

Editorial

Introduction to Special Issue on New Studies in EROI (Energy Return on Investment)

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Abstract: Energy Return on Investment (EROI) refers to how much energy is returned from one unit of energy invested in an energy-producing activity. It is a critical parameter for understanding and ranking different fuels. There were a number of studies on EROI three decades ago but relatively little work since. Now there is a whole new interest in EROI as fuels get increasingly expensive and as we attempt to weigh alternative energies against traditional ones. This special volume brings together a whole series of high quality new studies on EROI, as well as many papers that struggle with the meaning of changing EROI and its impact on our economy. One overall conclusion is that the quality of fuels is at least as important in our assessment as is the quantity. I argue that many of the contemporary changes in our economy are related directly to changing EROI as our premium fuels are increasingly depleted.

Keywords: energy; EROI; economic; fuels; quality of fuels

The concept of Energy Return on Investment (EROI) is a concept originally derived in ecology but increasingly applied to oil and other industrial energies. It had precedents in the idea of “net energy analysis” used by Leslie White, Kenneth Boulding and especially Howard Odum [1,2]. Similar but less explicit and focused ideas can be found in the newer field of “life cycle analysis” that is better developed in Europe than in the US. The word investment usually means *energy* investment but sometimes may also include *financial*, *environmental* and/or other kinds of investments. Some people like the term EROEI as a more explicit term, but we find it less useful and harder to pronounce. The term EROI has been around since at least 1970, but it gained relatively little traction until the last five

or ten years. Now there is an explosion of interest as peak oil and the general economic effects of increasingly constrained energy supplies are becoming obvious to investigators from many fields. This special issue examines various aspects of EROI with many exciting new studies from all around the world. It is very special as there had been almost no new studies since the original studies of the 1970s and 1980s and as the critical importance of the concept becomes ever more apparent as our highest quality fuels are increasingly depleted.

There have been questions about the degree to which we should use EROI vs. more familiar ways (e.g., price, financial return on financial investment in the oil business) to examine energy and other resource choices. In addition there have been criticisms that EROI has some severe flaws: that different studies give different answers to what appears to be the same question, that the boundaries of the analysis are controversial, that market pricing is always superior to scientific studies, and that EROI too often is dependent upon monetary data for its results. Explicit arguments for the virtues of EROI are found in the Murphy *et al.* protocol paper in this issue [3]. Many other papers in this volume take on these issues directly, often through sensitivity analysis, and we believe that the papers collectively make the case that EROI is an incredibly robust, useful and interesting tool. While we embrace “methodological pluralism”, that is different approaches to analysis, we favor EROI as the most basic and useful kind of analysis for examining and perhaps determining our energy future because, as developed by King and Hall in this issue, it ultimately determines the other ratios [4].

All of the papers in this special issue have been peer reviewed, usually very thoroughly, by appropriate professionals. Several papers did not make it through the review process. Several of the papers that did were nevertheless controversial, to say the least, and as editor of the whole issue I was faced with several situations where I had both strongly positive and strongly negative reviews. In that situation I sought additional reviewers, and generally received again mixed reviews. Where there were a balanced number of positive and negative reviews I chose to publish the papers as I thought they tended to be papers that I felt raised new and or important issues that later research is likely to sort out.

The issue is divided into four basic sections: Conceptual issues, EROI for Conventional fossil fuels, EROI for other fuels, and looking forward.

In my opinion this is a remarkably important group of papers. While EROI has yet to gain global popularity most of the contributors to this special issue would probably agree that few issues are likely to be more important for the future of civilization, whatever that might be. For many of us the financial crises that we have been experiencing since 2008 is a direct effect of the cessation of the growth of oil (and even of all liquid fuels if done on an energy, not volume, basis) and of the general decline in EROI. While this is not to discount the role of greed, corruption and mismanagement in all things financial, nor the enormous shift in wealth to the upper few percent over the past several decades, at the root of it all lies the decline in cheap, high EROI fuel that had once allowed the economy to do more work. This has been especially important as the economy has been shifting to higher labor productivity, meaning that each worker generates more value added per hour working. While increasing labor productivity is normally perceived as a good thing higher productivity is usually obtained by subsidizing each hour worked with increasing fossil fuel—in effect making each worker more productive but each unit of energy less productive than otherwise because there is less labor behind it! One result is that when Federal money is used to try to create jobs the money goes increasingly to energy, even energy from overseas, rather than salaries.

