Interesting Times

Challenges Facing Mankind

David Stein

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A summary of the major challenges facing the United States of America and the entire planet Earth, including a summary of possible approaches to mitigating and/or solving them.

Preface

We live in interesting times. Mankind is depleting our non-renewable resources, especially petroleum, coal, natural gas, and uranium. Energy Descent will commence in earnest within the next few years. Within 100 years the Age of Oil will be effectively over. Forecasts of the carrying capacity of the Earth after the Age of Oil range from 600 million to 2 billion people. The Earth's human population is currently over 7 billion people. Can massive die-back be averted?

Sound policy requires objective information.

The following fully referenced document covers the main challenges facing mankind in Part One and possible paths forward in Part Two. The monumental nature of these challenges could lead to despair, but there are possible paths to mitigate or solve these challenges. These possible paths are also opportunities for mankind. If we fail to plan, we plan to fail.

Richard Heinberg calls this Peak Everything while James Howard Kunstler calls it The Long Emergency. The world-wide "Transition Towns movement is an attempt to design abundant pathways down from the oil peak, to generate new stories about what might be waiting for us at the end of our descent, and to put resilience-building back at the heart of any plans we make for the future."[1]

T. Boone Pickens believes that energy is the best way to boost growth and pay down the national debt and the next president needs to embrace that. "We have the cheapest energy in the world in America. Cheap energy trumps cheap labor," Pickens said. [2] But the energy must be renewable and sustainable for this to work long range.

All of the following challenges have a probability of 100%. The only question is one of timing, but they *will* occur and soon, if not already. The question is how to mitigate and/or solve them. The problem of fossil fuels depletion cannot be *solved* because they cannot be regenerated, but the problem can be *mitigated* by switching mankind to renewable fuels. These great challenges are an opportunity for the United States to lead by example.

[1] The Transition Handbook by Rob Hopkins, pg. 15
[2] http://money.cnn.com/2016/04/27/investing/boone-pickens-oil-prices-100-dollars/index.html

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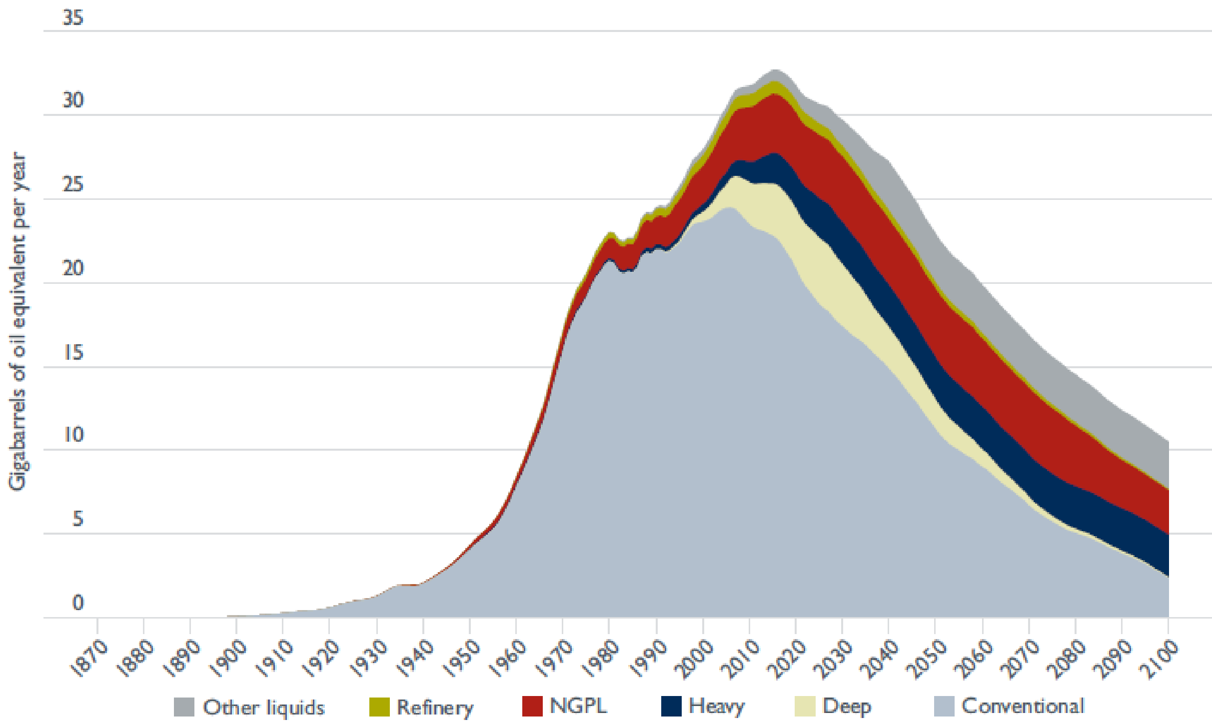
Part I - Interesting Times

By far the biggest challenge facing mankind is Energy Descent. Fossil fuels are a finite, non-renewable resource that we are using up. They are in the process of being literally exhausted. They are our inheritance from the Earth, and we're spending it. Another major challenge is that the United States' electrical grid is not protected against a major geomagnetic disturbance that would be induced by an Earth-directed major solar storm (coronal mass ejection or CME). Unless we protect the grid from this, it will end our civilization as we know it, and it's only a matter of time before another solar storm of the Carrington Event[3] scale hits the Earth. Worldwide fisheries depletion threatens the food security and oceanic ecosystems of the Earth with total collapse. Deforestation, soil depletion, and soil loss also threatens world food security as well as being the cause of major carbon and water cycles disruption. The dark green parts of the USA are the only parts still forested.

[3] The **Solar Storm of 1859** — known as the **Carrington Event**[1] — was a powerful geomagnetic solar storm during solar cycle 10 (1855-1867). A solar coronal mass ejection hit Earth's magnetosphere and induced one of the largest geomagnetic storms on record. ... In June 2013, a joint venture from researchers at Lloyd's of London and Atmospheric and Environmental Research (AER) in the United States used data from the Carrington Event to estimate the current cost of a similar event to the U.S. alone at $0.6–2.6 trillion.[2]
https://en.wikipedia.org/wiki/Solar_storm_of_1859

Petroleum depletion

"It is now widely acknowledged by the world's leading petroleum geologists that more than 95 percent of all recoverable oil has now been found. ... Worldwide discovery of oil peaked in 1964 and has followed a steady decline since. According to industry consultants IHS Energy, 90% of all known reserves are now in production, suggesting that few major discoveries remain to be made."4 The Australian government's 2009 analysis indicates "the decline of refinery gains and minor liquids (with declining oil) is tempered by the expected expansion of biofuels and NGPL[5], but the total is still not able to arrest the decline in total liquids once conventional oil starts downward in earnest after 2017. Moreover, after 2040 the downtrend in the production of total liquids is on the same path as that for crude oil alone."[6]



"China's Oil Industry Is Faltering, Production Falls 5%"[7] They will increasingly compete for oil resources on the international market.

"About one-third of the oil in North Dakota's Bakken Formation has already been removed, [Hughes] said, and even though the fields will continue to produce oil for a couple more decades, well productivity will inevitably drop."[8]

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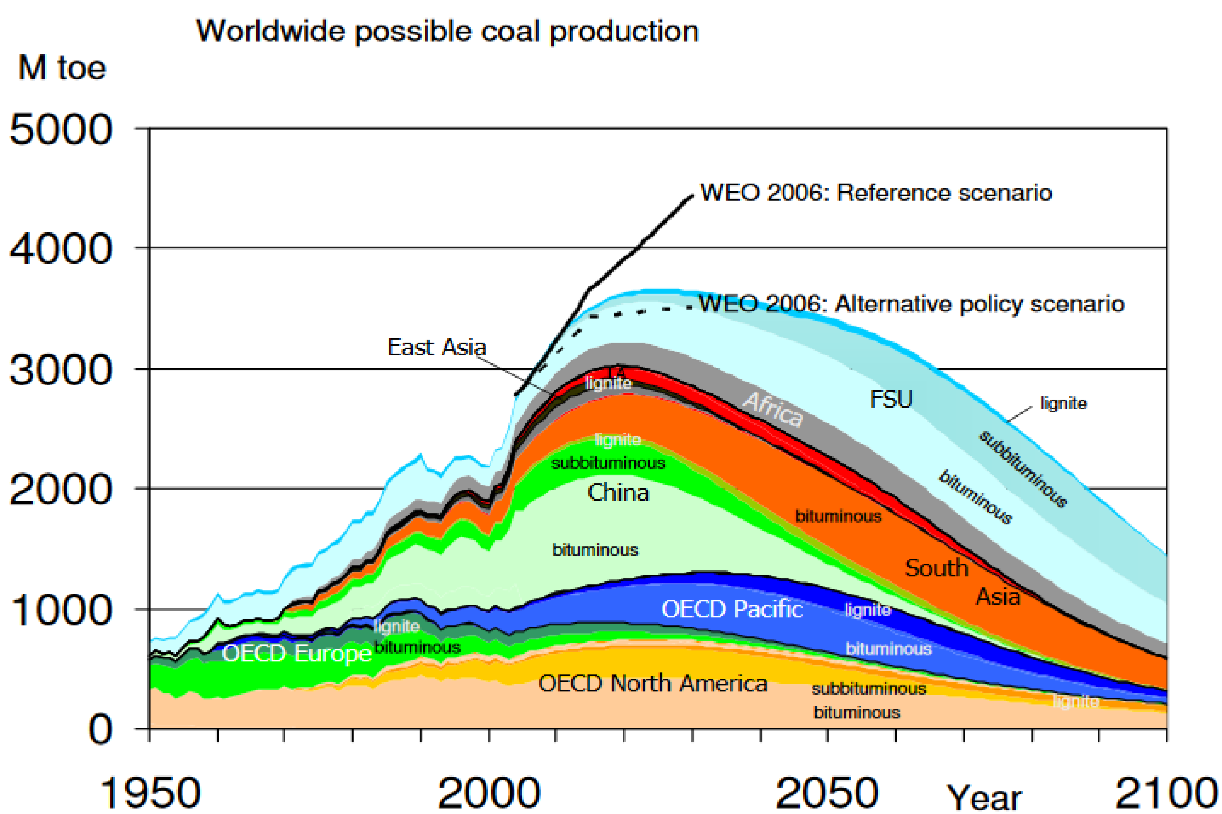
4 www.oildecline.com
5 NGPL: Natural Gas Plant Liquids, a byproduct of natural gas refining
6 http://www.manicore.com/fichiers/Australian_Govt_Oil_supply_trends.pdf page 379
7 http://oilprice.com/Energy/Crude-Oil/Chinas-Oil-Industry-Is-Faltering-Production-Falls-5.html
8 http://www.postcarbon.org/press/hughes-quoted-on-falling-shale-production-at-ami-newswire/

Coal depletion

"When discussing the future availability of fossil energy resources, conventional knowledge has it that globally there is an abundance of coal which allows for increasing coal consumption far into the future. This is either regarded as being a good thing as coal can be a possible substitute for the declining crude oil and natural gas supplies or it is seen as a horror scenario leading to catastrophic consequences for the world's climate. But the discussion rarely focuses on the premise: how much coal is there really?"[9]

"The following figure provides a summary of past and future world coal production in energy terms based on a detailed country-by-country analysis. This analysis reveals that global coal production may still increase over the next 10 to 15 years [as of 2007] by about 30 percent, mainly driven by Australia, China, the Former Soviet Union countries (Russia, Ukraine, Kazakhstan) and South Africa. Production will then reach a plateau and will eventually decline thereafter. "[10]

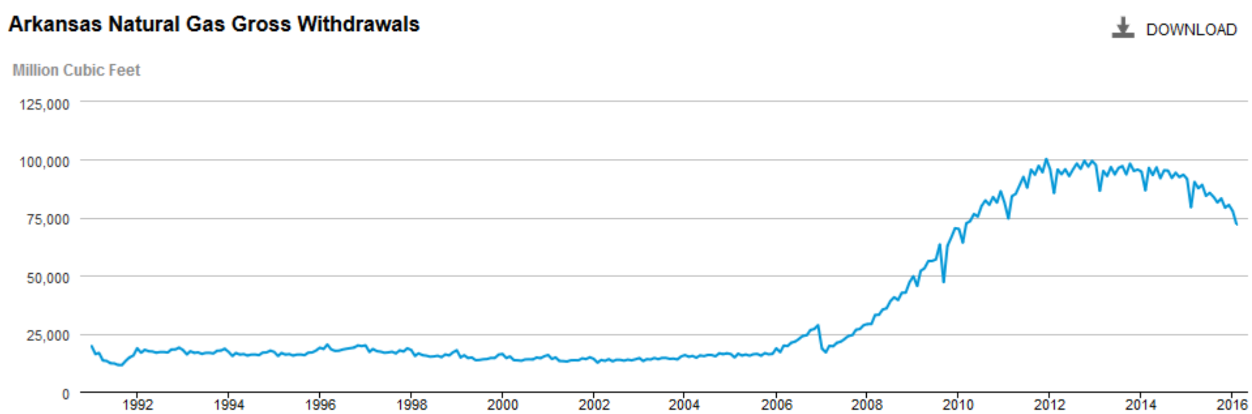


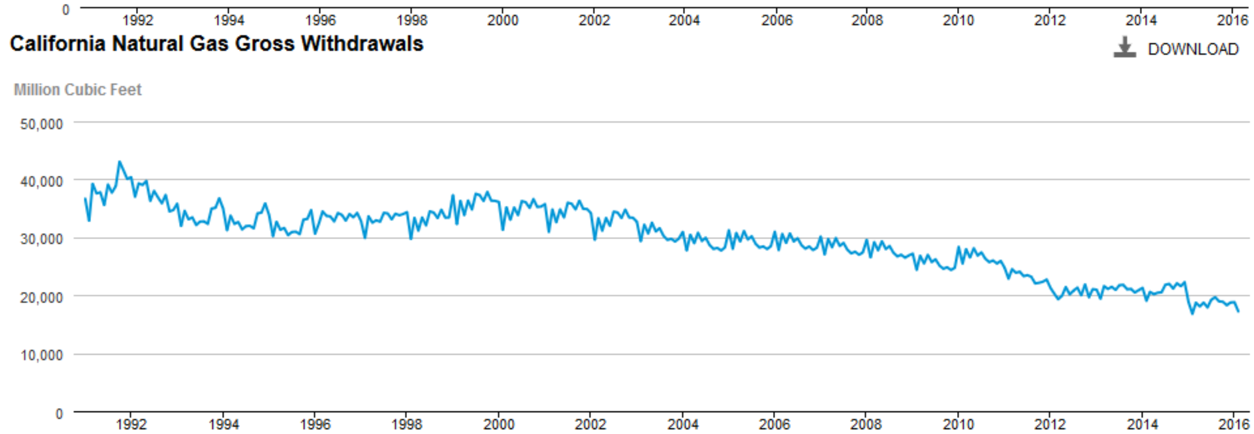
[9] http://energywatchgroup.org/wp-content/uploads/2014/02/EWG_Report_Coal_10-07-2007ms1.pdf page 4
[10] http://energywatchgroup.org/wp-content/uploads/2014/02/EWG_Report_Coal_10-07-2007ms1.pdf page 7

Natural Gas depletion

Fracking is a temporary respite, the best plays are depleting quickly. A very detailed analysis was performed to determine if "the EIA's expectation of long-term domestic oil abundance is founded. ... The analysis shows that U.S. tight oil production cannot be maintained at the levels assumed by the EIA beyond 2020. The top two plays, which account for more than 60% of production, are likely to peak by 2017 and the remaining plays will make up considerably less of future production than has been forecast by the EIA. Rather than a peak in 2021 followed by a gradual decline to slightly below today's levels by 2040, U.S. tight oil is likely to peak before 2020 and decline to a small fraction of today's production levels by 2040. The analysis also underscores the amount of drilling, the amount of capital investment, and the associated scale of environmental and community impacts that will be required to meet these projections. These findings call into question plans for crude oil exports and highlight the real risks to long-term U.S. energy security."[11]

