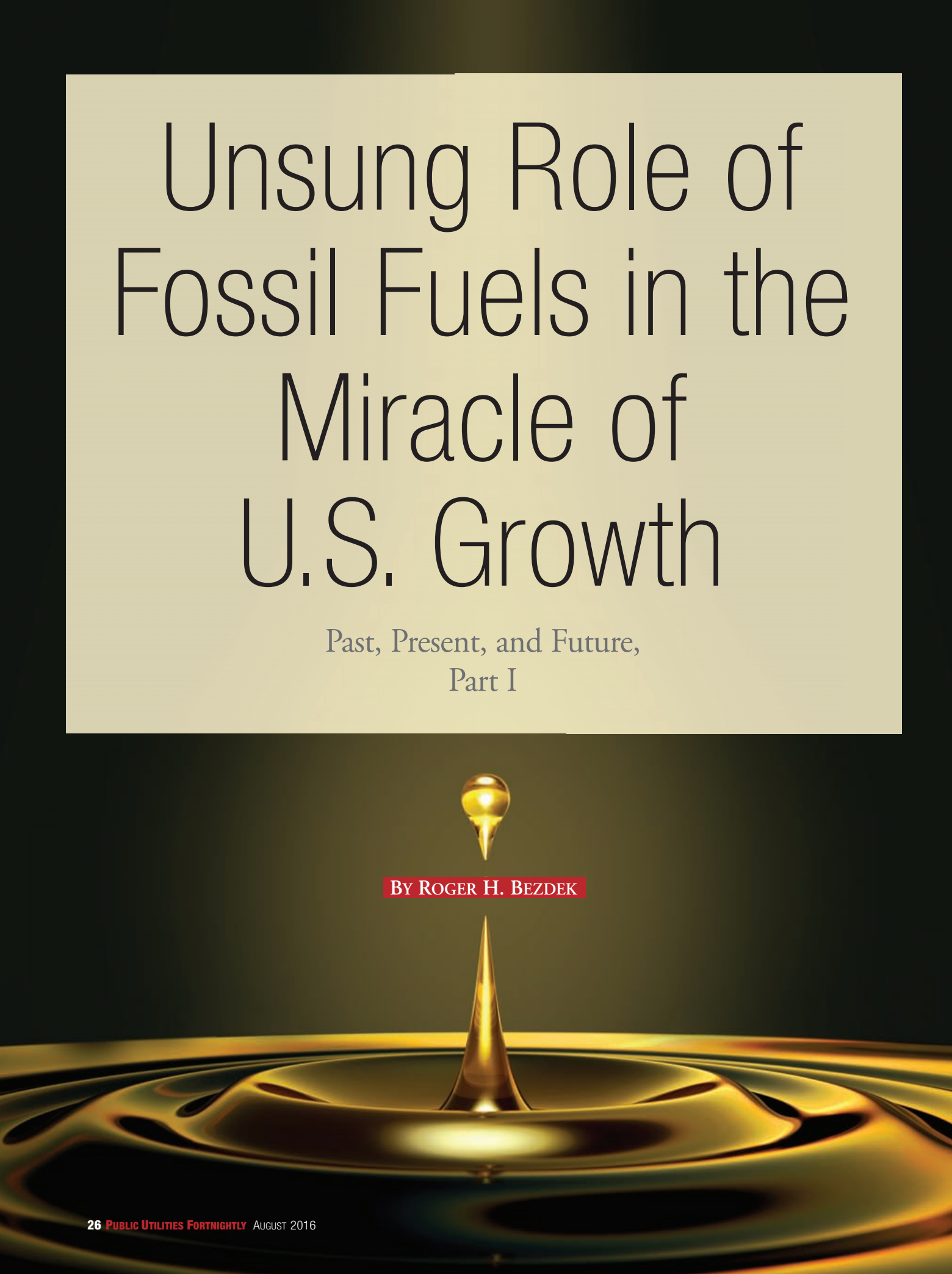
Unsung Role of Fossil Fuels in the Miracle of U.S. Growth

Past, Present, and Future, Part I



By Roger H. Bezdek

The recently published seminal book by Robert Gordon, *The Rise and Fall of American Growth*, has taken the policy establishment by storm and is the most discussed book in Washington, D.C.[1]

Dr. Gordon, who may win the Nobel Prize in Economics, is an eminent economist at Northwestern University outside of Chicago. His thesis is that the incredible technological innovations of the period from 1870 to 1920 were a one-time-in-history event that cannot be replicated.

