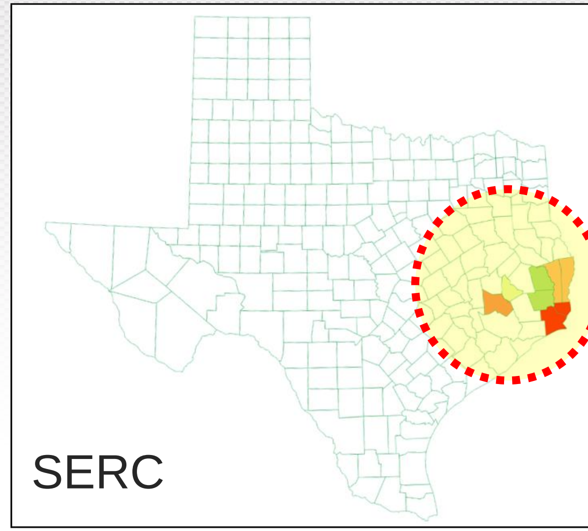
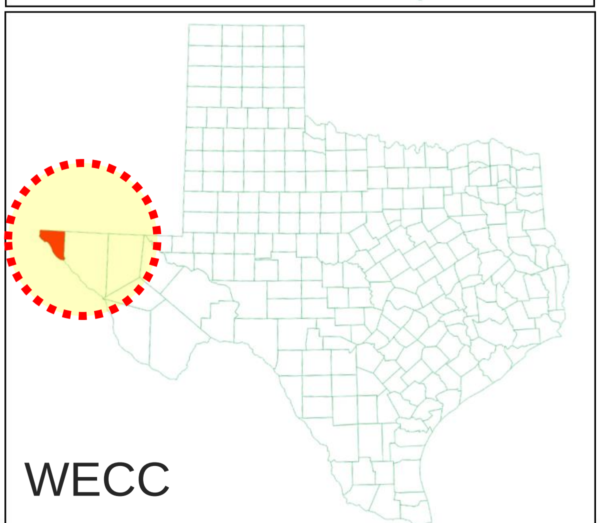
0	≤	0.0002
0.0002	≤	0.0004
0.0004	≤	0.0008
0.0008	≤	0.0016
0.0016	≤	0.0032
0.0032	≤	0.0064
0.0064	≤	0.0128
0.0128	≤	0.0256
0.0256	≤	0.0512
0.0512	≤	0.1024
0.1024	<	







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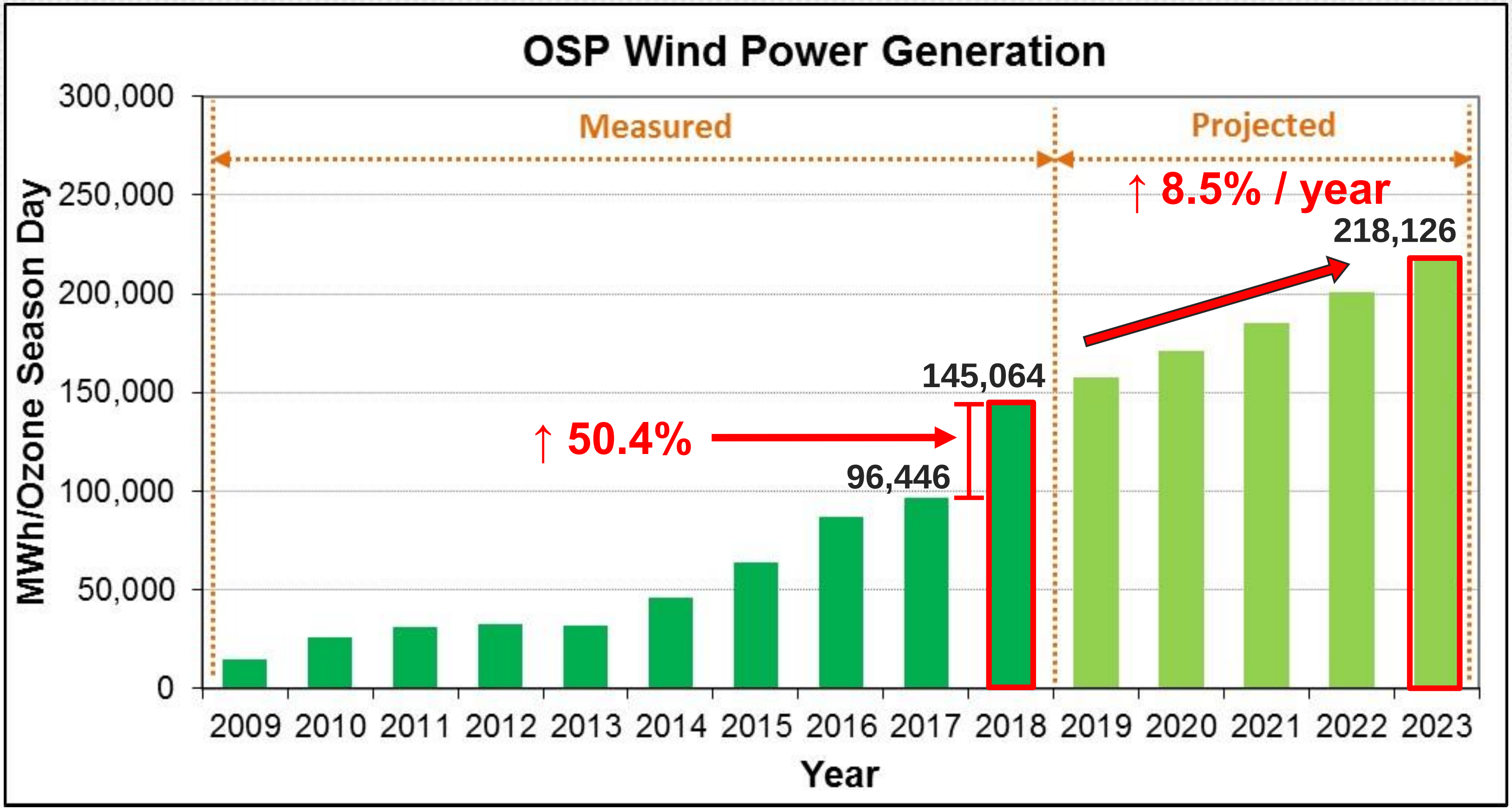
WECC: Western Electricity Coordinating Council

NOx REDUCTIONS FROM WIND POWER

OSP Power Generation and NOx Emissions Reductions (2008 base year)



Source: 15-min Wind Generation Data from ERCOT

OSP: The Ozone Season Period (OSP) was changed from the period of Jul 15 - Sep 15 to the period of May 1 - Sep 30

