COMMON SENSE SOLUTIONS FOR MANAGEMENT OF GLOBAL CARBON EMISSIONS[1]

Kimery C. Vories[2] and Joshua D. Vories

Abstract: On April 13, 2012 and January 8, 2014, the U.S. Environmental Protection Agency (USEPA) proposed new regulations that amounted to a prohibition on the Best Technologies Currently Available for constructing new coal-fired power plants. USEPA first proposed in 2012, that new coal power plants must not produce more carbon dioxide (CO_2) than a natural gas power plant. Then in 2014, it revised the standard to require that unless a coal-fired power plant met the same CO_2 emission levels as achievable with power plants utilizing Integrated Gas Combined Cycle (IGCC) combustion technology and in addition provide permanent sequestion of at least 25% of the CO_2 produced, it could not be built. This effectively changes the proposed standard from 454 to 499 grams/kilowatt-hour of CO_2 emissions in order to construct a new coal-fired power plant. The U.S. Energy Information Administration (EIA), however has calculated the construction cost for such technology at $6,599/kW which is signifcantly more costly that the construction of a nuclear power plant at $5,530/kW and not remotely affordable compared to a natural gas power plant at $971/kW. This prohibition, like the historic prohibition of alcohol, is more likely to have negative rather than positive consequences.

This paper focuses on facts concerning fossil fuel utilization and its impacts upon global climate, the global economy, and the world population. It contrasts the impacts of current popular notions in the media and the regulations that govern our nation, that fossil fuels are an evil that must be stopped, versus the utilization of common sense to assess how to best use and advance currently available science and technology. It highlights best available control technology (BACT) that could reduce the manmade contribution of CO_2 in the atmosphere in a way that does not bankrupt the global economy and jeopardize the global population. It will assess the growth of renewable energy and project the number of generations that would be required to have them replace fossil fuel as an energy source.

The paper will highlight the historical relevance of the impacts of the prohibition of alcohol in the United States from 1920-1933 that contributed to the rise of organized crime funded by the illegal trade in alcoholic beverages. It will examine this historic precedent on alcohol prohibition and contrast it with the probable result of government actions that seek to prohibit the production and use of fossil fuels. It will conclude that if existing proven technologies, such as those that are currently available for improving the efficiency and environmental performance of coal-fired power plants were utilized worldwide, then coal-power plant fuel efficiency would increase by 40% and the production of CO_2 would be reduced by another 40% for the remaining coal that is burned.

Additional Key Words: Fossil Fuels, Utilization Efficiency, Environmental Protection.

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Introduction

This paper does not take a position on the science behind the current global warming issue. It addresses instead the documentable increasing amounts of CO_2 that are produced in the process of the burning of fossil fuels as an energy source to fuel the engines of global civilization. Global annual CO_2 emission levels have increased from 29.733^6 metric tons in 2007 to 32.578^6 metric tons in 2011 (See U.S. Energy Information Administration (USEIA) at: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8, an increase of 2.845^6 metric tons or 0.711^6 metric tons per year or 2.4 % per year.

The paper assumes that excessive amounts of CO_2 in the global atmosphere have a negative impact on the environment and that it is in the best interest of everyone that we develop methods of reducing this unintended by-product of human civilization. It also assumes that most of the current products and services of human civilization of food, shelter, clothing, transportation, medicine, education, law and order, and the cornucopia of products and services produced by this civilization require current levels of energy inputs in order to provide the necessary quantities and qualities of infrastructure that allow for the current global population of over 7.21 billion souls to exist (See U.S. Census Bureau at: http://www.census.gov/popclock). The paper contrasts:

1) proposed solutions that constitute a prohibition on any current fossil fuel energy source without providing substitutes that are an equivalent in terms of both costs and availability both to this country and the rest of the world; with

2) solutions that assume that more acceptable progress can be achieved for advancing both human civilization and environmental protection by requiring fossil fuel as well as all other energy sources to be continually and systematically updated with achievable improved technologies that improve fuel efficiency and environmental performance.

All forms of energy are natural resources that can be harnessed to do productive work. They should produce a positive benefit to society and the economy but need to be managed so that they are compatible with a healthy environment. Harnessing of any energy resource, whether renewable or nonrenewable, has an impact on the environment that needs to be balanced with its value to society and the economy. Natural resources are material substances and as such can't be categorized with character traits, such as good, bad, evil, superior, or inferior. They are all necessary ingredients that make an advanced human civilization possible. The world we live in and the civilization that supports and sustains us is dependent upon affordable, sustainable, available, and reliable energy in a wide variety of forms and formats.

Our world and civilization are also dependent upon a healthy environment that sustains us and all other living creatures on the planet. The economy of the United States and the economies of all other countries on the globe provide the necessary engines and occupations that turn natural resources in the environment into products and services that benefit and sustain our civilization. Healthy economies have the necessary resources to protect adequately the environment. Poverty and environmental degradation go hand in hand because an impoverished population is forced to ravage the environment through deforestation, resource depletion, and contamination in order to meet minimal survival needs (See: http://borgenproject.org/deforestation-caused-poverty/).

Following World War II, the United States made huge improvements in harnessing natural resources while reducing the impact to the environment during their use. Passage of environmental protection regulatory programs such as the Clean Air and Water Acts, the Resource Conservation and Recovery Act, the Surface Mining Control and Reclamation Act, and others have not only changed how resources are regulated but also changed how both the public and professionals working in related industries prioritize the need for protection of the environment.

Currently, issues related to protecting the public and the environment while producing and harnessing these energy resources has taken on an increasingly alarmist tone. Highly emotionally charged terminology and graphics are used in the media and public arena to discredit and silence alternative viewpoints and values. In the current debate, it is easy to ignore or forget the basics about the necessity of beneficially integrating energy, environment, and the economy for an advanced human civilization to exist and continue to progress into the future.

