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ARTHUR B. ROBINSON CENTER ON CLIMATE AND ENVIRONMENT POLICY

MAY 2018 POLICY BRIEF

Summary

- Fossil fuels are lifting billions of people out of poverty.
- Fossil fuels are vastly improving human well-being and safety by powering labor-saving and life-protecting technologies.
- Fossil fuels are dramatically increasing the quantity of food humans produce and improving the reliability of the food supply.
- Fossil-fuel emissions are contributing to a "Greening of the Earth," benefiting plants and wildlife.
- Fossil fuels should be credited with saving lives by reducing deaths due to extreme cold weather.

The Social Benefits of Fossil Fuels

By Joseph L. Bast and Peter Ferrara

On May 25, U.S. District Judge William Alsup, presiding in the case *The People of the State of California* v. *BP PLC et al.,* issued an order to legal counsel of both parties that they "shall submit 10-page supplemental briefs on the extent to which adjudication of plaintiffs' federal common law nuisance claims would require the undersigned judge to consider the utility of defendants' alleged conduct."[1] The "alleged conduct" is the production and sale of fossil fuels known by the defendants to contribute to global warming, which in turn is alleged to harm the defendants by causing sea level rise and therefore a greater risk of flooding. The "utility" is the social benefit created by the use of those same fossil fuels.

During court proceedings on the day before he issued his order, Judge Alsup apparently commented, "We need to weigh in the large benefits that have flowed from the use of fossil fuels. There have been huge benefits."[2]

After a brief introductory comment about the scientific debate over the causes and consequences of climate change, this *Policy Brief* documents five benefits from the historic and still ongoing use of fossil fuels. Four direct benefits are:

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[1] Case 3:17-cv-06011-WHA Document 259, http://blogs2.law.columbia.edu/climate-change-litigation/wp-content/uploads/sites/16/case-documents/2018/20180525_docket-317-cv-06011_order-1.pdf.

[2] Nicholas Iovino, "Judge Skeptical of Cities' Climate Change Suits," Courthouse News Service, May 24, 2018.

- Fossil fuels are lifting billions of people out of poverty, reducing all the negative effects of poverty on human health.

- Fossil fuels are vastly improving human well-being and safety by powering labor-saving and life-protecting technologies, such as air conditioning, modern medicine, and cars and trucks.

- Fossil fuels are dramatically increasing the quantity of food humans produce and improve the reliability of the food supply, directly benefiting human health.

- Fossil-fuel emissions are contributing to a "Greening of the Earth," benefiting all the plants and wildlife on the planet.

> FOSSIL FUELS ARE VASTLY IMPROVING HUMAN WELL-BEING AND SAFETY BY POWERING LABOR-SAVING AND LIFE-PROTECTING TECHNOLOGIES, SUCH AS AIR CONDITIONING, MODERN MEDICINE, AND CARS AND TRUCKS.

A fifth benefit could be added only if fossil fuels are in fact responsible for a significant part of the global warming recorded during the second half of the twentieth century. That benefit would be:

- Fossil fuels should be credited with saving lives by reducing deaths due to extreme cold weather. Weather is also less extreme in a warmer world, resulting in fewer injuries and deaths due to extreme weather.

Most of the text in this *Policy Brief* will appear in an upcoming volume in the *Climate Change Reconsidered* series, which is produced by the Nongovernmental International Panel on Climate Change (NIPCC), an international body of scientists and policy experts brought together to fact-check the work of the United Nations' Intergovernmental Panel on Climate Change (IPCC). It appears here with permission of the publisher and lead authors. The four volumes in the series already in print are available online at www.climatechangereconsidered.org.

Introduction

Too few *scientists* take the time to understand economics and the contribution it can make to the debate over climate change. If they did, they would discover many issues at the center of the debate aren't as simple or obvious as newspaper articles and fundraising letters make them seem. Unfortunately, too many *economists* make a similar mistake, believing the popular myth "the debate is over" on the science of climate change and thinking their only contribution to the debate is finding the most efficient ways to reduce greenhouse gas emissions.

Probably the only "consensus" among climate scientists is that human activities can have an effect on local climate or that the sum of such local effects could hypothetically rise to the level of an observable global signal. The key questions to be answered, however, are whether the human impact on the global climate is large enough to matter, by how much is warming likely to accelerate, and will the damages caused by warming outweigh the benefits? On these questions, an energetic debate is taking place on the pages of peer-reviewed journals. In April, 2018, The Heartland Institute responded to a request to legal counsel from Judge Alsup for a brief tutorial on the state of the scientific debate (Lehr, Haapala, Frank, and Moore, 2018).[3]

The scientists who wrote *Climate Change Reconsidered II: Physical Science* found neither the rate nor the magnitude of the reported late twentieth century surface warming (1979–2000) lay outside normal natural variability, nor were they in any way unusual compared to earlier episodes in Earth's climatic history. A doubling of carbon dioxide (CO_2) from pre-industrial levels (from 280 to 560 ppm) would likely produce a temperature forcing of 3.7 Wm-2 in the lower atmosphere, for about ~1°C of prima facie warming. The recently quiet Sun and extrapolation of solar cycle patterns into the future suggest a planetary cooling may occur over the next few decades (Idso, Carter, and Singer, 2013).

The recently quiet Sun and extrapolation of solar cycle patterns into the future suggest a planetary cooling may occur over the next few decades.

