The Marginal Energy Return On (Energy) Investment (MEROI)

By Douglas B. Reynolds*

Many physicists look at the specific concept of the energy return on (energy) investment (EROI), or more generally energy return ratios (ERR), as a way to help explain a relationship between economic growth and energy in the tradition of Meadows et. al (1972, 2004) or Forrester (1958, 1961). See Cleveland et. al (1984), Hall et. al (1986), Hall (2008), and Bardi (2011). Although as Brandt et. al (2013) say:

> Energy return ratios (ERR) are often easy to describe, but generally challenging to operationalize in a rigorous and specific manner. Thus ERRs are often defined loosely.

Of course such problems have not stopped economists before from making assumptions around science or engineering, so why should it stop us now. After all, how many economists reading this have actually gone out to a local factory and measured, not estimated, what the marginal cost is? Nevertheless economists are suspicious of the ERR concepts, just like many physicists are, and suggest that the more appropriate concept for analyzing energy is energy costs, including marginal costs and marginal benefits of energy, and not ERR or EROI. See Gordon (2009) and Adelman (1995). There may be, though, a compromise concept that can help bridge the gap between economists and physicists on the energy/economy relationship similar to Hall and Klitgaard (2012) and Kümmel (2011).

Consider first that one of the most important energy resources in the economy is oil for a number of reasons as Reynolds (1994), and Hamilton (1983) explain. So instead of trying to define energy in general, it may be helpful to simply look at oil in particular as its own energy resource market. Even if the economy can use oil substitutes that use many different energy resources such as electricity, nevertheless, most of the substitutes for oil include a liquid energy resource and not a general energy substitute. Therefore, in this article, as far as the energy product is concerned, we look at oil or a liquid oil substitute specifically, called here "oil" for simplicity, and not at energy supplies in general.

The Supply of Oil

When it comes to finding, extracting and transforming oil, or liquid oil alternatives, then the more oil that the market is able to supply, the higher is the pecuniary cost per barrel of oil for each additional barrel, i.e., the marginal cost rises, as conventional microeconomic supply theory suggests. The costs would include the capital and labor costs used in more elaborate replacements for oil, such as producing corn ethanol. However, in an alternative but parallel manner, we can think about all the energy that goes into finding and extracting conventional and unconventional oil when looking at the EROI concept: the more oil that the market is able to supply, the higher is the energy cost per barrel of oil for each additional barrel.

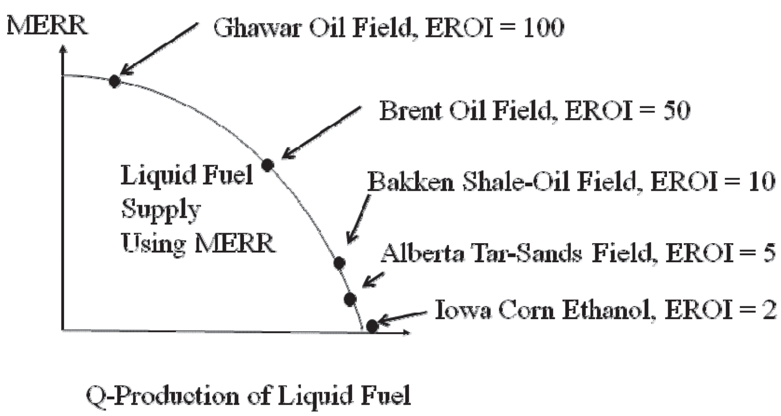

Figure 1. The aggregated MERR of supplying oil or liquid oil substitutes.
As more oil is supplied, the market provides increasingly lower EROI oil or oil alternatives.

Consider, not all energy costs of producing oil are the same for various oil fields and oil resources, and, therefore, not all oil and oil substitute EROI's are the same. Clearly, Saudi Arabian light crude-oil takes less energy to extract, refine and get to market than does Alberta's tar-sand bitumen (oil). Therefore, there are many different EROI's for different oils. Indeed, we can create a sort of hierarchy of EROIs for each oil resource starting with high EROI oils and gradually going to low EROI oil substitutes. This hierarchy is a sort of supply curve, in the traditional economic sense, only instead of a cost-oriented supply curve, it is an EROI-oriented supply curve as shown in Figure 1. Furthermore, each specific oil resource has its own marginal EROI (MEROI) energy cost for that particular oil, called here the marginal energy return ratio (MERR). In general the market supplies high MERR oil first and low MERR oil later creating a sort of aggregated MERR supply curve. Instead of a supply curve made up of aggregated marginal costs, which increase as more oil is produced, it is a supply curve

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made up of aggregated marginal EROIs, which decrease as more oil is produced.

However, we cannot only look at extraction alone, as there is also the cost and MERR of exploration too. It takes energy to look for new oil fields, and if the probability of finding a new field is say 10%, than on average you need to drill ten exploration wells, or conduct ten seismic surveys, to find that one field. All that exploration takes energy and the more energy it takes to find the marginal field, the lower the MERR is.

