Sustainability and economic growth are not mutually exclusive

Peter Baker's book, The Jolly Pilgrim, called for a longer term view of civilisation. In this follow-up article he argues that environmentalists should be more imaginative about the possibilities for economic evolution

In the past two centuries, human civilisation has experienced an unprecedented increase in global gross domestic product (GDP) – economic growth associated with a precipitous rise in material prosperity, which has left sixth sevenths of Earth's population enjoying living standards beyond those of all but a small minority who lived prior to the Industrial Revolution.

That economic transformation continues to lift tens of millions of people out of absolute poverty each year, and further economic growth is a prerequisite to every proposed strategy for making absolute poverty history. The physical manifestations of all this growth, however, have had well-documented side effects on our planet's ecosphere, in the form of pollution, ecosystem degradation and the release of heat-trapping gases.

Concern regarding where all this will lead has prompted the astrophysicist Tom Murphy – a prolific blogger on energy fundamentals – to calculate that if civilisation's energy use were to continue increasing at its recent trend rate (between 2% and 3% per year), we would be using every watt of sunlight hitting the Earth in 275 years, every watt released by the sun in 1,350 years, and all the energy in the Milky Way galaxy within 2,450 years.

Striking a more populist tone, Dr Albert Bartlett, in his lecture series spread around the world via YouTube in *The Most Important Video You Will Ever See*, uses the exponential function to demonstrate how open-ended increases in anything from population to hydrocarbon use soon sends them beyond physically feasible limits. The conclusion is that open-ended economic growth intrinsically leads to open-ended ecological side effects, that such growth is therefore unsustainable, and that civilisation's current golden age of material prosperity is built on a house of cards.

That conclusion is a fallacy. It is a fallacy based partly on a misunderstanding about what economic growth means and partly on a presupposition that the nature of future economic growth will predictably mirror that of recent history. But at its root is the false assumption that an intrinsic link exists between the energy use of civilisation (which is an objectively quantifiable feature of physical reality) and global GDP (which is a subjective human social construct).

This fallacy has been unthinkingly swallowed by too many people. It has had a negative effect on the quality of debate regarding the environmental consequences of the changes sweeping the human world, and it hampers our ability to think clearly about how the improvements in quality of life achieved during recent history can be captured for posterity in an environmentally sustainable manner.

What is unquestionably true is that anything tangible or entropy-producing (and that includes civilisation's energy use, its physical manifestations and the global population) cannot grow exponentially, for long, in a finite universe. But global GDP does not measure those things – it measures the market 'value' of goods and services in a country's economy over a given period. It is primarily a mental, rather than a physical, thing.

Today's economic realities as a phase in history

The cultural setting which has given rise to this fallacy is a period of history during which civilisation's energy consumption has closely (although not precisely) tracked GDP growth.

Before the Industrial Revolution, civilisation's energy use was more or less proportional to population (so the energy density of economic activity was basically constant). However, the phase of economic history inaugurated by the industrialisation of western Europe (and followed by that of North America, East Asia, Latin America, China and India etc) has been characterised by huge rises in the energy appetite of civilisation's physical artefacts and hardware. This has taken the form of the mechanisation of manufacturing, the construction of a vast transport infrastructure, massively improved building stock and the host of machines which have replaced manual labour.

But that industrialisation is a one-off phase of history. Once everybody has a car (perhaps three), mod cons from dishwashers to televisions, along with good living arrangements with heating and/or air conditioning systems, rises in per capita energy consumption will start trending towards zero. In fact, as the ancient civilisations of China and India undergo this physical upgrade, we may now be living through the biggest proportional increase in energy consumption civilisation will ever see.

To extrapolate forward recent exponential increases in per capita energy use is to predict that everybody will have cars which are twice as fast, eat hamburgers which are twice as big and own washing machines that are twice as energy-hungry. Letting the compound exponentials run forward another century would see everybody on Earth with their own rocket ship and personal robot fleet.

The energy density of economic activity

Per capita energy use in the developed world is already stabilising. According to the US Department of Energy, between 1980 and 2006, per capita energy consumption fell by 3% in North America and by 8% in the former-USSR countries. It rose by 8% in Europe, although this was accompanied by a far larger increase in economic activity.

During that 1980 to 2006 period, the energy intensity of each unit of GDP fell by 42% in the USA, 42% in the UK, 31% in the Netherlands and 20% in France. Since 1994, it has fallen by 32% in the former-USSR countries. These numbers are distorted by the relocation of energy-intensive industries to the developing world. Despite that, the overall energy intensity of economic activity, globally, fell by 14% between 1994 and 2006. None of this means we don't have an energy crisis, but it is consistent with the decoupling of GDP from energy consumption and the levelling off of overall energy consumption, once industrialisation has taken place.

