Chapter Three: Energy, The Master Currency

"Always drink upstream from the herd"
Will Rogers

In Chapter Two we briefly covered:

- How we filter data to decide whether an issue is a high priority,
- Why systemic thinking is critical to getting to the root of challenges, and
- Why energy is a high priority in dealing with the challenges we face regarding both the environment and the economy.

Outside of only rare and brief periods of the best economic times, there is an old political saying that is truly apropos for this discussion: '*It's always about the economy stupid*.' Not many more things are more basic than is our rice bowl supplied? This Chapter covers several key areas including connecting the dots on how both energy and the environment's critical impact on the economy is mistakenly left out of almost all economist models. This includes, clearly defining just how fundamental and pervasive energy is to our world and why it is such a high priority to understand and face the energy matters before us, at this point in time. Once we understand the problem and begin to explore intelligent responses, we are better able to weed out 'so called solutions' that ultimately are or could become additional parts of the problem. And very unfortunately there are powerful players hijacking environmental problems for navarious purposes. See https://youtu.be/utjJ5LagMGI for a view of the big picture.

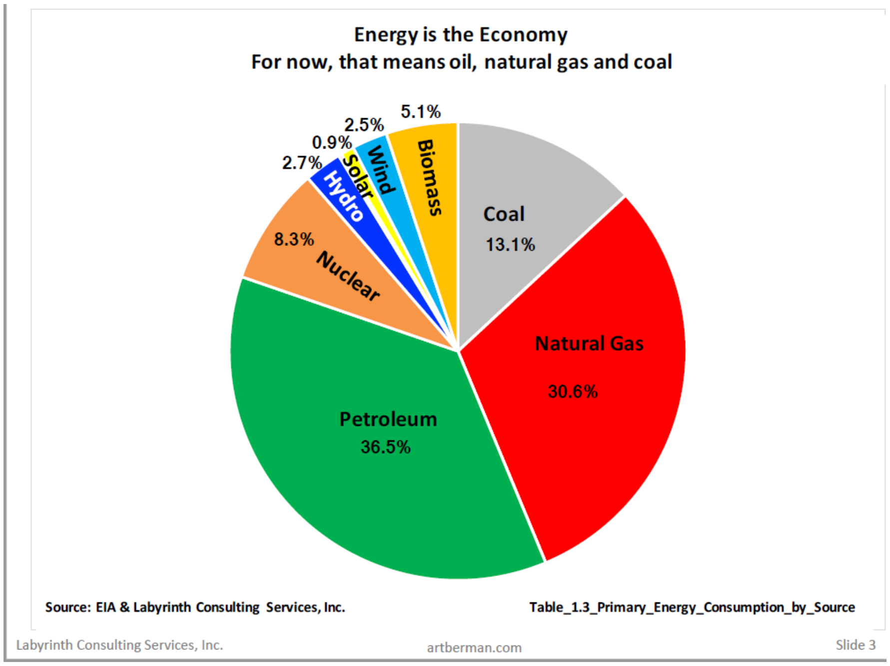
"All of life, including human life in all of its manifestations, runs principally on contemporary sunlight that enters the top of our atmosphere at approximately 1.4 kilowatts per square meter (5.04 MJ per square meter per hour). Roughly half that amount reaches the Earth's surface. This sunlight does the enormous amount of work that is necessary for all life. Major work that sunlight does on the Earth's surface is to evaporate water from that surface (evaporation) or from plant tissues (transpiration) which in turn generates elevated water that falls back on the Earth's surface as rain, especially at higher elevations. The rain or snow in turn generates rivers, lakes, and estuaries and provides water that nurtures plants, animals, hydroelectricity, and civilizations. Differential heating of the Earth's surface generates winds that cycles the evaporated water around the world, and sunlight of course maintains habitable temperatures and is the basis for photosynthesis in both natural and human-dominated ecosystems. These basic resources have barely changed such that humans have always been essentially dependent upon a constant although limited resource base.

Over time humans increased their ability to exploit larger parts of that natural solar energy flow through technology, initially with spear points, knives, and axes that could concentrate human muscular energy, and then with agriculture and dams, and now with fossil fuels. The development of agriculture allowed the redirection of photosynthetic energy captured on the land from the many diverse species in a natural ecosystem to the few species of plants (called cultivars) that humans can and wish to eat, or to the grazing animals that humans controlled. Curiously, the massive increase in food production per unit of land brought on by agriculture did not, over the long run, increase average human nutrition but mostly just increased the numbers of people. Of course, it also allowed the development of cities, bureaucracies, hierarchies, the arts, more potent warfare, and so on, that is, all that we call civilization, as nicely developed by Jared Diamond in Guns, Germs and Steel. For most of humanity's existence most of the energy used was animate – people or draft animals – and derived from recent solar energy". Hall, Charles A. S.; Klitgaard, Kent A. (2011-10-27). Energy and the Wealth of Nations: Understanding the Biophysical Economy . Springer New York.

A person must work about 4.5 years to expend energy equivalent to one barrel of oil.

Cornelius Vanderbilt was by far one of the richest people in the world in the early 1900's. His home remains something of a marvel to this day. Today, of North Americans officially designated as "poor", 99 percent have electricity, running water, flush toilets, and a refrigerator; 95 percent have a television, 88 percent a telephone, 71 percent a car and 70 percent air conditioning. Cornelius Vanderbilt had none of these! His life was in the pre-fossil fuel and coal era's for the most part.

Today, the average person on the planet consumes power at the rate of about 2,500 watts (although about 1/3 of the world's population does not have electricity), or put in a different way, uses 600 calories per second. About 85 percent of that comes from burning coal, oil and gas, the rest from nuclear and hydro (wind, solar and biomass are mere asterisks on the chart, as is the food you eat). Since a reasonably fit person on an exercise bicycle can generate about 50 watts, this means it would take 150 people working for you, working eight-hour shifts each, to peddle you to your current lifestyle. (Americans and Canadians would need 660 such workers, French 360 and Nigerians 16) Next time you lament human dependence on fossil fuels, pause to imagine that for every family of four you see in the street, there would need to be 600 unpaid slaves back home, living in abject poverty: if they had any better lifestyle they would need their own slaves (work now undertaken by what is sometimes referred to as fossil fuel energy slaves namely in appliances). To achieve this lifestyle leveraging human slaves would require close to a trillion people.



Source: https://www.artberman.com/wp-content/uploads/2019/11/LSU-NOV-22-2019_REDUCED-1.pdf

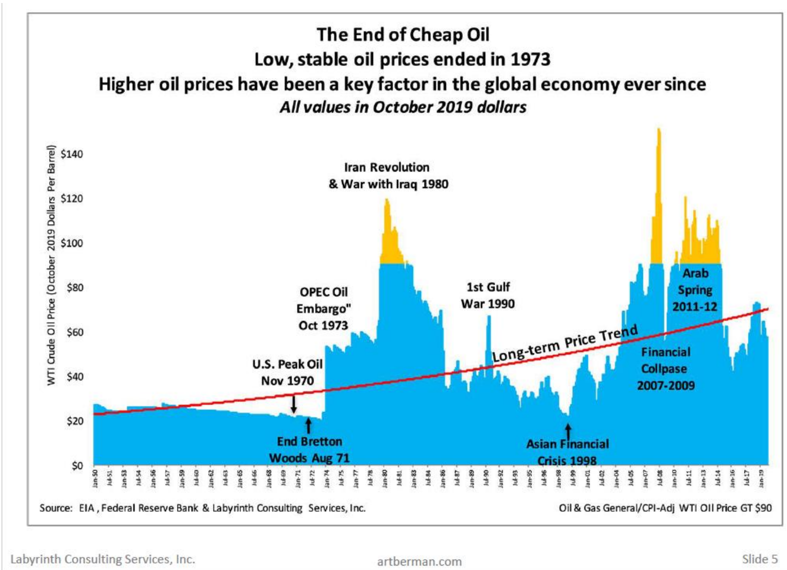
Artificial light lies now on the border between necessity and luxury. In monetary terms, the same amount of artificial lighting cost 20,000 times as much in England in the year 1300 as it does today.

Civilization, like life itself, has always been about capturing energy. That is to say, just as a successful species is one that converts the sun's energy into offspring more rapidly than another species, so the same is true of nations.