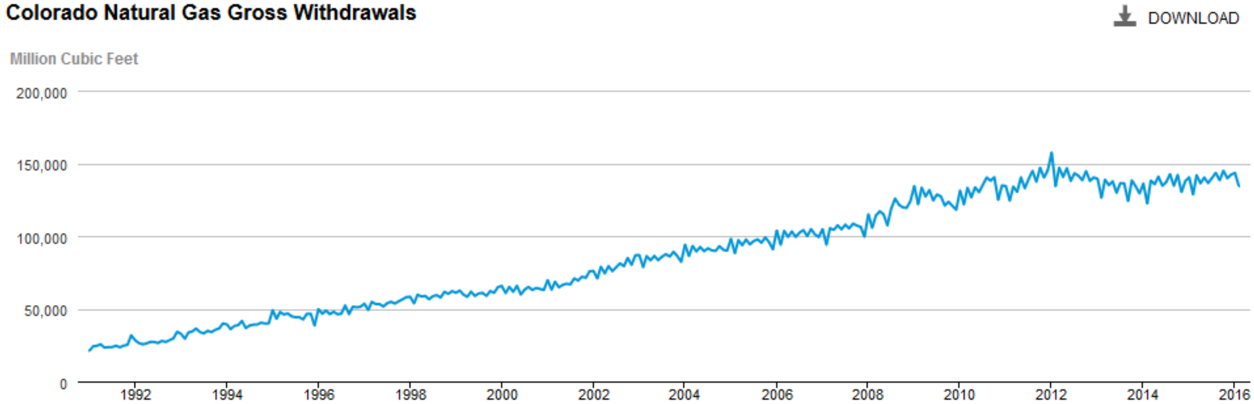
The following charts are historical data from www.eia.gov and are actual production figures.[12]



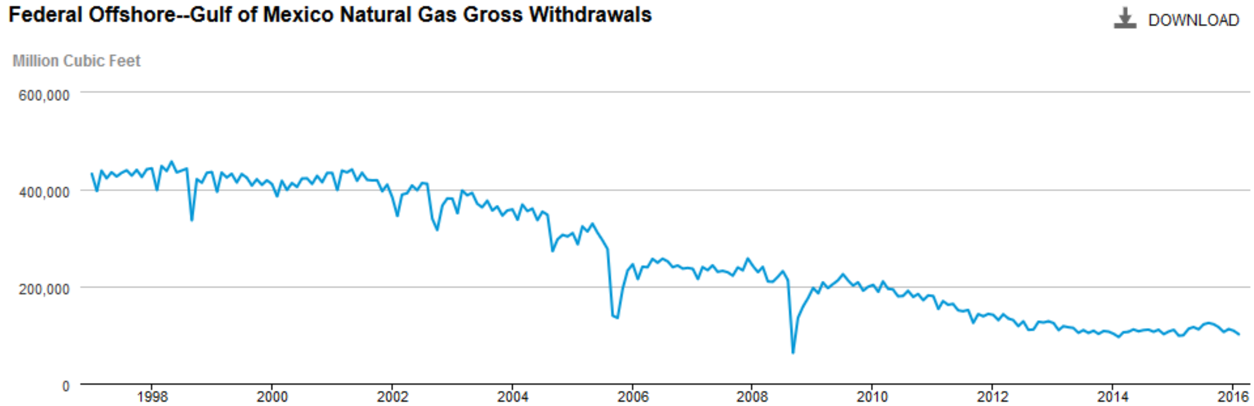


[11] http://www.postcarbon.org/wp-content/uploads/2014/10/Drilling-Deeper_FULL.pdf page 25
[12] http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_r98_m.htm After selecting Area, Monthly then click View History 1991-2016.

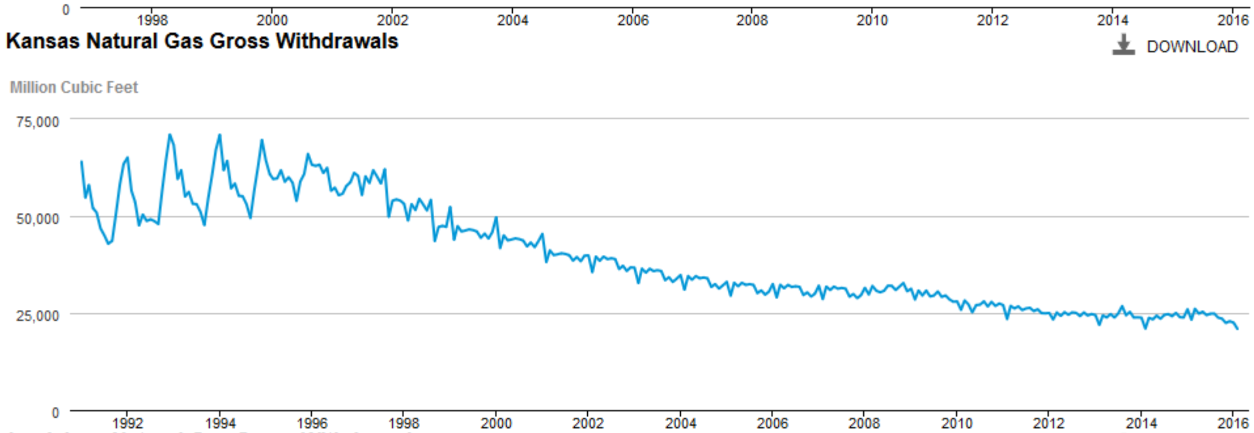
Colorado Natural Gas Gross Withdrawals



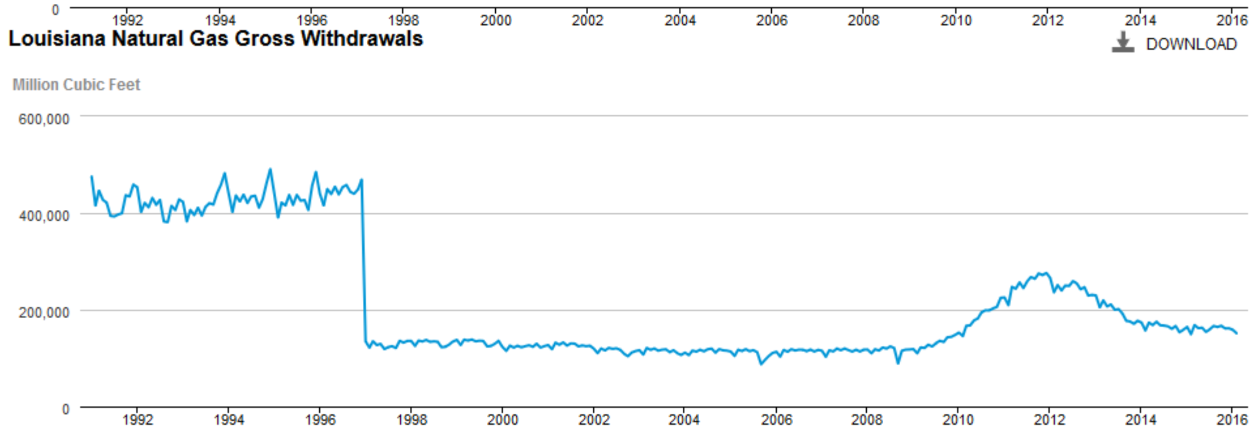
Federal Offshore--Gulf of Mexico Natural Gas Gross Withdrawals



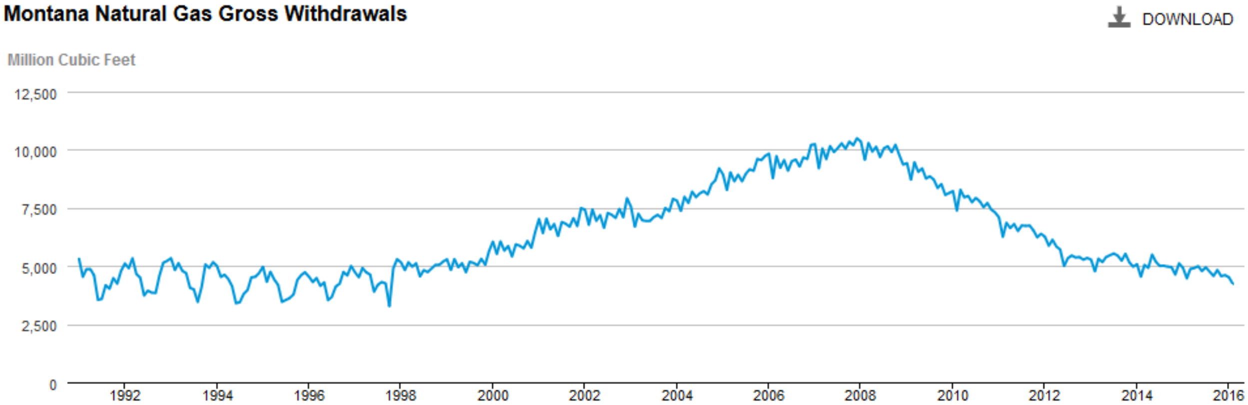
Kansas Natural Gas Gross Withdrawals



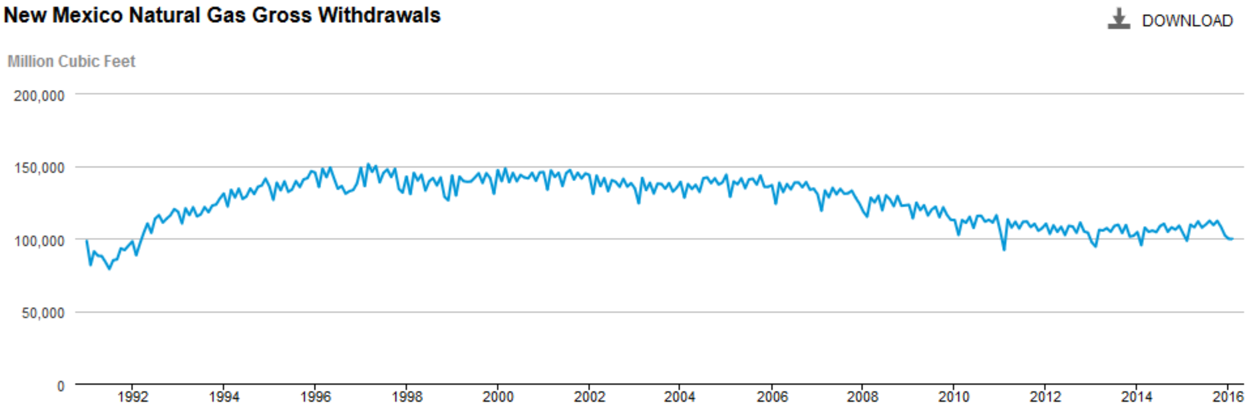
Louisiana Natural Gas Gross Withdrawals



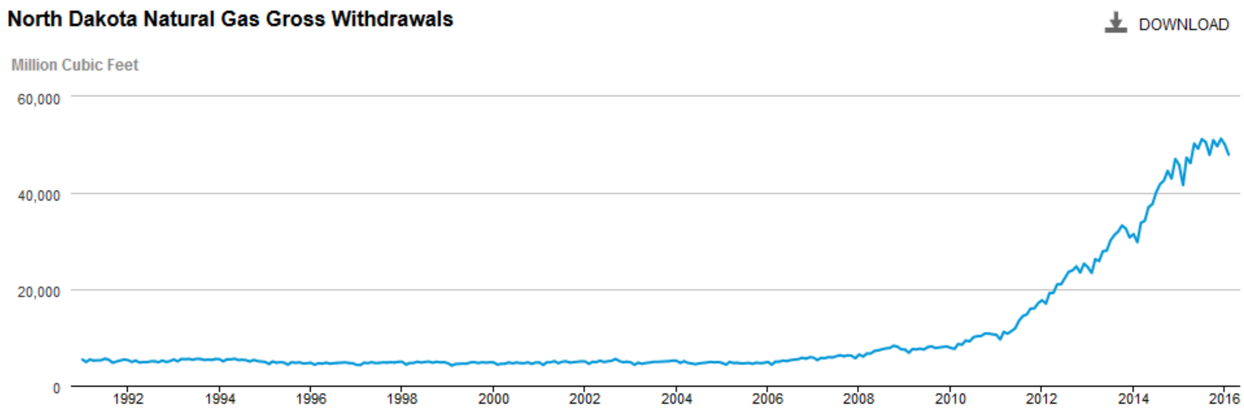
Montana Natural Gas Gross Withdrawals



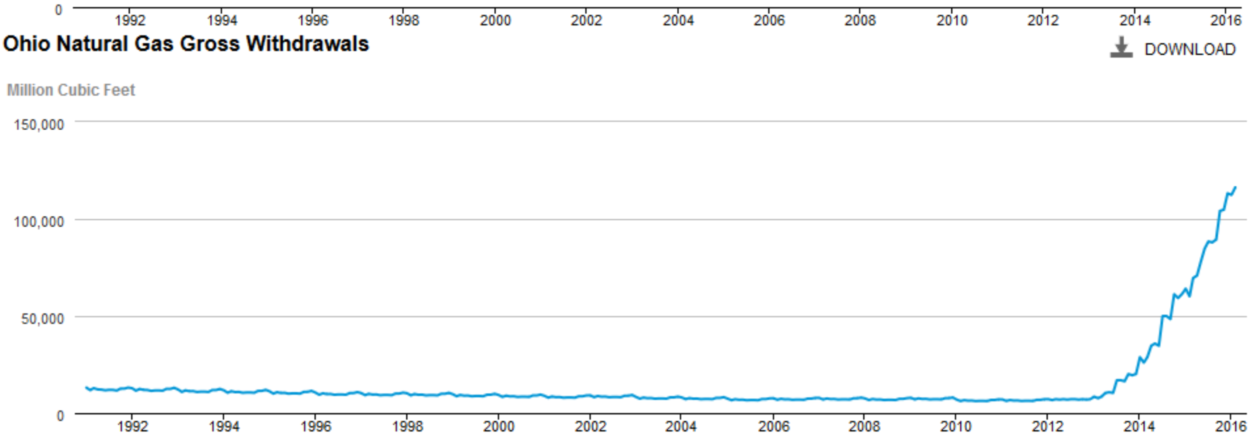
New Mexico Natural Gas Gross Withdrawals

