5-8-2015

An Analysis of U.S. and World Carbon Dioxide Emissions from the Consumption of Coal for Energy from 1980 to 2012

Kadir Goz
The College at Brockport, k.goz@hotmail.com

An Analysis of U.S. and World Carbon Dioxide Emissions from the Consumption of Coal for Energy from 1980 to 2012

A Senior Honors Thesis

Submitted in Partial Fulfillment of the Requirements
for Graduation in the Honors College

By
Kadir Goz
Meteorology & Water Resources Management Major

The College at Brockport
May 8, 2015

Thesis Director: Dr. Stephen Jessup, Assistant Professor, Meteorology

Abstract

The purpose of this research is to examine the impact of carbon dioxide (CO_2) emissions from U.S. coal consumption for energy on total global anthropogenic CO_2 emissions from coal from 1980 to 2012. This study investigated whether the U.S. to world proportion of CO_2 emissions from coal have been greater than expected when compared to global CO_2 emissions on a per person basis over this time period. Data was obtained from the U.S. Energy Information Administration (U.S. E.I.A.), U.S. Census Bureau, IHS Global Insight, Inc., and Population Reference Bureau for U.S. and global coal consumption, CO_2 emissions from coal, and population. This data was used to create percentages for each year of the study, which were then graphed and analyzed. The results of the study found that the U.S. has emitted more CO_2 than expected for a country of its population and that U.S. CO_2 emissions from coal have been decreasing with no influence on the recent increasing trend of global CO_2 emissions. The driving force behind the recent increases was China. A secondary study involved analyzing the negative correlation between CO_2 emissions from U.S. coal and natural gas consumption from 1980 to 2012. Data from the U.S. E.I.A. for coal and natural gas consumption was tested using graphical analysis and Pearson's correlation coefficient tests. The results were that there was no significant negative correlation of CO_2 emissions between coal and natural gas consumption. The findings of the study confirmed the first research question of the U.S. having a disproportionate influence on global CO_2 emissions from coal, while rejecting the secondary question of the negative relationship between CO_2 emissions from coal and natural gas consumption in the U.S.

Table of Contents

Introduction

The purpose of this research is to examine the impact of carbon dioxide (CO_2) emissions from U.S. coal consumption for energy on total global anthropogenic CO_2 emissions from coal. In this study, the term energy will be restricted to electricity generation and ‘coal and natural gas consumption’ will be referred to as the use of coal and natural gas for the sole purpose of energy production. The importance of this research is in understanding the emissions of CO_2 from energy production in the U.S. and around the world since this activity is the single largest source of anthropogenic CO_2 emissions in the world.

The principal agents of anthropogenic climate change are the emissions of greenhouse gases, such as carbon dioxide, methane, water vapor, and nitrous oxide (Dilip and Lashof, 1990). During the pre-industrial era, CO_2 levels in the atmosphere remained rather steady, but since the Industrial Revolution greenhouse gas levels have been significantly increasing (Quadrelli and Peterson, 2007). Since 1800, CO_2 concentration in the atmosphere has increased from ~280 parts per million volume (ppmv) to over 400 ppmv (Melillo, 1996). In terms of overall importance, CO_2 comprises about 0.03% of the Earth’s atmospheric volume, but due to the combustion of fossil fuels and deforestation, its concentration has increased by over 25% since the pre-industrial era (Raghuvanshi et al., 2006). The increase of CO_2 levels in the atmosphere is relevant because of the effect that CO_2 has on the atmosphere. As CO_2 reaches the stratosphere, radiation from the sun enhances the longwave opacity of the CO_2 molecules. This enhancement leads to an increase in the downward emission of radiation, whereby radiative heating increases the surface and tropospheric temperatures (Ramanathan et al., 1979). This process creates a feedback loop where the increase in temperature leads to greater evaporation of water into the atmosphere, which then amplifies water vapor’s influence as a greenhouse gas due to its strong absorption bands that account for roughly 50% of the greenhouse effect on Earth (Lacis, 2012). Recognizing how CO_2 concentrations change in the atmosphere is vital to understanding our own influence on the atmosphere through anthropogenic CO_2 emissions.

In response, this study analyzes trends in U.S. and world CO_2 emissions by examining the largest contributor to anthropogenic CO_2 emissions: energy production. The research question focuses on whether the U.S. emits more CO_2 from the consumption of coal for energy per person than the rest of the world. The hypothesis being tested is that U.S. CO_2 emissions from the combustion of coal for energy have been greater than expected when compared to global CO_2 emissions on a per capita basis from 1980 to 2012. The secondary hypothesis being tested is that the trends in CO_2 emitted from U.S. coal and natural gas consumption for energy are negatively correlated such that as one increases the other decreases over the same time period.

Background

As the world's population has increased and technological advancements have become more available due to economic developments over the last century, the need for energy has increased. Energy is the prime driver of economic growth and development and is the basic component of industry, public service, and transport (Raghuvanshi et al., 2006). The production, transformation, handling, and consumption of various energy commodities comprises over 80% of global anthropogenic greenhouse gas emissions (Quadrelli and Peterson, 2007). Coal has become a major international commodity for use in electricity generation and coke for steelmaking (Longwell et al., 1995). Due to its wide availability and relatively low cost, coal has become the single largest resource for the world's energy, comprising more than 40% of the world's electricity supply (Branco et al., 2013; Campbell, 2013). It accounts for roughly 40% of total global greenhouse gas emissions from electricity generation (Li et al., 2014).

Given the continuing availability of low cost coal and the changes in energy consumption patterns in the U.S. and the world, coal is likely to continue to be a significant part of the growing U.S. energy demands over the next few decades for a number of reasons, including: known coal reserves are large enough to meet expected demands throughout the 21st century; domestic natural gas is relatively limited in availability so that price and competition will weaken its ability to compete with coal in the near-term; and renewable and nuclear energy sources are not expected to overtake a large share of energy production until 2040 and beyond (Longwell et al., 1995). Coal is such an important energy commodity because its combustion creates heat energy, which is used to create electricity; however, this process produces CO_2 as a byproduct (Raghuvanshi et al., 2006). A study by Bashmakov et al. (2013) found that U.S coal consumption has been decreasing over the past decade due to the advancements in renewable energies and expanded use of natural gas, while global coal consumption has actually increased. Global coal consumption grew in 2001 to 2010, led by increasing demand in Asia, and coal contributed 44% of the growth in energy use (Bashmakov et al., 2013).

In recent years, natural gas has become an increasingly utilized energy source in the U.S. Natural gas is an important energy source for the residential, commercial, and industrial sectors (Jaramillo et al., 2007). It is a much cleaner fuel than coal, emitting 70% less CO_2 per unit of energy produced (Li et al., 2014). Due to rapidly expanding natural gas reserves, surges in output capacity, and sharp price falls in the market, natural gas has become the fuel of choice for new power plants (Longwell et al., 1995; Darmstadter, 2013). The U.S. is the largest consumer of natural gas in the world and comprises 21% of the world's natural gas consumption, and nearly a third of all natural gas consumed is used by the energy sector (Macmillan et al., 2013). Since the 1990s, coal's dominance in the U.S. energy market has been significantly eroded by the sustained upflow in domestic natural gas production, predominately from shale gas reserves (Darmstadter, 2013). From 2007 to August of 2012, the ratio of net coal-fired electricity generation to net gas-fired generation dropped from 2.25:1 to 1.16:1 (Macmillan et al., 2013). Since the U.S. power sector forms a significant part of both the global coal and natural gas markets, the changes that have occurred in the U.S. power sector over recent years have had and will continue to have profound implications for the world (Macmillan et al., 2013).

