Of the historical net emissions from 1800 to 1994 (244 + 39 = 283 Pg carbon), Sabine *et al.* (2004) estimated that about 58% ended in the atmosphere and 42% ended in the oceans. It has been suggested that over the past two decades, about half of net emissions remained in the atmosphere and half was taken up by the oceans. Douglass (2005) pointed out that the common approach is to treat nature as unchanging, and attribute all increases in atmospheric CO_2 concentration to anthropogenic sources. However, he argued that natural emissions of CO_2 increased in the latter part of the 20th century due to prevalence of El Niños that raised surface ocean temperatures, and some major volcanic eruptions that emitted large amounts of CO_2. When these factors were taken into account, he found that some of the increase of the late twentieth century atmospheric CO_2 was due to natural causes. After taking this into account, he concluded that the rate of increase of the late twentieth century atmospheric CO_2 concentration was approximately constant at around 44% of nominal anthropogenic emissions. In addition, he argued that massive coal fires in northern China and biomass burnings have added large amounts of CO_2 to the anthropogenic side of the ledger. Thus, his estimate of anthropogenic CO_2 emissions is greater than other estimates, and he concluded that only about 30% of late twentieth century CO_2 emissions from anthropogenic sources (other than biomass burnings) ended up in the atmosphere. This is considerably lower than the nominal figure 50% that is often used.

However, as we discuss in Sections 5.2.8 and 7.3.4, even the transitions between glacial and interglacial states may be initiated by solar inputs to high northern latitudes, the expansion of regional effects to a global climate change requires strong forcings via albedo changes (ice sheets, sea ice, expansion of land area, vegetation changes) as well as greenhouse gas effects. Several investigators (e.g. Hansen and Sato, 2011) have estimated the greenhouse gas effect in transitions between glacial and interglacial states and found that the greenhouse gas effect provides roughly half of the total forcing needed for such a transition. Soon’s claim that solar influences exceed the greenhouse effect by several fold cannot be correct.

Visser *et al*. (2003) found that sea surface temperatures decreased by larger amounts in the LGM than others had estimated, and thereby suggested that “a substantial portion of the atmospheric decrease in CO_2 during glacial periods” could be attributed to a simple difference in solubility. They based this on a previous estimate that “for a 1°C increase in temperature, the equilibrium partial pressure of CO_2 exerted by seawater increases by 11–16 ppm”. However, Sigman *et al*. (2010) concluded:

> “Global climate and the atmospheric partial pressure of carbon dioxide (pCO_2) are correlated over recent glacial cycles, with lower pCO_2 during ice ages, but the causes of the pCO_2 changes are unknown. The modern Southern Ocean releases deeply sequestered CO_2 to the atmosphere. Growing evidence suggests that the Southern Ocean CO_2 ‘leak’ was stemmed during ice ages, increasing ocean CO2 storage. Such a change would also have made the global ocean more alkaline, driving additional ocean CO_2 uptake. This explanation for lower ice-age pCO_2, if correct, has much to teach us about the controls on current ocean processes”.

6.1.4 CO_2 and global warming

It has been estimated that an increase of CO_2 concentration from 280 ppm to 560 ppm will produce a forcing of roughly 4 W/m^2 and the climate sensitivity neglecting feedbacks and secondary processes is roughly 0.3°C per W/m^2 (Hansen and Sato, 2011). Hence the expected global average temperature rise for a hypothetical Earth that did not change in any other way except to warm, would be about 1.2°C. Many studies have attempted to estimate the climate sensitivity taking into account all feedbacks and secondary processes. Because of uncertainties in estimating these effects, climate models have produced a wide range of estimates ranging from about 2°C to about 10°C. As we pointed out in Section 5.2.2.4, Roe and Baker (2007) showed that the predicted temperature rise is very sensitive to assumed feedback factors at the high end, leading to great uncertainty in the results. Hansen *et al*. (2008) emphasized the original work of Charney (1979) who came up with an estimate of 3°C ± 1.5°C. Amidst the great uncertainty in climate model predictions, Charney's figure has often been taken as a benchmark, not too great to lack credibility, but large enough to cause concern. Hansen *et al*. (2008) seem to take satisfaction in saying: "Climate models in the current IPCC assessment still agree with Charney's estimate".

Another approach for estimating the temperature rise caused by a doubling of CO_2 from the pre-industrial era utilizes paleoclimatic data, comparing climate parameters at the Last Glacial Maximum with condition in the recent pre-industrial era. As we showed in Section 5.2.8, Hansen and Sato (2011) arrived at a figure of 3°C for the temperature rise due to doubling CO_2. However, other estimates suggest a range from 2 to 3°C. This would seem to erase the high-end tail from climate models.