Innovations such as electricity, telephones, indoor plumbing, air conditioning, cars, airplanes, radio, sanitation, refrigeration, and antibiotics, etc. transformed the U.S. The innovations were responsible for the extraordinary growth in U.S. and world productivity, Gross Domestic Product, and incomes over the past one hundred-fifty years, especially the golden period from 1945 to 1970.

According to Gordon, no other similar period in history has brought comparable progress or, more importantly, is likely to again.

His controversial argument is that U.S. growth has been much slower since 1970 and will continue to be slow in the future. Thus, the U.S. should get used to annual productivity and growth rates of about one percent or less. Instead of nearly three percent. This is a huge difference.

Further, he contends that there is little that the government can do in terms of monetary, fiscal, tax, or other policies to measurably change this.

This is a pessimistic message with profound economic, social, and political implications.

Growth rates in the range of three percent permit rapidly increasing incomes and standards of living. Growth rates of one percent or less imply stagnant incomes and little increase in living standards.

The firestorm of debate Gordon has generated focuses on whether he is correct in saying that the U.S. faces an inevitable future of anemic growth. Or whether techno-optimists who are predicting a bountiful future with robots, artificial intelligence, nanotech, space colonies, and flying cars, etc. are correct.

However, a critical issue is not being discussed. Nowhere in Gordon's entire 762-page book does he give credit to fossil fuels for the economic miracle of the past two centuries.

None of the disruptive revolutionary economic and technological innovations he identifies would have been possible without massive amounts of abundant, reliable, affordable energy. This energy was overwhelmingly generated by fossil fuels, which powered the nineteenth and twentieth centuries.

Dr. Roger Bezdek is an internationally recognized energy analyst and president of MISI, in Washington D.C. He has over thirty years of experience in the energy, utility, environmental, and regulatory areas in private industry, academia, and the federal government. He served as senior adviser in the U.S. Treasury Department, and as U.S. energy delegate to the European Union and the North Atlantic Treaty Organization. He also served as a consultant to the White House, federal and state government agencies, and numerous corporations and research organizations.

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In this article, I focus on the critical historical role that fossil fuels played in creating the technological and economic miracles that Gordon articulates so well. In a subsequent article, I will discuss the necessary critical role that fossil fuels will continue to play in fostering continued technological and economic progress in the twenty-first century.

Three Industrial Revolutions

To be succinct, the successful development and utilization of fossil fuels facilitated successive industrial revolutions, created the modern world, created our advanced technological society, and enabled the high quality of life and standard of living currently taken for granted.

While this may appear to be a self-obvious truism, the centrality of fossil fuels to everything in society can be appreciated from Gordon's work. Although he fails to make the connection.

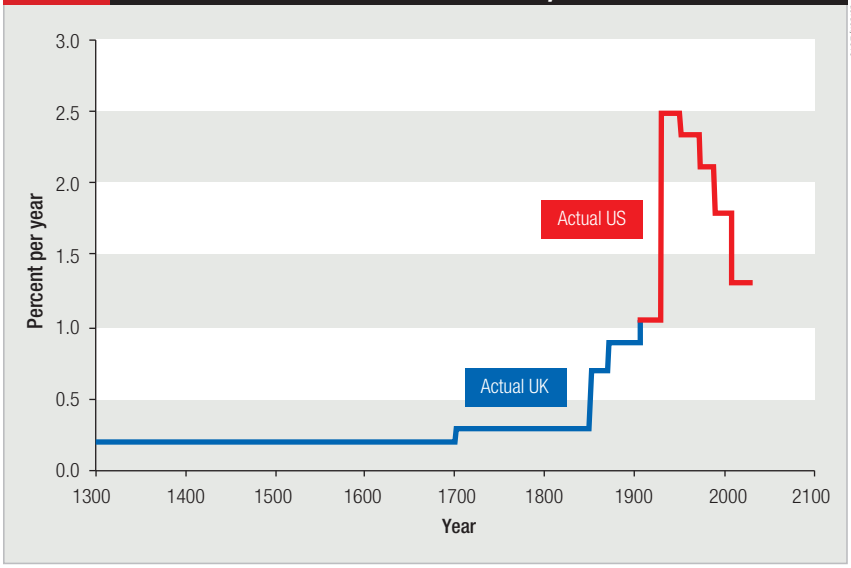
He raises basic questions about the process of economic growth and questions the assumption that economic growth is a continuous process that will persist indefinitely. Gordon notes that there was virtually no growth before 1750, and thus there is no guarantee that growth will continue indefinitely.