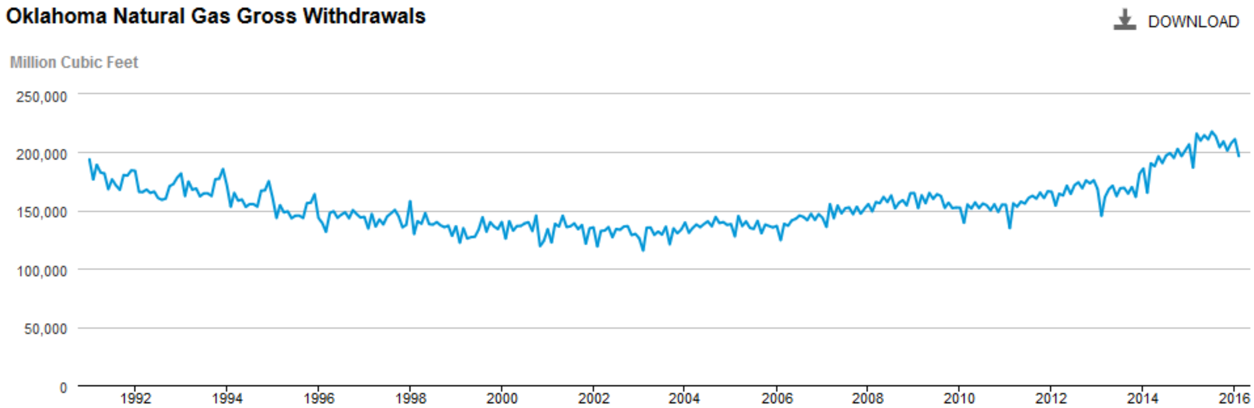


North Dakota Natural Gas Gross Withdrawals



Ohio Natural Gas Gross Withdrawals




Oklahoma Natural Gas Gross Withdrawals
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Million Cubic Feet
250,000
200,000
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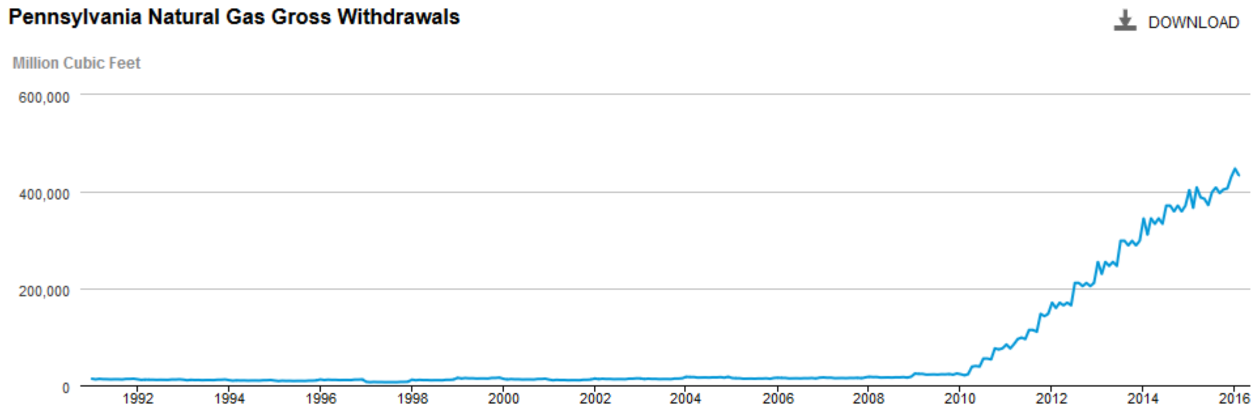
Pennsylvania Natural Gas Gross Withdrawals
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Million Cubic Feet
600,000
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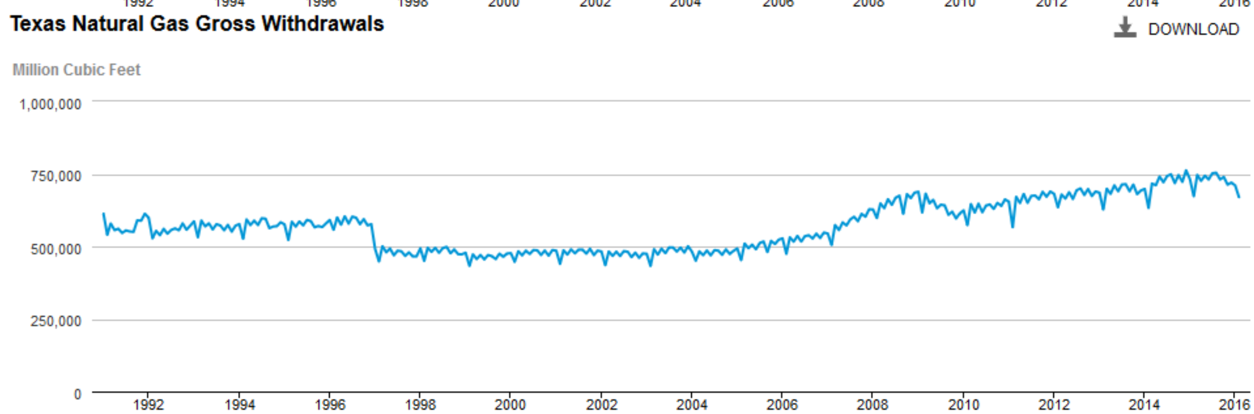
Texas Natural Gas Gross Withdrawals
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Million Cubic Feet
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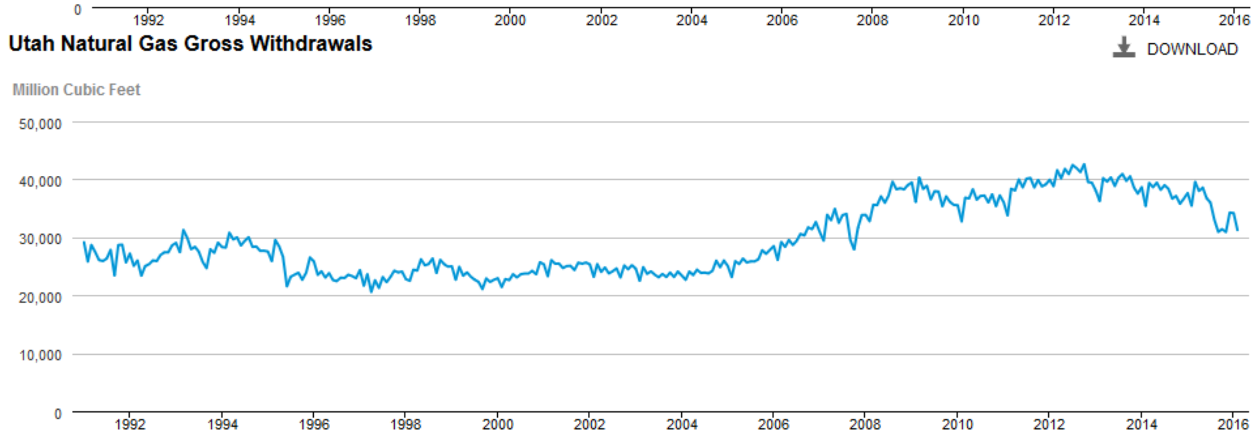
Utah Natural Gas Gross Withdrawals
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Million Cubic Feet
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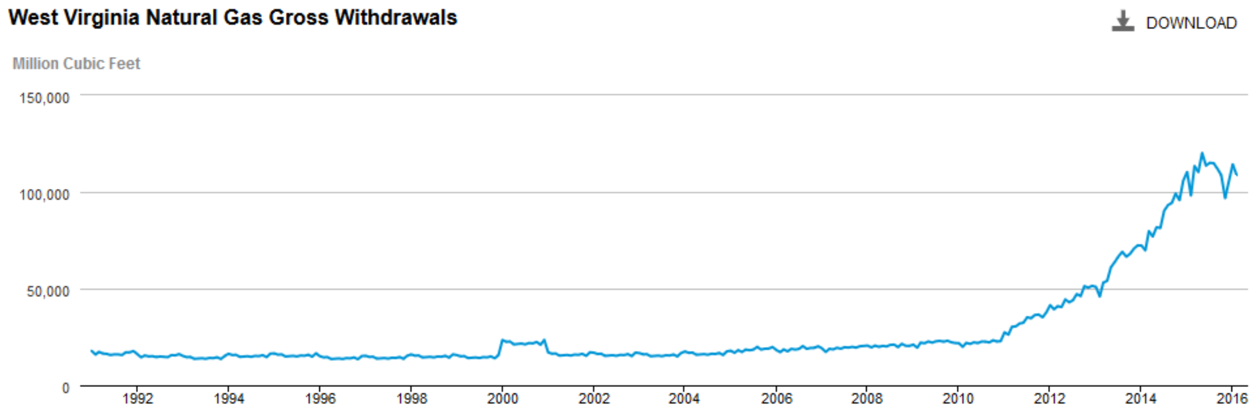
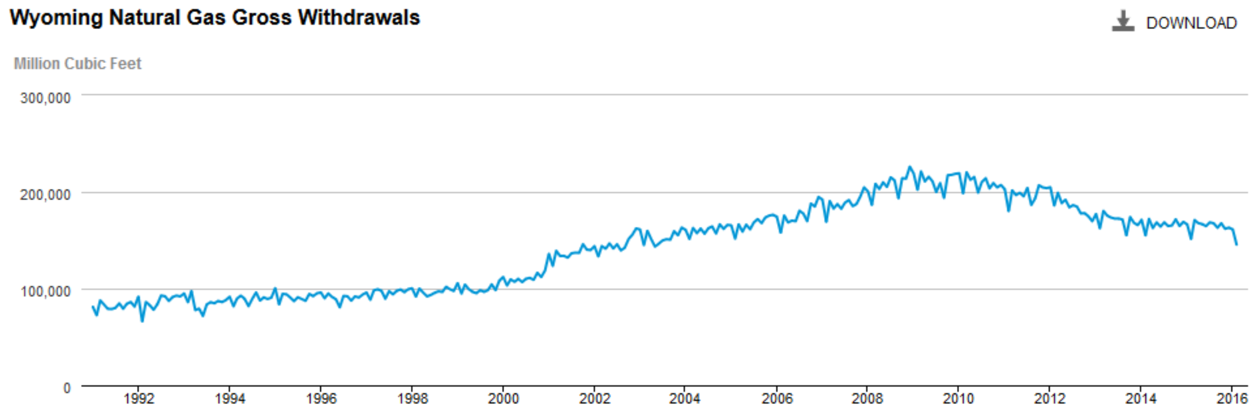
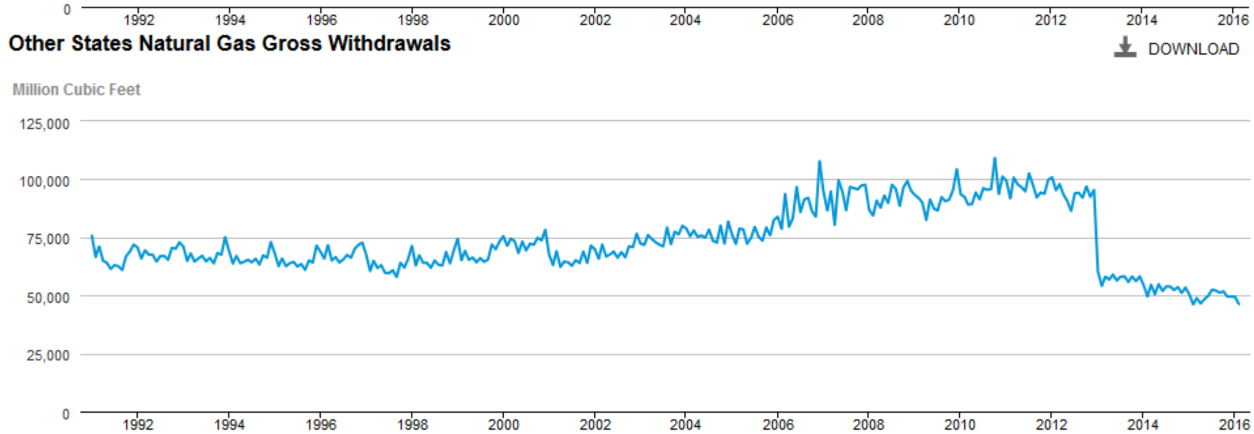






Many states are obviously beyond peak. Only Colorado, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas and West Virginia show any promise.

"Drilling Deeper reviews the twelve shale plays that account for 82% of the tight oil production and 88% of the shale gas production in the U.S. Department of Energy's Energy Information Administration (EIA) reference case forecasts through 2040. It utilizes all available production data for the plays analyzed, and assesses historical production, well-and field-decline rates, available drilling locations, and well-quality trends for each play, as well as counties within plays. Projections of future production rates are then made based on forecast drilling rates (and, by implication, capital expenditures). Tight oil (shale oil) and shale gas production is found to be unsustainable in the medium- and longer-term at the rates forecast by the EIA, which are extremely optimistic. ...

Over the short term, U.S. production of both shale gas and tight oil is projected to be robust—but a thorough review of production data from the major plays indicates that this will not be sustainable in the long term. These findings have clear implications for medium and long term supply, and hence current domestic and foreign policy discussions, which generally assume decades of U.S. oil and gas abundance."[13]

Pennsylvania (the Marcellus play) appears one of the most promising due to the volume and current production curve. It is forecast to peak in 2018 or 2019.[14]

[13] http://www.postcarbon.org/wp-content/uploads/2014/10/Drilling-Deeper_FULL.pdf page 4
[14] http://www.postcarbon.org/wp-content/uploads/2014/10/Drilling-Deeper_FULL.pdf page 286

Summary:

"Figure 3-115 illustrates the sum of shale gas production from the plays analyzed in this report through 2040 in the "Most Likely" drilling rate scenario, along with the number of wells required to achieve it. Production from these plays peaks in 2016 at nearly 34 Bcf/d and declines to below 16 Bcf/d by 2040, or more than 50%. Total production over the 2000 to 2040 period is projected to be 291.7 trillion cubic feet. The Marcellus will make up 55% of production from these plays in 2040. Approximately 130,000 additional wells will need to be drilled by 2040 to meet the projections in Figure 3-115, on top of the 50,000 wells drilled in these plays through 2013. Assuming an average well cost of $7 million, this would require $910 billion of additional capital input by 2040, not including leasing, operating, and other ancillary costs.

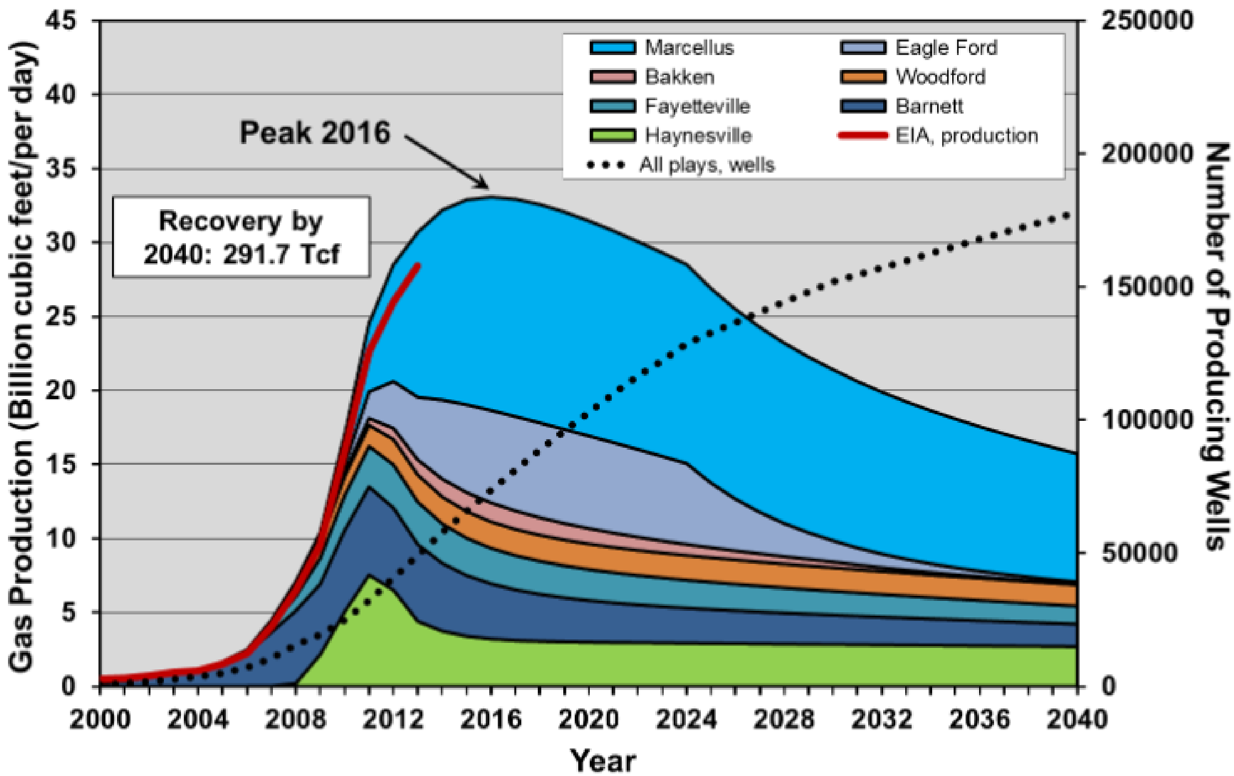


Figure 3-115. "Most Likely Rate" scenarios for the seven shale gas plays analyzed in this report and number of producing wells, through 2040.

