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Session: "Climate Change and Chemicals Use: Adaptation and Mitigation Measures for Minimizing the Emerging Environmental and Health Issues."

Title:

Lead Toxicity and Climate Change

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Theme:

Climate change abatement actions must also reduce exposure to lead, the most common industrial contaminant, or lead poisoning rates will rise globally.

Objectives:

To examine the tradeoffs between climate change abatement and lead management; to explore the potential to reduce greenhouse gases (GHGs) **and** lead use/contamination **concurrently;**

To examine the interactions between climate change and elevated blood lead levels (EBLLs) and how global warming and climate variability modify the health impacts of EBLLs.

To suggest policy and regulatory solutions that minimise these problems.

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Sources of data:

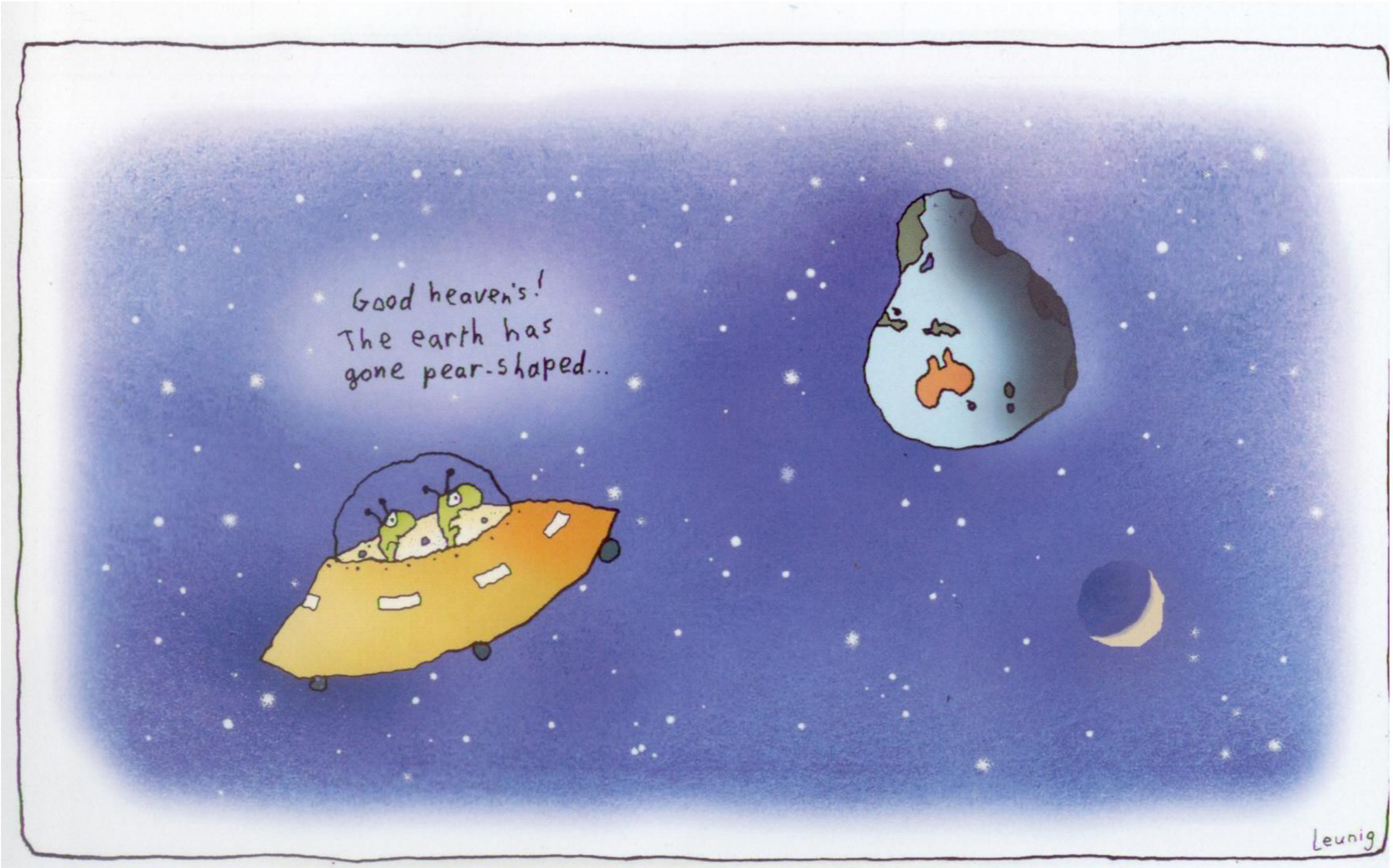
GLASS & NRCLPI case studies, government reports on GHG (IPCC, Garnaut, Stern), lead/metal association reports, journals, newspaper articles and electronic newsletters including LEAD Action News, published by The LEAD Group (Whitton, 2009). See Reference List at the end.

