Energy Research & Social Science xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

# Economics of energy, big ideas for the non-economist☆

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ARTICLE INFO

*Article history:*
Received 23 January 2014
Received in revised form 10 March 2014
Accepted 10 March 2014

*Keywords:*
Energy markets
Market failures
Big ideas

ABSTRACT

The interdisciplinary nature of energy issues calls for a 'big ideas' approach to both energy teaching and research. To devise a suitable framework, it is necessary to develop simple narratives for relevant disciplines based on big ideas found therein, and to link them to other disciplines.

This paper focuses on energy markets, their successes and failures, and outlines basic remedies for the latter. It suggests that the tension between market forces and market failures is not only a focal point of today's most pressing energy issues, but that it also provides a central geopolitical narrative of the 20th century. The importance of understanding energy policy logic within a broader political context, both domestic and global, is also emphasized.

Finally, the paper illustrates, through examples, that the search for interconnections between energy economics and ideas in the sciences, humanities and other social sciences can only deepen our understanding.



## 1. Introduction

If, as Norbert Weiner said, "Change comes most of all from the unvisited no-man's land between the disciplines", then the interdisciplinary nature of energy calls for a 'big ideas' approach to both energy research and teaching. Many fields inform our understanding of energy. The theoretical and applied sciences underpin the fundamental potentialities of energy and its impacts – beneficial and detrimental, constructive and destructive. Humanities document and elaborate the human consequences of energy. Indeed, the pursuit of energy is a fundamental driver of human history. The social sciences analyze societal aspects. Energy has shaped world economics and politics, and even the social structures within which humans live.

To devise a suitable framework for the interdisciplinary study of energy, it is necessary to develop simple narratives for relevant disciplines based on big ideas found therein. Constructing a narrative of the economics of energy for the non-economist is a daunting task.[2] What are the 'big ideas'? There are many. We will try to content ourselves with focusing on two: markets and their failures.

In devising energy policies, nations worldwide are attempting to balance competing objectives of economic growth, environmental protection and energy security. The instruments vary depending on cultural and historical roots.[3] Economics, and more generally political economy, inform these debates. In this discussion, markets are critical, both economically and politically. But how does one integrate sound (social) science into good (social) policy? There are alternate economic and political approaches to advancing environmental and economic objectives. There are various economic instruments for promoting innovations that can increase energy efficiency, as well as encouraging the search for needed breakthrough technologies (such as carbon sequestration, large scale storage of electricity, or integration of renewable resources).

This paper is organized as follows. Section 2 outlines two 'big ideas' – markets and their failures – illustrates these in the context of energy markets, and describes remedies for market failures. Section 3 demonstrates the power of these ideas, not only in framing discussions of contemporary energy issues, but also in

☆ The author is grateful to Ben Akrigg, Carol A. Dahl, Lester C. Hunt, David M. Newbery, James E. Pesando, James L. Smith, Yanqin Wu and four anonymous referees for helpful comments.

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[2] One only need peruse texts on energy economics, such as Dahl [5] or Bhattacharyya [6].

[3] For example, carbon taxes have been resisted particularly strongly in the United States (think 'Tea Party') while Europeans have been more amenable to higher tax loads. Some leaders have attempted to promote a combined agenda of 'growth and the environment' by seeking to create jobs in renewables industries.

http://dx.doi.org/10.1016/j.erss.2014.03.004
2214-6296/

understanding tidal changes in history. We argue that energy issues are best understood within the broader economic and geopolitical context.

This paper is premised on the idea that a rich understanding of energy requires one to journey into other disciplines.[4] To this end, Section 4 provides several examples to whet the appetite. It illustrates how the Bernoulli Principle (a.k.a. the foil) contributed to globalization; it provides examples of connections between energy economics and literature and the arts; it demonstrates the elegance and concision of science in representing the hydrocarbon economy and its global warming externalities; and, it points to the benefits of viewing history through the lens of energy related developments, *energy qua history*, as it were.

In our view, a 'big ideas' approach helps to bridge the edifices that house academic disciplines (some would call them fortresses). By nurturing broad perspectives at the outset, the creative mind is more likely to take the leap into Norbert Weiner's "no-man's land".

## 2. Markets and their failures – two big ideas

### *2.1. Markets*

The idea that humans respond to incentives is fundamental to economic thinking. The pursuit of one's interests is the departure point from which one builds theories of economic behavior, many of which deal with material goods.[5] To pursue their interests, individuals organize themselves into groups with common or related interests. The most basic of these in economics are firms. The process of self-organization is a direct consequence of self-interest.[6]

Two key variables which help to explain world-wide patterns of energy consumption are income (richer countries consume more energy), and prices (more energy is consumed where it is cheap and abundant). Geography also plays a central role. Heating is required in colder climates. Air conditioning is often relied upon in hotter climates. Where population density is lower and distances are greater, increased amounts of energy are consumed in transportation. Thus, demand for energy is a 'derived demand' resulting from our demand for energy services such as heat, light, refrigeration, washing and drying, various functions performed by commercial and industrial equipment, and, of course, transportation.