Global Production and Consumption of Fossil Fuels

Background

The USEIA maintains an accurate set of data and statistics on all forms of energy both nationally and globally (See USEIA at: www.eia.gov). Data is available on all energy sources both historically and currently, with projections provided for probable changes for the next 30 years. Although most of my audience is from the United States, it is crucial that the discussion look at the global facts and possible solutions related to energy production and use, environmental impacts, and manmade carbon emission rates. The reason for this is simple: reducing CO_2 emissions in the U.S. means little if the rest of the world continues to emit at record rates. For any solution that reduces CO_2 emissions to be *feasible and effective*, it must necessarily be *global*.

No solution adopted in the United States will have an impact globally if it is not globally applicable. The current shift in the production of electrical energy from coal to natural gas in the U.S. may have little impact on global emission rates if the rest of the world does not have access to both available and affordable natural gas resources. Natural gas prices from 2011 in the U.S. ran about $4 16 per million Btu while it cost $8 in the UK and $ in Japan (See at: http://www.eia.gov/todayinenergy/detail.cfm?id=3310). The lack of abundant and affordable natural gas supplies over a very long period in much of the rest of the world would suggest that at best such a conversion would have limited rather than universal application worldwide.

World Total Energy Consumption

According to the USEIA,

> *"…world energy consumption increases from 524 quadrillion Btu in 2010 to 630 quadrillion Btu in 2020 and 820 quadrillion Btu in 2040, a 30-year increase of 56 percent. More than 85 percent of the increase in global energy demand from 2010 to 2040 occurs among the developing nations outside the Organization for Economic Cooperation and Development (non-OECD), driven by strong economic growth and expanding populations. In contrast, OECD member countries are, for the most part, already more mature energy consumers, with slower anticipated economic growth and little or no anticipated population growth"* (http://www.eia.gov/forecasts/ieo/world.cfm).

In 2005, the total world consumption by fuel type shows that fossil fuels accounted for 395.3 quadrillion Btu or 84.3% of the total, nuclear accounted for 27.5 quadrillion Btu or 5.8%, while all other energy sources accounted for 46.0 quadrillion Btu or 9.8%. By 2014, the total world consumption by fuel type shows that fossil fuel consumption increased to 464.9 quadrillion Btu or 83.2% of the total, nuclear accounted for 28.5 quadrillion Btu or 5.2% while all other energy sources accounted for 64.3 quadrillion Btu or 11.5%. Although fossil fuel consumption has increased over this 9-year period by 69.6 quadrillion Btu, its percentage of the total has decreased by 1.1% while the other energy sources (solar, wind, hydropower, etc.) not only increased by 18.3 quadrillion Btu but increased its percentage of the total by 1.7% (See USEIA at: http://www.eia.gov/oiaf/aeo/tablebrowser/#release=IEO2013&subject=0-IEO2013&table=2-IEO2013&region=0-0&cases=Reference-d041117). The following graphs developed from data provided by the USEIA (Fig. 1and 2) illustrate recent relative contribution of fossil fuels (petroleum, natural gas, and coal), nuclear, and other (solar, wind, hydropower, etc.) to total world consumption levels.

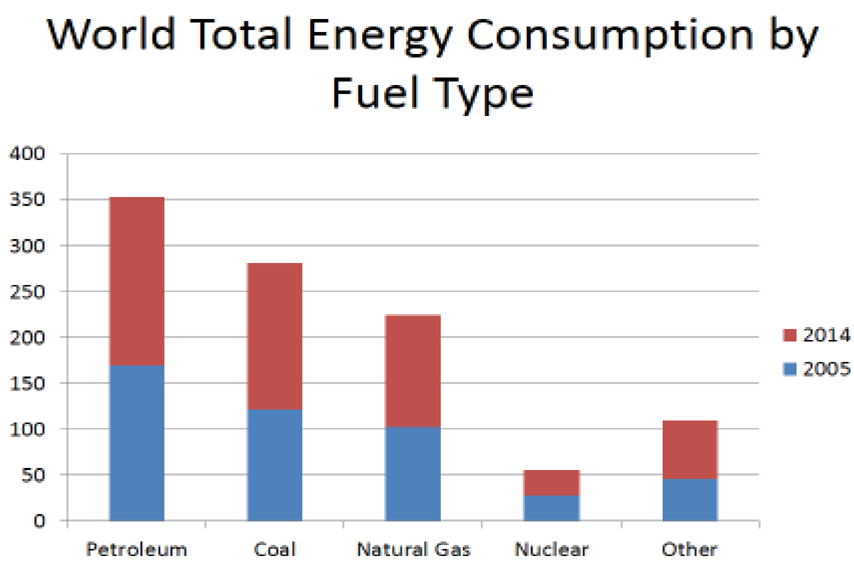

Figure 1. Total World Energy Consumption by Fuel Type from 2005 to 2014.

In the next generation (30 years is used to define a generation in the developed world), from 2010 to 2040 (Fig. 3), USEIA projects that total world fuel use will increase from 540.4 to 820 quadrillion Btu (http://www.eia.gov/oiaf/aeo/tablebrowser/#release=IEO2013&subject=0-IEO2013&table=2-IEO2013&region=0-0&cases=Reference-d041117). The percentage of the total fuel mix in 2012 was fossil fuels 84% and non-fossil fuels (nuclear and renewables) was 16%. The percentage of the total fuel mix in 2040 is projected to be fossil fuels 78% and non-fossil fuels 22% or a reduction in the fossil fuel input by 6% in a generation. If the same trend could be expected to continue in the future, it would take 14 generations for non-fossil fuels to replace fossil fuels as a global energy source. Clearly, fossil fuels are going to play a major role as a global energy source for a very long period of time.

