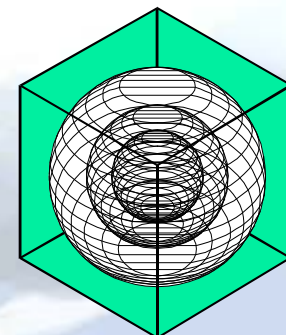


# **EMISSIONS REDUCTION IMPACT OF RENEWABLES**

**October 2012**

**Jeff Haberl, Bahman Yazdani, Charles Culp**  
**Energy Systems Laboratory**  
**Texas A&M University**





# ACKNOWLEDGEMENTS

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**Faculty/Staff:** Juan-Carlos Baltazar, Jaya Mukhopadhyay, Hyojin Kim, Patrick Parker, Vic Reid, Gali Zilbershtein, Rose Sauser, Stephen O'Neal, Tammy Jennings, Larry Degelman, Ed Dryden, Shirley Muns, Tom Fitzpatrick

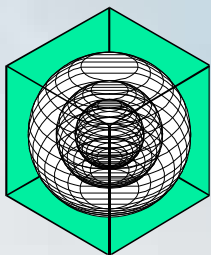
**Students:** Chunliu Mao, Sung Lok Do

**TCEQ:** Vince Meiller, Bob Gifford

**ERCOT:** Warren Lasher

**USEPA:** Art Diem, Julie Rosenberg

# RENEWABLES



Solar PV



Solar Thermal



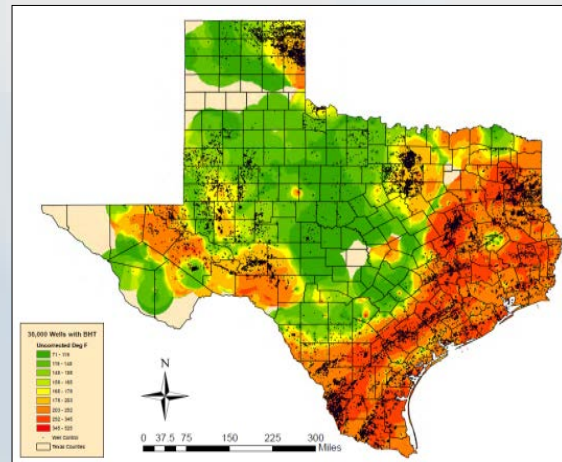
Hydro



Biomass

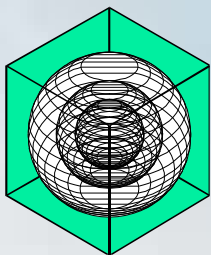


Landfill Gas



Geothermal

# RENEWABLES



Solar PV



Hydro



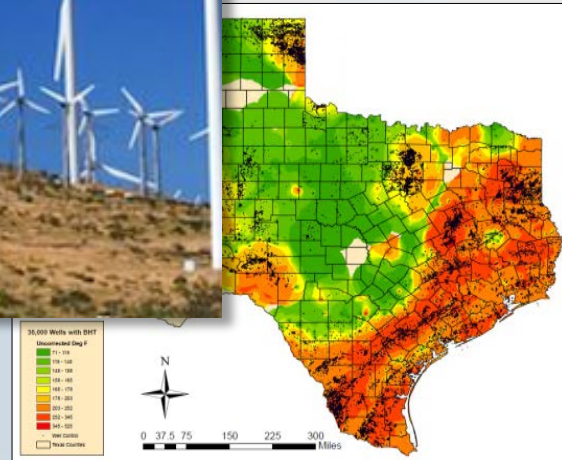
Wind



Biomass



Landfill Gas

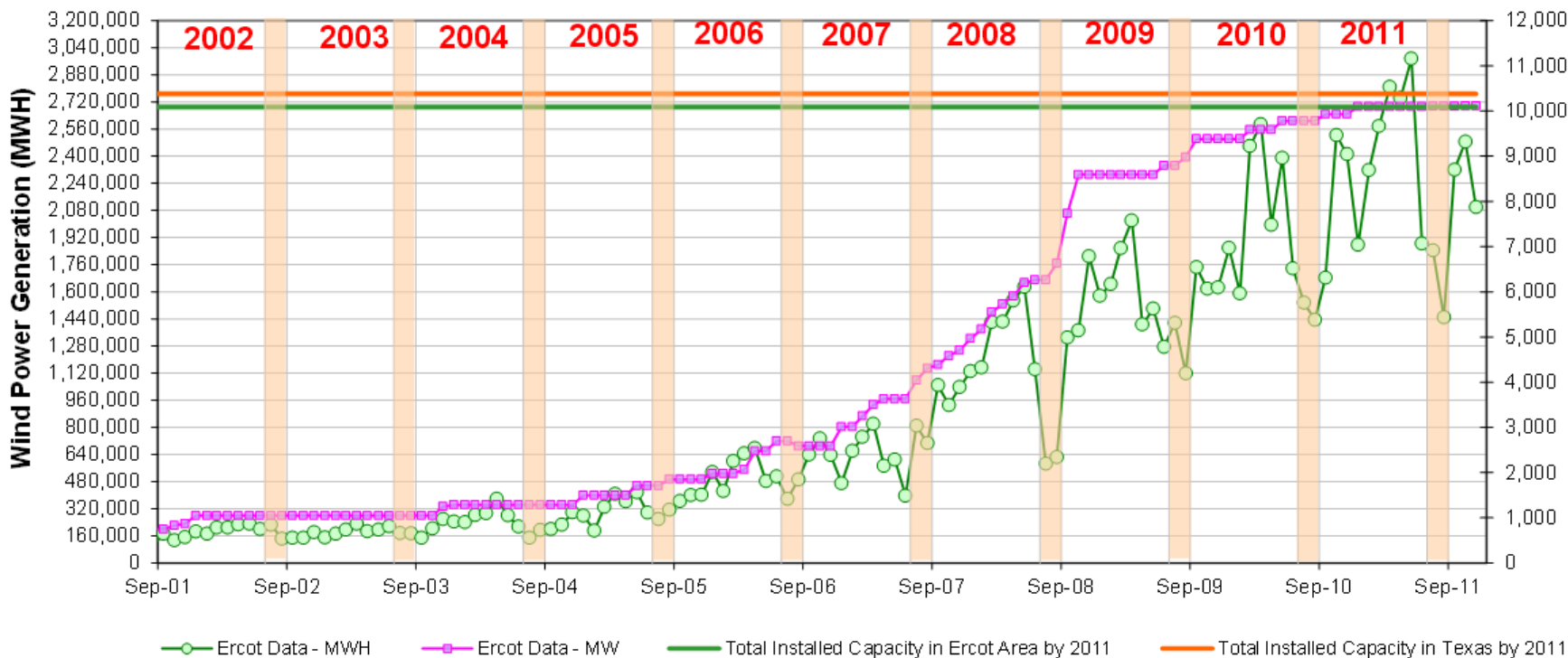


Geothermal

# WIND PROJECTS IN TEXAS (2011)

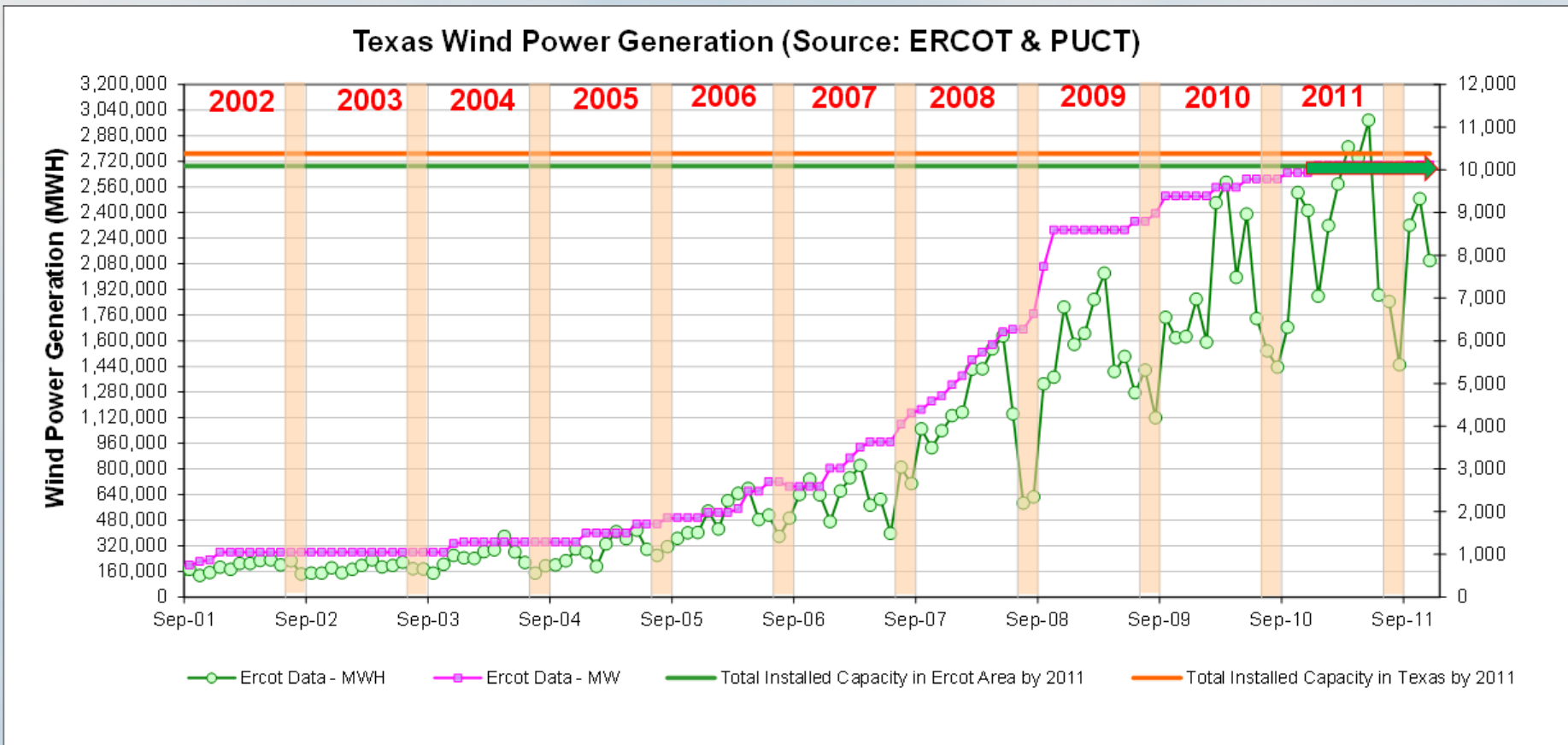
Substantial increases in measured electricity from wind energy.

Texas Wind Power Generation (Source: ERCOT & PUCT)



# WIND PROJECTS IN TEXAS (2011)

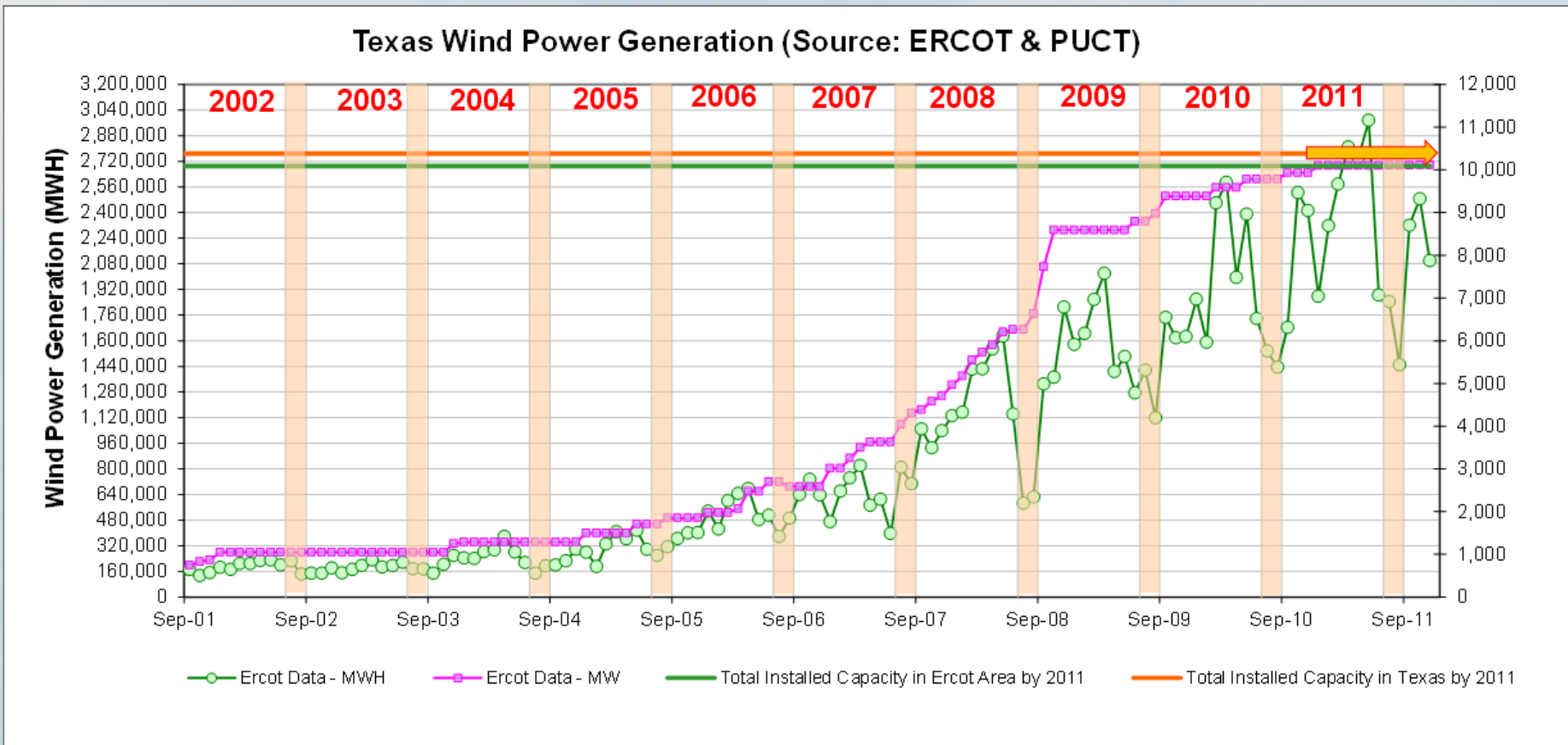
Substantial increases in measured electricity from wind energy.



