Twentieth Century Sources of Methane in the Atmosphere

Tom Quirk
Institute of Public Affairs
Melbourne
Australia
twquirk@labyrinth.net.au

43rd Seminar on Planetary Emergencies
World Federation of Scientists (Erice, Sicily)
pp 365-374
19-24 August 2010
World Scientific

Abstract

Present global and national schemes for carbon regulation often include methane alongside carbon dioxide. It is therefore important to understand the sources, sinks and control of methane in the atmosphere and then consider if methane should be part of any carbon regulation scheme. Atmospheric measurements over the last 50 years show substantial changes in methane concentration. Natural gas leakage from pipelines has been the major contributor up to 1990. For the last 15 years there has been little increase in concentration and natural climate variability has been the dominant control in changing methane concentrations.

The role of methane in the atmosphere has been emphasized by the IPCC to the point that many governments regard methane as almost as important as carbon dioxide amongst the greenhouse gases. The result is that emissions from natural gas pipelines, coal seams and agricultural livestock have been included in schemes to limit the growth of greenhouse gas concentrations. Analysis of changes to atmospheric methane within the last one hundred years suggests that the annual increases from 1930 to 1990 were due to losses from the production, transmission and distribution of natural gas that have now been reduced. Measurements over the last fifteen years show only natural variability. The data provide no justification for any attempts to reduce methane from industrial or agricultural activity[1]

The time development of methane concentrations is shown in Figure 1 from measurements at the South Pole. These direct in air measurements are part of a network that extends up to the Arctic Ocean. The data covers the period from the 1980s to the present. Figure 1 shows seasonal variations in methane concentration with minima in summer and maxima in winter. Methane is removed from the atmosphere by its interaction with OH radicals derived from ultra-violet sunlight, ozone and water vapour. These are at a maximum concentration in summer with higher levels of sunlight and water vapour in the atmosphere. The OH radicals combine with methane to produce a methyl radical through the reaction

$$CH_4 + \text{-}OH \rightarrow \text{-}CH_3 + H_2O.$$

Thus methane is removed from the greenhouse gas inventory with a lifetime of 11 years and the methyl radical through further chemical reactions is finally reduced to CO_2.

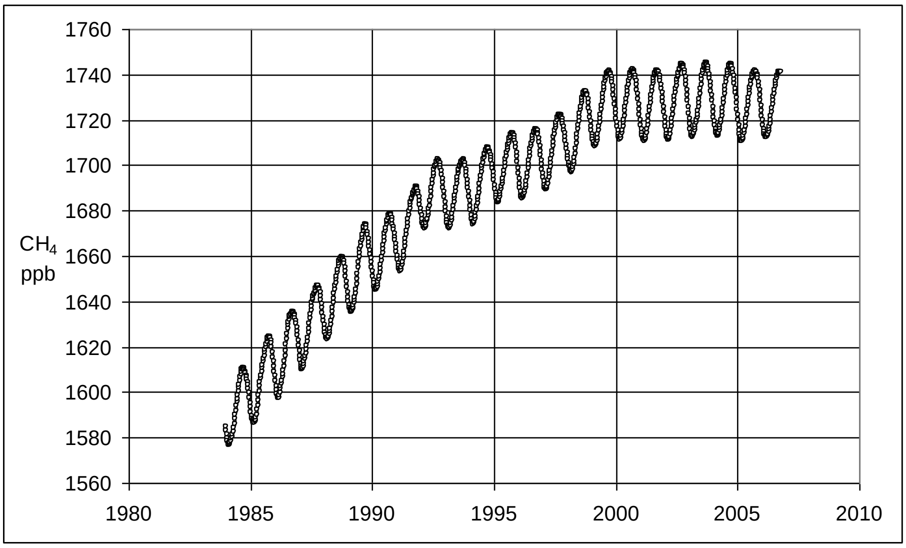

***Figure 1** Methane measurements at the South Pole from NOAA-ESRL Dataset*

In addition to this it is possible to get methane measurements from sampling air trapped in bubbles in ice cores. Extensive measurements have been made by a CSIRO group from ice cores in Antarctica. Figure 2 shows an example of atmospheric methane concentrations measured in ice cores at the Law Dome in Antarctica. Where there is overlap, the measurements agree with the direct atmospheric results from Cape Grim, a CSIRO station in Tasmania, Australia.