In the face of such scientific findings, many experts recommend a "no regrets" strategy of making strategic investments in emissions reductions or adaptation to future climate change that produce more benefits than costs (NCPA, 1991; Goklany, 2001; Adler *et al.*, 2000; Lomborg, 2008; Murray and Burnett, 2009; Carter, 2010; The Hartwell Group, 2010, 2011; van Kooten, 2013; Vahrenholt and Luning, 2015; Bailey, 2015; Moore and Hartnett White, 2016). Such a strategy might focus on funding research and development (R&D) projects that promise to lower emissions from fossil fuels or reduce the energy intensity of the economy (allowing us to use less energy while producing the same or higher levels of goods and services or discover new energies that do not release greenhouse gases) or investments in adaptation that cost less than reducing emissions while offsetting any adverse effects of climate change.

"No regrets" is not the direction the plaintiffs in *The People of the State of California* v. *BP PLC et al.* and the activists and spokespersons they cite as authorities on the climate change issue wish to go. They advocate instead for major reductions in CO_2 emissions, which they say must occur as soon as possible. Relying on IPCC's models, they claim CO_2 emissions must be reduced by 80 percent by 2050 in order to keep CO_2 concentrations in the atmosphere from exceeding 480 ppm, the level they think will cause a 2°C increase in global temperatures, the most they believe could occur without causing catastrophic negative effects (European Commission, 2011; Long and Greenblatt, 2012; National Research Council, 2013; World Energy Council, 2013).

If we reject the "no regrets" option, either be-

[3] Heartland's brief was completed too late to meet Judge Alsup's deadline and was not submitted as an amicus brief, but instead published as a *Heartland Policy Brief.* It appears in the list of references at the end of this section.

cause of genuine disagreement over economics and science or ideological fervor, we are not relieved of the obligation to weigh and measure the costs of our decision. What benefits from the use of fossil fuels would we forego by forcing a rapid reduction in their availability? How much would it cost to reduce emissions so steeply? How would that cost compare to the alleged benefits of fewer heat waves, fewer or less severe droughts, and fewer instances of coastal flooding? These are the questions asked or inferred by Judge Alsup in his May 25, 2018 request to counsels in in *The People of the State of California* v. *BP PLC et al.* We endeavor to answer them, albeit briefly, here.

> What benefits from the use of fossil fuels would we forego by forcing a rapid reduction in their availability?

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Benefit #1: Reducing Poverty

Fossil fuels have lifted billions of people out of poverty, reducing all the negative effects of poverty on human health.

Fossil fuels have raised the standard of living and helped elevate billions of persons out of poverty. In the words of distinguished historian Vaclav Smil (2005), "The most fundamental attribute of modern society is simply this: Ours is a high energy civilization based largely on combustion of fossil fuels."

PRIOR TO THE DISCOVERY OF FOSSIL FUELS, HUMANS EXPENDED NEARLY AS MUCH ENERGY PRODUCING FOOD AND FINDING FUEL TO WARM THEIR DWELLINGS AS THEIR PRIMITIVE TECHNOLOGIES WERE ABLE TO PRODUCE.

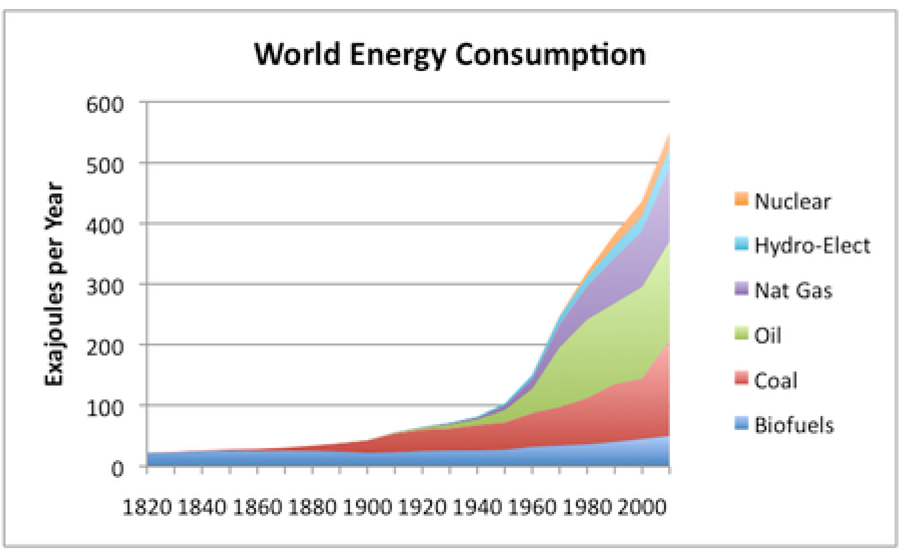
Prior to the discovery of fossil fuels, humans expended nearly as much energy (calories) producing food and finding fuel (primarily wood and dung) to warm their dwellings as their primitive technologies were able to produce. Back-breaking work to provide bare necessities was required from sun-up to sun-down, leaving little time for any other activity. The result was a vicious cycle in which the demands of the immediate present prevented the investment of the time and capital needed to think about and discover ways to improve productivity (Simon, 1981; Bradley and Fulmer, 2004; Epstein, 2014).

According to Indur Goklany, a contributor to the reports of the Intergovernmental Panel on Climate Change, "For most of its existence, mankind's well-being was dictated by disease, the elements and other natural factors, and the occasional conflict. Virtually everything required – food, fuel, clothing, medicine, transport, mechanical power – was the direct or indirect product of living nature" (Goklany, 2012). Generations of farmers and craftsmen used the same tools and worked the same land as their ancestors. Prior to 1820, progress—whether measured by lifespan, population, or per-capita income—was almost nonexistent (Maddison, 2006).