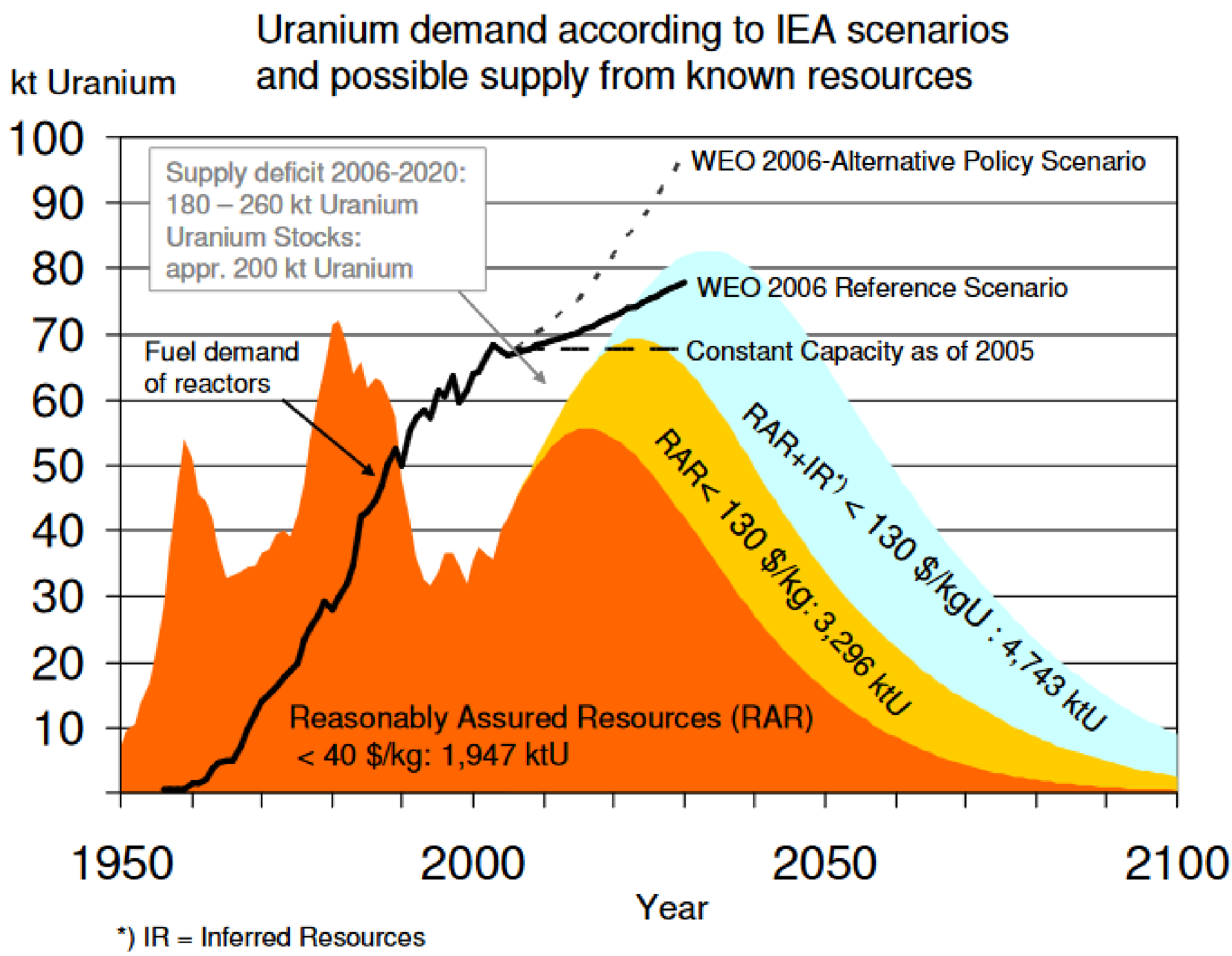
The "Most Likely Rate" scenario projections here are made on a "raw gas" basis. 180,000 wells will be producing by 2040 in this scenario. Also shown is the EIA's production data for dry gas through August 2014 for these plays."[15]

[15] http://www.postcarbon.org/wp-content/uploads/2014/10/Drilling-Deeper_FULL.pdf page 306

Uranium depletion

"Any forecast of the development of nuclear power in the next 25 years has to concentrate on two aspects, the supply of uranium and the addition of new reactor capacity. At least within this time frame, neither nuclear breeding reactors nor thorium reactors will play a significant role because of the long lead times for their development and market penetration. The analysis of data on uranium resources leads to the assessment that discovered reserves are not sufficient to guarantee the uranium supply for more than thirty years."[16]

Fukushima Daichi, Chernobyl, and Three Mile Island have really illustrated the dangers of nuclear power. Coupled with a super solar storm or EMP attack, it could be extremely deadly.



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[16] http://energywatchgroup.org/wp-content/uploads/2014/02/EWG_Report_Uranium_3-12-2006ms1.pdf page 4
[17] http://energywatchgroup.org/wp-content/uploads/2014/02/EWG_Report_Uranium_3-12-2006ms1.pdf page 5

Major Solar Storm or EMP Attack and the Resultant Geomagnetic Disturbance

"Well-known physicist Michio Kaku and other members of the American Physical Society asked Congress to appropriate $100 million to harden the country's electrical grid against solar flares. As shown below, such an event is actually the *most likely* Armageddon-type event faced by humanity.

Congress refused.

Kaku explains that a solar flare like the one that hit the U.S. in 1859 would – in the current era of nuclear power and electric refrigeration – cause widespread destruction and chaos.

Not only could such a flare bring on *hundreds* of Fukushima-type accidents, but it could well cause food riots globally.

Kaku explains that relief came in for people hit by disasters like Katrina or Sandy from the "outside". But a large solar flare could knock out a lot of the power nationwide. So – as people's food spoils due to lack of refrigeration – emergency workers from other areas would be too preoccupied with their own local crisis to help. There would, in short, be no "cavalry" to the rescue in much of the country.

In fact, NASA scientists are predicting that a solar storm will knock out most of the electrical power grid in many countries worldwide, perhaps for months. See this[18], this[19], this[20], this[21] and this[22].

News Corp Australia noted in February:

A 2009 study by the National Academy of Sciences warned that a massive geomagnetic assault on satellites and interconnected power grids could result in a blackout from which the nation may need **four to ten years** to recover.

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In May 2012, a US Geological Survey report estimated a 6 percent chance of another Carrington event[23] occurring in the next decade.

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[18] http://www.sfgate.com/news/article/Huge-solar-storms-could-zap-Earth-scientists-2502767.php
[19] http://www.foxnews.com/story/2009/01/09/powerful-solar-storm-could-shut-down-us-for-months.html
[20] http://www.foxnews.com/story/2009/05/28/scientists-us-not-prepared-for-strong-solar-storm.html
[21] http://www.empcommission.org/
[22] http://www.thespacereview.com/article/1553/1

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But we do not know whether or not the Carrington event was as bad as sun storms get.

[University of Kansas physicist Adrian] Melott proposed that material from a solar megaflare **10 times the strength of the Carrington** kind bombarded this planet around the year 775."[24]

" There are nearly 450 nuclear reactors in the world, with hundreds more being planned or under construction…. Imagine what havoc it would wreak on our civilization and the planet's ecosystems i**f we were to suddenly witness not just one or two nuclear meltdowns, but 400 or more**! How likely is it that our world might experience an event that could ultimately cause **hundreds of reactors to fail and melt down at approximately the same time**? I venture to say that, unless we take significant protective measures, **this apocalyptic scenario is not only possible, but probable**.

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In the past 152 years, Earth has been struck by roughly 100 solar storms, causing significant geomagnetic disturbances (GMD), two of which were powerful enough to rank as "extreme GMDs." If an extreme GMD of such magnitude were to occur today, in all likelihood, it would initiate a chain of events leading to c**atastrophic failures at the vast majority of our world's nuclear reactors, similar to but over 100 times worse than, the disasters at both Chernobyl and Fukushima**.

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The good news is that **relatively affordable equipment and processes could be installed to protect critical components in the electric power grid and its nuclear reactors, thereby averting this "end-of-the-world-as-we-know-it" scenario**. The bad news is that even though panels of scientists and engineers have studied the problem, and the bipartisan Congressional electromagnetic pulse (EMP) commission has presented a list of specific recommendations to Congress, **our leaders have yet to approve and implement any significant preventative measures**.

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Unfortunately, the world's nuclear power plants, as they are currently designed, are critically dependent upon maintaining connection to a functioning electrical grid, for all but relatively short periods of electrical blackouts, in order to keep their reactor cores continuously cooled so as to avoid catastrophic reactor core meltdowns and fires in storage ponds for spent fuel rods.

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[23] [referring to the solar flare of 1859 (http://en.wikipedia.org/wiki/Solar_storm_of_1859) which was so strong that telegraph lines, towers and stations caught on fire at a number of locations around the world, and sparks showered from telegraph machines]

[24] http://www.globalresearch.ca/an-inexpensive-fix-to-prevent-armageddon/5377338

If an extreme GMD were to cause widespread grid collapse (which it most certainly will), in as little as one or two hours after each nuclear reactor facility's backup generators either fail to start, or run out of fuel, the reactor cores will start to melt down. After a few days without electricity to run the cooling system pumps, the water bath covering the spent fuel rods stored in "spent-fuel ponds" will boil away, allowing the stored fuel rods to melt down and burn. Since the Nuclear Regulatory Commission (NRC) currently mandates that only one week's supply of backup generator fuel needs to be stored at each reactor site, it is likely that, after we witness the spectacular nighttime celestial light show from the next extreme GMD, we will have about one week in which to prepare ourselves for Armageddon.

To do nothing is to behave like ostriches with our heads in the sand, blindly believing that "everything will be okay" as our world drifts towards the next natural, inevitable super solar storm and resultant extreme GMD. Such a storm would **end the industrialized world as we know it, creating almost incalculable suffering, death and environmental destruction** on a scale not seen since the extinction of the dinosaurs some 65 million years ago.

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The federal government recently sponsored a detailed scientific study to better understand how much critical components of our national electrical power grid might be affected by either a naturally occurring GMD or a man-made EMP. Under the auspices of the EMP Commission and the Federal Emergency Management Agency (FEMA), and reviewed in depth by the Oak Ridge National Laboratory and the National Academy of Sciences, Metatech Corporation undertook extensive modeling and analysis of the potential effects of extreme geomagnetic storms on the US electrical power grid. Based upon a storm as intense as the 1921 storm, Metatech estimated that within the United States, induced voltage and current spikes, combined with harmonic anomalies, would severely damage or destroy over 350 EHV power transformers critical to the functioning of the US grid and possibly impact **well over 2000 EHV transformers worldwide**.

EHV transformers are made to order and custom-designed for each installation, each weighing as much as 300 tons and costing well over $1 million. Given that there is currently a three-year waiting list for a single EHV transformer (due to recent demand from China and India, lead times grew from one to three years), and that the total global manufacturing capacity is roughly 100 EHV transformers per year when the world's manufacturing centers are functioning properly, you can begin to grasp the implications of widespread transformer losses.

The loss of thousands of EHV transformers worldwide would cause a catastrophic grid collapse across much of the industrialized world. **It will take years, at best, for the industrialized world to put itself back together after such an event, especially considering the fact that most of the manufacturing centers that make this equipment will also be grappling with widespread grid failure**.

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In the event of an extreme GMD-induced long-term grid collapse covering much of the globe, if just half of the world's spent fuel ponds were to boil off their water and become radioactive, zirconium-fed infernos, the ensuing contamination could far exceed the cumulative effect of 400 Chernobyls.

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The Congressionally mandated EMP Commission has studied the threat of both EMP [i.e. an electromagnetic pulse set off by terrorists or adversaries in war] and extreme GMD events and made recommendations to the US Congress to implement protective devices and procedures to ensure the survival of the grid and other critical infrastructures in either event. John Kappenman, author of the Metatech study, estimates that **it would cost about $1 billion to build special protective devices into the US grid to protect its EHV transformers from EMP or extreme GMD damage and to build stores of critical replacement parts should some of these items be damaged or destroyed**. Kappenman estimates that it would cost significantly less than $1 billion to store at least a year's worth of diesel fuel for backup generators at each US nuclear facility and to store sets of critical spare parts, such as backup generators, inside EMP-hardened steel containers to be available for quick change-out in the event that any of these items were damaged by an EMP or GMD.

For the cost of a single B-2 bomber or a tiny fraction of the Troubled Asset Relief Program (TARP) bank bailout, we could invest in preventative measures to avert what might well become the end of life as we know it. There is no way to protect against all possible effects from an extreme GMD or an EMP attack, but we could implement measures to protect against the worst effects. Since 2008, **Congress has narrowly failed to pass legislation** that would implement at least some of the EMP Commission's recommendations."[25]

From the Congressional EMP Commission report:

"EMP is capable of causing catastrophe for the nation.

The high-altitude nuclear weapon-generated electromagnetic pulse (EMP) is one of a small number of threats that has the potential to hold our society seriously at risk and might result in defeat of our military forces.

The damage level could be sufficient to be catastrophic to the Nation, and our current vulnerability invites attack. Briefly, a single nuclear weapon exploded at high altitude above the United States will interact with the Earth's atmosphere, ionosphere, and magnetic field to produce an electromagnetic pulse (EMP) radiating down to the Earth and additionally create electrical currents in the Earth. EMP effects are both direct and indirect. The former are due to electromagnetic "shocking" of electronics and stressing of electrical systems, and the latter arise from the damage that "shocked"—

[25] http://www.globalresearch.ca/an-inexpensive-fix-to-prevent-armageddon/5377338

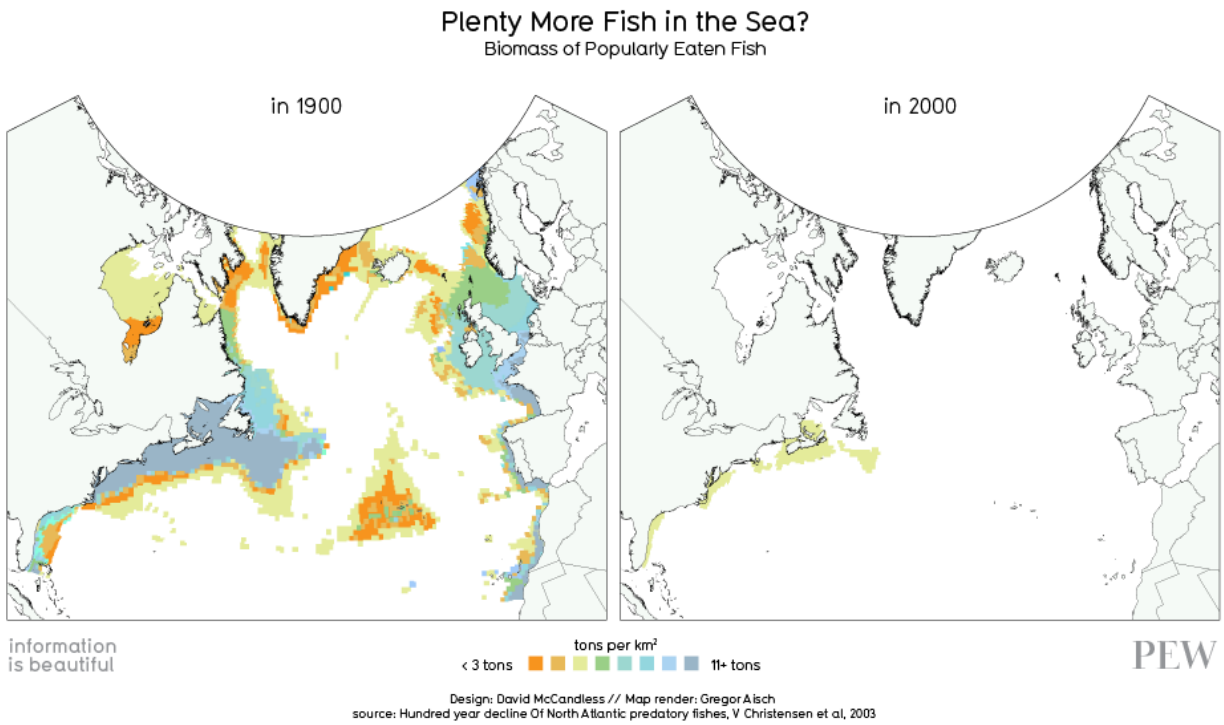
upset, damaged, and destroyed—electronics controls then inflict on the systems in which they are embedded. The indirect effects can be even more severe than the direct effects.

The electromagnetic fields produced by weapons designed and deployed with the intent to produce EMP have a high likelihood of damaging electrical power systems, electronics, and information systems upon which American society depends. Their effects on dependent systems and infrastructures could be sufficient to qualify as catastrophic to the Nation.

Depending on the specific characteristics of the attacks, unprecedented cascading failures of our major infrastructures could result. In that event, a regional or national recovery would be long and difficult and would seriously degrade the safety and overall viability of our Nation. The primary avenues for catastrophic damage to the Nation are through our electric power infrastructure and thence into our telecommunications, energy, and other infrastructures. These, in turn, can seriously impact other important aspects of our Nation's life, including the financial system; means of getting food, water, and medical care to the citizenry; trade; and production of goods and services. The recovery of any one of the key national infrastructures is dependent on the recovery of others. The longer the outage, the more problematic and uncertain the recovery will be. It is possible for the functional outages to become mutually reinforcing until at some point the degradation of infrastructure could have irreversible effects on the country's ability to support its population. "[26]

[26] http://www.empcommission.org/docs/empc_exec_rpt.pdf page 1

Fisheries depletion/collapse



[27]

According to the U.N Food and Agriculture Organization, 85 percent of global fish stocks are "overexploited, depleted or recovering from depletion."

"Commercial overexploitation of the world's fish stocks is severe," UN Secretary General Ban Ki-moon said back in 2012[28]. "Many species have been hunted to fractions of their original populations. More than half of global fisheries are exhausted, and a further third are depleted."

According to the UN Food and Agriculture Organization, 85 percent of global fish stocks are "overexploited, depleted, or recovering from depletion."