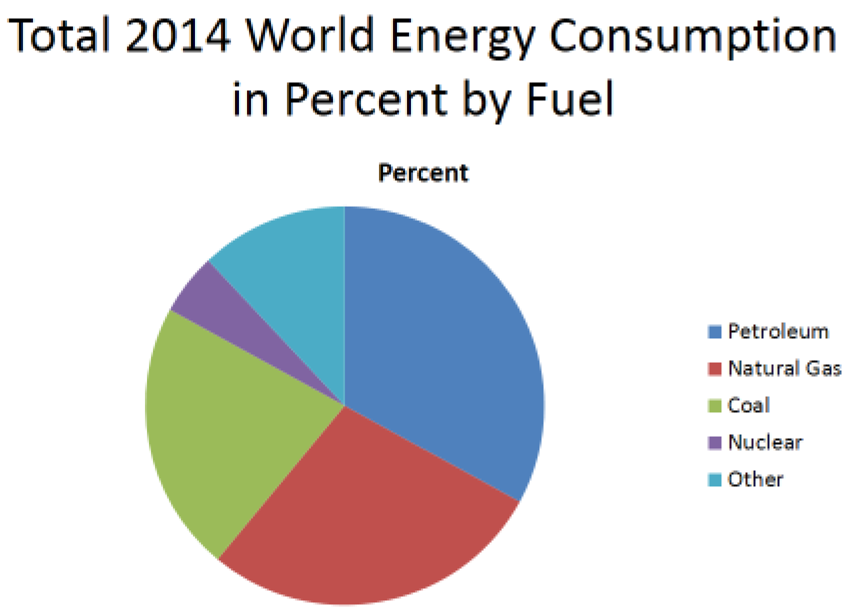

Figure 2. 2014 Total World Consumption of Energy in Percent by Fuel type

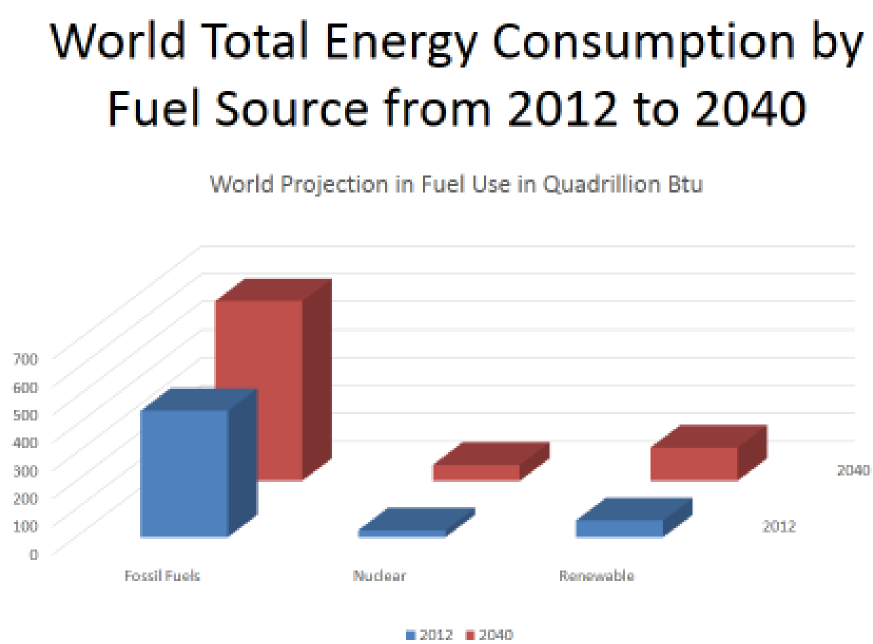

Figure 3. World Total Energy Consumption by Fuel Source from 2012 to 2040

In the recent past and in the foreseeable future, total world energy consumption has been and will be dominated by fossil fuels. Given the length of time it would take to replace fossil fuels with non-fossil fuels, the only viable option is to continually make progress in finding affordable technologies that would increase fossil fuel efficiency and improve environmental performance. Prohibiting the use of fossil fuels instead of focusing on how to use them responsibly inhibits this advancement of the necessary technologies. An ongoing advance of improved technologies for utilization of fossil fuels would steadily increase efficiencies and environmental performance that will translate into actual reductions in global CO_2 levels.

Global Electric Power Generation by Fuel Source

World Electric Power Production

According to the USEIA,

> *"...**world net electricity generation increases by 93 percent**, from 20.2 trillion kilowatt-hours in 2010 to 39.0 trillion kilowatt-hours in 2040. Electricity supplies an increasing share of the world's total energy demand and is the world's fastest-growing form of delivered energy. World electricity delivered to end users rises by 2.2 percent per year from 2010 to 2040, as compared with average growth of 1.4 percent per year for all delivered energy sources. Of the 20.2 trillion kilowatt-hours generated in 2010 (http://www.eia.gov/forecasts/ieo/electricity.cfm), 8.05 is with coal, 4.48 is with natural gas, 4.18 is with renewables, 2.62 is with nuclear, and 0.91 is with liquids. Of the 39.0 trillion kilowatt-hours projected to be generated in 2040, 13.89 is with coal, 9.6 is with renewables, 9.37 is with nuclear, and 0.68 is with liquids" (See Fig. 4).*

The Role of Renewables in Electricity Production in the USA

The breakdown of each component of fossil fuels and renewables has been thoroughly documented for United States Electric Power Generation for 2012. (See at USEIA: http://www.eia.gov/electricity/annual/html/epa_01_02.html). Figure 5 (developed from data provided by the USEIA) shows the total fuel distribution of 4.047 [6] megawatts in thousands of megawatts as Coal 1,514,043; Natural Gas 1,237,792; Petroleum 23,190; Nuclear 769,331; Hydro 271,290; Wind 140,822; Biomass 57,622; Geothermal 15,562; Other 13,787; and Solar 4,327. The relative percentage of major fuel sources for electric power generation for 2012 was fueled by fossils fuels at 68.6%, nuclear at 19%, and renewables 12.4%. Figure 6 shows the same simplified information in percentages developed from data provided by the USEIA.

