Kentucky Energy Data & Modeling

Presentation to the

University of Kentucky

Patterson School of Diplomacy and International Commerce

DIP 735-Energy Security

April 16th, 2015

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Kentucky Energy and Environment Cabinet

Department for Energy Development and Independence

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Facebook: **facebook.com/KentuckyDEDI**

Website: **energy.ky.gov**

Overview

- **Kentucky Renewable Energy Potential:** *Limited*
- **Kentucky Coal Production & Employment:** *Declining*
- **Kentucky's Electricity Portfolio Today:** *Coal*
- **Electricity Expenditures as a Percentage of Household Income:** *It's a lot*
- **United States Electricity Prices, 1998-2012:** *Going up*
- **Another Significance of Electricity to the United States:** *Manufacturing*
- **The Mathematics behind the Models:** $Y_{it} = \beta_0 + \sum_{j=1}^{k-1} \beta_j X_{jit} + \alpha_i + \varepsilon_{it}$!
- **Portfolio Model Exercise**

Kentucky Renewable Energy Potential

Wind Resources

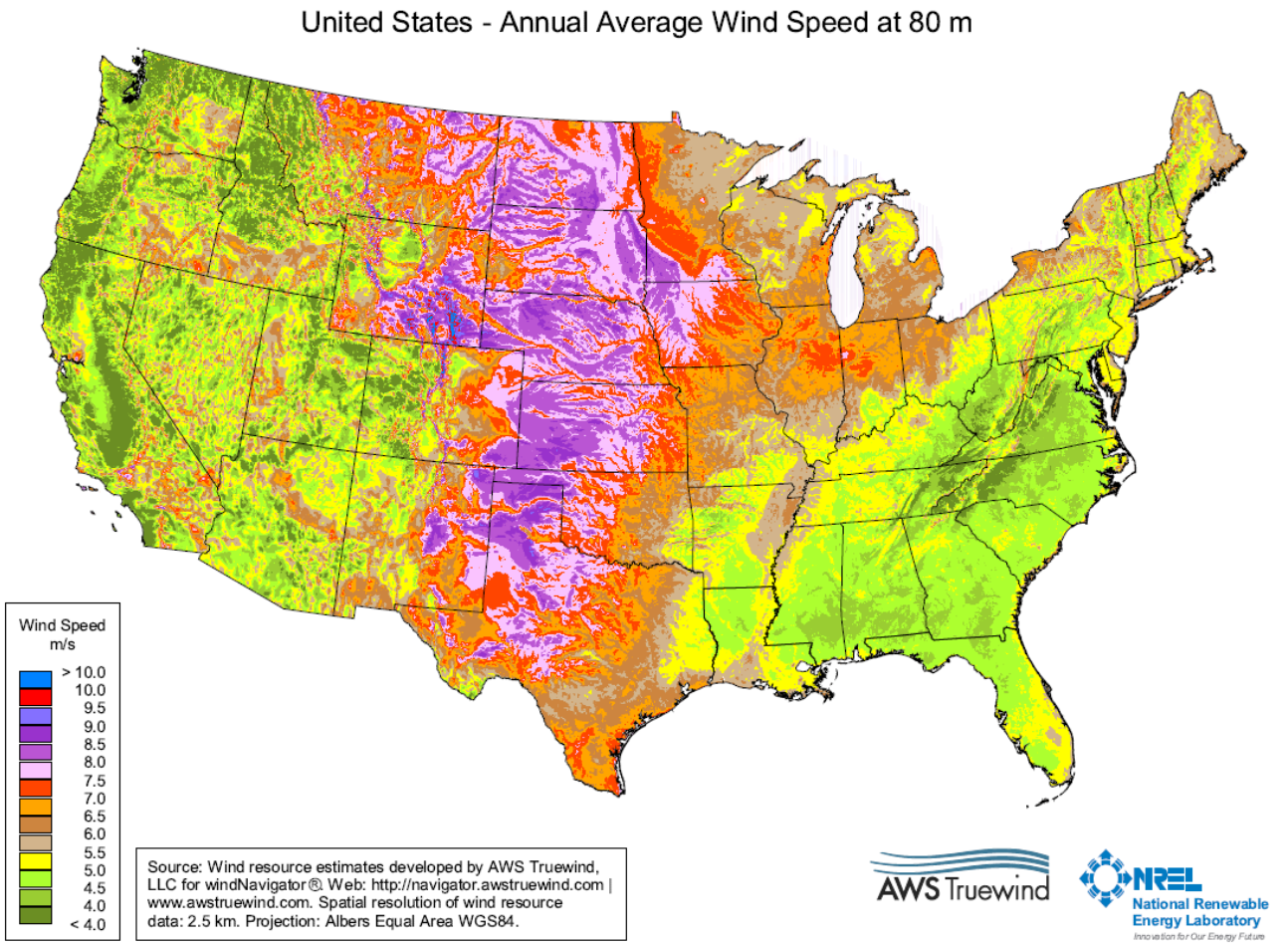
Photo: Kentucky Energy and Environment Cabinet Staff, Buffalo Mountain Wind Farm, Tennessee, 2010.

Wind Resources

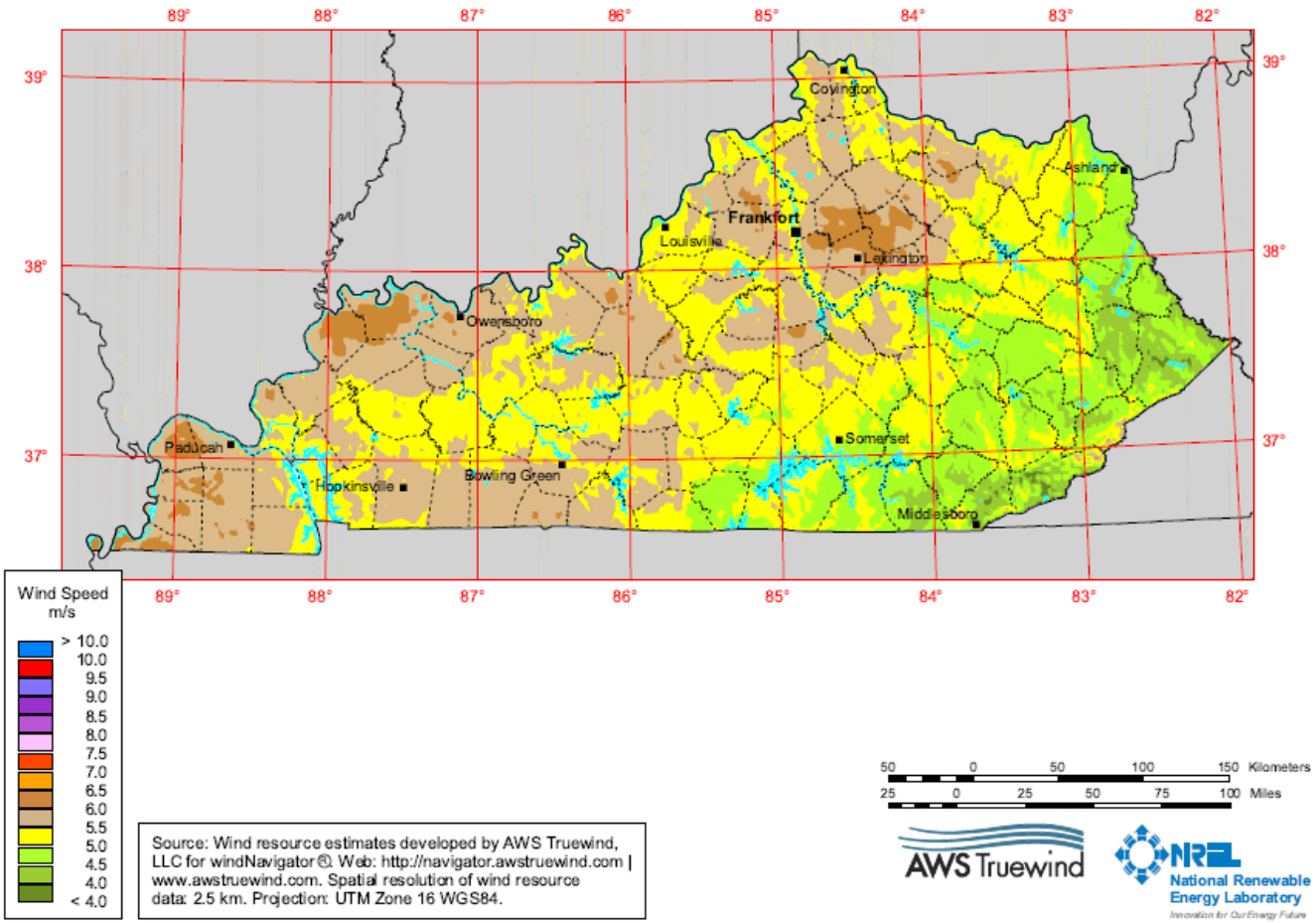
EEC Staff Video of Buffalo Mountain Wind farm in Tennessee

Photo: Kentucky Energy and Environment Cabinet Staff, Buffalo Mountain Wind Farm, Tennessee, 2010.

Wind Resources

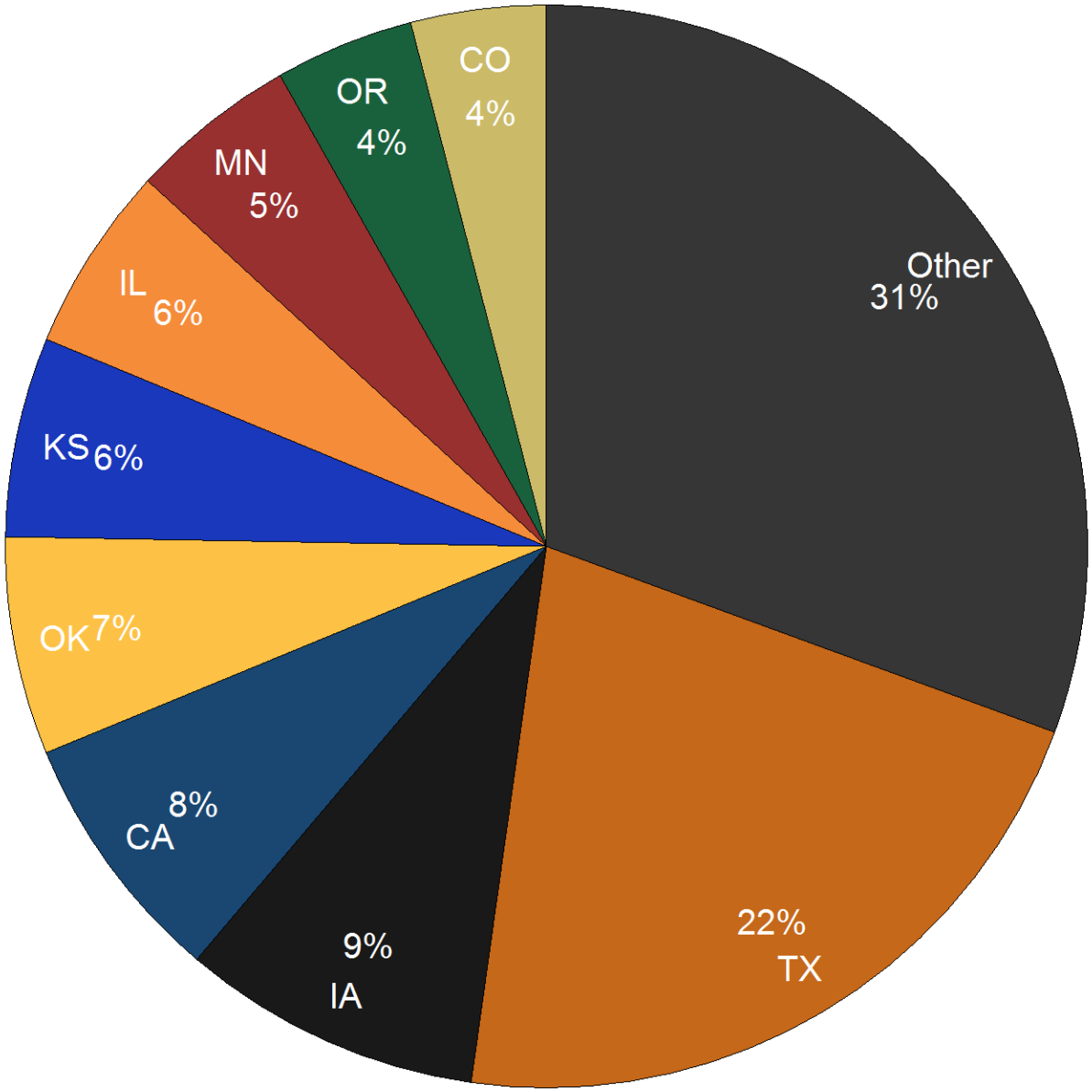


Wind Resources



EEC Staff Video of Buffalo Mountain Wind farm in Tennessee

Wind Generation in the United States, 2014

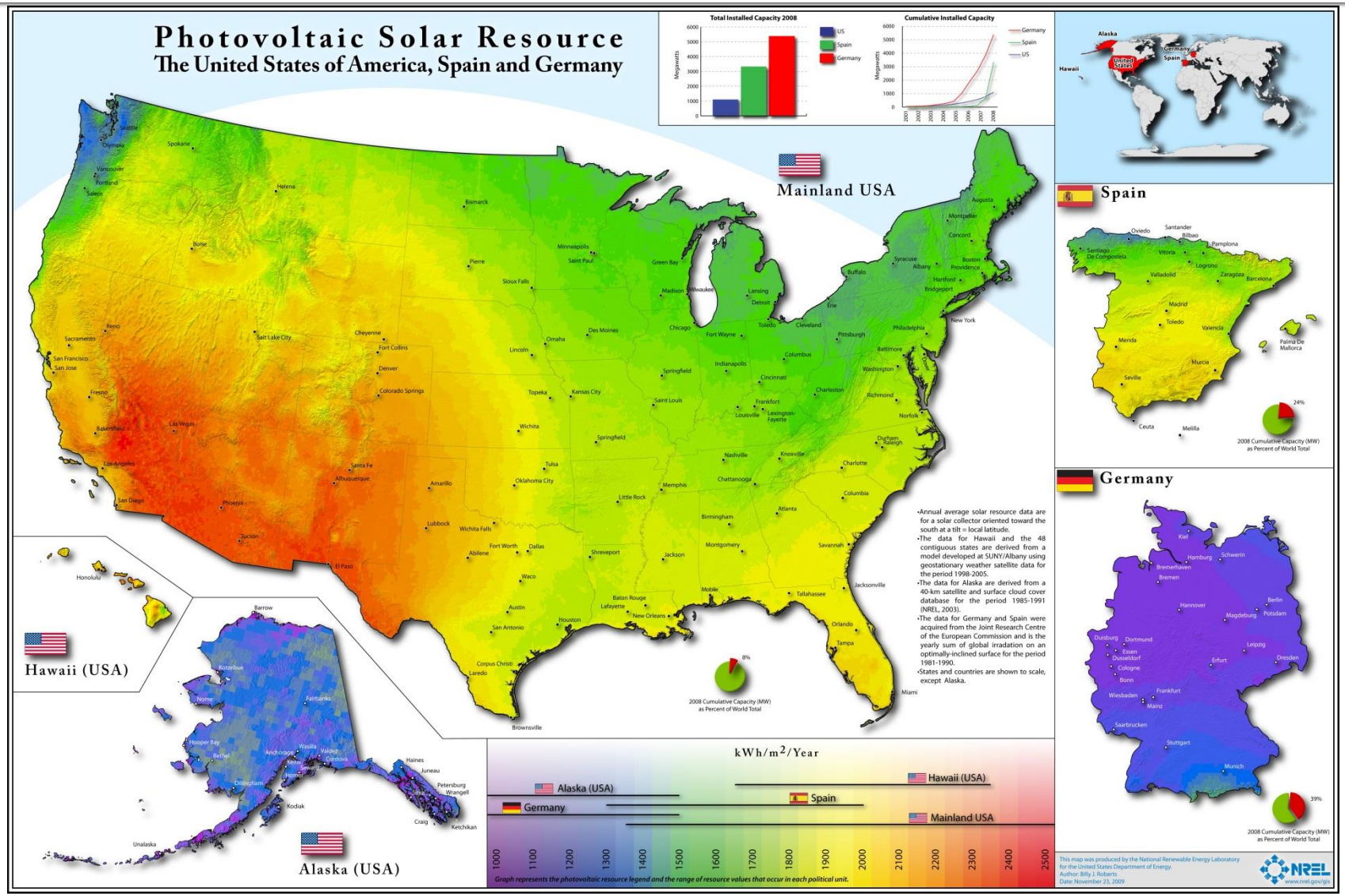


Kentucky Energy Database, EEC-DEDI, 2015

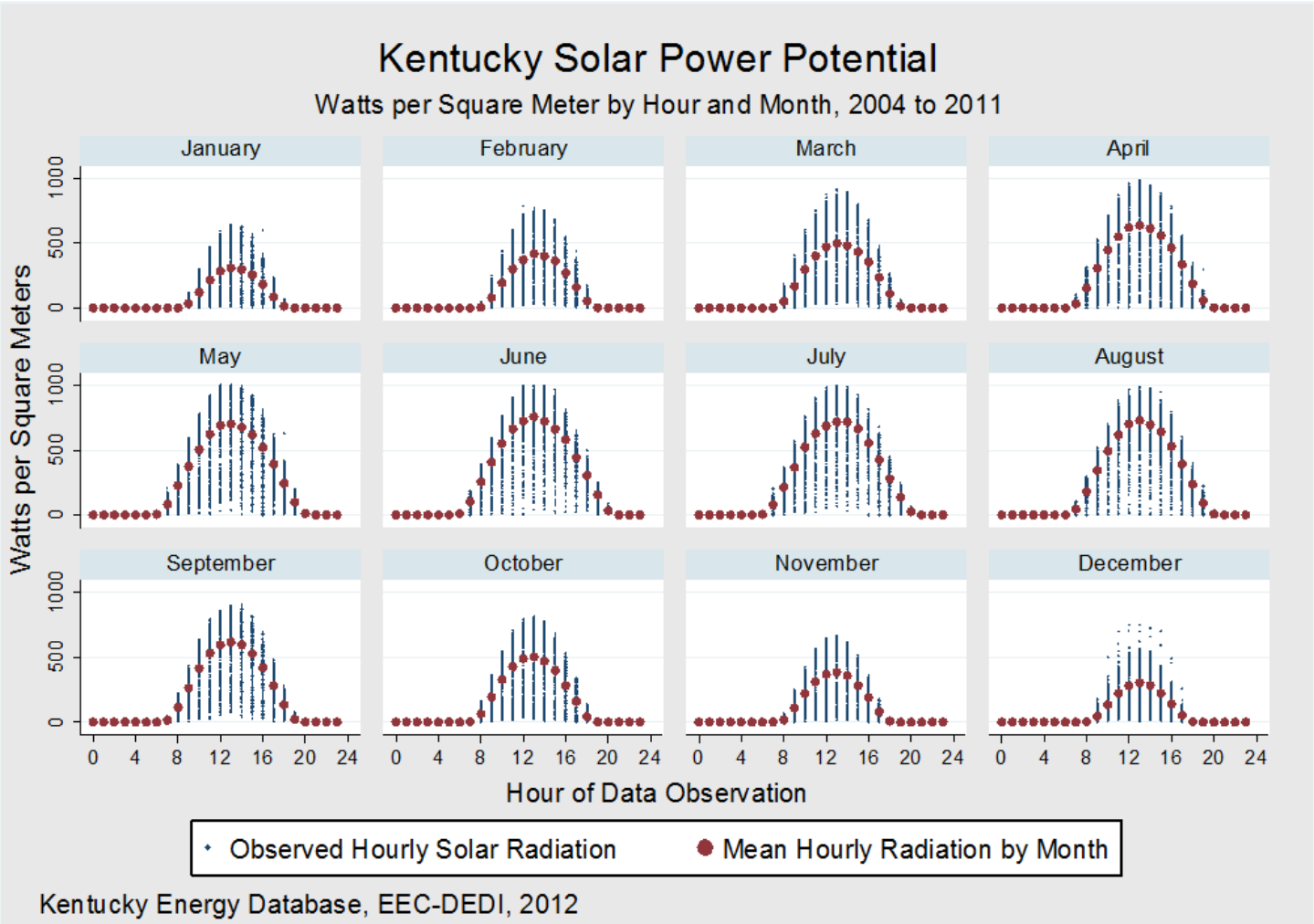
Solar Resources

Photo: University of Kentucky S·KY Blue Solar House at the Solar Decathlon in Washington D.C., 2009

Solar Resources



Solar Resources



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Solar Resources

Kentucky Average Maximum Achievable Solar Capacity Factors, 2004-2011													
Hour	Annual		January	February	March	April	May	June	July	August	September	October	November	December
24/7	14.85%		6.60%	9.60%	12.87%	18.20%	21.10%	23.34%	22.09%	20.91%	16.56%	12.27%	8.47%	6.14%
5:00	0.000%		0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
6:00	0.196%		0.000%	0.000%	0.000%	0.012%	0.673%	1.192%	0.525%	0.024%	0.000%	0.000%	0.000%	0.000%
7:00	2.997%		0.000%	0.000%	0.115%	3.261%	8.242%	10.378%	7.927%	4.402%	1.355%	0.259%	0.000%	0.000%
8:00	10.651%		0.210%	0.656%	4.967%	15.233%	22.615%	25.471%	21.379%	17.934%	11.319%	6.276%	1.541%	0.080%
9:00	22.358%		3.412%	7.930%	16.790%	30.558%	37.324%	40.458%	36.529%	34.413%	26.143%	19.309%	10.667%	4.435%
10:00	35.151%		12.071%	19.269%	29.657%	44.536%	50.266%	54.952%	52.302%	49.250%	41.347%	32.614%	21.920%	13.331%
11:00	45.633%		21.521%	30.015%	40.180%	54.893%	62.083%	66.078%	62.548%	61.545%	52.872%	42.529%	30.914%	22.198%
12:00	52.219%		28.232%	37.108%	46.994%	62.072%	68.977%	72.146%	68.565%	69.879%	59.308%	48.674%	36.653%	27.839%
13:00	54.647%		30.928%	41.754%	49.742%	63.652%	69.912%	75.576%	71.583%	72.809%	61.501%	50.065%	38.182%	29.999%
14:00	52.430%		29.661%	40.038%	48.129%	61.288%	67.462%	71.968%	71.549%	69.383%	59.444%	46.759%	35.593%	28.040%
15:00	46.760%		25.494%	36.249%	43.110%	55.708%	61.769%	66.218%	66.383%	63.844%	52.556%	39.604%	28.153%	21.972%
16:00	37.260%		18.213%	26.923%	36.366%	46.214%	51.793%	57.906%	55.296%	52.742%	41.795%	28.159%	18.733%	13.908%
17:00	25.275%		8.653%	16.055%	23.433%	33.288%	39.210%	44.043%	42.394%	39.128%	28.148%	15.850%	7.701%	5.212%
18:00	13.378%		1.339%	5.230%	10.832%	18.635%	24.233%	33.032%	27.881%	23.669%	13.263%	4.091%	0.588%	0.209%
19:00	4.833%		0.000%	0.150%	1.492%	5.810%	9.846%	15.339%	13.753%	9.173%	2.097%	0.055%	0.000%	0.000%
20:00	0.669%		0.000%	0.000%	0.000%	0.095%	1.144%	3.249%	2.722%	0.765%	0.002%	0.000%	0.000%	0.000%
21:00	0.001%		0.000%	0.000%	0.000%	0.000%	0.000%	0.005%	0.003%	0.000%	0.000%	0.000%	0.000%	0.000%
22:00	0.000%		0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

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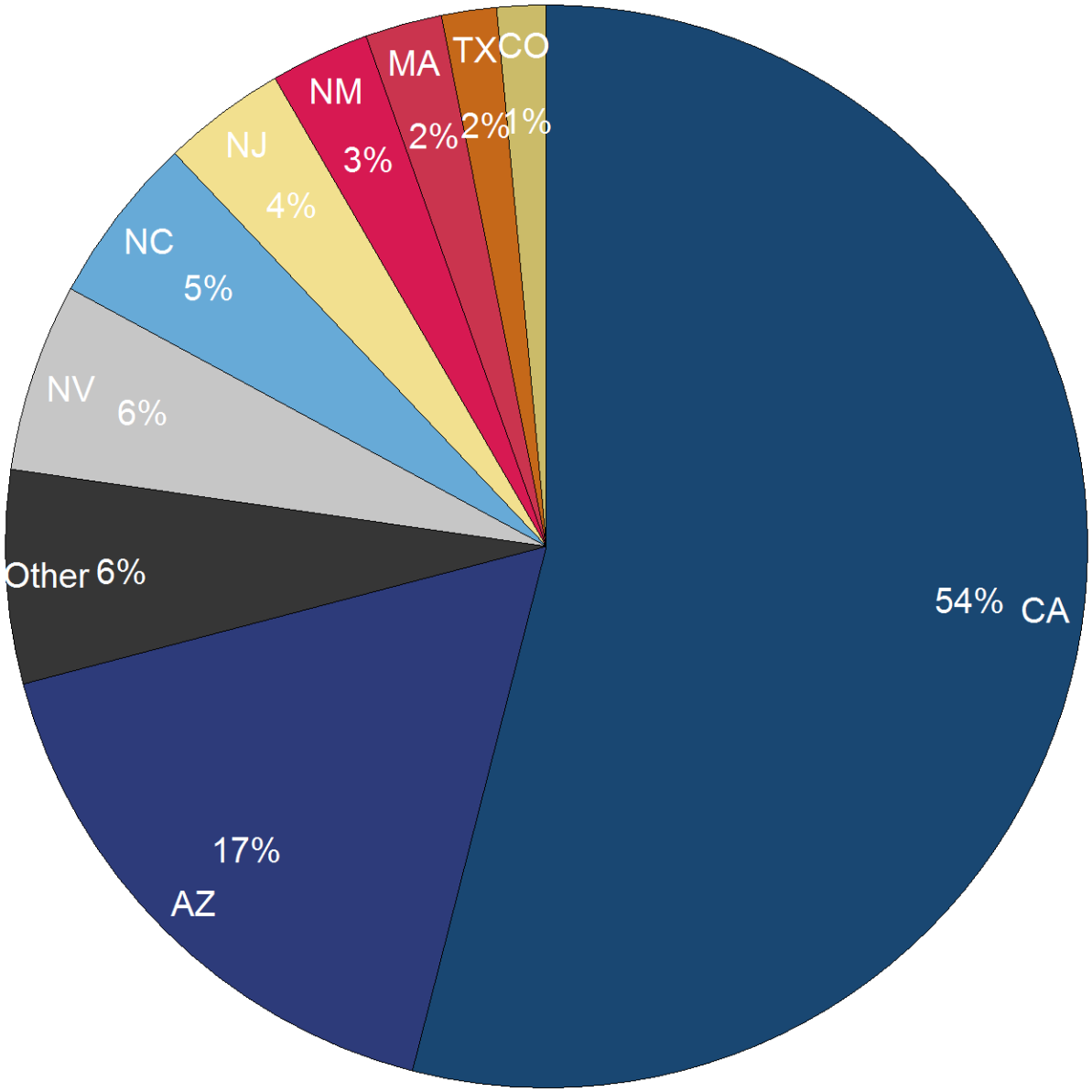
Solar Generation in the United States, 2014

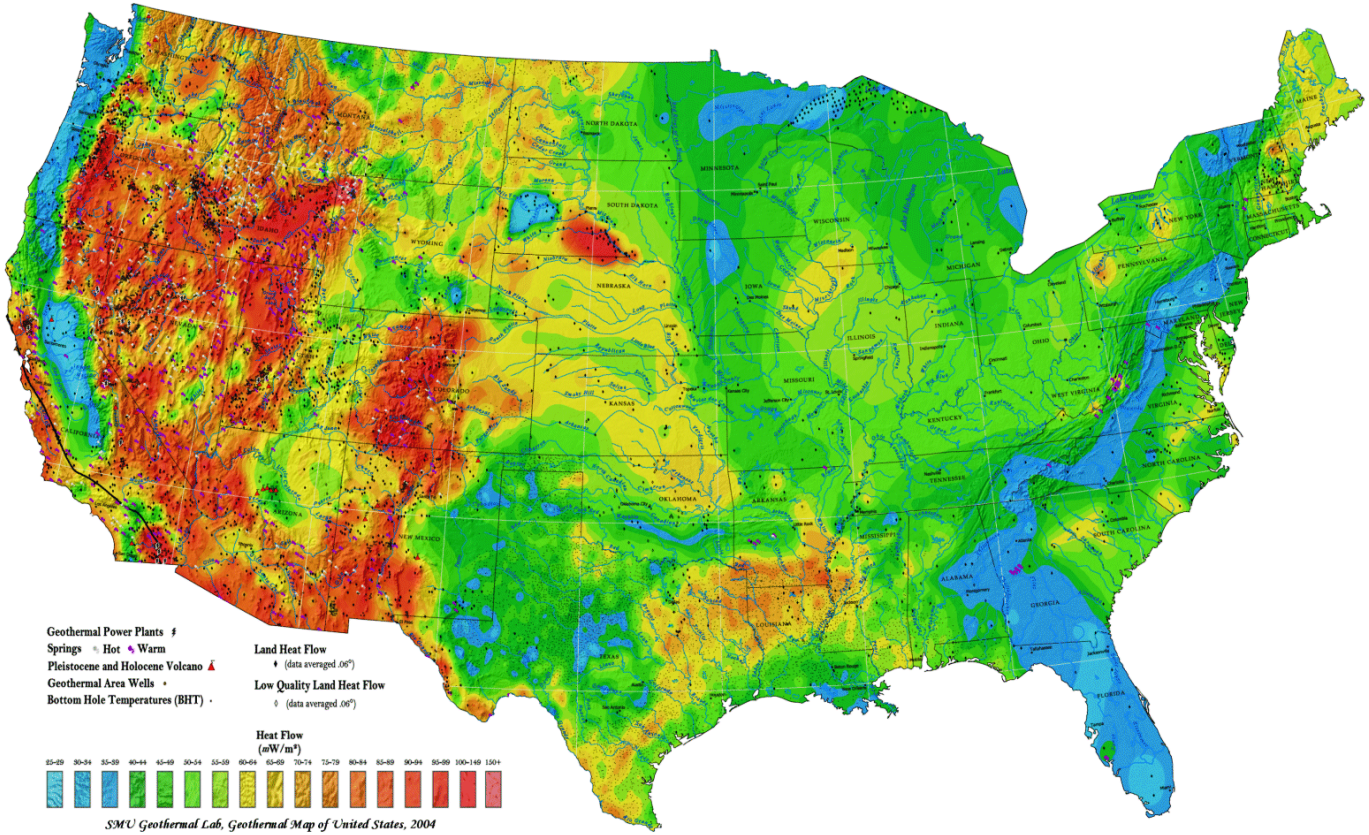


Kentucky Energy Database, EEC-DEDI, 2015

Geothermal Resources

Photo: Nesjavellir Geothermal Power Station in Iceland. Wikimedia Commons.