Yet despite these alarms having been sounded loud and clear, life in the oceans is continuing to deteriorate at an ominously rapid pace.

Total Collapse?

Fisheries for the most sought-after species of fish have already collapsed.

[27] http://www.businessinsider.com/weve-eaten-all-the-fish-in-the-sea-2011-6
[28] http://www.un.org/sg/STATEMENTS/index.asp?nid=6067

The populations of all large predator fish in the oceans have declined by 90 percent in the 50 years since modern industrial fishing became widespread around the world, according to a shocking paper by scientists with Dalhousie University in Halifax, Canada, published in Nature in 2003.

Three years after the paper's publication, the same scientists, along with colleagues from across the world, published an even more startling paper that predicted **a total collapse of all fish that are currently caught commercially by 2048**.

Many scientists, like Daniel Pauly of the University of British Columbia, have estimated that the total fish catch for the planet peaked back in the mid-1980s, and has been declining ever since.

This also impacts the phytoplankton and zooplankton in the ocean due to trophic cascades.

Phytoplankton decline:

"The microscopic plants that form the foundation of the ocean's food web are declining, reports a study published July 29 in *Nature*.

The tiny organisms, known as phytoplankton, also gobble up carbon dioxide to produce half the world's oxygen output—equaling that of trees and plants on land.

But their numbers have dwindled since the dawn of the 20th century, with unknown consequences for ocean ecosystems and the planet's carbon cycle."[29]

Zooplankton decline:

"Experts on invertebrates have expressed "profound shock" over a government report showing a decline in zooplankton of more than 70% since the 1960s."[30]

Coral reefs decline:

"The degradation of reefs will also have significant economic impact due to declining fisheries and increased coastal storm damage. *Acropora* species (elkhorn and staghorn coral) have been the dominant reef builders in the Caribbean and in Florida over the past 500,000 years. However, since the 1980s, *Acropora* species have declined by 97% due to global warming, disease, increasing hurricane impact, and direct human damage."[31]

[29] http://www.scientificamerican.com/article/phytoplankton-population/
[30] http://news.bbc.co.uk/2/hi/uk_news/scotland/highlands_and_islands/7499834.stm
[31] https://earthscience.arc.nasa.gov/sge/coral-health/research/index.html

Deforestation

"Trees have helped to create both our soils and atmosphere. The first by mechanical (root pressure) and chemical (humic acid) breakdown of rock, adding life processes as humus and myriad decomposers. The second by gaseous exchange, establishing and maintaining an oxygenated atmosphere and an active water-vapor cycle essential to life.

The composition of the atmosphere is the result of reactive processes, and forests may be doing about 80% of the work, with the rest due to oceanic or aquatic exchange. Many cities, and most deforested areas such as Greece, no longer produce the oxygen they use."[32]

"Felling of the forests causes rivers to dry up, swamps to evaporate, shallow water to dry out, and drought to grip the land. All this can occur in the lifetime of a person."[33]

"Let us now be clear about how trees affect total precipitation. The case taken is where winds blow inland from an ocean or large lake.

1. The water in the air is that evaporated from the surface of the sea or lake. It contains a few salt particles but is "clean". A small proportion may fall as rain (15-20%), but most of this water is CONDENSED out of clear night air or fogs by the cool surfaces of leaves (80-85%). Of this condensate, 15% evaporates by day and 50% is transpired. The rest enters the groundwater. Thus, *trees are responsible for more water in streams than the rainfall alone provides.*

2. Of the rain that falls, 25% again re-evaporates from crown leaves, and 50% is transpired. This moisture is added to clouds, which are now at least 50% "*tree water*". These clouds travel on inland to rain again. Thus trees may double or multiply *rainfall* itself by this process, which can be repeated many times over extensive forested plains or foothills.

3. As the air rises inland, the precipitation and condensation increases, and moss forests plus standing clouds may form in mountains, adding considerably to total precipitation and infiltration to the lower slopes and streams.

4. Whenever winds pass over tree lines or forest edges of 12m (40 feet) or more in height Ekman spirals develop, adding 40% or so to rainfall in bands which roughly parallel the tree lines.

5. Within the forest, 40% of the incident air mass may enter and either lose water or be rehumidified.

6. And, in every case, rain is more likely to fall as a result or organic particles forming nuclei for condensation, whereas industrial aerosols are too small to cause rain and instead produce dry, cloudy conditions.

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[32] Permaculture - A Designers Manual page 142
[33] Permaculture - A Designers Manual page 144

Thus, if we clear the forest, what is left but dust?"[34]

What is the state of worldwide deforestation? If a picture is worth a thousand words, the following satellite views from Google Earth are worth 9,000 words.

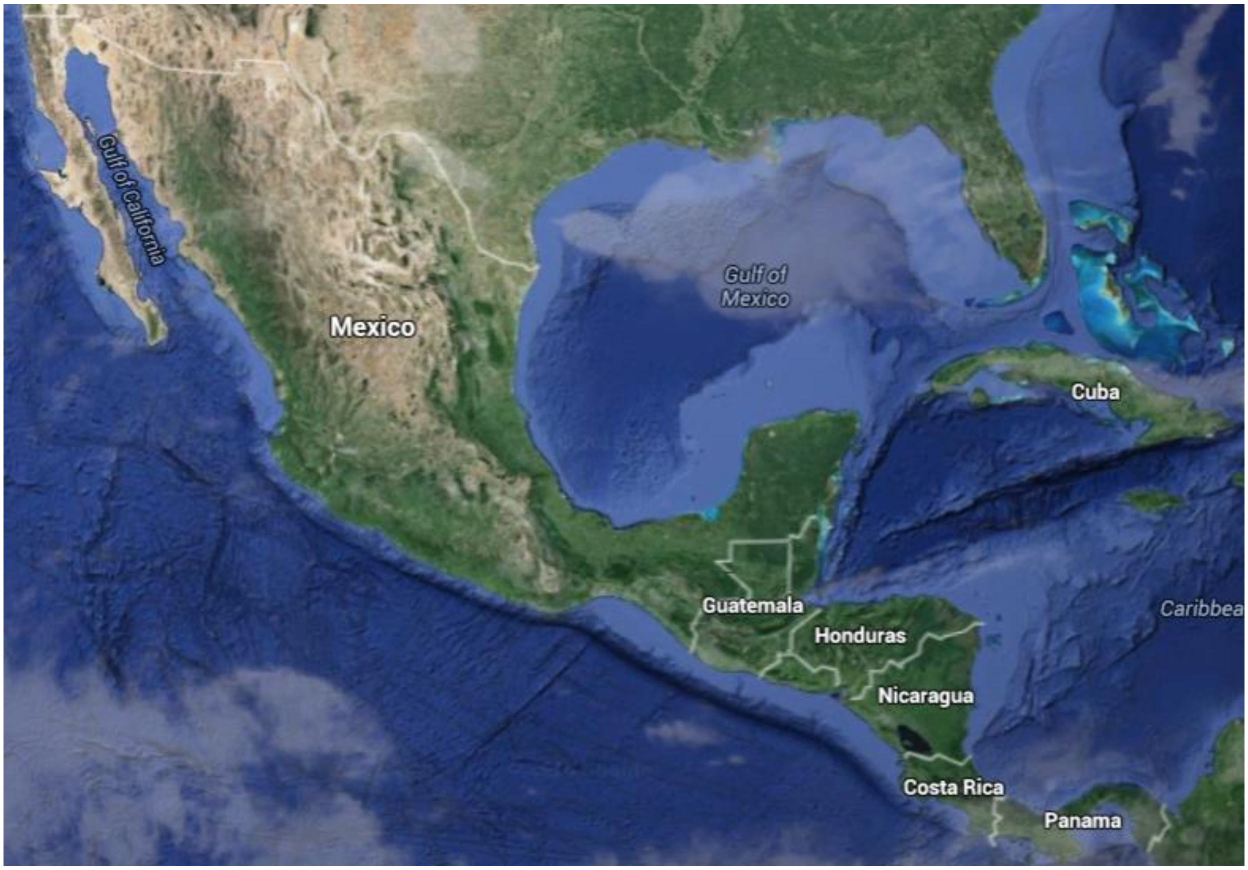
First let's look at the United States.

35

Only the dark green portions are forested significantly, and zooming in with Google Earth shows you the degree of deforestation. Much of the drought affected regions of the country have the worst deforestation, not coincidentally.

Central America and the Caribbean? Haiti, for example, has already cleared all but a fraction of a percent of its original forest, 99.2% to be exact.

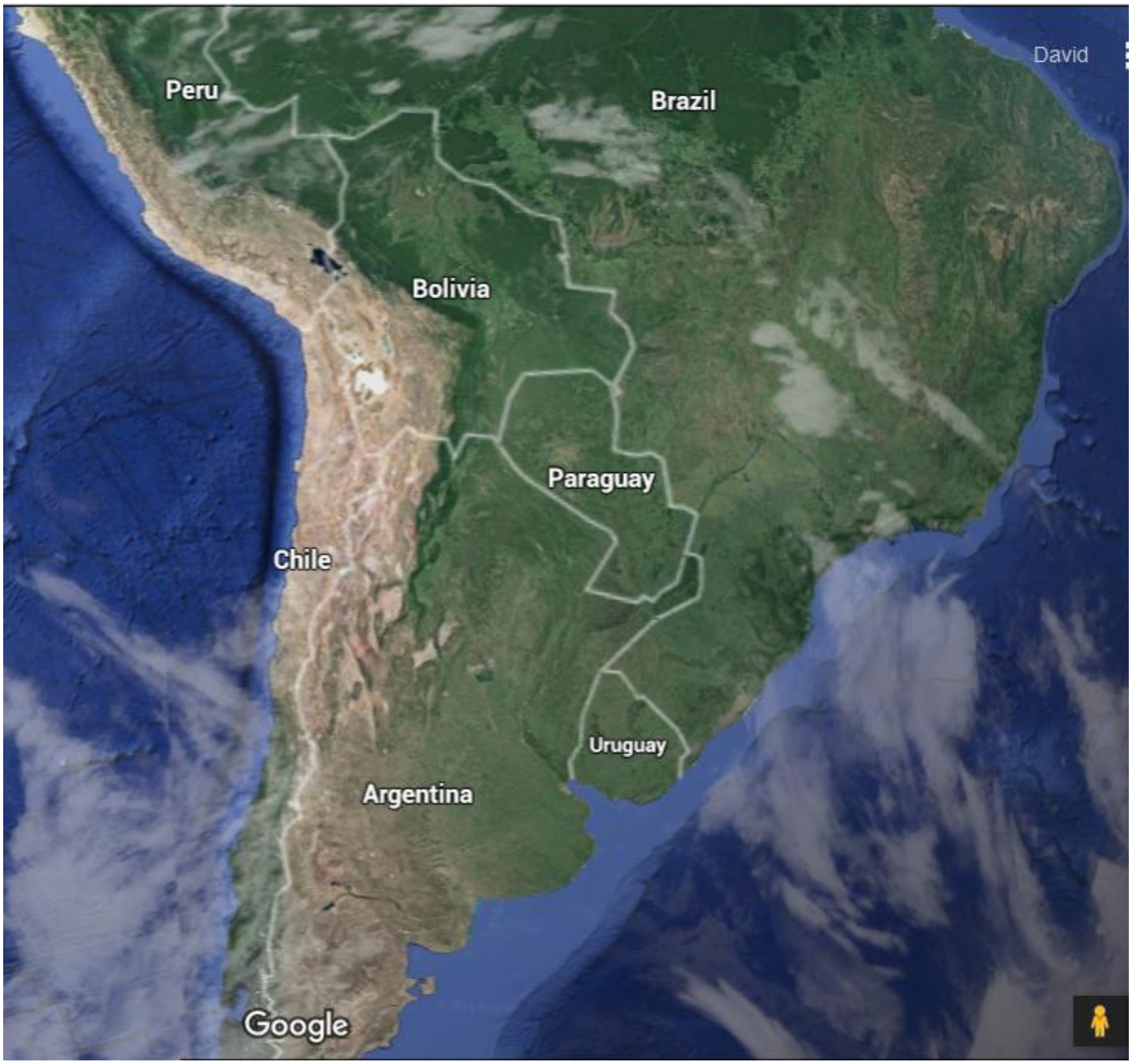
[34] Permaculture - A Designers Manual page 150
[35] www.google.com/maps



Very little dark green patches of forests remain. How about South America? The Amazon is being deforested at a slower rate than in the mid 1990's, but "more than 580,000 square kilometers (224,000 square miles) of Amazon forest has [been] destroyed in Brazil since 1980. ... Farmers typically use fire for clearing land and every year satellite images pick up tens of thousands of fires burning across the Amazon. The deforestation process usually starts with logging of high value trees, which are sold to local dealers or used by the farmer for construction. Understory shrubbery is then cleared and remaining trees are cut. The area is left to dry for a few months and then burned. The land is planted with crops like bananas, palms, manioc, maize, or rice. After a year or two, the productivity of the soil declines, and the farmer may move on to new forest areas for more short-term agriculture. The old, now infertile, fields are often used for small-scale cattle grazing or left for waste. ... In 1987 during a four-month period (July-October), about 19,300 square miles (50,000 sq. km[, more than twice the area of New Jersey]) of Brazilian Amazon were burned in the states of Parà, Rondonia, Mato Grosso, and Acre. The burning produced carbon dioxide containing more than 500 million tons of carbon, 44 million tons of carbon monoxide, and millions of tons of other particles and nitrogen oxides. An estimated 20 percent of fires that burn between June and October cause new deforestation, while another 10 percent is the burning of ground cover in virgin forests.

Fires and climate change are having a dramatic impact on the Amazon. Recent studies suggest that the Amazon rainforest may be losing its ability to stay green all year long as forest degradation and drought make it dangerously flammable. Scientists say that as much as 50 percent of the Amazon could go up in smoke should fires continue. Humidity levels were the lowest ever recorded in the Amazon in 2005."[36] Perfect recipe for desertification and climate change. It's called *rain*forest for a reason.

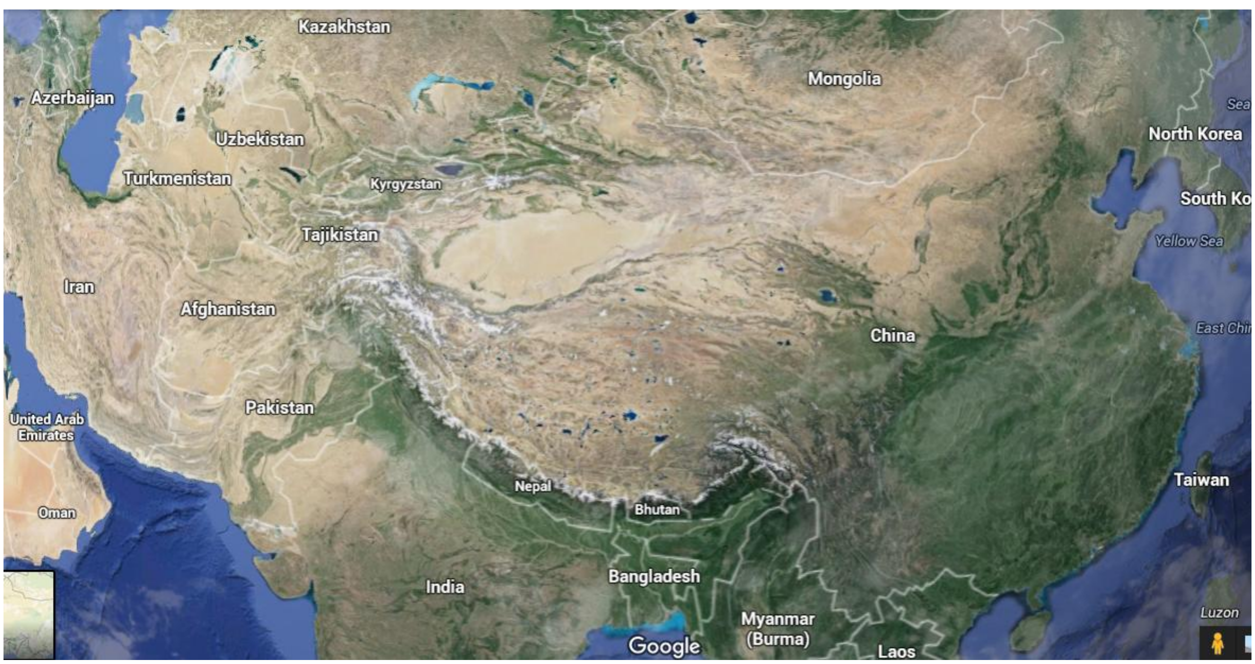
Paraguay, Uruguay, Chile, and Argentina are already almost completely deforested.