Schmidt *et al*. (2010) published a paper that said (amongst other things):

> "Ample physical evidence shows that carbon dioxide (CO_2) is the single most important climate-relevant greenhouse gas in Earth's atmosphere. This is because CO_2, like ozone, N_2O, CH_4, and chlorofluorocarbons, does not condense and precipitate from the atmosphere at current climate temperatures, whereas water vapor can and does. Non-condensing greenhouse gases, which account for 25% of the total terrestrial greenhouse effect, thus serve to provide the stable temperature structure that sustains the current levels of atmospheric water vapor and clouds via feedback processes that account for the remaining 75% of the greenhouse effect. Without the radiative forcing supplied by CO_2 and the other non-condensing greenhouse gases, the terrestrial greenhouse would collapse, plunging the global climate into an icebound Earth state."

If you started with an Earth that had no greenhouse gases at all, it would be a very cold earth indeed. Now if you add greenhouse gases (water vapor, CO_2, CH_4, ...) to that hypothetical earth in proportion to how much we have today, you will get the percent contribution that each greenhouse gas makes to the present climate of the earth. Lacis, Schmidt, Ruedy and Miller (2010) carried out a study to estimate this. They found that water vapor accounts for 50%, clouds 25%, and CO_2 20%, with all others amounting to 5% of the total greenhouse effect that produces the present climate compared to how cold it would be if there were no greenhouse gases or clouds at all. There is no reason to doubt these results even though at least some of the authors do have a track record of emphasizing the importance of CO_2.

Given that there are enough water vapor, clouds and CO_2 in the atmosphere to account for 95% of the present greenhouse effect (present temperature compared to what it would be with no greenhouse gases), what were the drivers that caused the present distribution? If you had a cold earth with low humidity and few clouds, permanent non-condensible greenhouse gases will nevertheless act to warm the atmosphere, and therefore, in some sense, CO_2 is more of a controlling factor than humidity and clouds. As CO_2 warms the atmosphere and more water evaporates and more clouds form, they produce an even greater greenhouse effect than CO_2, but CO_2 (via volcanic emissions and such) gets the ball rolling so to speak. In that sense, one must agree with Lacis, Schmidt, Ruedy and Miller (2010) that as the press release states: "Water vapor and clouds are the major contributors to Earth's greenhouse effect, but a new atmosphere-ocean climate modeling study shows that the planet's temperature ultimately depends on the atmospheric level of carbon dioxide". But we did not need their study. It is just common sense. Humidity and clouds will not form on their own. They will occur in response to some other factor warming the atmosphere. However, in addition to responding to CO_2-induced warming, they might also form as a consequence of volcanic emissions, variability of total solar irradiance, variability of solar activity, variability of ocean currents, changes in ocean cycles (e.g. El Niño – La Niña), land development, soot deposition in polar areas, aerosol formation, etc.

Starting from the present (or perhaps from 100 years ago prior to buildup of CO_2 in the industrial era), how much will the global temperature rise if we raise the CO_2 level to say 560 ppm, and what fraction of this temperature rise will be due to rising CO_2? The answer is that directly and indirectly, all of the temperature rise will be due to CO_2. The direct part is due to CO_2 absorption while the indirect part is from the consequent increase in humidity and cloud formation (as well as other secondary effects) as the Earth warms. So, the issue is what are the numbers? How much warming due to CO_2 alone? Hansen and Sato (2011) assert that this is 1.2°C. How much due to humidity and clouds? In the case of clouds, is it warming or cooling? Climate models estimate that CO_2 is the prime mover, but that secondary effects due to humidity and clouds greatly amplify the putative 1.2°C temperature rise due to CO_2. Some skeptics challenge those results. It seems clear that CO_2 *is* a driver for climate change. Humidity and clouds tend to form as a consequence of other factors. But we didn't need a funded study to reach that conclusion. As Pielke said on his website:[1]

> "My conclusion is that their paper does not present new scientific insight but is actually an op-ed presented in the guise of a research paper by Science magazine."

Roy Spencer said:[2]

> "Just because water vapor responds quickly to temperature change does not mean that there are no long-term water vapor changes (or cloud changes) — not due to temperature — that cause climate change. Asserting so is a *non sequitur*, and just leads to circular reasoning."

