Predicting CO₂ Emissions

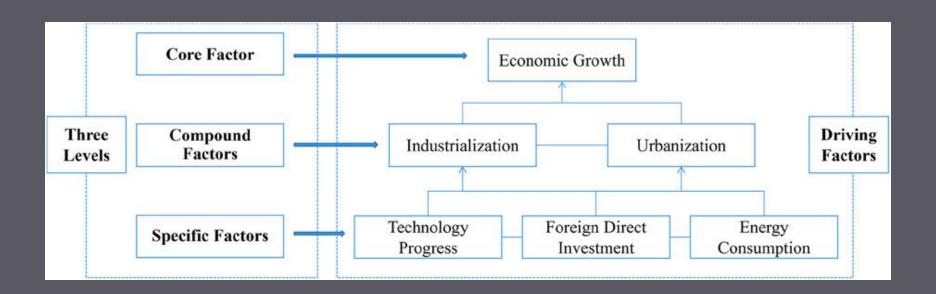
Jack Hlavka and Gabrielle Walrath STATS/DATASCI 112

Research Question

How well can we predict a country's CO, emissions?

What about if we don't use any factors relating to what type of energy it uses?

Data Collection



Our World in Data

Population Division World Urbanization Prospects 2018



FORTUNE



1	Walmart
2	Amazon
3	State Grid
4	China National Petroleum
5	Sinopec Group
6	Saudi Aramco
7	Apple
8	Volkswagen
9	China State Construction Engineering
10	CVS Health

ISO 3166-1 numeric	Landa.	Note	1950	1951	1952	1953	1954	
	World	INDIG	2 536 275	2 583 817	2 630 584	2 677 230	2 724 302	2 772 243
	More developed rea		814 865	824 213	834 074	844 284	854 632	865 069
	Less developed regis		1 721 410	1759 604	1 796 510	1 832 967	1 869 671	1 907 173
	Least developed cou		195 259	199 052	202 905	206 885	211 045	215 421
934	Less developed in		1 526 151	1 560 552	1 593 605	1 626 082	1 658 626	1 691 752
934		gions, excluding Chin		1 179 836	1 203 955	1 229 495	1 256 404	1 284 637
	High-income countri		672 896	680 630	688 859	697 440	706 262	715 241
	Middle-income course		1 734 481	1 772 394	1 808 889	1 844 730	1 880 558	1 916 892
	Lower-middle-incom		778 277	792 199	807 013	822 677	839 156	856 427
	Upper-middle-incom		956 204	980 195	1 001 876	1 022 054	1.041.402	1 080 465
	Low-income countrie		128 097	129 969	131 992	134 194	136 594	139 196
	Sub-Saharan Africa		179 621	183 039	186 626	190 378	194 295	198 380
	Africa		228 670	233 277	238 113	243 178	248 471	253 995
	Eastern Africa		228 670 66 758	68 208	238 113 69 712	71 272	72 896	74 586
	Busindi		2 309	2 359	2 404	2 445	2 487	2 531
	Comoms		2 309	2 359	2 404	2 445	2 487	2 531
			159	163	167	170	173	
	Djitouti							1 249
	Eritrea		1 142	1 160	1 180	1 201	1 224	19 947
	Ethiopia		18 128		18 820	19 184		
	Kenya		6 077	6 240	6 412	6 593	6 782	6 980
	Madagascar Malawi		4 084 2 954	4 168	4 257	4 349	4 444 3 187	4 544 3 252
								3 252
	Mauritius	- 1	493	506	521	537	554	
	Mayotte		15	16	16	17	18	
	Mozambique		6 152	6 249	6 353	6 463	6 580	6 702
	Réunion		248	259	268	277	284	
	Rwanda		2 186	2 251	2 313	2 378	2 449	2 526
	Seychelles		36	37	37	38	38	
	Somalia		2 264	2 308	2 352	2 397	2 444	2 492
	South Sudan		2 583	2 602	2 625	2 653	2 685	2 722
	Uganda		5 158	5 309	5 456	5 601	5 748	5 899
	United Republic of 1	2	7 650	7 847	8 056	8 275	8 503	8 741
	Zambia		2 310	2 367	2 428	2 494	2 562	2 634
	Zimbabwe		2 747	2 830	2 917	3 009	3 104	3 202
	Middle Africa		26 454	26 965	27 490	28 032	28 593	29 173
	Angola		4 548	4 659	4 775	4 890	5 005	5 116
120	Cameroon		4 307	4 383	4 460	4 539	4 621	4 704
140	Central African Repu	iblic	1 327	1 340	1 353	1 368	1 383	1 399