Major findings:

- Lead poisoning, since the rise of the motor vehicle, has caused loss of human intelligence amounting to hundreds of billions of IQ points, and this consumerist era of anthropogenic climate change has been aptly named "The Age of Stupid" (BCM Spanner Films, 2008)
- Intelligence needs to be applied such that efforts to mitigate climate change and lead problems are directed towards win-win scenarios
- Governments need to more carefully manage lead because of global warming
- Our exposure to a toxic substance that cannot yet be effectively removed from the body must be examined, in particular the increased risk of exposure to lead due in part to efforts to mitigate climate change
- Individuals and governments must realise our ability to prevent climate change is likely to be limited and adjustments (and investments) need to be made on a permanent basis
- Increased incidence of drastic weather events such as tornadoes, wildfires, floods and droughts will compromise current methods of lead waste storage and enable distribution of all lead uses/sources particularly in the form of dust
- Lead-related problems created by addressing climate change will include:
    - increased lead use in storage batteries for electric bikes and vehicles and for renewable energy, and
    - higher blood lead levels in children with warmer temperatures.
- Gains of lead-conscious climate change policy include:
    - removal of ceiling dust safely before installing ceiling insulation, and
    - reducing both GHGs and lead pollution by reducing the rate of vehicles being manufactured, and the burning of fossil fuels, especially by reducing the need for transport of goods and people, and
    - reducing the need for newly-mined lead.

Introduction

This paper explores on the interactions between the problems caused by the most common industrial contaminant, lead, and global warming with its associated increased climate variability**.** Lead poisoning has been a persistent problem which has resulted in a considerable reduction inhuman potential by it capacity to injure one of our most important organs: the brain. Having almost ended one of the most destructive practices mankind ever introduced, the adding of tetrahedral tetraethyl lead to petrol, we face new lead related problems as the amount of lead in circulation rises due to increased use in batteries and static storage associated with variable renewable power production and increased electrical appliance use in developing countries which lack reliable grids. Some believe that the world would look strange to an outsider as the following cartoon demonstrates. **Aliens: "Good heavens! The earth has gone pear-shaped…"**



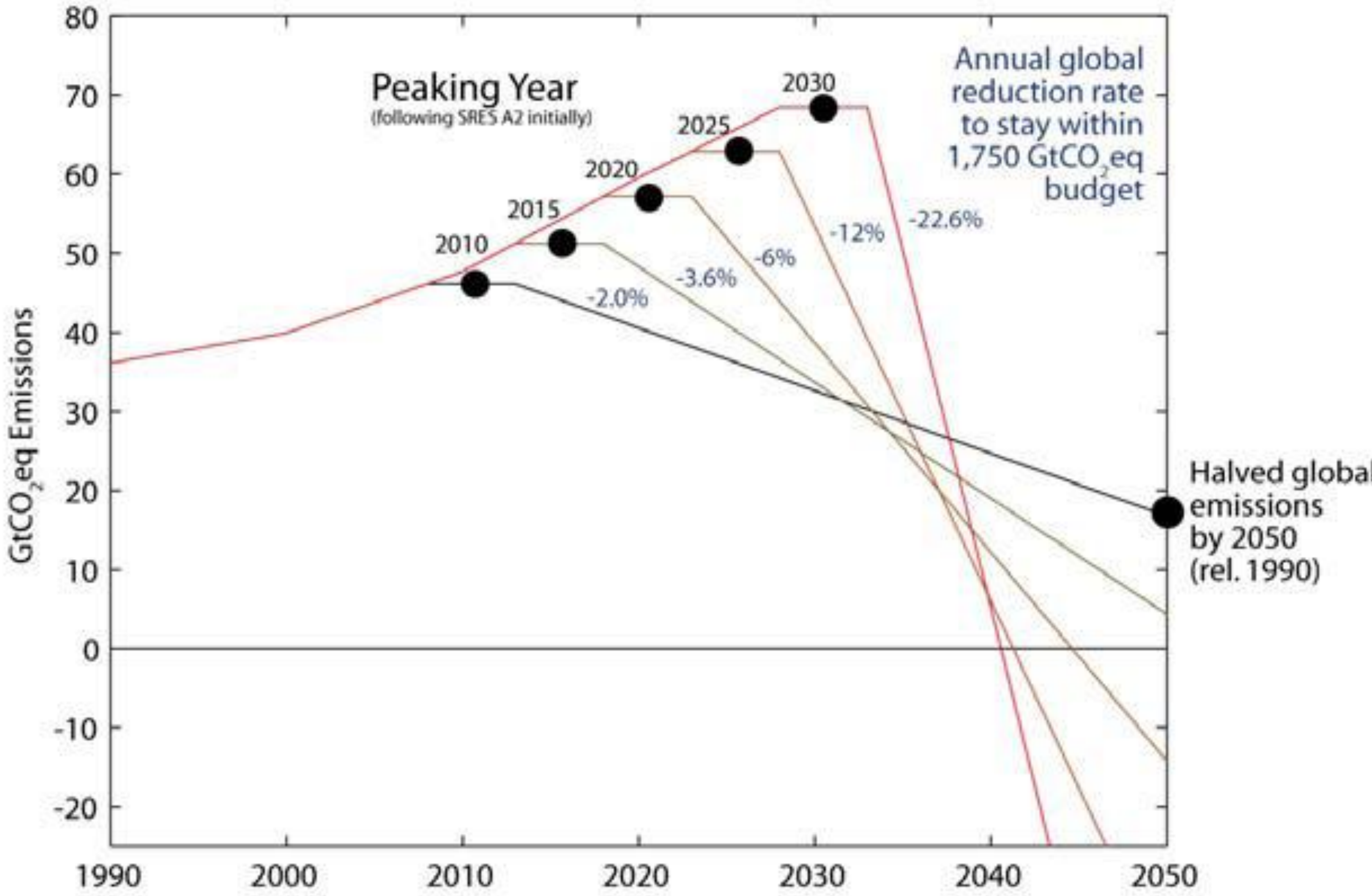
Cartoon with the kind permission of Michael Leunig.

