Methane: Its Sources, Sinks, Myths, Risks, Accounting, Solutions and our Imperatives.

As the dangerous hydrological extremes from climate change intensify, demands are growing for urgent effective action to limit their impact. This has focused on reducing our emission of greenhouse gases, largely CO2 and Methane which models assume drive these climate changes.

Despite 50 years of talk and effort, CO2 emissions are still increasing as economies and policies often rely on our ongoing use of fossil fuels and thus increased emissions. While in the air at much lower levels and for less time, methane is seen as another emission reductions target that may be easier to meet as it is assumed to be mostly due to agriculture, and grazing animals that are less protected.

Given the pressure to be seen to do something, interests in some countries want to tax methane emissions or even replace grazing animals with manufactured meat due to their methane emissions. In this context it is critical that we objectively review the global reality of methane, what it is, its sources, sinks and processes, its myths and risks and how we can account for it so as to design and implement effective solutions to the climate and ecological imperatives facing humanity this decade.

The following review seeks to do this using the available scientifically verified science. While there is always more to know about the detailed processes involved, the evidence from nature and science is very clear and provides us with an effective understanding of our methane reality and solutions.

1. What is methane

Methane is a simple compound made up of 1 carbon and 4 hydrogen atoms. It is a gas that was emitted from Earth as it cooled from over 4 billion years ago. It formed much of the Earths initial atmosphere before oxygen was produced biologically and oxidised most of it to CO2 and water.

While it is still continually emitted geologically via volcanoes and as fugitive emissions from the anaerobic microbial bio-degradation of organic matter such as in swamps, coal deposits and gas fields as well as by insects and animals such as termites, herbivores and humans digest plant matter, its recent natural concentration in the air has been miniscule at some 700 parts per billion.

As such there must be a natural process which also continuously and rapidly removes methane from the air or serves as a methane sink to prevent its build up. While there are also some 10,000 billion tonnes of Carbon in the form of methane stored under pressure in cold anaerobic marine hydrates and some 5,000 btC of methane stored in tundras, these frozen stores are largely derived from local organic matter decomposition and don't serve as sinks of the methane removed from the air.

These frozen methane stores are however of existential importance, because if they are released with the warming of these oceans and tundras they could, as in geological history, create massive methane fires that can destroy bio-systems and threaten extinction of much higher life on Earth.

Methane is of course also important to us economically as natural gas, a fossil fuel we now mine and use as an energy source and feedstock for much of the industrial fertilizer and plastics we produce. Our use of it of course generates and contributes to our CO_2 emissions and its greenhouse effects.

Of greater concern are our direct emissions of methane as on a molecular basis it can be some 30 times more effective as a greenhouse gas in abnormally warming the Earth than CO_2. Hence there is much concern about how much is released and for how long it may survive to add to this warming.

2. The sources of methane contributing to the Earth's recent atmospheric levels.

While only trace amounts of methane, some 700 ppb existed naturally in the Earth's atmosphere for most of its recent history; significant quantities of methane at up to 640 million tonnes per annum or 640 x 10 to the power 15 grams, were continuously being emitted into the atmosphere naturally from a wide range of geological and biological sources. These include (UNEP Review 1990):

- Rice fields 60-140
- Natural wetlands 40-160
- Landfill sites 30-70
- Oceans 15-35
- Intestine of ruminant herbivores 66-90
- Termites 6-42
- Natural gas exploration 30-40
- Coal mining 35
- Biomass burning 55-100
- Other non biogenic (ie geological) 1-2

These very low natural levels were understood to occur, despite these annual additions, due to natural processes or 'sinks' that were estimated to annually remove some 650 mt/an from the air and previous studies indicate could potentially oxidize and remove up to 2860 mt/an.

This natural source data is revealing as it indicates that most of the current methane emissions come from microbial not geological sources and that wetlands including rice farming and the burning of biomass that we largely control are the major sources. Similarly our landfill waste disposal sites.

While ruminants emitted 10-15% of the total, this production needs to be proportioned as to what comes from residual wild herbivores, naturally grazed animals and the up to 90% of industrial milk and meat animals that are raised in concentrated animal farms and fed largely on grains not grass.

