THE POLITICS OF POWER PLANTS

IS CONGRESSIONAL VOTING ASSOCIATED WITH POLLUTION EMISSIONS?

Joseph Zoller

Janelle Walker

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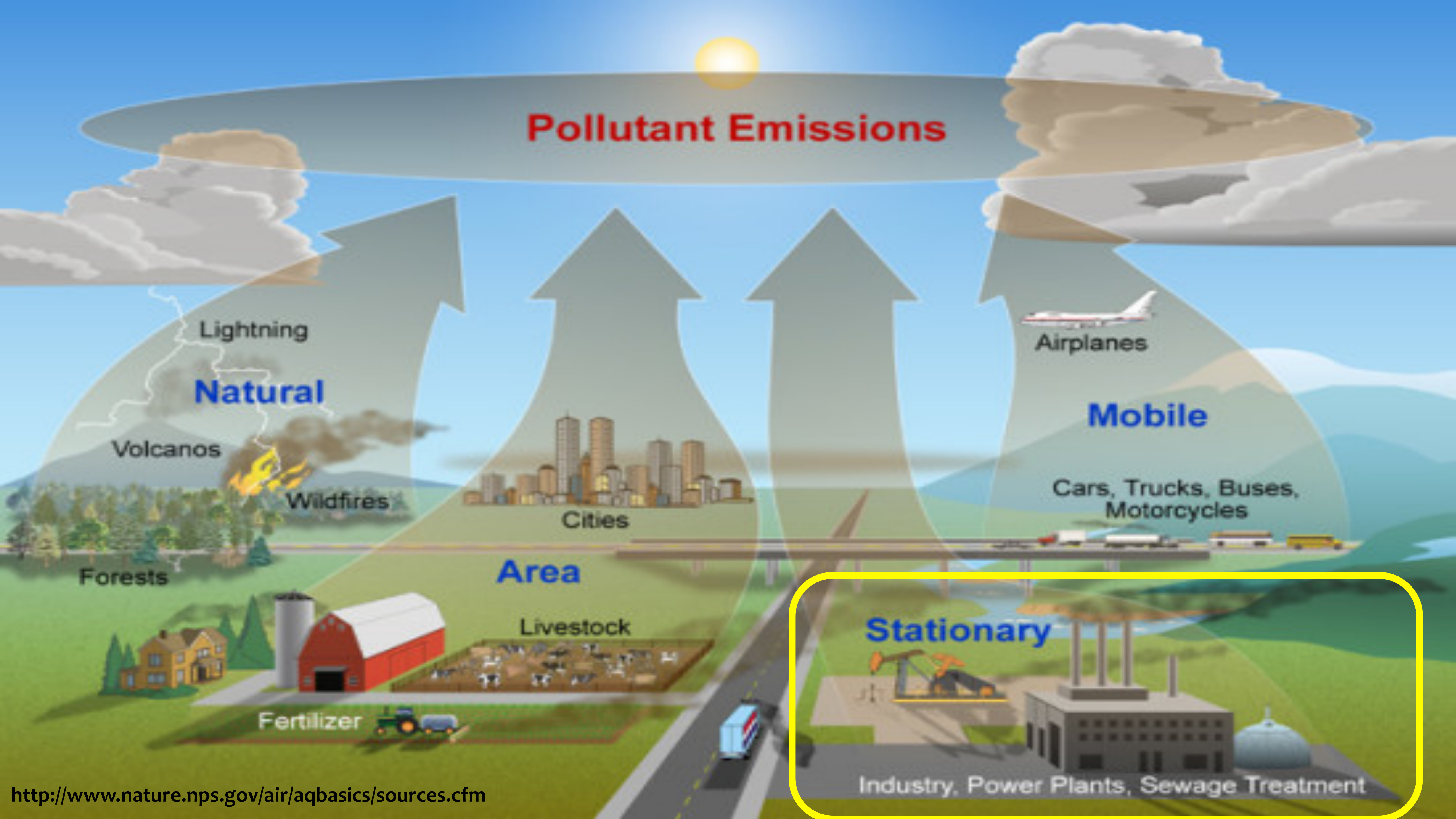
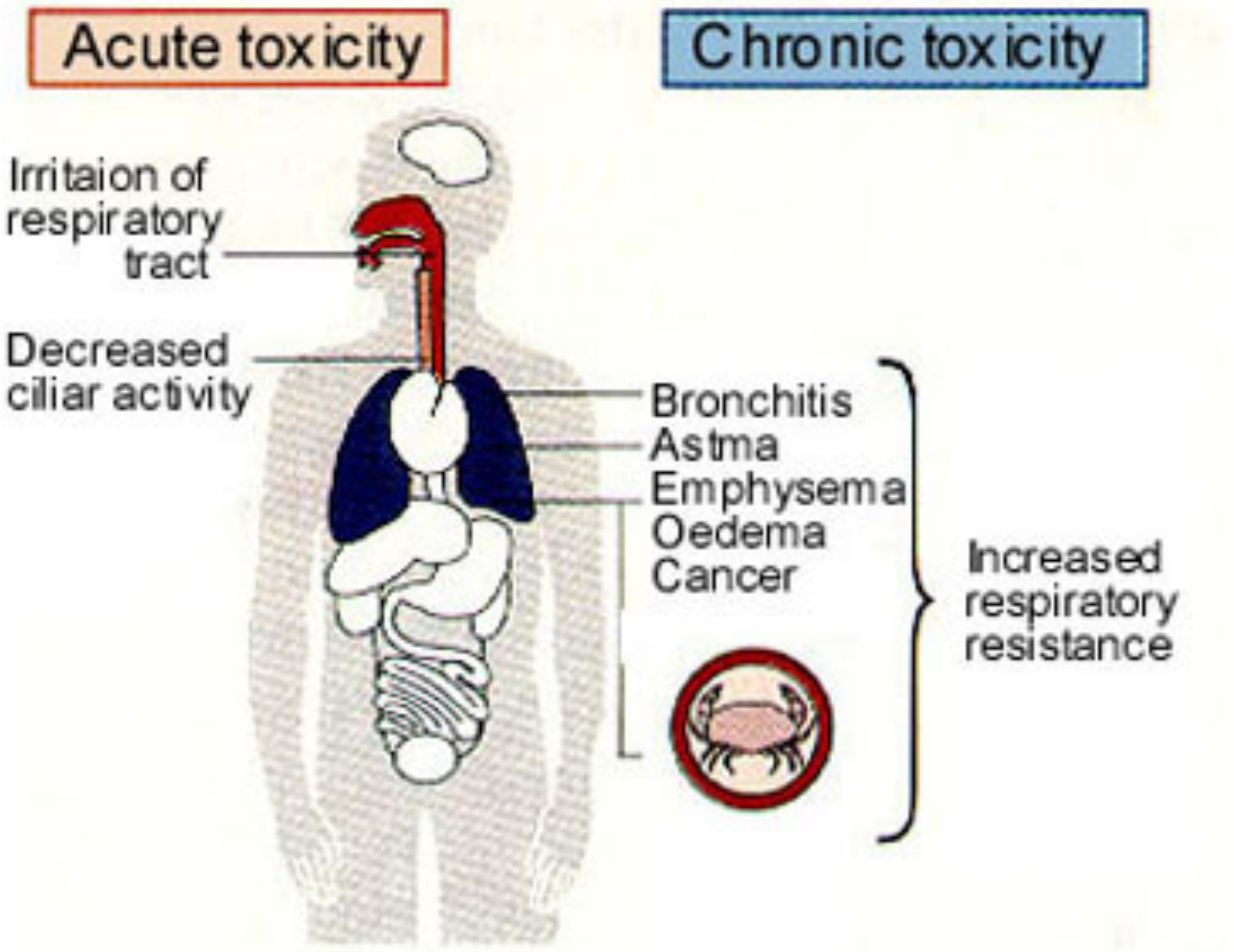
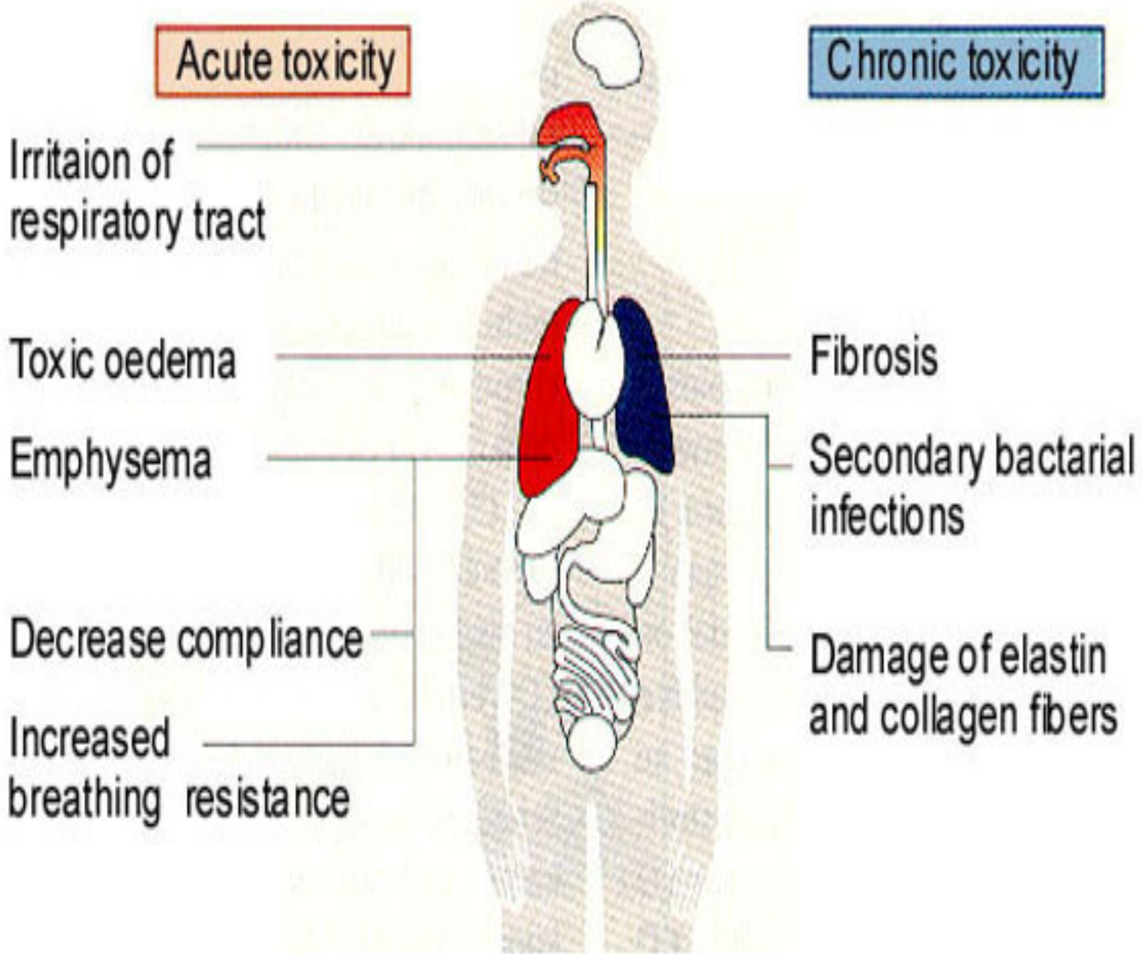


http://www.nature.nps.gov/air/aqbasics/sources.cfm

Symptoms upon SO_2-Exposure



Symptoms upon NO_X-exposure



Outdoor Air Pollution

US CLEAN AIR LEGISLATION

- 1955 Clean Air Legislation
- 1963 Clean Air Act
- The Clean Air Quality Act of 1967
- 1970 Clean Air Act Amendments
- 1977 Clean Air Act Amendments
- 1990 Clean Air Act Amendments

Groups sue EPA over air pollution standards

COMMENTS 26

16 13

The New York Times

A Model for 'Clean Coal' Runs Off the Tracks

BY IAN URBINA

A Mississippi project, a centerpiece of President Obama's climate plan, has been plagued by problems that managers tried to conceal, and by cost overruns and questions of who will pay.

The New York Times

2 of 10 article

...litics

Numerous States Prepare Lawsuits Against Obama's Climate Policy

By CORAL DAVENPORT OCT. 22, 2015

States sue EPA over carbon rule for new power plants

25 8

COMMENTS 53

By Timothy Cama - 07/01/16 03:51 PM EDT

A coalition of conservative states is again suing to stop President Obama's carbon dioxide rule for newly built power plants.

The 23-state group filed a lawsuit Friday in the Court of Appeals for the District of Columbia Circuit.

They're challenging the Environmental Protection Agency's (EPA) decision in May to reject their formal requests to reconsider the carbon rule that was made final last year.

The regulation at issue sets specific carbon emissions limits for newly built coal- and gas-fired power plants. It is separate from the Clean Power Plan, a more sweeping and controversial regulation that limits the entire power sector's emissions and is currently on hold by the Supreme Court.

The New York Tim...

Move to Fight Obama's Climate Plan Started Early

BY CORAL DAVENPORT AND JULIE HIRSCHFELD DAVIS

A group of lawyers, lobbyists and political strategists started devising a strategy for dismantling President Obama's climate change regulations before he had even put forth a draft proposal.

The New York Times

THE BIG FIX

Corralling Carbon Before It Belches From Stack

BY HENRY FOUNTAIN

Many scientists say capturing the carbon that spews from power plants and locking it away is necessary to stave off the worst effects of climate change.

Air Markets Program Data (AMPD)

* The Air Markets Program Data tool allows users to search EPA data to answer scientific, general, policy, and regulatory questions about industry emissions.
* The program is designed to improve air quality and ecosystems by lowering outdoor concentrations of fine particles and other significant air emissions. The most well-known of these programs are EPA's Acid Rain Program which reduce emissions of sulfur dioxide (SO_2) and the NO_x Trading Programs which reduce emissions of nitrogen oxides (NO_x)

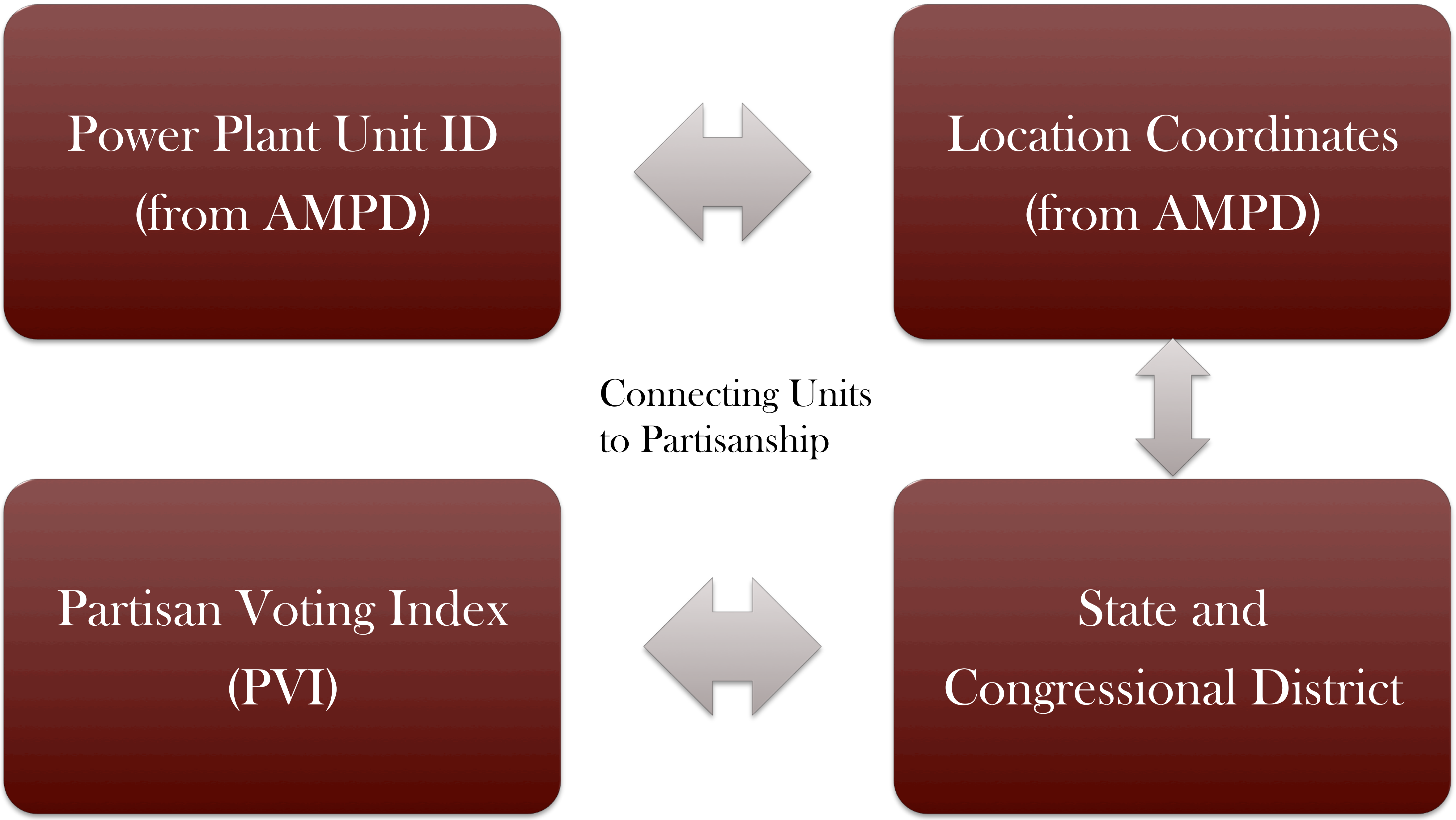
AMPD Information

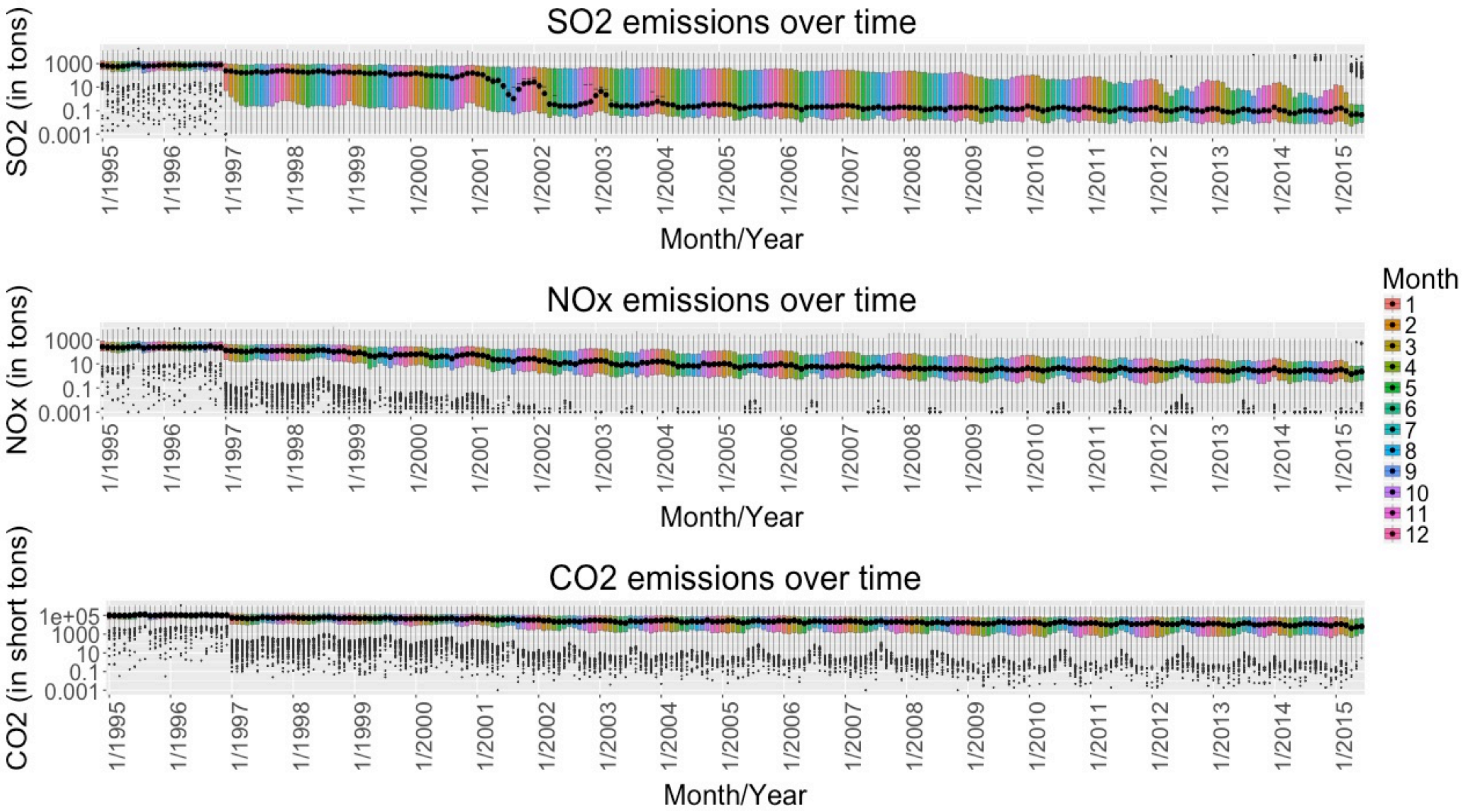
* 1,708 Facilities in 48 States + Washington D.C.
* 5,755 Units
* 21 Years (1995-2015)
* Emissions for SO_2, NO_x, and CO_2
* Other data about units (e.g. Heat Input)

