

Article

Looking for a Silver Lining: The Possible Positives of Declining Energy Return on Investment (EROI)

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Abstract: Declining energy return on investment (EROI) of a society's available energy sources can lead to both crisis and opportunity for positive social change. The implications of declining EROI for human wellbeing are complex and open to interpretation. There are many reasons why frugal living and an energy diet could be beneficial. A measure of wellbeing or welfare gained per unit of energy expended (WROEI) is proposed. A threshold is hypothesized for the relation between energy consumption and wellbeing. The paper offers a biophysical-based social science explanation for both the negative and positive possible implications of declining EROI. Two sets of future scenarios based on environmental and economic trends are described. Six types of social change activism are considered essential if the positives of declining EROI are to balance or exceed the negatives.

Keywords: energy; EROI; human wellbeing; thresholds; degrowth; scenarios; social change

1. The Implications of Declining EROI for Human Wellbeing

Energy Return on Energy Invested (EROI) represents a simple ratio; the amount of energy obtained from any energy-producing activity divided by the energy used to make that amount of energy available for productive activities. EROI is a ratio while a related term, Net Energy, refers to the remainder from subtracting energy *input* from energy *output*. Total Net Energy represents the "productive energy", the energy available for all the economic, social, cultural and other activities of daily life. Fossil fuels represent dense concentrations of energy available to apply to modern industry and convenience. These qualities are captured mathematically in higher EROI values for fossil fuels compared to other energy sources. The EROI of most alternatives do not come close to producing the

net energy of fossil fuels. As reported in Hall *et al.* [1] and in various papers in this special issue, the recent precipitous decline in EROI for oil and gas, by far the most important energy source of modern industrial economies, suggests that we have utilized (or squandered) what may well be a one-time gift that has powered economic growth since the Industrial Revolution.

Society must make difficult energy choices that have serious consequences for the environment and future generations and they must be made increasingly under conditions constrained by declining EROI, the related phenomenon of Peak Oil and accompanying upward pressures on energy prices. In my opinion, EROI and Net Energy analysis should be considered essential data for informing political and economic choices among alternative energy investments and policies but so far this has rarely been done. It is equally important to understand the many ambiguous and negative consequences of a hyperactive economy driven by cheap energy.

The decline in EROI and Net Energy of fossil fuels results from the fact that most of the readily available high quality reservoirs are already in production. Newer discoveries tend to be in deep water, in remote and hostile surroundings, at great depths, bound in shale or sand or otherwise in conditions requiring considerably more energy to bring to market than has been the norm in the petroleum age. In addition to the increasing energy needed to obtain new oil, EROI also declines when the quality of available fuels is poorer and therefore burns with less intensity. Declining EROI of a nation's energy sources must necessarily lead to reductions in that portion of national income available for discretionary consumption and investment. More energy has to be used simply to obtain energy and therefore less is available for everything else a nation produces or invests in. This will have social consequences. The negative consequences are foreseeable as economic decline of various sorts. Some of the consequences of reduced energy availability, however, might be positive. The reason for this is the focus of this paper.

The implications of declining EROI for human wellbeing are complex and open to interpretation. The most obvious implication is that discretionary spending is likely to decline substantially as more and more of society's output is required to maintain necessary inputs. Economic growth may stall and stagnation could settle in. But considering that a significant but not readily quantified portion of the energy consumed in modern industrial societies powers activities that are destructive to human wellbeing and the environment, choices made to reduce them could benefit everyone. There are many reasons why frugal living and an energy diet could be beneficial. A shift of emphasis towards increasing the amount wellbeing or welfare derived per unit of energy used or invested (Welfare Returned on Energy Invested, or WROI) would make it possible to imagine and plan for a *prosperous way down* [2] or what the European advocates of *décroissance* [3] have defined as “an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level, in the short and long term.” [4]. It also is in agreement with the nascent movement in the U.S. for a “Steady State economy” [5,6].