"For the past 5 years I have espoused a general thesis that in a post credit bubble world there is less money–less money to waste on non-essentials, less money to spend on essentials, less money to export to other countries. Seems obvious: getting more for less is key. (Always is really, but while credit and cash flow are easy many people forget about efficiency). As one of our largest necessary expenditures, energy is an obvious area of focus. Countries, like households, must find every intelligent way to stitch up the pocket holes that are draining precious cash flow and escalating debt. All western countries must focus on reducing their imports and developing domestic energy sources of all kinds for different applications. The solution is not one type of energy, **but many (with maximized Energy Return On Energy Invested (EROEI).** This is no time for pig-headed dogma and rigid attachment to old ideas." Danielle Park, June 1, 2013 www.jugglingdynamite.com

As James Kunstler correctly, in my view, points out, *"Oil it is the primary resource of our techno-industrial society and its troubles lie behind much of the present disturbances of our times. Despite the triumphal agitprop of the past few years, peak oil is for real. It just manifests more strangely than most people thought, namely, the simpleminded idea that it would only show up as ever-rising prices. No, I made point in The Long Emergency (2005) — and other commentators did too — that peak oil would manifest as volatility. And so since the actual moment of peak conventional crude around 2005, we've seen pretty wild oscillations in the price of oil. This is due to the harsh reality that the price people and enterprises can afford to pay for increasingly harder-to-get oil is less than the price that makes it possible to get it. This sets up a yo-yoing instability in economic performance that exacerbates even normal wave patterns in the business cycle (which are, in turn, aggravated by banks and governments' interventions to suppress those cycles). Below $70-a-barrel the producers go broke; above $70-a-barrel the customers go broke. So the price wobbles up and down as financial Ponzis like shale oil are introduced onto the scene in the hope that debt finagling and mineral rights leasing scams can substitute for physics and geological reality. One trouble with this is that each violent oscillation generates more economic and financial destruction. Activities like motoring, aviation, manufacturing, and retail are badly affected and the entire financial system is made more fragile by worsening increments. Most importantly, the cost structure of the oil industry itself gets battered to a degree that fewer companies can survive to produce the remaining oil.*

The big story for 2014 was the crash of oil prices. It is yet being celebrated as a boon to America. Wait until they find out that almost all of the "good jobs" added in recent years were associated with the shale drilling industry that is now being put out of business by low oil prices. Wait until they find out how the failure of junk bond financing thunders through the bond markets and the savage wilderness of derivatives — and ultimately into their ruined pension funds. Wait until they discover that it was but a symptom of the compressive deflationary depression now gripping the entire techno-industrialized world…The particular brand of stupidity on display also points to another signal of vanity of our time: the conviction that if you measure things enough, you can control them." This is akin to saying: 'I can read the clock therefore I have control over time!'



Source: LSU Slide Deck

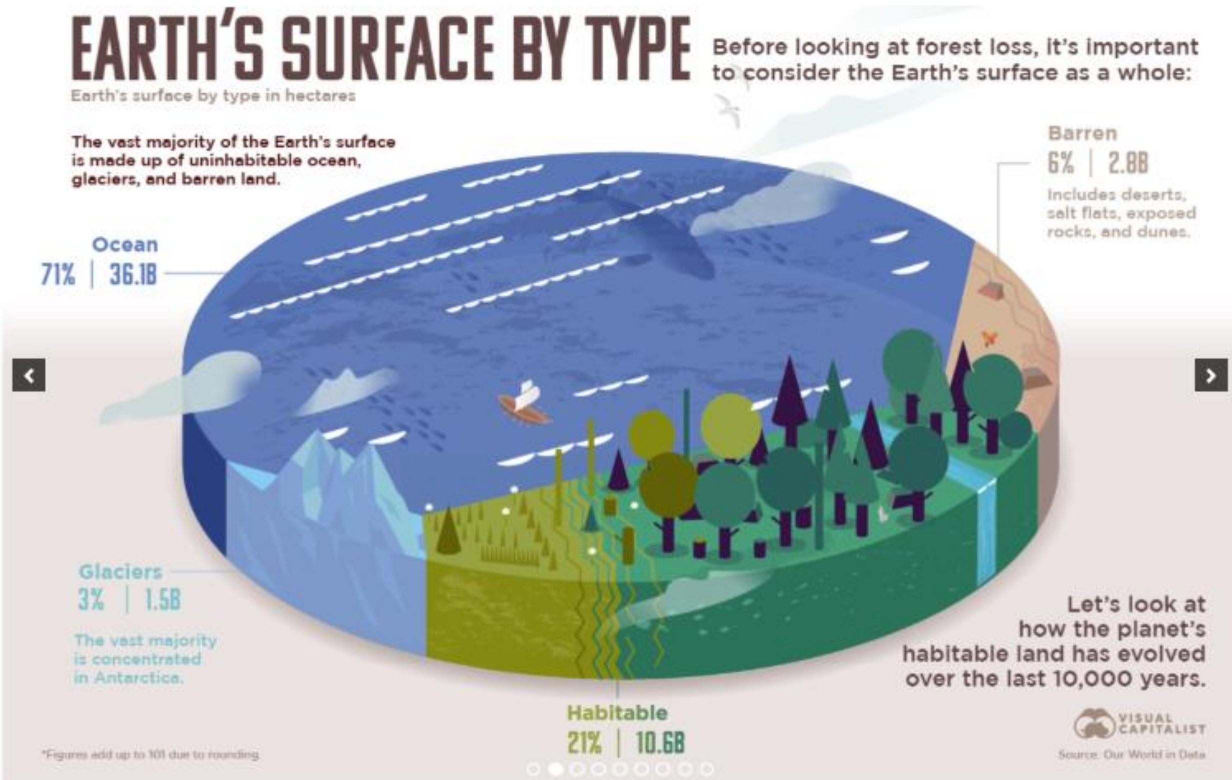
In his book The Other Road to Serfdom and the Path to Sustainable Democracy, Eric Zencey states “Industrial Civilization as a Pyramid Scheme - If I said to you, “Give me a thousand bucks today, and in forty-five days I’ll give you fifteen hundred bucks,” you’d think I was stupid or crooked or both. That kind of interest rate works out to a phenomenal 2,466 percent per year, and it’s what Carlo Ponzi offered investors in Boston in 1920. If I said to you, “Give me a barrel of oil today, and in a month and a half I’ll give you a barrel and a half back,” I’d be making the same deal—but, thanks to the generous **energy return on investment (EROI)** of oil back in the 1920s, I could have made good my promise. I could have used the energy in your barrel of oil to help drill a well, which would have returned to me one hundred barrels of oil for every barrel I invested in the effort of extraction. (The EROI of oil back then was about 100:1 versus todays shale oil being about 3:1.)” **Thus the spectacular GDP growth we witnessed since the dawn of wide spread fossil fuel use up to recent years**.

Too bad Ponzi wasn’t an oilman. He went to jail for what he did — as have some others, like Bernie Madoff, who imitated his basic business model. Ponzi’s spirit lives on, though, not just in the pyramid schemers’ who defraud investors but in economists who assure us that infinite economic growth is possible on a finite planet — and that resolution of the problems created by growth can only come from continued exponential expansion of the economy’s extractive base. The pyramided structure of our industrial economy and society becomes even clearer when you use EROI to think about what Ponzi did.

As any accountant will tell you, treating capital as income is a ‘no-no’. Any company that cashes out its capital stock (sells off its productive assets, like factories and infrastructure) and treats the result as income is going to go broke. And here is the connection with oil. The fossil fuels of the planet are a capital stock; they represent past solar income the planet received in its 4-billion-year history that was not consumed at the time but was ‘saved’ — locked away as fossil energy. We are drawing down our capital stock and treating the inflow of money as income. Does this make our economy a pyramid scheme? Consider this: anyone who offers you interest in exchange for a loan of money is betting that the economy will grow. Suppose I borrow the price of a gallon of milk today and promise to pay you a gallon and a pint next year. Multiply by billions: for all those promises to be kept, the economy must grow as it has got to produce a gallon and a pint next year for every gallon it produced this year. If it doesn’t, some lenders are going to be left holding either worthless claims or collateral assets. I suspect there are many instances of lending, where the lender actually wanted the collateral assets from the onset (e.g. seized state assets of seaports and airports seized from Greece).

There are only two ways an economy can grow. It can suck up a larger flow of matter and energy, or it can achieve internal efficiencies—keep the rate of uptake of matter and energy stable (which more and more renewables would help us do if they were exceeding fossil fuel reductions but they certainly are not), but lose less to waste and entropy within the productive cycle (energy efficiency efforts such as the use of cogeneration is within our grasp right now and offers huge value but for some reason almost all governments refuse to see it as reflected by their not assisting cogeneration). That is it – there are no other ways to enable economic growth. And there are limits to both avenues.

