Twenty-First Century Collapse

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Introduction to Collapse

In this article collapse is defined as peaking and then rapidly falling population. Undoubtedly population collapse will be caused by lack of food and protection from global-warming-caused disasters and wars over resources.

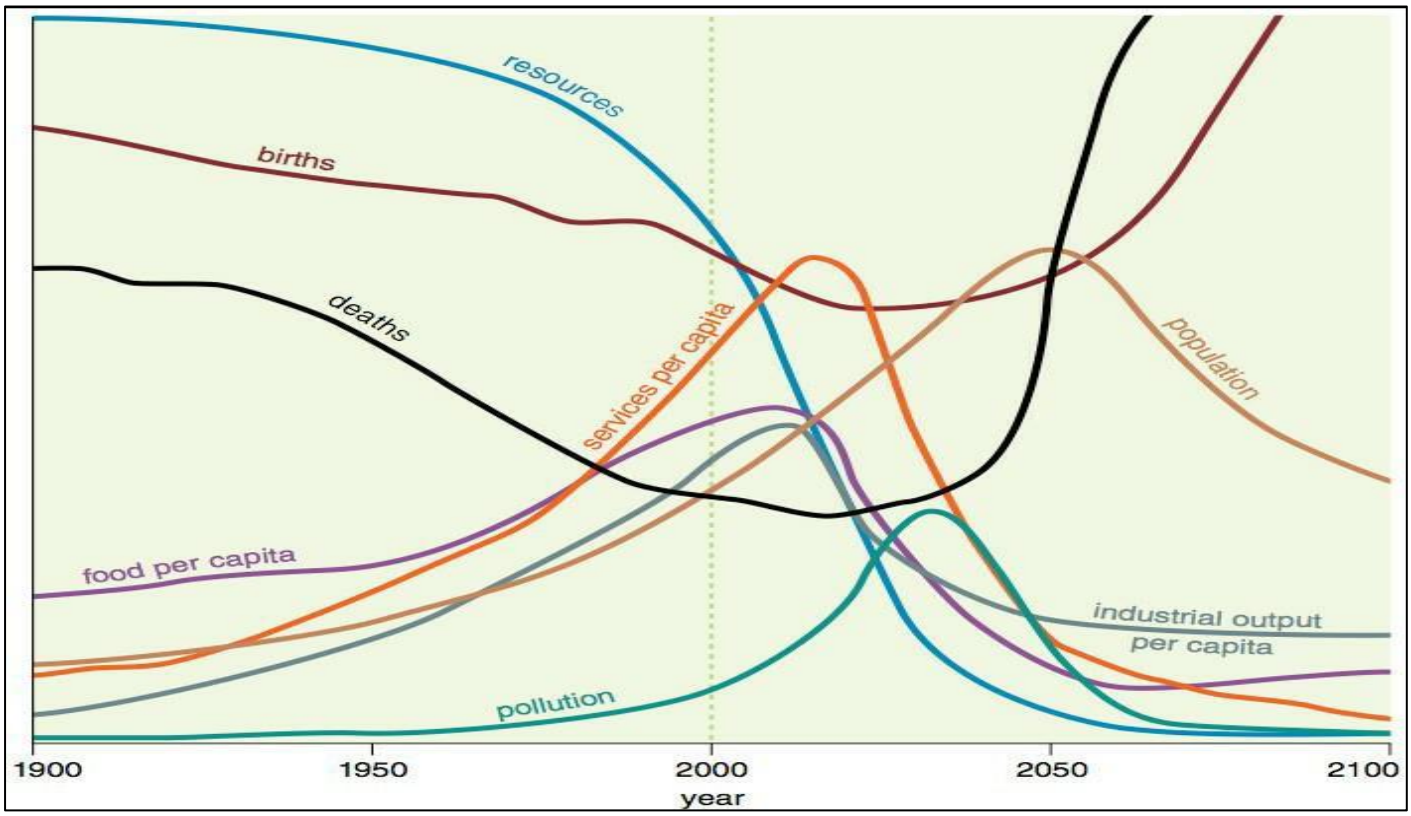
Limits to Growth

In 1972 a ground-breaking research project was initiated at MIT to study the complex interactions of the many variables that determine the future of human civilization. The results were published in a book *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind* by Donella H. Meadows, Jorgen Randers, Dennis L. Meadows and William W. Behrens. (http://en.wikipedia.org/wiki/The_Limits_to_Growth)

Limits to Growth: The 30-Year Update

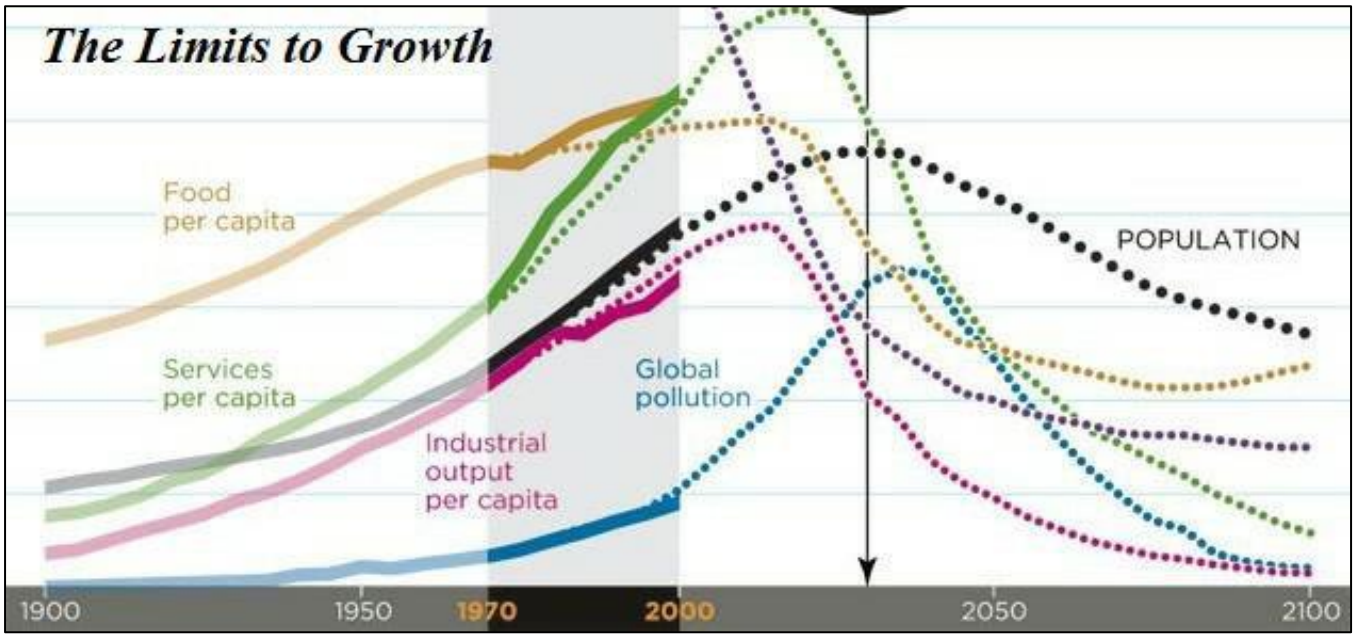
The original model interconnected five variables: world population, industrialization, pollution, food production and resources depletion. Two of the scenarios for the future led to "collapse" in the twenty-first century in the sense that population would peak and then fall rapidly.

Later versions of the study included more variables. Here is the Business-As-Usual (BAU) scenario published in 2000:



Population collapse begins at about year 2050.

A more recent version of the project shows that recent data are close to the BAU collapse scenario:



Population collapse begins at about year 2030.

(http://www.smithsonianmag.com/science-nature/looking-back-on-the-limits-of-growth-125269840/)

Here is another recent study of world collapse: http://www.sciencedirect.com/science/article/pii/S0921800914000615

This document will show many reasons why there is likely to be a twenty-first century collapse similar to the one in the Limits to Growth study.

Energy Availability

Without sufficient energy no society can last for a long period of time, let alone grow. Even as lack of large energy availability has become obvious, world societies are fixed on economic growth.

Fossil-Fuels Extraction

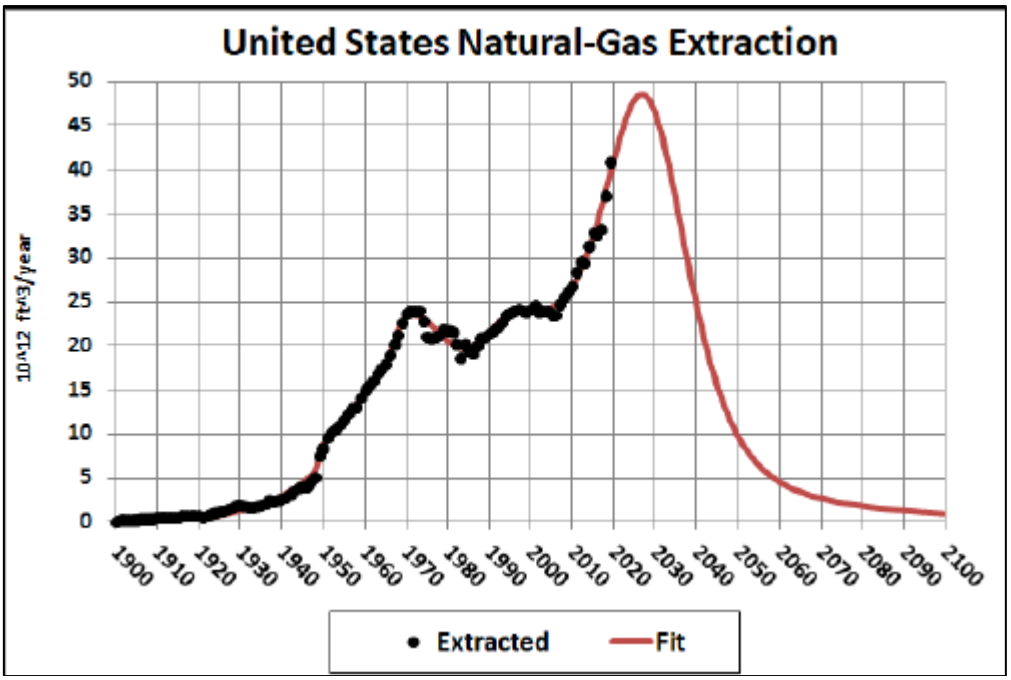
The discovery of fossil fuels to burn for fuel brought on the Industrial Revolution. It started with coal in the 18th century, and then progressed to crude oil and natural gas in the 20th century, and finally to renewable (solar/wind) energy late in the 20th century and full-fledged in the 21st century.

The graphs below for the projected extraction of fossil fuels for the U.S. and theworld show that it is reasonable that the collapse of world civilization will occur around the years 2040-2050, similar to the prediction of the Limits to Growth study described above.