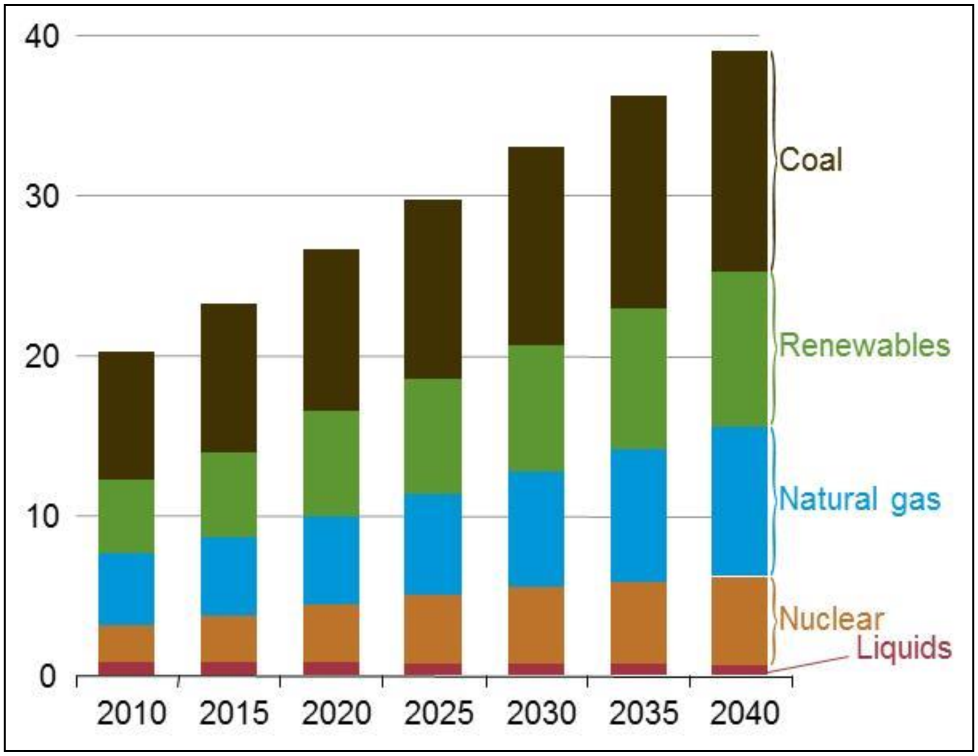

Figure 4. Projection of World Electricity Production by Fuel type in trillion kilowatt-hours.

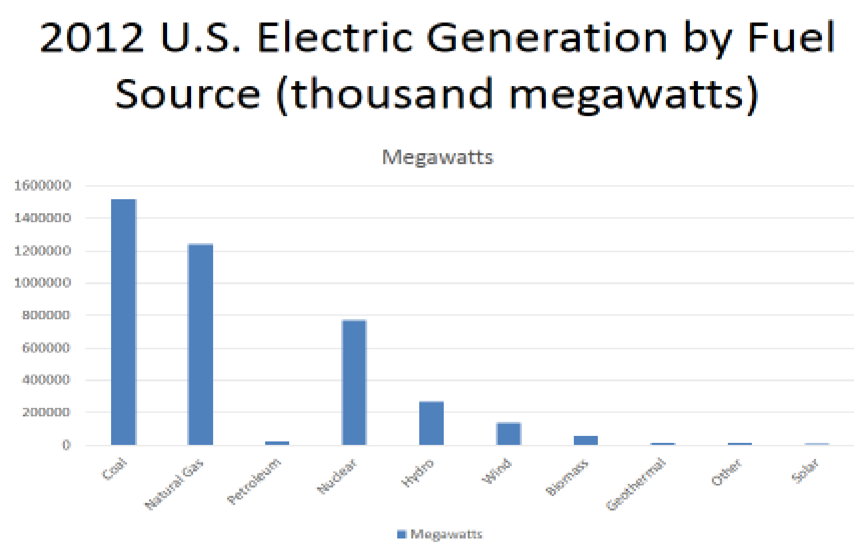

Figure 5. 2012 U.S. Electric Generation by Fuel Source in thousands of megawatts.

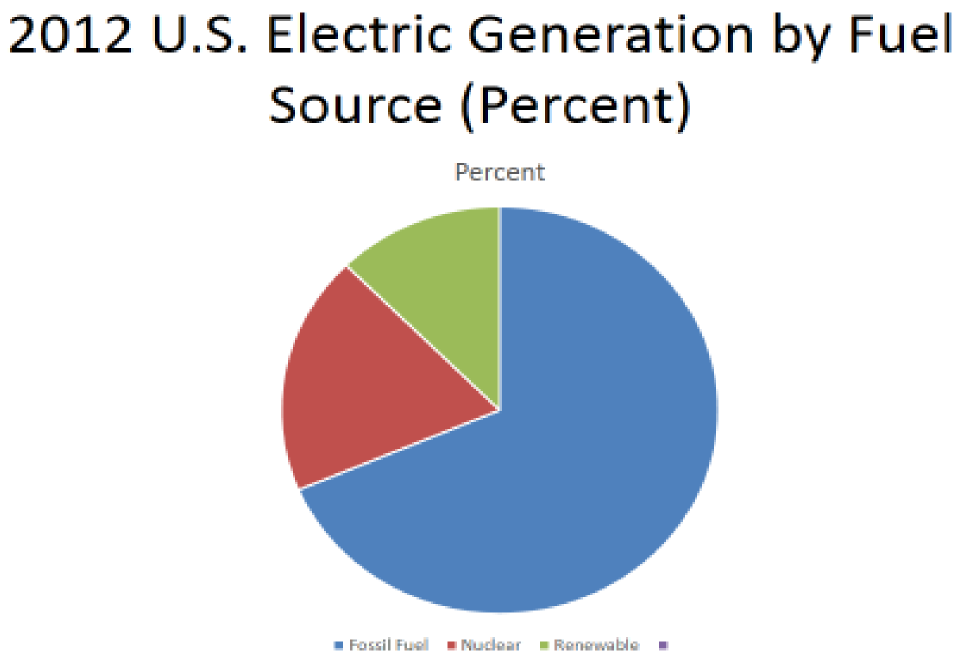

Figure 6. 2012 U.S. Electric Generation by Fuel Source in Percentage.