Fossil fuels, chiefly coal, provided the energy that produced nearly all the revolutionary technologies of the Industrial Revolution, as well as today's high-tech manufacturing and mobile computer devices (Gordon, 2012; Ayres and Warr, 2009). "Without cheap supplies of electricity produced from coal, the ongoing revolution in information technology, as well as the age of biotech and nanotech, simply wouldn't be possible," wrote energy journalist and author Robert Bryce (2014, p. 191). Fossil fuels are an energy-dense resource available in enormous quantities that can be mined or drilled and refined into an energy source with wide applications in producing goods and services, heating and cooling living spaces, transporting and storing food and other essential products, and providing light to extend days beyond the rising and setting of the Sun (Kiefer, 2013). Fossil fuels enabled humanity to develop technologies to augment or displace other resources that were in shorter supply or less efficient.

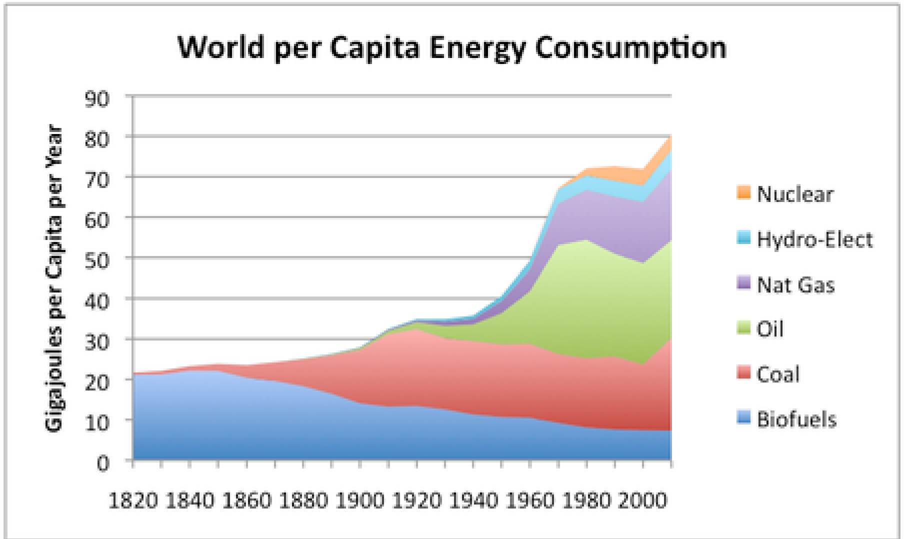
Figure 1 shows the rapid increase in world per-capita annual primary energy consumption by type of fuel since 1850. Almost all the growth (89 percent) has resulted from increased fossil-fuel utilization (the increased use of hydropower, dams, has offset decreased use of wood). Figure 2 demonstrates how this increased use of fossil fuels correlates with the growth of world population.

Figure 1. World energy consumption by source.



Note: based on estimates from Vaclav Smil, *Energy Transitions: History, Requirements and Prospects*, Praeger, 2010, together with BP Statistical Data for 1965 and subsequent.
Source: Gail Tverberg, https://ourfiniteworld. com/2012/03/12/world-energy-consumption-since-1820-in-charts/.

Figure 2. Per capita world energy consumption.



Note: calculated by dividing world energy consumption shown in Figure 1 by population estimates, based on Angus Maddison data.
Sources: Angus Maddison, https://www.rug.nl/ggdc/historicaldevelopment/maddison/; and Gail Tverberg, https://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/.

From these two figures, four findings are apparent: Over the period 1850–2010, (a) world population increased 5.5-fold; (b) total world energy consumption increased nearly 50-fold; (c) world per-capita energy consumption increased nearly 9-fold; and (d) nearly all the world's increase in energy consumption was met by fossil fuels.

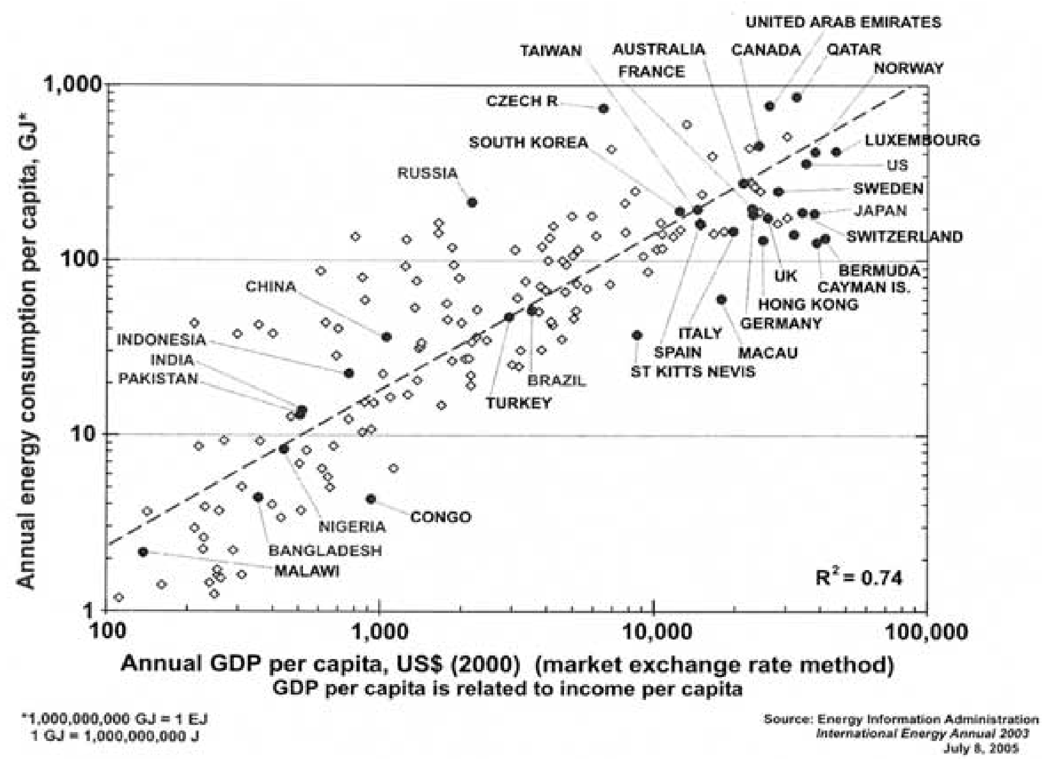
Figure 3 shows the global relationship between per-capita annual energy consumption and per-capita gross domestic product (GDP) continues today.