2. A Threshold Hypothesis for the Relation Between Energy Consumption and Human Wellbeing

In one of the early issues of the journal, *Ecological Economics*, the Chilean economist Manfred Max-Neef [7] offered a threshold hypothesis. He argued that “For every society there seems to be a period in which economic growth (as conventionally measured) brings about an improvement in the quality of life, but only up to a point—the threshold point—beyond which, if there is more economic

growth, quality of life may begin to deteriorate". Niccolucci *et al.* [8] reviewed data on Index of Sustainable Economic Welfare (ISEW) and Genuine Progress Indicator (GPI), two indicators commonly offered as alternatives to GDP as a measure a nation's progress. Analyzing the relation between GDP and a nation's Ecological Footprint the authors concluded that, "increase in economic wealth often results in worse, not better, conditions for people because the welfare related to a given GDP is 'polluted' and diminished by environmental stress and social pressures". This is consistent with Herman Daly's [5] concept of "uneconomic growth" defined as occurring when "increases in production come at an expense in resources and well-being that is worth more than the items made." Given the tight correlation and logical link between economic growth and total energy use, a similar inverted U curve holds for the relation between increased energy use and a number of measures of wellbeing. The United Nations Development Program estimates that it requires one Ton of Oil Equivalent (TOE)/per capita to reach a fairly high state of national health and development. Energy consumption beyond that buys little additional benefit [9]. Energy analyst Vaclav Smil [10] has estimated that consumption of 1.194–1.672 TOE of commercial energy per person is enough to meet essential physical needs plus high quality education and social services. On average, in 2005 the world's population consumed 1.778 TOE/capita annually [11]. The world's energy glutton, Qatar consumed over 19,000 TOE/capita while in the United States and Canada annual consumption hovers around 8,000 TOE/capita. In general, as annual per capita energy use increases, measures of quality of life increase in step, up to a point after which increases in quality of life are no longer evident. As Smil concluded, "Higher energy use does not guarantee anything except greater environmental burdens" (p. 386). Measures of WROEI would likely demonstrate a significant decline at the margins beyond the modest levels of energy consumption associated with frugal and energy efficient lifestyles.

Similarly, self-reported levels of happiness among the poor tend to rise with increased income while levels of emotional depression decline. The relation between self-reported state of happiness and personal income, however, largely disappears beyond moderate levels of income [12]. Up to a point, one can buy at least a chance at happiness but that point may be well below what is taken for granted in affluent societies. None of this is surprising. Too much energy introduced into a system can overwhelm it. For analogy consider the problem of eutrophication of a lake or pond. An overabundance of fertilizing nutrients entering the water stimulates the growth of plankton and thus excessive photosynthesis and a decline in oxygen that leads to rapidly degrading conditions for most fish. The shore becomes awash in rotting algae and dead fish. Think Lake Erie in the 1970s. Consider also how a starving person rapidly improves by increasing caloric intake. However, the average North American who presently takes in 3,600 calories a day (world average is 2,700 calories) is not well served by adding another pound of steak to his daily diet. Consider the energy that goes into producing, processing, storing, transporting and preparing the average American meat-eating diet emits 8,800 pounds of CO₂ per day, just less than the average US car [13]. The WROEI beyond these points turns rapidly negative.

Many of the means we have to reduce energy use are also steps toward improving one's health. Walk, ride bikes, drive less. Eat more fruits and vegetables, preferably organic and locally grown. The WorldWatch Institute in its State of the World report [14] points out how our isolated, lonely lives expand our energy consumption: "A one person household in the United States uses 17% more energy per person than a two person household". Friendship and sharing meals, tools, conversation,

skill-sharing and other community-building activities go a long way toward reducing our dependence on individual consumption to achieve satisfaction and maintain health, while significantly reducing ecological footprints.