The whole point of the paper by Lacis, Schmidt, Ruedy and Miller (2010) is to counteract the anti-warmistas who insist that humidity and clouds account for 75% of the greenhouse effect and are far more important than CO_2. The warmistas say, yes that is true, but CO_2 is the cause of it all, and thus CO_2 is *the* driver for climate change. Except for the fact that volcanic emissions, variability of total solar irradiance, variability of solar activity, variability of ocean currents, changes in ocean cycles (e.g. El Niño – La Niña), land development, soot deposition in polar

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[1] *http://pielkeclimatesci.wordpress.com/2010/10/15/comment-on-the-science-paper-atmospheric-co2-principal-control-knob-governing-earth%e2%80%99s-temperature-by-lacis-et-al-2010/*

[2] *http://www.drroyspencer.com/2010/10/does-co2-drive-the-earths-climate-system-comments-on-the-latest-nasa-giss-paper/*

areas, aerosol formation, etc. may also drive humidity and clouds changes thus causing climate change independent of CO_2, the warmistas would be correct. As it stands, the warmistas are at least partly right that rising CO_2 is a driver for global warming; the real question is how much?

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Brown *et al*. (2011) analyzed the relationship between energy use and economic growth. They concluded:

> "Empirically, the central role of energy in modern human economies is demonstrated by the positive relationship between energy use and economic growth.... To support a projected global population of 9.5 billion in 2050 with an average standard of living equivalent to the current US lifestyle would require about 268 terawatts, 16 times the current global energy use. Even maintaining this increased population at the more modest Chinese standard of living would require 2.5 times more energy than is used today.... The bottom line is that an enormous increase in energy supply will be required to meet the demands of projected population growth and lift the developing world out of poverty without jeopardizing current standards of living in the most developed countries".

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[3] *http://pielkeclimatesci.wordpress.com/2010/10/15/comment-on-the-science-paper-atmospheric-co2-principal-control-knob-governing-earth%e2%80%99s-temperature-by-lacis-et-al-2010/*
[4] *http://www.drroyspencer.com/2010/10/does-co2-drive-the-earths-climate-system-comments-on-the-latest-nasa-giss-paper/*

The problem with the over-emphasis on global warming by the warmistas is that they have lost focus on the real problem facing humanity in the 21st century: providing the people of the world with energy as the developing countries gradually industrialize. While some naïve futurists think we can solve our problems with wind and solar energy and electric cars, it is difficult to see how we can make it through the current century without continued heavy use of fossil fuels. Meanwhile, the future looks pessimistic as the world population grows. Maybe we can store CO_2 in water and bottle soda water in huge quantities?

More recently, Bond (2010) estimated that in 2000, BC energy-related emissions (in ktons/year) were approximately as follows:

China	1,300
India	500
Other Asia	800
Latin America	300
North America	500
Europe	500
Former USSR	300
Middle East	100
Africa	500
Total	4,800

These figures do not include open burning which would add another 55% to the total for energy-related alone.

The BC emissions prior to about 1940–1950 were primarily from the U.S., Europe, and the former U.S.S.R. These locations are proximate to high-latitude regions of the NH. Beginning around 1970, BC emissions from the U.S., Europe and the former U.S.S.R. diminished and the increase in total BC emissions was due to Asian nations, further removed from the high-latitude regions of the NH. Hence, it is to be expected that BC deposition in high-latitude regions of the NH would have peaked around 1925. As Bond (2010) showed, BC emissions in the United States peaked at around 1,200 ktons/year in the late 1920s, and has now dropped to about 400 ktons/year despite growth in energy usage, due to regulation of power generation and industry.

Ruckstuhl *et al*. (2008) reported:

> "... aerosol optical depth measurements from six specific locations and surface irradiance measurements from a large number of radiation sites in Northern Germany and Switzerland. The measurements show a decline in aerosol concentration of up to 60%, which have led to a statistically significant increase of solar irradiance under cloud-free skies since the 1980s. The measurements confirm solar brightening and show that the direct aerosol effect had an approximately five times larger impact on climate forcing than the indirect aerosol and other cloud effects. The overall aerosol and cloud induced surface climate forcing is +1 W/m^2 per decade and has most probably strongly contributed to the recent rapid warming in Europe."

This was followed by another article (Philipona *et al*., 2009) that pointed out that

> “Mainland Europe’s temperature rise of about 1°C since the 1980s is considerably larger than expected from anthropogenic greenhouse warming”.

> “[They] analyzed the radiation and energy budgets using measured short-wave and empirically derived long-wave radiative forcings at the surface, and related them to observed temperature and humidity changes in Switzerland and Northern Germany.”

They estimated roughly that perhaps 2/3 of the temperature rise since the 1980s was due to declining aerosol concentrations. This may be related to the finding by Pinker *et al*. (2005) that solar intensities at the surface in Europe underwent a “sustained increase after 1990”.