NOx REDUCTIONS FROM WIND POWER

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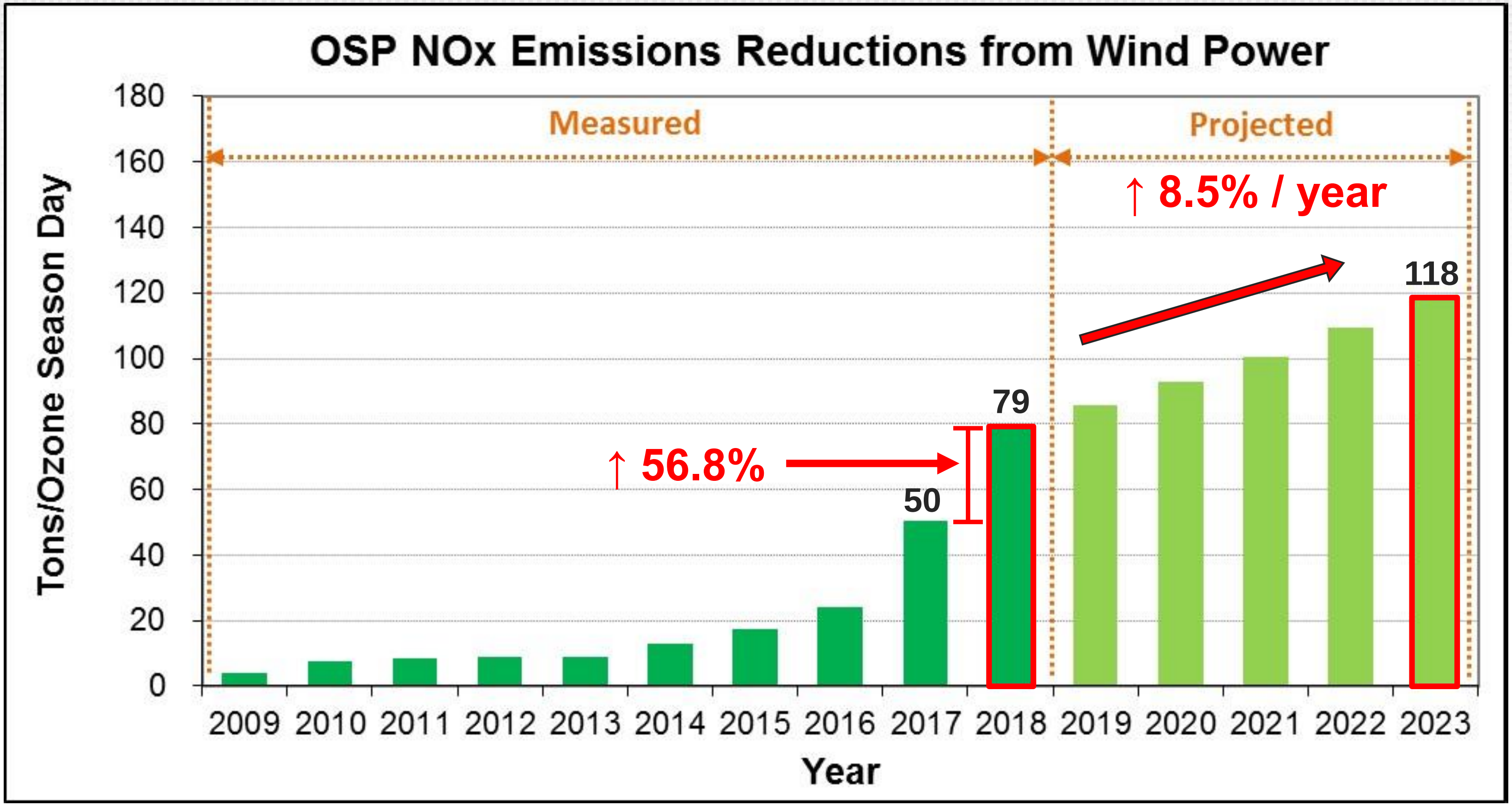
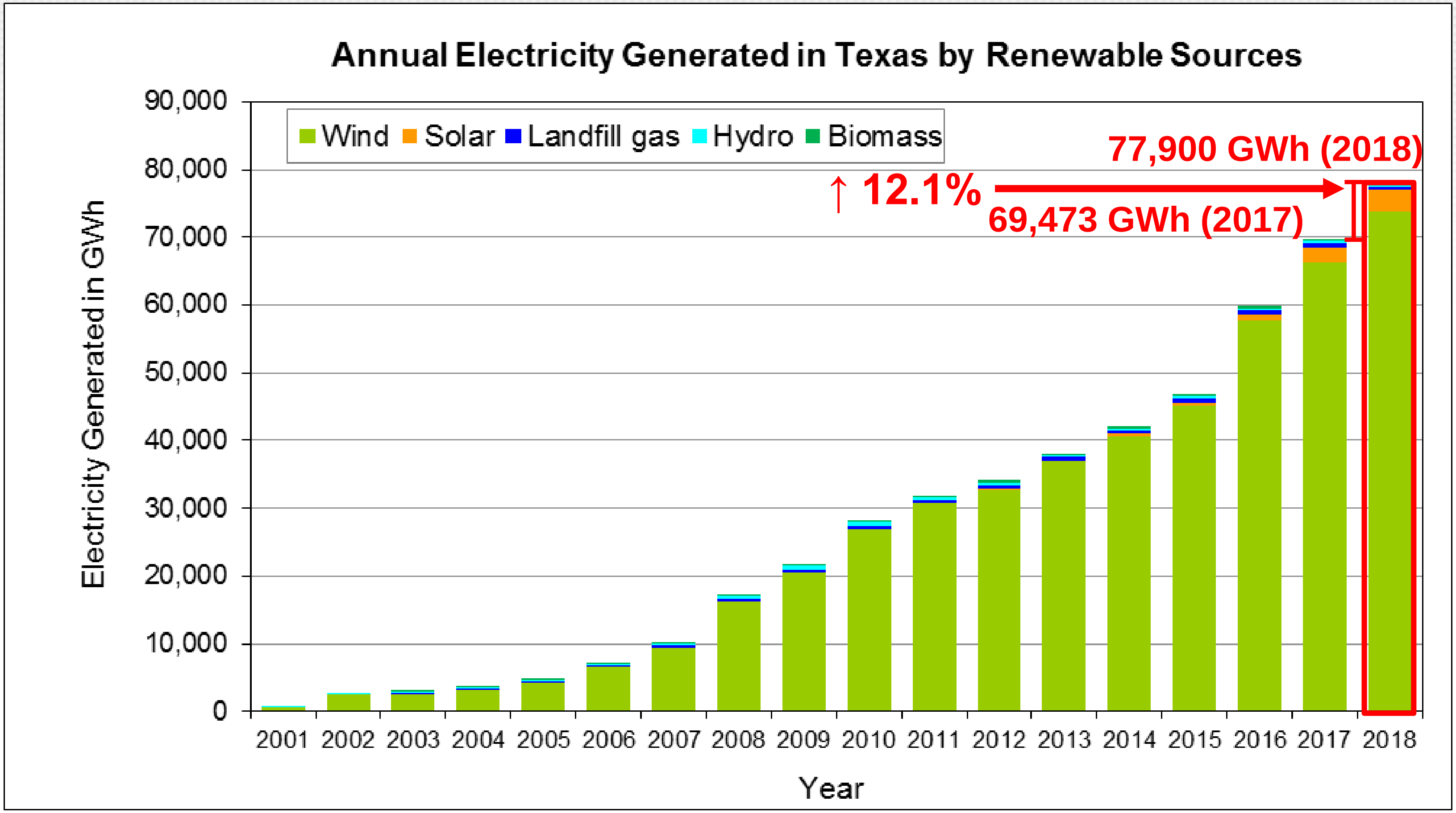


Source: 15-min Wind Generation Data from ERCOT

SAVINGS FROM OTHER RENEWABLES (2001-2018)

Renewables: Biomass, Hydro, Landfill Gas, Solar, Wind

✓ Wind energy is the largest portion



Source: Renewable Generation Data from ERCOT-REC (Renewable Energy Credit)

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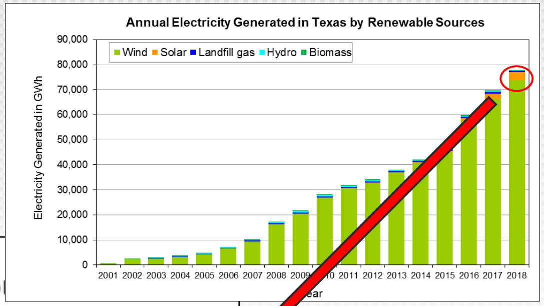
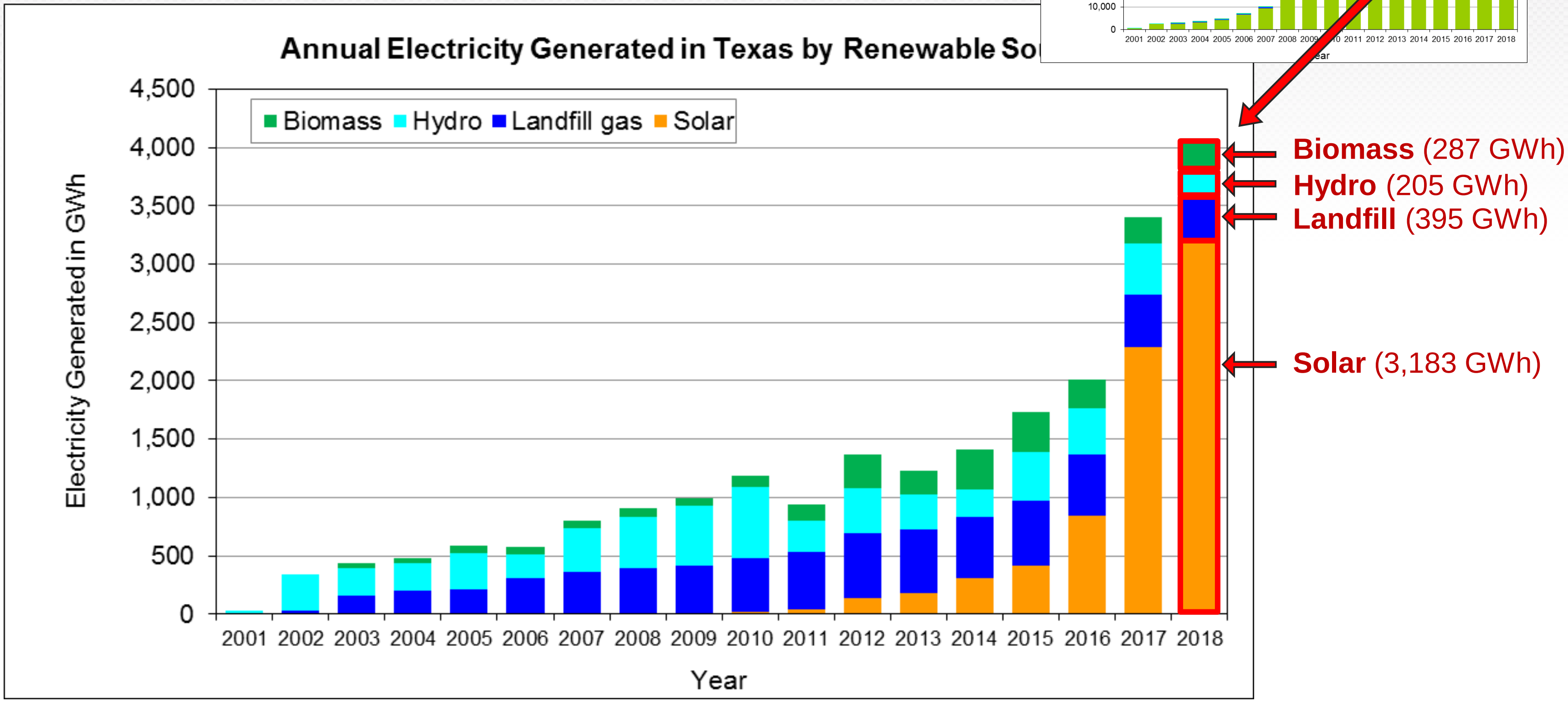


Excluding Wind



Source: Renewable Generation Data from ERCOT-REC (Renewable Energy Credit)

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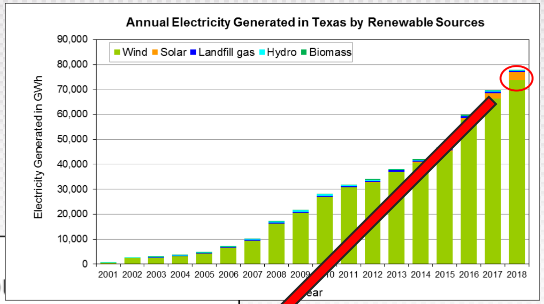