Total capacity: 10,088 MW/month in ERCOT

# WIND PROJECTS IN TEXAS (2011)

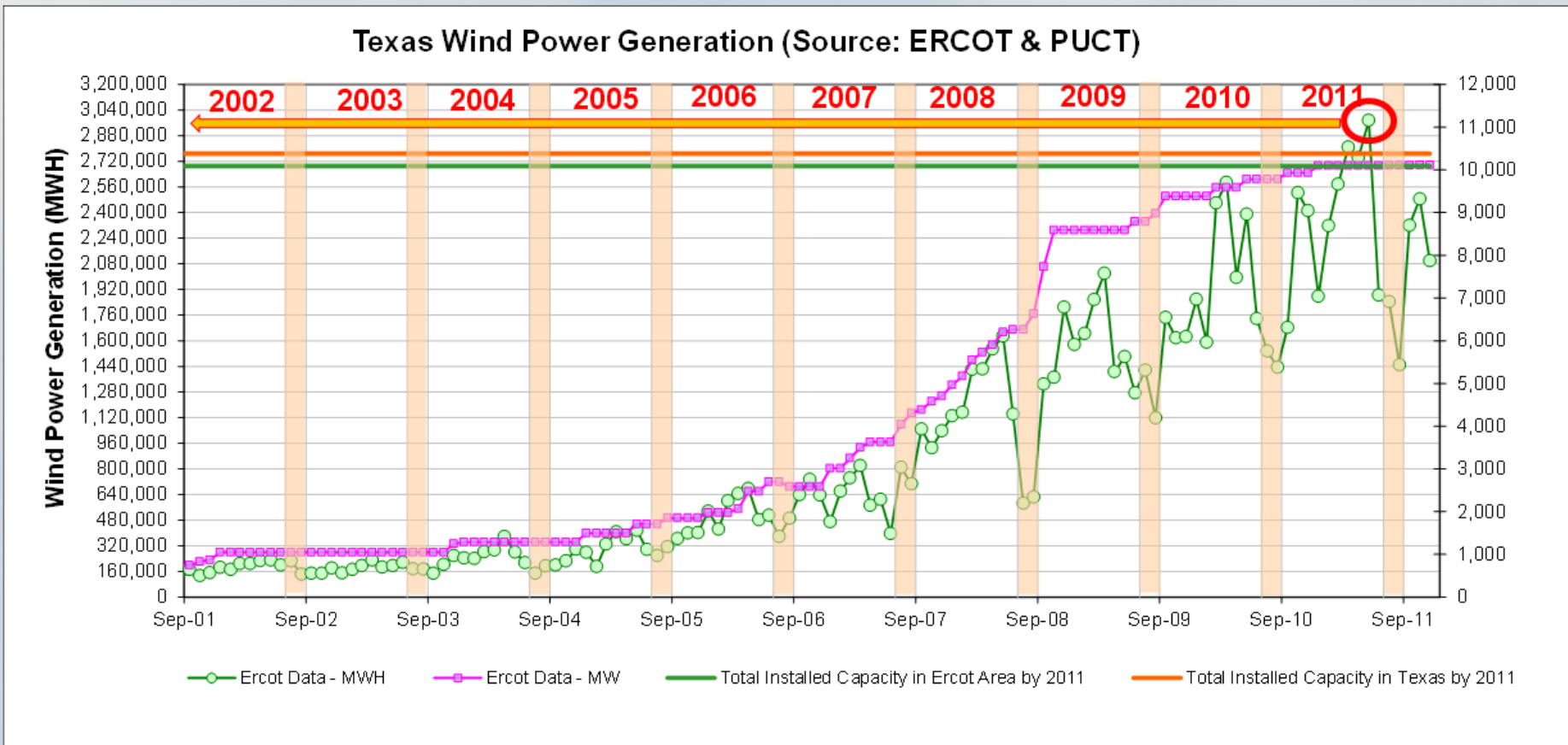
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 10,380 MW/month in Texas

# WIND PROJECTS IN TEXAS (2011)

Substantial increases in measured electricity from wind energy.



Total capacity: 10,088 MW/month in ERCOT

10,380 MW/month in Texas

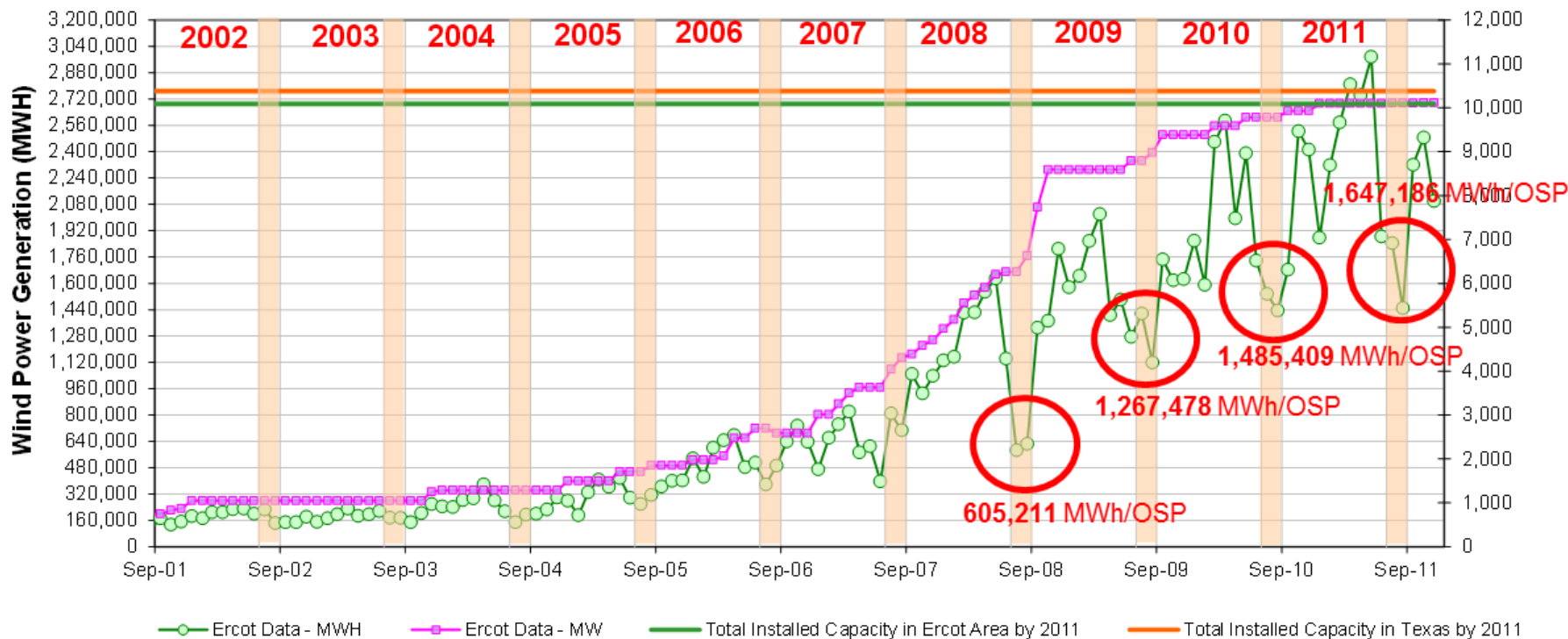
New peak wind power generation in 2011: 2,975,145 MWh/month



# WIND PROJECTS IN TEXAS (2011)

Substantial increases in measured electricity from wind energy.

Texas Wind Power Generation (Source: ERCOT & PUCT)

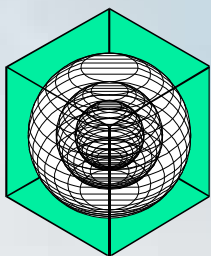


Total capacity: 10,088 MW/month in ERCOT

10,380 MW/month in Texas

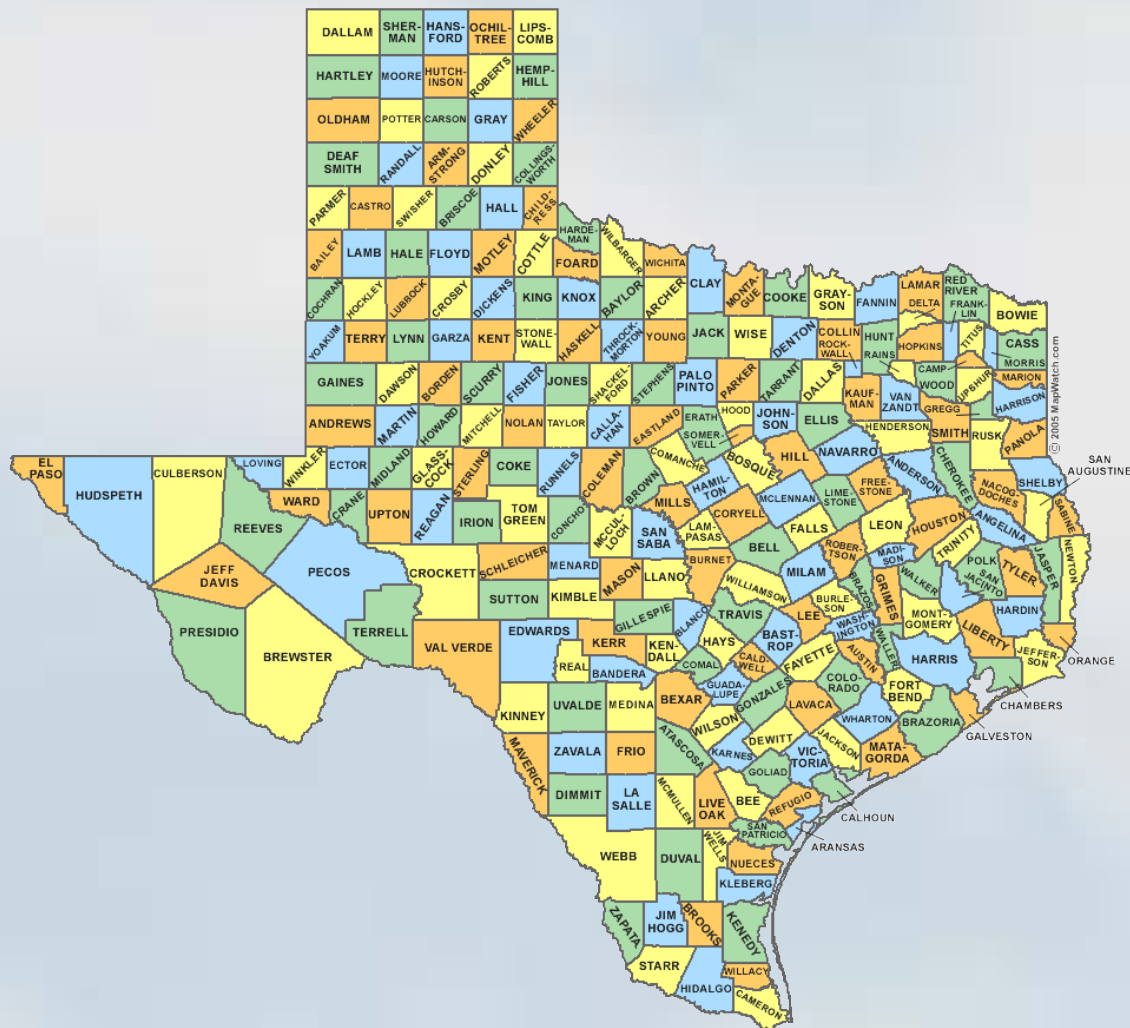
New peak wind power generation in 2011: 2,975,145 MWh/month

Average Ozone Season Period (OSP) power generation increasing



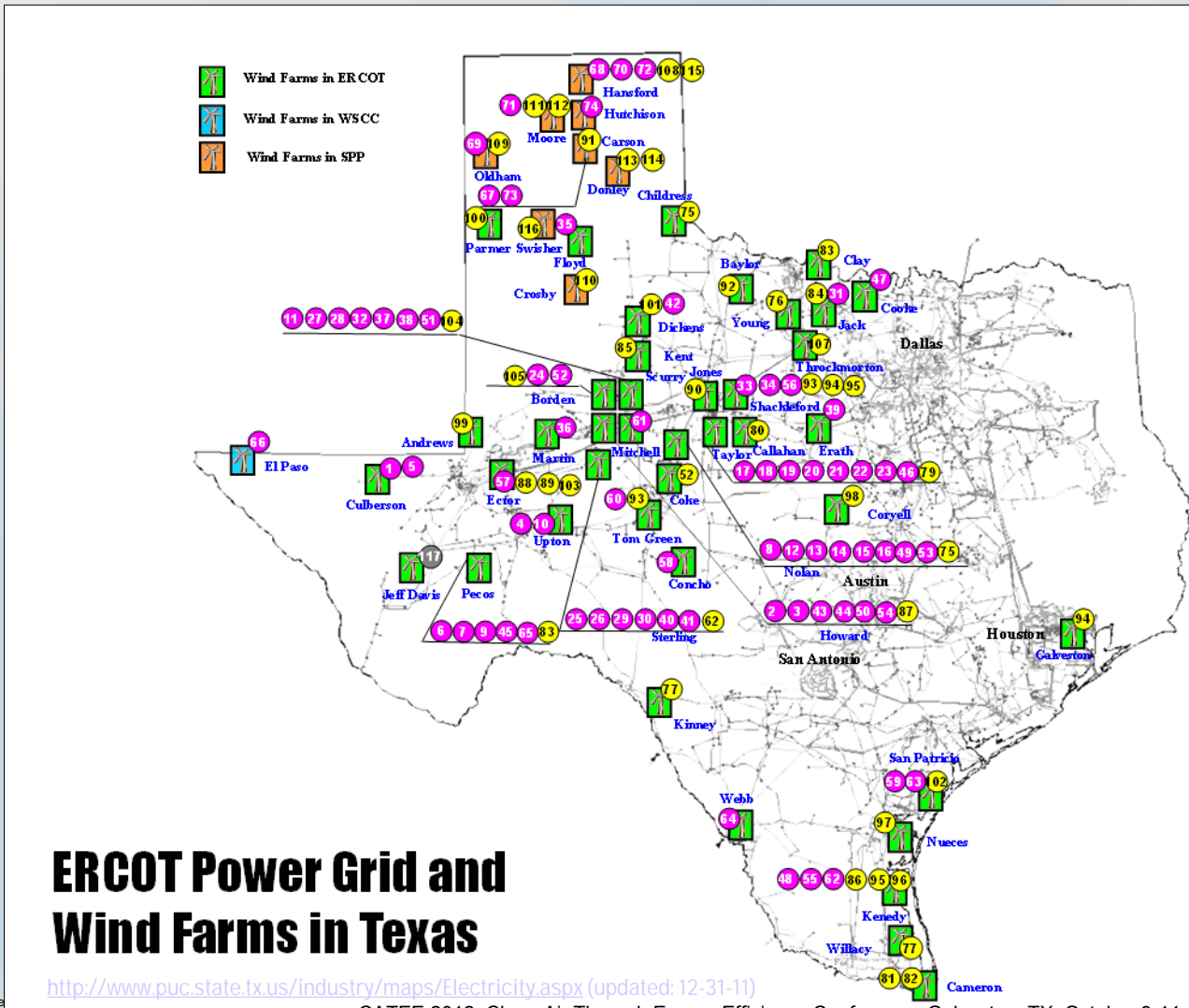
# WIND PROJECTS IN TEXAS

Completed, Announced, and Retired Wind Projects in Texas, as of December 2011

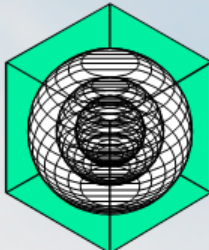


# WIND PROJECTS IN TEXAS

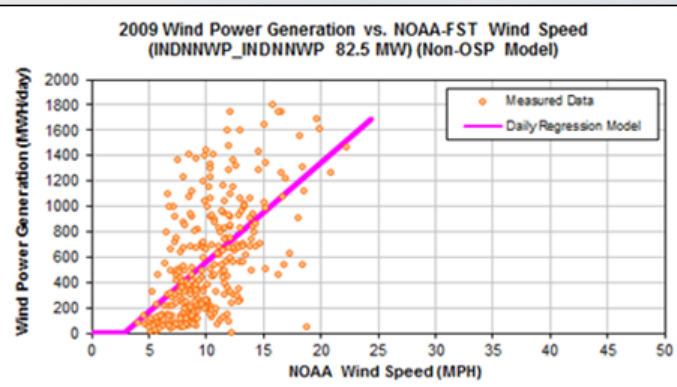
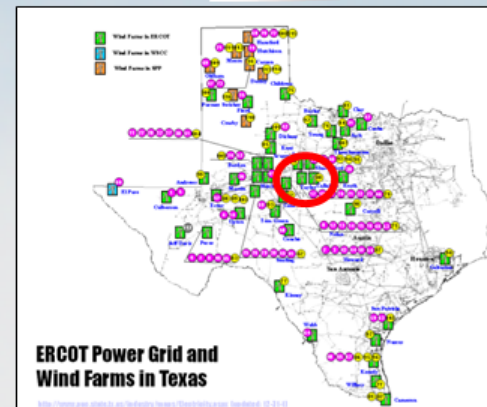
Completed, Announced, and Retired Wind Projects in Texas, as of December 2011