Political Background Information

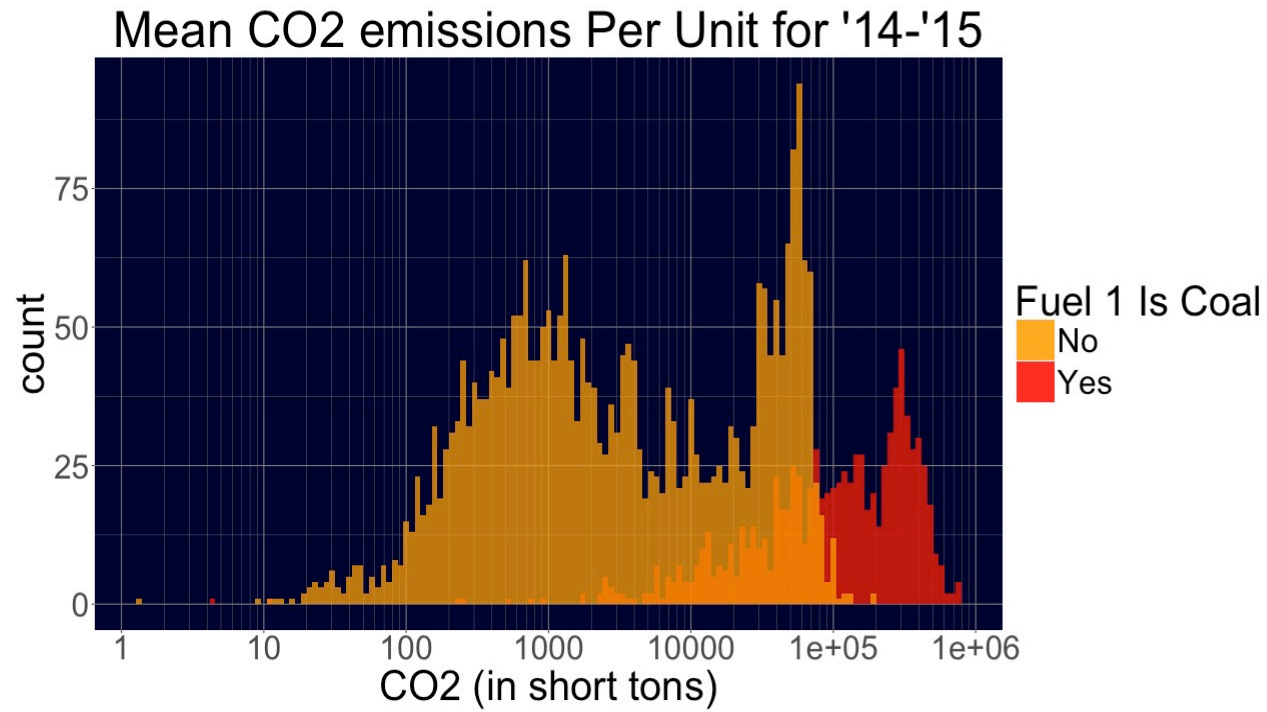
* USA Congressional Districts – The states are divided into 435 congressional districts with a population of approximately 710,000 each. Each district elects a representative of the House of Representatives for a 2-year term.

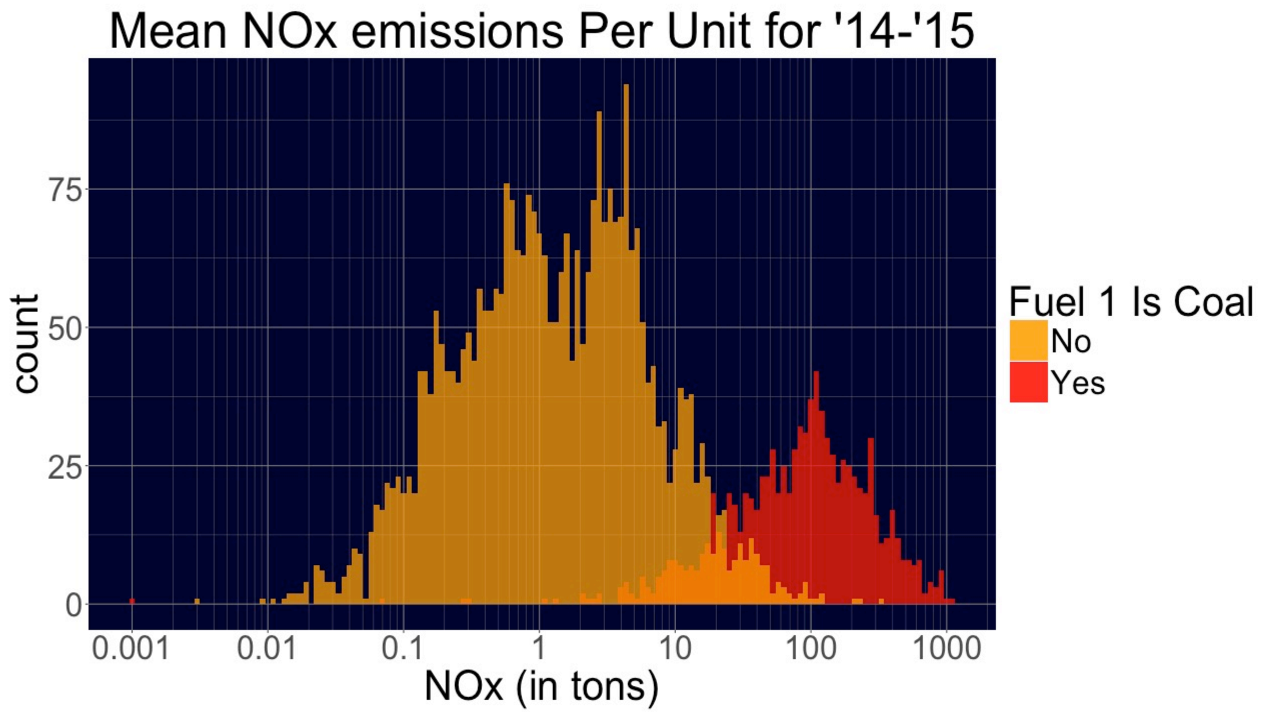
* The Cook partisan voting index (Cook PVI) is a measurement of how strongly a United States congressional district leans toward the Democratic or Republican Party, compared to the nation as a whole.

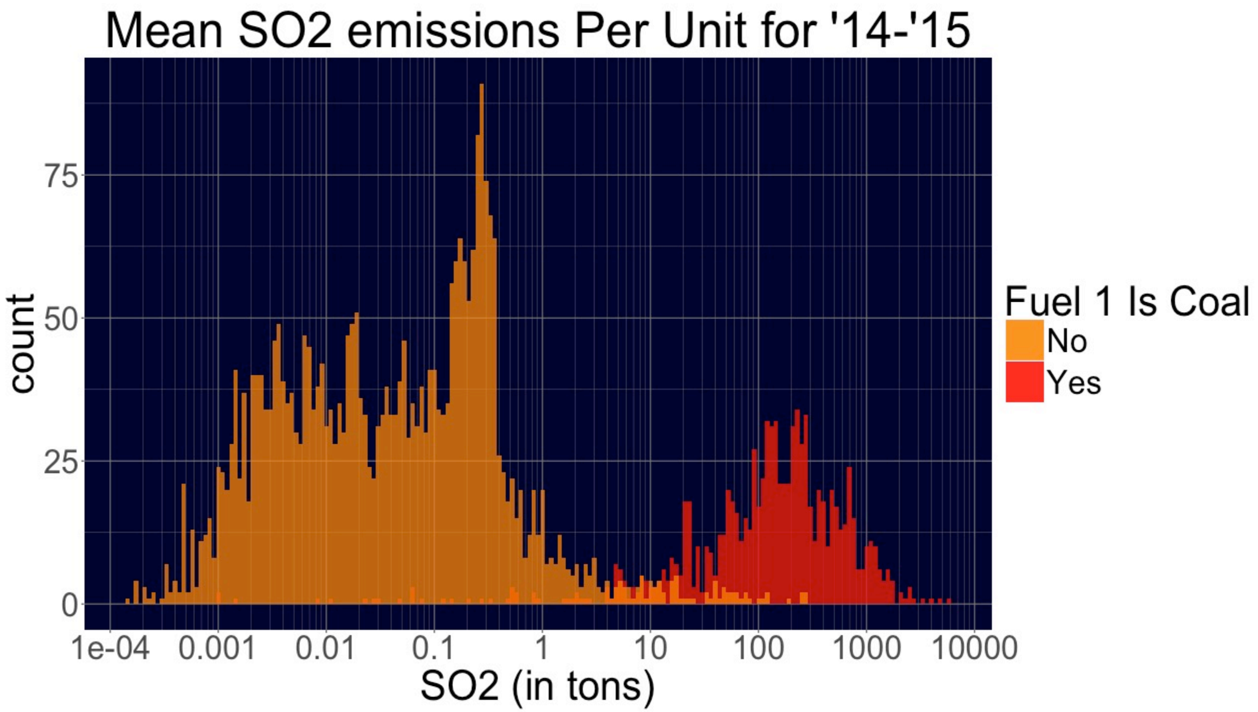

Power Plant Unit ID (from AMPD)
Location Coordinates (from AMPD)
Connecting Units to Partisanship
Partisan Voting Index (PVI)
State and Congressional District

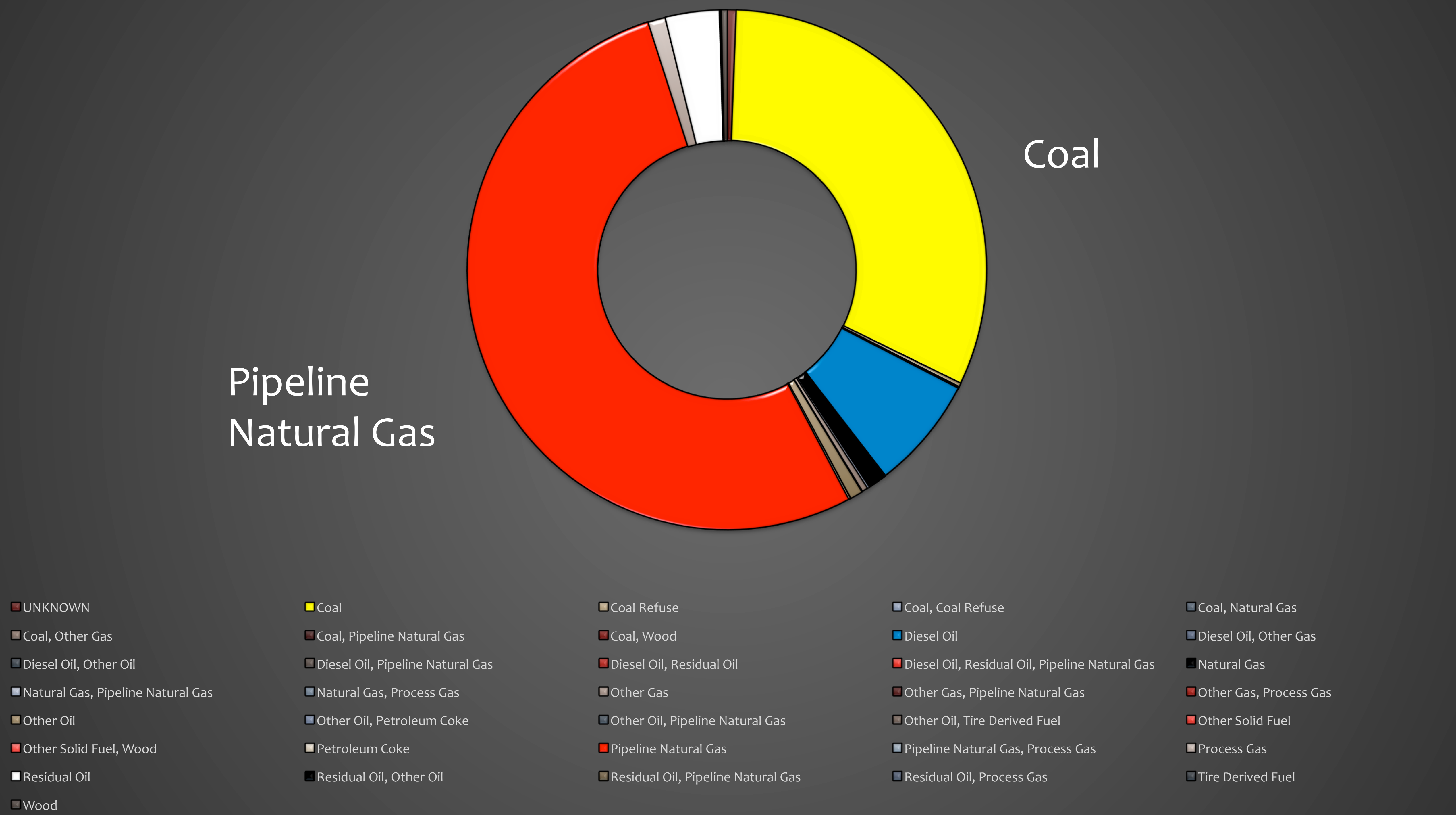


SO2 emissions over time
SO2 (in tons)
1000
10
0.1
0.001
1/1995
1/1996
1/1997
1/1998
1/1999
1/2000
1/2001
1/2002
1/2003
1/2004
1/2005
1/2006
1/2007
1/2008
1/2009
1/2010
1/2011
1/2012
1/2013
1/2014
1/2015
Month/Year
NOx emissions over time
NOx (in tons)
1000
10
0.1
0.001
1/1995
1/1996
1/1997
1/1998
1/1999
1/2000
1/2001
1/2002
1/2003
1/2004
1/2005
1/2006
1/2007
1/2008
1/2009
1/2010
1/2011
1/2012
1/2013
1/2014
1/2015
Month/Year
Month
1
2
3
4
5
6
7
8
9
10
11
12
CO2 emissions over time
CO2 (in short tons)
1e+05
1000
10
0.1
0.001
1/1995
1/1996
1/1997
1/1998
1/1999
1/2000
1/2001
1/2002
1/2003
1/2004
1/2005
1/2006
1/2007
1/2008
1/2009
1/2010
1/2011
1/2012
1/2013
1/2014
1/2015
Month/Year