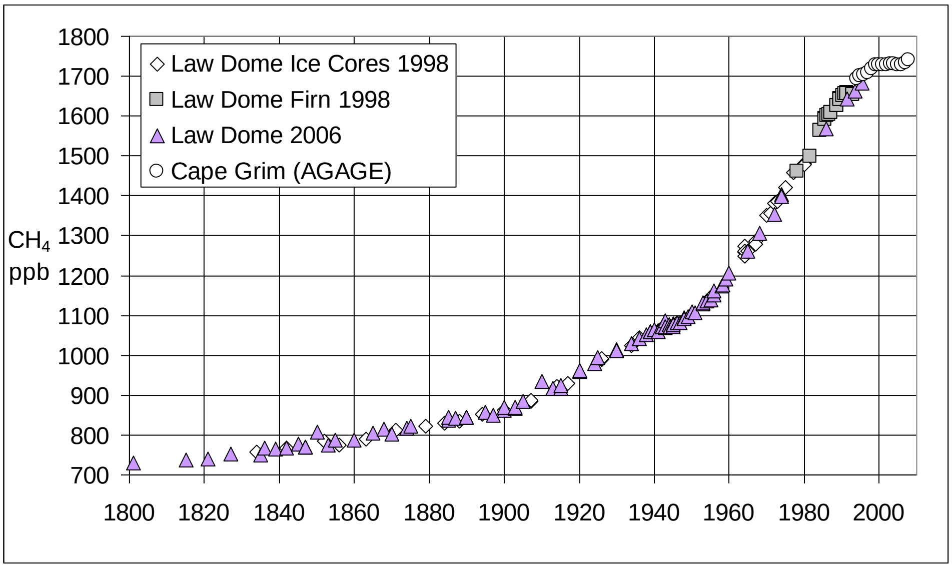

***Figure 2**: Atmospheric methane concentrations from ice cores and Firn samples at the Law Dome. The ice core sampling uncertainty is estimated at 4 ppb standard deviation from multiple samples and re-sampling in 2006 while the Firn measurements have a 1 ppb standard deviation. Cape Grim are direct atmospheric measurements. Note that ice core measurements in this period sample the atmosphere with about a 12 year window*

These measurements may be used to derive the annual increases in atmospheric methane and this is shown in Figure 3. The ice core derived data has been averaged in ten year intervals and the differences have then given the annual methane changes in the atmosphere. The errors are derived from the stated measuring errors and the scatter of values within each 10 year interval

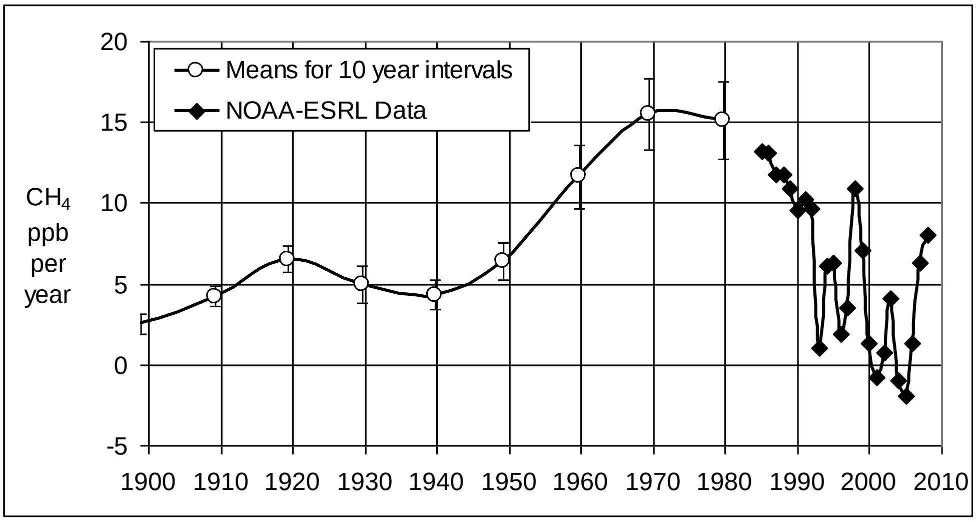

Figure 3: *Annual changes in atmospheric methane derived from the Law Dome measurements and direct annual atmospheric measurements from NOAA-ESRL data.*

The fall in methane emissions during 1984-1990 implied by the plateau of Figure 1 and clearly shown in Figure 3 may be explained by reduced gas pipeline losses and a major part if not all due to reduced losses in the old Soviet Union and Eastern bloc countries[2] as shown in Figure 4. The magnitude of the uncertainties in these estimates is large. In terms of the database definitions[3] it is “medium” with a 50% uncertainty! It is more likely that the uncertainty is a systematic error rather than a random error as the uncertainties arise from assumptions made in deriving emissions from well documented production or consumption statistics.