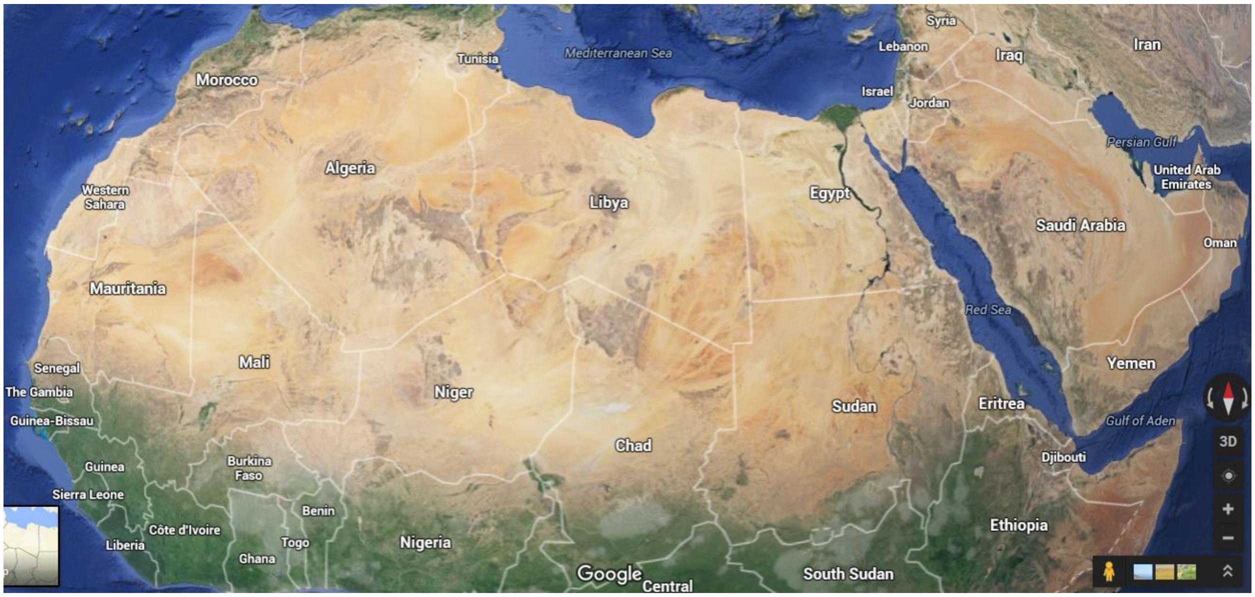
[36] https://www.mongabay.com/brazil.html

Southern Europe has very little dark green forested territory. Some in eastern France, southwestern Germany, the southwest corner of Ukraine, some of Romania. Almost none of the UK and Ireland, Portugal, Spain, Moldova, Czech Republic, Netherlands, Belgium, Italy, and Greece.

Worse yet are Asia:



Africa:



The only significant forests are in Cameroon, Equatorial Guinea, Gabon, northern Republic of the Congo and Democratic Republic of the Congo.

Southern Africa is almost completely deforested. Large portions of Namibia, Botswana, and South Africa are desert or undergoing desertification. Madagascar has been referred to as a "moonscape."

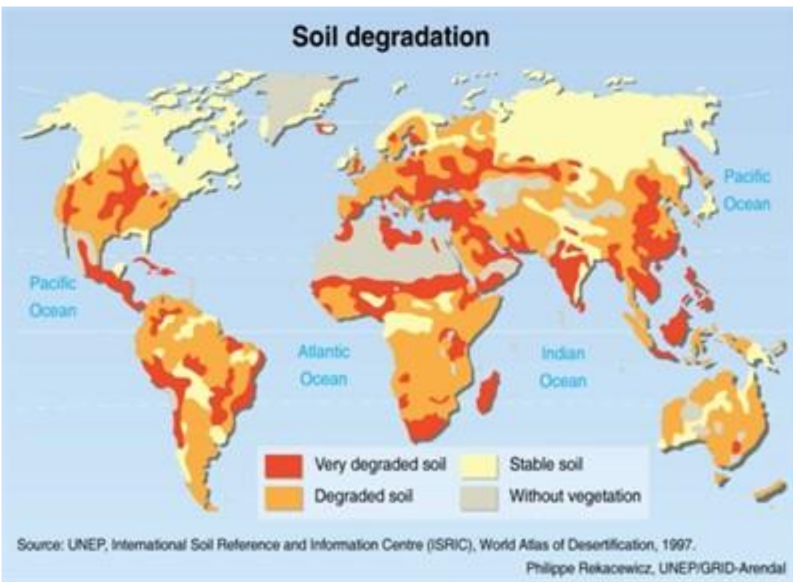
And Australia.

Soil Loss and depletion

The previous section on deforestation and the Google Maps satellite views illustrates perfectly the state of soil loss and depletion in areas that are either desert or undergoing desertification. What about the light green areas?

"[Between 1954 and 1994] nearly one-third of the world's cropland (1.5 billion hectares) has been abandoned because of soil erosion and degradation."[37]

"From the Dust Bowl of the 1930s to the barren moonscapes of today's Haiti and Madagascar, history is littered with evidence that what nature has provided, unwise practices and policies can rapidly squander."[38]



"A 2008 report entitled "Global soil degradation"[39] estimated that land degradation (about 2 billion hectares of land worldwide) affects **38% of the world's cropland and has reduced water and nutrient availability** (quality and access). For perspective, that represents about 15 per cent of the Earth's land area (an area larger than the United States and Mexico combined) that has been degraded through human activities."[40]

"Because of soil depletion, crops grown decades ago were much richer in vitamins and minerals than the varieties most of us get today."[41] Note that all crops grown with glyphosate (the active ingredient in Roundup® herbicide) are mineral deficient compared with crops grown without it due to glyphosate being an excellent mineral chelator. It is patented for that capability and that's how it kills weeds.

[37] David Pimentel and Mario Giampietro, *Food, Land, Population and the U.S. Economy*, Nov. 1994
[38] http://www.ewg.org/losingground/report/executive-summary/3.html
[39] http://www.grida.no/graphicslib/detail/global-soil-degradation_9aa7
[40] http://www.fewresources.org/soil-science-and-society-were-running-out-of-dirt.html
[41] http://www.scientificamerican.com/article/soil-depletion-and-nutrition-loss/

Nitrogen/Phosphorus fertilizer depletion

Fertilizer has three main ingredients, Nitrogen, Phosphorus, and Potassium. The nitrogen is obtained using the Haber (also called the Haber-Bosch) process. "The Haber process now produces 450 million tons (440,000,000 long tons; 500,000,000 short tons) of nitrogen fertilizer per year, mostly in the form of anhydrous ammonia, ammonium nitrate, and urea. 3–5% of the world's natural gas production is consumed in the Haber process (around 1–2% of the world's annual energy supply).[15][16][17][18] In combination with pesticides, these fertilizers have quadrupled the productivity of agricultural land:

With average crop yields remaining at the 1900 level the crop harvest in the year 2000 would have required nearly four times more land and the cultivated area would have claimed nearly half of all ice-free continents, rather than under 15% of the total land area that is required today.[19]

Due to its dramatic impact on the human ability to grow food, the Haber process served as the "detonator of the population explosion", enabling the global population to increase from 1.6 billion in 1900 to today's 7 billion.[20] Nearly 80% of the nitrogen found in human tissues originated from the Haber-Bosch process.[21]"[42]

The impending peak and decline of natural gas will impact nitrogen fertilizer production.

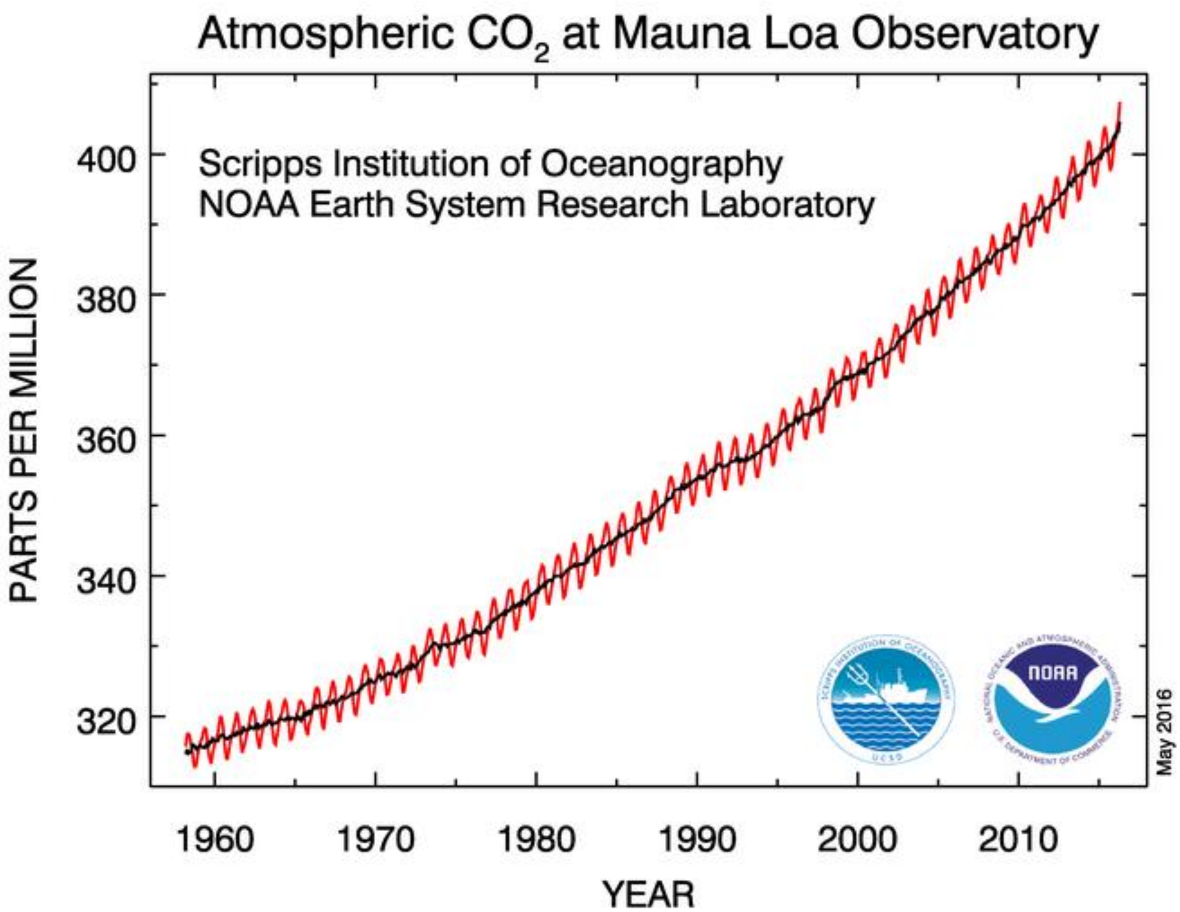
Of phosphorus and potassium, phosphorous is the more immediate concern: "Some experts predict that the high-grade reserves of phosphorus will be depleted anywhere from 50 to 100 years and peak phosphorus could occur as soon as 2030."[43]

"Global phosphorus production most likely peaked in 1989. If global phosphorus production has not yet peaked, it will likely do so by 2033."[44]

[42] https://en.wikipedia.org/wiki/Haber_process
[43] http://www.fool.com/investing/general/2014/02/23/should-we-be-concerned-about-peak-phosphorus.aspx
[44] http://www.global.ucsb.edu/climateproject/publications/pdf/Morrigan_2010_Energy_CC4.pdf page 137

Climate Change

The most prevalent opinion (and propaganda) is that climate change is only a function of fossil fuel burning. This is not totally accurate. CO_2 content of the atmosphere undergoes seasonal variation. During the winter it rises and during the growing season it lowers as photosynthesis absorbs it.



[45]

The upward trend is quite likely mainly a function of the reduced photosynthesis capacity of the Earth due to deforestation, desertification, soil loss and depletion causing a shortfall in the summer reduction matching or exceeding the winter increase. Soil fertility is determined by measuring the organic (carbon) content. As the soil and vegetation carbon content goes down, atmospheric and oceanic carbon content goes up and photosynthetic capacity goes down. Climate change is also a factor of carbon-cycle disruption and water-cycle disruption caused by mankind. Deforestation has a direct

[45] http://www.esrl.noaa.gov/gmd/ccgg/trends/full.html

impact on rain patterns as well as quantity (see Deforestation section and references[46]). "Even if emissions stop, carbon dioxide could warm Earth for centuries"[47]

> "NASA recently released data[48] showing that the planet has just seen seven straight months of not just record-breaking, but record-*shattering* heat. It is clear, through the space agency's data, that this year we are already well on track to see what will likely be the largest increase in global temperature a single year has ever seen.
>
> The NASA data also show that April was the hottest April ever recorded, as well as the fact that it crushed the previous April record by the largest margin of increase ever recorded.
>
> That makes it three months in a row[49] that the monthly record has been broken, and easily at that, by the largest margin ever. When record-smashing months started in February[50], it was then that scientists began talking about a "climate emergency," and since then our situation has only escalated."[51]

[46] Permaculture: A Designers Manual pages 142-150
[47] https://www.princeton.edu/main/news/archive/S38/51/51I69/index.xml?section=topstories
[48] http://data.giss.nasa.gov/gistemp/graphs_v3/
[49] http://www.theguardian.com/environment/2016/apr/15/march-temperature-smashes-100-year-global-record
[50] https://www.theguardian.com/science/2016/mar/14/february-breaks-global-temperature-records-by-shocking-amount
[51] http://www.truth-out.org/news/item/36133-atmospheric-carbon-dioxide-concentration-has-passed-the-point-of-no-return

Summary

“We are in a crisis in the evolution of human society. It's unique to both human and geologic history. It has never happened before and it can't possibly happen again. You can only use oil once. You can only use metals once. Soon all the oil is going to be burned and all the metals mined and scattered.”

– M. King Hubbert, geophysicist and energy advisor Shell Oil Company and USGS, 1983

These challenges all have a 100% probability of happening. They are not theoretical, they are factual. What lies in our immediate future is the most "interesting time" in human history. We have never had a global civilization with this population before. We've never faced global fossil fuels peaking and declining before. We've never faced planet-wide fisheries decline and collapse before. We've never faced global deforestation to this scale before. We've never faced almost one third of the world's arable land having to be abandoned due to soil loss and depletion and more being abandoned each year before. We've never faced all these at once, before now. Unfortunately these situations are real and they are now or in the *very* near future.

These are not problems we can fix by "doing more". You can't get more resources by drilling, mining, or fishing more if the resource isn't there anymore. The interactions between the problems makes them even more difficult to solve. What if the solution to one problem requires resources that are in decline?

What will happen if we continue along the Business As Usual path? Resource wars? Collapse? The Three Horsemen of the Apocalypse (disease, war, and famine)? The forecasts about what the carrying capacity of the Earth will be, after the Age of Oil has passed, vary widely but they are all dire.

"There does seem to be some fairly ominous handwriting on the wall. Homo sapiens have degraded the planet’s soil (half the earth’s topsoil has been lost in the past 50 years), heated its atmosphere past the tipping point (scientists say the melting polar ice caps are now irreversible), acidified its oceans (some ecologists predict saltwater fish will be gone by 2048), and ushered in the greatest mass extinction since dinosaurs were wiped out (environmental writer J. B. MacKinnon estimates humans have reduced the natural variety and abundance of life on the planet to one tenth of what it once was). This March, a NASA-funded team of mathematicians projected that unless humanity manages to employ drastic reductions to inequality and population growth in coming decades, the collapse of human civilization will be “difficult to avoid.”[52]

Where do we go from here?

[52] http://geezmagazine.org/magazine/article/preparing-for-a-beautiful-end/

Part II - Paths Ahead

Is it not already too late if one waits until one is thirsty to begin digging a well?
-- Chinese proverb

The Five Axioms of Sustainability

1. *Any society that continues to use critical resources unsustainably will collapse.*

2. Population growth and/or growth in the rates of consumption of resources cannot be sustained.

*3. To be sustainable, the use of **renewable** resources must proceed at a rate that is less than or equal to the rate of replenishment.*

*4. To be sustainable, the use of **non-renewable** resources must proceed at a rate that is declining, and the **rate of decline** must be greater than or equal to the **rate of depletion.***

*(The **rate of depletion** is defined as the amount being extracted and used during a specified time interval, usually a year, as a percentage of the amount left to extract.)*

5. Sustainability requires that substances introduced into the environment from human activities be minimized and rendered harmless to biosphere functions.