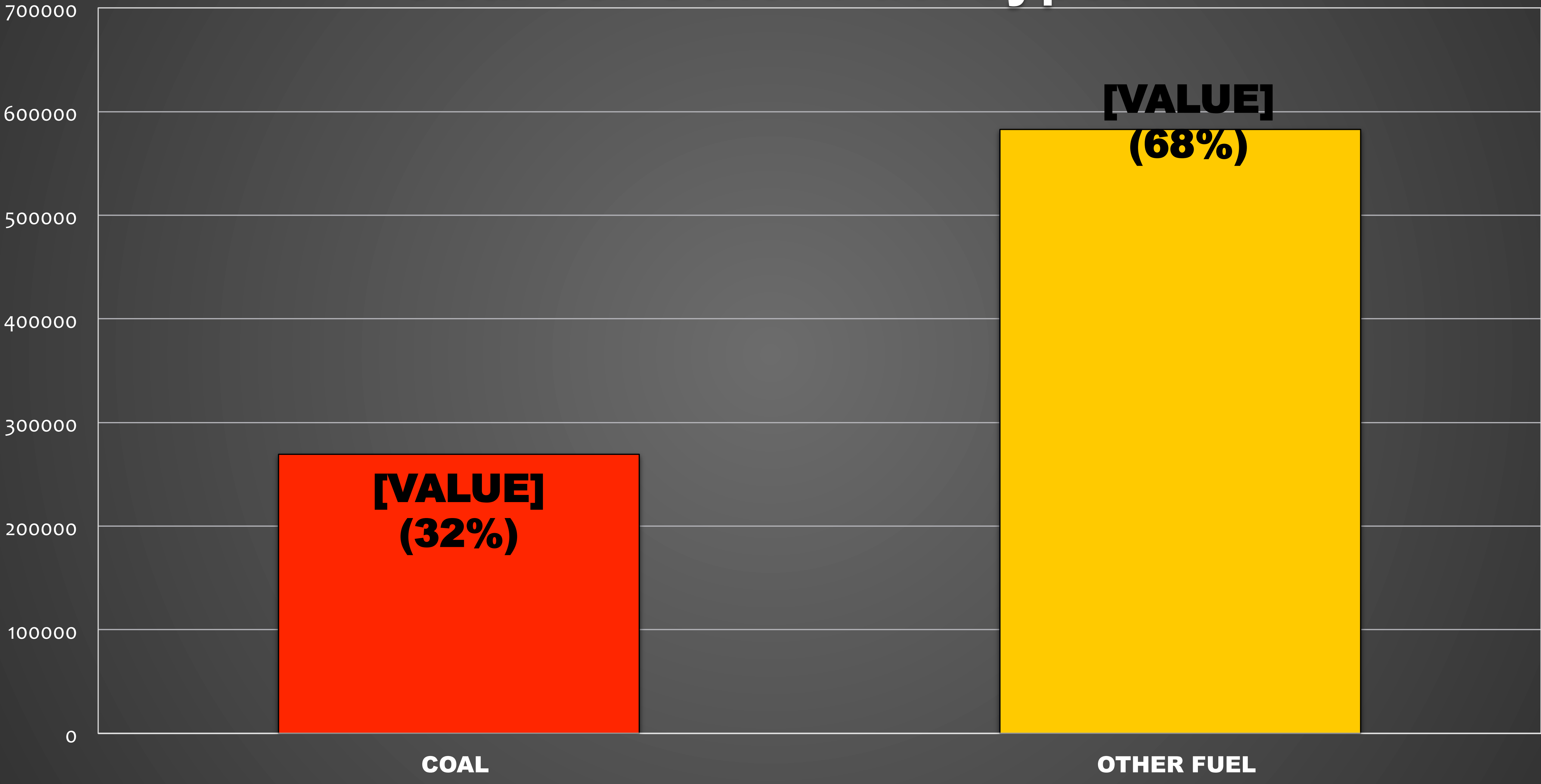

Mean CO2 emissions Per Unit for '14-'15
count
75
50
25
0
1
10
100
1000
10000
1e+05
1e+06
CO2 (in short tons)
Fuel 1 Is Coal
No
Yes


Mean NOx emissions Per Unit for '14-'15
count
75
50
25
0
0.001
0.01
0.1
1
10
100
1000
NOx (in tons)
Fuel 1 Is Coal
No
Yes

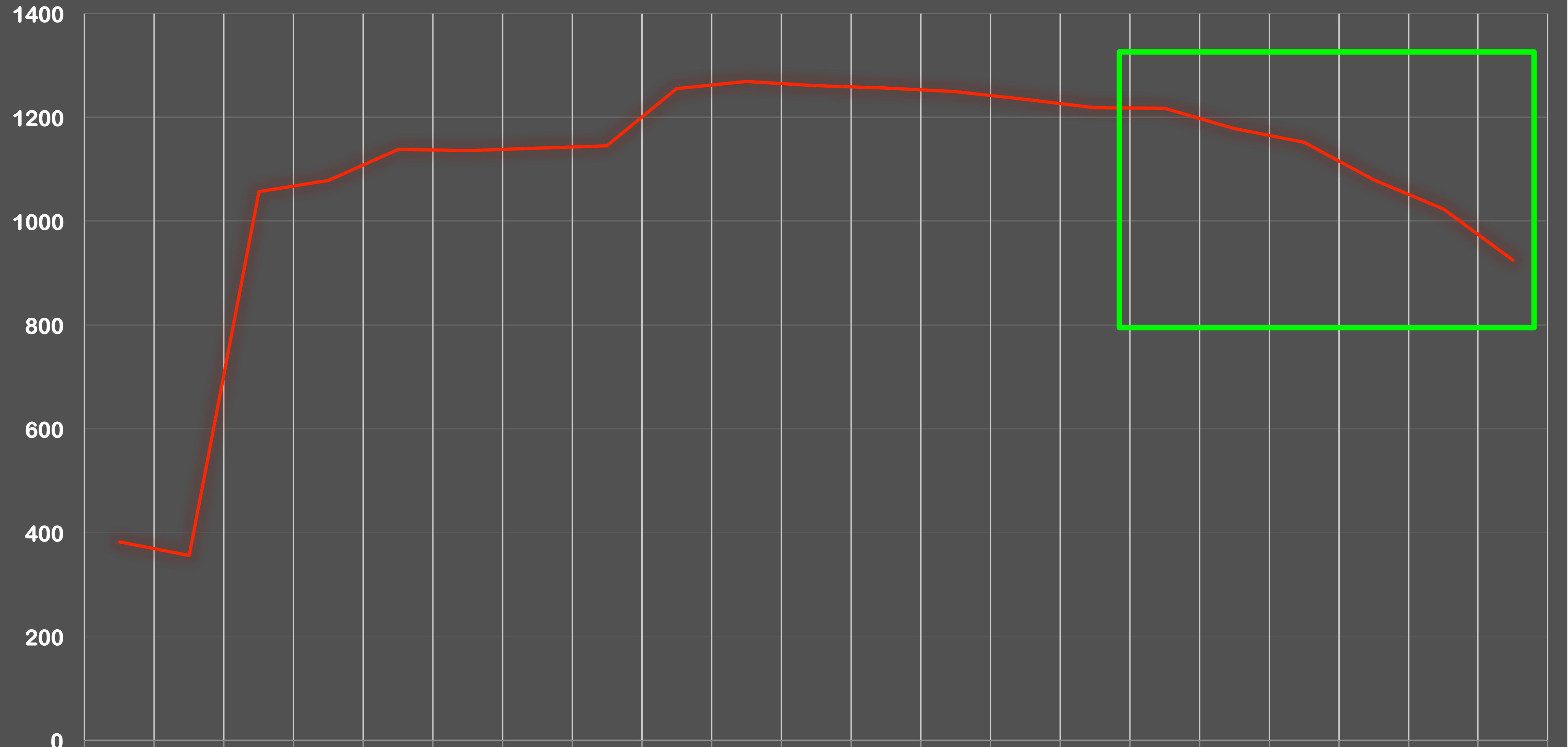

Mean SO2 emissions Per Unit for '14-'15
count
75
50
25
0
1e-04
0.001
0.01
0.1
1
10
100
1000
10000
SO2 (in tons)
Fuel 1 Is Coal
No
Yes


Coal
Pipeline Natural Gas
UNKNOWN
Coal
Coal Refuse
Coal, Coal Refuse
Coal, Natural Gas
Coal, Other Gas
Coal, Pipeline Natural Gas
Coal, Wood
Diesel Oil
Diesel Oil, Other Gas
Diesel Oil, Other Oil
Diesel Oil, Pipeline Natural Gas
Diesel Oil, Residual Oil
Diesel Oil, Residual Oil, Pipeline Natural Gas
Natural Gas
Natural Gas, Pipeline Natural Gas
Natural Gas, Process Gas
Other Gas
Other Gas, Pipeline Natural Gas
Other Gas, Process Gas
Other Oil
Other Oil, Petroleum Coke
Other Oil, Pipeline Natural Gas
Other Oil, Tire Derived Fuel
Other Solid Fuel
Other Solid Fuel, Wood
Petroleum Coke
Pipeline Natural Gas
Pipeline Natural Gas, Process Gas
Process Gas
Residual Oil
Residual Oil, Other Oil
Residual Oil, Pipeline Natural Gas
Residual Oil, Process Gas
Tire Derived Fuel
Wood

Coal vs. Other Fuel Types

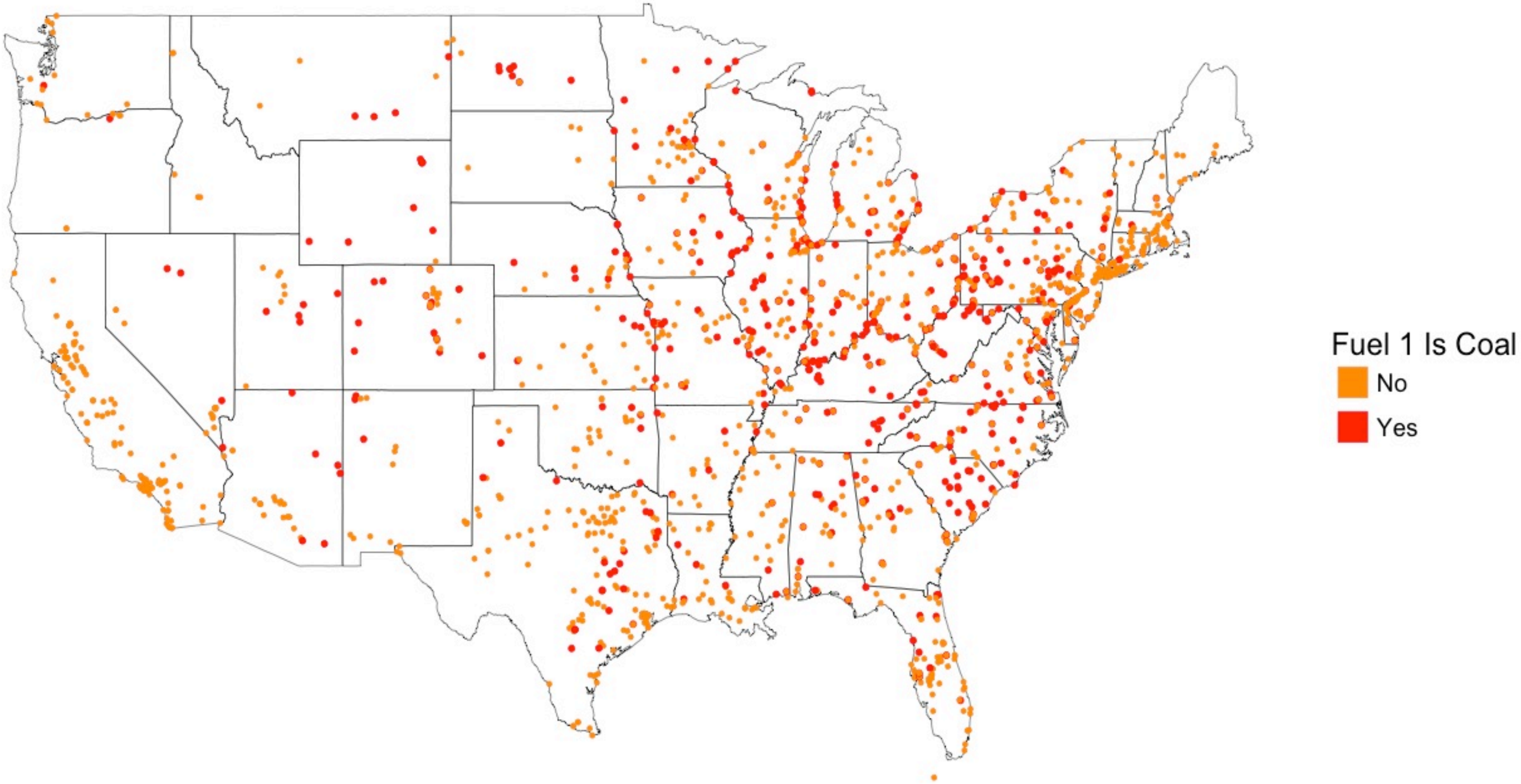


Number of Coal Power Plants Per Year in America

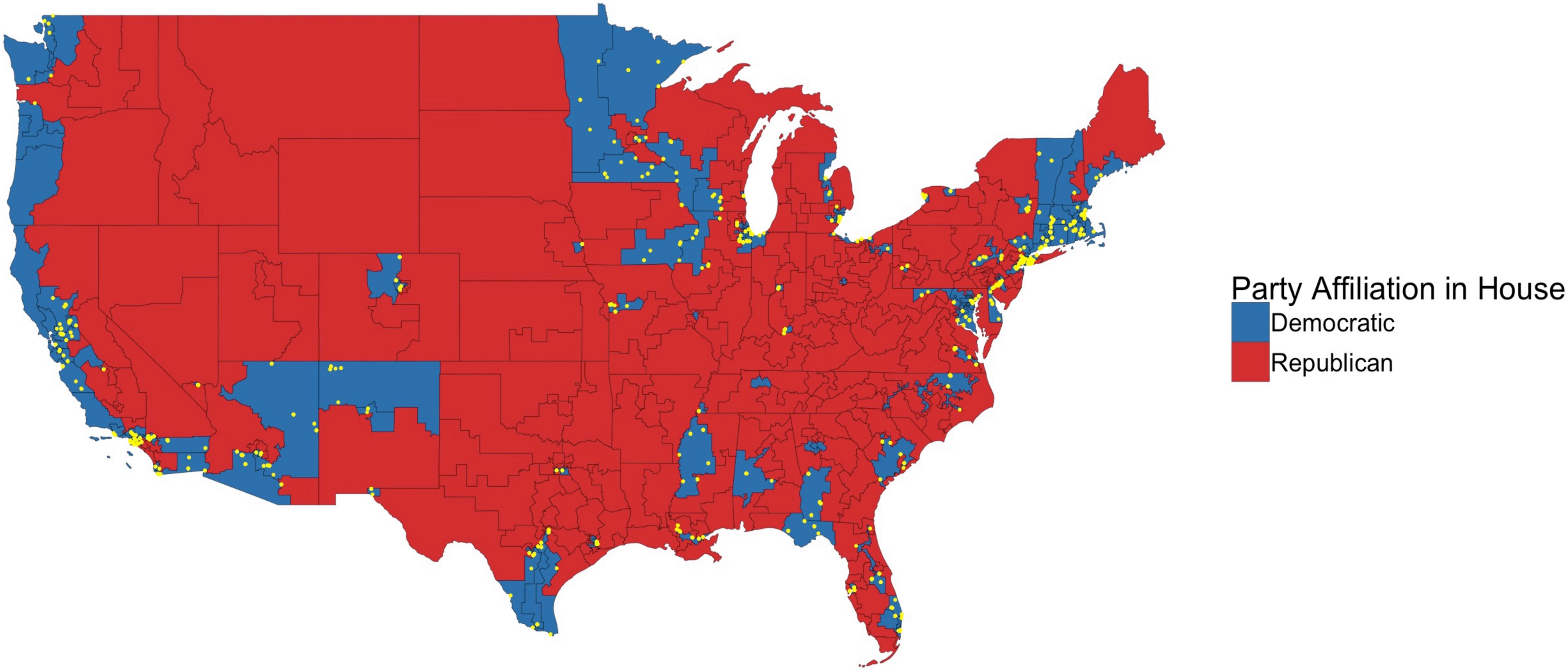


	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
# of Power plants	382	356	1057	1079	1138	1136	1141	1145	1255	1269	1261	1256	1249	1234	1219	1217	1178	1152	1080	1023	925