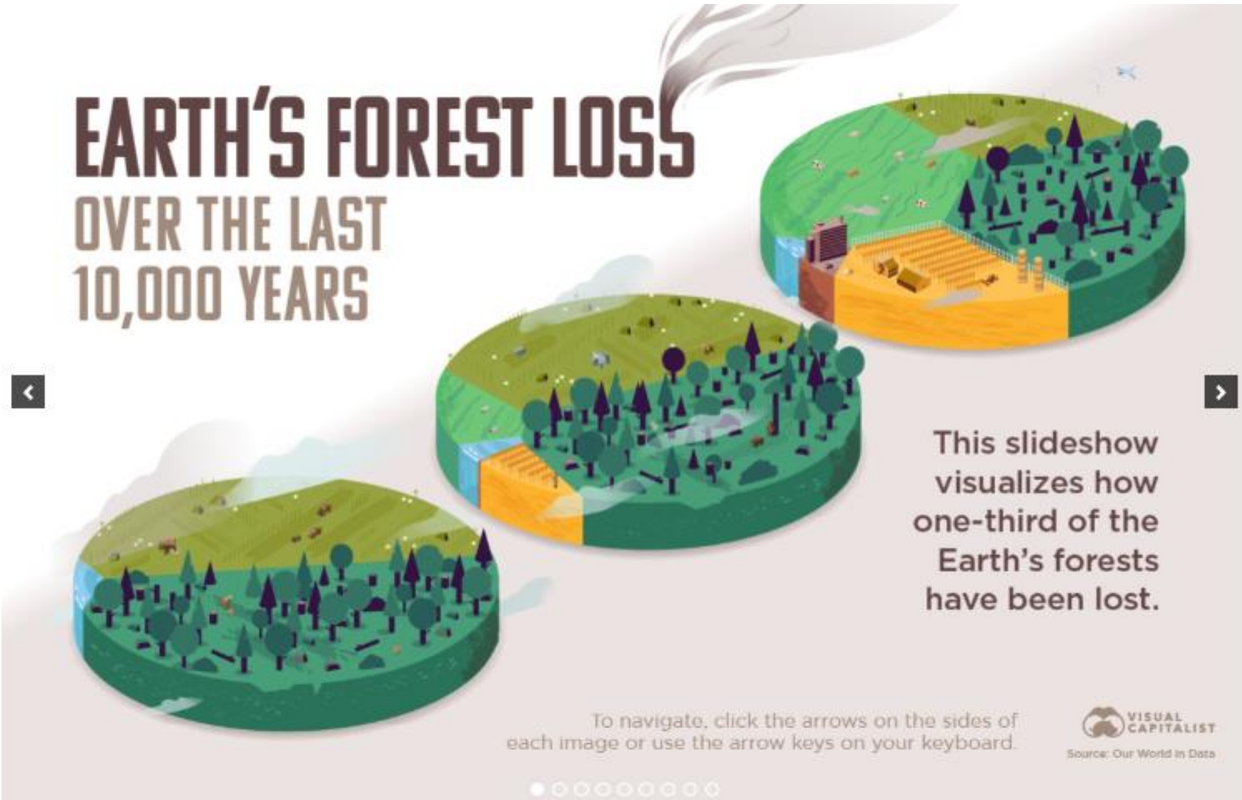
When we increase the rate at which the economy sucks matter and energy out of nature, we increase the economy’s ecological footprint — which has already exceeded a sustainable size. And while there is still plenty of room for additional efficiencies in how we use that matter and energy, we achieve those efficiencies within physical limits. Many of the things we make, we could make using less matter and energy.


EARTH'S SURFACE BY TYPE
Earth's surface by type in hectares
Before looking at forest loss, it's important to consider the Earth's surface as a whole:
The vast majority of the Earth's surface is made up of uninhabitable ocean, glaciers, and barren land.
Ocean
71% | 36.1B
Barren
6% | 2.8B
Includes deserts, salt flats, exposed rocks, and dunes.
Glaciers
3% | 1.5B
The vast majority is concentrated in Antarctica.
Habitable
21% | 10.6B
Let's look at how the planet's habitable land has evolved over the last 10,000 years.
VISUAL CAPITALIST
Source: Our World in Data
*Figures add up to 101 due to rounding


10,000
Years ago
Breakdown of Habitable land in hectares
10,000 years ago
Present
Grassland
42% | 4.6B
Wild grassland and shrubs.
Freshwater
1% | ~150M
Lakes and rivers.
Forest
57% | 6.0B
Includes tropical, temperate, and boreal forests.
VISUAL CAPITALIST
Source: Our World in Data

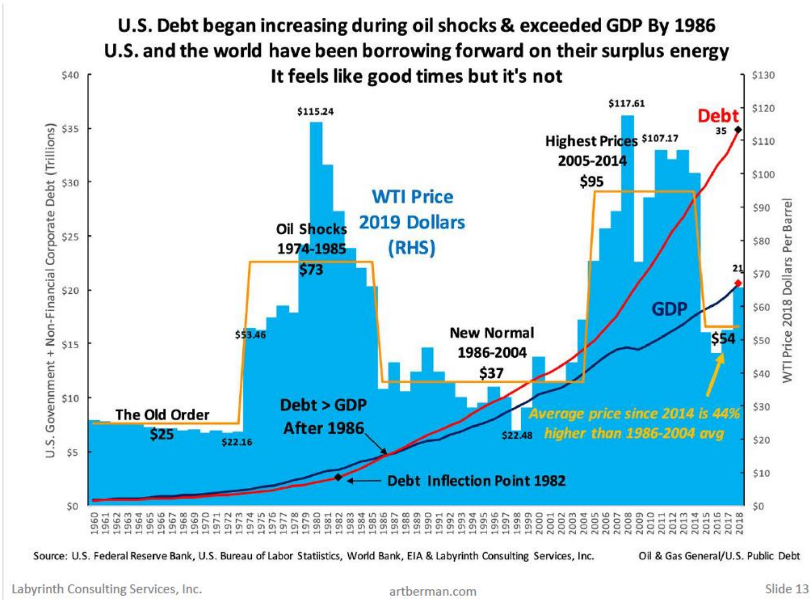

1700
Breakdown of Habitable land in hectares
10,000 years ago
Present
1700
Grassland
38% | 4.2B
The spread of civilizations and repurposing of land for agriculture becomes apparent on a macro scale.
Grazing
6% | 668M
Grasses and wild vegetation for livestock grazing.
Freshwater
1% | ~150M
Urban
<1% | 41M
Forest
52% | 5.5B
Crops
3% | 318M
Includes human food, cash crops, and animal feed.
VISUAL CAPITALIST
Source: Our World in Data


2018
Breakdown of Habitable land in hectares
10,000 years ago
Present
2018
Grassland
14% | 1.7B
Over time, used up agriculture and forestry land becomes grassland.
Grazing
31% | 3.2B
Freshwater
1% | ~150M
Urban
1% | 150M
Includes settlements and infrastructure.
Forest
38% | 4.0B
Since the last ice age, one-third of the world's forests have been lost.
Crops
15% | 1.6B
VISUAL CAPITALIST
Source: Our World in Data



Source: https://www.visualcapitalist.com/visualizing-the-worlds-loss-of-forests-since-the-ice-age/

We cannot make things — cannot create real wealth of any sort — using no matter and energy. When debt — a claim on the future productivity of an economy — grows faster than productivity grows, then somebody who holds a claim is going to have to have that claim go unfulfilled. There are some basic ways this happens in an economy: inflation, bankruptcy, defaults on loans and bonds, stock market crashes, loss of pension promises or paper assets of any kind. You could, with some effort, correlate the amount of debt that is erased by these mechanisms every year to the difference between claims on future income and actual increases in productivity. It would be interesting to examine the recurring inflationary episodes and bankruptcy crises of the system in this light — from the savings and loan scandals of a few decades ago, through Enron, on up into the supposedly never to be repeated subprime mortgage crisis in 2008 which the banksters knowingly reinflated and are now popping with great profits in 2022. It seems that the system is always shedding claims on future income, because it systematically allows those claims on income to grow faster than the income itself can grow. (As ought to be clear, this structural need for spasms of debt repudiation is a fundamental driver behind the economy's cyclical swings, the boom-and-bust cycles that have characterized the market at least for the past 100 years. Note that sometimes developed nations can insulate themselves from the phenomenon by outsourcing the necessary debt repudiation and forcing it abroad, as when the World Bank forgives loans to developing nations, or those nations experience high rates of inflation.)



From this thermodynamically enlightened perspective, it is clear that compounding interest is a wager that says we will continue to increase our economy's capacity exponentially—which usually comes down to increasing the economy's ecological footprint exponentially. Or, to see it from another angle: one of the strong drivers of our economy's rapacious drawdown of natural capital in all its forms (including our loss of ecosystems that provide crucial ecosystem services) is the practice of compounding interest on loans.

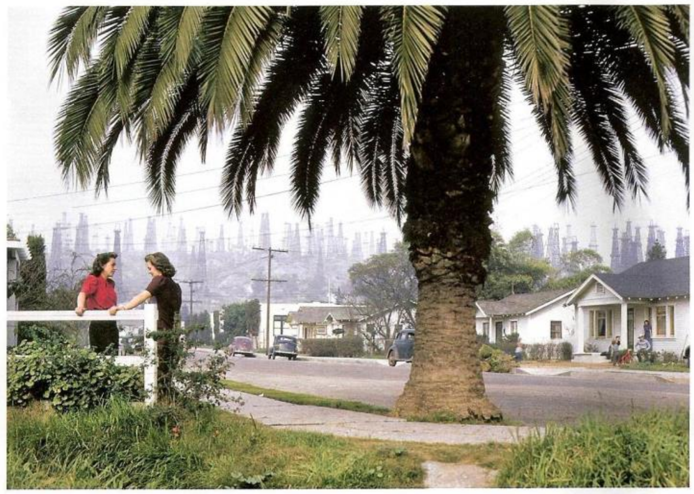
"So, a hypothesis: for much of the twentieth century, this essential element of the relationship between money and physical reality was obscured by the increasing exploitation of fossil fuel with a high energy return on investment. Just as word of Ponzi's great investment opportunity swept like wildfire through the immigrant neighborhoods of Boston and beyond, postponing his inevitable day of reckoning, we've raced through the hydrocarbon endowment of the planet, spending capital as income, obscuring financial reality as effectively as Ponzi and Madoff did... Energy return on investment is a fundamental measurement that we're all going to learn more about as we face the end of the oil era" says Eric Zencey.