Virtually all economists agree there is a negative relationship between energy price increases and economic activity. Here is a sample of recent expert opinion:

- "The rather standard assumption that economic growth is independent of energy availability must be discarded absolutely. It is not tenable. It implies, wrongly, that energy-related emissions (GHGs) can be reduced or eliminated without consequences for growth" (Ayres *et al*., 2013).

- "The bottom line is that an enormous increase in energy supply will be required to meet the demands of projected population growth and lift the developing world out of poverty without jeopardizing current standards of living in the most developed countries" (Brown *et al*., 2011).

Figure 3. Per-capita GDP and per-capita energy consumption.



Source: Manheimer, 2012. The author says "Chart compiled by D. Lightfoot from information available from Energy Information Agency (EIA); see also www.mcgill.ca/ gec3/gec3members/ lightfoot]."

- "The theoretical and empirical evidence indicates that energy use and output are tightly coupled, with energy availability playing a key role in enabling growth. Energy is important for growth because production is a function of capital, labor, and energy, not just the former two or just the latter as mainstream growth models or some biophysical production models taken literally would indicate" (Stern, 2010).

- "Economic growth in the past has been driven primarily not by 'technological progress' in some general and undefined sense, but specifically by the availability of ever cheaper energy – and useful work – from coal, petroleum, or gas" (Ayres and Warr, 2009).

According to energy economist Roger Bezdek, the best available research suggests a 10 percent increase in the price of electricity in the United States results in a loss of approximately 1.3 percent of GDP, about $233 billion in 2015 dollars (Bezdek, 2014).

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Benefit #2: Improving Human Well-Being and Safety

Fossil fuels have vastly improved human well-being and safety by powering labor-saving and life-protecting technologies, such as air conditioning, modern medicine, and cars and trucks.

While it is popular to claim that prosperity fuels resource depletion and environmental destruction (e.g., Heinberg, 2007; Klare, 2012), data show the opposite has been true. As Ronald Bailey wrote, "It is in rich democratic capitalist countries that the air and water are becoming cleaner, forests are expanding, food is abundant, education is universal, and women's rights respected. Whatever slows down economic growth also slows down environmental improvement. By vastly increasing knowledge and pursuing technological progress, past generations met their needs and vastly increased the ability of our generation to meet our needs" (Bailey, 2015, p. 72).

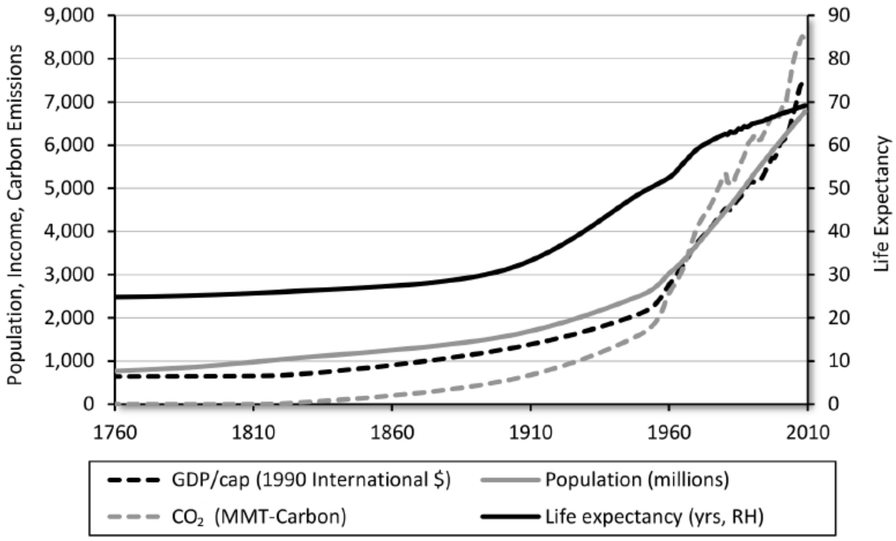
Similarly, Robert Bryce wrote, "The pessimistic worldview ignores an undeniable truth: more people are living longer, healthier, freer, more peaceful, lives than at any time in human history. … The plain reality is that things are getting better, a lot better, for tens of millions of people all around the world. Dozens of factors can be cited for the improving conditions of humankind. But the simplest explanation is that innovation is allowing us to do more with less. We care continually making things and processes Smaller Faster Lighter Denser Cheaper" (Bryce, 2014, p. xxi-xxii).