# NO<sub>x</sub> EMISSIONS REDUCTIONS FROM WIND

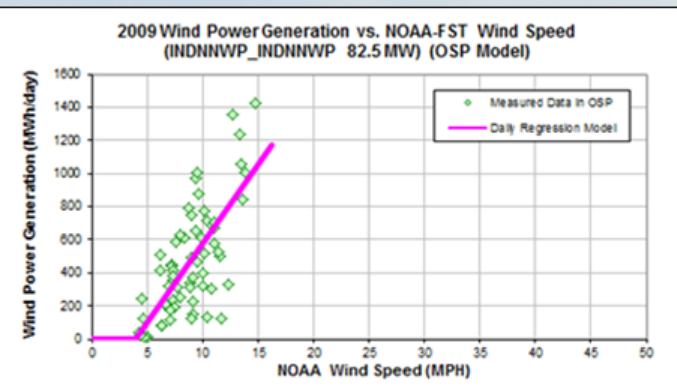


## Regression Analysis for Indian Mesa



IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-224.9053
Left Slope (MWh/mph-day)	78.4270
RMSE (MWh/day)	356.9138
R2	0.3307
CV-RMSE	62.5%

For Non-OSP Model

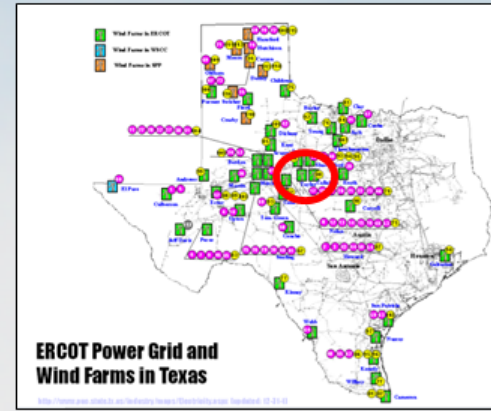


IMT Coefficients	NOAA Daily Model
Ycp (MWh/day)	-376.8179
Left Slope (MWh/mph-day)	95.0668
RMSE (MWh/day)	238.3325
R2	0.5038
CV-RMSE	50.9%

For OSP Model

# NOx EMISSIONS REDUCTIONS FROM WIND

## Regression Analysis for Indian Mesa



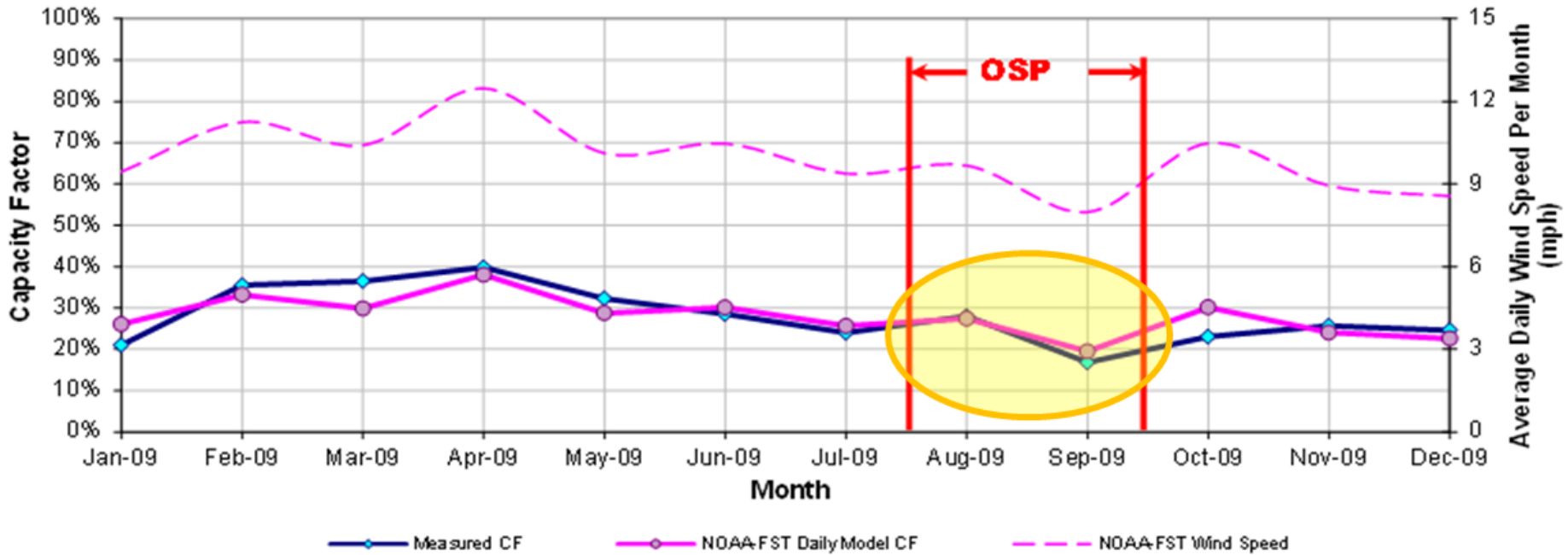
Annual

1999 Estimated MWh/yr (2009 Daily Model)	2009 Measured MWh/yr
239,087	201,716

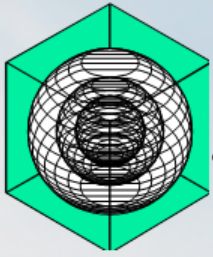
OSD

1999 OSD Estimated MWh/day (2009 Daily Model)	2009 OSD Measured MWh/day
570	469

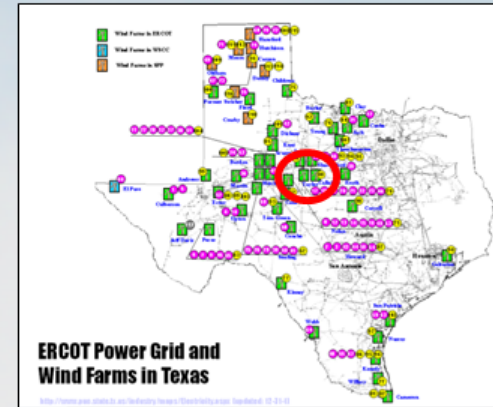
Capacity Factors Using N-OSP & OSP Model



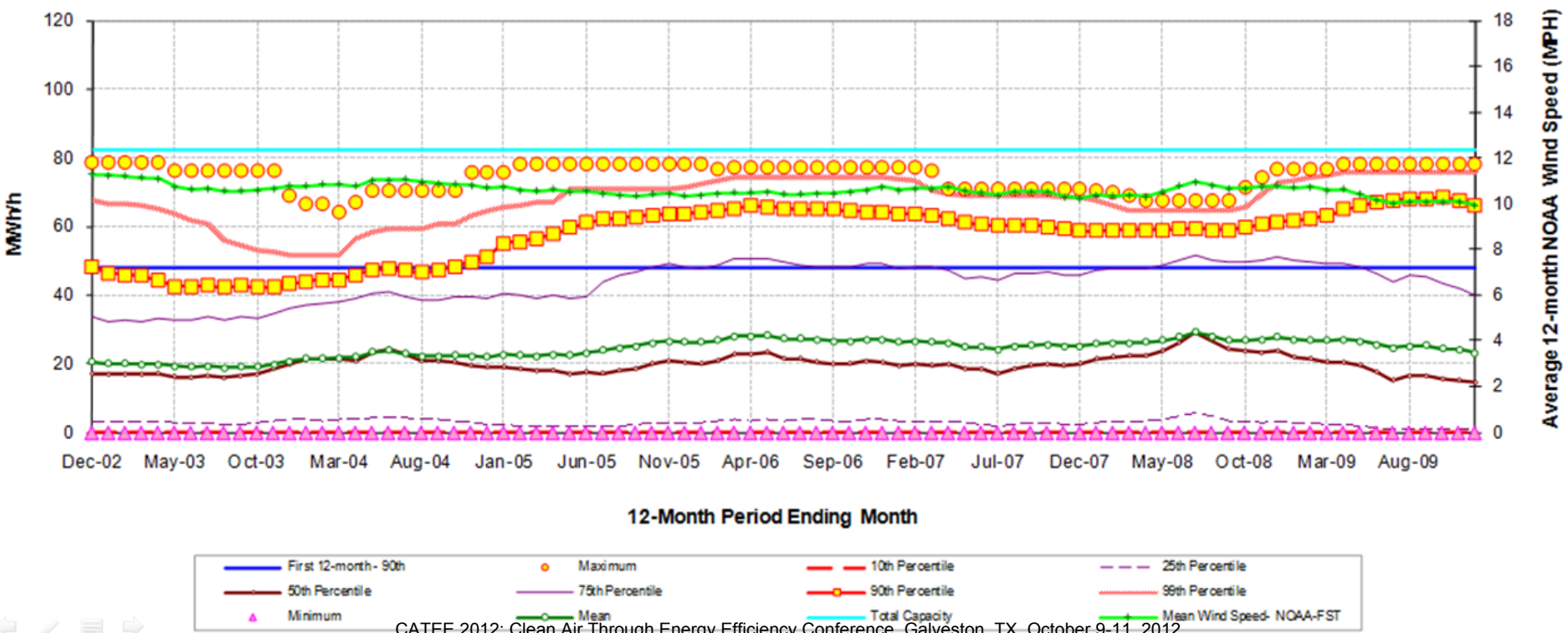
# TRACKING WIND POWER GENERATION



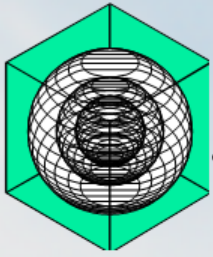
Example: Indian Mesa  
: 82.5 MW



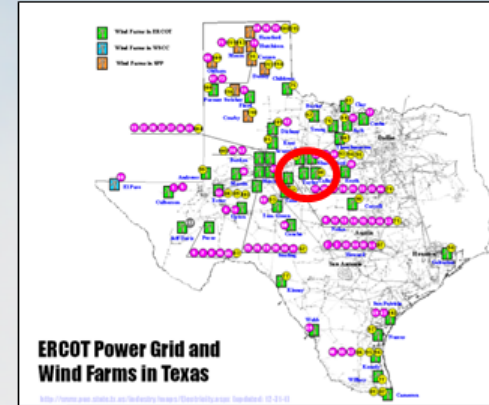
Indian Mesa (82.5MW) - Wind Power Generation of Sliding 12-Month Period (2002-2009)



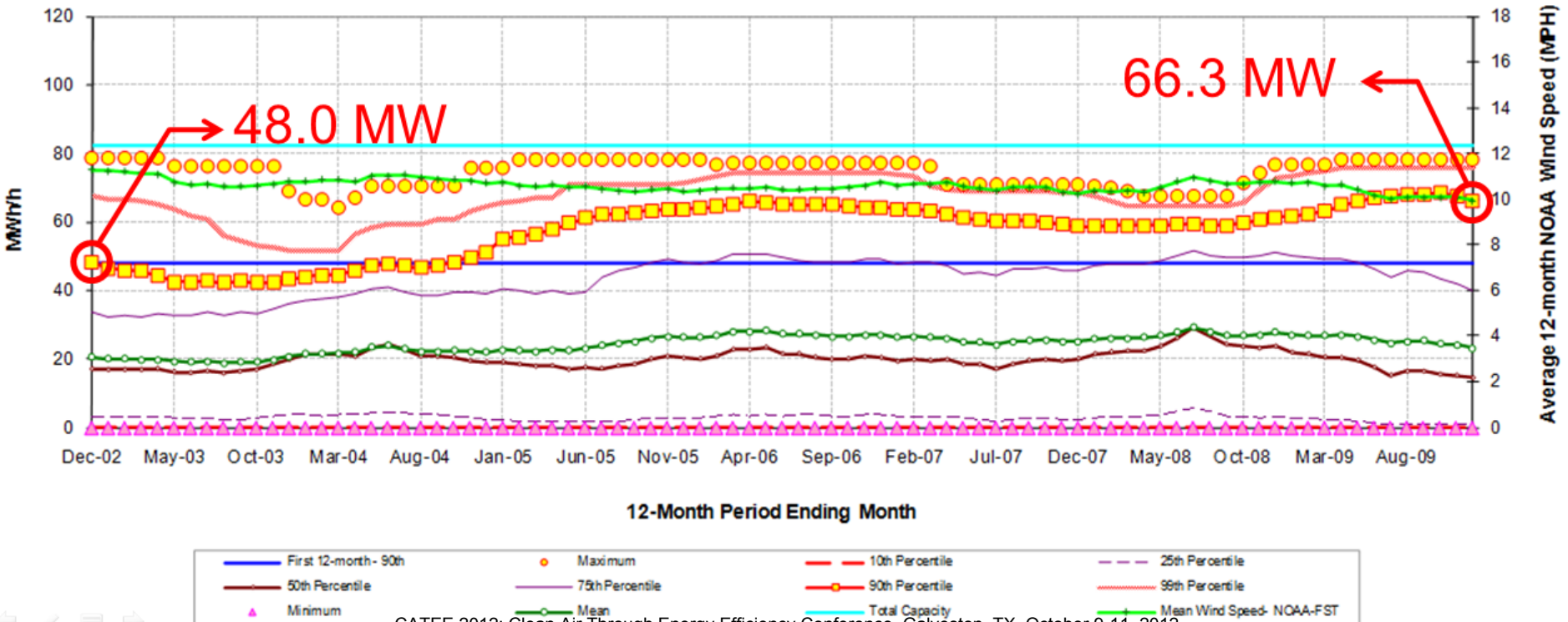
# TRACKING WIND POWER GENERATION



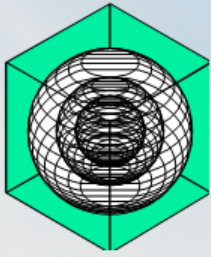
Example: Indian Mesa  
 : 82.5 MW  
 : Is There Degradation?