Rather, his research suggests that the rapid progress made over the past two centuries could well turn out to be a unique episode in human history. And, ominously, one that may never be repeated.

Of central importance here, Gordon's analysis of past economic growth is anchored by the three industrial revolutions:

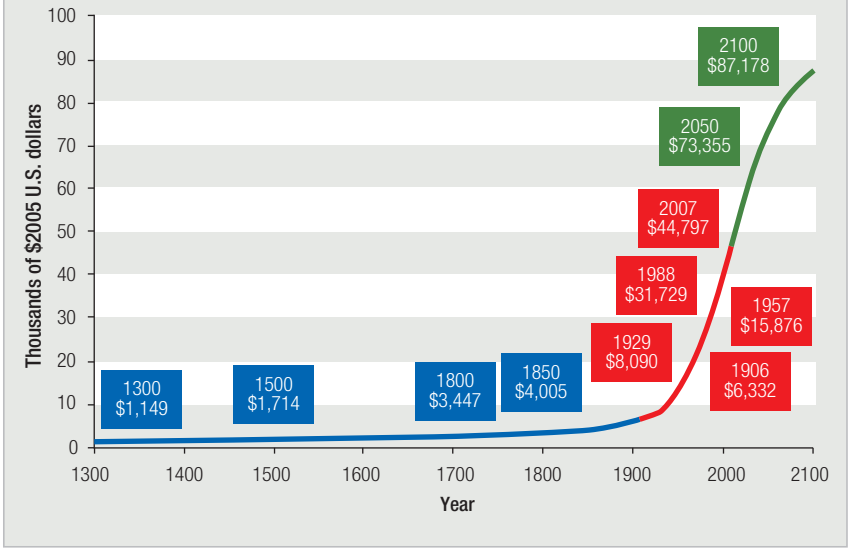
1. The first industrial revolution, IR-1, centered from 1750 to 1830, resulted from the inventions of the steam engine and

FIG. 1 GROWTH IN REAL PER CAPITA GDP, 1300 - 2100



Source: Gordon, 2016

FIG. 2 ACTUAL AND HYPOTHETICAL LEVELS OF GDP PER CAPITA, 1300 - 2100



Source: Gordon, 2016

cotton gin through the early railroads and steamships. Although much of the impact of railroads on the American economy came later, between 1850 and 1900.

2. The second industrial revolution, IR-2, from 1870 to 1900, created the inventions that made the biggest difference in the standard of living: electric light, the internal combustion engine, municipal waterworks and subsidiary and complementary inventions, including elevators, electric machinery and consumer appliances.

It also created the invention of motor vehicles and airplanes, highways, suburbs, supermarkets, sanitation, television, air conditioning, and the interstate highway system.

3. The third revolution, IR-3, is associated with the invention of the web and Internet around 1995.[2]

Gordon's analysis links periods of slow growth and rapid growth to the timing of the three industrial revolutions:

- IR-1 brought steam and railroads from 1750 to 1830.
- IR-2 brought electricity, the internal combustion engine, running water, indoor toilets, communications, entertainment, chemicals, and petroleum from 1870 to 1900.
- IR-3 brought computers, the web, mobile phones, and social media from 1960 to the present. As noted, he finds that IR-2 was more important than the others and was largely responsible for eighty years of relatively rapid productivity growth between 1890 and 1972.

Once the spin-off inventions from IR-2 such as airplanes, air conditioning, and interstate highways had matured, productivity growth during 1972 to 1996 was much slower than before.

In contrast, IR-3 created only a short-lived growth revival between 1996 and 2004. Many of the original and spin-off inventions of IR-2 could happen only once: urbanization, transportation speed,[3] the freedom of females from the drudgery of carrying tons of water per year, and the role of central heating and air conditioning in achieving a year-round constant temperature.

