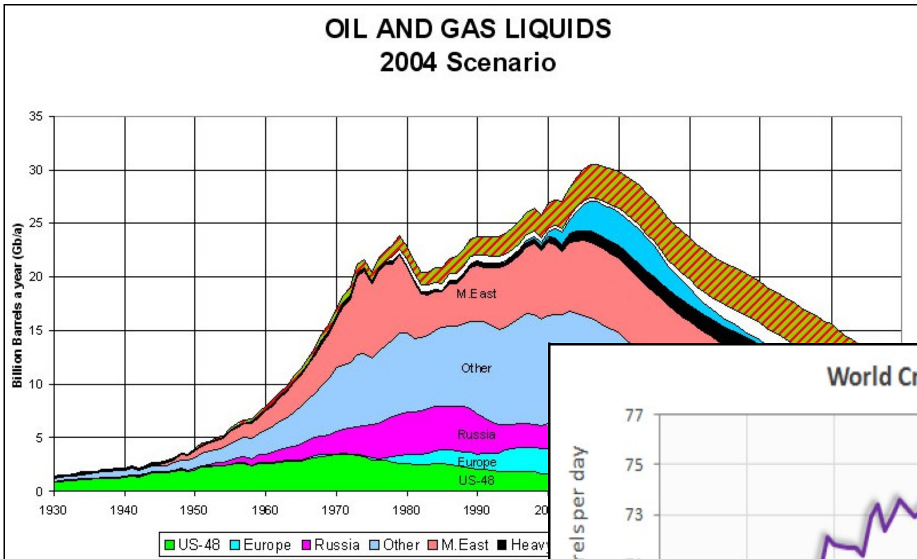
Peak Oil and Our Future

How Energy Depletion Will Change Our Lives



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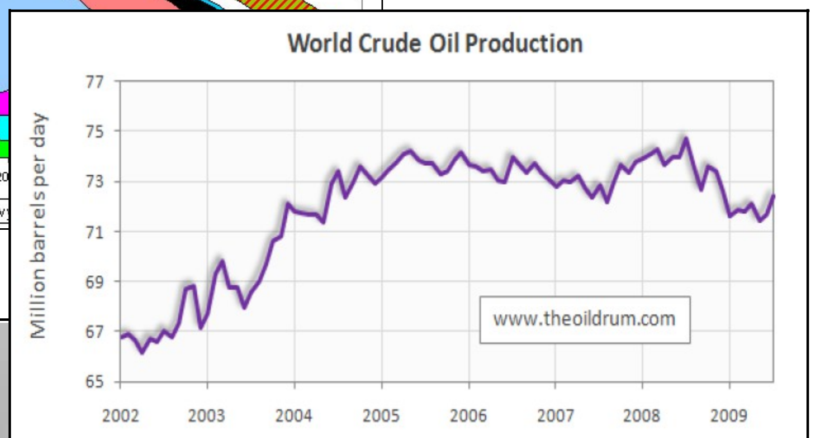

Image Sources (ASPO Spain 2002, DOE 2004, EIA 2007b)

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Summary

Peak Oil and declining energy supplies represent the most serious crisis we have ever faced as a species.

Current world population and our relatively luxurious way of life in America are completely dependent on cheap and readily available energy. Our civilization has developed over the past 150 years because we have discovered and exploited abundant – but finite – fossil fuels for cheap energy. Coal, oil, and natural gas were formed millions of years ago, and our use of this one-time planetary energy endowment has significantly increased food production and has led to exponential population growth. Cheap energy has produced social progress and technological wonders, but it has also allowed our population to expand seriously beyond the ability of the earth's natural (non-fossil fuel) carrying capacity.

Production of all finite natural resources over time follows a bell-shaped curve of increasing production, peaking maximum production, and then decreasing production. Unfortunately, this behavior is a fundamental property of nature and the laws of thermodynamics. While there's a large amount of underground oil remaining in the world, we have already used the higher quality and easy to produce half of known reserves and are at or very near the ultimate peak of world production – Peak Oil. From here on out, the remaining half of oil reserves will be of lower quality and much more difficult and energy intensive to produce and refine, so the rate of production will decline and oil will cost progressively more over time.

Oil is our highest quality and most important fossil fuel but we are also facing resource peaking crises for other fossil fuels and essential resources such as phosphorus, strategic metals, water, and topsoil. At the same time, our population growth has produced a growing need for more and more food and energy and this demand is now outstripping our ability to produce food and deliver energy. So, the era of cheap oil and cheap energy has ended and our way of life, level of comfort, and world population will have to make serious adjustments in the very near future.

This essay will help explain resource peaking and energy depletion and how this process is likely to affect us. I think that energy decline explains much of why nations and the global economy are behaving the way they are and why energy prices will only increase over time. I will provide my views on how Peak Oil and energy declines will affect us long-term and over the next 30 years. And I will identify common sense and positive things we can all do to deal with this imminent crisis.

43 pages of text (34,000 words), 8 pages of references and resources, 5 pages of energy data

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INTRODUCTION

This is an essay about Peak Oil and energy depletion and how these issues are already affecting and will continue to affect our lives. The information may come as a rude shock to many of you and disrupt your sense of comfort and security. I apologize for that up front. It is not my intention to scare you or make you feel uncomfortable but rather provide information and food for thought that you, your family, friends, and community might find helpful.

I was an environmental research chemist for 34 years studying water quality in the western US. During the mid 1980s, acid precipitation became an active environmental issue and I performed a study evaluating the potential impacts of acid deposition to Bureau of Reclamation water resources (Craft 1989). Acid precipitation is caused by nitrogen and sulfur compounds created when we burn fossil fuels like coal and petroleum. The atmospheric nitrogen and sulfur compounds form acids which end up in snow, rain, and dry deposition. In this study I compared data on the acid neutralizing capacity of lake and reservoir waters, watershed topography, surface geology, soil properties, weather patterns, and atmospheric emissions sources. I also looked at data on population, economic growth, and the projected trends for energy usage and supply – all related to emissions of acid forming compounds from power plants and automobiles.

I was familiar with the *Club of Rome's* sobering 1972 book *The Limits of Growth* (Meadows, et al. 1972), and its updating of theories about exponential population growth and finite resources originally proposed by Thomas Malthus. But the information from my own climate research really hit me. I suddenly *felt* what exponential population growth really meant – unprecedented numbers of humans literally swarming everywhere, eating up everything, and creating energy use pollution that was poisoning the entire planet. *We* were the Biblical plague of locusts – the voracious hoard of tropical ants covering and devouring the wildebeest carcass. At least that is how the realization seemed. I knew then that unless politics and human consciousness changed quickly (within a few decades), the jig was up for most of wild nature – and eventually mankind. These harsh realizations were depressing but like many who hear unpleasant facts, I compartmentalized the knowledge and moved on with my life and career. Carl Jung wisely observed that we can only handle so much truth.

Since then, I have noted that we have done almost nothing to address exponential population growth or our increasing use of and dependence on fossil fuels. Since I was born in 1953, US population has *doubled* and world population has almost tripled (U.S. Census Bureau – USCB 2006). It has been over *650,000* years since atmospheric CO_2 has been as high as it now is (Siegenthaler, et al. 2005, Brook 2005) and the reality and expression of human global warming is only disputed by a small minority of scientists who are supported or paid by financial and energy interests. Since 1990, explosive economic growth in China and India has accelerated global energy demand and atmospheric pollution – and the rich countries continue to use and waste immense amounts of energy. Nightmare scenarios voiced by the environmental and climate scientists in the 1980s (climate shifts, glacial and polar melting, desertification, seawater dilution, ocean acidification, extreme weather) are now happening.

The new data were more uncomfortable but not yet enough to cause personal panic. I thought, "Maybe when I am an *old* man I will see dramatic effects in America..." Then my rational coping strategy met the concept of Peak Oil.

How Peak Oil Found Me— While on a trip to visit my parents in 2006, I picked up a book at the airport, *The Long Emergency*, by James Howard Kunstler. This book immediately scared the absolute hell out of me. Kunstler described one of the most harrowing and realistically plausible visions of the future I have ever read – and I could not stop turning the pages. You have to realize that I am big fan of apocalyptic porn like Neville Shute's *On the Beach*, Walter Miller's *Canticle for Leibowitz,* or Whitley Strieber and James Kunetka's *Nature's End*, and have always delighted in scenes of mass panic where crazed and frightened people run screaming from – whatever – in natural disaster, nuclear war, or alien invasion movies. I am no humanist. Sorry – I think humans might be nice as *persons* but collectively they are the greediest, meanest, and dumbest animals on the planet.

But Kunstler's book was nonfiction. His thesis was that our high tech civilization, world overpopulation, and our relatively luxurious way of life are *all* based on the discovery and exploitation of a one-time endowment of cheap petroleum and other fossil fuels. Oh, and by the way, the cheap high quality oil is gone and natural gas is disappearing! We have burned through approximately half of the known world oil reserves and are very near or just past the ultimate production peak in geologically available petroleum – *Peak Oil*. This does not mean that oil is "running out." It means that from here on out, oil will be increasingly more difficult, time consuming, and expensive to produce, refine, and transport. It means that worldwide demand for oil is starting to permanently outstrip supply. It means that our population, agriculture, economy, and way of life – utterly dependent on cheap fuel for survival and growth – are about to step off a cliff.

My first reaction after reading *The Long Emergency* was emotional. *Oh My God! I better sell my guitars and buy guns, ammo, a mule, and manual farm implements!* But after some further study and reflection on the subject, I realized that selling my guitars was, well... *crazy talk!* I began to realize that things will not fall apart overnight and that the Road Warriors are not on the Interstate. Not yet. I also realized that the radical changes arising from Peak Oil will also provide opportunities for *positive* adaptations in our lives, especially if we can rise to the occasion and pull together at the family, neighborhood, and local community level.

I still believe that Peak Oil and resource depletion represent the most significant crisis and calamity we have ever faced as a species. In terms of potential human deaths, this crisis of our generation could well be greater than the Dark Ages, the Black Plague, the Great Depression, or World War II. The coming dislocation may even compare with the severe population bottleneck that is thought to have been caused by the Toba supervolcano eruption 70,000 years ago. I think Peak Oil is for real, it's happening right now and it's important enough to write this essay to warn others. So, I will share my own understanding of energy resource peaking and attempt to explain why you should take it seriously. I will provide you with references and sources for further reading and study, if you are interested. If you read this essay on your computer as an Acrobat PDF file, there will be active website hyperlinks you can ctrl+click on to learn more and I have included some supplemental energy data and information in the references and appendices. Most important, considering the gloominess of this information, I have included some sensible, fairly inexpensive, positive, and empowering things we can all do to prepare for this developing crisis.

Why is Energy So Important?

For the past 300 years we have lived in an unprecedented era of a continuously expanding fossil fuel supply. Burning around half of our one-time geologic endowment of cheap fossil fuel energy has produced a world population of 7.0 billion and a technology and global social and economic organization someone from the 18th Century could not have even imagined. Thanks to cheap energy, even fairly poor Americans and Europeans enjoy comforts and conveniences only the very rich could afford in pre-industrial times.

Consider a common example from our daily lives: driving to the shopping mall in your family's automobile. You and a 4,000-lb, 150-horsepower automobile travel 10 miles at 60 mph. Along the way you go over a fairly steep 500-ft hill and you arrive in 10 minutes. Now, how much manual labor and time would it take to *push* your car to the grocery store? Another version of the problem is, how many slaves would it take to convey twenty 200-lb people in seated comfort 10 miles? It is estimated that the energy used by an average American *every day* is the equivalent of having 100 personal slaves working for us all the time (Hartmann 2004).

Energy is the essential mysterious essence that supports life, our food production, and our civilization. It is the *fundamental* resource that is needed to obtain all the food and secondary resources we require to survive. Until recently, energy has been so cheap, plentiful, and available, that many people do not even realize that producing food, creating technology like computers, or performing work (moving and building things) depends fundamentally on energy.

What is Energy?— A simple analogy for energy is *useful heat*, and we know that fire gives off heat. Fire is the heat and light given off when a fuel, such as wood, coal, or petroleum burns. Because we burn fuel to create fire, fuel is a good analogy for energy and energy supplies are often discussed directly in terms of the price and availability of different fuels.

The original fire and source of all energy for Earth is the sun, whose hydrogen-fueled thermonuclear fire and light provides enough ambient heat to allow liquid water to exist and provides from 100 to 500 Watts per square meter

(W/m^2) of continuous energy on earth's sunlit surface. This abundant solar energy enabled and sustains life and performs work by helping create weather (wind, rain, and snow) and ocean currents. Using the mysterious miracle of photosynthesis, solar energy is embedded or stored as complex carbon compounds (carbohydrates) by plants. All of the beautiful complexity and structure we see in wild nature is possible because of energy from the sun and all the combustible fossil fuels we burn for energy can trace their origin to solar energy.

Another metaphor for energy is *food*. Solar energy and photosynthesis allow life to exist, but living organisms must continuously obtain food to grow, reproduce, and survive. Animals obtain the energy they need to sustain life by eating and metabolizing (burning) the carbon compounds in plants and other smaller animals. So food is also a fuel and source of fire for living things and so another analogy for energy.

Energy is also the ability to perform work. Work was originally defined by Sadi Carnot as "weight *lifted* through a height," and manual labor – using our body's muscle strength to perform work – is a good example. We all know that manual labor requires physical effort and a healthy body that is well nourished and rested. If we are exhausted and tired, we might say we lack the "energy" or capacity to keep working.

Free Energy and Entropy— Thermodynamics is the scientific study of energy, specifically how heat and different forms of energy in a system change. The First Law of Thermodynamics states that energy cannot be created or destroyed, it can only change from one form to another. Thermodynamics suggests that energy has two principal components: free energy, the *excess* or usable/available energy in a system available to perform work or to create and sustain order; and entropy, the "shadow side" of free energy that represents the tendency of systems to wear out or develop disorder and randomness. Think of it as a dynamic balance in our universe between order and chaos. Free energy is the useful and usable energy in a system. A system with lots of free energy can perform lots of useful work or be highly ordered, structured, and complex, whereas a system without free energy will maximize entropy – and exhibit disorder and randomness.

Entropy, analytically defined by the Second Law of Thermodynamics, is characterized by dissipation, mixing, friction, erosion, dilution, decay, aging, and death. Examples of entropy are present everywhere in our lives. Free energy in the form of manual labor is needed to build and maintain a house, to plant and maintain a garden, or to arrange and keep a room tidy. The house, garden, and a tidy room are examples of structure and order. Without free energy being available and applied on an ongoing basis to create and maintain order, entropy will increase and the house will fall apart, the garden will fill with weeds, and the room will become dusty and cluttered. In the automobile internal combustion engine, the free energy released by burning a fuel must overcome friction of the mechanical components of the engine, drive train, and the road surface before the car can move. Much of the free energy of the fuel is lost as friction-caused heat that dissipates into the surrounding environment and increases entropy. Entropy is also the reason why no engine using heat will ever be completely efficient – or even close to efficient. Free energy must be available to counter the tendency for nature to increase entropy, disorder and randomness. The bad news is that entropy ultimately reigns supreme in nature: we all die and all material things fall apart – rust never sleeps.

Compared to inanimate matter, life represents a higher level of order and complexity that requires continuously available free energy from the sun, photosynthesis, and food. Organisms maintain their order and complexity by creating disorder and increasing entropy in their surroundings (Lehninger 1982) – that is, by eating and digesting other complex organisms. If free energy as food is not available, the organism dies. When an organism dies, entropy increases and the organism decays into the base chemical compounds and elements that were formerly a complex living structure.

Human culture is yet another level of organization and complexity that requires additional free energy beyond the food needed by the human population for sustenance. Larger populations and more complex social structures require correspondingly greater free energy supplies. Likewise, if the fuel source of free energy for a culture – firewood, for example – is depleted, the added cultural complexity (specialization of roles, social classes, technology, education) quickly collapses and entropy increases. We now depend on carbon-based fuels to provide the free energy to sustain our culture.

Carbon Fuel Quality and the Complexity of Human Culture— Tainter (1989) suggested that the complexity, size, and stability of a society are dependent on the availability and quality of free energy resources and that the loss of free energy resources can lead to collapse. From a thermodynamic perspective, societies cannot overcome increasing entropy when free energy resources are reduced. For example, destruction of local forests from unsustainable wood burning leads directly to increased erosion, siltation, and changes in local rainfall that ruin farmland. The inability to grow food leads quickly to a breakdown of social order and cultural disintegration. Tainter's thesis suggests that lower quality fuels limited the size, complexity, and technology of human culture and that higher quality fossil fuels are responsible for the complexity of our current civilization and world population.

Humans originally lived with baseline solar energy supplying food and human labor supplying the energy to gather food and modify the environment. At some early point, we learned to control fire and began burning carbon-based fuels wood and dung. This basic energy source and tool technology derived from wood and stone enabled hunter-gatherer culture. After domestication of animals augmented wood and dung burning, we developed herding, simple metallurgy, agriculture, slavery, and the first known civilizations. Over thousands of years we were able to create technology and social organization comparable to the Roman Empire. This level of free energy exploitation supported a world population of around 200 million humans.

Even with much smaller populations and less complex technology than we enjoy, many previous civilizations and cultures have collapsed because overpopulation depleted local forests, topsoil, and other fundamental energy and ecological resources. Cultures such as the Polynesians on Rapa Nui and civilizations like the Maya likely collapsed when deforestation eliminated wood as a source of free energy (Diamond 2005, Tainter 1989).

During the 17th century, the English began to exhaust their firewood supply and gradually began using coal for a cooking and heating fuel. Coal was formed from plant materials that accumulated in swampy wetlands mostly during the Carboniferous Period 360 – 300 million years ago. Increasing demand for coal and the need to drain water from coal mines led to the development of primitive steam engines. The greater energy density (amount of energy per unit volume or weight) of coal provided the free energy that built the first railroads, replaced wrought iron with stronger cast iron, and fueled the first wave of the industrial revolution. The English built a global empire using coal and steam engine technology and the free energy supplied by coal led to the accelerated development of chemistry, physics, and engineering. By the early 20th century, coal had enabled the development and spread of electrical power which led to a whole range of new technologies such as electric motors and lighting, telephony, refrigeration, and radio.

Oil was first exploited in the US starting in the 19th century, and its early development helped the US win World War II and become a global superpower. Most oil was formed from plankton and algae that accumulated in shallow seas during the Permian to the Cretaceous periods from 290 – 100 million years ago. The development and expansion of this highest quality fossil fuel led to the internal combustion engine, stainless steel and exotic metallurgy, aviation, nuclear weapons, space travel, synthetic fertilizers, the mechanization of agriculture, chemical pest control, plastics, pharmaceuticals, and technologies such as television, electronics, lasers, fiber optics, computers and robotics. Oil was also instrumental in revolutionizing agriculture, mining, and construction and it enabled expansion of the national electrical grid and rural electrification. Ours is the civilization made by oil, the most energy dense and portable transportation fuel ever discovered (see appendix 2 for a comparison of carbon-based fuels), and the greatest source of free energy *ever* exploited by humans.

Oil and Agriculture— World population was less than 500 million up until 1500 AD and did not reach 1 billion until 1800 – 1850 (U.S. Census Bureau 2006, 2007). In Europe during the late middle ages, population actually declined from 75 million to 50 million between 1340 to 1450 (Russell, 1972). This was a world modern Americans and Europeans no longer remember: completely dependent on natural fertilizers, wood or dung for heating and cooking, human and animal energy inputs, and moisture and weather supplied by solar energy. Drought, pestilence, or severe weather that destroyed or reduced harvests often caused widespread famine and sudden losses in population. The effects of famine were compounded by limited food surpluses and disease epidemics. While famine still affects poor and war-torn countries, no industrialized region experienced natural famine in the 20th Century. This extended period without famine in Europe and America is *unprecedented* in world history (Ponting 1993, Diamond 2005), and it was all due to cheap and plentiful energy.

The *green revolution* of the mid-20th century – the application of fossil fuels to food production – was enabled by artificial fertilizers (ammonia made from natural gas and petroleum-mined phosphorus and potassium), chemical pest management (made from petroleum), and large scale mechanized agriculture (fueled by petroleum). Worldwide, cheap energy was used to build massive and extensive water storage and irrigation infrastructure that also contributed to increasing agricultural productivity. Currently, some of the most productive land in the US is the intensively farmed and irrigated Central Valley of California. This application of cheap energy worldwide to agriculture was directly responsible for increasing crop yields and food productivity and it kicked exponential population growth into high gear.

Almost all of our food is produced on large factory farms that utilize large diesel-fueled machinery requiring substantial applications of synthetic fertilizers, pesticides, and herbicides. Small sustainable farms exist only as a novelty portion of total agricultural production. Even the organic food segment of production is composed of large-scale operations dependent on cheap oil for delivering compost and natural manure to fields, mechanized cultivation, harvesting, packaging, and long distance refrigerated shipping.

Food processing, preservation, refrigeration, packaging, and distribution were also developed and industrialized by cheap oil and we now burn 10 calories of energy for every calorie of food we produce. Trucking and shipping food worldwide is now thought of – if we think of it at all – as being unremarkable and normal. The *average* distance our supermarket food is shipped is 1,500 miles in the US. Because of cheap oil and its application to agriculture, citizens in the developed world until very recently payed the *historically lowest* percentage of their income for food (around 10%) (Heinberg 2005, Diamond 2005).

The ability to feed ourselves is called food security and any loss in the availability of energy resources will have a profound effect on oil-based agriculture. While poorer countries already suffer fuel and food shortages, the advent of Peak Oil has raised the issue of food security for developed countries. The European Parliament recently published a report identifying the issues surrounding Peak Oil and food security in Europe (Lucas, et al. 2006), and Greenauer (2006) summarized some of the energy use issues that will affect food security in the US:

- After crops leave the farm, two times more energy is expended to transport, process, package, and sell food as was used to cultivate and harvest it.
- Without massive inputs from fast depleting reserves of oil and natural gas, most crops, especially grains, could not be grown at their present industrial scale.
- Even without energy depletion, worldwide agricultural production per acre has declined since the mid 1990s, apparently because of water availability, changing climate patterns, soil depletion, and resistance to pesticides. (This is an example of how entropy causes the law of diminishing returns.)
- Processed foods – which require the most energy to prepare – now account for 75% of all food sales globally.
- Americans buy 90 percent of their food in supermarkets, and only a small percentage of the population lives within walking distance of supermarkets.
- Demographers estimated that in 2006, for the first time, over half of humanity will be urbanized, living in towns or cities. This was the level of urbanization in the US during the Great Depression. Now, less than 5% of Americans are still involved in farming, and less than 1% know how to farm sustainably with natural fertilizers.

We Are Using LOTS of Energy— Another reason why energy is important and depletion is a critical issue is that we burn though an extraordinarily large amount of energy on a continual basis. Data available from the

Energy Information Administration (EIA) shows that globally, we are burning around 70 – 75 million barrels of oil per day (Mbbl/d) and every day in the US we go through around 19 Mbbl – around 7 *billion* bbl/yr. Americans are also burning 21.9 *trillion* ft^3/yr (cubic feet per year) of natural gas (around 700,000 ft^3 every second) and around 1 billion tons of coal per year (2.7 million tons/d). We burn all of that fossil fuel plus use hydroelectric and nuclear power to keep the US economy running and people fed.

As I studied Peak Oil and began looking at US energy data, I noticed that the annual consumption numbers were huge – *quadrillions* of BTUs (British Thermal Units) per year – called *quads.* A quadrillion is a thousand *trillion*. These numbers were so large I could not even visualize them in a meaningful way – they were truly mind-boggling. So, I did some calculations just to try and get a grasp on the magnitude of how much energy we are burning through every day. Because we use different kinds of energy and fuels, I decided to summarize all the major sources calculated as if they were barrels of oil – hence the term "barrel of oil *equivalent*" or "gallon of oil *equivalent"* (boe or goe). Table 1 provides a summary of American energy consumption using crude oil equivalent units (see appendix for calculations) and shows our energy usage on a collective and personal basis.

Table 1 – Author's summary of US energy usage (EIA 2007, 2011).

Energy Source	***Barrels of Oil Equivalent per Year, boe/yr***	***Gallons of Oil Equivalent per Second, goe/s***	***Per Capita Daily Energy Use, gallons of oil equivalent per day, goe/d***
Petroleum	7.556 billion	10,060	2.90
Natural Gas	3.663 billion	4,868	1.41
Electricity	4.823 billion	6,518	1.87
Total	16.040 billion	21,450	6.18

On average, every day, every American man, woman and child burns though the equivalent of a 6.2-gallon tank of light crude oil. Think about that fact for just a few seconds. If we all had to actually carry that much North Sea Brent Crude, it would fill a 4" x 12" x 20" jerry can and weigh around 50 lbs. Placed end to end, these jerry cans of daily American energy consumption would extend almost 95,000 miles – enough to circle the earth **four times**! If our daily consumption were spread 1" deep, it would cover 114.1 mi^2/d, or 41,600 mi^2/yr. That means that our current consumption could cover 14.3-mi^2 Santa Rosa Island, Florida, with an inch of oil in a little over 3 hours, the entire 8,400 mi^2 Denver-Boulder metropolitan area in a little over 2 months, and the state of Alabama (151,000 mi^2) within 3.8 years. Every 30 seconds, we are burning through the equivalent of an Olympic-sized swimming pool of oil (over 660,000 gallons).

Folks, that's a helluva lot of energy!

So . . .To Summarize— Low-cost energy supply and availability is critically important because our society owes *all* its advances, technology, conveniences, and modernity, to the historically unique appearance and exploitation of cheap fossil fuels. Cheap oil and energy have influenced *every* dimension of our lives, from the way we live practically and interact socially, to the ways we organize our economy, and even how we formulate and adopt religious beliefs, scientific theories, and philosophical ideas. Because of cheap energy we enjoy the luxuries of cinema, cosmology, abstract art, and experimental music. The idea of progress itself has been fostered by the expanding availability of cheap energy.

We are all aware of the deleterious effects of our energy exploitation but there have been very positive social benefits that were directly enabled by cheap energy. An expanding economy, prosperity, and replacement of human labor with cheap energy have been major factors ending slavery, promoting racial equality and tolerance, women's rights, and until 1970, an expansion of the working middle class.

Because we – and our parents and grandparents generations – have all grown up when oil and energy were cheap and abundant and supply expanding, we have a hard time appreciating that the entire oil-driven industrial age only accounts for around 2.5% of recorded history (4000 BC to today), and only 0.06% of species history

(250,000 BC to present). Now, our economy, agriculture, financial system, technology, transportation, and culture are completely dependent on cheap oil and energy for our food, economic growth, and social stability. Any constraint reducing the flow of energy or increasing the price will have a direct and negative effect on our civilization and population.