Going back to the original quote on ERR, which says that ERRs and EROIs are loosely defined, it is clear that there is not a one-to-one relationship between economic marginal costs and MERRs. That means that Figure 1 cannot be mapped into a true economic supply curve, nor can Figure 1 accurately map out what the true cost of supplying oil is. Some high energy-intensive, oil-producing processes actually produce cheap oil, while some low energy-intensive, oil-producing processes produce expensive oil. Nevertheless, Figure 1 does explain to the average physicist looking at ERRs how markets tend to operate. Figure 1 is a proximate supply curve.

The Demand for Oil

On the demand side, the economy prefers to buy low cost oil over high cost oil, and in general will buy more oil the lower is the price. Therefore, the demand for oil is not tied to an average price of oil, rather the demand for oil explains how the economy prefers different quantities of oil at different prices. If we aggregate the marginal benefits of each additional barrel of oil used, we create a demand curve for oil, which is a hierarchy of economic values of (needs for) oil. In a similar manner, we can create a hierarchy of the marginal beneficial uses of low or high EROI oil. Since the EROI implies a certain value, then we can conclude that high value oil uses can occur even if only low MERR oil is available, but low value oil uses can only occur if high MERR oil is available. Therefore, we can likewise create a hierarchy of the demand for oil based on the MERR. The lower the MERR, the less the economy will demand oil or oil substitutes. The higher the MERR, the more the economy will demand oil or oil substitutes. The MERR demand curve for consumers looks like a normal demand curve except that the MERR demand curves starts at a low MEORI and gradually increases. This is shown in Figure 2.

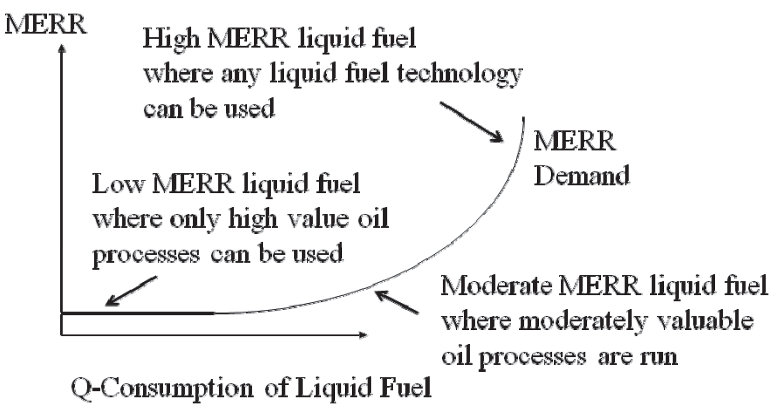

Figure 2. The MERR of oil that the economy demands.
The higher the MERR available, the more oil that an economy will want to use, all other factors staying the same.

Once again, Figure 2 is only a proximate demand curve as there is not a one-to-one correspondence between the aggregated MERR curve and the marginal benefit curve (pecuniary demand). It is possible to have situations where certain high MERR oil gives a high marginal benefit, or vise-versa. Nevertheless, Figure 2 does show how the economy might roughly organize its demand for various oil resources along the lines of MERR.

The Market Clearing MERR for Oil

If we put supply and demand together, we get a kind of MERR market. The MERR cost of oil will just meet the MERR benefit of oil at the market clearing MERR. See Figure 3. However, the market clearing MERR is only proximate as both the MERR demand and MERR supply are only proximate values in comparison to actual marginal costs and marginal values. Nevertheless, Figure 3 gives a good picture of how the physical economy works.

When we look at the MERR market, most high, pecuniary, marginal-value consumers will be able to consume low MERR oil, but most low, pecuniary, marginal-value consumers will not be able to consumer low MERR oil. Alternatively, high MERR oil producers will be able to sell their oil for a low MERR price on the market and keep the rent. Low MERR producers may not be able to sell their oil at a low MERR price. This creates a MERR oil-producer energy-surplus, and a MERR oil-consumer energy-surplus.

For example, if I own the East Texas oil field, and it can still produce oil at an average EROI of 20, (20 Btus produced for every 1 Btu used in production, refining and distribution) but the economy is buying and selling oil at the marginal tar-sands MEORI of say 5, then I get all the energy rent from the East Texas oil field. I will use that energy rent to build a big house, go on vacations and drive a big car all of which I receive from simply owning the field and without having to do any additional work. These splurges will in turn require energy use. The economy then, when they buy my East Texas oil, is forced to pay me for all that extra energy I use up on these luxury endeavors. The net effect is that society still pays a high energy price for low EROI liquid fuel based on the equilibrium MERR. It is as if the high MERR fuel were a low MERR fuel. The rent receiving energy producer, with high MERR fuel, spends much of his revenue on luxuries while non-rent receiving energy producers with low EROI tar-sands spend their revenue on necessary labor, capital and energy input costs. The net cost effect of obtaining energy is the same to the economy whether the cost of energy is to build luxury swimming pools for the rent receiving oil producers or build mining machinery for the non-rent receiving oil-alternative producers. Either way, there is less general goods and services for energy consumers.