Data and Methodology

The coal consumption, CO_2 emissions from the consumption of coal, and natural gas data for the U.S. and world were obtained from the U.S. Energy Information Administration (E.I.A.), which compiled the data using a number of domestic and international sources. Coal data for the U.S. was collected using surveys of electric power companies (electric utilities and independent power producers), industrial plant companies (coking, manufacturing, and coal preparation plants), and commercial and residential coal distributors (U.S. Energy Information Administration, 2012). World coal data was obtained from a number of international governmental agencies and industry sources, and then compiled by the U.S. E.I.A. into an online database (U.S. Energy Information Administration, 2014b). The U.S. natural gas data was collected from surveys of natural gas production, transmission, and distribution companies and electric power generation companies (U.S. Energy Information Administration, 2012; U.S. Energy Information Administration, 2014b). Population data was obtained from the U.S. Census Bureau, IHS Global Insight, Inc., and Population Reference Bureau (P.R.B.). IHS Global Insight, Inc. is a private company that provides information, analytics, and expertise to businesses and governments around the world (U.S. Energy Information Administration, 2014b; IHS Global Insight, Inc., 2015). The P.R.B. is a private, non-profit organization that provides population, health, and environment information to the public and research and academic institutions (Haub and Kaneda, 2012).

The data collected from the U.S. E.I.A. was used to examine the hypotheses by using a graphical analysis and statistical tests. The coal consumption, CO_2 emissions from the consumption of coal, and population data were used to calculate the proportion of U.S. to world CO_2 emissions from 1980 to 2012, which were then converted to percentages. These percentages of CO_2 emissions from coal and population were then compared for each year. The CO_2 emissions data for the U.S. and world were graphed over time to see if there was a linear relationship. The percentages for population and CO_2 emissions from coal were plotted over time to determine if there was a trend. When the population percentage was higher than the CO_2 emissions, it was concluded that the U.S. used less coal and emitted less CO_2 per capita for that year and when the population percentage was lower, then the U.S. used more coal and emitted more CO_2 per capita for that year, thus having a disproportionate influence on global emissions. The results of this comparison for every year were compared using a graphical analysis.

The secondary hypothesis was tested using the U.S. E.I.A. coal and natural gas consumption data from 1980 to 2012. The data was converted to kilowatt hours produced using a conversion factor from the U.S. E.I.A.: .95 kWh generated per pound of coal and 99 kWh generated per 1,000 cubic feet of natural gas (U.S. Energy Information Agency, 2015). Then, the data was converted to British thermal units (Btu's) and, using another conversion factor from the U.S. E.I.A., was again converted to pounds of CO_2 emitted per pound of coal and per cubic foot of natural gas: the four types of coal used for energy produce 216 pounds of CO_2 emitted per million Btu on average, while natural gas emits117.0 pounds of CO_2 per million Btu (U.S. Energy Information Agency, 2014a). A Pearson's correlation coefficient test was performed on both data sets to determine whether there was an association between electricity generated or CO_2 emitted from the consumption of coal and natural gas for energy. A Pearson correlation coefficient of less than – 0.01 was considered a strong inverse correlation and a P-value of less than 0.01 was considered significant.

Results

The results after completing the graphical analysis on the data show that U.S. coal consumption and CO_2 emissions from coal have been higher on a per capita basis when compared to the global values. In 1980, U.S. coal consumption made up nearly 25% of all coal consumed in the world, but by 2012 that number decreased to below 12% (Figure 1). Similarly, the U.S. made up nearly 20% of CO_2 emissions in 1980, but by 2012 that number was just under 10% (Figure 2). When analyzing the graph of percentages of U.S. to global CO_2 emissions from coal and population, a trend developed whereby for every year of the study, the percentages of CO_2 emissions from coal were greater than the population (Figure 3). Since the U.S. to world population percentages are lower, the U.S. consumed more coal and released more CO_2 emissions than should be expected for its population size.

The secondary hypothesis of this study focused on the trends of natural gas and coal consumption in the U.S. from 1980 to 2012. An overall increasing trend was found over the time period for both the kilowatt hours generated and pounds of CO_2 emitted from coal and natural gas consumption (Figures 8 and 9). The Pearson test on the data found a correlation of 0.753 and a P-value of < 0.001 for both data sets. This indicates that there was a strong positive correlation in both the natural gas and coal consumption data in terms of kilowatt hours produced and CO_2 emitted. The Pearson's test results disprove the secondary research question and led to the rejection of the secondary hypothesis.

Discussion

The hypothesis of this study that the U.S. has had a disproportionate influence on global CO_2 emissions from coal is in line with the results attained from the graphical analysis of the coal data. Coal is the single largest source of CO_2 emissions in the U.S., comprising 43% of emissions from fuel combustion in 2010 (Hoeven, 2012). The views in the principal literature agree with the results of this study as discussed by Longwell et al. (1995), Roy et al. (2008), Hoeven (2012), and Boden et al. (2014).

In analyzing the trend in U.S. CO_2 emissions from coal, a slight decreasing trend occurs from 2008 to 2012 (Figure 2). However, since 1998 there has been a sharp decrease in the percentage of U.S. to world CO_2 emissions from coal, whereas the population proportion has remained relatively constant (Figure 3). Using the post-1998 trend, a linear regression was performed and projected into the future for each data line, which revealed that the two trend lines would intersect each other around the year 2021 with a statistical P-value of less than .001 for each data set (Table 1). This projection indicates that the U.S. will not have a disproportionate influence on global CO_2 emissions from coal after the year 2021.

Two determinations were made from the data that could explain the decrease in the U.S. contribution to global CO_2 emissions: the U.S. population is decreasing relative to world population and global emissions from coal have been increasing, while U.S. emissions have not, which has led to a smaller U.S. component of global emissions. The decrease in U.S. CO_2 emissions from coal can be explained by the combination of expanded availability and use of natural gas and renewable energy sources and the aging and decreasing efficiency of coal-fired power plants around the country (Campbell, 2013). The increase in global CO_2 emissions are a result of increased demand of coal for energy from developing countries around the world

(Shealy and Dorian, 2009). Roy et al. (2008) states that the expected increases in energy demands due to economic growth and population increases in the near future will lead to a continuous rise in coal consumption and emissions unless there are fundamental changes to the world energy system, which is currently dominated by fossil fuels (Roy et al., 2008). From these results the increase in global emissions can be better explained by Chinese coal consumption and CO_2 emissions from coal.