When it takes a barrel of oil to get a barrel of oil out of the ground, refined and transported to market, the oil era will be over, no matter what its monetary price happens to be. As noted below, the global average is currently about 19:1 with oil sands oil at about 3:1. With this perspective, obviously it is critical to know the real numbers now and to leverage strategies to prioritize accordingly. We fully acknowledge someone might invent cold fusion in a coffee cup and then the game changes entirely. Perhaps at the same time they might finally invent the perpetual motion machine too, but until it is proven and commercialized, should our strategy really be wishing upon that star and counting on it to come true, any minute now?

Yes, the existing state of technology sets limits on the amount of wealth we can create from a given throughput of matter and energy. But can technology improve forever, indefinitely? Can humans, through technological development, solve any problem brought on by resource scarcity and the limited capacity of ecosystems to absorb our acts and works? When all is said and done, can technological development allow us to enlarge the economy's ecological footprint forever to create wealth? Gradually, we are coming to recognize that the answer is no. That answer becomes clearer when we model an economy as an open thermodynamic system, a system that exchanges matter and energy across its border (that mostly conceptual, sometimes physically apparent line that separates culture from its home in nature).

An economy sucks up valuable low-entropy matter and energy from its environment, uses these to produce products and services, and emits degraded matter and energy back into the environment in the form of a high-entropy waste. (Emissions include waste heat and waste matter of all sorts—not just 'pollution' – but the matter embodied in products that have reached the end of their useful lives: yesterday's newspaper, last year's running shoes, last decade's dilapidated automobile.) Thus, an economy has ecological impact on both the uptake and emission side. The laws of thermodynamics dictate that this is so. "You can't make something from nothing; nor can you make nothing from something," says the first law—the law of conservation of matter and energy. With enough energy we could recycle all the matter that enters our economy, even the molecules that wear off the coins in our pockets. But energy is scarce: "You can't recycle energy," says the second law, the law of entropy. Or, in a colloquial analogy: the check book must balance, and the bills must be paid. Physically the inflow and outflow of the economy must be equal; to operate our economic engine we pay an energy bill, ever taking in energy anew. No matter how inventive we turn out to be, our technology will not ever give us perpetual motion. We will never invent a way around the first and second laws. This means that to establish an ecologically sustainable economy, we must accept limits on the amount of scarce low entropy that we take up from the planet and on the amount of degraded matter and energy that we emit back into it.

FLASHBACK



Boom and Town A forest of derricks rises beyond a Signal Hill, California, neighborhood in this photo from the June 1941 *National Geographic*. Oil had been discovered there just 20 years earlier. The caption accompanying this photo notes: "If one man drills and strikes oil, his neighbor at once drills, too, lest the first drain the pool." Today the area's Long Beach oil field is much depleted, but it still yields more than a million barrels a year. According to John Huff, an engineer for California's Department of Conservation, extraction technology has moved on to more efficient pumping units. Huff's team at the Division of Oil, Gas, and Geothermal Resources placed this photo's scene at the corner of present-day Dawson Avenue and Village Way. Some of the houses pictured are still standing, but no derricks compete with the palm trees there anymore. *–Margaret G. Zackowitz*

Flashback Archive Find all the photos at **ngm.com.**

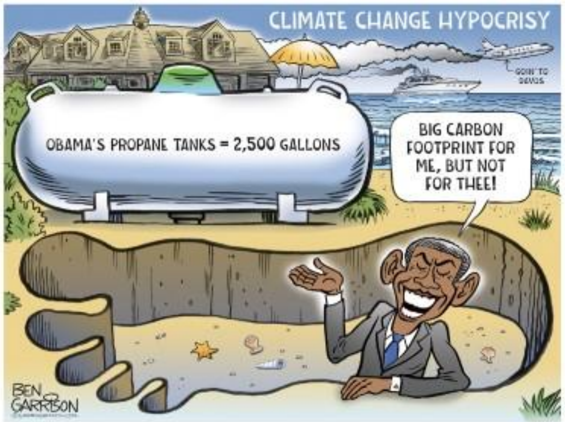
Nature's rhythms are much, much longer than ours, longer than our news cycles and election campaigns, and when dire environmental predictions do not come true right away – the general public tends to think the predictions were wrong. Then on the other side of the coin fear is used to control the many so the few can enjoy more spoils for themselves. It is really tough to sort through what is real and what is fear mongering propaganda.

Those who warn us about Global Warming are buying beachfront property.

WESTERN Standard

NEWS

Gates' renovates San Diego beachfront estate that he predicts will be underwater with climate change



Obama's Martha's Vineyard home; he paid $11.75 million in 2019 (Photo: Realtor.com)

One of two such houses, the other in cheap Hawaii. Not bad for a former social worker, 8 year sort of president, who "earned" less than $500k per year

https://www.zerohedge.com/political/new-fossil-fuel-fan-obama-orders-2500-gallon-propane-storage-vacation-home

Humans are hardwired to flee from or fight with fearsome things, and goodness knows that visions of ecological catastrophes are certainly frightening. No wonder our common responses of denial (flight) or aggressive challenges (fight) when presented with disturbing issues and they occur almost automatically with most people as a reflex rather than after careful contemplation.

Humans are motivated by fight and flight in the face of danger, but they have other motivations as well. Two of them could be engaged by environmentalism: most of us want to bring to fruition one or another appealing vision of our own future, and most of us are familiar with the satisfaction that comes from meeting a meaningful challenge. Our culture's lack of sustainability can be cast in dire, frightening terms, but also as an occasion demanding that we envision an attractive future and rise to the challenge of making that vision real.

It is no accident that oil barons—Rothchilds, John D. Rockefeller, J. Paul Getty—became some of the richest people on earth. Some of that wealth went into extravagance: mansions, yachts, Adirondack lodges, balls, parties and other forms of material self-indulgence. Some went to philanthropy: it built museums and libraries and universities. Some "trickled down," establishing a middle-class in which the benefits of our EROI-fueled prosperity were widely shared. Eventually, through taxes, some of that went to creating our impressive infrastructure: bridges, railways, water systems, schools, parks, public buildings. As we watch our infrastructure age, as we begin calculating what it might cost to replace it, as we struggle to find the wherewithal to pay for an educational system that keeps us competitive in a globalized world, we're led to this sobering thought: we'll never have the previous decades of fossil fuel wealth again. Everything we accomplish will more and more have to be achieved on the EROI that energy predominantly from the sun can give us.

With the 100:1 energy engine of the economy having declined to 19:1 or less, there's simply less money to spend on anything else and no surprise the impact is only starting to be felt.

I refer to oil a lot but it is not just oil, it's all of energy and the subject of energy is a vast, technical and complex one, that all too few people care to understand. They tend to ask instead for the Readers Digest version, or worse, the elevator pitch and then are surprised to find out they are as gullible as all get out because they understand so very little about the most basic currency of our economy. The most dramatic case in point in recent years is that most, even oil and gas insiders, bought the silly story that we have a 100 years of shale oil and gas supply at cheap prices within 'Saudi America'. We will try to stay brief here by relying on pictures and charts being worth a thousand words. While we hope to help dispel these myths, experience shows us that our chances of success are minimal because as we noted in the previous chapter, most people that need to read such evidence probably won't, as it affronts what they want to believe. Regardless, once the evidence becomes obvious and irrefutable (and we are quite certain that process is now well underway) then those that have corrected for how best to deal with energy should be well upstream from the herd. These charts and graphs are intended to present why energy proactivity will get people ahead. Thinking through energy challenges and real intelligent responses is of the highest priority.

"Facts are hard…

Understanding is harder…

Wisdom is hardest!" Stephen Becker

"Facts do not cease to exist because they are ignored."~ Aldous Huxley

- Salient point: Despite some of the G7 countries shrinking their use of energy, the use of fossil fuels has grown almost each and every year since 1850. We haven't stopping cutting down trees or using coal for fuel either, we have just added natural gas, more hydro and more renewables to the mix. The dense inventory of ancient sunlight that is used daily is equal to 7 years of ancient, stored sunlight. That is a straightforward, unsustainable, supply and demand equation.
- Prior to 1850 the majority of GDP expenditure went to energy costs. Cheap and abundant fossil fuels changed that for about 175 years, but now heavy oil and shale gas prove we are moving to the 'expensive to get' sources and energy as the master currency is resuming owning a growing share of GDP expenditure…price increases in energy ripple out causing price increases in every facet of the economy – whether we acknowledge the facts or attempt to statistically deny these facts.