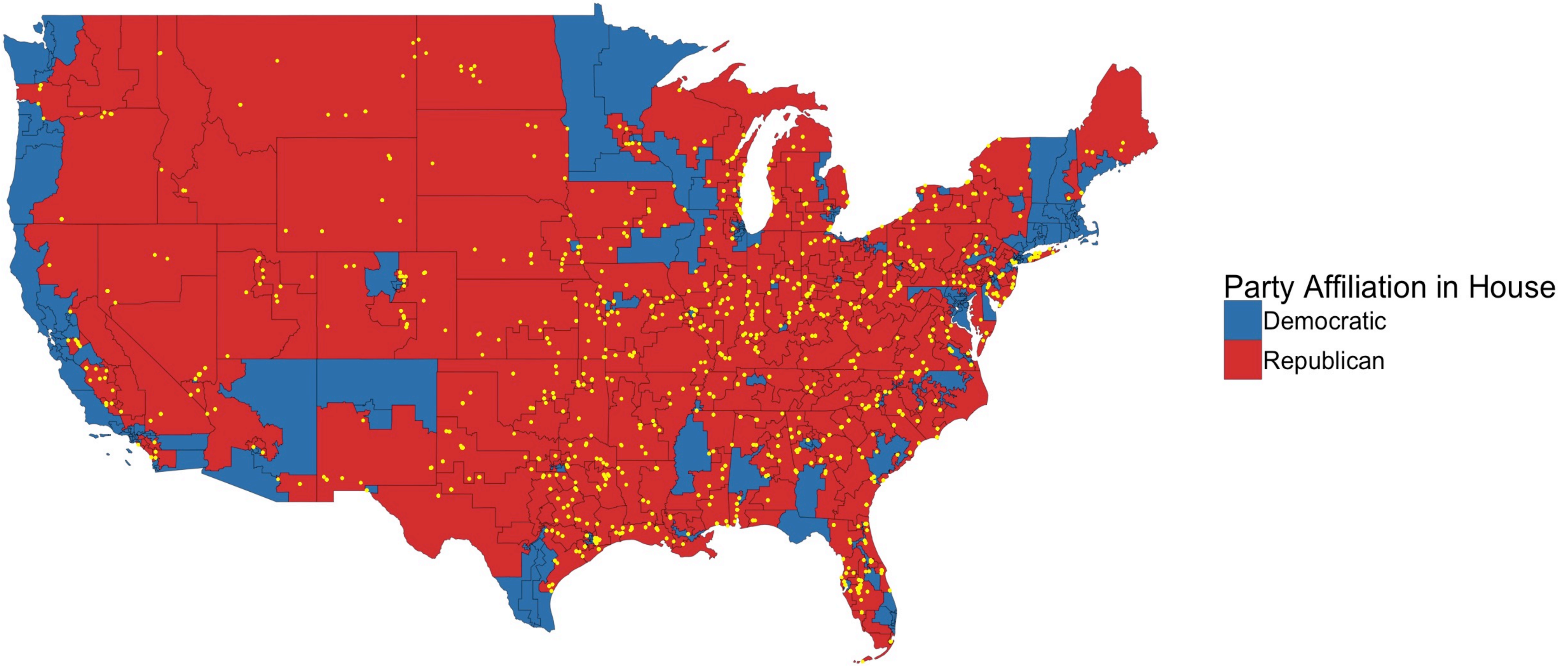
Location of Units by Fuel 1 Type

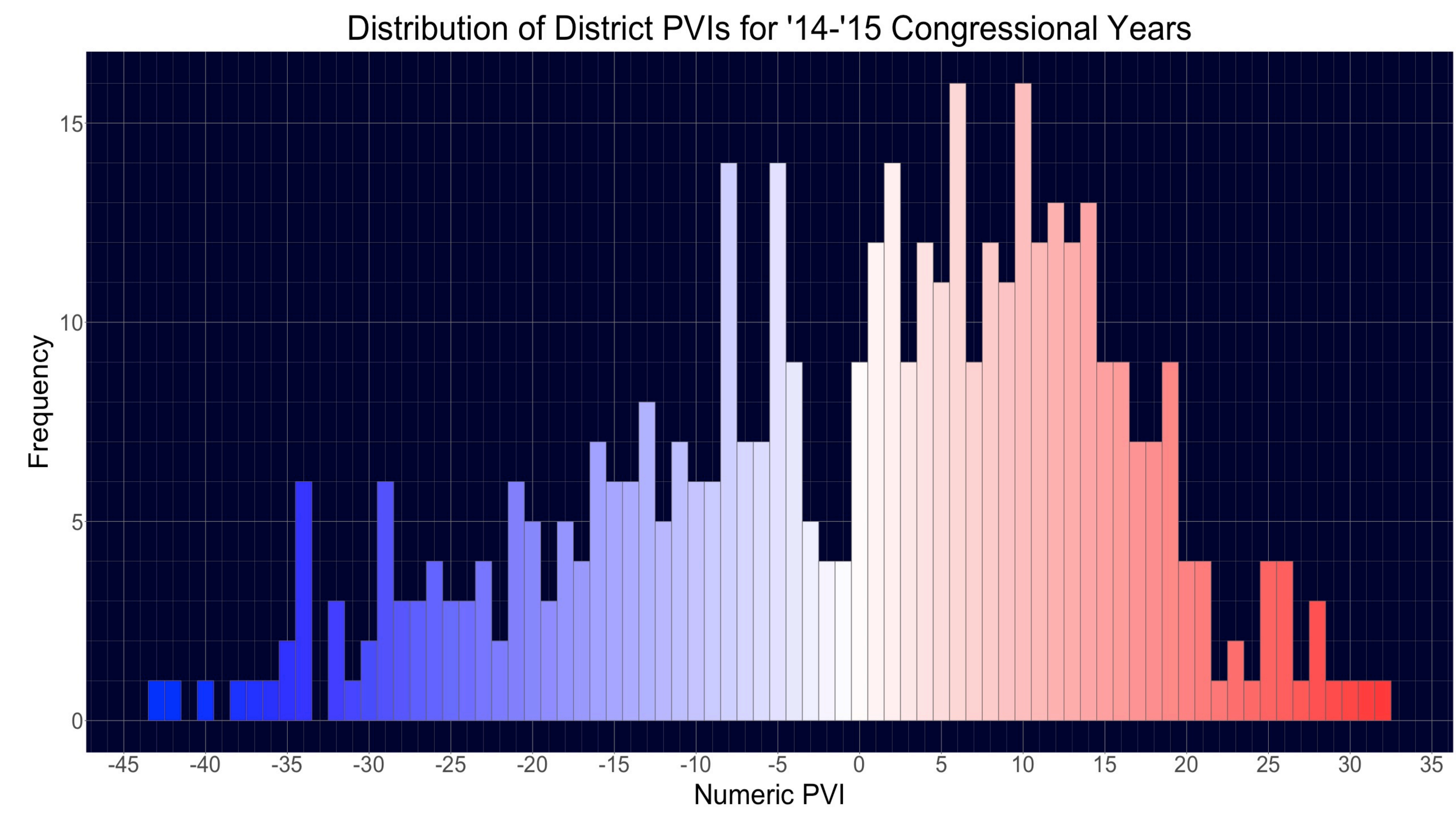


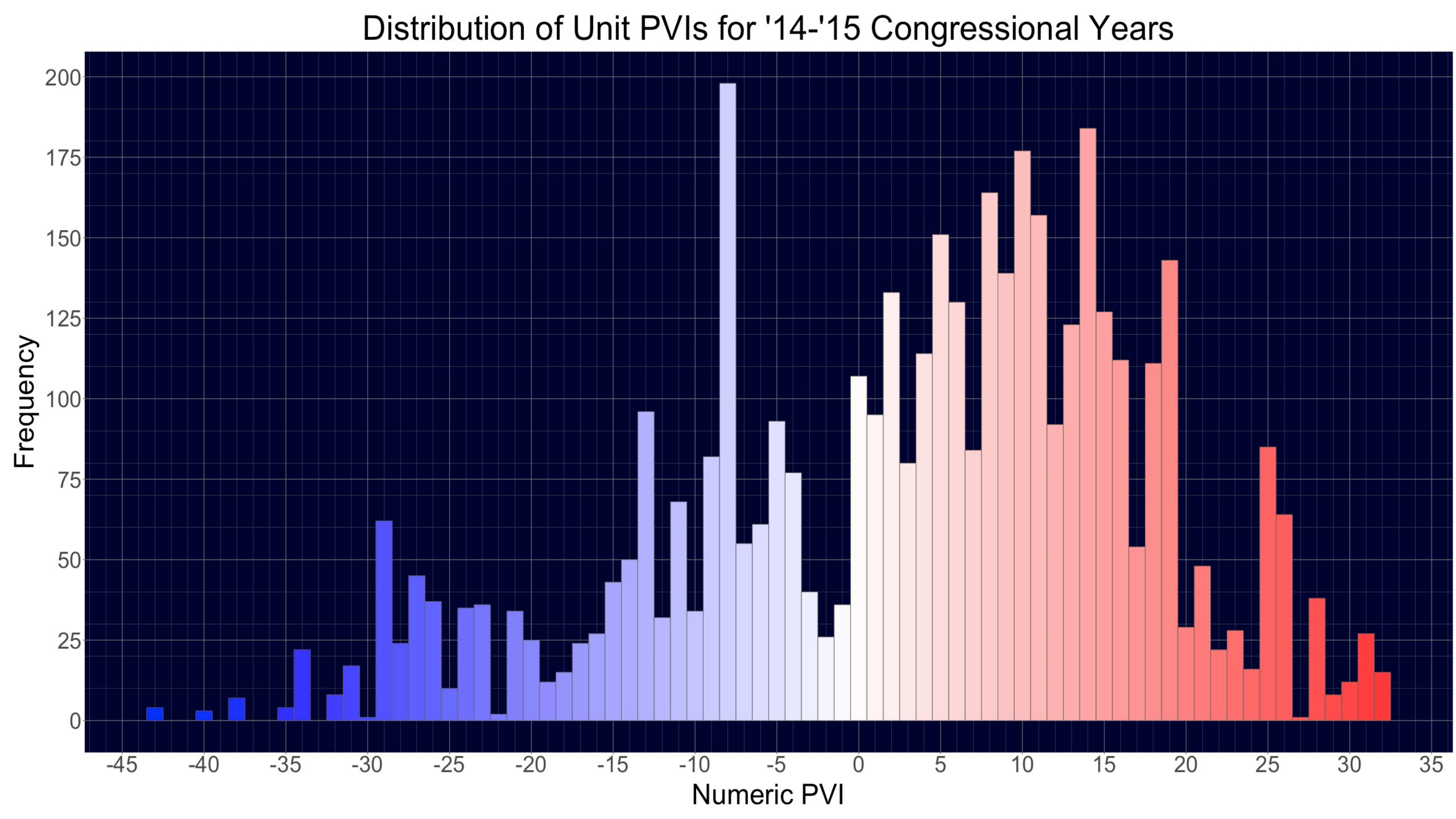
Units by Congressional District in '14-'15 Congressional Years - Democratic



Units by Congressional District in '14-'15 Congressional Years - Republican

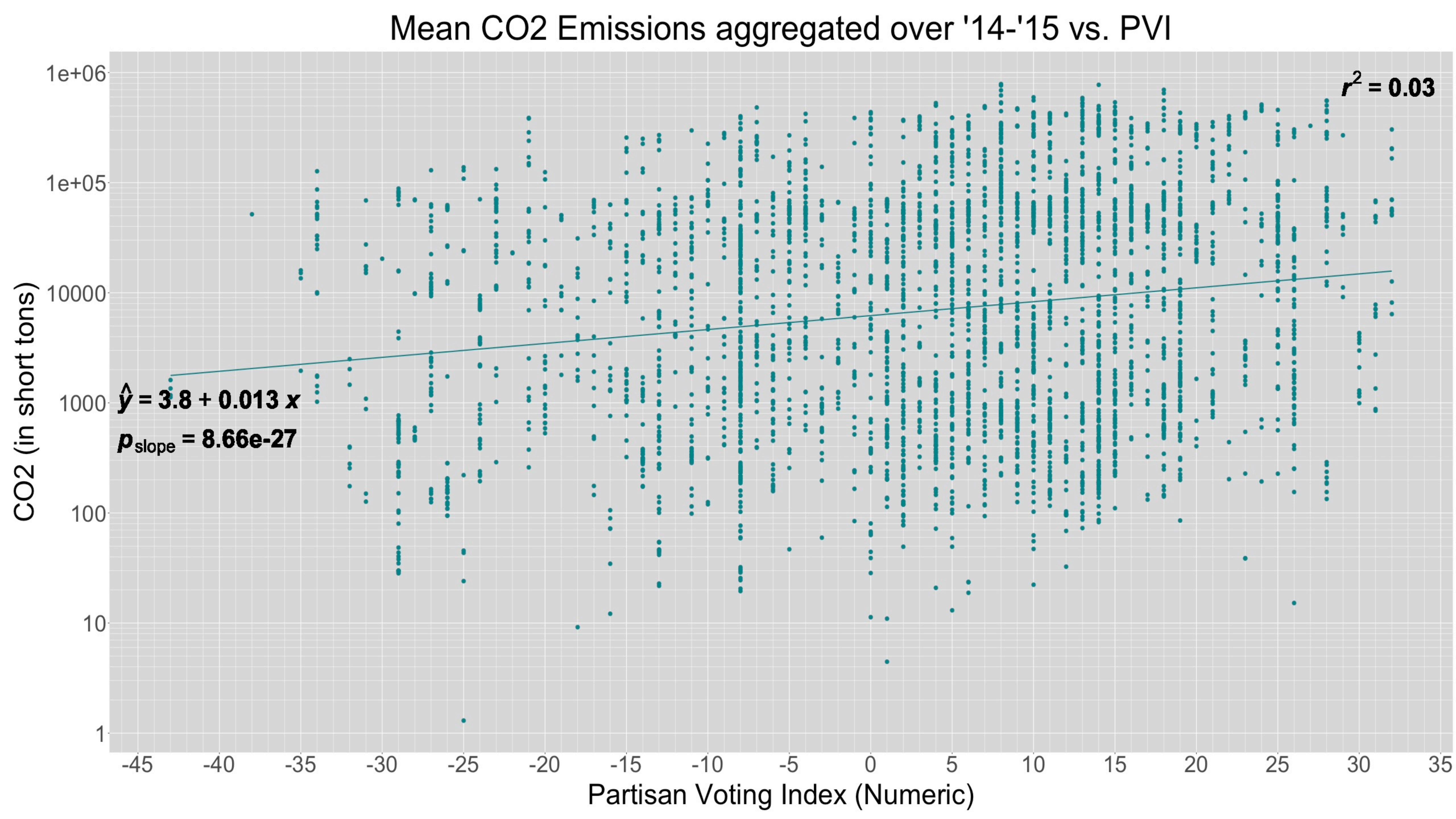


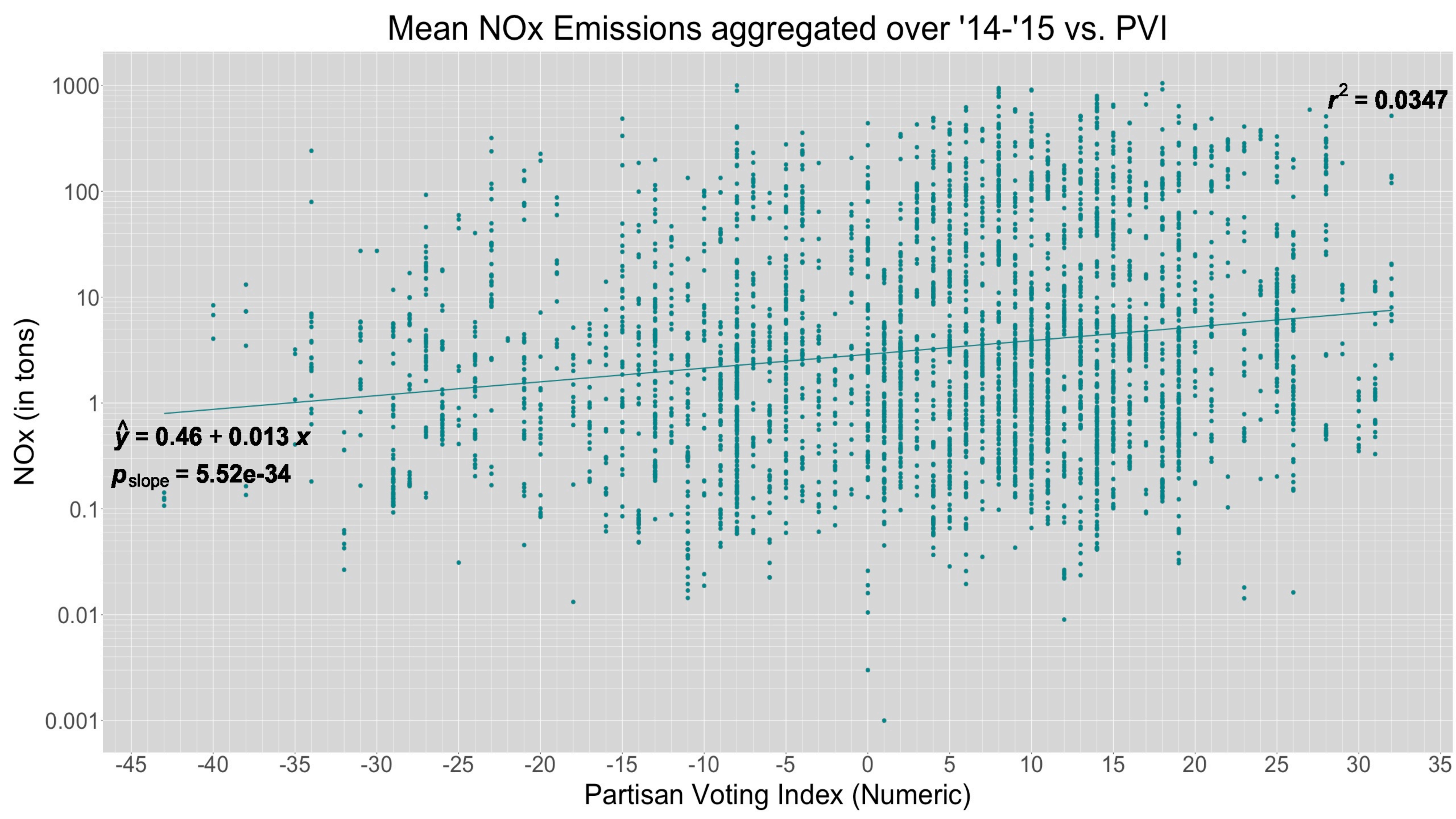

Distribution of District PVIs for '14-'15 Congressional Years
Frequency
0
5
10
15
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Numeric PVI


Distribution of Unit PVIs for '14-'15 Congressional Years
Frequency
200
175
150
125
100
75
50
25
0
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Numeric PVI

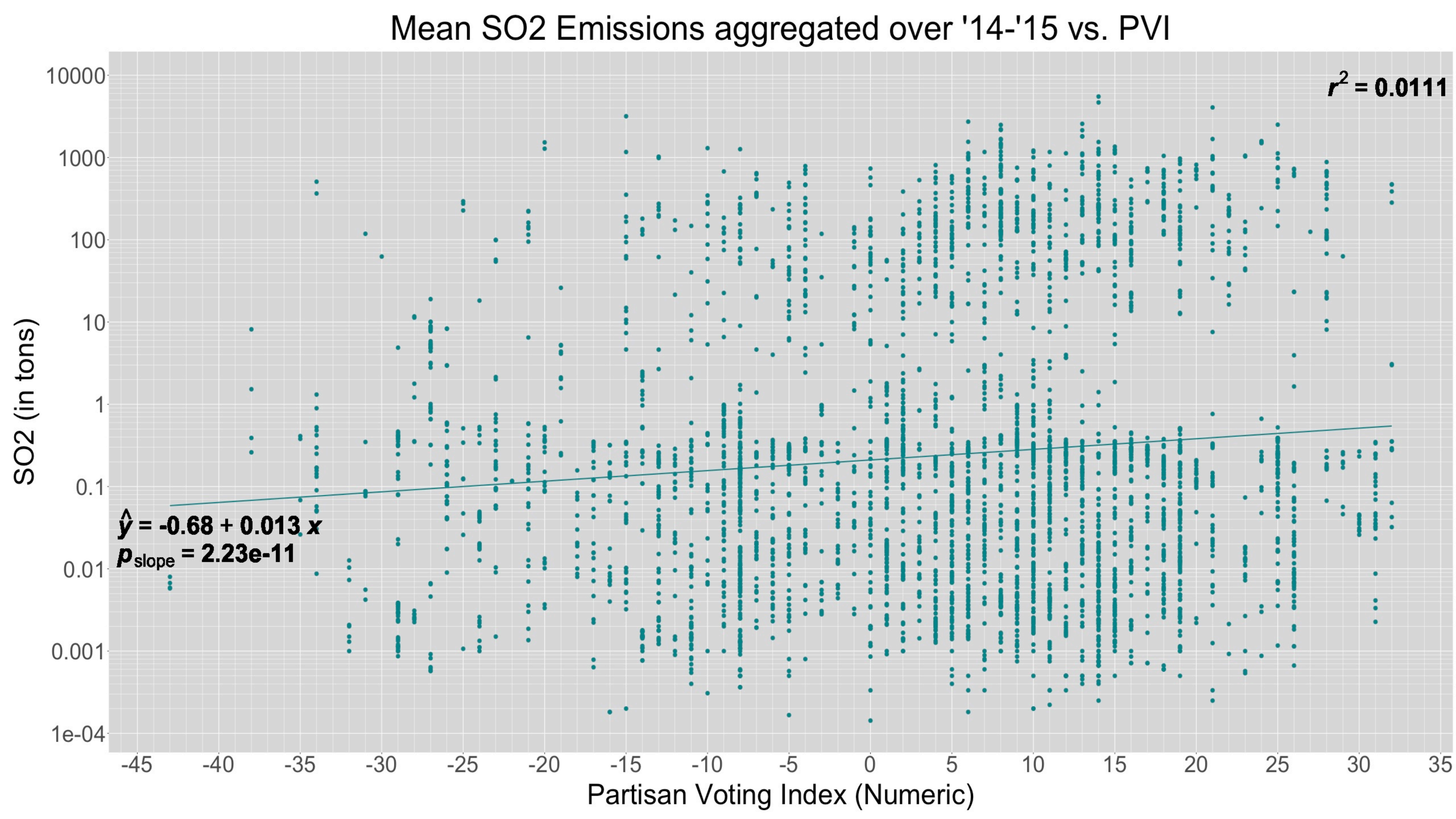
Naïve Regression Formula

$$\log_{10}(Emission) = \boldsymbol{\beta}_{\mathbf{0}} + \boldsymbol{\beta}_{\mathbf{1}}\ NumPVI$$


