TCEQ

Emissions Impacts of Electrifying Passenger Cars in Texas

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Key Points About NO_X Benefits of Gasoline versus Electric Vehicles

- Modern gasoline-powered passenger vehicles emit roughly 1-2% of the nitrogen oxides (NO_X) that were emitted by unregulated vehicles from the 1960s:
  - stringent Tier 2 standards applied to the 2004-2016 model years; and
  - even more stringent Tier 3 standards apply to the 2017-and-later model years.

- The very low NO_X emission rates from modern gasoline-powered passenger vehicles are due primarily to:
  - on-board computer control with electronic fuel injection;
  - robust exhaust after-treatment from catalytic converters; and
  - gasoline with very low sulfur content that prolongs the operating life of emission controls.

- Since modern gasoline-powered passenger vehicles have very low NO_X emission rates, there is no significant increase or decrease in total NO_X emissions between:
  - operating a Tier 2 or Tier 3 gasoline-powered vehicle; and
  - an electric vehicle powered by a battery charged from local electrical generating units (EGUs).

- Wind power accounted for 15% of Texas electricity generated in 2017 and its growth continues, but can't be relied upon for vehicle charging on high ozone days:
  - wind power is at its lowest levels during ozone season when overall demand for electricity is high; and
  - the ozone season days with the lowest average wind speeds typically have the highest ozone levels.

Key Points About Tailpipe Emission Standards and Fuel Economy

- Tailpipe exhaust emission standards for NO_X, volatile organic compounds (VOC), and carbon monoxide (CO) are not directly correlated with fuel economy standards in units of miles per gallon (mpg).

- Common Question: But don't bigger vehicles with larger engines consume more fuel and therefore emit more NO_X, VOC, and CO on a per mile basis?
  - "Engine-out" emissions for NO_X, VOC, and CO from larger vehicles/engines are typically greater than for smaller engines/vehicles.
  - However, "tailpipe-out" emissions are based on the capacity of the catalytic converter(s) located in the exhaust stream.

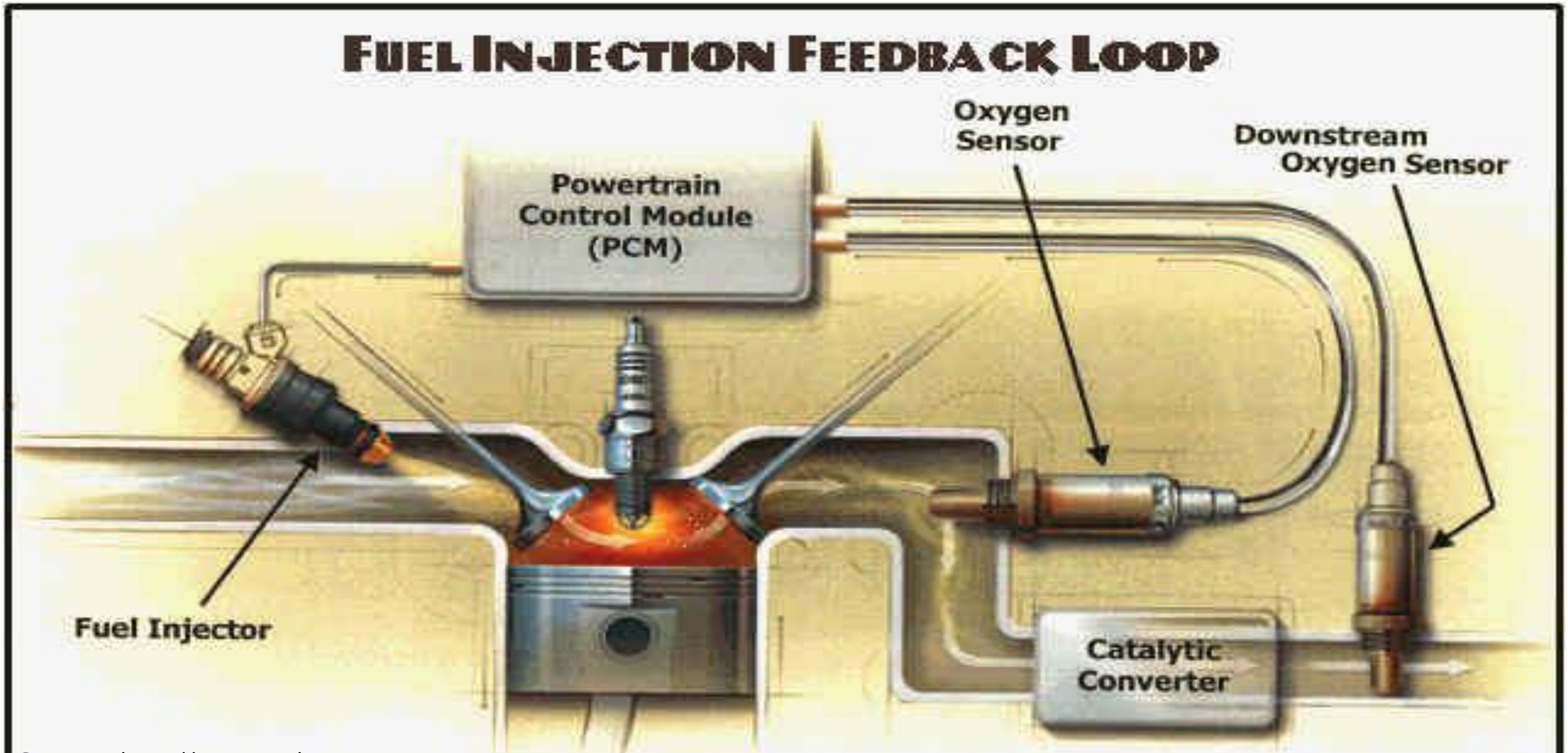
- EPA has not announced any changes to the Tier 3 exhaust emission standards for light-duty vehicles and trucks that phase-in from the 2017 through 2025 model years.

- If increasing overall energy efficiency is a primary goal, then increased use of electric vehicles versus gasoline ones can be beneficial, but it depends on the primary fuel source used to generate electricity.

- In order to match the operational energy efficiency of electric vehicles on a per mile basis, gasoline-powered vehicles would need to achieve:
  - roughly 50 mpg if natural gas is the sole source of electrical power; or
  - roughly 24 mpg if coal is the sole source of electrical power.

Schematic of Basic On-Road Emission Controls for Modern Gasoline Vehicles

- Reducing NO_X, VOC, and CO from modern engines:
  - on-board computer (e.g., powertrain control module) connected to various sensors;
  - electronic fuel injection instead of mechanical carburetion used on older vehicles; and
  - exhaust after-treatment (e.g., catalytic converter).



Source: http://www.tradezz.com

Comparison of Emission Rates from Modern Vehicles to Unregulated Vehicles

Vehicle Type and Emissions Standard Description	NO_X	NMOG*
	(grams per mile)	
Unregulated 1960s Gasoline Passenger Car (Source: MOBILE6.2 Model Default)	4.28	16.00
Tier 2 Bin 5 Fleet Average Standard (Equivalent to Tier 3 Bin 160 Standard)	0.07	0.09
Relative Reduction from Unregulated Levels for Tier 2 Bin 5	98.4%	99.4%
Tier 3 Bin 30 Fleet Average Standard (Equivalent to Tier 2 Bin 2 Standard)	0.02	0.01
Relative Reduction from Unregulated Levels for Tier 3 Bin 30	99.5%	99.9%
Tier 3 Bin 0 Standard – Electric Cars (Equivalent to Tier 2 Bin 1 Standard)	0.00	0.00

* NMOG: Non-methane organic gases, which are volatile organic compounds (VOC) plus ethane.

Source: U.S. Environmental Protection Agency (EPA) Regulations for Emissions from Vehicles and Engines, ttps://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-smog-soot-and-other-air-pollution-passenger

Federal Light-Duty Vehicle Certification Summary: Tier 2 (2004-2016) and Tier 3 (2017-and-Later)

Federal Tier 2 Bin	NO_x	NMOG*	NO_x + NMOG*	Federal Tier 3 Bin
	(grams per mile)		(milligrams per mile)	
Bin 1	0.00	0.000	0	Bin 0
				Bin 20
Bin 2	**0.02**	**0.010**	**30**	**Bin 30 (Tier 3 Average)**
				Bin 50
				Bin 70
Bin 3	0.03	0.055	85	
Bin 4	0.04	0.070	110	
				Bin 125
Bin 5 (Tier 2 Average)	**0.07**	**0.090**	**160**	Bin 160 (Tier 3 Maximum)
Bin 6	0.10	0.090	190	
Bin 7	0.15	0.090	240	
Bin 8 (Tier 2 Maximum)	0.20	0.125	325	

* NMOG: Non-methane organic gases, which are VOC plus ethane (or total hydrocarbons minus methane).

Federal Light-Duty Certification Summary: 2015 Model Year by Vehicle Fuel Type

Tier 2 Bin	Gasoline	Gasoline/ Electricity	Electricity	Diesel	Ethanol/ Gasoline	Natural Gas	Natural Gas/ Gasoline	Hydrogen	Total
Bin 1			15					1	16
Bin 2	24					1			25
Bin 3	72	5							77
Bin 4	26	1					1		28
Bin 5	847	5		14	34				**900**
Bin 6									
Bin 7									
Bin 8									
Total	969	11	15	14	34	1	1	1	1,046

The 2015 model year was chosen to represent a “mature” Tier 2 passenger fleet that is dominated by vehicles meeting the Bin 5 standard of 0.07 grams per mile of NO_X.

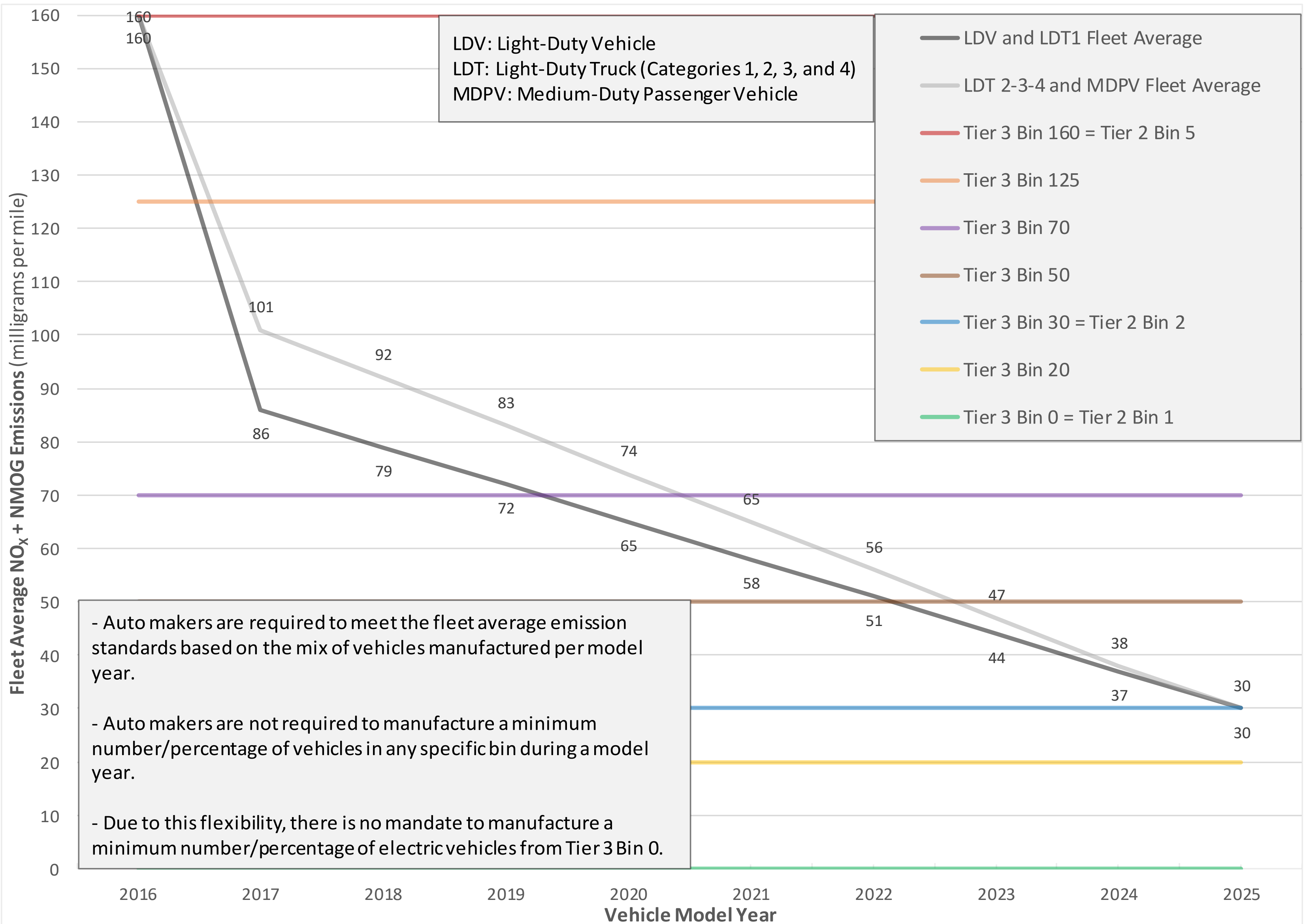
Source: EPA Green Vehicle Guide, which is available at http://www.fueleconomy.gov/feg/download.shtml

Federal Light-Duty Certification Summary: 2015 Model Year by Vehicle Use Type

Tier 2 Bin	Small Car	Midsize Car	Large Car	Station Wagon	Small SUV	Standard SUV	Pickup	Minivan	Special Purpose	Total
Bin 1	6	2	5	1	2					16
Bin 2	15	8		2						25
Bin 3	27	29	4	1	11	5				77
Bin 4	5	3	1	4	9		6			28
Bin 5	399	133	86	33	134	74	23	8	10	**900**
Bin 6										
Bin 7	The 2015 model year was chosen to represent a "mature" Tier 2 passenger fleet that is dominated by vehicles meeting the Bin 5 standard of 0.07 grams per mile of NO_X.									
Bin 8										
Total	452	175	96	41	156	79	29	8	10	1,046

Source: EPA Green Vehicle Guide, which is available at http://www.fueleconomy.gov/feg/download.shtml

Tier 3 Phase-In of Fleet Average Emission Standards through the 2025 Model Year



Source: Final Rule for Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3

Federal Light-Duty Certification Summary: 2019 Model Year by Vehicle Fuel Type

Tier 3 Bin	Tier 2 Equivalent	Gasoline	Gasoline/ Electricity	Electricity	Diesel	Ethanol/ Gasoline	Hydrogen	Total
Bin 0	Bin 1			28			3	31
Bin 20			1					1
Bin 30	**Bin 2**	206	18					**224**
Bin 50		77	1					78
Bin 70		383	4			10		397
Bin 85	Bin 3	2						2
Bin 110	Bin 4	34				7		41
Bin 125		397	7		11	25		440
Bin 160	**Bin 5**	95			13	1		**109**
Total		1,194	31	28	24	43	3	1,323

For the current 2019 model year, Tier 3 Bin 160 vehicles (equal to Tier 2 Bin 5) no longer dominate. Many vehicles meet more the more stringent requirements of "lower" bins with 224 make/models certified to the 2025 fleet average of Tier 3 Bin 30.