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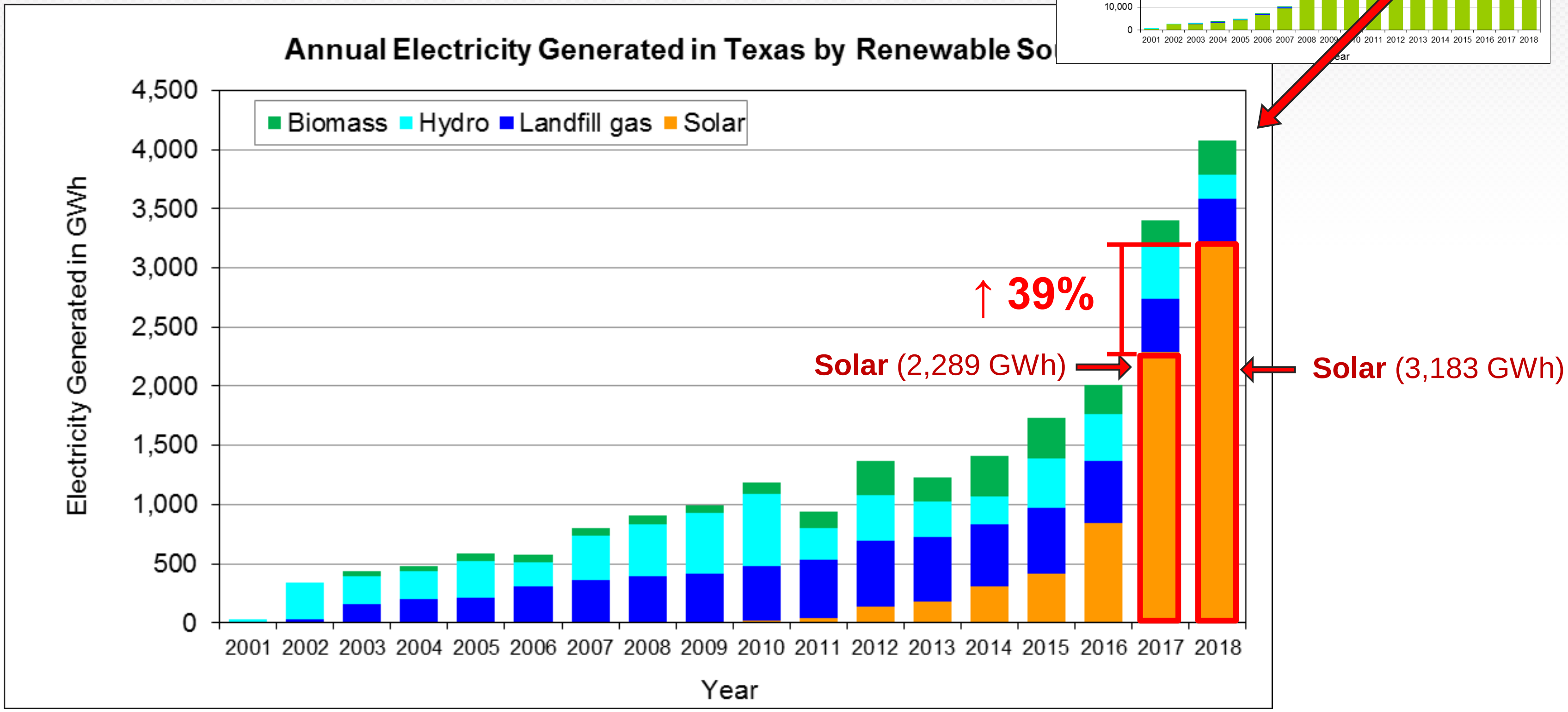
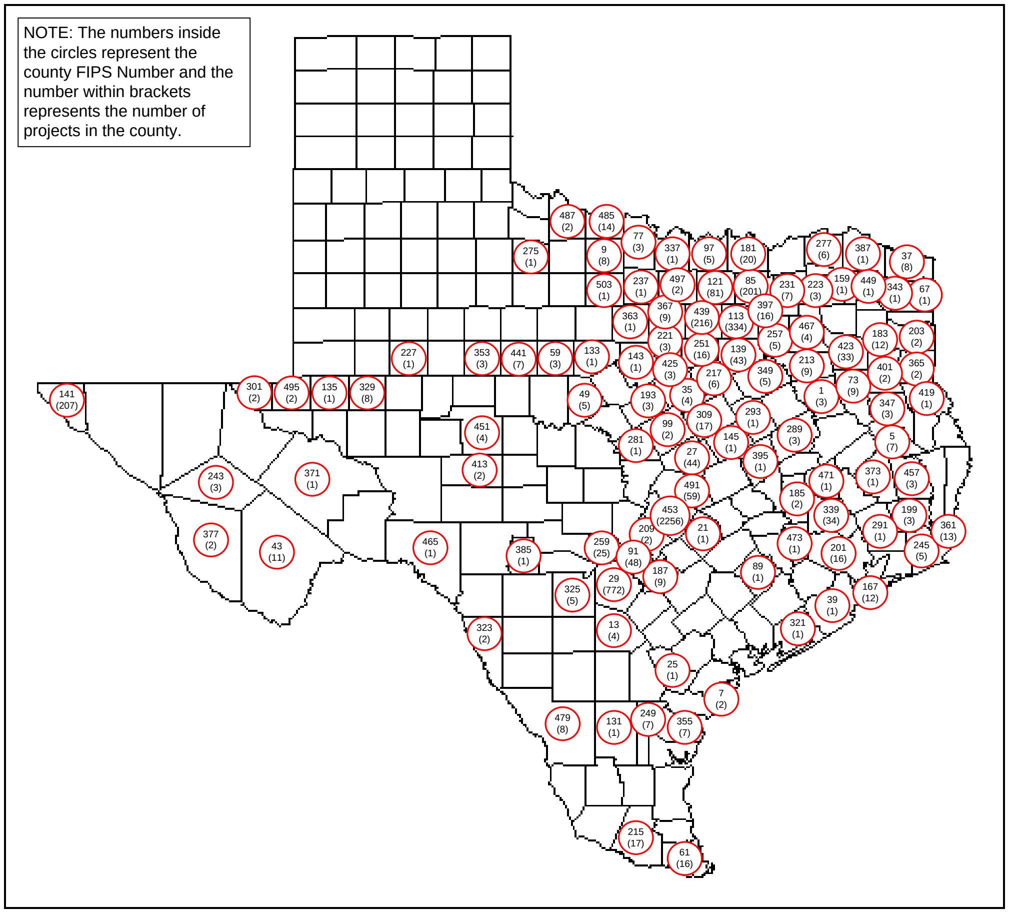


Source: Renewable Generation Data from ERCOT-REC (Renewable Energy Credit)

RENEWABLE PROJECTS IN TEXAS (2018)

Solar PV



Renewables*:

Solar PV - non utility scale (4,794 projects) +8 projects

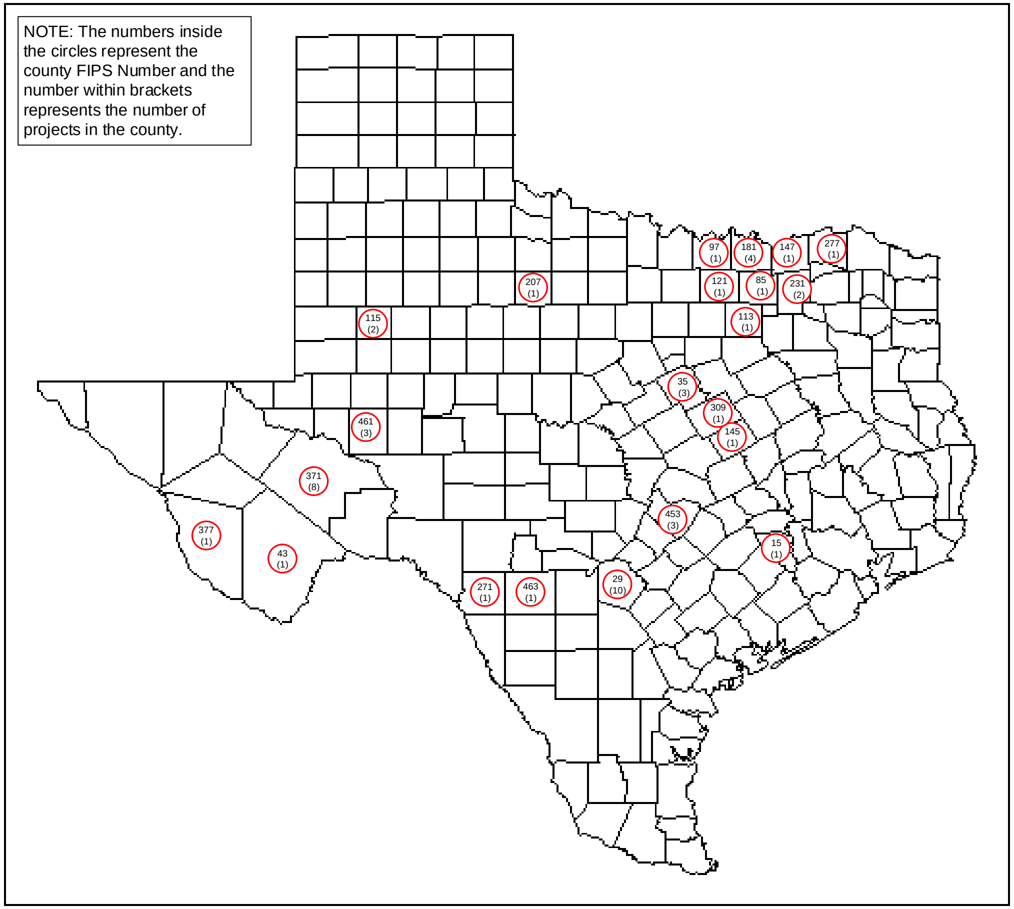
Solar Pv - non utility scale

https://openpv.nrel.gov

* Included renewable projects if their information/data are available

RENEWABLE PROJECTS IN TEXAS (2018)

Solar PV

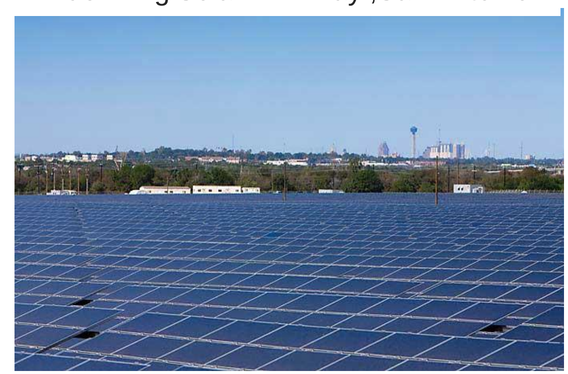


Renewables*:

Solar PV - non utility scale
(4,794 projects) +8 projects

Solar PV- utility scale
(49 projects) +18 projects

Blue Wing Solar PV Array ,San Antonio

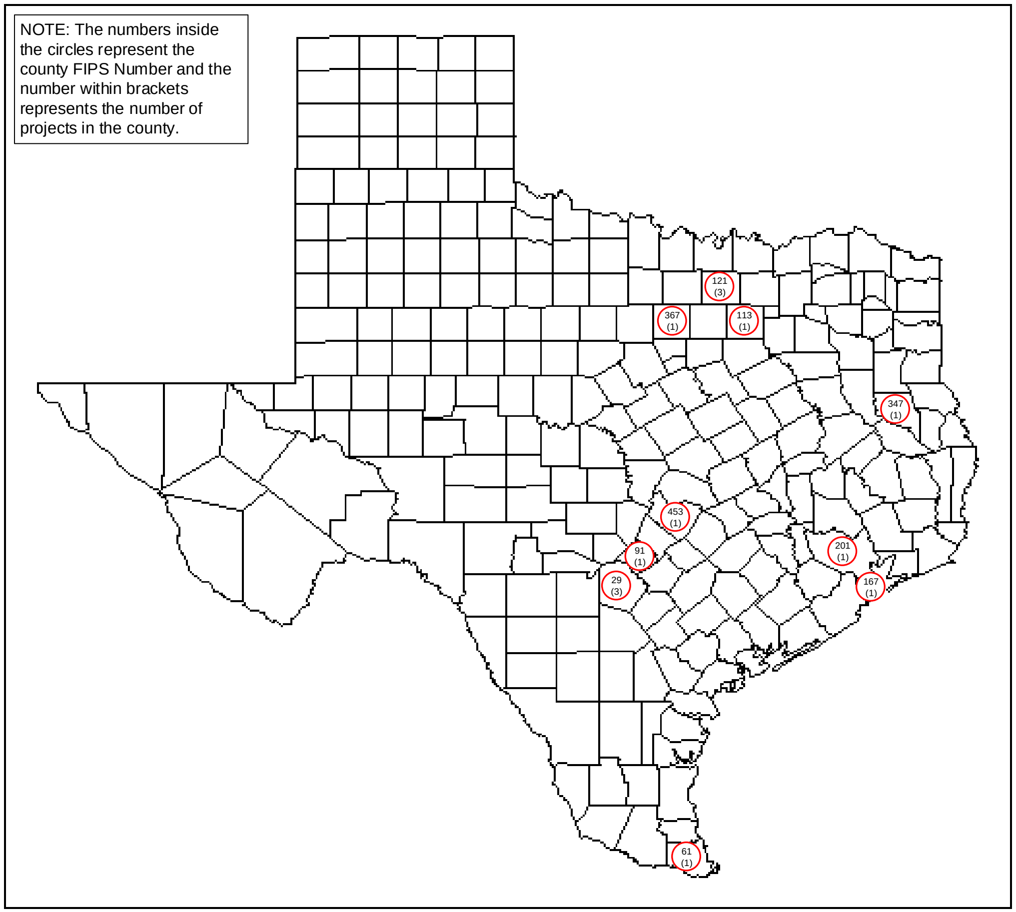


https://openpv.nrel.gov

* Included renewable projects if their information/data are available

RENEWABLE PROJECTS IN TEXAS (2018)

Biomass



Renewables*:

Solar PV - non utility scale
(4,794 projects) +8 projects

Solar PV- utility scale
(49 projects) +18 projects

Biomass (14 projects)

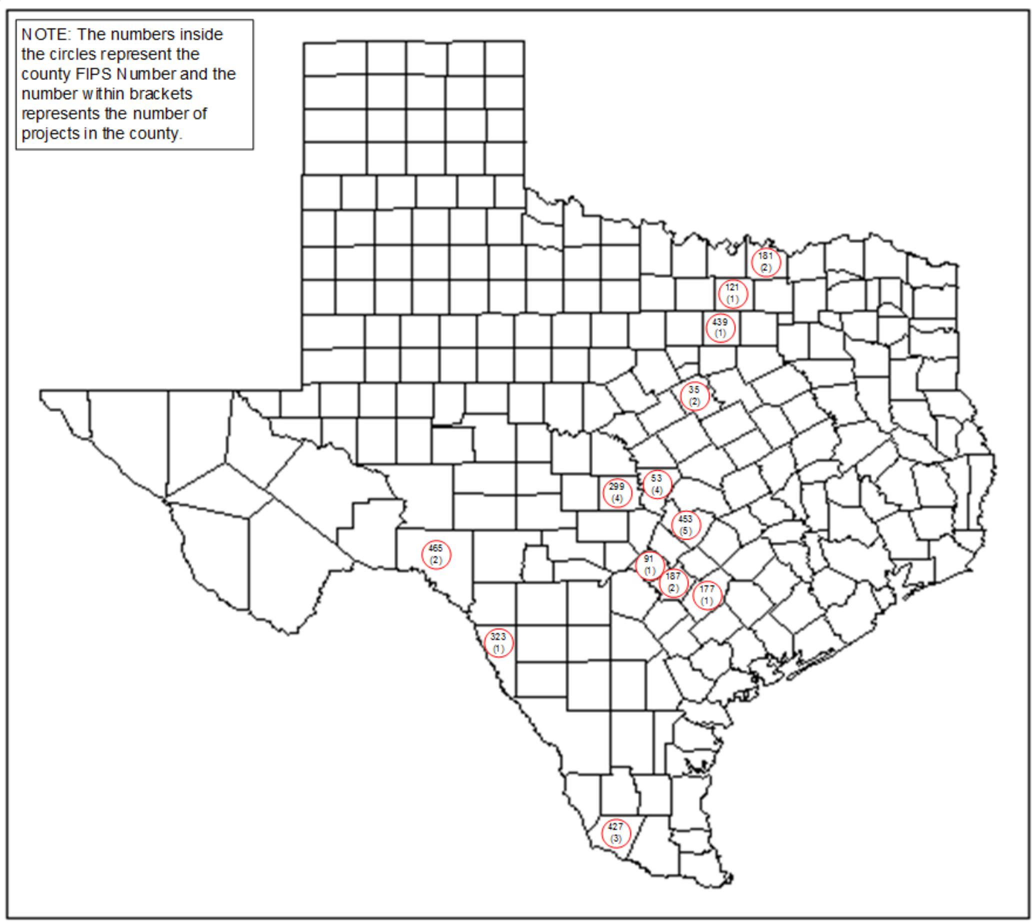
2.5 Miles Southwest of Woodville, TX

https://openpv.nrel.gov

* Included renewable projects if their information/data are available

RENEWABLE PROJECTS IN TEXAS (2018)

Hydro



Renewables*:

Solar PV - non utility scale (4,794 projects) +8 projects

Solar PV- utility scale (49 projects) +18 projects

Biomass (14 projects)

Hydro (29 projects)

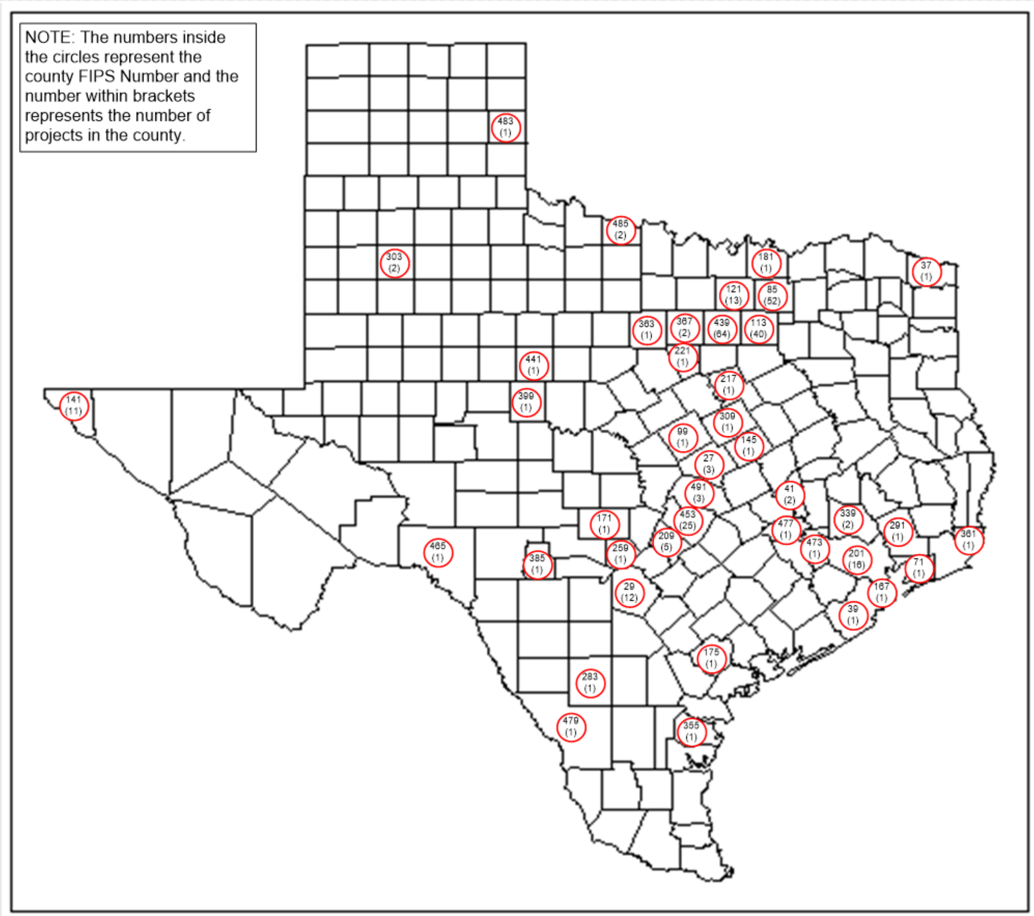
Dam at Elephant Butte, El Paso, TX

https://openpv.nrel.gov

* Included renewable projects if their information/data are available

RENEWABLE PROJECTS IN TEXAS (2018)

Geothermal



Renewables*:

Solar PV - non utility scale (4,794 projects) +8 projects

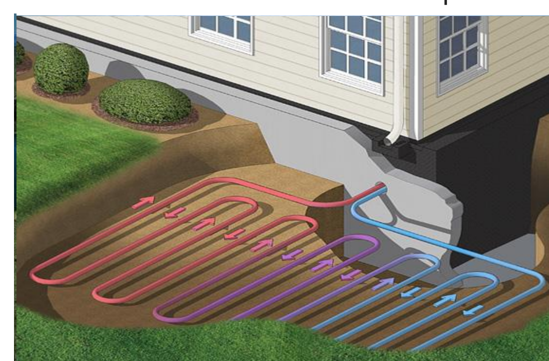
Solar PV- utility scale (49 projects) +18 projects

