Carbon Budget
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A "carbon budget " is defined as the amount of CO2 that the atmosphere can hold to provide a 66% chance that the increase of the Earth's average temperature can be kept below 2°C (3.6°F).

Assuming a "climate sensitivity" of about 3*°C* for a doubling of atmospheric CO2, we need to limit atmospheric CO2 concentrations to about 450ppm. We are currently at about 400ppm and adding about 2.1ppm per year. It is estimated that we can only emit another 280 billon tons of carbon before atmospheric CO2 concentrations reaches 450ppm. Since we currently emit about 10GTC/year and the rate is increasing, this could happen in less than 25 years.

Assumptions:

1. The Earth has warmed 0.8 degrees Celsius since pre-industrial times
2. About 45% of annual CO2 emissions remain in the atmosphere
3. Climate sensitivity is very likely about 3 degrees C for a doubled CO2
4. A 2 degree C increase will most likely cause significant climate disruption
    a. Recent studies indicate that even 1 degree C increase will be harmful
    b. Limiting the rise to 2 degrees C is seen as impossible

Concentrations and Emissions

1. The pre-industrial CO2 concentration was about 280 parts per million (ppm)
2. The current CO2 concentration is about 400 parts per million
3. The CO2 concentration is growing at about 2.3 ppm/year
4. The Earth's atmosphere contains about 830 gigatons of carbon (GTC)
5. Current CO2 emissions are about 10GTC/year
6. CO2 emissions are increasing at about 3%/year

Calculations

- To limit the increase to 2 degrees C, CO2 must be less than 450 ppm
- Total atmospheric CO2 must be limited to about 954 GTC
- Total atmospheric CO2 must not increase more than about 125 GTC
- The carbon emissions budget to keep within 2 degrees C warming is 280 GTC
- At current accelerating rate of emissions, the emissions budget will be exceeded in 2030
- If we consume all known fossil fuel reserves (not including either "recoverable resources" or undiscovered fossil fuels)
    - The Earth's atmosphere will contain about 1200GTC
    - The CO2 concentration will be about 580ppm
    - The equilibrium temperature will increase over 3 degrees C just from the CO2

Conclusions

- **We have to leave a significant portion (2/3) of known fossil fuels reserves in the ground**
- Hitting 800 to 1,000+ ppm — which is our current emissions path and the inevitable outcome of aggressively exploiting unconventional fuels like the tar sands — represents the near-certain destruction of modern civilization as we know it *as the recent scientific literature makes chillingly clear (Romm/McKibben/Hansen)*

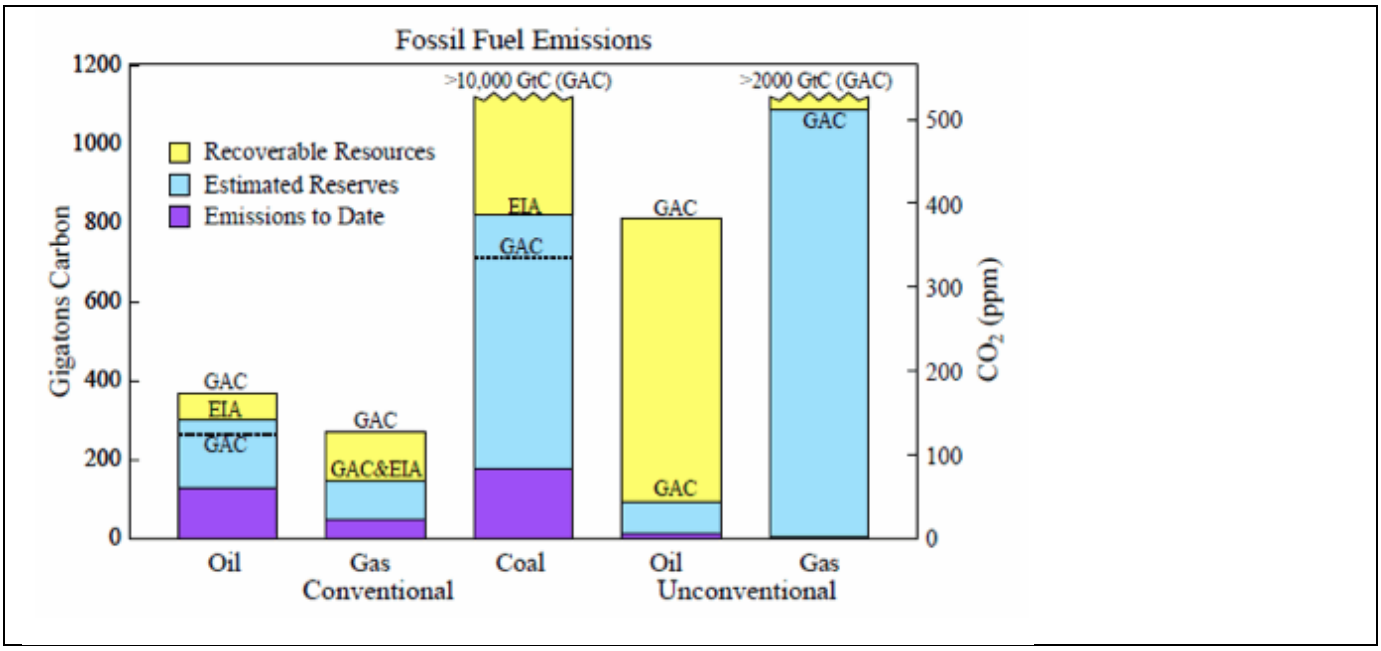
Accurate estimates of proven fossil fuel reserves are hard to come by.