Source: EPA Green Vehicle Guide, which is available at http://www.fueleconomy.gov/feg/download.shtml

Federal Light-Duty Certification Summary: 2019 Model Year by Vehicle Use Type

Tier 3 Bin	Small Car	Midsize Car	Large Car	Station Wagon	Small SUV	Standard SUV	Pickup	Minivan	Van	Special Purpose	Total
Bin 0	7	10	3	3	5	3					31
Bin 20		1									1
Bin 30	69	64	21	18	40	9		3			**224**
Bin 50	20	9	3	4	17	6	13			6	78
Bin 70	69	51	37	17	120	24	60	3		16	397
Bin 85					2						2
Bin 110	4	5	10		11	3	4	2		2	41
Bin 125	159	58	48	8	39	81	41	2		4	440
Bin 160	73	13	5		2	9	4		3		**109**
Total	401	211	127	50	236	135	122	10	3	28	1,323

Source: EPA Green Vehicle Guide, which is available at http://www.fueleconomy.gov/feg/download.shtml

Equivalence Rates for NO_X from Gasoline Passenger Cars versus Electric Generating Units (EGUs)

Parameter Description	10-County DFW	Eight-County HGB	Eight-County San Antonio	Five-County Austin	Remaining 223 Counties	254-County Texas
Summer EGU NO_X Generation Rate for 2018 (pounds per Megawatt-Hour)	0.2138	0.3237	0.8484	0.4999	0.7236	0.6171
EGU NO_X Generated for 377 Megawatt-Hours to Travel One Million Miles (pounds)	80.56	121.96	319.66	188.35	272.64	232.51
EGU NO_X Generated for 377 Megawatt-Hours to Travel One Million Miles (grams)	36,539	55,322	144,995	85,435	123,666	105,465
NO_X Equivalence Rate for Electric Cars versus EGUs (grams per mile)	0.04	0.06	0.14	0.09	0.12	0.11
Federal Tier 2 Certification Bin(s) Closest to NO_X Equivalence Rate	Bin 4	Bins 4-5	Bins 6-7	Bins 5-6	Bins 6-7	Bins 6-7

- Federal Tier 2 Bin 5 has a NO_X certification rate of 0.07 grams per mile, which is the fleet average standard that vehicle manufacturers must meet.
- The majority of passenger vehicles sold from 2004 through 2016 were certified to Bin 5 under Tier 2.
- Tier 3 standards phase in from 2017 through 2025 by reducing the fleet NO_X average from 0.07 to 0.02 grams per mile.
- The 2018 Summer EGU NO_X generation rates shown were obtained for June through August from queries of the U.S. Environmental Protection Agency Air Markets Program Data (AMPD) Web page, https://ampd.epa.gov/ampd/.

Energy Efficiency Equivalence for Gasoline Passenger Cars versus Coal and Natural Gas EGUs

Electric Generating Unit Fuel Type	Number of Texas Facilities Reporting to AMPD in 2018	2018 Carbon Dioxide (CO_2) Emission Rate (pounds per Megawatt-Hour)		
		Minimum	Maximum	Average
Natural Gas	106	752	1,868	992
Coal	20	1,844	2,686	2,104

Parameter Description	Electrical Generation Source Mix		
	100% Natural Gas	100% Coal	50% - Gas, 25% - Coal, 25% - Wind and Nuclear
2018 CO_2 Emission Rate (pounds per Megawatt-Hour)	992	2,104	1,022
CO_2 Emitted for 377 Megawatt-Hours for 1 Million Miles of Electric Car Travel (pounds)	373,766	792,745	385,069
CO_2 Emitted for 377 Megawatt-Hours for 1 Million Miles of Electric Car Travel (grams)	169,536,411	359,581,259	174,663,520
CO_2 Rate for 1 Million Miles of Electric Car Travel (grams per mile)	169.54	359.58	174.66
CO_2 Emitted per Gallon of Gasoline with 10% Ethanol (grams per gallon)	8,521		
Fuel Consumption Equivalence Rate for Electric Cars (miles per gallon)	50.3	23.7	48.8

Modern Electric Vehicle Battery Sizes, Operating Ranges, and Energy Consumption

Vehicle Make	Model Name	Model Year	Battery Size	Range (miles)	Energy Consumption (Watt-Hours per mile)		
					City	Highway	Combined
Audi	e-tron	2019	95.0	204	455	462	455
BMW	i3	2019	42.2	153	272	330	298
BMW	i3s	2019	42.2	153	272	330	298
Chevrolet	Bolt EV	2019	60.0	238	263	306	283
Fiat	500e	2019	24.0	84	279	327	301
Honda	Clarity Electric	2019	25.5	89	267	327	296
Hyundai	IONIQ Electric	2019	28.0	124	225	276	248
Hyundai	Kona Electric	2019	64.0	258	255	312	281
Jaguar	I-PACE	2019	90.0	234	421	468	443
Kia	Niro EV	2019	64.0	239	274	330	301
Kia	Soul EV	2019	30.0	111	272	362	312
Kia	e-Soul	2020	64.0	243	265	334	296
Nissan	LEAF	2019	40.0	150	272	340	301
Nissan	LEAF e+ S	2019	62.0	226	286	347	312
Nissan	LEAF e+ SV/SL	2019	62.0	215	296	359	324
smart	EQ fortwo Coupe	2019	17.6	58	272	359	312
smart	EQ fortwo Cabrio	2019	17.6	57	301	370	330
Tesla	Model 3 Standard Range	2019	59.5	220	244	272	257
Tesla	Model 3 Standard Range Plus	2019	59.5	240	241	272	253
Tesla	Model 3 Long Range RWD	2019	80.5	325	248	274	259
Tesla	Model 3 Long Range AWD	2019	80.5	310	281	301	291
Tesla	Model 3 Performance LR AWD	2019	80.5	310	281	301	291
Tesla	Model S Long Range	2019	100.0	370	293	315	304
Volkswagen	e-Golf	2019	35.8	125	267	304	283
24-Vehicle Average			55.2	197.3	283	332	**305**

Source: *Inside EVs*, May 2019, https://insideevs.com/reviews/344001/compare-evs/

Electric Vehicle Charging Efficiency from Outlet to Battery

Charging Scenario	Level 1 (120 Volts)	Level 2 (240 Volts)
Low-Energy (< 2 Kilowatt-Hours Charge)	70.7%	83.5%
High-Energy (> 2 Kilowatt-Hours Charge)	84.2%	86.5%
Combined	83.7%	86.4%

High-Energy Charging Scenario	Level 1 (120 Volts)	Level 2 (240 Volts)
Below 53 Degrees Fahrenheit	84.0%	87.3%
53 – 70 Degrees Fahrenheit	85.8%	87.8%
Above 70 Degrees Fahrenheit	82.2%	**85.3%**

- "Outlet-to-battery" charging efficiency is likely to improve over time.
- An 85.3% overall charging efficiency was assumed for this analysis.

Source: *An Assessment of Level 1 and Level 2 Electric Vehicle Charging Efficiency*, March 2013, Forward, Glitman, and Roberts, https://www.veic.org/docs/Transportation/20130320-EVT-NRA-Final-Report.pdf

Electricity Transmission and Distribution Losses in Texas

Electric Generation Category (Megawatt-Hours)	1990	1995	2000	2005	2010	2015	2017
Direct Use	28,031,066	37,852,016	42,458,738	45,497,429	33,873,361	36,116,457	35,220,381
Total Disposition	281,560,757	317,636,244	377,744,751	396,746,819	417,967,232	454,276,885	467,236,606
Total Disposition – Direct Use	253,529,691	279,784,228	335,286,013	351,249,390	384,093,871	418,160,428	432,016,225
Estimated Losses	18,024,745	20,094,800	24,755,499	22,340,398	22,146,761	19,567,214	21,861,661
Loss Portion	7.1%	7.2%	7.4%	6.4%	5.8%	4.7%	**5.1%**

- In general, relative transmission and distribution losses in Texas have declined over time.
- 2018 figures are not yet available from the U.S. Energy Information Administration (EIA).
- The 5.1% transmission and distribution loss figure for 2017 was assumed for this analysis.

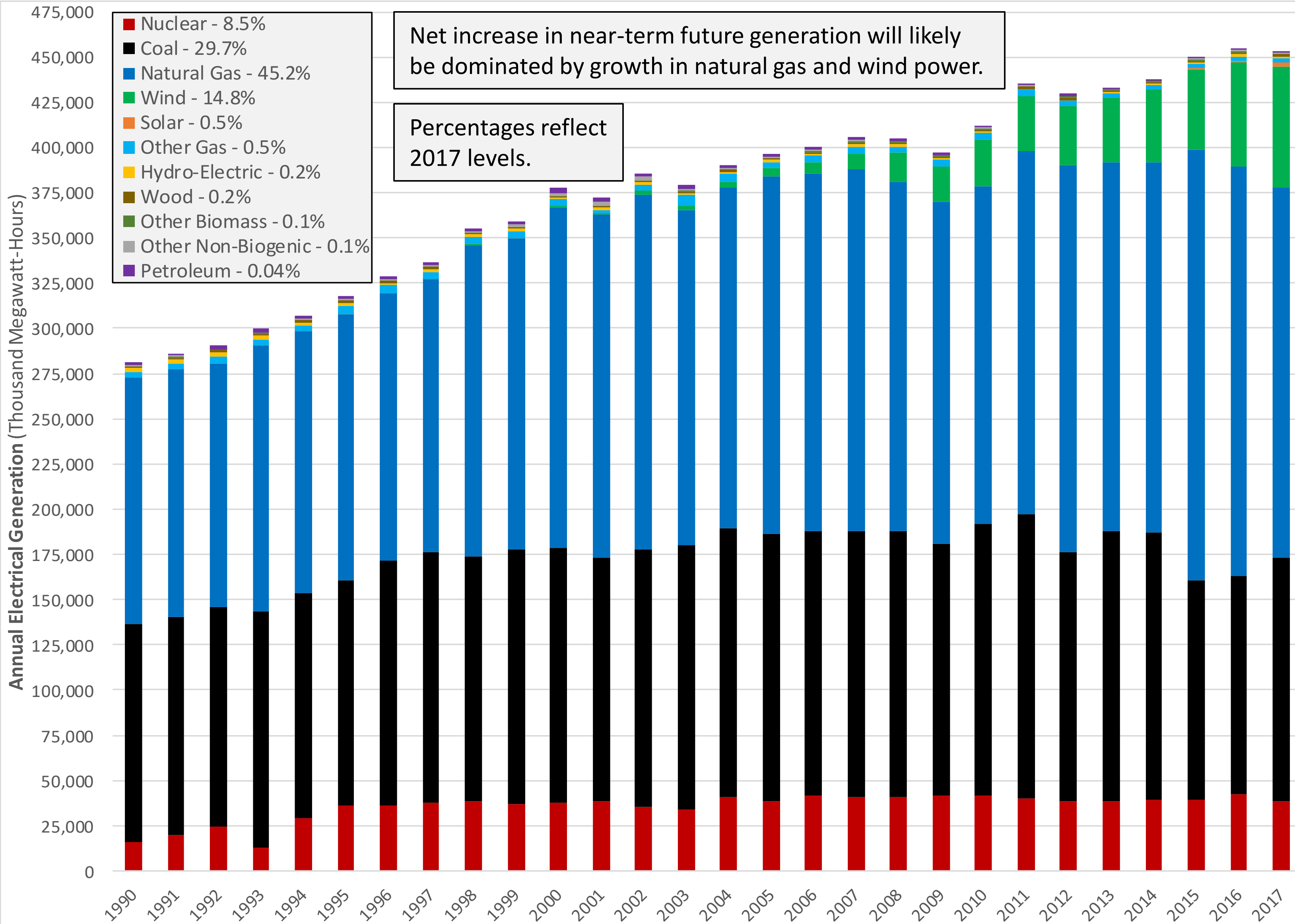
Source: U.S. Energy Information Administration (EIA) State Electricity Profiles, Table 10 for, Supply and Disposition of Electricity, 1990 through 2017, Texas, https://www.eia.gov/electricity/state/

Electrical Power Generation Requirements for One Million Miles of Passenger Car Travel

Parameter Description	Value
Vehicle Miles Traveled by Electric Cars	1,000,000
Average Energy Consumption per Mile (Watt-Hours)	305
Kilowatt-Hours Consumed by Batteries	305,000
Megawatt-Hours Consumed by Batteries	305
Charging Efficiency (14.7% Loss)	85.3%
Transmission/Distribution Efficiency (5.1% Loss)	94.9%
Megawatt-Hours Generated by EGUs	377

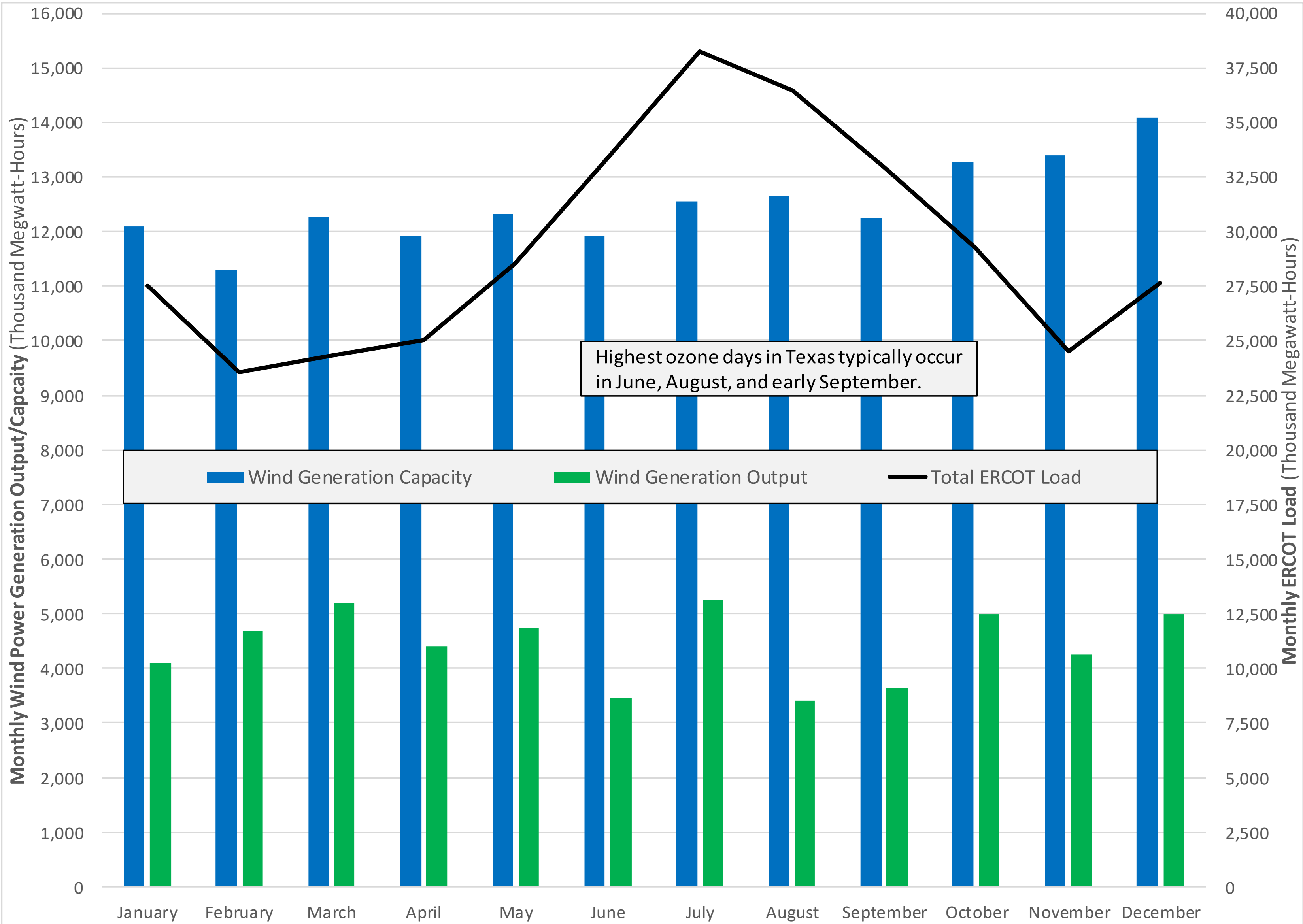
- For every one million miles traveled by electric cars, 377 Megawatt-Hours of power must be generated by an EGU or other source.
- Power generated from wind turbines is at its lowest levels during the ozone season months when overall demand for electricity is highest.
- High ozone days occur when average wind speeds are at their lowest levels, which is also when wind power generation is low.
- The majority of additional power needed for electric cars during high ozone periods is likely to be generated by natural gas and/or coal plants.

