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Coal and Sustainable Science Policy

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Abstract

In 2007, coal accounted for approximately 48%, 80% and 42% of the electricity generated in the U.S., China and the world, respectively. Increasing electricity costs increases the consumer price index, reduces aggregate demand and reduces a country's gross domestic product (GDP). Once a threshold level of development has been exceeded, government capacity for investment in research and development (R&D) increases with increasing GDP. Research intensity has spawned new products, processes and industries, which in turn increase GDP. At present, there is no cost-effective alternative to coal, for the U.S. or most other nations (e.g., China) in which significant reserves exist. Nor will one develop unless there is a sustained investment in the appropriate R&D activities. Low energy costs maximize the opportunity to find alternative energy sources and increase energy efficiency as well as to understand and mitigate anthropogenic climate change. In short, the current and foreseeable future of a sustainable science policy depends on coal.

Keywords: energy; coal; science policy

1. Introduction

The earth's climate is influenced by natural and anthropogenic factors. The precise fraction by which human activities affect climate change is unknown; however the Intergovernmental Panel on Climate Change (IPCC) notes that the largest known human contribution comes from the burning of fossil fuels [1]. As such, the future of the energy supply and its ostensible relationship with climate change is a source of increasing anxiety for many in the U.S. and abroad. Conventional wisdom suggests that countries should quickly reduce their use of coal so as to reduce carbon dioxide emissions and possibly mitigate global warming. This is the rationale behind the United Nations Framework Convention on Climate Change as well as U.S. legislative cap and trade proposals such as the Waxman-Markey Bill. These efforts seek to raise the costs of coal combustion so that it becomes less attractive relative to renewable fuel sources. Notwithstanding notions that the price of coal does not fully reflect environmental costs, it remains the most abundant and cheapest fuel from which to generate electricity. As such, coal is expected to be used more than any other fuel source for electricity production, accounting for 42-44% of the total in the U.S. through 2035 [2]. The purpose of this article is to review elements of coal-derived energy and its relationship with sustainable investments into scientific research and development.

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2. Coal-derived energy

The U.S. maintains the largest recoverable coal reserves in the world, with production occurring in 26 states as shown in Fig. 1 [3]. Approximately 53% of the coal was mined in either Wyoming or West Virginia in 2010.

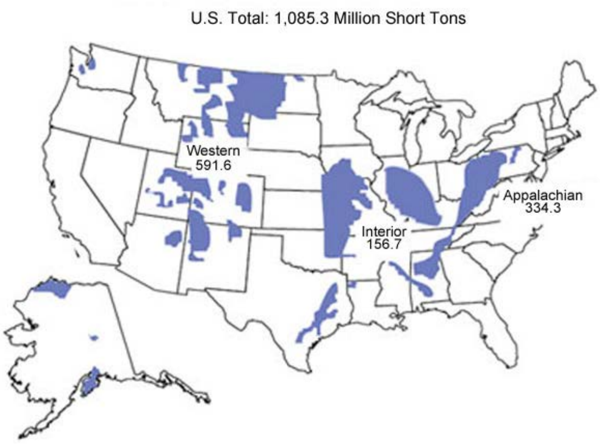

Fig.1 Coal Production by Coal-Producing Region, 2010 Source: U.S. Energy Information Administration [3].

In 2010, coal accounted for 45% of the net electricity generated in the U.S. as shown in Fig 2. [4]. In terms of overall U.S. Energy consumption (i.e., including the transportation sector), coal ranks third (21%) behind petroleum (37%) and natural gas (25%). Coal ranks second (35%) in terms of U.S. energy-related carbon dioxide emissions, behind petroleum (42%), but ahead of natural gas (23%).

Absent legislative intervention, large coal reserves allow for long-term contracts which insulate coal from the volatility associated with oil and natural gas. The costs for coal, residual fuel oil and natural gas as delivered to electric generating plants from 1985-2035 are presented as Fig. 3. Both historical and projected data are from the U.S. Energy Information Administration [2,3]. Power derived from fossil fuels, nuclear energy and hydroelectricity are all able to provide continuous power to serve the base load. While various innovations in battery technology and distribution systems may enable solar and wind power to expand, their current costs are significantly higher, as noted in Fig. 4.

