Energy Return on Energy Invested – EROEI

“Most economists are not too concerned about ‘peak oil’ (if they think about it at all) because they believe that markets will generate substitutes from which markets will choose. But today’s markets often give very misleading signals about the potential of various fuels. The boom and bust of ethanol is an obvious example.”

Charles Hall

Toto is an adult female African Cheetah sitting on a slightly raised mound surrounded by long grass. Her young cub is playing in the grass nearby. Suddenly, Toto sees two Thompson Gazelle’s, less than 100 metres away. Unaware of the Cheetahs presence, the gazelles continue with their grazing. The adult female Cheetah focuses in on the smaller gazelle and starts stalking its prey through the long grass. With grace and focus the Cheetah increases its speed from a slow stalking motion to a gentle canter. As the Cheetah gets closer to the young gazelle, it accelerates, pouncing on the gazelle. It uses its large claws to bring it to the ground. While the Cheetah ran further than it would normally, the female Cheetah exerts minimal energy in bringing down this small Gazelle. This is a real world example of Energy Returned on Energy Invested (EROEI).

In nature, predators instinctively understand the importance of how to minimise and control the amount of energy they expend. The Cheetah from experience, calculated the chances it had of capturing the prey, and how much effort would be needed to expend. Energy is a primary limiting resource in most natural systems. Large predators such as mammals are limited by their ability to convert energy. The energy cost in hunting, is a two edged sword. Energy constraints restrict certain mammals such as Cheetahs to niched environments where food is abundant, and competition is low. Research on Cheetahs proposes they are limited in their abilities to obtain and utilise energy. While a fully grown cheetah can reach speeds of up to 110 kph in less than 4 seconds, the downside for the cheetah is that its heart rate rockets from 60 beats per minute to 150 per minute. Hence why, the cheetah can only maintain high speeds for a few hundred metres. If a cheetah pushes past this natural limit, it risks exhaustion, or death, from overheating and stress. With such a high-speed hunting strategy, there are limits which affect all aspects of the Cheetahs life. This leaves them susceptible to starvation and hampers their ability to reproduce. This fine line between life and death, based on the energy constraints is known as the 'energetic edge.’ The ability of animals and populations to survive depends on how near individuals approach the evolutionary limits of energy supply and demand.

In physics, energy economics and ecological energetics, energy returned on energy invested (EROEI or ERoEI); or energy return on investment (EROI), is the ratio of the amount of usable energy acquired from a particular energy resource to the amount of energy expended to obtain that energy resource.

The simple calculation is:

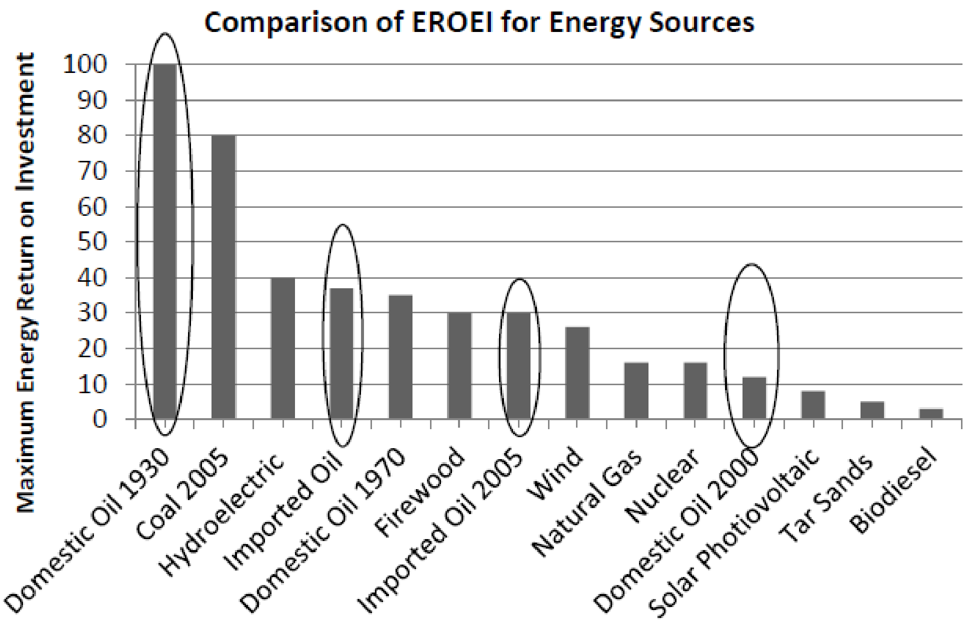
$$\textbf{EROEI} = \frac{\text{Usable Acquired Energy}}{\text{Energy Expended}}$$

When the EROEI of a resource is less than or equal to one, that energy source becomes an ‘energy sink’, and can no longer be used as a primary source of energy.[258] The EROEI is the energy delivered back to society, after the expenditure of energy used to get it. Typically animals as well as humans go after the easy more accessible energy resources first. The low hanging fruit are much easier to obtain than those at the top of trees. The fruit at the top of the tree will require a ladder and other equipment to enable one to collect the fruit.

Why is it Important to Understand Energy Return on Energy Invested?

"We need new production equal to a new Saudi Arabia every 3 to 4 years to maintain and grow supply... New discoveries have not matched consumption since 1986. We are drawing down on our reserves, even though reserves are apparently climbing every year. Reserves are growing due to better technology in old fields, raising the amount we can recover – but production is still falling at 4.1% p.a. [per annum]."

