Surplus Energy Economics
A brief guide

SEEDS

Surplus Energy Economics Data System

Data coverage

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Introduction

The central finding of surplus energy economics – a conclusion outlined in this Brief Guide, and discussed in far greater detail in *Life After Growth* – is that more than 200 years of growth are over, because the central economic dynamic of surplus energy has entered decline.

With the world economy seemingly recovering, albeit pretty gradually, from the 2008 crash, this may seem a strange conclusion. Energy scarcity, too, might seem a surprising point of view given the publicity that has attended the development of shale oil and gas in the United States.

The shale point is easily answered. So much data has now emerged from shale operations in the US that the subject is well on the way to being uncontroversial. The promises that the advocates of shale have made are proving false. Shell (which has taken a US$2bn write-down against the value of its shale acreage), and Exxon Mobil (whose CEO, Rex Tillerson, has said that "We're losing our shirts [on shale gas]"), are amongst disillusioned former enthusiasts for shales who are coming round to the view that, far from offering America energy independence, shale operations are, at best, economically marginal.

The main reason for this is that the output from shale wells falls away dramatically after production start-up. The Barnett shale experience – in which output declines by 61% in the first year of operations, 32% in the second year, 24% in the third, 18% in the fourth and 15% in the fifth – typifies this critical weakness. On this profile, initial production of 1,600 million cubic feet of gas per day (mmcf/d) drops to 320 mmcf/d in the third year, and to just 220 mmcf/d in the fifth. Once all remaining well locations have been drilled (which is likely to have happened by 2018 at the latest), shale production will enter a terminal decline.

Though put forward with greater objectivity, the case for global economic recovery is equally misleading. If, for example, the US$16 trillion American economy "grows" by 2.5% this year, that expansion will be *far less* – at just over US$400bn – than the US$900bn that the Fed will have pumped into the system through QE.

More critically still, most developed economies are running extraordinarily low interest rates. Though this is well known, its implications are widely misunderstood. In the United Kingdom, for instance, a nominal policy rate of 0.5% means that savers are losing 1.5% annually after deducting inflation. *An economy in which real interest rates are negative is incapable of capital formation*.

In other words, America, Britain, the Eurozone countries, Japan and many others are keeping their economies going by destroying their capital bases. An economy which has to keep pumping money into the system, which cannot invest and which is consuming its capital base, is not a recovering economy.

It is an economy in decay.

The brief discussion which follows explains why this is happening. The accompanying publication – *Energy Returns* – goes on to look at what investors can do about it.

Surplus Energy Economics
A brief guide

Surplus energy economics is a new approach to economic evaluation which recognises that the economy is an energy dynamic, not a monetary construct.

This new methodology explains that we need to think in terms of two economies, not one. The "real" economy is a surplus energy equation, which is paralleled, for convenience, by the "financial" economy of money and debt.

It is important to recognise that a "commonality of energy" links all forms of activity, and embraces nutrition and labour as well as more 'obvious' forms of energy such as oil, gas, coal and renewables. Direct numerical conversion can be undertaken between all forms of energy.

Before the discovery of farming, there was no energy surplus, and no economy, since the energy obtained by each individual through nutrition was wholly expended in obtaining his food. By capturing scale efficiencies, and by harnessing the labour of animals, farming generated the first energy surplus, thus creating the economy. That this economy was rudimentary reflected the narrowness of the surplus energy margin.

The scale of the surplus, and hence the complexity of the economy and of society, were enhanced enormously by the discovery of the heat engine, which enabled mankind to access enormous reserves of stored (fossil) energy. This applied huge leverage to the previously-constrained capabilities of human labour.