What is Peak Oil and Resource Depletion?

Peak Oil is the term used by petroleum geologists and oil economists that describes the ultimate and inevitable decline in world oil production. We often hear that there is still a lot of oil left in world. Indeed, there is – on the order of 900 to 1,200 billion barrels (depending on how and which reserves are counted). But Peak Oil does not mean 'running out of oil.' It means 'running out of cheap oil' (Energy Bulletin 2007). This occurs because the highest quality and readily available resource deposits (the "low hanging fruit" of rich ore veins or pressurized sweet crude) are extracted *first* when resource exploitation is developing and growing. Beyond the half-depletion point, extraction rates (production) decline because the remaining resource becomes increasingly difficult to find, is poorer in quality (lower energy content and more impurities), requires more energy and time to extract and process, and creates more pollution. The resource cost becomes increasingly expensive in both energy and money terms. The date when the halfway point in supply is reached is called the "peak," and worldwide, around half of the conservatively estimated original world reserves of 1,800 billion barrels of oil (Association for the Study of Peak Oil – ASPO 2007, Campbell 2002) have already been pumped, refined, and burned.

The Peak Oil concept was originally recognized and developed by petroleum geologists, engineers, and oil investment bankers – pragmatic oil company men of our parent's and grandparent's generations. This is not a group, generally speaking, you would associate with crackpots and lunatic conspiracies. I consider resource peaking a clearly supported law of nature that accurately describes how nature really operates. It is as "true" as Newton or Einstein's gravitation equations or the laws of thermodynamics. We can get some insight into why resource peaking happens by considering how nature distributes resources and deposits on our planet.

Entropy – Why Resource Production Peaks— One of the primary reasons that production of non-renewable resources peaks and declines after the halfway point is our old nemesis entropy. You may have heard Aristotle's maxim, "Nature abhors a vacuum." Well, a corollary to that statement could be, "Nature hates a pure substance." Both a vacuum (a completely empty space) and a large deposit of a pure element like gold or sweet crude oil are exceedingly rare in nature because these situations represent highly *ordered* systems that entropy always works to eliminate over time. The relentless action of entropy favors the scattering, breakup, erosion, and mixing of the large pure deposit into many smaller and less pure deposits. This unfortunate fact of nature can be visualized in Figure 1 which shows what I call the *Unavoidable Resource Triangle*:

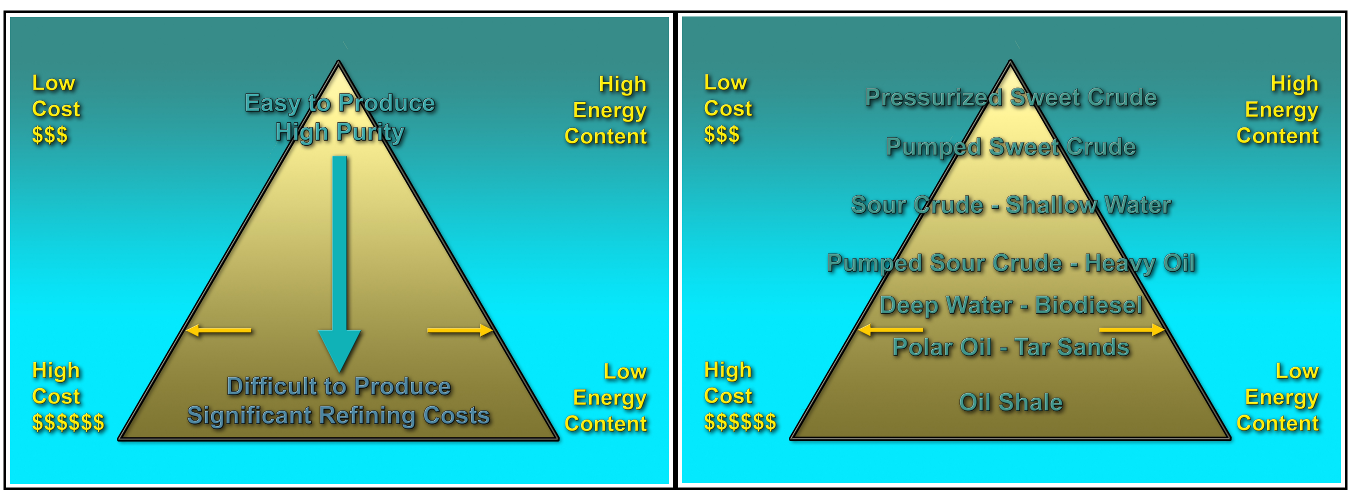


Figure 1 — The Unavoidable Resource Triangle. On the left is the general case showing how resources appear in nature and on the right is how different petroleum resources might be mapped on the triangle.

The entire triangle represents the total amount of a finite resource: oil, gold, diamonds, etc., and the yellow arrows indicate the half-depletion point for the resource. Entropy only allows a *small proportional amount* and a *few large deposits* of a relatively pure resource, and in figure 1 we see that the purest and highest quality deposits are located at the very top of the Unavoidable Resource Triangle. This is the good stuff, the "low-hanging fruit" that is easy to produce and cheap to refine, but it only represents a small percentage of the total resource available.

The farther down the triangle you go, the absolute amount of resource increases but the quality goes down. More free energy is needed to find, produce, and refine the material, so the rate of production slows and the cost to produce goes up. Another entropy caused effect for bottom of the triangle fuel sources is the greatly increased pollution and waste flows generated from production of poorer quality sources (strip mining overburden waste for tar sands, deep water blowouts like the 2010 BP Disaster, and groundwater contamination from fracking chemicals).

The largest deposits are at the bottom of the triangle and in the case of oil (figure 1 right) this is represented by petroleum produced from oil shale (shale rock with high carbon content). Yes, there are many cubic miles of waxy shale rock kerogen all over the western US but it has to be mined, retorted (cooked at high temperature), and refined a hell of a lot before it can be shipped in a pipeline or burned in a car engine. You have probably also heard that there's a lot of gold dissolved in the world's oceans. There really is – around 75 billion kilograms – but it exists at such low *concentrations* (around 0.000000011 grams per liter, or 11 nanograms per liter) that collecting it would take way more time, energy, and cost than the gold is worth. Don't blame me – it's just the way things are on this strange beautiful planet where entropy is king.

The Nut Picker Analogy— You have very likely experienced resource peaking in your every day life. Let's say you are at a party and you are assaying the munchie table. You inspect the vegetable plate (*rabbit food! yuck!)* – the rumaki (*ugh – liver*) – and you try the 7-layer dip (*whoa! too dang hot!*). You sample a few other items. *Who brought the damn jello fruit salad, and where are the chips?* Ho hum. Then you see a bowl of mixed nuts, and you remember you really love almonds, so you move in for the kill.

The bowl contains around 10% almonds (analogous to oil reserves) and the rest are peanuts and those damn bitter Brazil nuts (some greedy *bastard* already mined all the cashews!) So you start picking out the almonds. Go ahead, nobody's looking. At first it is easy to find the almonds complete and intact – you lightly shake the bowl and the big boys readily appear on the surface ready to pluck. Your rate of discovery and munching of almonds (analogous to production) is now high and you waste very little time (energy) finding those lovely nuggets. Then the almonds are no longer visible on the surface – you have now eaten around half of the almonds. You have to start digging through the nuts and spend more and more time stirring and searching (expending more energy) to find the almonds. The almonds still turn up but they are getting smaller and broken pieces are showing up more often. Eventually, you have to spend more and more time stirring and digging through the junky peanuts and Brazil nuts to find ever smaller and poorer quality almond fragments. At this point, your munching has been reduced to a small fraction of your initial consumption rate and sometimes you actually eat peanut fragments thinking they might be almond bits. Uh oh, here comes the hostess, and she knows you have been mining nuts! Busted! Run!

The nut picker analogy tells us something profound and universal about the structure of nature and resource depletion. All these processes begin slowly, reaching a fast growth phase where readily accessible and high quality resources are quickly gathered (the low-hanging fruit). Then the high quality deposits are depleted and more and more work is required to get less of the resource. This is the peak – the point of maximum production or extraction. Even though there may be half the total resource left, you have reached the end of the easy pickings. From here on out, it will require more and more energy and more time per unit of resource extracted. You have reached the point of diminishing returns and production will inexorably decline over time.

The Normal Curve and Growth Curve— The decline phase of resource discovery or extraction will often show symmetrical behavior to the development phase and the entire process approximates a bell-shaped curve called a *normal* or *Gaussian* curve (figure 2 left). Resource discovery and extraction is just one of many growth and maturity processes in nature that follow the same kind of symmetrical growth and decline. If you graph production or discovery *rate* (let's say in millions of barrels of oil per year, Mbbl/yr) or growth *rate* (in inches per year for a child) over time, you get the classic bell–shaped curve (figure 2 left). Another way to visualize resource development and depletion, or growth and maturity processes generally, is to plot *cumulative* production or growth (height every 6 months, for example) over time to create a sigmoidal or S-shaped curve. In math, this curve is called a *logistic* curve and example growth curves are seen in figure 2 right.

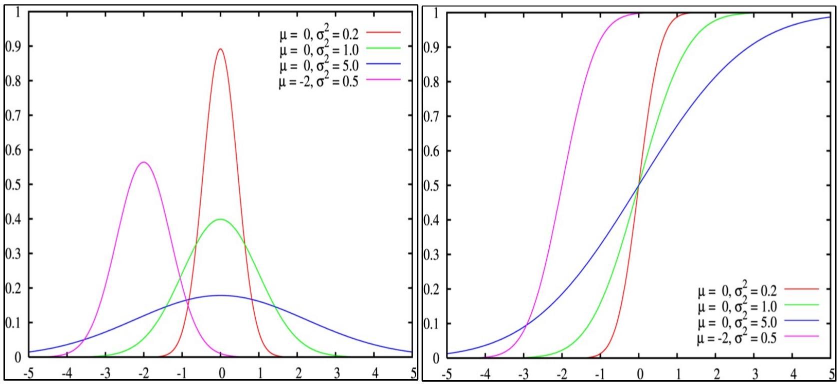


Figure 2.— The normal or Gaussian curve, left, and the logistic curve, or growth curve (right). Source: Wikipedia.

Both the growth curve and normal curve can be used to describe the same process and assuming that production or growth data are accurate, these curves can be used to predict future production or growth. Your child's pediatrician can accurately predict how tall your son or daughter will be at maturity from their height measured at age 2 and she can tell you at what age your child will be fully grown (Modis 1992). They use growth curves to make these predictions and scientists have used similar methods to estimate dates for Peak Oil. The problem for all such methods is that accurate and up-to-date data are often not available.

Hubbert's Peak Oil Predictions

Peak Oil is also known as *Hubbert's Peak*, named for petroleum geologist M. King Hubbert (1903 – 1989). Hubbert studied oil well and oil field discovery and production data, and first observed that discovery of oil deposits followed the normal curve (figure 2 left, and figure 3). The histogram graph in figure 3 shows a summary by decade of US oil field discoveries, demonstrating Gaussian behavior for resource discovery.

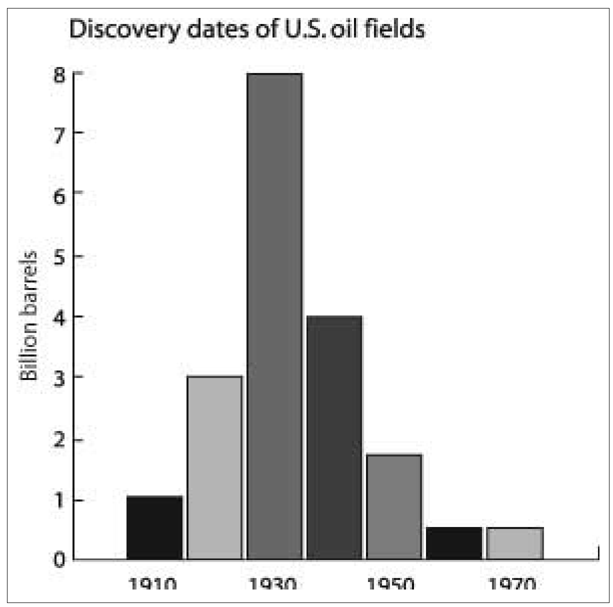


Figure 3.— Discovery of US oil fields (lower 48 states) summed by decade follows a normal curve.

Hubbert also found that *production* from an oil field also followed a normal curve and that production in American oil fields began a consistent decline around 30 to 40 years after *discovery* of new oil deposits peaked (ASPO 2007). Once the peak of production is reached for a field or region, the decline phase begins and production falls at a rate of 5% – 10% per year. This is a *significant* loss of production that is 'built in' to the geology of oil fields and the laws of thermodynamics. It makes sense that discovery must precede production and the nature of the technology used and the economic activity in a given country will produce a consistent time lag for production. The decline phase annual production losses following the Hubbert curve have been verified for every oil producing region that has peaked, for example, Pennsylvania, West Texas, Oklahoma, Cantarell, and the North Sea.

Hubbert's US Peak Oil Prediction— Hubbert observed that discovery of oil field deposits peaked in the US in the early 1930s (figure 3). Based on the consistent time lag he saw between discovery and production curve peaks in the US, Hubbert predicted (in 1956) that US domestic oil production in the lower 48 states would peak in 1970. During a period when the US was the world's number one oil producer and exporter, this prediction was treated skeptically. Shortly following Hubbert's prediction, the US Geological Survey (USGS) predicted that production in the US would not peak until 2000 (Campbell 2002, Heinberg 2007). In fact, oil production in the US peaked in 1970 – 1971, and has been steadily declining ever since (with the exception of an increased production bump on the down slope of the depletion curve from Prudhoe Bay Alaskan development). Figure 4 shows production curves for the US and the fundamental reason why we have to import more oil each year to meet current domestic demand. I also think our oil peak in 1970 is the primary reason why living standards have been eroding in America since the 1970s and why we are currently involved in Middle Eastern wars and occupations.

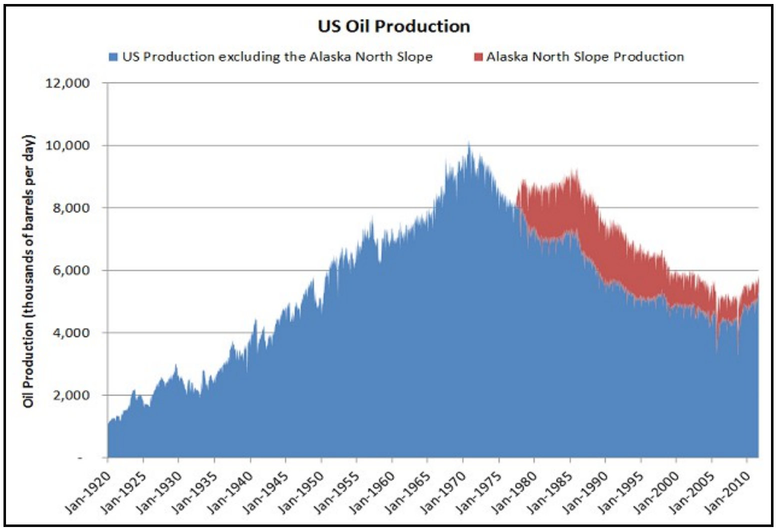
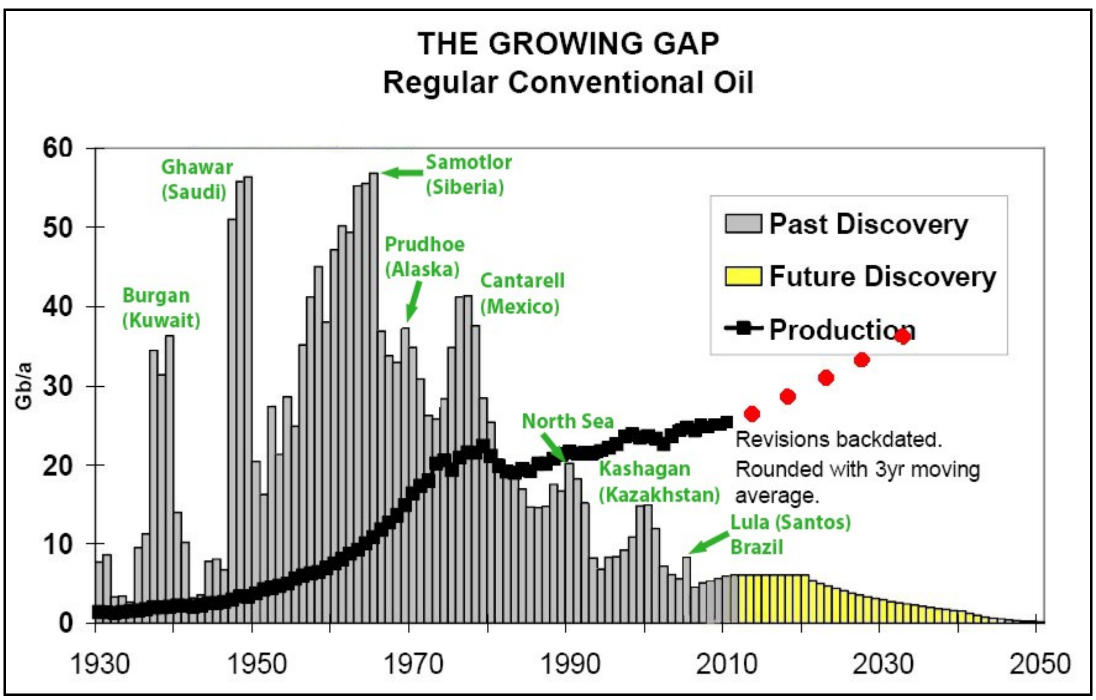


Figure 4.— Graph showing the US oil production and the 1970 production peak. While irregular, note that the production curve is symmetrical and approximates the normal curve. Source: The Oil Drum, and US Energy Information Administration (EIA 2007a).

Hubbert's Global Peak Oil Prediction— Worldwide, oil discoveries peaked in 1962 – 1964, leading Hubbert to predict that global Peak Oil would occur from 1995 – 2000. Hubbert based his world peak estimate on logistic curve models. Peak Oil did not occur during this period because the Arab oil embargoes of 1973 and 1979 produced significant American conservation activity during the 1980s, including a large increase in average automobile gas mileage, a reduction in highway speed limits, coupled with a large shift towards use of natural gas for electricity generation and as a home heating and cooking fuel. These factors delayed global Peak Oil by reducing petroleum demand (Darley 2004, Heinberg 2004, Deffeyes 2004). When global oil production continued to increase after 2000, controversy arose surrounding the validity of Peak Oil and Hubbert's predictions. However, figure 5 shows world oil discoveries and production data suggesting that Hubbert may not have been far off in his prediction.

Figure 5.— Graph showing global oil discoveries (gray bars) which peaked in the mid 1960s, and production (heavy black line). The red dots represent production that will be needed to meet economic growth to provide for projected growth in population. Source: ASPO USA



Refinements to Hubbert's logistic forecasting methods have produced a variety of more recent estimates that predict world Peak Oil occurring from 2004 (Bartlett 2000, Deffeyes 2003, Campbell 2002, Korpela 2006, Robelius 2007) to 2030 and beyond (USGS 2000, Adelman and Lynch 1997, Cambridge Energy Research Associates – CERA 2005, Exxon Mobil 2005). The reason why these predictions cover such a range of time is that values for total global oil reserves and production are necessary to estimate Peak Oil dates and a variety of global reserve estimates exist that are subject to revisions over time. Generally, higher values for total world oil reserves will calculate later dates for Peak Oil using algorithmic computational methods. Which reserves and resource estimates are counted will affect predicted dates.

An important issue to consider is that predicting a correct date for Peak Oil is irrelevant and certainly should not be the primary criterion used to judge the validity of the Peak Oil theory. Whether it has already occurred or will occur in the next 5 or 30 years matters less than what relentless entropy and constrained supplies will do to degrade the economy now and in the near future. There's plenty of data and evidence to support that our relationship with energy and our economy is undergoing major shifts. Predicting a date just invites opposing experts to post their blogs and argue about technical issues and data sourcing while we continue to do nothing about the fundamental problem. The important questions about Peak Oil to keep in mind are how will we respond nationally and locally to energy depletion and its knock-on economic woes? Will we pull together as a nation and community or pull apart?

How Peak Oil Will Appear: *The Plateau Period* — The term 'peak' suggests a clear maximum production level and well defined Gaussian shape to the decline curve – like we saw for US production in figure 4. However, the peak for global production is a much more complicated situation involving the interplay of many more variables.

Energy analysts suggest that the peak in global production assumes the shape of a bumpy plateau, called the *plateau period* of Peak Oil. This period and behavior is at or near the global peak when most producing regions are at or beyond their local production peaks and world oil demand initially begins to outstrip supply. The plateau is a complex period when increasing demand and oil price increases interact with a complex world economy and politics in unpredictable ways. The plateau produces an unstable time of sudden and sometimes severe oil price fluctuations (price volatility) and economic shocks (recession) yet there is no *significant* net increase in global supply or production capacity.

The price volatility at the plateau is caused by several factors that interact: real imbalances in demand and supply, crises producing sudden loss of oil supply or refinery capacity (terrorism, natural disasters, war and civil unrest), the amount of reserve production capacity available to buffer price swings (the existence of swing producers with spare capacity who can ramp up production quickly), the state of national oil and gasoline stockpiles and strategic reserves, and finally, the amount of *demand destruction* that higher prices cause.

Demand destruction occurs when high prices permanently reduce the number of people or countries able to afford a commodity (ASPO 2007). Demand exceeding supply by very small amounts can produce fuel price spikes that quickly ripple through the supply chain and economy to produce a drop in consumption. Poor countries and the poor in rich countries, who simply lack the resources to pay for higher priced fuels, experience demand destruction first when orders for imported oil are simply canceled or gasoline and diesel is not bought. In richer countries, working people will conserve and reduce driving to maintain household budgets. Both of these factors reduce demand and temporarily increase the available supply of crude oil, thus weakening support for higher prices.

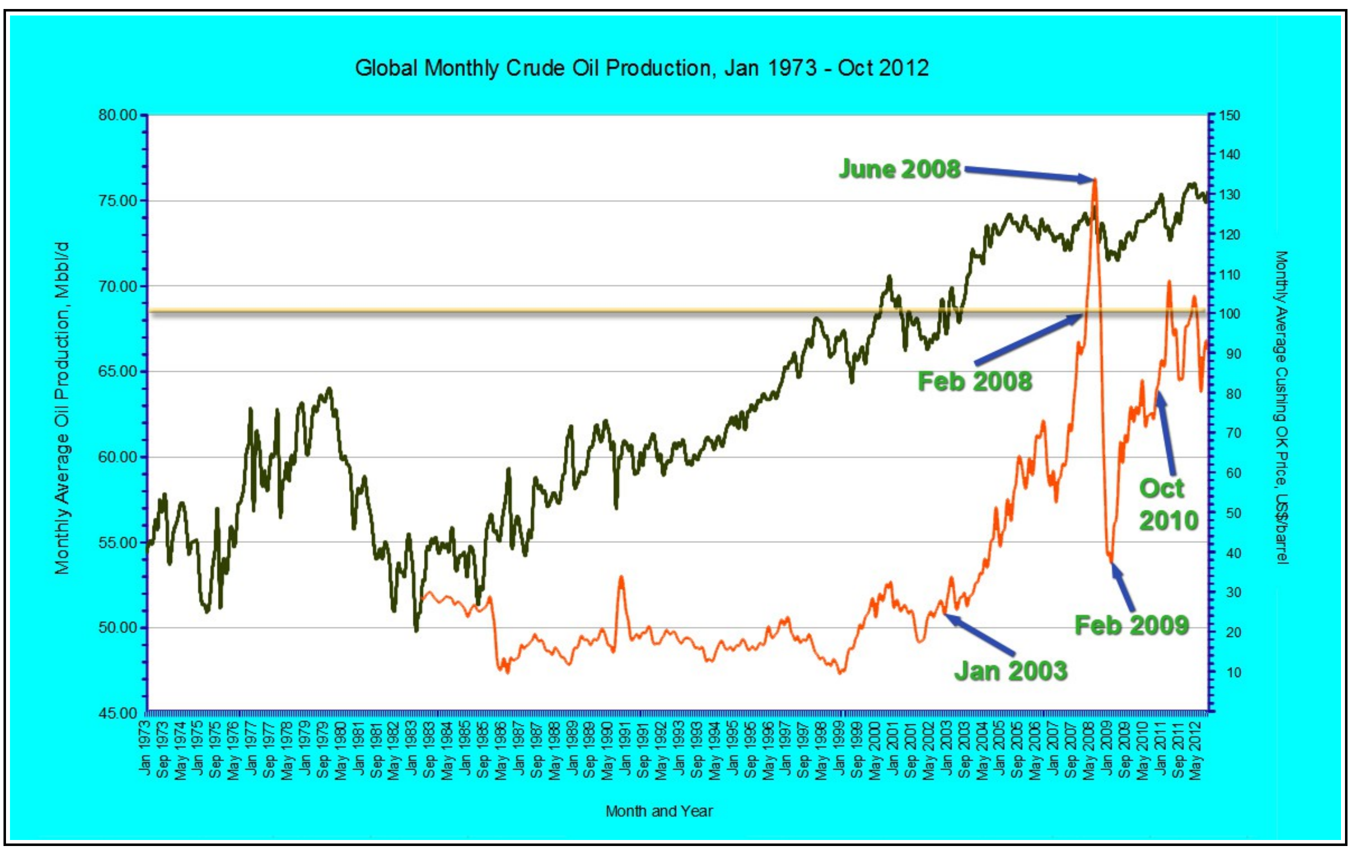
Assuming no new crises that reduce fuel supply (such as the Libyan uprising, or Hurricane Katrina), fuel costs will decline with weak demand and eventually fuel burning economic activity will resume. The new cycle of burning more oil then increases demand again. But during the plateau of Peak Oil, demand will soon begin to exceed production capacity, and price will increase again to compensate. These price shocks can be very steep because of commodity market psychology and speculation in commodities futures. The oil price spike that reached \$147/bbl in July 2008, while initially driven by demand outstripping supply, was also likely boosted (in the range of 10% – 20%) by speculation from many of the same investment banks involved in the sub-prime financial derivatives bubble. Since the 2009 crash in oil price, economic recovery and increasing demand from China and India has again increased oil prices to what appears to be a new base level between \$80 - \$110/bbl.