Although renewable energy resources are becoming an increasingly significant component of the fuel for electrical power, they will not be replacing significant fossil fuel supplies for this purpose within the foreseeable future even in more technologically advanced countries like the U.S., let alone in the developing nations of the world. This element of the lengthy time frame involved in any likely projection of the growth of renewables should mandate that the most important reductions in global CO_2 levels must come from the advancement of those technologies that increase the efficiency and environmental performance of all fuel sources, especially fossil fuels. Efforts that in any way inhibit this technological progress only delay any significant progress with global reductions in CO_2 levels.

<u>World Coal Consumption</u>

During 2011, the world produced 8.440^{6} short tons of coal (See at USEIA: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=1&pid=7&aid=1). The top producers were China at 3.845^{6} short tons, the U.S. at 1.094^{6} short tons, India at 0.640^{6} short tons, Australia at 0.457^{6} short tons, Indonesia at 0.415^{6} short tons, Russia at 0.368^{6} short tons, South Africa at 0.279[6] short tons, and Germany at 0.208[6] short tons. Although the U.S. is the second largest producer of coal in the world, it still only produced 13% of the total.

According to the USEIA,

> *"World coal consumption rises at an average rate of 1.3 percent per year, from 147 quadrillion Btu in 2010 to 180 quadrillion Btu in 2020 and 220 quadrillion Btu in 2040. The near-term increase reflects significant increases in coal consumption by China, India, and other non-OECD countries. In the longer term, growth of coal consumption decelerates as policies and regulations encourage the use of cleaner energy sources, natural gas becomes more economically competitive as a result of shale gas development, and growth of industrial use of coal slows largely as a result of China's industrial activities" (http://www.eia.gov/forecasts/ieo/coal.cfm).*

USEIA provides a graphic illustration of this growth in coal consumption highlighting the major coal producers in Fig. 7 below.

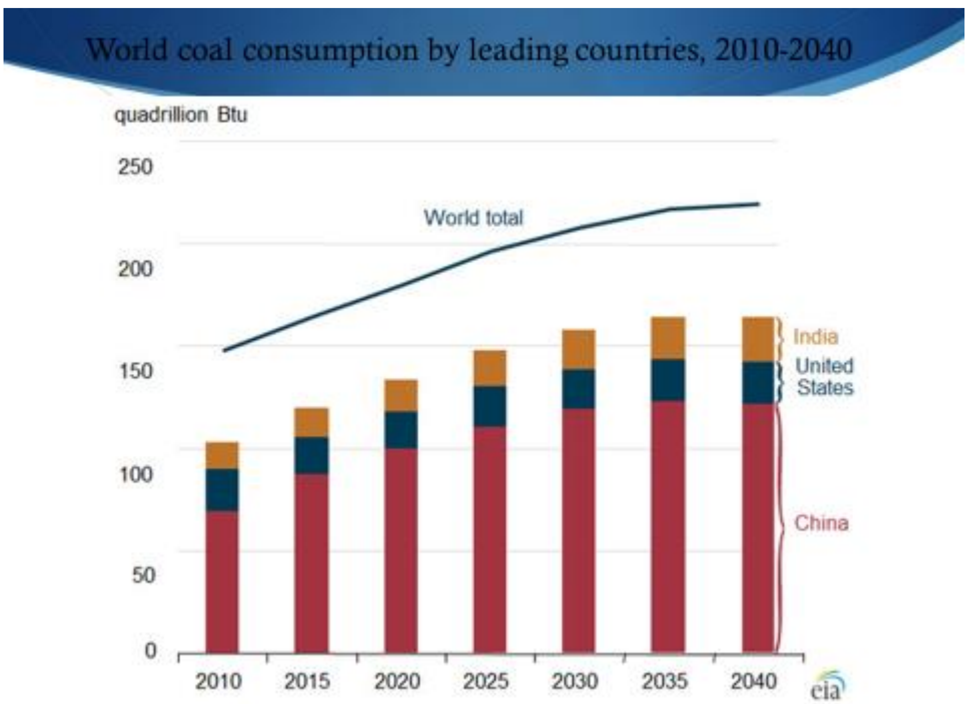

Figure 7. USEIA projection of the growth of world coal consumption from 2010 to 2040.

The quantitative role of coal production in the U.S., although significant, is expected to steadily decrease over time as a percentage of the world total. If the U.S. hopes to have any impact on global coal consumption and its related contribution to global atmospheric CO_2

levels, it will have to be in a qualitative manner that has the ability to impact other countries in terms of promoting affordable technologies that make coal utilization more efficient with reduced emission levels of CO_2.

<u>The Spector of a "Renewables Only World" on the Human Population</u>

According to the USEIA,
(http://www.eia.gov/forecasts/aeo/er/early_elecgen.cfm?src=Renewable-b1)

> *"…the share of U.S. electricity generation coming from renewable fuels (including conventional hydropower) grows from 12% in 2012 to 16% in 2040 in the* AEO2014 *Reference case, even with federal subsidies for renewable generation assumed to expire as enacted. Extensions of such subsidies could have a large impact on renewable generation. The long-run projections for renewable capacity are also sensitive to natural gas prices and the relative costs of alternative generation sources."*

Renewable energy sources, even in technologically advanced countries like the U.S., deal almost exclusively with electric power generation and not with total fuel supply. In the 30 years of the EIA projection, the increase in the use of renewables for electric power generation increased by 4% and coal consumption for that same purpose was reduced by 5%. If the same trend were continued into the future, it would take 7 generations (210 years) for renewables to replace coal as a fuel source for electrical power. Since natural gas, also a fossil fuel, increases by 5% over the same time span, and if that trend were continued in the future, renewables would continue to be out paced by natural gas over the same period.

The projected time required for renewables to replace all fossil fuels as an energy source on a global basis would be at least twice as long as that required to replace it for electric power. Figure 3 indicates that it would take 14 generations (420 years) for non-fossil fuels to replace fossil fuels as a global energy source assuming that current trends could be continued indefinitely into the future.

