The end of cheap fossil fuels

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Global Monitoring Annual Conference
20 May 2013
Boulder, CO

British coal production history

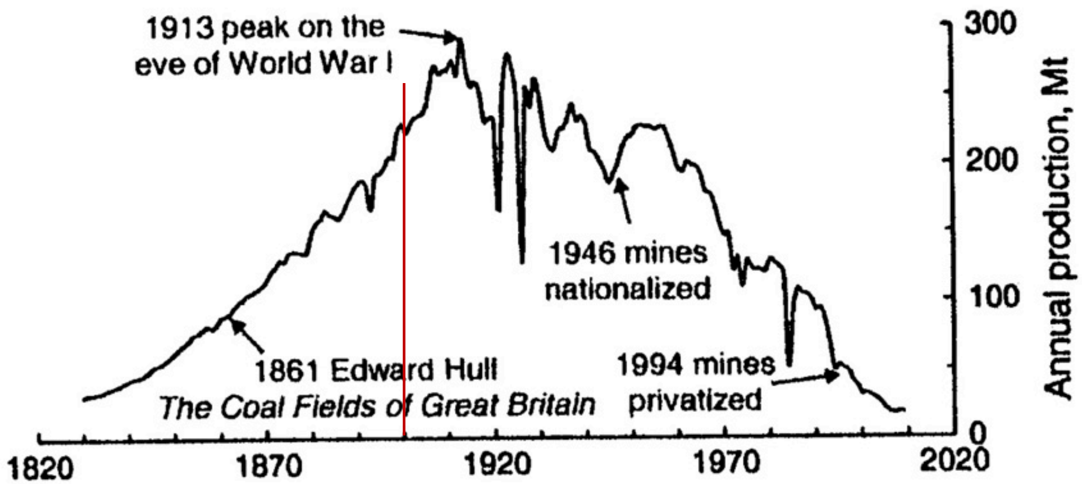


Fig. 1. British coal production (Mitchell, 1998b, for production through 1980, and BP, 2010 for more recent production).

David Rutledge, Int. J. Coal Geology, 2011

HOW MUCH ARE WE LIKELY TO BURN?

Rate of production = $dq/dt = kq(1-q/Q)$
Cumulative production: $q(t)$
Ultimate production: Q

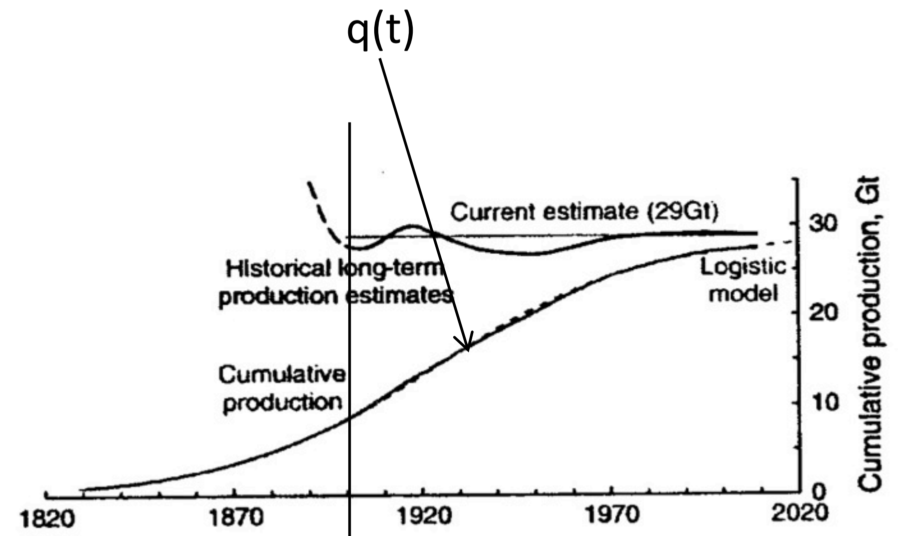
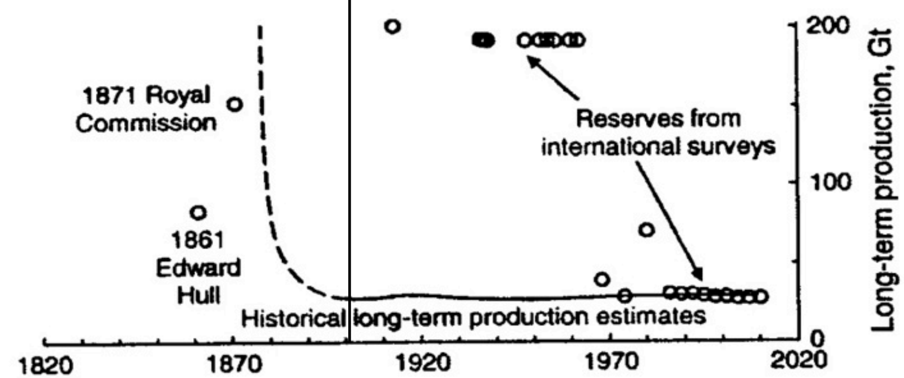


Fig. 5. Historical long-term production estimates for British coal. The cumulative production and the logistic model are shown for comparison.