There is a clear trend between the CO_2 emissions from China and the world from 1980 to 2012, indicating that China has been the driving force behind the increase of CO_2 emissions from coal since 1998 (Figure 4). In 1987, Chinese CO_2 emissions from coal were equal to what was expected for a country of their population size. Since 1987, CO_2 emissions have increased as the Chinese population has steadily decreased (Figure 5). Beginning around 2002, there was a sharp and dramatic increase in the CO_2 emissions from coal in China that corresponded to an increase in global CO_2 emissions (Figure 4) and as a result, the U.S. contribution decreased proportionally. The surge in economic growth in China since the 1980's has led to increased coal demand as coal is their principal energy source, accounting for 70% of total energy consumed and 77% of total energy produced in the country (National Bureau of Statistics, 2009). Future research should focus on China, and to a lesser extent India, as these two countries have the world's largest populations and fasting growing economies that will likely see the greatest increases in demand for energy in the near term.

The significance behind the U.S. natural gas and coal consumption study lies in the appeal of natural gas as a substitute for coal. Natural gas is seen as a clean transitional fuel that societies can utilize as they move away from the large greenhouse gas emitting resources of coal and oil (Pacala and Socolow, 2004). It is considered a cleaner source of energy because the amount of CO_2 emitted per unit of energy for natural gas is roughly half that for any type of coal (U.S. Energy Information Administration, 2014a). In the U.S., natural gas has become the second most important energy commodity behind petroleum, accounting for 27.4% of U.S. energy consumption in 2012. Natural gas was also one of the main contributing factors for the decrease in CO_2 emissions from the combustion of fossil fuels in the U.S. by energy producers (U.S. Environmental Protection Agency, 2014).

Longwell et al. (1995), Darmstadter (2013), and Macmillan et al. (2013) argue that natural gas consumption has been increasing in the U.S., while coal consumption has decreased. In analyzing the data, an increasing trend can be found in natural gas consumption since 1986 (Figure 7), while there has also been a similar increasing trend in the coal data up until 2008, when the consumption of coal begins to decrease drastically (Figure 6). By comparing the energy produced from coal and natural gas, it can be determined that over the time period there has been more electricity produced from natural gas consumption than coal (Figure 8). A Pearson correlation coefficient test was performed to determine whether there was a negative correlation between the coal and natural gas electricity generation data. The correlation test found that the data had a positive correlation of 0.753 and a P-value of less than 0.001 (Table 2). This indicates that the kilowatt hours generated from coal and natural gas consumption data was statistically significant and correlated over time.

In analyzing CO_2 emissions from coal and natural gas consumption for energy, an average of the four types of coal was taken and used to create a graph since different types of coal emit different amounts of CO_2 (U.S. Energy Information Agency, 2014a). For the majority of the time period from 1980 to 2012, coal consumption for energy produced larger emissions of CO_2 than natural gas (Figure 9). Around 2011, however, natural gas CO_2 emissions overtook coal emissions and this trend continued until the end of the data set. Ignoring fugitive natural gas emissions, if this trend continues into the near-term, natural gas will become a significant contributor to anthropogenic CO_2 emissions from energy production in the U.S. To determine if there was a negative correlation between the two data sets, A Pearson correlation coefficient test was performed. The correlation test found that the data had a positive correlation of 0.753 and a P-value of less than 0.001 (Table 3). This indicates that the CO_2 emitted from coal and natural gas consumption data was statistically significant and correlated over time.

The results of this study found that there was no inverse correlation between the trends in electricity produced or CO_2 emitted from coal and natural gas consumption in the U.S. from 1980 to 2012. These findings disagree with the views in the principal literature discussed by Longwell et al. (1995), Pacala and Socolow (2004), Darmstadter (2013), and the U.S. Environmental Protection Agency (2014). The downward trend of coal consumption in both data sets occurred over too short of a time period for any evaluation to be significant. The implications of the trends in the data are supported by the International Energy Agency (2010), which argues that future energy projections of coal in the U.S. will decrease, whereas natural gas will increase over the next two decades (International Energy Agency, 2010).

Conclusion

The use of coal as a resource for energy is projected to continue to grow as the world's energy demands increase due to greater availability of technology, economic developments in developing countries, and growing populations. The U.S. has been a world leader in economic, social, and political advancements in the nineteenth and twentieth centuries; however, the dawn of the twenty-first century has created numerous issues that the U.S. and world have been struggling with, including climate change. This study focused on coal and natural gas consumption and CO_2 emissions from the production of energy in the U.S. and around the world and found that the U.S. has consumed more coal and emitted more CO_2 than the rest of the world per capita from 1980 to 2012. It was also determined that there has been no inverse correlation in the electricity produced or CO_2 emitted from U.S. natural gas and coal consumption over the same time period. The trend over the study period was an increase in the kilowatt hours produced and CO_2 emitted from the consumption of coal and natural gas; however, from the late 2000's to the present, there has been a decline in both areas for coal in the U.S., while natural gas continues to increase.

The significance of these results are framed within the context of future environmental sustainability and climate change. Environmental issues will continue to be a major issue facing society in the near future. Developing environmentally friendly and greenhouse gas reducing technologies will be key to a sustainable future. Due to the projected increases in energy demand and the current landscape of human induced climate change, CO_2 emissions from coal and natural gas will be an important topic of research in the near-term. The rise of natural gas in the U.S. energy market in recent years will need greater attention in the context of climate change as a consequence of natural gas' impact as a greenhouse gas.

References

Bashmakov, I.A., Bruckner, T., and Mulugetta, Y., coordinating lead authors, 2013, Climate Change 2014: Mitigation of Climate Change: Intergovernmental Panel on Climate Change, p. 1 – 137.

Boden, T., Anders, B., and Marland, G., 2014, World's Countries Ranked by 2010 Total Fossil Fuel CO_2 Emissions: U.S. Department of Energy: Office of Science, http://cdiac.ornl.gov/trends/emis/top2010.tot (accessed 3 March 2015).

Branco, D.A.C., Moura, M.C.P., Szklo, A., and Schaeffer, R., 2013, Emissions Reduction Potential from CO_2 Capture: A Life-Cycle Assessment of a Brazilian Coal-Fired Power Plant: Energy Policy, v. 61, p. 1221 – 1235.

Campbell, R. J., 2013, Increasing the Efficiency of Existing Coal-Fired Power Plants: Congressional Research Service R43343, p. 1 – 26.

Cohen, B. and Winkler, H., 2013, Greenhouse Gas Emissions from Shale Gas and Coal for Electricity Generation in South Africa: South African Journal of Science, v. 110, p. 1 – 5.

Darmstadter, J., 2013, The Controversy Over U.S. Coal and Natural Gas Exports: Resources for the Future v. 13, no. 01, p. 1 – 20.

Dilip, A.R. and Lashof, D.A., 1990, Relative Contributions of Greenhouse Gas Emissions to Global Warming: Nature, v. 344, p. 529 – 531.

Haub, C. and Kaneda, T., 2012, 2012 World Population Data Sheet: Population Reference Bureau, http://www.prb.org/pdf12/2012-population-data-sheet_eng.pdf (accessed 7 March 2015).