Bryce goes on to write, "The energy sector is by far the world's biggest industry, and every sector of the global economy depends directly or indirectly on it. The availability of cheap, abundant, reliable energy is what separates the wealthy from the poor and fuels economic growth. That growth fosters both human liberty and environmental protection. As we go forward, we will need to make energy Cheaper so that more people can join the modern world. We will need more natural gas and more nuclear energy, more oil and solar energy, and yes, more coal" (*Ibid.*, p. xxv).

The economic growth that depends on fossil fuels is responsible for the almost incredible improvements made and still being made in the United States and around the world in human well-being and safety.

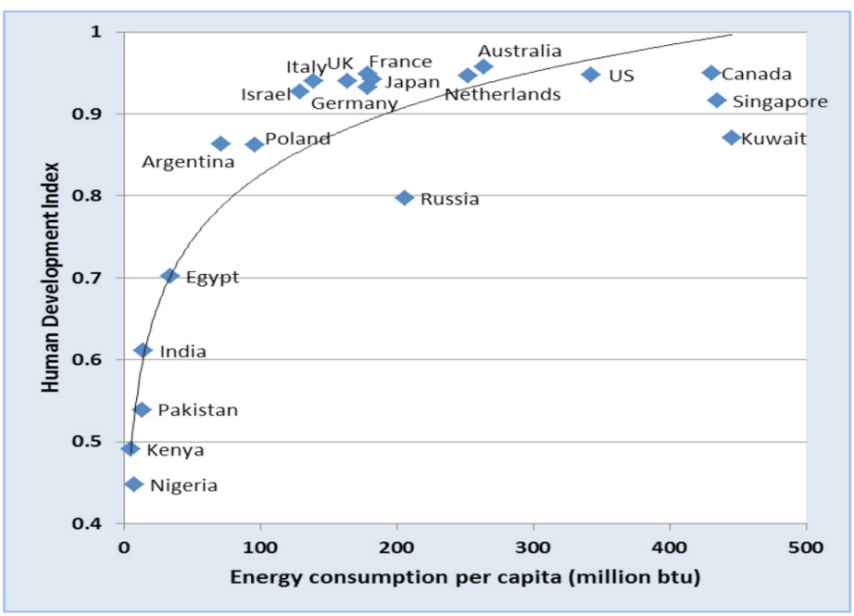
The economic growth that depends on fossil fuels is responsible for the almost incredible improvements made *and still being made* in the United States and around the world in human well-being and safety. Figure 4 plots the close correlation of carbon dioxide emissions, a way to measure the use of fossil fuels, with world population, per-capital GDP, and life expectancy. Figure 5 shows the close correlation between energy consumption and the United Nations' Human Development Index—a measure that includes per-capita GDP, consumption expenditure, urbanization rate, life-expectancy at birth, and the adult literacy rate. Both graphs show how access to affordable energy increases health, well-being, and longevity today.

Figure 4. Global progress, as indicated by trends in world population, per-capita GDP, life expectancy, and CO2 emissions from fossil fuels, over the period 1760 to 2009.



Source: Goklany, 2012.

Figure 5. United Nations Human Development Index and per-capita energy consumption.



Source: Šlaus and Jacobs (2011), using data from U.N. Development Program, Human Development Report, 2010 and U.S. Energy Information Administration, International Total Primary Energy Consumption and Energy Intensity.

Without cheap and reliable fossil fuels, there would be less food, no indoor plumbing, no air conditioning, no labor-saving home appliances such as washing machines, few hospitals, and no ambulances to take us to a hospital when we need urgent medical care. Fossil fuels transformed transportation, vastly increasing human mobility with positive effects on housing, working conditions, health care, education, and much more (Lomasky, 1997; O'Toole, 2001).

> As the United States grew richer, thanks to fossil fuels, the incidence of nearly every disease fell dramatically.

As the United States grew richer, thanks to fossil fuels, the incidence of nearly every disease fell dramatically. As Moore and Simon wrote, "Before 1900, major killers included such infectious diseases as tuberculosis, smallpox, diphtheria, polio, influenza, and bronchitis. Just three infectious diseases – tuberculosis, pneumonia, and diarrhea [sic] – accounted for almost half of all deaths in 1900. Now few Americans die from these diseases, and many diseases have been completely eradicated due to a medley of modern medicines" (Moore and Simon, 2000, p. 34).

Fossil fuels gave rise to electricity, widely regarded as the most important technological innovation in the history of mankind (Constable and Somerville, 2003; National Academy of Engineering, 2000; Fallows, 2013). Starting with the telegraph and telephone and then safe and efficient lighting, electrification revolutionized virtually every aspect of human life, making the Modern Age possible (Platt, 1991; Nye, 1992; Smil, 1994 and 2005; Jonnes, 2003).

Electricity from existing fossil-fuel resources is considerably less expensive than electricity from new alternative energies, especially when the costs imposed on conventional power generation by intermittent non-dispatchable renewable fuels are taken into account. Electricity from new wind capacity costs nearly three times as much as existing coal generation and 2.3 times as much as combined-cycle gas (Stacey and Taylor, 2015). Due to their intermittency and large surface-area requirements, wind and solar energy cannot replace more than a fraction—probably less than one-fifth—of the energy produced today by fossil fuels.

The high cost and limited supply of alternatives to fossil fuels means a forced transition from affordable fossil fuels to alternative energies would be costly, measured as hundreds of billions of dollars of GDP and hundreds of thousands of jobs annually. Fossil fuels deliver economic benefits to residents of the United States amounting to $1.275 trillion to $1.76 trillion per year in added GDP and 6.8 million jobs (Rose and Wei, 2006). Globally, displacing fossil fuels with alternative fuels such as solar and wind could cause global per-capita GDP to decline by 42 percent by 2050, some $137.5 trillion in 2015 dollars (Tverberg, 2012).