Natural-Gas Extraction

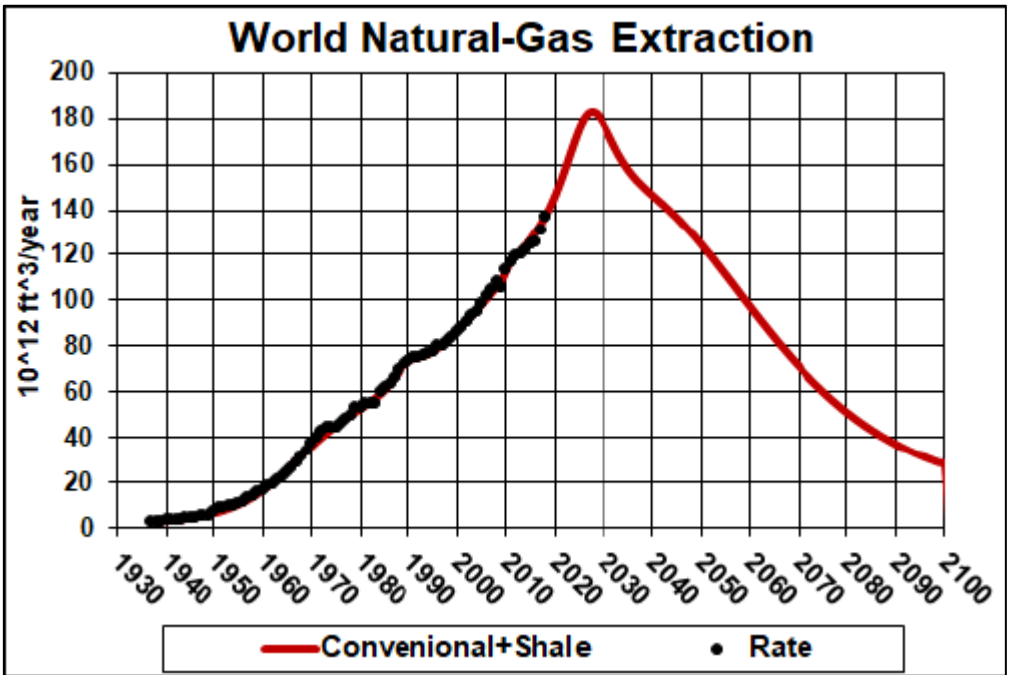
The fossil fuel which emits the least carbon dioxide, a potent Global Warming gas, when burned for fuel is natural gas. (However, fugitive natural gas at wells, pipelines and usage points makes methane extraction and usage about equal to coal in causing global warming due to methane being a more potent global-warming gas than carbon dioxide. It reacts with oxygen in the atmosphere to produce carbon dioxide and water with a 7-year half-life.) Natural gas is mainly used for home heating, electricity generation, making chemicals and making nitrogen fertilizer.

The extraction history for natural gas in the United States and its projection into the future is shown in the following graph:



The future peak is the projected extraction of shale natural gas by fracking.
(http://www.roperld.com/science/minerals/USGasBoom_Bust.htm)

Assuming that extraction of shale natural gas for the world is similar to that for the United States, the following graph shows the extraction history and the future projection for world extraction:

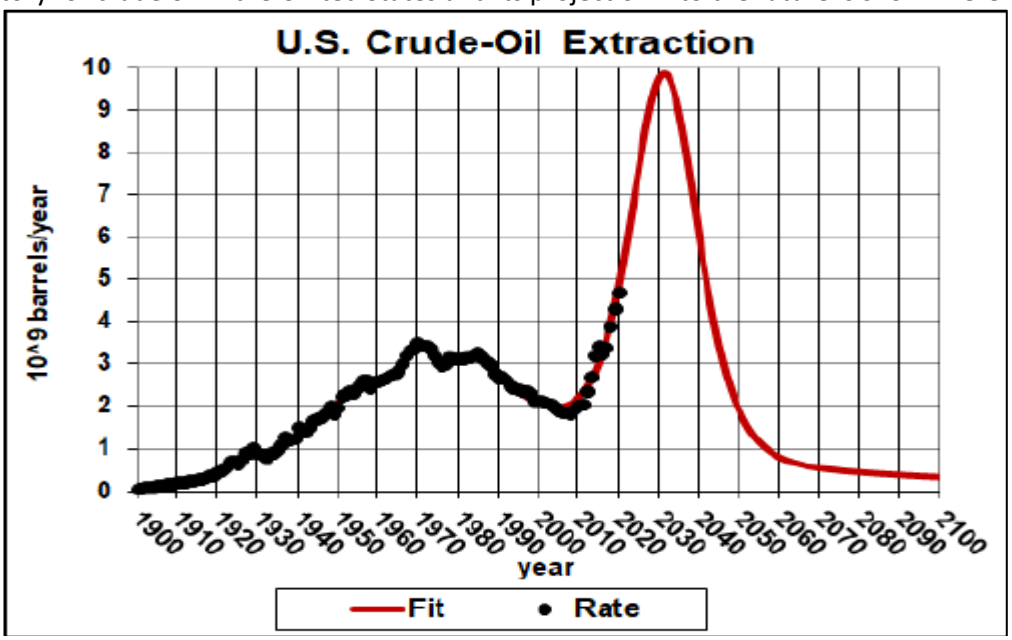


The future peak makes it reasonable that the collapse date for modern human civilization would be about 2030. (http://www.roperld.com/science/minerals/WorldNaturalGasFuture.pdf)

Crude-Oil Extraction

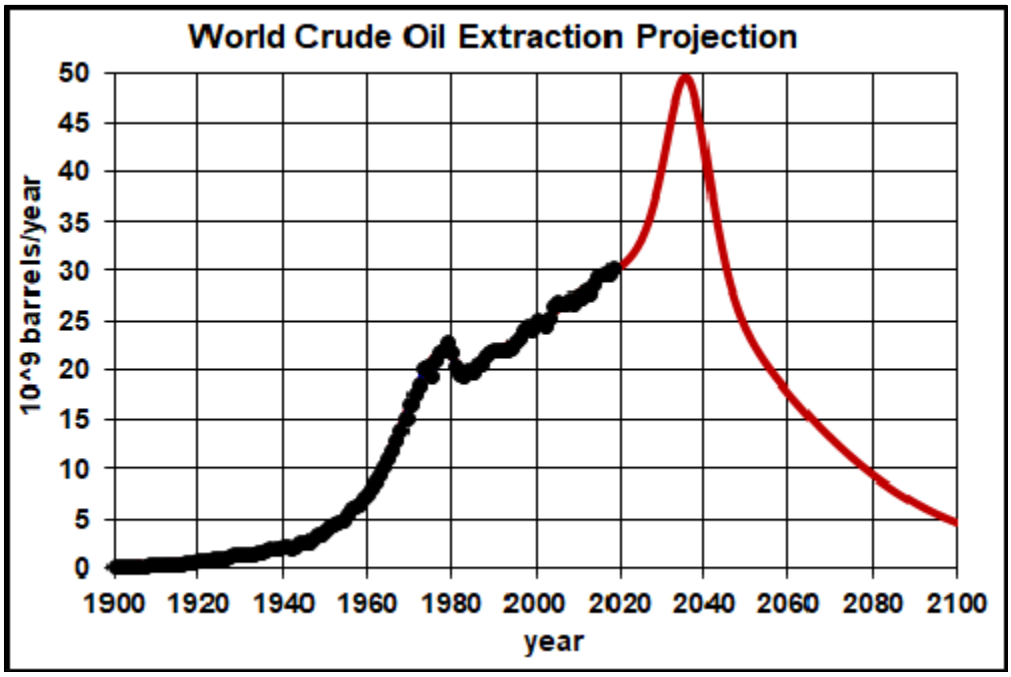
The fossil fuel that is most heavily used for world transportation (gasoline, diesel and airplane fuel) is crude oil. Its large extraction started in the early twentieth century

The extraction history for crude oil in the United States and its projection into the future is shown here:



The future peak is the projected extraction of tight oil by fracking. It is large because the "reserves" used in the fit to the data includes estimates of future discoveries. Probably it will be smaller.
(http://www.roperld.com/science/minerals/USOilBoom_Bust.htm)

Assuming that extraction of shale crude oil for the world is similar to that for the United States, the following graph shows the extraction history and the future projection:

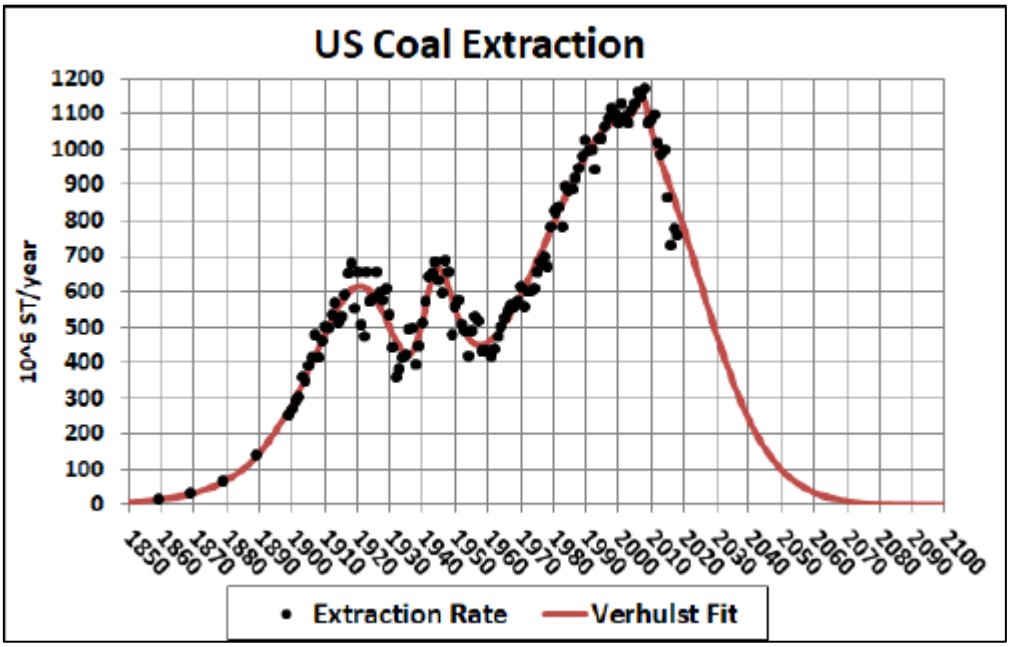


The future peak makes it reasonable that the collapse date for modern human civilization would be about 2040. (http://www.roperld.com/science/minerals/WorldCrudeOilFuture.pdf