The main driver for contemporary increases in global per capita energy use is the industrialisation of the developing world. In the coming century, the main driver will be the industrialisation of those societies still currently mired in penury – increasingly concentrated in sub-Saharan Africa and south and central Asia.

It's critically important that those areas undergo this phase of economic evolution, for it involves not only massive increases in per capita GDP, but the stabilisation of population and a transformation in human welfare outcomes, which are the whole point of 'development'. Once this process is complete (which could perhaps happen within as little as a century from now) we can focus on the central long-term issues of bringing down humanity's environmental impact and constructing a sustainable-energy infrastructure.

Three questions are implicit to this state of affairs:

1) What will the energy consumption of civilisation be when it has completely industrialised, and has a stable or declining population?
2) What will the renewable energy infrastructure to run such a civilisation look like and how difficult will it be to construct?
3) How much ecological damage will be done between now and such a renewable infrastructure being put in place, and what steps can be taken to mitigate that damage?

Debates regarding all three questions are, quite properly, raging. However, for the purposes of this article, we'll concern ourselves with how the evolving character of economic activity means that the world's GDP can continue to rise, even while its energy consumption is stable or declining.

Rising global GDP, with steady-state energy consumption

To understand the possibilities of a civilisation run via a sustainable, steady-state energy infrastructure, we must bear in mind its limitations: crucially, the limits of the energy efficiency of physical devices.

Currently, overall energy efficiency in the developed economies improves by about 1% per year (allowing us to light more homes and manufacture more goods with a fixed energy income). Refrigerators now use half the energy they did in the 1970s. Cars travel twice as far per unit of petrol (and emit 1% as many smog-causing pollutants). Jet engine efficiency has nearly doubled.

However, the laws of physics – critically the second law of thermodynamics – impose hard limits on how far such efficiency improvements can take us. For example, heat engines (which include the internal combustion engine and the turbines in most power stations) are already within a factor of two of hard theoretical limits to efficiency. Refrigeration systems are within a factor of two to three of such limits. The best LEDs are within a factor of three. Electric motors, pumps, battery chargers and hydroelectric power plants already operate at near perfect efficiency (often around 90%). Furthermore, heating a fixed physical quantity of material (be that a meal-sized portion of food or the water for a shower) will always involve a fixed quantity of thermal energy.

In the coming centuries, market forces and engineering ingenuity can bring down the energy efficiency of civilisation's physical hardware by maybe a factor of two. But total energy consumption (assuming a certain standard of living) can never be brought below a level proportional to the global population. Physical devices will, of course, improve in numerous other ways (today's cars are better than those of the 1970s for reasons other than better energy efficiency) and their GDP value will consequently continue to rise.

However, long-term continued GDP growth, after energy efficiency, and consumption, have plateaued, implies:

1. A decreasing energy intensity per unit of GDP.
2. That the non-negotiable, energy-consuming parts of the economy (e.g. farming and manufacturing) will come to constitute an ever smaller proportion of global GDP.

The next phase of economic history

These are precisely the trends now playing out in the advanced economies. To make sense of why and how, it is useful to think in terms of the three-sector hypothesis of economic activity, dividing it into primary (extraction of raw materials), secondary (manufacturing and industry) and tertiary sectors (services, education, healthcare, the arts etc).

In all pre-modern economies the primary sector overwhelmingly dominated. Following industrialisation, the second sector comes to predominate (think: Russia in the mid-twentieth century, or China now). But as economies mature the tertiary sector (sometimes further divided into quaternary and quinary – distinctions irrelevant to this analysis) ultimately comes to dominate, and that tertiary sector is not only less energy intense than the first two, it doesn't require increased energy consumption to grow.

The clearest example of this process of economic evolution is in the most fundamental part of the primary sector: farming, which has already changed in ways that would have been inconceivable 300 years ago. In medieval Europe, agriculture overwhelmingly dominated the economy. By the 1970s it had fallen to 6% of Europe's GDP. It's now less than 2%.

Equivalent trends – driven by ever greater mechanisation and spiralling technological competence – are gradually playing out in the secondary sector. Factories are slowly evolving into places where people sit behind screens, making use of computer aided design and 3D printers, and grow materials with pre-specified properties using genetically engineered micro-organisms. The effects of this economic evolution will include lower inputs of labour, better and more innovative products, less waste, lower environmental impact, and the secondary sector constituting an ever smaller proportion of total GDP.