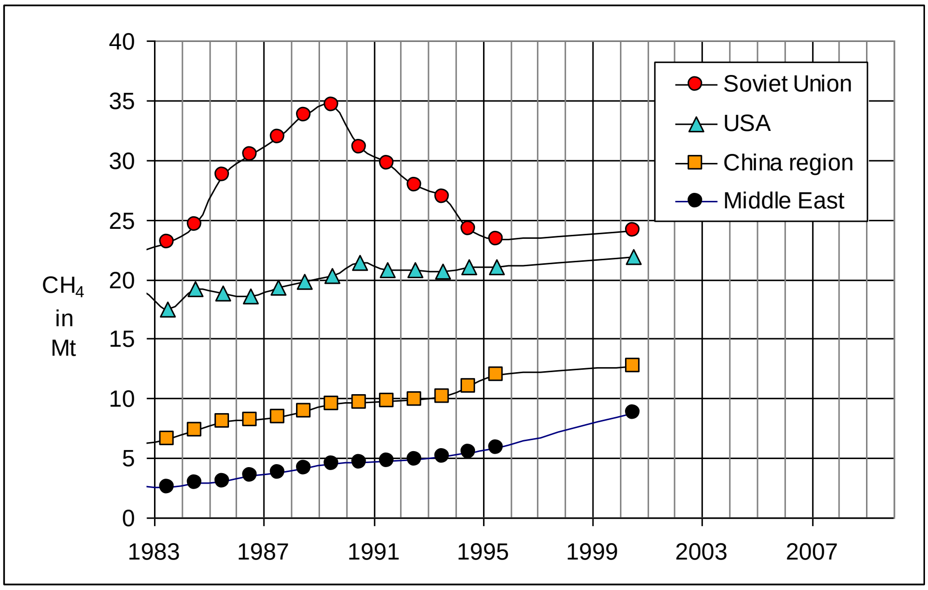

Figure 4: *Annual regional emission of methane from fossil fuel production and delivery. Source: Databases EDGAR-HYDE 1.4-CH4 and EDGAR 32FT2000*

The data have been replotted in Figure 5 to show the relationship with the consumption of natural gas. The natural gas estimates come from BP Statistical Review of World Energy June 2008[4] for the period 1970 to 2006 while the estimates for 1930 to 1970 come from C J Campbell[5]. The Campbell data overlaps the BP data and agree to within 5%. An estimated background of an annual increase of 3 ppb is shown. This accounts for natural variability of

El Nino induced changes, continuing modest natural gas losses into the atmosphere and volcanic effects. The volcanic effects are uncertain. In the twentieth century, there were 4 volcanic eruptions estimated to have had substantial impact on the atmosphere. Analysis shows that Pinatubo created a pulse of some 26 Mt of methane in 1991. The amount and timing of methane pulses of Santa Maria in 1902, Agung in 1964 and El Chichon in 1983 would add to the uncertainty in the non-natural gas contribution to the atmosphere from natural causes.