Entity	Code	Year	Annual CO, emission
Afghanistan	AFG	1949	14656
Mghanistan	AFG	1960	84272
Afghanistan	AFG	1961	91600
Afghanistan	AFG	1952	91600
Afghanistan	AFG	1953	106256
Afghanistan	AFG	1964	108258
Mghanistan	AFG	1965	153888
Afghanistan	AFG	1966	183200
Afghanistan	AFG	1957	293120
Alghanistan	AFG	1951	329760
Afghanistan	AFG	1969	384571
Mghanistan	AFG	1990	413885
Afghanistan	AFG	1961	490798
Afghanistan	AFG	1962	688594
Alghanistan	AFG	1963	706736
Afghanistan	AFG	1964	838551
Afghanistan	AFG	1965	1006917
Afghanistan	AFG	1966	1091159
Afghanistan	AFG	1967	1281865
Afghanistan	AFG	1961	1223391
Afghanistan	AFG	1903	941232
Afghanistan	AFG	1970	1670397
Mghanistan	AFG	1971	1893554
Afghanistan	AFG	1972	1530347
Afghanistan	AFG	1973	1635454
Afghanistan	AFG	1974	1913152
Afghanistan	AFG	1975	2121383
Mghanistan	AFG	1976	1980859
Afghanistan	AFG	1977	2384175
Afghanistan	AFG	1978	2153300
Afghanistan	AFG	1979	2232754
Afghanistan	AFG	1980	1756302
Afghanistan	AFG	1981	1978463
Afghanistan	AFG	1982	2094580.9
Afghanistan	AFG	1983	2519954
Afghanistan	AFG	1984	2821540
Afghanistan	AFG	1985	3501422
Afghanistan	AFG	1986	3133645
Afghanistan	AFG	1987	3113826
Afghanistan	AFG	1968	2856896
Afghanistan	AFG	1903	2764855
Afsheriaten	AFG	1993	2024326.1