Before the plateau of Peak Oil, oil price variability could be moderated or dampened if a *swing producer* had reserve production capacity and could "open the spigot" and increase production. Before 1970, the US was the swing producer and recently, Saudi Arabia has filled this role. If this Middle Eastern buffering capacity is no longer available (Mathew Simmons and T. Boone Pickens suspect this is the case), it is a sure sign that we have reached peak world production and oil price volatility can be expected to continue. President Bush was flatly turned down when he requested that the House of Saud increase its oil production in the spring of 2008 when oil prices had begun an unprecedented spike – perhaps because the Saudis were *not able* to 'open the spigot.' Stagnant production in the 70 – 75 Mbbl/d range for liquid petroleum has persisted since 2005, and we have seen the unprecedented 2008 price spike help create a near global financial system collapse. Stagnant production despite high demand and high prices is precisely the kind of behavior predicted by Peak Oil analysts during the plateau period.

The rough and unstable plateau will continue until there is no longer any reserve production capacity in the global oil supply – and all available discretionary demand is destroyed. At this point, world oil production will begin a relentless decline as we reach the downward slope of the production curve. Beyond the plateau of Peak Oil, any increases in demand – or simple demand to meet essential fuel needs – will begin to produce permanent oil price increases and increasing frequency and duration of shortages – much deeper shocks that will, over time, completely change our very comfortable way of life (Simmons 2002, Deffeyes 2004).

Recent Oil Production and Price Data— To me, the most obvious evidence that suggests we are at or near Peak Oil is the actual production data available to the public from the US Energy Information Administration (EIA) website. Until the 2008 financial crisis, worldwide use and demand for oil had been steadily increasing because of the rapid industrialization and economic growth of China and India along with continued increasing demand from economic growth in the US and the developed world. Despite increasing demand and claims of spare production capacity, figure 6 shows that world liquid petroleum production began to flatten and stagnate during 2005 and did not significantly increase above 75 million bbl/d despite oil prices as high as $147/bbl during July 2008. Many resource economists and energy experts suggest that the rapid price rise in oil that began in 2003 and culminated in the economically damaging June-July 2008 price spike was initially triggered by demand exceeding world production. I think the figure 6 oil production and price data since 2005 suggest that we are in the plateau period of Peak Oil.

Figure 6.— Author's graph of EIA 1973-2012 world crude oil production data (dark line, scale to the left, million bbl/d) showing a flattening of production that started in 2005, and average monthly oil price (orange line, price scale to right). The horizontal yellow bar represents the historical maximum oil price (inflation adjusted) during the 1979 oil crisis. Monthly average production did not exceed 75 million bbl/day until sustained prices were over $80/bbl (in October 2010) for almost a year.



I have included several dates on the price curve in figure 6 that I feel are significant. First note the January 2003 point on the price curve, indicating the beginning of a rising price trend from what had been a fairly flat and stable range of $10/bbl to $20/bbl that started in May 1986. Accounting for inflation during this 17-year stable period would show that real prices for oil actually declined before the change in the market in 2003. The horizontal yellow bar represents the inflation adjusted maximum oil price seen during the 1979 – 1980 oil crisis and recession (the previous historical maximum was $39.50/bbl in 1979 dollars). This benchmark ($101/bbl) was exceeded in February 2008 exposing our economy to record high energy prices. The rising trend in price peaked in June 2008 at $135/bbl before the financial panic and recession saw prices crash to below $40/bbl in Feb 2009. The last notable point is October 2010, when monthly average oil prices rose above $80/bbl and have remained above $80/bbl as of this update.

Other Data Supporting Global Peak Oil— If the recent production and price of oil data are not sufficiently suggestive of a big change in our relationship with energy, there's other compelling reasons to suspect that we are at or very near the global peak. The figure 4 graph of global oil discovery and production clearly shows that new discoveries are not keeping up with production and that we have been producing more oil than we have discovered each year since 1984. The Brazilian Tupi (now called Lula) deep water find in the Santos Basin, announced in 2008, contains around 8 billion barrels of producible oil. This is not a small field, but it is only 5% – 10% the size of the Saudi Ghawar super-giant field (around 120 billion barrels) discovered in the late 1940s. And the Lula oil lies beneath 5,000 – 7,000 ft. of seawater, and then another 18,000 ft of sand, and salt deposits.

50% of current oil production still comes from a small group of aging super-giant and giant oil fields, including, Ghawar, Burgan (Kuwait), and Samotlor. Common sense tells us that the absence of new large field discoveries since 1984 (when annual production exceeded discoveries) is not a good omen and suggests that available resources are limited. More recent analysis of announced and planned large oil production projects (> 100,000 bbl/d expected production) by Skrebowski (2010) (figure 7) also suggests that there is a dearth of new oil projects planned beyond 2018, reinforcing the declining trend in global oil field discoveries seen in figure 4.

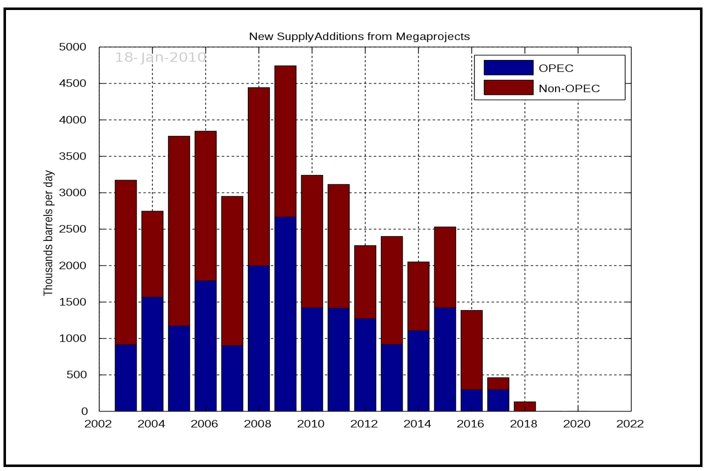


Figure 7.— Summary of the Oil Megaprojects Database for planned and funded oil production projects. Source: Skrebowski (2010).

Figure 8 shows that all non-OPEC oil production had *already* peaked by 2004 and there are now indications that all OPEC countries are also at or beyond their production peaks (The Oil Drum 2007, Simmons 2002). Actual recent OPEC production data and a demonstrated lack of capacity to act as swing producers to meet demand by OPEC during price spikes are not encouraging. Non-OPEC world oil peaking prompted a strategic security assessment of US oil shale (kerogen) reserves (US Department of Energy – DOE 2004), a topic of keen interest to our military planners.

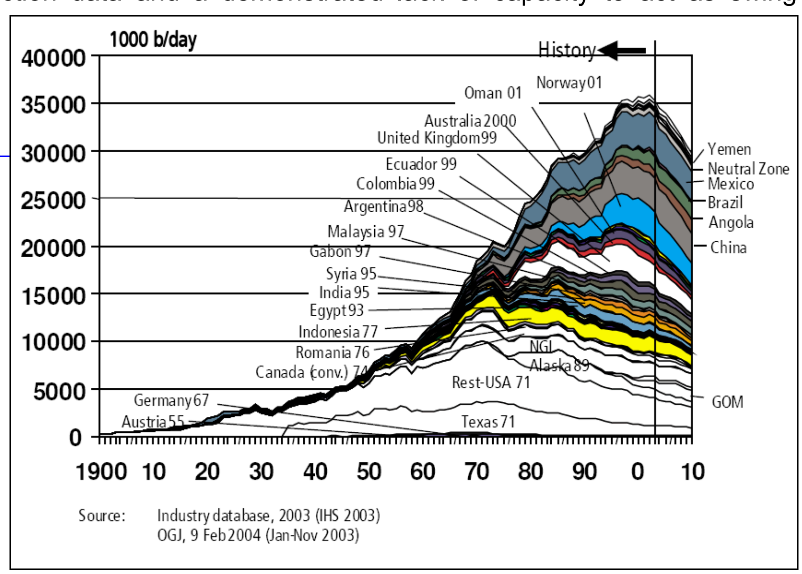


Figure 8.— Non-OPEC world oil production by country, showing peaking production in all oil producing countries. Source: DOE (2004).

Recall that Peak Oil is defined by the depletion of cheap, easy to produce, and high quality oil. When you have to drill more exploratory wells to find smaller deposits, and drill more production wells to simply maintain past production, or process the crude more before refining, you have begun to expend more energy and money per barrel to produce. Energy analysts refer to a concept called *energy returned on energy invested*, EROI or ERoEI for an energy fuel source – which is a thermodynamic version of financial return on investment (*ROI*) familiar to business school grads. EROI for different sources and kinds of energy are summarized in figure 9. During the early days of the East Texas oil boom in the Spindletop field, shallow drilling produced explosive "gushers" that produced up to 100 barrels of oil for each barrel of oil energy equivalent expended to produce (Heinberg 2005). This is an EROI of 100 – comparable to hydroelectric power (Murphy and Hall 2010). This is the sort of 'get rich quick' return on investment that helped build the infrastructure of the second petroleum industrial revolution.

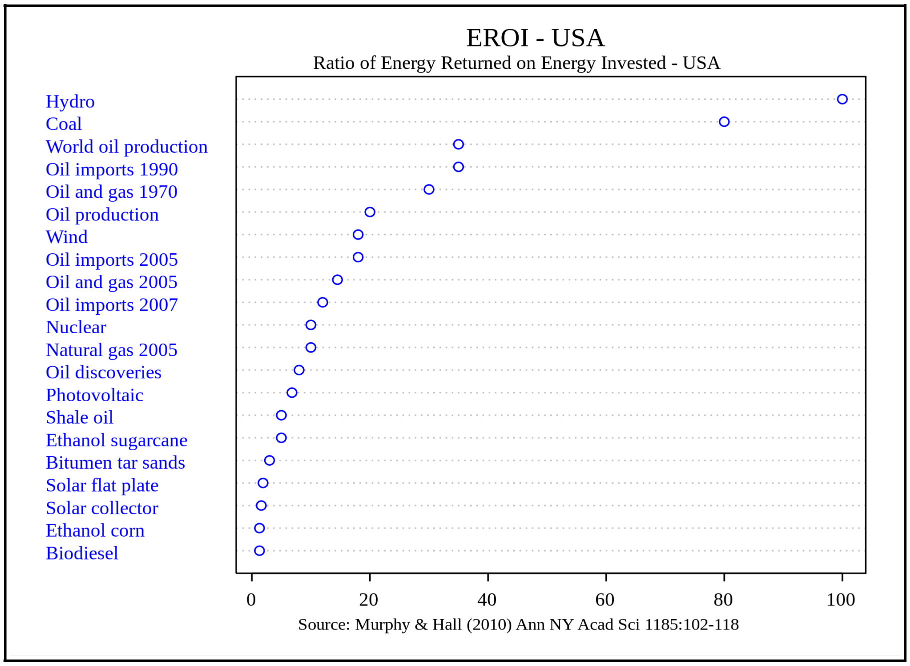


Figure 9.— Summary of EROI for different sources of energy: Source: Murphy and Hall (2010).

Figure 9 data show that imported oil in 1990 had an EROI around 35, while by 2007, the EROI for imports had fallen to below a value of 10. Tight oil like that being produced in the Bakken Shale of North Dakota has an EROI around 7 – suggesting that it is a considerably poorer source of energy. The poorest EROI – around 1, the break even point to make any energy or financial sense – is found for corn-based ethanol and biodiesel. These low EROI fuels reflect the energy required to grow the crop, ship it to a refinery, ferment the biomass, and distill the usable fuel.

Figure 10 shows the number of active oil and gas drilling rigs superimposed over production data since 1995 (Mearns and Koppelaar 2013). Worldwide in 1995 there were around 1,000 active drilling oil rigs in operation and we were producing around 63 million bbl/d of "crude + condensate" (C+C only). As of February 2013, there are around 2,650 oil rigs and we are producing around 75 million bbl/d. ***From 1995 to 2013, drilling has increased by 265%, while production has only increased by 19%.*** This is a very clear example of working harder (over 10-times harder) and expending more energy to produce less, and another piece of evidence that the oil supply is finite, and that we are nearing the peak of production.

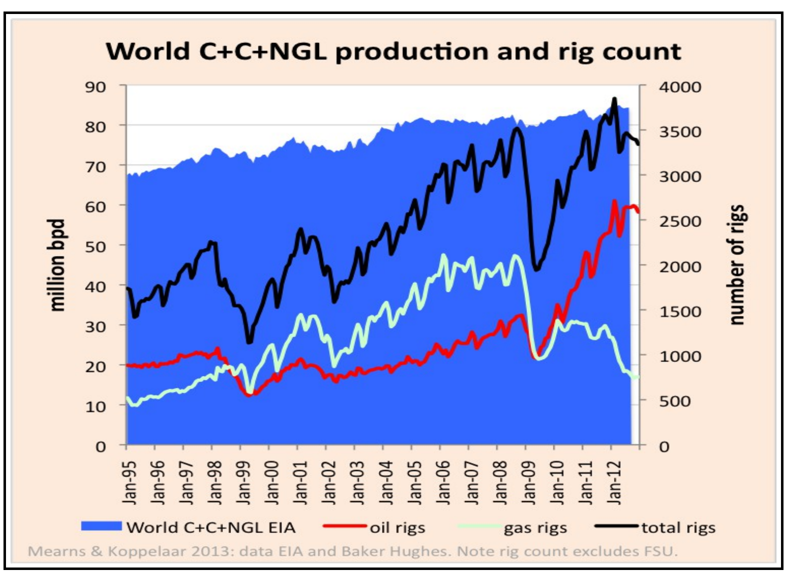


Figure 10.— Graph of global trends since 1995 in numbers of deployed oil and gas drilling rigs (colored lines) superimposed on oil production data (blue area = C+C and Natural Gas Liquids - NGL). The black line = total rigs, white line = gas rigs, and red line = oil rigs. Source: Mearns and Koppelaar, 2013, EIA and Baker Hughes.

The final supporting data suggesting that we are at or near the peak in oil production can be seen by comparing the oil price trends in figure 6 to the estimated marginal costs of production summarized in figure 11 (Timera Energy 2013). The cheapest to produce oil, around $20/bbl, is on the left side of the graph in Saudi Arabia, Other Middle East sources, and Russia. Around 60% of the remaining oil supply is more than double the price to produce compared to Saudi crude. Deep water oil from rigs like the BP Deepwater Horizon or the BP/Exxon Thunder Horse also require consistent oil prices above $70/bbl to be profitably produced.

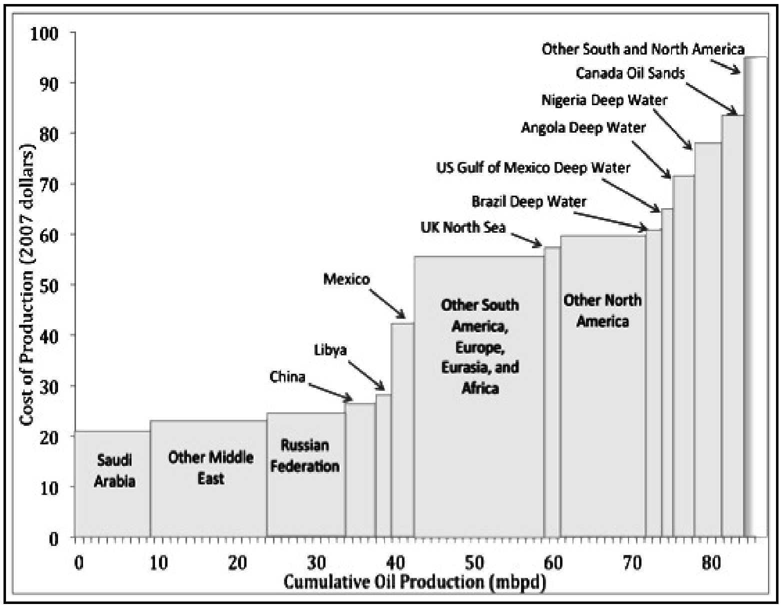


Figure 11.— A comparison of production costs for different sources of oil – EROI goes from around 30 on the left of the chart to less than 10 at the right. Source: Timera Energy/Cambridge Energy Research Associates (CERA).

Oil prices since October 2010 (figure 6) seem to have found an new minimum price level which has stayed over $80/bbl. Yes, the price will likely drop below this level if recession worsens and demand falls off a lot, but this appears to be a new pricing behavior for oil that suggests production is now coming from more expensive and lower EROI sources of crude – one of the symptoms associated with Peak Oil.

The business media has been reporting recent oil production from the Bakken Shale in the Williston Basin of North Dakota, where horizontal (directional) drilling and hydraulic fracturing (fracking) of oil in thin oil-bearing shale strata are creating a boom and increasing US oil production as of this revision. Horizontal drilling and fracking requires much more drilling and repeated fracking to maintain production, and the production life for both unconventional oil and gas wells is much shorter (around 5 years) compared to conventional oil and natural gas wells (around 20 years). Likvern (2012) estimated the cost to produce Bakken tight oil around $80 - $90/bbl, so it is a poor EROI substitute for Middle Eastern sweet crude. It is true that the Bakken oil has increased US production in the past several years and is currently accounting for 700,000 to 800,000 bbl/d. But compare the tight oil in the Bakken shale with the Prudhoe Bay fields that contained around 20 billion bbl and produced around 2 million bbl/d for over 15 years.

The fact that we were not producing significant amounts of oil from these more expensive and lower EROI sources until oil price stayed above $80/bbl is notable. And, the lack of additional production capacity from the Middle East and Russia available in sufficient quantity to lower prices suggests that the cheaper Middle Eastern and Russian oil supply is constrained if not already declining in production. More evidence strongly suggesting we are already at the peak. Former Federal Reserve Chairman Alan Greenspan noted in 2006 that world demand for oil was then exceeding production and that very little reserve supply capacity remained (Greenspan 2006). And oil billionaire and corporate raider T. Boone Pickens said in 2007 that we were already at peak production and that the price of oil is now being driven by supply scarcity.

Government and NGO Reports— Despite a lack of coverage for Peak Oil in popular media (like we at least sometimes see for anthropogenic global warming issues), government energy agencies, military planners, and non-governmental organizations (NGOs) have funded several scientific reports that are available on the Internet. These reports not only examine the technical depletion issues for oil, but also other political and economic factors that are likely to exacerbate post-peak production declines.

Two important US government reports provide detailed assessments of Peak Oil issues and their potential economic impacts along with surveys of published studies predicting dates for Peak Oil (Hirsch 2005, US Government Accountability Office – GAO 2007). The 2005 DOE report, called the *Hirsch Report*, primarily addresses the effects of Peak Oil on transportation while the more recent GAO report addresses wider implications of Peak Oil and energy depletion. These reports clearly acknowledge that Peak Oil represents a serious and final physical or geological limit to oil supplies but also emphasize that international political factors and economics are also likely to restrict production and oil available for export. Exporting countries that are experiencing exponential population and energy demand growth are now restricting oil exports to meet their own domestic needs (called the *export land effect*), withholding oil from the world spot market and in some cases negotiating exclusive long-term delivery contracts with other countries. Many exporting countries, such as Nigeria or Libya, are also politically unstable and vulnerable to disruption of production from insurrection or civil war.

If we were still an oil exporting country, these factors would not affect us negatively. Unfortunately, we remain a big time oil *importing* country despite recently reported increases in US production. These geopolitical variables now matter greatly. They have the potential to aggravate the already serious geologic depletion issues by further reducing the amount of oil offered for sale internationally. Both reports also repeated themes previously raised by Matthew Simmons and Colin Campbell: that there is an urgent need for accurate and unbiased data for global oil and energy reserves and current production so that international and national resource agencies can begin the task of developing sensible mitigation responses to Peak Oil.

In October 2009, the environmental NGO Global Witness released a report, *Heads in the Sand: Governments Ignore the Oil Supply Crunch and Threaten the Climate*. This report recommended immediate government action to deal with oil depletion and a predicted oil supply crunch in order to minimize social unrest and to address global warming. In February 2010, the Industry Taskforce for Peak Oil and Energy Security (ITPOES), a coalition of British corporations concerned about Peak Oil, released a report, *The Oil Crunch – A wake-up call for the UK economy.* Airline owner, Virgin Group Founder, and ITPOES member Richard Branson, speaking at a press conference for the release of the report warned of a Peak Oil fuel crunch as soon as 2015 and that government policy action and coordination among energy and energy-dependent companies needs to begin immediately. In the summer of 2010, the Center for German Army Transformation, a military think tank, issued a report, *Peak Oil: Implications Of Resource Scarcity on National Security,* that was leaked to *Der Spiegel* and warned of catastrophic effects on the world economy from Peak Oil-caused energy shortages.

Also notable is that several city governments are not waiting for national governments to act, with Portland, Oregon (City of Portland 2007), Bloomington, Indiana, Seattle, Washington, and Kinsale, Ireland (Kinsale 2005) organizing working groups and developing what are called transition or descent plans to start the local preparation process for Peak Oil and energy declines.

Peak Oil Controversy and Confusion

For many of you, this essay may be the first time you have heard of Peak Oil. Peak Oil remains a fringe subject for mainstream print and Internet media, radio, and television, and the majority of even educated people have not heard of it – for good reasons. Any solution or mitigation strategy for Peak Oil is going to directly affect very powerful and politically connected sectors of the economy: the energy extraction and processing industries, utilities, agribusiness, and investment banks. Not only do politicians want to please their benefactors in the corporate sector, but they are loathe to ask their constituents to do anything that might look like hardship or sacrifice. And no politician wants to tell their constituents that the party is over and the economy will not get better. I can definitely see the need for lowering speed limits again, but even I chafe at driving 55 mph. Because of these factors, Peak Oil coverage and discussion has been marginalized in the mainstream media. When it has been mentioned in the business or energy media, it usually creates a serious amount of denial from official sources in Government and very artful spin from the industry's economists and specialists.

Peak Oil is not an intuitively simple concept to grasp and the global oil industry is very complicated and not amenable to sound bite coverage or glib talking point summaries. World energy production involves thousands of production and transport entities and scores of nationalities. Even the official data from the EIA can be confusing and misleading (see sections below), and it takes some deliberate research and some scientific and math background to appreciate the details of the debate. When a significant segment of the adult population thinks the moon is bigger than the earth and could not find Iraq on a globe, don't expect mass movements to form.

Further, Peak Oil is a *downer* that will not help sell boner pills, X–Boxes, or SUVs. It runs counter to the constant barrage of general misinformation from corporate media, that features prominent distractions like polarized conflict between liberals and conservatives, sensational crimes against white people, and celebrity scandal (Anna Nicole

Smith, Paris Hilton, Tiger Woods) – sadly pandering to public ignorance, sensationalism, class envy, and ironic ennui.

When Peak Oil issues do become news – I will not be surprised if network and cable news stories are handled much like global warming stories where the gravity of the issue is downplayed by presenting it as a "controversy" where the pessimists are countered by the optimists, environmentalists and Peakists dismissed by free-market economists, and the average viewer is left with apathetic confusion. Expect bias towards mainstream pundits who will likely describe Peak Oil advocates as doomers, Chicken Little wackos, and scaremongers. This strategy is used because it works to create enough doubt amongst voters to prevent any collective demand from the public to take action. There are also very powerful personal emotional reasons for denying we face a serious near term emergency, so even a little doubt is effective in preventing action.

Optimistic and Pessimistic Resource Experts— Even the most optimistic scientists and resource economists who study energy do not claim that the theory of resource depletion, production peaking, and production declines after the peak is wrong. That would be akin to saying that gravity or entropy is not real. Almost everyone agrees that oil and other fossil fuels are finite resources, that we have already extracted – or nearly extracted – around half of the conservatively estimated global oil supply of 1.8 – 1.9 trillion barrels, and that current world demand for oil is beginning to outstrip our ability to pump it out of the ground. Also, everyone agrees that the actual date for global Peak Oil will only be verified in hindsight because of the complexity and time lags in gathering data from multiple sources and the unreliability of much of the reserves and production data. Given the general agreement on resource depletion and peaking among scientists, there are two camps among the oil industry and resource intelligentsia: the *optimists* and the *pessimists*.

The optimists, or *cornucopians,* generally believe there is plenty of oil remaining, minimize negative impacts from oil depletion, and believe in the power of financial markets and our scientific and technological creativity to make rapid and efficient adjustments to match supply to demand (Adelman and Lynch 2000, Kunstler 2005). The optimists appeal to faith in the idea of progress and the natural tendency for people to prefer good news over bad and to try and maintain a positive outlook on life. Since Elisabeth Kübler-Ross noted in her book, *Death and Dying* (1969) that denial was frequently the first stage of the grieving process, any optimistic argument is bound to find a receptive ear to unwelcome and distressing Peak Oil news.

The optimists are composed of consultants like CERA, founded by the noted oil historian Daniel Yergin, and IHS Energy (formerly Petroconsultants, SA), oil industry trade groups such as the American Petroleum Institute, official governmental agencies such as the USGS, the US department of Energy (DOE's) Energy Information Administration (EIA), and the International Energy Agency (IEA), along with mainstream economists, the banking and financial sector, and many oil and energy companies. The optimists generally represent vested financial interests who dominate economic activity and government policy and they endorse the upper range of estimated values for estimated oil reserves, claim that future production capacity will expand to meet demand, and argue against resource scarcity, the need to mitigate for Peak Oil shortages, or implementation of energy policy changes (Heinberg 2004, Simmons 2002).

When discussing supplies and sources of oil, the optimists tend to cite larger reserve estimates that also often include what is called non-conventional, unconventional, or *heavy crude oil*. These are the poorer quality hydrocarbon resources towards the bottom of oil's Unavoidable Resource Triangle and to the right in figure 10. These lower-quality petroleum resources are composed of deep water or arctic deposits in hostile and unforgiving environments, tight oil like the Bakken Shale, or bitumen-like tar sands in Alberta and Venezuela that must be mined and processed at high cost before it can be sold as petroleum or shipped to refineries. Optimists will sometimes include oil shales (kerogen) that are much more difficult and expensive to extract and refine even compared to tar sand bitumen, let alone high viscosity sulfur-rich liquid oil (sour crude). As Richard Heinberg and others have noted, Peak Oil is ultimately about *flow rates* – the ability to keep fuel deliveries moving to meet demand, and tar sands and heavier oil cannot match the current ease and rate that liquid petroleum is produced.