Q is estimated by fitting the logit transform of the data for different values of Q to a straight line:

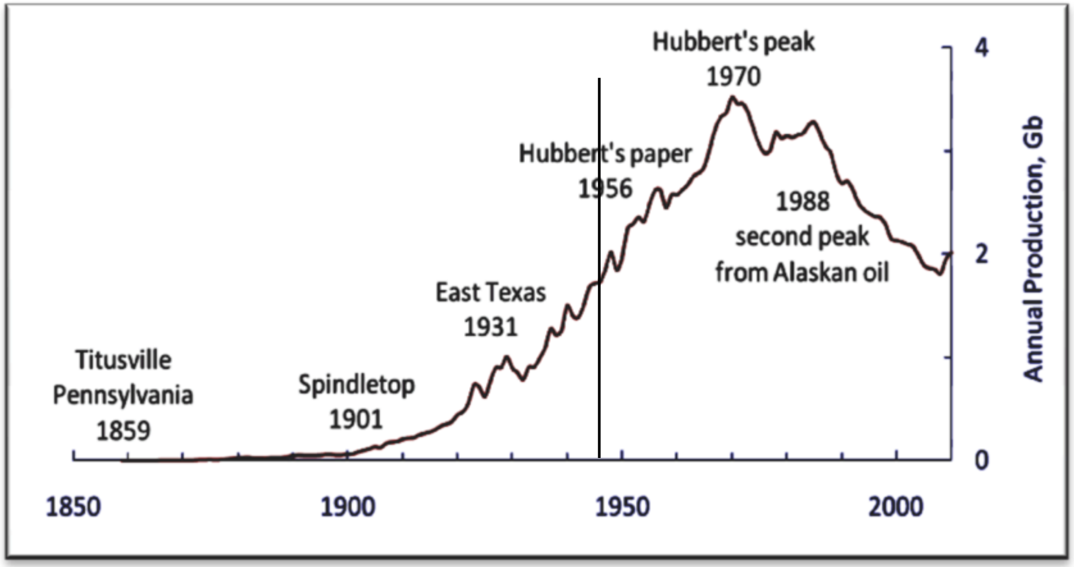
$$ {}^{e}\log\left(\frac{q(t)/Q}{1-q(t)/Q}\right) \rightarrow Q=29 \text{ Gton coal} $$



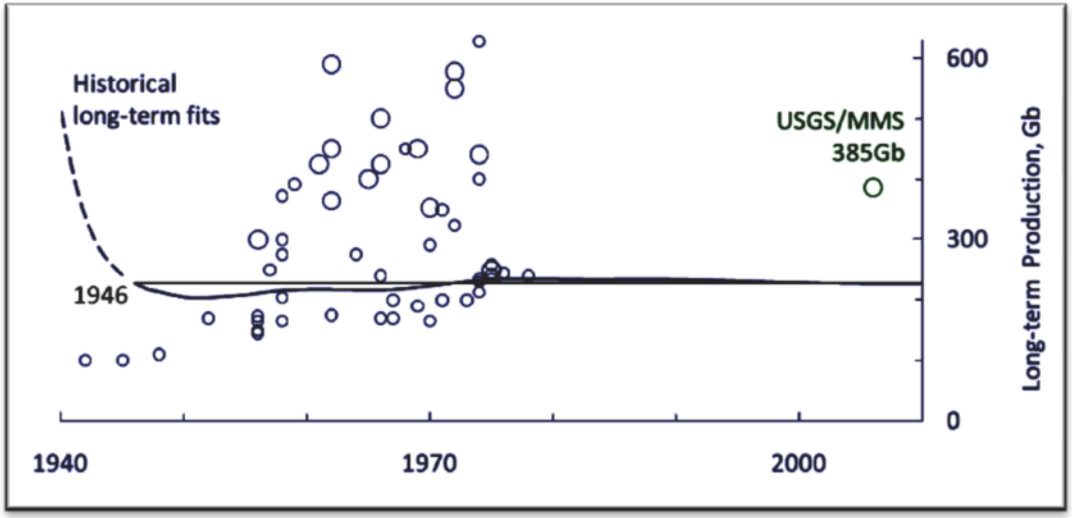
	year when historical projections stabilize	percent of total production consumed
UK	1900	31
Australia	1995	12
China	2000	23
South Africa	1955	16
Western US	1995	20

HOW MUCH ARE WE LIKELY TO BURN?

U.S. oil and gas production history

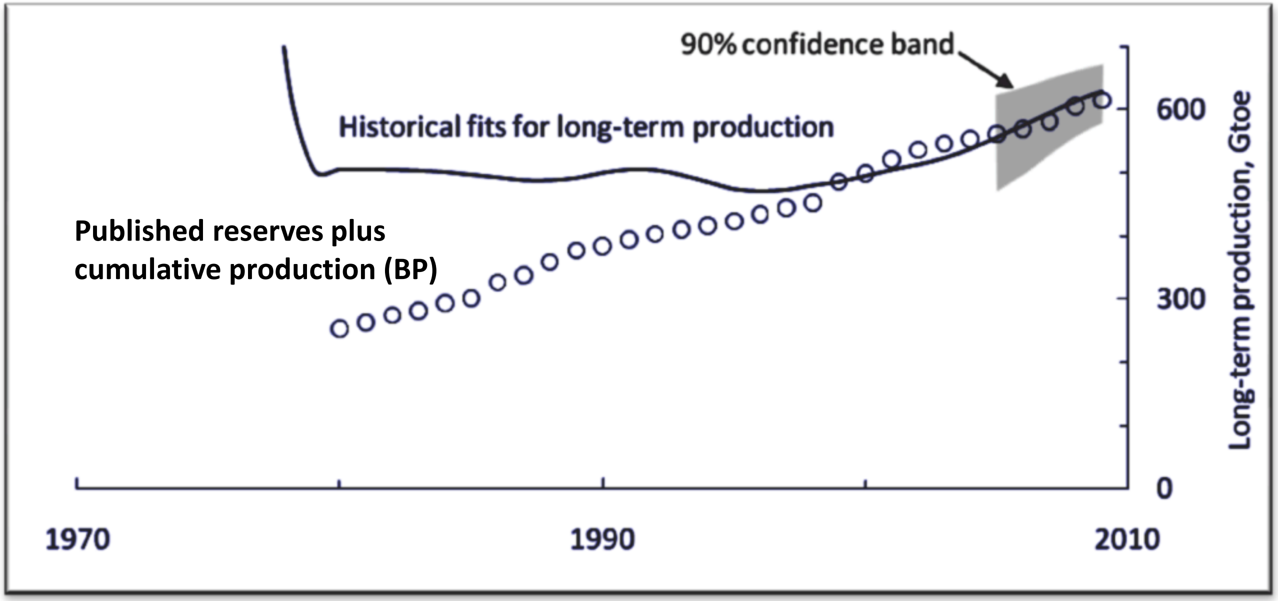


U.S. oil and gas projection and reserve estimates



HOW MUCH ARE WE LIKELY TO BURN?