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Data Analysis

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6 Australia AUS 1966 18677000 84.8 20246 100 13268875165 0 41.562 96.089 16.03 6 Australia AUS 1966 18272000 84.8 22020 100 4569052446 0 42.106 96.08 16.313 7 Australia AUS 1967 1846000 84.6 23045 100 808005992 0 43.239 96.146 15.023 8 Australia AUS 1998 18685000 85.5 21.176 100 759751028 0 44.139 96.246 15.023 10 Australia AUS 1969 1868000 84.4 2008 100 221037916 0 44.911 96.233 15.742 11 Australia AUS 2000 19066000 84.2 21853 100 14892375160 0 45.039 96.241 15.649 11 Australia AUS 2001 19280000 84.1 1998 100 10777133150 0 44.177 96.00 11.724 11 Australia AUS 2002 19475000 84.2 20291 100 14695237500 0 44.517 96.00 11.724 13 Australia AUS 2003 1987000 84.3 22705 100 889524029 0 45.10 96.341 196.39 14 Australia AUS 2004 1948000 84.5 30819 100 4589532800 0 45.10 96.275 116.339 15 Australia AUS 2004 20374000 84.5 30819 100 4589532800 0 45.00 96.24 116.039 16 Australia AUS 2004 20374000 84.5 30819 100 889524029 0 45.00 96.24 116.039 17 Australia AUS 2006 20374000 84.7 36570 100 30551100566 0.063 43.576 96.146 17.747 16 Australia AUS 2007 20977000 84.6 41023 100 4440000007 0.239 43.046 96.19 10.226 17 Australia AUS 2008 2124000 85.9 40979 100 30551100566 0.063 43.376 96.146 17.747 16 Australia AUS 2008 2124000 85.9 40979 100 30551100566 0.063 43.576 96.14 11.509 19 Australia AUS 2008 2124000 85.2 62134 100 3551100566 0.063 43.576 96.14 11.509 10 Australia AUS 2016 2220000 85.2 62134 100 3551100566 0.063 43.576 96.14 195.48 11.509 10 Australia AUS 2016 22120000 85.3 6.596 100 6556490649 1.726 37.14 93.74 93.596 22.43 20 Australia AUS 2016 22120000 85.5 6819 100 6556490649 1.726 33.266 93.756 22.513 21 Australia AUS 2016 2242000 85.6 6819 100 6556490649 1.726 33.266 93.756 22.513 22 Australia AUS 2016 2242000 85.8 6875 100 6556490649 1.726 33.266 93.756 22.513 23 Australia AUS 2016 2242000 85.8 6875 100 6556490649 1.004 33.414 99.14 23.500 24 Australia AUS 2016 2242000 85.8 6875 100 6556490647 1.005 33.076 93.756 22.513 24 Australia AUS 2016 2247000 85.8 6875 100 6659006	4.346 37.79
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19 Australia AUS 2010 2210000 85.2 62134 100 35210733743 1.255 39.77 94.963 22.123 20 Australia AUS 2011 22400000 85.3 62596 100 65554800449 1.276 37.415 93.707 22.299 21 Australia AUS 2012 2322000 85.4 68044 100 75750426822 1.1572 35.474 93.359 22.643 22 Australia AUS 2013 23151000 85.5 68158 100 54465480054 1.084 33.414 93.14 23.606 23 Australia AUS 2014 22475000 85.6 62513 100 63207272079 1.025 32.667 93.756 22.103 24 Australia AUS 2015 2380000 85.7 65710 100 45892808567 0.917 33.326 93.756 25.103 25 Australia AUS 2016 24128000 85.8 49875 100 4296960135 0.776 33.045 92.793 25.535 26 Australia AUS 2016 24128000 85.8 49875 100 4296960135 0.776 33.045 92.793 25.535 26 Australia AUS 2017 24451000 85.9 63936 100 44596808547 0.917 33.326 92.793 25.535 26 Australia AUS 2017 24451000 85.9 63936 100 4459680747 0.9592 30.764 91.847 24.873 28 Australia AUS 2018 2218 22679000 86.1 54941 100 38959497515 0.87 27.819 91.43 33.144	3.852 33.4
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20 Australia AUS 2011 22480000 85.3 62596 100 65554890645 1.276 37.415 93.707 22.299 21 Australia AUS 2012 22820000 85.4 68044 100 67556489262 1.192 33.457 93.859 22.643 22 Australia AUS 2015 2315000 85.5 68198 100 54465460054 1.084 33.414 93.14 23.806 22 Australia AUS 2016 22475000 85.6 62513 100 63207278079 1.025 32.667 93.756 22.513 24 Australia AUS 2016 22800000 85.7 56710 100 48290278079 1.025 32.667 93.756 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.97 25.9	5.037 33.07