EROEI and the energy cost of energy

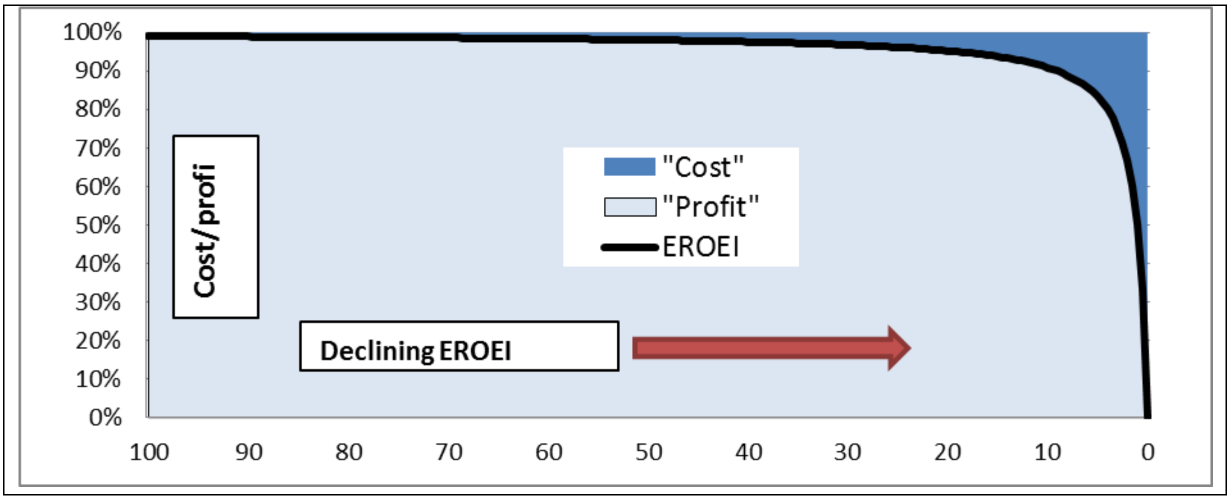
Of course, energy cannot be extracted (or otherwise accessed) at zero cost. The development of an oil field, for example, requires steel and other materials whose provision requires the use of energy. An equation therefore exists between energy accessed and energy consumed in the access process, and this equation is critical, because *it quantifies the surplus energy available to the economy*.

This equation is known as the Energy Return On Energy Invested (EROEI), and is expressed as a ratio. For example, if 50 units of energy are accessed and 1 unit is consumed in the process, the EROEI ratio is 49:1.

EROEI ratios are plotted on a "cliff chart" (fig. **1**), on which the EROEI ratios on the horizontal axis correspond to the "surplus"-to-"cost" percentage split shown vertically. Thus, at an EROEI of 49:1, the "cost" element is 2% (1 divided by 50) and the "surplus" is 98%. At an EROEI of 24:1, the cost-profit split is 4:96, and at 9:1 it is 10:90.

As fig. 1 shows, *the relationship between EROEI and the cost/surplus split is non-linear*. Moving from an EROEI of 100:1 to one of 30:1, for example, increases the cost element only modestly, from 1.0% to 3.2%. Below an EROEI of about 15:1, however, the cost element escalates, from 6.3% at 15:1 to 9.1% at 10:1 and 16.7% at 5:1.

Fig. 1: EROEI cliff-chart



In Surplus Energy Economics research, the inverse of the EROEI equation is known as the Energy Cost Of Energy (ECOE). ECOE functions as a levy on the economy and, since this has a critical bearing on the quantity of surplus energy, it is the progression in ECOEs that determines prosperity.

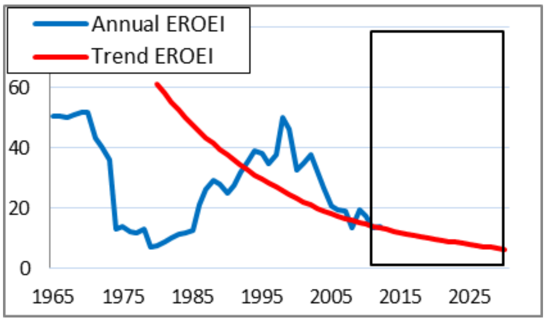
Cost escalation is under way

Analysis undertaken using SEEDS (the Surplus Energy Economics Data System) suggests that the global average EROEI has been deteriorating (and the ECOE rising) since the 1960s. Until comparatively recently, this deterioration has not been of major economic significance. The global average EROEI is estimated to have declined from 55.7:1 in 1980, and 37.2:1 in 1990, to 24.3:1 in 2000, but the effect of this was modest, increasing the average ECOE "levy" on the economy from 1.8% in 1980 to 3.9% in 2000. Given the propensity of energy markets to extreme short-term swings, this long-term trend has tended to go largely unnoticed.