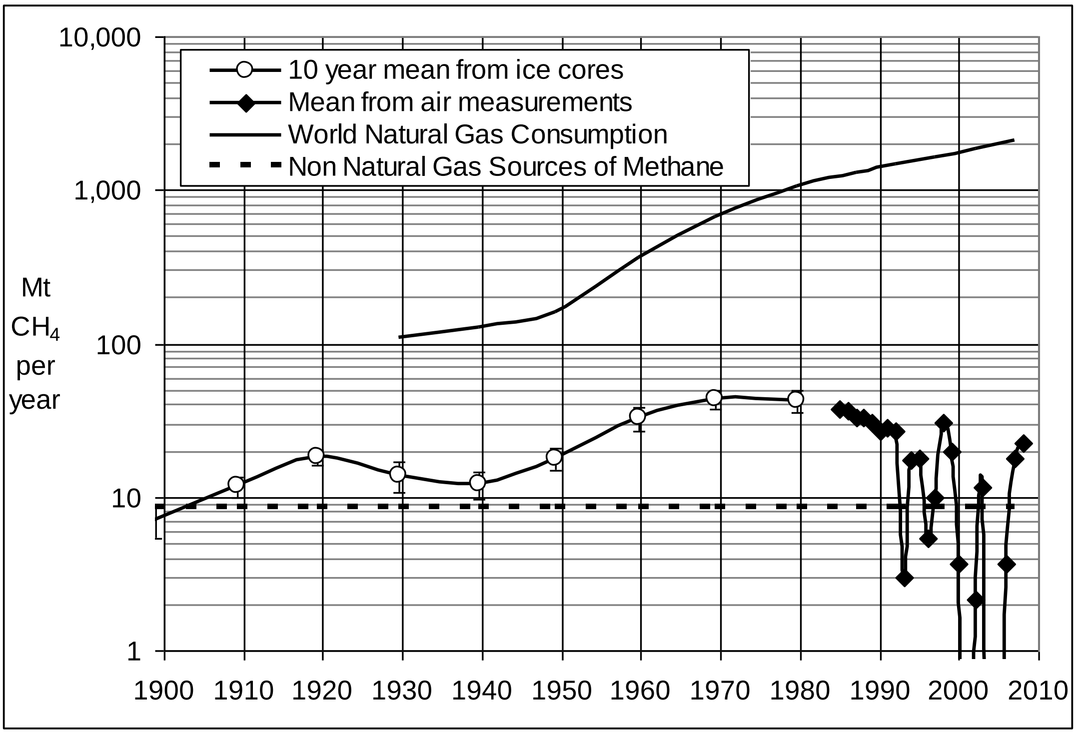

Figure 5: *Annual changes in atmospheric methane averaged in 10 year intervals from ice core derived data and year intervals for direct air sampling. The world natural gas consumption is from the BP Statistical Review and estimate from C J Campbell . The non-natural gas sources are estimated at 8.4 Mt per year (3 ppb per year) from 1900-1910 and 1993-2008.*

Figure 6 shows the estimated natural gas losses to the atmosphere measured by the adjusted annual increase in atmospheric methane as a percentage of annual natural gas consumption.

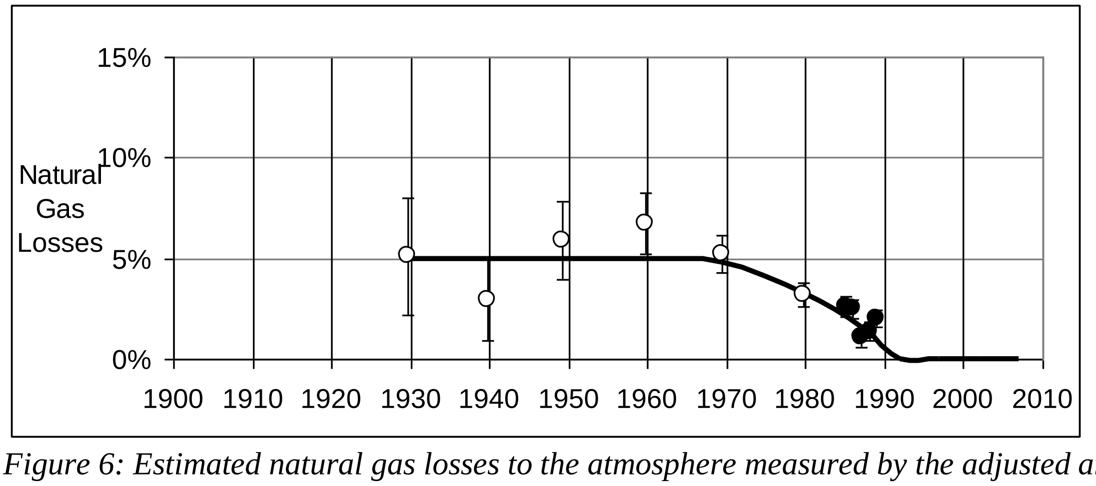

Figure 6: Estimated natural gas losses to the atmosphere measured by the adjusted annual increase in atmospheric methane as a percentage of annual natural gas consumption. Estimates derived from 10 year intervals of ice core data and annual air measurements. The

solid line is the average value from 1930 to 1970 and then follows the averages from 1970 to 1990

Estimation of pipeline losses is notoriously difficult[6]. Flow meter reading errors, unmetered off-takes, bypassed meters and the loss and use of gas in compressors all contribute to the uncertainty of as much as 1.5%. From the late 1950's on, there was a changeover from the use of coal or town gas to natural gas worldwide. There would have been substantial leakage from old town networks of cast iron pipes. These losses were reduced by their slow replacement with more secure piping. It is also clear from discussions with those familiar with the gas supply industry and particularly Soviet practice[7] that large pipeline losses of up to 10% are possible in old gas transmission and reticulation networks. In fact troubles on the Trans-Siberian pipeline led to a massive explosion in June 1982 estimated at 3,000 tonnes equivalent TNT[8]. It was the largest non-nuclear explosion and fire ever seen from space.