Biomass (14 projects)

Hydro (29 projects)

Geothermal (286 projects)

Ground Source Heat Pump

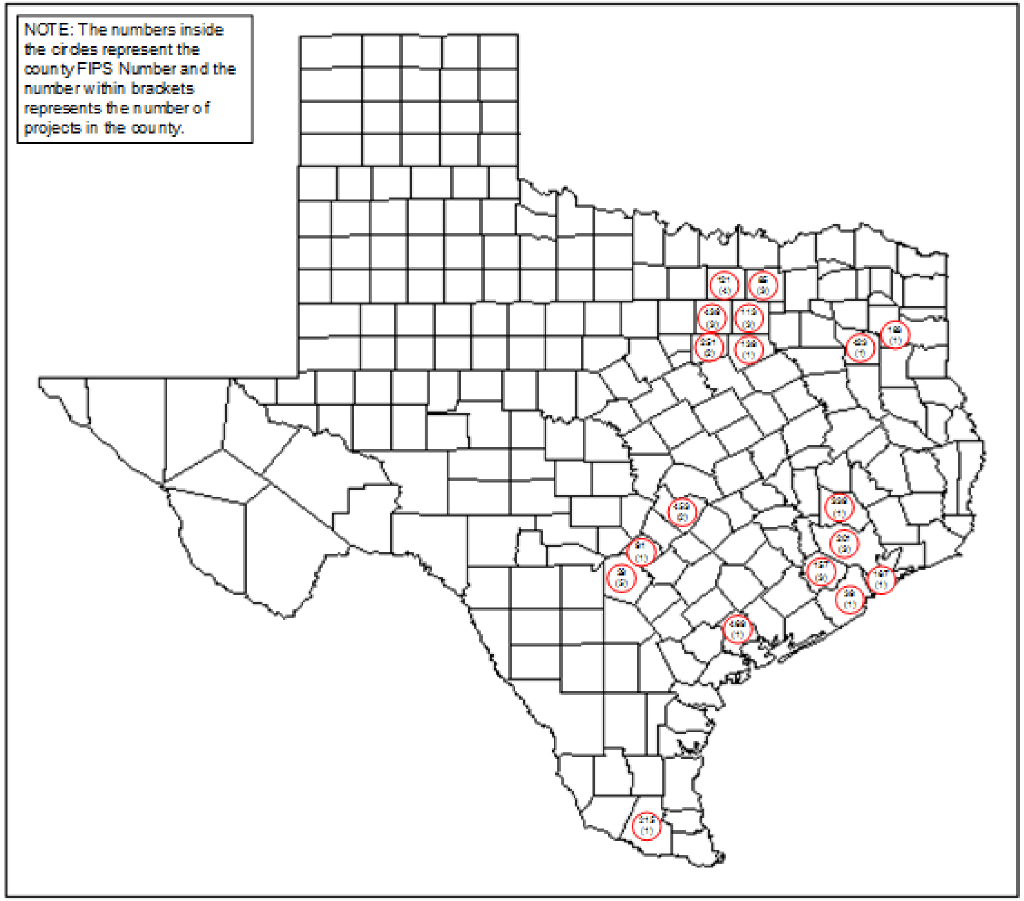


https://openpv.nrel.gov

* Included renewable projects if their information/data are available

RENEWABLE PROJECTS IN TEXAS (2018)

Landfill Gas



Renewables*:

Solar PV - non utility scale (4,794 projects) +8 projects

Solar PV- utility scale (49 projects) +18 projects

Biomass (14 projects)

Hydro (29 projects)

Geothermal (286 projects)

Landfill Gas (37 projects)

Aspen Power plant in Lufkin, TX

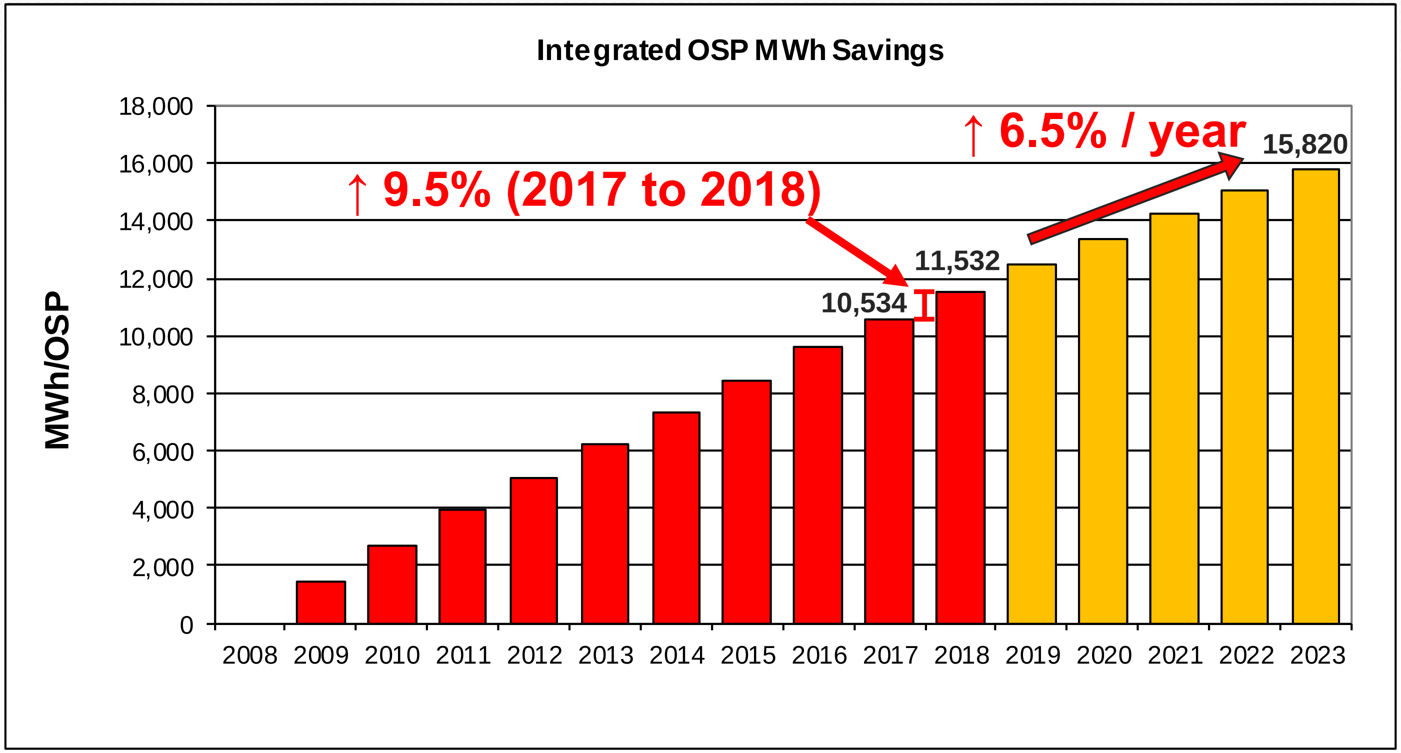
https://openpv.nrel.gov

* Included renewable projects if their information/data are available

ENERGY SAVINGS FROM PUC SB7

PUC SB7 Savings and Projections

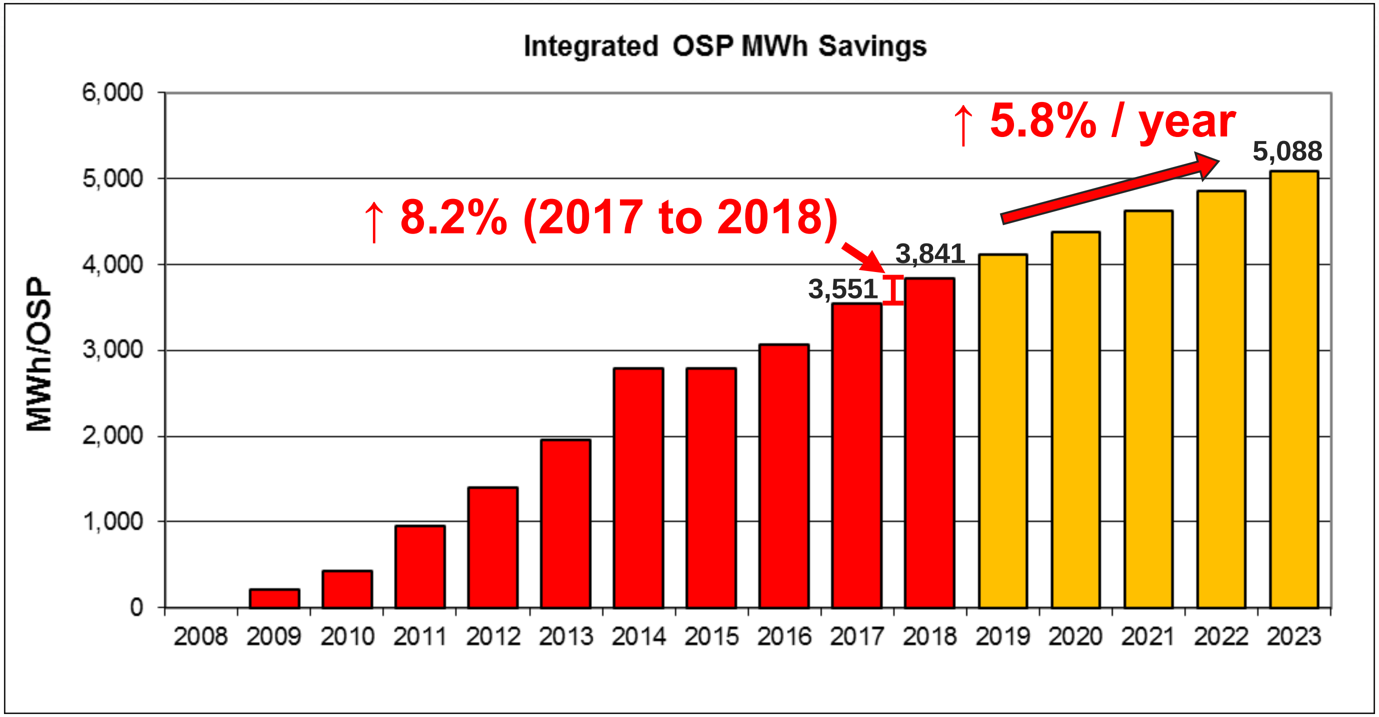
- The Public Utility Commission of Texas (PUC) Senate Bill 7 program includes their incentive and rebates programs managed by the different Utilities for Texas.
- These include the Residential Energy Efficiency Programs (REEP) as well as the Commercial & Industrial Standard Offer Programs.