Texas Annual Electrical Power Generation by Energy Source from 1990 through 2017



Source: U.S. Energy Information Administration (EIA) State Electricity Profiles, Table 5, Electric Power Industry Generation by Primary Energy Source, 1990 through 2017, Texas, https://www.eia.gov/electricity/state/

Monthly Electric Power from Wind Energy Sources in Texas During 2016



Source: Electric Reliability Council of Texas (ERCOT) Hourly Aggregated Wind Output Tables for 2016, http://www.ercot.com/gridinfo/generation

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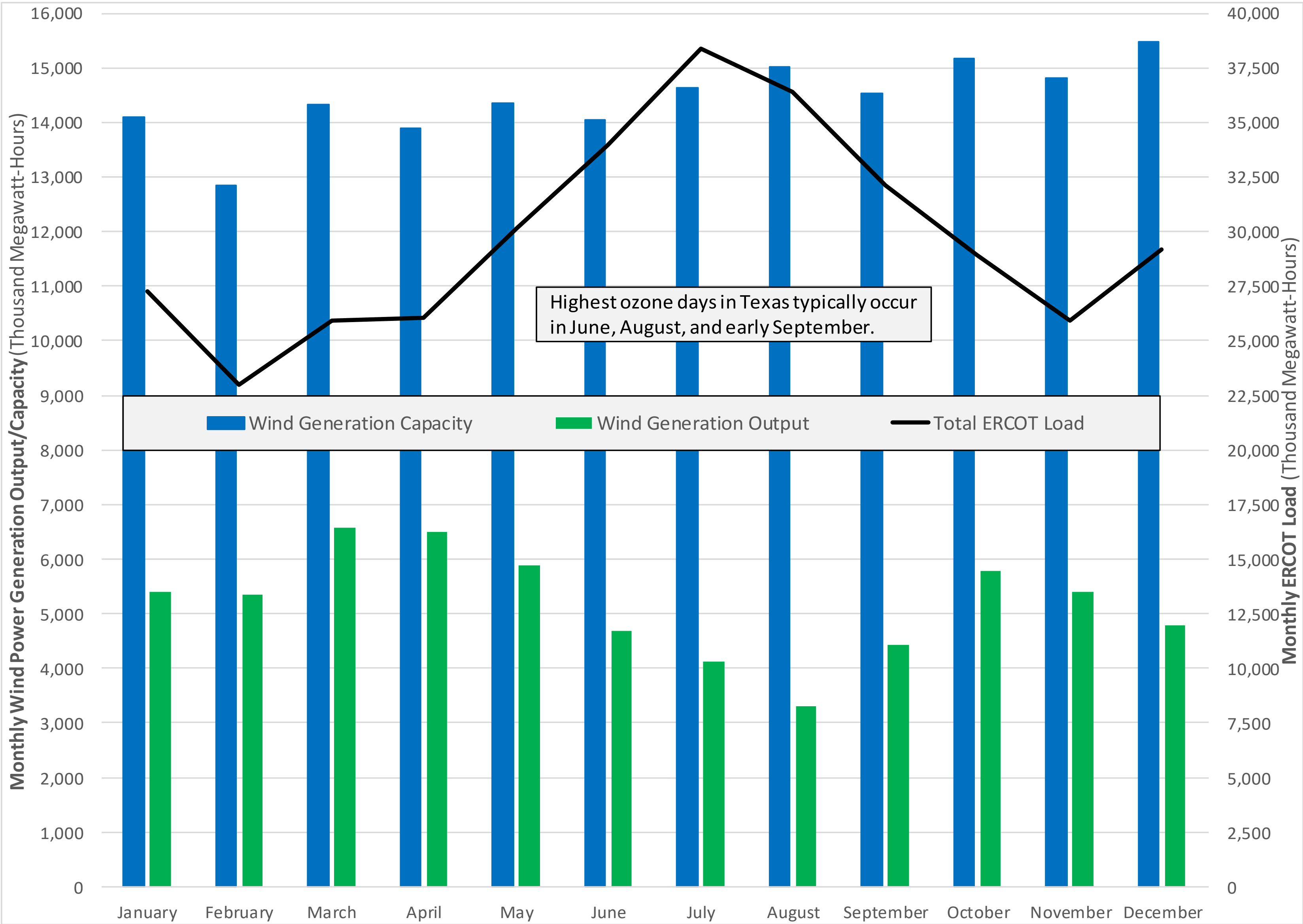

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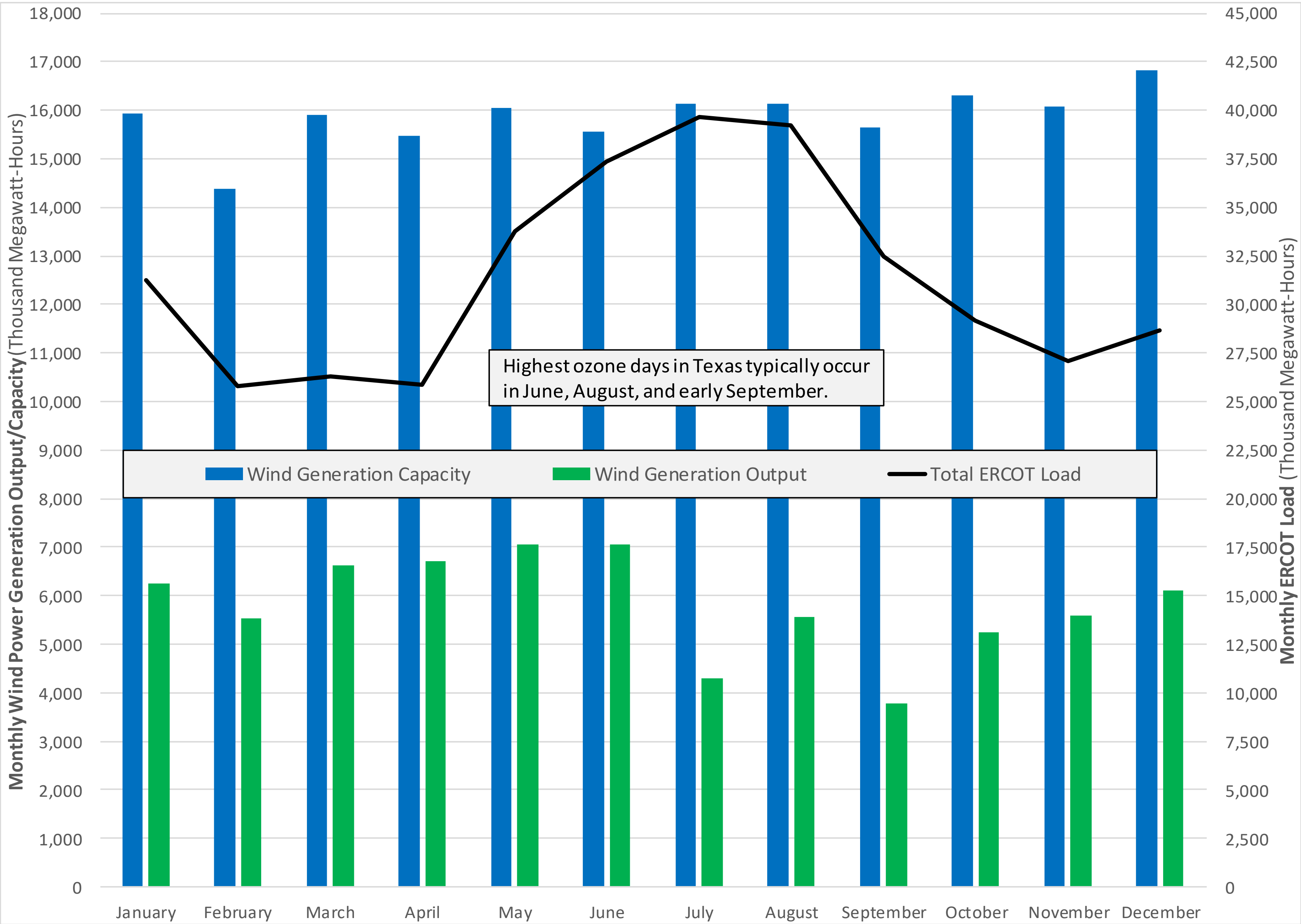

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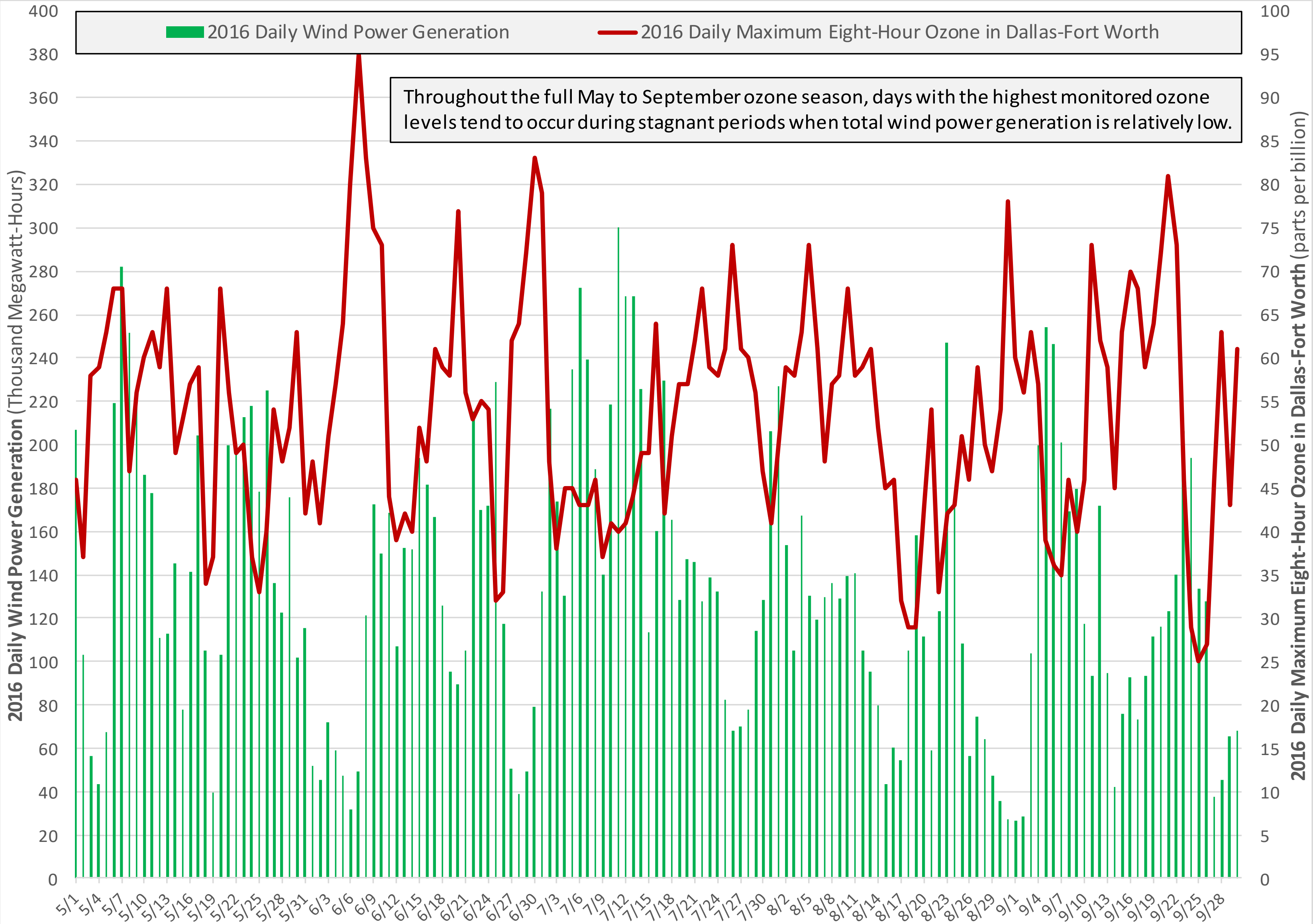
2016 Daily Wind Power Generated from May through September with Maximum DFW Area Ozone Levels



Source: Electric Reliability Council of Texas (ERCOT) Hourly Aggregated Wind Output Tables for 2016, http://www.ercot.com/gridinfo/generation, and TCEQ TAMIS, http://www.tceq.texas.gov/goto/tamis/

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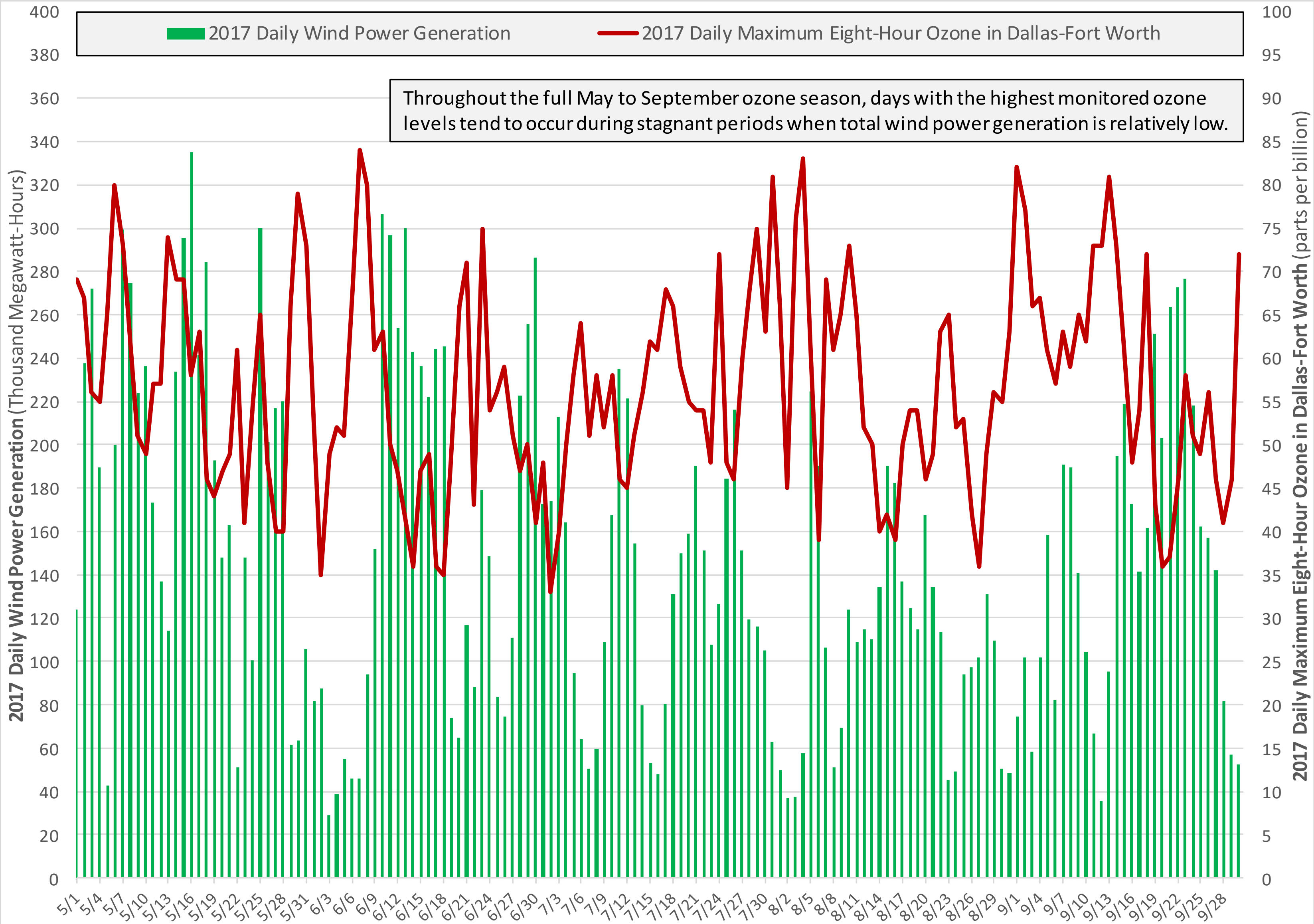