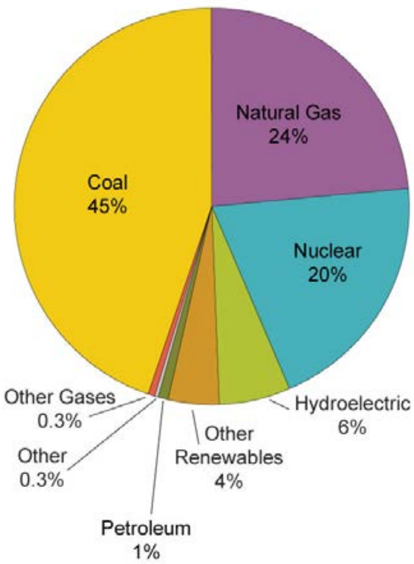

Fig. 2 Net electricity generation by fuel source, 2010 Source: U.S. Energy Information Administration [4].

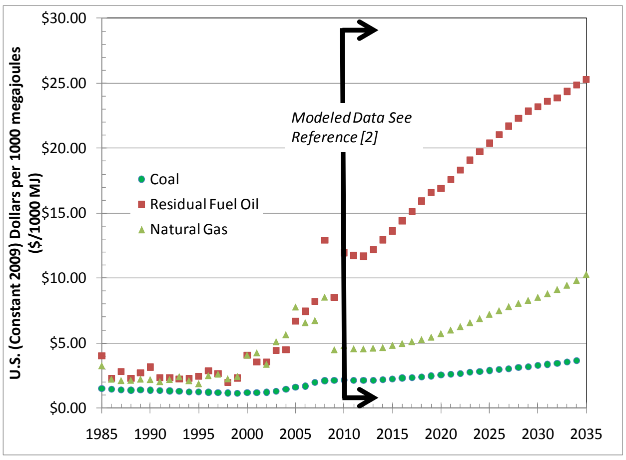

Fig. 3 Cost of fossil fuels receipts at electric generation plants, data from the U.S. Energy Information Administration [2,3]

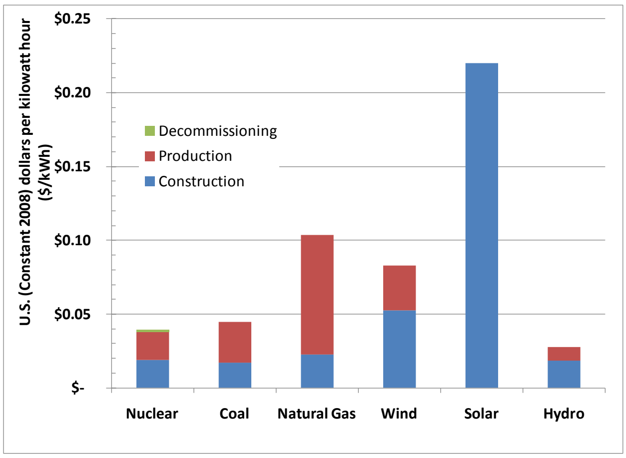

Fig. 4 Fuel source costs for electricity production [5]

3. Energy, Environment and GDP

There are reports that suggest the price of coal does not fully reflect its effect on human health and the environment [6]. Bachmann notes that since 1970, emissions of regulated pollutants have consistently declined, notwithstanding increases in population, economic output and energy consumption [7]. Much of this improvement has been ascribed to regulations. The U.S. EPA estimated that between 1970 and 1990, the Clean Air Act (CAA) legislation of 1970 resulted in a variety of health-related benefits valued in the range of US$ 6-50 trillion dollars. Compliance with this legislation was estimated at US$ 520 billion [8]. During this time the U.S. economy grew from $1,038 to 5,800 billion [9]. Given that many of the compliance costs were amortized over the subsequent decades, we can scale these costs to the growth in economic capacity over the same time period, i.e., $520 billion divided by the change in GDP (5,800 - 1,038). In other words, 10.9% of the growth was spent on compliance. In addition to GDP growth, efficiency gains have allowed the U.S. to invest in environmental compliance costs. For example, the amount of energy required per dollar of GDP decreased 33.8% from 1970 to 1990 [4].