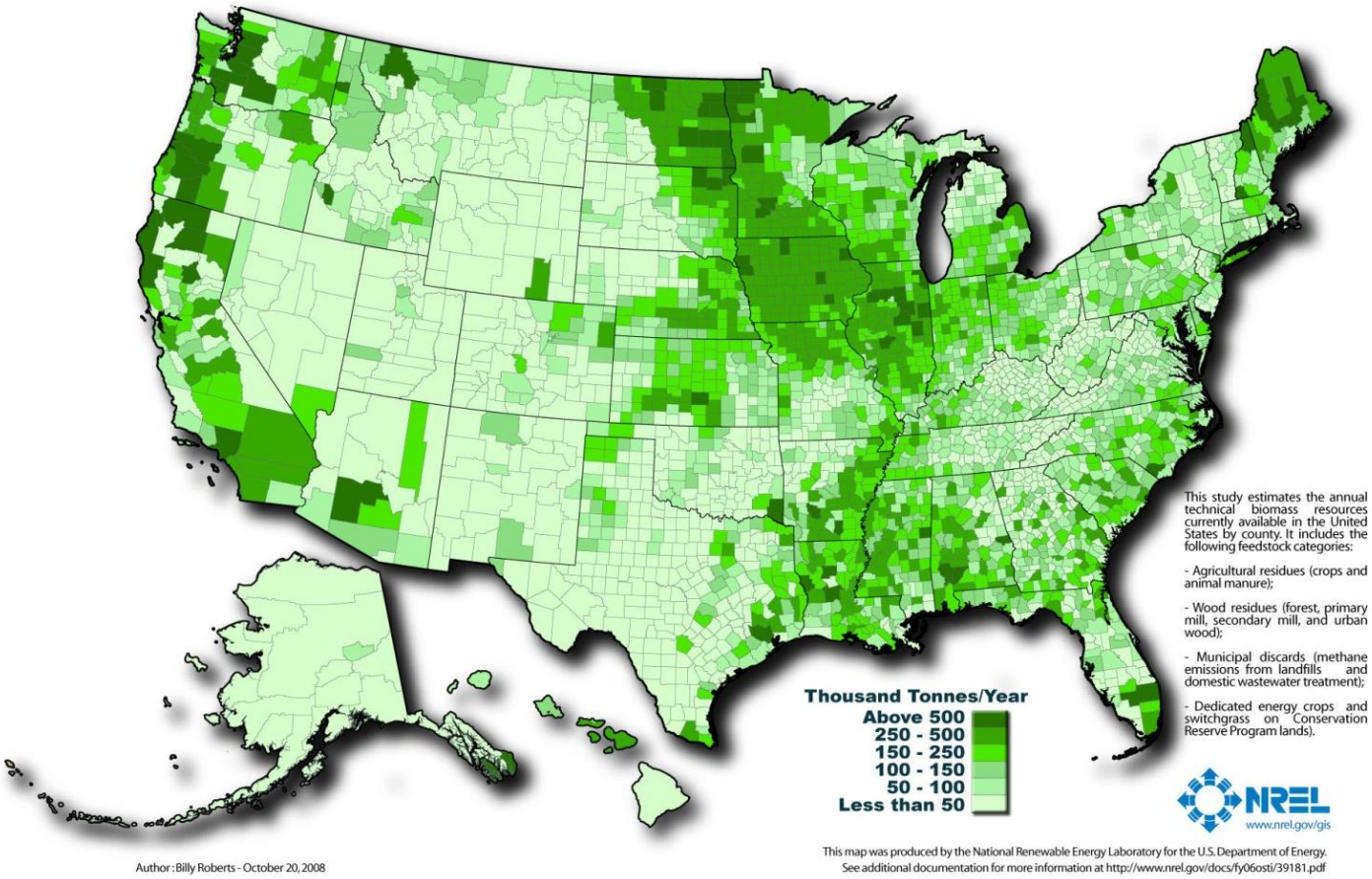
Geothermal Resources



Biomass Resources

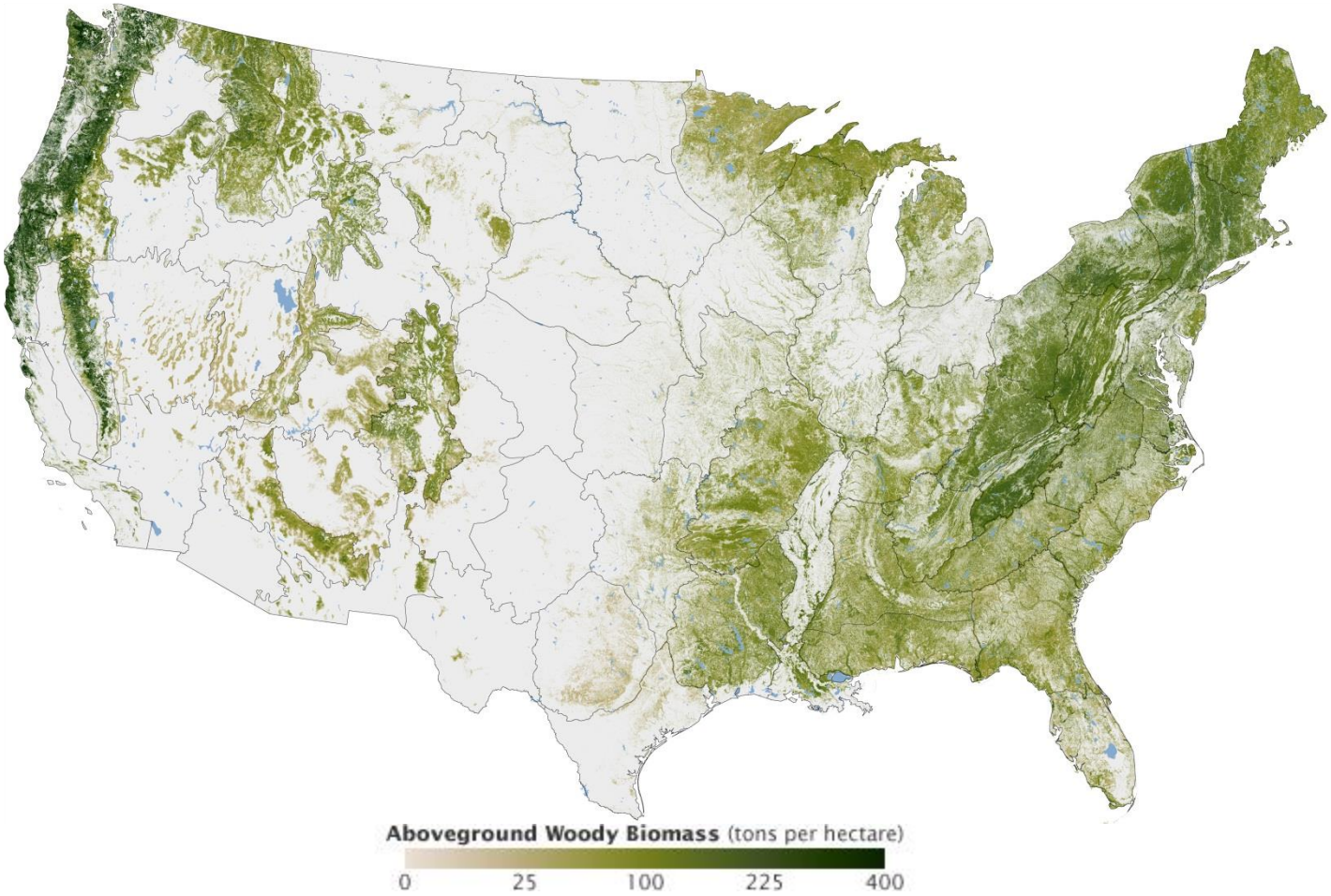
Photo: Kentucky Energy and Environment Cabinet Staff, Recast Energy, Louisville, Kentucky, 2012.

Biomass Resources



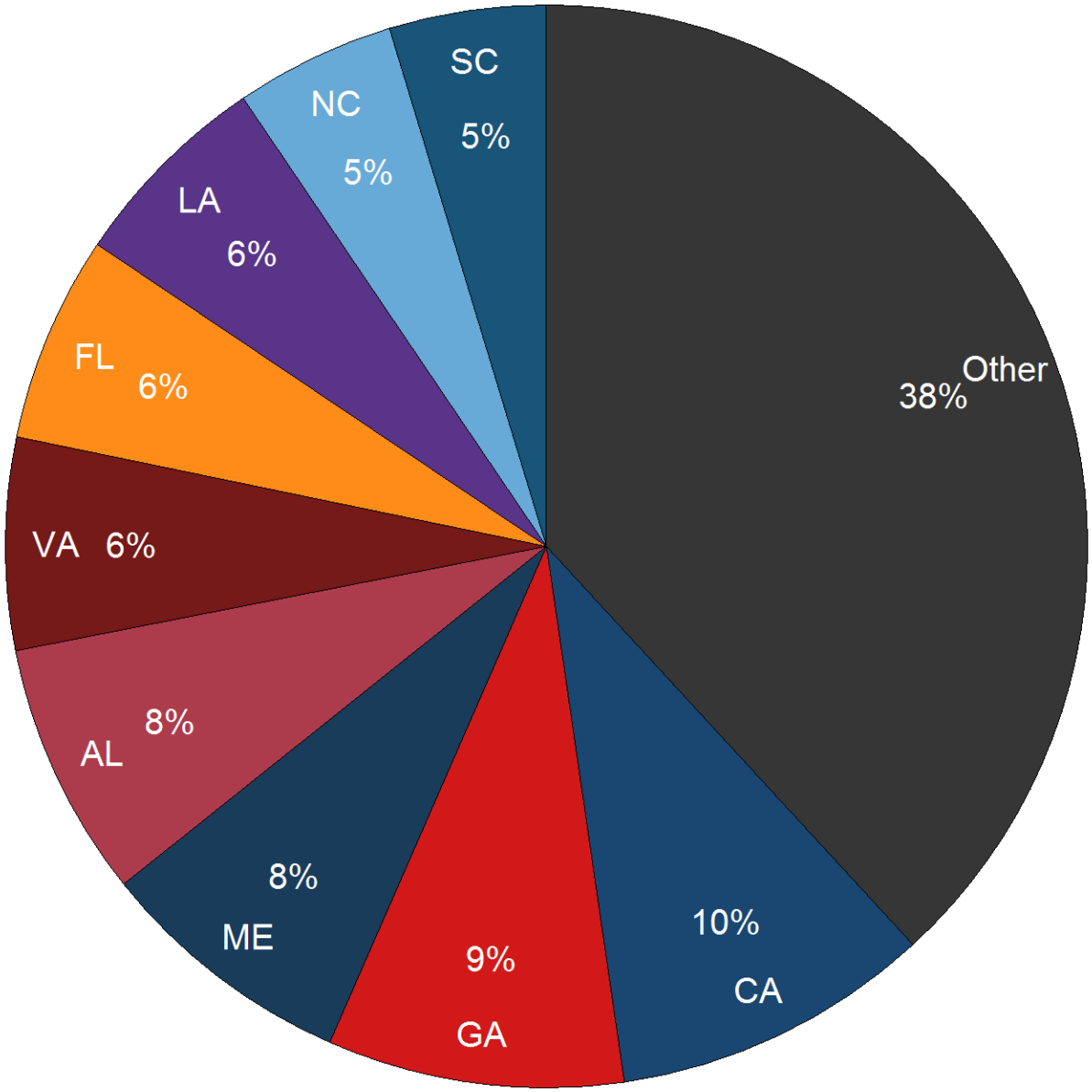
Full Report: http://www.nrel.gov/docs/fy06osti/39181.pdf

Woody Biomass Resources



Full Report: http://earthobservatory.nasa.gov/Features/ForestCarbon/page4.php

Wood Electricity Generation in the United States, 2014

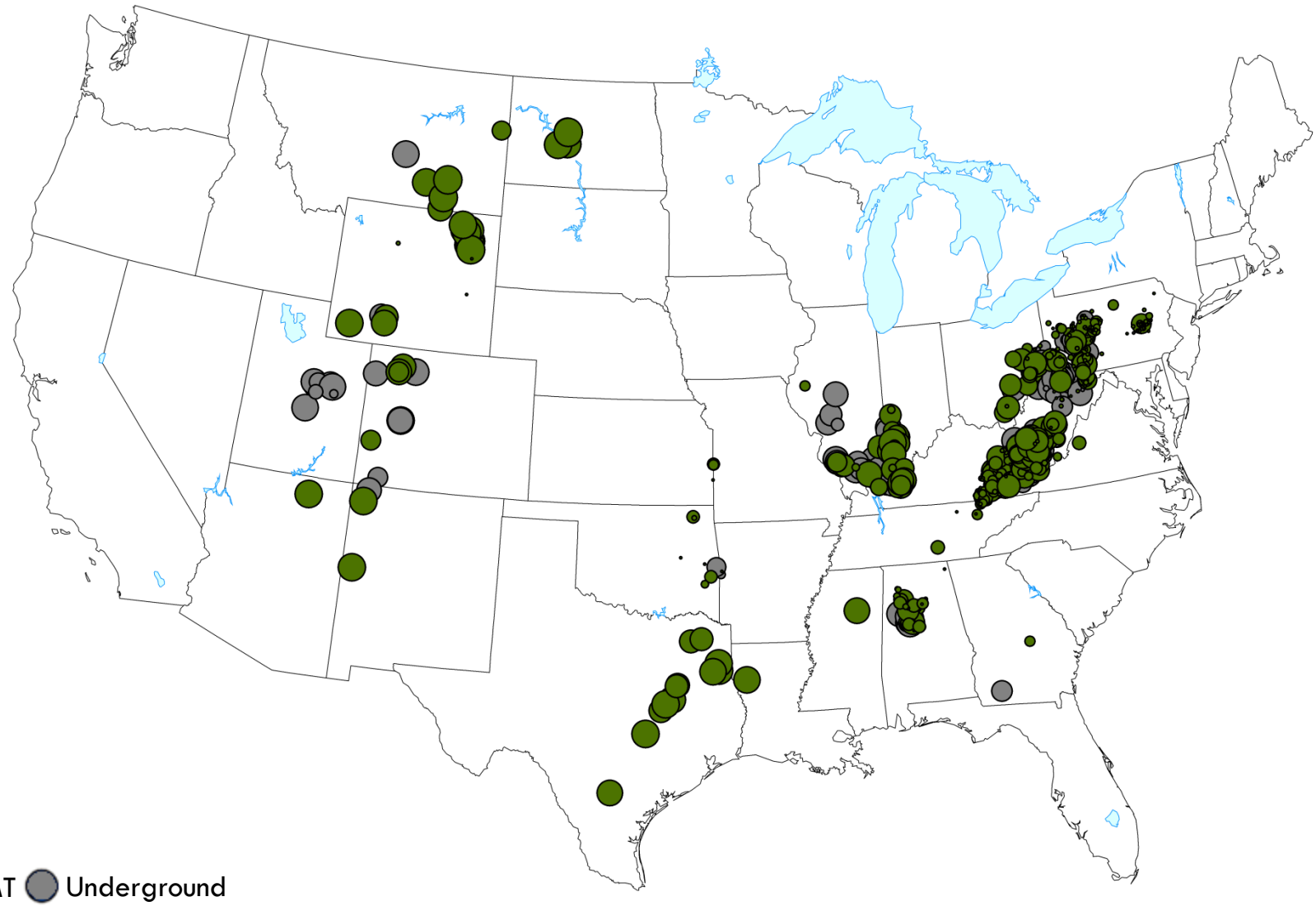


Kentucky Energy Database, EEC-DEDI, 2015

Kentucky Coal Production & Employment

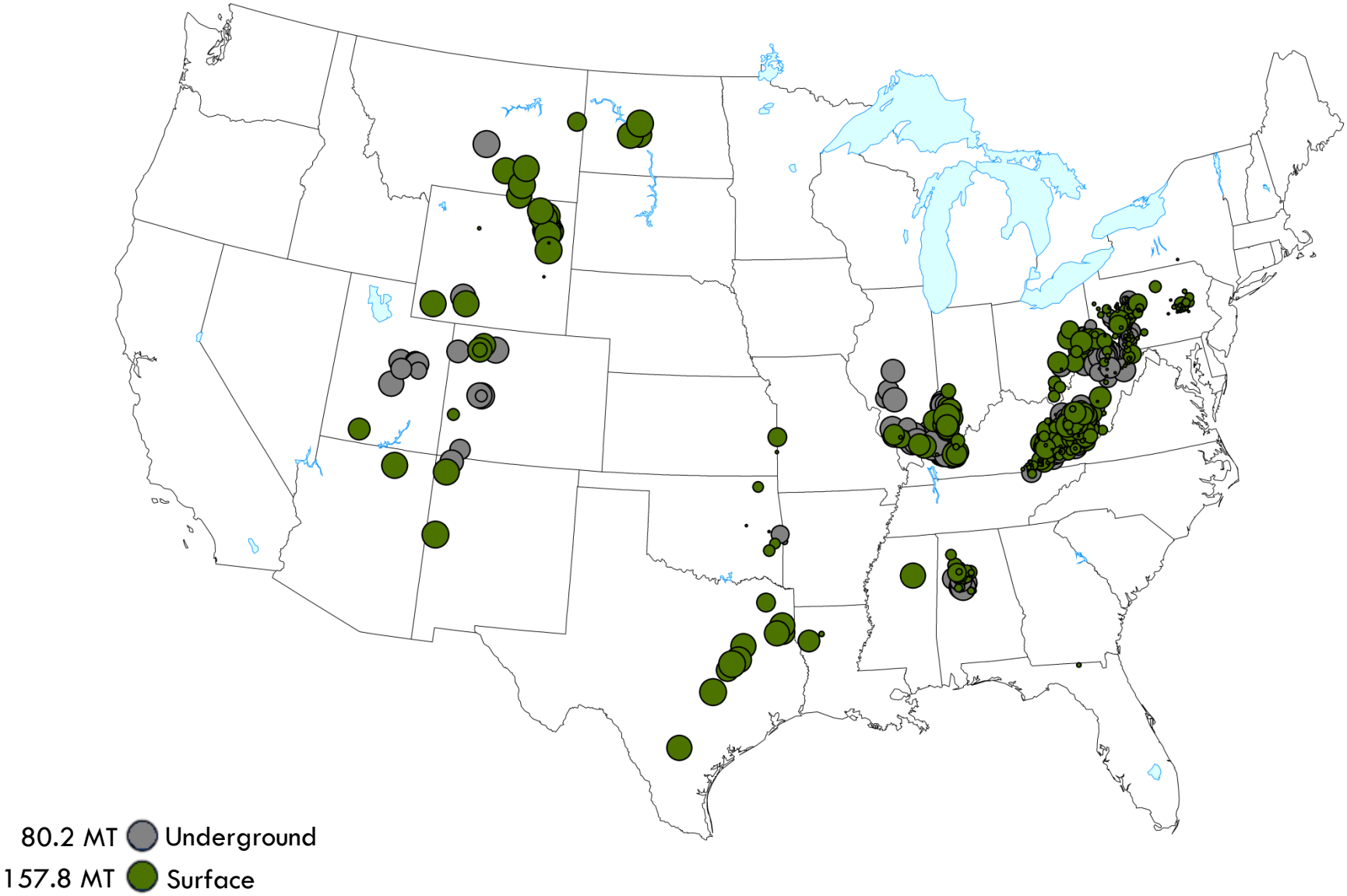
Animated versions of these maps are online at:
https://www.youtube.com/watch?v=1JckcUUTSsA