Overview

What do we want our planetary situation to look like in seven generations (140 years)? Our descendants will have very little fossil fuels left on the planet. Mankind will need our energy portfolio to be entirely based on renewable energy as that is the *only* way that will still work 2000 years from now. That energy will need to be produced in ways that are harmless or beneficial to biosphere functions.

Mankind's food will also need to be produced in ways that are harmless or beneficial to biosphere functions. Local production of food will aid in minimizing transportation fuel usage. We need to become smarter about how to lessen the fuel requirements of mankind.

Since almost all waste that isn't buried eventually runs downstream and ends up in the oceans, we will eventually need to harness methods to benignly harvest those, especially phosphorus, at industrial scale.

"Forces are converging very fast that make whether we choose to retain and enhance resilience, rather than just let it crumble, much more than just a philosophical discussion. It is no longer just a case of whether we should be questioning the forces of economic globalization because they are unjust, inequitable or a rapacious destroyer of environments and cultures. Instead it is about looking at the Achilles heel of economic globalization, one from which there is no protection other than resilience: its degree of oil dependency. The very notion of economic globalization was only made possible by cheap liquid fossil fuels, and there is no adequate substitute for those on the scale we use them. the move towards more localized energy-efficient and productive living arrangements is not a choice; it is an inevitable direction for humanity.

... the Transition movement is an attempt to design abundant pathways down from the oil peak, to generate new stories about what might be waiting for us at the end of our descent, and to put resilience-building back at the heart of any plans we make for the future.

Transition Initiatives are not the only response to peak oil and climate change; any coherent national response will also need government and business responses at all levels. However, unless we can create this sense of anticipation, elation and a collective call to adventure on a wider scale, any government responses will be doomed to failure, or will need to battle protractedly against the will of the people. Imagine if there were a way of creating that sense of positive engagement and new storytelling on a settlement-wide, even a nation-wide scale. ... The time for seeing globalization as an invincible and unassailable behemoth, or localization as some kind of lifestyle choice, is over. The end of the Age of Cheap Oil is rapidly coming upon us, and life will radically change, whether we want it to or not. This book represents a new way of looking at what our future might hold, arguing that by taking a proactive response rather than a reactive one, we can still shape and form that future, within the rapidly changing energy context, in such a way that it ends up preferable to the present."[53]

"If you don't know where you're going, you'll probably end up somewhere else." The Transition movement uses a technique called back-casting. Design the final destination, then the steps between from each direction (forward from the present and backwards from the destination future) become easier to plan.

The major issues boil down to reduced biomass (estimates are that mankind has 90% depleted the Earth's biomass) including forests and native grasslands and fish and wildlife depletion. What would a sustainable future Earth look like 140 years (seven generations) from now? It must be totally based on renewable energy and obey the Five Axioms of Sustainability and utilize currently available and proven or easily developed techniques and be more productive than now and beneficial to biosphere functions.

In no particular order:

- The world's grasslands are all rejuvenated and green with building soil depth and fertility using Holistic Management techniques (already proven, see below).
- Desertification has largely been reversed and the world's grasslands and forests have been restored to a great extent. Reforestation includes both sustainably managed forests and Permaculture designed food forests for improved yield and long-term health. World-wide use of firewood for cooking and heating has been replaced by ethanol, solar (both thermal and PV), and bio-gas.

[53] The Transition Handbook - From oil dependency to local resilience, pages 14,15

- The continental shelves are managed fisheries with improved habitat for fish and managed for greatly increased yields using Permaculture and Green Wave techniques (see below).
- Kelp and seaweed farms are extensive along the coasts, harvesting phosphorus and other valuable elements from the oceans to yield ethanol, methane (natural gas), and organic fertilizers at industrial scale (see below). AirCarbon® has replaced petroleum based plastics[54]. The increased photosynthetic capacity has cooled the surface of the ocean (by turning incoming solar energy into plant carbohydrates), possibly reducing El Niño but definitely having a positive impact on the dead zones that develop yearly off the coasts where rivers draining agricultural regions empty into the oceans.
- Permaculture belts in agricultural regions have increased yields while improving wildlife and pollinator habitat along pollinator and avian migration routes.
- Organic and Permaculture techniques have greatly increased soil depth and fertility building and eliminated soil loss and soil depletion. These techniques have also greatly improved the livelihoods of the world's small farmers and world-wide health.
- Bio-fuel production (both liquid and gaseous) has replaced and eclipsed fossil fuels and ramped up faster than fossil fuel production decreased. It is distributed relatively evenly world-wide, decreasing fuel transportation costs and geopolitical tensions and resource conflicts. Ethanol is made from a variety of non-food feedstocks.
- Farms utilizing aquaponics, Permaculture, and local ethanol production has greatly decreased pressure on wild fish stocks, allowing them to recover over the last century.
- Atmospheric CO_2 levels have returned to preindustrial levels and are stable.
- Wind and solar power with grid-scale storage (see below) have replaced fossil fueled electricity production. Intermittency is a non-issue due to storage capacity.
- The world's vehicle fleet runs on renewable biofuels and electricity. Diesel engines now run on ethanol with Cetane improvers[55] and a small amount of bio-diesel to improve lubrication characteristics of the fuel. Jet aircraft now run on ethanol. Corn ethanol is now a minor contributor to the world's supply. "Oxygenated alcohol fuels such as ethanol meet the emission reduction standards set by the CAAA. Ethanol is cleaner and cooler in use than avgas, prolongs engine life, delivers more power, and is likely to present a much cheaper option as supplies become more readily available."[56]

Permacultural Organic Farming

"Permaculture (**perm**anent agri**culture**) is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of landscape and people providing their food, energy,

[54] http://newlight.com/
[55] https://en.wikipedia.org/wiki/Cetane_Improver
[56] http://www.caddet-re.org/assets/no51.pdf

shelter, and other material and non-material needs in a sustainable way. Without permanent agriculture there is no possibility of a stable social order.

Permaculture design is a system of assembling conceptual, material, and strategic components in a pattern which functions to benefit life in all its forms.

The philosophy behind permaculture is one of working with, rather than against, nature; of protracted and thoughtful observation rather than protracted and thoughtless action; of looking at systems in all their functions, rather than asking only one yield of them; and of allowing systems to demonstrate their own evolutions."[57]

"... the end result of the adoption of permaculture strategies in *any* country or region will be to dramatically reduce the area of the agricultural environment needed by the households and the settlements of people, and to release much of the landscape for the sole use of wildlife and for re-occupation by endemic flora. Respect for all life forms is a basic, and in fact essential, ethic for all people."[58]

Permaculture designs have been used to change this 10 acre parcel of Jordan, in one of the driest parts of the planet, two kilometers from the Dead Sea:

to this:

[57] Permaculture: A Designers' Manual, pages ix-x
[58] Permaculture: A Designers' Manual, page 9 (of 576)

Search for "greening the desert" in YouTube.[59]

This next example is located at Wadi Rum in southwestern Jordan:

[59] https://www.youtube.com/watch?v=sohI6vnWZmk and https://www.youtube.com/watch?v=it4ru0HvrfE and https://www.youtube.com/watch?v=keQUqRg2qZ0
Keyline water systems video: https://www.youtube.com/watch?v=_X-BMbLBozA

Turning this "before" land:

Into this "after" permaculture oasis:

[60]

Three excellent books on Permaculture:

1. Introduction to Permaculture by Bill Mollison with Reny Mia Slay
2. Permaculture: Principles & Pathways Beyond Sustainability by David Holmgren
3. Permaculture: A Designers' Manual by Bill Mollison

A key feature of permaculture is that systems can be designed to be largely self-maintaining or not, depending on the goals of the designers.

"Green Wave - Imagine a vertical underwater garden: seaweed and mussels grow on floating ropes, stacked above oyster and clam cages below. Imagine a farm designed to restore rather than deplete our oceans.

- More Biodiversity, Higher Yields - By using the entire food column, our farm model has the capacity to grow 20 tons of sea vegetables and 500,000 shellfish on each acre per year.
- Zero Inputs - Since there is no need for fresh water, fertilizer, or pesticides, restorative ocean farming is the most sustainable form of food production on the planet.
- Food Security - As a food crop, seaweed is rich in nutrients such as protein, calcium, and vitamin-C. Recent studies demonstrate that a network of seaweed farms the size of Washington State could produce all of the dietary protein needs of the human population.
- Energy Security - According to the US Department of Energy, a network of farms totaling an area half the size of Maine could grow enough bio-fuel to replace all of the oil used in the US."[61]

[60] https://www.youtube.com/watch?v=ycLbO02lb7w
[61] http://greenwave.org/3d-ocean-farming/ and https://www.youtube.com/watch?v=j8ViaskDSeI

Holistic Management a la Allan Savory

Holistic Management, a Whole Farm/Ranch Planning System that addresses and improves environmental health, sustains economic viability, and enhances the quality of life of farm and ranch communities.[62] The following video frame is of land close to holistically managed land in Zimbabwe, just after four months of rain:

This is holistically managed land nearby on the same day, after the same rainfall:

[63]

[62] http://holisticmanagement.org/
[63] https://www.youtube.com/watch?v=vpTHi7O66pI

This was done by increasing the stocking rate of cattle and goats 400%, planning the grazing to mimic nature and integrate them with all the elephants, buffalo, giraffe, and other animals that we have. But before they began, their land looked like the relatively barren photo. The following site was bare and eroding for over 30 years, regardless of what rain it got.

After using livestock to mimic nature:

And another site where at the base of the marked tree, over 30 cm of soil had been lost:

And again the change, using livestock to mimic nature:

This land in Mexico was in terrible condition:

Allan had to mark this hill due to the change being so profound:

Case study of Brown's Ranch, ND: ... key components of his holistic plan. “Now we utilize dozens of different cash and cover crops along with high stock density grazing. We move our livestock daily. We’ve also added sheep, laying hens, broilers, turkeys and we make our land available to bee keepers,” says Gabe. By focusing on the regeneration of their resources, they have been able to eliminate the use of chemical fertilizer, pesticides and fungicides, all while seeing increasing yields. The county average corn yield where the Browns live is 100 bushels per acre yet their average yield is 127 bushels per acre which is achieved at a cost of only $1.42 per bushel. The average cost to produce a bushel of corn in the United States is over $5.00 per bushel. “It is much easier to make money in agriculture when you practice Holistic Management,” says Gabe. “In twelve years we went from facing a mountain of debt to having enough money to retire.” [64]

Allan Savory: "What we are doing globally is causing climate change as much as, I believe, fossil fuels and maybe more. But worse than that, it is causing hunger, poverty, violence, social breakdown and war. And as I am talking to you, millions of men, women, and children are suffering and dying. And if this continues, we are unlikely to be able to stop the climate changing, even after we have eliminated the use of fossil fuels. I believe I've shown you how we can work *with* nature, at *ver*y low cost, to reverse all this. We are already doing so on about 15 million hectares on five continents. And people who understand far more about carbon than I do calculate, for illustrative purposes, if we do what I'm showing you here, we can take enough carbon out of the atmosphere and safely store it in the grassland soils for thousands of years. And if we just do that on about half the world's grasslands, that I've shown you, we can take us back to pre-industrial levels, while feeding people. I can think of almost nothing that offers more hope for our planet, for your children, and their children, and all of humanity."[65]

Solar PV and Wind Energy Combined with Storage

Under power purchase agreements signed this year, developers will deliver power from large utility-scale solar plants will be selling at below the price of electricity from natural gas by 2021, according to a new report from Lawrence Berkeley National Laboratory. Between 2017 and 2040, the lifetime of the solar plants, the average levelized cost of power from these solar plants will come to $42.1 per megawatt hour, wrote Mark Bolinger and Joachim Seel, versus $48.1 for the cost of gas alone.[66]

Electricity generated by large wind farms is now cheap enough in many places around the world to compete effectively with electricity generated by coal and natural gas.[67]

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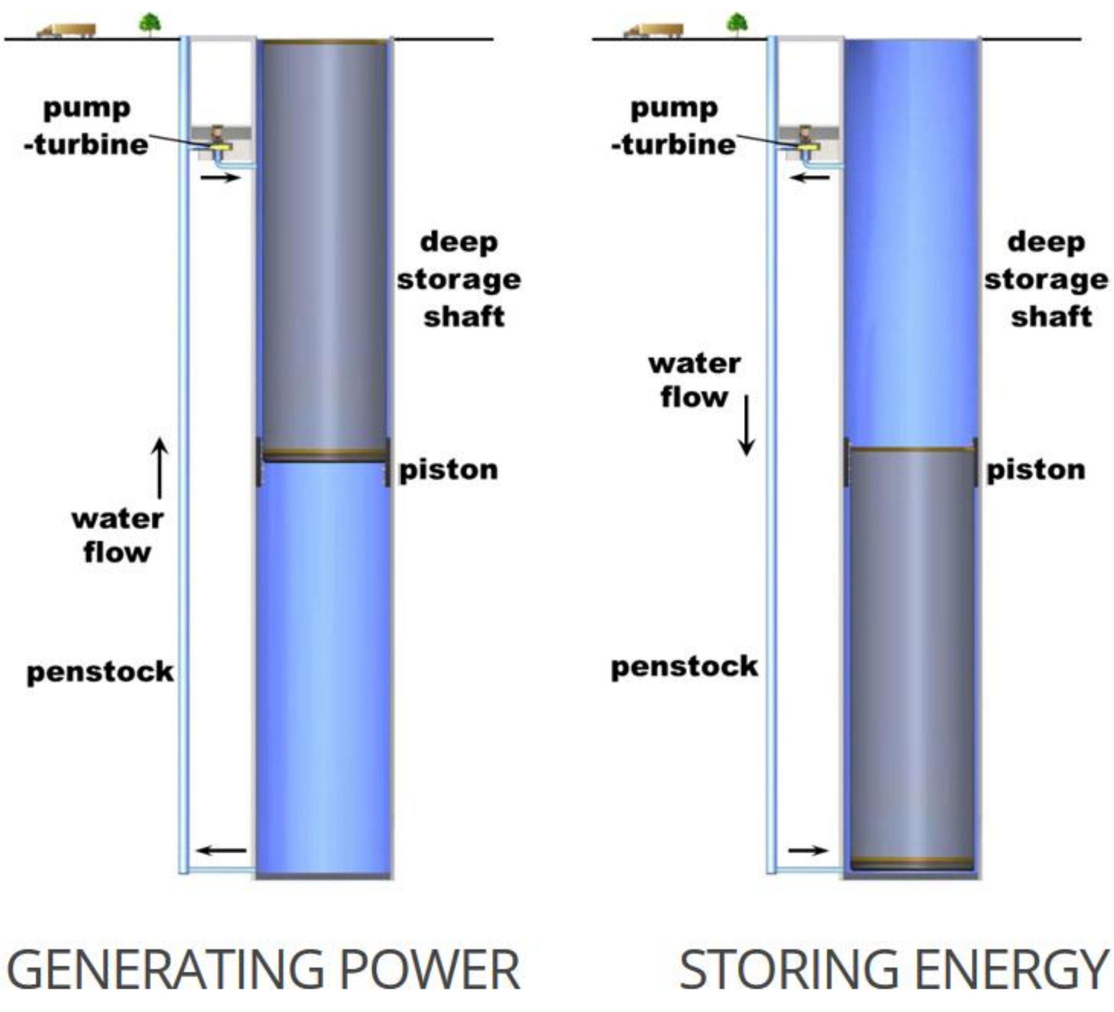
[64] http://holisticmanagement.org/holistic-management/case-studies/case-studies-browns-ranch/
[65] https://www.youtube.com/watch?v=vpTHi7O66pI 18:49-20:30
[66] http://www.forbes.com/sites/michaelkanellos/2015/10/05/solar-cheaper-than-natural-gas-its-happening/#15cb55d35f19
[67] http://fortune.com/2015/10/06/wind-cheap-coal-gas/

Battery storage is currently available via Tesla's Powerpacks. Grid-scale electric storage will be available soon via Ambri's liquid metal batteries (the chemistry works fine, they're working out high-temperature seal issues).

Pumped storage is used to store power using water and elevation. Usually two open-air reservoirs at different elevations. The system below uses underground vertical bore holes instead. They can be sited practically anywhere vs. conventional pumped storage with limited sites available.