Mean CO2 Emissions aggregated over '14-'15 vs. PVI
r^2 = 0.03
$\hat{y}$ = 3.8 + 0.013 x
p_{slope} = 8.66e-27
CO2 (in short tons)
1e+06
1e+05
10000
1000
100
10
1
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Partisan Voting Index (Numeric)



Mean NOx Emissions aggregated over '14-'15 vs. PVI
r^2 = 0.0347
ŷ = 0.46 + 0.013 x
p_slope = 5.52e-34
NOx (in tons)
1000
100
10
1
0.1
0.01
0.001
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Partisan Voting Index (Numeric)


Mean SO2 Emissions aggregated over '14-'15 vs. PVI
r^2 = 0.0111
$\hat{y}$ = -0.68 + 0.013 x
p_{slope} = 2.23e-11
SO2 (in tons)
10000
1000
100
10
1
0.1
0.01
0.001
1e-04
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Partisan Voting Index (Numeric)

Complex Regression Formula

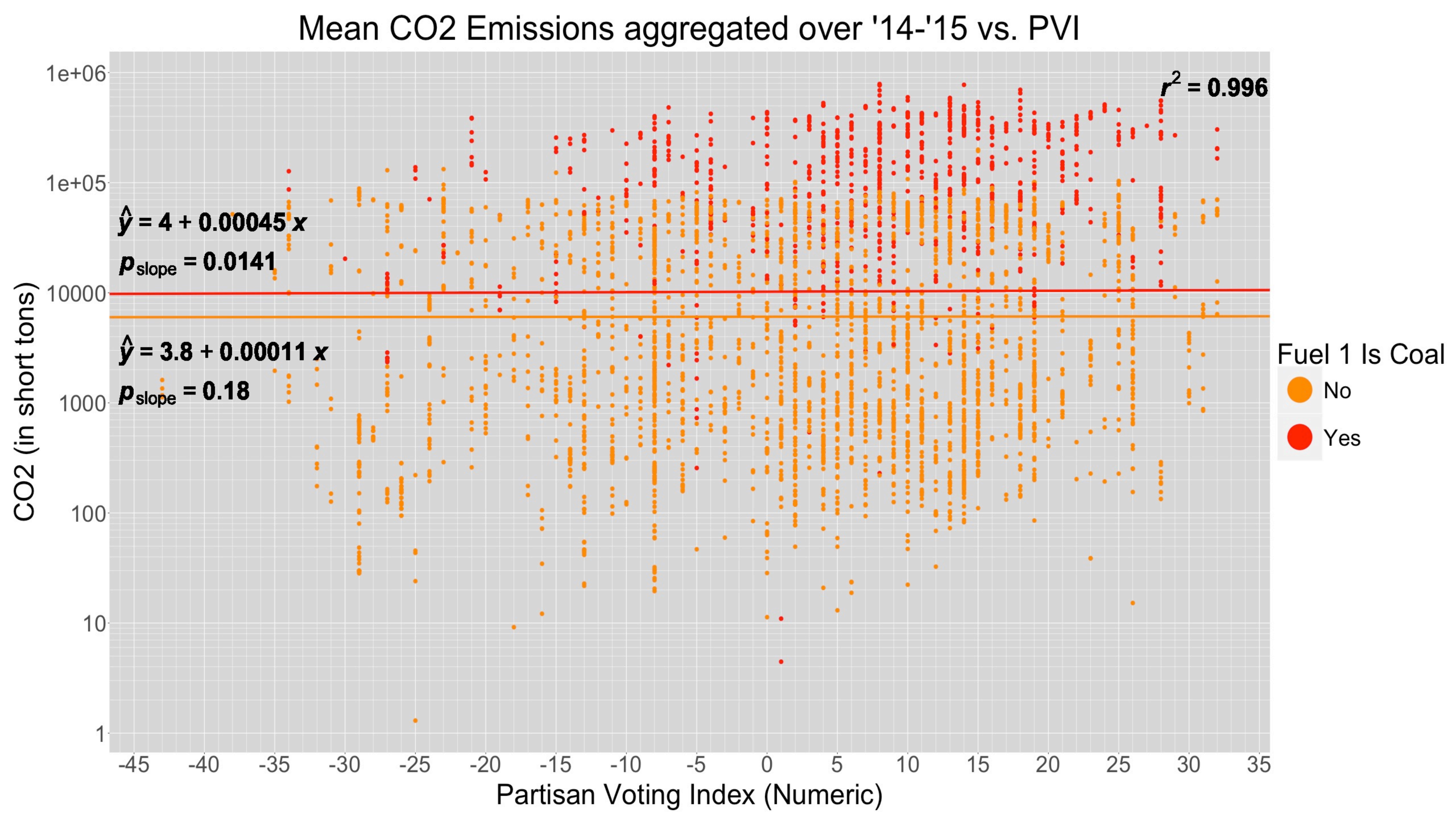
$$\log_{10}(Emission) = \boldsymbol{\beta}_{\mathbf{0}} + \boldsymbol{\beta}_{\mathbf{1}}\ NumPVI + \boldsymbol{\beta}_{\mathbf{2}}\ I(Fuel1\ IsCoal = 0)$$
$$+ \boldsymbol{\beta}_{\mathbf{3}}\ \log_{10}(Heat\ Input) + \boldsymbol{\beta}_{\mathbf{4}}\ I(Is\ Phase\ 1 = 0)$$
$$+ \boldsymbol{\beta}_{\mathbf{5}}\ [NumPVI * I(Fuel1\ IsCoal = 0)]$$

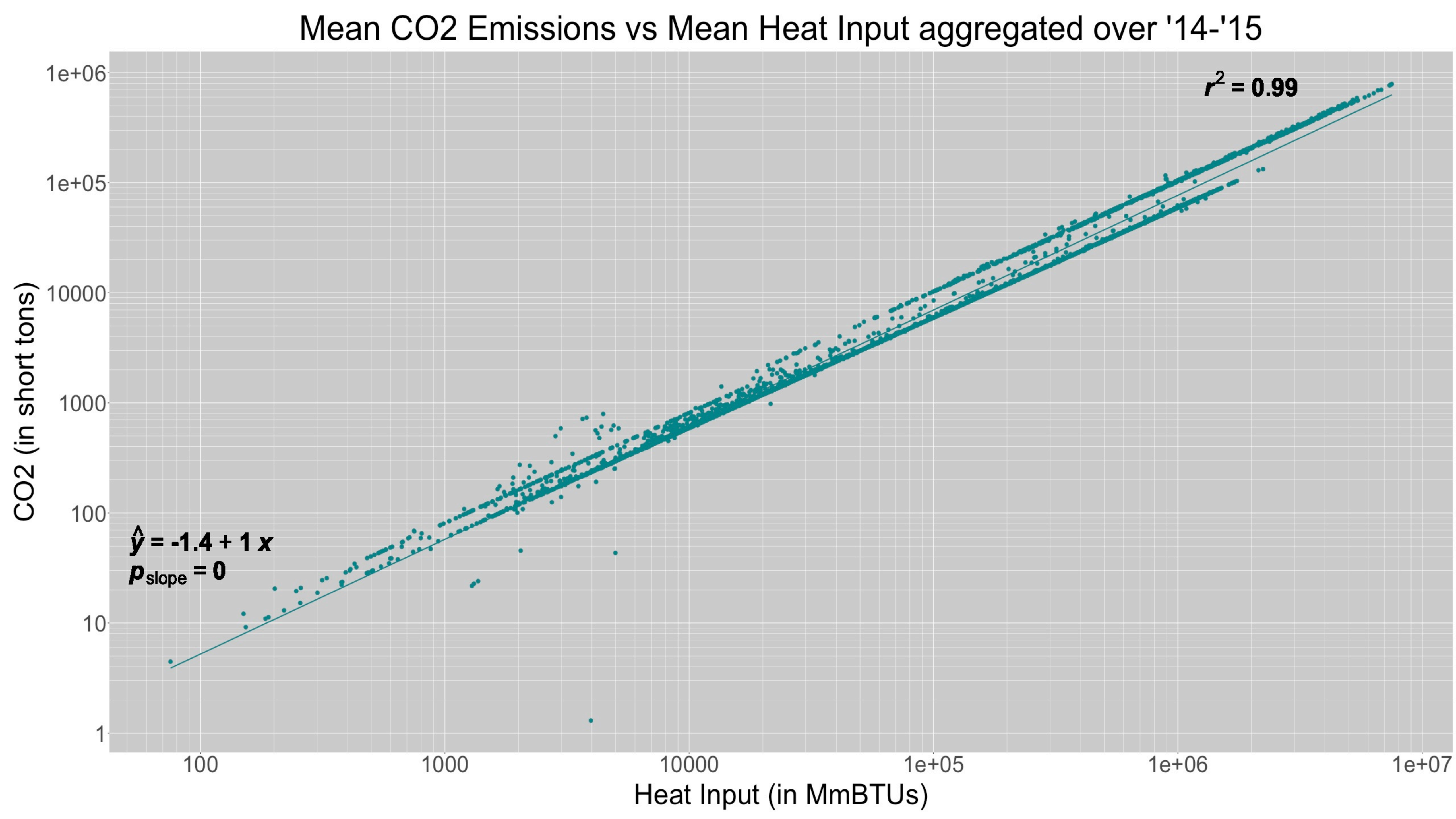
Final CO2 Regression with NoCoal as base

	V1	V2	V3	V4	V5
1	log10(mean.CO2) ~ Current.numPVI * Fuel1.IsCoal.Mode + log10(mean.Heat.Input) + Is.Phase1	F(5,3769)	Prob > P	R-Squared	Adj-R2
2	data = cdat.meanCO2_cnumPVI_meanHeat_F12_P1.complete	197857.3328	0.0000	0.9962	0.9962
3					
4		Estimate	Std. Error	t value	Pr(>|t|)
5	(Intercept)	-1.1600	0.0060	-194.4447	<<0.0001
6	Current.numPVI	0.0001	0.0001	1.3403	0.1802
7	Fuel1.IsCoal.Mode1	0.2278	0.0033	68.4210	<<0.0001
8	log10(mean.Heat.Input)	0.9897	0.0012	794.4062	<<0.0001
9	Is.Phase1	0.0079	0.0051	1.5330	0.1254
10	Current.numPVI:Fuel1.IsCoal.Mode1	0.0003	0.0002	1.7110	0.0872

Final CO2 Regression with YesCoal as base

	V1	V2	V3	V4	V5
1	log10(mean.CO2) ~ Current.numPVI * Fuel1.NotIsCoal + log10(mean.Heat.Input) + Is.Phase1	F(5,3769)	Prob > P	R-Squared	Adj-R2
2	data = cdat.meanCO2_cnumPVI_meanHeat_F12_P1.complete.flip_F1	197857.3328	0.0000	0.9962	0.9962
3					
4		Estimate	Std. Error	t value	Pr(>|t|)
5	(Intercept)	-0.9322	0.0078	-119.9463	<<0.0001
6	Current.numPVI	0.0005	0.0002	2.4558	0.0141
7	Fuel1.NotIsCoal0	-0.2278	0.0033	-68.4210	<<0.0001
8	log10(mean.Heat.Input)	0.9897	0.0012	794.4062	<<0.0001
9	Is.Phase1	0.0079	0.0051	1.5330	0.1254
10	Current.numPVI:Fuel1.NotIsCoal0	-0.0003	0.0002	-1.7110	0.0872


Mean CO2 Emissions aggregated over '14-'15 vs. PVI
$r^2 = 0.996$
$\hat{y} = 4 + 0.00045\,x$
$p_{\text{slope}} = 0.0141$
$\hat{y} = 3.8 + 0.00011\,x$
$p_{\text{slope}} = 0.18$
CO2 (in short tons)
1e+06
1e+05
10000
1000
100
10
1
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Partisan Voting Index (Numeric)
Fuel 1 Is Coal
No
Yes



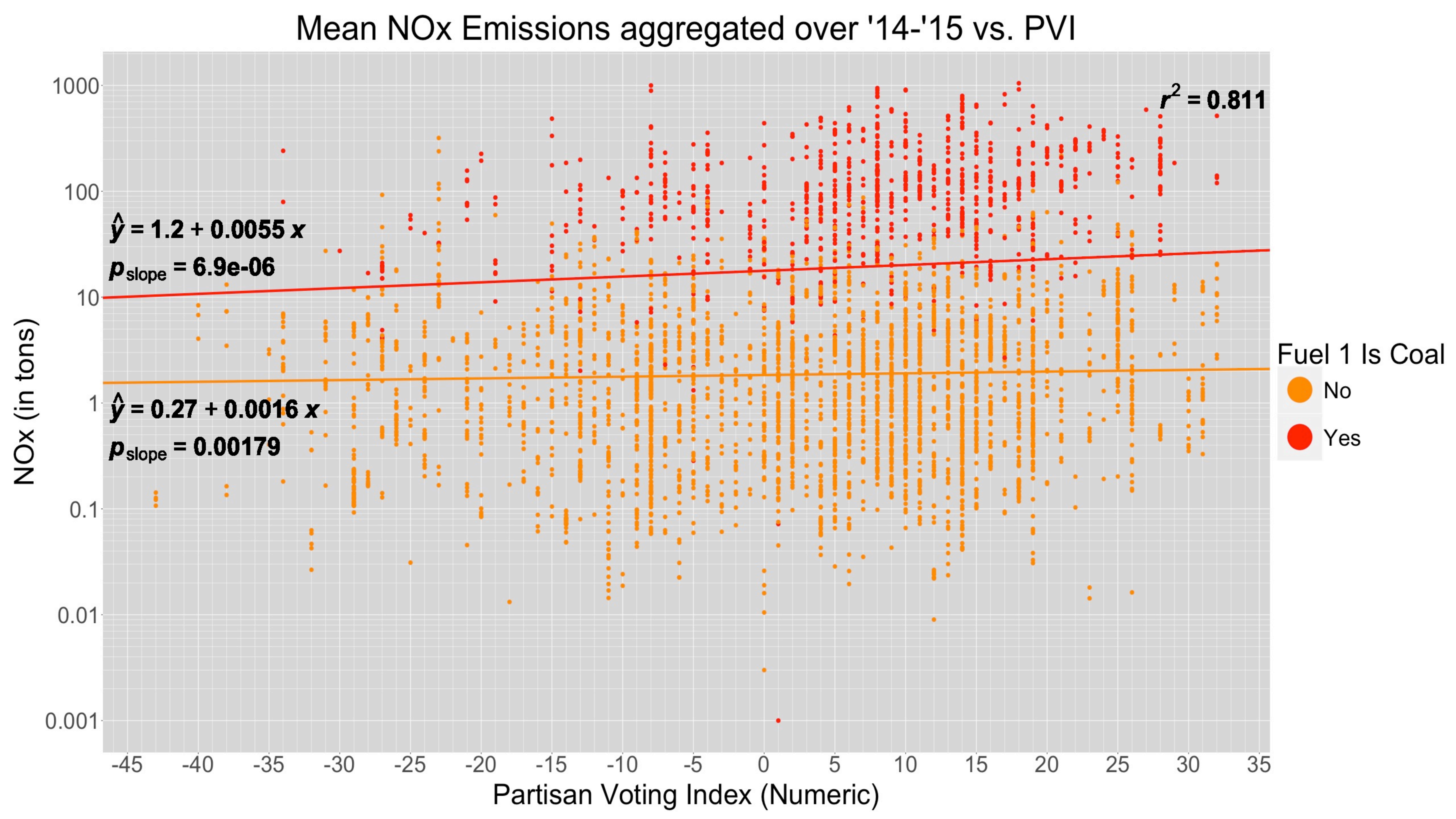
Mean CO2 Emissions vs Mean Heat Input aggregated over '14-'15
r^2 = 0.99
$\hat{y}$ = -1.4 + 1 x
p_{slope} = 0
CO2 (in short tons)
1e+06
1e+05
10000
1000
100
10
1
Heat Input (in MmBTUs)
100
1000
10000
1e+05
1e+06
1e+07

Final NOx Regression with NoCoal as base

	V1	V2	V3	V4	V5
1	log10(mean.NOx) ~ Current.numPVI * Fuel1.IsCoal.Mode + log10(mean.Heat.Input) + Is.Phase1	F(5,4178)	Prob > P	R-Squared	Adj-R2
2	data = cdat.meanNOx_cnumPVI_meanHeat_F12_P1.complete	3584.6880	0.0000	0.8110	0.8107
3					
4		Estimate	Std. Error	t value	Pr(>|t|)
5	(Intercept)	-2.5637	0.0365	-70.2618	<<0.0001
6	Current.numPVI	0.0016	0.0005	3.1247	0.0018
7	Fuel1.IsCoal.Mode1	0.9849	0.0216	45.5658	<<0.0001
8	log10(mean.Heat.Input)	0.5763	0.0077	74.4751	<<0.0001
9	Is.Phase1	0.0920	0.0344	2.6712	0.0076
10	Current.numPVI:Fuel1.IsCoal.Mode1	0.0039	0.0013	2.9260	0.0035

Final NOx Regression with YesCoal as base

	V1	V2	V3	V4	V5
1	log10(mean.NOx) ~ Current.numPVI * Fuel1.NotIsCoal + log10(mean.Heat.Input) + Is.Phase1	F(5,4178)	Prob > P	R-Squared	Adj-R2
2	data = cdat.meanNOx_cnumPVI_meanHeat_F12_P1.complete.flip_F1	3584.6880	0.0000	0.8110	0.8107
3					
4		Estimate	Std. Error	t value	Pr(>|t|)
5	(Intercept)	-1.5789	0.0483	-32.6590	<<0.0001
6	Current.numPVI	0.0055	0.0012	4.5024	<<0.0001
7	Fuel1.NotIsCoal0	-0.9849	0.0216	-45.5658	<<0.0001
8	log10(mean.Heat.Input)	0.5763	0.0077	74.4751	<<0.0001
9	Is.Phase1	0.0920	0.0344	2.6712	0.0076
10	Current.numPVI:Fuel1.NotIsCoal0	-0.0039	0.0013	-2.9260	0.0035