There are a number of issues that emerge from the foregoing discussion. First, the production of goods and services, as defined by the GDP, requires energy. Increases in energy costs can be offset in revenue gains and efficiencies, however there is a limit. This limit becomes more visible during periods of relatively high energy costs. For example, consider a historical plot of GDP versus energy costs during the period from 1973 to 1984, with data drawn from the U.S. Federal Reserve Economic Data [10], as presented in Fig. 5. Note that a rise in the energy component of the Consumer Price Index (CPI) is followed by a reduction in GDP during the three recessions that occurred during that period.

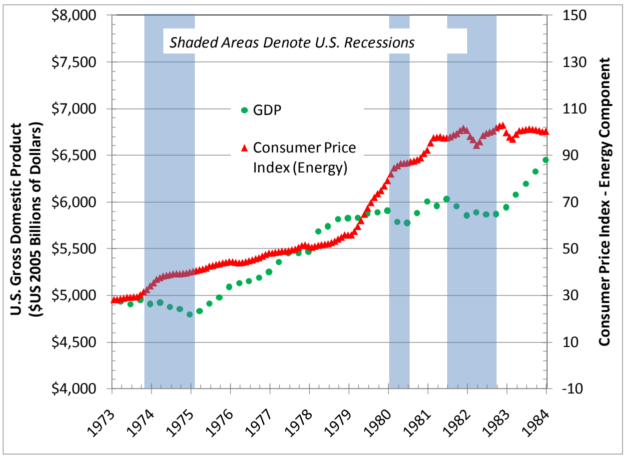

Fig. 5 Historical relationship between GDP and energy costs, data from the U.S. Federal Reserve [10]

As with the original CAA, regulations are often justified, in part, on the basis of modeling which seeks to translate environmental and human health benefits into monetary cost savings. While few would question the existence of such savings, their determination is based on assumptions and correlations that render them far less precise than actual compliance costs. Estimates of the cost of a new electrostatic precipitator are far more accurate than the monetary gain from reducing particulate matter from 10 μm to 2.5 μm, for example. Moreover, the actual costs for compliance with the original CAA were incrementally small enough such that coal remained financially viable as a fuel source in the U.S. market.

Within developed countries, higher energy prices have the greatest effect on the poorest citizens. Bearing such compliance costs would not have been appropriate in the U.S. in the late 19th century when coal replaced wood as the nation's primary source of energy. Likewise, as electrification continues to improve the standard of living throughout the world, it is difficult to argue that developing nations should immediately leap frog to the most expensive technology. As with any budgetary-bound organization, the extent of investment by a country in any given area (e.g., environmental, infrastructure, defense, scientific research) must be scaled appropriately to the available resources. Arbitrarily large expenditures in any one area decreases sustainability and resiliency while increasing vulnerability. A comparison of health and prosperity indicators is provided in Table 1.

Table 1: Indicators of health and prosperity

Country	**Population** **Millions** **[11]**	**Life Expectancy** **years** **[11]**	**Energy Consumption** **Thousands of kt of oil equiv** **[12]**	**GDP** **Billions 2011 US $** **[13]**
China	1,331	73.3	2,116	4,985
India	1,155	64.1	620	1,377
U.S.	308	78.7	2,172	14,119
Brazil	194	72.6	248	1,594
Nigeria	155	48.1	111	173
Germany	82	79.9	318	3,330

4. Research and GDP

The capacity to invest in research and development (R&D) is dependent on a country's GDP. Likewise, many economists have suggested that investments in research lead to advances which, in turn, increase GDP [14]. Solow [15] has estimated that 87.5% of the increase in U.S. economic growth between 1909 and 1949 was a function of technological advances. Likewise, while reflecting on his service as Chair of the committee that wrote the National Academies report *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* [16], Augustine [17] observed that 50-85% of the U.S. growth in GDP in the last half of the 20th century was also "attributable to advancements in science and engineering." The National Academies [16] reviewed a number of studies in which the rate of return on government supported R&D ranged from 20-67%. Similarly the return on investment for private R&D was found to range between 7-43%, with "social rates of return" ranging from 20 to 147% [16]. Absent this growth, the U.S. would remain an under developed country.

In 2008, U.S. government support for R&D was approximately US$ 84.7 billion while private firms invested $240 billion [18]. While increasing in amount, the federal fraction of R&D expenditures has declined in the U.S. since 1975. In 2008, the total ratio of R&D expenditures to GDP was 2.79. In general, this ratio is often taken as an indication of the level of commitment to scientific advancement and likelihood of technologically-driven growth. The European Union has set a target of 3% for its members [19,20]. Fig. 6 provides a plot of this ratio for the U.S. and various other countries.