Global oil and gas projection



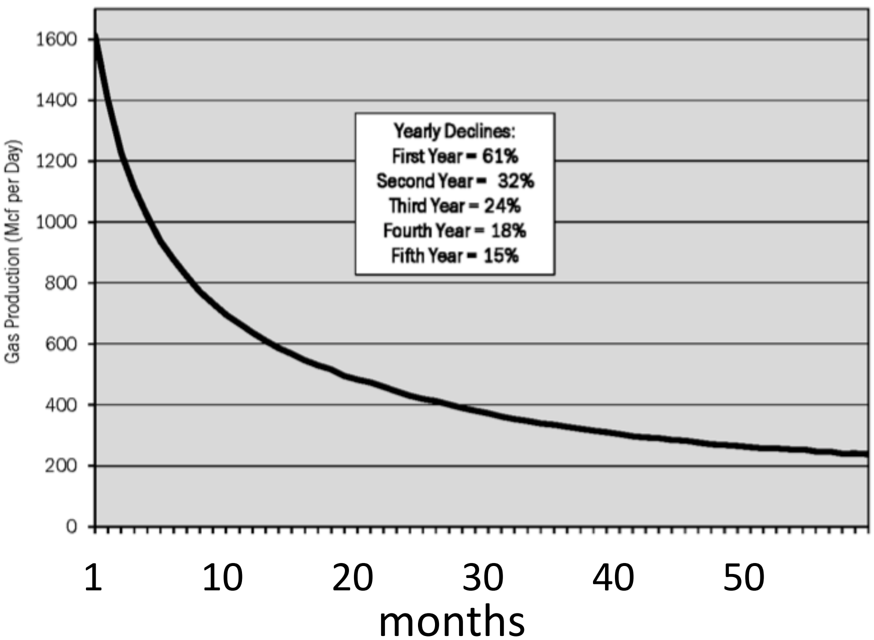
Projections translated to carbon emissions (billion metric ton C):

	cumulative production	reserves + cumul.prod.	long-term projection	range
oil & gas	193	467	495	362-495
coal	172	629	390	361-410
total	364	1069	885	743-885

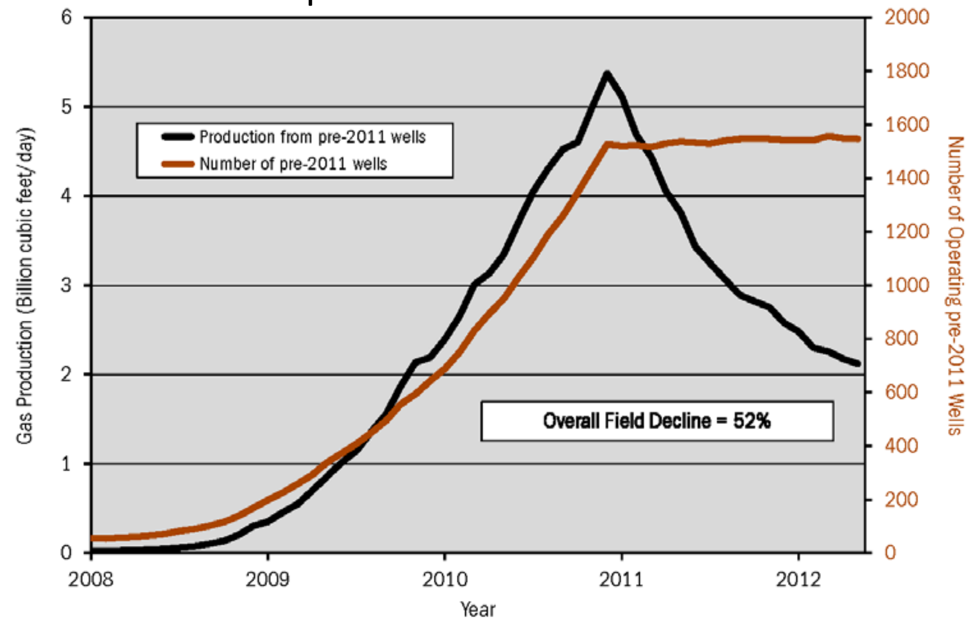
Source: David Rutledge, priv. communication

HOW MUCH ARE WE LIKELY TO BURN?