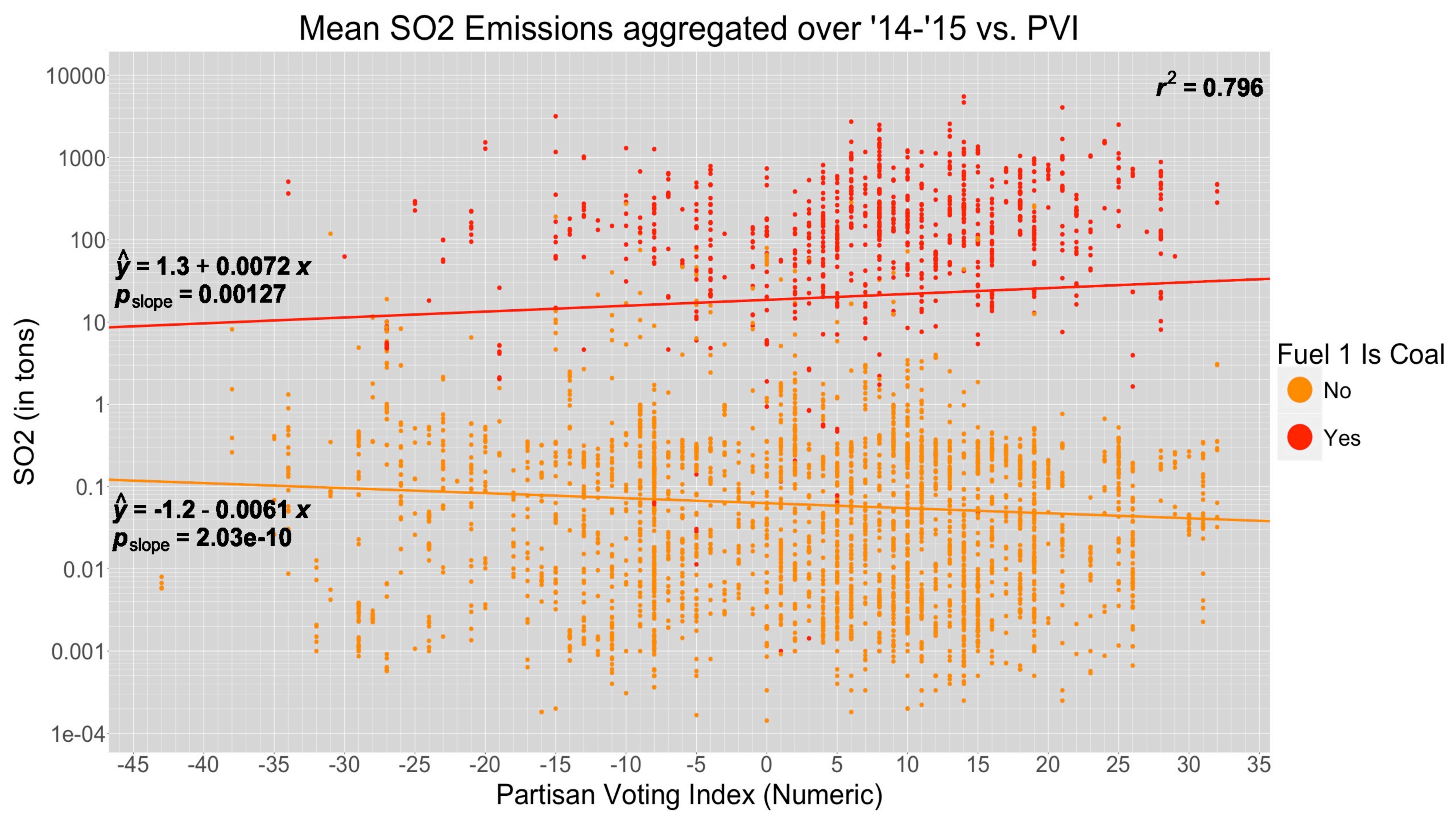

Mean NOx Emissions aggregated over '14-'15 vs. PVI
$\hat{y}$ = 1.2 + 0.0055 x
p_{slope} = 6.9e-06
$\hat{y}$ = 0.27 + 0.0016 x
p_{slope} = 0.00179
r^2 = 0.811
NOx (in tons)
1000
100
10
1
0.1
0.01
0.001
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Partisan Voting Index (Numeric)
Fuel 1 Is Coal
No
Yes

Final SO2 Regression with NoCoal as base

	V1	V2	V3	V4	V5
1	log10(mean.SO2) ~ Current.numPVI * Fuel1.IsCoal.Mode + log10(mean.Heat.Input) + Is.Phase1	F(5,4005)	Prob > P	R-Squared	Adj-R2
2	data = cdat.meanSO2_cnumPVI_meanHeat_F12_P1.complete	3131.8209	0.0000	0.7963	0.7961
3					
4		Estimate	Std. Error	t value	Pr(>|t|)
5	(Intercept)	-4.4142	0.0681	-64.8146	<<0.0001
6	Current.numPVI	-0.0061	0.0010	-6.3756	<<0.0001
7	Fuel1.IsCoal.Mode1	2.4728	0.0398	62.1399	<<0.0001
8	log10(mean.Heat.Input)	0.6508	0.0144	45.3103	<<0.0001
9	Is.Phase1	0.2986	0.0622	4.8043	<<0.0001
10	Current.numPVI:Fuel1.IsCoal.Mode1	0.0133	0.0024	5.4957	<<0.0001

Final SO2 Regression with YesCoal as base

	V1	V2	V3	V4	V5
1	log10(mean.SO2) ~ Current.numPVI * Fuel1.NotIsCoal + log10(mean.Heat.Input) + Is.Phase1	F(5,4005)	Prob > P	R-Squared	Adj-R2
2	data = cdat.meanSO2_cnumPVI_meanHeat_F12_P1.complete.flip_F1	3131.8209	0.0000	0.7963	0.7961
3					
4		Estimate	Std. Error	t value	Pr(>|t|)
5	(Intercept)	-1.9414	0.0899	-21.5941	<<0.0001
6	Current.numPVI	0.0072	0.0022	3.2247	0.0013
7	Fuel1.NotIsCoal0	-2.4728	0.0398	-62.1399	<<0.0001
8	log10(mean.Heat.Input)	0.6508	0.0144	45.3103	<<0.0001
9	Is.Phase1	0.2986	0.0622	4.8043	<<0.0001
10	Current.numPVI:Fuel1.NotIsCoal0	-0.0133	0.0024	-5.4957	<<0.0001



Mean SO2 Emissions aggregated over '14-'15 vs. PVI
r^2 = 0.796
$\hat{y}$ = 1.3 + 0.0072 x
p_{slope} = 0.00127
$\hat{y}$ = -1.2 - 0.0061 x
p_{slope} = 2.03e-10
SO2 (in tons)
10000
1000
100
10
1
0.1
0.01
0.001
1e-04
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
Partisan Voting Index (Numeric)
Fuel 1 Is Coal
No
Yes

Interpretation of data

* A **more conservative** voting pattern (higher PVI) in a district is positively associated with a **higher NO_x** emission levels **regardless of primary fuel type.**
* For Non-Coal Plants: **A 10-unit increase in PVI** is associated with **1.038 times greater NO_x** emission levels
* For Coal Plants: **A 10-unit increase in PVI** is associated with **1.135 times greater NO_x** emission levels

Interpretation of data (cont.)

* A **more conservative** voting pattern (higher PVI) in a district is associated with **SO_2** emission levels, but **depends on primary fuel type.**
* For Non-Coal Plants: A **10-unit increase in PVI** is associated with **1.151 times fewer SO_2** emission levels
* For Coal Plants: A **10-unit increase in PVI** is associated with **1.18 times greater SO_2** emission levels

Conclusion

* There is **evidence** to suggest that there is an association between the **PVI** for a power plant and the **SO_2** and **NO_x** emissions of a power plant.

* There is **no evidence** to suggest that there is an association between the **PVI** for a power plant and the **CO_2** emissions of a power plant.

Limitations/Future Work

* Geographical features of the data
* Demographic features of the data

* More data from previous congressional years

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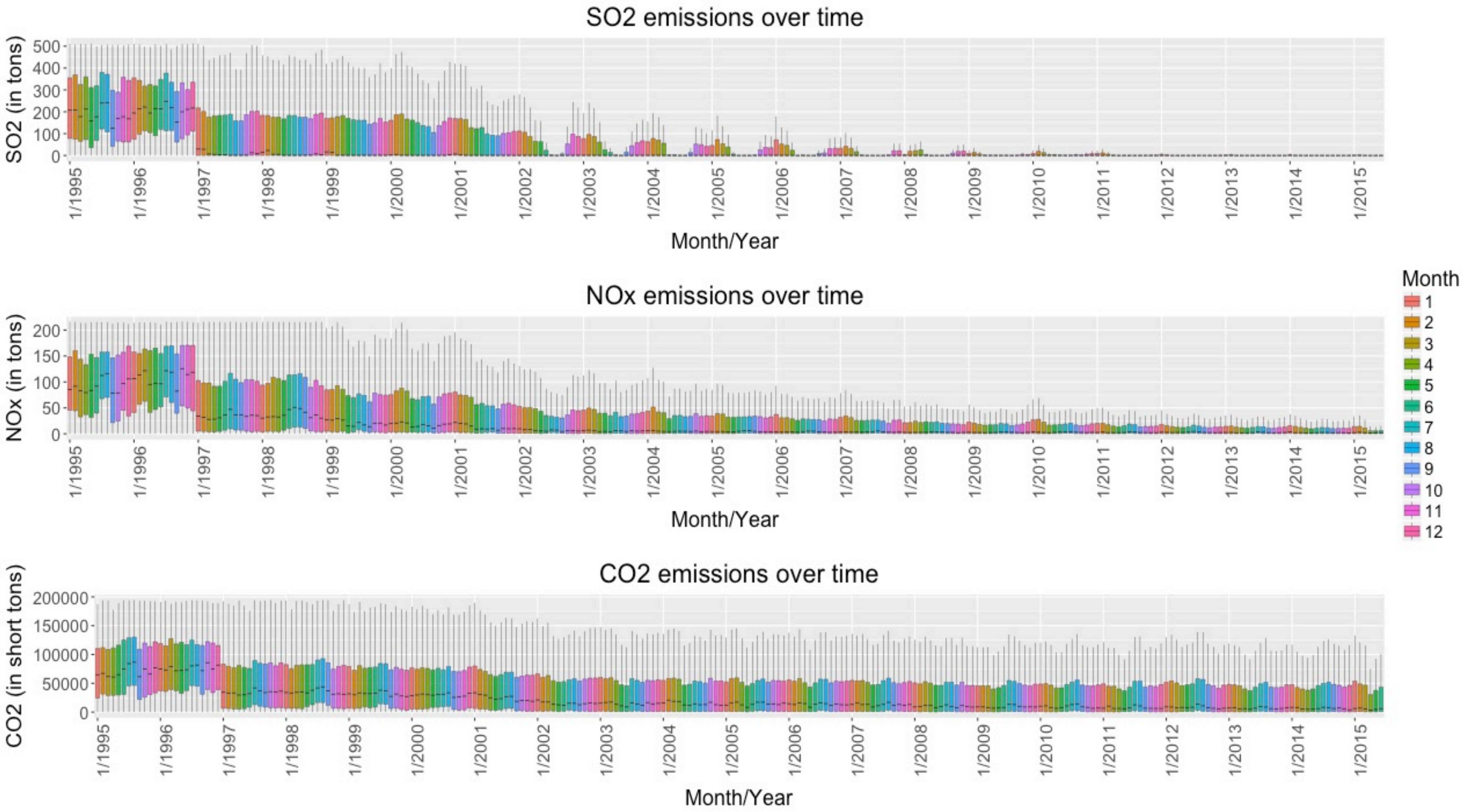
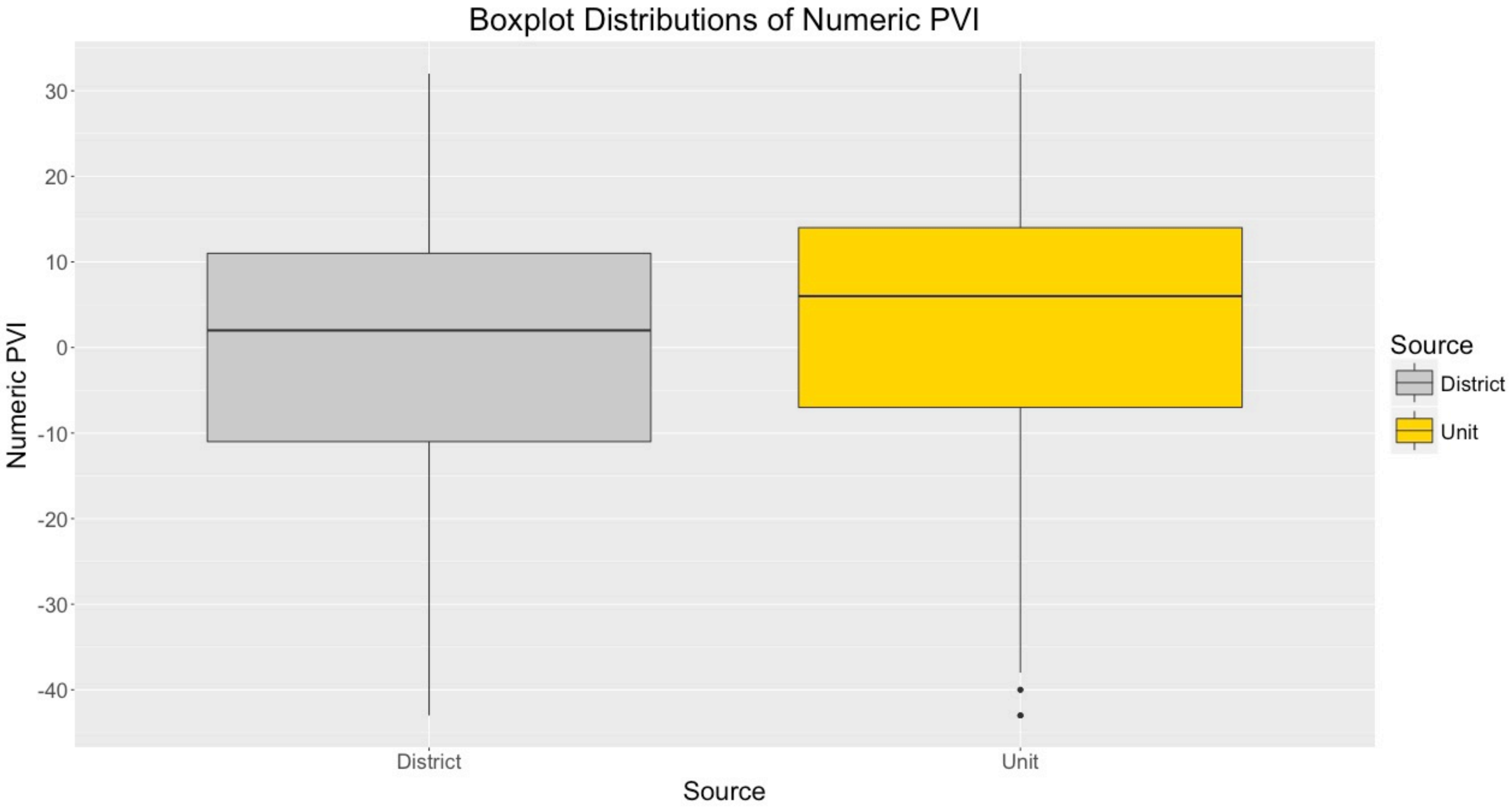
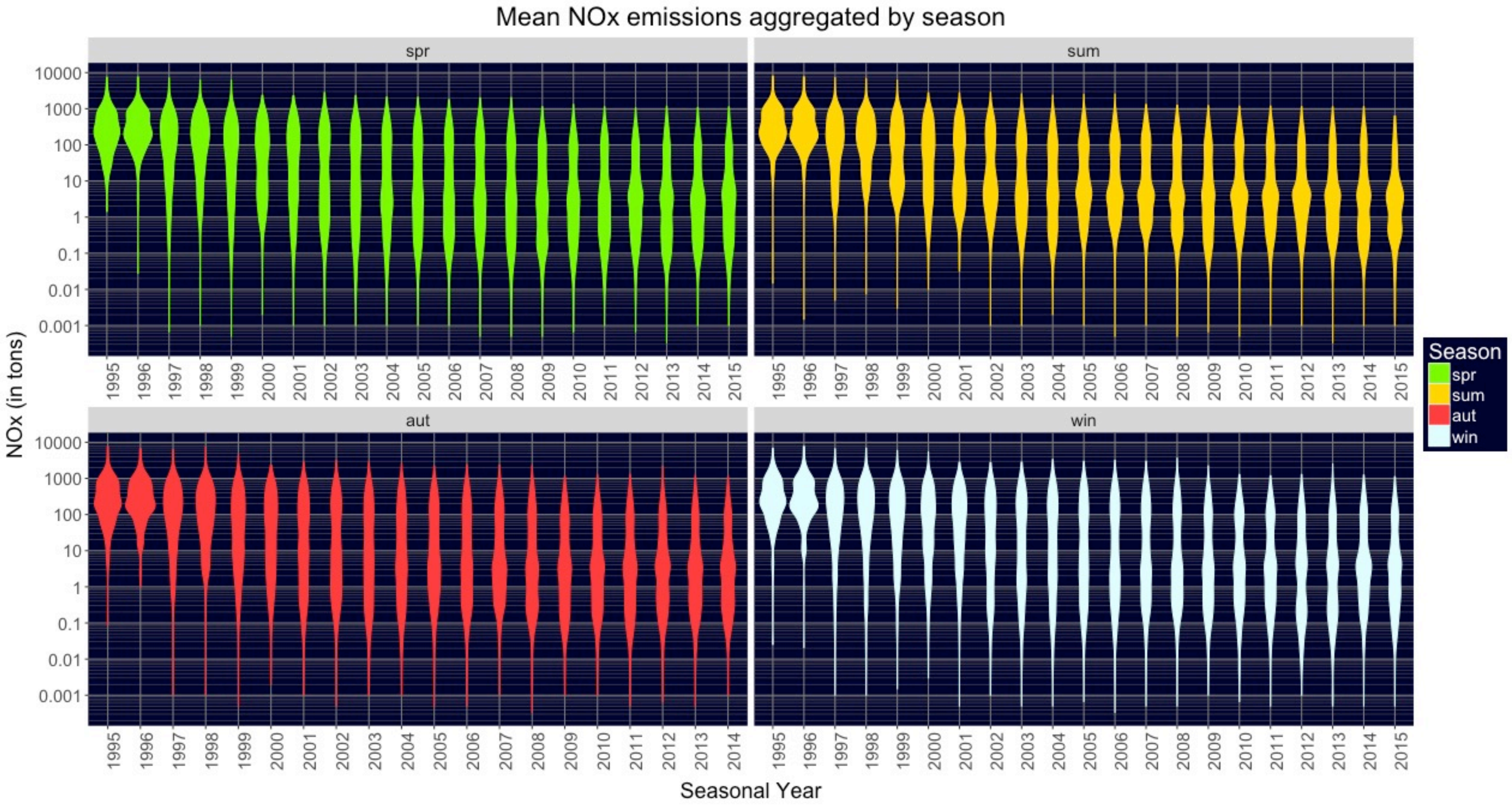
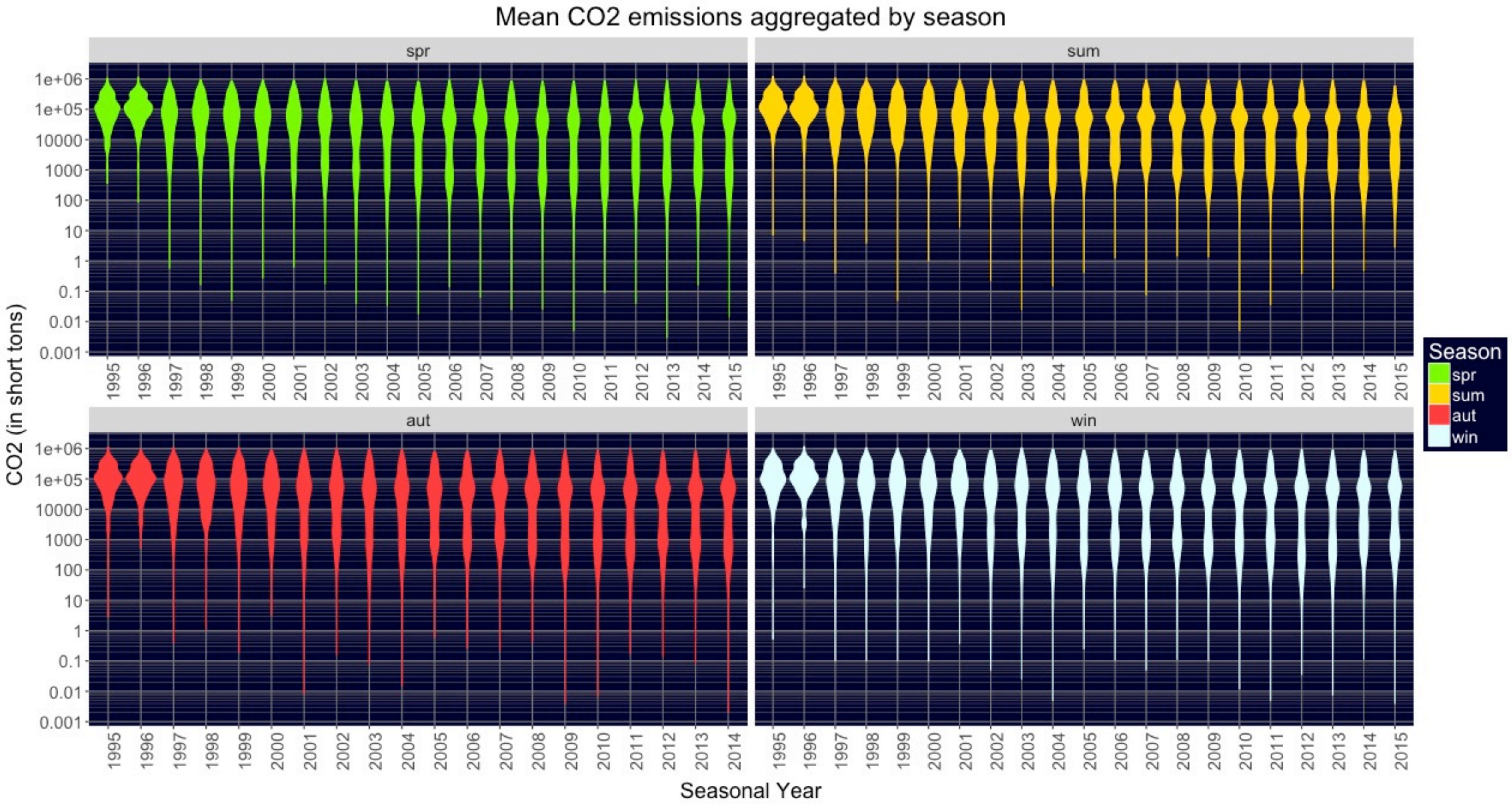