Dr. Richard G. Miller



Source: Heinberg The End of Growth et al Charles Hall 2010

The previous graph illustrates the returns each energy source receives back from the initial one unit of energy invested. In other words, domestic oil (U.S.) in 1930 shows for every barrel of oil used in extraction there would be a return of one hundred barrels of oil. If you invested $1 to extract oil you would receive $100 back, a pretty good investment. The interesting point to note in this graph is how significantly oil has declined in terms of its EROEI. From 100:1 in the 1930's to around 12:1 in 2000.

So how did this significant decline in the energy return drop so dramatically? Over time the extraction of oil increased to the point that all wells 'peak' and enter a decline phase. As mentioned earlier the point at which an oil reservoir reaches its maximum rate of extraction, is the 'peak' of production, hence the term 'peak oil'. When an oil field reaches this point, productivity of the well declines, along with the resource coming from it. The nature of the geological formation will determine if further investment is needed to enhance continued extraction.

As Charles Hall an energy specialist and distinguished professor at the State University of New York, explains, "energy return on investment (EROEI) is crucial to our understanding of the world because it provides us with a ratio of energy returned from an energy-gathering activity compared to the energy invested in that process. While EROI by itself is not enough to judge the virtues or vices of particular fuels or energy sources, it is a crucial component for such assessments because it indicates whether a fuel is a net energy gainer or loser (and to what extent). EROI studies for most energy resources show a decline, indicating that depletion has been more important than technological improvements over time."

The understanding of energy return is crucial in our ability to fully comprehend how our economies and society at large function, and what the future may look like. Unfortunately the current economic paradigm does not incorporate the use and impact of energy returns. If we have a 1:1 ratio of energy return on energy invested then it is very difficult to have an economy as we do now. Hence, it is important in helping us plan for the future. The higher the EROEI the more things can be done within an economic and social system. An abundant source of energy with a high return (100:1), gives us a surplus of energy, allowing us to engage in a whole raft of activities and pursuits outside the realm of survival and maintenance of critical services.

The tourism industry is an example of the use of this excess or surplus energy. In the early part of the first millennium the tourism industry was virtually none existent compared to today. Travel outside one's own region for leisure was predominately confined to the wealthy. Through the middle ages, as certain religions gained in popularity, there was an increase in pilgrimages by the lower classes to endure longer journeys into other regions and countries for spiritual and or health benefits. Most of these journeys occurred on foot, with horses, camels or donkeys providing additional cartage. It wasn't until the Industrial Revolution leisure travel evolved on such a broad scale. Today, international tourist arrivals between countries exceed 1 billion. Trillions of dollars of capital investment has developed around the globe primarily due to the relatively high EROEI over the last century. This surplus energy has shaped the world in which we live, enabling us to grow economies and develop highly interconnected and complex systems entirely dependent on cheap abundant energy.

The typical pattern or sequence of events which leads to depletion and lowering EROEI is as follows. A resource is discovered, the appropriate technologies are employed to either extract or develop a resource. As the resource is developed new investors are attracted to projects bringing more capital investment. These capital inflows help bring increasingly more resources to market, as increased investment generally leads to advanced technology. Increased investment drives demand as economies of scale bring cost efficiencies to operations. As investors see initial profits grow and potential upsides from the increase in demand, they become increasingly eager to pursue additional investments. Over time the resource base begins to decline, as technological improvements hasten the depletion of the resource base. As the easy to extract, higher grade resources are used first there is a subsequent decline in EROEI. The lower grade and harder to extract resources remaining are more costly to produce and have a lower EROEI. This forces drilling and mining companies to increase efficiencies throughout their operations, in an effort to offset the declining EROEI. As resources begin to decline and technological innovation reaches its limits, further expansion and exploitation of resources are needed. Much like a mouse on a treadmill, the cycle of never ending discovery, exploitation and depletion will always occur with non-renewables such as oil, gas and coal.

As Charles Hall explains in his paper *'Energy Return on Energy Invested,'* for the Post Carbon Institute, "Many prominent earlier researchers and thinkers have emphasised the importance of net energy and energy surplus as a determinant of human culture. Farmers and other food producers must have an energy profit for there to be specialists, military campaigns, and cities, and substantially more for there to be art, culture, and other amenities. Net energy analysis is simply a way of examining how much energy is left over from an energy-gaining process after correcting for how much of that energy—or its equivalent from some other source—is required to generate a unit of the energy in question. If the EROEI for this oil was 1.1:1 then one could pump the oil out of the ground and look at it … and that's it. It would be an energy loss to do anything else with it. If it were 1.2:1 you could refine it into diesel fuel, and at 1.3:1 you could distribute it to where you want to use it. If you actually want to run a truck with it, you must have an EROEI ratio of at least 3:1 (at the wellhead) to build and maintain the truck, as well as the necessary roads and bridges (including depreciation). If additionally you wanted to put something in the truck and deliver it, that would require an EROEI of, say, 5:1.3 Now say you wanted to include depreciation on the oil field worker, the refinery worker, the truck driver, and the farmer; you would need an EROEI of 7:1 or 8:1. If their children were to be educated you would need perhaps 9:1 or 10:1, to have health care 12:1, to have arts in their lives maybe 14:1, and so on."

Our current society is enormously reliant on abundant cheap energy which provides everything for modern life. Housing, transportation, agriculture to schools and medical facilities, all need a constant and ongoing supply of cheap energy. The energy required to maintain the infrastructures which support our current Western way of life is significant. Any surplus energy goes towards driving economies and Rethink allowing economic growth to occur. With most economists and politicians understating the importance of energy, it is easy to fall into the trap of thinking that energy is not that important in the grand scheme of things. Not understanding the significance of EROEI is detrimental to society as it hampers any meaningful discussion, and limits our ability for a timely transition to occur.