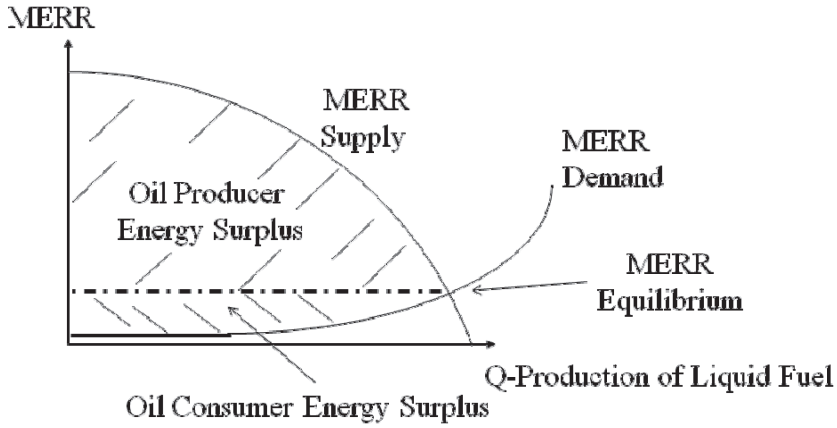

Figure 3. MERR supply and MERR demand on the same market.

It will be the case that because the energy owner spends his rent by splurging on all these goods and services from the general economy that that producer rent adds value to the economy. Nevertheless, the rent is unearned from any extra work or capital inputs or risk taking, and so society has to provide much goods and services to the producer for no additional productivity to the economy. For those who believe that allowing all that rent to the producer is fair or unfair, read Friedman and Friedman (1980) or Mander (2012). Nevertheless, no matter who gets the rent, the economy will then reduce its demand and production for normal goods and services as the equilibrium MERR goes down. Granted, having more EROI rent is better than having less EROI rent, all other factors the same, however, the market clearing MERR still represents a constraint on economic performance. Also over time, the MERR of the high EROI energy producer tends to decline due to exhaustion of any given field, and the MERR and the quantity of liquid fuels produced in the entire economy can decline due to scarcity of high MEROI oil sources.

Note, that the oil-producer and oil-consumer energy-surpluses on the MERR market do not correspond exactly to social/economic pecuniary value. That is, the energy-surpluses do not have a one-to-one correspondence between the area represented by the surpluses and the pecuniary value of energy. In general, the marginal value of each incremental increase in MERR is increasingly smaller. For example, the difference in value to society, or alternatively the difference in costs of production, of an energy source with a MERR of 50 as compared to an energy source with a MERR of 100 is small. However, the cost change and value change of going from a MERR of 5 to a MERR of 10 is large. Therefore, the area of oil producer and consumer energy-surplus as shown in Figure 3 is only a representation of a cardinal value not an ordinal value, i.e., greater area only infers a greater rank in value not an exact value increase.

The bottom line is the average MERR for oil production is not important. What is important is that the market clearing MERR, or a close approximation, is the MERR that determines the general market value and cost of oil. Therefore, anyone who wants to look at oil alternatives has to look at the MERR of that alternative in comparison to the market clearing MERR, such as for example in Pimentel and Patzek (2005). If an alternative has a MERR of less than three (3), then, as Hall, et. al (2009) suggest, it is not a viable alternative.

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IAEE Welcomes New Institutional Member: The Inter-American Development Bank

The Inter-American Development Bank (IDB) initiative, The Energy Visualization Database, provides an entirely new way of understanding energy. Created by IDB’s Energy Innovation Center, it shines a new light on the energy sector in the Americas. By conveying complex information in visually compelling ways, it helps scholars as well as policy-makers, and citizens develop a better understanding of the most important energy issues facing the region today.

This goes to the heart of open government and transparency—a core commitment of the IDB. The IDB’s Energy Innovation Center created the Energy Visualization Database as a tool that is practical, flexible, and easy to use. Built on Linked Open Data, it allows search engines to connect information in new and useful ways.

The database contains energy information, by fuel source and sector, on the IDB’s 26 borrowing countries plus Cuba. For comparison purposes, it also includes other major producing or consuming countries and regions. It identifies the leading industry players and institutions in each country and puts energy sector legal framework documents at your fingertips.

The Energy Visualization Database consolidates information sourced from the International Energy Agency and other institutions, as well as data gathered by IDB staff. It presents the information in accessible ways that make it possible to view the energy sector from different perspectives and quickly zero in on key challenges, pitfalls, and opportunities.