The positive consequences of declining EROI may be less obvious than the negatives but when one looks at the range of inverted U relations between energy consumption and human wellbeing the notion begins to dawn that society should be guided by the concept of an optimal level of energy consumption rather than by the push to maximize economic activity and thus energy. It is completely possible and to some, obvious that wealthy industrial societies have exceeded a sustainable optimum, in particular those nations that can be considered energy gluttons. For those societies on the upward slope of the energy and wellbeing U curve, more available energy should lead to more social and individual wellbeing, increasing WROEI. For modern industrial societies that appear to be on the downward slope where marginal cost of energy use exceeds marginal benefit, declining WROEI, an energy diet would be beneficial. Like most addicts people in modern industrial societies are unlikely to voluntarily choose to live less energy intense lifestyles, despite the best persuasive efforts to encourage simpler living. But facing less availability and higher prices associated with declining EROI, less energy is what we will have.

3. Towards a Biophysical-Based Social Science Understanding of the Inverted U Relation Between Energy and Wellbeing

Declining EROI will likely lead to social change. To understand the nature of this change, consider how in biophysical terms, a society can be thought of as consisting of networks of flows of materials and networks of flows of energy. Through these flows and the products in which these flows are embodied we meet our basic needs for food, clothing, shelter, transportation and warmth as well as all our luxuries and conveniences [15]. People make daily livelihood and lifestyle decisions, consciously and not, based on their notion of how to connect to these flows in order to support themselves, their families and communities. These flows add up to society's metabolism and the combination of these flows and the decisions people make to connect themselves with these flows becomes the self-organizing entity we call an economy.

As society experiences change, whether through new technology, new ideas, changes in financial circumstances, or changes in energy quality and availability; individuals must realign themselves in relation to the altered networks of energy and material flows. Some individuals experience the accompanying changes as threats, others as opportunities, many as both.

The networks of energy and material flows involve transactions at various points of connectedness. Most, if not all, of these connections are through interactions with markets, communities or ecosystems. As citizens, neighbors, family members, and friends we are connected to families and communities; as consumers, producers workers, buyers and sellers we are connected to markets; and as physical beings, mammals, we are connected to land, air, water, sunlight, ecosystems. Obviously these nodes of connectedness, or roles, do not exhaust what it means to be human and they overlap in the life experience of any individual; but they largely structure our relation to energy. Through these connections, people also find much of our meaning and belonging. Throughout history, societies have differed in the degree to which one or the other mode of connectedness has dominated, in other words, through which networks most of the throughput has traveled. In hunter-gatherer societies, energy

and material flows were mediated through earth-based and small community-based connectedness. As Hall *et al.* [16] details, “the history of human cultures can be viewed as the progressive development of new energy sources and their associated conversion technologies”. Each new energy source increased EROI and thus the amount of energy available for social and economic development. Cities became possible and large community-based connected through institutions became dominant. Further energy gains reduced the cost of long-range transport and market-based connectedness became the node through which individuals and groups became connected to the massive networks of energy and material flows. How, where and to what degree one connects to resource flows depends on a person’s place in a community, market, and ecosystem.

Prior to the era of cheap high EROI energy, networks of flows of energy and material resources were far more limited than at present and connections to these networks were primarily community-based and earth based, in other words they were accessed through tribe, guild, family, clan, neighborhood, institutions of governance or directly from fields, forests and waters.

In most modern societies these networks have come to be represented by money in circulation. Each unit of currency, in effect, grants us power to lay claim to or purchase either a certain amount of embodied energy and material resources or to hold rights to claim a certain amount of future resources. The flow of money is thus the means through which present societies primarily participate in the networks of energy and material flows that structure society, whether or not we actually experience and perceive it in that way. First the invention of the global circulatory system of money, and most importantly interest and debt, followed by its computerization has created conditions in which claims and rights for access to energy and material resources has exponentially increased in volume and rate of flow. Thus claims to energy have increased enormously at the same time that EROI, and thus energy availability, is in decline.