A useful organizing principle to understand the pace of growth since 1750 is the sequence of the three industrial revolutions.

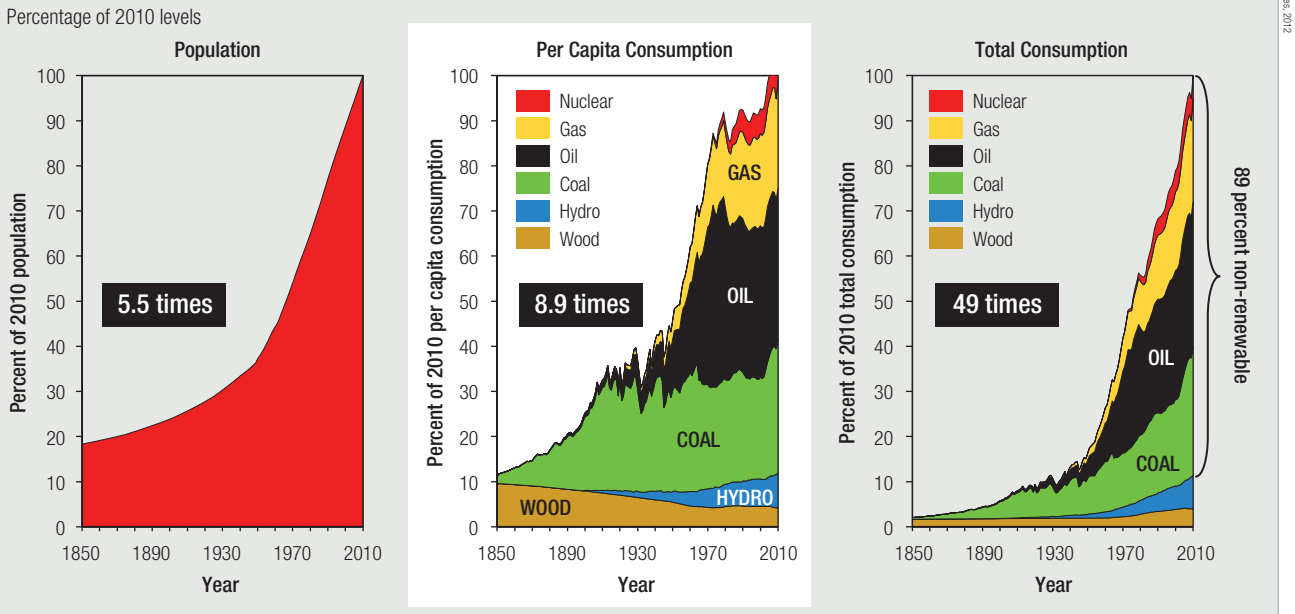
The first, IR-1, with its main inventions between 1750 and 1830 created steam engines, cotton spinning, and railroads. The second, IR-2, was the most important, with its three central inventions of electricity, the internal combustion engine, and running water with indoor plumbing, in the relatively short interval from 1870 to 1900.

Both of the first two revolutions required about one hundred years for their full effects to percolate throughout the economy.

During the two decades from 1950 to 1970, the benefits of the IR-2 were still transforming the economy, including air conditioning, home appliances, and the interstate highway system. After 1970, productivity growth slowed markedly. This is most plausibly because the main ideas of IR-2 had by and large been implemented by then.

Importantly, the computer and Internet revolution, IR-3, reached its climax in the dot.com era of the late 1990s. But

FIG. 3 WORLD POPULATION, PER CAPITA AND TOTAL ENERGY CONSUMPTION, 1850-2010



Source: Hughes, 2012

its main impact on productivity has withered away over the past decade.

Many of the inventions that replaced tedious and repetitive clerical labor by computers happened a long time ago, in the 1970s and 1980s.[4]

Gordon developed a graph that links together decades of research by economic historians to provide data on real output per capita through the ages.

Figure 1 displays the record back to the year 1300. It traces the frontier of per-capita real GDP for the leading industrial nation, the U.K. or the U.S.

The blue line represents the U.K. through 1906, approximately the year when the U.S. caught up. The red line represents the U.S. from then through 2007.