United States Coal Production, Q1-2011

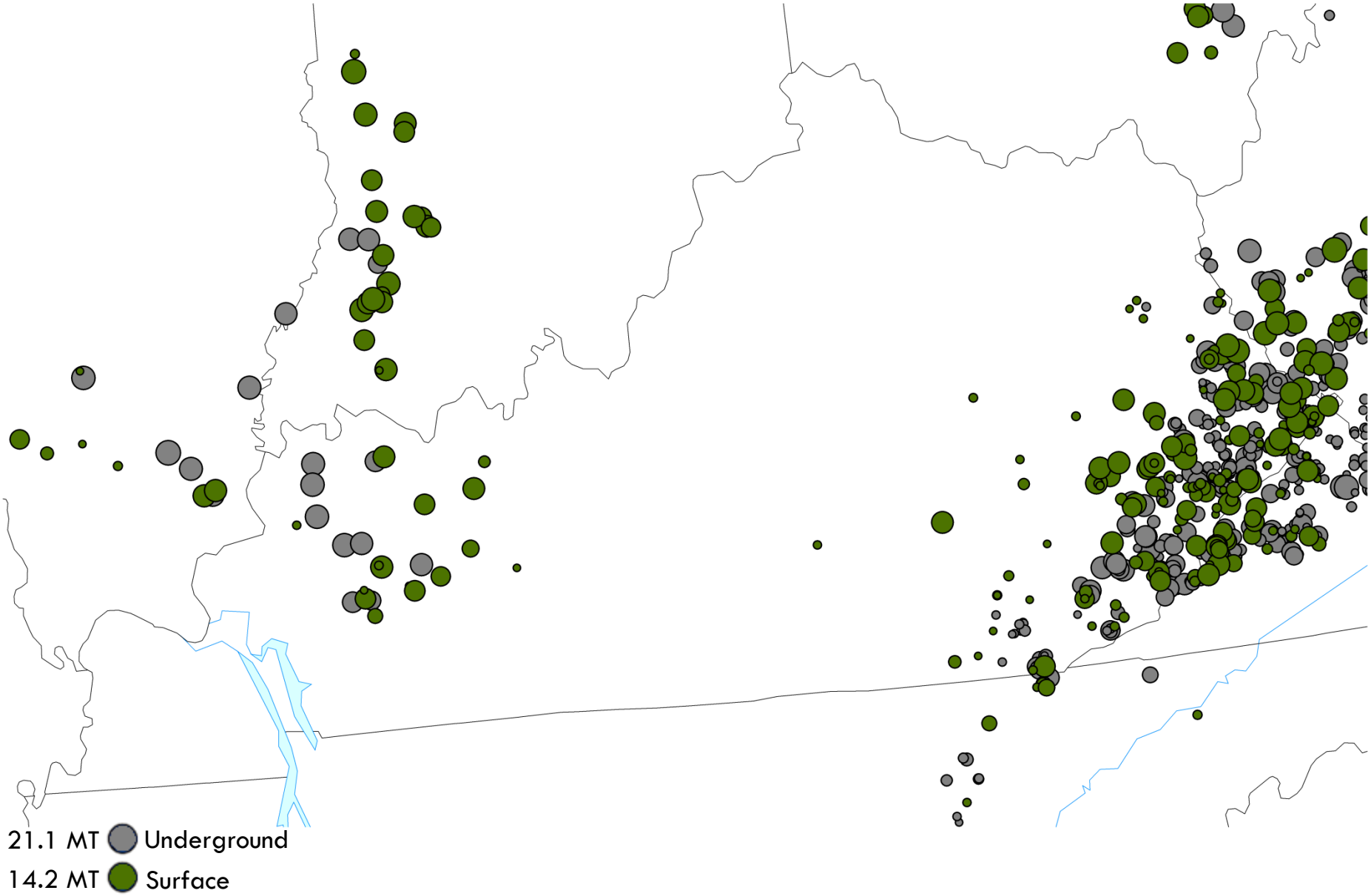


87.2 MT Underground
186.2 MT Surface

United States Coal Production, Q4-2013



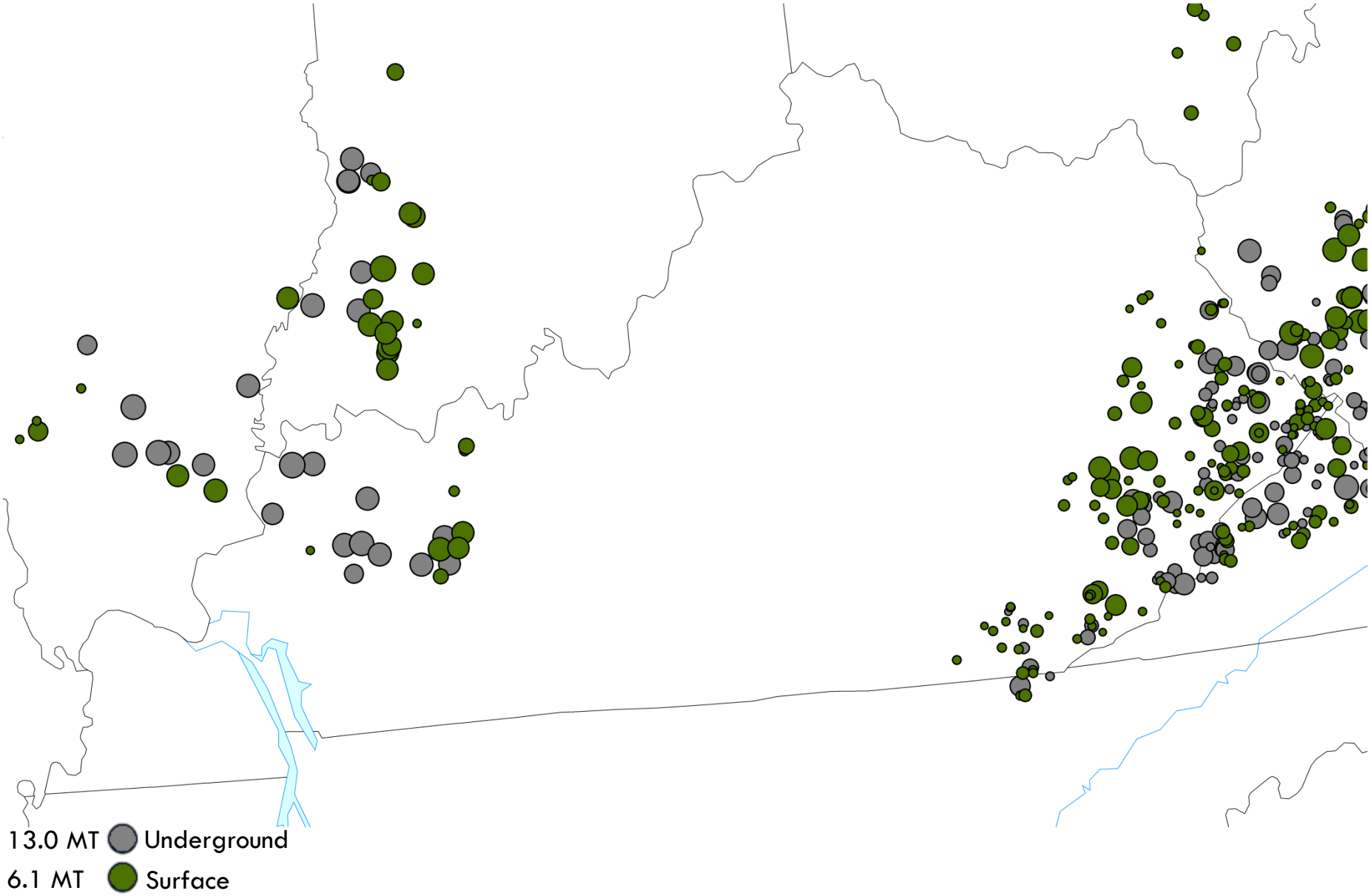
Kentucky Coal Production, Q1-2000



Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov

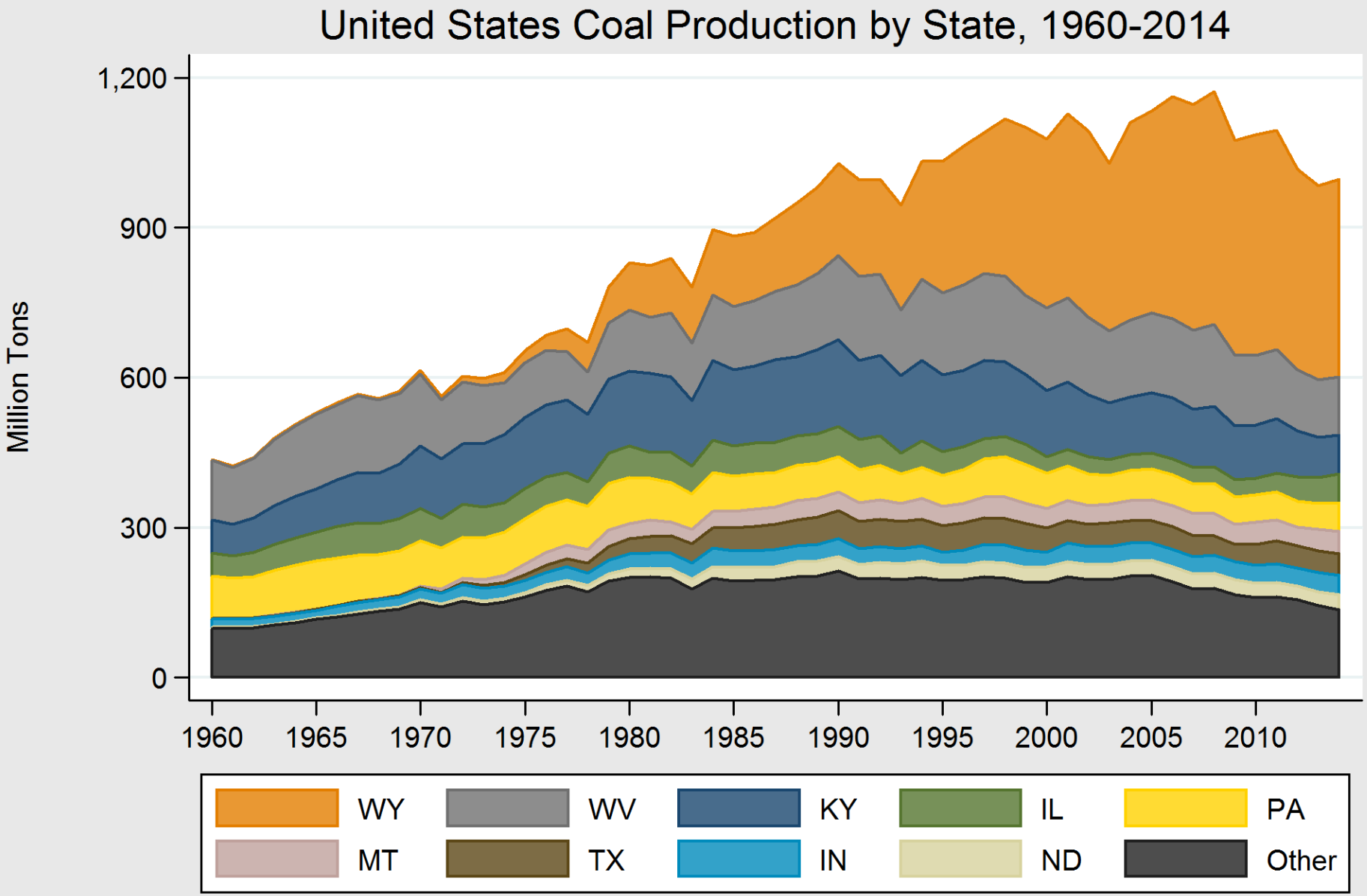
Kentucky Coal Production, Q4-2013



Kentucky Energy Database, EEC-DEDI, 2014

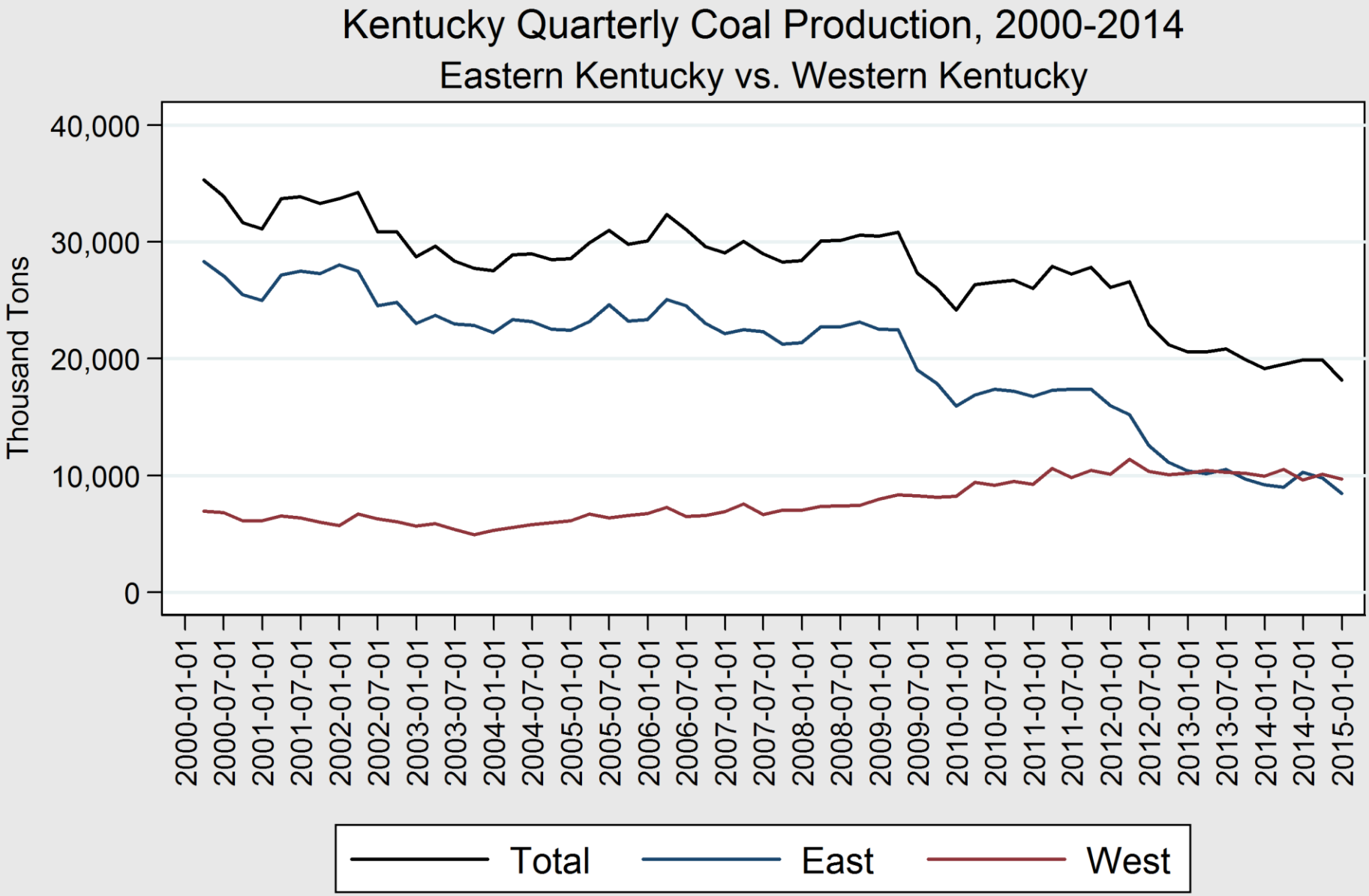
energy.ky.gov

Aron and Adam inside Warrior Coal Mine
~900 feet below Madisonville, Kentucky



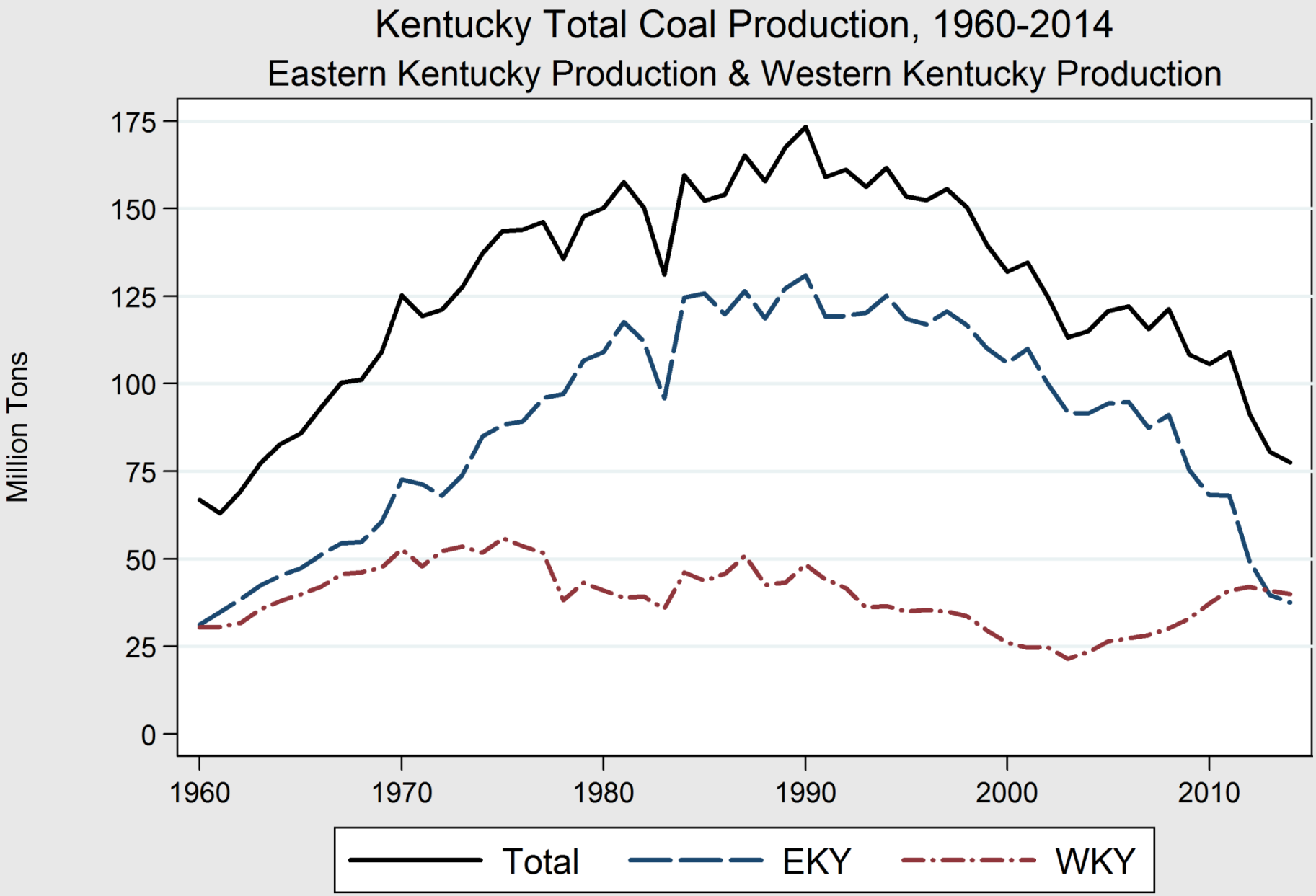
Kentucky Energy Database-EEC, DEDI, 2015

Data Source: United States Mine Safety and Health Administration (MSHA)

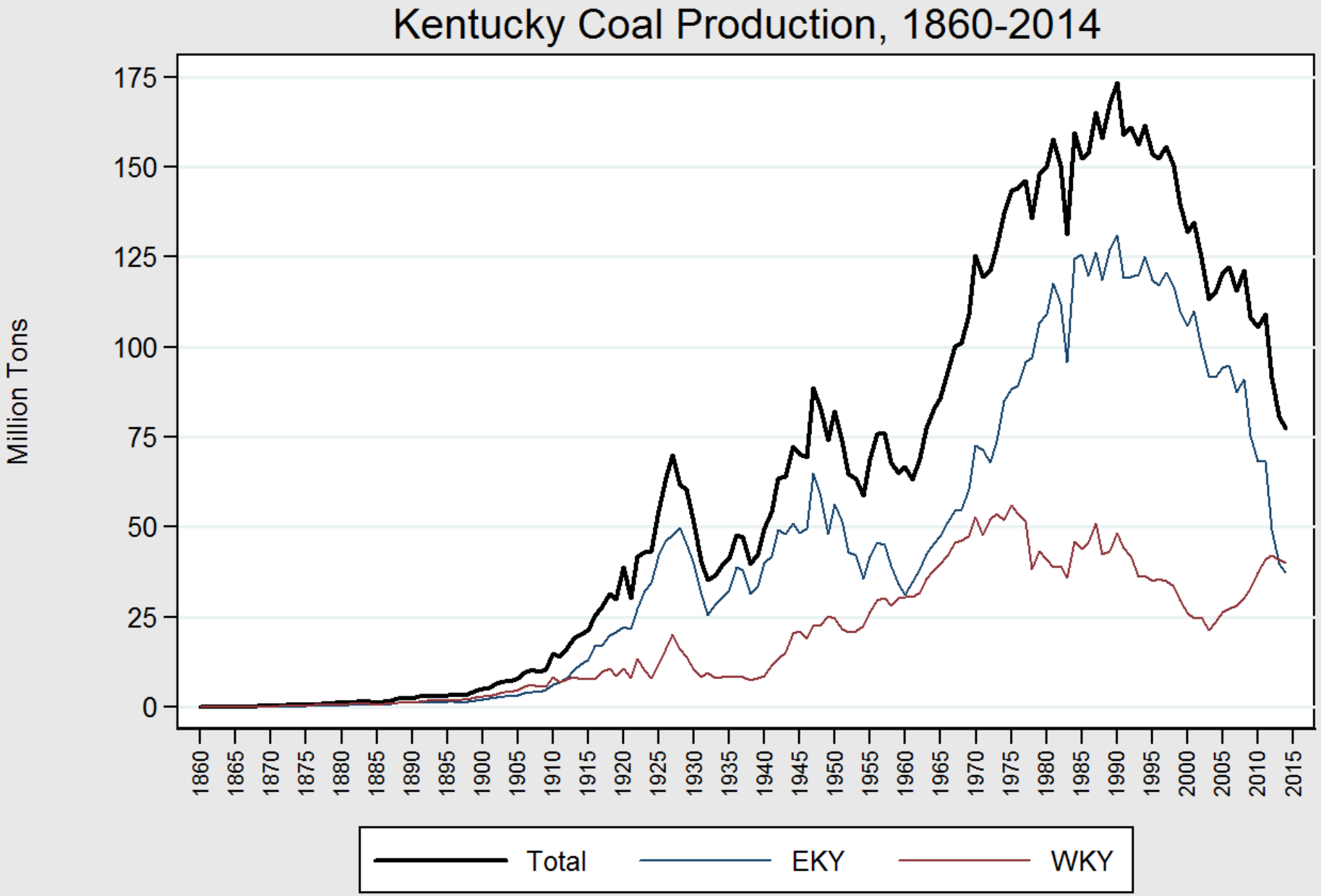


Kentucky Energy Database, EEC-DEDI, 2015

Microdata Source: MSHA-MDRS Queried on: 2 Feb 2015



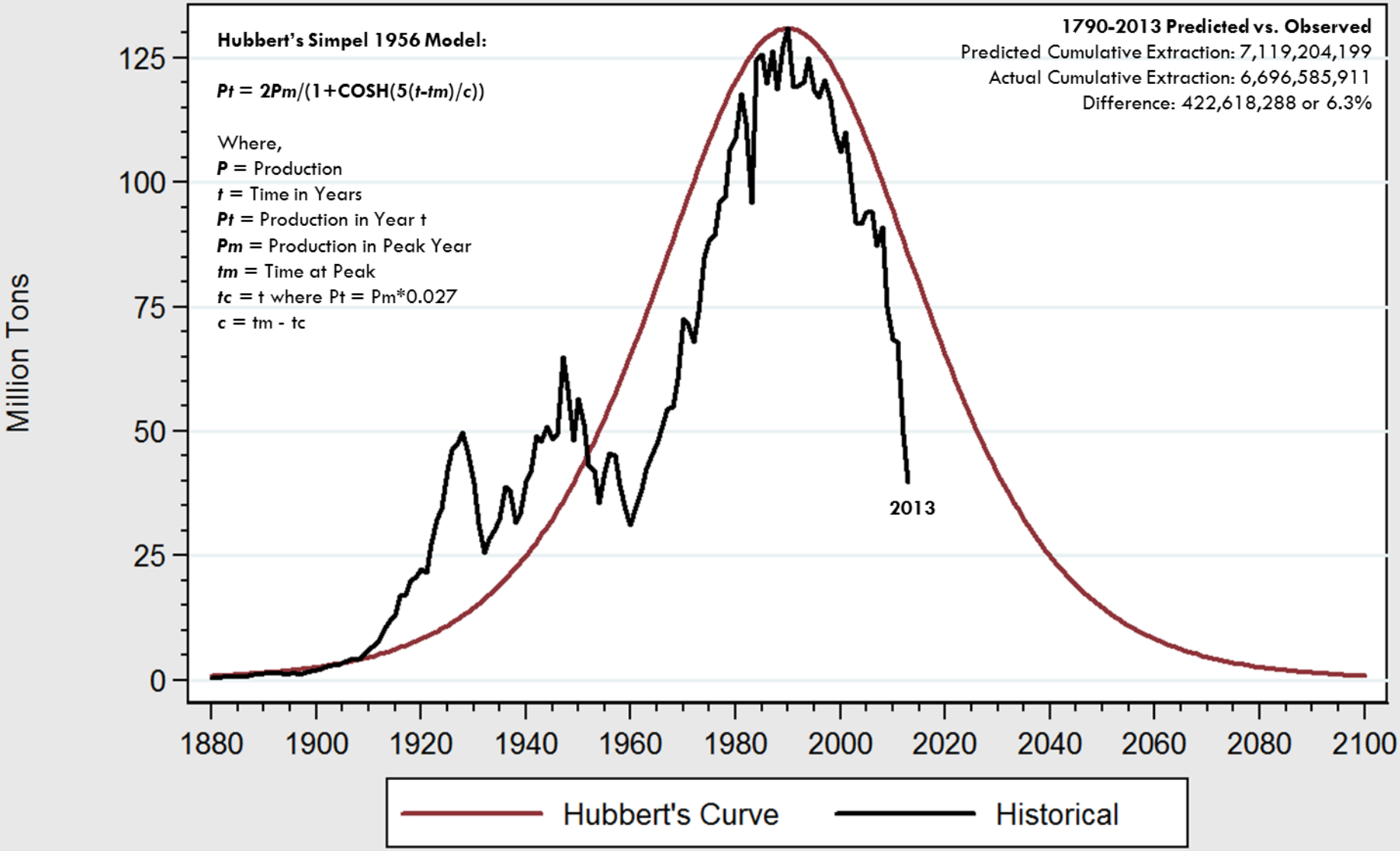
Kentucky Energy Database, EEC-DEDI, 2015



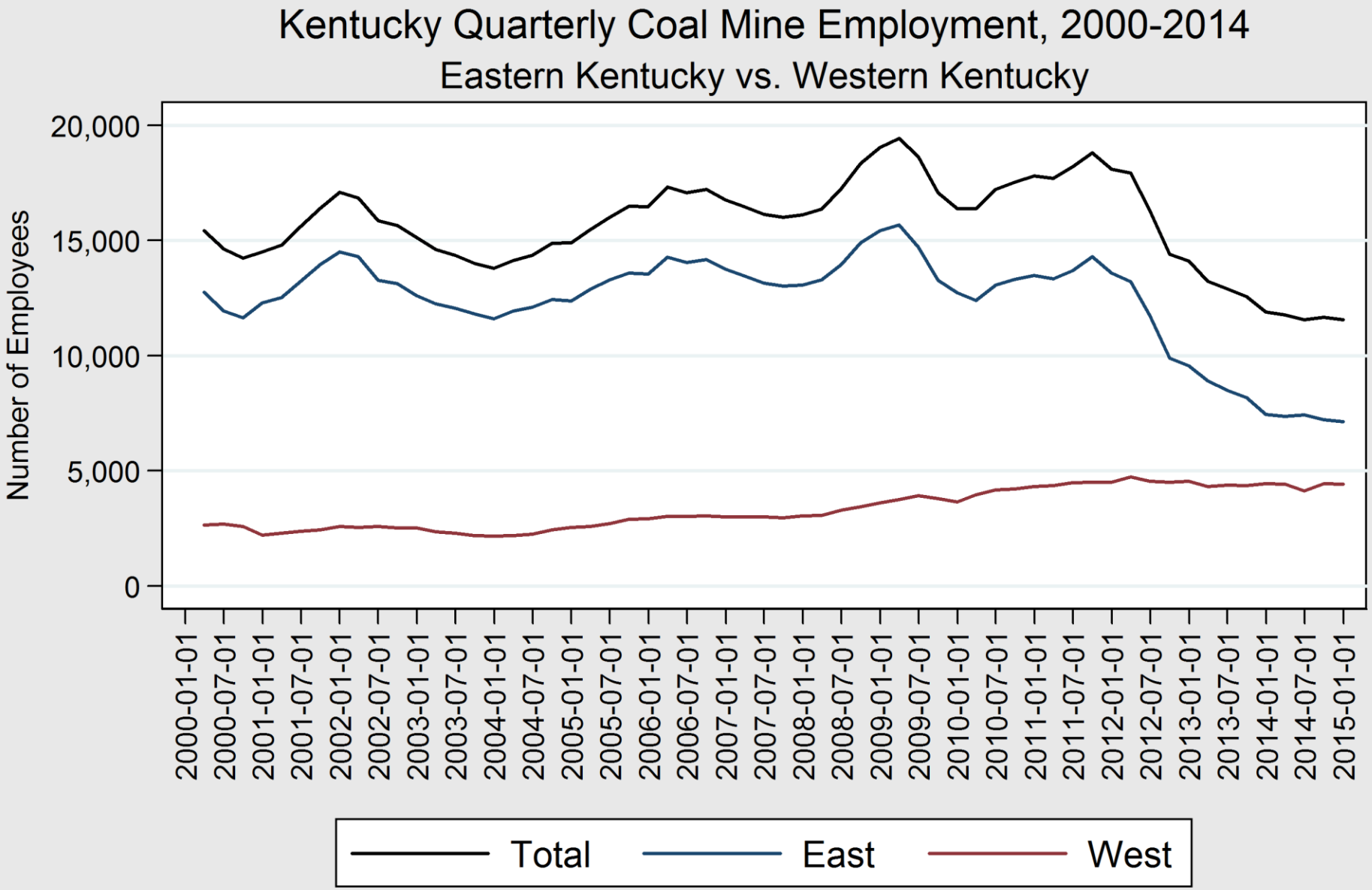
Kentucky Energy Database, EEC-DEDI, 2015

Eastern Kentucky Coal Production, 1880-2100

Hubbert's Curve Applied to Eastern Kentucky Coal Production



Kentucky Energy Database, EEC-DEDI, 2014



Kentucky Energy Database, EEC-DEDI, 2015

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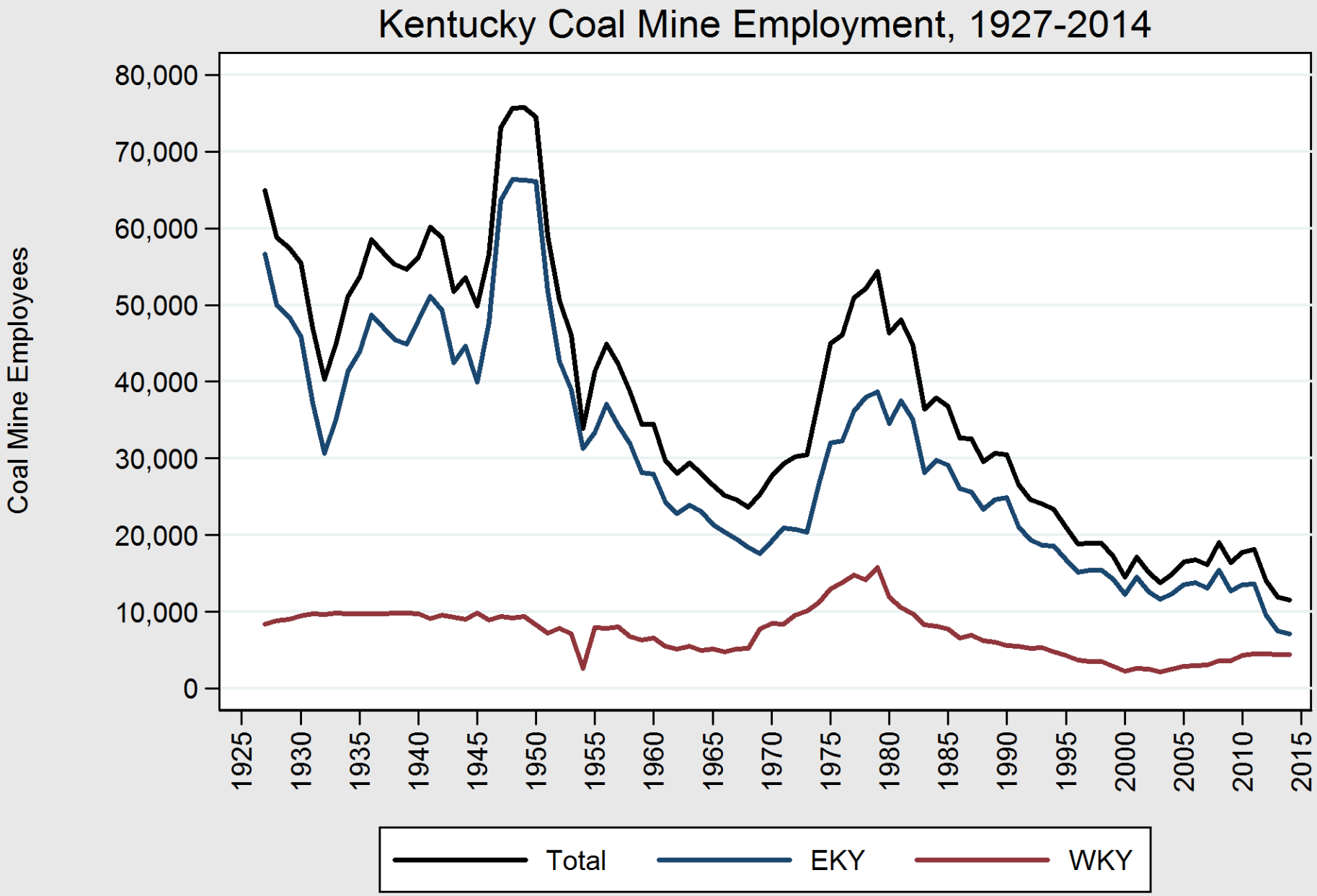
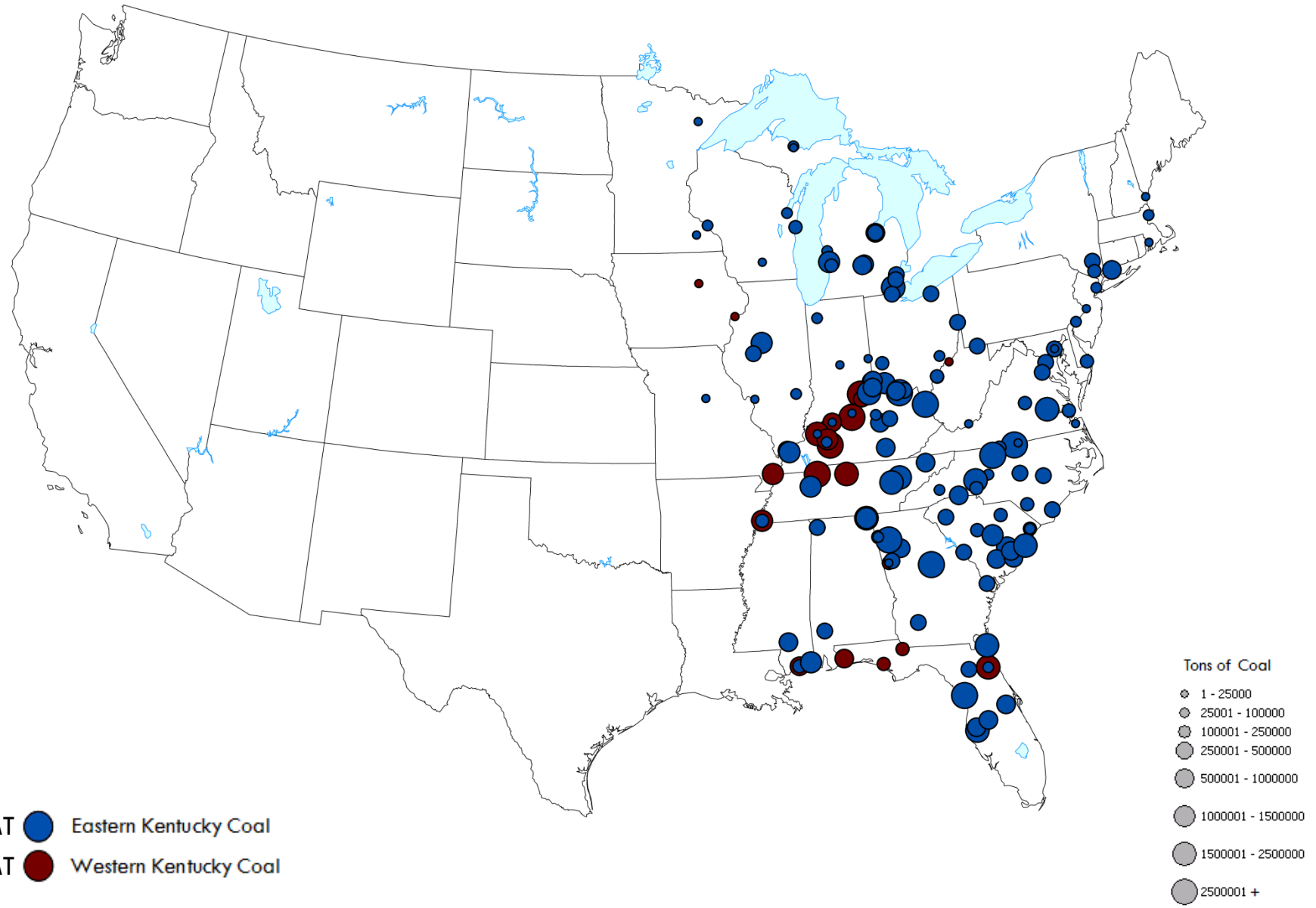


Kentucky Energy Database, EEC-DEDI, 2015

Kentucky Coal Markets

Animated versions of these maps are online at:
https://www.youtube.com/watch?v=ofNBO8g9xuohttps://www.youtube.com/watch?v=ofNBO8g9xuo

Kentucky Coal Deliveries, 1990



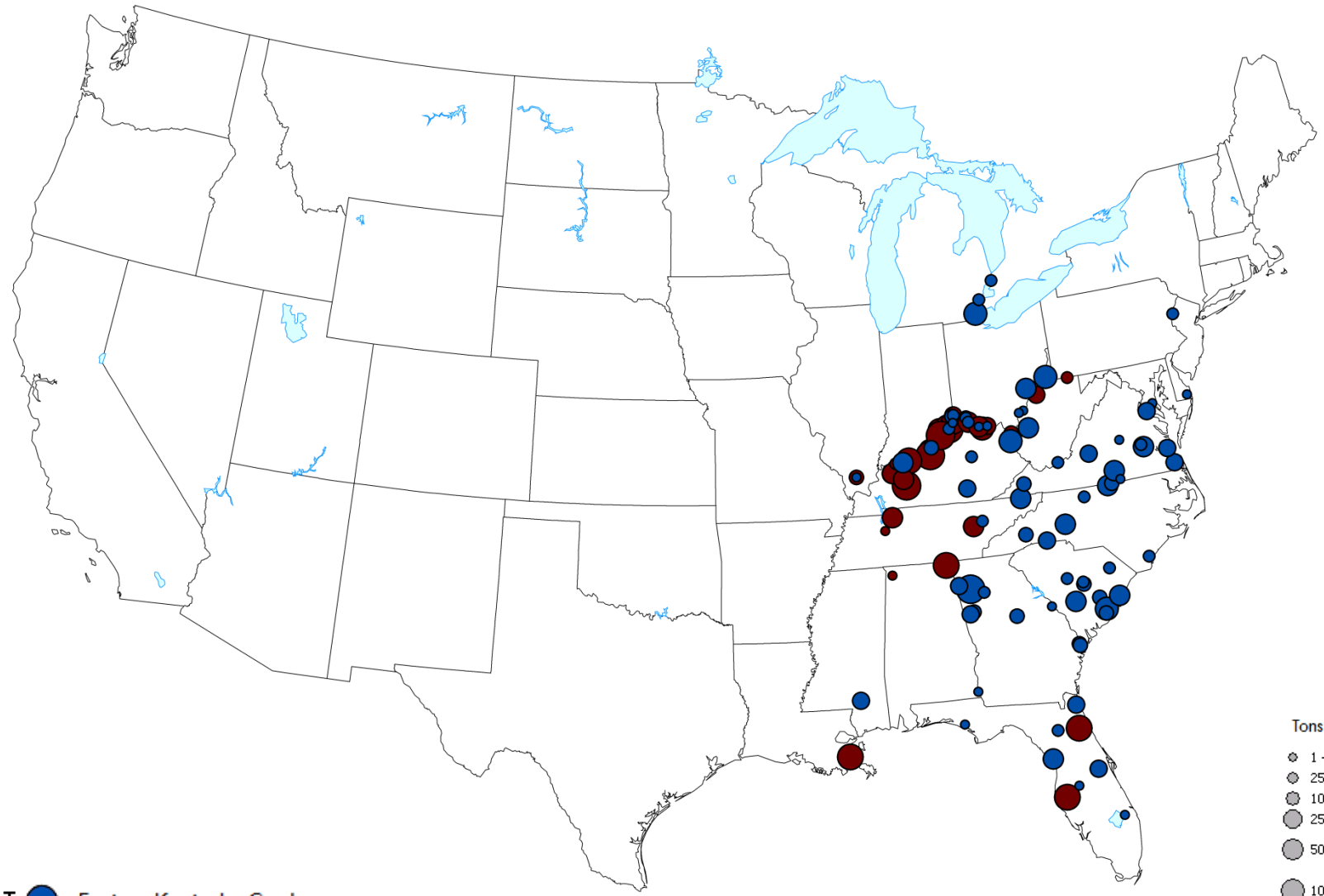
85.2 MT Eastern Kentucky Coal

43.6 MT Western Kentucky Coal

Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov

Kentucky Coal Deliveries, 2013



23.7 MT Eastern Kentucky Coal

38.3 MT Western Kentucky Coal

Tons of Coal

- 1 - 25000
- 25001 - 100000
- 100001 - 250000
- 250001 - 500000
- 500001 - 1000000
- 1000001 - 1500000
- 1500001 - 2500000
- 2500001 +