High EROI cheap energy made possible the consolidation of international and then, global, networks of energy and material flows with greatly increased volume, velocity and geographic reach. Eventually access to these networks depended almost entirely on financial means. The connectedness that came to matter most was the connection to money. The result has been the overdevelopment of the economy of commodities (goods and services) and the underdevelopment of the economy of relations (between people and between people and the natural world). For a more complete development of this argument see Manno [17,18].

Changes in the patterns of flows, as may result from declining EROI, can trigger powerful fears and, for some, excitement at the opening of new possibilities. These periods of change are both creative (as in necessity birthing invention) and chaotic. Early 20th century historians and social theorists like Toynbee and Spengler focused on the rise and fall of civilizations. More recently others have shown the role of environmental factors, reckless consumption and resource limits in the collapse of complex societies [16,19-22].

Hall *et al.* [16] and many others have suggested that energy availability has been a very important factor in the progressive evolution of human cultures. With more energy available “progress” ensues, populations expand, and complex civilizations become possible. In other writing Hall has suggested that there may be a minimal EROI to support civilization at a given level of complexity and that declining EROI and the related impending peak in oil production threatens very large changes, perhaps even catastrophic collapse. I would argue that the cause is more likely too much energy rather than too

little. The core of my argument is that cheap energy and neoliberal ideology have combined so that an ever-increasing portion of the world's energy and material resources now flows in networks of market-based connections. This has caused critical aspects of human connectedness and social life to become systematically underdeveloped, starved of energy and material resources. As EROI continues to decline, we will need to rediscover and revitalize community-based and ecosystem-based connectedness which are required for lower energy intense forms of meeting human needs, in other words for increasing WREI.

The rise and fall of civilizations is the rise and fall of cultures that have structured people's connections with each other and to resources. Therefore the experience of decline is also experienced as a crisis of meaning. It is likely to be associated with religious conflict and cultural insecurities. New less energy-intensive technologies and social arrangements will emerge. There may be conflict between those experimenting with and adopting new low-energy livelihood strategies and those clinging to old norms and beliefs associated with the outdated expectation of cheap energy. Over time, new generations may mature under conditions of more frugal flows of energy and material. One likely outcome is some combination of a renaissance of conviviality in some parts of society and globe along with conflict and decline in others, with both often occurring at the same time and place.

4. Alternative Future Scenarios: Not Just Societal Collapse

Two recent efforts have formalized alternative scenarios related to limits to growth: The Tellus Institutes' Global Scenarios for the Century Ahead: Searching for Sustainability [23] and the scenarios developed for the Millennium Ecosystem Assessment [24]. The similarity between these scenarios and others suggest that while the future may be unknowable, given energy and environment trends, plausible scenarios are not unlimited. Each project posited four scenarios they considered most plausible. Each referred to similar uncertainties: a wide range of possible climate change feedbacks and ecosystem responses, whether and how human values may change, the potential for global cooperation or conflict and many other potential feedback loops that could seriously alter any given scenario. Both seriously question the sustainability of the "business as usual" scenario and suggest social change will happen, the question is toward what end?

4.1. Tellus Scenarios

4.1.1. Conventional Worlds:

- Market Forces–Business as usual. Global incomes, GDP and population grow. Profound inequalities. Conflicts over scarce resources. Collapse.
- Policy Reform–Government directed reforms toward sustainability objectives. Serious reduction in GHG emissions. Internationally agreed poverty reduction strategies.

4.1.2. Alternative Visions:

- Fortress World–Authoritarian order imposed. Elites retreat to protected enclaves. Environmental degradation exacerbated.

- Great Transition—Values shift to a just, sustainable world. Human solidarity and environmental stewardship. Reduction in consumption through frugal lifestyles. Voluntarily reduced population pressures.