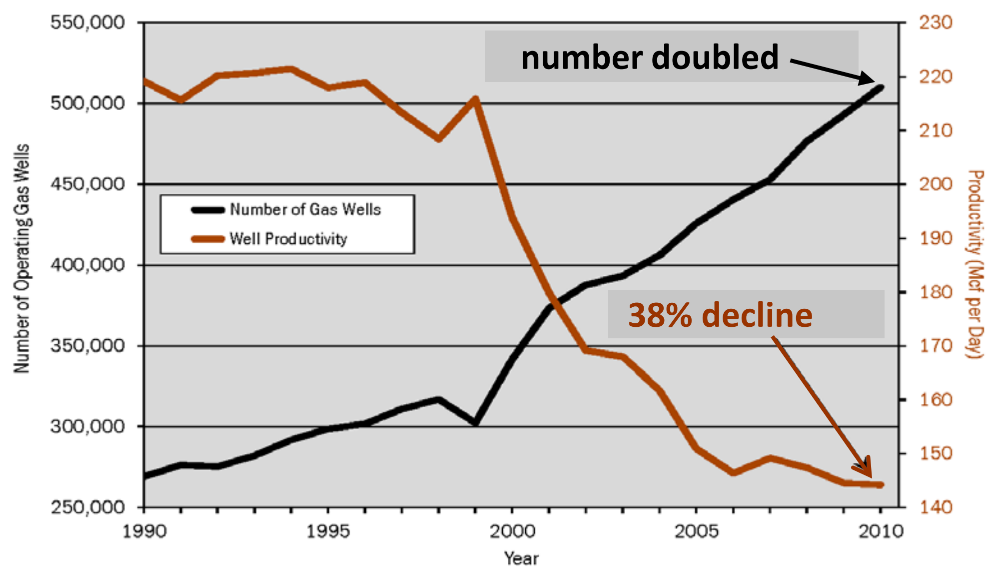
Typical decline curve for shale gas wells in the Barnett play.



Haynesville play: declining production of wells drilled prior to 2011



Operating U.S. gas wells and average productivity



One has to drill new wells every year just to stay even.

Source: J.D. Hughes, “Drill, baby, drill” Feb 2013, Post Carbon Institute

HOW MUCH ARE WE LIKELY TO BURN?

"Sweet spots" in Barnett play

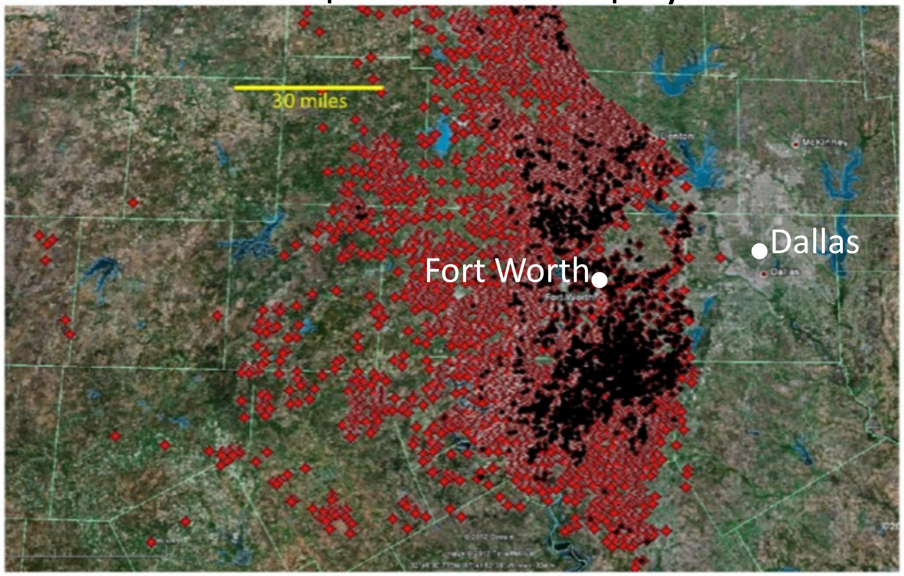


Figure 51. Distribution of wells in the Barnett play.[97]
Wells in black are the top 20 percent in terms of initial productivity. Many of these sites are multi-well pads with two or more wells. The highest-productivity wells tend to be concentrated in "sweet spots."

After the best spots have been found, the productivity of new wells starts declining

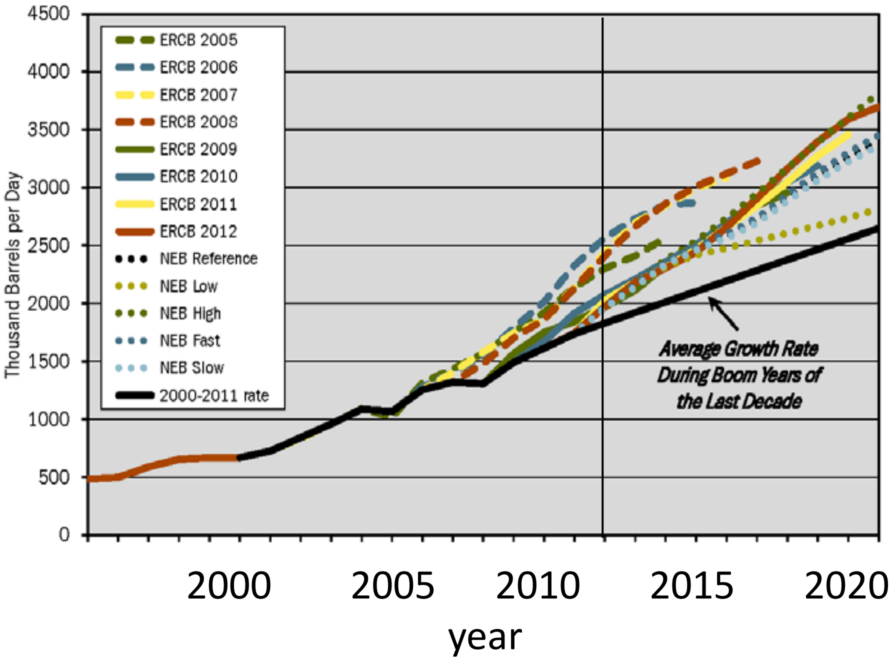
Seven largest shale gas producing regions

Field	Rank	Number of Wells needed annually to offset decline	Wells Added for most recent Year	October 2012 Rig Count	Prognosis
Haynesville	1	774	810	20	Decline
Barnett	2	1507	1112	42	Decline
Marcellus	3	561	1244	110	Growth
Fayetteville	4	707	679	15	Decline
Eagle Ford	5	945	1983	274	Growth
Woodford	6	222	170	61	Decline
Granite Wash	7	239	205	N/A	Decline