Latterly, however, the energy cost of energy has taken on far greater significance as average EROEIs have moved inexorably closer to the cliff-edge. By 2013, an EROEI of 13.6:1 meant that the global average ECOE had risen to 6.8%, a real cost increase of 50% over a decade. By 2020, the average EROEI is expected to have fallen to 10:1, equating to a further increase of 32% in the real cost of energy in the space of just seven years.

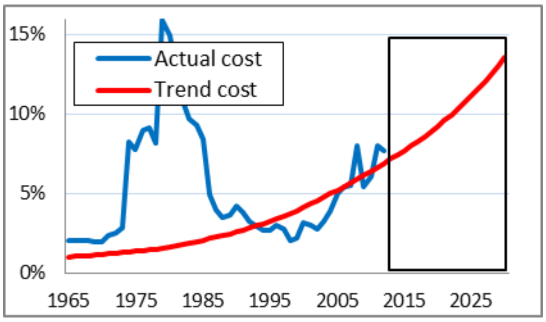
This trend is already having an unmistakable impact on the economy. The escalation in crude oil prices, dismissed by some observers between 2000 and 2008 as mere a function of economic and demand growth, can no longer be disregarded, given that prices have not retreated in the face of the biggest economic slump for at least eighty years. It should be regarded as highly noteworthy that the post-2008 economic crisis did *not* result in the kind of slump in crude oil prices which has occurred routinely after each of the smaller economic setbacks of earlier years. From a level of US$71 per barrel in 2007 and US$97/b in 2008, crude prices averaged US$105/b in 2012.

2. Trend EROEI*



*Energy Return On Energy Invested

3. Trend ECOE**



**Energy Cost Of Energy

The enormous quantities of liquidity sucked out of the energy importing economies (which include China as well as the West) by escalating energy prices played a crucial (though often under-estimated) role in creating the financial and economic crises of 2007 and 2008.

The very sluggish pace of the subsequent recovery – a recovery so dependent on cheap money that it may not deserve the name at all – owes a great deal to the escalating real cost, not just of energy itself, but of energy-intensive products including food, minerals and plastics.

In figs. **2** and **3** , the long-term trends in EROEIs and ECOEs are plotted against shorter-term oscillations. Fig. 3 shows that the steady decline in the global trend EROEI shown in fig. 2 is only now beginning to have a very material effect on the energy cost of energy.

No more giants – the end of an era

The trend in EROEIs should not be regarded as surprising, as the cost-effectiveness of energy access has been subject to steady erosion for as much as 50 years. In the pioneering days of the petroleum industry, huge fields could be accessed using rudimentary, low-cost techniques. As the super-giant finds (such as the Al Ghawar field in Saudi Arabia, discovered in 1948) have given way to ever smaller, more challenging and costlier developments, there has been a steady deterioration in oil industry EROEIs, with much the same happening in the natural gas and coal industries. Today, the petroleum industry routinely develops low-margin prospects such as tar sands and shale formations, resources which the industry of the past could afford to ignore.

In retrospect, the failure of the Caspian to yield huge oil discoveries marked the end of "super-giant" era. To be sure, unexplored regions may yet be found to contain very large amounts of oil and gas, but ultra-high development and operating costs will ensure that any such finds *cannot* repeat the economic largesse of Al Ghawar.

Some have argued that the application of fracturing ("fracking") technology to "tight" reserves of oil and gas contained in shale formations offers a solution to the escalation in energy costs. Shale development has indeed boosted American oil and gas production, but it has done so only on a short-term basis, and at enormous cost.

The reason for the failure of shales to live up to their much-hyped early promise is simple – output drops away alarmingly after initial production, with declines of 80% over just three years by no means untypical. These rates of decline put the industry on a "drilling treadmill", in which ever more wells have to be drilled to stave off a rapid fall in production. Once well location saturation is reached – which is likely to happen by 2018 at the latest – volumes will slump, and the "shale revolution" will be over.

Just as the fossil fuel industries are moving into ever more marginal territories, new energy sources (including wind and solar power) are being developed, again at EROEIs far lower than those enjoyed in the past.