4.2. *Mea Scenarios*

- Global Orchestration—Economic cooperation, global growth, trickle-down benefits for environment and other public goods.
- Techno-garden—Ecological engineering and biotechnology follow adoption of reforms based on natural capitalism, profits from mimicking efficiencies of natural processes.
- Adapting Mosaic—Managing socio-ecological systems through adaptive management. Free flow of information, more restricted flow of trade goods and services. Great regional variation. Local/regional co-management.
- Order from Strength—Breakdown of global cooperation, authoritarian responses to social and environmental crises

It is not surprising that plausible scenarios would generally follow along the lines of business-as-usual, utopian and dystopian futures. There will be, as there always is, a struggle for the future among competing perspectives on justice, fairness, righteousness and faith. Energy analysis and social theories can inform what is possible but not necessarily what is likely. Dystopian and utopian tendencies will emerge together and the outcome may be a mix of both for a long time to come. While the state of economic disparity, global climate, biodiversity, water, etc all trend toward the dystopian, social movements are growing to bring about what the Tellus scenarios call the Great Transition and author and organizer Joanna Macy refers to as the Great Turning, the essential adventure of our time: the shift from the industrial growth society to a life-sustaining civilization. Social change activism to bring the Great Turning about groups into six forms of social change activism:

- (1) Softening the blow. On-the-ground work to protect and restore the most vulnerable and endangered ecosystems and people whether through seed banks or food banks, preserves or shelters.
- (2) Institutional and economic reform. Co-housing, web based sharing networks, and larger institutional reforms including community and earth-based stakeholder representation on corporate boards, environmental financial and tax reforms, payments for the provisioning of ecosystem services and many more policy reforms with an eye to improving wellbeing while minimizing energy and material throughput and waste. Other policies will be needed that help communities to adjust to lower levels of energy consumption. These include: reduced working hours, parental leave, benefit packages for part time work, regulation of advertising; tying corporate charters to achievement of social and environmental objectives, innovative models of local-living economies, sustainable communities and transition towns and many more.
- (3) Developing new tools and technology. The crafts of a less energy-intense lifestyle will bring back the small-scale engineer who develops tools specific to crop, hydrology and other local ecosystem-based phenomena. These will include a range of green technologies, permaculture, ecological engineering and the like.

- (4) Developing a theory base. Intellectual work to explain how overconsumption of resources has led to environmental destruction. The field of Environmental Studies is crucial here. The development of a biophysical social theory based on thorough analysis of networks of energy and material flows could make significant contributions. Comparison of alternative patterns of energy and material use in terms of wellbeing generated per unit of energy invested (WREI) would be valuable.
- (5) Cultural work. The era of cheap energy helped market-based connectedness overwhelm the importance and awareness of culture-based and earth-based connectedness. The building and symbolizing of these “lost” connections is essential work of art, music, and poetry.
- (6) Interpersonal and psychological work. Culture alone may not be enough to bring about a new ecological consciousness. As Clive Hamilton [25] has written, it “will depend not so much on a change of beliefs and attitudes but on the emergence of a new sense of self and the relationship of that self to the natural environment. In the first instance, we therefore need to understand how people construct their sense of self, that is, how they form their personal identity and how they act out those identities in their behavior.” Can renewed forms of culture-based and earth-based connectedness help people handle the stress, fear, anger and other powerful emotions likely to be stimulated during times of major social and cultural transition? Healing from the effects of broken connections between people and the earth may be crucial throughout the transition. Self-identities formed in the age of the consumer will need to be reconstructed as people newly identify themselves as active inhabitants and participants of an ecosystem and engaged citizens in a social system. Declining EROI has the potential to reverse the emphasis back to production from consumption, to actors rather than consumers.

The negative effects of the end of cheap energy are likely to predominate unless a strong movement for social change can explain broadly what is happening and why it is happening. Such a movement must include the restoration of community-based and earth-based connectedness. If social movements pick up their pace and effectiveness in the coming period and create conditions for change that foster human wellbeing while conserving resources and reducing total system throughput, there is a chance, perhaps the only hopeful chance, for a new social renaissance as constraints on the availability of cheap energy necessitate and foster new patterns and networks of flows of energy and material resources.

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