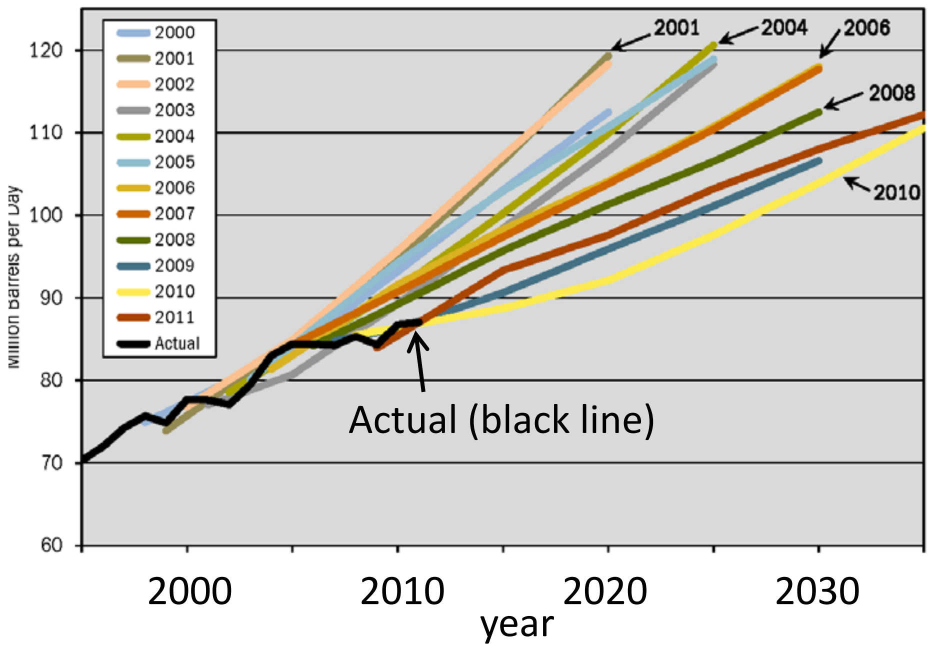
Source: J.D. Hughes, "Drill, baby, drill" Feb. 2013, Post Carbon Institute

HOW MUCH ARE WE LIKELY TO BURN?

Tar sands projected and actual production increase



EIA world oil production forecasts

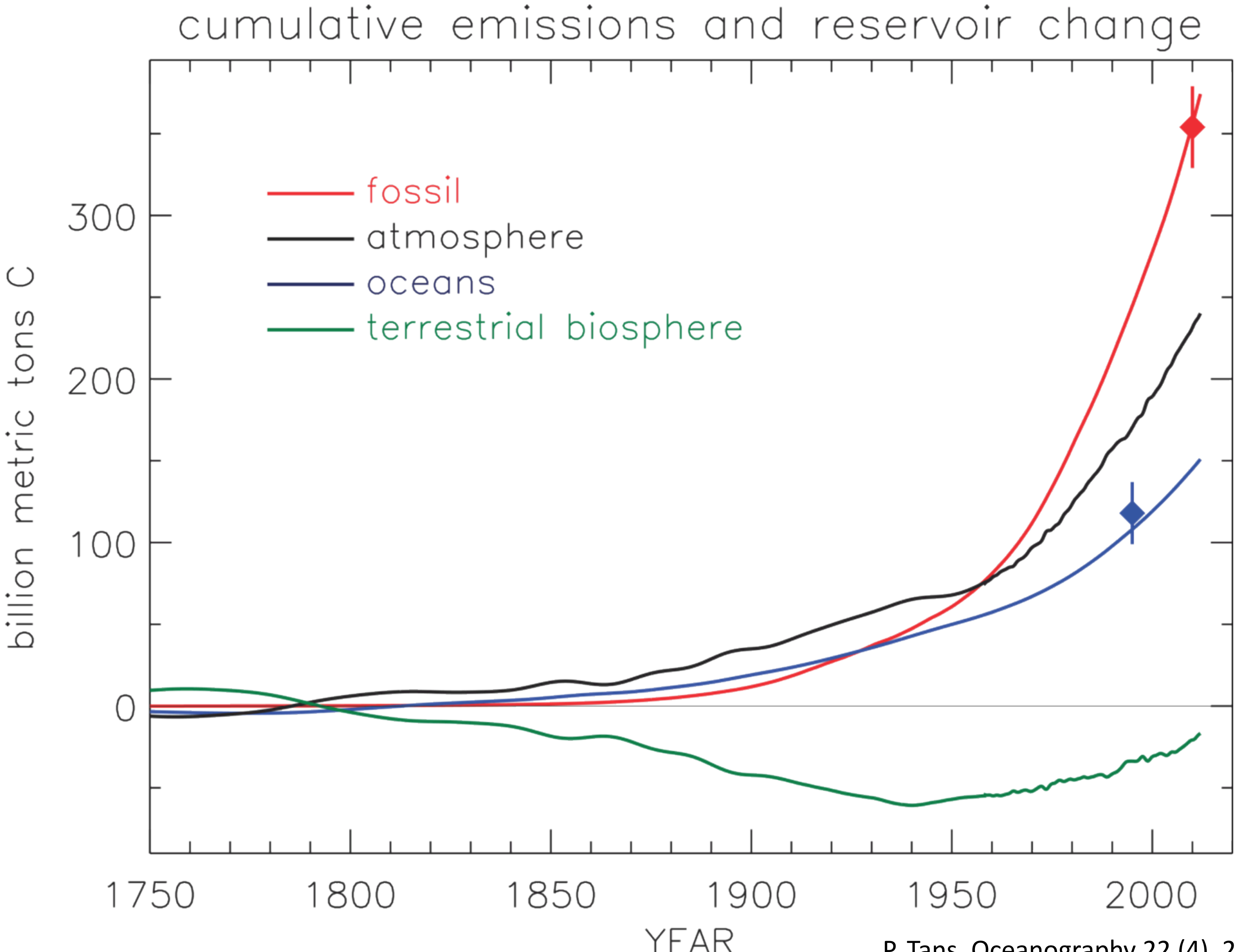


Energy return on energy invested
(not including transportation, refining, distribution)

old conventional oil	100:1
new conventional oil	25:1
mineable tar sands	4.5:1
in-situ tar sands	2.4:1
ethanol from corn	1.3:1