ENERGY SAVINGS FROM SECO

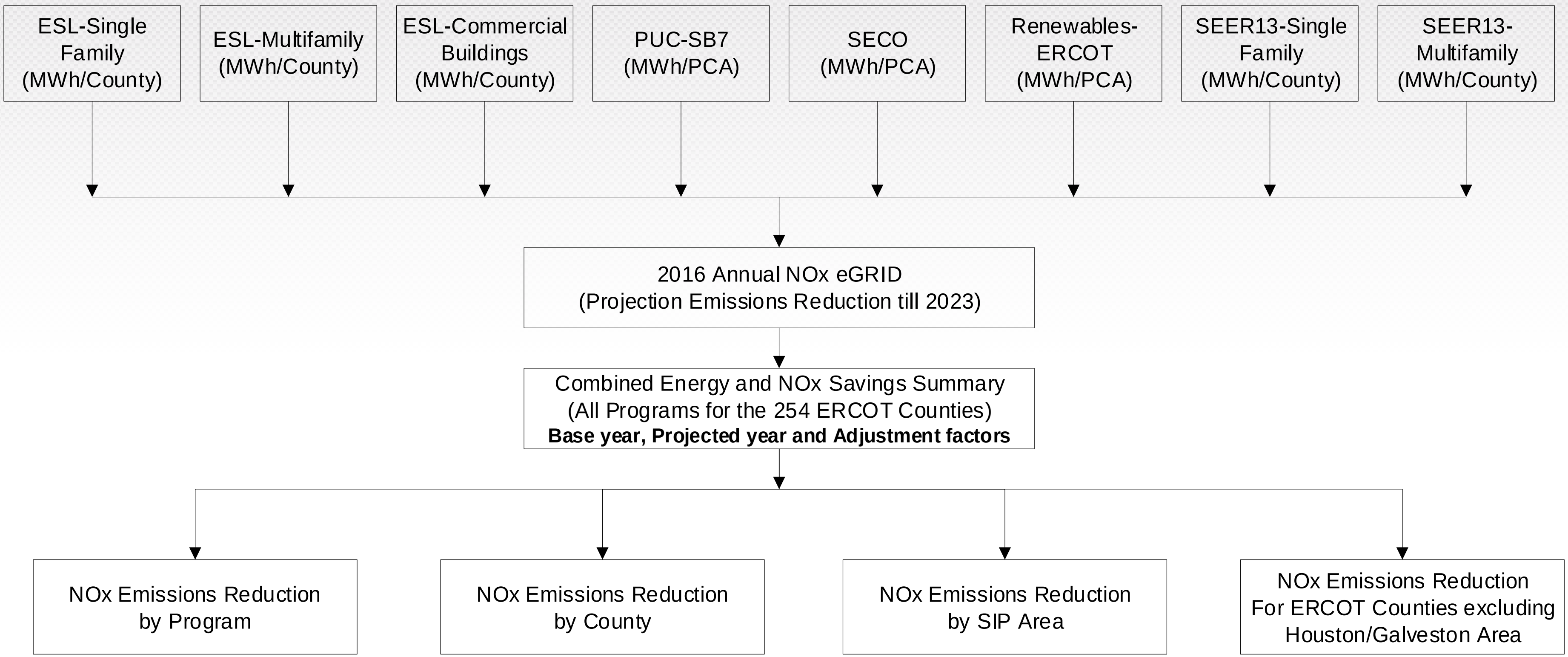
SECO Savings and Projections

- The Texas State Energy Conservation Office (SECO) funds energy-efficiency programs directed towards school districts, government agencies, city and county governments, private industries and residential energy consumers.
- The annual electricity savings are obtained from SECO's energy conservation projects reported by political subdivisions



INTEGRATED NOx EMISSIONS REDUCTION

Integrated Emissions Savings Across Agencies To Report Savings To TCEQ and EPA



INTEGRATED NOx EMISSIONS REDUCTION

Integrated Emissions Savings Across Agencies To Report Savings To TCEQ and EPA

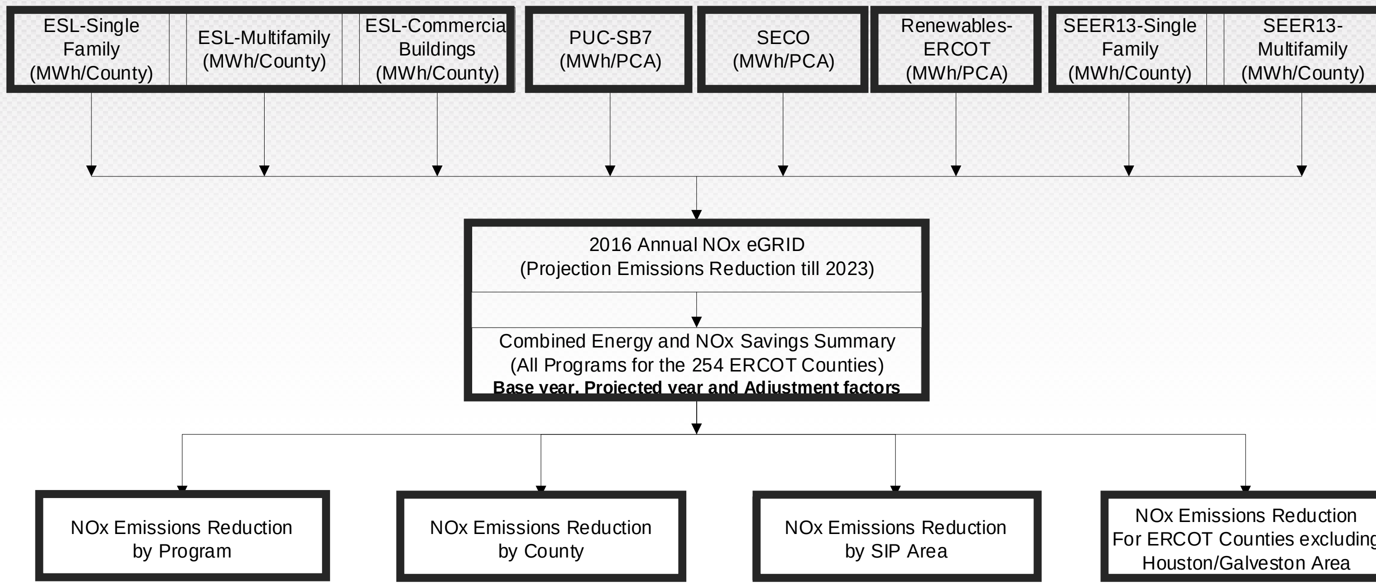
State agencies included:

- **TEES/ESL**
- **PUC**
- **SECO**
- **ERCOT/Wind**
- **SEER 13/14 Single/Multifamily**

Total savings across agencies

Annual emissions reductions:

- **By program**
- **By county**
- **By SIP area**
- **By ERCOT counties**

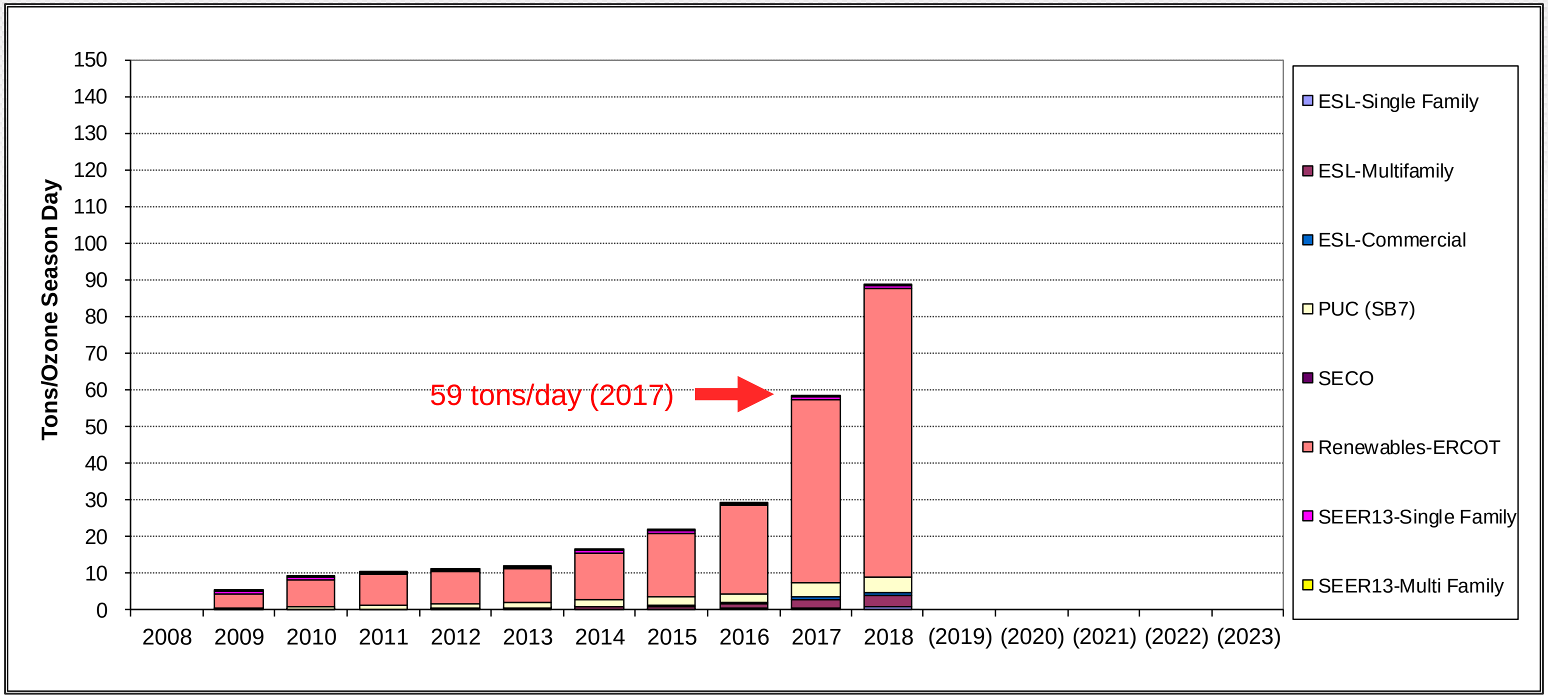


TCEQ

State Energy Conservation Office

INTEGRATED NOx EMISSIONS REDUTION (2008 Baseyear)