Fossil Fuel Reserves http://www.iea.org/Textbase/npsum/resources2013SUM.pdf

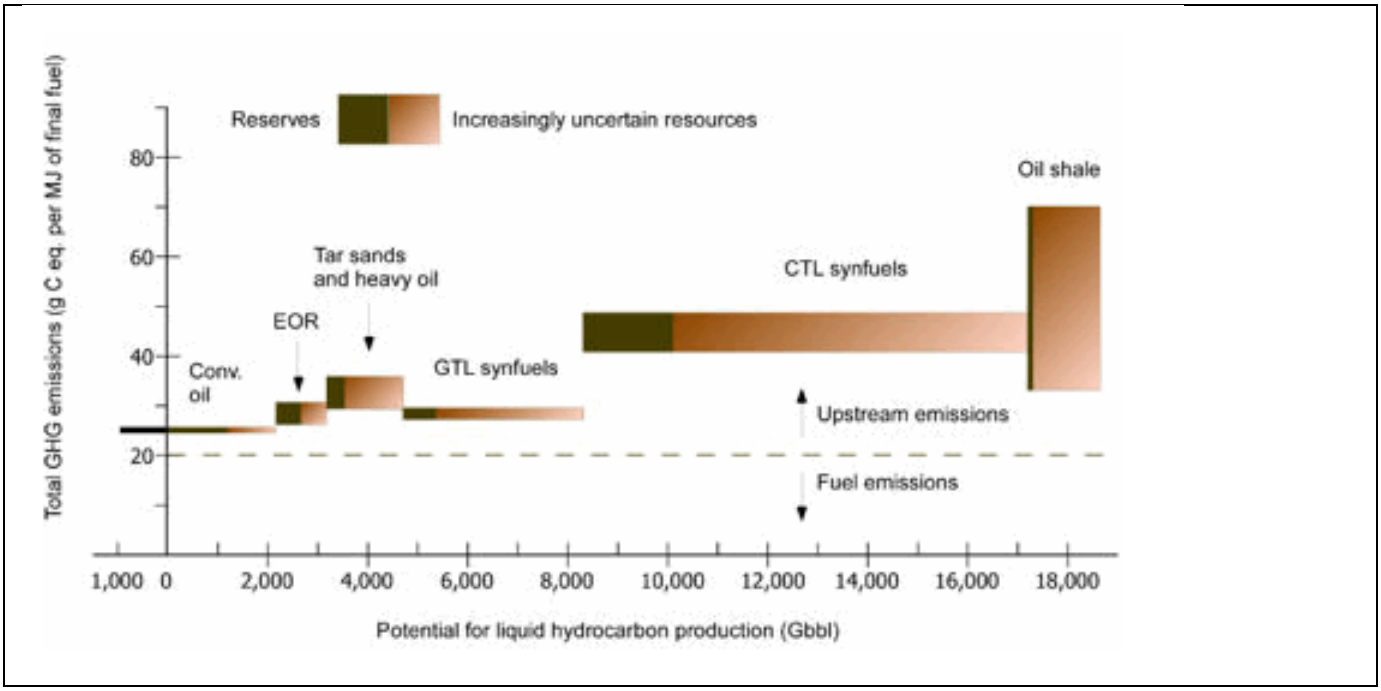
		Proven Reserves		Recoverable Resources		2010 Consumption		Total GTC thru 2030 at 3% growth
Source	GTC Factor		GTC Carbon		GTC Carbon		GTC	
Conventional Oil (trillion barrels)	117	1.3	152	2.7	316	.031	3.64	104
Unconventional Oil (trillion barrels)	117	.4	47	3.2	374	.0005	.06	2
Conventional Gas (trillion cubic meters)	.5454[1]	220	120	460	250	31.4	2	57
Unconventional Gas (trillion cubic meters)	.5454[1]			330	180			
Coal (gigatons)						7.27	4.3	123
Coal – Hard (gigatons)	.526[1]	730	384	3650	1920			
Coal – Soft (gigatons)	.382[1]	280	107	1600	611			
Total			**810**		**3561**		**10**	**286**