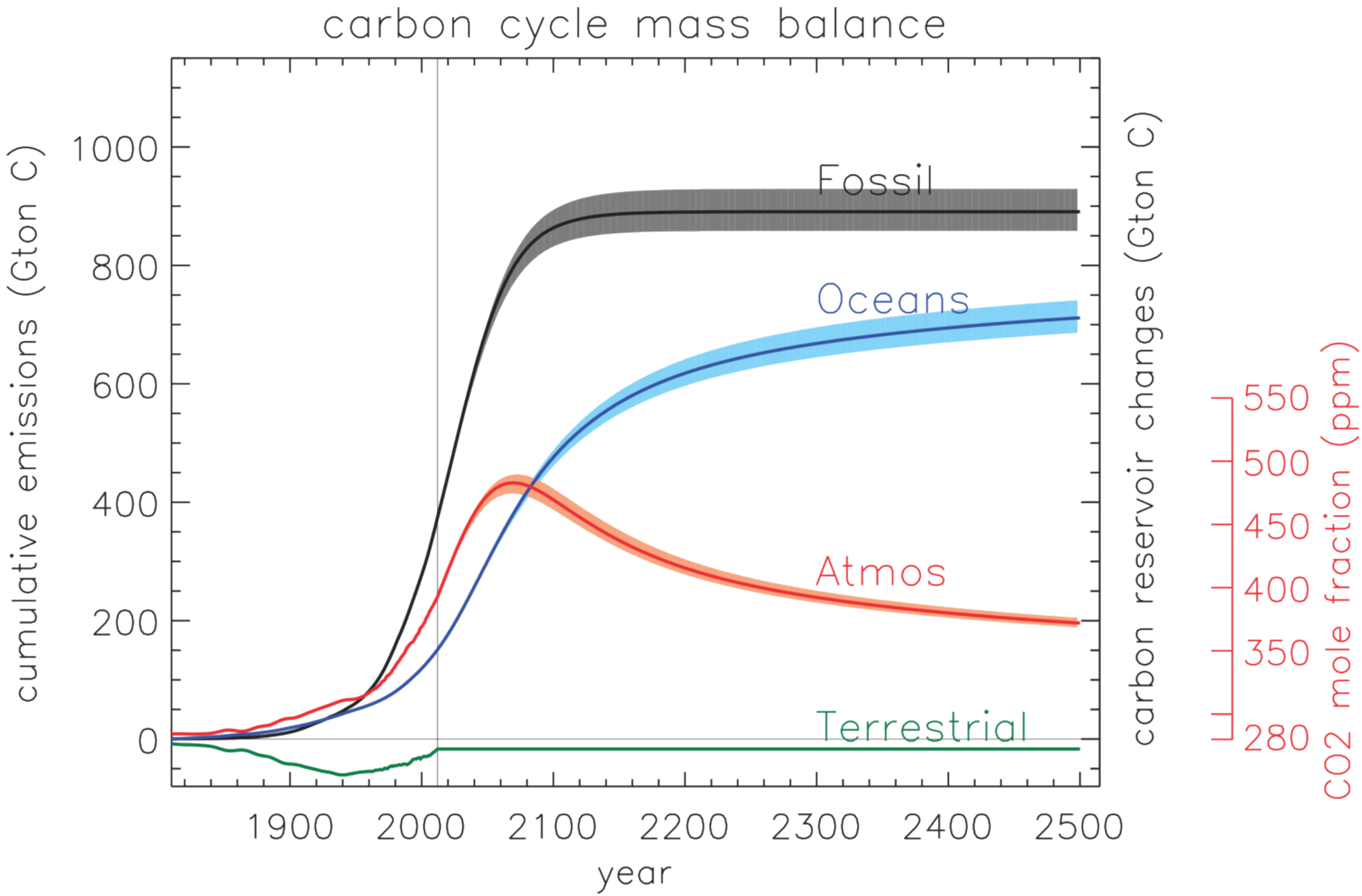
Source: J.D. Hughes, “Drill, baby, drill” Feb. 2013, Post Carbon Institute