The cornucopians are usually the experts who are cited and interviewed by major corporate business and news media. They are quick to point out when new oil discoveries are made, such as the 8 billion bbl Lula deep water field or the 4 billion bbl Bakken Shale tight oil. However, they almost never mention the *relative size* of the new oil discovery (by comparing it to the old super-giant fields in the Middle East), or what it costs to produce the new oil. And potential pollution costs are rarely mentioned. Oil reserve announcements in the business media create a perception in the public mind of resource abundance, yet the higher cost to produce and smaller relative size of the new oil field discoveries is what Peak Oil is all about – almost all the newly discovered oil requires deep ocean rigs, fracking, mining and *in situ* processing (tar sands in Canada and Venezuela), or hazardous climatic or political environments (arctic oil or production in failed states like Nigeria).

The pessimists – more accurately, *realists* – are concerned that global oil reserves have been grossly overestimated or purposely overstated, oil production may not be able to respond to price signals, the economic impacts of Peak Oil will be significant, and that Peak Oil is either already here or imminent. Pessimists predicting and promoting more immediate dates for Peak Oil include the petroleum geologists M.K. Hubbert, Kenneth Deffeyes (2005 peak) and Colin Campbell (2006 – 2007 peak), physicist Albert A. Bartlett (2004 peak) (Bartlett 2000), resource ecologist Richard Heinberg, petroleum engineer Jean Laherrère*,* oil investment banker Matthew Simmons, economist Jeff Rubin, and British businessman Richard Branson. Simmons served on former vice president Cheney's controversial Energy Task Force convened shortly after the Bush administration took power. Based on their analyses, these specialists think Peak Oil either has already occurred or will likely occur before 2015.

Just like the optimists have their free market propagandists and outright Peak Oil deniers, the pessimists are also home to a fringe of apocalyptic doomers, a group that shares some overlap with the fringe survivalist cadre. These are usually not industry veterans, but rather legitimately frightened people who are convinced the wheels are coming off the wagon and that the Great Humungus is already rallying his bezerkers (see *Road Warrior*) in the outback. These bloggers and activists are frequently predicting dire consequences and imminent threats – that more often do not occur, leading to ridicule by the optimists in the media. But the apocalyptic fringe does not characterize most Peak Oil advocates who continue to offer reasoned analysis of actual data concerning energy issues.

Despite the doomer fringe in the pessimist camp, my own research and evaluation of the available data lead me to side with the pessimists. These independent oil industry veterans, scientists, and businessmen do not trust the higher estimates for reserves or the optimistic forecasts for large future increases in production. As the next sections discuss, there are too many legitimate reasons to suspect official and media pronouncements regarding new production and discoveries of oil, and the complexities surrounding how energy depletion shocks will affect the economy are significant.

Resource Estimates are Biased High— If a potential source of oil is called a *resource* estimate, it is just that – a guess for the total amount of oil that *might* be produced with no consideration to cost of extraction. These numbers are the most general estimates with very little supporting data to confirm or deny, and are most likely to be high-biased. Petroleum engineers refer to the term *producible fraction* of an oil field, which is the volume that can be technically produced with current technology while ignoring the law of diminishing returns. This term is also prone to high bias, because entropy always reduces the practical amount of oil that can be produced – by around *half*.

Peak Oil advocates point out that much of the reported global reserves data are often inaccurate, misleading, or simply fudged for commercial or political purposes. Oil companies have historically inflated their reserve estimates (to maintain support for stock prices) and OPEC countries with nationalized oil systems treat production, discovery, and reserve estimates as state secrets (Simmons 2002). Nations seeking World Bank or International Monetary Fund loans often use their energy reserves as justification for likely repayment – another reason many official resource estimates are biased high. In the 1980s, OPEC oil reserve estimates were upwardly adjusted by 30% – 50% without any accompanying discoveries – and were likely increased to justify higher export quotas desired by member states (Simmons 2002).

For oil production projects seeking investors, the SEC requires the prospectus to verify that the reserve is a *proven reserve* – an estimate with a 90% probability that the oil volume can be produced with current technology at current price (called *1P*). Despite the guidelines and 3rd party verification (from a consultant) that are required, the SEC does very little to audit or independently validate 1P estimates in a prospectus. Why should they? The free market requires risk, and caveat emptor. SEC filings are usually accompanied by fanfare and hype that are intended to attract investor money to develop and produce the oil. Many foreign investment markets only require the reporting of what are called *probable reserves* (*2P*) which have a 50% probability of being produced.

Careful news media consumers should pay attention to whether the reserve estimates are called proven reserves, probable reserves, or resources. The terms are often used interchangeably and reported without explanation that they may imply a high bias.

Higher Oil Prices can "Increase" Proven Reserves— The total amount of oil never changes, but the amount of oil that can be produced at a profit will increase as the price of oil increases. This phenomenon is called *reserve growth*, and is often cited by optimists as the big reason why Peak Oil is wrong. Optimists point to the power of free markets to respond to higher prices will always assure an adequate supply to meet demand. Unfortunately, the secondary economic effects of higher energy prices can't simply be ignored – not by working people who have budgets or nations with significant debt. High oil prices can cause recessions that create an unstable price environment that discourages investment to produce.

Production Data can be Biased High— Production data can also be fudged to create the appearance of abundance or the lack of a problem. One way that official production data are being altered to make it look better to the casual observer is to change the definition of what is considered oil. This is a subtle practice that even a journalist may not notice. Now, barrels of oil are included in what is called "total liquids." This new trend is misleading, because it combines volumes of chemicals that don't have the same energy content as crude oil, and can't be used to make the essential transportation fuels that can be refined from crude oil. The inclusion of other non-crude oil liquids can make world oil production look better than it really is.

Until the past several years, the EIA usually reported oil production as crude + condensate (C+C) – simply the number of 42-gal barrels of petroleum taken out of the ground plus the condensation products that occur during oil production. Because natural gas is present in the oil at depth (at very high pressure), it will separate from the heavier crude oil when the oil reaches the low pressure of the atmosphere, and will condense in pipes, storage vessels, and designed traps in the production rig. Condensate contains the simple hydrocarbons ethane, propane, butane, pentanes and some higher molecular weight compounds that add volume to production but can't be used to make diesel or other transportation fuels. Nonetheless, C+C is what can legitimately be called "oil production."

Total liquids data also commonly includes what are called natural gas liquid (NGL) that is collected from rigs producing only natural gas – not oil. NGLs are very similar in composition to oil condensate. Since the unconventional shale gas drilling boom and production of 2003 – 2009 there has been a large increase in the production of NGLs. These light hydrocarbons are commercially useful as bottled gas, and as feedstock chemicals (raw materials used to synthesize other organic compounds), but they can't be processed into transportation fuels and industrial lubricants.

Another misleading category being added into total liquids reporting is *refinery processing gains.* When crude oil is distilled and refined into lighter and less dense hydrocarbon products like bulk oil, gasoline, solvents, diesel, and jet fuel, the volume of the less dense products can exceed the original volume of crude oil. Including this extra volume strikes me as dishonest because you are basically counting the crude oil twice by adding the extra volume created during the refining process – something unrelated to production volume that *ignores* the energy costs of transportation and refining. These extra liquid volumes will not help offset the dislocations of lost oil production, but they do add around 6 to 10 million bbl/d to production data – around a 10% boost over simple C+C reporting.

The Oil Business and Peak Oil— Only Exxon Mobil continues to deny that Peak Oil – and global warming – are problems worth public concern. They have funded a campaign to dispute global warming research, fund climate change denier think tanks, and regularly run full-page opinion ads in the *New York Times* saying there's plenty of oil left. Chevron now passively acknowledges Peak Oil with their *Will You Join Us* campaign but neither American major is investing significantly in expanding oil exploration, well development, or renewable energy. Given Exxon Mobil's 2007 profits (the largest ever reported by a publicly traded company), this strategy is certainly paying off in the short term. British Petroleum (BP) and Royal Dutch Shell have been investing more than American companies in renewable energy but even these investments remain meager – below 1% of capital spending (Reuters 2007). These companies do, however, acknowledge Peak Oil and global warming, for example BP's advertising campaign, *Beyond Petroleum.*

Even before the 2008 financial crisis contracted credit and energy investment, the EIA, IEA, and the Federal Reserve Chairman had been expressing concern that oil exploration and production investment was not keeping up with growing demand, spare production capacity was declining, and that national strategic reserves shortages were expanding (Energy Bulletin 2009, Greenspan 2006). Most of the existing oil exploration, production, and refinery infrastructure – as well as the technical expertise and skilled workforce – have gotten long in the tooth. The average land based drill rig is 25 – 30 years old and the average floating oil platform is over 26 years old (Heinberg 2007). A whole generation of baby boomer petroleum geologists and engineers are retiring, and their ranks are only just now starting to be filled by recent graduates. Drilling rig rental and lease costs have steadily increased since 2000 (Rigzone 2006, Simmons 2007), suggesting that equipment for exploration and production was in shortage. Steel pipe for oil and gas drilling must compete with steel demand by a rapidly growing Chinese economy that is now the manufacturing sector for the entire global economy.

If the market is supposed to respond to the incentives of higher oil prices, why aren't national and private oil companies investing more in new oil rig equipment, staff, and refineries? I think oil companies know that world production has peaked and that exploration for oil will be progressively more costly and less successful (a riskier investment with poorer returns). Even with oil prices well above $100/bbl, big oil companies get less bang for the buck for risky exploration and production activities and most drilling in North America is currently performed by smaller energy companies. Spindletop era profits are gone. Exxon can make a better profit buying their own stock or smaller energy companies rather than building new refineries or investing in new equipment and exploration. Big oil corporations can make good profits selling what oil they already have.

Regardless of the public relations campaigns from the major oil companies or their public positions regarding Peak Oil, their long-term influence on supplies and future ability to deliver supplies are not going to be significant. Over 90% of remaining oil reserves (80% of current production) are controlled by nationalized oil companies whose investment decisions are driven by regional politics and national self-interest (GAO 2007). There are indications that governments all over the world are keenly aware of Peak Oil and most foreign policy, planning, and strategic alliances are now being driven by the need for energy supplies and security of those supplies (Hiro 2006, Klare 2004).

Other Resources Vulnerable to Peaking Production

Peak Oil will directly affect all economic activity dependent on petroleum (notably, agriculture, mining, and the entire transportation sector), but it is only one of several resources currently being depleted at alarming rates. The depletion of these other natural resources makes our energy predicament even more perilous. Here are other strategic resources at risk under current depletion pressure:

Natural Gas— Natural gas (NG) is an essential feedstock for nitrogen fertilizer (ammonia, NH_3) production using the Haber–Bosch process, is extensively used to generate electricity in gas fired turbine generators, and as a home cooking and heating fuel. In the US, 20% of our electricity is generated using NG, mostly during peak electricity usage periods when gas turbines are fired up to meet peak demand. It is also the prime fuel for heating in 50% of homes (Darley 2004). North American conventional or "dry" NG (the cleanest and easiest to produce) peaked in 1973 (figure 12) and growing US demand has only been met since then with increasing imports from Canada and Mexico, and significantly increased drilling and development of unconventional gas sources. Nitrogen fertilizer production has declined significantly in the US over the past 10 years as ammonia synthesis plants have moved overseas where NG supplies are still plentiful. While NG worldwide is not yet at peak, it can only be economically used on the continent where it is found and where pipelines can be built and safely maintained.

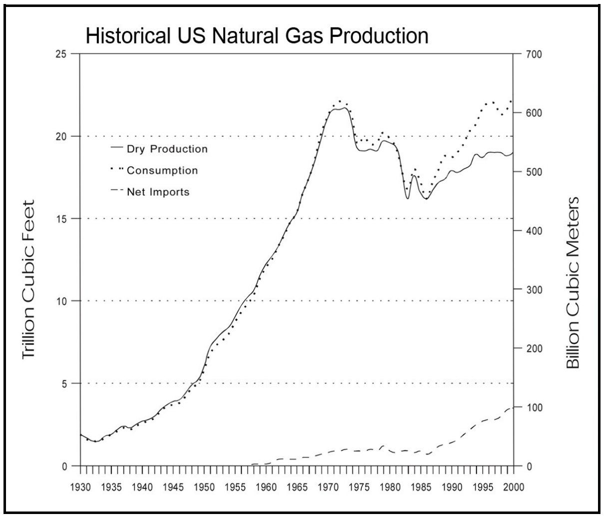


Figure 12.— Dry NG production in the US from 1930 to 2000 showing the prominent peak in 1973 and increasing net imports since then (lower dashed line at bottom of graph). Source: EIA (2001).

While NG prices collapsed with oil in 2009 from the drop in demand caused by severe recession, previously increasing demand caused supply and storage capacity strain, producing significant price increases since 1998. Supply limit problems occurred in 2003 and contributed to electrical brownouts and blackouts. Concern among industry insiders and government officials about future gas shortages and pipeline pressure losses during high demand periods helped produce the recent expansion of exploration and drilling for unconventional natural gas in previously protected and undeveloped areas in the western states and elsewhere.

There are very large reserves of shale bed methane located in deposits such as the Barnett Shale in Texas, the Marcellus Shale in the Northeastern US, and the Fayetteville Shale in Arkansas. These deposits can be developed using horizontal drilling and hydraulic fracturing; however, like fracking for oil in the Bakken, these enhanced production methods are more expensive and energy intensive. Hydraulic fracturing accelerates depletion of the gas from a given well, shortening the production cycle to as little as 5 – 7 years (compared to 10 – 20 years for a conventional dry NG well) and this complicates assessment of amortization and depreciation for investors. All unconventional gas production methods have significant impacts to land and also have the potential to contaminate surface waters and groundwaters.

The shale gas deposits may well provide an important buffer to Peak Gas, but the biggest problems now lie with market supported prices, credit, and finance. Claims that we have a 100-year supply of shale gas are ignoring that such reserves need *sustained* prices in the \$10 – \$15/thousand ft^3 to be produced. Since NG prices collapsed to below \$3/thousand ft^3 in April 2009 (from a high of \$12.92/thousand ft^3 in June 2008), many of the recent active shale plays were shut down or are producing NG at a loss to maintain leases. There was a glut in NG storage through summer 2010 because of shale gas production during the oil price spike and continued weak demand from the recession. NG prices bottomed out at \$1.99/thousand ft^3 in April 2012, and is currently (May 2013) trading around \$4.00/thousand ft^3. If recession persists and demand remains low, the more expensive to produce shale gas may suffer from prices too low to justify the risky exploration inherent in this production technology. Most drilling is also done by smaller outfits who are not considered good credit risks by banks – banks that still have trillions of toxic assets (mortgage based securities and derivatives) on their books. If the credit system is broken, so is free market energy production.

NG can be imported at significantly higher cost by compressing and "freezing" at the point of production (Qatar or Russia, for example) and shipping in specialized container ships as liquid natural gas (LNG). The LNG must be offloaded in special port facilities and processed in re-gasification plants before entering the US natural gas pipeline system. In 2004 there were only four LNG terminals and today only ten of these facilities are currently operational in the US. That level of infrastructure can only process around 3% – 5% of our current demand for natural gas (Darley 2004). While there are plans for construction of up to 24 more LNG terminals, most of the currently available LNG production is already obligated to China, India, Australia, Japan and other countries who have negotiated long-term delivery contracts with producing countries (Hiro 2006, Klare 2005). Alan Greenspan endorsed expansion of investment in LNG (Greenspan 2006) – a banking insider's admission that our natural gas supply crisis is serious.

However, if current world demand increases and LNG production expands, a global NG peak could occur by 2020 (Darley 2004). Because we depend on NG for home heating and electrical generation, North American natural gas depletion is a very serious situation and dramatic economic and social effects will occur when supplies are stressed and shortages appear.

Coal— Despite coal trade group commercials saying that the US has a 100-year supply of cheap coal, most estimates suggest a peaking for coal in the US within 50 – 60 years at current usage rates (which assumes no growth in demand), and a recent report suggested peak coal production within 30 years (Zittel and Schindler 2007). Peaking oil and gas, however, will undoubtedly spur greater burning of coal for electricity generation, the expanded use of coal for coal gasification plants to generate synthetic motor fuels (probably to be reserved for military uses), and for processing heavy oil resources like the Alberta tar sands or western oil shale. If consumption rates for coal increase by as little as 2% per year in the near term, the US production peak for coal may arrive within as little as 20 years (Heinberg 2007, 2009).

We have a lot of lower grade and high sulfur bituminous coal, and sub-bituminous coal from the Powder River Basin in Montana and Wyoming but a scarcity of high quality and (relatively) low emission anthracite, which peaked in the US in 1990 (Zittel and Schlinder 2007). The coal that remains in the US is getting towards the bottom of the Unavoidable Resource Triangle, and requires deep mining of thin coal seams or mountaintop removal strip mining. Both of these mining methods require significant energy inputs and have much greater waste and pollution flows (Heinberg 2009).

Accelerating coal burning might keep the lights on longer but at the expense of much greater pollution (such as mercury emissions and acid rain precursors) and greenhouse warming CO_2. Will we keep the grid operational and further destroy the environment? Count on it. We are past the point of minor environmental effects without burning *any* additional coal – so a mad rush to mine and burn more coal could also help produce worst case global warming scenarios.

Uranium— Nuclear power advocates promote fission electricity as the solution to our climate and energy dilemma – and after accounting for the fossil energy required to build and fuel nuclear reactors, nukes do provide low CO_2 emission electricity. However, there are legitimate technical problems and political issues that must be overcome for nuclear fission to expand in a significant way. The recent earthquake and tsunami which caused meltdowns and significant radiation releases from the Fukushima reactors in Sendai, Japan, underscore the environmental risks of disasters with nuclear power. The problem of nuclear waste has also not been solved to anyone's satisfaction.

A major complication for fission reactors riding to our energy rescue is that a whole generation of existing plants, currently supplying around 20% of domestic electric power, is due for retirement and decommissioning in the next 10 years and will need to be replaced or refurbished. This is not a small problem, as almost all of the planned new fission generators will be replacing existing reactors that are well beyond their designed lifetimes. We will likely build more nuclear power plants in near term but the lead time for new plant construction is now more than 10 years and investment risks are so high that private capital will not invest without significant public subsidy.

Uranium fuel is also subject to depletion pressures. Estimates for peak uranium range around 2055 – 2060 given current nuclear electrical power production and power plant replacement expected over the next 20 years (Heinberg 2005, Darley 2004). While breeder reactors that produce plutonium may help alleviate demand for uranium, there may not be enough inexpensive high quality uranium ore deposits to fuel a doubling in nuclear power electricity production capacity required to meet the demand gap created when natural gas runs out. We have already started using weapons-grade uranium and plutonium to power reactors and there is a market using reprocessed Russian nuclear warheads for blended reactor fuel.

It is easy to forget that the US was only able to develop nuclear weapons and fission reactors with an abundance of cheap oil energy and gargantuan government subsidies. For nuclear energy to rapidly expand as an energy source, it needs continued cheap fossil fuel energy and a large increase in production and refinement of uranium. Nuclear power also requires a functional government and economy until reactors are finally dismantled and retired. We are hostages to our nuclear reactors because all abandoned nuclear reactors will inevitably lose cooling, experience core meltdown and containment failure, and release significant amounts of radioactive isotopes into the environment. This is a major incentive to maintain civic order at all costs.

Metals— Copper has passed its US production peak and is nearing its world peak, significantly increasing in price since 2000. Lester Brown (2008) estimates that we only have a 30-yr supply of copper if current demand levels continue. While *low-grade* iron ore remains abundant, demand for chromium, molybdenum, nickel, cobalt, platinum, and other important industrial metals is outstripping supply and driving up prices. Semiconductor and cell phone manufacturing is also rapidly depleting supplies of indium, tantalum, gallium, neodymium, and other rare earth elements. Despite the 2008 oil price shock and credit crisis, continued high demand for metals and steel for economic expansion in China and India is once again creating price increases and material shortages that are increasing the time required to build existing technology power plants or alternative energy infrastructure. Even without resource peaking and energy depletion, this demand growth for metals is driving up prices and producing shortages. Energy resource peaking will only exacerbate the declines in metals production because mining and smelting are highly energy intensive.

Phosphorus— Besides ammonia nitrogen made from natural gas, another resource and nutrient essential to plant growth is phosphorus. While phosphorus can be recycled using crop rotation, manure, and composting associated with sustainable agriculture, energy intensive agriculture depletes phosphorus from soil. Phosphate rock must be mined and chemically treated to create artificial phosphate fertilizer which is now an essential nutrient for world crop production (Abelson 1999). Unfortunately, mined phosphate rock is a non-renewable resource and Déry and Anderson (2007) estimated the world rock phosphate peak production around 165 megatons/yr in 1989 (figure 13). The US is a major supplier and user of mined phosphate rock but its phosphate rock production peaked in 1988 at 54 megatons/yr.

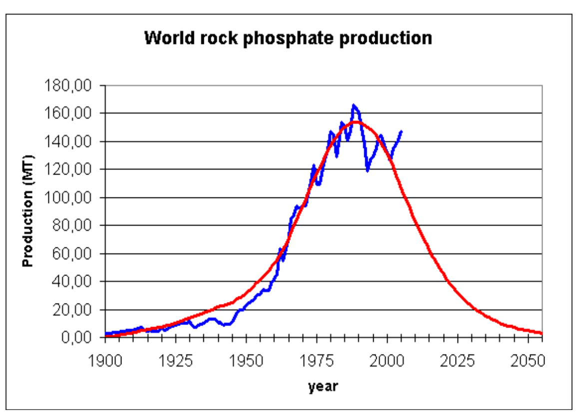


Figure 13.— World production of rock phosphate (blue line) with Hubbert peak estimate (red curve) (Déry and Anderson 2007).

Topsoil— Energy intensive agriculture, irrigation, and the abandonment of traditional soil conservation practices have increased topsoil erosion and loss of topsoil fertility. The US Soil Conservation Service estimates that the US loses 1 billion tons/yr of topsoil from wind erosion and 4 billion tons/yr from water erosion. Crop productivity in the extensively irrigated western US suffers from salinization of topsoil and other effects of factory farming. Worldwide, unwise soil stewardship and population pressure contribute to the abandonment of cropland and the spread of desertification, most dramatically in sub-Saharan Africa, China, and the Amazon Basin (Brown 2008). This process is being exacerbated by climate change from global warming that is creating prolonged droughts in continental and equatorial areas. Population growth, urbanization, and unchecked suburban development have also destroyed prime agricultural lands located near cities.

Fresh Water— Even though fresh water is a renewable resource, 7.0 billion people are using it up faster than it can be replenished by the hydrologic cycle. Worldwide, spreading drought and changing weather patterns are already reducing traditionally available sources of potable water to already stressed third world populations. Sea level rises from global warming and glacier melting will cause sea water intrusion into coastal ground waters used for drinking water. This already a serious issue in southern Florida. In the southwestern US, the lower Colorado River Basin has experienced extended drought since the mid 1990s, with the lowest water levels ever seen in reservoirs. Without this water supply, and cheap power to pump and divert it to farms, the entire arid western US would be subject to collapse of agricultural productivity and depopulation pressures.

Across the high plains in the US, center pivot irrigation pumping has significantly depleted the Ogalala Aquifer, raising the energy costs of this irrigation approach and causing widespread abandonment of land, farm failures, and loss of drinking water supplies for rural towns. Worldwide, depletion of aquifers from over-pumping has lowered aquifers to levels where irrigation is no longer possible, leaving abandoned land vulnerable to erosion (Brown 2008) and reducing agricultural productivity. Groundwater contamination from nitrate fertilizers, feedlots, and industrial wastes is also reducing available drinking water sources. Regions dependent on groundwater for their drinking water supplies must contend with depletion of aquifers and will face shortages when pumps cannot be powered or when municipal water treatment plants cannot function due to energy shortages or costs.

Fisheries— The Food and Agriculture Organization of the United Nations (FAO 2010) estimates that 75% of world fisheries are being depleted faster than they can naturally replenish. The Newfoundland cod fishery completely and suddenly collapsed in 1992 (figure 14) shutting down the Newfoundland fishing fleet and eliminating 40,000 jobs. Serious declines in all North Atlantic fisheries have occurred for cod, herring, swordfish, bluefin tuna, and haddock, forcing negotiated reductions in catch and fishing fleets. Since 1950, over 90% of large predator fish species have been eliminated from world fisheries (Myers and Worm 2003). Aquaculture has been able to replace some of the losses reported in wild catch, but wild catch is declining worldwide and commercial fleets are fishing in much deeper waters and harvesting smaller fish over time (FAO 2010). Factory fishing has been the leading factor depleting fish stocks (World Resources Institute 2005).

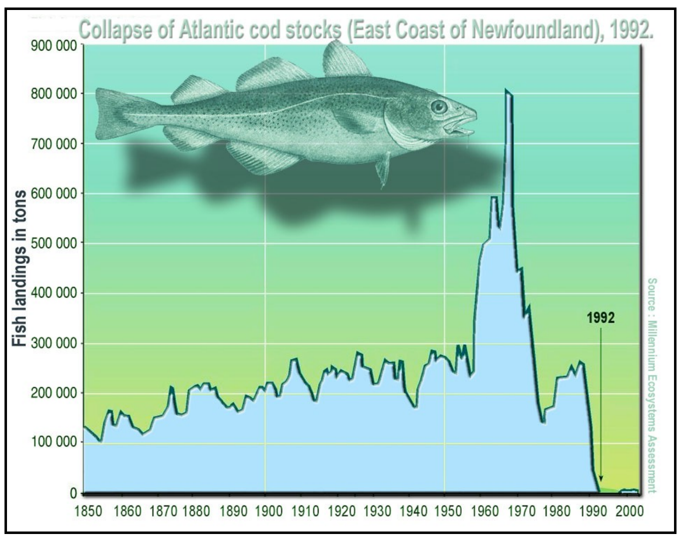


Figure 14.— Collapse of the Newfoundland cod fishery was caused by factory overfishing (World Resources Institute 2005).

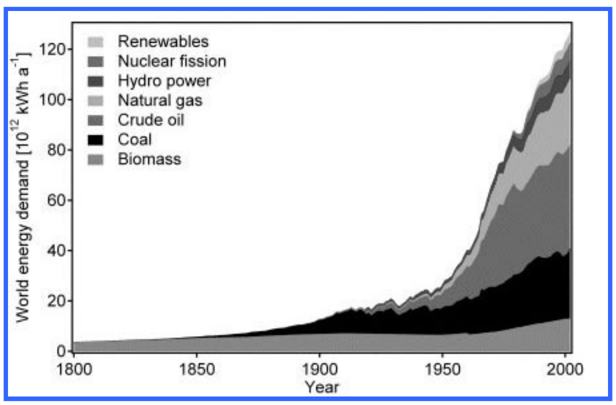
Elevated CO_2 and other global warming stressors are beginning to threaten plankton in many areas of open ocean. Higher dissolved CO_2 lowers pH and increases the acidity of seawater. Lower pH messes with the proper formation of carbonates that are essential to diatoms. If you mess with the lowest level of the food chain – that effect will move up the chain and add another stressor to fish who enjoy top predator status in the oceans. Fisheries have also suffered from damage to supporting ecosystems such as the loss of mangroves and spawning zones in coastal bays and rivers, and increasing contamination from sewage discharges and atmospheric pollution. Next time you have wild salmon, enjoy it – because the collapse of major fisheries is no longer a distant threat for our great-grandchildren. It could happen well within the next 10 years. While our diet will become more expensive and limited, fishery collapses will decimate large poor coastal populations heavily dependent on fish as their dietary staple.