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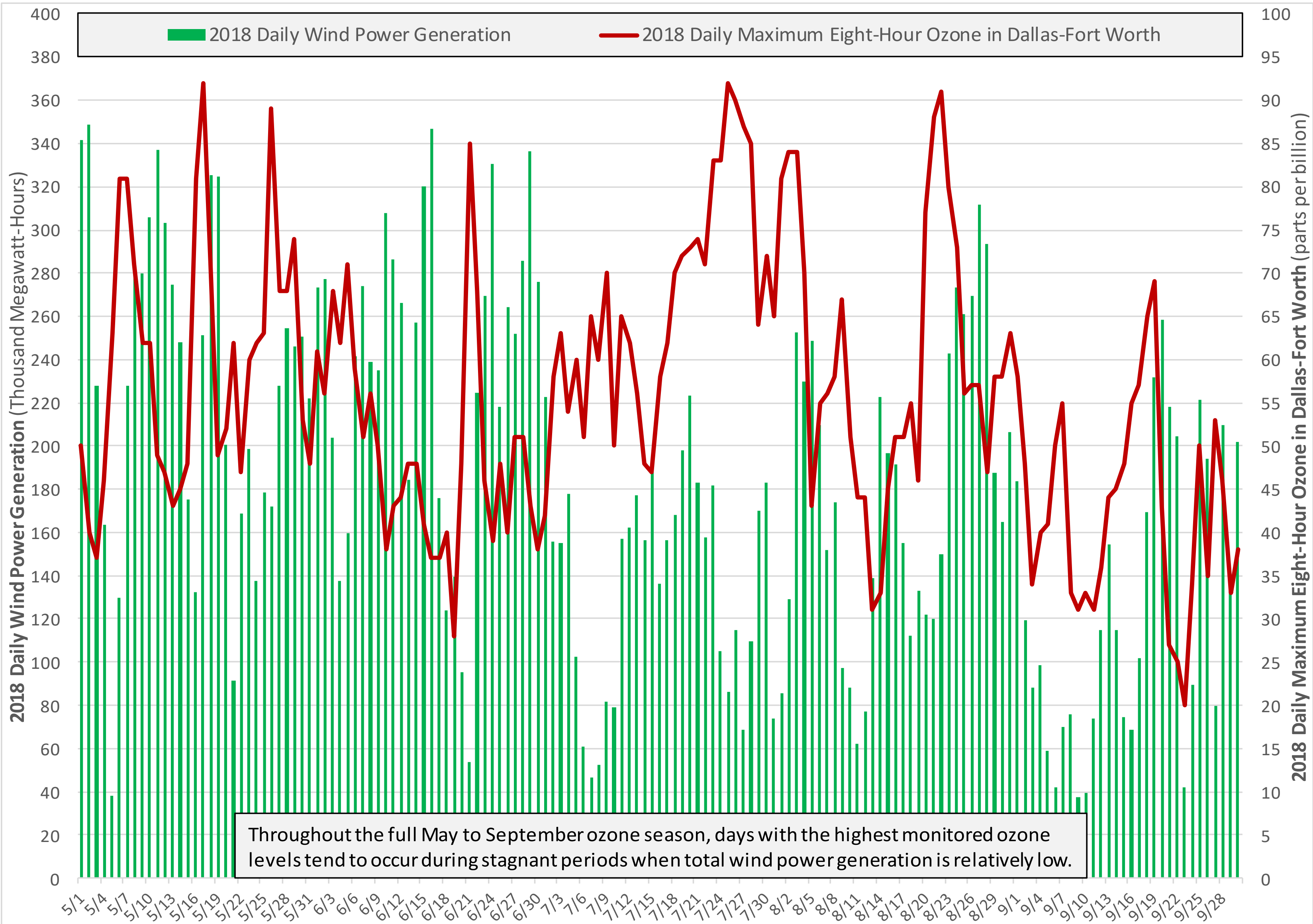

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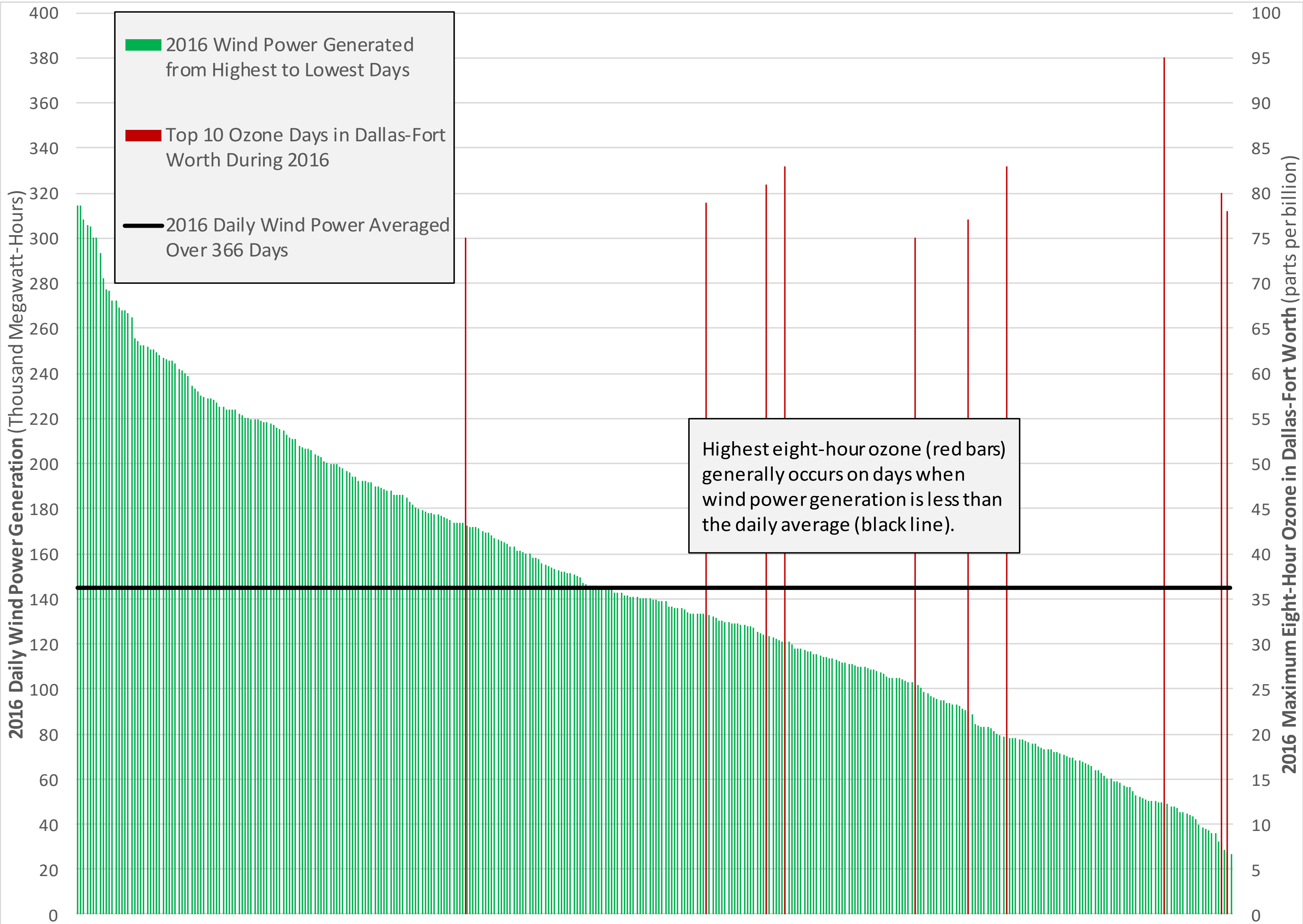
2016 Highest to Lowest Texas Wind Power Days Correlated with Top 10 Ozone Days in DFW



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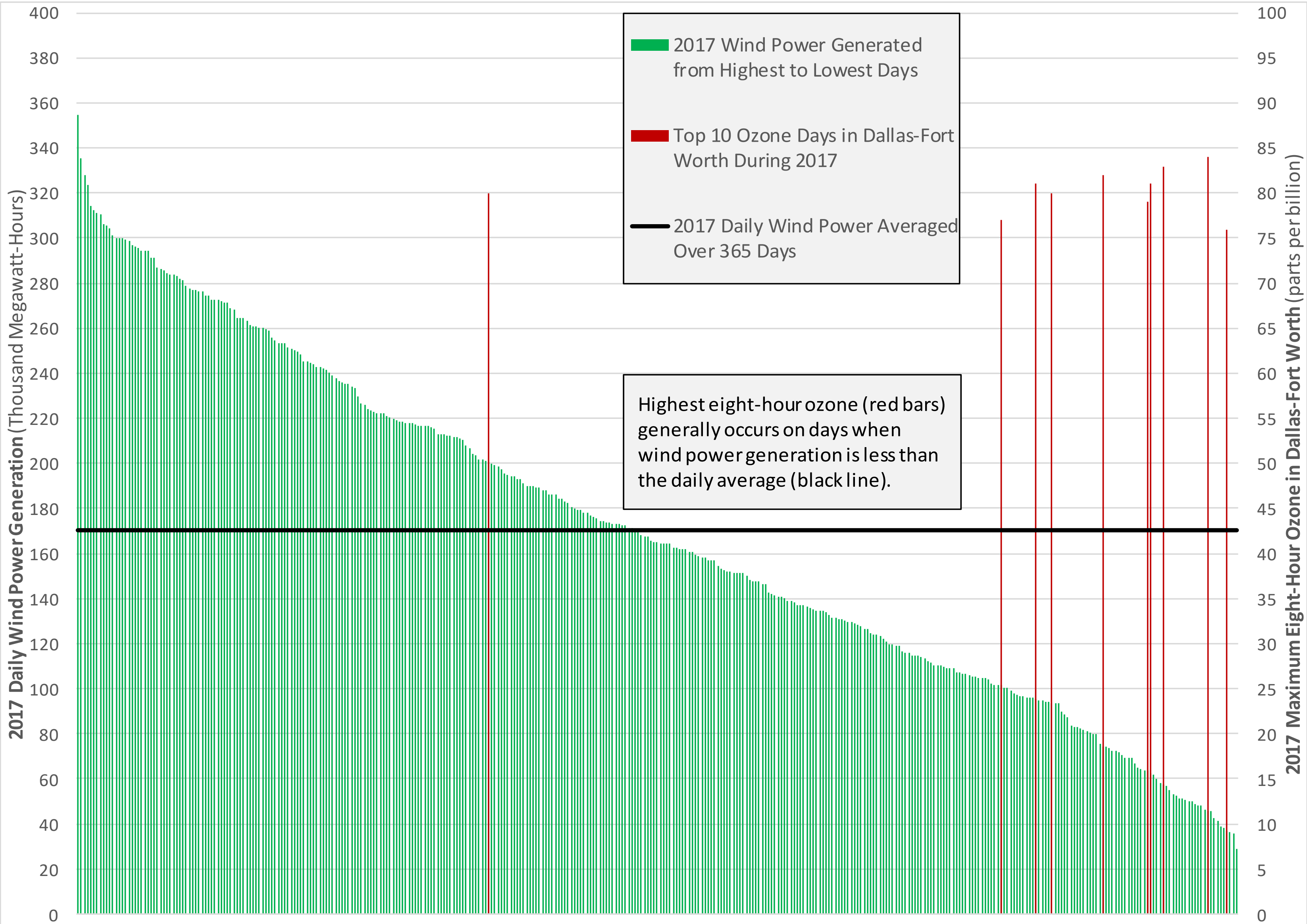

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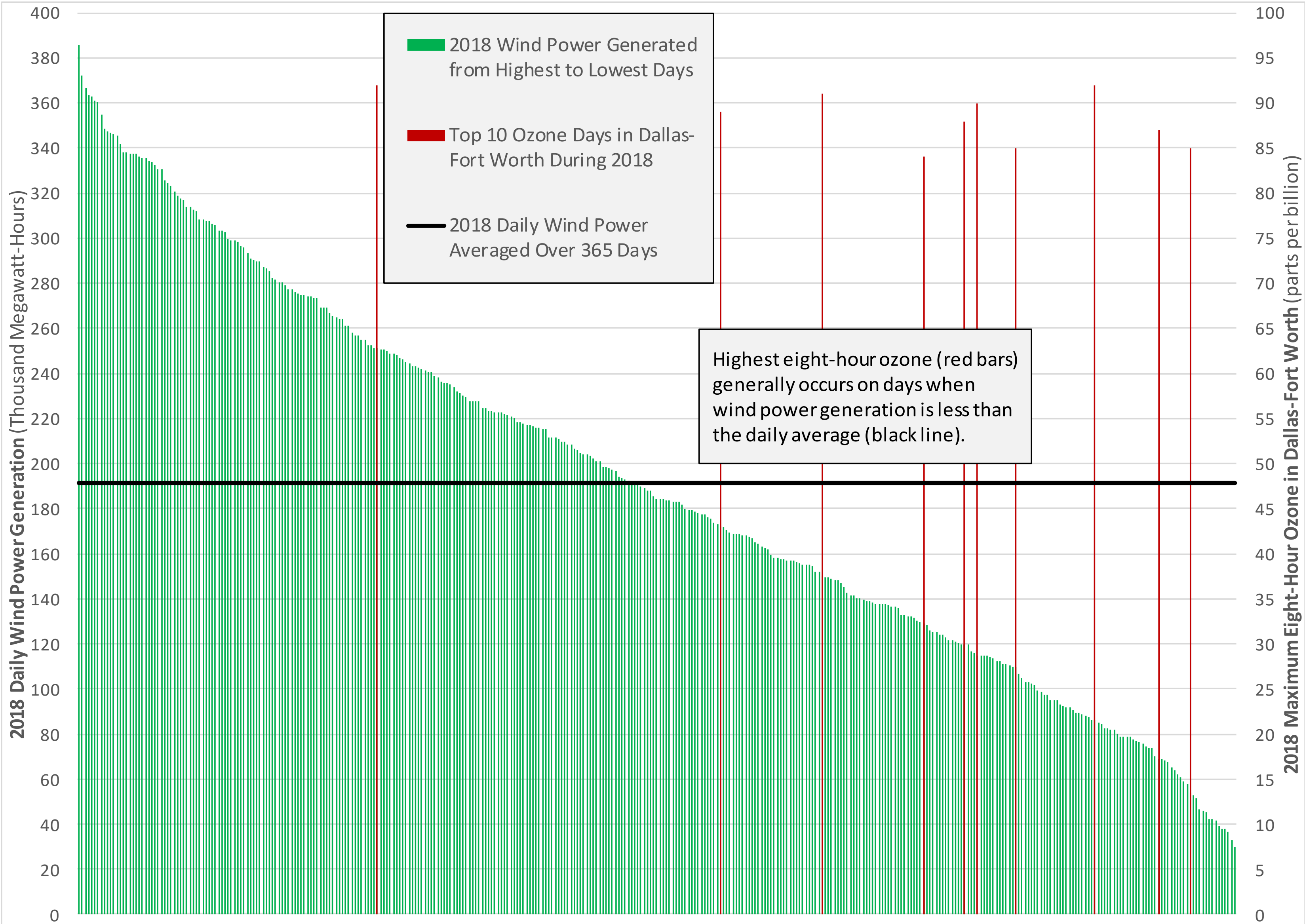