Hoeven, M. V. der., executive director, 2012, CO_2 Emissions from Fuel Combustion Highlights 2013: International Energy Agency, p. 1 – 158.

IHS Global Insight, Inc., 2015, About Us: IHS Global Insight, Inc., https://www.ihs.com/about /index.html (accessed 4 February 2015).

International Energy Agency, 2010, World Energy Outlook 2010: http://www.worldenergy outlook.org/media/weo2010.pdf (accessed 16 January 2015).

Jaramillo, P., Griffin, W.M., and Mathews, H.S., 2007, Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation: Environmental Science and Technology, v. 41, p. 6290 – 6296.

Lacis, A., 2012, Greenhouse Effect, *in* Greenhouse Gases - Emission, Measurement and Management, Liu, G., eds., InTech (March): Rijeka, Croatia, p. 275 – 294.

Li, W., Younger, P., Cheng, Y., Zhang, B., Zhou, H., Liu, Q., Dai, T., Kong, S., Jin, K., and Yang, Q., 2014, Addressing the CO_2 Emissions of the World's Largest Coal Producer and Consumer: Lessons from the Haishiwan Coalfield, China: Energy, v. 2014, p. 1 – 14.

Longwell, J.P., Rubin, E.S., and Wilson, J., 1995, Coal: Energy for the Future: Progress in Energy and Combustion Science, v. 21, p. 269 – 360.

Macmillan, S., Antonyuk, A., and Schwind, H., 2013, International Energy Agency Insights Series 2013: Gas to Coal Competition in the U.S. Power Sector: International Energy Agency, p. 1 – 36.

Melillo, J.M., Houghton, R.A., Kicklighter, D.W., and McGuire, A.D., 1996, Tropical Deforestation and the Global Carbon Budget: Annual Review of Energy & The Environment, v. 21, p. 293 – 310.

Metz, B., Davidson, O., Bosch, P., Dave, R., and Meyer, L., eds., 2007, Climate Change 2007: Mitigation of Climate Change, Intergovernmental Panel on Climate Change: New York, NY, Cambridge University Press, p. 1 – 852.

National Bureau of Statistics, 2010, China Compendium of Statistics 1949–2008: Beijing, China, Statistics Publishing House, 1167 p.

Pacala, S. and Socolow, R., 2004, Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies: Science, v. 305, p. 968 – 972.

Quadrelli, R. and Peterson, S., 2007, The Energy-Climate Challenge: Recent Trends in CO_2 Emissions from Fuel Combustion: Energy Policy, v. 25, p. 5938 – 5952.

Raghuvanshi, S.P., Chandra, A., and Raghav, A.K., 2006, Carbon Dioxide Emissions from Coal Based Power Generation in India: Energy Conversion and Management, v. 47, p. 427 – 441.

Ramanathan, V., Lian, M.S., and Cess, R.D., 1979, Increased Atmospheric CO_2: Zonal and Seasonal Estimates of the Effect on the Radiation Energy Balance and Surface Temperature: Journal of Geophysical Research, v. 84, p. 4949 – 4958.

Roy, J., Sarkar, P., Biswas, S., and Choudhury, A., 2008, Predictive Equations for CO_2 Emission Factors for Coal Combustion, their Applicability in a Thermal Power Plant and Subsequent Assessment of Uncertainty in CO_2 Estimation: Fuel, v. 88, p. 792 – 798.

Shealy, M. and Dorian J.P., 2009, Growing Chinese Coal Use: Dramatic Resource and Environmental Implications: Energy Policy, v. 38, p. 2116 – 2122.

U.S. Energy Information Administration, 2012, Annual Energy Review 2011: U.S. Department of Energy DOE/EIA-0384(2011), 390 p.

U.S. Energy Information Administration, 2014a, How Much Carbon Dioxide is Produced when Different Fuels are Burned?: U.S. Department of Energy: http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11 (accessed 8 April 2015).

U.S. Energy Information Administration, 2014b, International Energy Statistics: U.S. Department of Energy, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm (accessed 16 December 2014).

U.S. Energy Information Administration, 2015, How Much Coal, Natural Gas, or Petroleum is Used to Generate A Kilowatt Hour of Electricity?: U.S. Department of Energy: http://www.eia.gov/tools/faqs/faq.cfm?id=667&t=2 (accessed 2 May 2015).

U.S. Environmental Protection Agency, 2014, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2012: U.S. Environmental Protection Agency EPA 430-R-14-003, 529 p.

Appendix

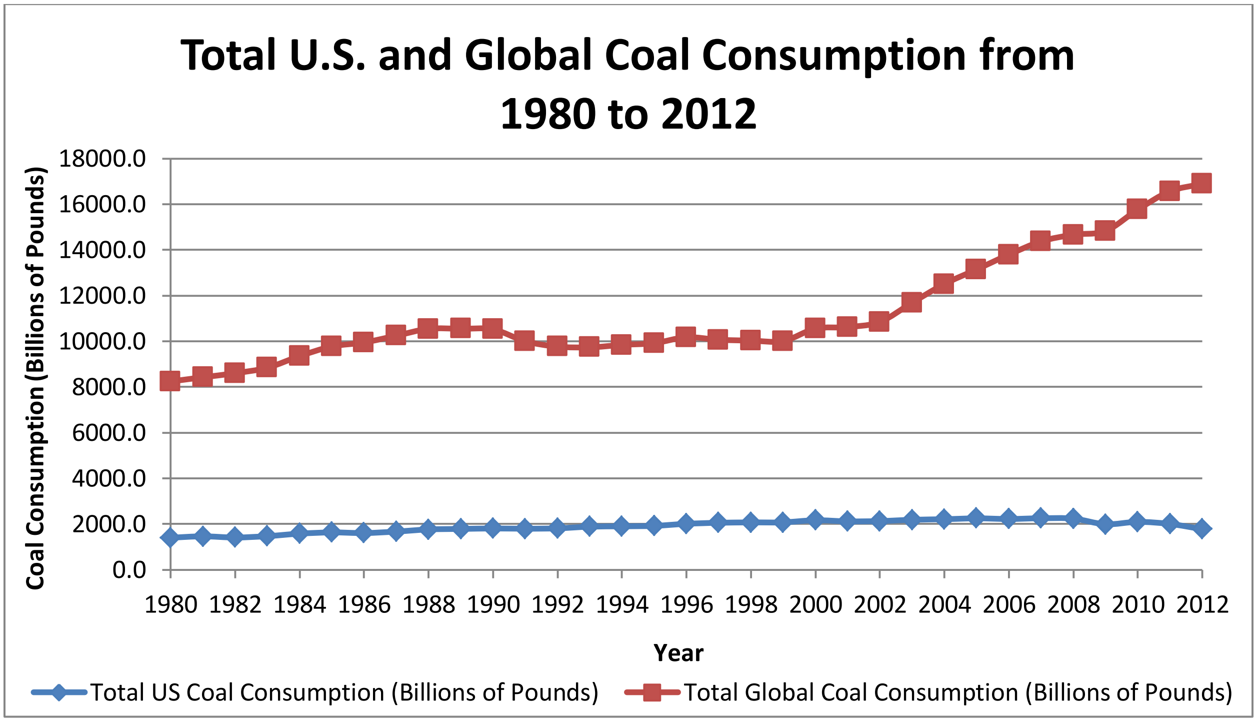

Figure 1: This graph shows total U.S. and global coal consumption from 1980 to 2012 in billions of pounds.