Energy Return on Energy Invested (EROEI) and Cents per kilowatt-hour

Energy mechanism	EROEI	Cents/kWh	Comments:
Hydro	11:1 to 267:1	1	Most of the best sources are being harvested already
Coal	50:1	2 to 4	Efforts to phase coal out in the G8 are occurring at the same time as coal use rose 54% from 2000 to 2011 in the rest of the world.
Oil (Ghawar supergiant field)	100:1		Ghawar and other elephant fields have been producing since the 1950's. Not one new elephant field has been found since the 1970's. Oil is 29% of global energy used mostly via transportation. Electric cars are coming out but the transition will be decades and the energy for power plants will be found where?
Oil (global average)	19:1		
Natural gas	10:1	4 to 7	In Canadian buildings 51% of our energy use is space heating, 14% domestic hot water and 36% electricity on average. Green thermal pipes are desperately needed. Is the great shale gas reprieve largely over as much evidence and recent price action suggests?
Wind	18:1	4.5 to 10	
Wave	15:1	12	
Solar Photovoltaic	3.75:1 to 10:1	21 to 83	
Geothermal	2:1 to 13:1	10	Limited locations for electricity production

Tidal	~ 6:1	10	
Tar sands	3:1 to 5.8:1		Heavy oil uses huge amounts of natural gas currently in its production process.
Oil shale	1.5:1 to 4:1		Many issues with its production
Nuclear	1.1:1 to 15:1	2 to 9	U.S. expenditures on nuclear fuel totaled $5.7 billion in 2012, a 5 percent increase from 2011.
Biodiesel	1.9:1 to 9:1		Fuel versus food except for algae which remains mostly in the lab
Solar thermal	1.6:1	6 to 15	
Ethanol	0.5:1 to 1.4:1		Fuel versus food problem

"For the 2008 Summer Olympics in Beijing, China built the world's biggest sports arena – the idiosyncratic Bird's Nest Stadium. Twenty-five storeys high, the stadium has an official volume of 4.9 million cubic metres. Fill this stadium with crude oil 850 times, and you equal annual global oil consumption. How best express this much oil? Forget billions of barrels. Try a cubic mile.

Here's an original, illuminating and entertaining way to experience the energy debate, *A Cubic Mile of Oil: Realities and Options for Averting the Looming Global Energy Crisis*. Written by three California-based scientists (bioengineer Hewitt Crane, energy technologist Edwin Kinderman and organic chemist Ripudaman Malhotra) and published by Oxford University Press, *Cubic Mile* uses a simple volumetric metaphor to eliminate a bewildering technocratic Babel: a pool of oil one mile wide, one mile long and one mile deep.

One cubic mile of oil (CMO) equals the oil that the world consumes every year. Three CMOs equal the energy that the world consumes every year. (More precisely, one CMO equals global oil consumption in 2000; by 2006, consumption had increased to 1.06 CMO.) Cited in cubic miles of oil, energy consumption can be expressed without reference to barrels and gallons of oil, tons (or tonnes) of coal or cubic feet of natural gas – or, for that matter, to British thermal units, joules, calories, watt-hours and all the associated mind-numbing multipliers that accompany them, such as trillions and quadrillions, gigawatts and terawatts.

Messrs. Hewitt, Kinderman and Malhotra are all affiliated with SRI International, an independent research institution based in Menlo Park. Or were affiliated: Mr. Hewitt died shortly before publication of the book. It was he who devised the concept of the CMO, as he sat in a gas pump lineup during the energy crisis of 1974. (Readers offended by the reference cubic miles of oil can convert a CMO to a CKO: 4.1 cubic kilometres of oil. Feel free, the authors suggest, to round it off to an even four.)

But *Cubic Mile* is more than an introduction to a new unit of measurement. It is an encyclopedic embrace of energy issues, with dispassionate but compelling analysis of the energy conundrum.

People shouldn't count, for example, on bio-waste. Convert all of the world's garbage into electrical energy, *Cubic Mile* asserts, and you might meet 1 or 2 per cent of the world's energy needs. Biomass now provides a mere 0.15 CMO – and this mostly from the old-fashioned burning of wood. Similarly, the energy contributions of wind, photovoltaic and solar thermal "barely register on the CMO scale."

The authors calculate that global demand for energy will rise from three CMOs to six CMOs by 2050 – or, perhaps, to nine CMOs. They describe this task as daunting. They note that it took 200 years (1700 to 1900) for coal to replace wood as the world's primary energy source. It took almost 100 years (1870 to 1960) for oil to equal coal. And it took 100 years (1900 to 2000) for natural gas to equal coal in energy usage.

To increase **coal**-sourced energy by one CMO a year, however, would require 1,300 new surface coal mines; 2,600 new underground mines; 300,000 more trucks (running from mine to railhead) – and 2,600 more trains (each consisting of 130 cars drawn by three 3,500-horsepower locomotives). And each mine will leave behind 750,000 tons of excavated material spread – 50 feet deep – across 20 square miles at the same time as sending CO^2 well beyond the current 400PPM and thereby making the planet mostly uninhabitable.

The reserves that never were

Fortunately led by the USGS, many others including the EIA the SEC, and even the coal companies themselves are finally starting to come to terms with the fact that a huge chunk of what we've been calling coal *reserves* are actually economically unattractive *resources* which are unlikely to be extracted, given production cost increases coal is subject to. In this vein, Arch Coal now says that their Black Thunder mine — the nation's single most productive coal mine, once responsible for about 10% of all US coal — is likely to start playing out. (Arch Coal Inc 2013 10-K, page 15). There are potential leasing tracts nearby.

Producing one CMO of energy a year from **hydro power** will require the construction of 153 of China's Three Gorges Dams – or one every four months for the next 50 years. But this number of undammed rivers do not exist.

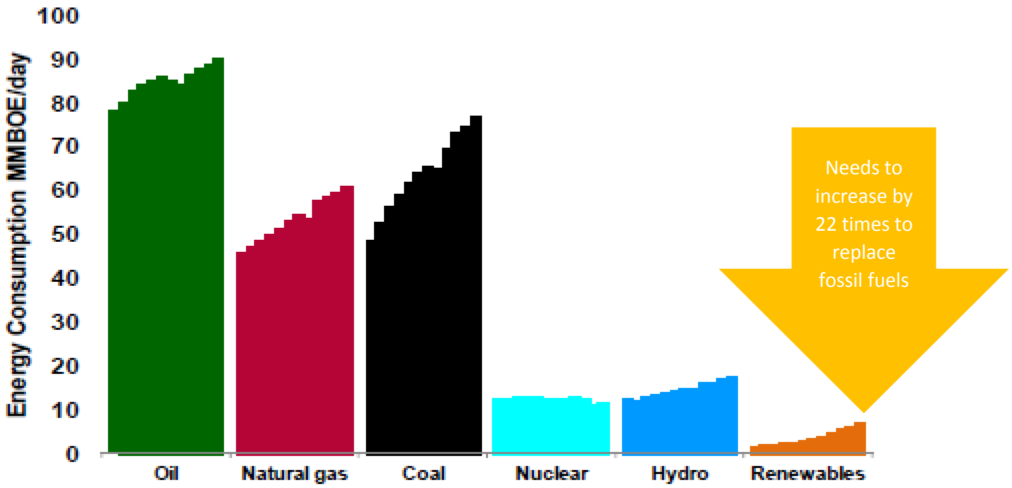
Producing one CMO of electricity from **wind** will require three million two-megawatt wind turbines. These turbines would occupy 580,000 acres of combined space. We show available space calculations below.

And **nuclear**? The world might go increasingly nuclear – but every CMO of nuclear energy will require 500 new surface uranium mines; 1,000 new underground uranium mines; and 2,280 nuclear reactor operations." https://www.zerohedge.com/energy/mapping-worlds-nuclear-reactor-landscape