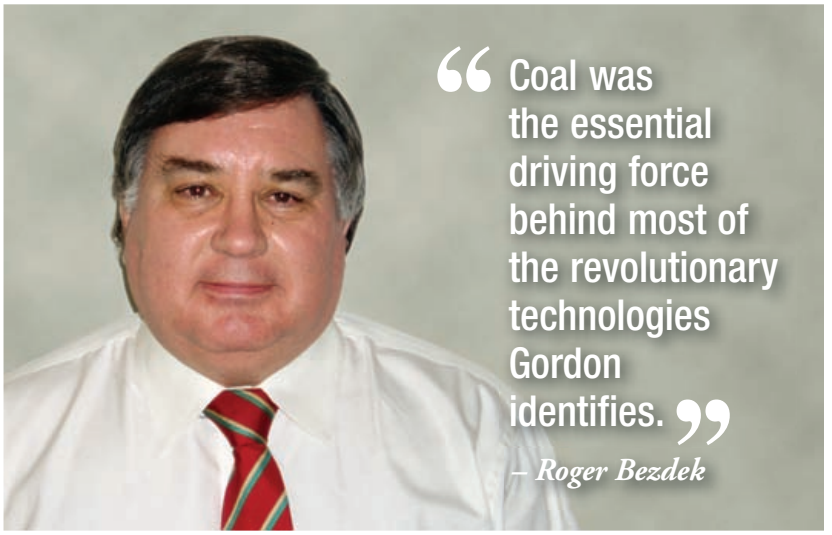
British economic historians estimate that the U.K. grew at about 0.2 percent per year for the four centuries through 1700. The graph shows the striking lack of progress. There was almost no economic growth for four centuries and probably for the previous millennium.

Gordon combined the historical U.K. and U.S. growth records with a forecast and overlaid a curve showing growth steadily increasing to the mid-20th century and then declining to 0.2 percent annually by 2100.

He translated these growth rates into corresponding levels of per-capita income, 2005 dollars, which for the U.S. in 2007 was $44,800. See Figure 2.

The level for the U.K. in 1300 was $1,150, and it took five centuries for that to triple to $3,450 in 1800. And over a century to double to $6,350 in 1906, his transition year from U.K. to U.S. data.

Even with the slowdown in the growth rate after 1970, the forecast level implied in Figure 1 for 2100 is $87,000. It's almost double that of 2007. Gordon's research, as summarized in this figure, is of profound importance for several reasons.

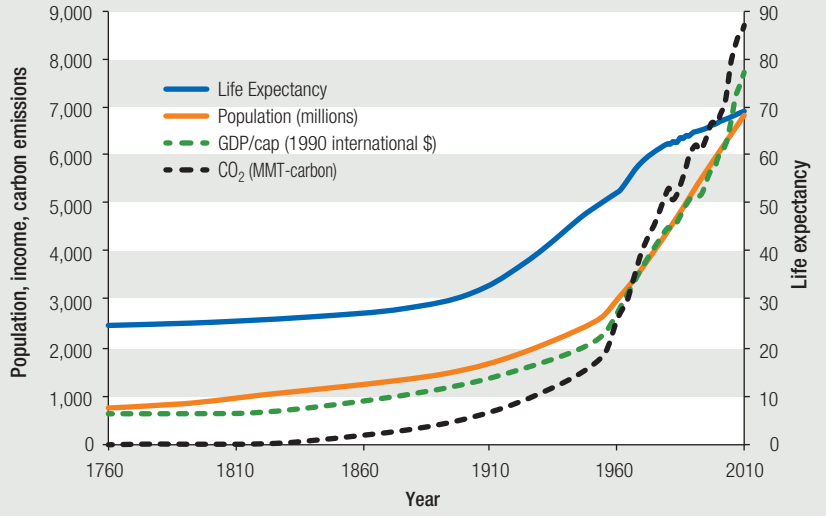


First, it forcefully and poignantly illustrates the critical importance of the industrial revolutions that began in the late 1700s in dramatically improving economic growth rates, productivity, and persons' standards of living and well-being.