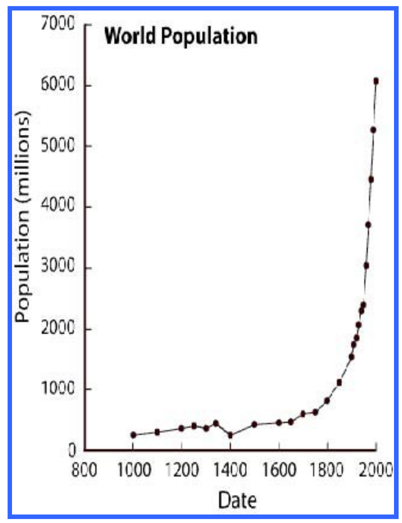
Exponential Population Growth and Our Complex and Vulnerable Global Economy

Another factor that will greatly affect how the Peak Oil and energy depletion crisis evolves is how our complex global economy reacts to the loss of cheap free energy supplies. Because population is experiencing exponential growth our economy must also grow exponentially. Constant percentage increasing economic growth is exponential, and growth rate for the GDP (gross domestic product) is monitored closely by economists and governments. Today, the global economy depends on constant expansion and if the economy does not grow and keep up with population increases, we have recessions or price inflation. If a city is not expanding, it is dying. If a company does not expand markets or increase market *share* and profit *margins*, its stock will decline in value and the company will be absorbed by a larger competitor.

This exponential growth is readily seen in the graphs of fossil energy usage (left) and population growth (right) in figure 15 (ASPO Spain 2002). I think that our current global economic system is a self–organizing process that has evolved as humans behave more and more like a planetary-scale organism. While the population explosion was initiated by cheap energy and agricultural productivity, the economy must now co-adapt by growing exponentially just trying to keep up with the increasing numbers of hungry people.

Figure 15.— Historical energy use (below), and exponential population growth (right) suggesting a causal relation between cheap energy exploitation and population. Source: ASPO Spain.





Our exponential population and economic growth have produced the following interacting phenomena that will directly affect how our civilization will respond – or be able to respond – to Peak Oil and permanent energy shortages.

Complexity and Vulnerability— The global economy represents an organization of capital, resources, and labor on an *unprecedented* size and complexity scale. From an entropy perspective alone, the complexity of our global economy makes our situation regarding declining free energy very precarious. We have "stolen" a huge amount of entropy from the planetary environment to build and run our highly interdependent and computer coordinated economic system and to feed our oversized population. Cheap free energy created and has so far sustained this complexity but entropy stands waiting for cheap energy to disappear.

A serious problem with complex systems is that they are inherently prone to instability, nonlinear behavior, and positive feedback processes where small changes in a subsystem's behavior can produce huge unexpected changes or collapse of the entire system. A familiar example of positive feedback is when a PA microphone is too close to the speaker and the amplified sound is picked up by the mic and quickly re-amplified into a progressively louder squeal. This squeal can destroy speaker coils and amplifier output circuits and is a good example of how positive feedback can lead to system failure and collapse.

In the complex infrastructure of our economy, positive feedback can amplify minor problems in small subsystems into major market meltdowns, painful job losses and recession, electrical blackouts, or fuel and food shortages. This instability is especially prominent when subsystems within the complex system lack reserve capacity and resilience which leads to what are called *cascading system failures* (Heinberg 2005, Kunstler 2006). This instability applies to our current physical infrastructure, food production, and financial trading markets. Now, even minor interruptions in our complex global supply chain, credit markets, or energy infrastructure ripple in unpredictable ways through interlinked business segments all over the world.

- During August 1996, a strained transmission line on the US Western Inter-tie Grid shorted out on a tree and caused a cascading power failure affecting nine western states. Another record hot summer in 2003 produced the largest and most costly electrical blackout in US history as the northeastern US and Ontario grids experienced a cascading system failure. Failure of a subsystem in the Midwest during peak demand produced a blackout that affected 50 million people for two days. Two weeks later, the grid in Italy failed affecting 56 million people for nine hours.

- After the December 2006 blizzard in Denver, we managed to dig out after 48 hours and make it to the grocery store. It was an eye-opening experience to see the number of empty shelves. I was shocked that a 2-day disruption in deliveries had created such shortages. It took 4 – 6 days for inventories of perishable items like milk, meat, and bread to return to pre-blizzard stocking levels.

- Most of the world stock trading volume involves not common stocks, but derivative investments like options and futures, and even more exotic investment instruments based on derivatives of derivatives or pooled debt. These highly complex derivatives are essentially bets on the future price of a stock, bond, commodity, currency, or another derivative. A large volume of these investments by speculators use borrowed money (called leveraged speculation). Leveraged speculation increases market instability and widespread buying on margin contributed to the great 1929 Crash.

  Highly leveraged "plays" (note the casino gambling terminology) on derivatives are utilized by many large hedge funds which can generate significant instability and risk exposure for real stocks, currencies, and banks (Leeb 2007). Hedge funds were implicated in national currency value collapses such as the British pound in 1992 and the Malaysian Ringgit in 1997. The collapse of the hedge fund Long Term Capital Management (LTCM) in 1998 involved huge leveraged bets on failed Russian bonds that threatened the safety of several major private and national reserve banks. With so much money at stake, the Federal Reserve Bank of New York organized a $3.5 billion bailout of LTCM involving a group of Wall Street and European banks. This prompt bailout was widely hailed as preventing the financial equivalent of the August 2003 cascading grid failure and blackout.

- In late 2007 through 2008, increasing numbers of much bigger bailouts were announced for large insurance companies (AIG), quasi-governmental mortgage funder Fannie Mae, and several Wall Street investment banks (Lehman Brothers, Morgan Stanley) who had taken significant positions in sub-prime mortgage derivatives. These bankrupt and failed institutions were again bailed out to prevent system-wide financial collapse and panic. The early bailouts from the Federal Reserve and the US Treasury Department involved amounts 10 – 20 times larger than the LTCM bailout and culminated in the largest emergency bailout in history – over $1 trillion – approved by Congress in October 2008. The jury is still out on whether the latest bailouts are working or what their long-term implications will mean for the value of the dollar.

Many Peak Oil experts and growing numbers of economists are suggesting that the current credit and financial crisis represents a cascading system failure directly caused by the first large Peak Oil plateau energy price spike that emerged in 2008. Increased energy prices caused a rapid increase in sub-prime mortgage defaults that quickly led to the collapse in values of the mortgage backed derivatives based on these risky loans. Investment banks suddenly saw huge losses in their derivative portfolios and credit quickly dried up. Businesses and importers who depended on short-term credit to operate (the overnight markets) suddenly faced bankruptcy and the effects quickly rippled to other businesses who reduced output and eliminated jobs.

Shrinking Time Horizons— As population grows exponentially, there is progressively less time to adjust to increasing numbers of people and the expanded economic activity needed to meet their food and shelter requirements (resources directly derived from energy). This process is similar to the way that the rate of chemical reactions (kinetics) will speed up when the concentrations of the reactant chemicals are increased. The accelerating economic and technological activity means that the rate of change and the perceived sense of time speed up. Time compression has contributed to expansion of short-term profit maximization and shrinking time horizons for business and personal planning that have shortened from generations, to years, and now to months. These trends also mean that prudent long-term investment needed to shift our economy to renewable energy – or to simply maintain existing infrastructure – may not happen quickly enough to match the expected losses of cheap energy.

Exponential Growth and Debt Expansion— Exponential economic growth requires a very flexible and expanding system of finance and exchange. Many realize that money is no longer based on the gold standard and that the dollar has experienced steady erosion in value from inflation since the early 1970s. But few realize the enormous scale upon which modern money is created out of thin air though our system of fractional reserve credit. Up until very recently, the availability of cheap energy has allowed credit and the money supply to expand without apparent limit.

If resources were really unlimited, then human population could theoretically continue to grow exponentially and the economy could also expand to match population. Except for pollution and waste (significant issues, by the way), there would be no problem with continually increasing credit. As long as payments on loans can be made and debts repaid over time, the constant influx of new borrowers and payments in an expanding economy keep the engine of fractional reserve credit running. The basic principle is that money supply can be expanded using credit as long as there will be more people in the future to pay off the interest. You might have noted that this sort of credit expansion follows a theory of financial fraud similar to a Ponzi Scheme.

The problems with expanding credit begin when cheap essential resources start becoming scarce. For example, when energy prices increase significantly, lower income families can be forced to choose between making loan and mortgage payments or paying for food and heat. For many heavily indebted people, this means that loans and credit cards go unpaid and bankruptcies and mortgage foreclosures increase. Families who manage to make ends meet and keep up with loan payments will still reduce spending on non-essential goods. Because consumer spending accounts for around 70% of our GDP , a drop in consumer spending can produce a recession. If the economy weakens and numerous people lose jobs, then the premise that loans and interest will be paid off in the future ceases to apply and extending credit becomes much more risky.

The unfortunate effect of the credit explosion and collapse since 2008 is that we now face a serious depression and yet desperately need economic growth and credit to invest in infrastructure maintenance, to prepare for Peak Oil mitigation, and to transition to a renewable energy infrastructure and local manufacturing. Our national debt is now the largest in history and we depend on economic competitors (potential enemies) to finance our debt. While personal debt has slightly decreased since 2007, home foreclosures continue and personal savings are lower now than they were during the Great Depression.

Resilience is Sacrificed to Efficiency— During the earlier phases of the industrial revolution, slower and more expensive transport encouraged warehousing of raw materials, supplies, and finished inventory so that the system contained significant spare capacity. There was a buffer or "cushion" in both materials and the system response time that allowed interruptions (strikes, material shortages, natural disasters, etc.) to pass without major economic effects beyond the factory or area affected. Spare capacity and resilience is the idea behind personal savings, maintenance of national strategic oil reserves, and minimum deposit to loan ratios for banks. Much like fat deposits and muscle mass in a healthy body, these reserves can be called on during emergencies to escape or thwart an enemy, sustain and survive injury, or continue activity under stress.

Over the past 50 years spare capacity has increasingly been considered waste and overhead to be eliminated in the global economy. Efficiency has become the driving force to squeeze greater profits at all scales of economic activity – from computerized split second arbitrage transactions on currency and stock markets to robotic manufacturing and just in time integrated shipping and inventory systems. The drive for efficiency has eliminated much of the static, old style, warehousing located in urban industrial districts next to rail lines. Instead, we use huge fleets of petroleum dependent 18-wheel trucks on the interstate highways and cargo aircraft to both ship and store supplies and inventory. These complex computerized operations are an excellent example of how cheap free energy has been used accommodate exponential population growth by adding complexity to the economy

(Tainter 1989). The downside is that the promotion of efficiency has eroded investment in activities that traditionally have been important to long-term economic strategy: plant and equipment maintenance, worker and public safety, ongoing training and retention of experienced workers, research and development, and strategic planning.

The most visible symptom created by the drive for efficiency is the sorry and dangerous state of our physical infrastructure (roads, bridges, water and sewer systems, waste treatment and disposal, schools and public buildings, the electrical power grid, and oil and gas pipeline networks). The deregulation of power utilities now enables American energy companies to put off or ignore maintenance and replacement activity for gas pipelines and the electrical grid's transmission lines, transformers, and power plants (15% less since 1992) – sacrificing long-term stability for short-term profits. The American Society of Civil Engineers' (ASCE) *2005 Report Card for America's Infrastructure* (ASCE 2005) gives the US physical infrastructure an overall grade of "D." Currently, 27.1% of our bridges are rated as "obsolete or structurally deficient" and the ASCE estimated that $1.6 trillion will need to be spent over 5 years just to address these critical deficiencies. The August 2007 collapse of the I-35 bridge in Minneapolis and the September 2010 gas line explosion in San Francisco are shocking reminders of the current dismal condition of our physical infrastructure. Unfortunately, we had to bail out Wall Street in 2008 so there's a trillion dollars we will not have for infrastructure investment.

The Global Economy's Effects on America— While cheap energy has produced the greatest standard of living in history (for the developed world), the current global economic adaptations to exponential population growth have also negatively affecting American working classes. The domination of the global economy by Wall Street and financial interests has produced growing emphasis on efficiency, cheap labor productivity, short term profits, tax avoidance, and free trade. These trends have produced a relentless drive towards ever cheaper foreign labor and larger scales of complexity, organization, and automation – even to the detriment of national and local economies. This process has produced an unprecedented concentration and accumulation of wealth controlled by multinational corporations and has increased mergers and monopoly formation. This wealth accumulation has also produced significant corruption of all governments and democratic processes and it has rigged the rules of the economic game in favor of large corporations and the rich.

In America, globalization and domination of the economy by financial interests have seriously impaired our manufacturing capacity (Phillips 2008). We no longer have an American-based machine tool manufacturing company, *essential* infrastructure for serious war production and national defense in an extended war. We also lack skilled machinists and metalworkers. Our national railroad freight system and roadbed have deteriorated significantly and we have no real passenger rail system. Regionally based coastal shipping and barge transport infrastructure has also deteriorated along with shipbuilding and its associated skilled trades. Manufacturing companies undergoing monopoly takeover are often looted for the salvage value of their factory equipment (often bought by Chinese companies) and the cash in their employee retirement funds. Investment banks like Goldman Sachs have been in the forefront of the business merger and factory sell off trend, collecting handsome fees as they dismantled manufacturing and eliminated jobs.

Local small business failures are increasingly common as globalized businesses have used their size advantage, low wage foreign labor, cheap transportation, and subsidies from American and foreign governments to deliver cheaper products and services: Home Depot has driven out the local independent hardware store, cheap foreign labor has wiped out US appliance manufacturing, and Blockbuster has chased out the local video store. Of considerably greater importance, the small family farm and the knowledge and experience base of family farming have been severely eroded by large scale and energy intensive factory farming. This deficit in farming knowledge occurs just as we need to be able to grow much more of our own food locally.

The loss of small- to medium-sized local businesses, living wages in the working classes, and family farms have also destroyed the local economies and social fabric of small farming towns and cities in formerly industrial regions like Detroit. This is not just a rural or rust belt economic problem. We are all finding it increasingly difficult and more expensive to maintain quality public education and highway and bridge infrastructure as state and local tax bases erode from progressively diminished manufacturing jobs and corporate tax revenues. State and local governments are forced to rely on sales, property, and income taxes that shift the funding burden from corporations to working people.

Globalism has raised living standards in China, India, Korea, and Malaysia but it has eroded American income as formerly unionized factory workers with benefits have become unemployed or low-wage service industry employees. If you think this is a process that has only affected factory and skilled labor, then you haven't been paying attention. Many middle class professional jobs for engineers and scientists are drying up along with the manufacturing base. For example, if semiconductor manufacturing plants move offshore, there are fewer jobs for American electrical and process engineers. This reduction of working wages, a trend which began in the early 1970s, has been partially offset by the increased number of dual-income families but individual wage stagnation (adjusted for inflation) has been progressive since the 1970s (Drum 2010, Phillips 2008). This relentless erosion of the American middle class is partly to blame for the recent increases in mortgage and debt defaults and other social ills that accompany family money troubles.

Our once proud public and vocational education infrastructure becomes shabbier and more expensive by the year and the US lead in *graduate* technical education is also disappearing. India, China, Korea, and Malaysia have all established ambitious national goals for developing state of the art graduate and technical education. These countries can now produce their own mathematicians, geneticists, electrical engineers, and scientists, who are eagerly hired by their own emerging manufacturing base. The US is now being challenged as the world innovation and graduate education leader because the Harvard finance MBA's running the country forgot that innovation and a good public education infrastructure need a national manufacturing infrastructure and corporate tax base.

What are you, a damn commie?— While some of you may think I hate free enterprise or the American Way of Life, I don't. I am an Eagle Scout and I believe in working hard and taking work seriously. I think honest business people making money by providing society with useful products or services is a great idea. And I think *fair* and *ethical* competition among *locally owned* businesses produces a public good. But I completely agree with Kevin Phillips that the current financialized economy controlled by Wall Street investment bankers is an out of control and destructive system that needs serious overhaul and real regulation. Pampered and privileged clowns like Lloyd Blankfein, CEO of Goldman Sachs, could care less whether their investment strategies destroy economies or people's lives and they are absolutely not loyal to our country. If they could legally make a big ass profit from selling our military to the Chinese, they would do it in a heartbeat.

As to the American Way of Life, I dig road trips, enjoy having a house with a garage door opener, and I love my electric guitars, amplifiers, synthesizers, cameras, and computers – all dependent on cheap oil. I have worked long and hard at, and am living and enjoying the American Dream. It's not bad – at all – and I am very grateful I get to enjoy such a lavish lifestyle. The engines of economic growth and capitalism have also produced many wonderful and inspiring things: electric lights, wonder drugs (thank you Prozac!), recorded music, literacy and publishing, string theory and chaos science, the Internet, the Hubble and Spitzer space telescopes, and indoor flush toilets. But to deny that there are significant environmental, social, and ethical costs associated with the American lifestyle and the current global economy is naive, if not irresponsible.

All economic systems – hunter-gatherer, agrarian, capitalist, or socialist – produce winners and losers and will deplete resources and generate waste. A communist industrial world with 7.0 billion hungry mouths would destroy the planet just as effectively (maybe better given Chernobyl and the Aral Sea) as the capitalist world is currently doing. Resource depletion is not new and globalism did not deforest the Mediterranean periphery by 500 AD (Ponting 1993). All economic systems operate best to optimize the common good at *appropriate* scale and with *appropriate* regulation and balance. But the current hyper-population and hyper-economy are dangerously out of balance with planetary resources, individual human needs, local community stability, and traditional notions of ethics, responsibility, and social obligation.

I do not "blame" capitalism, globalism, Goldman Sachs, or free trade for our problems... (Well – maybe a few Goldman Sachs executives ought to be tarred and feathered – to send a shot across the bow.) They may be making our situation worse and hastening our decline, but I think these *human* systems are simply *consequences* and *symptoms* of the root disease: **cheap oil and energy have produced exponential population growth that is now reaching its natural resource limits.** Except for the scale, complexity, and planetary impacts, the current human population and economy functions no differently from algae in a pond filled with nitrogen and phosphorus or a population of rabbits released into an environment with unlimited food and no natural predators. With 7.0 billion people, how could it be different? Our population growth imposes an almost inevitable social and economic dystopia to deal with feeding that many people: either runaway individualism and greed, or runaway social control and repression. The center can no longer hold.

The Economy and Peak Oil Mitigation— The important point of this section is that our current economic system will likely interact with Peak Oil and energy supply shortfalls to exacerbate the energy crisis, rather than quickly adjusting infrastructure and fuel alternatives to maintain current energy use and living standards. The collapse in oil and natural gas prices after 2008 coupled with tight credit caused the cancellation of many energy exploration and drilling projects. Energy development activities cannot be re-started as quickly as they were abandoned, and many projects have been permanently canceled. While the lower energy costs may act to help stimulate economic recovery, any expansion of demand may quickly cause supply shortages and produce another serious price spike (Rubin 2009).

If mitigation activities are undertaken to soften our transition beyond Peak Oil, they need to be large and significant efforts involving risky long-term investments. While the economic crisis has produced greater public support for government regulation of finance and job creation, the end of cheap energy also signals the end of easy credit. Significant capital will be needed to fund a shift to renewables and rebuilding localized manufacturing and shipping infrastructures or even to fund expansion of emergency stocks and reserves. Any widening economic depression that accompanies resource depletion will destroy the value of assets and dry up capital that will be desperately needed to invest in Peak Oil mitigation. And finally, globalism has left America with a looted manufacturing economy and a gigantic, overstressed, and poorly maintained energy and transportation infrastructure just as the permanent energy crisis looms. We are truly facing a "perfect storm" of Peak Oil and other peaking essential resources interacting in unpredictable ways with a highly complex and unstable global economic system, and the specter of climate change disasters and war.

Alternative Fuels and Renewable Energy – Reality Checks

What about solar, wind and alternative fuels? Optimists and mainstream economists suggest that our energy demand will be magically met as increased prices stimulate a rapid and efficient switch to alternative fuels and renewable energy creation. The economic theory of substitution and the power of unregulated free markets are advocated as the mechanisms that will save us from Peak Oil and energy depletion. Another idea promoted by optimists is the wonderful ingenuity and creativity of the American people. This plays well to most peoples' sense of national pride and ideas of American Exceptionalism, and is often heard as a calming and reassuring response to Peak Oil doomsayers and unwelcome energy news developments: *Some smart person will rise to the occasion and innovate an answer to our energy dilemma. Right?* Unfortunately, these optimistic assumptions must square with the following reality-based issues.

The Expectation of Business as Usual— Much of the economic analysis suggesting an optimistic energy future based on free market substitution assumes continuing cheap energy, economic growth, and flexible capital. Cheap energy will just not be available after Peak Oil and the cost of producing alternative fuels and building the new infrastructure needed to distribute new fuels will be increasingly expensive as depletion proceeds and energy prices increase. I also seriously doubt that credit and venture capital will be as widely available going forward.

With plenty of cheap energy, business as usual meets the needs of many people but when price volatility makes investment too risky, energy companies will not produce unprofitable fuel even if the fuel is desperately needed. This disconnect will introduce what are called market failures, where legitimate human and national energy needs are not met by the free market economy. For example, what guarantees do we have that the oil companies won't sell *our* oil to the Chinese who will be able to outbid us for scarce petroleum? Will we stand down and support the 'unfettered free market' when we have critical energy needs at home?

Post-Peak Energy Declines Accumulate over Time— By now, you know that we are burning an enormous amount of fossil fuel and that we need that energy to keep our economy and civilization on the tracks. Another reality check is that once we leave the plateau of Peak Oil, the losses in available energy become permanent. Beyond Peak Oil, production losses range from 5% to 9% per year and these permanent declines *accumulate* over time. Production from Mexico's giant Cantarell Field and the North Sea is currently declining at around 7% per year (The Oil Drum 2007). Post-peak, a 5% per year loss of production means that we will have have around 35% – 45% less energy in 10 years. You don't have to be an economist to understand what a train wreck that loss of energy will represent.

Assuming current world oil consumption around 75 million bbl/day (that's around 800 bbl/*second,* by the way), the world will need to find replacement fuel production for an additional 4.0 – 7.2 million bbl/day (0.80 – 1.44 million bbl/day in the US alone) *every year*. Where will we find 1.5 to 3.1 *billion* barrels of new oil production *every year* after the decline starts? That's a huge amount of oil to discover, develop, and get to market – the equivalent of finding and developing a new super-giant deposit on the scale of the Saudi Ghawar oil field with 120 billion barrels producing around 5 million bbl/d (1.83 billion bbl per year). **We will need to bring that much *new* oil production**

on line *every year!* The peaking of oil reserve discoveries in 1962 and the paucity of recent *substantial* discoveries strongly suggests that this will simply not happen. Given the scale of our consumption, it is doubtful whether new discoveries or *any* combination of alternative fuels (biofuels, tar sands, etc.) can replace the progressively larger energy losses once oil and natural gas production declines.

Net Energy and EROI of Alternative Energy— Liquid petroleum is the most energy dense fuel ever discovered, and we need to consider the energy production costs and energy content of any proposed alternative technology, fuels or electrical power generation that are intended to replace our current use of petroleum and natural gas. Recall that a fuel with an EROI near 1 is at the "break even" point where it takes as much energy to produce the fuel as the fuel can provide in energy. EROI values less than 1 mean that more energy is required to produce the fuel than the fuel contains when burned – meaning it's not worth doing in any practical thermodynamic or business sense. EROI suggests a physical limit on what is feasible for large-scale alternatives implementation and net energy needs to be used to more accurately evaluate proposed new energy technologies and fuels, or newly discovered oil deposits.

Lag Times and Existing Infrastructure— Besides net energy, the amount of *time* required to shift to new fuel or renewable energy is a significant variable. Even newly discovered oil fields take at least 10 years before any significant production can be realized. Our existing railroad and highway networks took over 50 years to build during a period of expanding cheap energy supplies (Modis 1993). The infrastructure for currently planned (and limited) LNG distribution will take at least 20 years to build and require significant capital investment with uncertain risks (Darley 2004).

The ghosts of infrastructure investments past also haunt us and contribute to a psychological unwillingness to act in a timely manner. We have huge sunken investments in the current oil, natural gas, and electrical infrastructure (on the order of tens of *trillions* of dollars), and our own personal investments in automobiles, cheap air travel, and a profligate energy use lifestyle. The psychological attachments to these investments will bias judgment and reduce our ability to respond in a timely manner to build new alternative energy or expanded rail infrastructure (Kunstler 2006, Roberts 2002).

Alternative Fuels and Renewable Energy – Rating The Candidates

We need to think seriously about any strategy that will effectively lower energy demand and help replace non-renewable and peaking energy sources like oil and natural gas, but we also need to prioritize our efforts in light of the above reality checks. Given these practicality issues, alternatives proposed to mitigate energy depletion can be divided into 4 categories: conservation with more efficient replacement technologies, alternative transportation fuels, renewable energy sources for electricity generation, and conservation through reduction of energy use.

Conservation through Replacement Technology— Conservation or reducing energy demand by shifting to more efficient replacement technology – or technology substitution – is subject to significant time and net energy issues. It currently takes 9 years for half the current US private automobile inventory to be replaced – with expanding economic activity and cheap energy (Heinberg 2004). Replacing the current vehicle inventory with high mileage hybrids or city cars requires 17 barrels of oil equivalent (bboe) energy per car to build (Maclean and Lave 1988 – other sources suggest up to 35 bboe per vehicle). Replacing half our auto fleet means building around 100 million new vehicles. That's an extra 1.7 billion bboe energy on top of our annual consumption of 7.5 billion bbl/yr of oil over a 9-year period. Given current world energy demand in the face of Peak Oil, where will that extra energy come from?