21 Australia ALS 2012 22822000 85.4 680.44 100 37550-428622 1.152 35.47 93.859 22.643 22 Australia ALS 2013 23151000 85.5 68158 100 65465540000 1.025 32.467 93.756 22.5006 23 Australia ALS 2014 22475000 85.6 62513 100 63202728076 1.025 32.667 93.756 22.5103 24 Australia ALS 2015 22800000 85.7 66710 100 64892808667 0.917 33.269 32.469 25.57 25.67 25 Australia ALS 2016 242000 85.8 48975 10.0 4289680615 0.776 33.646 92.793 25.515 26 Australia ALS 2017 24451000 85.9 53936 100 4319864224 0.476 31.577 93.115 25.249 27 Australia ALS 2018 2477200 86 5727 100 6088590478 0.952 30.764 91.647 24.673 24.673 28 Australia ALS 2018 2477200 86 5727 100 6088590478 0.952 30.764 91.647 24.673 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.87 27.719 91.143 30.144 10.0 38956497515 0.97 27.719 91.143 30.144 10.0 38956497515 0.97 27.719 91.143 30.0 38056497515 0.97 27.719 91.143 30.0 38056497515 0.97 27.719 91.143 30	6.293 33.99
23 Australia AUS 2014 23475000 8.5.8 482513 100 632027281075 1.025 32.867 93.756 25.103 24 Australia AUS 2016 23800000 85.7 66710 100 46982808667 0.917 33.326 93.496 22.537 25.807 25 Australia AUS 2016 242000 85.8 48975 100 42806805135 0.776 33.645 92.793 25.535 26 Australia AUS 2017 24451000 85.9 63936 100 4819864324 0.878 31.977 93.115 25.289 27 Australia AUS 2018 2477200 86 57207 100 60685908478 0.952 30.764 91.647 24.873 28 Australia AUS 2019 25098000 86.1 54041 100 38950497515 0.87 27.919 91.433 30.184	6.141 35.74
24 Australia AUS 2015 23800000 85.7 56710 10 46892208567 0.917 33.326 93.496 25.97 25 Australia AUS 2016 24120000 85.8 49875 100 4289656115 0.776 33.045 92.793 25.535 26 Australia AUS 2017 24451000 85.9 5398 10 48198614234 0.876 31.977 93.117 93.117 25.289 27 Australia AUS 2018 24772000 86 67207 100 6088590478 0.952 30.764 91.647 24.873 28 Australia AUS 2019 25889000 86.1 54941 10 38956497519 0.87 27.819 91.43 30.184	6.86 36.11
25 Australia AUS 2016 24126000 85.8 49875 100 42969506135 0.776 33.045 92.793 25.535 26 Australia AUS 2017 24451000 85.9 53936 100 4519641224 0.476 31.577 93.115 25.289 27 Australia AUS 2018 2477200 86 5727 100 6068590478 0.592 30.764 91.647 24.873 28 Australia AUS 2019 25099000 86.1 54941 100 38955497519 0.87 27.819 91.433 30.184	6.244 35.98
26 Australia AUS 2017 24451000 85.9 53936 100 48198614234 0.878 31.977 93.115 25.289 27 Australia AUS 2018 24772000 86 57207 100 60685908476 0.952 30.764 91.647 24.873 28 Australia AUS 2019 25089000 86.1 54641 100 38955497515 0.87 27.819 91.433 30.184	6.504 34
27 Australia AUS 2018 24772000 86 57207 100 60885908476 0.952 30.764 91.647 24.873 28 Australia AUS 2019 25089000 86.1 54941 100 38955497515 0.87 27.819 91.433 30.184	7.207 34.21
28 Australia AUS 2019 25089000 86.1 54941 100 38959497515 0.87 27.819 91.433 30.184	6.885 35.84
28 Australia AUS 2019 25089000 86.1 54941 100 38959497615 0.87 27.819 91.433 30.184	8.353 36.0
	8.567 33.4
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43 celand ISL 1994 265000 91.5 24018 100 2394198 0 2.821 40.389 0	59.611 37.56
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45 Iceland ISL 1997 273000 92 27919 100 148012830 0 2.976 39.155 0	60.845 36.17
46 Iceland ISL 1998 275000 92.1 31030 100 154082591 0 2.47 36.741 0	63.259 34.27
47 Iceland ISL 1969 278000 92.3 32381 100 66639312 0 2.637 33.872 0	66.128 31.23
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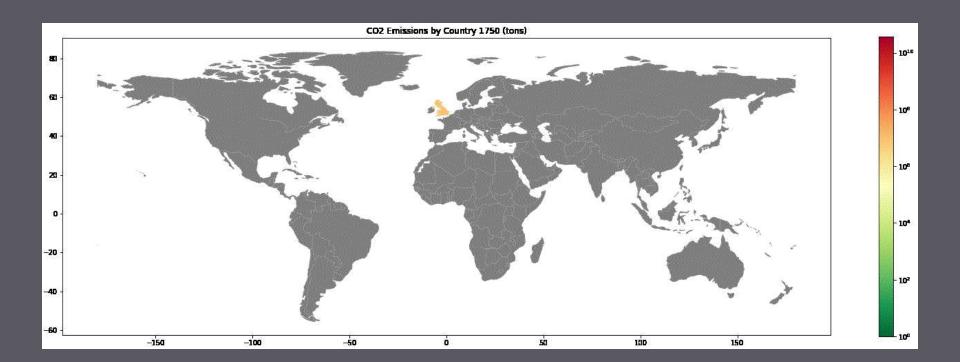
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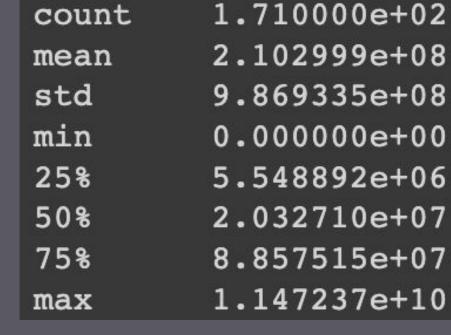
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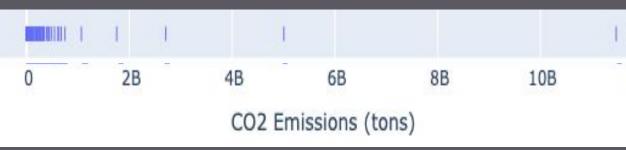
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CO₂ Emissions







