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A theory of ossification of energy services

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ABSTRACT

This paper points out that energy efficiency has been an important driver of economic growth in the past but notes stagnation of efficiency in the electric power sector since 1960. The “ossification” of electric industry efficiency gains trace in part to the industry’s exemption from the anti-trust laws, but also to the unfortunate formulation of pollution regulations. These allows plants to operate forever at whatever emissions were allowed when the plant was built, but force a plant that improves its conversion efficiency to meet latest rules. This severely penalizes the owners of electricity generation plants who would otherwise gain from investments in greater efficiency and in the process cut emissions, by requiring immediate reduction of all “criteria” pollutants to current best available control levels. The added cost of this essentially eliminates any economic incentive to improve efficiency. The paper lists steps that could change this situation and “de-ossify” the industry.

1. Introduction

Increasing access to useful energy has improved standards of living. There is no doubt that the global doubling of fossil fuel use every 30 years since 1850 has powered economic growth, but rising prices are slowing the economy. Moreover, rising carbon dioxide concentrations are warming the globe, causing increased frequency and intensity of storms and threatening devastating feedback effects.

Robert Ayres and Allen Kneese were arguably the first to discuss the massive and unavoidable ‘externalities’ of extracting natural resources from the earth’s crust and producing useful products (including fuels) (Ayres and Kneese, 1969). In 2011, the U.S. National Academy of Sciences and National Academy of Engineering, at the request of the U.S. Congress, quantified some of the externalities of

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producing useful energy, calculating that health and environmental costs of generating a megawatt-hour of coal-fired electricity averaged $32, roughly the cost of the coal to produce that power (National Research Council, 2010). That was a conservative estimate. Other studies indicated even larger health and environmental costs. The analysis did not include costs of global warming. Today, these externality costs are either unpaid or paid indirectly by governments and consumers. However, the externality costs do not show up on electric bills and thus fail to impact economic behavior. The coal companies and coal-based electric power producers are literally getting a "free ride" versus cleaner generation.

Another recent research result concluded that access to useful energy services (i.e. work) explained roughly half of observed GDP growth in the US since 1900 (Ayres and Warr, 2009), and later in four different countries for the last century (Warr et al., 2010). Conventional economic theory continues to treat energy as a negligible factor of production, with an importance (output elasticity) limited to the cost-share of energy in the economy, typically around 5% until recently. The model underlying the "theorem" (that output elasticity must be equal to cost share) is not applicable to the real world, as demonstrated by Kümmel et al. (2010). So, according to standard neo-classical economic theory energy explains only 5% or so of observed growth, whereas Kümmel et al. (2010) and Ayres et al. (2007) have shown that consumption of useful energy as useful work explains a much larger fraction of observed growth. It follows that macro-economic policies all over the world focus too much on labor productivity and not enough on energy (resource) productivity, as argued by von Weizsaecker (this volume).

Scientists have presented comprehensive evidence showing that human induced greenhouse gas emissions are responsible for observed global warming, with increased frequency and intensity of major weather events and drought causing rising damage and rising levels of species extinction (IPCC, 2007; Walker and King, 2009). Despite the evidence, organizations with huge stakes in sales of fossil fuel deny the evidence, question the integrity of the climate research community, and fund campaigns promoting public objection to climate change mitigation policies. Science is under attack.

Of course, the emissions responsible for the climate problem, and others, are consequences of the materials-intensity of the economic system, and – above all – the energy inefficiency of the economy. Ayres was one of the first to identify energy inefficiency as such as a global environmental problem (Ayres et al., 1981; Ayres, 1989). Fig. 1 shows the efficiency of converting the energy in fuel to delivered electricity over the past 105 years, using data from the U.S. Federal Power Agency. Note that only 6% of the potential energy in electric plant fuel arrived at consumers as electricity in 1900. Technology improved. By 1959, the delivered electrical efficiency had increased fivefold to 33% – three units of fuel energy burned to produce one unit of delivered electricity.

A visit to the Smithsonian's Museum of Technology illustrates the efficiency gains of other industries compared with generating and delivering electricity. Start with exhibits on the history of computers. On October 5, 1959, IBM introduced the fully transistorized 1401 computer and went on to rent/sell over 10,000 units. The 1401 came with memory options from 1.4 to 32 kilobytes, leased for about $20,000 per month in today's dollars[1] and represented the apex of computer technology; its use required air conditioned space, white-coated technicians, and card readers. When I visited the exhibit, I caried my personal laptop that cost $1200, has 3 gigabytes of memory (over 90,000 times the largest memory 1401) and operates much faster. This rapid technological progress between 1960 and today has helped increase the production and delivery efficiency of nearly every good or service.

Other Smithsonian exhibits show the steady efficiency gains over the past half century of nearly every technology – motors, refrigerators, engines, gas turbines, refrigerators, light bulbs, photography and photographic images. Every industry but one has racked up continuous improvement in producing more with less – every industry but the production and delivery of electricity.

The production of useful energy services underwent steady progress over centuries, but then progress stopped about 1960. We see almost all production of useful energy from muscles until about 5000 years ago, then introduction of windmills, later waterpower, and in 1770s, commercial conversion of coal into useful energy services with steam engines. Then engineers developed internal combustion engines able to burn oil-based fuels. Parsons developed the first steam turbines in the

[1] http://en.wikipedia.org/wiki/IBM_1401.