As herbivores that evolved eating grass often can not optimally digest starch from their feed grain they convert more of this into methane than animals on their natural cellulose based grass diets. Similarly while the dung of pasture raised animals is naturally rapidly incorporated into soils where it is oxidised with minimal methane emissions, much of the carbon in dung is converted into methane in the anaerobic effluent pools generated under these intense industrial animal farming practices.

As the regional variance in these proportions and from these feeding and dung practices is large, all herbivores must not be treated as having similar methane emissions under the same policy or taxes. Natural pasture raised herbivores may be contributing less than a third or 5% to the total emissions. Each of these radically different industry components needs to fully account and pay for their emissions and impacts and not be cross subsidised by other components or the wider public.

While the above detail the baseline data prior to 1990, methane levels have risen abnormally since then to some 1600 ppb in the 1990s and 2400 ppb from 2010. Science has confirmed these to be due to increased fugitive emissions from the expansion of natural gas exploration and extraction. The impact and cost of these increased methane emissions must similarly been met by this industry, and not blamed on or subsidised by other methane sources under invalid generic policies or taxes.

3. The processes and sinks for removing methane and it risks and impacts from the atmosphere.

The simple reality that methane levels were naturally so low at some 700 ppb despite their annual emission of some 650 mt dictates that there must be a significant natural process that removes it.

Science has long confirmed that this removal occurs via the rapid photo-oxidation of methane into CO_2 and water largely by hydroxyl (OH-) ions formed when sunlight converts molecules of water vapour into hydroxyl ions and ozone via complex physical-chemical reactions in the lower air. While some of these complex reactions may warrant further study their existence or role is not in dispute. In fact this process and these hydroxyl ions are critical in removing carbon pollutants from the air.

Studies indicate that these processes can also occur rapidly, within seconds, and partly account for the inability to record the presence of either methane molecules or hydroxyl ions in many field sites.

Given that methane, water vapour and sunlight all need to be present at the same time and space for this reaction to occur, it may be significant that this occurs consistently naturally as ruminating cows lying in the sun exhale water vapour and methane into the air. As the essential co-existence of sunshine, methane and water vapour does not occur in most experimental or industrial settings, this explains some of the variability and uncertainty about the operations of this process.

As with most chemical reactions and processes, it is not simply the reagents that matter but the correct conditions in time, space and initiation energy need to be created for that reaction to occur. Studies, experiments and industrial settings without these correct conditions will by definition not benefit from and discount such methane removal or sink processes. Conversely our informed creation of the correct condition can allow them to occur naturally; negating our methane problem.

Much of the difficulty and uncertainty about confirming the sink for methane may also arise from the term and attempts to find some fixed methane compound. As the 'sink' for methane is the CO2 and water it is converted into which are both already ubiquitous, they mask finding this compound. Given that sunshine, water vapour and the production of hydroxyl ions is also ubiquitous, involved in many reactions and disappears within seconds, it is difficult to document its rapid oxidative role.

While the above focuses on the natural processes that can remove the methane produced by grazed ruminants rapidly from the air, they are also likely to operate to various degrees to oxidize the methane produced from many of the other biological sources such as wetlands and rice farming. They may be far less effective at doing this for other sources such as landfills, dry termite habitats, fire emissions, mining and industrial sites where these water, time and space criteria are not met.

The design of methane reduction strategies for such sources may need to create these conditions. This could be as simple as regenerating grasslands able to sustain the natural herbivore processes.

The design of effective methane removal processes and sinks also needs to consider other natural processes including the role of soil microbes that are able to oxidize methane as their energy source. Such methanotrophs are common in many soils particularly those with anaerobic micro-sites where methane may be produced and convert most of this into CO2 and water before it leaves the soil. While such soils produce methane internally they do not normally emit much into the air. As the tundras warm they will emit vastly more methane well beyond the capacity of soil methanotrophs to oxidise it. Only hydroxyl ions have a chance of doing this, provided we enable them to do so.

4. Our agency by understanding and regenerating key methane source and sink processes.

The above evidence on methane sources and removal and sink processes provide us with powerful safe tool to wisely negate all threats from methane to our climate from our current activities.