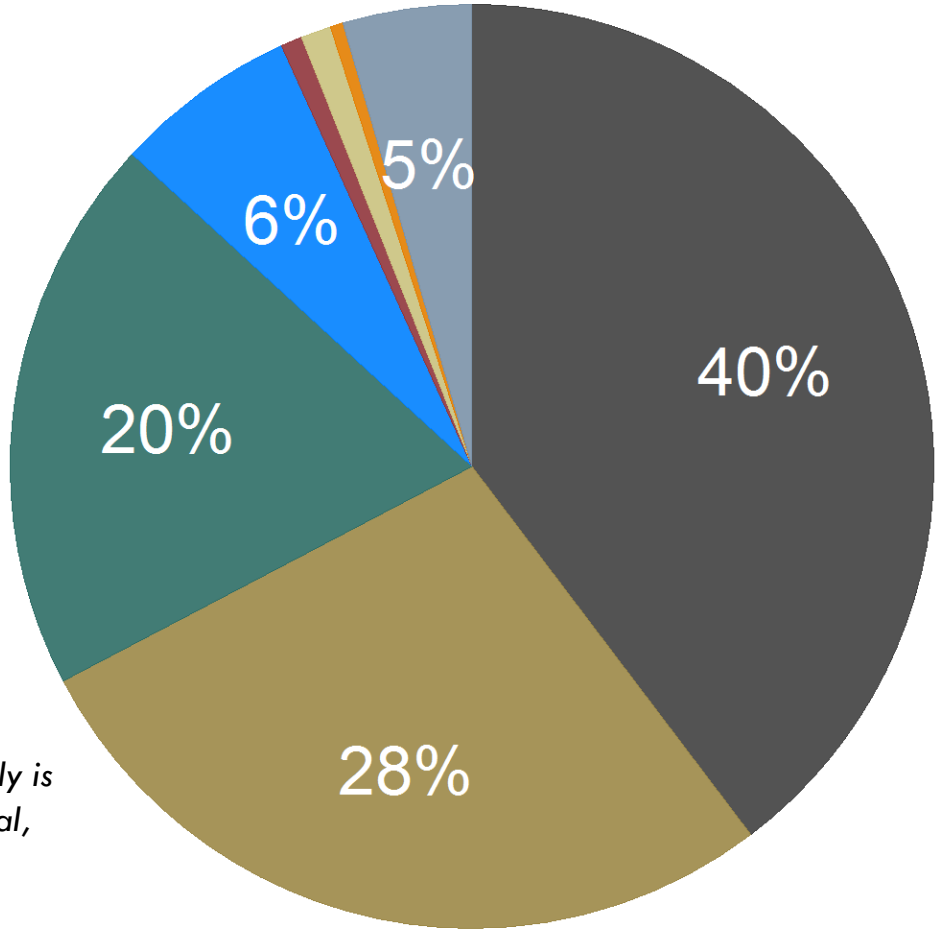
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov

A Quick Introduction to

Kentucky's Electricity Portfolio

United States Electricity Generation by Fuel Type, 2014

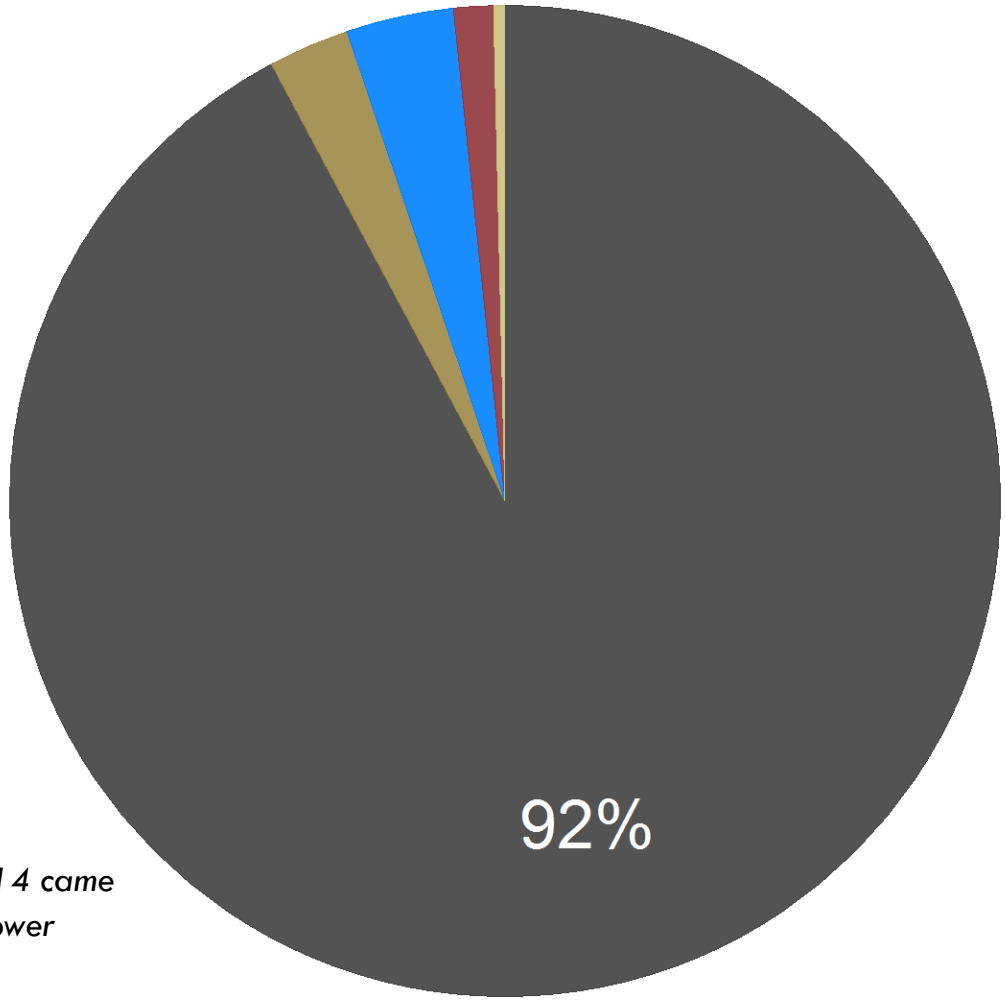


Electricity consumption nationally is relatively balanced between coal, natural gas, nuclear power, hydroelectric, and wind.

Coal	Natural Gas	Nuclear
Hydro	Petroleum	Wood
Solar	Wind	

Kentucky Energy Database, EEC-DEDI, 2015

Kentucky Electricity Generation by Fuel Type, 2014

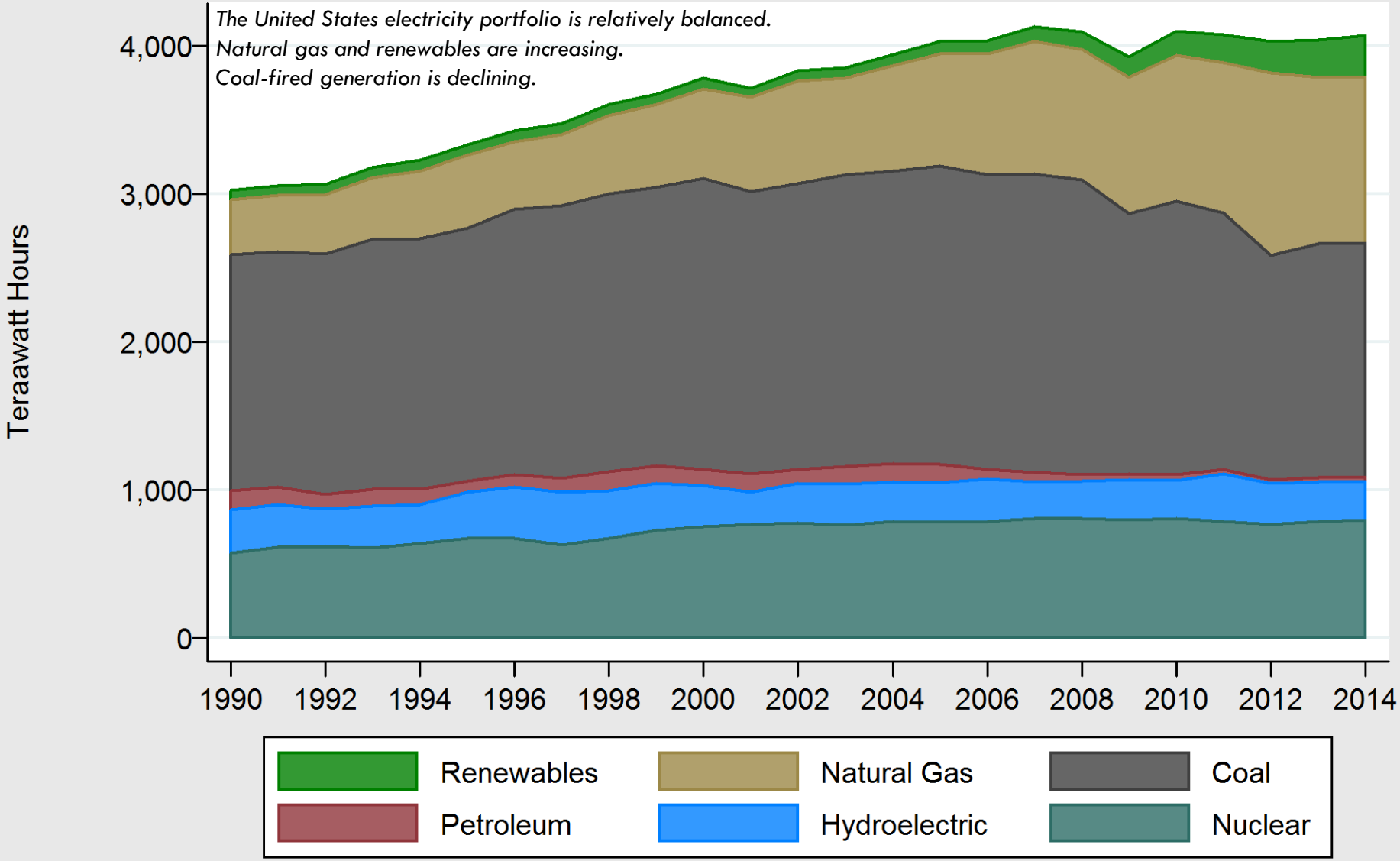


Over 92% of the electricity generated in Kentucky in 2014 came from Kentucky's coal-fired power plants.

Coal
Natural Gas
Hydro
Petroleum
Wood

Kentucky Energy Database, EEC-DEDI, 2015

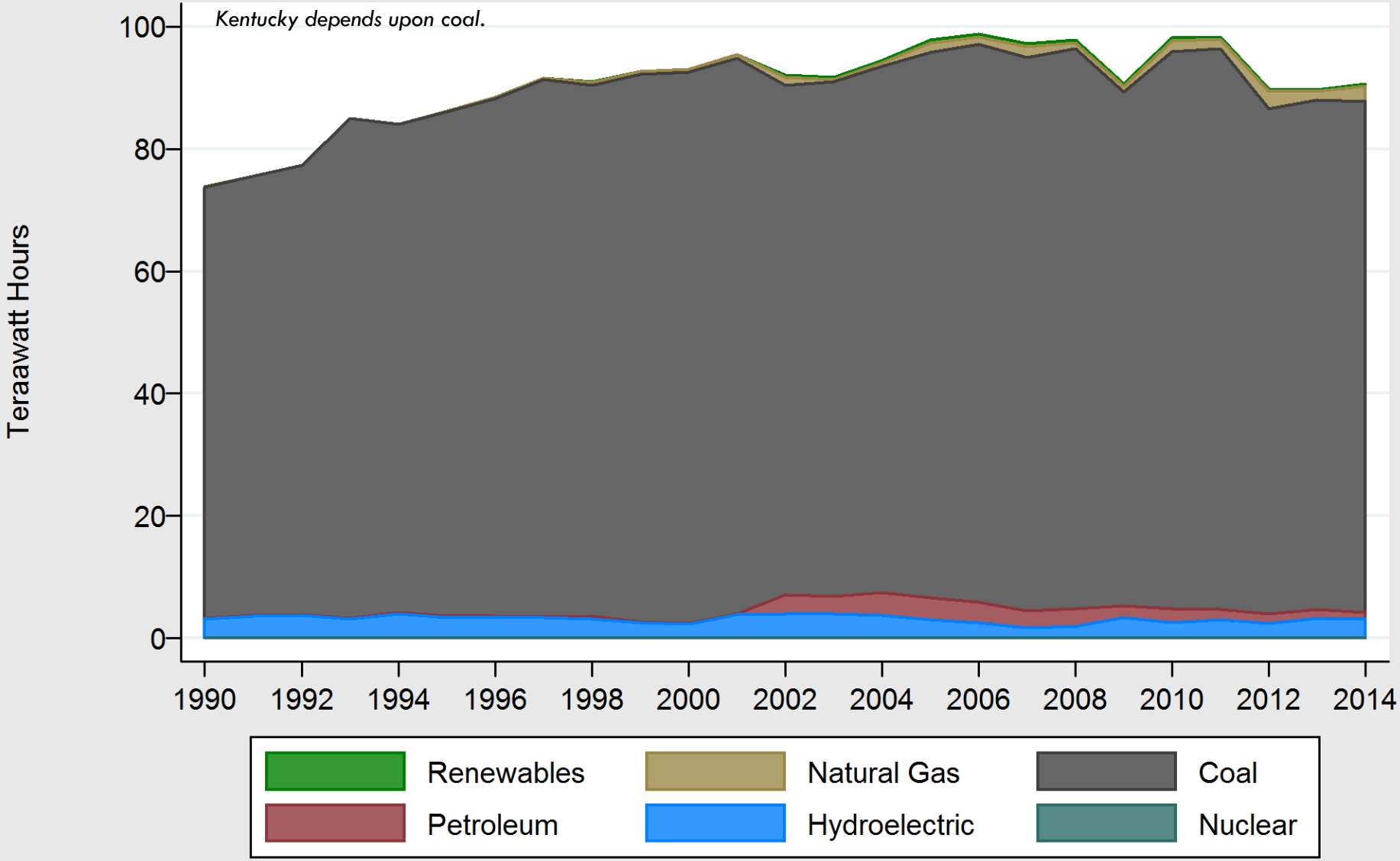
United States Electricity Generation by Fuel, 1990-2014



Kentucky Energy Database, EEC-DEDI, 2015

Data Source: EIA Electric Power Annual

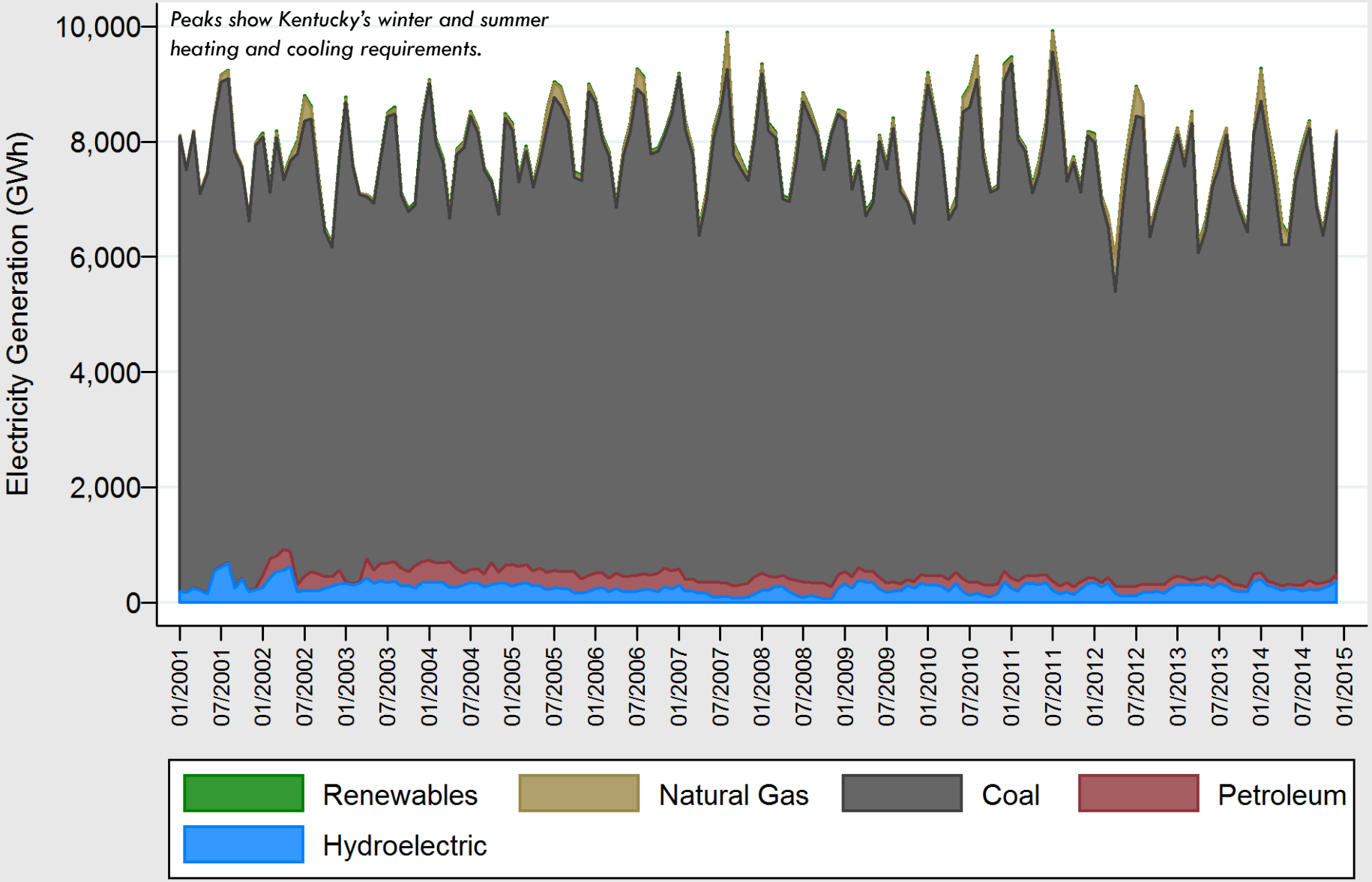
Kentucky Electricity Generation by Fuel, 1990-2014



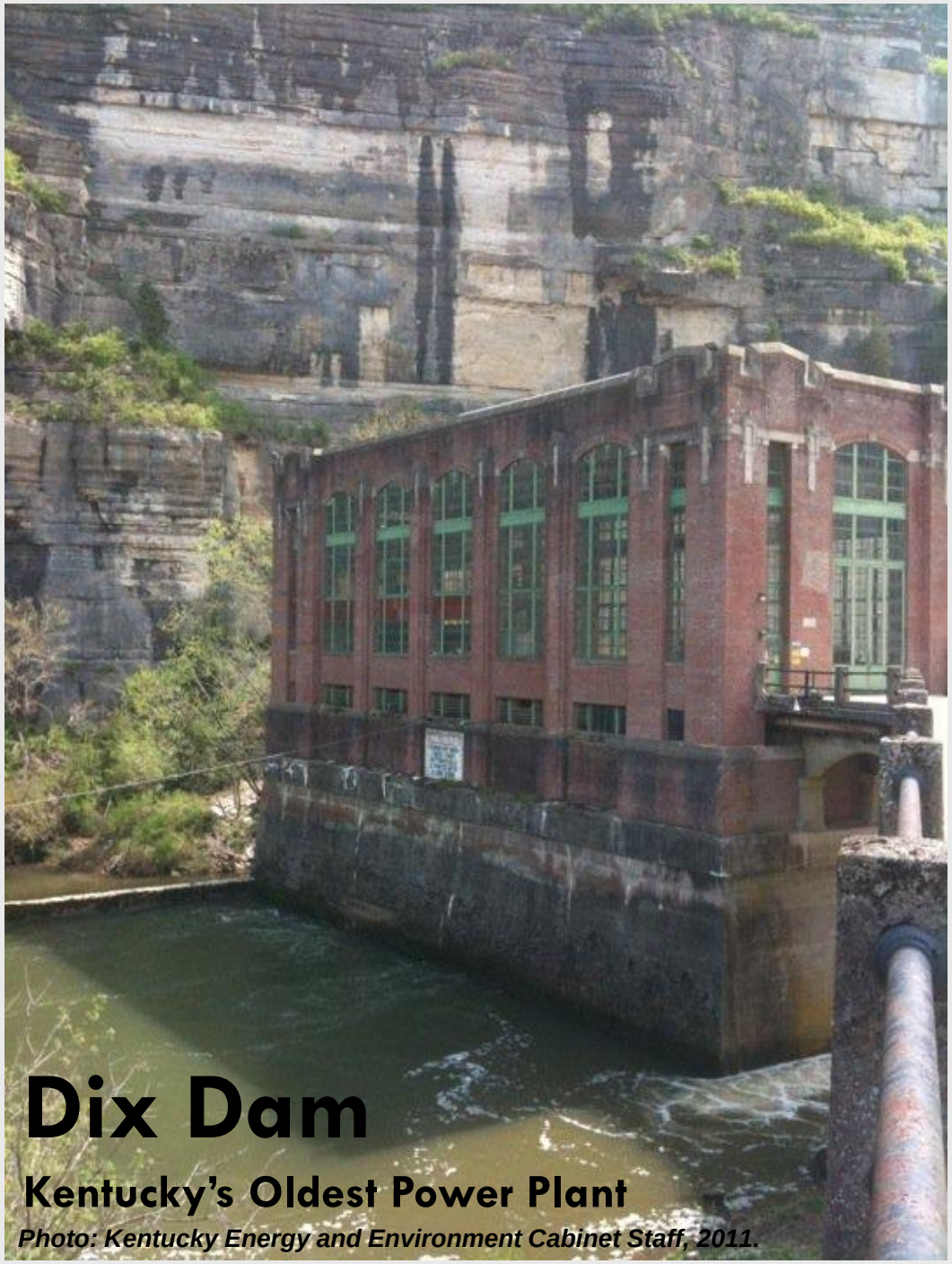
Kentucky Energy Database, EEC-DEDI, 2015

Data Source: EIA Electric Power Annual

Kentucky Electricity Generation by Fuel Type, 2001-2014



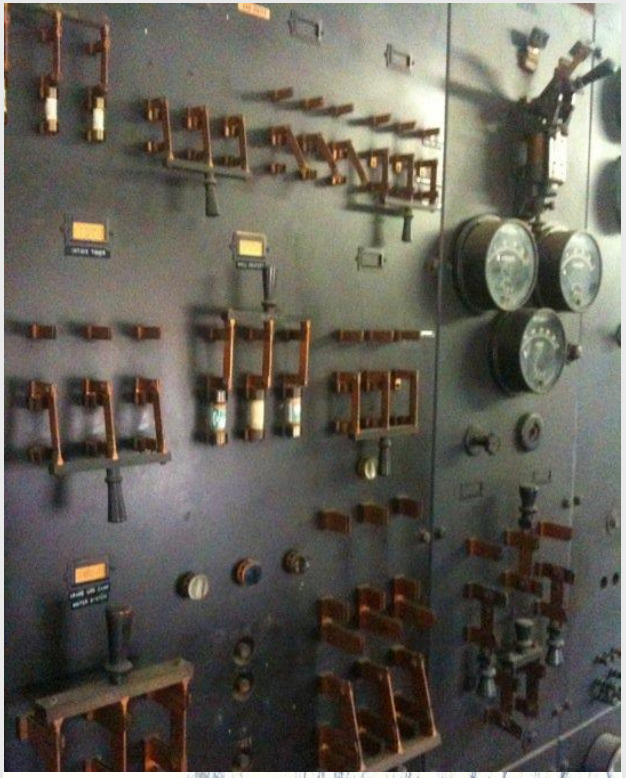
Kentucky Energy Database, EEC-DEDI, February 2015

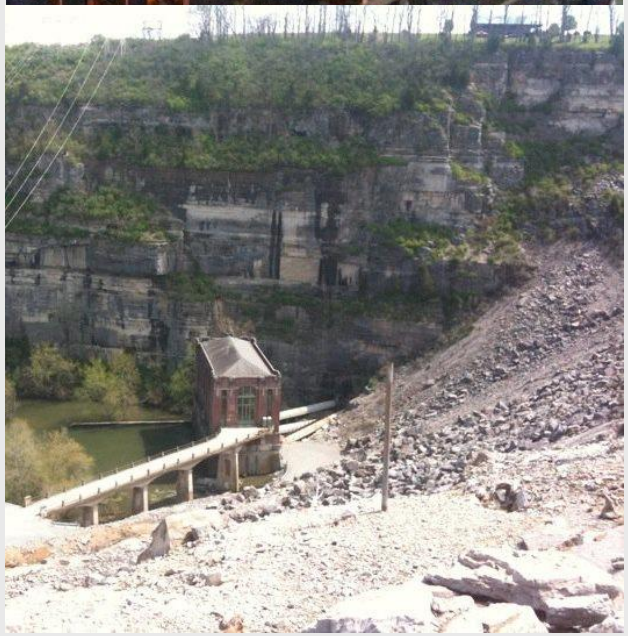


Dix Dam

Kentucky's Oldest Power Plant

Photo: Kentucky Energy and Environment Cabinet Staff, 2011.