The net effect of decreasing net energy supplies coupled with increasing labor productivity is that 10 to 20 percent of Americans have no job at all, a poorly paying job in the service sector, or work part time. Incomes for the middle class have been stagnant at best for decades while the size of the middle class shrinks. Many, perhaps most, new college graduates have had to greatly reduce their aspirations. The stock market and real estate have become far less reliable ways to amass wealth. Some 46 of our 50 states and many of our municipalities face crippling budget deficits, and many colleges, pension plans, charities and other institutions are operating with diminished funds or going bankrupt. It is increasingly difficult to pay for the repair of storms and other environmental disasters. Even the United States Government has seen its credit rating diminished. “Tea Partiers” seek to cut debt and the role of government even while pole after pole shows the public does not want its health care or most other benefits cut. Keynesian deficit spending that worked in the past and might work again has few advocates today because of crippling debt, nor is there the likelihood of future growth to repay any such deficit spending because, unlike in 1946, the possibilities biophysical constraints make the potential for sustained economic expansion seem very thin indeed. As individuals and as a nation we have been living beyond our energy means for decades. We collectively do not know how to change that situation because tax increases have become so unpopular even while such previously unheard of programs as Medicare have become sacred. In earlier times the growth of the economic pie defused arguments about how to cut it, but now the growth of the pie, constrained by the end of cheap energy and the demise of energy growth, seems much less likely.

If the pie is no longer getting larger, indeed if because of energy constraints it can no longer get larger, how will we slice it? This may force some ugly debates back into the public vision. Indeed if EROI continues to decline then that will cut increasingly into discretionary spending (the engine for economic growth) and we will need to ask some very hard questions about how we should spend our money. One way to think about this is “Maslow’s hierarchy of human needs” [5]. This theory, proposed by Abraham Maslow in his 1943 paper “A Theory of Human Motivation”, proposes that humans will attempt to meet their needs in more or less the following order: First they will meet their physiological needs, which are the literal requirements for human survival, including breathing, nutrition, water, sleep, homeostasis, excretion and reproductive activity. Second, once physiological needs are satisfied an individual will attempt to meet safety needs in an attempt to attain a predictable, orderly world in which perceived unfairness and inconsistency are under control, the familiar frequent and the unfamiliar rare. Third, once the above needs are met humans seek love and belonging, *i.e.*, emotionally based relationships in general, such as friendship, intimacy and family. Fourth, again once the above have been met humans seek esteem, to be respected and to have self-esteem and self-respect and also the esteem of others. Finally, according to Maslow, people seek self-actualization, the need to understand what a person’s full potential is and to realize that potential, to become everything that one is capable of becoming—for example an ideal parent, athlete, painter, or inventor.

Such a hierarchy applies to our energy use. Think of a society dependent upon one resource: its domestic oil. If the EROI for this oil was 1.1:1 then one could pump the oil out of the ground and look at it. If it were 1.2:1 you could also refine it and look at it, 1.3:1 also distribute it to where you want to use it but all you could do is look at it. Hall *et al.* 2008 examined the EROI required to actually run a truck and found that if the energy included was enough to build and maintain the truck and the roads and bridges required to use it (*i.e.*, depreciation), one would need at least a 3:1 EROI at the

wellhead [6]. Now if you wanted to put something in the truck, say some grain, and deliver it that would require an EROI of, say, 5:1 to grow the grain. If you wanted to include depreciation on the oil field worker, the refinery worker, the truck driver and the farmer you would need an EROI of say 7 or 8:1 to support the families. If the children were to be educated you would need perhaps 9 or 10:1, have health care 12:1, have arts in their life maybe 14:1 and so on. Obviously to have a modern civilization one needs not simply surplus energy but lots of it, and that requires either a high EROI or a massive source of moderate EROI fuels. As we watch the magnificent Syracuse Symphony and our equally magnificent State University systems go broke we believe we are watching the beginning of the decline of civilization driven by a declining EROI. If things get a lot tougher, as many think, the low EROI energy that is available will go to growing food and supporting families. It is clear that we must understand energy and its changes if we are to understand changes in our economy.

Maslow's theory has been criticized from a number of angles including the supposed lack of evidence that humans in fact follow that hierarchy, or indeed any such hierarchy, and from the perspective that his "pyramids of needs" may be more representative of people from an individualist vs. socialist society. Nevertheless his theory is broadly accepted in psychology and even marketing. Our own research on the implications of declining net energy, while not consciously based on Maslow's theories, is consistent with them. We have the sense that discretionary spending will be increasingly abandoned as humans attempt to meet their basic needs for food, shelter and clothing [7]. Presumably as the amount of net energy declines due to peak oil and declining EROI, humans will increasingly give up categories higher on the pyramids and concentrate increasingly on the more basic requirements including food, shelter and clothing. What this may mean in modern society is that performance art, then expensive vacations, then education, then health care would be abandoned by the middle class as the economy is increasingly restricted. Whether this can be reversed by diverting where and by whom we chose to spend such surplus money or energy as we have will be an increasingly dominant challenge to society.

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Conflict of Interest

There are no conflicts of interest associated with this paper.

References and Notes

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