Since world CO_2 levels are influenced by global consumption of all fossil fuels, neither current nor projected data from USEIA give any indication that a "renewables only world" is probable in the foreseeable future. Based on data and projections from USEIA over the next 30 years, 78% to 83% of the world's energy will be supplied by fossil fuels. Any attempt to mandate a "renewables only world" would mean that: (1) at one extreme, somewhere between

78% to 83% of the human population or 5.984 billion people (The current world population is 7.210 billion, see at: U.S. Census Bureau http://www.census.gov/popclock) would be without any source of energy for a very long time (See Fig. 8); or (2) at the other extreme, that 100% of the world population would have to reduce its energy consumption by 78% to 83%. It is impossible to imagine how either alternative could achieve public acceptability.

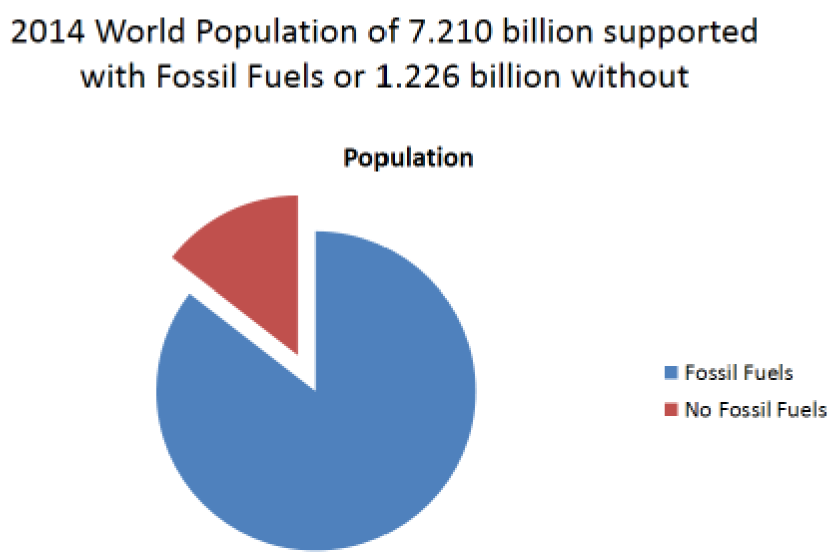

Figure 8. The 2014 World Population of 7.210 billion supported with Fossil Fuels or 1.226 billion without Fossil Fuels.

Prohibitions

Prohibition of Alcohol: An Example from History

On January 17, 1920, prohibition of alcoholic beverages became the law of the land in the USA.

> *"The **Eighteenth Amendment** of the United States Constitution established the prohibition of alcoholic beverages by the production, transport and sale of (though not the consumption or private possession of) alcohol. Following the 18th Amendment's adoption, although the consumption of alcohol was reduced by half, prohibition effectively resulted in a public demand for illegal alcohol, making criminals of producers and distributors. The criminal justice system was swamped although police forces and courts had expanded in recent years. Prisons were jam-packed and court dockets were behind in trying to deal*

with the rapid surge in crimes. Organized crime expanded to deal with the lucrative business, and there was widespread corruption among those charged with enforcing unpopular laws. The amendment was repealed in 1933 by ratification of the Twenty-first Amendment, the only instance in United States history that a constitutional amendment was repealed" (See at Wikipedia Free Encyclopedia: http://en.wikipedia.org/wiki/Eighteenth_Amendment_to_the_United_States_Constitution.

"From its inception, the Eighteenth Amendment lacked legitimacy in the eyes of the public who had previously been drinkers and law-abiding citizens. In some instances the public viewed prohibition laws as "arbitrary and unnecessary," and therefore were willing to break them. ***As the prohibition years continued, more of the country's populace came to see prohibition as illustrative of class distinctions, a law unfairly biased in its administration favoring social elites. Prohibition worked best when directed at its primary target: the working-class poor."****(See at Wikipedia Free Encyclopedia: http://en.wikipedia.org/wiki/Prohibition_in_the_United_States)*

Prohibitions of products or technologies that do not have overwhelming popular support may not be effective and may produce unexpected and extremely negative results.

Fossil Fuel Prohibition

On April 13, 2012, the U.S. Environmental Protection Agency (USEPA) promulgated new regulations for the permitting of fossil fuel fired power plants constructed after that date.

"…that would require covered units to achieve an emission rate of 1000 pounds of CO_2 per megawatt hour (454 grams/kilowatt-hour). This standard could be met by current natural gas combined cycle units without controls, or by units fueled by coal or petroleum coke that implement carbon capture and sequestration (CCS). EPA has proposed an alternative compliance pathway, whereby units implementing CCS could comply by meeting the standard on average over the course of a 30-year period. A company could build a coal fired plant and add CCS later, or a company that installs and operates CCS from the outset would have the flexibility to emit more CO_2 in the early years as it optimizes the controls over time" (See USEPA page 11 and 12 at: http://www.epa.gov/ocir/hearings/pdf/2012_GHG_testimony_final.pdf Standards of

Performance for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units, 77 Fed. Reg. 22392).

On January 8, 2014, the USEPA withdrew the above proposed rule and substituted a new proposed standard for new source coal-fired power plants which would replace the previous standard of 1000 lbs. of CO2 to a new standard of 1,100 lbs. of CO2 per megawatt hour (499 grams/kilowatt hour). The USEPA contends that this represents the "best system of emission reduction adequately demonstrated" or BESR (79 Fed. Reg. 1429, 01/08/2014). In addition, on June 18, 2014, the US EPA also proposed that States be required to submit State specific plans to reduce CO^2 emissions at existing electric power plants to 26 to 30 percent below 2005 levels depending upon the compliance year (79 Fed. Reg. 34829; 06/18/20114). The USEIA, however has calculated the construction cost for such technology at $6599/kW which is signifcantly more costly that the construction of a nuclear power plant at $5530/kW and not remotely affordable compared to a natural gas power plant at $971/kW (http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdfhttp://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf).