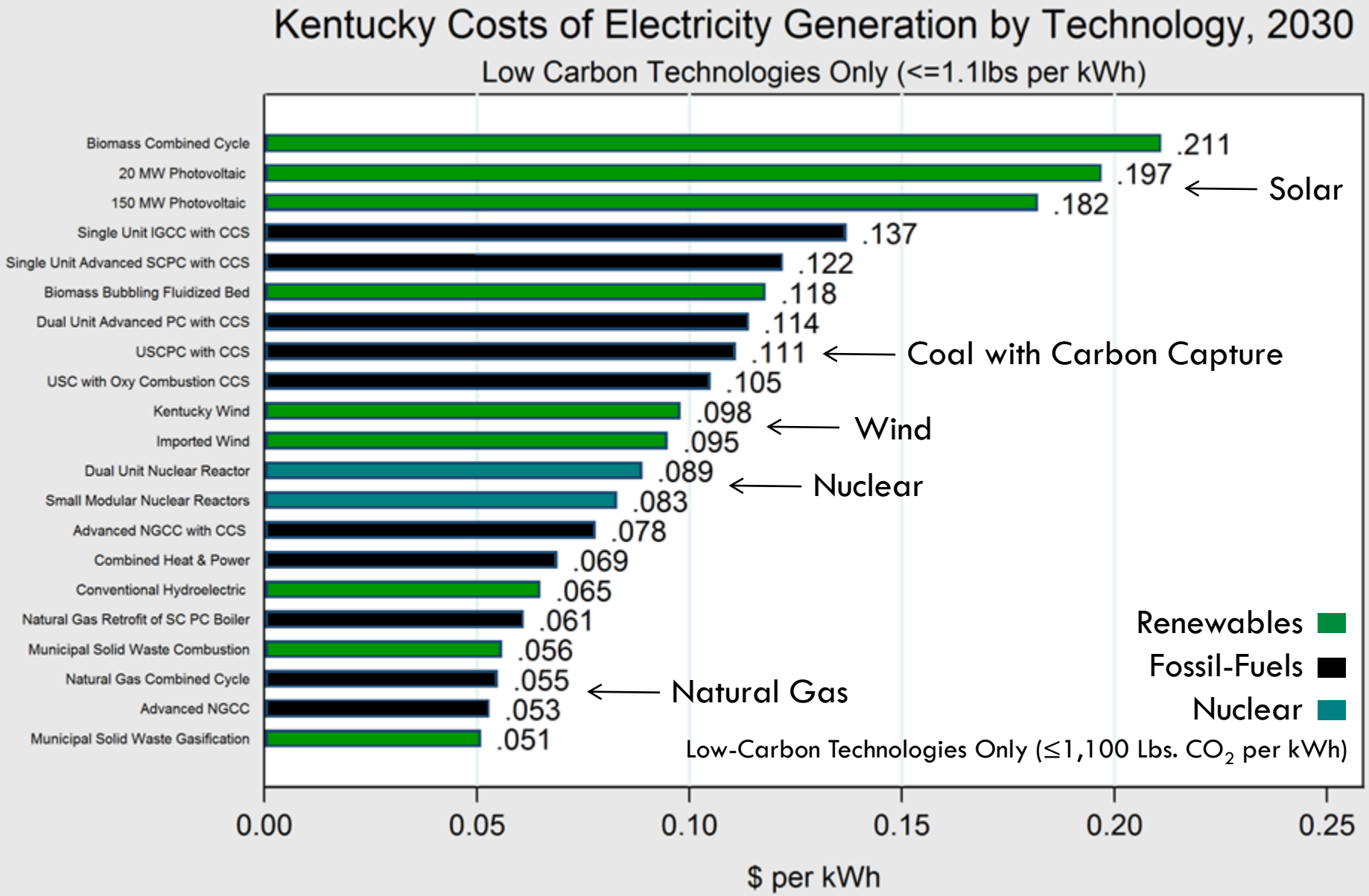




Trimble County

Kentucky's Newest Coal Plant

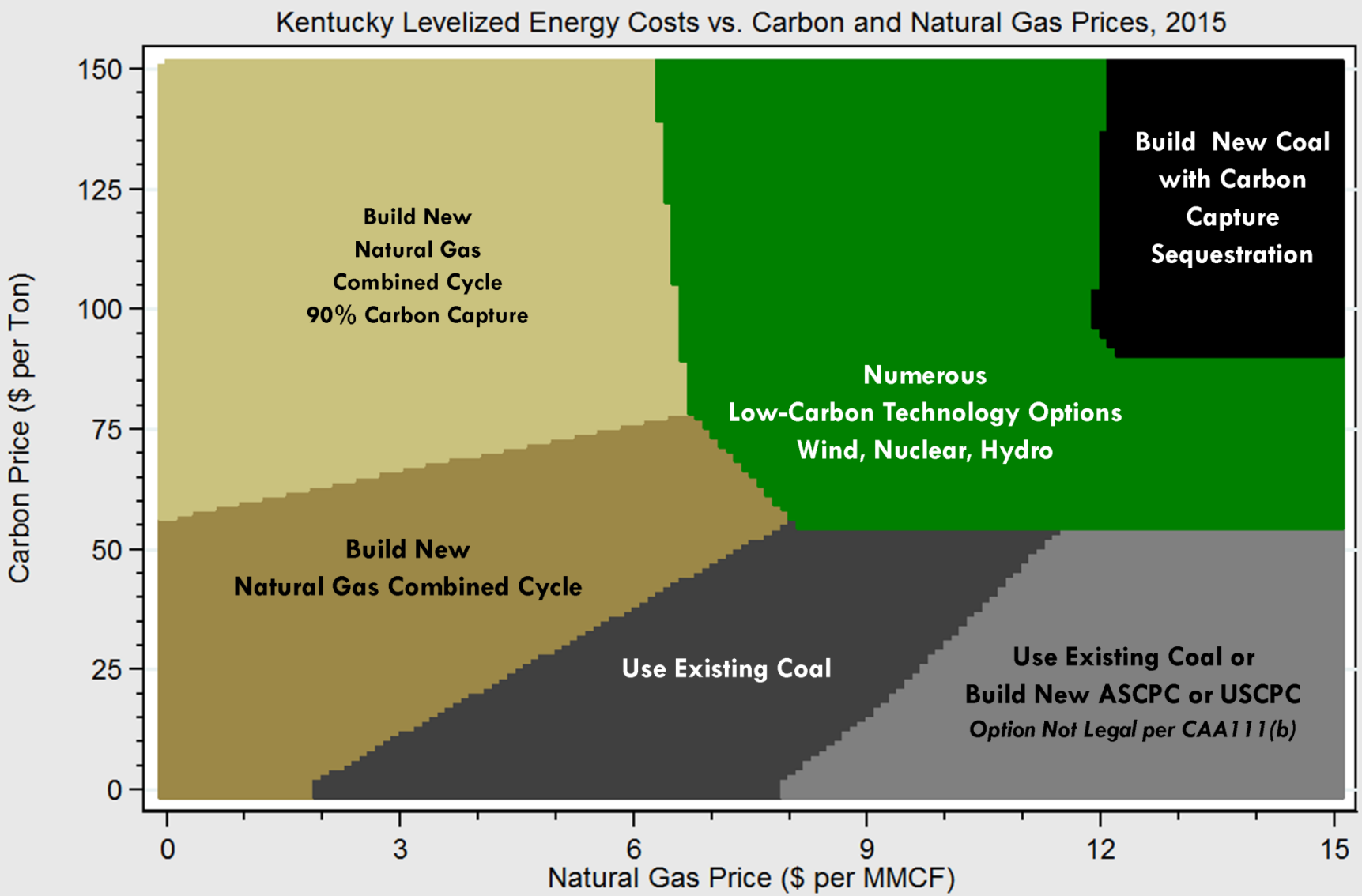
Photo: LG&E-KU, 2014



Kentucky Energy Database, EEC-DEDI, 2013

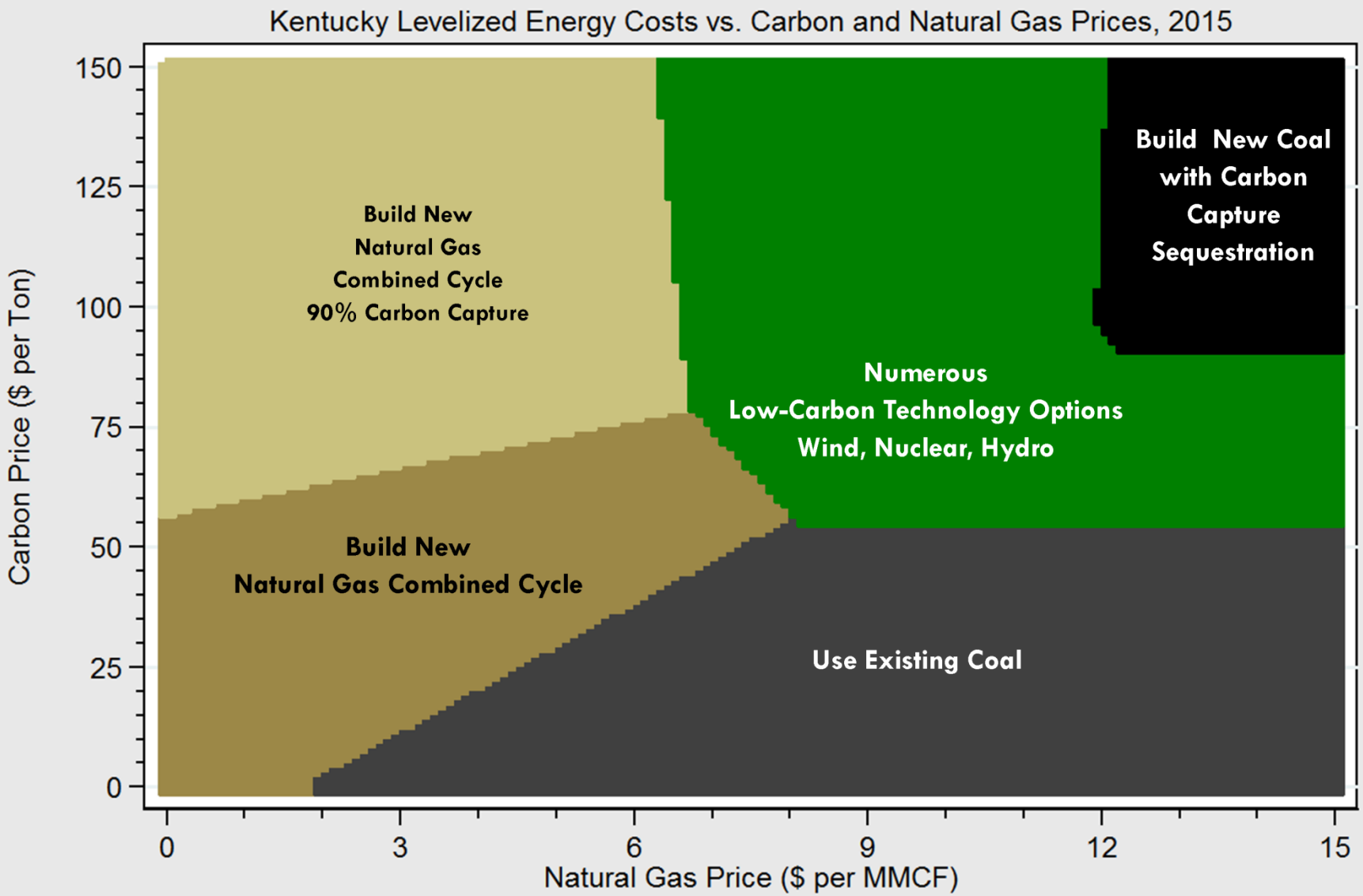
Kentucky Electricity Portfolio Model

Detailed Cost Data Available on Pages C.89 and C.90 of Complete Report



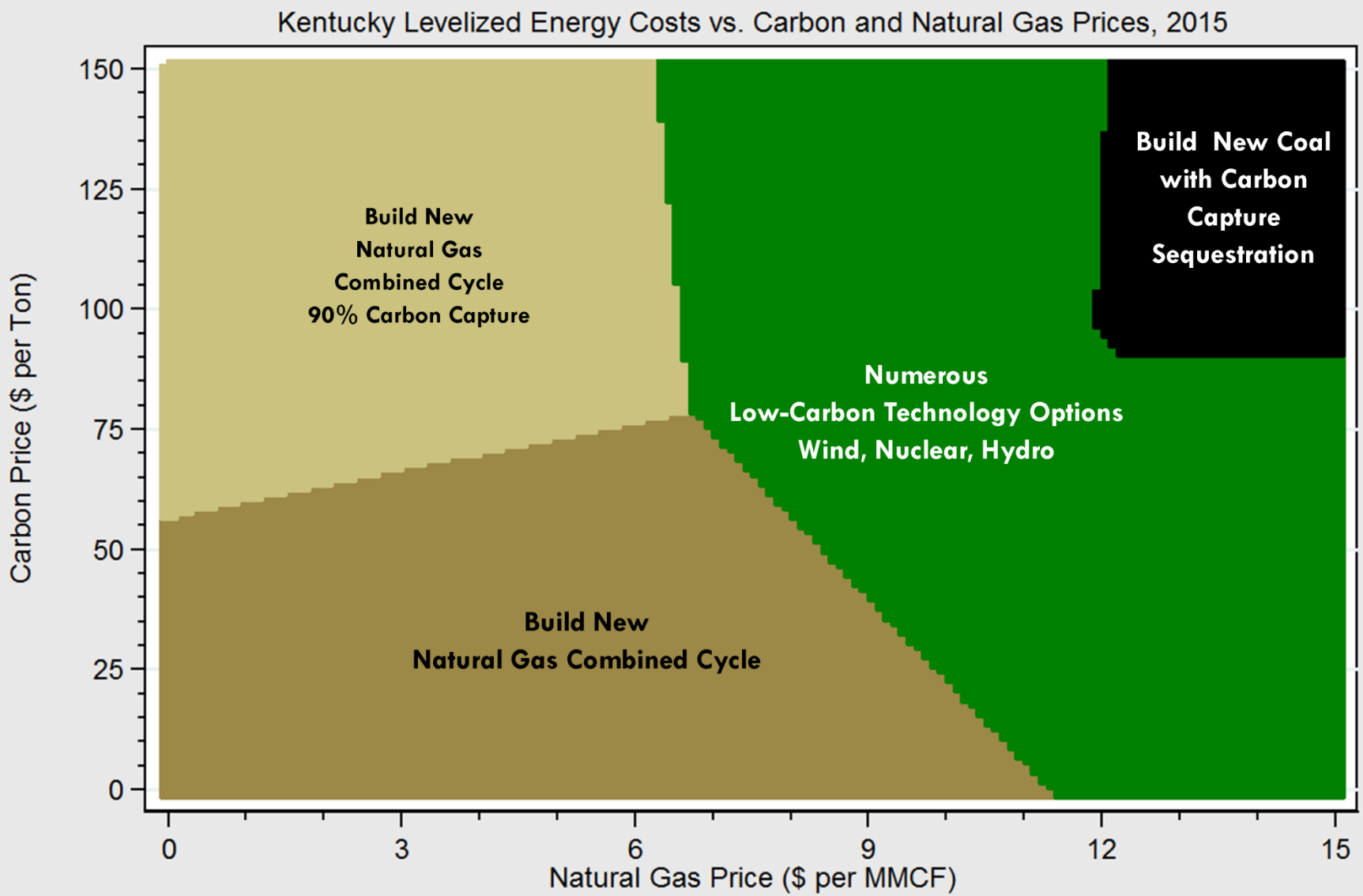
Kentucky Energy Database, EEC-DEDI, 2014

Kentucky Electricity Portfolio Model



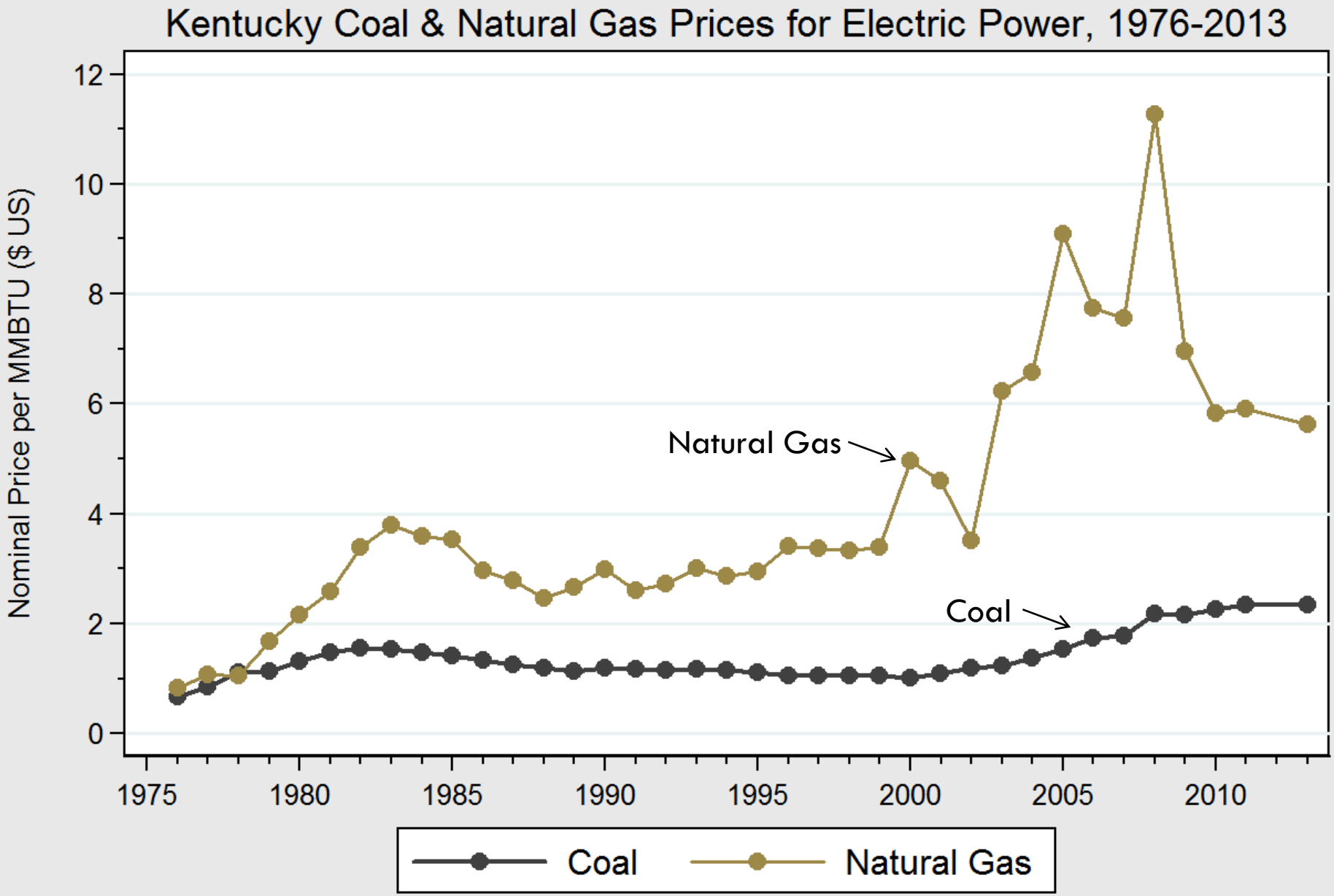
Kentucky Energy Database, EEC-DEDI, 2014

Kentucky Electricity Portfolio Model



Kentucky Energy Database, EEC-DEDI, 2014

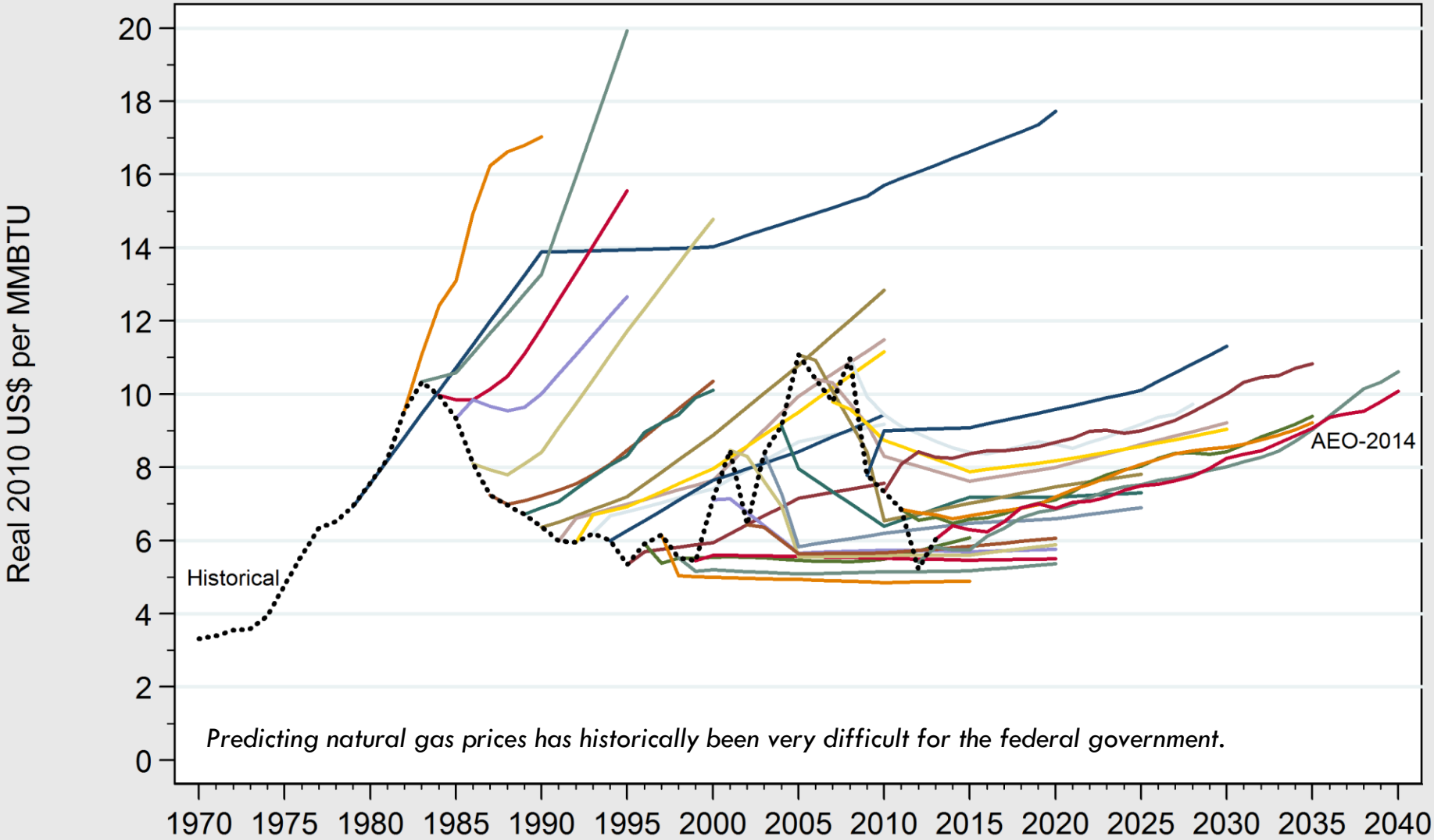
Kentucky Electricity Portfolio Model



Kentucky Energy Database, EEC-DEDI, 2014

EIA Natural Gas Price Forecasts, 1979-2014

Energy Information Administration Annual Energy Outlook Forecasts vs. Actual



Predicting natural gas prices has historically been very difficult for the federal government.

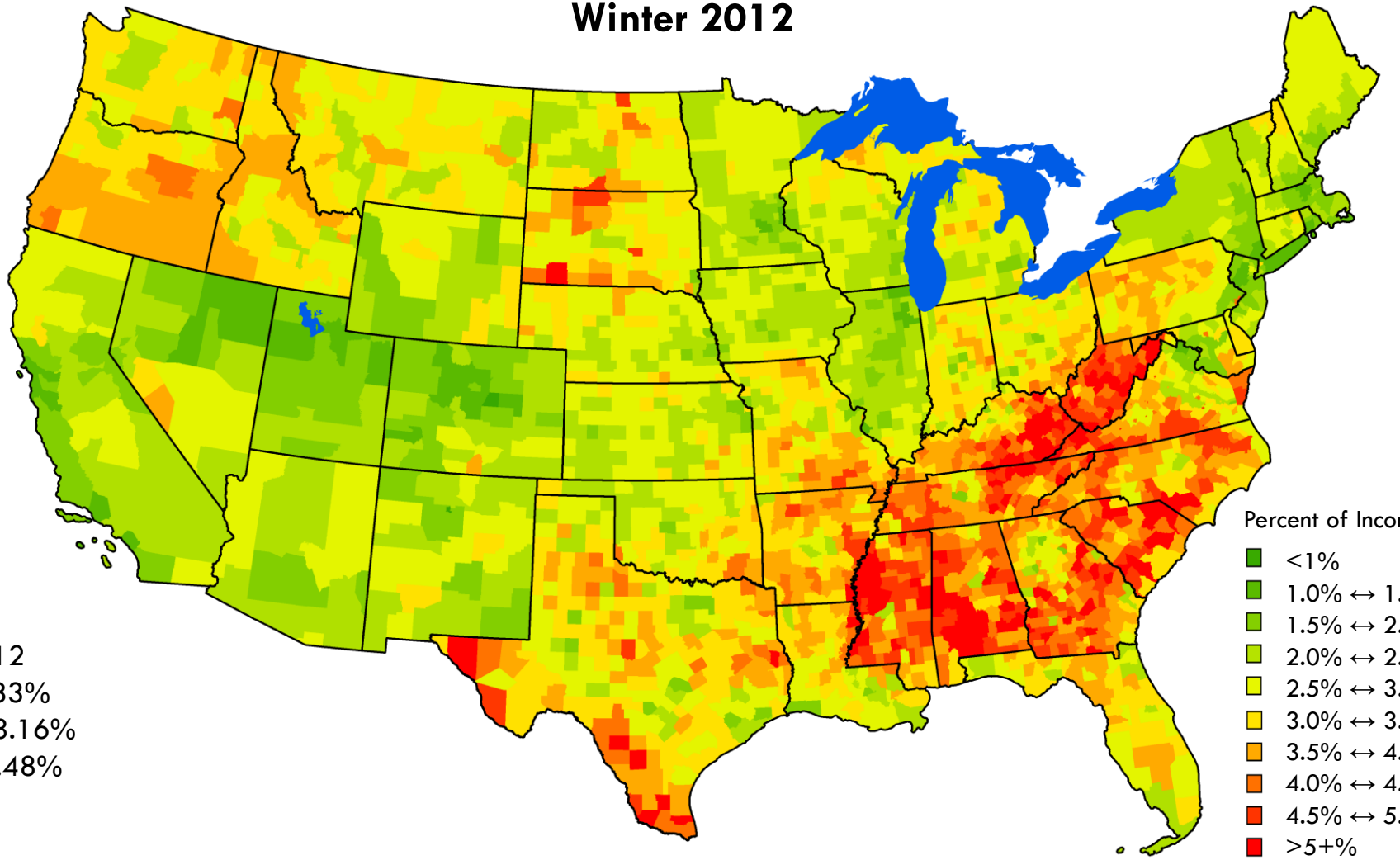
Kentucky Energy Database, EEC-DEDI, 2014

Data Sources: DOE-EIA-AEO 1979-2014 - Reference Case Delivered Price - All Sectors & DOL-BLS-CPI, 2014

Electricity Expenditures as a Percentage of Household Income

Animated versions of these maps are online at:
https://www.youtube.com/watch?v=mGl1DKJCaSA

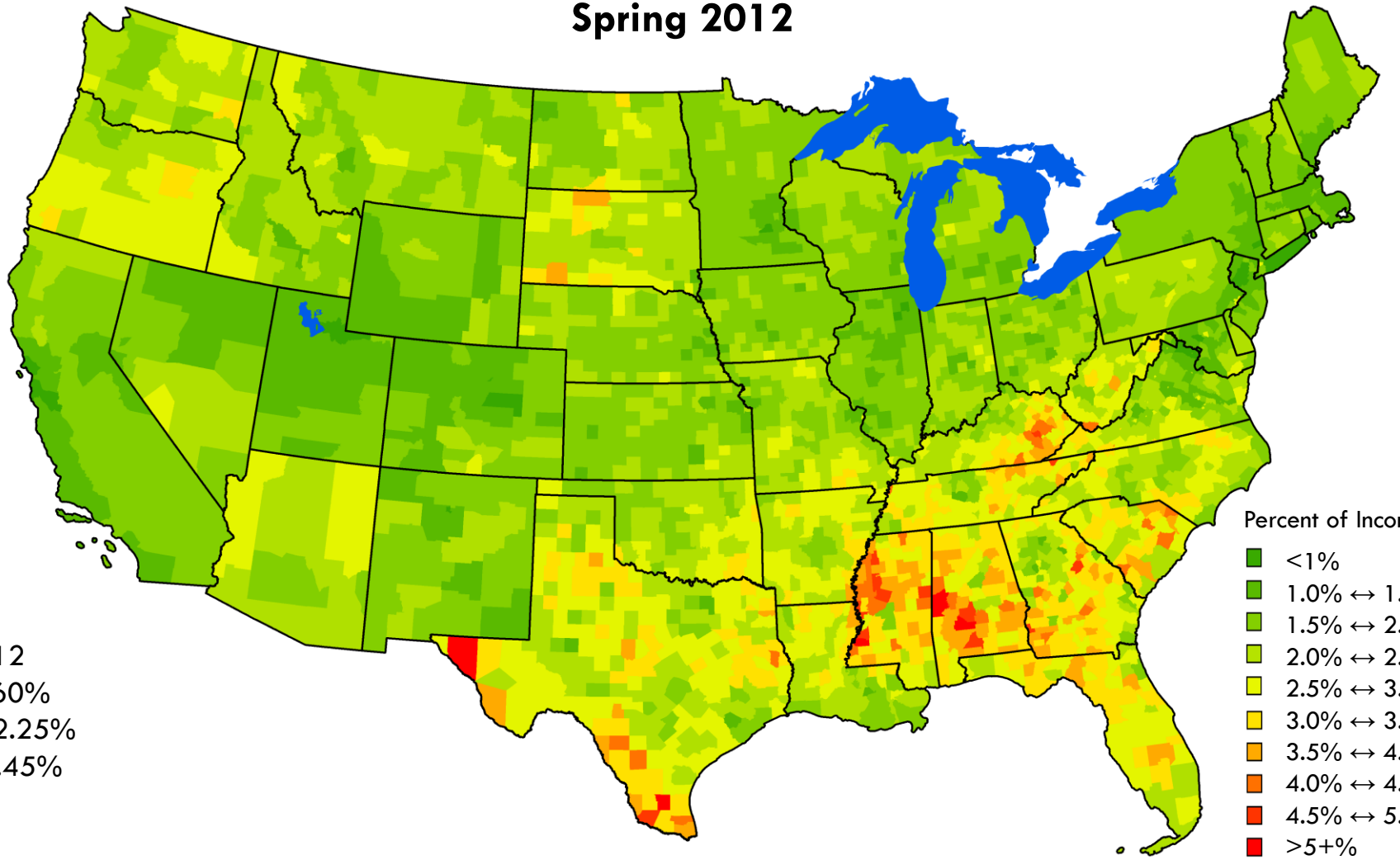
United States Household Electricity Expenditures as a Percentage of Income
Winter 2012



01/2012
Min: 0.83%
Mean: 3.16%
Max: 7.48%

Electricity expenditure data collected by electric service provider by the Energy Information Administration in Form EIA-826 and EIA-861, median household income data collected by the United States Census Bureau American Community Survey. Residential electricity bills vary by household and month not only with electricity prices, but also weather, housing quality, home size, occupancy, personal usage, and method of home heating. Household expenditures for direct heating with fossil fuels such as natural gas, propane, or fuel oil are not reflected in these data.

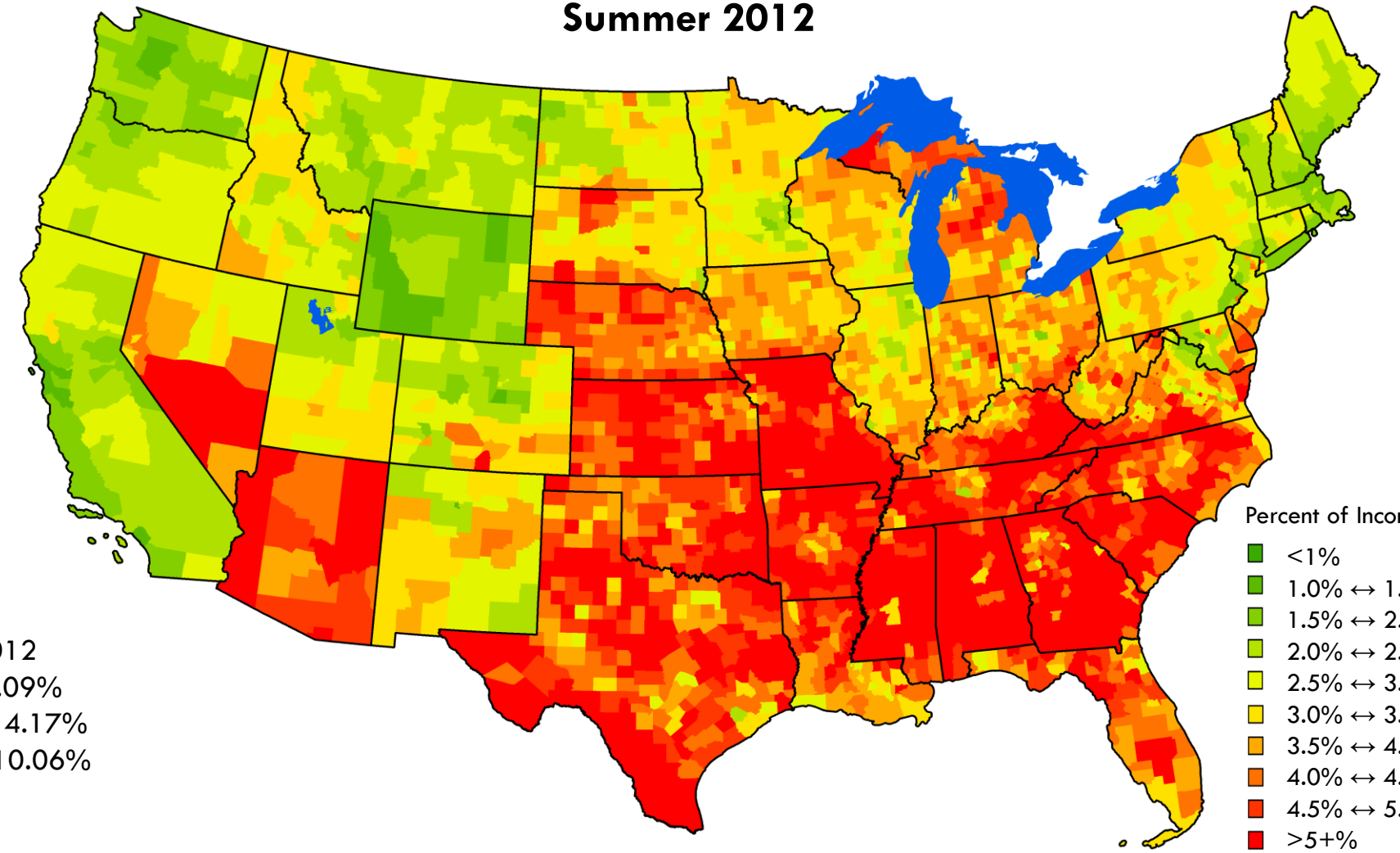
United States Household Electricity Expenditures as a Percentage of Income
Spring 2012



04/2012
Min: 0.60%
Mean: 2.25%
Max: 5.45%

Electricity expenditure data collected by electric service provider by the Energy Information Administration in Form EIA-826 and EIA-861, median household income data collected by the United States Census Bureau American Community Survey. Residential electricity bills vary by household and month not only with electricity prices, but also weather, housing quality, home size, occupancy, personal usage, and method of home heating. Household expenditures for direct heating with fossil fuels such as natural gas, propane, or fuel oil are not reflected in these data.

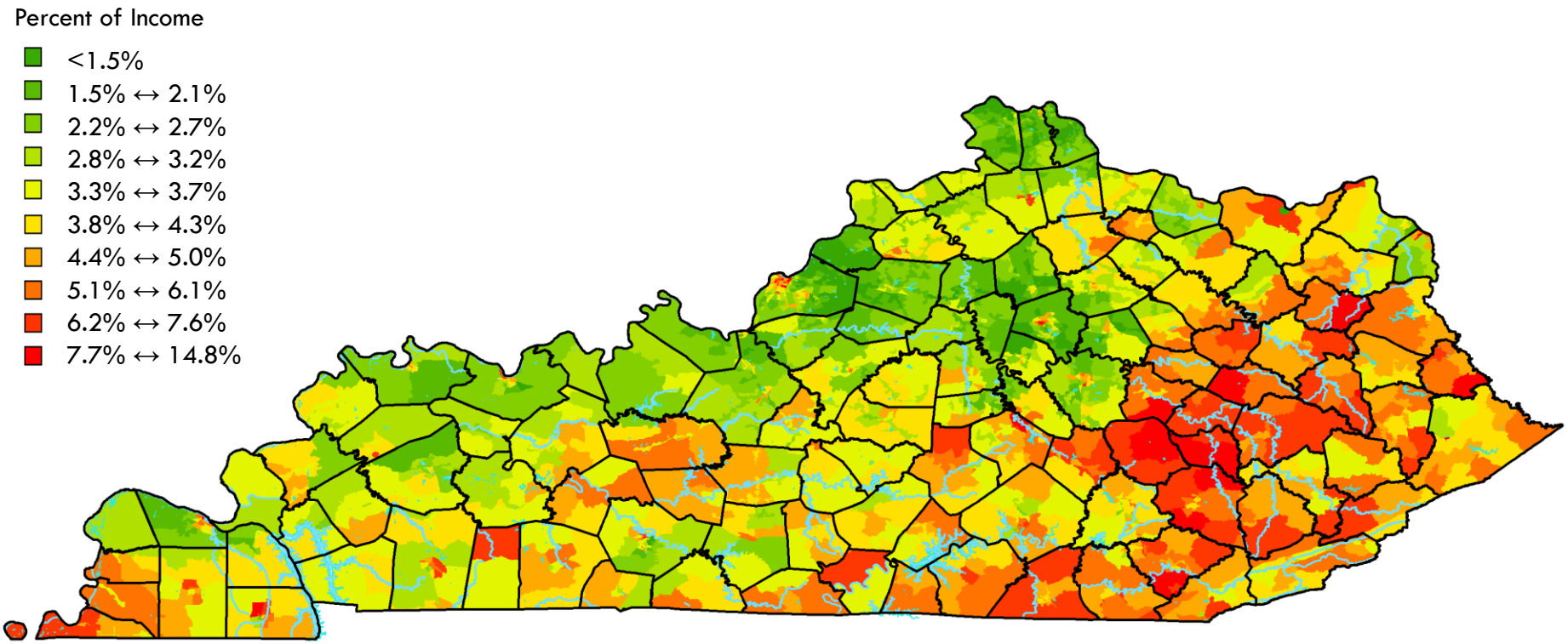
United States Household Electricity Expenditures as a Percentage of Income
Summer 2012



07/2012
Min: 1.09%
Mean: 4.17%
Max: 10.06%

Electricity expenditure data collected by electric service provider by the Energy Information Administration in Form EIA-826 and EIA-861, median household income data collected by the United States Census Bureau American Community Survey. Residential electricity bills vary by household and month not only with electricity prices, but also weather, housing quality, home size, occupancy, personal usage, and method of home heating. Household expenditures for direct heating with fossil fuels such as natural gas, propane, or fuel oil are not reflected in these data.