Coal Extraction

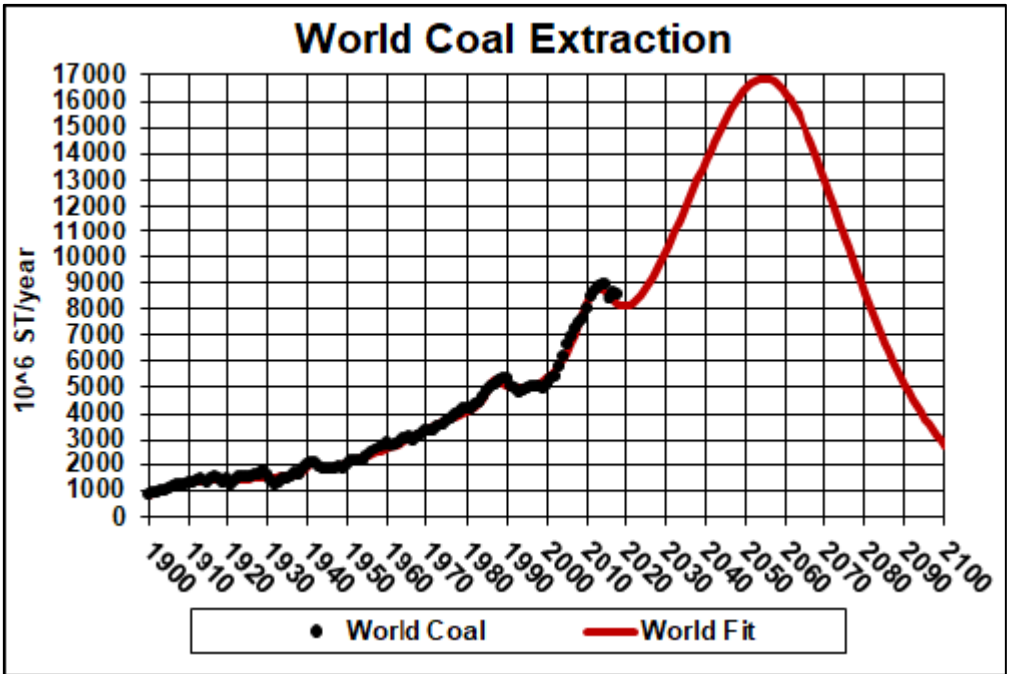
The most used fossil fuel to generate electricity is coal. It is also emits the most carbon dioxide per energy created of any fossil fuel.

The extraction history for coal in the United States and its projection into the future is shown in the following graph:



(http://www.roperld.com/science/minerals/CoalExtractionUS.pdf

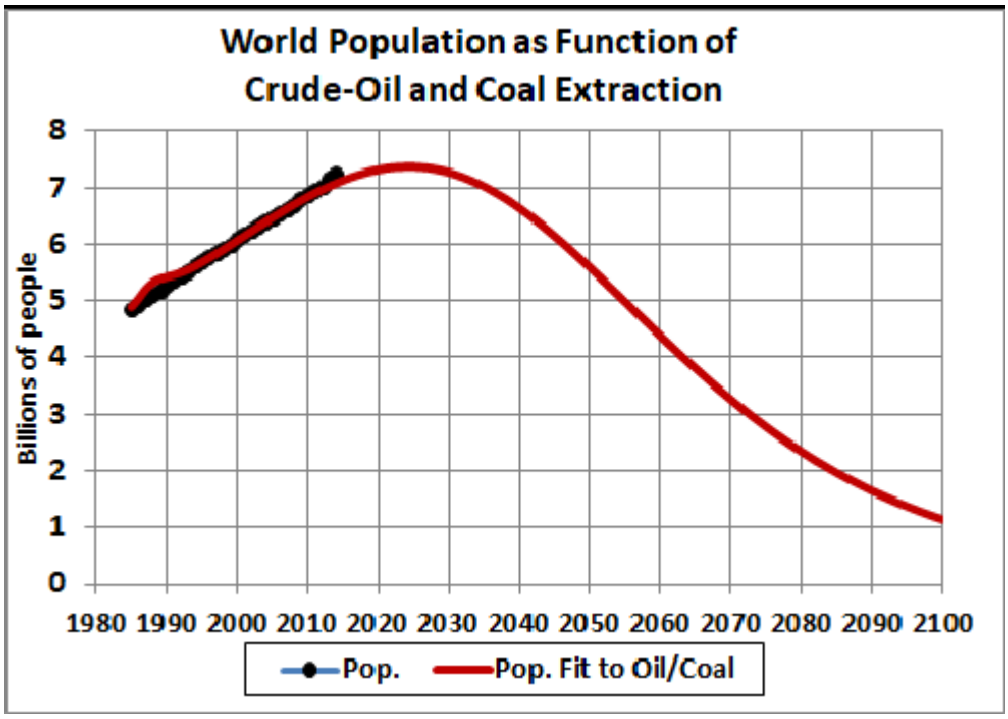
The world extraction history for coal and it projection into the future is:



The future peak makes it reasonable that the collapse date for modern human civilization would be about 2060. (http://www.roperld.com/science/minerals/WorldCoalFuture.pdf)

In order that global-warming disasters are kept to a minimum burning that much coal must be avoided.

A valid argument can be made that world population is a function of the amount of crude oil and coal extracted. Doing a linear fit of world population to both extraction rates from 1985 to 2014 yields:



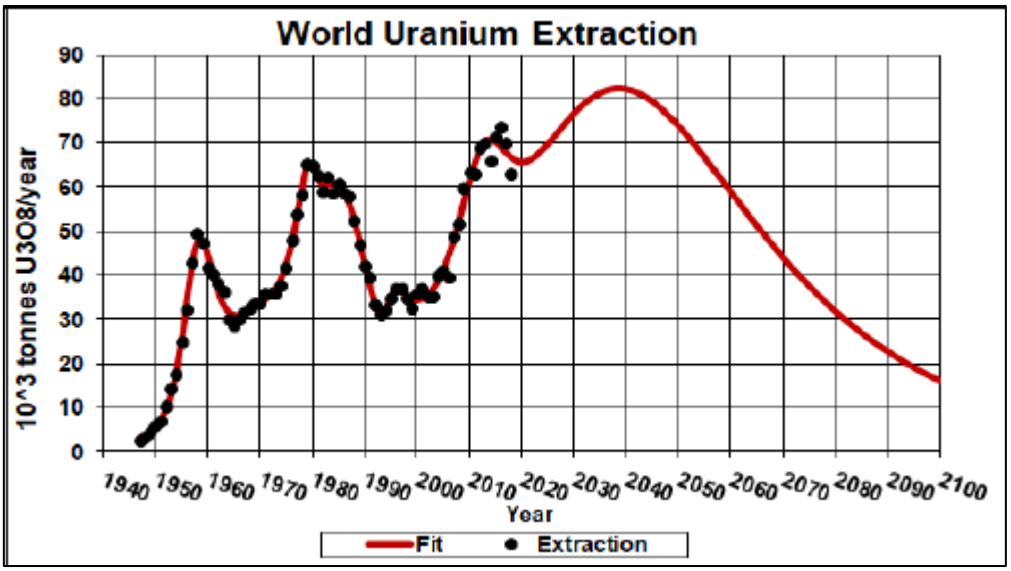
The effect of coal extraction is negligible compared to the effect of crude-oil extraction.

A fast onset of renewable energy could delay or, perhaps, prevent this population collapse at about 2030.

Uranium Extraction

For continued use of uranium energy new reactor designs need to be much safer and less expensive than current designs.

The extraction history for uranium for the world and its projection into the future is:

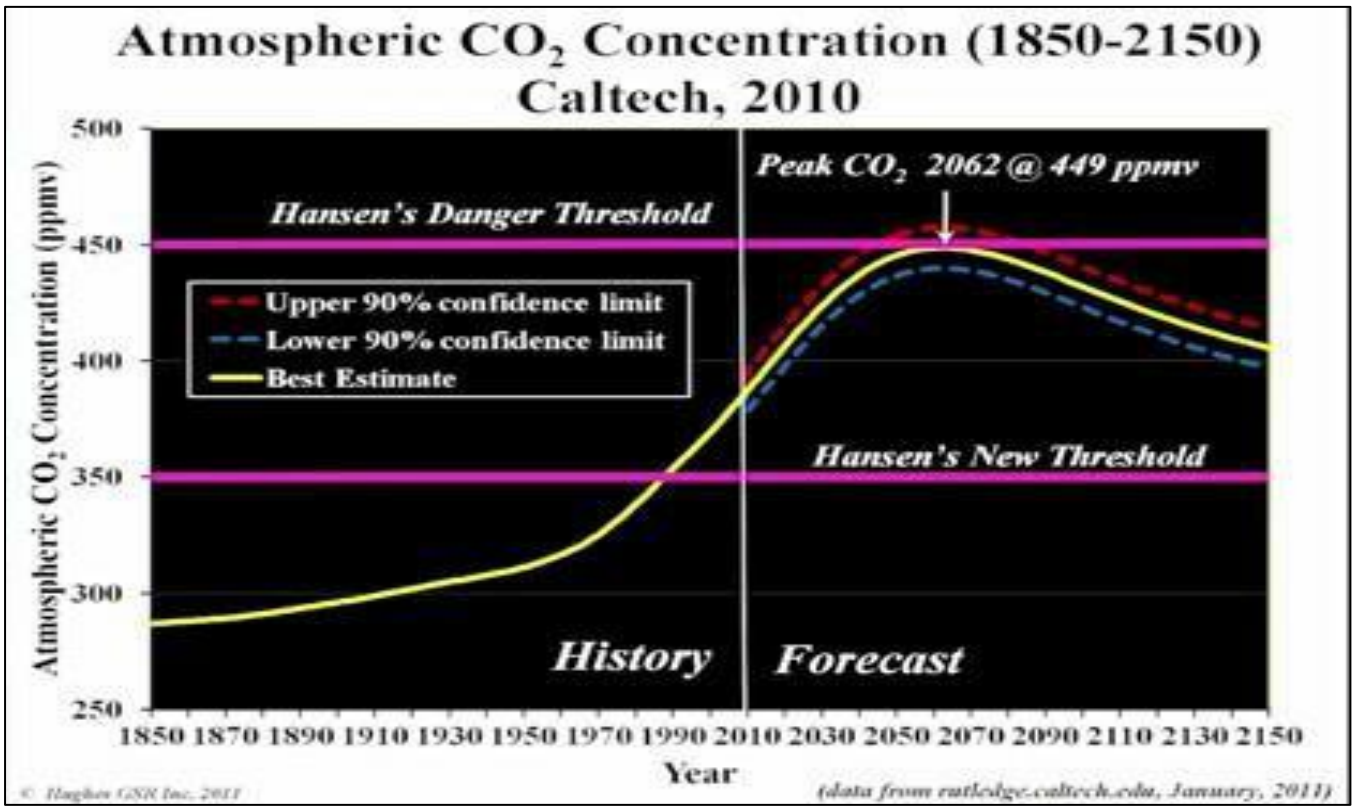


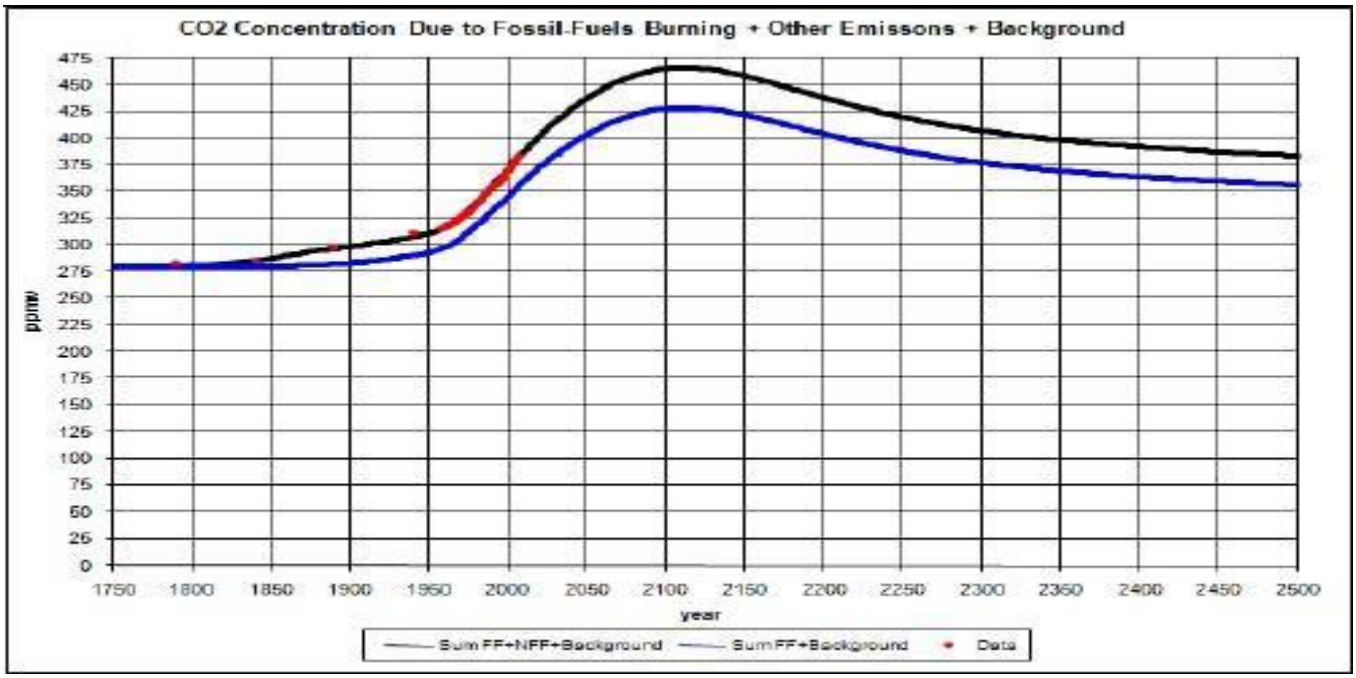
The future peak makes it reasonable that the collapse date for modern human civilization would be about 2040.

A fast onset of renewable energy could delay or, perhaps, prevent this population collapse at about 2030.

Global Warming

The ready availability of fossil fuels for energy and, thereby, increased population and many human activities, such as agriculture, has caused emission of global warming gases, especially carbon dioxide and methane, into the atmosphere. Two studies that use the projected extractions and uses of fossil fuels described above, show that the concentration of carbon dioxide in the atmosphere will peak as shown in the following graphs:

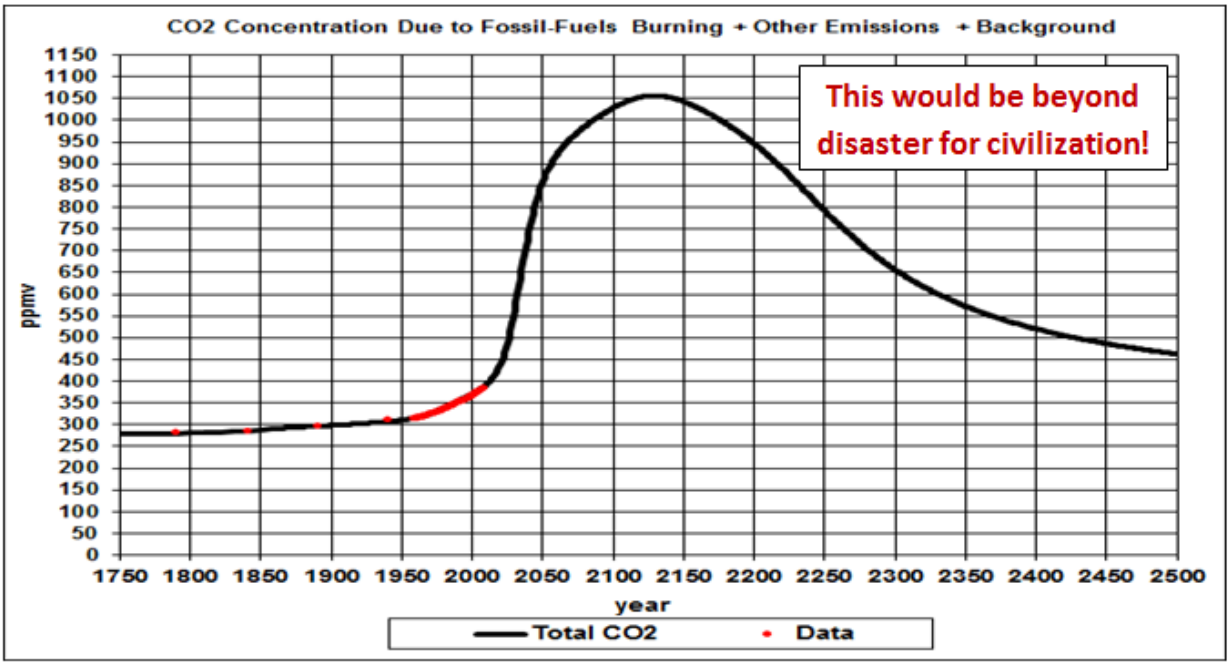




http://www.roperld.com/science/GlobalWarmingprediction.htm#NFF

The lower curve is due to burning fossil fuels and the upper curve is a fit to the measured data proportional to the lower curve; the upper curve allows for other sources of greenhouse gases besides burning fossil fuels.

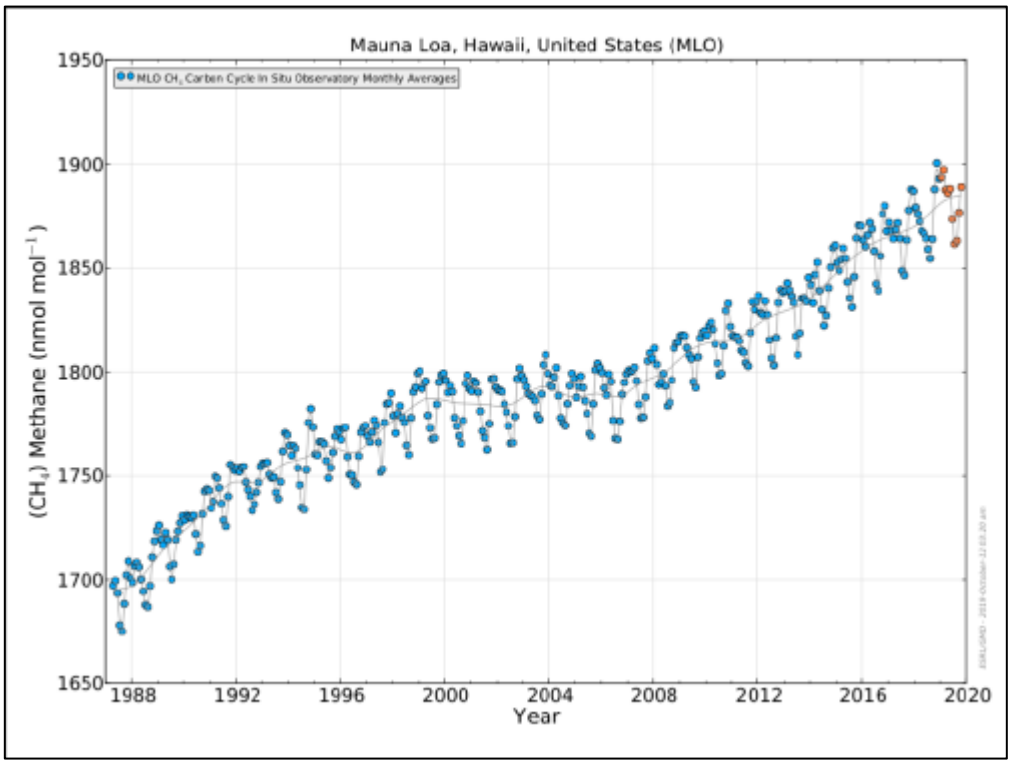
Neither of these two studies assumed the occurrences of tipping points for positive feedbacks such as methane release in the Arctic tundra. The second study allows for such tipping points and the increase of climate sensitivity from 3 to 6 as time progresses and gets the following curve for the worst case:



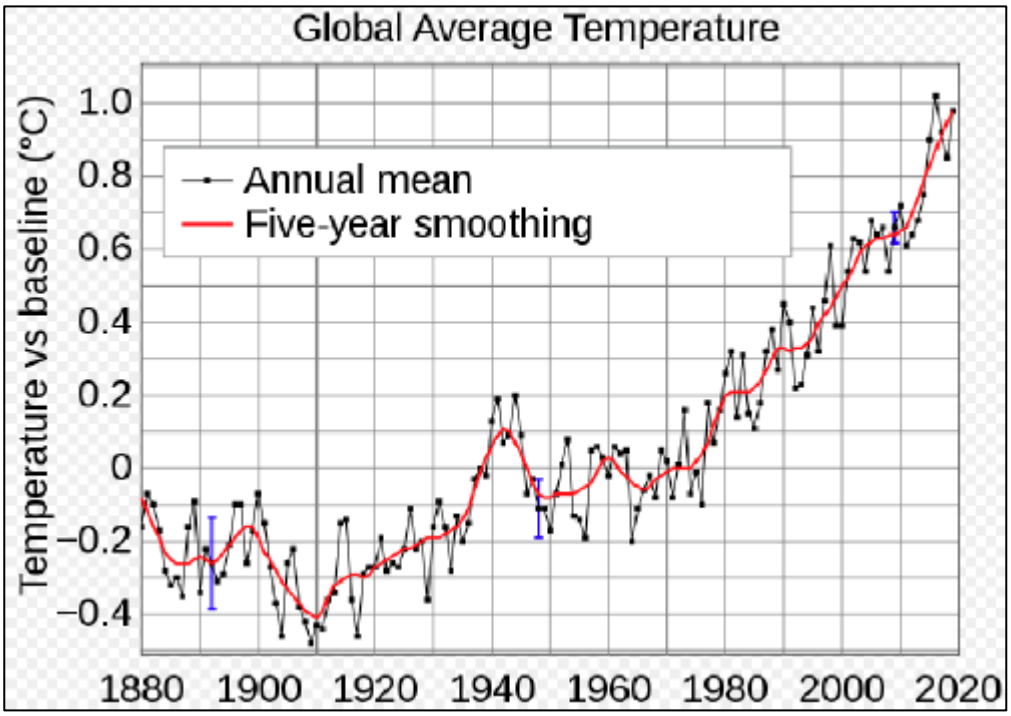
Worst case with tipping points by Roper

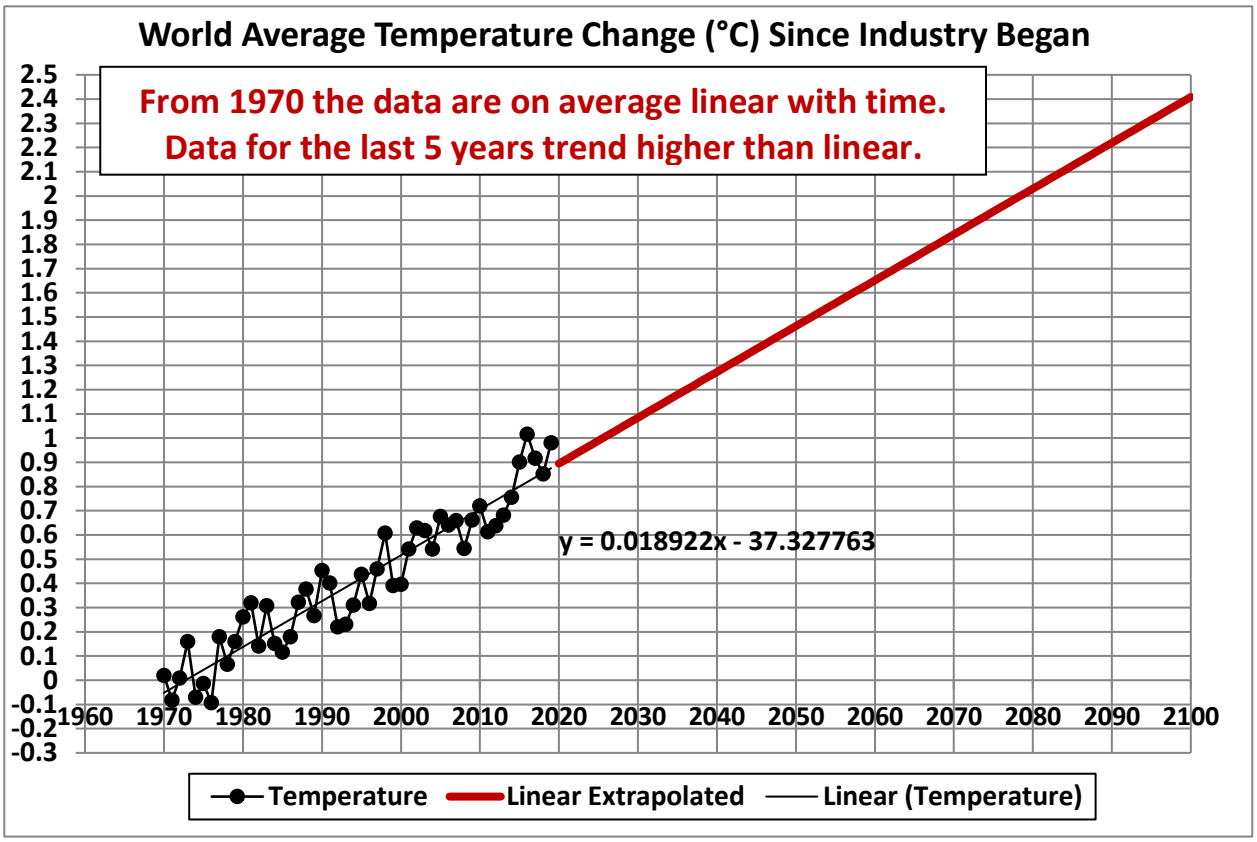
(http://www.roperld.com/science/GlobalWarmingprediction.htm#WorstCase**)**

Methane concentration in the atmosphere:



This is temperature change since industry began:





These results for Global Warming will likely cause a collapse at about year 2050.

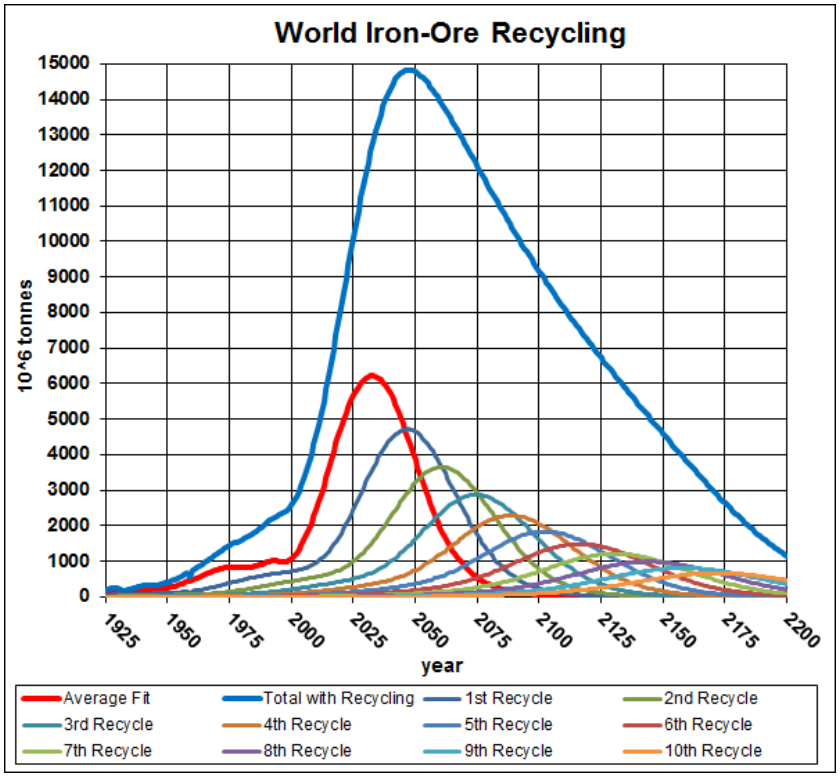
Metals Depletion

Modern human civilization depends heavily on metals for creating buildings, industrial machinery and transportation systems.

Much work has been done about depletion of metals extraction, including recycling.

Iron-Ore Extraction

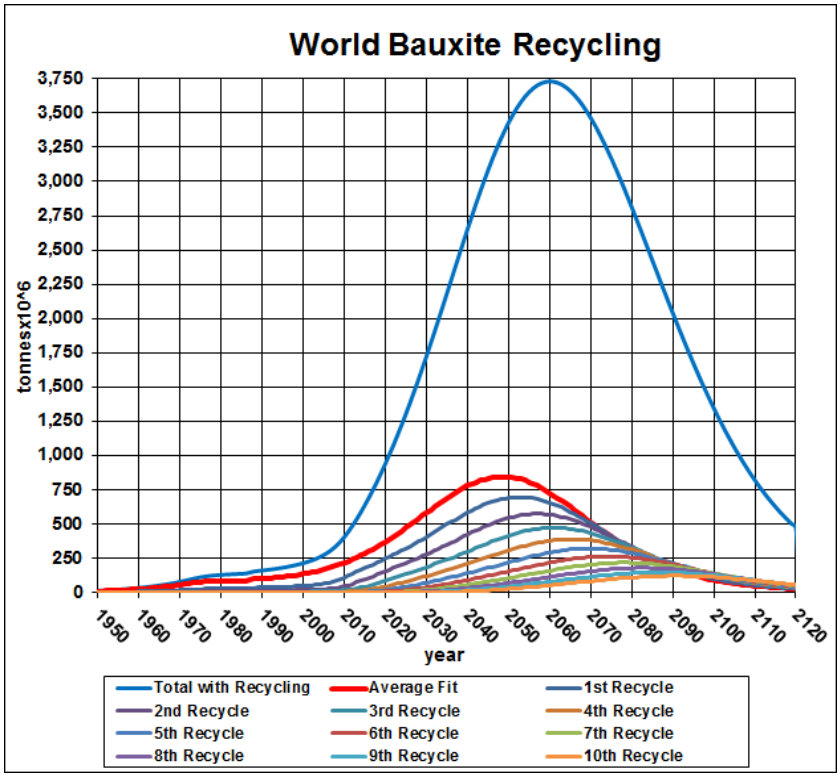
One of the most important metals is iron, from which steel is made. The following curve shows the depletion curve for world iron-ore extraction (red curve) and ten recycling cycles, yielding the blue curve for the amount of iron ore that will be available for use for any year:



(http://www.roperld.com/science/minerals/iron.htm

Bauxite-Ore Extraction

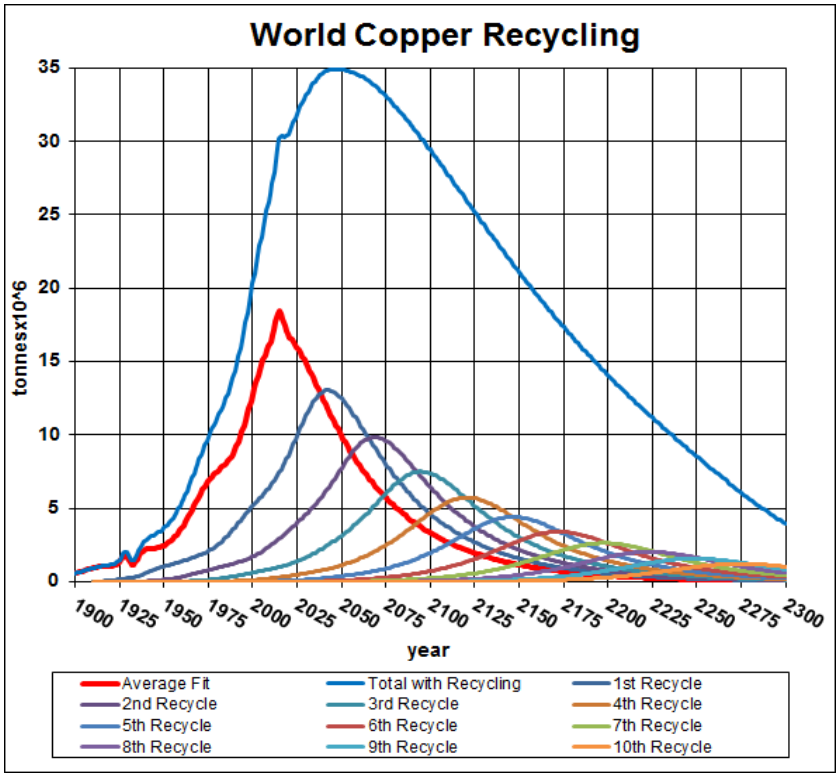
Aluminum, made from bauxite ore, is a widely used substitute for steel in manufacturing machinery and transportation systems. Aluminum is produced by using much electricity to refine bauxite ore. The following curve shows the depletion curve for world bauxite extraction (red curve) and ten recycling cycles, yielding the blue curve for the amount of bauxite ore that will be available for use:



(http://www.roperld.com/science/minerals/bauxite.htm)

Copper Extraction

Copper is essential for electricity production and transport and for computers and control systems. The following curve shows the depletion curve for world copper extraction (red curve) and ten recycling cycles, yielding the blue curve for the amount of copper that will be available for use:



(http://www.roperld.com/science/minerals/copper.htm)

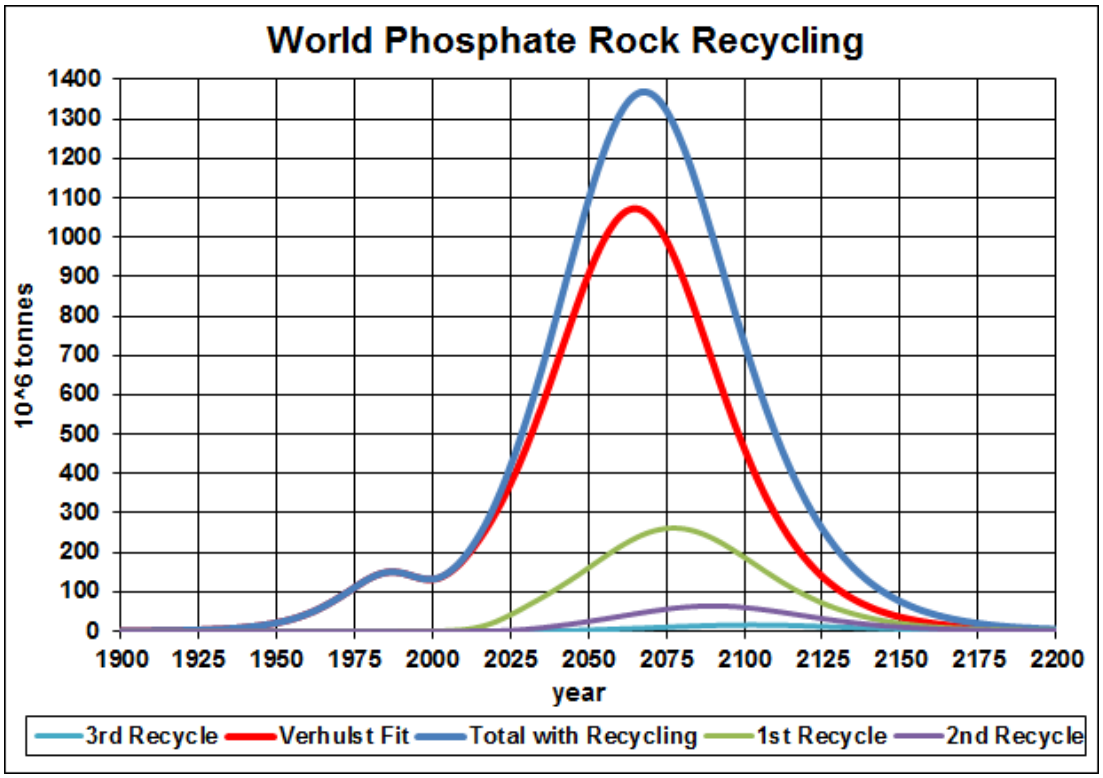
Similar graphs have been developed for other important metals, but the three given above for iron ore, bauxite ore and copper are sufficient to show that collapse will likely occur at about year 2050.
(http://www.roperld.com/science/minerals/minerals.htm)

Agriculture

Modern agriculture depends on arable land, water, sunshine and fertilizer. The three main components of fertilizer are nitrogen, phosphate and potassium. Nitrogen is extracted from the air by a process involving large amounts of natural gas. Potassium is obtained from potash.

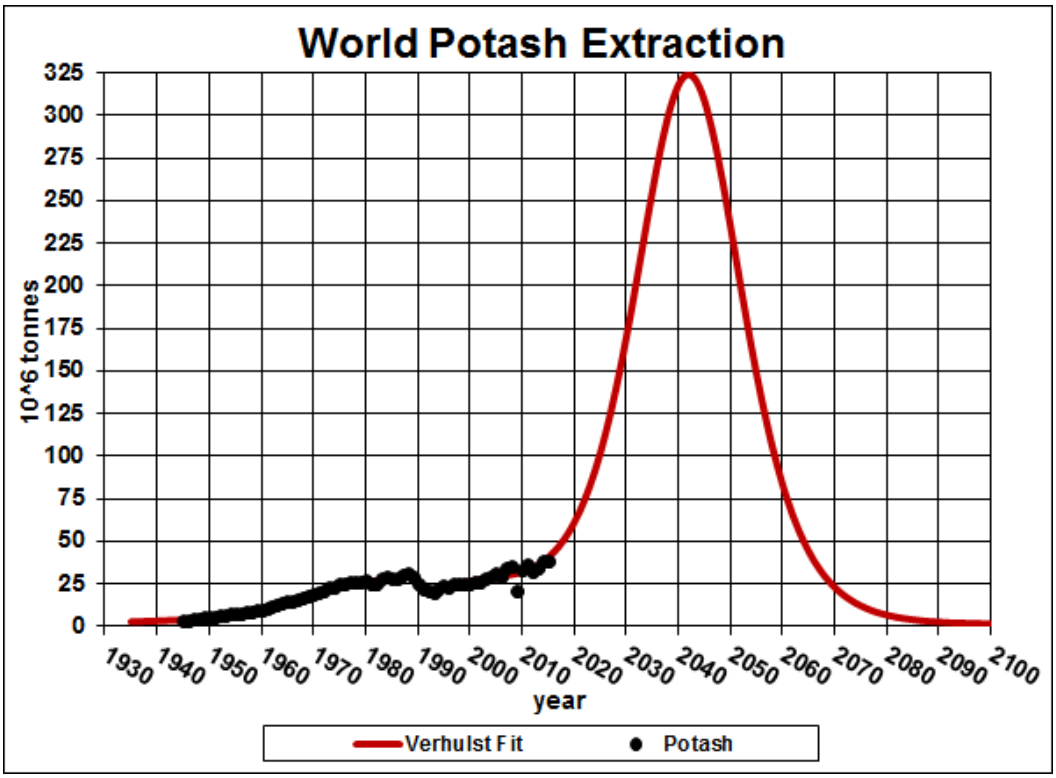
Phosphate-Rock Extraction

The following two curves show the depletion of world phosphate rock and potash:



It peaks at about 2065. (http://www.roperld.com/science/minerals/phosphate.htm)

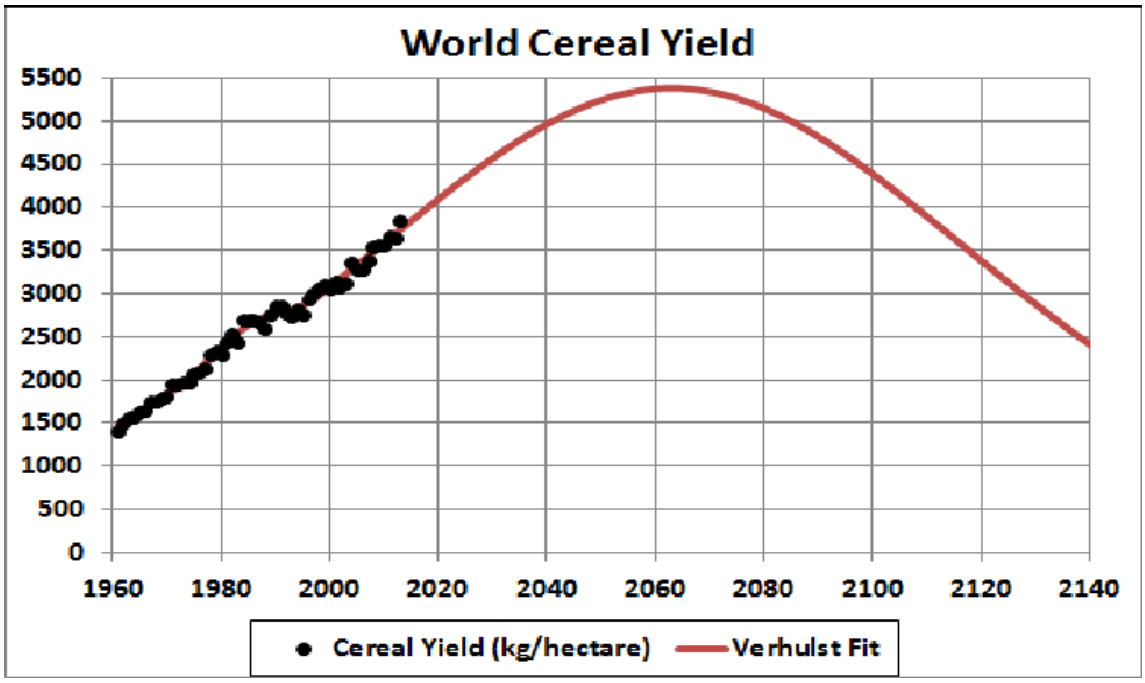
Potash Extraction



It peaks at about 2040. (http://www.roperld.com/science/minerals/Potash.htm)

Because cereal yield depends on available natural gas, phosphate and potash, world cereal yield will surely peak, also. The following graph shows a two-Verhulst fit to world cereal yield; the future peak is assumed symmetrical:

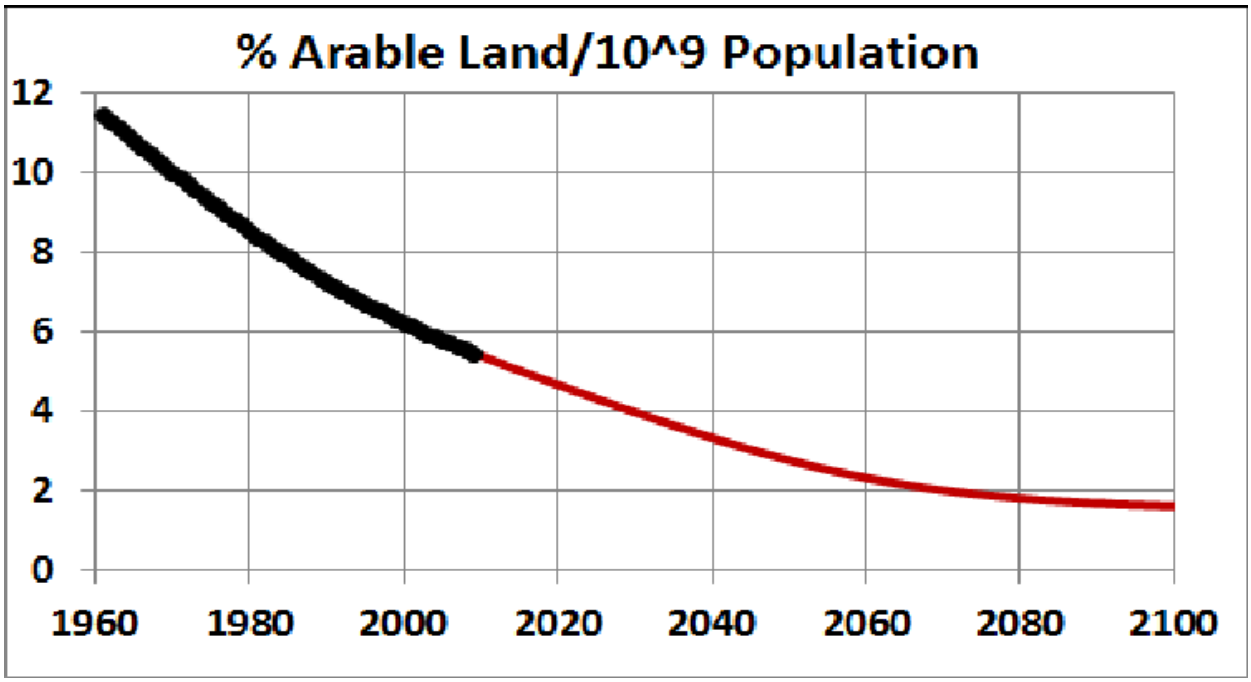
Cereal Yield



It peaks at about 2060. (http://www.roperld.com/science/peakagriculture.htm)

Arable Land

The following is a falling exponential fit to the % of Earth land that is arable divided by world population projected to asymptotically reach 10 billion:



Certainly the ratio is dangerously low from about 2040 on.

The four agriculture graphs above make it clear that collapse will occur around year 2050.

Conclusion about Collapse

This document has shown that many independent studies have implied that world population will start falling rapidly in the interval 2030-2060; such a rapid depopulation is labeled "collapse". The following table summarizes the studies:

Study	Collapse interval
Limits to Growth	2030-2050
World Natural-Gas Extraction	2030-2050
World Crude-Oil Extraction	2020-2040
World Coal Extraction	2030-2040
Uranium Extraction	2030-2040
Global Warming	2040-2050
World Iron-Ore Extraction with Recycling	2030-2060
World Bauxite Extraction with Recycling	2040-2060
World Copper Extraction with Recycling	2020-2050
World Phosphate-Rock Extraction	2060-2070
World Potash Extraction	2040-2050
World Cereal Yield	2050-2070
% Arable Land per Capita	2040-2080

The average collapse intervals of the first twelve upper and lower limits are in the range 2035-2059.

There are important mutual positive feedbacks between each of the variables mentioned in this document and world population. The greater the population the faster a variable changes and the faster a variable increases the more population increases.

An intelligent world society would know about this tendency for collapse at before year 2050 and would intentionally reduce population long before then to cause all of these curves to extend to much longer years to give time to convert energy and mineral sources to renewable ones to perhaps prevent a collapse.

How to Prevent Collapse

There are three general principal actions that would have to be done to turn the world from Business As Usual:

1. Quite burning coal for fuel to minimize global warming disasters
2. Use most of the remaining crude oil and natural gas to create the infrastructure for renewable energy to replace fossil fuels for energy.
3. Reduce population growth by a huge world-wide birth-control program.

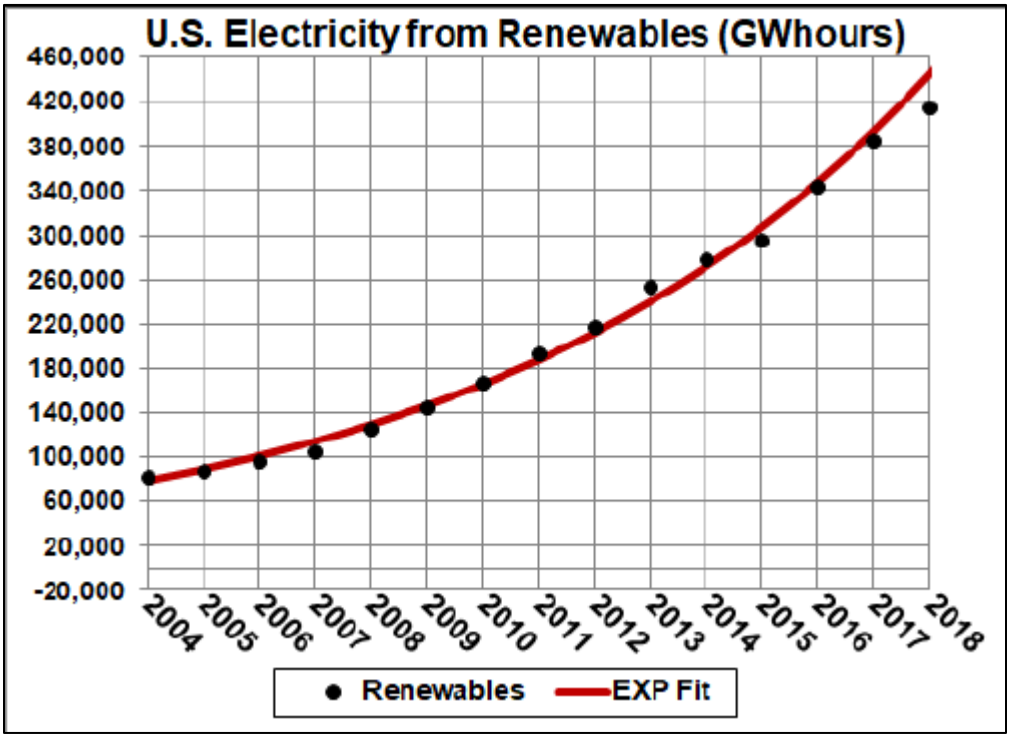
Here are some specific world-wide actions that could likely prevent collapse from happening:

- Provide free birth control across the world.
- Quickly use the remaining natural gas and crude oil to develop infrastructure for renewable energy.
    - Distributed solar photovoltaic systems on every suitable roof, every suitable parking lot and non-arable land.
    - Solar photovoltaic farms on the edges of towns and cities with battery storage for nights and cloudy days.
    - Distributed wind farms everywhere where the average wind speed is high enough with battery storage.
    - Solar thermal energy plants in all deserts with molten-salt energy storage.
    - Develop smart grids to share electrical energy and provide resiliency across nations.
    - Develop battery and other storage to smooth out renewable energy availability.
- Quickly phase out burning coal for energy, reserving it for making useful items.
- Quickly create high-speed rail across nations to replace air travel. China is providing a good example (10,000 miles in 2012 and 16,000 miles by 2020).
- Quickly phase out gasoline/diesel cars by electric cars.
- Create biodiesel fuel by non-food agriculture (e.g., algae) for trucks and airplanes.
- Quickly develop fuel-cell ships for international travel and use solar energy to create the hydrogen fuel.

Exponential Growth of Electricity from renewable sources

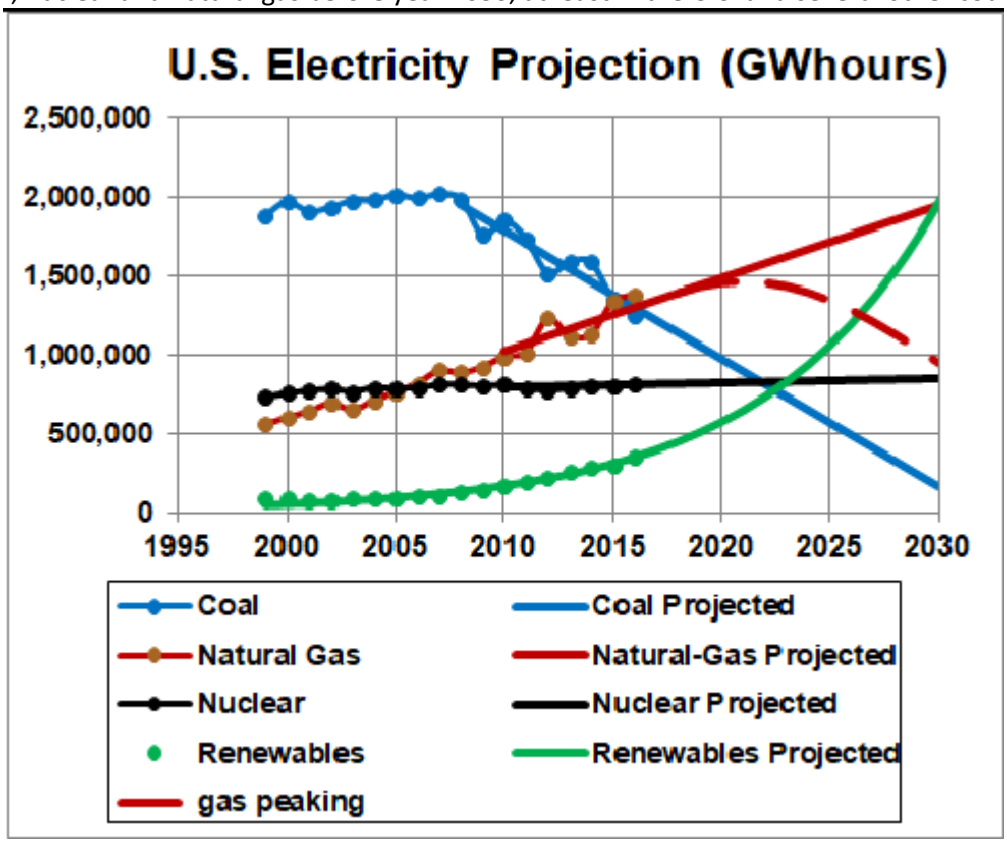
Can fast exponential renewable energy increase prevent collapse?

In my document http://www.roperld.com/Science/electricityus.htm I show that electricity generation from renewable energy (mainly wind and solar) is growing at an exponential rate in the United States, which is also true for many other countries:



The exponential curve is a fit to the data with exponential rate of about 7 years.