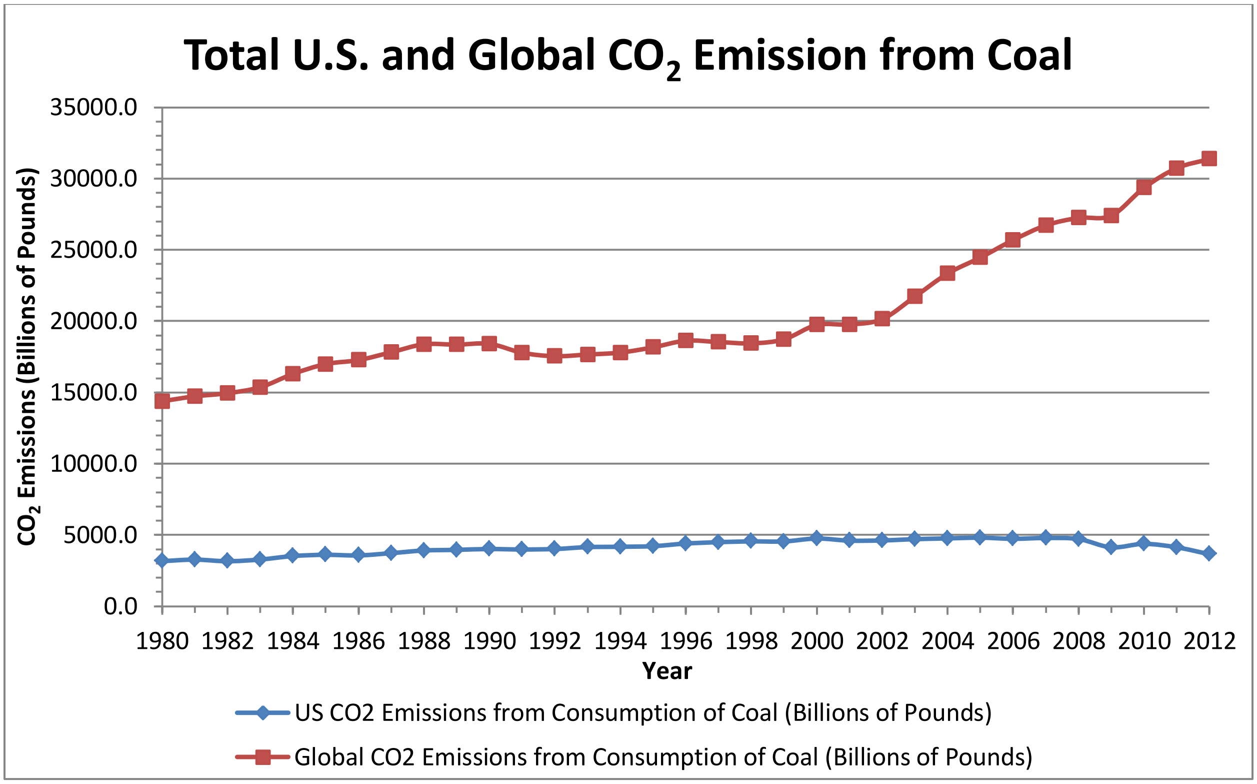

Figure 2: This graph shows total U.S. and global CO_2 emissions from the consumption of coal from 1980 to 2012 in billions of pounds.

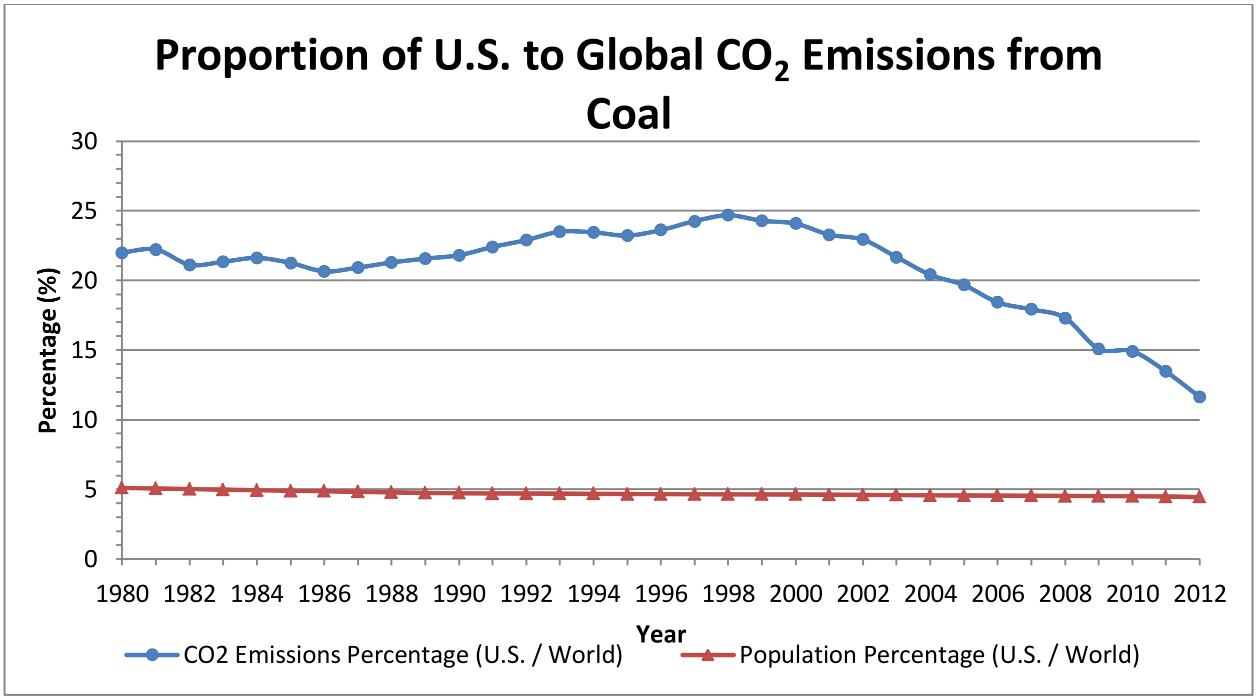

Figure 3: This graph shows the U.S. proportion of global CO_2 emissions from coal from 1980 to 2012.