Kentucky Household Electricity Expenditures as a Percentage of Income 2012



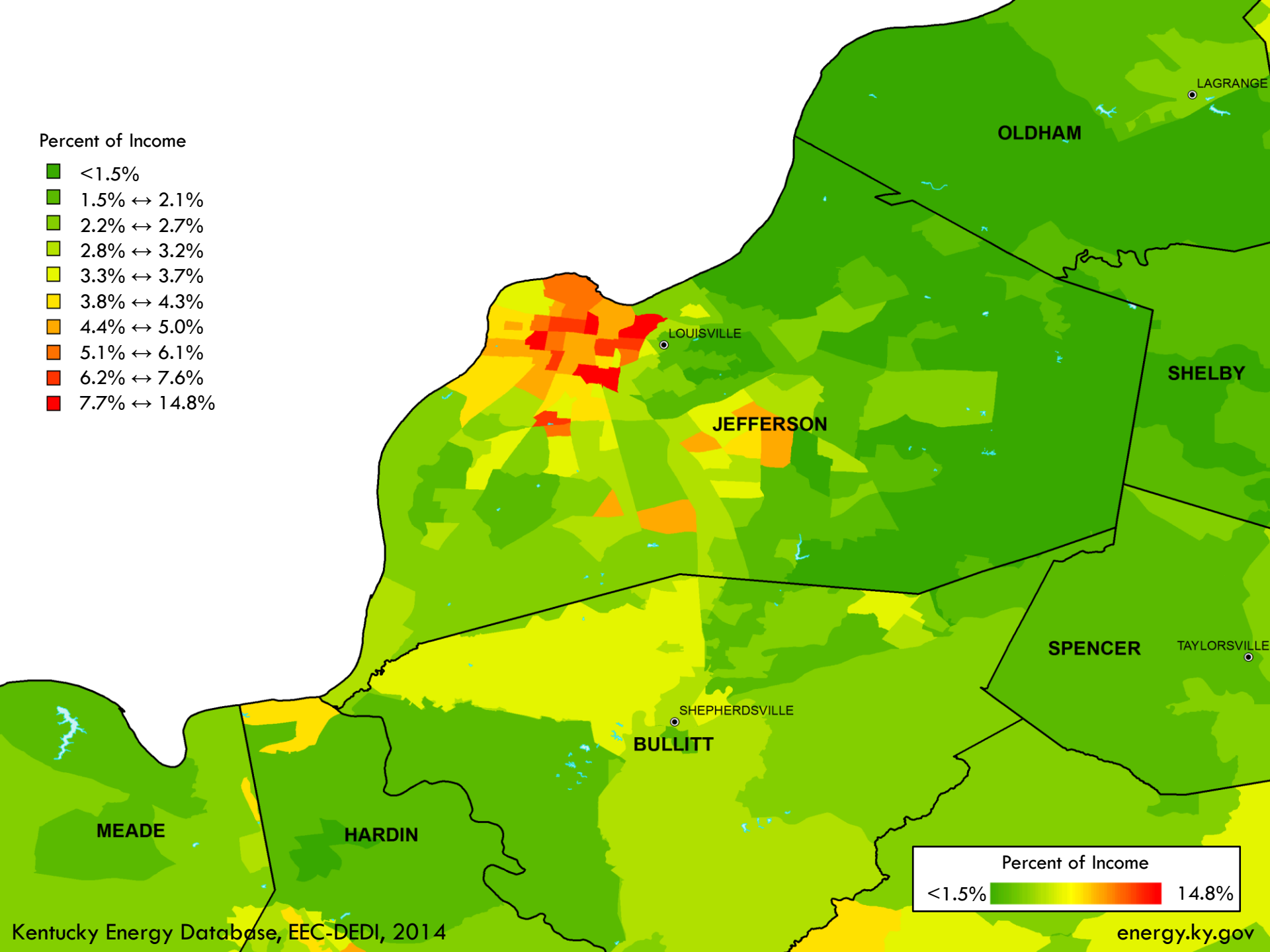
Electricity expenditure data collected by electric service provider by the Energy Information Administration in Form EIA-826 and EIA-861, median household income data collected by the United States Census Bureau American Community Survey. Residential electricity bills vary by household and month not only with electricity prices, but also weather, housing quality, home size, occupancy, personal usage, and method of home heating. Household expenditures for direct heating with fossil fuels such as natural gas, propane, or fuel oil are not reflected in these data.

Percent of Income

<1.5% 14.8%

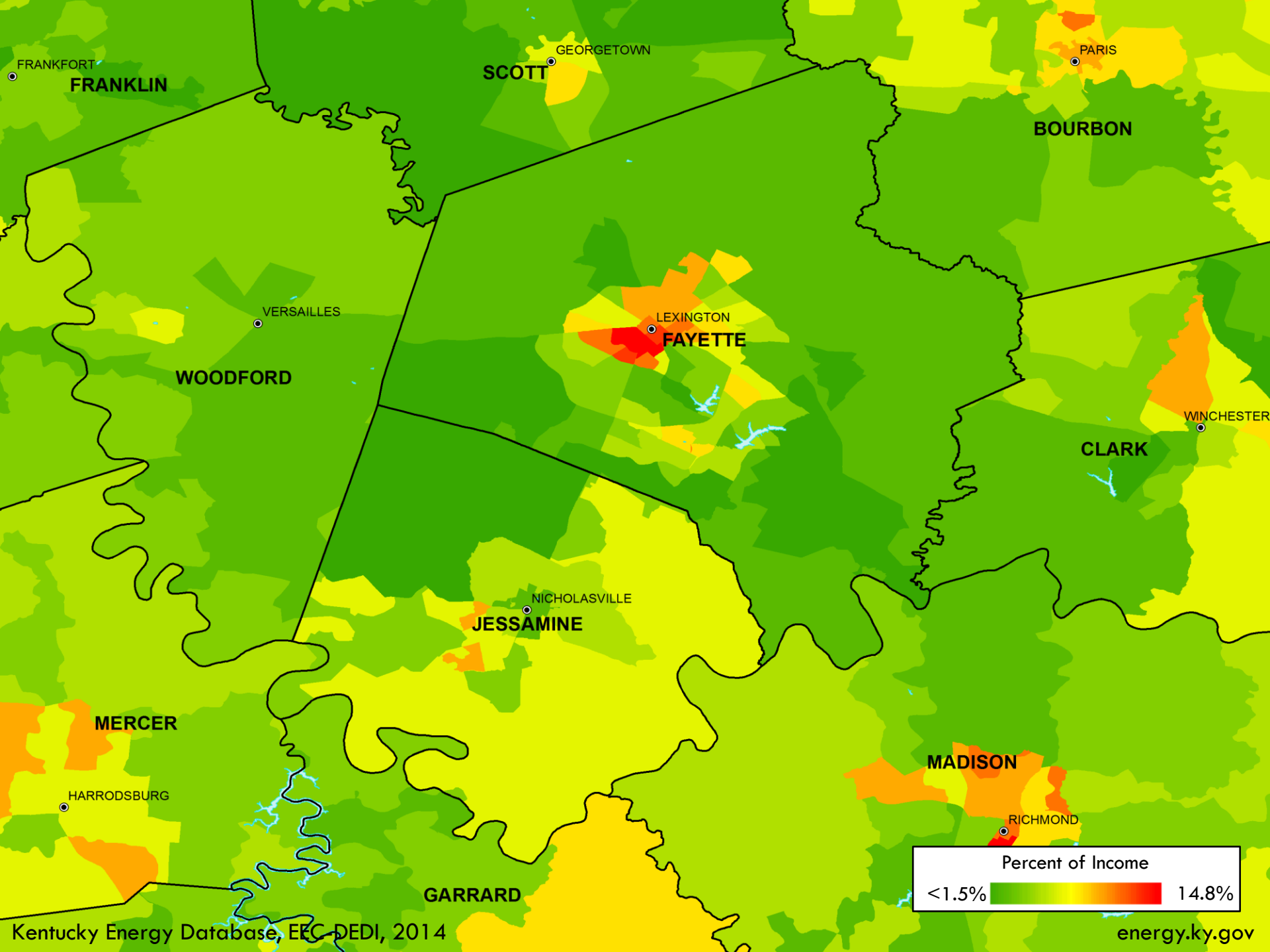
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



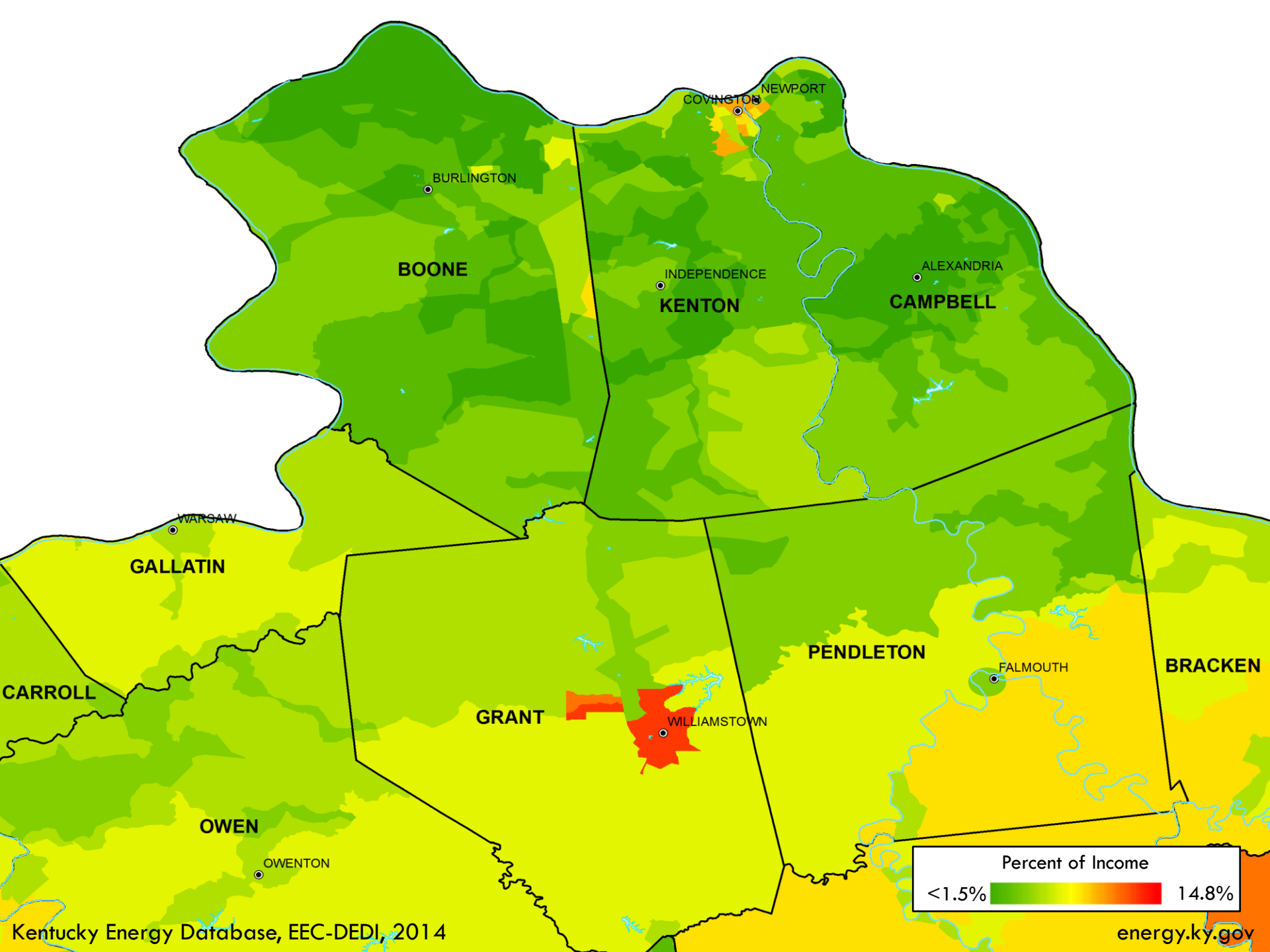
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



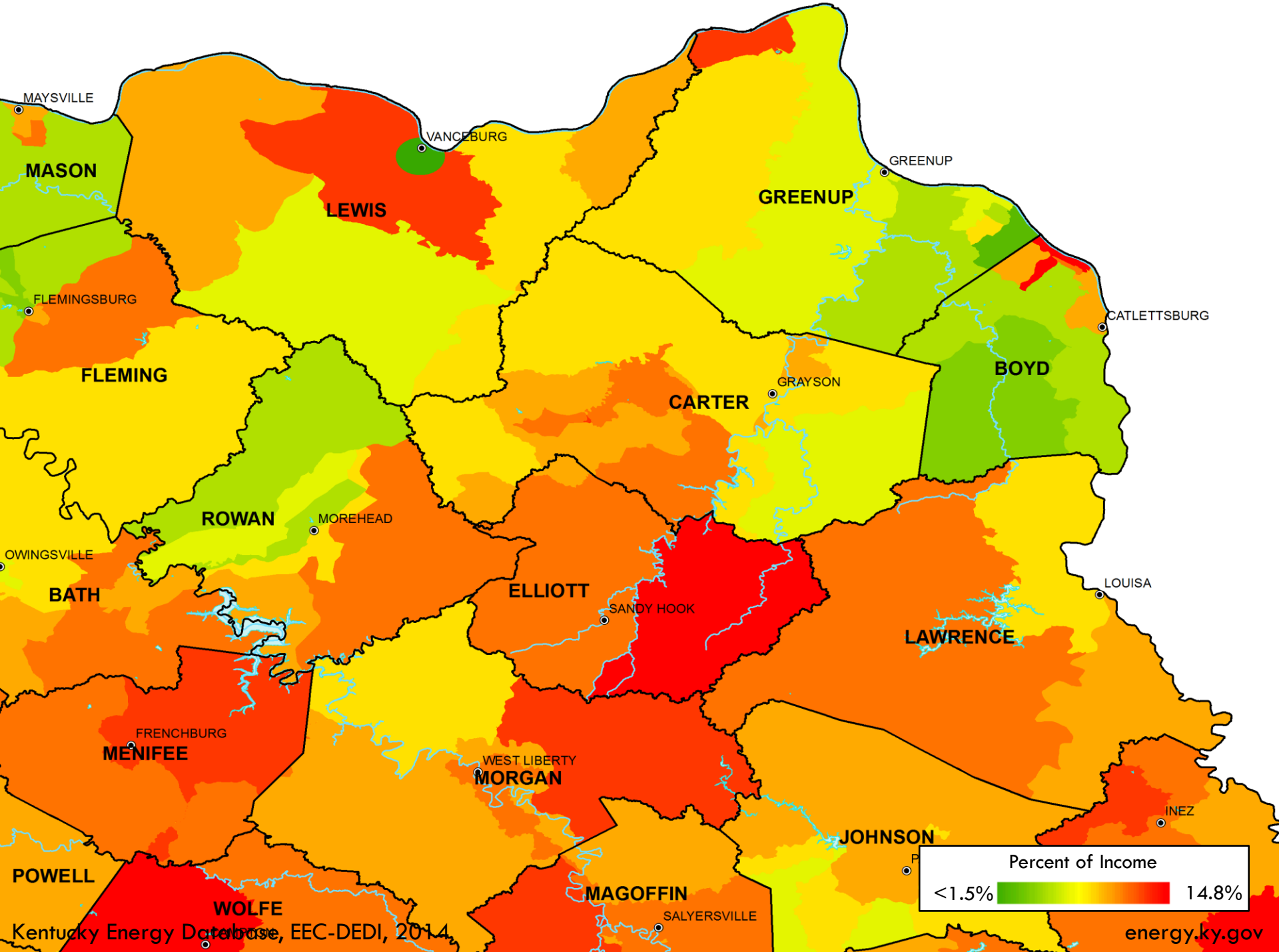
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



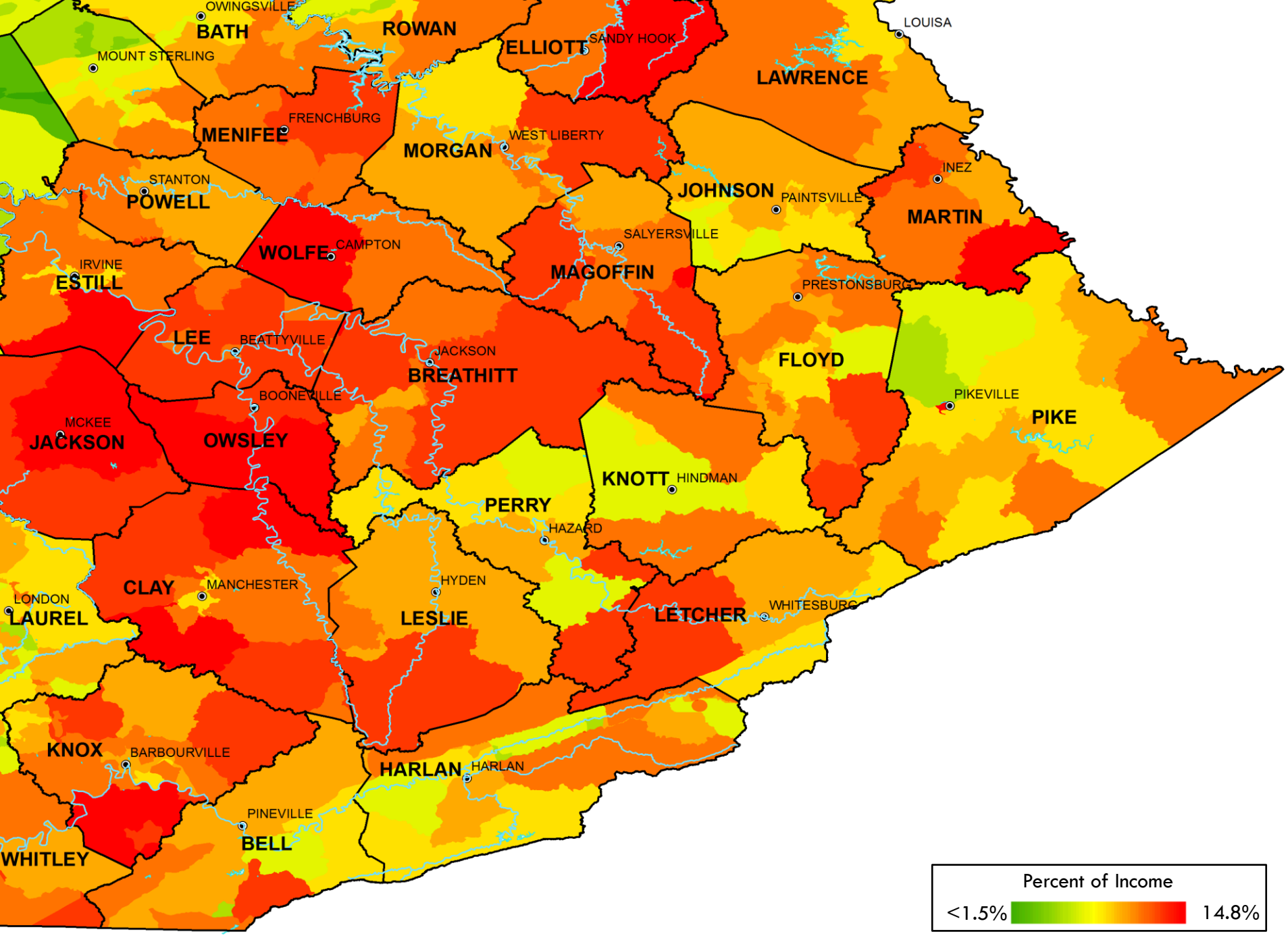
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



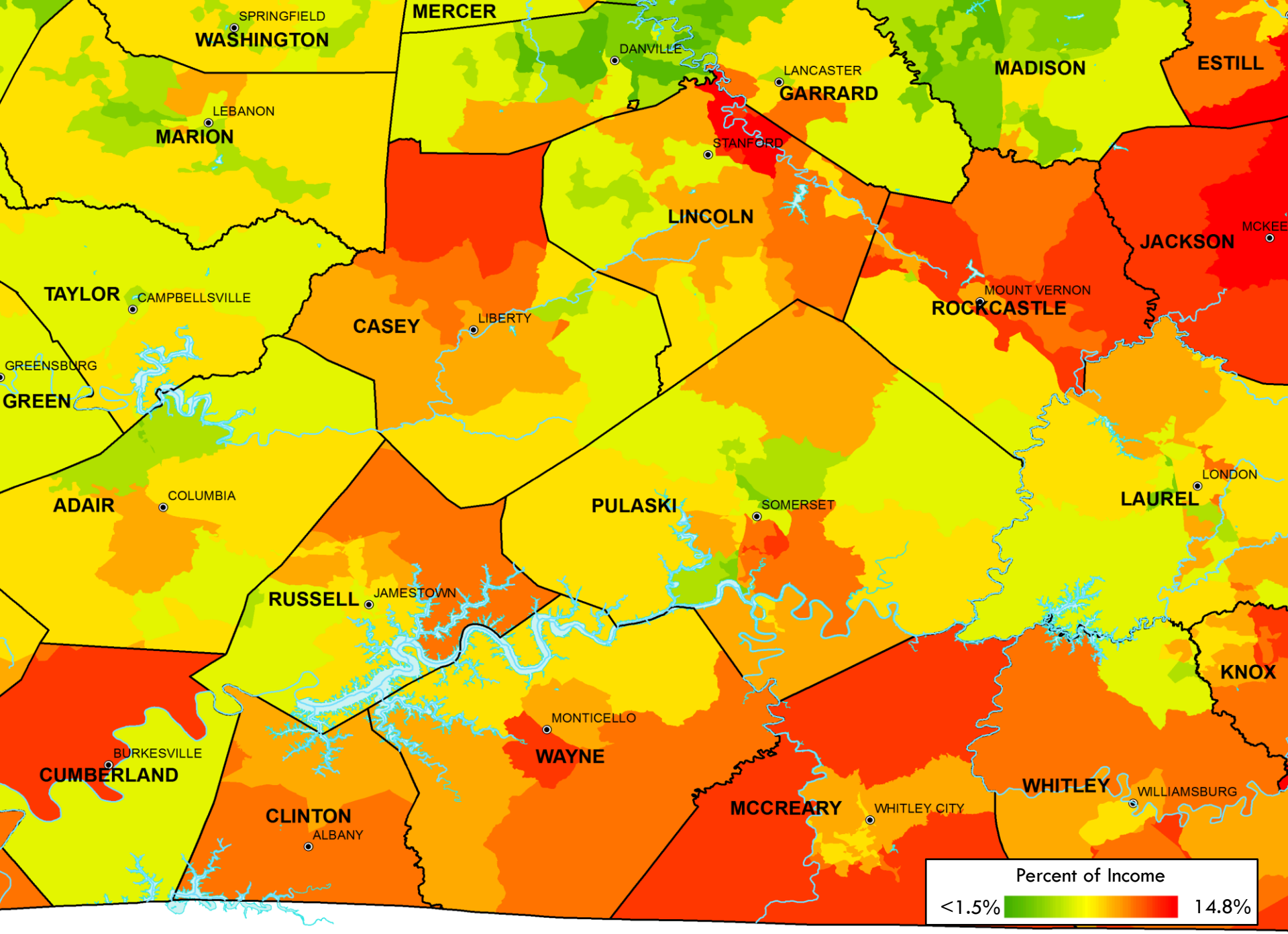
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



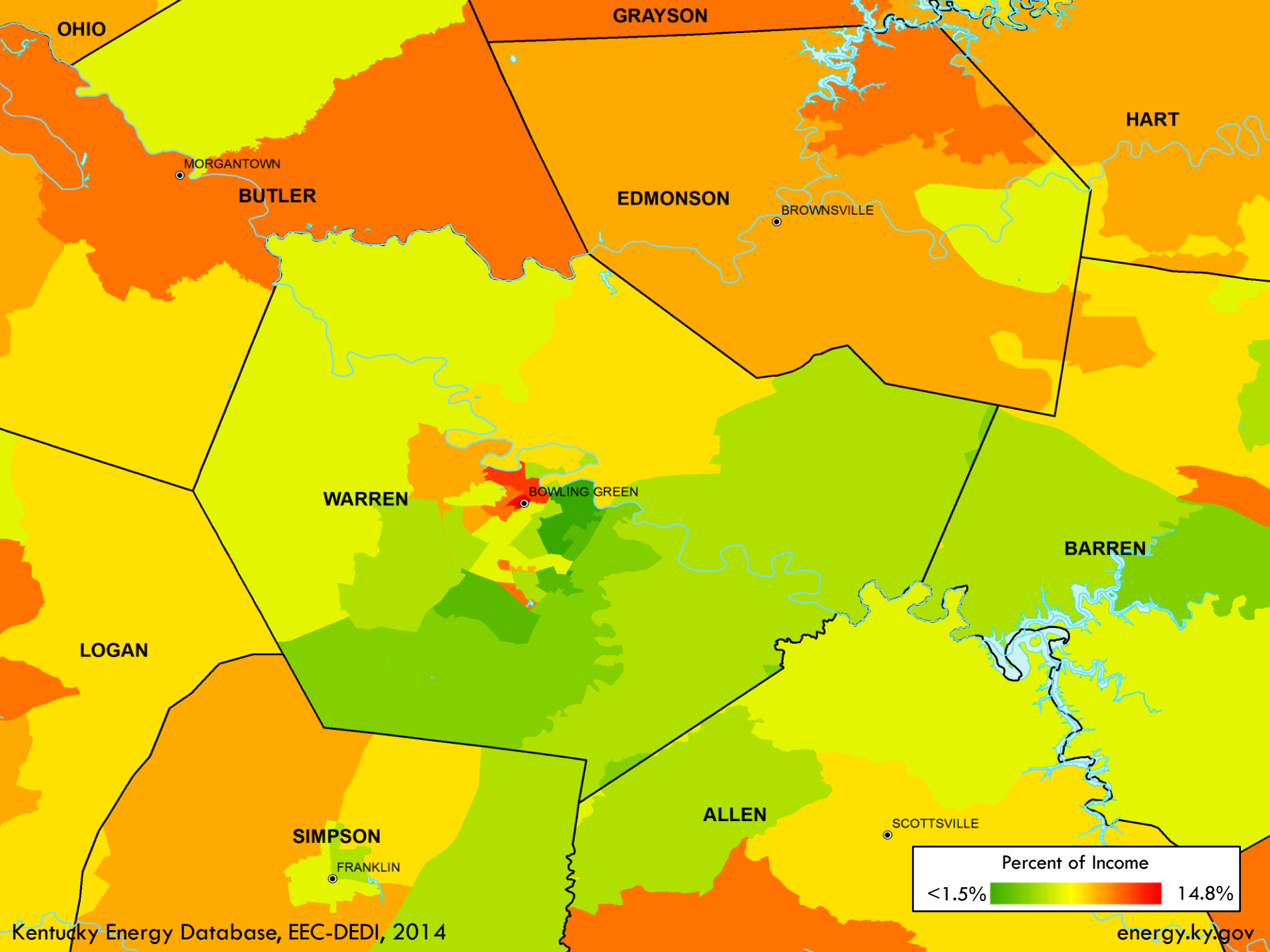
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



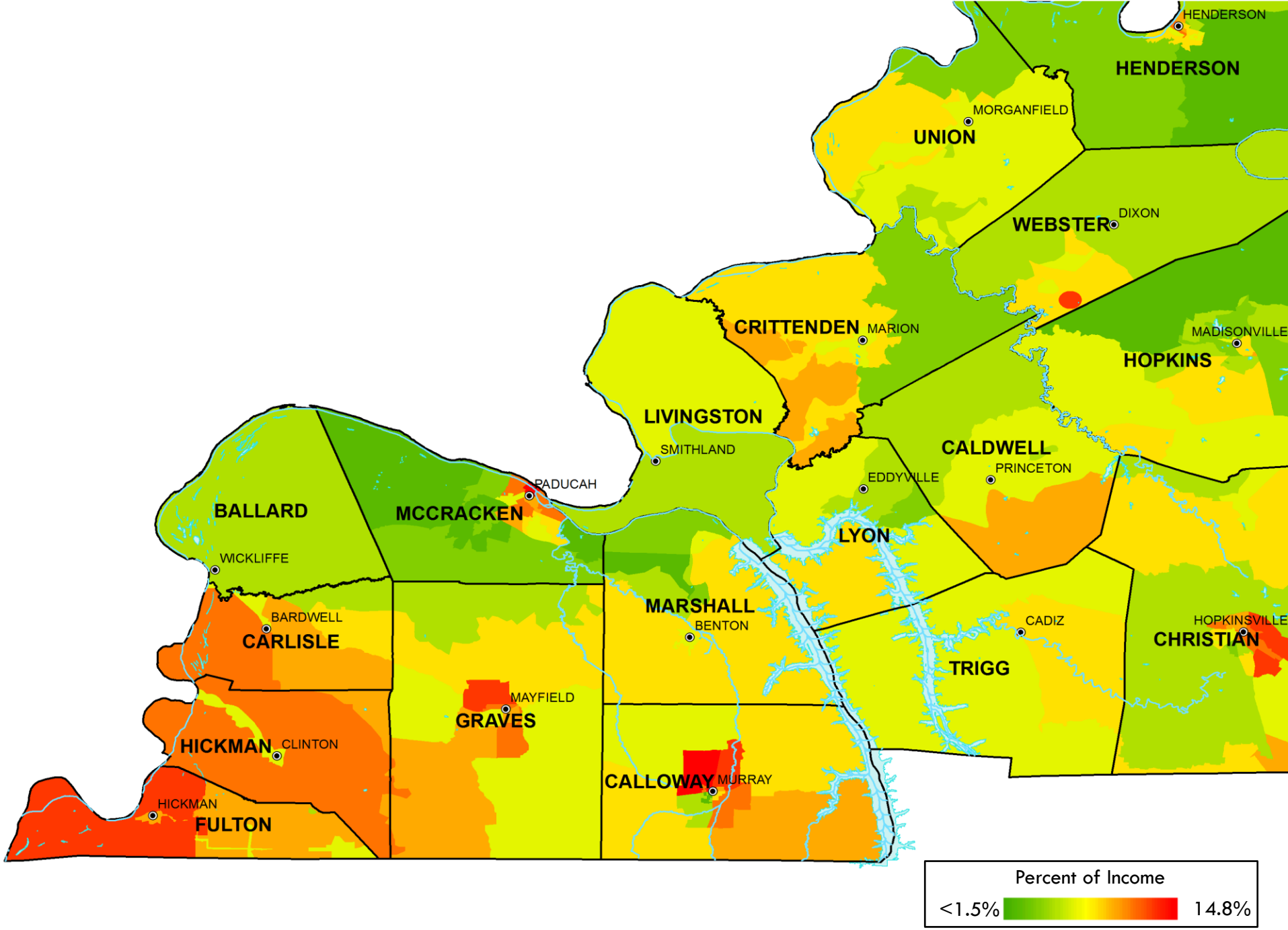
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