SO2 emissions over time
SO2 (in tons)
0
100
200
300
400
500
Month/Year
NOx emissions over time
NOx (in tons)
0
50
100
150
200
Month/Year
CO2 emissions over time
CO2 (in short tons)
0
50000
100000
150000
200000
Month/Year
1/1995
1/1996
1/1997
1/1998
1/1999
1/2000
1/2001
1/2002
1/2003
1/2004
1/2005
1/2006
1/2007
1/2008
1/2009
1/2010
1/2011
1/2012
1/2013
1/2014
1/2015
Month
1
2
3
4
5
6
7
8
9
10
11
12



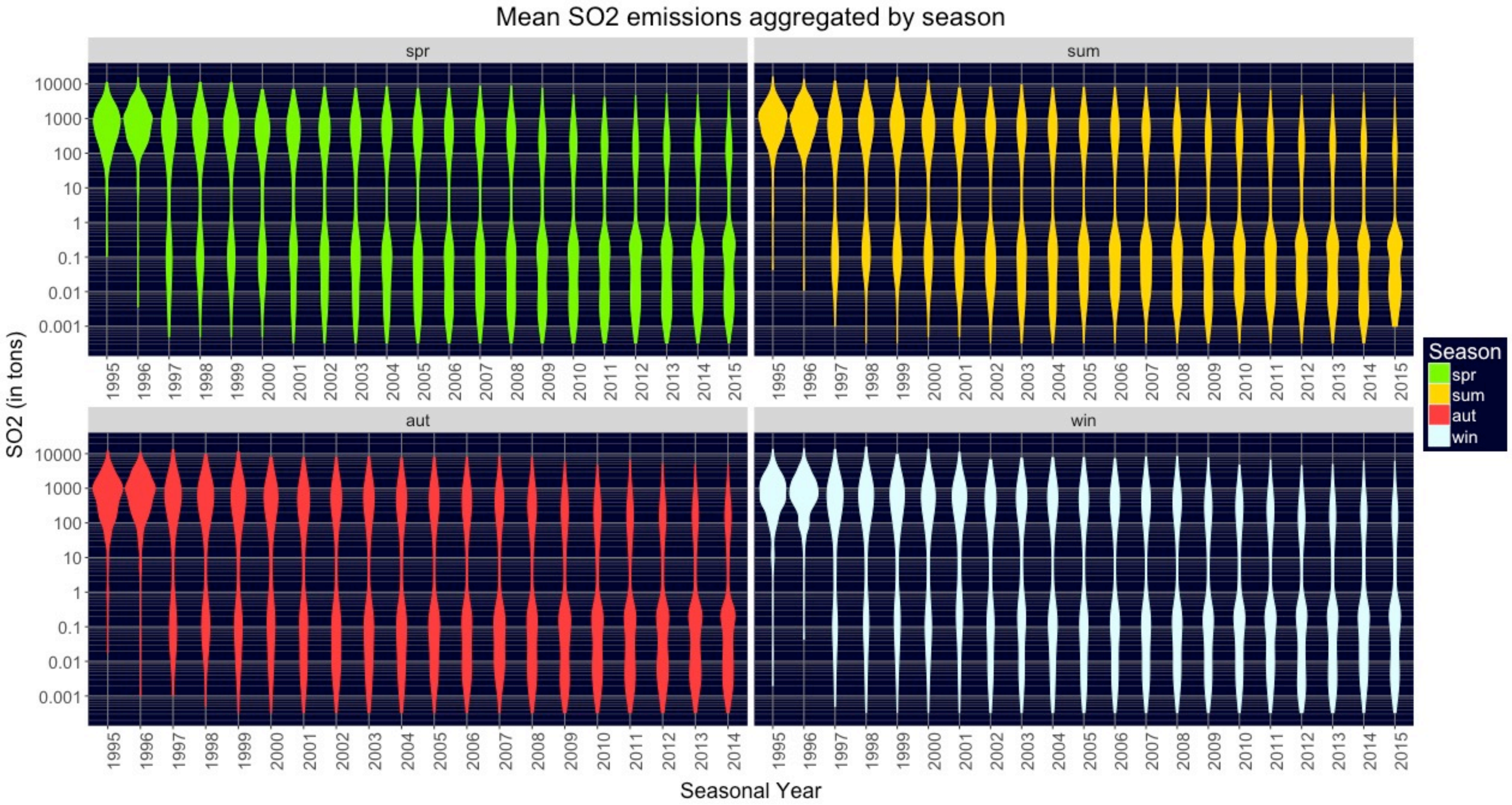
Boxplot Distributions of Numeric PVI
30
20
10
0
-10
-20
-30
-40
Numeric PVI
District
Unit
Source
Source
District
Unit

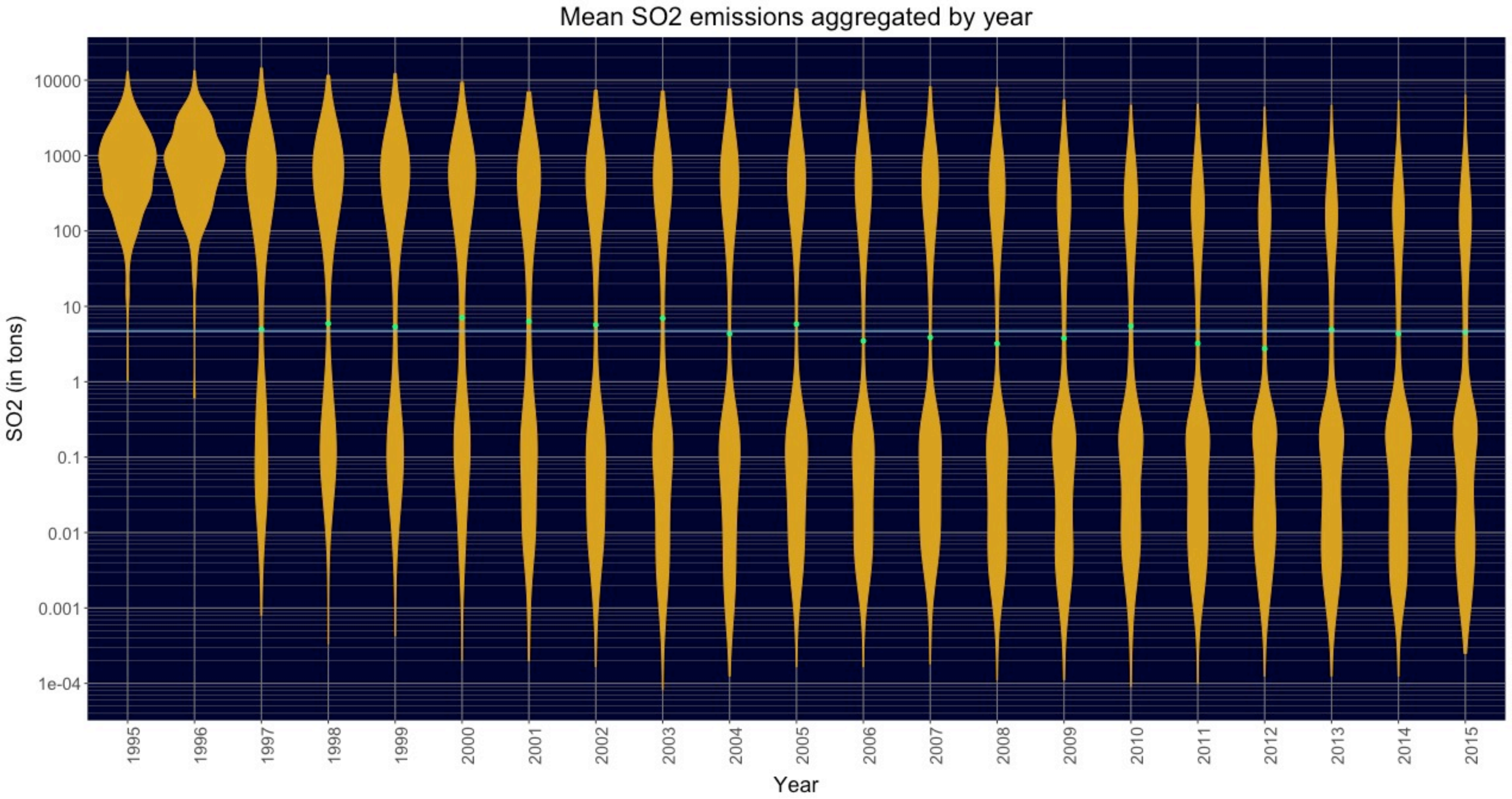


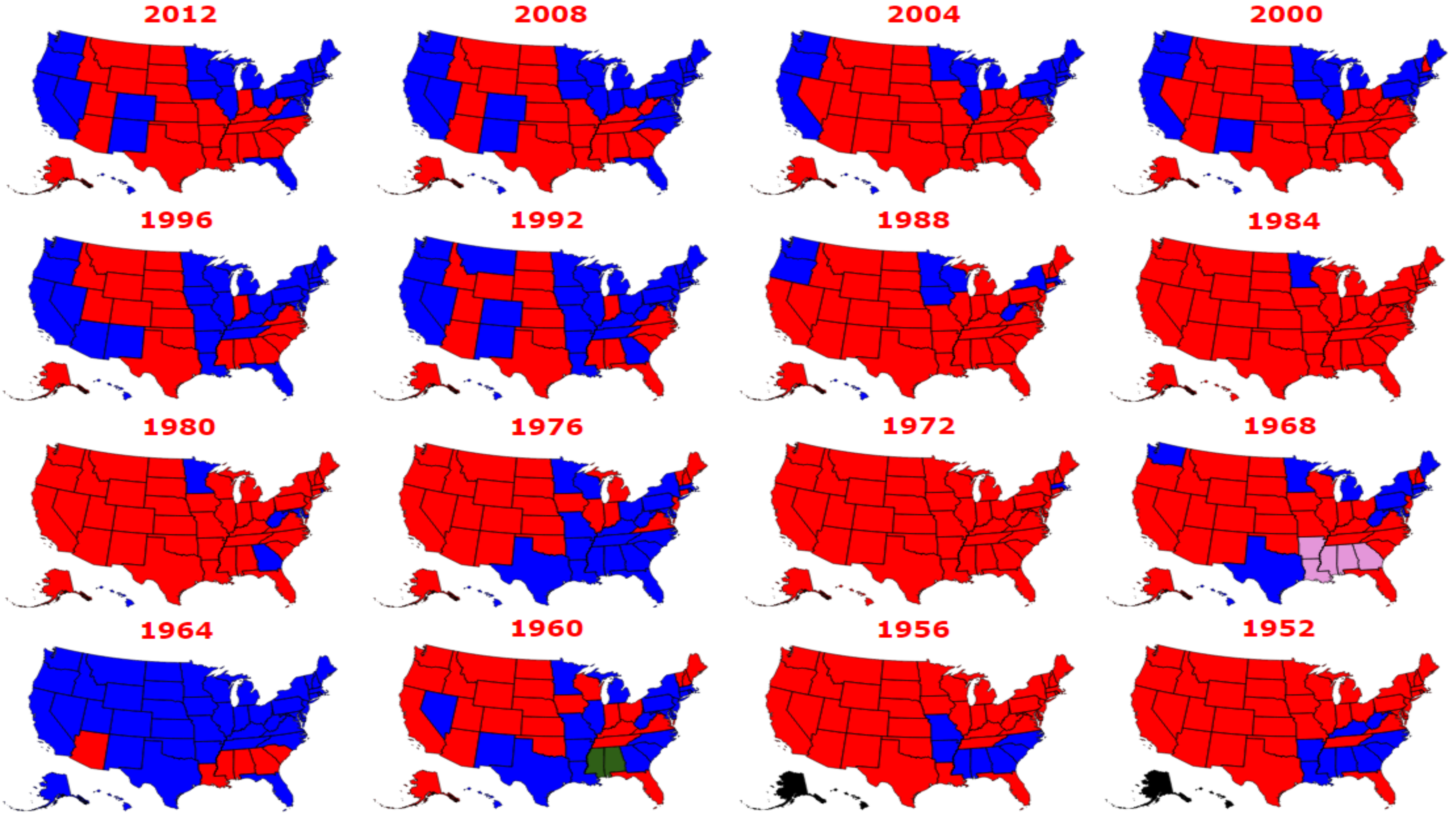
Mean NOx emissions aggregated by season
spr
sum
aut
win
NOx (in tons)
10000
1000
100
10
1
0.1
0.01
0.001
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Seasonal Year
Season
spr
sum
aut
win



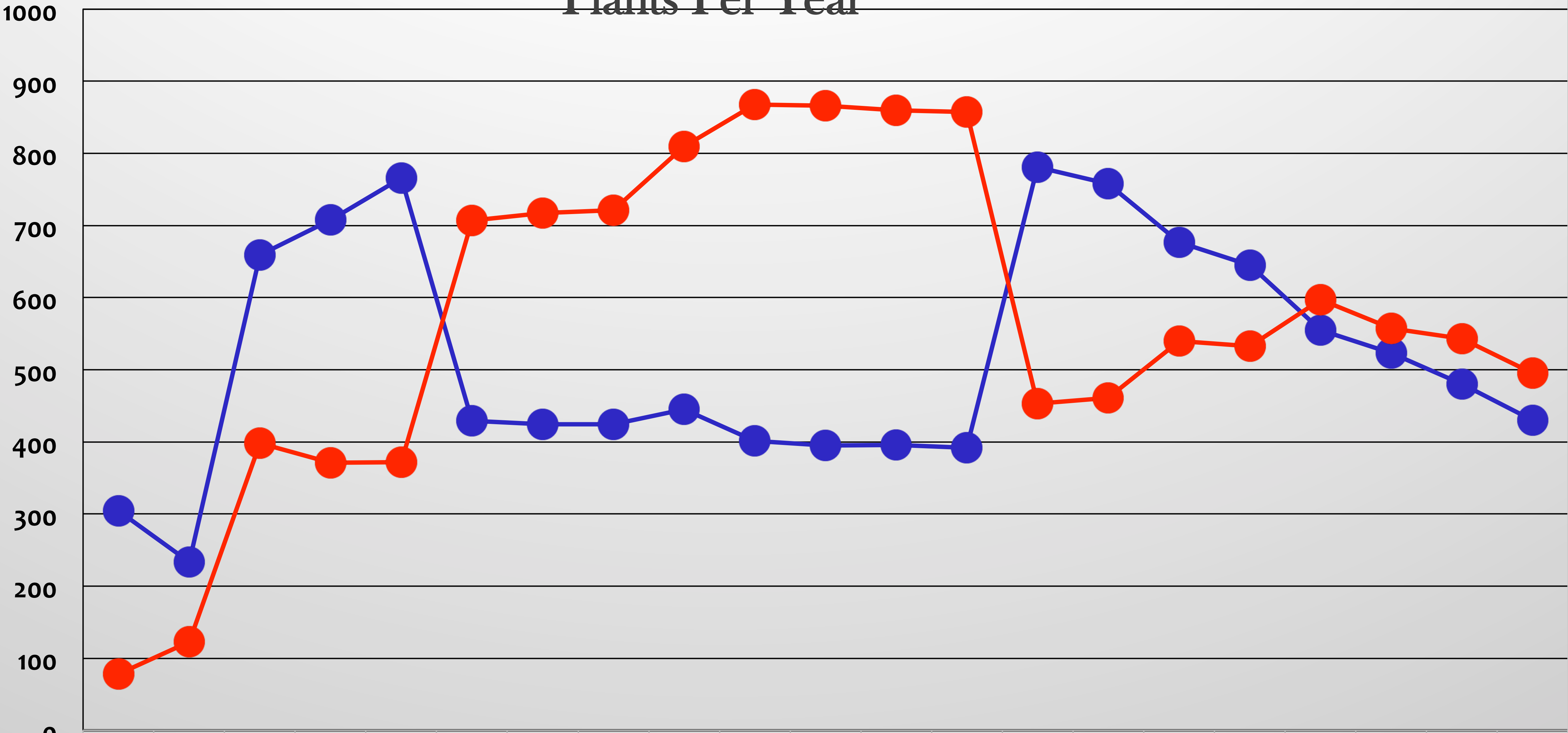
Mean CO2 emissions aggregated by season
spr
sum
aut
win
CO2 (in short tons)
1e+06
1e+05
10000
1000
100
10
1
0.1
0.01
0.001
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Seasonal Year
Season
spr
sum
aut
win