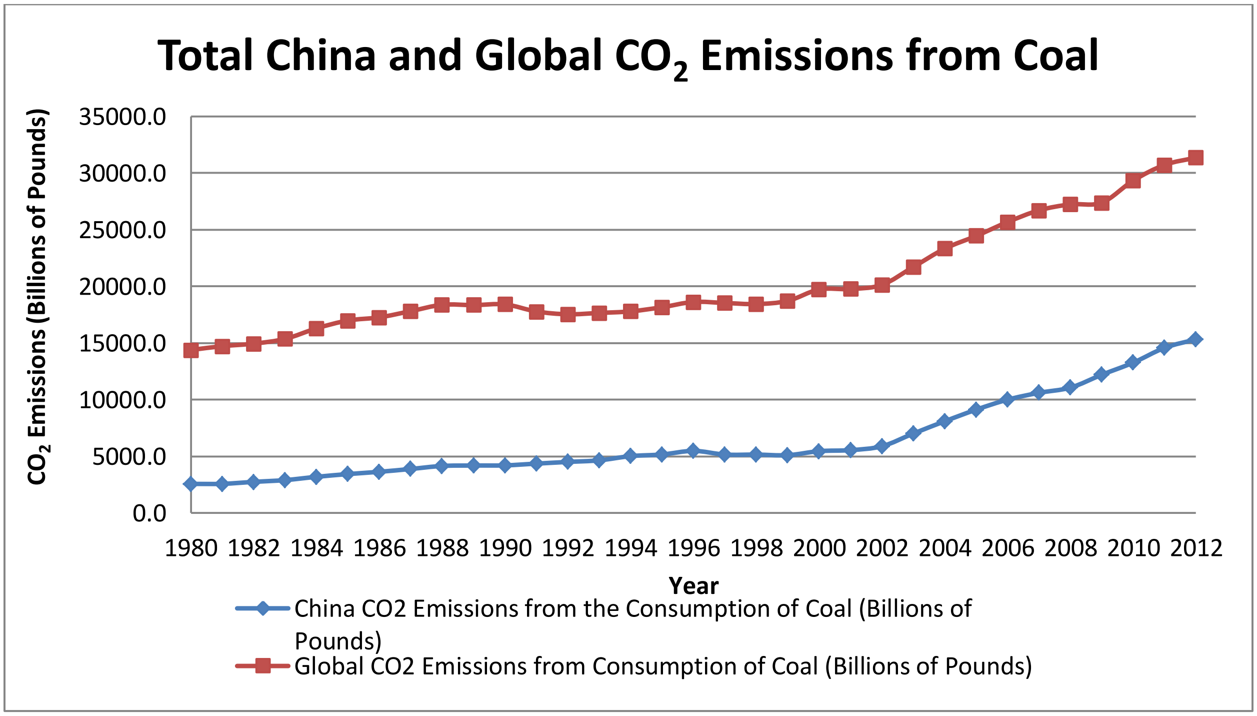

Figure 4: This graph shows total China and global CO_2 emissions from the consumption of coal from 1980 to 2012 in billions of pounds.

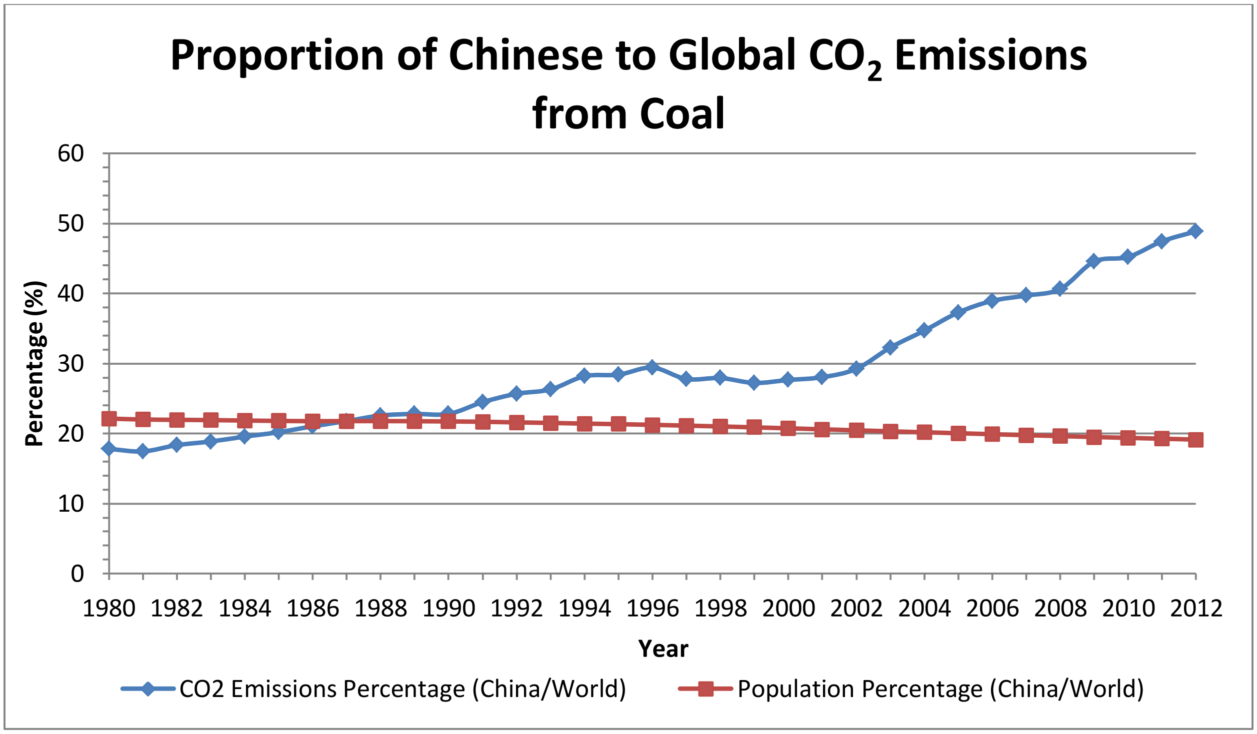

Figure 5: This graph shows the Chinese proportion of global CO_2 emissions from coal from 1980 to 2012.