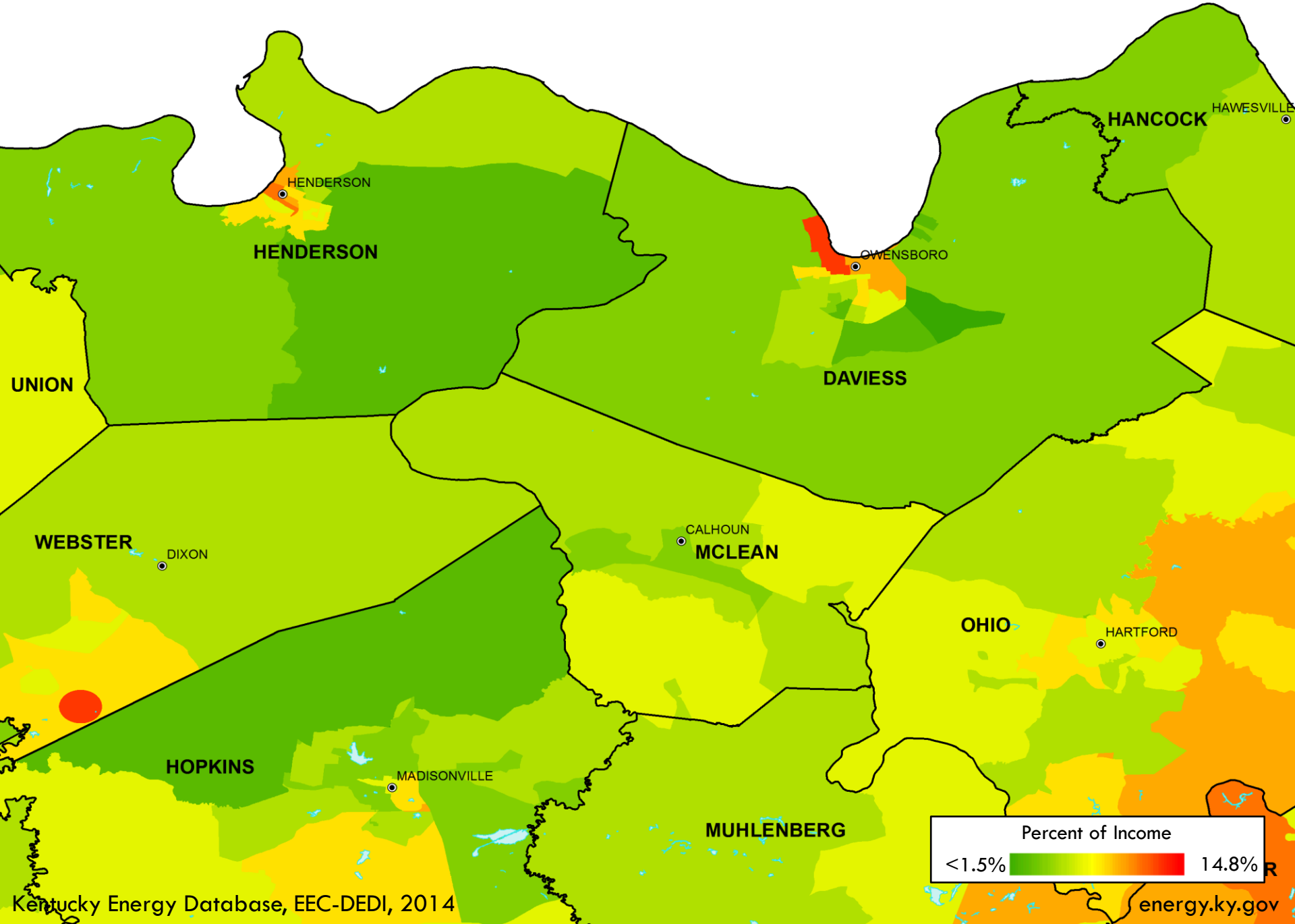
Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov



Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov

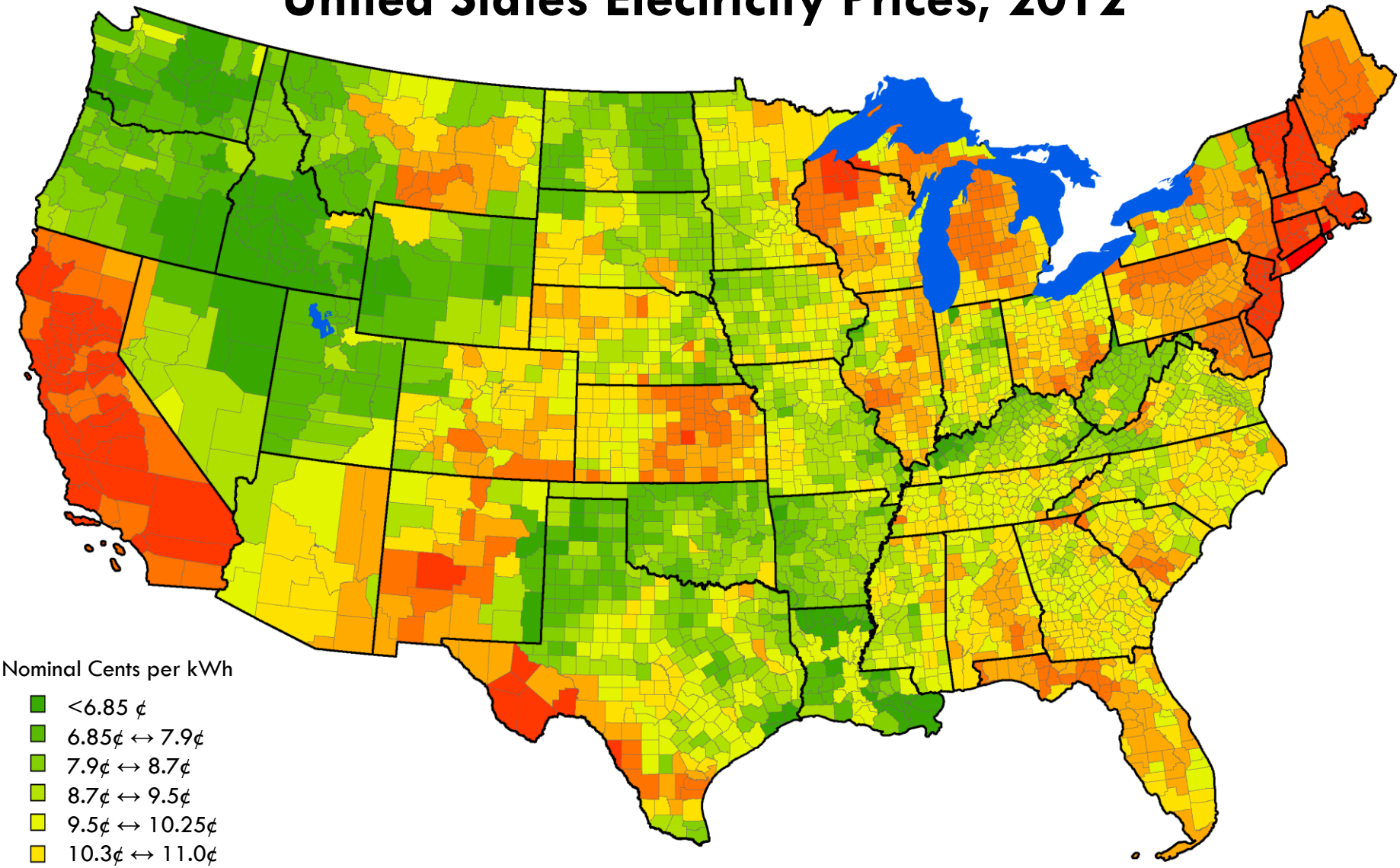
Vulnerability of the United States Economy to Increasing Electricity Prices

Draft Working Paper by Aron Patrick, Adam Blandford, and Leonard K. Peters

Download the Associated White Paper: http://1.usa.gov/1aVhOWu

An Excel VBA interactive version of this model is available for download at:
https://docs.google.com/uc?authuser=0&id=0B1Oi5D9dXqLJVTBVcE94bWU1UW8&export=download

United States Electricity Prices, 2012



Nominal Cents per kWh

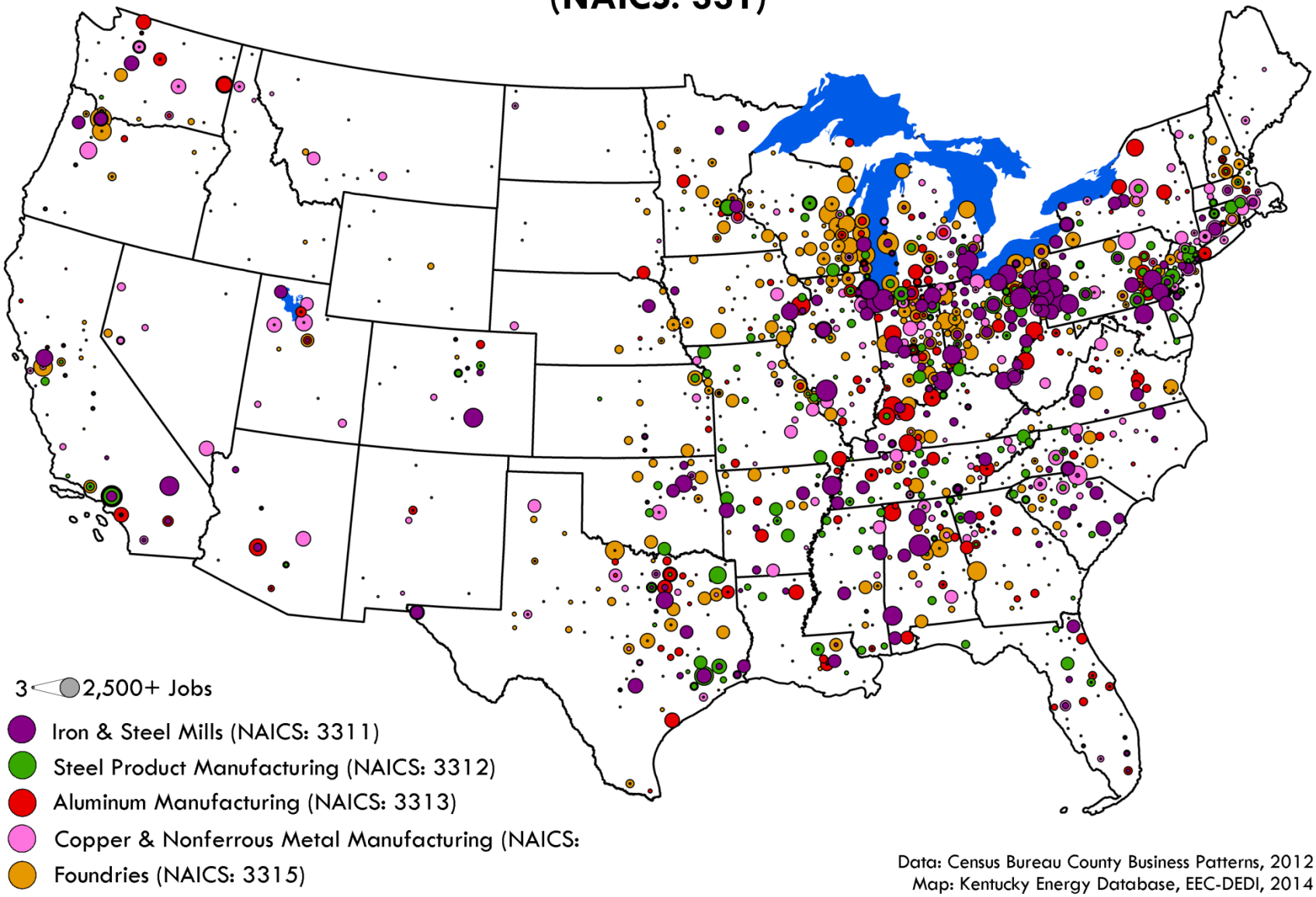
- <6.85 ¢
- 6.85¢ ↔ 7.9¢
- 7.9¢ ↔ 8.7¢
- 8.7¢ ↔ 9.5¢
- 9.5¢ ↔ 10.25¢
- 10.3¢ ↔ 11.0¢
- 11.0¢ ↔ 12.0¢
- 12.0¢ ↔ 14.0¢
- 14.0¢ ↔ 25.0¢
- 25.0¢ ↔ 55.0¢

Animated versions of these maps are online at:
https://www.youtube.com/watch?v=QExe0zRFzfE

Kentucky Energy Database, EEC-DEDI, 2014

energy.ky.gov

United States Primary Metal Manufacturing Employment, 2012 (NAICS: 331)



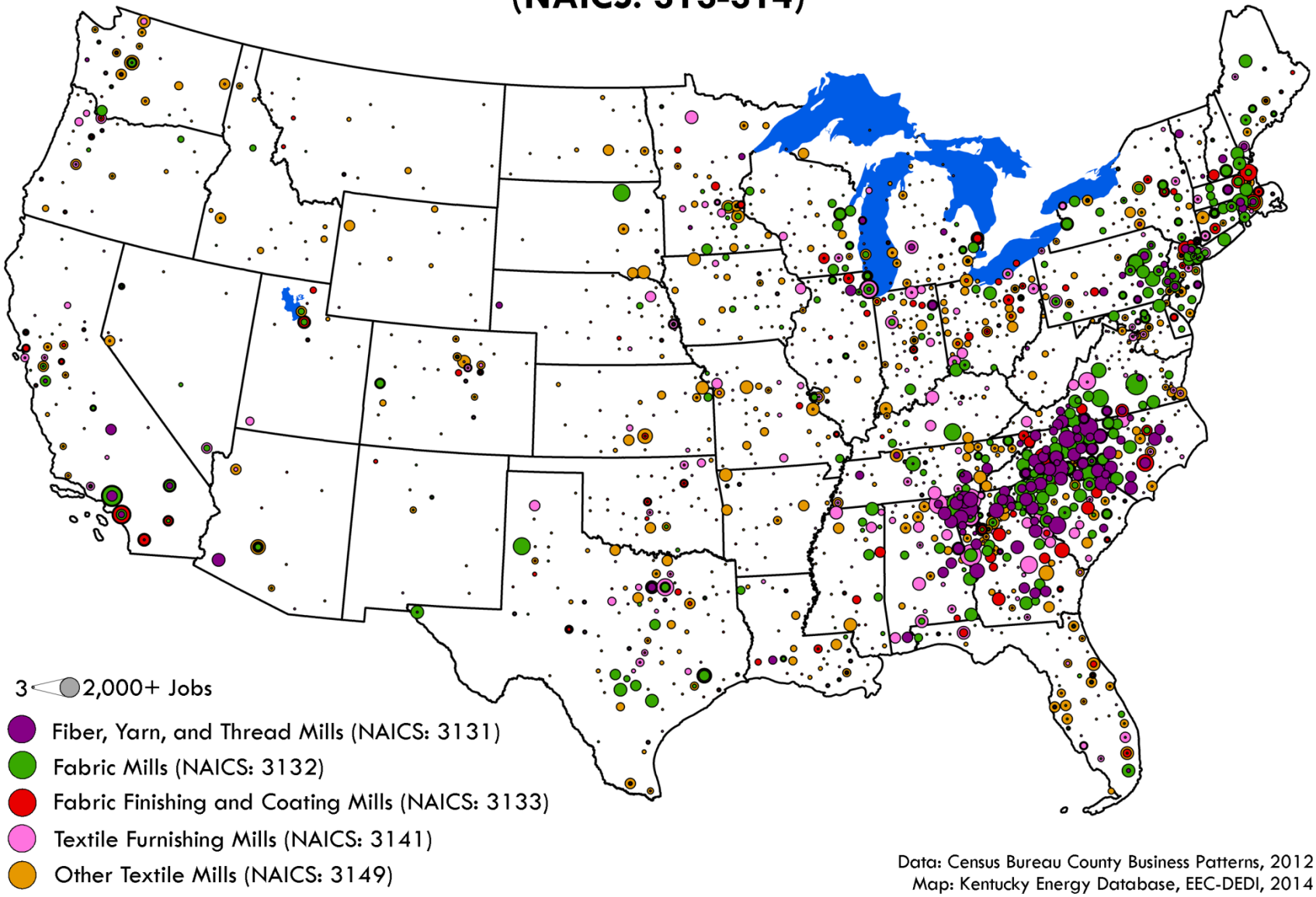
Data: Census Bureau County Business Patterns, 2012
Map: Kentucky Energy Database, EEC-DEDI, 2014

Aron & Adam touring Century Aluminum in Sebree, Kentucky in 2015

Aron & Adam touring Century Aluminum in Sebree, Kentucky in 2015

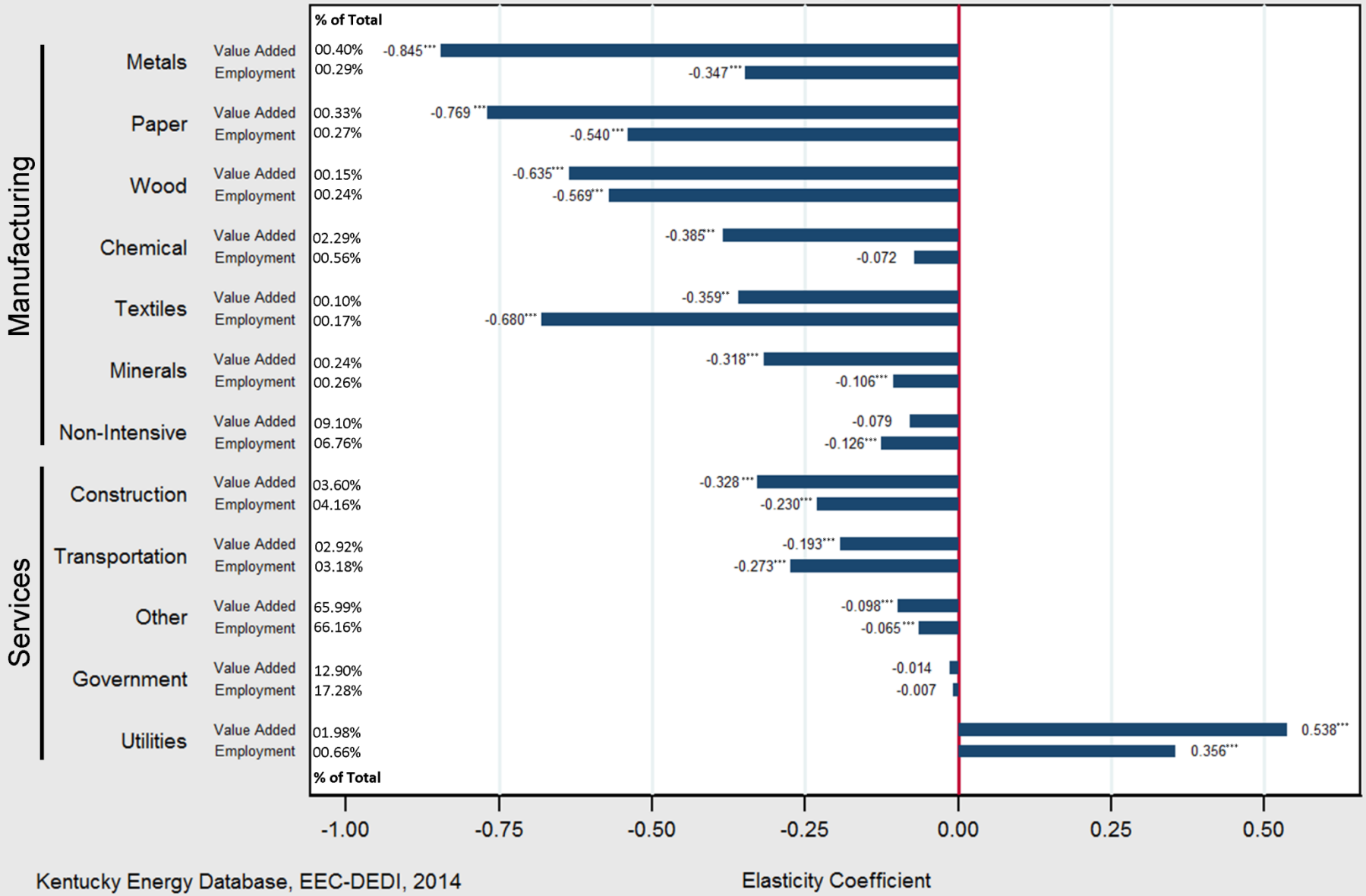
North American Stainless in Carroll County, Kentucky March, 2015

United States Textile Manufacturing Employment, 2012
(NAICS: 313-314)



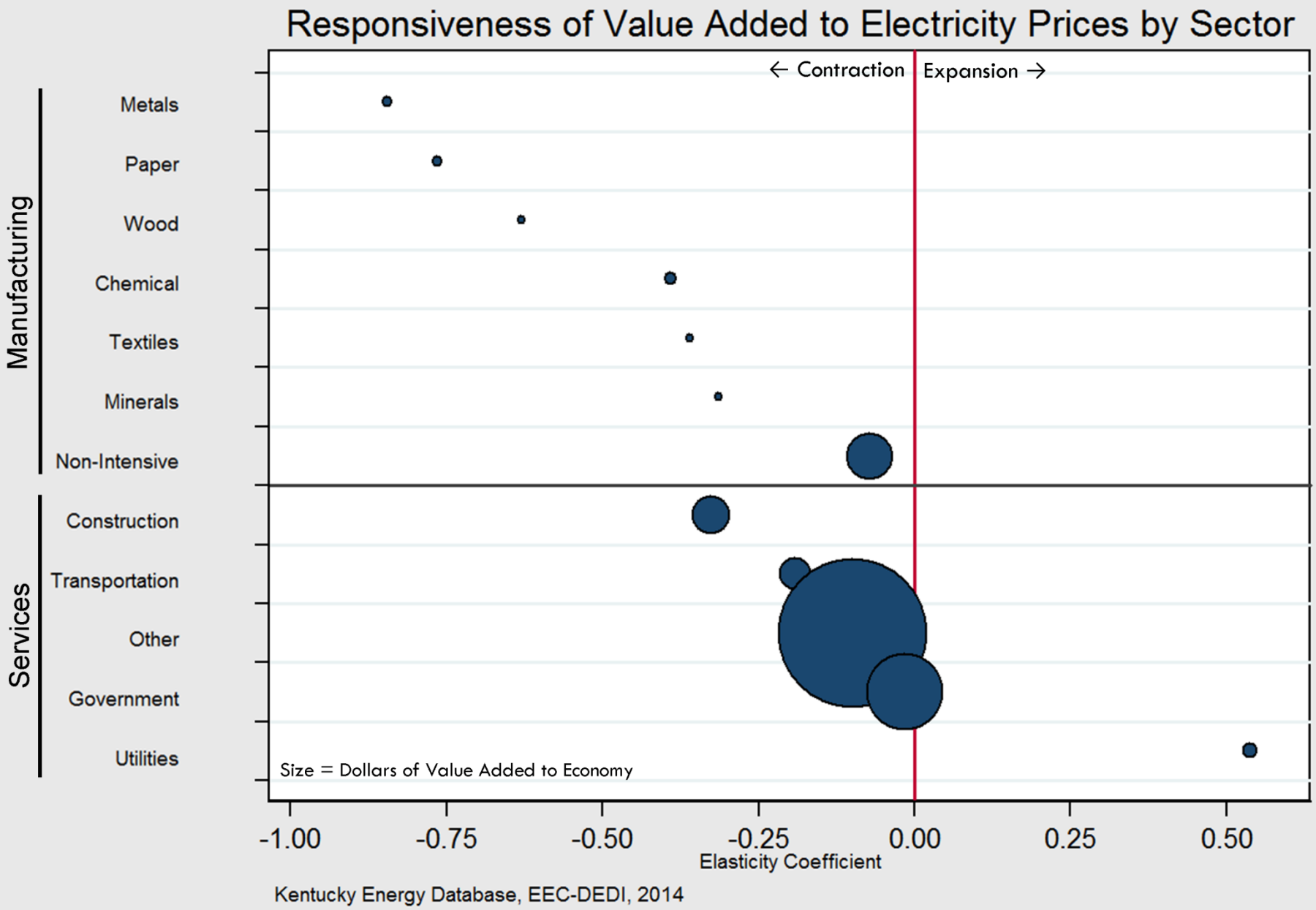
Data: Census Bureau County Business Patterns, 2012
Map: Kentucky Energy Database, EEC-DEDI, 2014

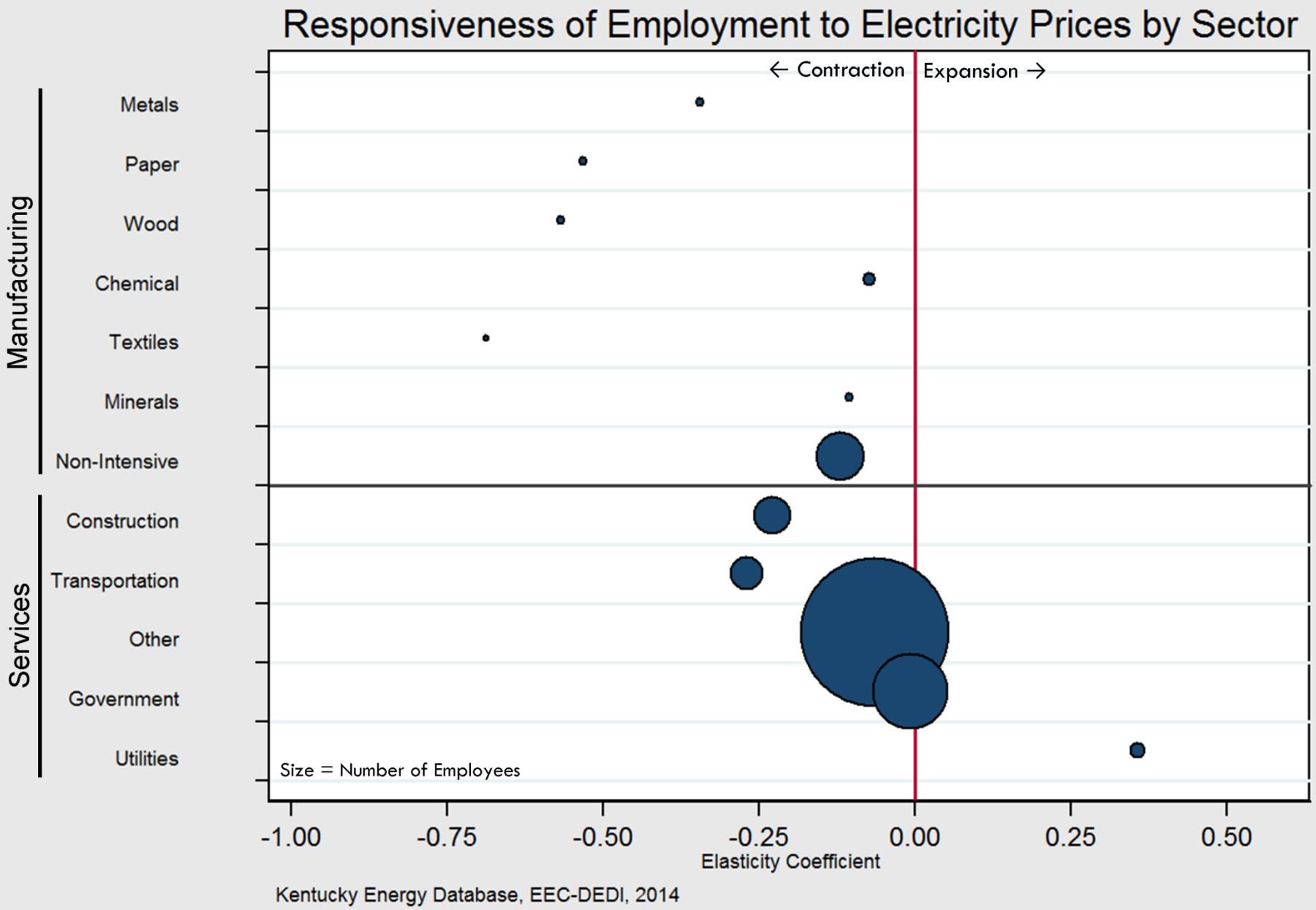
Electricity Price Elasticity Coefficients by Sector