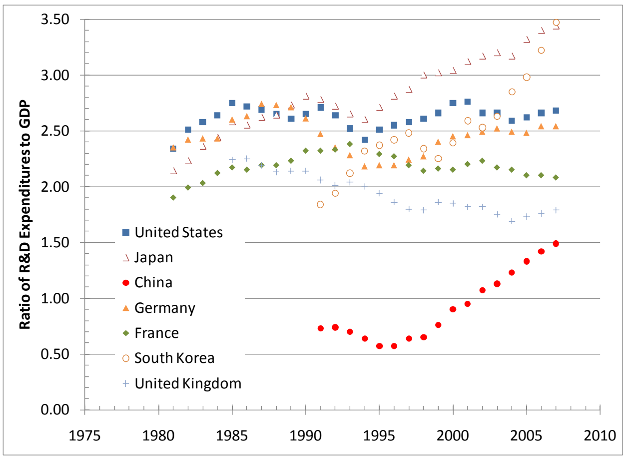

Fig. 6 Historical relationship between R&D and GDP for various countries, data from the U.S. National Science Foundation Federal Reserve [18]

5. Discussion

Holdren [21] summarizes what he calls the energy-economy-environment dilemma. He observes that: "First, reliable and affordable energy is essential for meeting basic human needs and fueling economic growth. Second, the harvesting, transport, processing and conversion of energy using the resources and technologies relied upon today cause a large share of the most difficult and damaging environmental problems society faces." Many of the efforts to address this dilemma focus on the latter while merely tolerating the former. In the case of coal, the key concern is carbon dioxide emissions and their role in accelerating climate change. So the typical approach is to develop regulatory schemes that place a tax on carbon and/or artificially increase the difficulty with which one can investigate new coal reserves, mine existing reserves, build new plants, achieve air emission targets and manage the byproduct materials such as fly ash. Such policies are guided by the notion that making coal more expensive will make renewable sources of energy such as solar and wind more economically competitive. Secondly, there is the implicit premise that innovation and technological advance can be dictated by regulatory fiat. This premise is reinforced by historical anecdotes, such as former U.S. President John F. Kennedy's declaration on May 25, 1961 that by the end of the 1960's, the U.S. would put a man on the moon. And sure enough, this was accomplished on July 20, 1969 by Neil Armstrong. Similarly, there have in fact been steady improvements in analytical technologies and waste treatment processes in response to various promulgations by the U.S. Environmental Protection Agency.

However the ability to put a man on the moon or measure the concentration of a contaminant to part per trillion levels is not a function of law but rather of the antecedent state of science and level of funding available, as well as the creativity and intellect of individual researchers. The level of understanding of rocket science and aerospace engineering prior to the 1960's was such that a viable space program could be developed with a relatively minor fraction of the U.S. GDP. Arbitrarily applying this lesson to other technological challenges is without basis. For example, carbon capture and storage (CCS) may one day be economically deployed for coal combustion on mass scale. However pilot scale efforts suggest this time is well into the future, regardless of funding provided or regulatory consequences. Therefore the result of requiring CCS, taxing carbon and/or artificially making coal more expensive simply increases energy costs. These energy costs propagate through the economy and manifest as reduced GDP and reduced capacity to invest in R&D. At present, there is no cost-effective alternative to coal, for the U.S. or most other nations (e.g., China) in which significant reserves exist. Nor will one develop unless there is a sustained investment in the appropriate R&D activities. Low energy costs maximize the opportunity to find alternative energy sources and increase energy efficiency as well as to understand and mitigate anthropogenic climate change. Indeed, the path to sustainable development is paved in coal.

6. Conclusions

Coal is the primary fuel source for the generation of electricity in the U.S. and much of the world. Its abundance and low cost have enabled the provision of basic human needs and a rising standard of living. Energy costs have a direct effect on a country's GDP, as has been demonstrated in the case of the U.S. Increasing energy costs reduces the GDP and decreases the ability for investments in any other activity, including R&D. Investments in R&D, in turn, lead to advances which improve GDP. Sustained investments in R&D are needed to develop technological advances to meet various challenges, including the primary concern of coal combustion: global warming and climate change.

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