Indian Mesa (82.5MW) - Wind Power Generation of Sliding 12-Month Period (2002-2009)



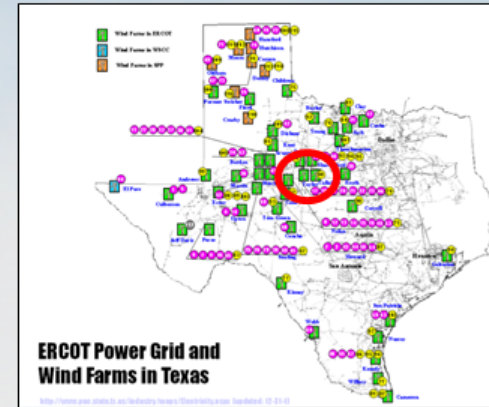
# TRACKING WIND POWER GENERATION



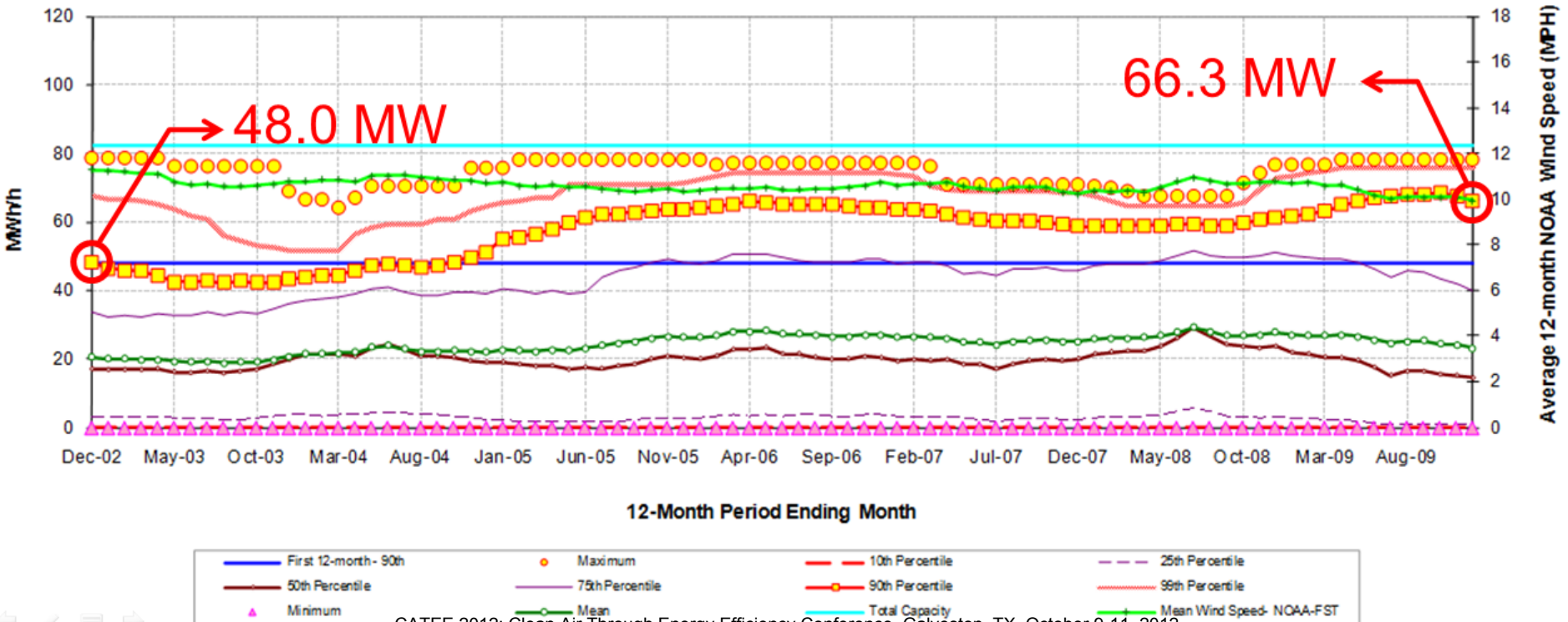
Example: Indian Mesa

: 82.5 MW

: Is There Degradation? NO !

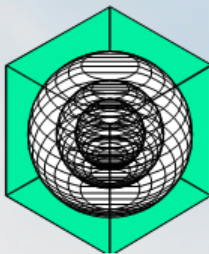


Indian Mesa (82.5MW) - Wind Power Generation of Sliding 12-Month Period (2002-2009)

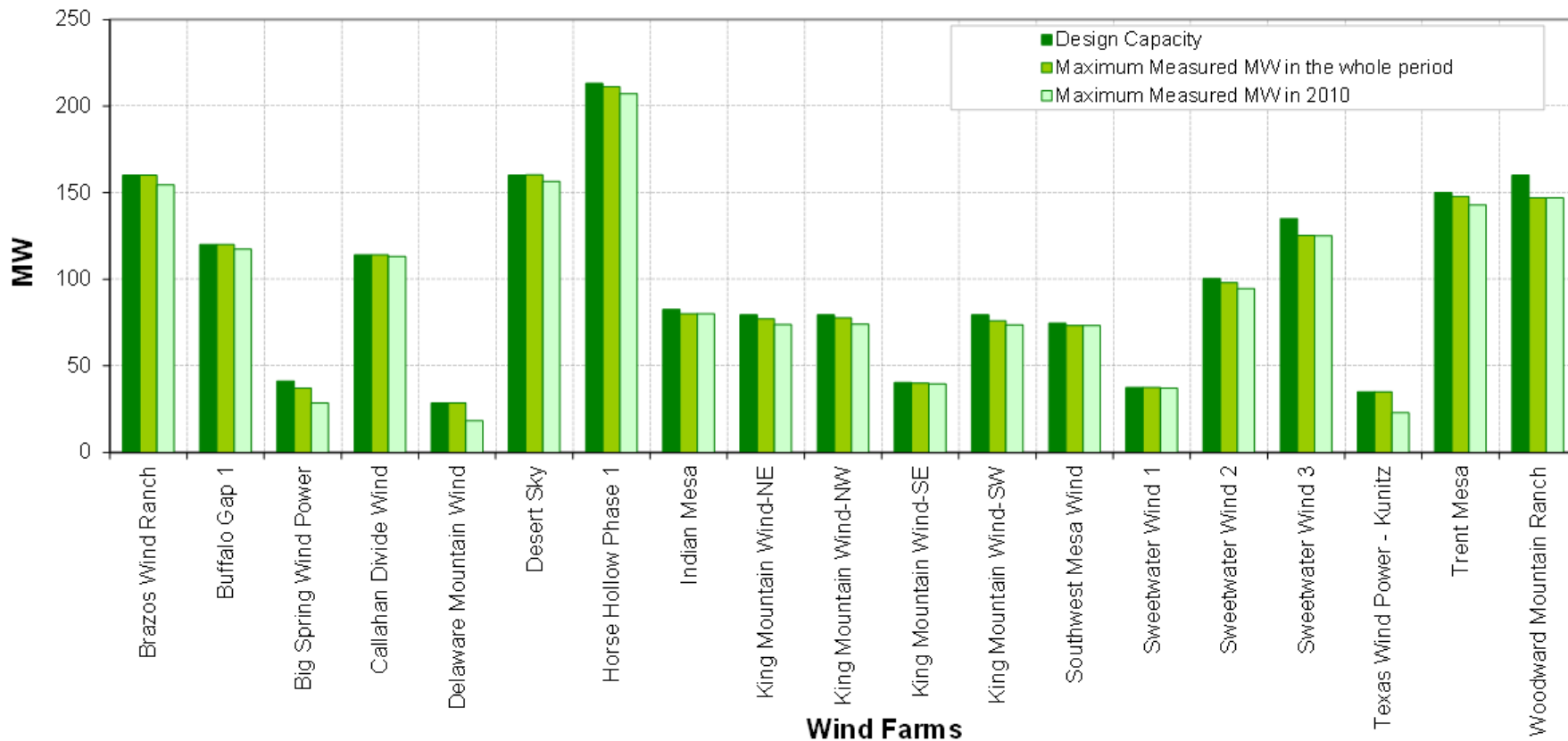




# WIND FARMS CAPACITY/PRODUCTION

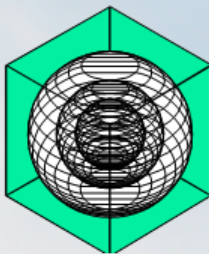


**Design and Measured Maximum Capacity for Wind Farms**

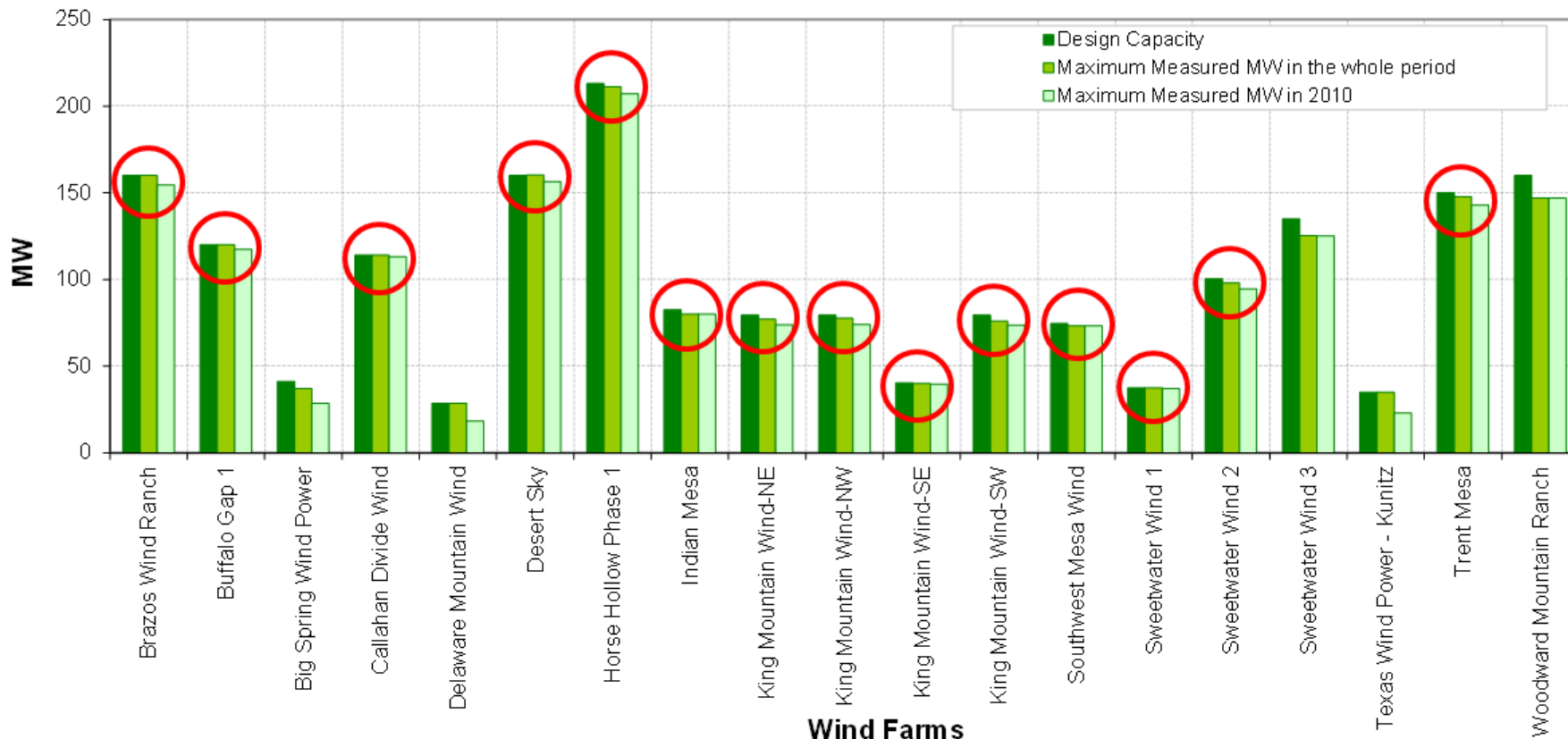


## Design and Measured Maximum Capacity

# WIND FARMS CAPACITY/PRODUCTION

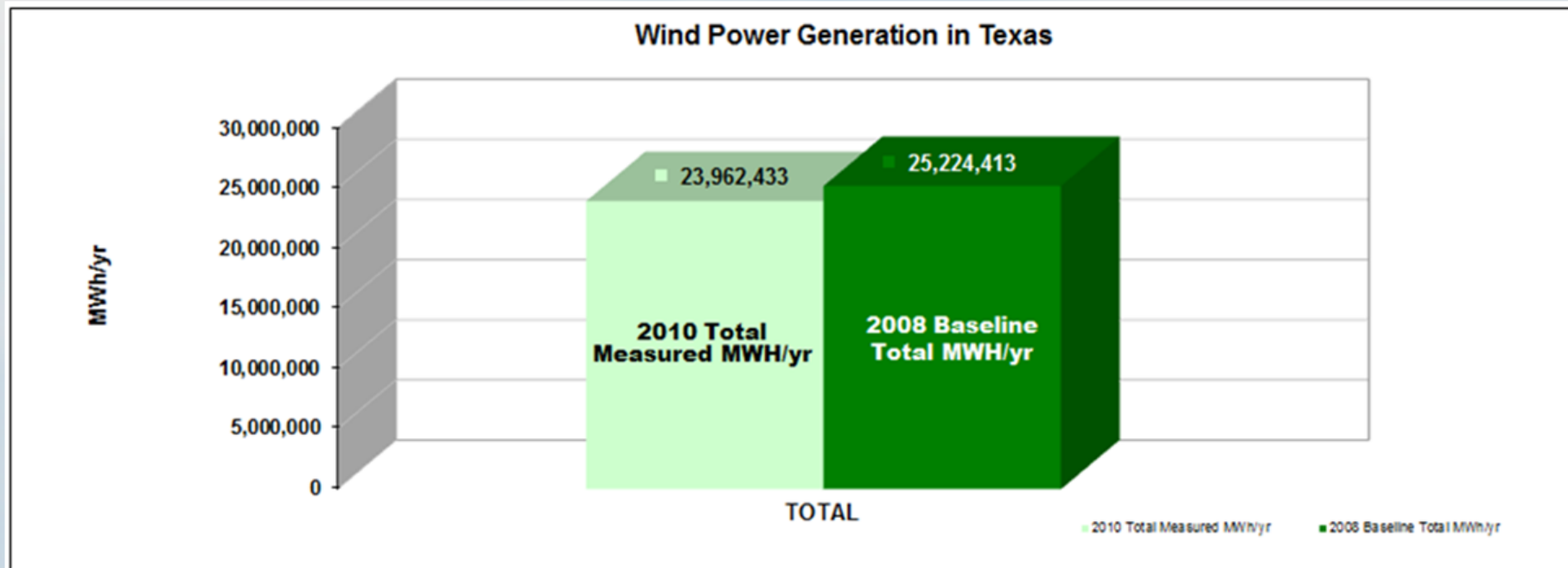
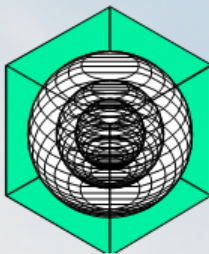