Predicting Variables

1 Population

Foreign Direct Investment

2 GDP Per Capita

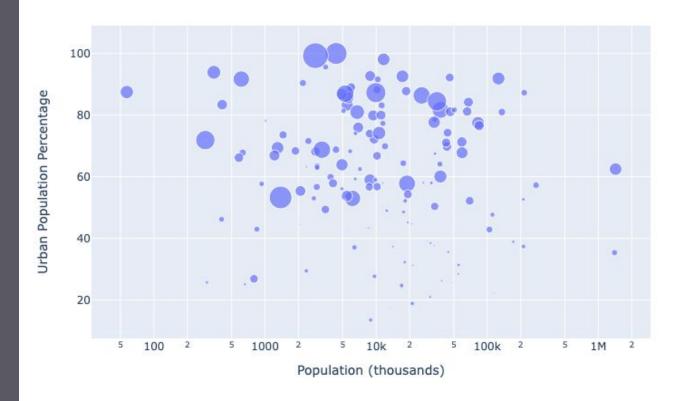
Fortune Global 500 Companies

Electrification

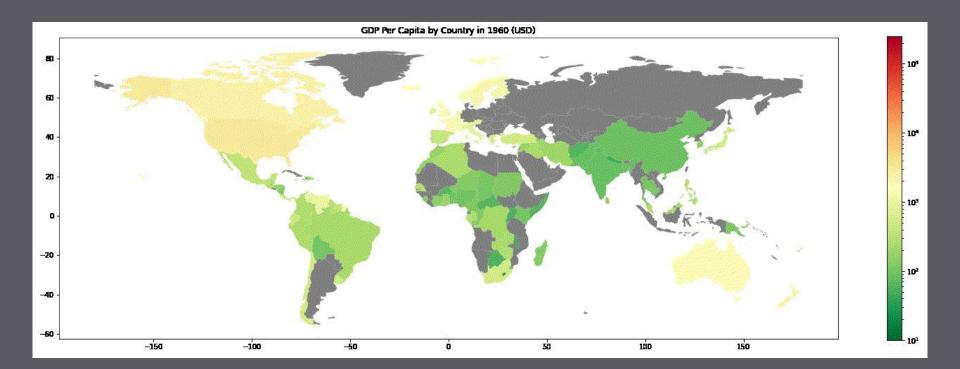
6 Energy Sectors

01 Population

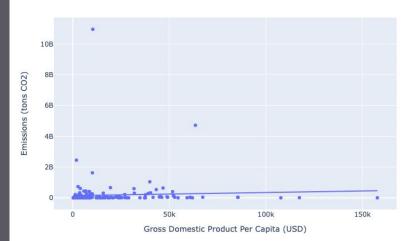
Per Capita Emissions vs Population and Urban Population Percentage