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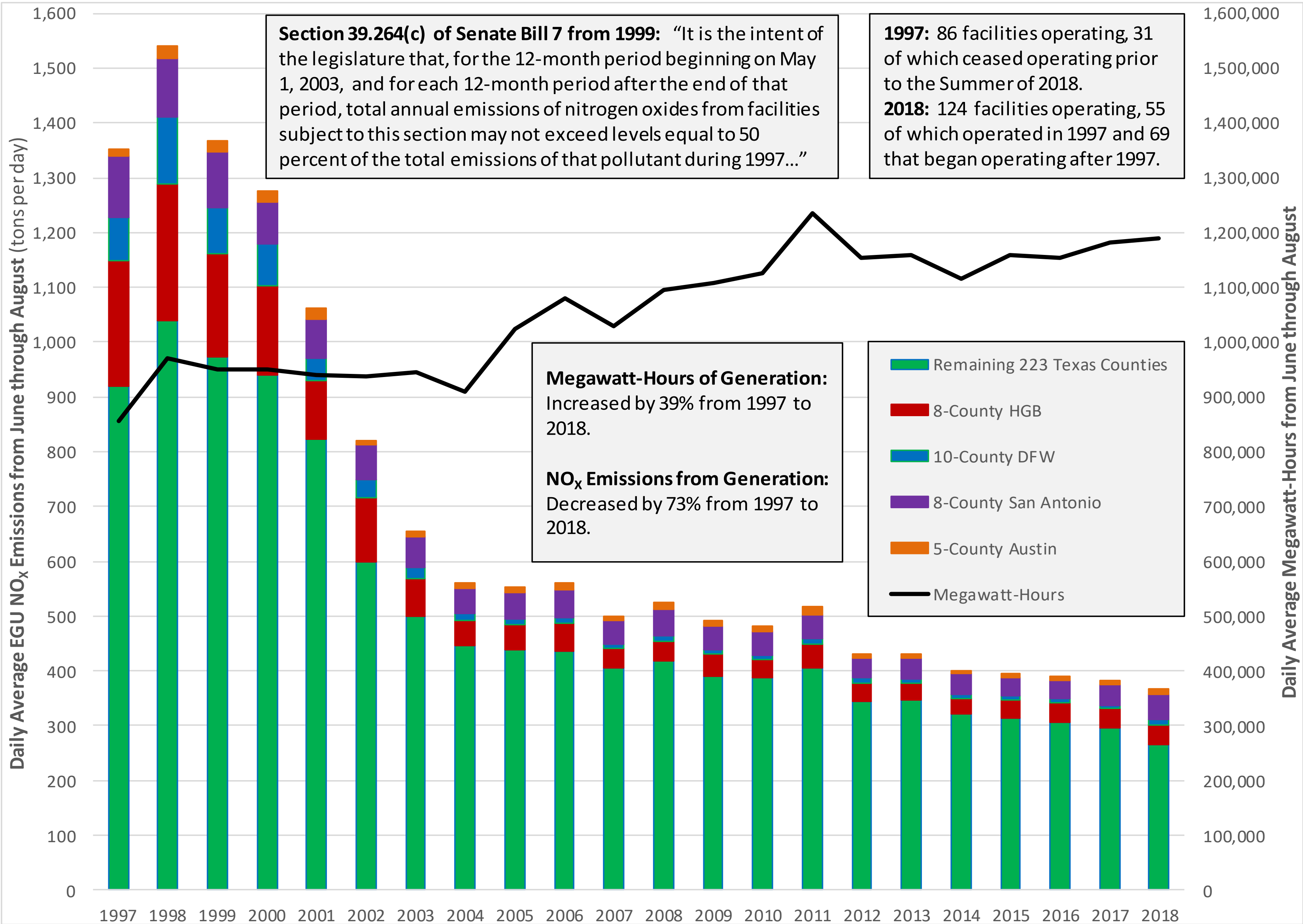
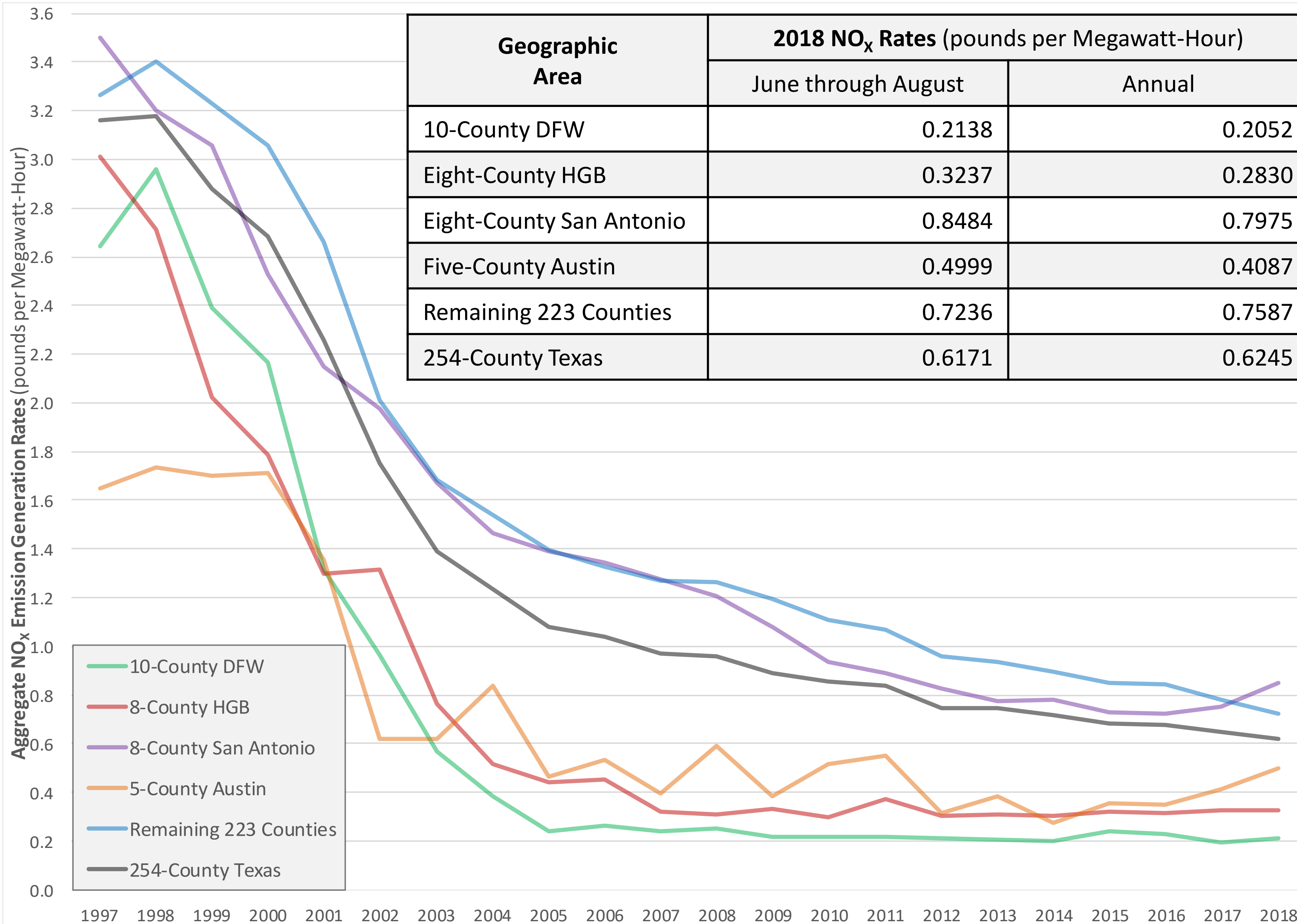
Texas Summer EGU NO_x Emission Trends from Fossil Fuel Plants from 1997 through 2018



Source: U.S. Environmental Protection Agency (EPA) Air Markets Program Data (AMPD), which is available at https://ampd.epa.gov/ampd/

Texas Summer EGU NO_X Emission Rates from Fossil Fuel Plants from 1997 through 2018

Geographic Area	**2018 NO_X Rates** (pounds per Megawatt-Hour)	
	June through August	Annual
10-County DFW	0.2138	0.2052
Eight-County HGB	0.3237	0.2830
Eight-County San Antonio	0.8484	0.7975
Five-County Austin	0.4999	0.4087
Remaining 223 Counties	0.7236	0.7587
254-County Texas	0.6171	0.6245



Source: U.S. Environmental Protection Agency (EPA) Air Markets Program Data (AMPD), which is available at https://ampd.epa.gov/ampd/

Comparison of EPA and TCEQ Modeled Ozone Benefits for Tier 3 and Low Sulfur Gasoline

- EPA performed nationwide air quality modeling in support of the rule for Tier 3 standards and 10 parts per million (ppm) sulfur gasoline.
  - *Air Quality Modeling Technical Support Document: Tier 3 Motor Vehicle Emission and Standards*, February 2014, EPA-454/R-14-002, is available at https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100HX23.TXT.
  - Appendix B includes benefits for select U.S. counties.
- EPA's modeled ozone benefits for 2018 in DFW area counties range from 0.46 – 0.92 parts per billion (ppb).
- The TCEQ modeled ozone benefits for 2018 at DFW area monitors range from 0.39 – 0.80 ppb based on the following on-road emission reductions:

Geographic Area	**2018 Summer Weekday On-Road Emission Reductions** (tons per day) **Use of Proposed 10 ppm Sulfur Gasoline for In-Use Fleet**		
	NO_X	**VOC**	**CO**
10-County DFW	**9.98**	2.39	13.25
Eight-County Houston-Galveston-Brazoria (HGB)	9.21	2.25	12.66
236 Remaining Texas Counties	26.97	5.52	27.74
Texas Total (254 Counties)	46.16	10.16	53.65
Non-Texas Continental U.S. (2,856 Counties)	698.57	126.58	873.91
Grand Total	744.73	136.74	927.56

Scenario: Electrifying Newest to Oldest DFW Area Gasoline Passenger Cars in 2023

Model Year Range	Number of Vehicles Electrified	On-Road NO_X Reduced (tons per day)	Megawatt-Hours Needed	EGU NO_X Generated (tons per day)	Gasoline Fuel Saved (gallons)	Tanker Truck Trips Avoided	Tanker Truck Miles Saved	Tanker Truck NO_X Reduced (tons per day)
2023 to 2020	891,988	1.00	16,329	1.75	1,194,575	133	5,309	0.0111
2023 to 2014	2,391,299	5.00	40,643	4.34	3,403,679	378	15,127	0.0317
2023 to 2007	3,547,573	10.00	55,995	5.99	5,173,710	575	22,994	0.0482
2023 to 1994	3,931,672	15.00	59,821	6.39	5,646,345	627	25,095	0.0526
All Vehicles	3,969,897	17.33	60,098	6.42	5,679,633	631	25,243	0.0529

- This scenario is premised on a program that focuses priority for electrification on the newest passenger cars in the fleet.
- Since the newest passenger cars have the lowest NO_X emission rates, many of them (e.g., 891,988) need to be electrified by 2023 to achieve 1 ton per day (tpd) of NO_X reduction.
- Since the new car emission rates are so low, more EGU NO_X (1.75 tpd) would be generated than reduced from the roadway network.
- Other scenarios are shown to see the number of passenger cars that would require electrification (from newest to oldest) to achieve 5, 10, and 15 tpd of NO_X reduction; corresponding EGU NO_X generation totals are shown.
- If all 4 million passenger cars projected to be operating in DFW during 2023 are electrified, then a total of 17.33 tpd of NO_X reduction would be achieved with a 6.42 NO_X tpd increase from EGUs.
- Under this “newest to oldest” electrification scenario, the newer vehicles will remain in the fleet for many years, so the overall electrification benefit has a long duration.

Scenario: Electrifying Oldest to Newest DFW Area Gasoline Passenger Cars in 2023

Model Year Range	Number of Vehicles Electrified	On-Road NO_X Reduced (tons per day)	Megawatt-Hours Needed	EGU NO_X Generated (tons per day)	Gasoline Fuel Saved (gallons)	Tanker Truck Trips Avoided	Tanker Truck Miles Saved	Tanker Truck NO_X Reduced (tons per day)
1993-and-Older	16,371	1.00	119	0.01	14,248	2	63	0.0001
1993 to 2002	115,698	5.00	910	0.10	110,789	12	492	0.0010
1993 to 2011	1,025,449	10.00	11,639	1.24	1,418,149	158	6,303	0.0132
1993 to 2017	2,373,766	15.00	31,814	3.40	3,481,562	387	15,474	0.0324
All Vehicles	3,969,897	17.33	60,098	6.42	5,679,633	631	25,243	0.0529

- This scenario is premised on a program that focuses priority for electrification on the oldest passenger cars in the fleet.
- Since the oldest passenger cars have the highest NO_X emission rates, fewer of them (e.g., 16,371) need to be electrified by 2023 to achieve 1 tpd of NO_X reduction.
- Since a smaller number of cars need electrification under this scenario, only 0.01 NO_X tpd is generated from EGUs to power these vehicles for the 1 NO_X tpd scenario of on-road reduction.
- Other scenarios are shown to see the number of passenger cars that would require electrification (from oldest to newest) to achieve 5, 10, and 15 tpd of NO_X reduction; corresponding EGU NO_X generation totals are shown.
- If all 4 million passenger cars projected to be operating in DFW during 2023 are electrified, then a total of 17.33 tpd of NO_X reduction would be achieved with a 6.42 NO_X tpd increase from EGUs.
- Under this “oldest to newest” electrification scenario, the older vehicles would soon be retiring from the fleet through attrition, so the overall electrification benefit has a short duration.

Scenario: Electrifying Weighted Average DFW Area Gasoline Passenger Cars in 2023

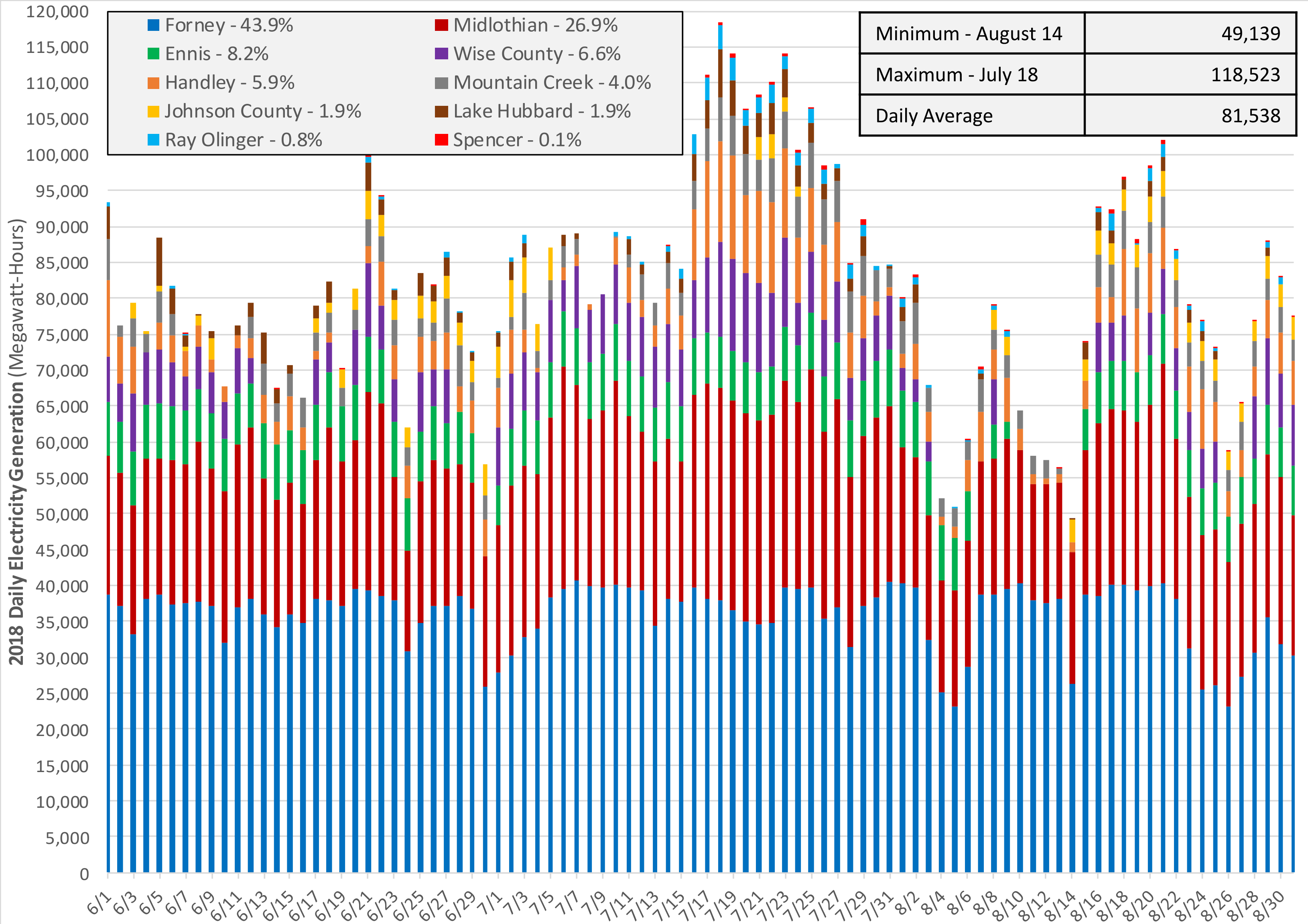
Model Year Range	Number of Vehicles Electrified	On-Road NO_X Reduced (tons per day)	Megawatt-Hours Needed	EGU NO_X Generated (tons per day)	Gasoline Fuel Saved (gallons)	Tanker Truck Trips Avoided	Tanker Truck Miles Saved	Tanker Truck NO_X Reduced (tons per day)
Fleet Average Across 1993 to 2023 Model Years - No Specific Age Preference	229,064	1.00	3,468	0.37	327,716	36	1,457	0.0031
	1,145,318	5.00	17,338	1.85	1,638,578	182	7,283	0.0153
	2,290,636	10.00	34,677	3.71	3,277,156	364	14,565	0.0305
	3,435,954	15.00	52,015	5.56	4,915,733	546	21,848	0.0458
	3,969,897	17.33	60,098	6.42	5,679,633	631	25,243	0.0529

- This scenario is premised on a program that does not focus priority for electrification on either the newest or the oldest passenger cars in the fleet.
- For a weighted average passenger car (across all operating model years) in 2023, 229,064 need to be electrified by 2023 to achieve 1 tpd of NO_X reduction.
- 0.37 NO_X tpd is generated from EGUs to power these 229,064 vehicles for the 1 NO_X tpd scenario of on-road reduction.
- Other scenarios are shown to see the number of passenger cars that would require electrification to achieve 5, 10, and 15 tpd of NO_X reduction; corresponding EGU NO_X generation totals are shown.
- If all 4 million passenger cars projected to be operating in DFW during 2023 are electrified, then a total of 17.33 tpd of NO_X reduction would be achieved with a 6.42 NO_X tpd increase from EGUs.