- To meet the entire world's energy demands would require 14,500 reactors (according to Pearce in 2008).
- In 2006, the Energy Watch Group of Germany studied world uranium supplies and issued a report concluding that, in its most optimistic scenario, the peak of world uranium production will be achieved before 2040. If large numbers of new nuclear power plants are constructed to offset the use of coal as an electricity source, then supplies will peak much sooner. Thomas Seltmann, "Nuclear Power: The Beginning of the End," *Sun & Wind Energy* (Energy Watch Group, November 2009).
- "If all of the world's electricity was nuclear-generated, the supply of accessible uranium would be exhausted in nine years." (source Dr. Helen Caldicott, https://www.helencaldicott.com/articles/older-articles/)
- Today, there are some 435 nuclear power reactors operating in 30 countries. These 435 reactors, with combined capacity of over 376 Gigawatts (One GWe equals one billion watts or one thousand megawatts), require 450 thousand pounds of uranium per day.
- According to the World Nuclear Association, about 58 power reactors are currently being constructed in 14 countries. In all there are over 148 power reactors planned and 331 more proposed. Each GWe of increased capacity will require about 195 tU per year of extra mine production – three times this for the first fuel load.
- In Europe's 2003 heat wave, France curtailed nuclear generation, the mainstay of its electricity supply, when depleted rivers became too warm too cool reactors but not before the temperatures were too high for fish survival. This "anomaly" repeated itself in July 2009 as France imported UK electricity as plants shut down again.
- In 2008, mines supplied 51,600 tons of uranium oxide concentrate containing 43,853 tU, which means mining supplied roughly 75% of nuclear utility power requirements. The remaining supply deficit used to be made up from stockpiled uranium held by nuclear power utilities, but their stockpiles are pretty much depleted. Mine production was primarily supplemented by ex-military material - the Megatons to Megawatts program which ended in 2013 – and the Russians have stated that the agreement will not be renewed.
- Currently the world does not have the technology to use most of the energy embodied in uranium or to use thorium.
- The March 2015 Globe and Mail Report on Business ran an article on Canadian nuclear energy. The article stated "Nuclear power is said to be cheap – but only if one doesn't count costs that either have been offloaded or are yet to be fully funded, such as accidental liability, waste management and the debts incurred in reactor construction. Moreover, the industry has a history of wild cost overruns: The bill for creating Ontario's Darlington facility during the 1980's climbed from a projected $3.9 billion to more than $14 billion…48,000 tonnes of nuclear waste have accumulated in Canada during the past 65 years which nuclear producers hope will eventually be lowered in a yet to be located Deep Geological Repository (DRG)…The estimated $24 billion cost of a deep repository – to be paid for by the producers (hence ultimately their customers) out of a fund that now stands at less than $3 billion – sounds like a lot for the existing quantity of nuclear-fuel waste in the country…At the moment, the US, Japan and Europe are also grappling with the challenge of nuclear middens, in particular the deep repository option and how-to of putting waste underground. "What they won't tell you is that there isn't a single functioning DRG for fuel waste anywhere in the world," says Brennain Lloyd. "So it is entirely unsubstantiated technology." The US government's test deep repository in New Mexico – which is not for fuel waste but waste from US nuclear weapons program – was closed to further stockpiling after a 2014 underground fire, which was followed by a leak of radioactivity into the surrounding area. Lloyd adds that two DGR's for low – and intermediate-level waste in Germany have been permanently closed because of radiation leaks – the sort of thing the OPG insist will never happen in Canada.
- At Bruce Power, the estimated costs of refurbishing two reactors in Bruce A jumped to $4.8 billion (from the original 2005 estimate of $2.75 billion). The projects were also nearly three years behind original time estimates. ReNew Canada magazine Aug 2011

The federal Nuclear Liability Act caps operator's liability at $75 million for off-site damages. The Fraser Institute calls the cap "an implicit subsidy" by all Canadians. The 2011 Fukushima nuclear disaster cost epically more than $75 million, with the costs still mounting as of 2019 (See https://www.zerohedge.com/geopolitical/japan-proposes-dumping-radioactive-waste-pacific-storage-space-dwindles)

Figure 1: World Energy Consumption by Source
2002 to 2013



Sources: BP Statistical Review, ARC Financial Research

Salient point: Every day the world uses 100+ million barrels of oil, 328 BCF of natural gas, 15 million tons of coal, 200,000 kilograms of uranium, 10.4TWh of hydroelectricity and millions of hectares of wind farms, solar panels, forests and cornfields.

"On a percentage basis, renewables take the gold for growth recently with an impressive rate of 13% per year since 2010. But from an absolute perspective the news is more sobering: systems like wind, solar and biomass are not taking market share away fast enough to make a difference to disconcerting metrics like carbon intensity. Because coal and natural gas are also growing at a good clip, on massively higher volumes, the share of renewables in the world's energy diet (currently 1.4%) is increasing by 0.1% per year. That means that unless something changes, under current conditions it's going to take 1,000 years to put the fossil fuel industry to bed! Arc Financial July 2, 2013

Table 1: Sectoral Shares of Renewable Energy in Recent Global Scenarios

Scenario	By Year	Electricity	Heat	Transport
By 2030–2040				
ExxonMobil *Outlook for Energy: A View to 2040* (2012)	2040	16%	—	—
BP *Energy Outlook 2030* (2012)	2030	25%	—	7%
IEA *World Energy Outlook* (2012) "New Policies"	2035	31%	14%	6%
IEA *World Energy Outlook* (2012) "450"	2035	48%	19%	14%
Greenpeace (2012) *Energy [R]evolution*	2030	61%	51%	17%
By 2050				
IEA *Energy Technology Perspectives* (2012) "2DS"	2050	57%	—	39%
GEA *Global Energy Assessment* (2012)	2050	62%	—	30%
IEA *Energy Technology Perspectives* (2012) "2DS High Renewables"	2050	71%	—	—
Greenpeace (2012) *Energy [R]evolution*	2050	94%	91%	72%
WWF (2011) *Ecofys Energy Scenario*	2050	100%	85%	100%

A detailed review of the very important role of natural gas and its supply and demand data is found in Chapter 6.

Net fuel cost comparison			
	Price per unit	Unit	Net cost per mmBtu
Grass bales (assumed price of $80 per ton at farm gate, and $30 per ton transportation costs)	$110.00	ton	$11.18
Wood chips	$65.00	ton	$8.81
Natural gas	$7.00	Mcf	$8.38
Grass pellets	$200.00	ton	$17.79
Wood pellets	$230.00	ton	$17.83
Propane	$2.10	gallon	$29.32
#2 Fuel oil	$3.50	gallon	$31.80

SOURCE: GRASS ENERGY IN VERMONT AND THE NORTHEAST, WILSON ENGINEERING

2004 Survey of Energy Resources

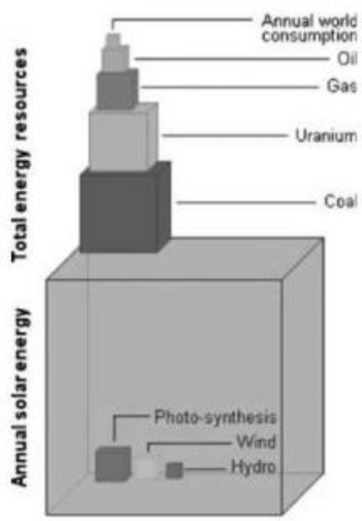
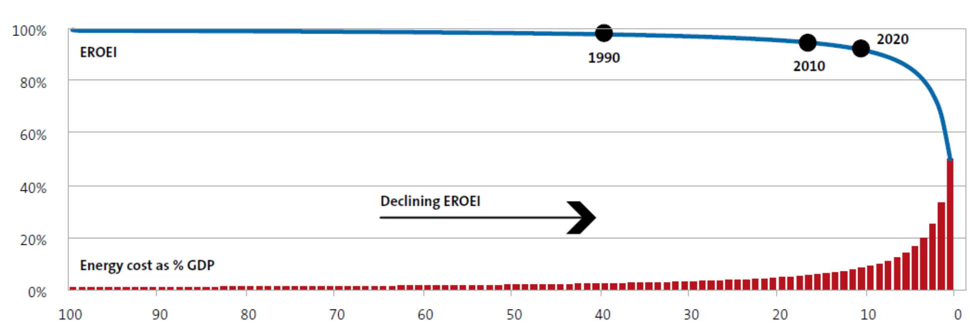


FIGURE 11.1 Order of magnitude of energy sources on earth (Source: Lomborg, 2001).