The economic significance of declining global EROEIs is that this trend has now reached the "cliff edge" portrayed in fig. 1. Indeed, the escalation in ECOEs has begun to have a profound effect on economic prospects. This is not surprising, as energy costs are critical to a series of industries, including the supply of minerals, food and water. Minerals production is highly mechanised and energy-intensive, as is agriculture, with the added proviso that modern farming relies on huge quantities of energy-derived inputs, most notably fertilisers, as well as costly transport, processing and distribution.

The subservience of money

Money was created as a quantification of the energy surplus economy. In the agrarian era, all monetary transactions involved the sale and purchase of the products of human labour, be that labour past (purchasing an existing item), present (paying for work to be done) or future (commissioning for an object or task). This linkage between money and work remain fundamental today, except that vastly more work is done now by energy inputs than by human labour.

From its beginnings as a more convenient replacement for barter, money has proved a useful medium for the exchange of real goods and services, and can also be used to manage cyclicality in the real (energy) economy. Properly considered, money is the *language* in which economics is expressed, but it is not the *substance* of the economy. Ultimately, the economy is governed by the demonstrable laws of thermodynamics, not the flawed and artificial "laws" of economics.

It will be obvious that money – and *fiat* currencies in particular – have no intrinsic worth. Any value that money has derives solely from its role as a "claim" on the goods and services produced by the real economy. Indeed, money is a human artefact that can be created, destroyed and manipulated at will. The economy has survived the extinction of more than 3,800 systems of paper money. Money is an effective unit of account, but it is poor store of value (the American dollar, for example, has lost 87% of its purchasing power over the last 50 years).

One virtue of money is that it enables *anticipatory* transactions to take place. Investment, insurance, lending and borrowing are all examples of anticipatory transactions. All such transactions require assumptions about the future, and the anticipatory virtue can become a vice when such assumptions prove to be inaccurate. Ultimately, money functions as a "claim" on goods and services, and debt, as a claim on future money, is a claim on future goods and services.

Problems arise when claims are created that exceed the deliverability capabilities of the real economy of the future. The explosion of debt during the years before the banking crisis showed this process in action.

The dangers of divergence

Problems arise when the "financial" economy is allowed to out-grow the "real" economy, because this process results in the creation of "excess claims".

The experience of Portugal shows a marked divergence between the financial economy (shown in blue) and the real economy (red). At the end of 2012, Portugal's cumulative "excess claims" totalled US$780bn, or 319% of GDP.

Barring a wholly implausible upturn in the real economy, these excess claims *must* necessarily result in one or more forms of "value destruction", since Portugal's financial economy has created claims that the real economy cannot meet.

The far more prudent conduct of the Dutch economy is in stark contrast to the situation in Portugal.

Fig. 4: Portugal

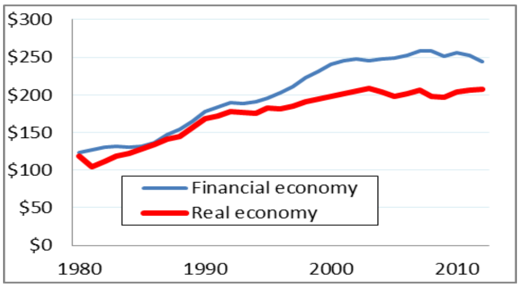
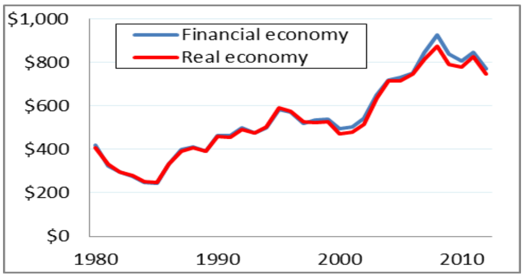


Fig. 5: Netherlands



Source: SEEDS. Both charts are denominated in 2012 US$ converted at PPP rates.

Two critical thresholds

When looking at EROEIs (and their energy cost corollaries), two thresholds need to be borne in mind. The lower of these is the *viability threshold*, which probably stands at an EROEI of about 6:1 (so an ECOE of around 14.2%).

The higher benchmark is the *investment threshold*, which stands at about 14:1. Once the energy cost "levy" reaches the 14:1 corollary of about 6.7%, all remaining surplus energy is required for current consumption, so the economy ceases to be capable of investment. Breaching the investment threshold means that, whilst an economy can continue to function, it is incapable of capital formation, and cannot replace wasting assets.