2018 Integrated OSP NOx Emissions Reduction Using new 2016 eGrid



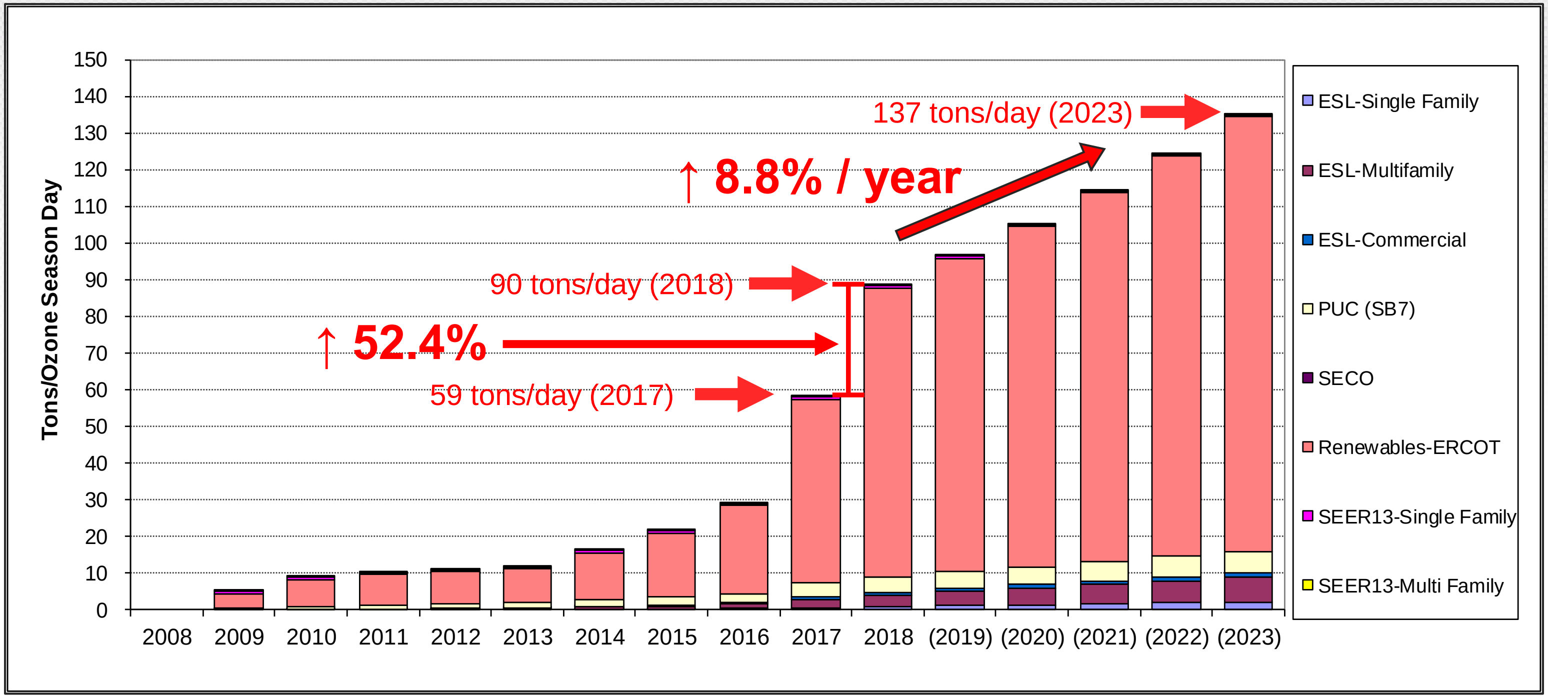
2017 integrated OSP NOx Emissions Reduction

- ESL Code Compliance (3.51 tons/day)
- PUC SB7 programs (3.75 tons/day)
- SECO Political Sub.* (1.14 tons/day)
- Green Power (Wind) (50.25 tons/day)
- Residential AC Retrofits (0.56 tons/day)

➢ **Total (2017) (59.21 tons/day)**

INTEGRATED NOx EMISSIONS REDUTION (2008 Baseyear)

2018 Integrated OSP NOx Emissions Reduction Using new 2016 eGrid



2018 integrated OSP NOx Emissions Reduction

- ESL Code Compliance (4.85 tons/day)
- PUC SB7 programs (4.21 tons/day)
- SECO Political Sub.* (1.30 tons/day)
- Green Power (Wind) (78.80 tons/day)
- Residential AC Retrofits (0.63 tons/day)

➢ **Total (2018) (89.79 tons/day)**

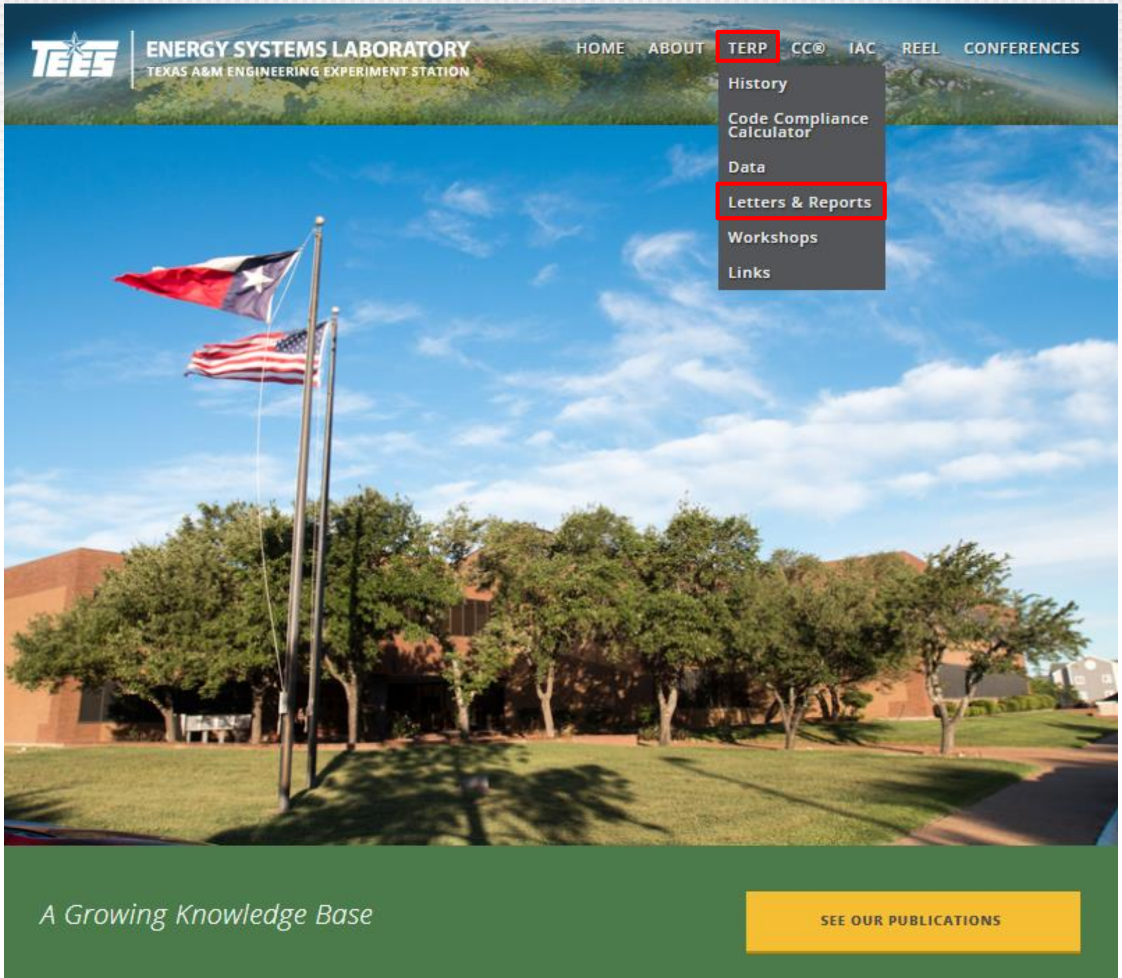
2023 integrated OSP NOx emissions reduction

- ESL Code Compliance (10.25 tons/day)
- PUC SB7 programs (5.78 tons/day)
- SECO Political Sub. * (1.75 tons/day)
- Green Power (Wind) (118.49 tons/day)
- Residential AC Retrofits (0.49 tons/day)