Second, and much more controversially, it indicates that the trends of the period from 1800 to about 1975 may have been

FIG. 4 GLOBAL PROGRESS, 1760–2009

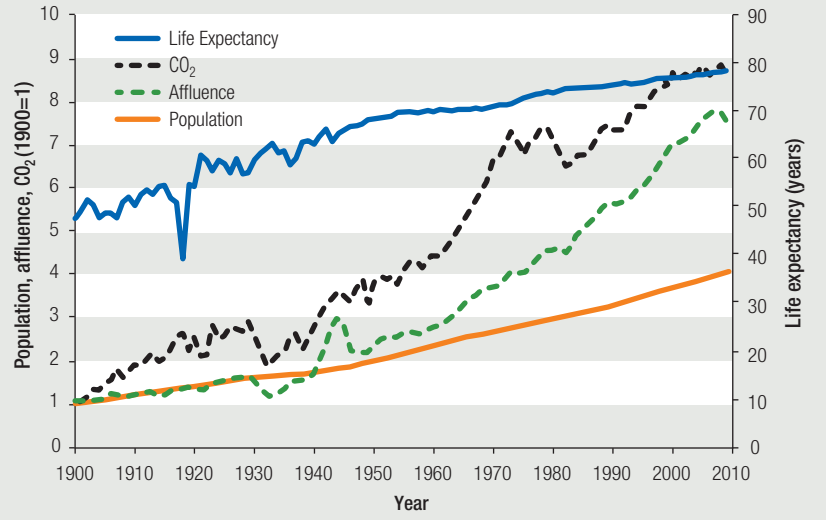
As indicated by trends in world population, GDP per capita, life expectancy, and CO_2 emissions from fossil fuels



Source: Gordon, 2012

FIG. 5 GLOBAL PROGRESS, 1900-2009

U.S. carbon dioxide emissions, population, GDP per capita, and life expectancy at birth, 1900–2009



Source: Gordon, 2012

one-time anomalies. And that prospects for continued productivity and economic growth may be much less favorable than most analysts anticipate.

Essential Historical Role of Fossil Fuels

A major implication of Gordon's work which, unfortunately, he does not recognize, is the key role in all of the Industrial Revolutions played by fossil fuels. Especially the early critical role of coal.[5]

The absolutely essential role of fossil fuels in creating this economic miracle is illustrated in Figure 3.

Between 1850 and 2010, world population increased 5.5-fold. World energy consumption increased 50-fold. Coal consumption increased over 700-fold. World per-capita energy consumption increased 8-fold. Nearly all of the world's increase in energy consumption was comprised of fossil fuels.

Simply stated, without the availability of adequate supplies of abundant, accessible, reliable, and affordable fossil fuels, none of the industrial and economic miracles of the past two centuries would have been possible.

This is an indisputable critical fact. It seems to be insufficiently appreciated, if at all, in the current debates over global warming, the social cost of carbon, wage stagnation, and economic growth.

For example, coal was the essential driving force behind most of the revolutionary technologies Gordon identifies: steam engines, cotton spinning, railroads, electric light, municipal waterworks and subsidiary and complementary inventions, including elevators, electric machinery and consumer appliances; television, air conditioning, and indoor plumbing, etc.

Further, coal and natural gas currently provide much of the world's reliable and inexpensive electricity that powers computers, the web and Internet, social media, mobile devices, high tech manufacturing, and numerous other more recent applications. Similarly, oil provides ninety-five percent of the world's transportation fuels.[6]

It is instructive to compare the growth in per capita GDP shown in Figures 1 and 2 with the increased use of fossil fuels over roughly the same period.

Figure 3 shows the enormous increase in world energy consumption that has taken place over the last two hundred years. This rise in energy consumption is almost entirely from increased fossil fuel use.[7]

It is seen that almost all of the increase, ninety percent, in per capita primary energy consumption resulted from increased fossil fuel utilization. The increased use of hydro offset the decreased use of wood.[8]

Figure 4 shows the growth of world population, per capita energy consumption, and total energy use over the past two centuries.

Comparison of Figures 1 and 2 with Figure 3 forcefully illustrates a central fact. World economic and technological progress over the past two centuries would simply have been impossible without the massive successful use of vast quantities of fossil fuels.

As Indur Gorklany has said, "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, and mechanical power, was the direct or indirect product of living nature."[9]

Subsequently, mankind developed technologies to augment or displace these resources. Food supplies and nutrition improved, and population, living standards, and human well-being advanced.

The Industrial Revolutions discussed above accelerated these trends. Growth became the norm. Population increased rapidly. Productivity and living standards improved dramatically.