Alternative forms of energy may be substituted for each other. Heating and cooking may be accomplished using natural gas or electricity (or, biomass). Road vehicles, most commonly fueled by gasoline or diesel, may alternatively be propelled using natural gas or electricity. In some cases, energy use can be reduced by additional capital expenditures on more efficient engines, higher-efficiency furnaces or additional home insulation. However, such substitution usually takes time because of the long-lived nature of many capital investments. (After the oil price shock of the early 1970s, the shift to more efficient cars was gradual.)

An especially useful visual representation of the supply of, and demand for energy is depicted in energy flow diagrams, such as in Fig. 1 where 'pipe' diameters are intended to be roughly proportional to energy flows. Even a cursory examination is fruitful.[7]

In this U.S. example, total 2012 energy use (at the bottom of the diagram) is 95.1 quads.[8] The boxes on the left margin depict supplies of energy from various sources. Adding up quantities of natural gas, coal and petroleum yields a value of 78.1 – that is about 82% of U.S. energy is derived from carbon based sources. Coal is predominantly used in the generation of electricity. Renewable sources – hydraulic, wind, solar, geothermal and biomass – together yield 8.8 quads, about 9% of the total. The remaining 9% is produced from nuclear sources.

Next, consider the demand side which is divided into residential, commercial, industrial and transportation uses. The energy in each sector either produces 'energy services' or is lost in the form of 'rejected energy', the latter comprising over 60% of total energy. The least efficient sector is transportation where almost 80% of the energy is 'rejected'. The most efficient is the industrial sector where only 20% is 'rejected'. Overall, it might appear that humans are very inefficient, 'wasting' well over half of the energy we produce, but this is primarily a reflection of the state of technology and the second law of thermodynamics which we will discuss below. In fact, we have already come a long way. Fires used to heat and cook in the pre-industrial era 'wasted' 95% or more of the energy embodied in the wood they burned.

Markets provide a remarkably responsive and adaptive mechanism for supplying energy. Coal is available in many parts of the world and is the cheapest hydrocarbon. Because there are many suppliers, coal prices are determined by competitive forces and price differentials across the world mainly reflect differences in quality and the costs of transportation. Easily accessible oil, so-called conventional oil, is concentrated in relatively few places on the planet, enabling the exercise of market power, OPEC being the prime example. Nonconventional oil, such as that extracted from shale using horizontal drilling and hydraulic fracturing (fracking), is much more widely distributed and has already had a material impact on prices. (There will very likely be significant geopolitical consequences if, as a result of shale oil, dependency on Middle Eastern oil declines.) Natural gas markets vary depending on where one is located. In North America, they are competitive, in part as a result of the shale gas revolution. Continental Europe, on the other hand, is supplied to a significant extent by Russia which exercises market power in setting prices.

### *2.2. Market failures*

In broadest terms, the historically unprecedented successes of the industrial revolution are testament to the efficacy of markets in general, and energy markets in particular. Why then should governments be involved in energy markets? Why can't markets solve societal problems on their own? From the perspective of an energy economist, there are three primary reasons. The first is the presence of consequences to market activities that are not borne by parties to the transaction, that is external effects or externalities (think pollution and today's challenges of global warming).[9] The second is the presence of market power, in the extreme case monopoly power (think OPEC or the Standard Oil Trust). The third involves goods that are not produced in sufficient

[4] Indeed, a central objective of this journal is to provide a venue for interdisciplinary analyses of energy issues, Sovacool [7].

[5] Although rarely acknowledged explicitly in economics textbooks, the idea is implicitly understood to be rooted in evolutionary concepts. After all, natural selection rewards self-preservation.

[6] The idea that humans can be motivated or incentivized to take a certain course of action is also fundamental to neighboring social sciences, such as political science and sociology, as well as psychology, which has played an increasingly important role in economics.

[7] The earliest known example of this type of diagram is attributed to Henry Harness who in 1837 used it to show volumes of passenger flows along railway segments. In 1869, Charles Minard used a similar diagram to show the decrease in Napoleon's troops over the course of the Moscow campaign. In 1898, Matthew Sankey used this type of diagram to show energy flows in a steam engine. Such diagrams have come to be known as Sankey diagrams. Those in Figs. 1 and 2 may be found at https://flowcharts.llnl.gov/.

[8] A 'quad' is a quadrillion BTUs. For our purposes, what will matter are proportions or relative quantities, not actual levels.

[9] In this issue, Hodbod and Adger [8] discuss the importance of considering externalities in a broader ecological context.