Design and Measured Maximum Capacity for Wind Farms



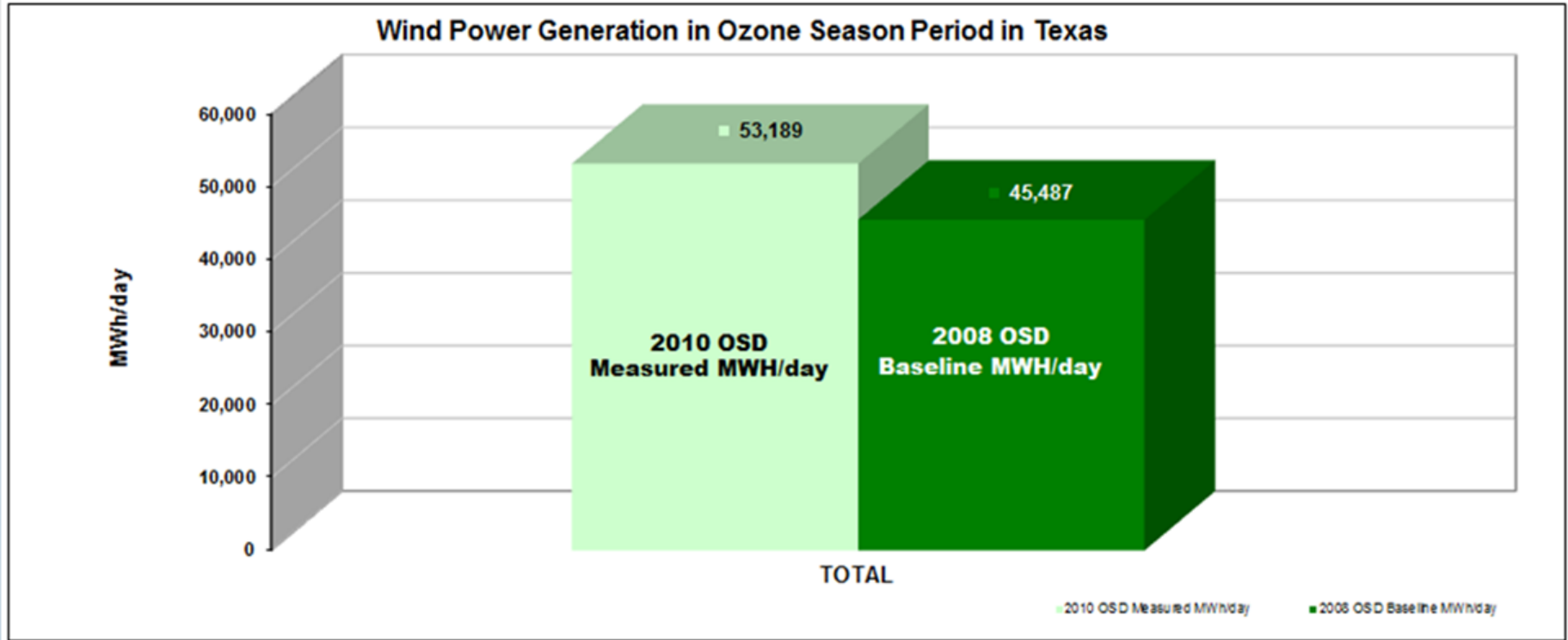
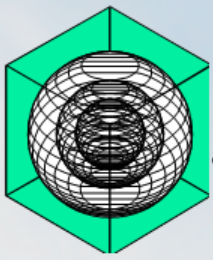
## Design and Measured Maximum Capacity

# WIND FARMS CAPACITY/PRODUCTION



2008 Calculated from 2010 Measured Annual Power Production

# WIND FARMS CAPACITY/PRODUCTION



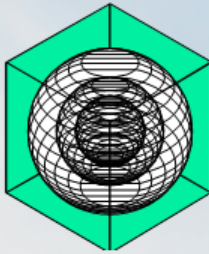
2008 Calculated from 2010 Measured OSD Power Production





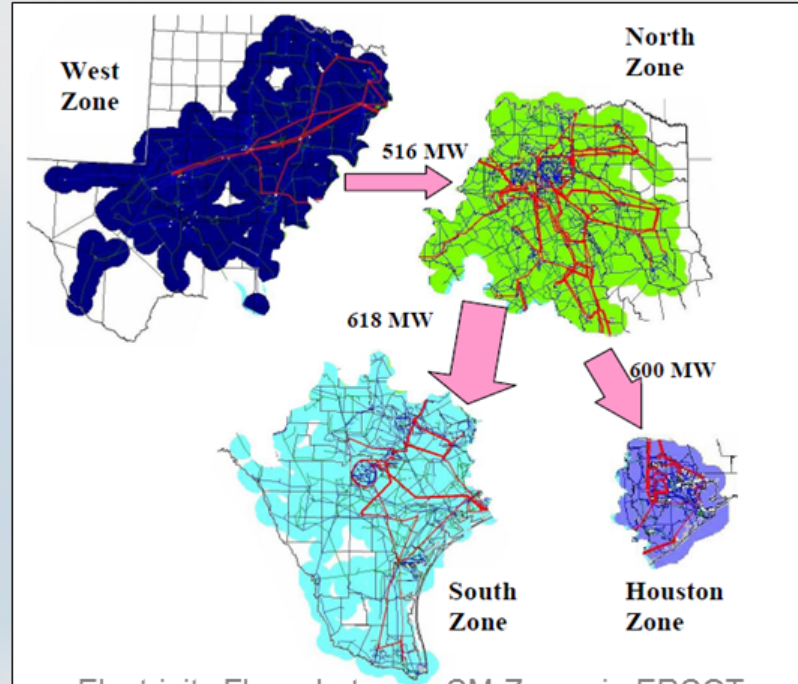
# NOx REDUCTIONS USING eGRID

## NOx Emissions Reductions Calculation



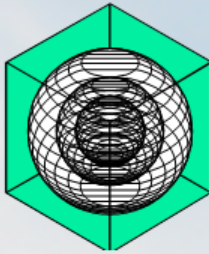
Area	County	CM Zones				Total NOx Reductions (lb/a)	Total NOx Reductions (Tons/a)
		M	N	W	S		
Houston-Galveston Area	Brazoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Chambers	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Fort Bend	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Harris	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Liberty	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
Total		0.4414603	0.4612643	0.4693256	0.4693256	0.4693256	0.00

**New 2010 eGrid  
4 Congestion  
Management (CM)  
Zones**



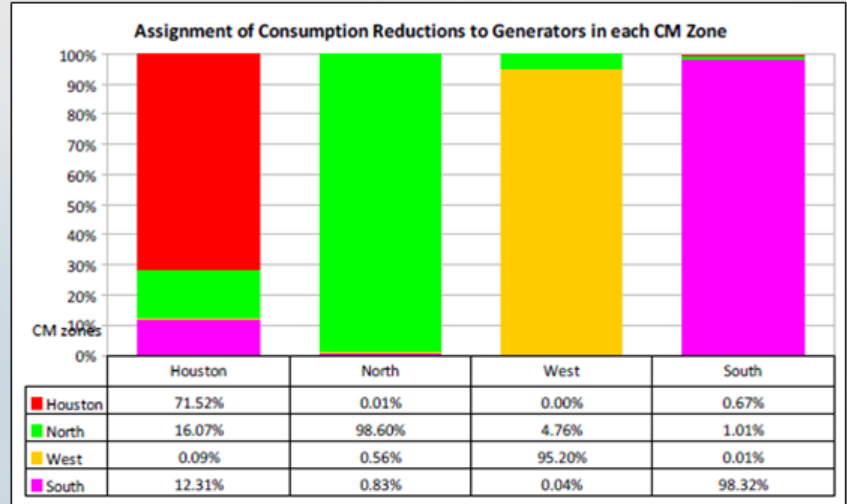
# NOx REDUCTIONS USING eGRID

## NOx Emissions Reductions Calculation



Area	County	CM Zones				Total eGRID Reductions (lb/a)	Total NOx Reductions (Tons/a)
		H	N	W	S		
Houston-Galveston Area	Brazoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Chambers	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Fort Bend	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Harris	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Liberty	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
Beaumont / Port Arthur Area	Beaumont	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Orange	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Polk	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Waller	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Waller	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
Dallas / Fort Worth Area	Dallas	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Tarrant	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Johnson	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Koehn	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Wichita	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
El Paso Area	El Paso	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Blanco	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Green	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Wink	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Wink	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
San Antonio Area	Bexar	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Brewster	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Comal	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Duval	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Guadalupe	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
Austin Area	Brewster	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Blanco	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Comal	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Duval	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Guadalupe	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
North East Texas Area	Collin	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Denton	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Rockwall	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Rockwall	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Rockwall	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
Corpus Christi Area	Corpus Christi	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	San Patricio	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
Victoria Area	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Victoria	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
Other eGRID Counties	Adair	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Adair	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Adair	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Adair	0.000000	0.000000	0.000000	0.000000	0.000000	0.00
	Adair	0.000000	0.000000	0.000000	0.000000	0.000000	0.00

**New 2010 eGrid  
4 Congestion  
Management (CM)  
Zones**

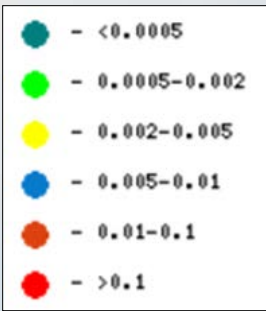
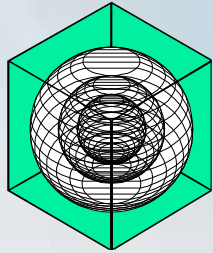


Assignment of Consumption Reductions to Generators in Each CM Zone

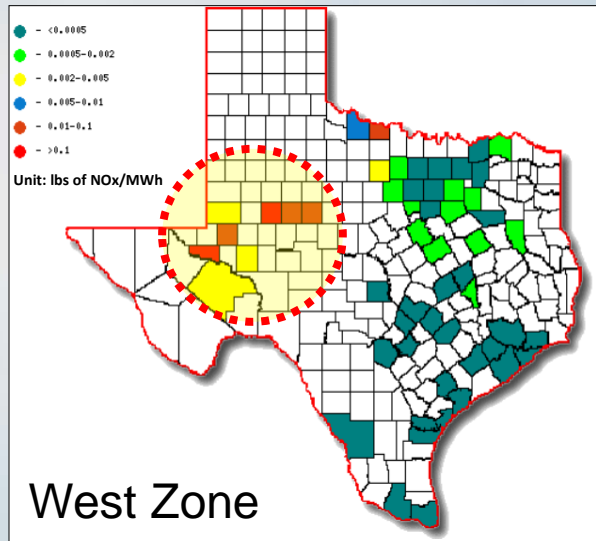


# NOx REDUCTIONS FROM WIND POWER

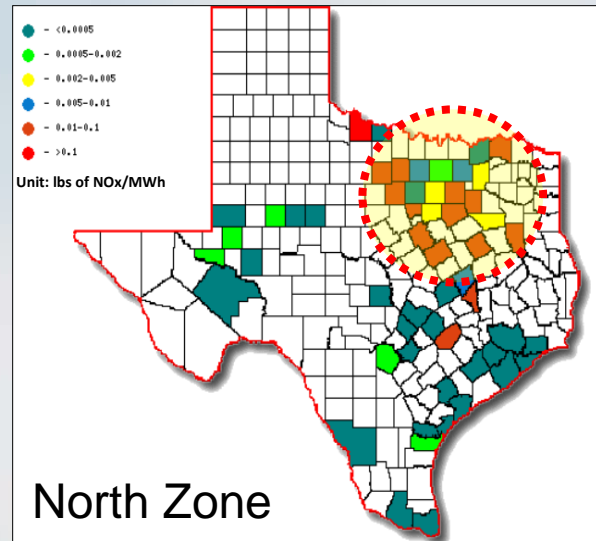
## New 2010 Annual eGrid for NOx Emissions