The technology replacement strategy also depends on a healthy economy with people earning enough to upgrade or replace inefficient appliances and vehicles with more efficient versions. Poor people are the most energy-*inefficient* segment of the population because they can't afford to replace their old cars and appliances with more energy efficient versions and they generally live in older, poorly maintained, and energy inefficient housing. If economic contraction from energy shortages produces more poor people, then replacing our cars and appliances will stall at some point as a viable way to conserve energy.

- *Electric Cars*— Despite being a popular cause for some environmentalists, I do not like the electric car as a solution to Peak Oil in America because it will simply shift oil usage to demand for coal-powered electricity from a grid already at maximum capacity. Even if the grid could handle the extra demand from powering, let's say 100 million Chevy *Volts*, we'd be burning a hell of a lot of more coal and natural gas. Realistic expansion of this technology in a healthy and growing economy would require significant expansion – essentially a doubling – of the electric power plant inventory and significant expansion and upgrades to the grid (Rubin 2009).

While a more efficient user and storer of energy, electric cars are still very expensive, so demand will be limited to affluent wage earners – unfortunately, a shrinking demographic. Manufacturing infrastructure is still undeveloped. Electrics need very large and strong-current lithium batteries which are very energy intensive to build. Vehicle batteries will need to be replaced at considerable expense (up to $10,000) and we do not yet know how long they will last in typical service. 100,000 miles? 50,000 miles? Batteries also contain hazardous wastes with significant disposal and re-cycling costs.

- *Electric Trains*— Electricity *would* be an appropriate energy choice for powering trains (as is mostly done in Europe), but there are no current US plans or programs for seriously expanding our light rail commuter, heavy rail passenger, or freight rail systems. And, there is no interest in subsidizing or developing US electric rail infrastructure. I agree with Jim Kunstler that rail improvement and expansion is the only viable way to maintain at least some of the mobility offered by our current use of personal vehicles.

- *Hybrid Gas–Electric Technology*— Hybrid gas-electrics are a much more practical technology approach to the personal automobile that will help reduce fuel consumption. Hybrids are not as expensive as electrics, but you still have to have good credit and a decent job to afford one. Hybrids are a proven technology, manufacturing infrastructure already exists, and consumer demand is available but small (only 3% of current inventory are hybrids in the US). However, hybrids also require large lithium or nickel-metal hydride batteries and all batteries have a replacement and disposal component in their energy cost cycle. As with electric cars, there are similar practical problems with materials and full cycle energy costs converting a large percentage of the vehicle inventory to hybrids

- *Fuel Cell Technology*— I really like fuel cells, especially those using waste methane for small-scale electricity generation and I think research and development funding for this technology should be increased. Unfortunately, these systems are very expensive, not ready to commercially deploy, and they are not yet a realistic option to replace natural gas for generating electricity or to power automobiles. Recent news stories about the natural gas fuel cells developed by Bloom Energy and ClearEdge neglect to mention that these electrical generating systems require natural gas fuel and are fairly expensive for average wage earners (the suburban home version of the Bloom Box currently sells for around $80,000).

- *Compact Fluorescent Lamps and Light Emitting Diodes (LEDs)*— These alternative technologies are an excellent way to conserve energy used in lighting. Fluorescents are now commercially viable, but still expensive relative to old-style incandescent lighting, and suffer from mercury contamination at disposal. LED lighting shows great promise in reducing the electricity needed to provide light, and prices are getting cheaper over time. Both technologies should be aggressively promoted and subsidized in order to conserve energy.

Alternative Fuels— Several alternative fuels are proposed as a replacement for transportation: heavy oil, biodiesel, ethanol, and hydrogen. It's important to note that there are no practical non-petroleum alternatives to kerosene-based jet aircraft fuel – extremely bad news for commercial aviation.

- *Heavy Oil*— This source is actually a *mined* solid bitumen or tar. It is a feasible alternative fuel source but is unlikely to meet our current level of demand. In 2005 we burned around 21 million bbl/d of oil and *maximum* output from Canadian tar sand development is projected to supply only 3 – 5 million bbl/d (Energy Bulletin 2007). There has been significant investment in developing the Alberta tar sands – but because of the remote location and the energy and water requirements for tar sand processing, electricity must be provided on site – both to extract and refine the tars enough to enable pipeline transport. EROI for tar sands is 2 to 4, so it is a low energy *quality* substitute for oil, and oil price must be stable and higher than $85/bbl if tar sands oil is to be produced at a profit. Alberta tar sand production was significantly curtailed in 2009, but has since recovered with recent oil price increases in 2011, and American tar sand resources in Utah are also being developed.

Besides strip mining, tar sand production also means burning more natural gas and coal and building power plants in a remote environments. Tar sand mining on a scale big enough to soften the blow from production declines and oil price increases will be environmentally devastating and take *huge* amounts of natural gas out of the Canadian natural gas pipeline to America. Canadian natural gas production is also declining. So, developing tar sands will exacerbate one shortage – natural gas we need for ammonia fertilizer, home heating, and electricity – without doing a lot in a timely manner to alleviate petroleum production declines. But it will absolutely have large environmental costs.

- *Ethanol* and *Biodiesel*— Ethanol production using genetically engineered microbes and algae *could* potentially help provide transportation fuel to help mitigate Peak Oil depletion; however, these technologies are not yet commercially developed or operating at production scales, and will require significant investment, research, and subsidies to expand. Producing ethanol from corn as it is now grown has an EROI of less than 1 (Murphy 2009). It takes more energy to produce than the ethanol will provide in fuel, so frankly, it's a stupid energy waste. Corn ethanol is a net energy loser and ethanol only provides 80% of the energy that gasoline provides. Similarly, gas-ethanol mixtures like E85 have lower gas mileage that ends up actually *increasing* demand for mixed fuel. So... current government corn-ethanol programs are essentially subsidies to big agribusiness such as Con Agra and Archer Daniels Midland. Small farmers may be reaping a bonus and we may be stretching our gasoline stocks by dilution with ethanol, but the small increases in corn ethanol production are already driving up commodity prices for corn and reducing exports of food to the rest of the world. This corn price spike already produced a crisis in Mexico, where corn tortillas – a dietary staple – became so expensive that food riots erupted (Reuters 2007).

  Richard Branson recently announced a plan to burn a biodiesel-derived jet fuel in some of his Virgin Atlantic airline jets. But biodiesel has an EROI only slightly greater than 1. If fuel cost corresponds to the difference in EROI between petroleum-based and bio jet fuel, biofuel will probably end up costing at least 5 – 10 times as much as currently available Jet A-1. How much would fares be on an airline flying bio jet fuel? This doesn't seem like a practical alternative fuel for the aviation industry that depends on mass utilization by the public and cheap fares as a business model. If only the wealthy can afford to fly, how do we justify the significant government subsidies (for air traffic control and safety enforcement) and infrastructure investment and maintenance (airports)? The future of aviation does not look good.

  Besides a crappy EROI, all crop biofuel potential must also reckon with our enormous current fuel usage. We simply cannot match our transportation fuel consumption using agriculture, even if *all* the available land in America were switched over to corn production. So, what will it be? Land for food, or land for happy motoring?

- *Hydrogen*— The hydrogen fuel cell car or the hydrogen fueled internal combustion automobile future is another option offered by optimists as a substitution solution. This concept is an EROI non-starter as an automotive fuel. Here on Earth, hydrogen must be produced. Industrial production of hydrogen is energy- and resource-intensive and requires either natural gas as a feedstock or electrolysis of water. There is no in-place infrastructure for distribution of hydrogen and the practical problems of fuel storage, vehicle range, and safe transportation are significant. Hydrogen would make economic and energy sense only on a small and localized scale through co-generation by wind and solar systems to fuel small-scale fuel cells – say, to provide lighting on a family farm. As a replacement for our current auto and motor transport usage, it is a ridiculous fantasy. I think any money spent on developing or subsidizing hydrogen fuel cars or infrastructure will be wasting limited resources that would be better applied to realistic mitigation strategies.

Renewable Energy— Solar and wind energy are good ideas, and any electricity we enjoy in the very long term will have to come from these sources. But even with enormous growth rates, they cannot meet a significant portion of current electrical demand. Because they only generate current when the wind is blowing or the sun is shining, they also can't be used to meet peak demand periods. In fact, it would be a serious challenge for an entirely renewable grid to provide the continuous electricity we are accustomed to.

Europe has been much more proactive than the US, but currently generates only 8% of their electricity with renewables – mostly wind power. The European Union has set goals for renewable expansion to 20% by 2020, but even that goal may be insufficient in the long term because of Europe's expansion of natural gas electricity generation. By contrast, we produce less than 2.5% of our electricity with non-hydroelectric renewable energy, and despite a change in political administration, serious plans and policy have only started to help expand solar (currently around 0.16%) and wind (0.65%) portions of total electricity generation (Kunstler 2006, EIA 2007, Roberts 2005).

Expanding the renewable energy infrastructure to meet current fossil fuel electricity usage with renewables would require significant resources and time. Wind turbine construction requires a lot of steel, scarce elements such as neodymium, high-tech composite materials, and also has fossil fuel-associated transportation and maintenance costs. Silicon is one of the most abundant elements on earth but *high purity* silicon needed for solar panels is very energy and water intensive. The 1960s era electrical grid also needs to be modified and upgraded to integrate more wind and solar generation at the community, neighborhood, apartment, and single-family home scales.

Conservation and the Oil Depletion Protocol— Conservation is appealing as a way to deal with Peak Oil and energy declines. It's cheap. It doesn't require additional or new infrastructure. It can reduce demand quickly and gives us time to adjust to a new energy reality. Unfortunately, conservation requires *sacrifice* – a willingness to get by with less energy. It also requires social control of one sort or another. Peak Oil and entropy will eventually force us to conserve and conservation is the *only* strategy that we can quickly implement to mitigate energy depletion. But sacrifice is not a popular message any current politician is likely to bring up, and frankly, most people will not voluntarily conserve or sacrifice. Ask Jimmy Carter, the last national leader to speak out about energy depletion and the need for mandatory conservation. A 2011 Washington Post op-ed piece by David Broder extolling the cornucopian view of plentiful energy supplies called Carter the "scold in-chief." Jimmy Carter was absolutely right about energy but the idea of conservation is anathema to an economic system that must constantly grow to survive.

Colin Campbell drafted and promotes a sensible and fair plan for a gradual increase in conservation called the *Oil Depletion Protocol* (Campbell 2002, Heinberg 2006). This protocol calls on national governments to voluntarily reduce oil imports in direct proportion to worldwide declines in production. This approach requires every oil *exporting* country to transparently and accurately report oil production and reserve estimates and importing countries to voluntarily reduce their imports to match supplies in a gradual and at least predictable manner. It is a sensible way for the world to slowly power down and minimize chaotic conditions and resource wars; however, I have serious doubts we will do something so sensible.

Will we as a nation recognize these issues soon enough? Will the financial markets rise to the occasion and make long-term investment capital available in time? It is important to note that *anything* we can do to enhance the shift to renewable electrical generation will help provide valuable shock absorbers for near-term energy depletion but I seriously doubt the free market will speed up a transition to solar and wind generation without swift and sizable government subsidies. As I see it, had we significantly shifted and continued subsidies, R&D, and investments in the 1980s toward efficiency, conservation, renewables, and alternative fuels, we would now be facing a much gentler transition towards Peak Oil rather than a crisis. Now, even maximum possible expansion of these mitigation strategies cannot maintain our current level of energy consumption or make up for post-peak energy declines. Conservation, contraction, economic hardship, and sacrifice are coming, whether we like it or not. The fundamental question is how quickly do we want to make that hard transition?

Oil Politics and National Security

Strategic oil supply has been a focus of foreign policy and defense strategy since Franklin Roosevelt was president (Klare 2001, 2004). Jimmy Carter first clearly stated that Middle Eastern oil resources were a strategic resource essential to our national security and that we would defend access to these supplies militarily. In fact, this is called the Carter Doctrine, one of the major components of current American foreign policy. Bush the 1st said, "The American way of life is non-negotiable." This was shortly after Operation Desert Storm, or the First Oil War, and Dick Cheney often repeated this statement.

Both political parties have told us all along they would fight and use military resources for oil and that is exactly what they have all done: overt missions in Iran (protecting shipping during the Iran–Iraq War), Kuwait, Somalia, Kazakhstan, Afghanistan, and Iraq, and covert activities in Nigeria, Angola, Iran, Venezuela, Columbia, Pakistan, and others. All of these activities were related to oil, defense of oil logistics (pipelines and establishing forward staging bases), or developing financial support for "black" covert activities related to oil (Ruppert 2004, Johnson 2004).

Oil Wars and Terrorism— Wars over oil and other resources are not new. Germany's first industrial empire expansion was frustrated by defeat in World War I and punitive war reparations helped cause the Wiemar economic collapse that produced Hitler and the Third Reich. When Hitler re-armed and restarted German manufacturing in the 1930s, Nazi Germany needed oil and North Africa, Romania and Soviet Russia had oil. The rapidly industrializing Japanese invaded Manchuria and China for coal. When the US instituted an embargo of oil and steel in July 1941 against Japan, the Japanese concluded that war with America was worth the risks and attacked Pearl Harbor. It is no coincidence that Japan invaded and secured oil and rubber resources in Indochina and Indonesia soon after their attack on the US Pacific Fleet.

Oil is not the *only* reason why we are entangled in the Middle East. As the world's only superpower after the collapse of the Soviet Union and having the world's largest military and weapons arsenal, it was probably inevitable that we would act like an empire. We are no different from the Romans, the Mongols, the Spanish, the Dutch, and the British – all who expanded and formed empires when local resources were limited and military advantage was in place. But, come on! Oil is the *huge majority* reason the Middle East is strategic to us. In the short arc of the Persian Gulf lies Saudi Arabia, Iraq, and Iran – the final repository of 66% of the remaining oil in the world. Iraq accounts for 112 billion barrels of oil – the world's *second largest* proven reserves. Iraq also contains 110 trillion cubic feet of natural gas (EIA 2007b).

Even if the real reasons for our involvement in the Middle East were altruistic (i.e. to spread democracy), our *behavior* in the oil region for the past 75 years (along with the British and French) has certainly given the locals plenty of reasons to hate our guts. This fact was even acknowledged by the 9–11 Commission Report. Our dependence on oil and our government's long-term willingness to support American commercial interests has led us to subvert democratically elected governments (as in 1953 when the CIA helped the Shah remove the elected prime minister of Iran, Mohammad Mossadegh) and to support repressive despots like Saddam Hussein and corrupt tribal monarchies like the House of Saud. These actions, along with our staunch support of Israel, have produced the inevitable consequences and blow back of resentment and terrorism from the Middle East and the fundamentalist Islamic world.

Bigger Badder Wars are Coming— The Hirsch and GAO reports both warned that energy geopolitics may exacerbate the geologic depletion of oil and we see news every day that this trend is building. As oil becomes more expensive, the payoff for terrorist attacks on oil supplies and infrastructure will increase and oil importing nations (like us) are more likely to engage in aggressive commercial and military activities to ensure access to supplies. Oil exporting nations will also be more likely to use their oil supply power to their own advantages and to reserve their oil for domestic consumption. These actions are likely to further reduce the amount of oil available on the spot market. The consequences of our losing the essential oil and energy we need will combine to increase the chances of provocations leading to new and expanded resource wars.

We already can't afford imperial adventures like the *trillion* dollar Iraq-Afghanistan war – which has been funded by increasing our national debt. As expensive and painful as our occupation of 'Iraqistan' has been, the *real* test will be when the Chinese decide to step in militarily to assure their access to Middle Eastern, Iranian, or African energy supplies and we take umbrage. It will be difficult to win a major conventional land war with the 1.5-million strong Peoples Liberation Army, especially if war lasts longer than 2 – 3 months. Our limited inventory of deadly but complex and delicate jet aircraft, expensive smart bombs, and cruise missiles won't last very long in an extended shooting war against a well-equipped and better financed industrial foe. Our deployed ground forces are highly trained and equipped warriors (and God bless them for their service and sacrifice), but they are already over deployed and overextended. We don't have the money, strategic raw materials reserves, or the manufacturing capacity for a serious war lasting longer than 6 months. So, any war with a significant military foe will tempt the thermonuclear option. The Chinese also have nuclear missiles (240+) and have recently launched nuclear missile submarines. Is going nuclear for oil supplies OK with everyone?

Even a more limited war – say with Iran – could have disastrous consequences. Besides likely causing the price of oil to again skyrocket, all of our carrier battle groups operating in the Persian Gulf are highly vulnerable to conventional rocket attacks or swarming attacks by small and fast corvettes and torpedo boats. The Iranian Navy has lots of these, as well as 3 quiet Russian-built Kilo-class submarines. The loss of any carrier battle group would be a significant blow and if it happened in the Strait of Hormuz, it could also disrupt tanker traffic and affect oil deliveries. Losing an aircraft carrier like the USS John C. Stennis would cost more than $4.5 billion to replace (some sources indicate up to $12 billion), not to mention the deaths of sailors, the loss of both conventional and nuclear munitions, and perhaps a carrier air wing. All of our Iraq- and Afghanistan-based ground forces would also be within range of Iranian (made in China or North Korea) medium range missiles and could face combat with between 100,000 to 200,000 troops of the Iranian Army. A real war with Iran would not be a cakewalk. I think we would "win" but it would likely be a Pyrrhic victory with another occupation quagmire to pay for and seriously eroded and much more hostile relations with both Russia and China.

We are Junkies for that Oil— I do not support our occupation and waste of national treasure in quagmire Iraq and Afghanistan or unconstitutional, anti-democratic, and immoral activities our government continues to do under the justification of a War on Terror. But get a grip, people! Whether we are conservative or liberal, environmentalist or industrialist, religious or atheistic, gay or straight, rich or poor, smart or stupid, we are *ALL* American oil junkies. And junkies will do *anything* to get their supply. While I did not think it a wise move, I was not really surprised that the Bush administration put a huge military presence on the ground and built the largest embassy complex in the world where the only oil supplies worth a damn still exist. The stakes on the line in the Middle East *are* profound and what politician wants to tell Americans they have to live with less?

We are in a real jam, folks, and facing, as Kurt Vonnegut called it, “the mother of all cold turkeys.” Even if we don't like what our government is doing in our name – and I most definitely do not – we have to admit that our own ignorance, laziness, apathy, and excessive energy use have helped create this situation. We are all "vested" in the current American energy use system and its Frankenstein world politics.

Conservation and National Security— Despite fears of economic and market consequences for telling the truth about Peak Oil, I think our national security would be much better served by our leaders being honest with us about the gravity of the energy situation and the need for serious conservation and sacrifice. While energy independence is another popular goal often mentioned by politicians, it is another unrealistic pipe dream – we currently use way too much energy to continue our current lifestyle and standard of living under any proposed energy independence strategy. However, we could make some *real* progress towards *real* energy self-sufficiency and *real* homeland security by embarking on a crash program that emphasized conservation, mobilizing state and local governments to start planning and preparing for sustainable local economies, decentralizing and repairing our electrical grid, rejuvenating our railroads, and seriously subsidizing wind and solar energy expansion. That would enhance our national security in very fundamental and positive ways – but not without significant sacrifice and adjustment. Can we or will we make these sorts of choices? Or have we already created an unstoppable aggressive and military momentum?

What Can We Expect?

Sustained oil prices above $101/barrel or gasoline higher than $3.50/gal are higher in inflation-adjusted dollars than they were during the worst of the OPEC embargoes in the 1970s. When oil prices approach these levels, we can expect strong and noticeable impacts on our pocketbooks and economy – comparable to the inflation and recession (stagflation) we experienced in the late 1970s. I believe we are *already* feeling significant Peak Oil-related effects from the 2008 oil price spike and the resulting recession and financial crisis.

When oil prices increased to the $80 to $120/bbl range from increased demand (driven by China and India), many more poor countries experienced permanent demand destruction for oil and growing hardship and hunger from increased oil-related food costs. This process helped produce the 'Arab Spring' revolts in Tunisia, Libya, Egypt, and Syria as these governments were unable to keep food and energy prices subsidized. The recent protests and regime changes in North Africa and the Middle East were triggered not by a love of democracy, but by relentlessly increasing food and fuel prices that are creating real hardship and impoverishment. This has created civil unrest and will produce failed states like Somalia and the Sudan where ethnic cleansing and genocidal human suffering expands and creates a regional domino effect from refugees escaping war and starvation (Brown 2008, Klare 2005). As prices continue to rise, deepening recession and increasing job losses will begin seriously affecting the wealthy developed countries – starting, of course, with their poor and lower wage people.

Because we depend on oil imports (around 65% of daily consumption), we are much more vulnerable to loss of supply because of the export land effect. Recall that this process occurs when countries that still have available oil production choose to keep it for domestic consumption and curtail exports to the spot market. We are also much more vulnerable to unexpected events in oil producing regions that shut in or reduce production capacity. An intensification of the civil war in Nigeria (#14 on the Failed States list), a Venezuelan embargo, or Mexico simply curtailing exports could produce sudden unexpected shortages of oil for us, fuel price spikes, and lines at gas stations. Similarly, any armed conflict or war with Iran would suddenly reduce oil exports and an attack on Saudi production facilities by terrorists would also quickly affect us. Savvy citizens will want to keep abreast of international news and developments.

In the next 10 years we face continued problems from prolonged recession and unemployment leading to severe budget reductions and insolvency for state and local governments, and increasing erosion of their services. Because of this, we can expect that physical infrastructure will likely show progressively more deterioration from lack of maintenance, and government at all levels will be increasingly unable to effectively respond to crisis situations. Each new oil price spike will cause an incremental intensification of the recession and increases in the ranks of the permanently unemployed, and this will lead to expansion of local underground economies. I expect national politics to become increasingly bitter and unstable, and we will be more vulnerable to demagogues who promise the quick fix or identify a convenient enemy or scapegoat to solve our dilemma.

As we enter the decline phase of Peak Oil – sometime within the next 5 years – we can initially expect geographically isolated and short duration fuel shortages that will cause lines at gas stations and sharp price spikes. These early shortage crises will be the last warning before the real trouble begins, and I hope they will act as a collective wake up call that will mobilize all of us to pull together and start serious preparations for energy declines. As oil decline continues, we can expect the onset of longer and more frequent fuel shortages that will cause transportation breakdowns and food delivery problems, some that will lead to hunger and social instability. The first food riots in America will signal that the full emergency is upon us.

Because petroleum and credit expansion is essential for maintenance and repair or expansion of the electrical grid, we can expect electricity blackouts to become more common as energy providers shift to load shedding strategies. As the decline period deepens, we will eventually experience the intermittent and unstable voltage electricity similar to that found in Pakistan and many African countries today. I believe this will be the point when the global Internet collapses as server farms and routers will be unable to reliably operate with unstable electrical power.

It is safe to say that over the next 10 years, we will experience lives with progressively more expensive energy and food, a collapse of asset values (stocks, real estate, nonessential stuff), diminished global economic activity, and greater social hardship and suffering. I also think we are at high potential risk from a costly major war within the next two decades and unpredictable climate change disasters (droughts, floods, storms) from here on out.

If these trends occurred in a slow and predictable way, we might be able to adjust – albeit with significant changes in our lifestyles and comfort. Unfortunately, Peak Oil, in combination with other resource depletion, economic and geopolitical crises, and climate and natural disasters, will introduce shocks that will truly test our cultural character and civic order. Because these effects will be directly related to a *permanent* loss of cheap energy and *real* fuel shortages, they will be permanent economic adjustments. There will not be any economic recovery from these shocks like there was in the past when energy supplies were still plentiful. Eventually, electrical grid collapse, famine, massive migrations, wars, governmental collapse, and social chaos could haunt the first world in ways we simply cannot imagine.

While it is easy to image nightmare scenarios (Mad Max!) arising from resource depletion, the future will evolve unpredictably and events will interact in unknown ways – and not necessarily all negatively. If the collapse of the global economy means that we will have to manufacture more goods and grow more food locally, there will be local entrepreneurial opportunities and jobs that will return (Rubin 2009). We will have to do more work and food production using manual labor and this increased physical activity will have public health benefits. As energy declines, by necessity our food will be much less processed and meat will become less of a staple. This will reduce our current dietary intake of sugar, salt, fat, and preservatives and dyes common in processed foods, so obesity, diabetes, and chronic heart disease will be reduced. People will have to depend on their neighbors to survive, and this return to pre-industrial community values will be a positive benefit that energy wealth nearly eliminated.

I sincerely hope that we can somehow manage to make the transition to localized and sustainable economies without extreme shocks. However, make no mistake: over the next 30 years, we are facing the gradual collapse of modern civilization, and a significant reduction of the world population. The collapse has actually already begun for many unemployed people. The changes from declining energy production have already begun to affect us and the likelihood of some technological rescue from our predicament (warp drive or cold fusion) is very low. Despite this unhappy news, the future we will all get to soon experience is still subject to how we respond to the energy depletion crisis. If we do nothing and allow business as usual to play out and brave leaders do not respond wisely to crises, then negative outcomes and greater suffering will be more likely and we can expect a very rough and uncertain road. We also have the choice to pull together and build new local economies

Relocalization and Personality— Because the scale of economies will significantly contract from the global to the local, the most important variable that will determine how energy depletion affects you personally is where you live. Peak Oil will suddenly place much greater importance on local economies and community self-reliance. We will have to rebuild local and regional manufacturing and supplier networks and produce what we need closer to home. This means that locations with natural advantages will be "winners" in the downsizing of the world economy and these natural resource and commerce centers should have plenty of opportunities for work in new local businesses and factories. Areas with good soils and abundant rainfall will be able to grow food using sustainable or lower energy agriculture. Smaller cities with deep natural harbors or located on navigable rivers will have access to lower energy transportation.

Is your home in an area with renewable resources and fossil fuels available locally? How's the drinking water supply? Are there local manufacturing infrastructure and farming? Are navigable rivers or ports nearby? How is the heavy rail infrastructure? Do you live close to where you work, and is public transportation available? Is local leadership honest, competent, and likely to organize in anticipation of energy depletion problems? Is the regional climate changing for the worse?

Another critical variable that will play a large role determining how energy depletion will affect you is who you are as a person. Are you adaptable? Do you have serious health management issues or an ongoing need for medications, and are you in good physical and mental shape? Do you have a strong social network of family, good friends, neighbors, and church or civic membership you can depend on? Are you a leader? Do you depend on gas or oil for your current livelihood? Do you have any skills or knowledge that will make you valuable in a post-carbon economy? How prepared are you and your family – mentally and materially – for emergencies?

What Can We Do?