At the same time the increasing volume of lead waste contained in dry storage or waste ponds will be exposed to the increasing intensity as climate variability. But what is global warming (GW) sometimes referred to as climate change?

Background: Anthropogenic Climate Change

The current scientific consensus is that we are undergoing a rise in average temperature caused by human activity. As almost everyone is aware the IPCC has estimated that global temperatures may rise by between 1.1 and 6.4 degrees (from a baseline averaging 1960-1990) sometime during the 21st century. The general scientific consensus that emerged in forums like the Bali conference is that for there to be an around 50% chance of limiting the rise of global temperature to a 2°C increase since industrialization, we would need to reduce greenhouse gas (GHG) emissions in developed countries by 25-40% by 2020 and at least 50% by 2050 relative to 1990 levels. Developing countries would need to reduce their total emissions by 2020. Global emissions would have to peak by 2020 but preferably by 2015. The reasons are graphically illustrated by the following graph by Clive Hamilton.

Peaking year and emissions reduction rates to stay within a budget aimed at limiting warming to 2ºC From "Is It Too Late to prevent Catastrophic Climate Change" Lecture to a Meeting of the Royal Society of the Arts Sydney, 21 October 2009. Reprinted with the kind permission of Clive Hamilton.



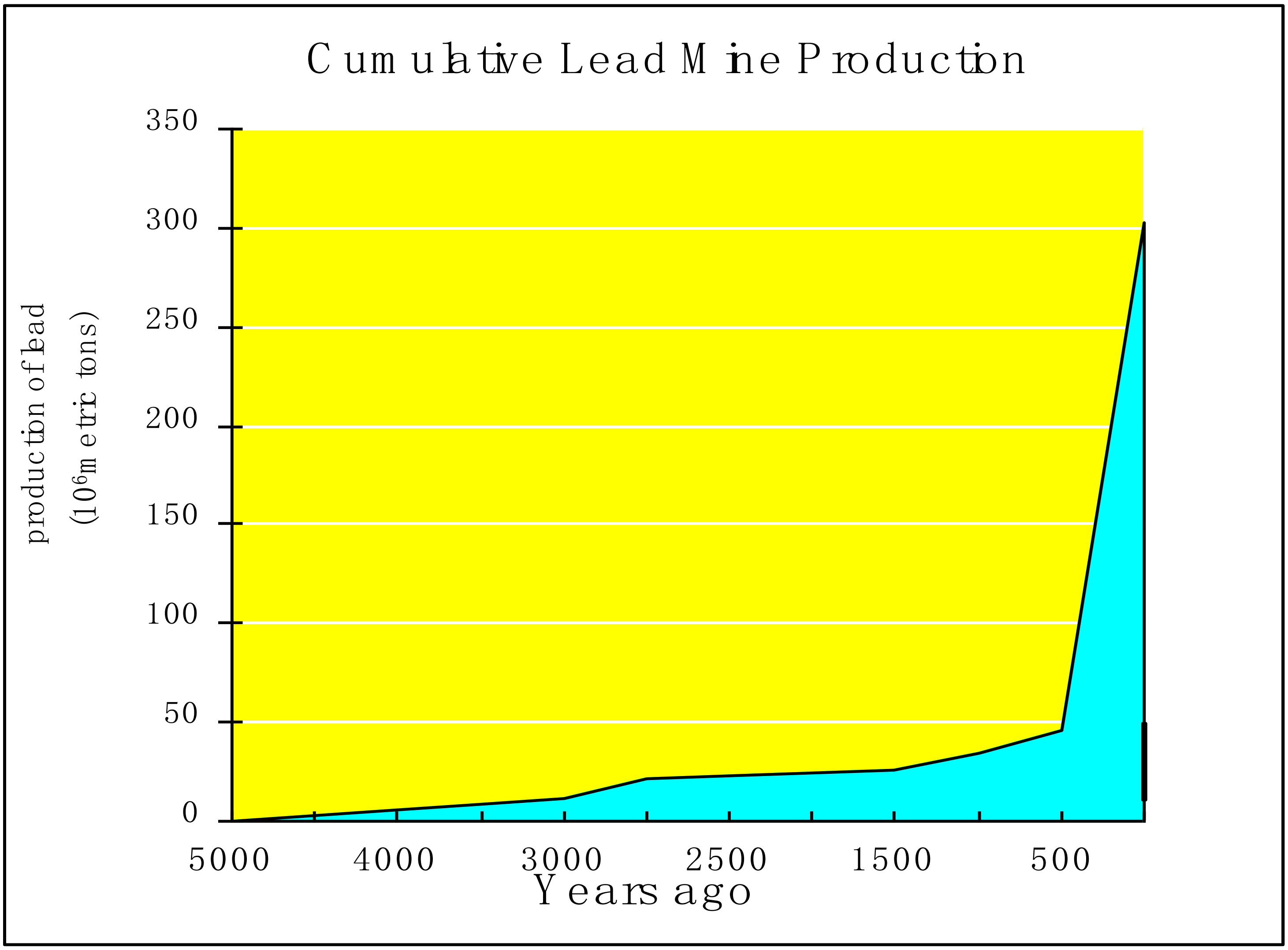
Even at 2°C the results would be the disappearance of mountain glaciers, damage to coral ecosystems, damage to the Sahel (Stern 2007 p. v) and the thawing of the arctic (Chylek 2009, Laurel 2009, Sommerkorn & Hossel 2009). And even these cuts may be inadequate. But before considering this further lead must be examined.

Lead & Health Impacts