An economy which has fallen below the investment threshold will necessarily be characterised by certain distinctive features.

Most notably, it will be characterised by negative real interest rates, which are the mechanism by which a sub-threshold economy concentrates resources on near-term needs whilst simultaneously starving off investment. A sub-threshold economy is also likely to engage in habitual borrowing (including borrowing from trade creditors) in an endeavour to maintain viability. The money supply can be expected to increase, in part in an effort to stave off the GDP effects of high ECOEs. Individuals are likely to find their disposable incomes squeezed by escalation in the real costs of energy itself and of energy-intensive commodities.

Examples of economies whose EROEIs are now below the 14:1 investment threshold include the United States (12.7:1), France (10.3:1), the United Kingdom (9.1:1) and Germany (8.2:1). Countries with strong resource positions, of course, are in the reverse position, benefitting from the rising global energy cost of energy. Examples include Australia and Norway as well as the Middle East oil exporting countries.

The developed economy which should cause particular concern is that of Japan, whose EROEI is estimated at 7.1:1. This interpretation largely explains the Abenomics policy of borrowing, devaluation and money-printing, all of which – together with negative real interest rates – are the predictable characteristics of an economy which has fallen perilously close to the viability threshold.

The inevitability of value destruction

If negative growth is one problem posed by a steady deterioration in EROEIs, the other is the accumulation of the “excess value” which is created when the financial economy is boosted artificially to levels far above underlying, “real” economic performance. By definition, claims which cannot be met must be destroyed, which means that a period of significant excess claims creation has rendered large-scale “value destruction” inevitable.

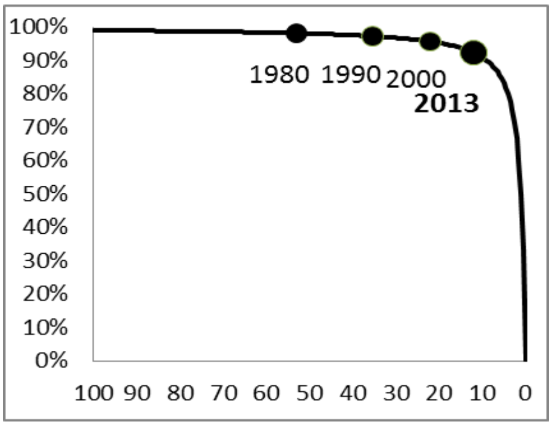
In large parts of the world, a number of factors have contributed to the creation of “excess claims”. Globalisation, in which borrowing was used to enable productive activities to be offshored *without a corresponding decrease in consumption*, has been one significant factor. Another has been a persistent policy of cheap money, in which real interest rates have been kept far too low for far too long. A third has been the widespread acceptance of borrowing as a way of life, with inflated property prices used as a conduit for channelling debt to consumers. Governments have discovered that, since GDP is a measure of *flow* which does not incorporate balance sheet changes, borrowing can be used to boost apparent prosperity.

SEEDS modelling puts the end-2013 total of “excess claims” at US$63.2 trillion, equivalent to 80% of GDP, or 85% of the (smaller) real economy. This overall number masks significant differences between countries. The countries most exposed to value destruction are all European - Greece (with excess claims equivalent to 361% of GDP), Portugal (336%), Hungary (263%), Spain (258%), Italy (211%), Slovakia (209%) and Ireland (204%). Together, these seven countries have excess claims totalling US$10.7 trillion, yet their aggregate GDP is just US$4.4 trillion.

Serious though these numbers are, these countries account for only 5.5% of global GDP, so their aggregate problems are containable. Of greater concern are the major economies which face value destruction. Excess claims total 186% of GDP in India, 177% in the United States, 158% in Japan, 156% in the United Kingdom and 154% in France. Here, it is necessary to discriminate between countries where the economy is relatively resilient (as in the United States) and those in which the economy is weakening sharply (examples include the United Kingdom and, of course, Japan).