The hard reality of Peak Oil poses a world in complete dissonance with how our lives are now, what we value, and how we think, judge, and plan for the future. In America and Europe, we have had it *so* soft and easy. The loss of our comfortable way of life just doesn't seem possible and so denial, fantasy, and despair are often the natural initial reactions. We either ignore the unpleasant information (like cigarette smokers), believe what we are being told by the techno-optimists and corporate media that help will arrive just in time (the rescue fantasy), or else we withdraw in cynical distrust and worried depression. I have experienced all three! If you let these initial reactions come and go; however, I think you will come to the same conclusions that I have:

> Peak Oil is going to be a huge personal and collective challenge, but it will not be entirely negative. There will be positive aspects to the adaptations we will need to adjust to energy scarcity. We are not helpless and we have strength, creativity, and flexibility beyond what we can imagine. We have meaningful choices and options that we can exercise to help make the inevitable energy depletion transition less dangerous and chaotic for our family, friends, and community. By stepping up to the plate and taking adult responsibility for the situation we face, we can all play important roles preserving what is good and truly valuable about civilization and our culture. We can all directly help our families and communities by becoming important sources of leadership, stability, wisdom, and practical information when ignorance and fear are widespread.

There are several ways that we can act as citizens to help prepare for and mitigate energy depletion: advocate immediate mitigation activity at the national level, organize at the local level, and prepare on a personal level. They are all important.

Advocate Common Sense National Mitigation and Preparation Strategies— When I first wrote this essay in spring of 2007, I still held out hope that the Federal government might be influenced by citizen activism spreading the word about Peak Oil and the need for mitigation. I contacted my Congressional representatives and state politicians on several occasions and received a resounding lack of meaningful response. The 2008 economic crisis caused by our first Peak Oil price spike has since revealed a Congress completely owned by corporate and financial interests, and operating under a toxic political discourse apparently unable to act on any fundamental reality-based problem we face. I will continue to contact my federal and state officials about the importance of preparation for Peak Oil – because I am a Boy Scout – but I am doubtful that Federal or State level governments will act until the crisis is both full blown and intractable. This situation is a personal disappointment for me because I worked my entire career for the Federal Government and still feel that much could be done at the national level to better prepare for the trouble ahead. Here are the issues I believe we should advocate:

- *Start Planning Now*— While we need to avoid fear mongering and stress the call for unity, cooperation, and solidarity in the face of a crisis, the Federal government *must* start talking about energy depletion and how serious the situation is and all levels of government must begin planning for energy depletion as soon as possible. The recommendations made by the GAO and Hirsch Reports should be *immediately* implemented.

- *Model Conservation*— The Federal government must model the behavior it expects from citizens. All Federal agencies should perform Peak Oil preparedness and conservation studies and implement stringent conservation plans. Travel by air should be severely reduced by all branches of government. The General Services Administration (GSA) should immediately begin installing small solar and wind generation systems on all office buildings (perhaps using public-private approaches and long-term power contracts like Whole Foods has done) and GSA and military motor pools should speed up the shift to hybrid or very high mileage vehicles.

- *Augment Fuel Reserves*— Immediately start enhancing and expanding the Strategic Oil Reserve and fund regional diesel fuel reserve depots to maintain fuel for food transportation during shortages and emergencies. Increase and encourage establishment and expansion of regional gasoline and natural gas reserves. Start expanding the caching of fuel for military purposes.

- *Increase Sustainable Agriculture and Food Security*— The Department of Agriculture has supported the Alternative Farming Systems Information Center (AFSIC) since the 1980s; however, their role should be expanded and funded to establish an *Office of Sustainable Agriculture*. The mission of the OSA would be to 1) coordinate dissemination of knowledge of sustainable agriculture and traditional low energy food preservation through the existing network of Cooperative Extension Offices at the state Land–Grant Universities, 2) establish state seed banks devoted to maintaining and distributing a large variety of self-germinating food crop seeds; and 3) to help establish state or more local level networks of emergency grain storage elevators for emergency food distribution.

- *Expand Research*— Federal research on small system renewable energy generation should be significantly boosted, including small manual operation generating and storage systems. New generation and higher efficiency solar cell research should be accelerated. A standardized safe nuclear reactor design should be formulated and tested. If successful, this prototype should be used as the standard reactor design to shorten licensing and construction time. Proven high EROI ethanol generation processes using genetically modified microbes should be developed and promoted.

- *Promote Renewable Energy*— Even in the EU, Germany did not make significant progress expanding solar and wind generation until the federal government initiated subsidies. We also need to immediately expand federal subsidies for solar and wind generation installation (especially small-scale generation) and modification of grids. We need to set very ambitious expansion goals (well beyond the 20% of renewable electrical generation currently planned by the EU) and encourage installations by homeowners, landlords, businesses, and utilities with generous rebates, tax credits, and other subsidies.

- *Fix Vulnerable Infrastructure*— Identify critical strategic rail and highway links and bridge infrastructure and accelerate repair of any *strategic* transportation resources. Subsidize as needs dictate. Identify vulnerable and substandard electrical transmission infrastructure and repair it. Examine how regional electrical grids can be made more resilient, local, and autonomous, and implement modifications and upgrades to allow small-scale power generation to cheaply connect to the grid.

- *Expand and Repair Rail Service*— Shift federal excise tax revenues on gasoline and diesel from road and highway maintenance to railroad expansion subsidies. Funds should initially go for improving existing roadbeds and developing a long-term re-expansion of short rail lines to communities with sustainable future potential. Passenger service and rapid development of electrically powered rail service should be subsidized. Urban light rail should also be expanded and subsidized, and locally owned feeder trolley systems should be encouraged.

- *Increase National Energy Efficiency*— Government needs to artificially alter the equation where cheap usually means energy inefficient. We should expand subsidies for purchasing the most energy efficient replacement automobiles and appliances and the most energy *inefficient* should have excise or carbon taxes applied to their cost. The heaviest private vehicles (except for qualified farm vehicles) with the lowest mileage should have to pay significant excise taxes that increase as mileage decreases. Conversely, higher mileage vehicles should qualify for a government rebate or tax credit on a graduated scale up to 20% for the best mileage models. Why not subsidize fluorescent or LED replacement bulbs so they are actually cheaper than incandescent bulbs? Or give large numbers of them away for free?

- *Reduce Oil Price Volatility*— Since most future oil production will require high marginal costs to profitably develop and produce, we need to help reduce price crashes caused by recession demand destruction following price spikes. Nobody likes to pay more for gas, but we need new supply to come on-line to continue to meet essential economic needs. This means we should seriously consider imposing an adjustable crude oil, gasoline, jet, and diesel fuel tax that is reduced as spot market oil prices exceed the cost of new oil production, but kicks in when prices collapse. The SEC should be funded and tasked to actively police commodities futures speculation and outlaw derivative investments based on food and energy commodities.

Organizing at the Local and State Levels— The lower the level of government, the more important your participation will be and the more your activities will bear fruit in your own day-to-day life. Start with your city council and address many of the same issues identified above for Federal government actions as they pertain to your locale. The issues for your area and local governments will involve identifying practical adjustments to energy decline, implementing plans, and mobilizing citizen participation. This will involve information gathering related to local resources and infrastructure, education and persuasion, and will take considerable organizing efforts, human energy, and footwork. Here are some of the issues to consider:

- *Local Preparation Plans*— Has your city organized an energy descent planning effort? If so, volunteer to participate. If not, consider organizing and leading these efforts yourself. Issues to consider include organizing at the neighborhood or even block level and establishing plans for dealing with both short-term emergencies and longer-term energy declines. During the planning phase it is important to gather data: to survey existing city service infrastructures (police, fire, water treatment, public health, sewage treatment, and waste removal), and identify energy shortage vulnerabilities and local resources (local farmers, garden clubs, food related businesses, utilities) that will need to be coordinated. Issues like rationing and emergency stockpiles are very important to develop effective local response plans, as are mobilization of local media, citizens, local businesses, and civic organizations.

- *Local Food Preparedness*— How will local officials and law enforcement respond to food shortages? How can we encourage all citizens to plant vegetable gardens? Can city, county, or state resources be re-directed to address needs? What about emergency food and grain storage? Are there food banks already operating that could become part of municipal emergency preparedness? What about local farmers and gardening clubs? Can zoning regulations be amended to allow local grocery supermarkets to establish small "satellite" stores in neighborhoods to minimize the need for driving?

- *Public Health Preparedness*— How will your local public health system respond during emergencies to critical needs populations like diabetics, the very young, and the very old? How will hospitals be kept running during energy shortages and extended power outages? How will local governments respond to epidemics?

- *Local Water Preparedness*— How vulnerable is your local water supply to energy depletion or drought? Is there a rationing system in place? Long term issues include expansion of gray water systems, xeriscaping, rainwater storage, human powered water pumps like the Roundabout, and low energy water treatment such as slow sand filtration.

- *Local Fuel Preparedness*— Local governments need to address the need for secure storage depots that can fuel and power essential services (fire, ambulance, police, hospitals) during emergencies. Local governments will also likely have to play an important enforcement role in fuel rationing and should have systems and procedures in place for reserving commercial supplies for public services.

- *Local Building Codes and Covenants*— Outdated, corrupt, or foolish building codes that encourage energy inefficiency in construction should be changed. Neighborhood covenants that prohibit installation of solar, wind, or lower energy cooling should be revised. Prohibitions on raising small farm animals (chickens, rabbits, goats) in neighborhoods should be lifted as the situation requires.

- *Mass Transit and Transportation Planning*— Extensions of light rail service should be accelerated and heavy rail commuter trains should be expanded as quickly as possible. No new developments should be allowed that do not use optimum solar siting or are not close to mass transit and include walking proximity for food and other life essentials. Contingency plans should be available that encourage block level car sharing and bicycles.

A Personal and Practical To Do List— The following will provide a lot of suggestions but to respond sensibly you don't have to go crazy and try to do everything at once. In fact, that is not a good idea at all. You are more likely to become overwhelmed or frustrated and just give up. Remember and honor the law of the Growth Curve! But you should start thinking now about how your lifestyle will be changing over the next 20 years and consider starting your preparations in the near future. Start slowly by first learning and then gradually expanding the scope of your activities. Here is my list of simple and basic things we can all do to deal with Peak Oil in a positive and mature way. Most of these suggestions do not involve spending a lot of money or changing the fundamental way you live short-term, but you need to accept that long-term, your life will change – big time. Even if I am insane and Peak Oil is not true, nothing I am suggesting here should hurt you significantly.

1. *Wake Up and Pay Attention***—** This might seem obvious, but I think we all have to start by simply realizing how important energy is to every aspect of our daily lives and that everything we do uses energy. We need to wake up and pay attention to this fact. If we understand how energy is central to every economic activity and social behavior on the planet, then we can anticipate and understand events when others are confused. If we know which activities and products are energy wasteful, making changes to conserve and implement alternative strategies can be much easier. I do not believe we have to completely shift our lives and activities overnight but we must become aware so we can start to imagine the possible alternatives and adaptations. This is not that hard if you are beyond the denial phase of reacting to Peak Oil but it is *really* cheap!

2. *Practice Gratitude***—** This essentially spiritual suggestion is much harder to implement but it's cheap too, and well worth the effort. It's really simple. Get in the habit of recognizing when life is being good to you and savor the moment in a mindful way. Recognize and appreciate the good times and do it regularly. Even when you are sick, in crisis, or things are bad, these precious moments will happen. If you practice gratitude regularly it can become a habit and it will build a reserve of personal strength and resilience when things are not so good. If you are religiously inclined, give thanks to God, but you can practice gratitude whether you are religious or not. The key to making it work is practice, repetition, and habit.

3. *Do Something***—** If reading this essay has left you feeling depressed or worried, consider counteracting these normal feelings by simply starting to do *something*. Initiating any constructive activity or response – even if it ultimately does not pay off – will help break the cycle of inertia and depression and make you feel a little better. Even if the nature of the problem is huge, doing *anything* constructive or positive will help you feel empowered and start to build some momentum for actually dealing with the future. Doing something works, if for no other reason, your mind is occupied and distracted from dwelling on the negative.

4. *Become Informed*— Don't rush off half-cocked and do things and spend your hard-earned money reacting to Peak Oil without becoming informed. Become informed so you can inform others, not only about Peak Oil and energy, but also about how to survive in a world with less energy. This will take some time and effort, but not a lot of dough, and many of the resources are available at your local library or from the Internet.

- Learn more about energy, Peak Oil, and sustainability. Do an energy audit of your home and your activities. Research your locale, and learn its ecological resources and weaknesses. Learn about your water supply and local food production.

- Learn more about your local and national governments, how they work (or don't), and who your federal, state, and local representatives are. Start writing letters and snail mail to your representatives. Emails are too easy to ignore.

- Learn the basics of disaster preparation and volunteer for local preparedness exercises. Learn basic first aid and CPR.

- If you do not garden organically, consider taking it up and learn about composting and natural pest control that are appropriate to your locale. Learn how to do canning and also low energy food preservation. Learn how to cook from scratch using basic ingredients.

- Learn about farm animals, breeding, and animal husbandry. We may soon need to raise these animals for food or use them for labor. And we need to at least start rebuilding the cultural base of "common knowledge" about chickens, rabbits, goats, sheep, cattle, horses, donkeys, and mules, et al.

- Learn how to repair small mechanical appliances and bicycles. Learn about small renewable energy systems, how they work, and how to install and repair them.

- Learn traditional skills using hand tools like spinning, sewing, leather working, carpentry, and simple masonry.

5. *Become Involved*— Strengthen and renew your relationships with family, friends, neighbors, and social contacts. The strength of your social network is a direct measure of your true wealth and ability to survive crisis.

- Meet and get to know your neighbors and consider organizing a block pot-luck/meeting to discuss general disaster preparedness and Peak Oil.

- Find out if there are already local organizing efforts or groups involved with sustainability or Peak Oil preparedness. Consider joining or participating in these groups' activities.

- Contact your government representatives. Start locally and spend the most time locally, but definitely move up the food chain and do not ignore state and federal officials and representatives. Write letters or offer to present briefings about Peak Oil and preparedness. Volunteer to help organize preparedness meetings or task forces through your local city councils, schools, and churches.

- Are you already a member of a civic, service, trade, religious, or organization like a union, Kiwanis, Chamber of Commerce, a church, the Freemasons or Shriners? Present a slide show on Peak Oil at your local meeting and propose Peak Oil preparedness as a possible issue for your organization or club to embrace. Use your existing organizations to leverage your efforts.

- Are you a youth volunteer or involved with Scouts, 4H, Key Club, church, or other organizations? The younger generation definitely needs to be involved in Peak Oil and sustainability issues. The younger generations will have to deal with more of the consequences of energy depletion and environmental damage and many of them are already hip to our problems. They also have something many geezers are short on – youthful idealism. This power of youth represents an important source of energy we will definitely need to make a graceful transition to a sustainable future.

6. *Be Prepared***—** Become a metaphorical Boy Scout and be prepared! The following items are sensible and fairly inexpensive things that you can do to prepare and you can consider them based on your own perception of need, your inclinations, and your available resources. Once again, I emphasize that your greatest security and buffer to changes from energy depletion will come from your social network: your family, neighborhood, and community. The better you are socially organized and connected, the better off and prepared you will be.

- The first and most practical action you can take is to enhance your preparedness for small or short duration emergencies by gathering supplies, food, and other essentials. FEMA and local governments *already* encourage citizens to prepare for emergencies and Peak Oil crises will have effects similar to terrorist attacks, storms, earthquakes, and other natural disasters. Initial Peak Oil emergencies will involve the same needs: first aid supplies, food and water, camping or outside grill cooking, heating, illumination, and information.

- Develop a family emergency plan and stock a cache of emergency supplies. The Department of Homeland Security, Ace Hardware, and most state and municipal governments all have helpful websites for putting together your emergency cache. If your supplies or caches have perishables or items with limited shelf lives, then your preparation plan also needs to include maintenance and restocking schedules. As you refresh these stocks, you can donate the old items to food banks or charity. Over time, and based on your own judgment, *quietly* expand your food storage and emergency supply cache space so you and your family can weather longer emergencies and shortages. By taking the time to secure a cache of supplies and preparing for emergencies, you will not only gain some peace of mind for yourself and your family, you will also be helping your community by not adding to the problem of panicky reactions during crisis.

- If you have camping supplies, check them out and replace the worn out stuff. Make sure you have a grill or camp stove and a supply of extra propane or Coleman fuel. Buy sleeping bags for everyone in your family rated for the coldest winter temperatures in your region. Buy thermal underwear for family members – the highest rated wicking fiber thermal insulation stuff. Buy a water purification filter hand pump and supplies for sanitizing iffy water.

- Start composting and raising your own vegetables, or at least begin the process of building up good garden soil by mulching. If you have no yard, participate in public gardens or invest in a local organic farm or food co-op. You can also support local farmers' markets and encourage grocery stores to stock local produce and agricultural products. Start canning and preserving the food you produce. Encourage family and neighborhood participation. When you plant new trees and shrubs, consider planting edible fruit- and nut-bearing plants.

- Get in better shape. Start walking more and get several pairs of good quality and comfortable walking shoes. Get a serious shopping cart/caddy with decent sized wheels, a collection of heavy-duty canvas shopping bags, and start walking to the grocery store when and if possible.

- Get a decent bicycle for each member of your family and install baskets and racks to carry stuff. Get rid of the racing bike with the ultra-light frame and chi-chi alloy wheels and replace it with a sturdier and more comfy city bike or a touring bike made to carry loads long distances. Make sure the frame is sturdy and can accommodate add-ons like panniers, fenders, and racks. Install thick heavy-duty inner tubes and get a good hand pump. Maintain a surplus stock of tires and heavy-duty inner tubes. I would recommend getting all the same models for your family and also maintaining a stock of typical maintenance replacement parts (bearings, chains, brakes, and cables) and specialized hand tools or jigs needed to maintain the bikes. Make sure that shopping cart/caddy can be hooked to your bicycle.

- If you can afford it, invest in energy saving upgrades to your house. Add extra insulation, caulk and maintain existing windows or upgrade windows, add insulated siding and insulating storm doors, and find and plug leaks. Cover and insulate your water pipes (interior if possible, exterior mandatory) and water heater. If you are replacing appliances, get the highest-rated energy efficient ones you can afford, especially for furnaces, stoves, and water heaters.

- If you live in a colder climate and have the resources, consider investing in a modern clean-burning wood stove and maintain a healthy woodpile.

- If you are already planning upgrades to your house, consider passive solar design modifications (better), or solar panels or solar hot water upgrades (active solar is currently still expensive and requires ongoing maintenance). If you are planning to build a new or retirement home, think seriously about siting to maximize solar benefits, alternative insulating building materials (adobe, straw bale, earth berming), and passive solar designs. Give more attention to the community where you plan to relocate and how they might respond to energy depletion.

- If you are going to replace your car soon, consider a hybrid, small models like a Honda Civic or Toyota Yaris, or even a micro city car. The better mileage you get, the less you will feel increased gas prices. If possible, buy a recent model *used* car. Remember, it takes a lot of energy to build a new car. At the very least, you can easily cut down gas use by shopping for groceries and sundries in bulk, combining shopping trips, and using public transportation, bikes, or walking.

- If you don't have hand tools, think about getting them and learn how to use and maintain them. This would include small hand tools for mechanical repairs, hand tools for carpentry, and heavier hand tools for gardening, firewood, and digging. Get good quality hand trucks, wheelbarrows, and small practical wagons one person can pull. Buy rope of all sizes and heavier chain if you foresee clearing land or stump removal. Learn about traditional lifting and the use of pulleys and block and tackle. Definitely check out used but not heavily worn tools and get the highest quality tools you can afford. Consider getting spares for expected heavy-use tools or to use for barter.

- If you are a musician, writer, craftsman, or artist, and would like to continue practicing your art or craft, then start caching expendable supplies you use. Cache items like guitar strings, picks, amplifier tubes, cables, paints, brushes, canvas and stretchers, glue, tape, pencils, acid free paper, fabric, buttons, thread, needles, etc. What supplies and gear you routinely use will become scarce when oil and energy are very expensive?

- If you hunt and have guns and archery gear, consider caching ammunition and arrows, investing in reloading gear and supplies, or fletching supplies and bowstrings. Learn traditional hunting and tracking methods, butchering, meat processing and preservation, weapons construction and maintenance, hide tanning and leather making, and tallow rendering. Be willing to pass on your hunting skills and knowledge to others, especially younger folks.

- This may be objectionable to some of you who do not already have guns, but I suggest you think seriously about obtaining hunting and personal protection firearms, and learn how to accurately and safely use them. Even if things are currently safe and stable and there is no apparent need to protect yourself, consider that when and if the situation does deteriorate, it will be difficult and expensive to obtain guns and ammo. And, if things do not develop as I fear, then you will likely be able to sell the guns without taking a loss.

  An important caveat about guns or any weapon: if you do not think you could use a gun lethally to protect yourself or family or have moral objections to guns, then definitely do not get one. And, of course, those of you with small children should not have guns around unless you feel *especially* vulnerable and are willing to take the appropriate security precautions and train your children in gun safety.

- If possible, pay off your existing debts and think carefully about taking on large new debts. You might consider investing in a small cache of gold and silver US currency – but don't go too nuts. You should look at this cash as an emergency stash that might buy you some food during a panic, not as an investment. Some of you may be thinking about your retirement savings or investments and how you might invest to anticipate or offset Peak Oil's economic effects. My financial philosophy in this life has apparently been to buy high and sell low, so I am clearly unqualified to offer any specific advice – other than don't do *anything* hastily with your nest egg. There are other investment advisers and financial gurus like Stephen Leeb or Peter Schiff, however, who have gone on record making investment recommendations for the apocalypse. Just remember, when making any investment decisions you should become educated first and then read their books and give it some time for rational evaluation.

Updates and Closing Thoughts

If you have gotten this far, hopefully I have managed to persuade you that Peak Oil and energy depletion are significant near term issues deserving your serious consideration – or have at least made you think about these issues. Fundamentally, it seems clear to me that our population is outracing the earth's support capacity and resource base and we are finally reaching Malthusian resource limits. Even without Peak Oil and energy depletion, our current civilization is facing limits imposed by nature and entropy in terms of diminishing returns for our efforts, ecological damage, depletion of other strategic resources, and climate change. I do not think it is an exaggeration to say we are in on the verge of some very serious trouble. Ultimately, we are debating when the serious unraveling will begin: very soon within years, or within a generation.

Since I originally wrote this essay in June 2007, depletion related developments and economic bad news have been accumulating. Most of the predictions made by Peak Oil advocates have come true since the 2005 stagnation in oil production signaled our entry into the Plateau of Global Peak Oil. I contend that the price escalation and spike in July 2008 were primarily caused by excess demand – from the OECD (the Organization for Economic Cooperation and Development) combined with new and growing oil demand from China and India. World demand finally exceeded global production. This unprecedented and record price spike was very likely a major cause for the economic crisis.

A complete collapse of the world financial system appeared to be developing in 2008 as cascading failures spread and businesses shut down or scaled back production laying off millions of workers. Unprecedented bailout actions taken by governments may well have been necessary to forestall an even greater collapse of investment banks deemed "too big to fail," who were choking on trillions of apparently worthless sub-prime mortgage based derivatives and credit default swaps. It has been five years since the credit panic and bailouts to Wall Street, yet credit remains tight and many critics claim the bailouts have only postponed the day of reckoning for banks who still have massive amounts of toxic assets on their books. Unfortunately, these bailouts have also created unprecedented new government debt and public assumption of risk that will severely limit our ability to marshal resources for Peak Oil mitigation, infrastructure repair and maintenance, and apparently, to even deal with expanding and persistent unemployment.

Besides the outright purchase of toxic assets, our Treasury Secretary also guaranteed an *additional* $7 trillion in potentially toxic investments. Incredibly, no one actually knows the full extent of Wall Street (and by extension, pension plan and IRA) exposure to financial folly and fraud because derivatives trading is not regulated or reported with any transparency. Figure 16 shows estimates from the Bank for International Settlements suggesting there may be more than $600 trillion in derivatives that may eventually prove to be "toxic assets." *That's over a half **quadrillion** dollars of potential exposure*.

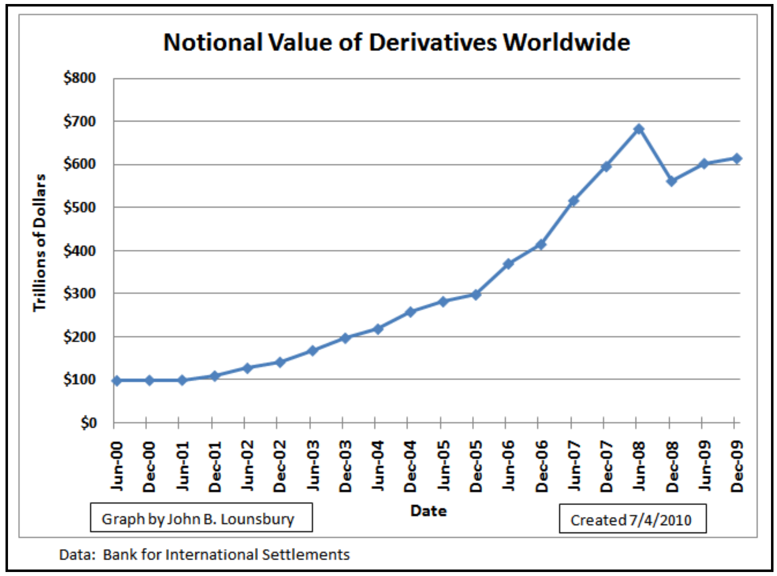


Figure 16.— Graph showing the dramatic growth in the notional value of derivatives since 2000. Source: John Lounsbury on Seeking Alpha

For comparison, the total world GDP in 2008 was estimated to be $61 trillion by the International Monetary Fund in their *World Economic Outlook* report. Some sources suggest that these estimates are grossly low – there may be as much as *$1.3 quadrillion* in this toxic funny money. If someone has a better example of creating wealth out of thin air, I would like to see it.

Demand for oil from the OECD nations has continued to decline since the oil shock through the spring of 2013 from persistently stalled jobs recovery, yet corporate profits and the stock market are at new historic highs and economists tell us that increasing GDP has ended the recession. Meanwhile, significant government stimulus applied in China has steadily increased demand and oil price recently topped $120/bbl. China has also significantly increased coal consumption since 2008. World oil production still cannot consistently exceed the 75 million bbl/d plateau, even with expanded production by Saudi Arabia and increased tar sands, deep water and tight crude production.