Technologies dependent on cheap, abundant, reliable fossil fuels enabled and facilitated these improving trends. Nothing can be made, transported, or used without energy. Fossil fuels provide eighty percent of mankind's energy and sixty percent of its food and clothing.[10]

Key to these developments was that these technologies accelerated the generation of ideas that facilitated even better technologies through, among other things, greater accumulation of human capital, via greater populations, time-expanding illumination, and time-saving machinery. These technologies also accelerated more rapid exchange of ideas and knowledge, via greater and more rapid trade and communications.

As shown in Figure 4, from 1750 to 2009, global life expectancy more than doubled, from twenty-six years to sixty-nine years. Global population increased 8-fold, from 760 million to 6.8 billion. Incomes increased 11-fold, from $640 to $7,300.

Living standards have advanced rapidly over the past two centuries. And, concurrently, as shown in Figure 5, carbon dioxide emissions increased 2,800-fold, from about 3 million metric tons to 8.4 billion metric tons.

Figure 5 illustrates that in the U.S., from 1900 to 2009, population quadrupled. U.S. life expectancy increased from forty-seven to seventy-eight years. Incomes (denoted affluence) grew 7.5-fold. While carbon dioxide emissions increased 8.5-fold.

Thanks largely to the extensive utilization of fossil fuels, again quoting Gorklany, "Americans currently have more creature comforts, they work fewer hours in their lifetimes, their work is physically less demanding, they devote more time to acquiring a better education, they have more options to select a livelihood and live a more fulfilling life, they have greater economic and social freedom, and they have more leisure time and greater ability to enjoy it."

And these trends are evident not just in the U.S. For the most part, they are evident elsewhere as well.

Note that, even with Gordon's pessimistic assumption that economic growth will decrease to 0.2 percent annually by 2100, the green forecast line in Figure 2 rises rapidly. Thus, even modest economic growth will require large increases in energy supplies.

World economic growth over the past two centuries was powered largely by fossil fuels. What energy sources are forecast to power future world economic growth? That is, what energy sources are required to enable the world to continue to increase technology, income, wealth, productivity, and standards of living and lift billions of people out of poverty?

This is the issue that will be addressed in part two of my article, forthcoming in *Public Utilities Fortnightly*. PUF

Endnotes:

1. Robert J. Gordon, *The Rise and Fall of American Growth: The U.S. Standard of Living Since the Civil War,* Princeton University Press, 2016.
2. However, he notes that electronic mainframe computers began to replace routine and repetitive clerical work as early as 1960. His treatment of IR-3 includes examples of the many electronic labor-saving inventions and convenience services that already were widely available before 1995.
3. Gordon notes that the speed of air travel has not increased appreciably since the introduction of commercial jets in the 1960s, whereas the costs have not decreased since about 1990, and the quality has seriously deteriorated.
4. As Gordon notes, "Invention since 2000 has centered on entertainment and communication devices that are smaller, smarter, and more capable, but do not fundamentally change labor productivity or the standard of living in the way that electric light, motor cars, or indoor plumbing changed it."
5. See, for example, Robert U. Ayres and Benjamin Warr, *The Economic Growth Engine: How Energy and Work Drive Material Prosperity*, Northampton, M.A., Edward Elgar, 2009.
6. Roger Bezdek, Robert Hirsch, and Robert Wendling, *The Impending World Energy Mess*, Toronto, Canada, Apogee Prime Press, 2010.
7. Gail Tverberg, "World Energy Consumption Since 1820," Our Finite World, March 12, 2012.
8. J. David Hughes, "The Energy Sustainability Dilemma: Powering the Future in a Finite World," presented at Cornell University, Ithaca, New York, May 2, 2012.
9. Indur M. Goklany, "Humanity Unbound How Fossil Fuels Saved Humanity from Nature and Nature from Humanity," *Policy Analysis*, Number 715, December 20, 2012, pages 1 to 33.
10. Thus, "Absent fossil fuels, global cropland would have to increase by one hundred-fifty percent to meet current food demand, but conversion of habitat to cropland is already the greatest threat to biodiversity. By lowering humanity's reliance on living nature, fossil fuels not only saved humanity from nature's whims, but nature from humanity's demands."