Programs and policies that would increase electricity prices—in a state, nation, or globally—compared to what they would be otherwise would have large adverse effects on the economy and jobs. Econometric analyses of time-series data have measured the relationship between changes in the economy and changes in health outcomes, and studies have determined declines in real income per capita and increases in unemployment led to elevated mortality rates over a subsequent period of six years (Brenner, 2005).

The U.S. Environmental Protection Agency (EPA) has acknowledged, "People's wealth and health status, as measured by mortality, morbidity, and other metrics, are positively correlated. Hence, those who bear a regulation's compliance costs may also suffer a decline in their health status, and if the costs are large enough, these increased risks might be greater than the direct risk-reduction benefits of the regulation" (EPA, 1995). The U.S. Office of Management and Budget, the Food and Drug Administration, and the Occupational Safety and Health Administration use methodologies similar to EPA's to assess the degree to which their regulations induce premature death among those who bear the costs of federal mandates (OMB Circular A-4, 1993).

The data make clear the dramatic increase in human prosperity made possible by the use of fossil fuels is responsible for major improvements in human health in the United States and globally.

The data make clear the dramatic increase in human prosperity made possible by the use of fossil fuels is responsible for major improvements in human health in the United States and globally. Those benefits would be lost if fossil fuel use were curtailed.

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Benefit #3: Improved Food Supplies

Fossil fuels have dramatically increased the quantity of food humans produce and improved the reliability of the food supply, directly benefiting human health.

Fossil fuels have revolutionized agriculture throughout the world, making it possible for an ever-smaller part of the population to raise food sufficient to feed a growing global population without devastating nature or polluting air or water. Historian Harold Platt wrote,

> The application of massive amounts of energy to every step in the commercial food chain was chiefly responsible for the revolution in what Americans ate. The war brought recent innovations to the manufacture of artificial fertilizers to technological maturity, helped ice makers kill off the natural ice business, turned shoppers toward the new cash-and-carry supermarkets, and made processed foods socially acceptable among the middle classes. During the 1920s, the food industry made intensive use of heat and refrigeration to offer a wider variety of better-tasting canned and baked goods as well as fresh fruits, dairy products, vegetables, and meats year round. 'Foods formerly limited to the well-to-do,' Hoover's economic experts noted in 1929, 'have come more and more within the reach of the masses' (Platt, 1991, p. 221).

GASOLINE-POWERED TRACTORS SIMILARLY TRANSFORMED AGRICULTURE WITH LIFE-SAVING CONSEQUENCES.

Gasoline-powered tractors similarly transformed agriculture with life-saving consequences. The gasoline-powered tractor was invented in 1892, and farmers swiftly began replacing their horses and mules with the new technology. By the start of the twenty-first century, U.S. farmers were using some five million tractors (McKnight and Meyers, 2007, p. 12, citing Dimitri *et al.*, 2005). Thanks in large part to productivity gains made possible by tractors and increasingly specialized gasoline-powered vehicles available today, the percentage of the U.S. working population engaged in agriculture fell from about 80–90 percent in 1800 to just 1.5 percent in 2010 (Goklany, 2012, p. 19). Other developed countries witnessed the same trend.

One of the greatest achievements in human history was the discovery of a way to make ammonia from natural gas, thereby enabling farmers to add it to their soil and dramatically increase crop yields. The discovery was made in 1909 by Fritz Haber, and the process is now known as the Haber-Bosch process. In 2014, American farmers applied 19 million tons of man-made ammonia-based fertilizer to their fields (USDA, 2018), helping to make possible the enormous increases in yields necessary to reduce to virtually zero the need to convert wildlife habitat into cropland.

Without this fertilizer, the global Green Revolution would not have been possible. Goklany found artificial fertilizer and other applications of technologies, virtually all of them powered by or derived from fossil fuels, reduced the impact of population and affluence on the amount of cropland used in 2006, relative to 1910, by 95 percent (Goklany, 2009). In other words, advances in technology alone erased all but 5 percent of the effect of population growth and increased affluence. Farmers in the United States were able to feed a growing and increasingly affluent population without substantially increasing land use.

Fossil fuels enable the world's farmers to increase their production of food at a faster rate than population growth, resulting in less hunger and starvation worldwide. In 2015, the Food and Agriculture Organization of the United Nations (FAO) reported "the number of hungry people in the world has dropped to 795 million – 216 million fewer than in 1990–92 – or around one person out of every nine" (FAO, 2015). In developing countries, undernourishment (having insufficient food to live an active and healthy life) fell from 23.3 percent 25 years earlier to 12.9 percent. A majority of the 129 countries monitored by FAO reduced under-nourishment by half or more since 1996 (*Ibid*.).

> FOSSIL FUELS ENABLE THE WORLD'S FARMERS TO INCREASE THEIR PRODUCTION OF FOOD AT A FASTER RATE THAN POPULATION GROWTH, RESULTING IN LESS HUNGER AND STARVATION WORLDWIDE.

Claims that global warming will reduce global food output are frequently made (e.g., Challinor *et al.*, 2014), but these forecasts invariably are based on computer models not validated by real-world data. Crop yields have continued to rise globally despite predictions and claims of higher temperatures, more droughts, etc.—in part because those claims of observable changes in temperature and precipitation are not validated by on-location measurements and also because biological science conclusively shows plants thrive in a warmer world with higher-than-current levels of carbon dioxide.