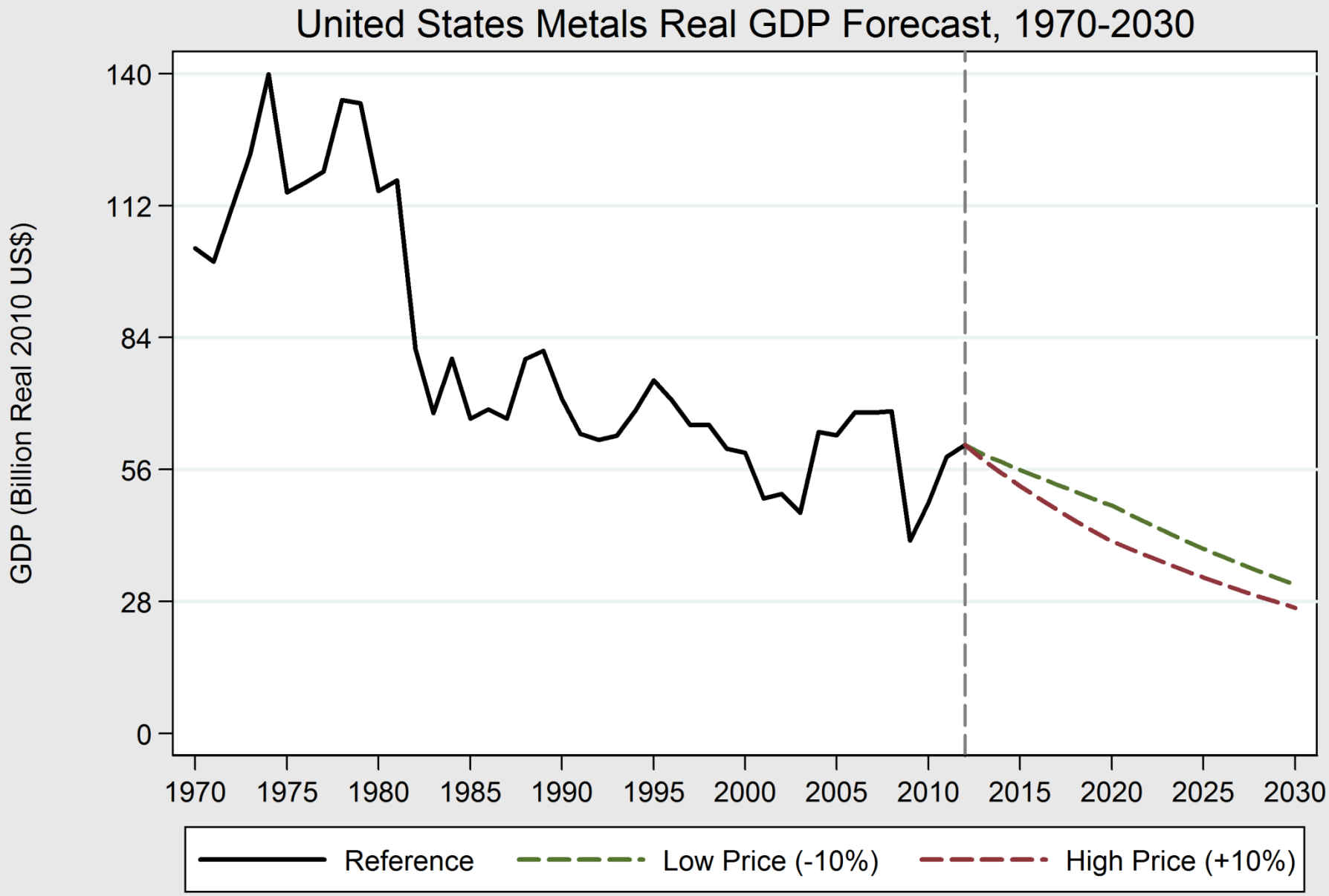


Kentucky Energy Database, EEC-DEDI, 2014

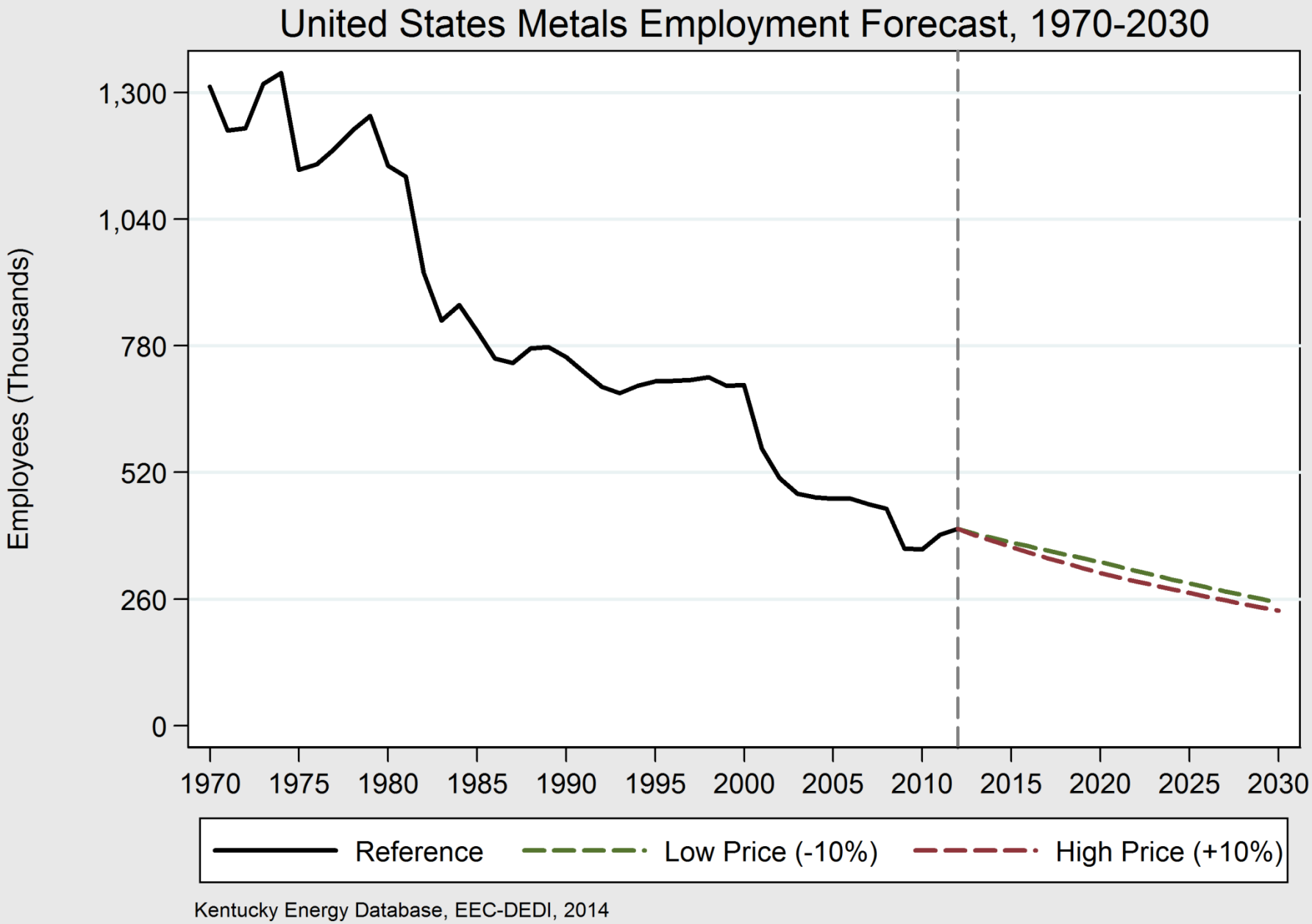
Asterisk Denotes Statistical Significance at the Following Levels: * P>|t|<0.05, ** P>|t|<=0.01, *** P>|t|<=0.001


Responsiveness of Value Added to Electricity Prices by Sector
← Contraction
Expansion →
Manufacturing
Metals
Paper
Wood
Chemical
Textiles
Minerals
Non-Intensive
Services
Construction
Transportation
Other
Government
Utilities
Size = Dollars of Value Added to Economy
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
Elasticity Coefficient
Kentucky Energy Database, EEC-DEDI, 2014


Responsiveness of Employment to Electricity Prices by Sector
← Contraction
Expansion →
Manufacturing
Metals
Paper
Wood
Chemical
Textiles
Minerals
Non-Intensive
Services
Construction
Transportation
Other
Government
Utilities
Size = Number of Employees
-1.00
-0.75
-0.50
-0.25
0.00
0.25
0.50
Elasticity Coefficient
Kentucky Energy Database, EEC-DEDI, 2014



Kentucky Energy Database, EEC-DEDI, 2014


United States Metals Employment Forecast, 1970-2030
Employees (Thousands)
1,300
1,040
780
520
260
0
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
Reference
Low Price (-10%)
High Price (+10%)
Kentucky Energy Database, EEC-DEDI, 2014

Electricity Intensity of United States Manufacturing, 2010

	NAICS	Description	Electricity Intensity Rank	Electricity Intensity (kWh/$)	Electricity Intensity Range (kWh/$)	Total Employees (US)	Electricity Consumed (TWh)	Value of Product (Billion $)
Intensive	**Electricity-Intensive Total**		**--**	**0.530**	**0.011 ↔ 5.829**	**1,479,071**	**313.202**	**590.986**
	322	Paper Manufacturing	1	0.646	0.195 ↔ 1.501	351,931	109.771	169.954
	331	Primary Metal Manufacturing	2	0.560	0.059 ↔ 5.829	353,671	129.524	231.185
	313	Textile Mills	3	0.453	0.123 ↔ 0.506	107,661	13.183	29.109
	327	Nonmetallic Mineral Product Manufacturing	4	0.422	0.011 ↔ 1.854	336,216	38.349	90.781
	321	Wood Product Manufacturing	5	0.320	0.053 ↔ 0.957	329,592	22.375	69.957
	325	Chemical Manufacturing	6	0.292	0.038 ↔ 2.887	703,280	204.749	701.230
Non-Intensive	**Non-Intensive Total**		**--**	**0.120**	**0.021 ↔ 2.887**	**9,088,286**	**436.645**	**3,624.430**
	326	Plastics And Rubber Products Manufacturing	7	0.288	0.125 ↔ 0.621	664,641	54.331	188.583
	323	Printing And Related Support Activities	8	0.178	0.145 ↔ 0.181	468,030	14.667	82.488
	314	Textile Product Mills	9	0.151	0.145 ↔ 0.641	108,934	3.295	21.818
	311	Food Manufacturing	10	0.150	0.026 ↔ 0.736	1,364,157	97.125	646.451
	332	Fabricated Metal Product Manufacturing	11	0.146	0.062 ↔ 0.398	1,242,904	43.157	295.187
	335	Electrical Equipment and Appliances	12	0.115	0.055 ↔ 0.558	327,441	12.714	110.993
	324	Petroleum And Coal Products Manufacturing	13	0.111	0.045 ↔ 0.182	99,225	69.689	627.572
	337	Furniture And Related Product Manufacturing	14	0.104	0.036 ↔ 0.171	332,316	6.094	58.795
	334	Computer And Electronic Product Manufacturing	15	0.090	0.021 ↔ 0.268	836,475	30.611	340.683
	336	Transportation Equipment Manufacturing	16	0.086	0.029 ↔ 0.346	1,181,363	54.540	633.275
	315	Apparel Manufacturing	17	0.083	0.028 ↔ 0.296	104,457	1.135	13.643
	333	Machinery Manufacturing	18	0.083	0.042 ↔ 0.213	930,290	26.310	317.694
	312	Beverage And Tobacco Product Manufacturing	19	0.082	0.046 ↔ 0.116	132,409	10.820	131.845
	316	Leather And Allied Product Manufacturing	20	0.082	0.128 ↔ 0.131	27,609	0.413	5.049
	339	Miscellaneous Manufacturing	21	0.078	0.042 ↔ 0.271	564,755	11.746	150.353

Complete Model of Employment & Value Added by Sector

		Manufacturing														Services									
		Metals		Paper		Wood		Chemical		Textiles		Minerals		Non-Intense		Construct		Transport		Other		Government		Utilities	
Logged Variables		V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp	V.Add	Emp
Electricity Price	β_1	**-0.845**	**-0.347**	**-0.769**	**-0.540**	**-0.635**	**-0.569**	**-0.385**	**-0.072**	**-0.359**	**-0.680**	**-0.318**	**-0.106**	**-0.079**	**-0.126**	**-0.328**	**-0.230**	**-0.193**	**-0.273**	**-0.098**	**-0.065**	**-0.014**	**-0.007**	**0.538**	**0.356**
	SE	0.089	0.064	0.091	0.064	0.059	0.041	0.062	0.051	0.124	0.114	0.039	0.031	0.045	0.034	0.025	0.023	0.022	0.020	0.015	0.008	0.010	0.008	0.028	0.022
	P>|t|	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.154	0.004	0.000	0.000	0.001	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.159	0.330	0.000	0.000
Personal Income	β_2	**0.427**	**-0.254**	**0.078**	**-1.160**	**0.042**	**-0.042**	**1.284**	**0.408**	**-0.870**	**-1.246**	**1.838**	**0.772**	**-0.058**	**-0.775**	**2.582**	**1.577**	**0.762**	**0.081**	**1.269**	**0.220**	**0.638**	**0.059**	**0.093**	**-0.004**
	SE	0.219	0.157	0.223	0.157	0.146	0.100	0.152	0.124	0.305	0.280	0.096	0.076	0.110	0.084	0.060	0.057	0.054	0.050	0.037	0.019	0.024	0.019	0.069	0.053
	P>|t|	0.052	0.106	0.727	0.000	0.774	0.677	0.000	0.001	0.004	0.000	0.000	0.000	0.601	0.000	0.000	0.000	0.000	0.107	0.000	0.000	0.000	0.001	0.178	0.933
Education	β_3	**1.589**	**0.839**	**2.586**	**1.459**	**3.392**	**2.449**	**0.238**	**0.646**	**-1.657**	**-0.413**	**0.199**	**0.305**	**0.504**	**1.077**	**-0.037**	**0.101**	**0.278**	**0.607**	**0.314**	**0.618**	**-0.174**	**0.147**	**0.756**	**0.411**
	SE	0.195	0.140	0.198	0.140	0.130	0.089	0.136	0.111	0.271	0.250	0.085	0.068	0.098	0.075	0.054	0.051	0.048	0.045	0.033	0.017	0.022	0.017	0.061	0.047
	P>|t|	0.000	0.000	0.000	0.000	0.000	0.000	0.079	0.000	0.000	0.098	0.019	0.000	0.000	0.000	0.496	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Population	β_4	**0.863**	**0.763**	**2.136**	**2.190**	**0.704**	**0.301**	**0.509**	**0.696**	**1.417**	**2.003**	**1.511**	**1.403**	**1.687**	**1.444**	**1.387**	**1.290**	**1.159**	**1.235**	**1.118**	**0.940**	**0.650**	**0.665**	**0.989**	**0.820**
	SE	0.115	0.082	0.117	0.083	0.077	0.053	0.080	0.065	0.160	0.147	0.050	0.040	0.058	0.044	0.032	0.030	0.029	0.026	0.019	0.010	0.013	0.010	0.036	0.028
	P>|t|	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Petroleum Price	β_5	**0.399**	**-0.101**	**-0.240**	**-0.223**	**-0.226**	**-0.192**	**0.104**	**-0.059**	**-0.368**	**-0.114**	**0.033**	**-0.045**	**-0.112**	**-0.191**	**0.105**	**-0.003**	**0.058**	**-0.098**	**0.061**	**-0.068**	**-0.019**	**-0.041**	**-0.248**	**-0.129**
	SE	0.050	0.036	0.051	0.036	0.033	0.023	0.035	0.028	0.069	0.064	0.022	0.017	0.025	0.019	0.014	0.013	0.012	0.011	0.008	0.004	0.006	0.004	0.016	0.012
	P>|t|	0.000	0.005	0.000	0.000	0.000	0.000	0.003	0.037	0.000	0.074	0.124	0.009	0.000	0.000	0.000	0.825	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Year	β_6	**-144.2**	**-81.3**	**-161.2**	**-85.3**	**-193.8**	**-134.9**	**-6.3**	**-48.9**	**87.4**	**13.0**	**-96.0**	**-78.1**	**-28.6**	**-60.9**	**-68.8**	**-46.7**	**-29.4**	**-24.2**	**-14.5**	**-3.7**	**22.6**	**0.3**	**-7.8**	**-12.0**
	SE	10.76	7.69	10.92	7.70	7.16	4.91	7.47	6.10	14.95	13.74	4.70	3.72	5.41	4.12	2.96	2.81	2.67	2.47	1.81	0.93	1.20	0.91	3.38	2.61
	P>|t|	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.02	0.00
Constant (β_0)	β_0	**1080**	**615**	**1192**	**633**	**1459**	**1024**	**34**	**364**	**-665**	**-105**	**694**	**572**	**201**	**458**	**484**	**330**	**206**	**174**	**90**	**24**	**-178**	**-1**	**49**	**86**
	SE	79.6	56.9	80.9	57.0	53.0	36.3	55.3	45.1	110.6	101.7	34.8	27.5	40.0	30.5	21.9	20.8	19.8	18.2	13.4	6.9	8.9	6.7	25.0	19.3
	P>|t|	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.05	0.00
N		2192	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2193	2192	2193	2193	2193	2193	2193
R^2 Within		0.145	0.262	0.191	0.305	0.394	0.441	0.504	0.072	0.128	0.134	0.365	0.451	0.435	0.422	0.910	0.761	0.751	0.787	0.951	0.979	0.961	0.915	0.711	0.549
R^2 Between		0.578	0.653	0.583	0.645	0.121	0.019	0.642	0.692	0.520	0.521	0.836	0.839	0.897	0.869	0.957	0.951	0.853	0.946	0.983	0.986	0.883	0.928	0.904	0.905
R^2 Overall		0.540	0.621	0.550	0.626	0.140	0.034	0.556	0.669	0.472	0.481	0.812	0.824	0.866	0.852	0.932	0.930	0.845	0.934	0.976	0.986	0.881	0.926	0.887	0.891

Analytical Methodology

A multiple regression of panel data model using fixed effects was estimated for each economic sector, both with and without robust standard errors, for a total of ten models. Fixed effects were used to control for the numerous factors inherently affecting sector-specific employment as well as electricity prices from state to state that have not been accounted for in the independent variables included in this study. The result is a conservative estimate of the isolated national effect of the variable of interest, real electricity prices on employment by industry.

The multiple regression of panel data model with fixed effects can be generally given by,

$$Y_{it} = \beta_0 + \sum_{j=1}^{k-1} \beta_j X_{jit} + \alpha_i + \varepsilon_{it}$$

Where i and t index states and years, such that y_{it} is the dependent variable of interest, employment by industry, in state i in year t, β_0 is the constant y intercept across all states, X is a k by 1 vector of explanatory variables, $\beta_j X_{jit}$ is the product of the observation for each independent variable j through k for state i in year t and the coefficient of X, k is the total number of included independent variables, α_i is the time-invariant fixed effect for state i, and ε_{it} are the residuals, and where $\varepsilon_{it} \sim N(0, \sigma^2)$, or are approximately normally distributed with a mean of zero.

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The multiple regression of panel data model with fixed effects can be generally given by,

Predicted Employment by Industry in State (i) and Time (t)

Stochastic Error Term (~ $N(0, \sigma^2)$)

$$Y_{it} = \beta_0 + \boxed{\sum_{j=1}^{k-1} \beta_j X_{jit}} + \alpha_i + \varepsilon_{it}$$

Constant Intercept Across States

Fixed Effect for State (i)

Sum of the product of the observation for each independent variable *j* through *k* for state *i* in year *t* and the coefficient of *Xj*

Where *i* and *t* index states and years, such that y_{it} is the dependent variable of interest, employment by industry, in state *i* in year *t*, β_0 is the constant *y* intercept across all states, *X* is a *k* by 1 vector of explanatory variables, $\beta_j X_{jit}$ is the product of the observation for each independent variable *j* through *k* for state *i* in year *t* and the coefficient of *X*, *k* is the total number of included independent variables, α_i is the time-invariant fixed effect for state *i*, and ε_{it} are the residuals, and where $\varepsilon_{it} \sim N(0, \sigma^2)$, or are approximately normally distributed with a mean of zero.

Fortunately, the computer does most of the hard work—this is what we actually see in Stata.

```
.
. dis "Primary Metal Employment"
Primary Metal Employment

. eststo emp_331_ln_fe : xtreg emp_331_ln rate_r_ln pcpi_r_ln edbdm_ip_ln_f   pop_ln patcd_
> r_ln year_ln if code!="US", fe

Fixed-effects (within) regression               Number of obs      =      2193
Group variable: code_n                          Number of groups   =        51

R-sq:  within  = 0.2623                         Obs per group: min =        43
       between = 0.6534                                        avg =      43.0
       overall = 0.6207                                        max =        43

                                                F(6,2136)          =    126.58
corr(u_i, Xb)  = 0.5662                         Prob > F           =    0.0000

------------------------------------------------------------------------------
  emp_331_ln |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   rate_r_ln |  -.3474572   .0639314    -5.43   0.000    -.4728315   -.2220828
   pcpi_r_ln |  -.2535152   .1567979    -1.62   0.106    -.5610077    .0539772
edbdm_ip_l~f |   .8390695   .1396222     6.01   0.000     .5652598    1.112879
      pop_ln |   .7629551   .0823382     9.27   0.000     .6014836    .9244266
  patcd_r_ln |  -.1011384   .0355641    -2.84   0.004    -.1708824   -.0313945
     year_ln |  -81.26569   7.688793   -10.57   0.000    -96.34399   -66.18739
       _cons |   615.4862   56.90711    10.82   0.000     503.8871    727.0854
-------------+----------------------------------------------------------------
     sigma_u |  1.5062896
     sigma_e |  .39200235
         rho |  .93656919   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(50, 2136) =   296.15            Prob > F = 0.0000

. estat ic

-----------------------------------------------------------------------------
       Model |    Obs    ll(null)   ll(model)     df          AIC         BIC
-------------+---------------------------------------------------------------
emp_331_ln~e |   2193   -1362.701   -1029.138      7     2072.277    2112.128
-----------------------------------------------------------------------------
               Note:  N=Obs used in calculating BIC; see [R] BIC note

. estimates store fe

. predict est_emp_331_fe, u
(8672 missing values generated)
```

Fortunately, the computer does most of the hard work—this is what we actually see in Stata.

We specify a multiple regression of panel data model. . .

We specify our dependent variable (Y_{it}) , which is what we need to predict or explain.

We specify all of our independent variables (X_{jit}), which explain Y_{it} .

```
.
. dis "Primary Metal Employment"
Primary Metal Employment

. eststo emp_331_ln_fe : xtreg emp_331_ln rate_r_ln pcpi_r_ln edbdm_ip_ln_f   pop_ln patcd_
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-----------------------------------------------------------------------------
               Note:  N=Obs used in calculating BIC; see [R] BIC note

. estimates store fe

. predict est_emp_331_fe, u
(8672 missing values generated)
```

Percentage of Variation Explained by the Model:
Intrastate
Interstate
Overall

We specify that we want to use fixed effects...

N = Total Population
i = 51, 50 States + DC
t = 43, Years 1970-2012
Note that $N = i \times t$

Standard Errors (σ)

Note that the 95% confidence intervals for β_j equal $\beta_j \pm \sigma$

The computer gives us our main objective, the resulting model coefficients β_j

Note that with the large p-value for per capita income, the 95% confidence interval extends from negative to positive, and thus includes zero, or no effect. Thus, we are uncertain of the effect of local income levels on employment in this industry.

β_0

σ from α_i

σ from ε_{it}

Interclass Correlation, i.e. the variance due to interstate differences

Remember that p-values are the probability of observing results as extreme as these if the null-hypothesis, that the independent variable is uncorrelated with the dependent variable, were true.

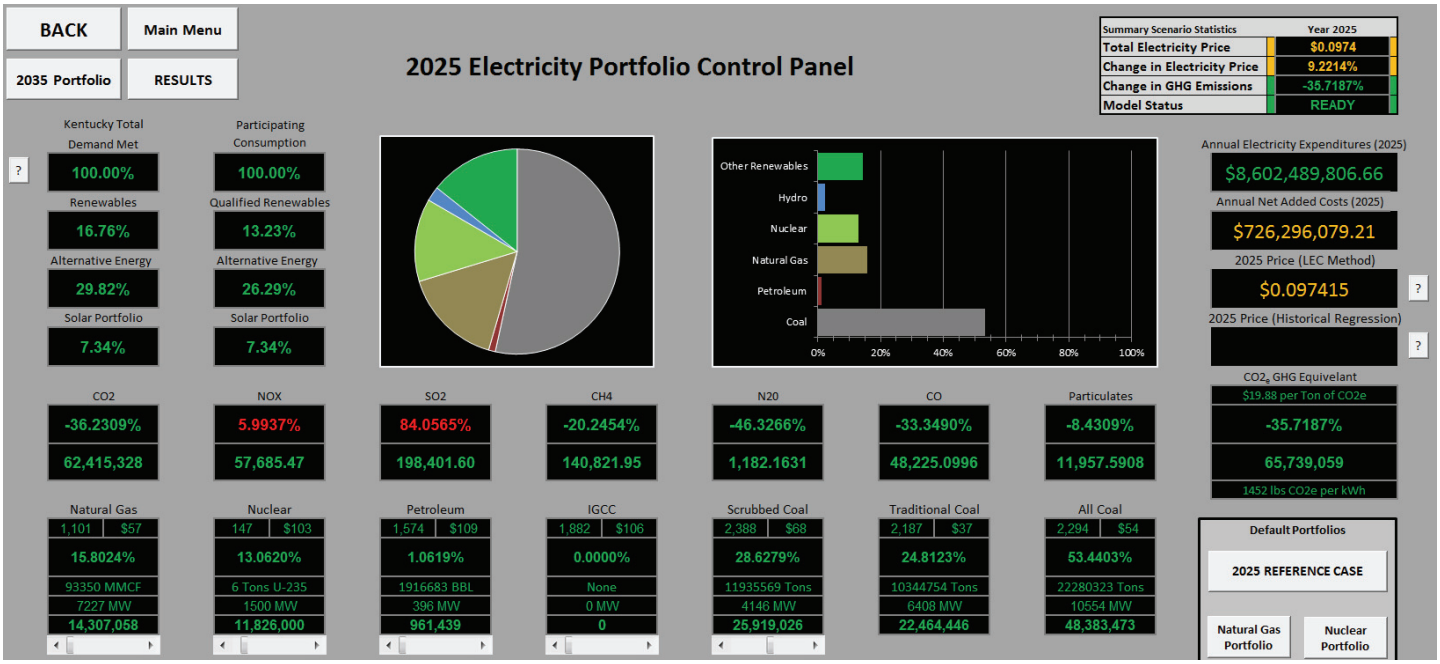
We store the fixed effects, or α_i ,as a variable...

Portfolio Model Exercise

Kentucky Electricity Portfolio Model Exercise

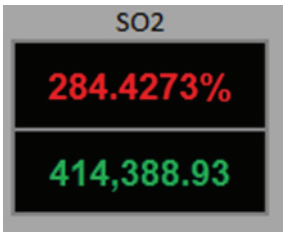
Exercise 1 (15 Minutes)

You and your teammates have been elected to manage Kentucky's electricity generation portfolio; however, the public has demanded 10% renewable electricity. Using the 2025 Electricity Portfolio Control Panel (keyboard shortcut <Ctrl P>) use only the toggles below renewable energy resources to adjust the allocation to each in order to achieve a qualified 10% Renewable Portfolio Standard (RPS). However, be sure to minimize any increases on the price of electricity (measured in $ per kWh), which will cause industry to leave the state and job losses, as well as to maximize reductions of Green House Gas (GHG) emissions (measured in tons of CO_{2e}), which is attributed to global climate change.

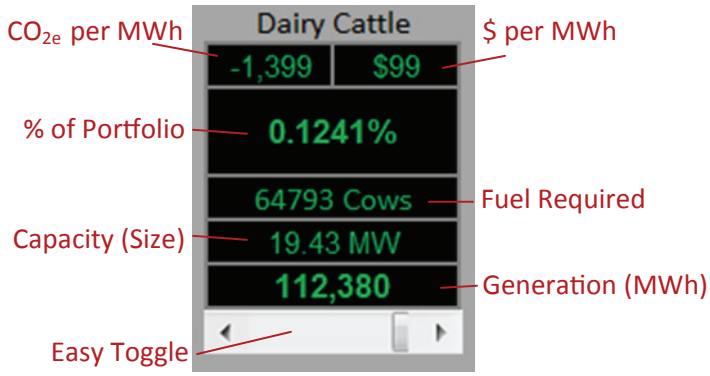


The portion of the portfolio that is specified as "qualified renewables", which excludes Kentucky's existing hydroelectric dams, is shown on the top left. Keep an eye on "Total Electricity Price" and CO_{2e} GHG Equivalent at the top right. For now, do not adjust non-renewable technologies or DSM. Do not change cost or other assumptions. You may not increase emissions of harmful pollutants such as sulfur dioxide (SO_2) or nitrous oxides (NO_X), which cause health problems and death.

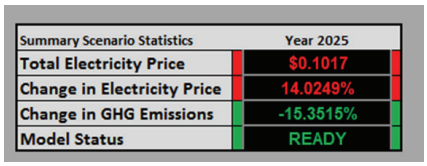
More SO_2 is Bad



Less SO_2 is Good



When you are satisfied with your portfolio, or when you run out of time, take a screen shot, or use a scrap piece of paper, to record the percentage of generation that you have allocated to each energy resource, the resulting price per kWh, and the resulting emissions (tons of CO_{2e}, SO_2, and NO_X). Be prepared to discuss your results and why you chose the portfolio you did.



Summary Scenario Statistics	Year 2025
Total Electricity Price	$0.1017
Change in Electricity Price	14.0249%
Change in GHG Emissions	-15.3515%
Model Status	READY

This is actually a very difficult task since there are innumerable combinations possible portfolios. In our new 2014 model, our fastest computer can take several hours to optimize each portfolio. You have 15 minutes.

Exercise 2 (10 Minutes)

Build upon your existing 10% RPS by exploring the potential for Demand Side Management (DSM) to contribute to further emission reductions by moving the DSM toggle to the right. Use keyboard shortcut <Ctrl E> to explore the specific types of energy efficiency being used in the background of your simulation and answer the following questions.

What effect to DSM programs have on emissions?

What effect do DSM programs have on costs, (i.e. total expenditures in $)?

What effect do DSM programs have on electricity prices ($ per kWh)?

Using the efficiency portfolio at the top, and controls for individual economic sectors and specific programs below, achieve a 15% Renewable and Energy Efficiency Portfolio Standard (REPS), with 10% renewables and 5% energy efficiency. Be sure to minimize the impact on electricity and maximize emissions reductions. Do not change program costs. Note that as you lower end use, the share that is renewables may increase. You only need 10%.

When you are satisfied with your efficiency portfolio, use keyboard shortcut <Ctrl P> to return to the 2025 Portfolio. You may want to adjust the renewables you used since efficiency programs will change the amount of electricity generated. You may not adjust non-renewable technologies. Be sure to take a screen shot or somehow record the percentage of generation that you have allocated to each energy resource, the resulting price per kWh, and the resulting emissions (tons of CO_{2e}, SO_2, and NO_X)

Exercise 3 (15 Minutes)

From the 2025 Portfolio screen, use any combinations of technologies or fuels, renewable or otherwise, to attempt to achieve a greater reduction in greenhouse gas emissions, a lower price per kWh, lower sulfur dioxide emissions, lower nitrous oxide emissions than you were able to in Assignments 1 or 2. When you are satisfied with your portfolio, take a screen shot, or use a scrap piece of paper, to record the percentage of generation that you have allocated to each energy resource, the resulting price per kWh, and the resulting emissions (tons of CO_{2e}, SO_2, and NO_X). Answer the following questions.

Is it possible to achieve more reductions of GHG's with non-renewables than renewables?

Is it cheaper to reduce GHG's with non-renewables or renewables?

What seem to be the best to reduce GHG's at low costs, and is this surprising to you?

Exercise 4 (10 Minutes)

Without changing your portfolio at all, you should perform a sensitivity analysis by testing what impact some of the highly variable and less predictable input factors—including weather, population, income, and fuel prices—might be having on your scenario results. Use keyboard shortcut <Ctrl W> to jump to the Weather Control screen. Notice the price of electricity in the top right hand corner. Use keyboard shortcut <Ctrl N> to randomize all variable input factors, including weather which is shown on this screen. Now perform a 10 round Monte Carlo Simulation by randomizing all of the input variables 10 times, using the keyboard shortcut <Ctrl N>, and record the resulting price of electricity for each round. Note the minimum, maximum, and average price of electricity that resulted from these rounds and be prepared to discuss the results.

Wrap Up

If you have extra time, please return to the Portfolio Control Panel, keyboard shortcut <Ctrl P> and discuss what you might have done differently or better. From the Portfolio Control Panel, you can run additional Monte Carlo rounds by pressing <Ctrl N> to reload randomized input assumptions.

Exercise 1

Qualified Renewables	2025 Price	Electricity Expenditures	Net Added Costs	CO_{2e} equivalent	NO_x	SO_2
%	¢/kWh	$	$	tons	tons	tons
Fuels	**Natural Gas**	**Nuclear**	**Petroleum**	**IGCC**	**Scrubbed Coal**	**Traditional Coal**
%						
MW						
Fuels	**Hydroelectric**	**KY Wind**	**Imported Wind**	**Solar**	**Efficiency-DSM**	**Landfill Gas**
%						
MW						
Fuels	**Dairy Cattle**	**Hog Waste**	**Poultry Litter**	**Wood-Direct**	**Cofired Crops**	**Crops-Direct**
%						
MW						

Exercise 2

Qualified Renewables	2025 Price	Electricity Expenditures	Net Added Costs	CO_{2e} equivalent	NO_x	SO_2
%	¢/kWh	$	$	tons	tons	tons
Fuels	**Natural Gas**	**Nuclear**	**Petroleum**	**IGCC**	**Scrubbed Coal**	**Traditional Coal**
%						
MW						
Fuels	**Hydroelectric**	**KY Wind**	**Imported Wind**	**Solar**	**Efficiency-DSM**	**Landfill Gas**
%						
MW						
Fuels	**Dairy Cattle**	**Hog Waste**	**Poultry Litter**	**Wood-Direct**	**Cofired Crops**	**Crops-Direct**
%						
MW						

Exercise 3

Qualified Renewables	2025 Price	Electricity Expenditures	Net Added Costs	CO_{2e} equivalent	NO_x	SO_2
%	¢/kWh	$	$	tons	tons	tons
Fuels	**Natural Gas**	**Nuclear**	**Petroleum**	**IGCC**	**Scrubbed Coal**	**Traditional Coal**
%						
MW						
Fuels	**Hydroelectric**	**KY Wind**	**Imported Wind**	**Solar**	**Efficiency-DSM**	**Landfill Gas**
%						
MW						
Fuels	**Dairy Cattle**	**Hog Waste**	**Poultry Litter**	**Wood-Direct**	**Cofired Crops**	**Crops-Direct**
%						
MW						

Exercise 4 Price (Cents/kilowatt hour)

Round 1	Round 2	Round 3	Round 4	Round 5
Round 6	**Round 7**	**Round 8**	**Round 9**	**Round 10**

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