And then there was the tragic blow-out of the BP Macondo oil well and sinking of the Deepwater Horizon drilling rig in the Gulf of Mexico on April 20, 2010. Eleven men died in the explosion and fire and the volume of oil released (actual volume unknown, but estimated from 1 – 5 million barrels of oil) polluted a large area of coastline from Louisiana to the Panhandle of Florida. Large volumes of Corexit oil dispersant were also released into the spill and as much as ¾ of the total oil spill remains dispersed as microscopic droplets at depth under water in the Gulf of Mexico. While microbial degradation is assumed to eventually eliminate the dispersed oil, nobody knows how a spill of this magnitude and such unprecedented use of dispersant will affect the food chain in the Gulf.

The full cost to the Gulf of Mexico ecosystem may never be known but it is catastrophic by any measure and will take many years to heal. Coastal fishing and tourism industries in affected areas essentially lost at least a year's worth of revenue, if not more. This disaster was likely caused by BP management negligence, lax safety, and piss-poor oversight by the US Mineral Management Service, and underscores the dangers and risks of drilling in the deep water off the continental shelf. This is a textbook example of the Unavoidable Resource Triangle after Peak Oil: compared to pressurized sweet crude on land, deep water oil has a much lower EROI, much higher production costs, and devastating externalized pollution costs when a well blows out at a depth of 5,000 ft.

The BP disaster could have been a perfect "teaching moment" for Peak Oil and our precarious energy situation yet mainstream media and political leadership still did not tell us there's a serious world energy supply crisis. Peak Oil and fundamental supply limitations are being mentioned more often and with less dismissal in the energy and financial press but popular media continue to obsess over celebrity scandals and blame storming partisan political discourse. Meanwhile, accumulating evidence continues to support Peak Oil predictions and the strong likelihood of energy shortage crises beginning within the next 5 – 10 years. I think that most people now sense that something is very very wrong and that energy just might have something to do with it.

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This report was prepared for the House of Representatives' Committee on Science and Technology, at the request of Rep. Roscoe G. Bartlett, R–MD., who co–chairs the Congressional Peak Oil Caucus with

Rep. Tom Udall, D–NM.

"To better prepare for a peak in oil production, GAO recommends that the Secretary of Energy work with other agencies to establish a strategy to coordinate and prioritize federal agency efforts to reduce uncertainty about the likely timing of a peak and to advise Congress on how best to mitigate consequences. In commenting on a draft of the report, the Departments of Energy and the Interior generally agreed with the report and recommendations."

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Michael Ruppert is a former Los Angeles policeman who happened to stumble onto CIA involvement in illegal drug smuggling activity in LA in the 1970s, and got fired for it. He has gone way down deep into the rabbit hole, and uncovered some very grisly and grim things. This book presents very interesting data suggesting that 9–11 was allowed to happen, if not coordinated by our government, and he details the sorry and corrupt involvement of our government and the banking system in drug production, smuggling, and money laundering. His website is called *From the Wilderness*: http://www.fromthewilderness.com

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Oil Depletion Analysis Centre – is an independent, UK–registered educational charity working to raise international public awareness and promote better understanding of the world's oil–depletion problem.

http://www.realclimate.org/

"RealClimate is a commentary site on climate science by working climate scientists for the interested public and journalists. We aim to provide a quick response to developing stories and provide the context sometimes missing in mainstream commentary. The discussion here is restricted to scientific topics and will not get involved in any political or economic implications of the science."

http://www.worldwatch.org/

Worldwatch Institute – long–standing NGO that studies sustainable development, climate change, energy depletion, renewables, etc.

http://www.clubofrome.org/

Club of Rome – Another established NGO that first sounded the population growth alarm in their 1972 report – brings together scientists, economists, businessmen, international high civil servants, heads of state and former heads of state from all five continents who are convinced that the future of humankind is not determined once and for all and that each human being can contribute to the improvement of our societies.

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"Cambridge Energy Research Associates, Inc. (CERA), an IHS company, is a leading advisor to international energy companies, governments, financial institutions, and technology providers. CERA delivers critical knowledge and independent analysis on energy markets, geopolitics, industry trends, and strategy. Our services help decision makers anticipate the energy future and formulate timely, successful plans in the face of rapid changes and uncertainty. CERA is valued for our independence, fundamental research, foresight, and original thinking. Our unique integrated framework enables us to offer new insights ahead of conventional wisdom, providing a comprehensive "early warning system" that has a direct impact on investment, decision making, and performance."

http://www.iea.org/index.asp

"The International Energy Agency (IEA) acts as energy policy advisor to 27 Member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973–74, the IEA's initial role was to co–ordinate measures in times of oil supply emergencies. As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection. Current work focuses on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world, especially major producers and consumers of energy like China, India, Russia and the OPEC countries."

http://www.postcarbon.org/

The Post Carbon Institute – an information clearing house with information and links to permaculture, intentional community organizing, and sustainable agriculture. Founded by Julian Darley.

http://globalpublicmedia.com/

"Global Public Media has been formed to help existing public service information organizations, which include broadcasting, print and online media, give a broader, deeper and more interactive public information service. During Phase One we are developing and presenting in–depth interviews, & pilot radio and television sites and programmes in response to a wide range of topics and issues in the world."

http://www.oildepletionprotocol.org/ original Rimini oil depletion protocol by Colin Campbell

"A Plan for a Sensible Energy Future... As we move into an era of oil depletion and energy constraint, everything from transportation to medicine to food to climate change response strategies will be affected. Almost everything we do is dependent on oil.

The transition to a future of reduced oil supply will require the development of clean, reliable, and renewable energy sources and reduced oil production and consumption. The Oil Depletion Protocol will allow us to accomplish both – simply, conservatively, and cooperatively. It is a plan for a sensible energy future."

http://www.relocalize.net/

"Relocalization is a strategy, which aims to build societies based on the local production of food, energy and goods, and the local development of currency, governance and culture. The main goals of Relocalization are to increase community energy security, to strengthen local economies, and to dramatically improve environmental conditions and social equity."

http://www.globalreporting.org/Home

Global Reporting Initiative – reports on economics of sustainable activities http://transitionculture.org/?p=129

Transition Culture – another sustainability website with a link to Kinsale, Ireland's community action plan for responding to peak oil issues. This is an excellent example of what we can do to organize and prepare on the local level for Peak Oil.

http://www.oaec.org/

Occidental Arts and Ecology – permaculture training – seed banks – intentional communities

http://store.altenergystore.com/

The Alternative Energy Store – home photovoltaic arrays and storage systems, low–head/flow hydroelectric power.

http://www.lifeaftertheoilcrash.net/

Life After the Oil Crash – Very doomer oriented but a good overall summary of peak oil by Matt Savinar – links to sustainability and survival issues and books

http://www.hubbertpeak.com/

Named after the late Dr. M. King Hubbert, Geophysicist, this website provides data, analysis and recommendations regarding the upcoming peak in the rate of global oil extraction.

http://www.dieoff.org/

It don't get more Malthusian than this! Run!!!

http://www.dailyreckoning.co.uk/

The Daily Reckoning – British clearinghouse – info and evaluations on alternative and sustainable energy investments.

Appendix 1: Some Supplemental Energy Data

Source: (EIA 2007a, 2007b) unless otherwise noted

Petroleum Production – World goe – gallons of oil equivalent, bboe = barrels of oil equivalent

World Total	84 million bbl/d	40,830 gal/s	***0.527 goe/d/person***
Estimated World Oil Reserves	1.9 trillion bbl		
World Reserves Remaining	0.9 trillion bbl		

Petroleum Consumption. US – 2005 data

Current Daily US Oil Use:	20.7 million bbl/d	10,063 gal/s	***2.90 goe/d/person***
Annual US Oil Use	7.556 billion bbl/yr		
Percentage of Oil Imports	65.5% = 13.5 million bbl/d		
US Percentage of World Oil Use	25%		
US Percentage of World Population	4.5%		

Natural Gas Consumption, Total, Annual, US – 2005 data in cubic feet (ft^3)

Residential	4,837 billion ft^3/yr
Commercial	3,054
Industrial	7,710
Transportation	583
Power Plants	5,797
TOTAL	21,981 billion ft^3/yr = 697,000 ft^3/s = 31,100 lb methane/s = 8.96 lb/d/person
	16,184 billion ft^3/yr = 513,191 ft^3/s = 22,824 lb methane/s = 6.60 lb/d/person (excluding power plants)
	148 ft^3/d/person 2.697 billion bboe/yr 3,592 goe/s ***1.04 goe/d/person***

Electrical Power Generation – 2006 total US generation = 4,052,968,000 Megawatts (MW)

Coal	48.9%		
Natural Gas	20.3%		
Nuclear	19.4%		
Hydroelectric	7.1%		
Renewables	2.4%		
Oil	1.5%		
TOTAL	4.05297×10^{15} W/yr		
	6.11 billion bboe/yr	8,137 goe/s	***2.34 goe/d/person***

TOTAL US Energy Usage = 1.000×10^{17} BTU/yr
17.240 billion bboe/yr = 47.237 million bboe/d = 22,960 goe/s ***6.61 goe/d/person***

Conversion Factors and other Calculations:

barrel of oil equivalent (bboe, sometimes BOE) = 42 gallons of oil equivalent (goe)
1 bboe = 5.8×10^6 BTU = 6.1178632×10^9 joules (J) = 6,117.86 megajoules (MJ) = 1.70 MWh.
1 bboe = 6,000 ft^3 of natural gas.
1 gallon gasoline = 114,100 BTU
1.0 BTU = 1055.056 J
1 watt = 1.00 J/s is approximately 3.41 BTU/h
1000 BTU/h is approximately 293 W
1 ft3 of Natural Gas = 1,031 BTU = 28.317 L @ STP = 20.2264 g methane/ ft^3
1 therm = 100,000 BTU
1 terajoule = 1,000,000 megajoules

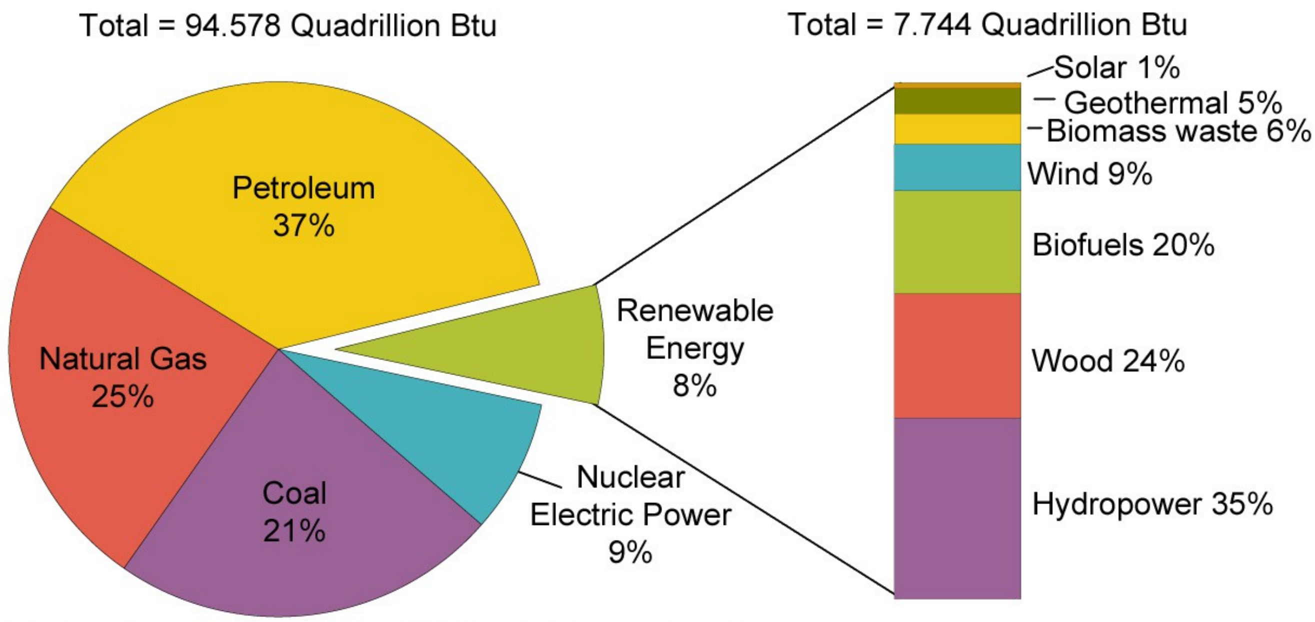
Energy Required to Build New Automobile (Maclean and Lave 1988)
assuming 12,000 mi/yr @ 20 mpg = 68,460,000 BTU = 11.8 bboe/yr
16.5 bboe = manufacturing energy per car
135 bboe = fuel usage over 14 yr life
12.9 bboe = maintenance energy usage
165 bboe = life cycle energy cost of car

Energy Required for Personal Computer Manufacture (Williams 2004)
6,400 MJ of energy (1.05 bboe)
Add 2,600 MJ/year of usage (0.425 bboe) (1.3 time a refrigerator)
3 year energy cost = 2.33 bboe

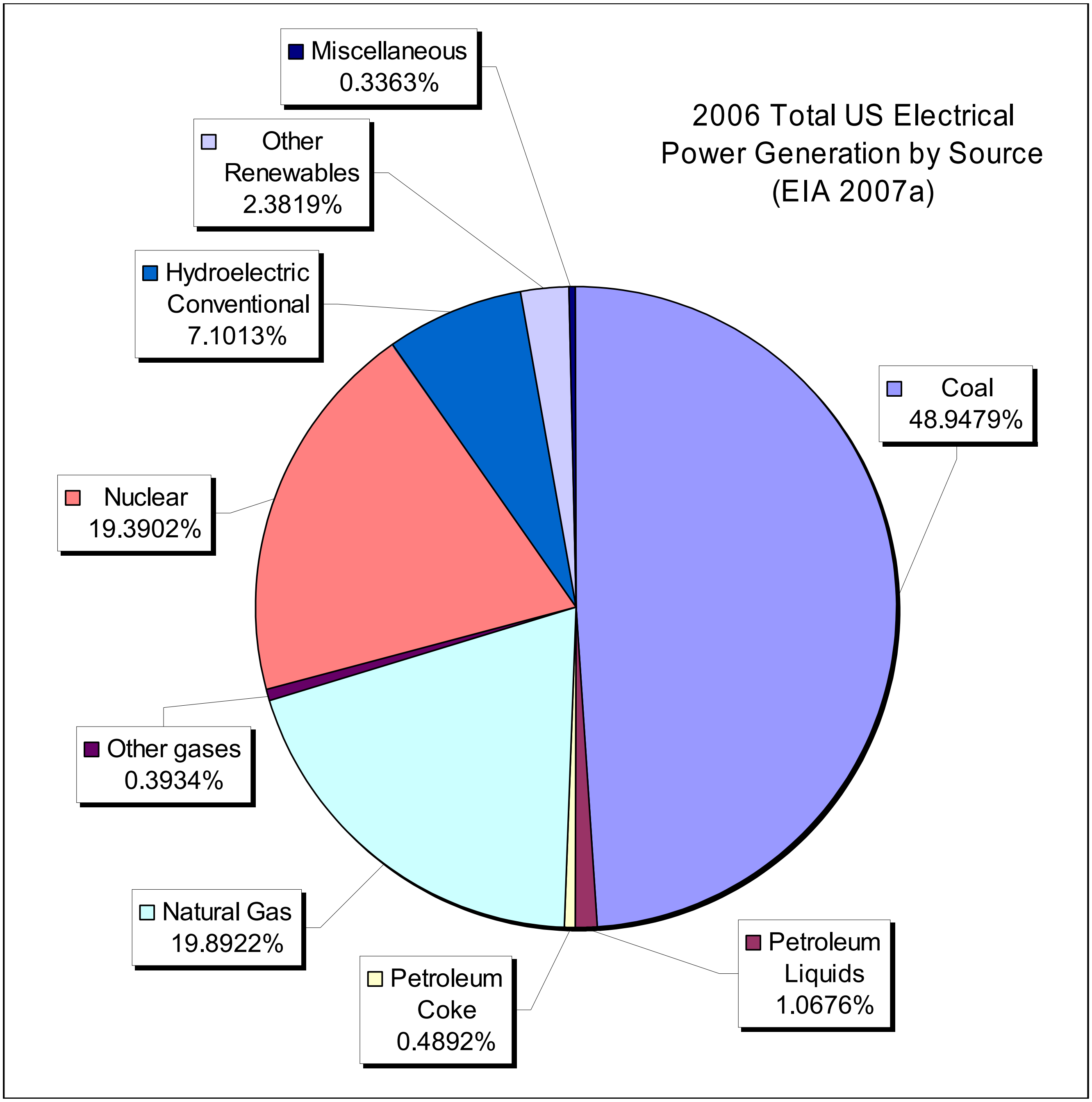
Energy Consumption in the US, 1973–2006, by method of generation. Values are in Quadrillion (10^{15}) BTUs.

	Fossil Fuel Energy Sources					Renewable Energy Sources						
Year	Coal	Natural Gas	Oil	Total Fossil	Nuclear	Hydro	Biomass	Geother–mal	Solar	Wind	Total Renewable	Total Energy
1973	12.971	22.512	34.840	70.316	0.910	2.861	1.529	0.043			4.433	75.708
1975	12.663	19.948	32.731	65.355	1.900	3.155	1.499	0.070			4.723	71.999
1980	15.423	20.394	34.202	69.984	2.739	2.900	2.475	0.110			5.485	78.280
1985	17.478	17.834	30.922	66.221	4.076	2.970	2.975	0.198			6.144	76.580
1990	19.173	19.730	33.553	72.46	6.104	3.046	2.687	0.336	0.060	0.029	6.158	84.730
1995	20.089	22.784	34.553	77.488	7.075	3.205	3.018	0.294	0.070	0.033	6.620	91.200
1996	21.002	23.197	35.757	79.979	7.087	3.590	3.098	0.316	0.071	0.033	7.107	94.226
1997	21.445	23.328	36.266	81.086	6.597	3.640	3.037	0.325	0.070	0.034	7.107	94.800
1998	21.656	22.936	36.934	81.592	7.068	3.297	2.843	0.328	0.070	0.031	6.569	95.200
1999	21.623	23.010	37.96	82.650	7.610	3.268	2.886	0.331	0.069	0.046	6.599	96.837
2000	22.580	23.916	38.404	84.965	7.862	2.811	2.922	0.317	0.066	0.057	6.173	98.976
2001	21.914	22.861	38.333	83.138	8.033	2.242	2.531	0.311	0.065	0.070	5.219	96.318
2002	21.904	23.628	38.401	83.994	8.143	2.689	2.586	0.328	0.064	0.105	5.774	97.808
2003	22.321	22.967	39.047	84.386	7.959	2.825	2.660	0.331	0.064	0.115	5.993	98.121
2004	22.466	22.993	40.594	86.191	8.222	2.690	2.828	0.341	0.065	0.142	6.066	100.218
2005	22.785	22.886	40.735	86.451	8.160	2.703	2.820	0.343	0.064	0.178	6.108	100.461
2006	22.556	22.495	40.217	85.329	8.208	2.889	2.965	0.346	0.064	0.258	6.523	99.661

U.S. Energy Consumption by Energy Source, 2009



Note: Sum of components may not equal 100% due to independent rounding.
Source: U.S. Energy Information Administration, *Annual Energy Review 2009*, Table 1.3, Primary Energy Consumption by Energy Source, 1949-2009 (August 2010).


2006 Total US Electrical Power Generation by Source (EIA 2007a)
Miscellaneous 0.3363%
Other Renewables 2.3819%
Hydroelectric Conventional 7.1013%
Nuclear 19.3902%
Other gases 0.3934%
Natural Gas 19.8922%
Petroleum Coke 0.4892%
Petroleum Liquids 1.0676%
Coal 48.9479%

Appendix 2: Energy Content of Carbon Based Fuels

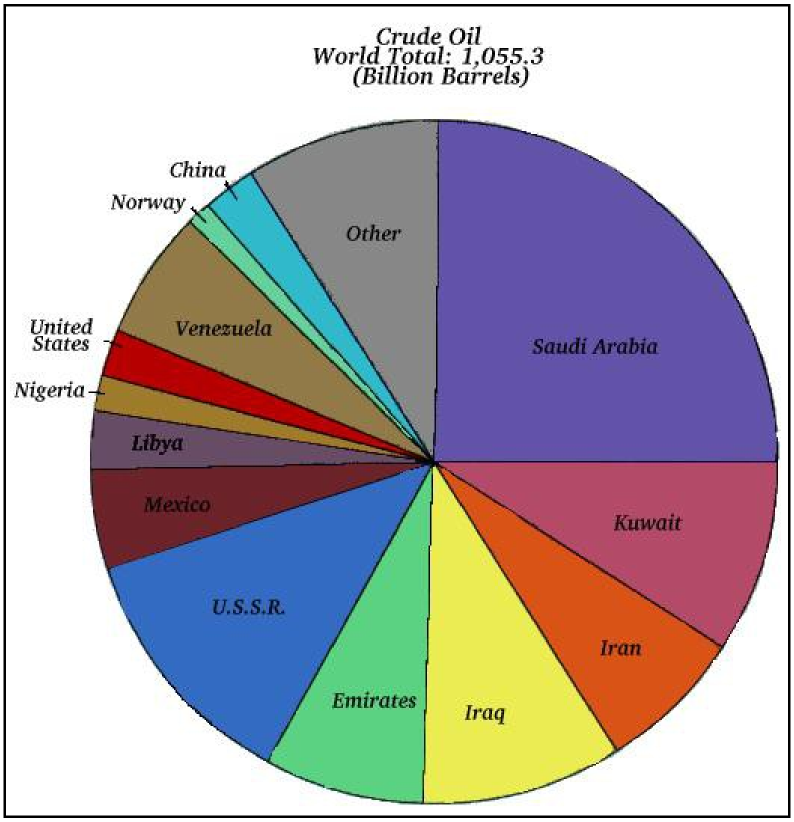
Our civilization currently depends on carbon-based fuels that include renewable wood and other biofuels, and the non-renewable fossil fuels coal, petroleum, and natural gas (methane, CH_4). Carbon-based fuels are not alike with respect to *quality*. Quality in a fuel is related to several factors or variables. The primary variable is energy density. How much free energy (measured in Joules, calories, or BTUs – British Thermal Units) is released when a given mass of fuel is burned? The next quality variable is net energy. How much energy is required to produce and transport the fuel compared to the energy released by burning the fuel? Finally, fuels vary according to non-carbon impurities like moisture, refractory materials like silica that produce solid residues (ash), nitrogen, sulfur, and toxic metals. How cleanly does the fuel burn and what are the detrimental environmental effects and wastes produced from burning the fuel?

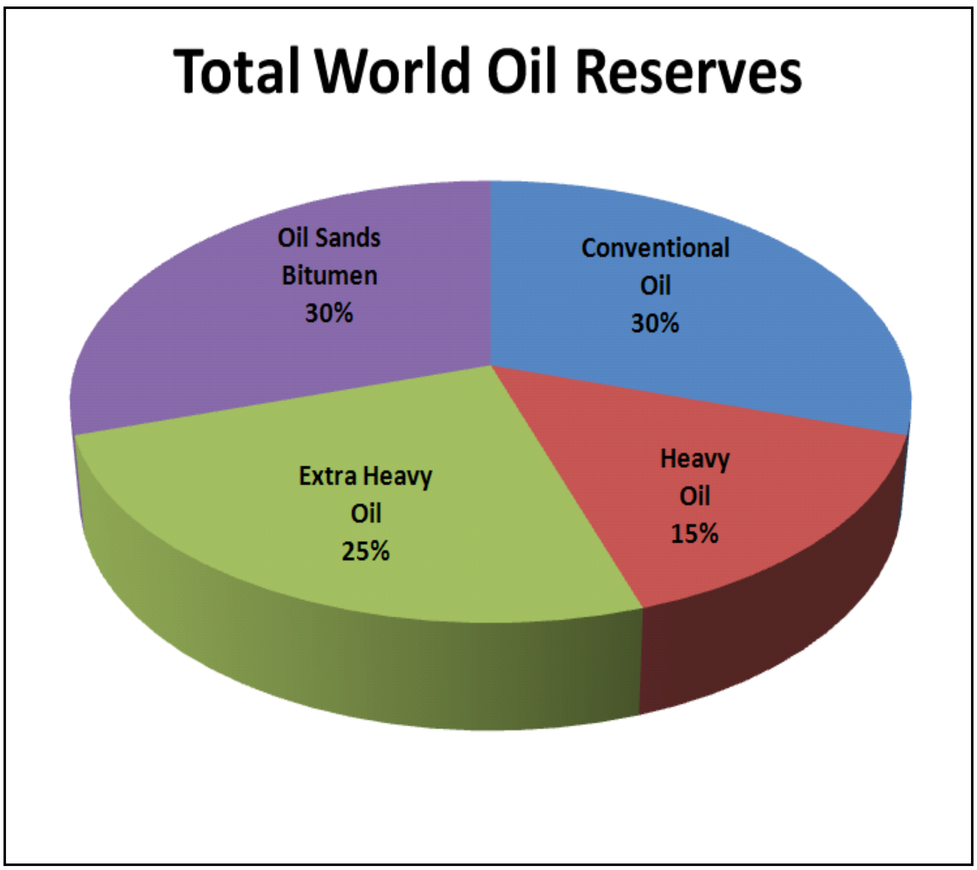
The table below shows the relative energy content of different fuels in kilocalories (thousands of calories) per pound. Dried animal dung is a common cooking and heating fuel in the Third World, and it represents the solar energy storage that grasses accumulate in one growing season (minus the energy used by the cow). As a result, dung has a fairly low energy content. Firewood is fuel from trees that have stored solar energy over several decades, and it has roughly twice the energy content per pound as dung. Fossil fuels represent many thousands (if not millions) of years of accumulation of plant litter or microscopic plankton that are then covered by sediments, compressed and "cooked" without oxygen over millions of years. Fossil fuels thus contain much more embedded solar energy per unit weight compared to dung or wood and so represent a more concentrated form of stored solar energy and much higher quality fuels.

Comparison of the energy content per pound in different fuels. (Oak Ridge National Laboratory 2009)

Fuel	***Kilocalories per pound***
Dung	985
Wood (air dry, 20% moisture)	1,613
Charcoal	3,200
Anthracite Coal	3,600
Bituminous Coal	2,900
Ethanol	2,900
Petro-Diesel	4,690
Gasoline	4,760
Crude Oil	5,120
Natural Gas	5260

Oil producers. Source: SUNYSB Geo 101 Class Notes





Composition of world oil resources. Source: Wikipedia http://en.wikipedia.org/wiki/Oil_reserve