Carbon dioxide is a potent plant fertilizer. Since atmospheric CO2 is the basic "food" of essentially all terrestrial plants, the more of it there is in the air, the bigger and better they grow. A nominal doubling of the air's CO2 concentration will raise the productivity of Earth's herbaceous plants by 30–50 percent (Kimball, 1983; Idso and Idso, 1994), while the productivity of its woody plants will rise by 50–80 percent (Saxe *et al.,* 1998; Idso and Kimball, 2001).

The economic value of CO2 fertilization of crops over the period 1961–2011 is estimated to be $3.2 trillion, and the benefit over the period 2012–2050 is forecast to be $9.8 trillion (Idso, 2013). The benefits of CO2 fertilization are so great they exceed the entire "social cost of carbon" claimed by the Obama-era EPA. And even these estimates do not include the benefits realized by the timber industry, outdoor recreation, and other industries that benefit from the general greening of the Earth.

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Benefit #4: Greening of the Earth

Fossil-fuel emissions are contributing to a "Greening of the Earth," benefiting all the plants and wildlife on the planet.

As noted previously, atmospheric carbon dioxide is the basic "food" of essentially all terrestrial plants. Since the inception of the Industrial Revolution, it can be calculated on the basis of the work of Mayeux *et al*. (1997) and Idso and Idso (2000) the 120-ppm increase in atmospheric CO2 concentration that has been caused by the historical burning of fossil fuels has likely increased agricultural production per unit land area by 70 percent for C_3 cereals, 28 percent for C_4 cereals, 33 percent for fruits and melons, 62 percent for legumes, 67 percent for root and tuber crops, and 51 percent for vegetables.

Long-term studies confirm the findings of shorter-term experiments, demonstrating numerous growth-enhancing, water-conserving, and stress-alleviating effects of elevated atmospheric CO2 on plants growing in both terrestrial and aquatic ecosystems (Idso and Idso, 1994; Ainsworth and Long, 2005; Bunce, 2005, 2012, 2013, 2014, 2016; Bourgault *et al.,* 2017; Sanz-Sáez *et al*., 2017; Sultana *et al*., 2017). Thus, it should come as no surprise the ongoing rise in the air's CO2 content is causing a great Greening of the Earth.

Zhu *et al*., in an article in *Nature Climate Change* titled "Greening of the Earth and its drivers," reported, "We show a persistent and widespread increase of growing season integrated LAI (greening) [from 1982 to 2009] over 25% to 50% of the global vegetated area, whereas less than 4% of the globe shows decreasing LAI (browning). Factorial simulations with multiple global ecosystem models suggest that CO2 fertilization effects explain 70% of the observed greening trend, followed by nitrogen deposition (9%), climate change (8%) and land cover change (LCC) (4%)."

Similarly, Campbell *et al.* found "growth in terrestrial gross primary production (GPP)—the amount of carbon dioxide that is 'fixed' into organic material through the photosynthesis of land plants," grew 31%±5% during the twentieth century (Campbell *et al.,* 2017). Cheng *et al.* found GPP increased by 0.83 ± 0.26 Pg C per year from 1982 to 2011 (Cheng *et al.,* 2017).

At locations across the planet, the historical increase in the atmosphere's CO2 concentration has stimulated vegetative productivity. As the air's CO2 content continues to rise, so too will the land use efficiency of the planet rise right along with it. Atmospheric CO2 enrichment typically increases plant nutrient use efficiency and plant water use efficiency. Aerial CO2 fertilization means we will need less land to raise the food we need, giving wildlife the space it needs to live. Preventing the extinction of untold numbers of unique and irreplaceable plants and animals has got to rank close to the top of all the environmental benefits of fossil fuels.

> THE PROSPERITY MADE POSSIBLE BY FOSSIL FUELS ALSO CONTRIBUTES TO THE GREENING OF EARTH.

The prosperity made possible by fossil fuels also contributes to the Greening of Earth. In a classic study by Grossman and Krueger (1995), ambient air quality was shown to deteriorate until average per-capita income reached about $6,000 to $8,000 per year (in 1985 dollars) and then began to sharply improve. Later research confirmed similar relationships, called an Environmental Kuznets Curve (EKC), for a wide range of countries and air quality, water quality, and other measures of environmental protection (Simon and Kahn, 1984; Simon, 1995; Goklany, 2007; Yandle, Vijayaraghavan, and Bhattarai, 2002). See Figure 5 for a schematic of a typical EKC.

Figure 5. A typical Environmental Kuznets Curve (EKC).

Source: Ho and Wang, 2015, p. 42.

Developed countries and even many developing countries are on the downward slope of the right side of EKCs measuring most potential threats to human health. Fossil fuels are responsible for some of the pollution that accompanies economic development in its early stages, but over time they lead to change in values and the creation of wealth that enable societies to invest in environmental protection, and this in turn produces human health benefits. For example, between 1970 and 2010, U.S. emissions of six air pollutants declined by 63 percent, and over the past decade, human exposure to toxic chemicals at Superfund sites declined by more than 50 percent (Simmons, 2012).

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Benefit #5: Lower Mortality Rates

If fossil fuels are responsible for some amount of global warming, then they should be credited with saving lives by reducing deaths due to cold weather. Weather is also less extreme in a warmer world, resulting in fewer injuries and deaths due to extreme weather.