Even in Germany – the quintessential advanced industrialised economy – manufacturing is only 28.1% of GDP, while agriculture is 0.8% and the tertiary sector 71%. Overall, in 2012, the primary and secondary sectors came to just over 37% of the global economy, while the tertiary sector made up 62.9%. Despite their declining impact on GDP, the physical artefacts of civilisation will continue, for the most part, to improve in quality (and, for some time, in terms of absolute scale), even while the largely non-physical tertiary sector increasingly dominates overall economic activity.

Economic evolution and the world around us

Given the early twenty-first century context in which this article is written, such an economic evolution may be difficult to envisage. So, for a sense of what such transformational changes in the significance of an economic activity mean over long time frames, consider salt.

Economically, salt was central to the development of civilisation. Enormous efforts were made to produce and distribute the stuff. China's Sung emperors partly funded their empire through a salt monopoly. Salt was a key trade good sustaining the Hanseatic League in the fourteenth and fifteenth centuries. Medieval camel trains would spend months carrying blocks of it across the Sahara. Yet today salt is almost universally accessible, a trivial part of the global economy and so cheap it's practically free.

Inhabitants of advanced economies may have noticed how, over time, more and more of their fellow inhabitants work in third-sector activities, such as the law, human resources, healthcare, education, information technology, the arts and other 'ephemera'. One hundred years ago it's likely those people would have worked in factories. Three hundred years ago they would almost certainly have experienced the unforgiving grind of subsistence agriculture.

In the future, economic activity will become ever less dominated by making things and moving them around, and ever more dominated by people teaching, healing, entertaining and providing other services to one another. If that's not social progress, I don't know what is.

Observers of pop culture may have noticed the fad for celebrity chefs and the associated phenomenon of haute cuisine becoming increasingly mainstream – an example of the same basic activity being performed with increasing refinement and skill: (arguably) improving life quality and (certainly) being assigned a higher GDP 'value', even while using up no substantially greater amount of physical energy. Get used to that sort of thing.

The exponential function, social constructs and spaceship design

Those with an eye on the inexorable nature of the exponential function may note that, while the energy density of economic activity can forever trend downwards, it can never reach zero. Even the most brilliant bionic internet entrepreneur, using the most sophisticated quantum computer, providing the most specialised high-value services to clients around the world, still needs to eat, heat water for tea and power their hardware. GDP cannot, therefore, grow exponentially *forever*.

Bear in mind that GDP ultimately measures the utility of a good and service to humans, so a practical restatement of the above hypothetical is that – assuming a certain steady-state energy consumption – a time will come when no one can think of any practical way of innovating to make things better (without using more energy).

Even if (some time in the next thousand years) a significant proportion of human economic activity moves off-planet and taps into the energy resources available there, the limits inherent to a finite universe (outlined by Professor Murphy and summarised at the top of this article), will ultimately become pertinent – even using the power of a star or a galaxy, there will still be some maximum sustainable energy consumption available to construct, for example, spaceships.

In such a maximum-sustainable-energy scenario, the GDP 'value' of such a civilisation's spaceships will ultimately become proportional to the artistry of their spaceship design.

Remember: 'GDP' is a social construct, dreamt up by humans because it's useful. It was devised as a proxy for economic development in 1932 and only became the main tool for measuring the size of economies in 1944.

So is there some ultimate theoretical limit to spaceship innovation? Probably. Would a civilisation which had reached such a limit have use for GDP as a conceptual tool in assessing its wealth and economic activity? Who knows. However, at this point we're speculating about the limits of a far-future civilisation in a way that holds few lessons for contemporary energy policy.

Physical commodities: a limiting factor to economic evolution?

While energy consumption is the global economy's most fundamental footprint on physical reality, another cited reason for a ceiling on economic growth is the limitations of physical commodities (minerals, metals etc) and, of course, fossil fuels. At this point, Paul Collier, Director of the Centre for the Study of African Economies at Oxford University, has this to say:

'The world has sustained overall economic growth, albeit with hiccups, for two centuries yet virtually no single economic activity has been sustained. Growth has not been a matter of everything getting bigger. Rather, it has been like running over ice floes: if you stand still you fall in and drown; if you keep going – even if each individual step is unsustainable – you survive.'

Civilisation does not require unlimited use of any particular physical commodity in order to sustain itself. In medieval Britain, the government was worried that it would run out of yew trees for longbows. But thanks to technology, we can now shoot people without yew wood. In the nineteenth century, Britain was worried about running out of tall trees for ships' masts, but at a certain point ships no longer needed trees. The high-value natural assets of the nineteenth century were nitrates, which are far less valuable now. The world value of commodities can be tracked for over a century and there is little basis for concluding that prices are rising.

Indeed, other than for oil they may well be falling. Whether the current high prices for hydrocarbons will be sustained as part of a prelude to peak supply (or be one more blip as the forces of supply and demand play out) is a moot point. But nothing will accelerate the development of alternatives to current energy sources more effectively than sustained high prices for them.