If the bulk of increased atmospheric methane is from natural gas leakage, can the mechanisms for the residual variations of concentration be understood?

Variations in methane concentrations are subject to both source and sink variations as illustrated in the upper part of Figure 7. The annual changes from 1985 to 1992 include a source, natural gas leakage, the 1987-88 El Nino that provides both a source and a sink and a reduced sink from the Mt Pinatubo eruption of 1991. Volcanoes produce SO_2 so the pulse of methane was caused by the reduction of the number of OH radicals through the competing reaction with the massive amounts of SO_2 produced in the eruptions with 17 M tonnes coming from Mt Pinatubo.

One of the controlling variables for OH radicals is humidity. Humidity in turn is influenced by El Ninos. Specific humidity at 1000 mb in the equatorial zone is about 16 g/kg and variations in humidity are shown in the lower part of Figure 7.

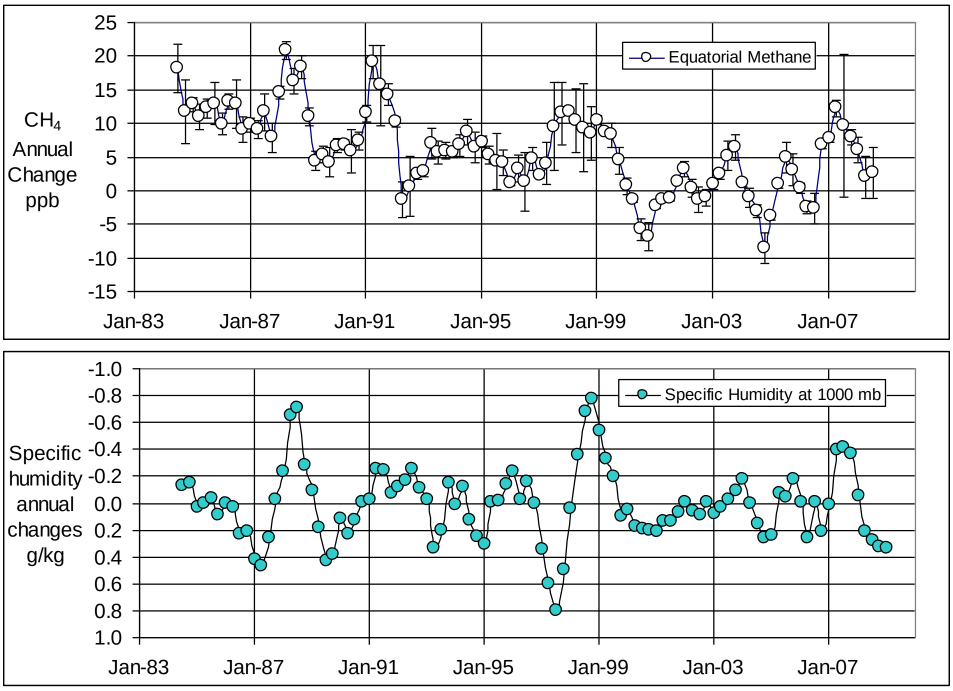

Figure 7: Upper *Year on year changes for* equatorial *quarterly average methane concentrations from global data (NOAA-ESRL and AGAGE),* **Lower** *Annual changes in specific humidity in the equatorial latitude band 22.5 S to 22.5 N at 1000 mb. Note that the scale is inverted as decreasing humidity and OH radical concentration implies more methane remains in the atmosphere.*

Much of the pattern of methane variations follows humidity variations. This can be seen in the upper part of Figure 8 where the humidity variations have been normalized to the methane variations from 2000 to 2007. This is a variation of the sink for methane.

The lower part of Figure 8 shows the variations of methane and an inferred source contribution following the variations in CO_2. El Ninos have a major influence on CO_2 with droughts and fires. In addition there are studies that suggest methane emissions occur where El Ninos trigger bush, brush and swamp fires..