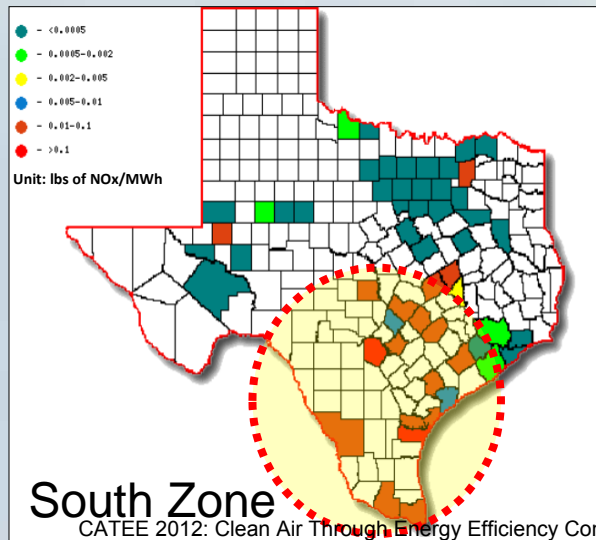
Unit: lbs of NOx/MWh



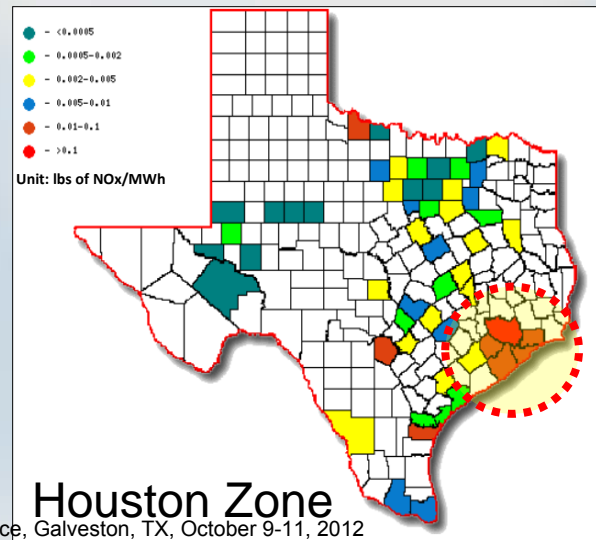
### West Zone



### North Zone



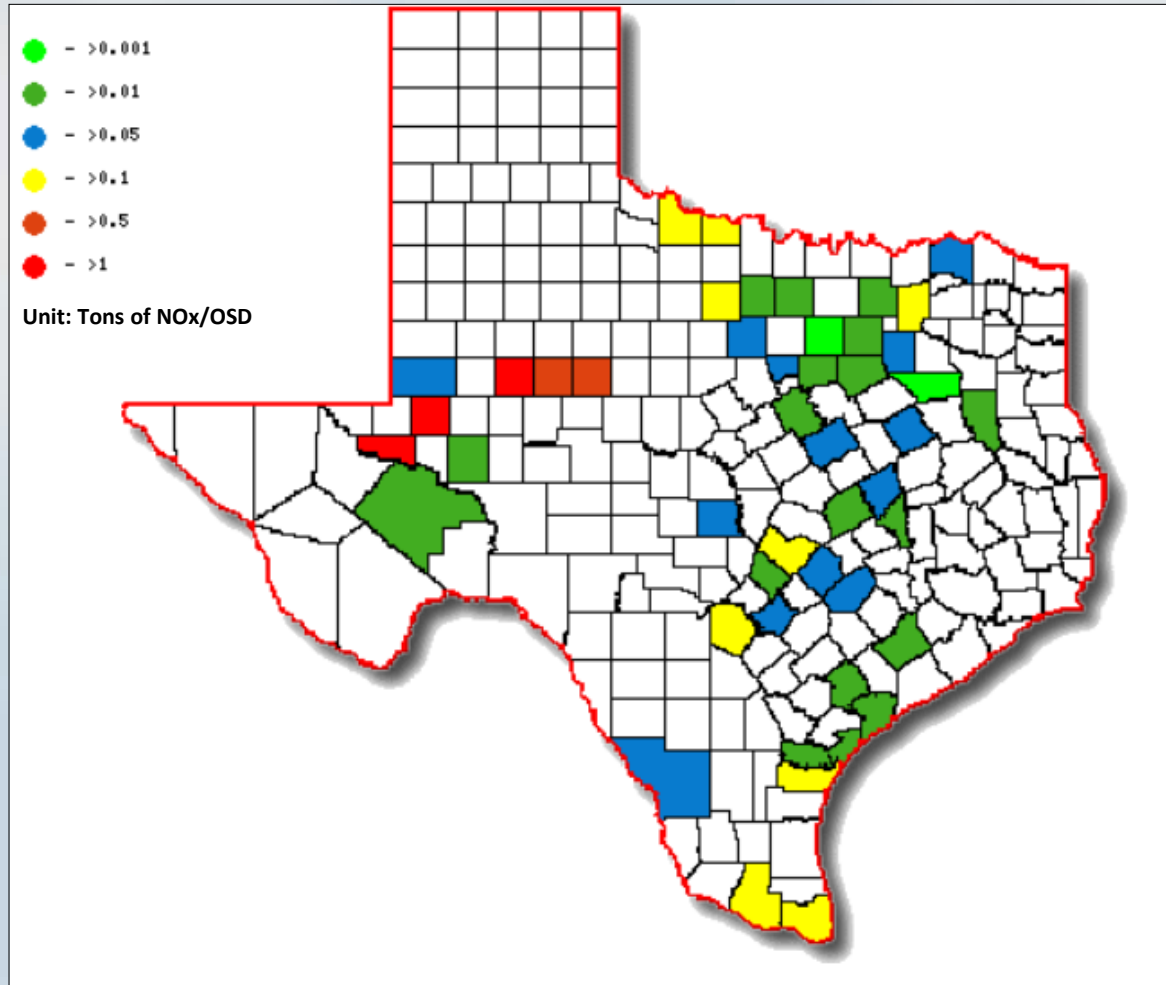
### South Zone



### Houston Zone

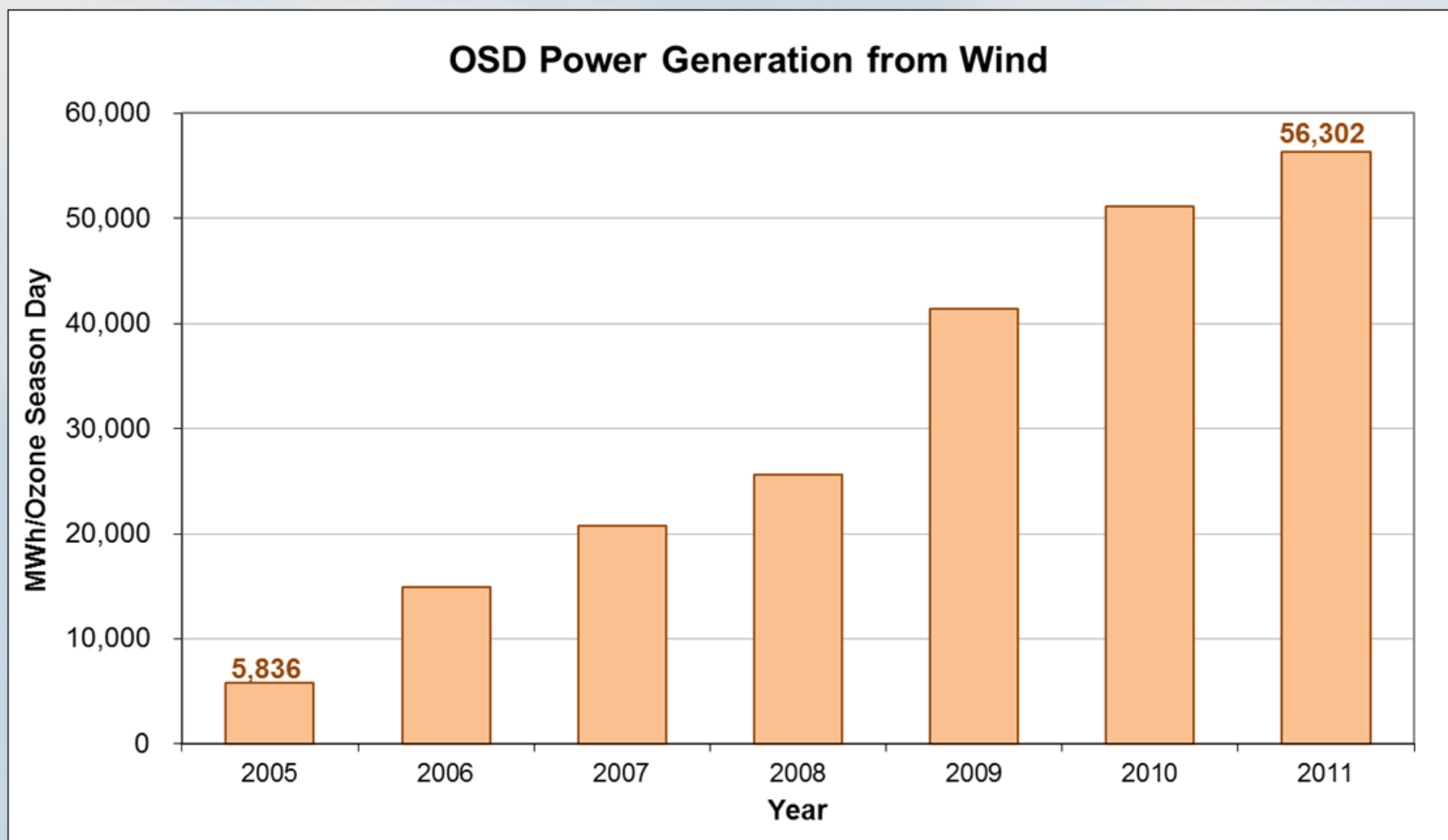
# NOx REDUCTIONS FROM WIND POWER

New 2010 OSD eGrid for NOx Emissions



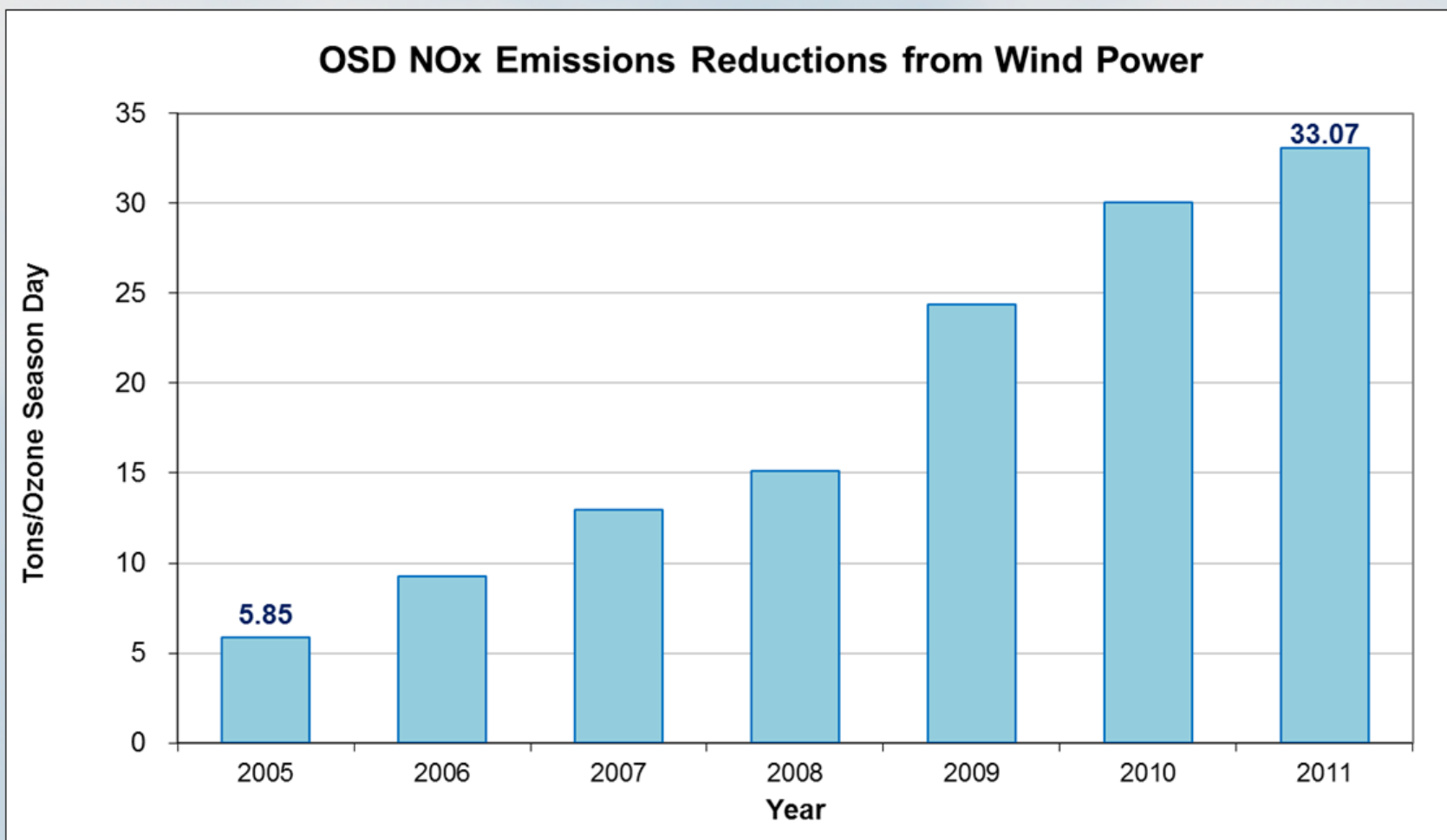
# WIND POWER IN TEXAS

## OSD Power Generation and NOx Emissions Reductions



# WIND POWER IN TEXAS

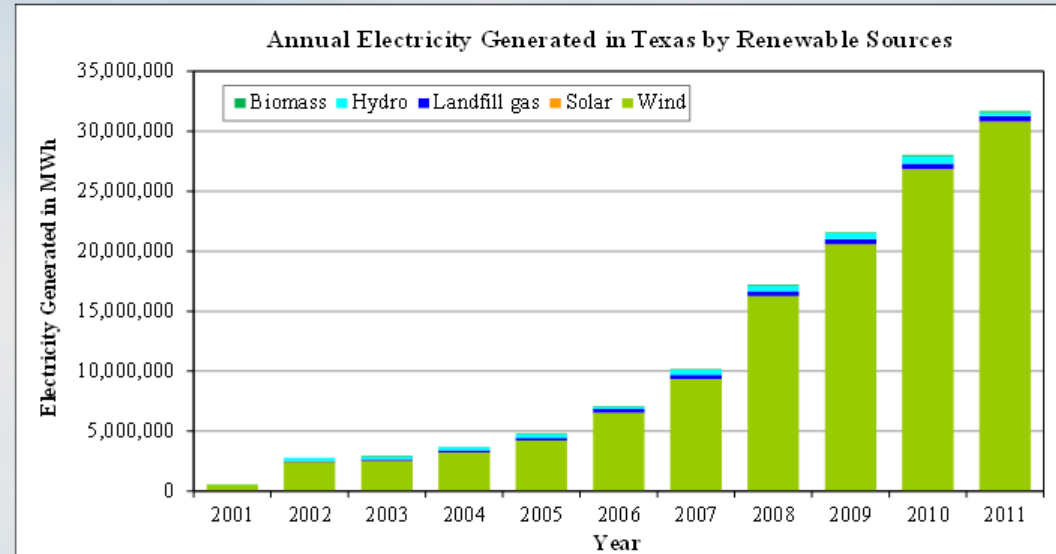
## OSD Power Generation and NOx Emissions Reductions



# OTHER RENEWABLES

Biomass, Hydro, Landfill Gas, Solar, Wind

Wind energy is the largest portion



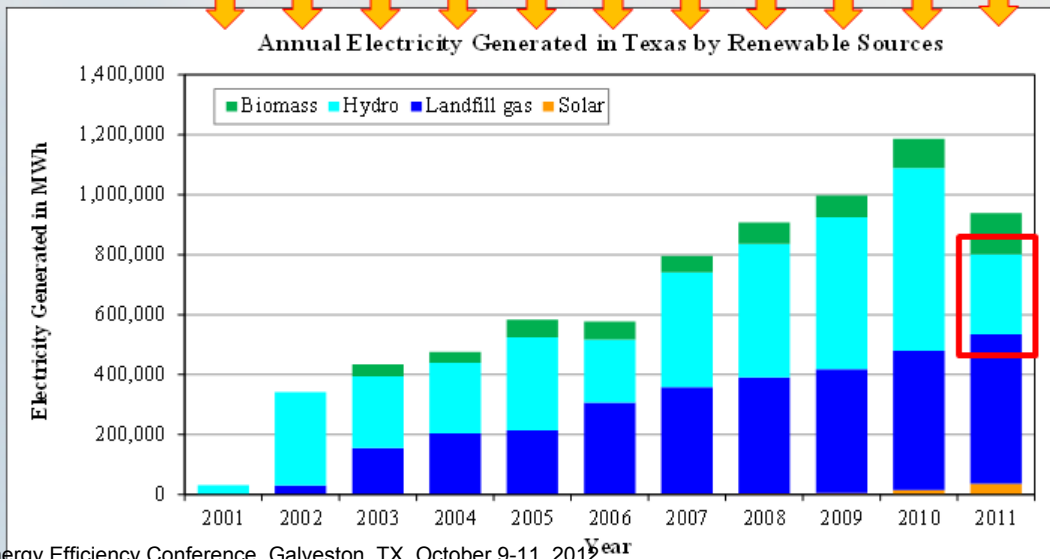
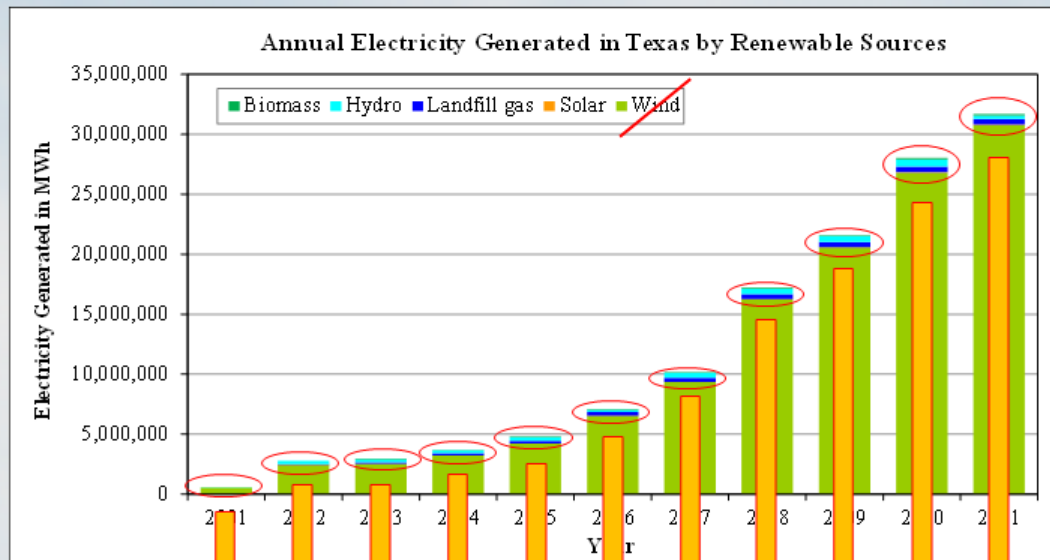
# OTHER RENEWABLES