Fig. 1.5: Nearing the energy returns cliff-edge*



* Source: Tullett Prebon analysis

Fig. 5.14: High EROEI

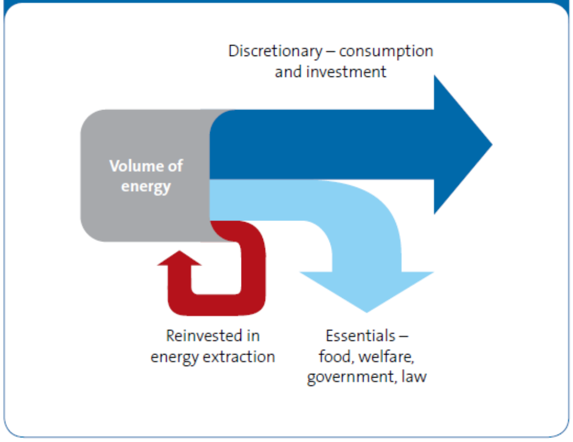
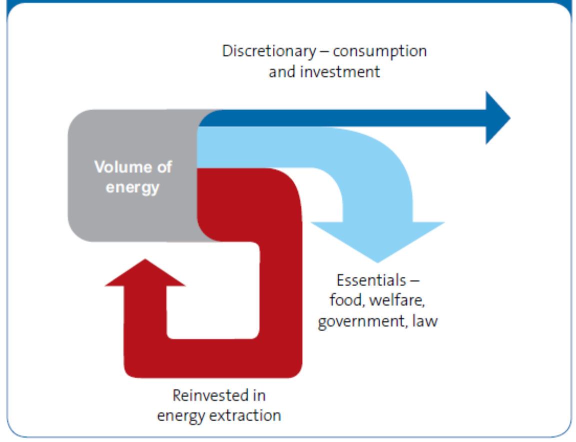
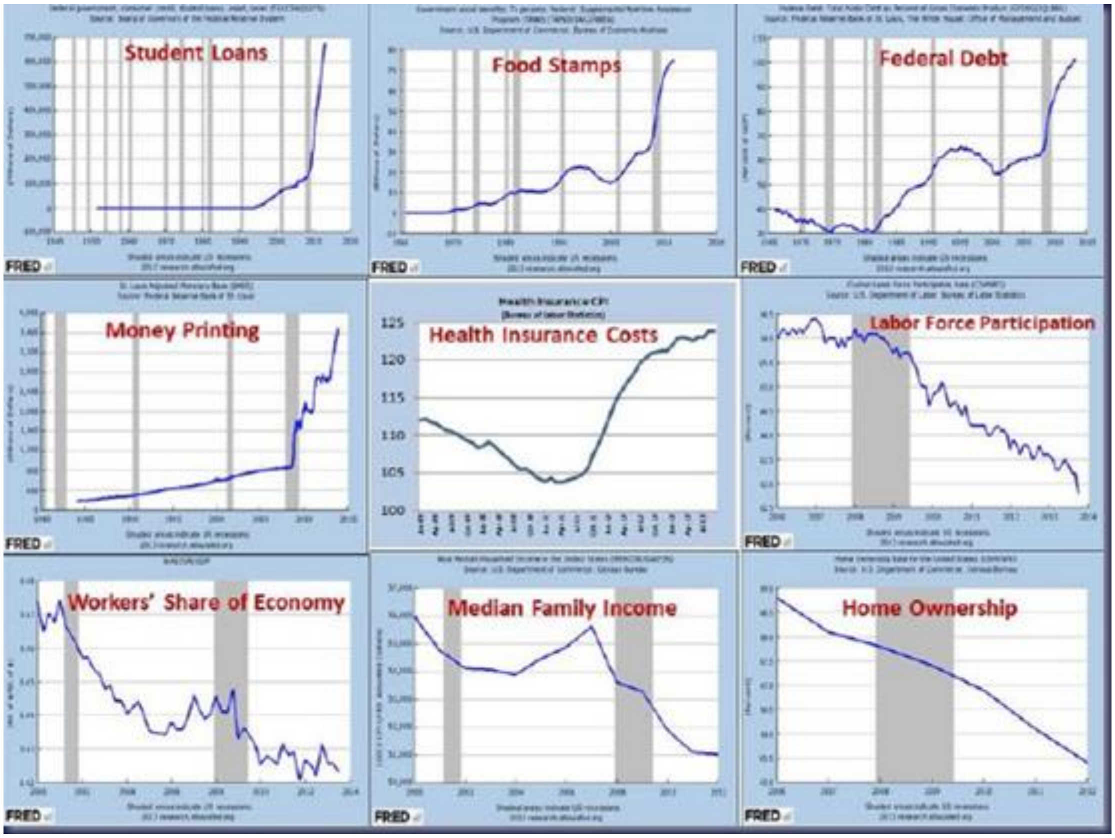


Fig. 5.15: Low EROEI



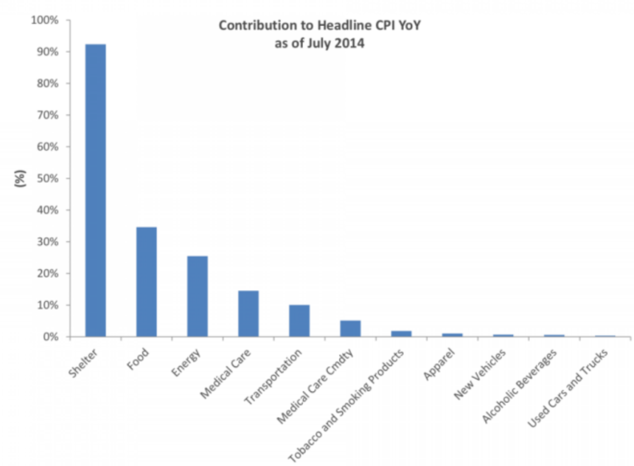
* Source: Tullett Prebon estimates, see text



Jeffrey Gundlach's "Fixed Income Playbook"

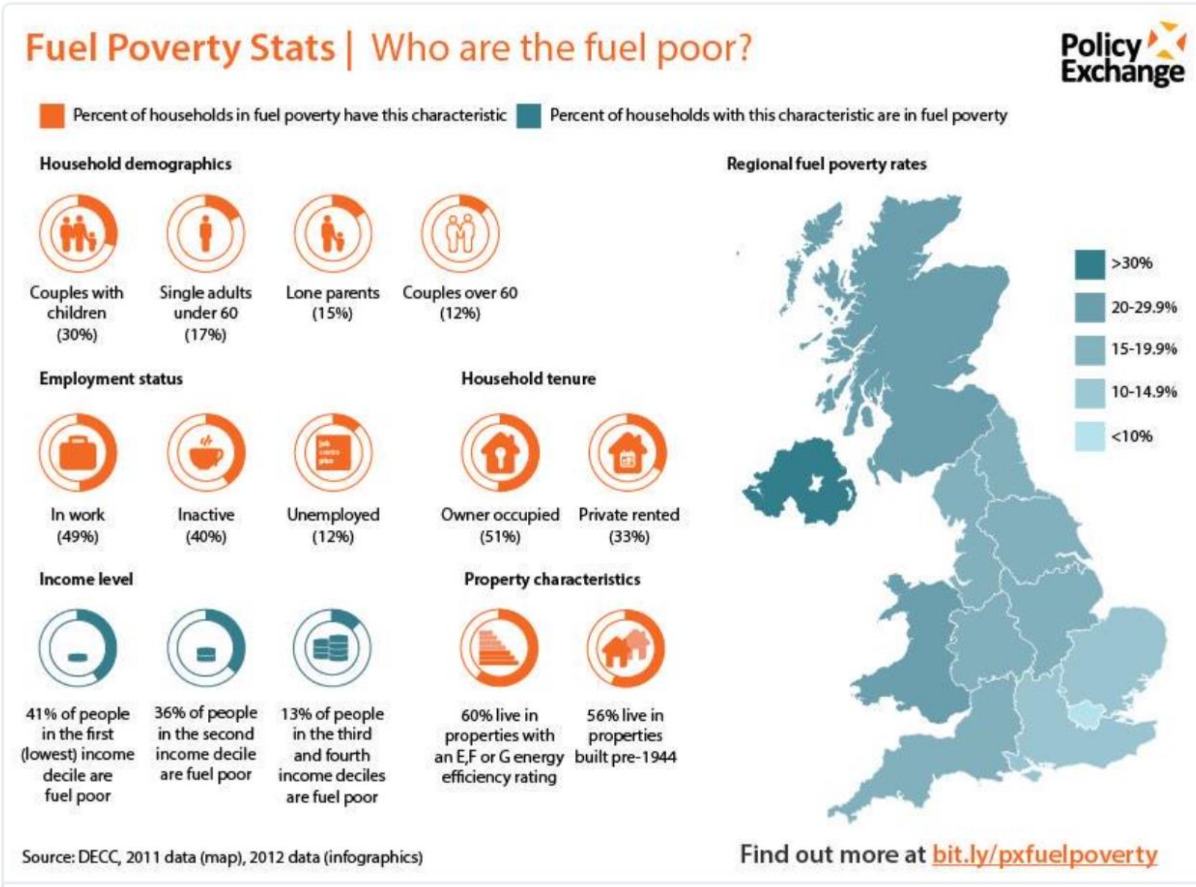
U.S. Inflation Driven by Shelter Costs

DoubleLine FUNDS



Source: BLS; Doubleline
CPI YoY = Year-over-year measure A measure that examines the weighted average of prices of a basket of consumer goods and services, such as transportation, food and medical care.

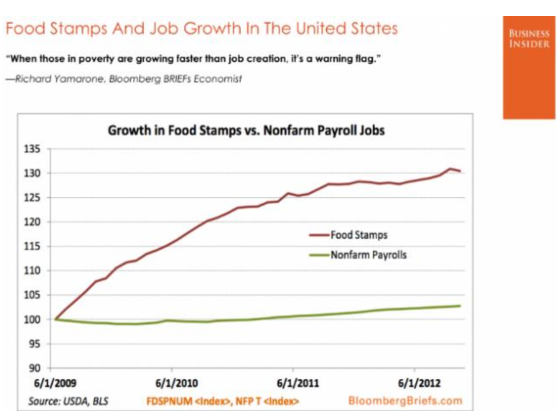
DoubleLine Funds



Yet in the suburbs, America's hungry don't look the part. They drive cars, which are a necessity, not a luxury here. Cheap clothes and toys can be found at yard sales and thrift shops, making a middle-class appearance affordable. Consumer electronics can be bought on installment plans, so the hungry rarely lack phones or televisions.

Challenges are reflected at the grocery store, where the price of fresh food has risen steadily while the cost of sugary treats like soda has dropped. Since the 1980s the real cost of fruits and vegetables have increased by 24 percent. Meanwhile, the cost of non-alcoholic beverages – primarily sodas, most sweetened with corn syrup – has dropped 27 percent.