Modeling Ozone Reduction Scenarios for Vehicle Electrification

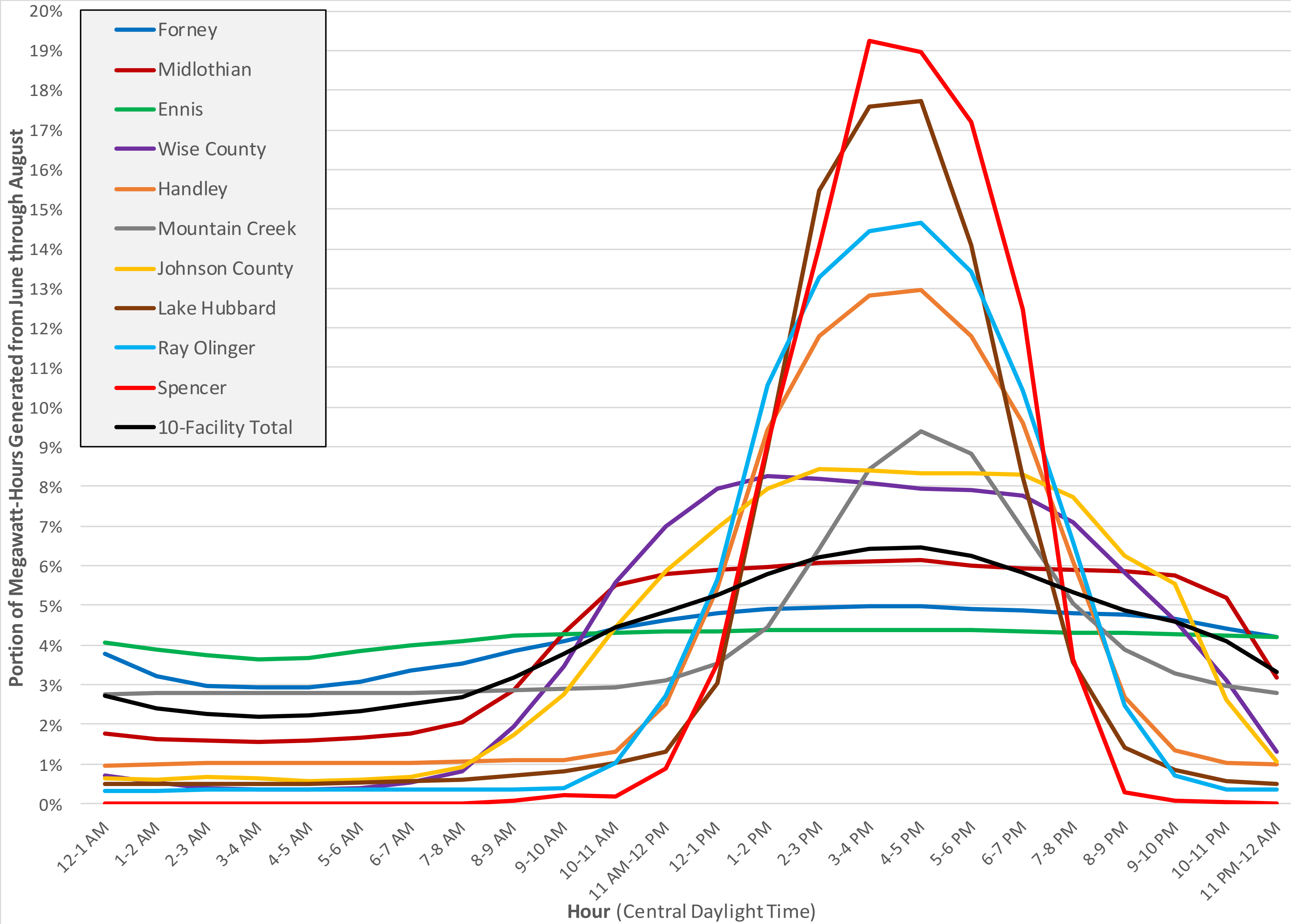
- Select a future year for which ozone modeling files are (or will be) available:
  - 2020 currently under development for DFW and HGB ozone attainment modeling;
  - 2023 currently available at 12 kilometer (km) resolution for ozone transport modeling; and
  - 2028 currently under development for regional haze modeling.
- Select a Texas metropolitan area for focus (e.g, DFW, HGB) or the entire state?
- Vehicle questions/issues to consider for modeling:
  - Vehicle category(ies) for electrification such as passenger cars, school buses, local transit buses, etc.
  - Portion of the fleet for electrification, such as 25%, 50%, 75%, 100%, etc.?
  - Targeting of candidate vehicles by age, such as oldest high-emitters, newest low-emitters, etc.?
- Modeling a completely unrealistic 100% penetration rate allows an answer along the lines of "Here is the maximum benefit you could achieve if…"
- Electrical generation questions/issues to consider for modeling:
  - Unless and until zero-NO_X electricity sources (e.g., wind, solar, nuclear) dominate the Texas grid, most of the ***increased*** generation needed to charge electric vehicles ***during high ozone periods*** is likely to come from natural gas and/or coal plants.
  - Should the increased power generated to charge the electric vehicles come from the metropolitan area? So DFW cars are powered by DFW EGUs, HGB cars are powered by HGB EGUs, etc.?
  - Should the increased power generated be allocated proportionally based on current EGU operation? So the Forney plant that provides 44% of current DFW power is allocated 44% of the increase?
  - Transmission/distribution losses increase with distance between the electricity source and vehicle being charged.
  - Should the temporal profile of increased power generation be the inverse of hourly vehicle miles traveled? This approach allocates most of the increased generation to occur overnight.

Daily Electricity Generated by DFW Area EGU Facilities from June through August 2018



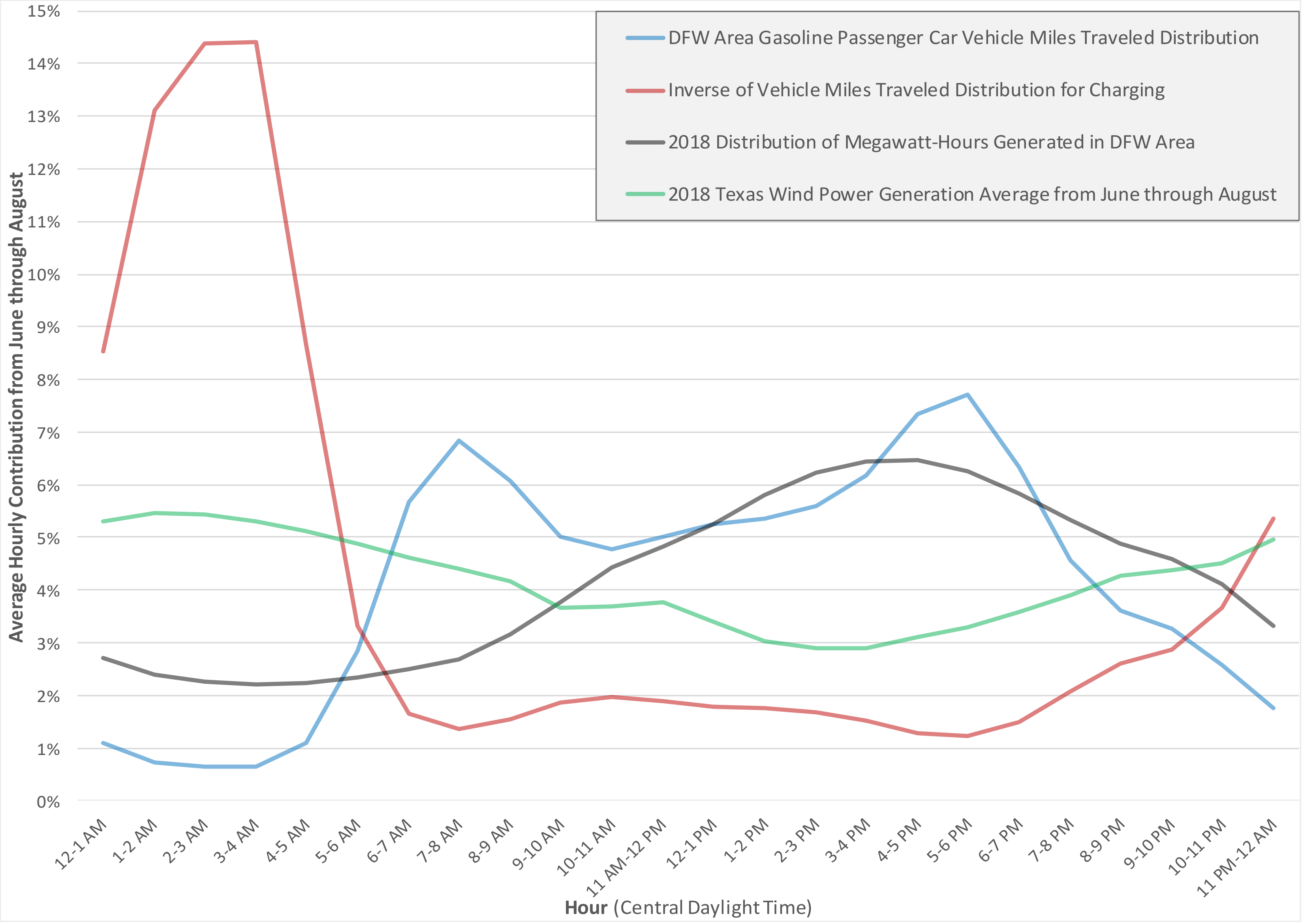
Source: U.S. Environmental Protection Agency (EPA) Air Markets Program Data (AMPD), which is available at https://ampd.epa.gov/ampd/

Hourly Electrical Generation Profiles by DFW Area EGU Facilities from June through August 2018

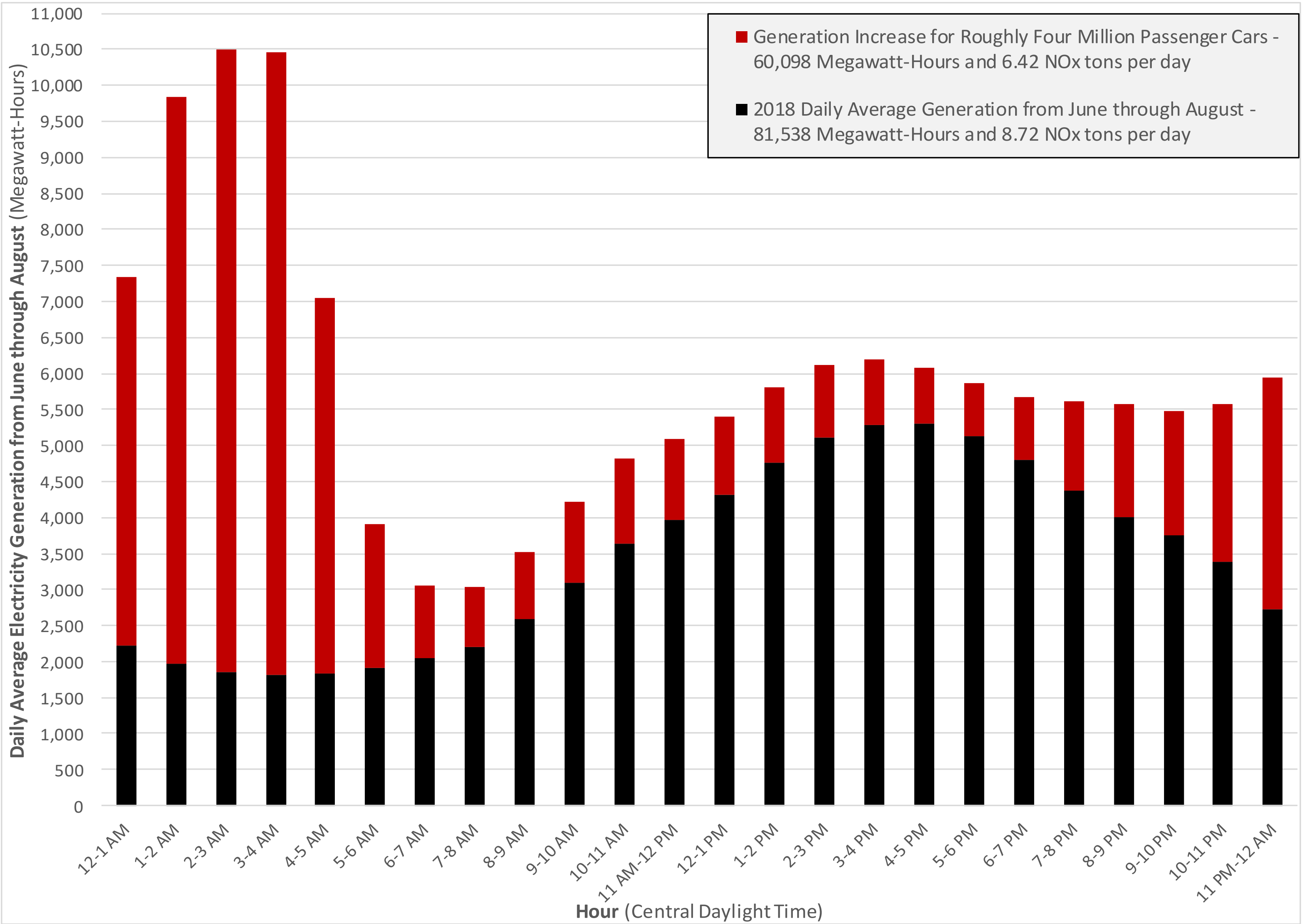


Source: U.S. Environmental Protection Agency (EPA) Air Markets Program Data (AMPD), which is available at https://ampd.epa.gov/ampd/