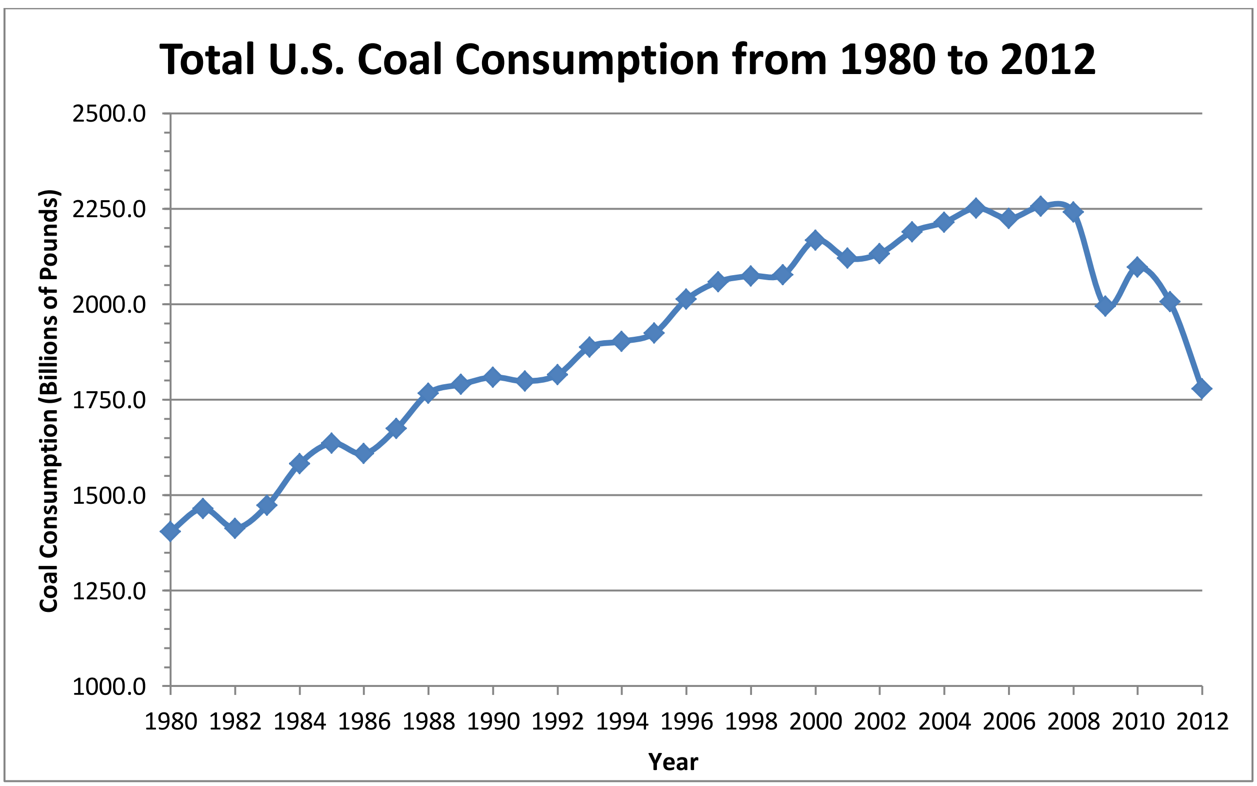

Figure 6: This graph shows the total U.S. consumption of coal from 1980 to 2012 in billions of pounds.

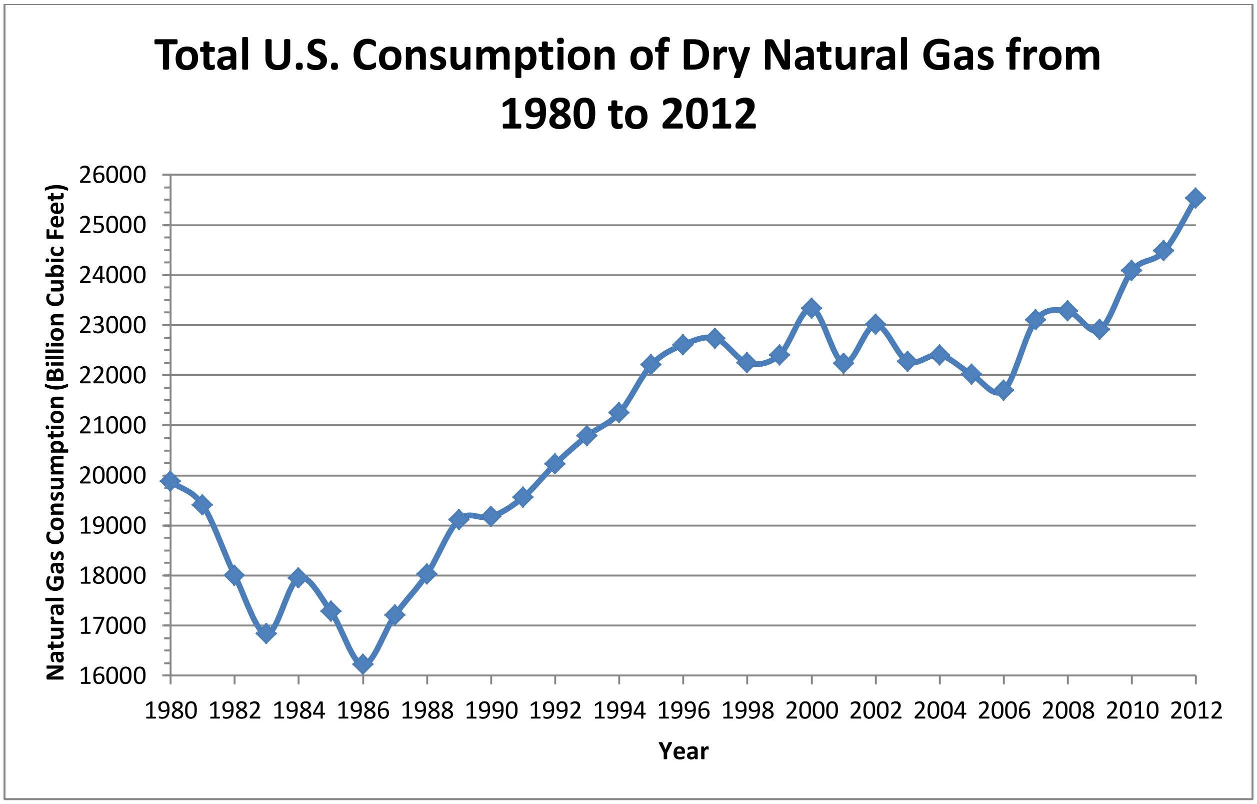

Figure 7: This graph shows total U.S. consumption of dry natural gas from 1980 to 2012 in billions of cubic feet.