Carbon dioxide is invisible, odorless, nontoxic, and does not seriously affect human health until the CO2 content of the air reaches approximately 15,000 ppm, more than 37 times greater than the current concentration of atmospheric CO2 (Luft *et al.*, 1974). There is no reason to be concerned about any *direct* adverse human health consequences of the ongoing rise in the air's CO2 content now or in the future, as even extreme model projections do not indicate anthropogenic activities will raise the air's CO2 concentration above 1,000–2,000 ppm.

> THERE IS NO REASON TO BE CONCERNED ABOUT ANY DIRECT ADVERSE HUMAN HEALTH CONSEQUENCES OF THE ONGOING RISE IN THE AIR'S CO_2 CONTENT.

The medical literature shows warmer temperatures and a smaller difference between daily high and low temperatures, which occurred during the late-twentieth and early twenty-first centuries, *reduce mortality rates* as well as illness and mortality due to cardiovascular and respiratory disease and stroke occurrence. Similarly, the available research shows climate has exerted only a minimal influence on recent trends in vector-borne diseases such as malaria, dengue fever, and tick-borne diseases.

Keatinge and Donaldson (2001) explain "cold causes mortality mainly from arterial thrombosis and respiratory disease, attributable in turn to cold-induced hemoconcentration and hypertension [in the first case] and respiratory infections [in the second case]." McGregor (2005) notes "anomalous cold stress can increase blood viscosity and blood pressure due to the activation of the sympathetic nervous system which accelerates the heart rate and increases vascular resistance," adding, "anomalously cold winters may also increase other risk factors for heart disease such as blood clotting or fibrinogen concentration, red blood cell count per volume and plasma cholesterol."

Wang *et al*. (2013) write "a large change in temperature within one day may cause a sudden change in the heart rate and circulation of elderly people, which all may act to increase the risk of cardiopulmonary and other diseases, even leading to fatal consequences." This is significant for the climate change debate because, as Wang *et al.* also observe, "it has been shown that a rise of the minimum temperature has occurred at a rate three times that of the maximum temperature during the twentieth century over most parts of the world, which has led to a decrease of the diurnal temperature range (Karl *et al*., 1984, 1991)."

Robeson (2002) demonstrated, based on a 50-

year study of daily temperatures recorded at more than 1,000 U.S. weather stations, temperature variability declines with warming, and at a very substantial rate, so this aspect of a warmer world would lead to a reduction in temperature-related deaths.

Keatinge and Donaldson (2004) report coronary and cerebral thrombosis account for about half of all cold-related deaths, and respiratory diseases account for approximately half of the remaining cold-related deaths. They say cold stress causes an increase in arterial thrombosis "because the blood becomes more concentrated, and so more liable to clot during exposure to cold." As they describe it, "the body's first adjustment to cold stress is to shut down blood flow to the skin to conserve body heat," which "produces an excess of blood in central parts of the body," and to correct for this effect, "salt and water are moved out from the blood into tissue spaces," leaving behind "increased levels of red cells, white cells, platelets and fibrinogen" that lead to increased viscosity of the blood and a greater risk of clotting.

Keatinge and Donaldson report the infections that cause respiratory-related deaths spread more readily in cold weather because people "crowd together in poorly ventilated spaces when it is cold." In addition, they say "breathing of cold air stimulates coughing and running of the nose, and this helps to spread respiratory viruses and bacteria." The "train of events leading to respiratory deaths," they continue, "often starts with a cold or some other minor infection of the upper airways," which "spreads to the bronchi and to the lungs," whereupon "secondary infection often follows and can lead to pneumonia." They also note cold stress "tends to suppress immune responses to infections," and respiratory infections typically "increase the plasma level of fibrinogen, and this contributes to the rise in arterial thrombosis in winter."

Keatinge and Donaldson also note "cold spells are closely associated with sharp increases in mortality rates," and "deaths continue for many days after a cold spell ends." On the other hand, they report "increased deaths during a few days of hot weather are followed by a lower than normal mortality rate," because "many of those dying in the heat are already seriously ill and even without heat stress would have died within the next 2 or 3 weeks."

EXTENSIVE RESEARCH CONDUCTED AROUND THE WORLD CONFIRMS THAT COLD KILLS FAR MORE PEOPLE THAN DOES HEAT.

With respect to the implications of global warming for human mortality, Keatinge and Donaldson state "since heat-related deaths are generally much fewer than cold-related deaths, the overall effect of global warming on health can be expected to be a beneficial one." They report "the rise in temperature of 3.6°F expected over the next 50 years would increase heat-related deaths in Britain by about 2,000 but reduce cold-related deaths by about 20,000."

Extensive research conducted around the world confirms that cold kills far more people than does heat. This research is expertly reviewed in *Climate Change Reconsidered II: Biological Effects* (Idso, Idso, Carter, and Singer, 2014), produced by the Nongovernmental International Panel on Climate Change and available online at www.climatechangereconsidered.org.

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Conclusion

Fossil fuels have benefited human health by making possible the dramatic increase in human prosperity that has occurred since the first Industrial Revolution, which made possible investments in goods and services that are essential to protecting human health and prolonging human life. Fossil fuels further improve human health by making environmental protection both valued and financially possible, and by powering technologies that protect human health and extend lives, including electricity, cars and trucks, and plastics.

If the combustion of fossil fuels leads to some amount of global warming, then the positive as well as negative health effects of that warming should be included in any cost-benefit analysis of fossil fuels. Medical science explains why colder temperatures often cause diseases and sometimes fatalities whereas warmer temperatures are associated with health benefits. Empirical research confirms that warmer temperatures lead to a net *decrease* in temperature-related mortality in virtually all parts of the world, even those with tropical climates. The evidence of this benefit comes from research conducted in nearly every major country of the world.

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