According to the USEIA, the very best technology currently available for producing electric power with coal is the Supercritical boiler technology that operates at 700º C. With this technology, you can achieve a level of 640 grams of CO_2 per kilowatt-hour (See Fig. 9). The world average for coal-fired generation is over 1,100 grams/kilowatt-hour. The revised new source performance standard proposed by USEPA on January 8, 2014, would be 499 grams of CO_2 per kilowatt-hour. The USEIA indicates that carbon capture and sequestration technology as advocated by USEPA is still in the "revolutionary" stage of development and is not yet "mature." Further, the World Coal Association states that

"*Reliability and availability have been challenges facing IGCC development and commercialization. Cost has also been an issue for the wider uptake of IGCC as they have been significantly more expensive than a conventional coal-fired plant.*" (http://www.worldcoal.org/coal-the-environment/coal-use-the-environment/improving-efficiencies).

From a common sense perspective, the USEPA revised proposed new source performance standard represents a prohibition on the construction of new coal-fired power plants in the U.S.

because the acceptable technologies advocated are neither commercially available nor affordable. This is in spite of the availability of the best available control technology that is 40% more efficient than the world average and produces 40% less CO_2. Since global CO_2 levels are a global problem, if the U.S. is going to have any impact on global CO_2 emission

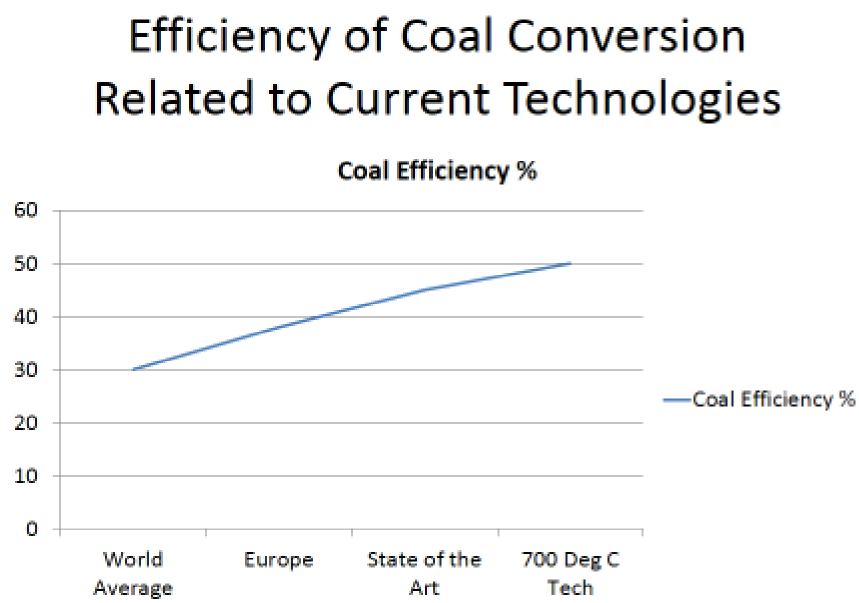

Figure 9. Efficiency of Conversion of Coal to Electrical Energy (USEIA)

levels, then it should promote technologies that are available and likely to be cost effective to the rest of the world. Otherwise, the action of the U.S. will ultimately be viewed by both the American public and the rest of the world "as a law unfairly biased in its administration favoring social elites" *(http://en.wikipedia.org/wiki/Prohibition_in_the_United_States)*. The USEPA prohibition of the best available control technologies for coal-fired power plants most probably will create unintended negative consequences that will:

1) create a public perception at home and abroad that "coal" is prohibited because it cannot be used in an environmentally protective manner;

2) remove the U.S. from any position for advancing the only available technologies that could be used by the world community to reduce global CO_2 emission rates for coal-fired power production;

3) confirm in the minds of the developing world that the U.S. has no interest in helping them solve this problem, and

4) do nothing to reduce CO_2 emissions by the large coal consuming nations like China and India.

Neither alcohol nor any particular fossil fuel is inherently good or evil. Efforts to establish prohibitions or regulatory barriers to the use of one or more fossil fuels will ultimately prove ineffective at reducing long-term CO_2emission levels. This is because they would result in significantly reduced levels of affordable and available energy that neither the public in the U.S. nor the rest of the world could support because energy production is directly related to the economic viability of this or any other economy.

Common Sense Solutions

Technologies for Improving the Efficiency of Converting Coal to Electrical Energy

The following quote concerning best available control technologies for coal fired power plants is provided by the World Coal Association (http://www.worldcoal.org/coal-the-environment/coal-use-the-environment/improving-efficiencies),

> *"Improving efficiency levels increases the amount of energy that can be extracted from a single unit of coal. Increases in the efficiency of electricity generation are essential in tackling climate change.* ***A one percentage point improvement in the efficiency of a conventional pulverized coal combustion plant results in a 2-3% reduction in CO_2 emissions. Highly efficient modern coal plants emit up to 40% less CO_2 than the average coal plant currently installed.***

Efficiency improvements must include the most cost-effective and shortest lead time actions for reducing emissions from coal-fired electricity. This is particularly the case in developing and transition countries where existing plant efficiencies are generally lower and coal use in electricity generation is increasing.

The average global efficiency of coal-fired plants is currently 33% compared to 45% for the most efficient plants. A program of repowering existing coal-fired plants to improve their efficiency, coupled with the newer and more efficient plants being built, will generate significant CO_2 reductions. Although the deployment of new, highly efficient plants is subject to local *constraints, such as ambient environmental conditions and coal quality,* ***deploying the most efficient plant possible is critical to enable these plants to be retrofitted with Carbon Capture and Sequestration (CCS) in the future. Efficient plants are a prerequisite for retrofitting with CCS because capturing, transporting and storing the plant's CO_2 consumes significant quantities of energy. Highly inefficient plants will undermine capacity to deploy CCS technologies.***

Improving the efficiency of the oldest and most inefficient coal-fired plants to that achievable with BACT would reduce CO_2 emissions from coal use by almost 27% representing nearly a 7% reduction in global CO_2 emissions. These significant emissions reductions can be achieved by the replacement of plants with greater than 300 MW capacity and older than 25 years, with larger and significantly more efficient plants and, where technically and economically appropriate, the replacement or repowering of larger inefficient plants with high-efficient plants of greater than 40%.