1. **https://www.theice.com/publicdocs/ccx/CCX_GHG_Factors.pdf**

Fossil fuels are abundant in many regions of the world and they are in sufficient quantities to meet expected increasing demands. However, most of them are still classified as resources and not yet as reserves. This distinction is important as it reflects the likelihood that the fossil fuels will be brought to the market. Resources are those volumes that have yet to be fully characterised, or that present technical difficulties or are costly to extract, for example where technologies that permit their extraction in an environmentally sound and cost- effective manner are still to be developed. Reserves are those volumes that are expected to be produced economically using today's technology; they are often associated with a project that is already well-defined or ongoing. As the more accessible, conventional supplies are exhausted, so more technically demanding resources will need to be exploited



CO2 emissions by fossil fuels [1 ppm CO2 ~ 2.12 GtC, where ppm is parts per million of CO2 in air and GtC is gigatons of carbon] via Hansen. Significantly exceeding 450 ppm risks several severe and irreversible warming impacts. [Estimated reserves and potentially recoverable resources are from EIA (2011) and GAC (2011).]



X-axis is the range of potential resource in billions of barrels. Y-axis is grams of Carbon per MegaJoule of final fuel. [Graph source: Farrell and Brandt, "Risks of the oil transition," 2006.]

(Image source: http://thinkprogress.org/romm/2012/02/13/423525/joe-nocera-wrong-unfair-keystone-xl-tar-sands-pipeline-mckibben-hansen-explain-why)

Three numbers (part of a major educational campaign by 350.org)

2 - the number of degrees of increase in temperature that was considered "safe" (recent thinking lowers this to 1 degree, and we are already at .8 degrees C)
565 - the number of gigatons of co2 that can be added to the atmosphere before "locking in" a 2 degree C rise
2795 - the number of gigatons of CO2 that will be released if all know fossil fuel reserves are burned

Therefore at least 2/3 of all fossil fuel reserves must be left in the ground - and what are the implications for the fossil fuel industry when this is finally recognized?

And the "limit" will be reached in less than 20 years at current emission rates

References:

1. The Earth has warmed 0.8 degrees Celsius
    a. http://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php
2. About 45% of annual CO2 emissions remain in the atmosphere
    a. http://cdiac.ornl.gov/pns/faq.html
    b. https://public.ornl.gov/site/gallery/detail.cfm?id=313&topic=&citation=24&general=&restsection=
    c. http://www.global-greenhouse-warming.com/anthropogenic-climate-change.html
3. Climate sensitivity is very likely about 3 degrees C for a doubled CO2
    a. http://www.skepticalscience.com/detailed-look-at-climate-sensitivity.html (Skeptical Science: A detailed look at climate sensitivity)
    b. http://thinkprogress.org/romm/2009/12/21/205242/agu-richard-alley-explains-biggest-control-knob-carbon-dioxide-in-earths-climate-history/((Richard Alley explains "The Biggest Control Knob: Carbon Dioxide in Earth's Climate History")
    c. http://web.mit.edu/newsoffice/2010/explained-climate-sensitivity.html (Explained: Climate sensitivity (From MIT Global Change)
4. A 2 degree C increase will most likely cause significant climate disruption
    a. http://www.ucsusa.org/assets/documents/global_warming/climate-costs-of-inaction.pdf (UCS - Climate Change in the United States - The Prohibitive Costs of Inaction)
    b. http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf (Global Climate Change Impacts in the United States)
    c. http://www.ucsusa.org/assets/documents/global_warming/us-global-climate-change-reportsoutheast.pdf (Global Climate Change Impacts in the United States (2009) - Southeast Assessment (Includes Virginia)
5. Recent studies indicate that even 1 degree C increase will be harmful
    a. http://www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf (Paleoclimate Implications for Human-Made Climate Change)
6. Tar Sands - We have to leave a significant portion of fossil fuels in the ground
    a. http://thinkprogress.org/romm/2012/02/13/423525/joe-nocera-wrong-unfair-keystone-xl-tar-sands-pipeline-mckibben-hansen-explain-why/
7. Carbon Budget
    a. http://www.nature.com/nclimate/journal/v1/n9/full/nclimate1302.html (Long-term climate implications of twenty-first century options for carbon dioxide emission mitigation)