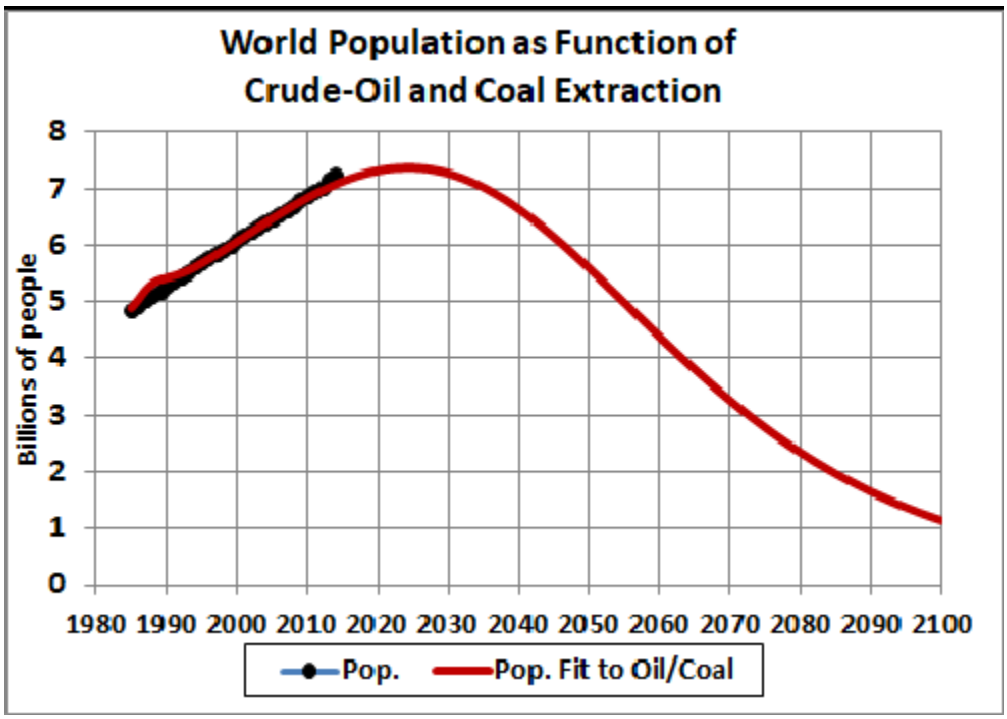
As a result, at that exponential rate, electricity generated from renewable sources will exceed electricity production from each of coal, nuclear and natural gas before year 2030, at least in the U.S. and several other countries:



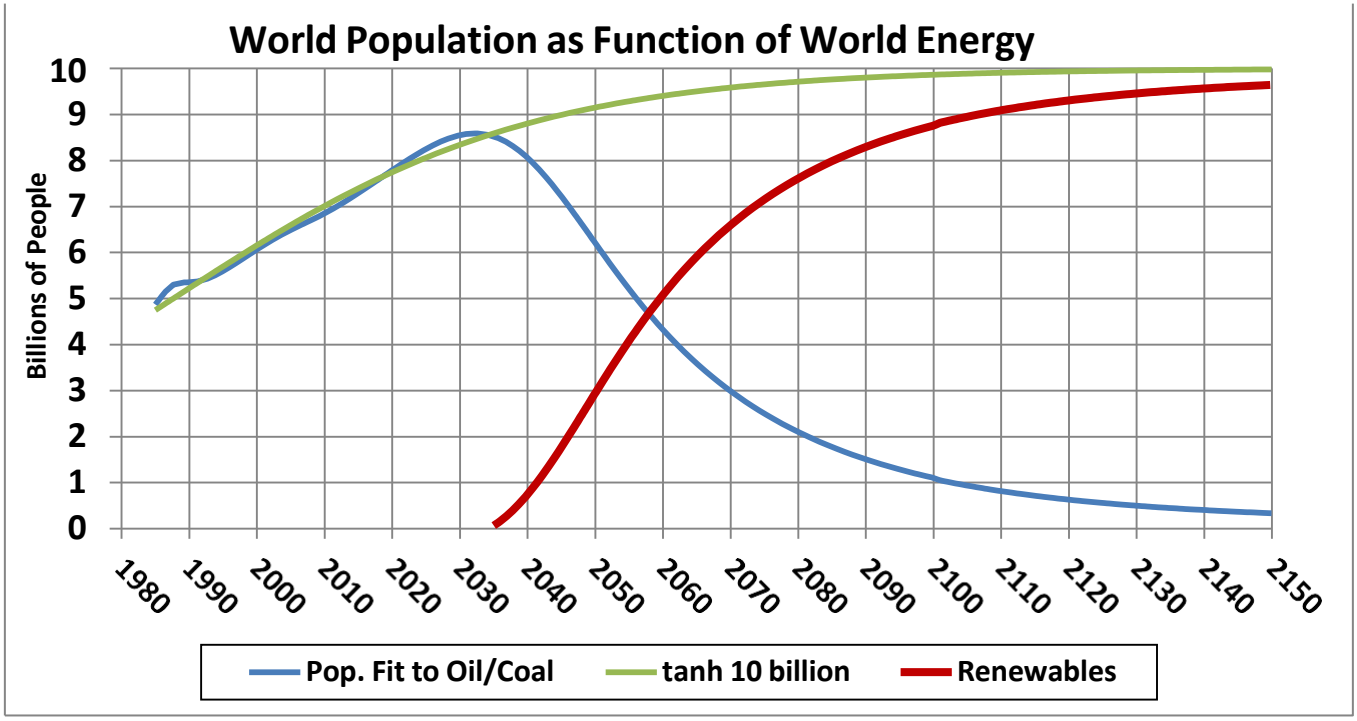
The solid curves are linear fits; the dotted red curve for natural gas falls due to U.S. natural gas peaking.

Similar curves will likely occur in other countries at different years in the future.

If this exponential rate of increase in renewable energy continues and lack of energy is the main cause of collapse, this is more than enough to prevent collapse. To see that this is so, consider the graphs shown below:



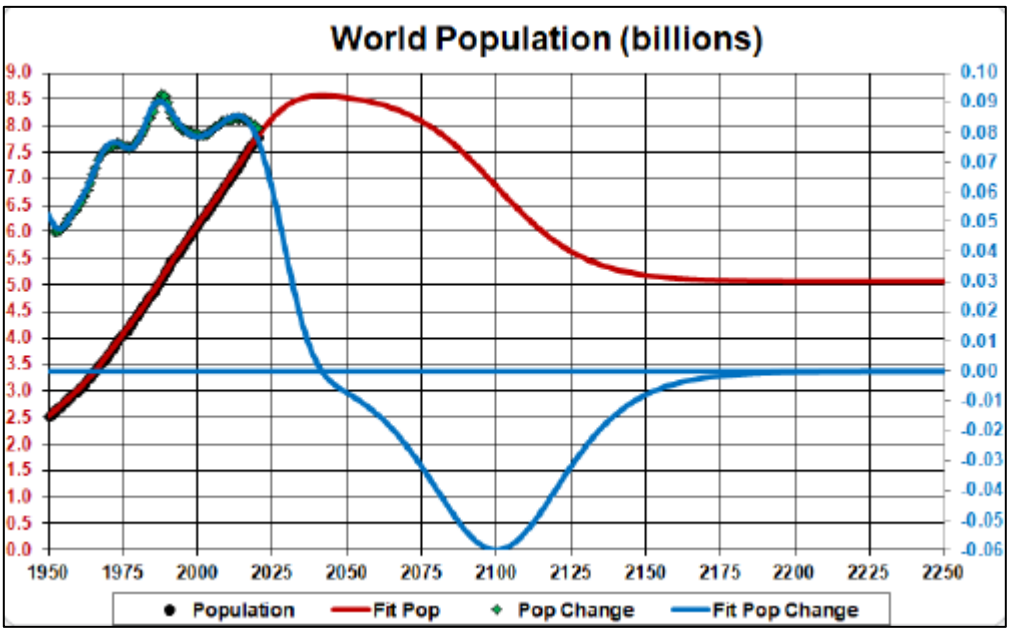
Fit a hyperbolic tangent function (http://www.roperld.com/science/Mathematics/HyperbolicTangentWorld.htm) to the curve up to year 2030 and with asymptote 10 billion people (green curve). Then the difference between the green curve and the blue curve (fit to fossil-fuels extraction) represents the amount of renewable energy that must be achieved, the red curve.



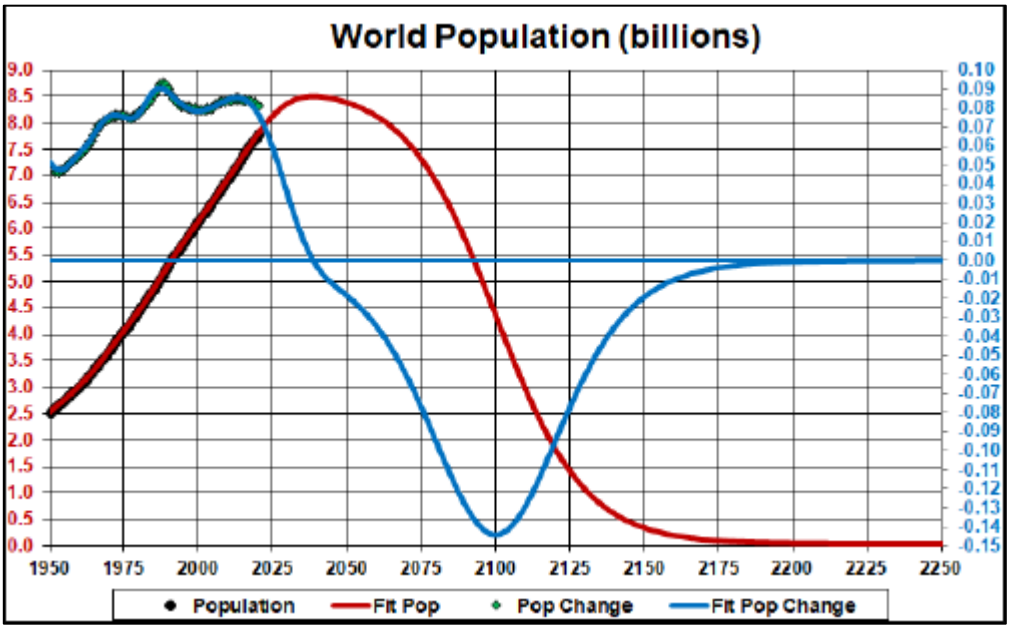
The exponential rate for the red curve is about 25 years, much longer than the ~7 years of renewable energy increase for the U.S. So, if the entire world can follow the U.S. lead, population collapse can be avoided as far as energy use is concerned.

However, collapse due to Global Warming will likely occur if all possible fossil fuels are burned for fuel. It appears that renewable energy could occur fast enough to replace fossil fuels to prevent collapse due to Global Warming. The world needs a carbon fee for dumping carbon into the atmosphere to limit the burning of fossil fuels.

Of course, the possibility of collapse due to extraction of material resources peaking still would likely occur. Humans will have to figure out how to provide material needs from plants; i.e., from the Sun. There needs to be a detailed study of how this might be possible. This author thinks that an asymptotic population as high as 10 billion would not be possible; he guesses it will more likely be less than 5 billion people. Here is what a collapse to 5 billion might be:



The scale for population change (blue curve) is on the right. Note that the recent population-increase drop continues and eventually become a population decrease and finally level off to a constant population of 5 billion. Of course, there may be several oscillations in population change over time. It is possible that humans will completely die off:



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