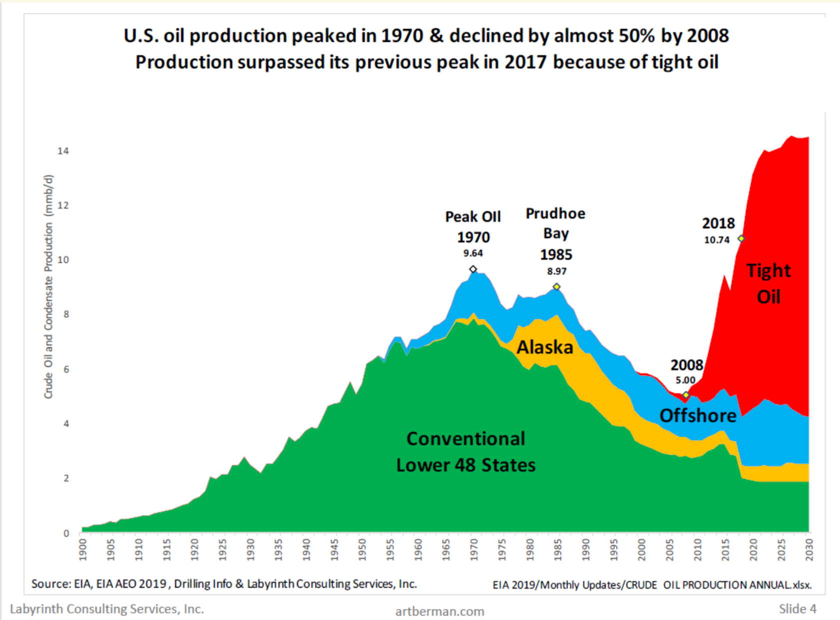
More than 48 million Americans rely on what used to be called food stamps, now SNAP: the Supplemental Nutritional Assistance Program. In 2013 benefits totaled $75 billion, but payments to most households dropped; the average monthly benefit was $133.07 a person, less than $1.50 a meal…Who qualifies for SNAP? Households with gross incomes no more than 130 percent of the poverty rate."

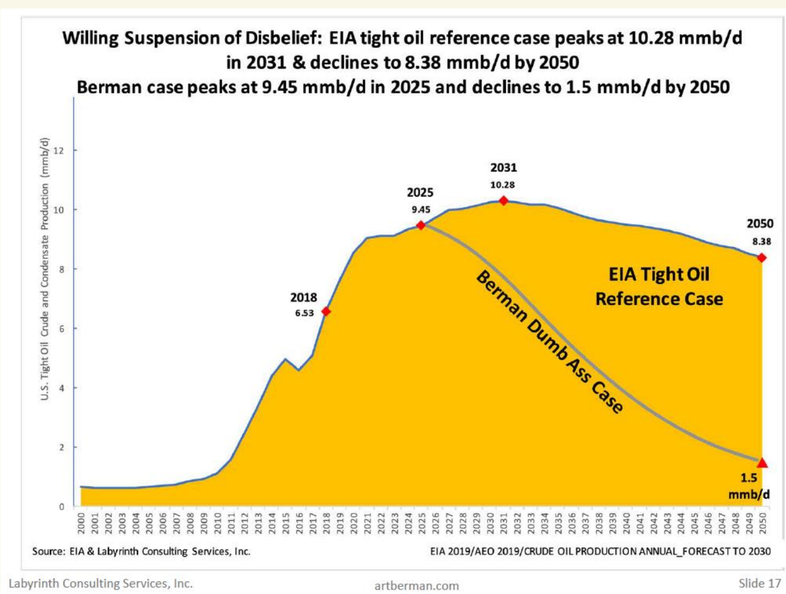


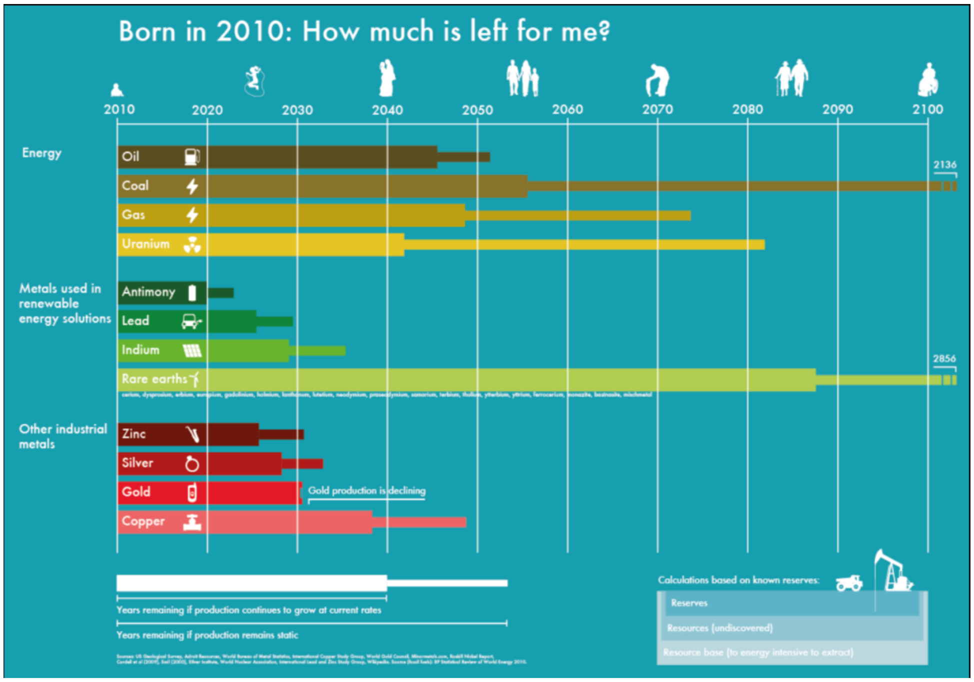
By way of a summary we offer the following three quotes:

Charles Maxwell, Senior Energy Analyst of Weeden & Co has the following to say "*In 1988, 23 billion barrels of oil were found, and the same number was consumed. By 2007, eight billion were found and almost 32 billion went up in smoke* (Thank goodness for the cushion "found reserves" provides for a period of years). *That's not going to change, which doesn't bode well for humanity. Fossil fuels made our society what it is, dragging us out of darkness. Those who don't have it will find it harder to catch up to those who do, and even the haves will find it hard to maintain their lifestyles* (In which case might a fair speculation be that the 1% say we can't use fossil fuel because we need to reduce CO² might be far more about saving the remaining energy for themselves?)

Former CIBC Chief Economist Jeff Rubins commenting on his book "Why Your World Is About to Get a Whole Lot Smaller". "Though the book grew out of my experience as an economist on Bay Street, this is not a book about financial markets," Mr. Rubin said around 2008. "It's a book about the way the world is about to change. We've all got our eyes right now on the global financial meltdown, but I believe that oil (energy) scarcity will change the global economy even more profoundly and in the process change all of our lives – from where we work to where we live to what we eat."







Source: https://www.zerohedge.com/markets/were-living-borrowed-time

"We have spent decades looking for the next cheap energy source and exhausted them as quickly as we find them since mankind first depleted whale oil late in the last century and almost harvested every last tree in England." Peter Tertzakian, Chief Energy Economist, Arc Financial in his book 1000 Barrels A Second (we were using 85 million barrels of oil per day in 2008 but about 100 million barrels per day as of 2020). He added in his Nov 3, 2008 market commentary *"The financial crisis has trashed the economy, but it hasn't solved any of the root energy problems that led to rapidly rising commodity prices prior to the banking meltdown. The core issues – supply tightness and unchecked energy demand growth among 5.8 billion people in emerging economies – have paused for the moment, but still loom large in the background. So too does North America's addiction to all types of energy, which on a per capita basis is two-to-three times the average of other wealthy, industrialized regions like the European Union and Japan.* ***The leverage to proactively avoid the adverse effects of future price shocks lies in controlling the demand side.****"*

With, in my view, the highest priority problem so framed, we will soon turn to discussing some intelligent responses from where we work, live and what we eat and finally to alternative energy solutions. We have squandered any extra time for partial solutions we once had, now we must carefully prioritize and try to be certain.

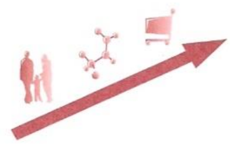
Sustainability is about making decisions today that do not compromise the opportunity for future generations to enjoy a rich quality of life. Every day, news headlines reveal ways we are already compromising these opportunities: stories about climate change, water scarcity, housing shortages, contaminated food, and air pollution. These stories are all part of a bigger picture that is unfolding: a result of choices individuals make at home and as part of a larger community.

For example, in Canada we are **decreasing** our:

- Fish stocks and forests
- Clean, available freshwater
- Air quality
- Connection to the outdoors

At the same time, we are **increasing** our:

- Water consumption
- Energy consumption
- Encroachment into natural and agricultural lands
- Demand for health care and other social services



We can visualize these challenges as society moving through a funnel.