02 GDP Per Capita



Emissions vs GDP Per Capita

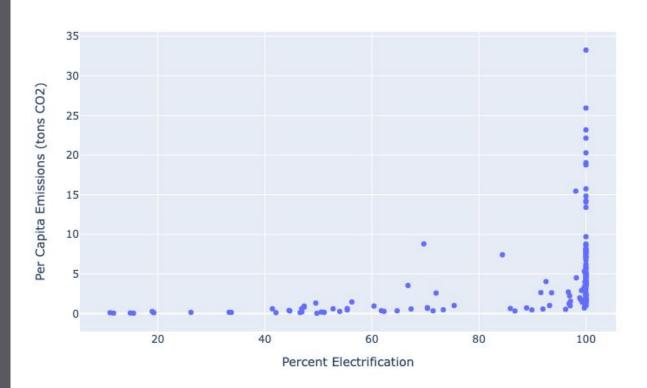


Per Capita Emissions vs GDP Per Capita



03 Electrification

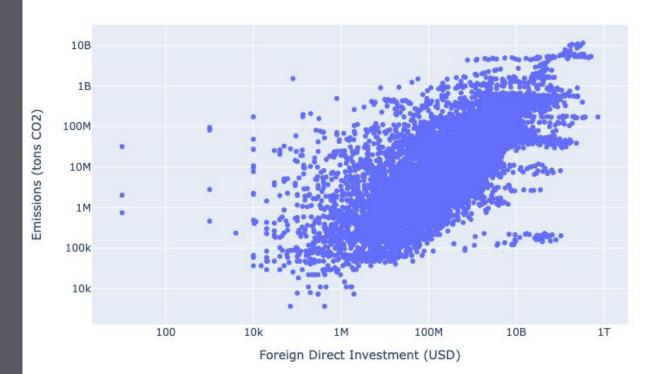
Electrification vs Per Capita Emissions



04

Foreign Direct Investment

FDI vs Emissions



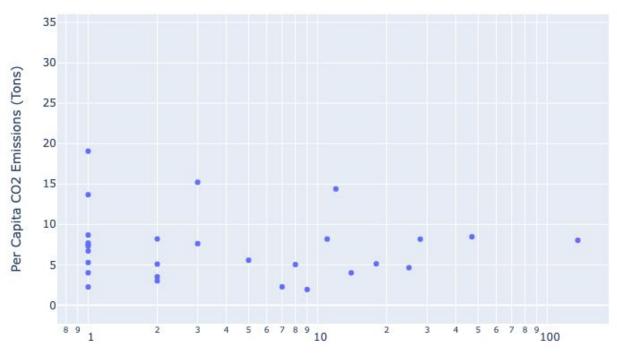
05

Fortune Global 500 Companies

Fortune Global 500 Countries by City

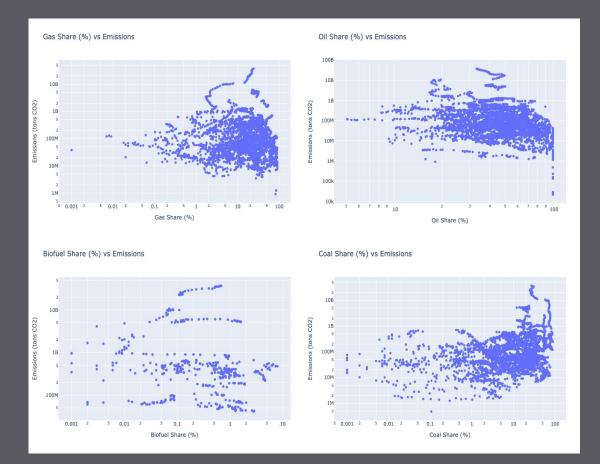


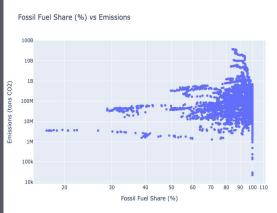
Fortune 500 Companies vs Per Capita Emissions