Hourly Profiles for Passenger Car Activity and Electricity Generation

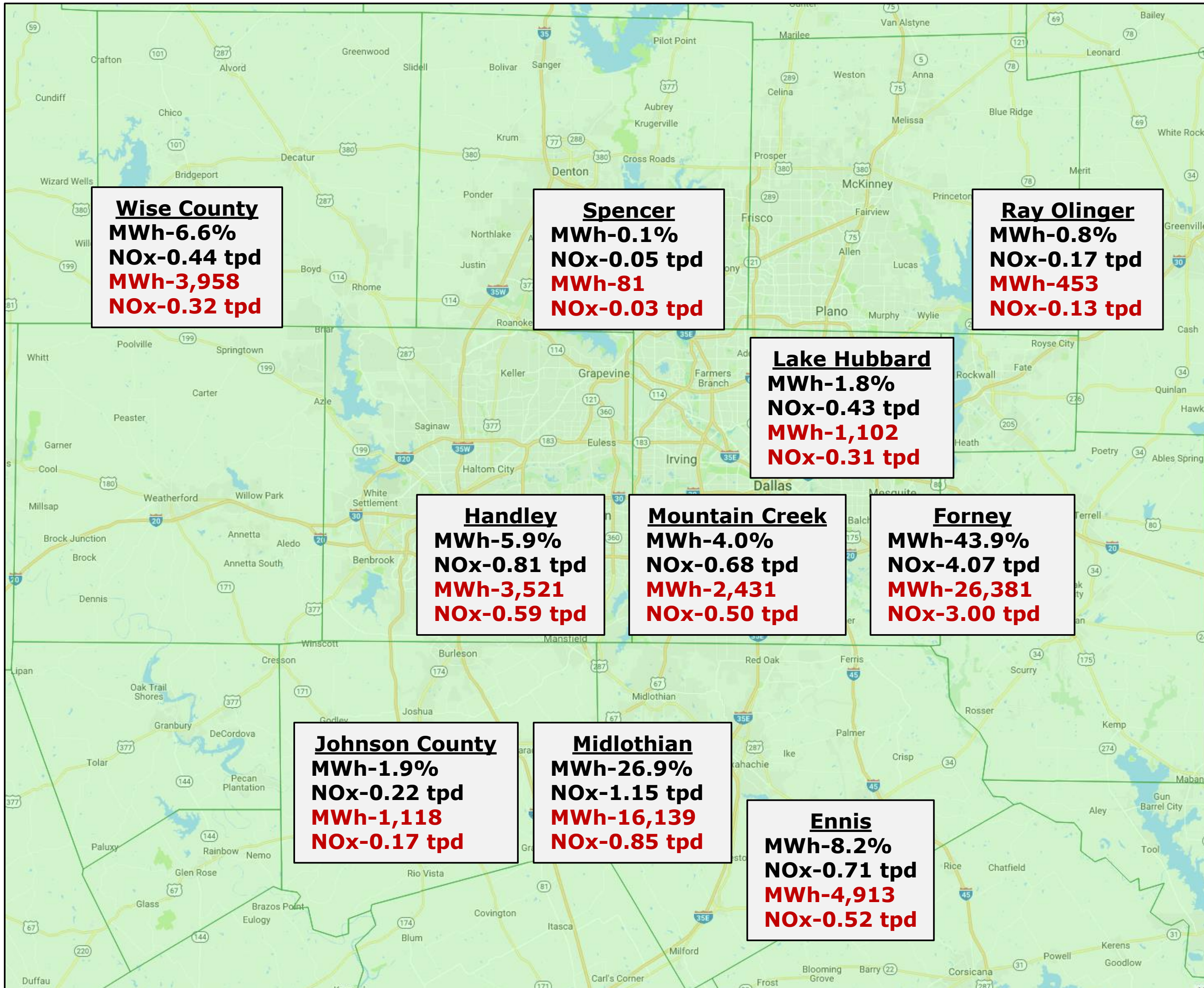


Temporal Distribution of Increased Electricity Generation for Passenger Cars



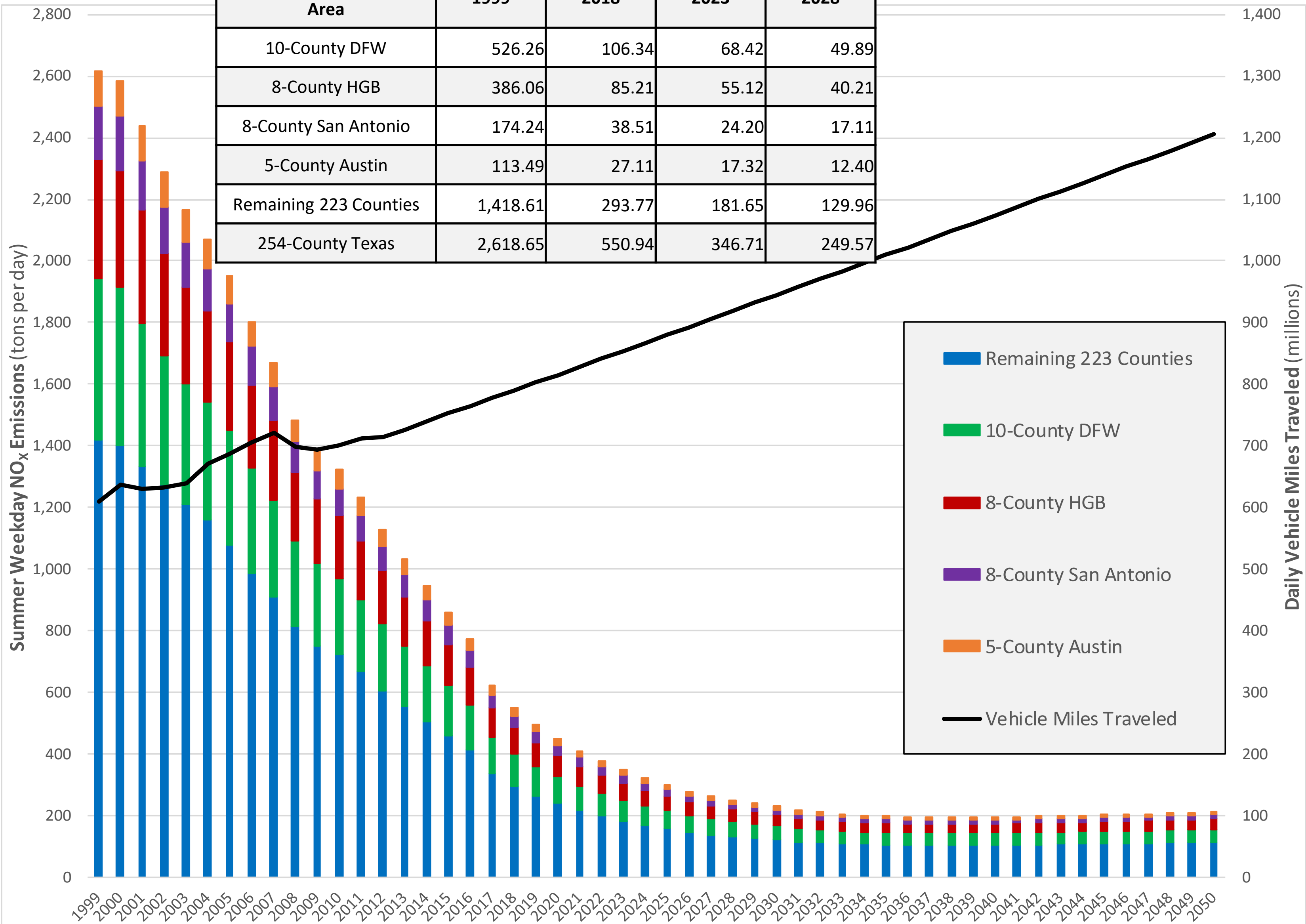
DFW Spatial Distribution of EGU NO_X from Electricity Generation for Passenger Cars

- MWh percentages in black reflect distribution of DFW power generated in June through August of 2018.
- NO_X emissions in black are daily average values from June through August of 2018.
- MWh values in red are the 60,098 MWh needed to power electric cars allocated based on generation distribution from June through August of 2018.
- NO_X emissions in red are the additional amounts needed per EGU to generate power for electric cars totaling 6.42 NO_X tpd.



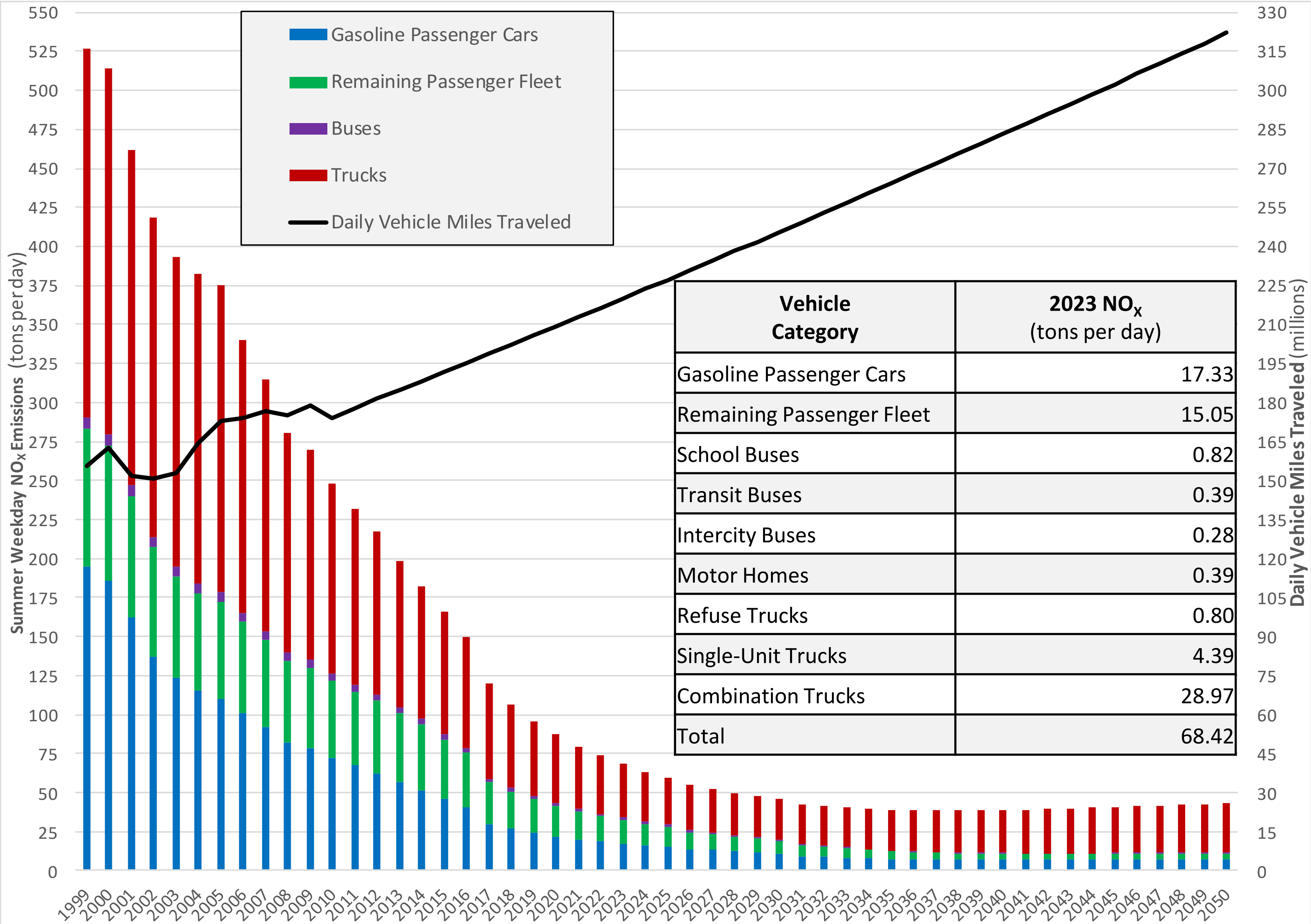
Texas On-Road NO_X Emission Trends from 1999 through 2050

Geographic Area	1999	2018	2023	2028
10-County DFW	526.26	106.34	68.42	49.89
8-County HGB	386.06	85.21	55.12	40.21
8-County San Antonio	174.24	38.51	24.20	17.11
5-County Austin	113.49	27.11	17.32	12.40
Remaining 223 Counties	1,418.61	293.77	181.65	129.96
254-County Texas	2,618.65	550.94	346.71	249.57



Source: Texas Transportation Institute On-Road Trends Study for 1999-2050 with MOVES2014, August 2015, which is available at ftp://amdaftp.tceq.texas.gov/EI/onroad/mvs14_trends/.

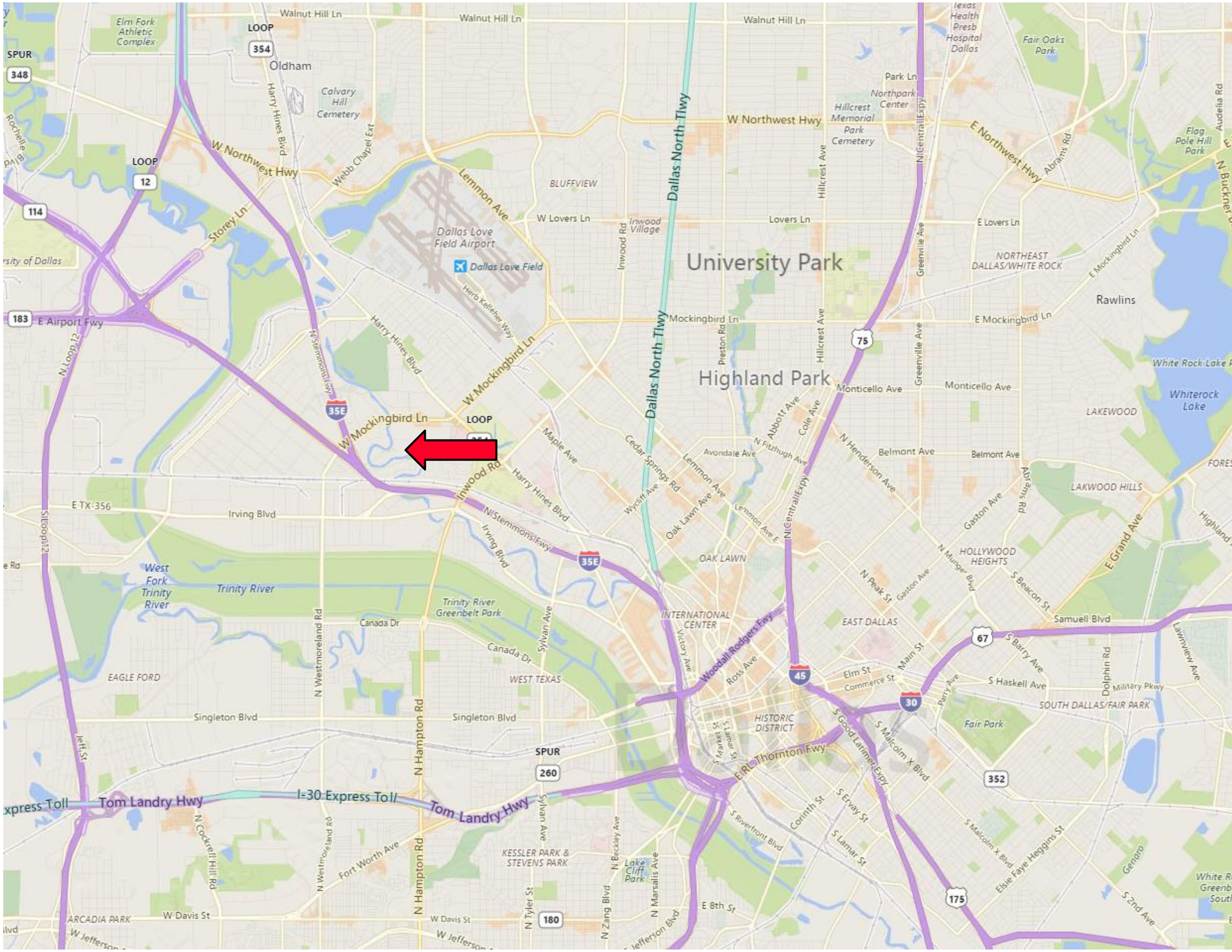
10-County DFW On-Road NO_X Emissions by Vehicle Category from 1999 to 2050



Vehicle Category	2023 NO_X (tons per day)
Gasoline Passenger Cars	17.33
Remaining Passenger Fleet	15.05
School Buses	0.82
Transit Buses	0.39
Intercity Buses	0.28
Motor Homes	0.39
Refuse Trucks	0.80
Single-Unit Trucks	4.39
Combination Trucks	28.97
Total	68.42