To quote Sheikh Zaki Yamani, the former Saudi Oil Minister, 'The Stone Age didn't end because the world ran out of stone.' Likewise, the Age of Oil will not end when the world runs out of oil. Technology will move on. Even fossil fuels, despite civilisation's uncomfortable recent addiction to them, are not irreplaceable. In the most developed economies of North America, Europe and Japan, consumption of oil has already peaked, due to stabilising demographics, increased efficiency and substitution for other energy sources.

Earth's fossil fuel endowment is sometimes contextualised as a one-off, irreplaceable gift of nature. Even if that's fair, given that fossil fuels have been used to help lift billions of people out of poverty, create a planet-spanning technological civilisation, and multiply humanity's understanding of its universe by several orders of magnitude, we've hardly wasted them.

Possibilities for future economic evolution

In my view, the irreplaceable-gift position has a hint of presentism about it. After all, it was the conditions of the eighteenth century – the result of thousands of years of cultural evolution – that put human civilisation in a position to make use of fossil fuels in the first place. Fossil fuels didn't produce cleverness and industry, cleverness and industry empowered us to dig up and burn fossil fuels. They have, in turn, created the prerequisite conditions for constructing a renewable energy infrastructure which can power civilisation for millennia to come.

The world's economy will keep evolving. The throw-away culture of today will be brought to an end, as market forces kick in to deal with the developing realities of the availability of physical commodities. The recycling systems being set up in today's advanced economies will one day be seen as crude prototypes in a world where automated recycling systems strip down physical goods to their component materials, and feed them back into solar-powered manufacturing units.

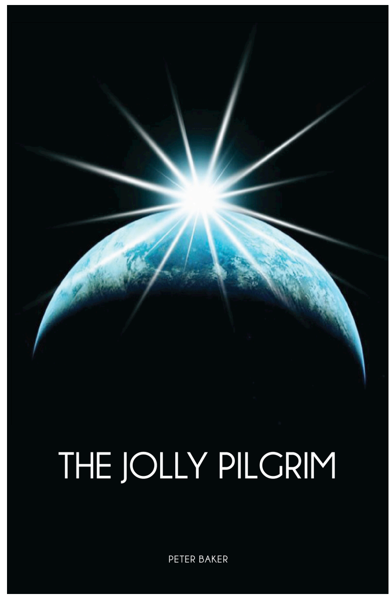
The limiting factors to the scope of the physical civilisation we can build are ingenuity and imagination. These are qualities which humans possess in abundance.

Ultimate character of a long-term sustainable civilisation

As I repeatedly stress in my book: the world around us (including the nature of its economy) is just a phase in history. Civilisation in the grandest scales is not circular, but linear. Not long ago, the idea that only 1 in 100 people would need to work in agriculture in order to feed everybody would have struck most people as absurd.

Our ultimate guide to the physical characteristics of a long-term civilisation is nature. She provides the exemplary model for a self-sustaining physical system, powered by the sun. If nature can do it, so can we.

I'm no better than anyone at predicting which technologies will take hold and prove themselves in the future. But there is nothing unfeasible about a world in which all transport is electrified, where the planet is criss-crossed by super-fast maglev trains moving in partial vacuums, recycling systems are elegant and cost-effective, people live in eco-friendly cities with access to a health and educational infrastructures far beyond those we know, and the whole arrangement is powered by vast solar arrays in the Sahara, and Earth's other deserts.



Anything could happen next

None of that is contrary to the laws of physics. None of it is unreachable. None of it requires technology that isn't feasible within foreseeable timeframes. It is just several stages of cultural and technological evolution beyond where we stand today. The GDP of such a world's physical and non-physical systems will be astronomical by our twenty-first century standards. Its energy consumption and environmental impact do not have to be.

If you think such a world sounds like science fiction, remember that today's world would have seemed as such to those living 300 years ago. If you think it sounds like paradise, remember that the material prosperity of almost everybody reading this would have seemed as such to their very recent ancestors.

Just as the business end of economic activity moves from the physical to the ephemeral, so do humanity's concerns. That future world will have a new set of problems. No doubt they will be – or appear – as grievous as ours.

It is in the interests of everybody alive that we work towards such a world – by adjusting lifestyles, according to our improving understanding of environmental best practice, and doing our bit to ensure technological and economic evolution drive human civilisation forward in a sustainable direction.

As debates regarding sustainability intensify, there is much talk of the bleak futures which must be avoided. Let us also remember the bright and sustainable future, for ourselves and this planet, which is well within our grasp.

Peter Baker, 2012

More thoughts on the long-term trajectory of human affairs: www.thejollypilgrim.org

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