Mean SO2 emissions aggregated by season
spr
sum
aut
win
SO2 (in tons)
10000
1000
100
10
1
0.1
0.01
0.001
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Seasonal Year
Season
spr
sum
aut
win

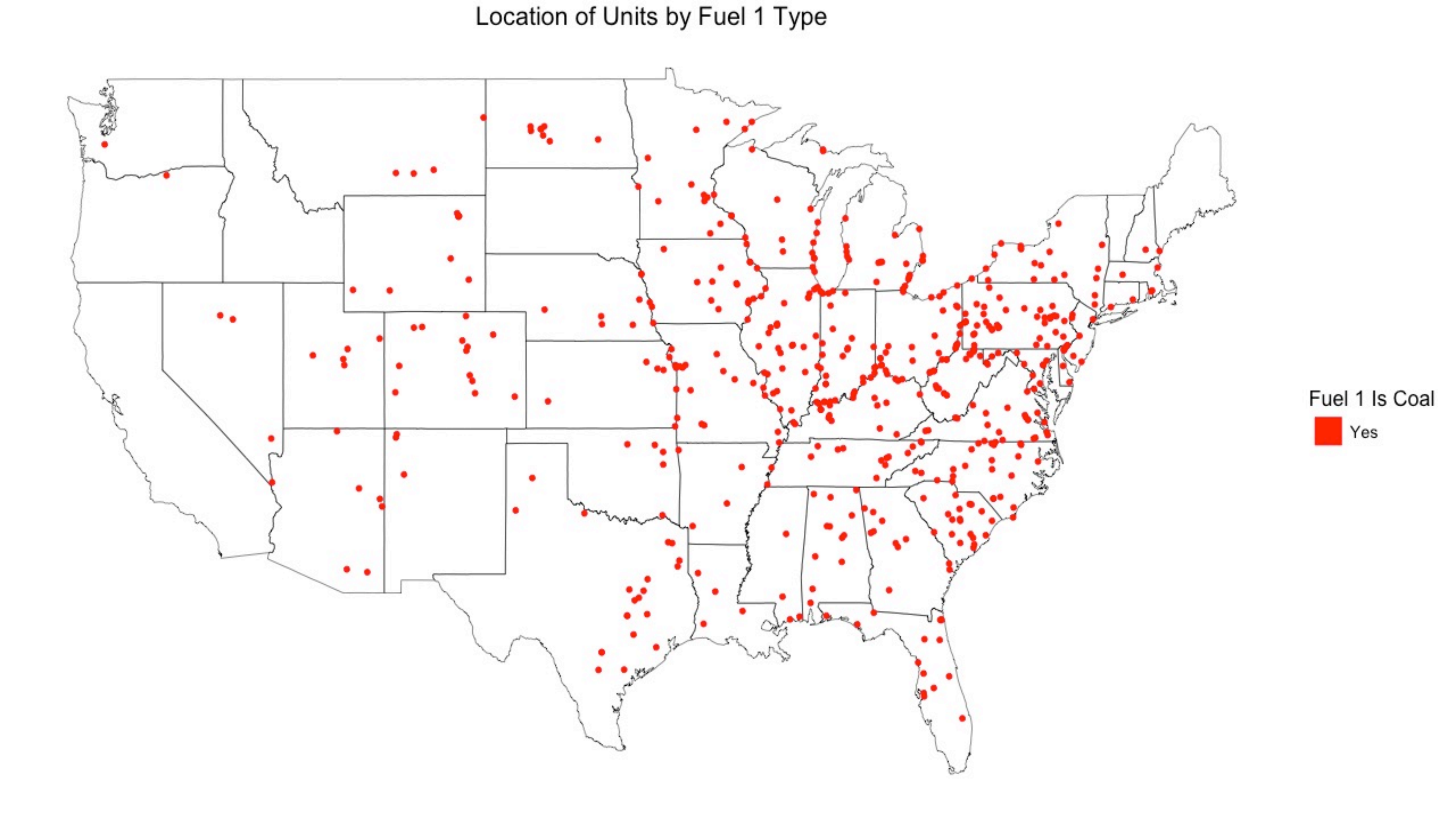

Mean SO2 emissions aggregated by year
SO2 (in tons)
10000
1000
100
10
1
0.1
0.01
0.001
1e-04
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year


2012
2008
2004
2000
1996
1992
1988
1984
1980
1976
1972
1968
1964
1960
1956
1952

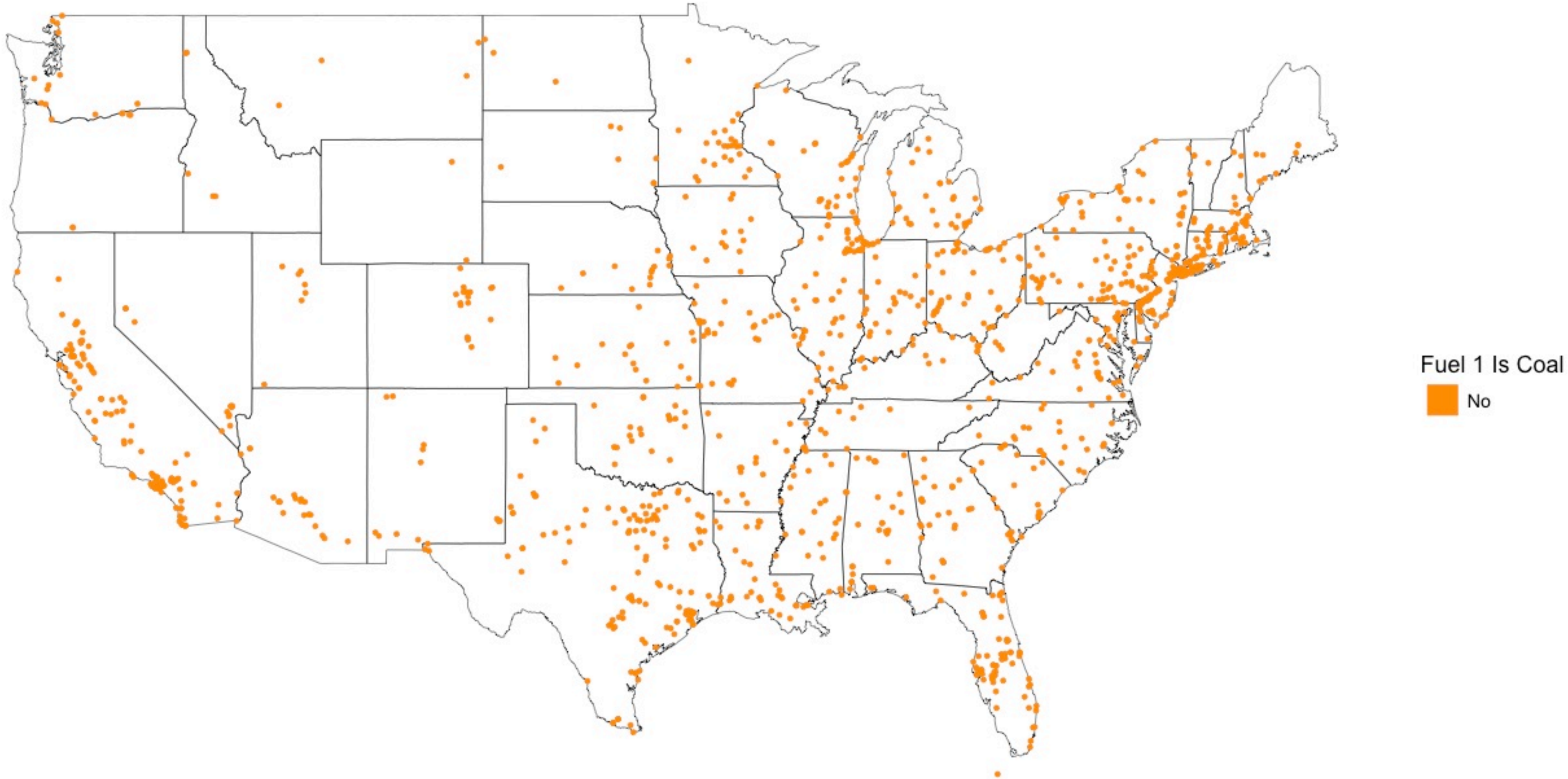
Democratic vs. Republican (State Level) - Number of Coal Power Plants Per Year



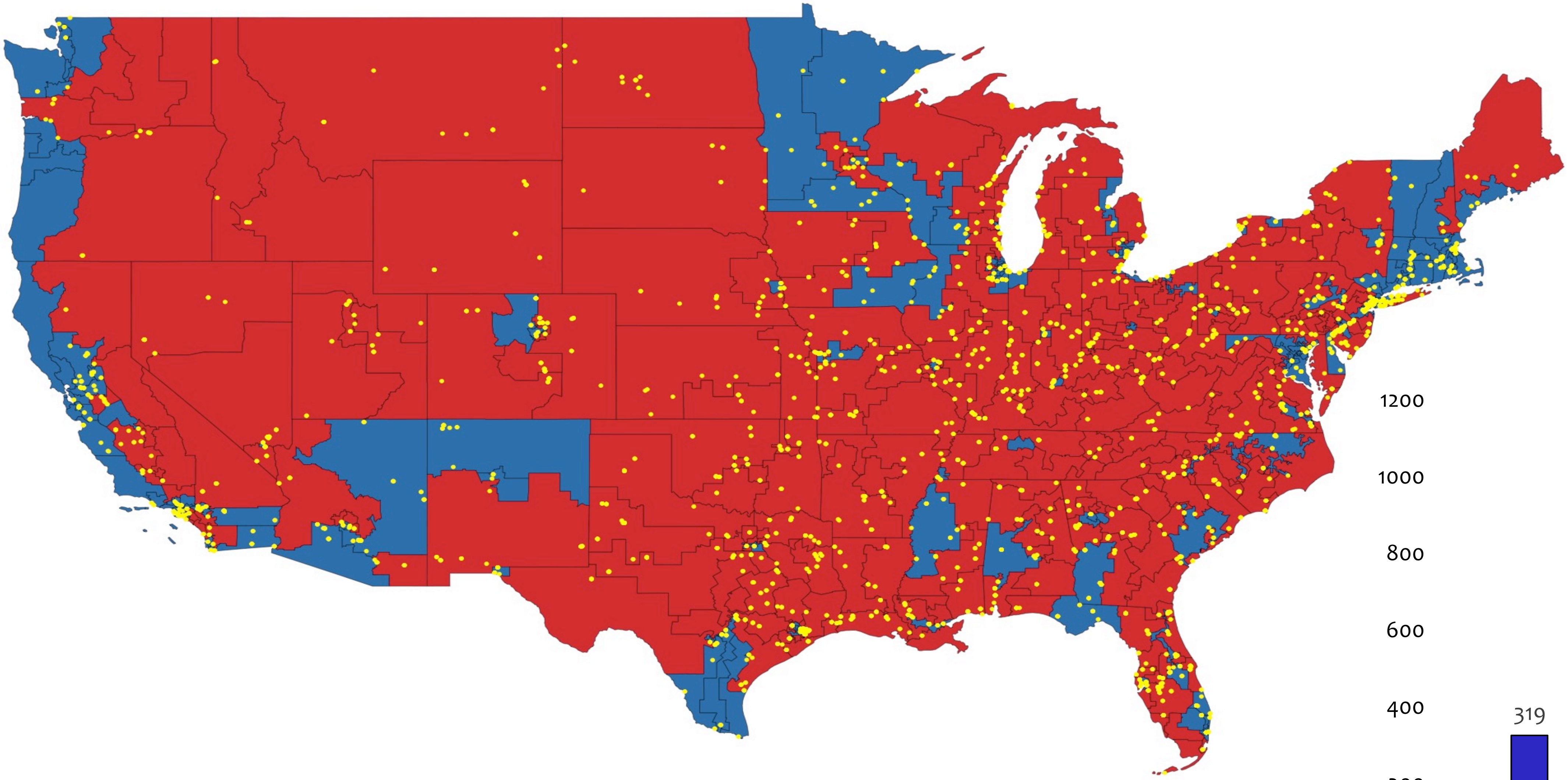
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Democratic	304	233	659	708	766	429	424	424	445	401	395	396	392	781	758	677	645	555	523	480	430
Republican	78	123	398	371	372	707	717	721	810	868	866	860	857	453	461	540	533	597	557	543	495

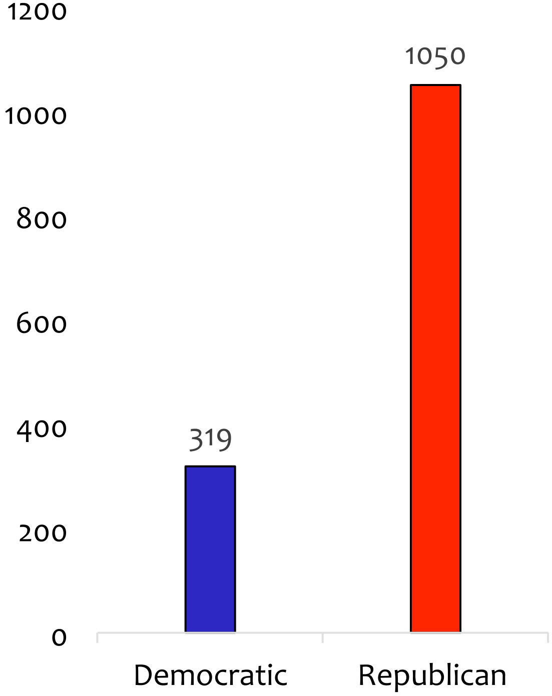

Location of Units by Fuel 1 Type
Fuel 1 Is Coal
Yes

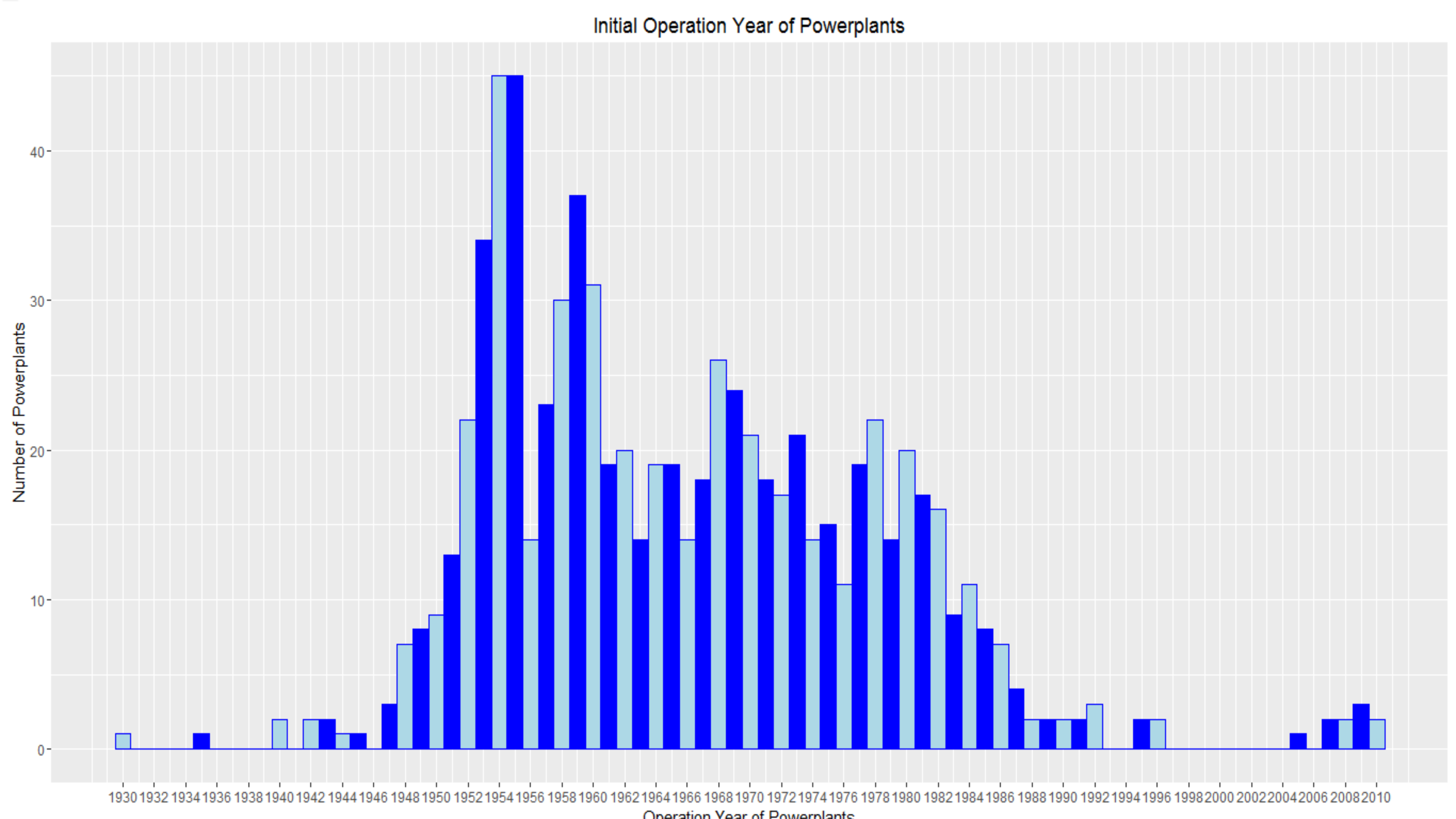
Location of Units by Fuel 1 Type



Location of Units by HoR Party in '14-'15 Congressional Years






Initial Operation Year of Powerplants
Number of Powerplants
0
10
20
30
40
1930 1932 1934 1936 1938 1940 1942 1944 1946 1948 1950 1952 1954 1956 1958 1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010
Operation Year of Powerplants