Biomass, Hydro, Landfill Gas, Solar, Wind

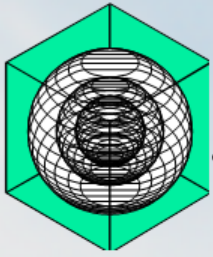
Wind energy is the largest portion

Biomass and solar are smallest

Drought in Texas 2011



# RENEWABLE PROJECTS IN TEXAS

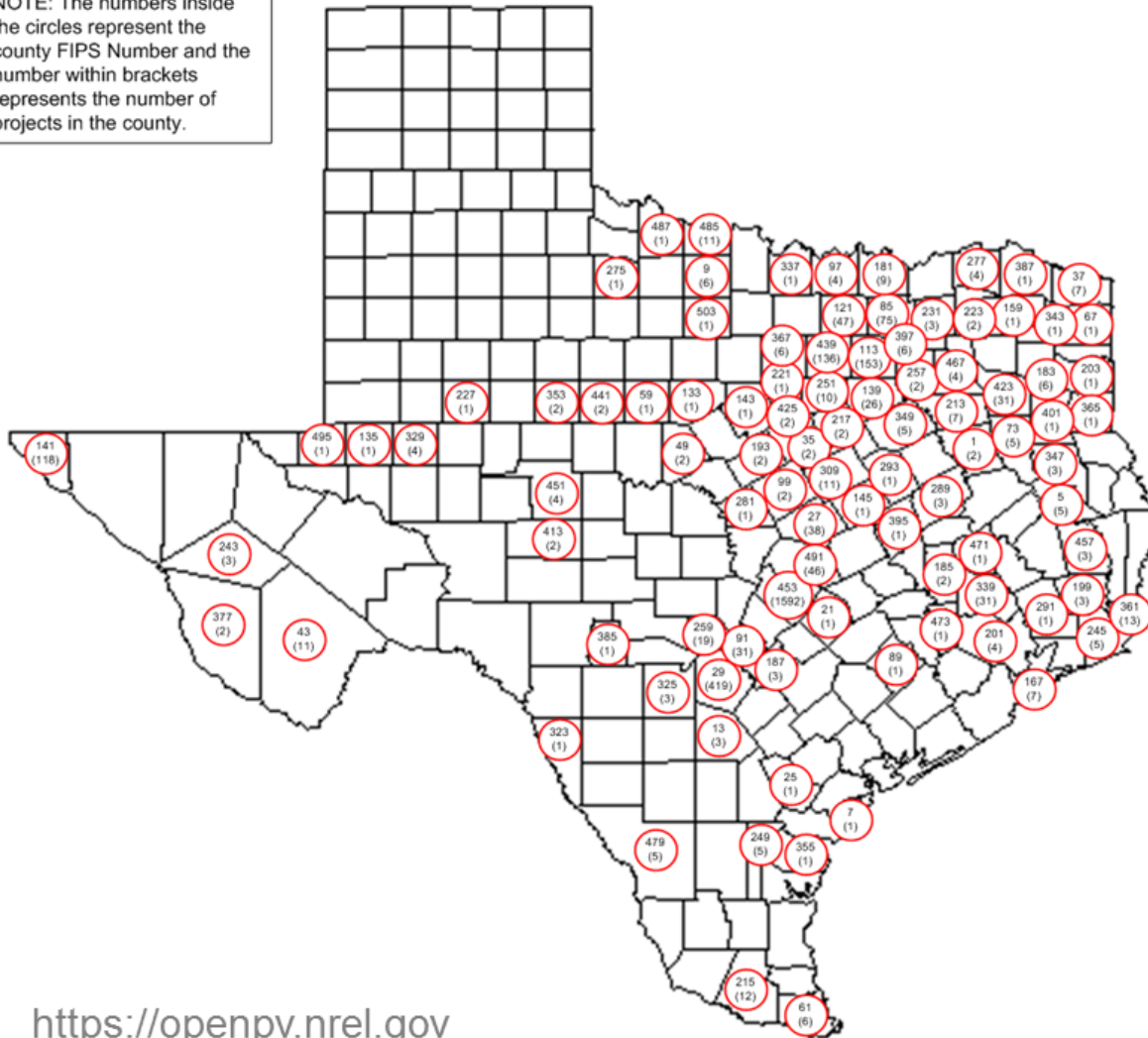


## Solar PV

## Renewables:

Solar PV  
(3,033 projects)

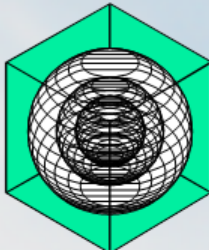
NOTE: The numbers inside the circles represent the county FIPS Number and the number within brackets represents the number of projects in the county.



<https://openpv.nrel.gov>

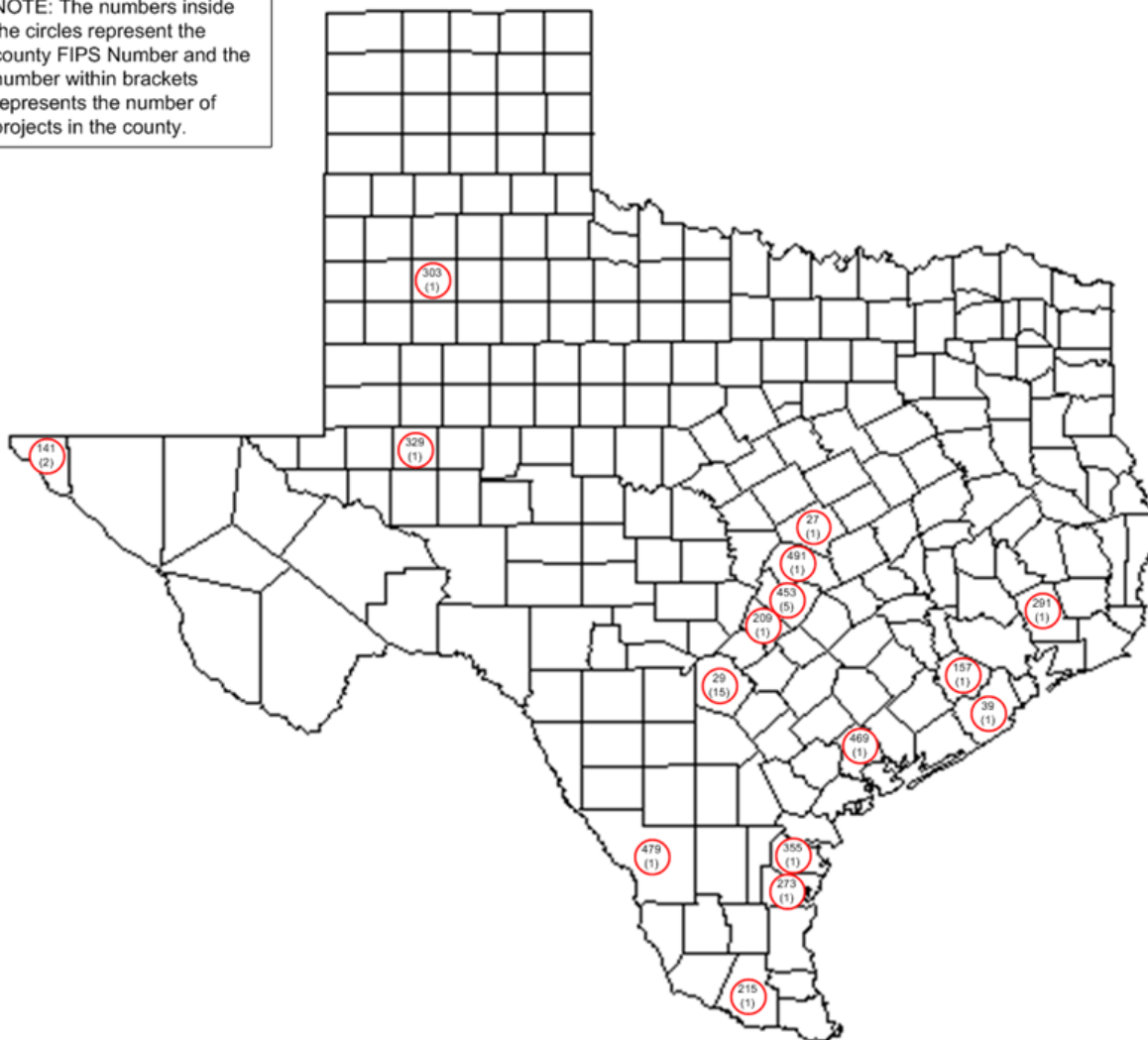


# RENEWABLE PROJECTS IN TEXAS



## Solar Thermal

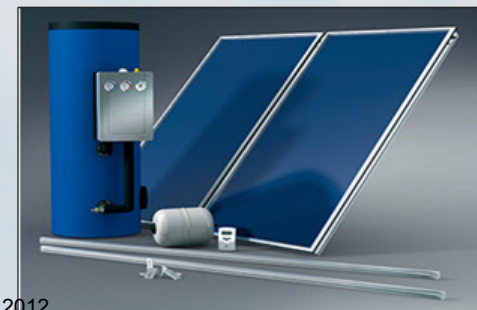
NOTE: The numbers inside the circles represent the county FIPS Number and the number within brackets represents the number of projects in the county.



## Renewables:

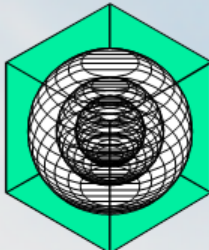
Solar PV  
(3,033 projects)

Solar Thermal



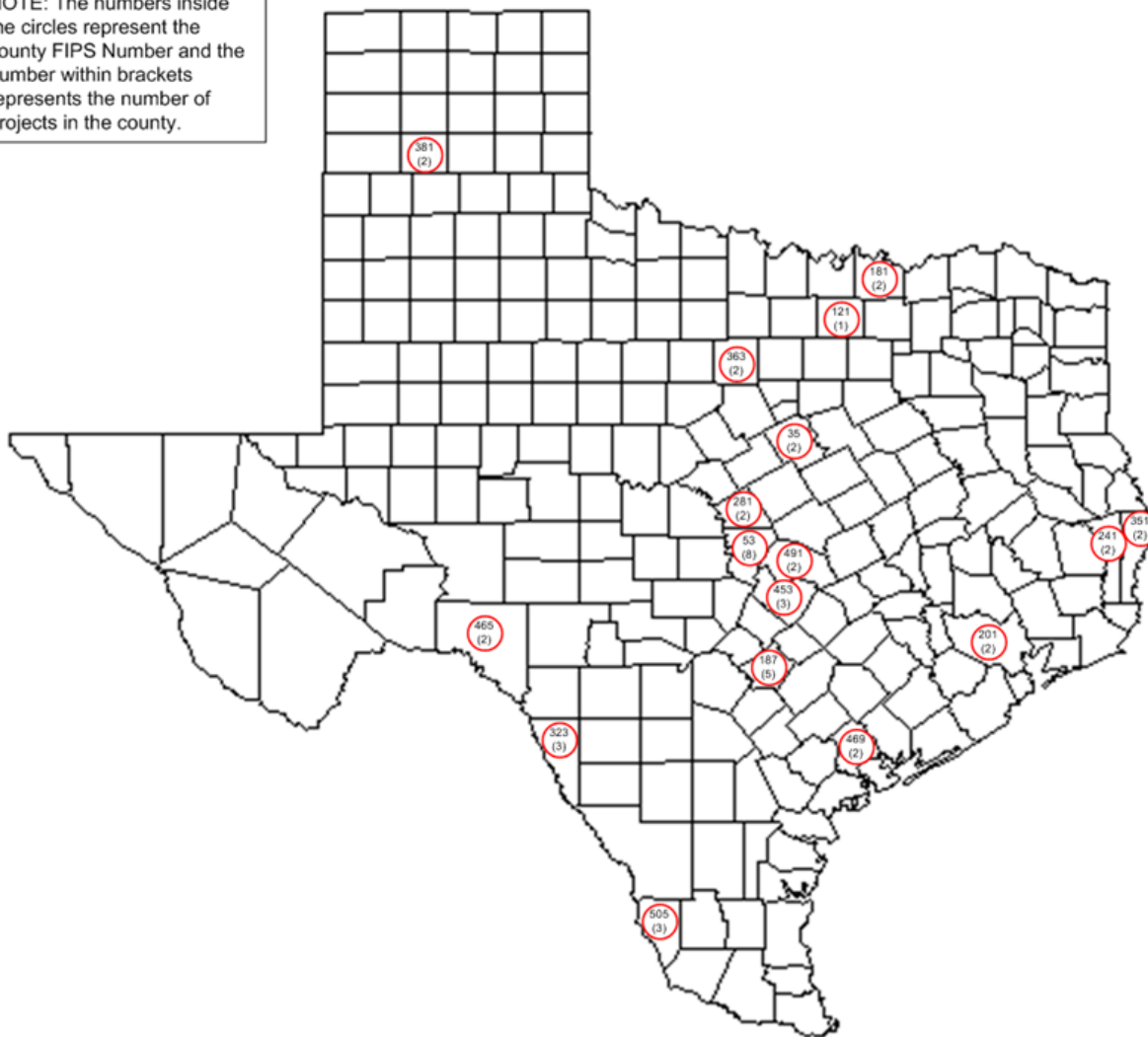


# RENEWABLE PROJECTS IN TEXAS



## Hydro

NOTE: The numbers inside the circles represent the county FIPS Number and the number within brackets represents the number of projects in the county.



## Renewables:

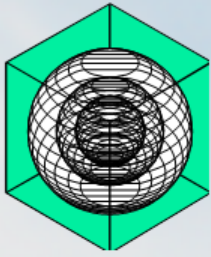
Solar PV  
(3,033 projects)

Solar Thermal

Hydro

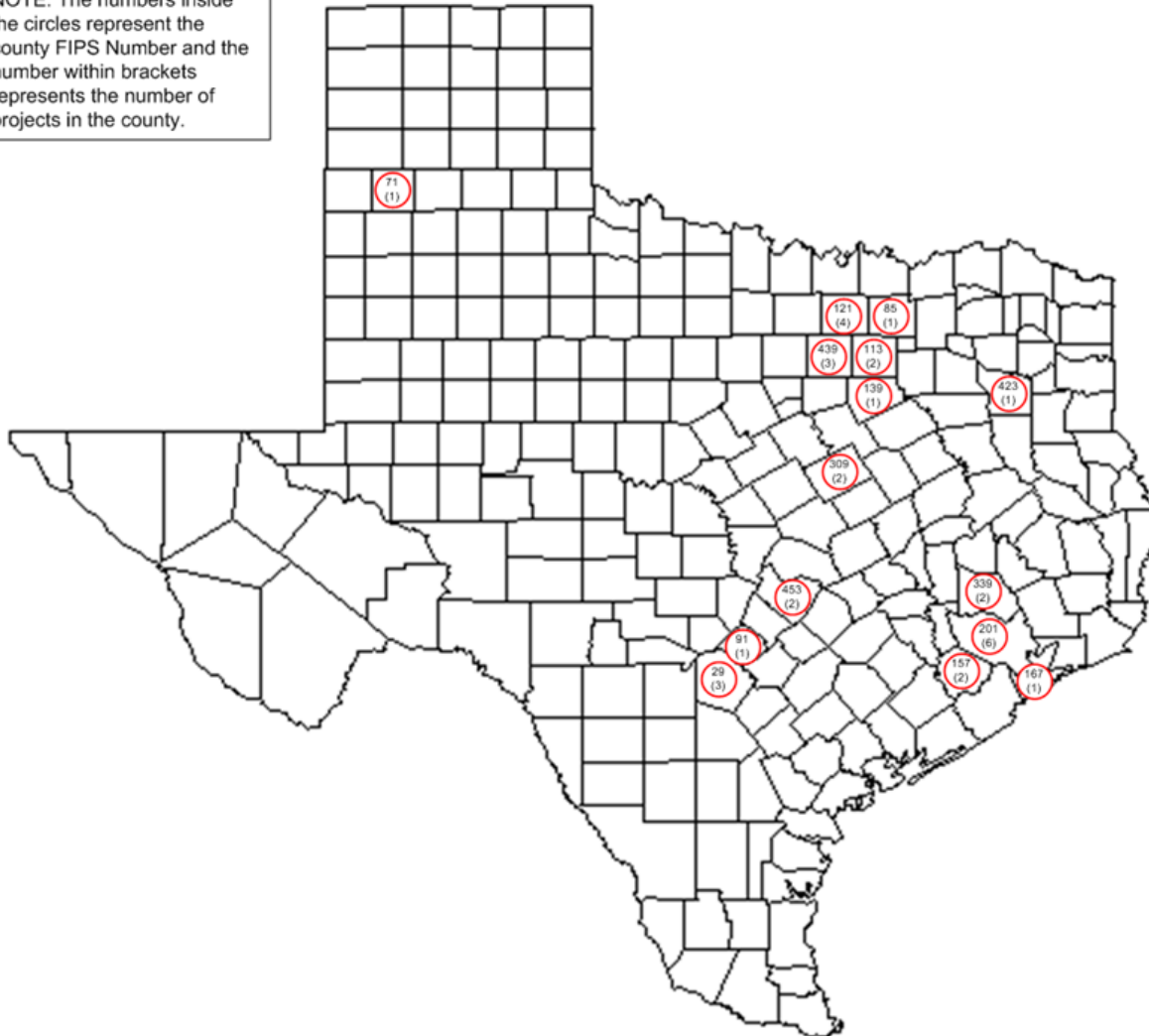


# RENEWABLE PROJECTS IN TEXAS



## Landfill Gas

NOTE: The numbers inside the circles represent the county FIPS Number and the number within brackets represents the number of projects in the county.