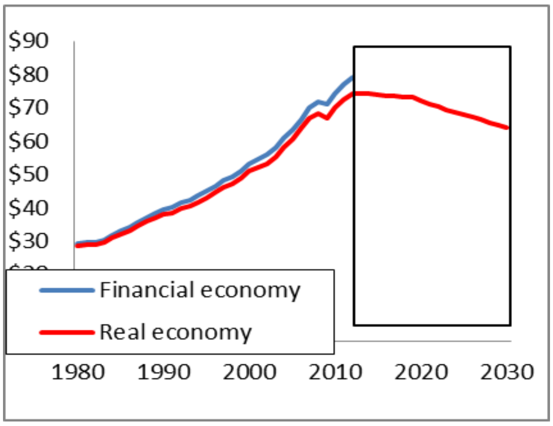
Selected forward projections

6: Global EROEI evolution*



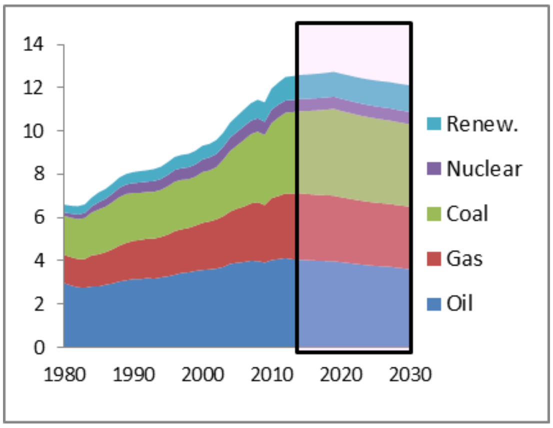
*Energy Return On Energy Invested

7. Global economic outlook**



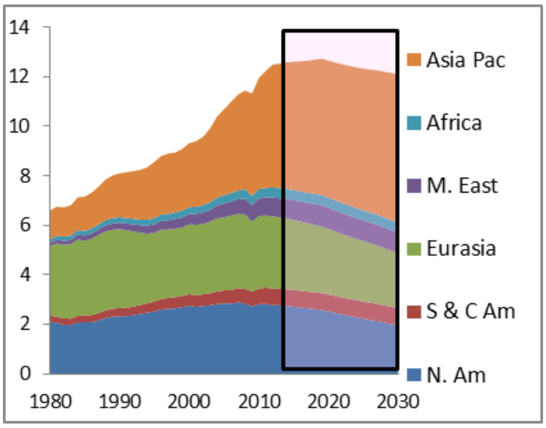
**US$ trillion, 2012 values

8: Energy consumption by fuel type*



*mmtoe

9. Energy consumption by region*



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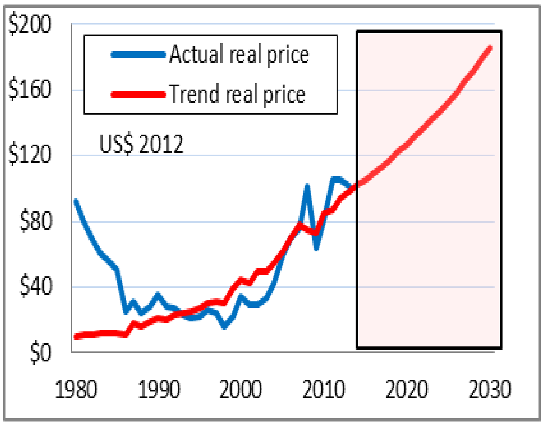
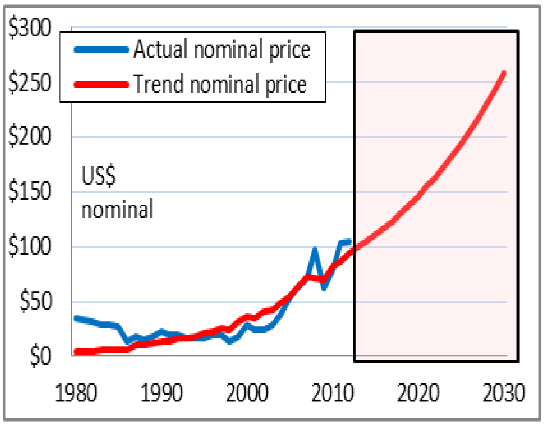
10: Real oil prices*



*US$ per bbl

11. Nominal oil prices*



*US$ per bbl