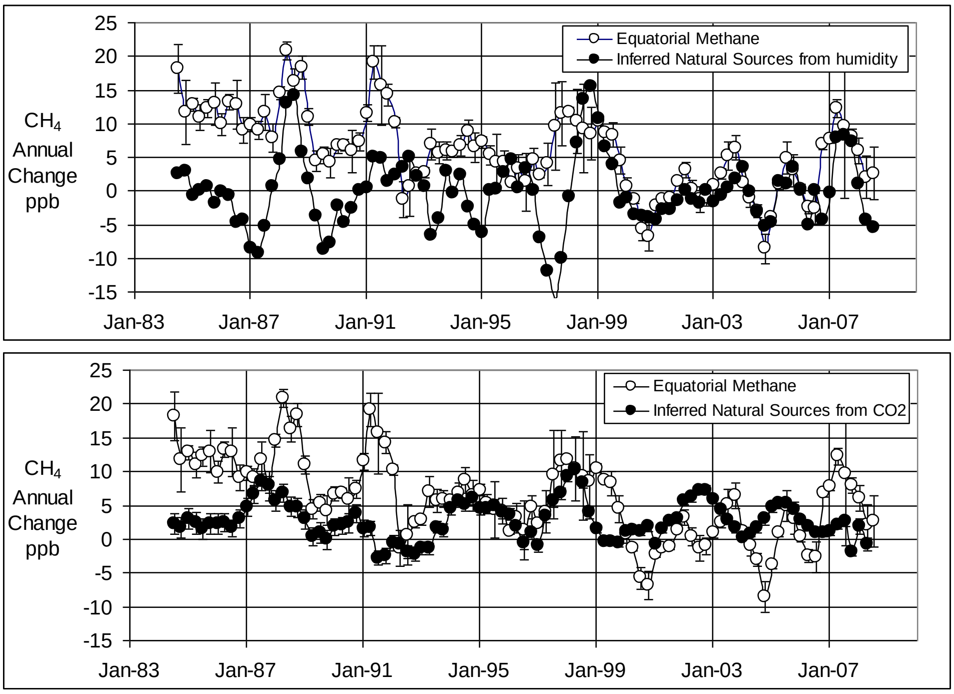

***Figure 8: Upper**: Equatorial and inferred natural variations from variations in humidity and **Lower**: Equatorial and inferred natural variations from variations in CO_2.*

Thus the El Ninos are acting as a trigger for variations of both sources and sinks for methane.

Conclusions

- Natural gas leakage from gas pipelines was largely responsible for increased atmospheric methane concentrations in the twentieth century.
- Through better pipeline management and maintenance, the leakage was greatly reduced in the late 1980s and early 1990s.
- In 1991 volcanic emissions of SO_2 from Mount Pinatubo reduced methane removal giving an apparent spike in methane emissions.
- The main determinant of variations in atmospheric methane from 1992 on is variations of the sink not the sources of methane.
- Variations of the sink are controlled by humidity and subject to El Nino and La Nina events and
- There are also source methane emissions from bush, brush and swamp fires triggered by El Ninos.

There is no strong reason to regulate methane emissions that appear subject to natural variability alone.

[1] See also ENERGY & ENVIRONMENT VOL 21 p 251-266, 2010

[2] Database EDGAR-HYDE 1.4; Van Aardenne et al. (2001) adjusted to Olivier and Berdowki (2001). and EDGAR 32FT2000 - EDGAR Fast Track 2000 dataset

[3] Database definitions of uncertainty see: http://www.mnp.nl/edgar/documentation/disclaimer/

[4] BP Statistical Review of World Energy June 2008, http://www.bp.com/statisticalreview

[5] C.J.Campbell, J H Laherrère. 1995 "The world's oil supply -1930-2050" Petroconsultants report -Oct ., 650p, CD-ROM data

[6] David A. Kirchgessner, Robert A. Lott, R. Michael Cowgill, Matthew R. Harrison, Theresa M. Shires, 1997 Estimates of Methane Emissions from the US natural gas industry. U.S. Environmental Protection Agency Air Pollution Prevention and Control Division

[7] Francis W Carter and David Turnock, 2002 Environmental Problems of East Central Europe, Routledge p 94 "…substantial pipeline leaks meant the loss of 10-15 per cent of all oil and gas produced."and
Private Communication Bob Foster.

[8] Thomas C. Reed At the Abyss: An Insider's History of the Cold War New York: Ballantine Books, 2004