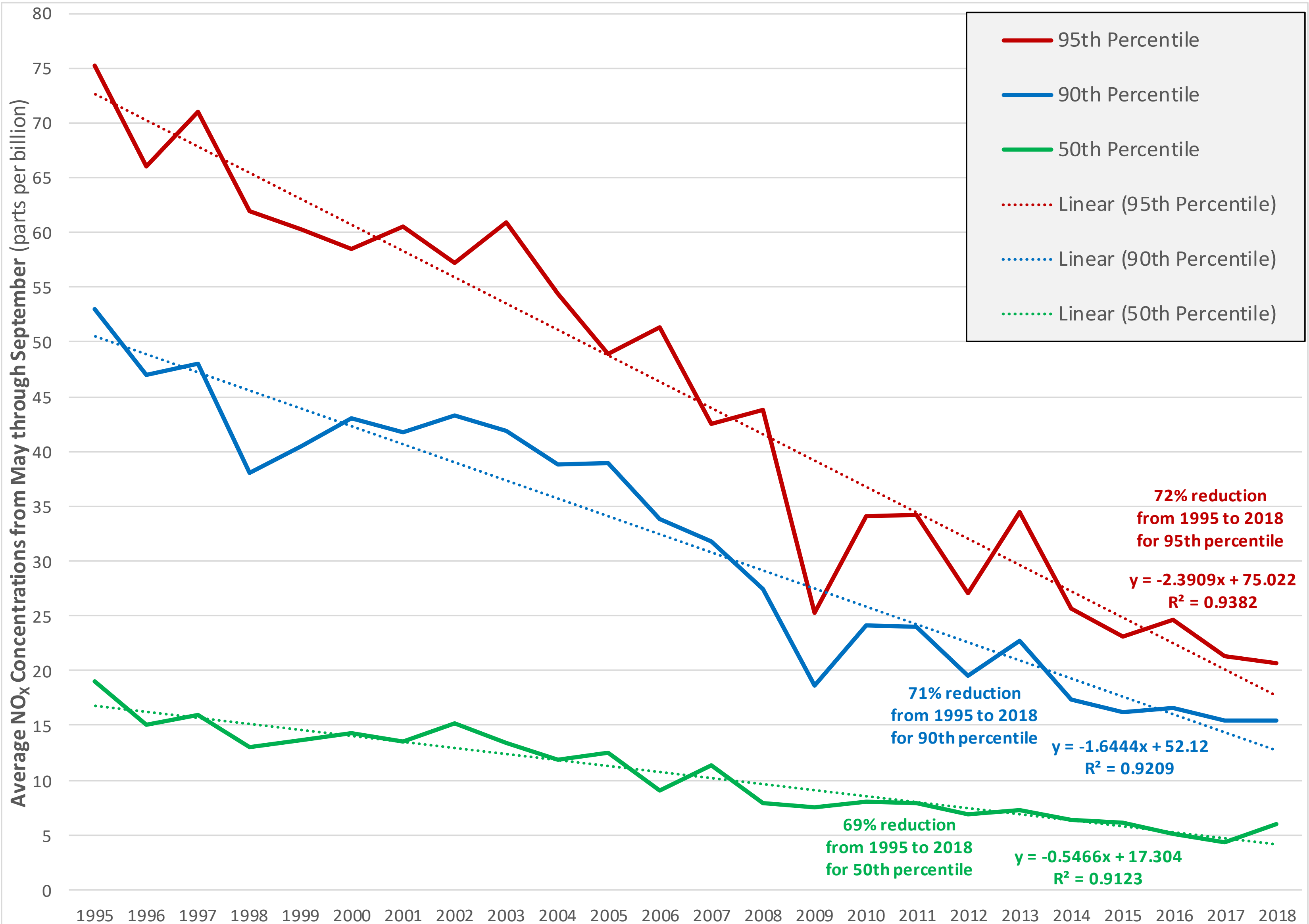
Source: Texas Transportation Institute On-Road Trends Study for 1999-2050 with MOVES2014, August 2015, which is available at ftp://amdaftp.tceq.texas.gov/EI/onroad/mvs14_trends/.

Geographic Location of Dallas Hinton Street Monitor



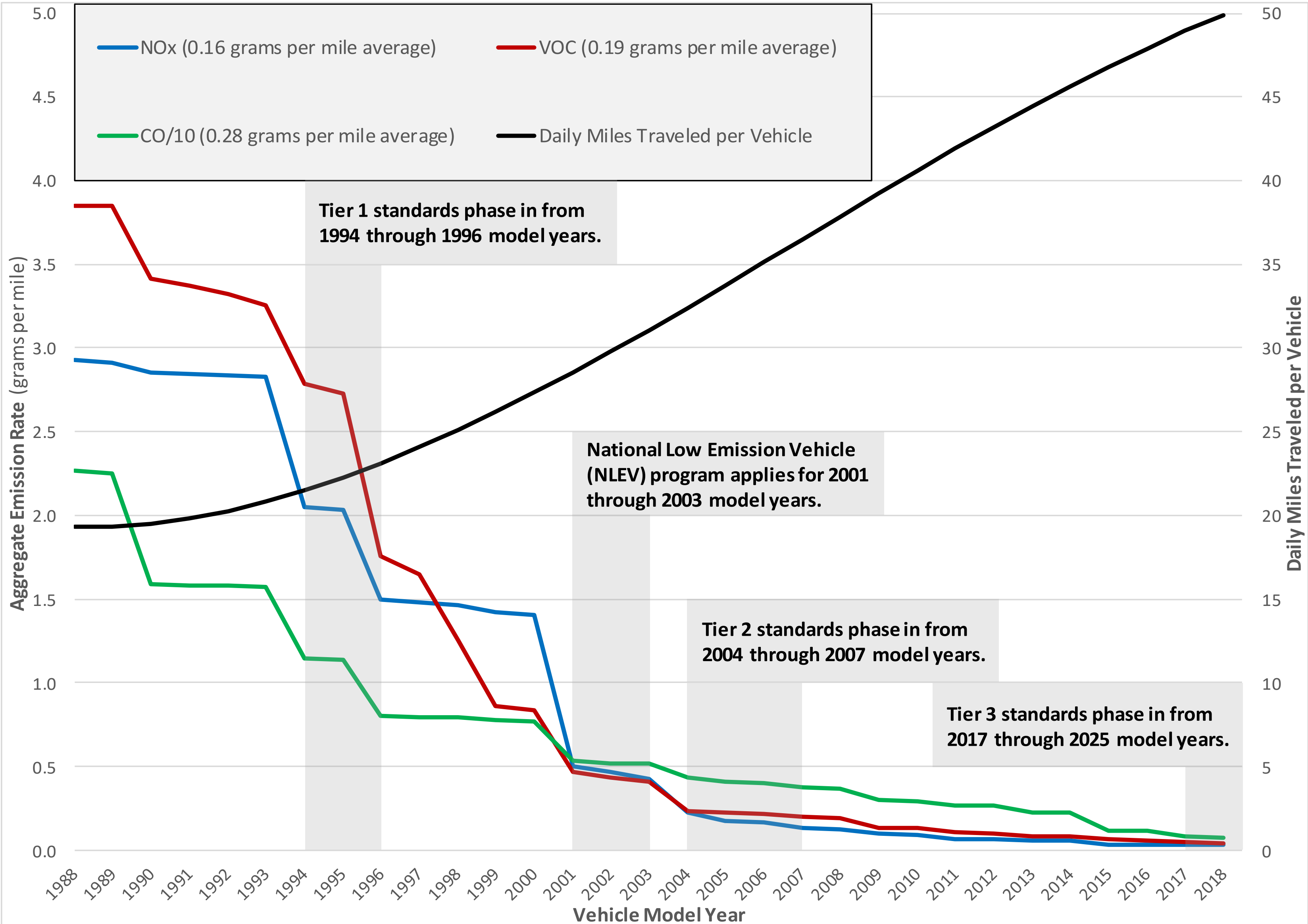
Source: TCEQ *Air Monitoring Sites*, which is available at https://www.tceq.texas.gov/airquality/monops/sites/air-mon-sites.

Average Monitored NO_X Concentrations at Dallas Hinton Street from 1995 through 2018



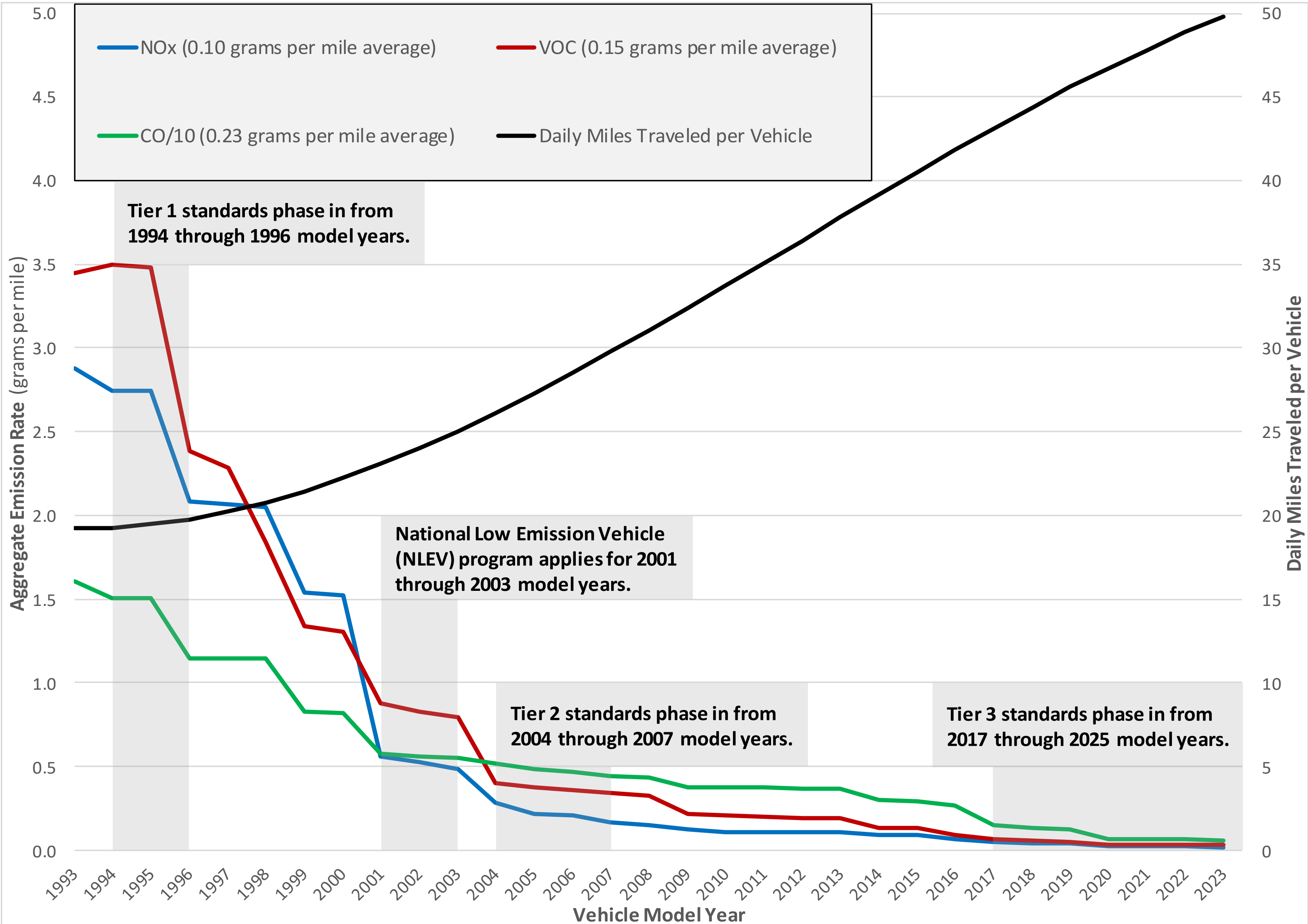
Source: TCEQ Air Monitoring Information System (*TAMIS*), which is available at http://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome.

MOVES2014 Emission Rates by Model Year for DFW Gasoline Passenger Cars Operating in 2018



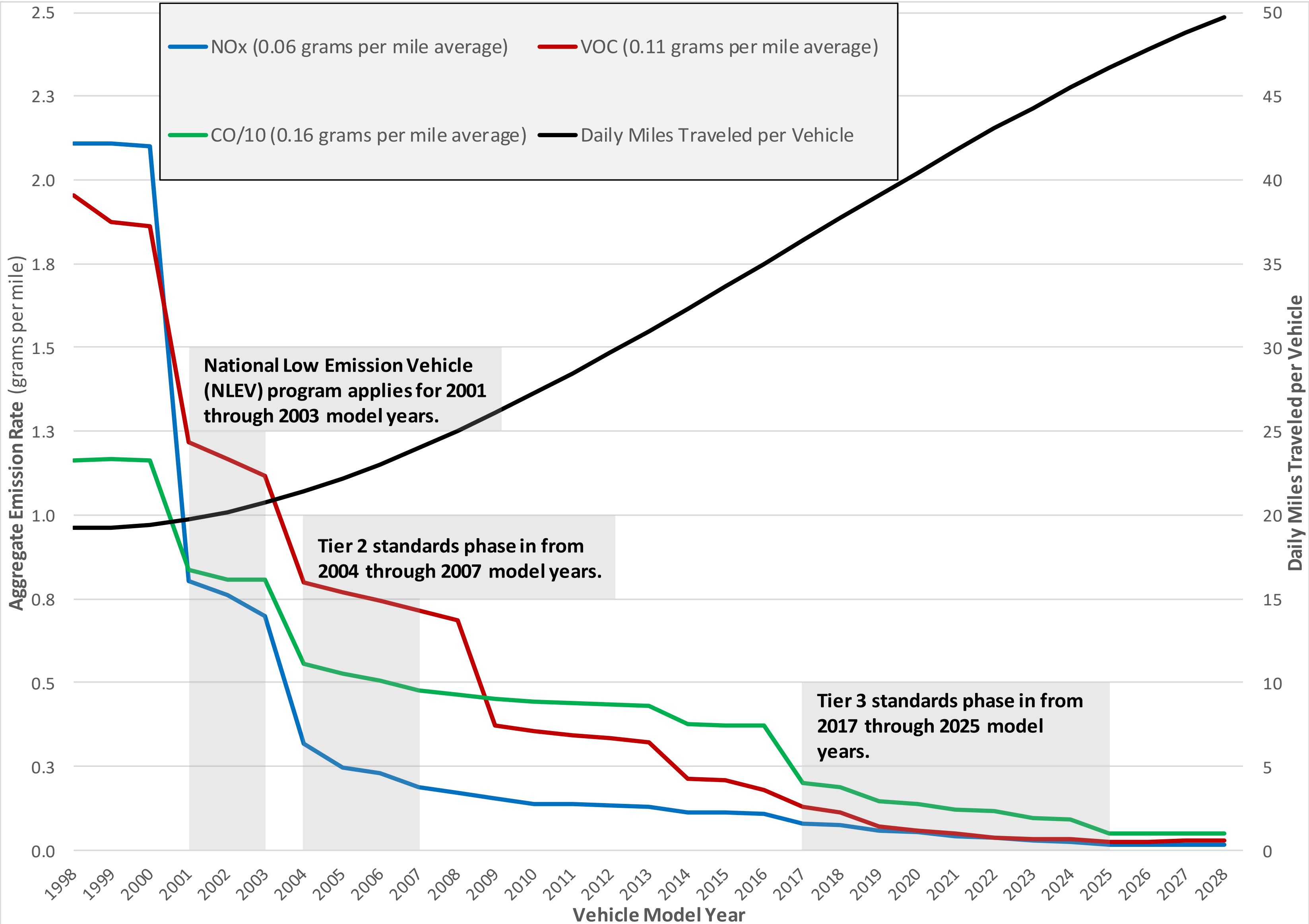
Source: Texas Transportation Institute On-Road Trends Study for 1999-2050 with MOVES2014, August 2015, which is available at ftp://amdaftp.tceq.texas.gov/EI/onroad/mvs14_trends/.

MOVES2014 Emission Rates by Model Year for DFW Gasoline Passenger Cars Operating in 2023



Source: Texas Transportation Institute On-Road Trends Study for 1999-2050 with MOVES2014, August 2015, which is available at ftp://amdaftp.tceq.texas.gov/EI/onroad/mvs14_trends/.

MOVES2014 Emission Rates by Model Year for DFW Gasoline Passenger Cars Operating in 2028



Source: Texas Transportation Institute On-Road Trends Study for 1999-2050 with MOVES2014, August 2015, which is available at ftp://amdaftp.tceq.texas.gov/EI/onroad/mvs14_trends/.

Questions?

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