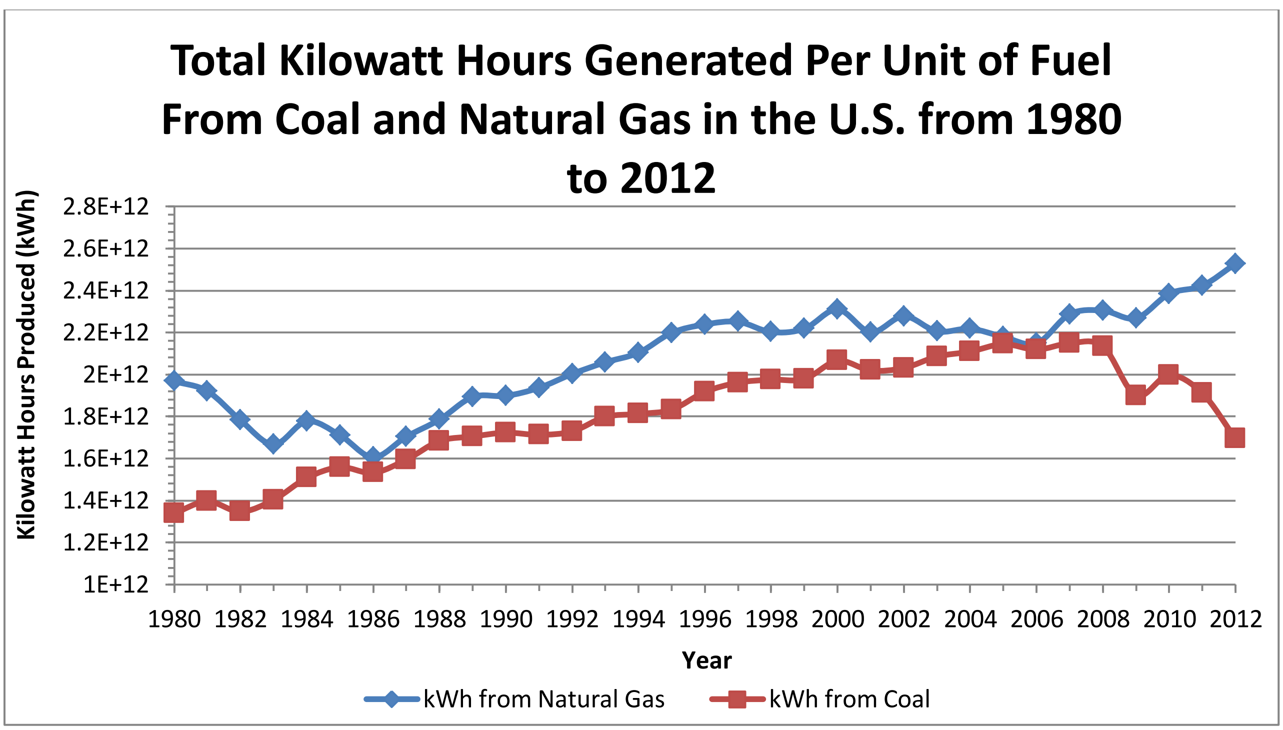

Figure 8: This graph shows the total kilowatt hours generated per unit of fuel of natural gas and coal in the U.S. from 1980 to 2012.

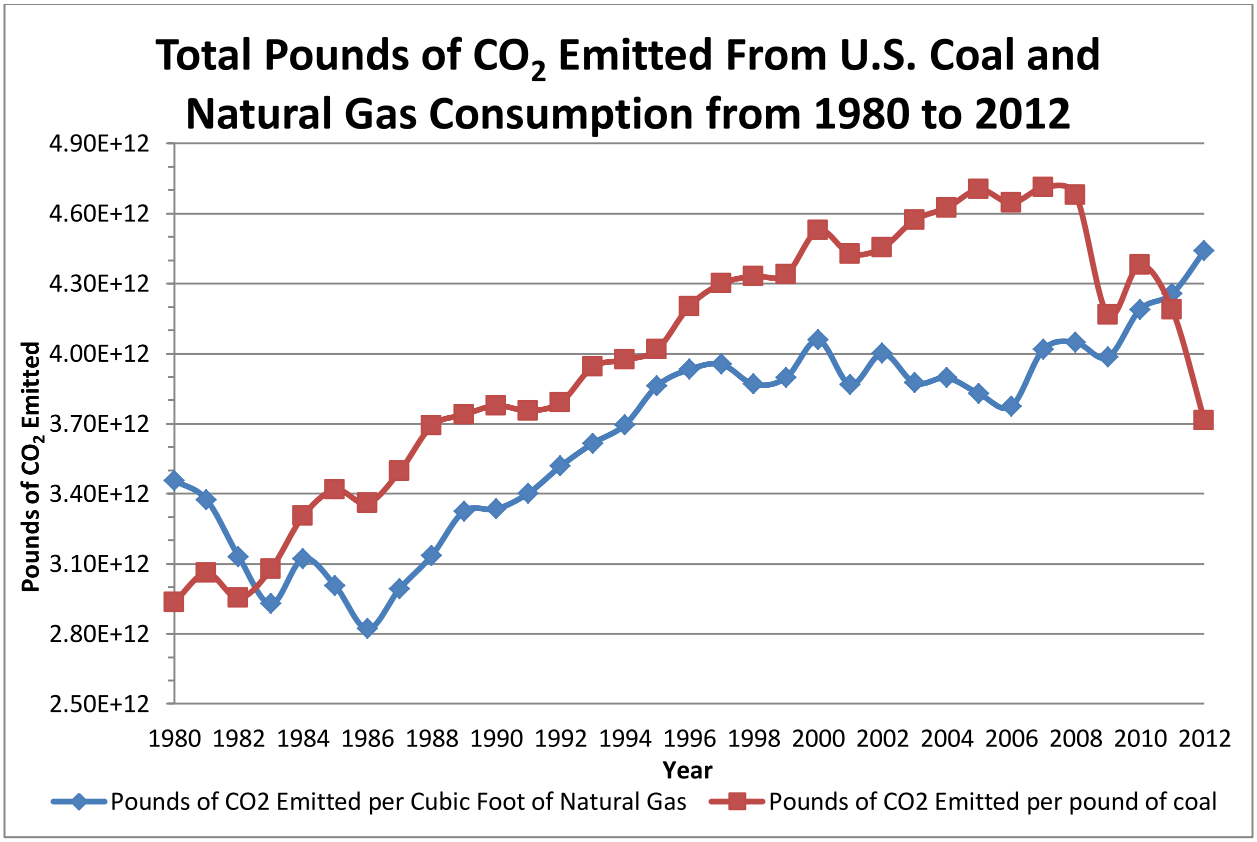

Figure 9: This graph shows the total pounds of CO_2 emitted from U.S. coal and natural gas consumption from 1980 to 2012 in pounds per cubic feet of natural gas and pounds per pound of coal.

Table 1: Excel Regression analysis results of the proportion of U.S. to global CO_2 emissions from coal from 1998 to 2012 indicating a statistically significant trend in both the U.S. to world CO_2 emissions and population data.

Proportion of U.S. to Global CO_2 Emissions From Coal From 1998 to 2012				
CO2 PERCENTAGES (U.S. / WORLD)				
Regression Statistics				
Multiple R	0.989014356			
R Square	0.978149397			
Adjusted R Square	0.976468581			
Standard Error	0.647006324			
Observations	15			
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1889.513496	77.52555699	24.37278195	3.09349E-12
X Variable 1	-0.932764622	0.038666023	-24.12362429	3.52606E-12
POPULATION PERCENTAGES (U.S. / WORLD)				
Regression Statistics				
Multiple R	0.989644144			
R Square	0.979395532			
Adjusted R Square	0.977810572			
Standard Error	0.008769738			
Observations	15			
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	30.68588671	1.050807084	29.20220769	3.06894E-13
X Variable 1	-0.013027997	0.000524092	-24.85822001	2.40596E-12

Table 2: Minitab Pearson correlation coefficient test results of kilowatt hours produced from U.S. coal and natural gas consumption from 1980 to 2012.

Correlation: Kilowatt Hours from Natural Gas, Kilowatt Hours from Coal

```
Pearson correlation of Kilowatt Hours from Natural Gas and Kilowatt Hours from Coal =
0.753
P-Value = 0.000
```

Table 3: Minitab Pearson correlation coefficient test results of pounds of CO_2 emitted from U.S. coal and natural gas consumption from 1980 to 2012.

Correlation: Pounds of CO2 Emitted per Cubic, Pounds of CO2 Emitted per pound

```
Pearson correlation of Pounds of CO2 Emitted per Cubic and Pounds of CO2 Emitted per
pound = 0.753
P-Value = 0.000
```