THE CARBON CYCLE

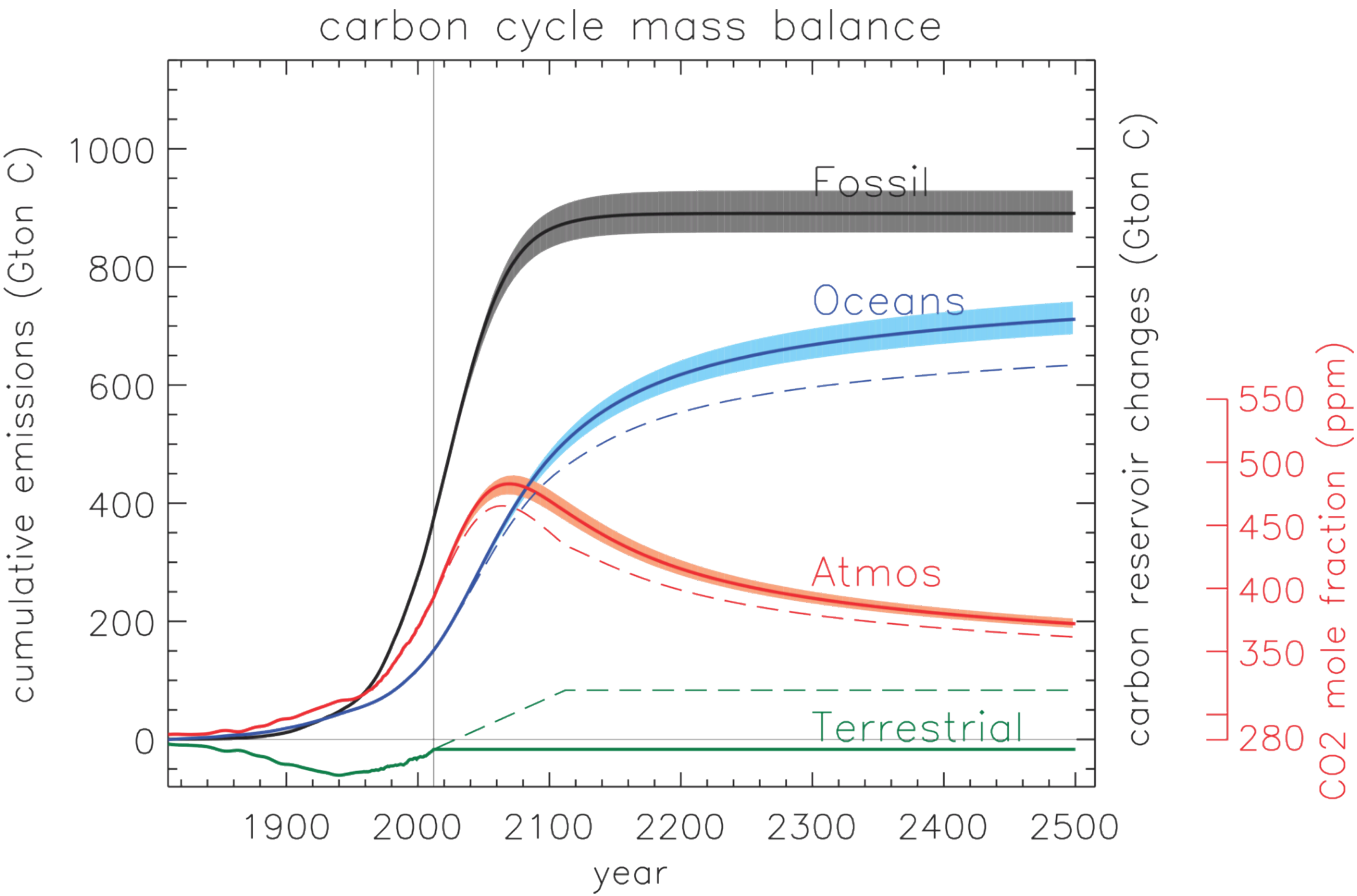


P. Tans, Oceanography 22 (4), 26-35, 2009.

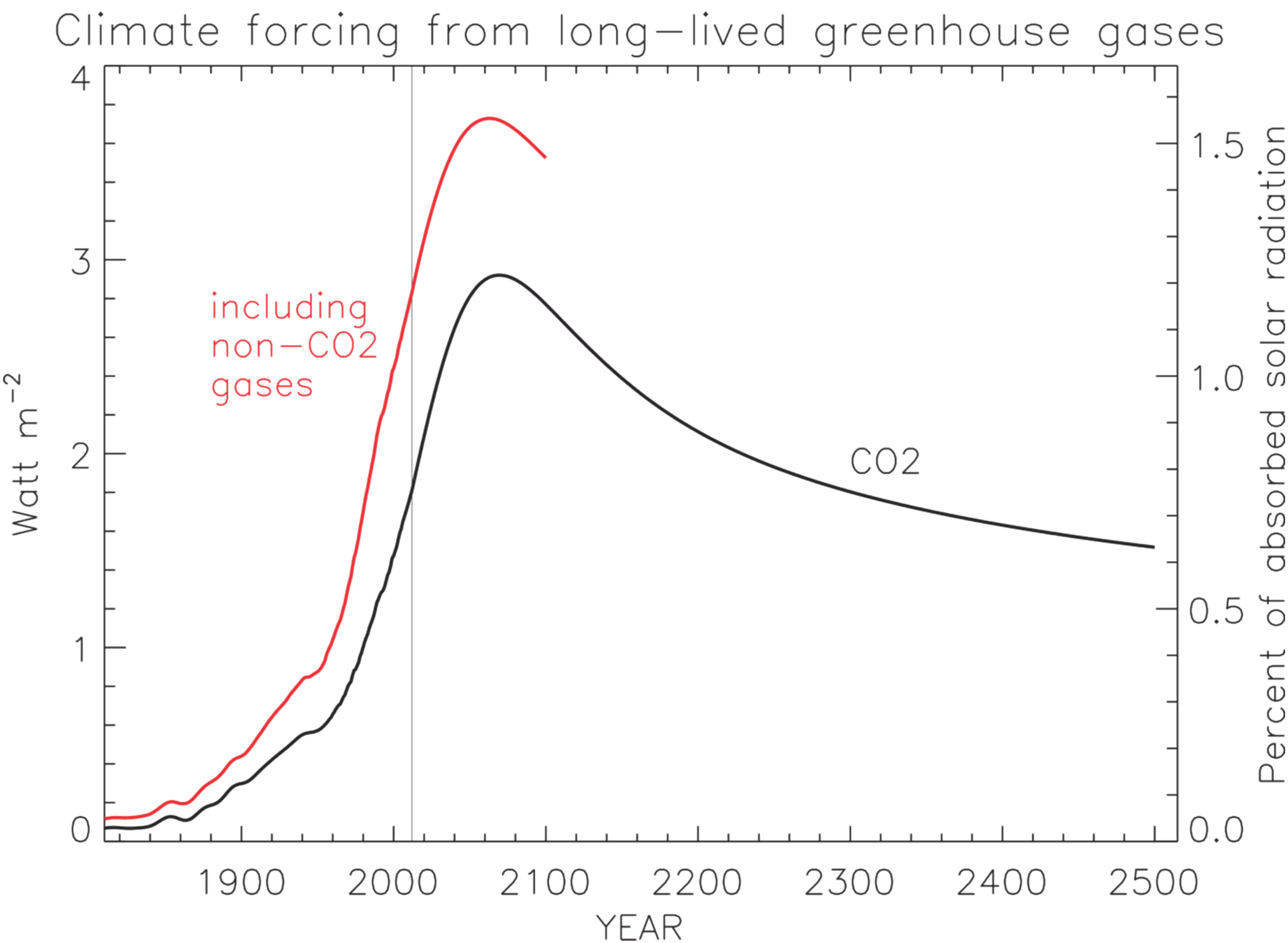
THE CARBON CYCLE



THE CARBON CYCLE



FORCING OF CLIMATE CHANGE



Our predicament:

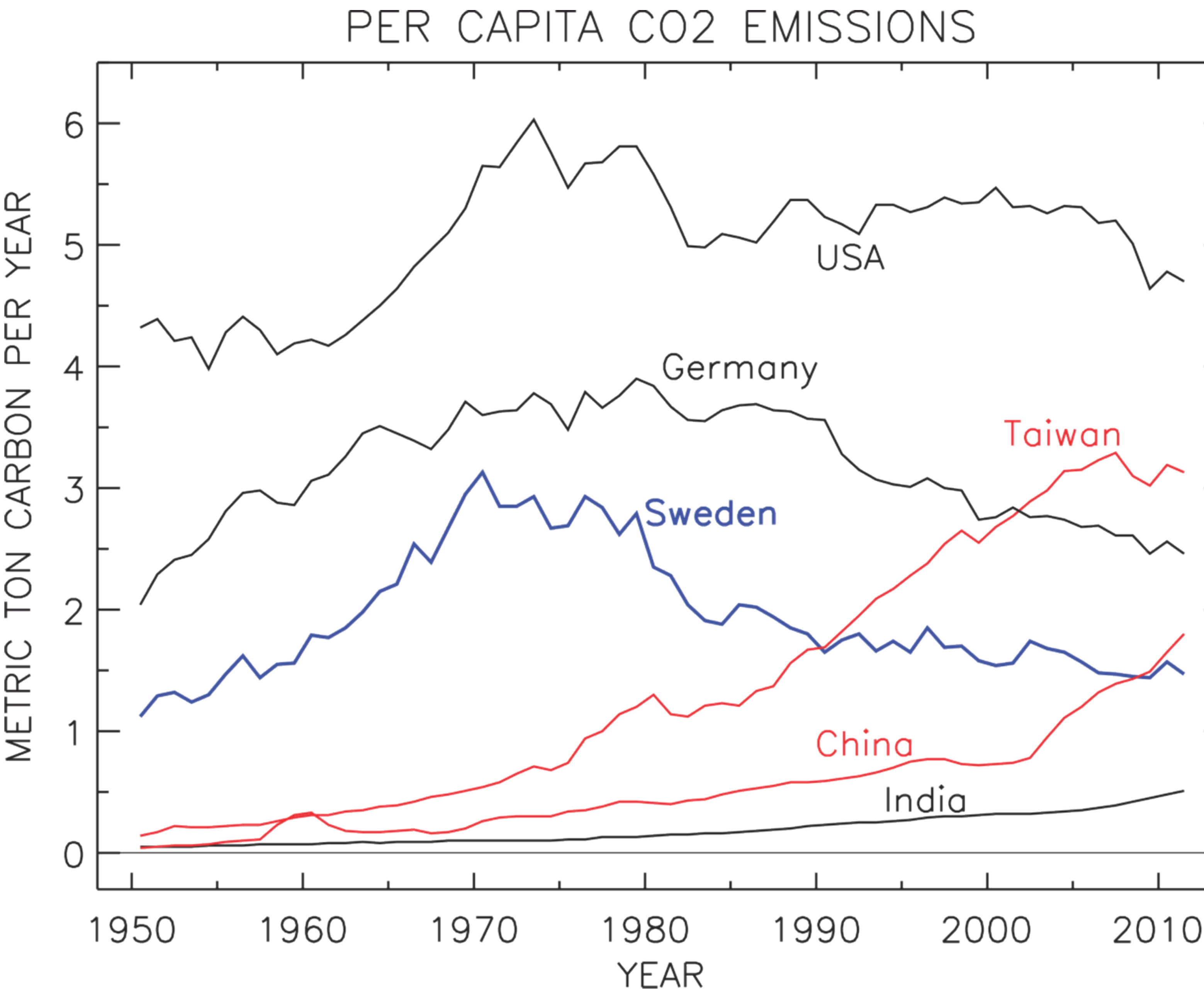
To minimize the probability of catastrophic climate change emissions will have to be lowered at an aggressive pace. Net CO_2 emissions have to go to zero or negative.

Most emissions until now have come from the developed countries.

Developing countries will likely cause most of the future emissions.

We need a demonstration that development with *very* low emissions is an attractive option.

WE KNOW HOW TO DECREASE EMISSIONS



Several countries have demonstrated that development with much lower emissions is entirely feasible, with technology already known in the 1970s, and that it can be managed responsibly at an aggressive pace.

Independent of the threat of climate change, this is our choice:

We can let ourselves be *forced* to decrease emissions though recurring supply shortages, causing recurring economic recessions, strongly fluctuating prices, unemployment and poverty,

or

We adopt an energy policy to manage an orderly transition to zero carbon emissions.