Gravity Power's Gravity Power Modules (GPMs) are almost to market. "For the ancillary services market, existing combustion turbines and emerging flywheel and battery companies are Gravity Power's principal competitors. GPMs will ramp far faster than gas turbines, have no emissions and be competitive on a cost/kW basis. Compared to batteries and flywheels, GPMs are projected to be significantly lower – at around $1000/kW – with much longer lifetimes."[68]

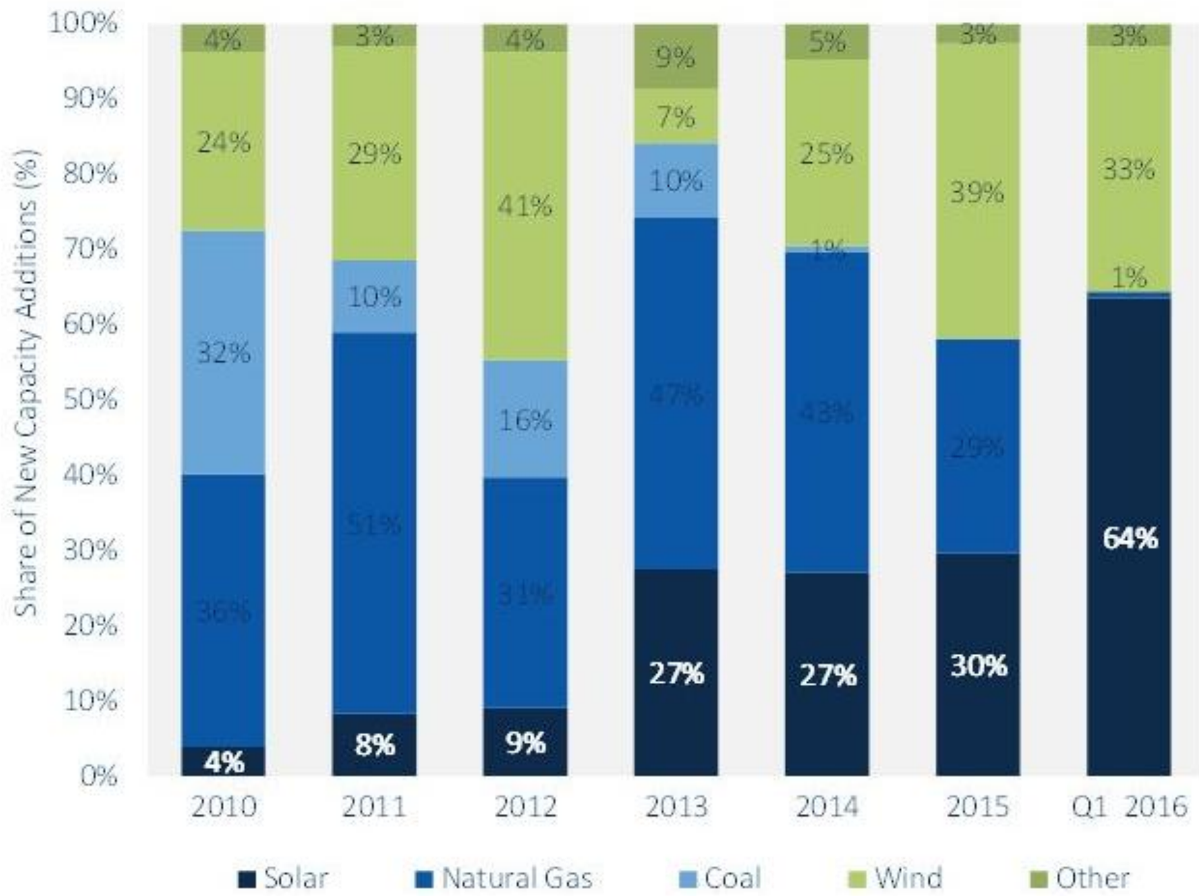


[69]

[68] http://www.gravitypower.net/markets-and-products/
[69] http://www.gravitypower.net/technology-gravity-power-energy-storage/

Storage smoothes the intermittency of solar and wind and also handles peak loads with faster response time than either coal or natural gas peaker plants. Excess power when storage is full can be utilized to generate hydrogen from water for use in hydrogen fuel-cell vehicles.

FIGURE: Share of New U.S. Electric Generating Capacity Additions



Source: GTM Research / SEIA U.S. Solar Market Insight, Q2 2016

70

[70] http://www.greentechmedia.com/articles/read/solar-accounted-for-64-of-new-electric-generating-capacity-in-the-us-in-q1

Alcohol Fuel Production from Flexible Feedstocks

"Alcohol Can be A Gas! - This book is the distilled essence of the most pertinent information ever assembled in one place on alcohol fuel--the technology that can help us finally become producers of almost limitless energy, instead of extractors of finite resources."[71]

Chapters:

1. A History of Alcohol
2. Busting the Myths
3. The Permaculture Solution to Fossil Fuel Dependency
4. Darker Visions of Our Energy Future
5. Brazil
6. Selecting Feedstocks
7. Feedstock Preparation and Fermentation
8. Information on Various Feedstocks
9. Distillation
10. Designing Your Fuel/Feed Plant
11. Alcohol Fuel Is Only the Beginning: Turning Waste Into Profit
12. Micro-Distillery Model Farm
13. Surprise! Ethanol Is the Perfect Fuel
14. Alcohol Versus Gasoline In Your Engine
15. Carburetion
16. Fuel Injection
17. Cold-Start Systems
18. Ignition Timing
19. Assorted Adjustments
20. Converting to High Compression
21. Smaller Engines
22. Flexible-Fuel and Dual-Fuel Systems
23. Methanol and Butanol
24. Cogeneration and Other Systems to Provide Energy from Alcohol
25. How Diesel Engines Can Run on Alcohol
26. Economic and Legal Considerations
27. Practical Experiences with Alcohol Production
28. Fueling a Revolution: Proposed Incentives and Regulatory Changes to Rapidly Make the U.S. a Renewables-Powered Country
29. Community-Supported Energy (CSE)

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[71] Alcohol Can be A Gas! page 1

This book details how to set up and operate farms that produce abundant food and renewable energy without any fossil fuel inputs. The farming is permaculturally based which uses most "wastes" as inputs to other processes and products so that very little is wasted and more is produced. The author's permaculture farm in the 1990's produced "100,000 pounds of food per acre, without a tractor, using only hand tools, on a terraced, 35-degree slope."[72] Compare that with corn's record national yield of 171 bushels per acre in 2014. Since a bushel of corn weighs 56 pounds, that's 9,576 pounds per acre or less than 10% of a permaculture farm's yield. Even strawberries top yield of 50,000 pounds per acre is half the yield.

"Permacultural wisdom totally changes the modern-day question of how many square miles can one person farm growing monoculture crops; the new question is how many good jobs for how many people can we produce per acre with energy/food polycultures?"[73]

Distributed Farms Integrating Aquaponics, Crops, Ethanol, and Methane Production

"So what do the numbers add up to in a model micro-farm? In this simplified version, our main products are alcohol, fish, fish emulsion, mushrooms, earthworm castings, and high-value greenhouse vegetable crops. Surplus distillers solubles would go out as fertilizer along with surplus fish water, to provide all the fertilizer we need for the next year's energy crop and wood for process heat. The estimated gross receipts of $484,000 are detailed in Figure 12-7.

These are the gross figures, of course. A lot of labor would be involved in handling this much production, and that's a good thing. We can generously assume the non-labor costs of production and marketing are 25% of the gross. That's $363,000 dollars available for labor and profit. Ten good rural incomes would be met by this amount, even if the laborers only worked about 25 hours a week.

And this is a simple permaculture design. There are much more complex and remunerative layers of production that can be built onto this simple model. A somewhat larger plant, producing 200-300 gallons 325 days per year (65,000-97,500 gallons) would take very little additional equipment, but the number of opportunities and complexity of products would multiply. What's more *the density of jobs per acre would go up.*

So is it more efficient to produce alcohol in 50-million-gallon-per-year plants that have only one or two low-priced co-products? It depends on what you call efficiency. If you are trying to make the most alcohol with the least number of people, then *maybe* a big plant would be more efficient. If efficiency is defined as producing the most money from a given ton of corn, *maybe* wet mill corn bio-refinery plants can do better.

[72] Alcohol Can be A Gas! page xv
[73] ibid., page 318

But when it comes to how much money you can produce from an acre of energy crop, being small enough to get full retail from your value-added products sold locally makes the small scale far and away more efficient than large plants.

A most important yield is the number of jobs per acre you can create. If you look at the maximum number of farmer-owners who can make a good living on such an integrated farm, there is no comparison; large plants barely produce one direct alcohol plant job for every million gallons of alcohol and increase the [value] of a bushel of corn only about 20 cents. Yes, alcohol plants do circulate a lot of money into the local economy, and that creates jobs. But our small model farm can produce several good jobs for every 9000 gallons of alcohol produced, and circulate even more money locally.

In the long run, large plants cannot compete with smaller, multiple yield, multiple-feedstock, permaculturally designed plants when it comes to benefits to a state and its people. Right now, there are places for all sorts of production scales in a national system of combined energy/food production. As time passes and the concern over energy is no longer price, but whether it is even available--decentralized, local production of fuel and food becomes vitally important. We should fill all the niches at each level of fuel production until we are energy-independent, self-sufficient in food, and fully employed."[74]

Two of the major issues with incorporating wind and solar as far as the grid is concerned are intermittency and handling demand peaks. Permaculture food/energy farms will produce methane (natural bio-gas) twenty-four hours a day. Since methane is CH_4, when it is burned in engines running generators it yields water, CO_2, electricity and heat. The CO_2 is valuable for enriching greenhouse atmosphere to increase growth rates. The heat is useful when heat pumped up to more useful levels for distillation. The electricity will be used on the farm and the excess exported to the grid. Excess CO_2 during the night will be stored until useful during the day. The methane will be stored until grid operators need dispatchable peak shaving power. Since these farms would be best sited near population concentrations, that is also synergistic from an energy point of view.

Summary

Richard Heinberg and David Fridley, in their recent book *Our Renewable Future,* outline succinctly the challenging paths ahead. I started work on this article before their book was published. We both agree that fossil fuels are an unsustainable dead end and mankind *must* push forward as quickly as possible with the transition from fossil to renewable energy.

"The rapid build-out of renewables constitutes an enormous infrastructure project that will itself consume significant amounts of fossil-fuel energy ... A bootstrap transition scenario (in which renewables provide the energy needed to build more renewables, while still supplying much of the rest of the energy that society needs) seems daunting in principle. Where *will* the energy for the transition come from, then? Realistically, most of it will have to come from fossil fuels--at least in the early-to-middle stages of the process. And we will be using fossil fuels whose economic efficiency is declining

[74] ibid., page 320

due to the ongoing depletion of existing stocks of high-quality oil, gas, and coal. Again, this implies higher overall costs. But using only renewable energy to build renewables would be slower and even more expensive."[75]

"In all likelihood, the real future of carbon sequestration lies elsewhere -- with reforestation and agricultural methods that build topsoil. Atmospheric carbon levels are currently at 400 parts per million (ppm) of carbon dioxide, while a consensus has emerged that a "safe" level would be below 350 ppm. One ppm is equal to 2.125 gigatons (Gt) of carbon; thus we need to safely sequestration 106.25 Gt of carbon in order to return to a safe climate regime. Is there sufficient potential absorptive capacity in forests and soils to accomplish this?

Society has removed 136 Gt of carbon from soils through agriculture and land use. There is the potential to reverse the trend by minimizing tillage, planting cover crops, encouraging biodiversity, employing crop rotation, expanding management-intensive pasturing, and introducing biochar to soils.

Deforestation has also contributed significantly to the historic increase in atmospheric carbon dioxide. It makes sense therefore that reforestation could diminish atmospheric carbon. Unfortunately, climate change is putting pressure on forests, even as we want them to recover. Nevertheless, a recent study shows large regional potential for sequestration, especially in the tropics."[76]

"The advantages we will reap from an all-renewable energy economy will include the absence of financial and social costs associated with extracting, refining, transporting, and burning depleting fossil fuels--costs that will only increase as extractive industries have to drill deeper into lower-grade deposits; and the absence of the environmental externalities from burning those fuels--health and climate costs that would otherwise balloon to the trillions of dollars per year by midcentury. If we have fewer consumer products, they will likely be ones that are more durable and of higher quality."[77]

"Now we arrive at a crossroads, where the wealth-generating energy sources of the past two centuries (fossil fuels) must give way to different energy sources. While the decades ahead may see declining per capita energy consumption in the wealthy industrialized world, the transition to renewable energy does not automatically herald a more egalitarian future. As everyone else adjust to lower consumption levels, entrenched economic interests that benefited disproportionately during the fossil fuel era may seek to maintain their advantages, attempting to ensure that their slice of a diminishing pie is left untouched. It is also possible that nations, and wealthy communities within nations, will build robust, largely self-contained renewable energy systems while everyone else continues to depend upon increasingly dysfunctional and expensive electricity grids that are increasingly starved of fuel. In either case, current levels of economic inequality could persist or worsen.

Pursuing the renewable energy transition without equity in mind would likely doom the entire project. Unless the interests of people at all economic levels are taken into account and existing inequalities are reduced, the inevitable stresses accompanying this all-encompassing societal transformation could result in ever-deeper divisions both between and within nations. On the other

[75] Our Renewable Future by Richard Heinberg and David Fridley, pages 119-121
[76] ibid. page 137
[77] ibid. page 141

hand , if everyone is drawn along into a visionary project that entails shared effort as well as shared gains, the result could be overwhelmingly beneficial for all of humanity. This is true not only for the renewable energy transition but also for our response to impacts of climate change that are by now unavoidable."[78]

"Since the economic crisis of 2008-2009 there has been an upwelling of political and economic discussion about inequality within industrialized nations. Many people are aware that wages have stagnated, partly as a result of globalization and mechanization. Proposals merely to stimulate more consumption, manufacturing, and trade--the twentieth century solutions to stagnation and inequality--will not work during the renewable energy transition, at least not in the same way. The parts of the economy that will require stimulus--and that will accommodate an increase in consumption, manufacturing, and trade--are those related to renewable energy (solar panels, wind turbines, energy storage, grid upgrades) and energy efficiency (building retrofits, rail revitalization, public transit). Some other parts of the economy may need to shrink significantly as investment capital and energy are directed to these key transitional sectors. Policy will need to be crafted to make sure the burden of these shifts does not fall too heavily on workers in shrinking industries, by providing skills and training that will be relevant in the renewable future.

As globalization stalls and retreats as a result of constraints and trends outlined in chapter 4, it will be important to rebuild local economies--local manufacturing, investment, and food systems. This in itself will offer opportunities for increasing equity and justice, through the formation and promotion of local cooperative institutions (co-ops and credit unions), and through the devolution of a great deal of political organization and decision making. Localization efforts can create jobs that pay living wages and help individuals within the community develop critical skills that directly benefit themselves and their neighbors. They can build resilience in communities that face a future filled with economic and environmental challenges. And such efforts can focus on the inclusion of groups that have historically been disadvantaged.

Finally, the forms of ownership adopted for new renewable energy systems will likely go a long way toward determining the degrees of economic equity or inequity in the renewable future. Centralized ownership through for-profit corporations will tilt the playing field toward continued accumulation of wealth in fewer hands; distributed generation and ownership of generating capacity and grid-related infrastructure by communities, through cooperative, nonprofit financing and revenue-sharing models, will result in more equity. Equity and justice will not be automatic outcomes of relocalization. They will require intentional, organized effort and struggle.

Decentralized energy democracy could be a significant driver of equity. ... while distributed generation, distributed storage, microgrids, and community choice aggregation all serve to create a more equitable power infrastructure, they can also provide technical advantages, such as resource diversity and system resilience."[79]

"One way or another, our descendants a few decades from now will inhabit an all-renewable world (or nearly so), and it will be a world that works differently, in many significant ways, from the

[78] ibid. pages 147-148
[79] ibid. pages 153-155

world we know today. It could be a better world in which to live, or it could be much worse, depending on the decisions we make in the next decade or two. Right now society is putting off even the most obvious and pressing of those decisions... Successive waves of problems and requirements for decision will follow. Failing to see those next waves from a distance only makes the worse possibilities for our renewable future more likely. We hope this exploratory effort shines a light into the future implications of the renewable energy transition, so that we can start now to see and understand the territory, consider our options, and act intelligently."[80]

These possible paths forward are the most promising we are aware of, but these paths will evolve over time as we steer into the future. Since our current path is a dead end, we must start down these new paths *now*.

[80] ibid. page 197