Supercritical and Ultra-supercritical Coal Fired Technology

New pulverized coal combustion (PCC) systems – utilizing supercritical and ultra-supercritical technology – operate at increasingly higher temperatures and pressures and therefore achieve higher efficiencies than conventional PCC units and significant CO_2 reductions.

Supercritical steam cycle technology has been used for decades and is becoming the system of choice for new commercial coal-fired plants in many countries.

Research and development is under way for ultra-supercritical units operating at even higher efficiencies, potentially up to around 50%. The introduction of ultra-supercritical technology has been driven over recent years in countries such as Denmark, Germany and Japan, in order to achieve improved plant efficiencies and reduce fuel costs.

Integrated Gasification Combined Cycle (IGCC) coal fired technology

An alternative to achieving efficiency improvements in conventional pulverized coal-fired power stations is through the use of gasification technology. Integrated Gas Combined Cycle (IGCC) plants use a gasifier to convert coal (or other carbon-based materials) to syngas, which drives a combined cycle turbine.

Coal is combined with oxygen and steam in the gasifier to produce the syngas, which is mainly H_2 *and carbon monoxide (CO). The gas is then cleaned to remove impurities, such as sulphur, and the syngas is used in a gas turbine to produce electricity. Waste heat from the gas turbine is recovered to create steam, which drives a steam turbine, producing more electricity – hence a combined cycle system.*

By adding a 'shift' reaction, additional hydrogen can be produced and the CO can be converted to CO_2*, which can then be captured and stored. IGCC efficiencies typically reach the mid-40s, although plant designs offering around 50% efficiencies are achievable.*

Reliability and availability have been challenges facing IGCC development and commercialization. Cost has also been an issue for the wider uptake of IGCC as they have been significantly more expensive than a conventional coal fired plant."

According to the USEIA, the very best technology currently available for producing electric power with coal is the Supercritical boiler technology that operates at 700º C. With this technology, you can achieve a level of 640 grams of CO_2 per kilowatt-hour (See Fig. 9 and 10). The world average for coal-fired generation is over 1,100 grams/kilowatt-hour. The new source performance standard mandated by USEPA would be 454 grams of CO_2 per kilowatt-hour. The USEIA does not address carbon capture and sequestration technology as suggested by USEPA, presumably because it is not yet a proven technology that is currently available.

Carbon emission reductions can be achieved by using more efficient technologies for converting coal to electrical energy. Each step in the process, however, depends upon the prior steps. The infrastructure costs in time, money, and manpower for constructing electrical power plants are so large that each improvement must be made with a plan in mind for changes that will come later. It is unlikely that any one in this country or any other will consider leaps into the unknown from proven technologies to unproven ones. Every successful journey begins with the first step followed by the next step. Those who will not begin the journey until perfection has arrived, will wait in vain.

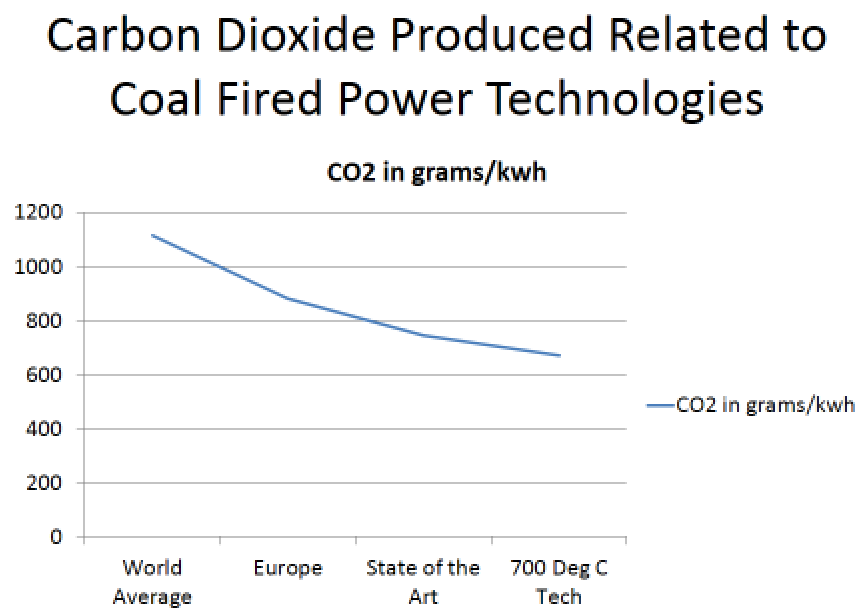

Figure 10. CO_2 emission rates related to coal-fired boiler technology (USEIA)

Conclusion

In conclusion, the major concerns in managing gobal CO_2 emissions are:

(1) Managing levels of CO_2 in the global atmosphere is a global problem. The U.S. must address how solutions developed in the U.S. are likely to impact other global efforts to reduce CO_2 generation in other countries.

(2) If the U.S. hopes to have any impact on global coal consumption and its related contribution to atmospheric CO_2 levels, it will have to be in a qualitative manner that has the ability to impact other countries in terms of promoting affordable technologies that make coal utilization more efficient with reduced emission levels of CO_2.

(3) Any solution related to CO_2 reduction must evaluate its impact on the total supply of global energy which will directly impact the global economy. Solutions that are in effect a prohibition on any given energy commodity are not likely to find acceptance in the global economy without the introduction of affordable and available replacements.

(4) Since technological progress is evolutionary rather than revolutionary, prohibitions on resource specific technological progress will ultimately be interpreted by the public as

the worst sort of public policy proving grossly inadequate in limiting global CO_2 levels as well as promoting social injustice.

(5) And, common sense would dictate that the U.S. place all of its efforts into promoting the systematic advancement of the best technologies currently available for improving the efficiencies and environmental performance of all energy resources if we are to help the rest of the globe reduce CO_2 emission rates in a positive and significant manner.

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