➢ **Total (2023) (136.77 tons/day)**

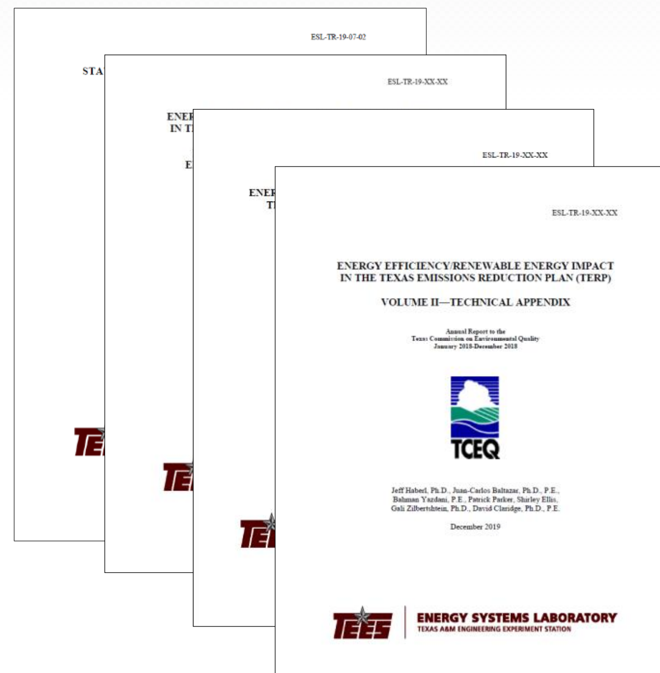
REPORTS AND PAPERS: TERP

Reports: 2002 through 2018



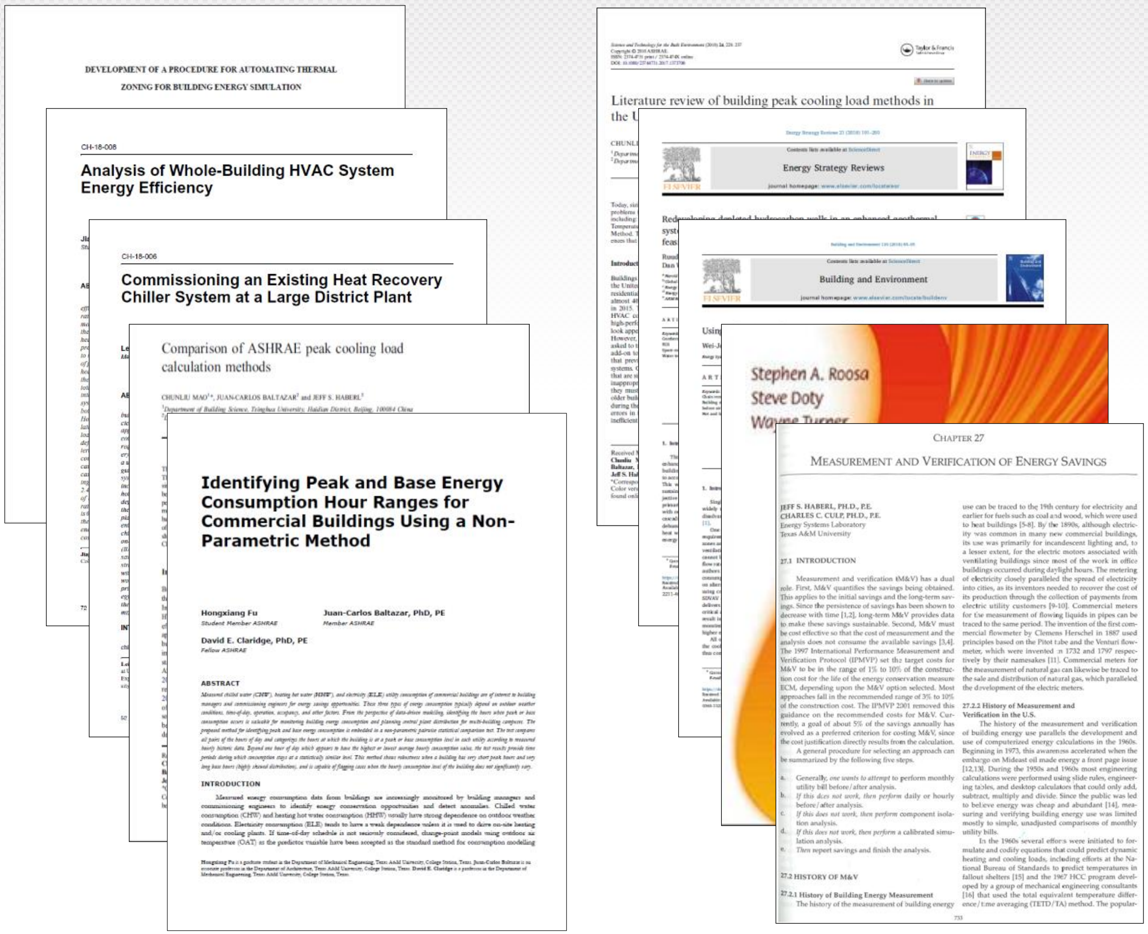
Recent Reports:

- Statewide 2018 Air Emission Calculations from Wind and Other Renewables (Vol I and Vol II)
- TCEQ 2018 Annual Preliminary Report: Integrated NOx Emissions Savings from EE/RE Programs Statewide
- TCEQ 2018 Annual Report Volume I: Technical Report
- TCEQ 2018 Annual Report Volume II: Technical Appendix



REPORTS AND PAPERS: TERP

Publications: 2018



Dissertation 2018:

- Shin, M. “Development of a Procedure for Automating Thermal Zoning for Building Energy Simulation",PhD., Department of Architecture, August 2018.

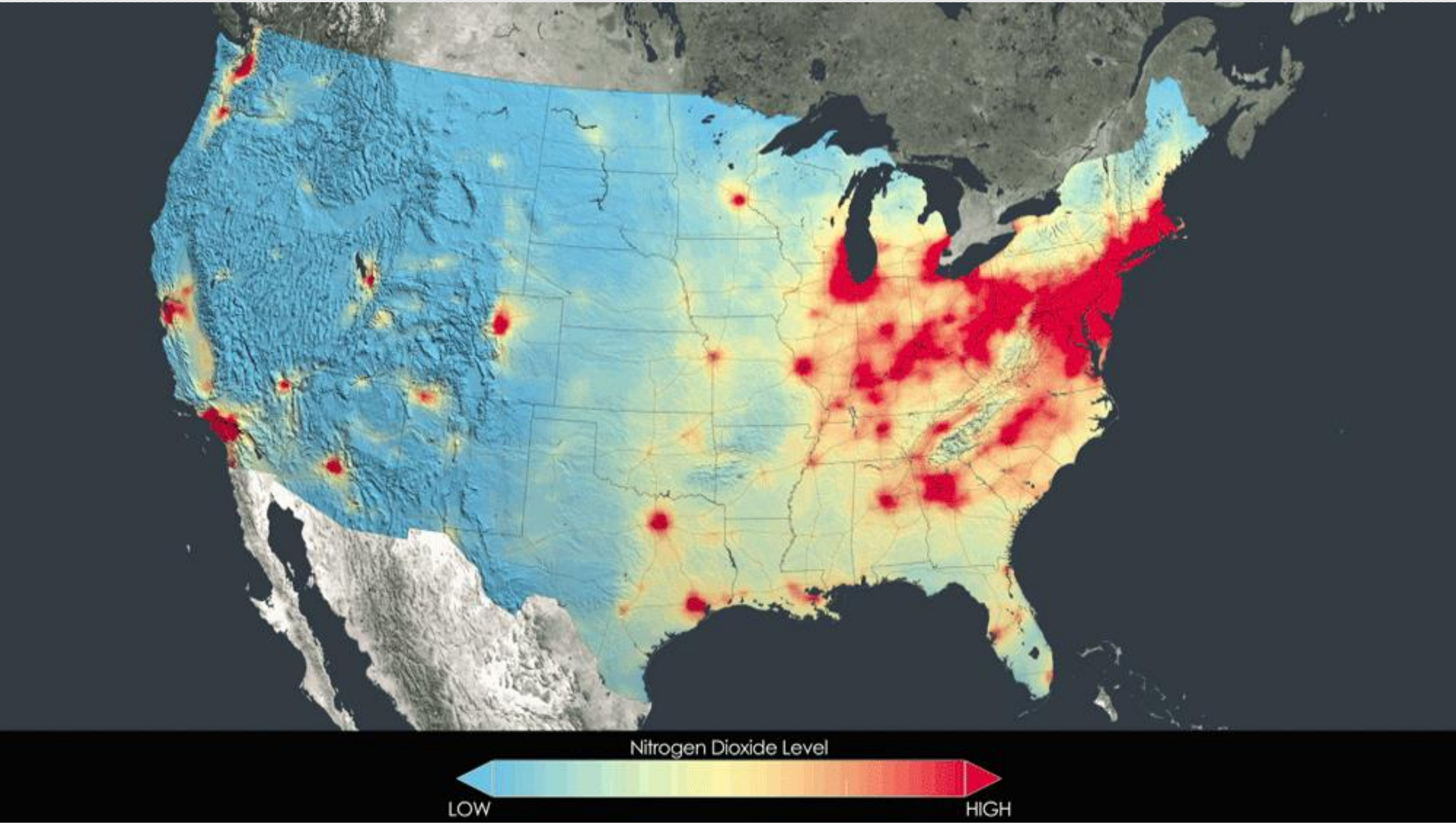
Papers 2018:

- Liao, J., Wang, L., Claridge,D.E.,2018. "Analysis of Whole-Building HVAC System Energy Efficiency", ASHRAE Transaction.
- Wang, L., Sakurai, Y., Bowman, S.J., Claridge, D.E., 2018. "Commissioning an Existing Heat Recovery Chiller System at a Large District Plant", ASHRAE Transaction.
- Mao, C., Baltazar, J., Haberl, J.S., 2018. “Comparison of ASHRAE Peak Cooling Load Calculation Methods”, Science and Technology for the Built Environment, Vol 25, pp.189-208.
- Fu, H., Baltazar, J., Claridge, D.E., 2018. “Identifying Peak and Base Energy Consumption Hour Ranges for Commercial Buildings Using a Non-Parametric Method”, ASHRAE Winter Meeting.
- Mao, C., Baltazar, J., Haberl, J.S., 2018. "Literature Review of Building Peak Cooling Load Methods in the United States", Science and Technology for the Built Environment, Vol 24, pp.228-237.
- Weijermars, R., Burnett, D., Claridge, D.E., Noynaert, S., Pate, M., Westphal, D., Yu, W., Zuo, L., 2018. "Redeveloping Depleted Hydrocarbon Wells in an Enhanced Geothermal System(EGS) for a University Campus: Progress Report of a Real-Asset-Based Feasibility Study", Energy Strategy Reviews.
- Chen, W.j., Claridge, D.E., Liao, J., 2018. "Using a Chain Recooling System on Buildings in Hot and Humid Climates", Building and Environment.

Chapters Written and Volumes Edited 2018:

- Haberl, J.S., Culp, C., 2018, “Measurement and Verification of Energy Savings,” Chapter 27 in Roosa, S., Doty, S. and Turner, W.C., eds., Energy Management Handbook, 9th edition, Fairmont Press.

U.S. AIR QUALITY IMPROVEMENT FROM 2005 - 2018



Source from NASA: http://www.nasa.gov/content/goddard/new-nasa-images-highlight-us-air-quality-improvement/#.U_-CNxzKbxQ

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http://esl.tamu.edu/terp