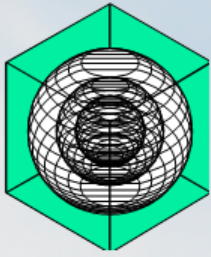


## Renewables:

- Solar PV  
(3,033 projects)
- Solar Thermal
- Hydro
- Landfill Gas

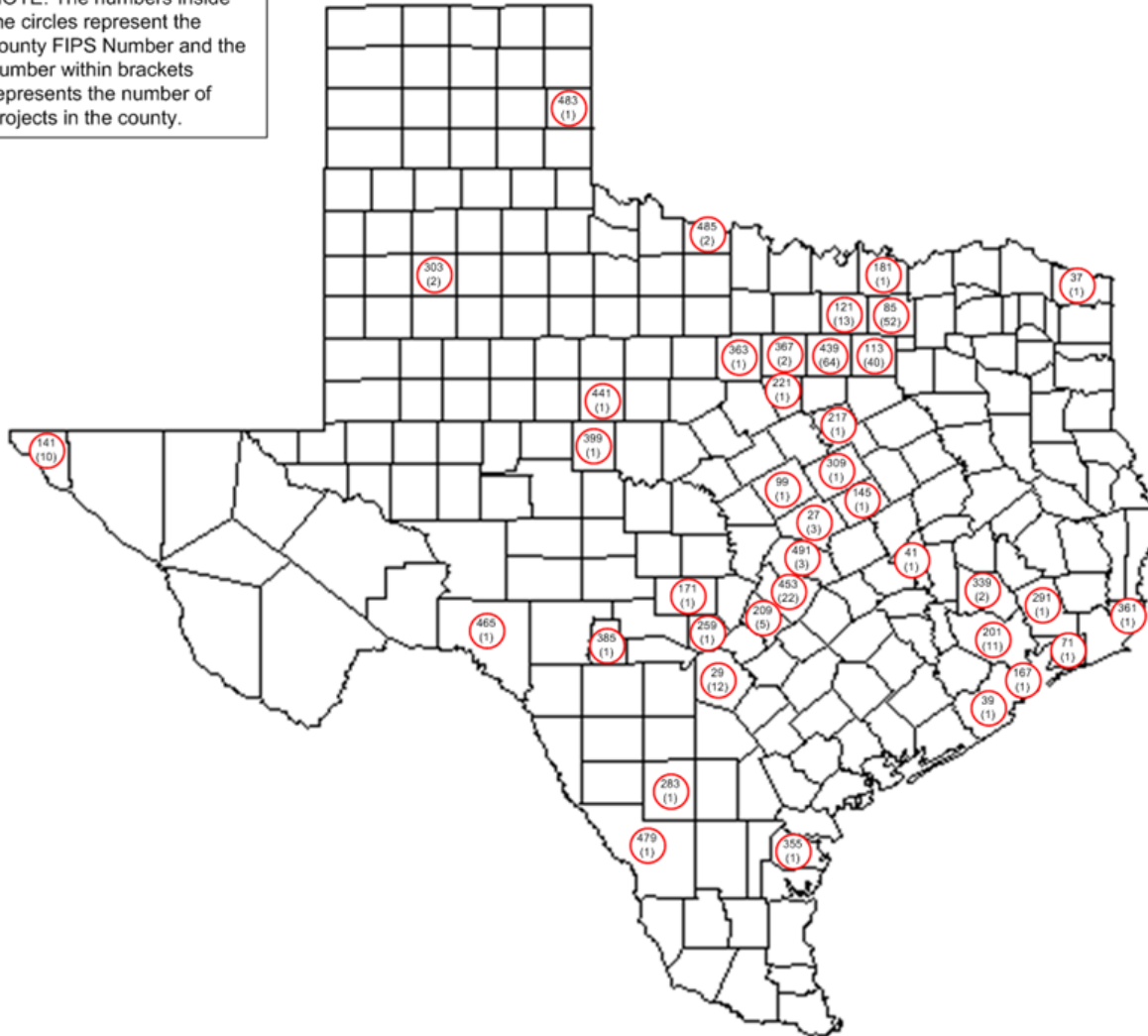


# RENEWABLE PROJECTS IN TEXAS



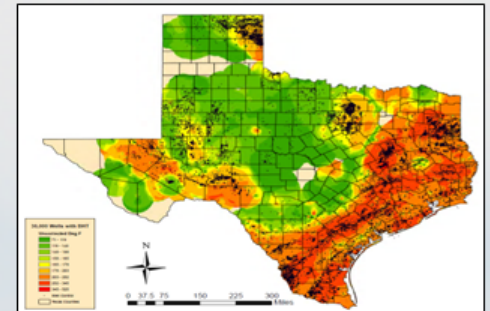
## Geothermal

NOTE: The numbers inside the circles represent the county FIPS Number and the number within brackets represents the number of projects in the county.



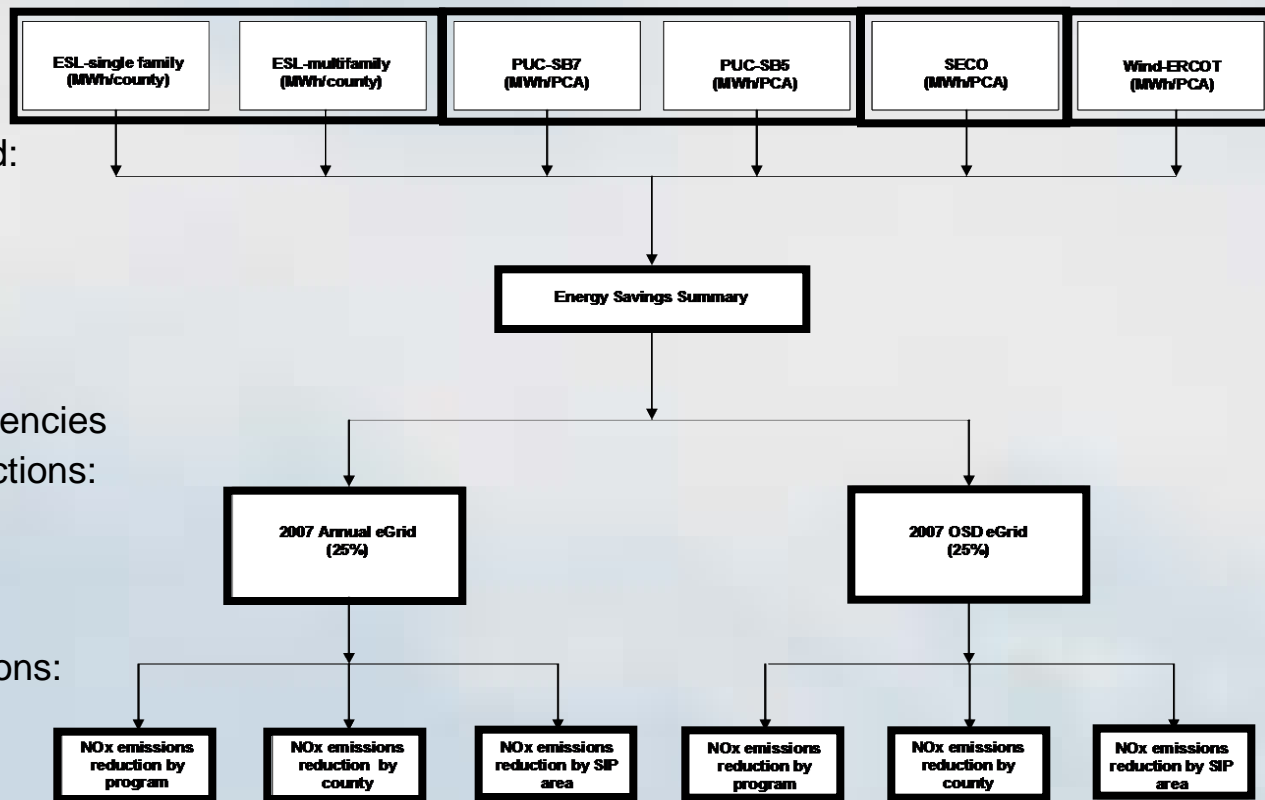
## Renewables:

- Solar PV (3,033 projects)
- Solar Thermal
- Hydro
- Landfill Gas
- Geothermal



# INTEGRATED NOx SAVINGS

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



State agencies included:

- TEES/ESL
- PUC
- SECO
- ERCOT/Wind

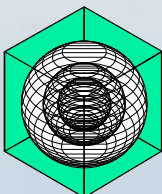
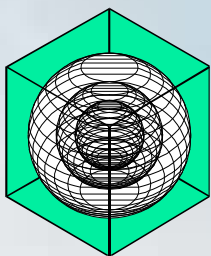
Total savings across agencies

Annual emissions reductions:

- By program
- By county
- By SIP area

OSD emissions reductions:

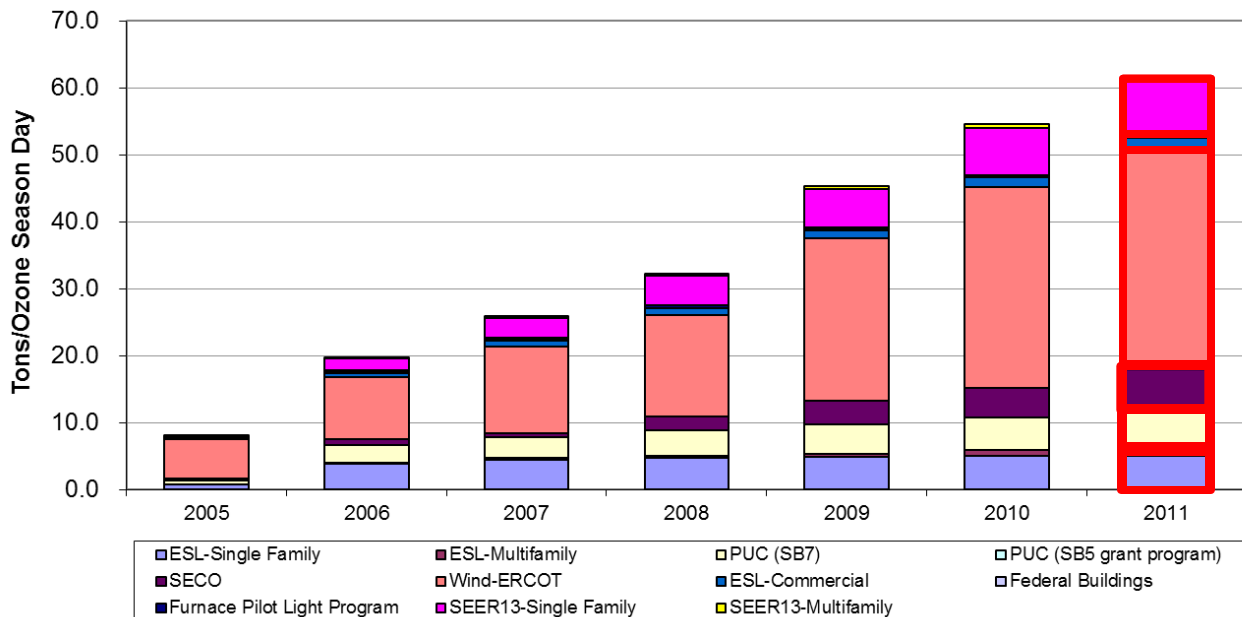
- By program
- By county
- By SIP area



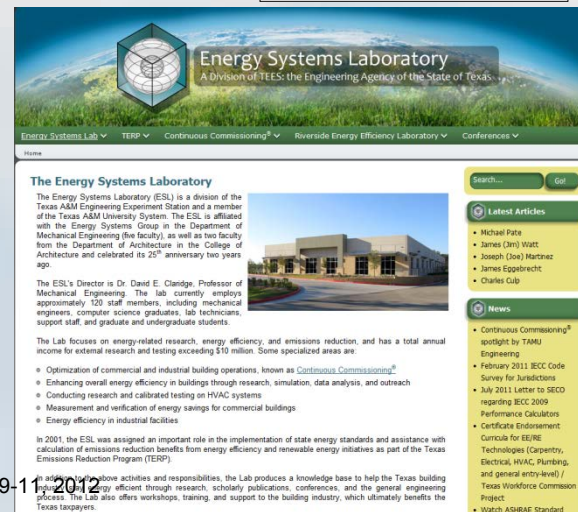
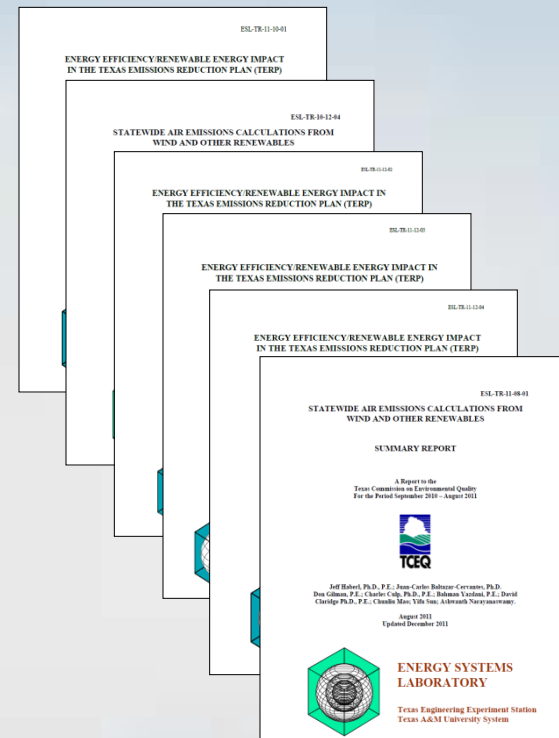
# INTEGRATED NOx SAVINGS

## 2011 Integrated Emissions Savings

OSD NOx reduction levels (Preliminary Estimates) All ERCOT



- ESL Code Compliance (8.17 tons/day)
- PUC SB5, SB7 programs (5.24 tons/day)
- SECO Political Sub. (6.03 tons/day)
- Green Power (Wind) (33.07 tons/day)
- Residential AC Retrofits (8.78 tons/day)
- Total (2011) (61.69 tons/day)**



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