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An EROEI Review

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Introduction

I can be a very persistent (some might say hard-headed) person. If someone doesn't understand something that I think is important - and readily understandable - I will often continue to explain it until I am sure they either understand it and won't admit it, or they are incapable of understanding it. Because the topic of EROEI continues to be misunderstood (especially by those in the camp of "*the only thing that matters is economics*"), I will once again try.

Nate Hagens and I have discussed this subject at length on a number of occasions. He has written extensively on it, and I don't pretend that this essay can hold a candle to his *magnum opus* - and in my opinion best ever EROEI essay written at TOD - A Net Energy Parable - Why is EROI Important? (There's your dopamine fix for today, Nate.) This is just a little review of why I think EROEI matters.

EROEI Basics

There are a couple of important EROEI equations. The first is that **EROEI = Energy Output/Energy Input**. In other words, if we have to spend 10 BTUs (Input) to extract and refine 100 BTUs of oil (Output), then the EROEI is 100 to 10, or 10 to 1. Digressing for a moment, I recently had a conversation with someone who suggested that this is completely different from finance, where $105 returned on a $100 investment is a 5% return, not 105%. As I explained, the situation is the same. EROEI is a ratio. If I divide the $105 I get back from my $100 investment, then I get an output/input ratio of 1.05, but my return on investment is 5%. Likewise, if I input 100 BTUs and output 200 BTUs, the EROEI is 2 to 1, but the rate of return on my energy investment is 100%.

The second important equation concerns the net energy; that is how much energy was left after the energy input is accounted for. This equation is **Net Energy = Energy Output - Energy Input**. In our previous example, the net energy is (100 BTUs produced - 10 BTUs input), or 90 BTUs.

A couple of points here. First, the break even for EROEI is 1.0. In that case, you have input just as much energy into the process as you got back out. In some cases, that may make *economic* sense. For instance, if you input coal BTUs but got back out ethanol or diesel BTUs, then you have converted the coal into something of greater value. This is a source of the "*only economics matter*" argument. But this misses the larger point: EROEI is going to have a huge impact on economics, because it shows that in order to maintain current net energy for society, energy production must accelerate as EROEI declines. It isn't that planners are looking to EROEI to make their decisions; it is that a declining EROEI can indicate what those decisions will inevitably be.

However, if you input one transportation fuel and got another transportation fuel as output - as is mostly the case with corn ethanol (natural gas, diesel, and gasoline in; ethanol out) - then you are really just spinning your wheels. In a case like this, it would make more sense - given all of the negative externalities - to use the inputs directly as a transportation fuel. Funny that the shills will suggest that CNG infrastructure is lacking; these same shills are screaming for E85 pumps. Somehow countries like Brazil and India have managed to build out an impressive CNG infrastructure - yet we are being asked to believe this is not practical in the U.S.

Net Energy can also be negative and yet still make economic sense. But an important point here is that society can't run for long on an EROEI of less than 1.0 or on a negative Net Energy. Doing so is equivalent to withdrawing money from a bank - at some point you have to make some deposits - or at least stop the withdrawals.

The EROEI of Brazilian Ethanol

The case of Brazilian sugarcane ethanol deserves special mention. It is often quoted as having an EROEI of 8 to 1. I have even repeated that myself. But this is misleading, and I have to give credit to Nate for challenging me on this. The oft-cited Brazilian EROEI is really a cousin of EROEI. What is done to arrive at the 8 to 1 sugarcane EROEI is that they only count the fossil fuel inputs as energy. Boilers are powered by burning bagasse, but this energy input is not counted. (Also, electricity is sometimes exported, and credit is taken for this). For a true EROEI calculation, all energy inputs should be counted. So what we may see is that the EROEI for sugarcane is 2 to 1 (hypothetically) but since most inputs are not fossil-fuel based the EROEI based only on fossil-fuel inputs is 8 to 1.

That isn't to say that the 8 to 1 is an invalid measurement; just a different one. We need to bear that in mind when making comparisons. What is overlooked by touting the EROEI of 8 to 1 and skipping over the true EROEI is an evaluation of whether those other energy inputs could be better utilized. For instance, that bagasse that doesn't get counted could be used to make more electricity instead. Probably in the case of sugarcane, firing boilers is the best utilization. But the lesson from this digression is to be careful when people are touting very high EROEIs. They probably aren't really talking about EROEI.

Calculations

Now for some calculations that show the challenge of energy production if the EROEI of our energy sources continues to decline. In the early days of oil production, the EROEI was over 100. Now, it has declined to somewhere between 10 and 20. So let's look at the implications as the EROEI declines from 20. Here is what it takes to get 10 units of energy (**gross**, not net) at various EROEI values.

A 20 to 1 EROEI takes an investment of 0.5 energy units to get 10 out

At 10 to 1 it takes 1 energy unit to get 10 out

At 5 to 1 it takes 2 energy units to get 10 out

At 2 to 1 it takes 5 energy units to get 10 out

At 1.5 to 1 it takes 6.67 energy units to get 10 out

At 1.3 to 1 it takes 7.69 energy units to get 10 out

At 1 to 1 it takes 10 energy units to get 10 out

So, **dropping from an EROEI of 20 to 1 down to 1.3 to 1 takes over 15 times the energy inputs (7.69/0.5) to output the same amount of energy**.

Net Energy

But here is where many miss the plot. Look at the net energy.

At 20 to 1, an investment of 0.5 units got 10 back out. The net is 9.5 units.

At 1.3 to 1, it took an investment of 7.69 units to get 10 back out. The net is 2.31 units.

At 1 to 1, an investment of 10 units got 10 back out. The net is 0 units - all you have done is converted one energy form into another. (And of course at less than 1 to 1, you have actually lost usable energy during the process - clearly an unsustainable process).

If we wish to net 10 units, then at 20 to 1 we have to produce a total of 10.53 units (you are solving 2 equations here; EROEI = Out/In and Net = Out - In; For EROEI = 20, the solution is Out = 10.53 and In = 0.53). For an economy that requires 10 units of energy to run, we need an excess of 0.53 units to net that 10. (And if you want to pick nits or do the calculation yourself, 10.53 is rounded from 10.5263157894737).

Now drop the EROEI to 1.3. We now have to produce a total of 43.33 – an excess of 33.33 - to get the 10 we need to run the economy (Out = 43.33, In = 33.33; EROEI = 1.3 = 43.33/33.33; Net = 10 = 43.33 - 33.33). Thus, **the requirement from dropping the EROEI from 20 to 1 down to 1.3 to 1 requires a production excess of (33.33/0.53), or over 60 times the high EROEI case**.

Running Faster to Stay in Place

Therein EROEI illustrates clearly the challenge we face. As EROEI declines, energy production must accelerate just to maintain the same net energy for society. At an EROEI of less than 2, the amount of energy required to net our current energy usage far exceeds even the most optimistic proposals for our production capacity. Others have concluded much the same: The *status quo* can't be maintained if EROEI continues to decline. But by understanding the implications of EROEI, we can see this coming, and perhaps(?) start to change the *status quo*.

Yet I say with confidence that some will comment and still not grasp this concept. If they did, they would understand why a falling EROEI is reason for concern - and that concern is why I can be persistent over explaining the implications.

Previous Essays on EROEI/EROI

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The Energy Return on Time
Peak Oil - Why Smart Folks Disagree - Part II
Ten Fundamental Truths about Net Energy
The North American Red Queen - Our Natural Gas Treadmill
Energy From Wind - A Discussion of the EROI Research

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