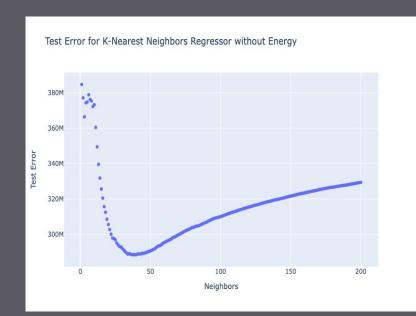
Number of Fortune Global 500 Companies

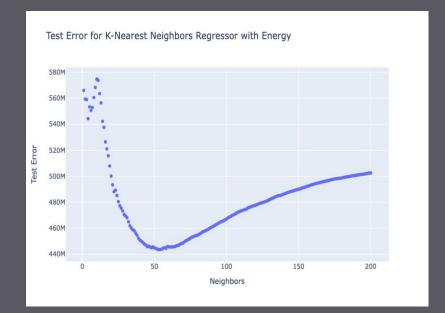
06Energy Sectors





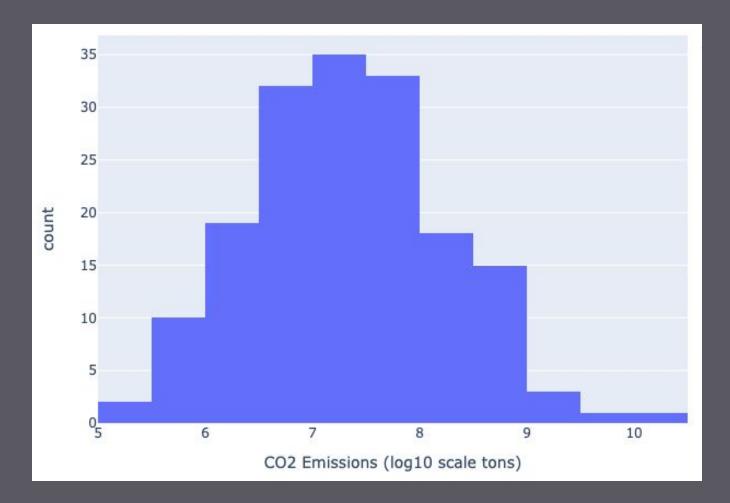
Machine Learning





	Without Energy Data	With Energy Data
K-Nearest Neighbors	2.9 x 10 ⁸ tons CO2	4.4 x 10 ⁸ tons CO ₂
Linear Regression	4.4 x 10 ⁸ tons CO ₂	7.9 x 10 ⁸ tons CO ₂
Voting Ensemble	3.3 x 10 ⁸ tons CO ₂	5.6 x 10 ⁸ tons CO ₂
XGBoost	3.2 x 10 ⁸ tons CO ₂	6.4 x 10 ⁸ tons CO ₂
XGBoost with Hyperparameter Tuning	2.7 x 10 ⁸ tons CO ₂	5.1 x 10 ⁸ tons CO ₂

Log Normal Distribution



	Without Energy Data	With Energy Data
K-Nearest Neighbors	0.711	0.411
Linear Regression	0.846	0.423
Voting Ensemble	0.739	0.374
Stacking Ensemble	0.707	0.385
XGBoost	0.325	0.268
XGBoost with Hyperparameter Tuning	0.301	0.258

Accuracy

Normal RMSE

RMSE > Mean

RMSE ≈ 30% std

ML is about 3x as accurate as guessing the average value

Log Scale RMSE

RMSE = 0.258

ML is within a factor of 2 on average

Questions?