Lead is a metal for which the body has no use, yet lead can replace essential minerals (predominantly iron and calcium) in all their uses in organisms. Even tiny amounts have significant neurological and cardiovascular effects and large quantities are fatal (Patrick 2006). Lead kills brain cells directly through apoptosis (programmed cell death) and replaces calcium in the nervous system and brain (Verstraeten et al 2008). High lead levels in expectant mothers have been linked to schizophrenia in their offspring (Opler 2008). High blood lead levels in childhood have recently been linked with decreased activity in parts of the brain associated with attention and impulse control in young adults. In other words, lead has lasting effects on executive functioning which includes decision-making, abstract thinking and problem solving (Fiore, 2009).

Lead has toxic impacts on the kidneys and liver. It produces anaemia by preventing the formation of haemoglobin inside red blood cells eviscerating the blood's ability to carry oxygen (Patrick 2006). Children are particularly vulnerable being more likely to ingest lead through normal hand-to-mouth activity, more able to absorb lead through ingestion (up to 50%), more likely to store lead in soft tissue and less able to handle its impact on still developing body systems, particularly the brain(Patrick 2006).. Lead can be absorbed either through ingestion 10-15% or (more efficiently) through inhalation (30-40%), and to a notable extent in the case of tetraethyl lead (found in leaded petrol), through the skin, especially when the skin is sweaty (Patrick 2006). Blood levels above 10 µg/dL (micrograms per decilitre) were seen as a cause for concern by the World Health Organisation (WHO) in 1992, but there may be significant health impacts even below this level and a number of scientific reviews have suggested lowering this threshold by at least half (Rossi 2008) and even as low as 2 µg/dL to prevent IQ loss and early death (Roberts et al, 2009).

Background: Anthropogenic Lead Pollution



Source: NRC, 1993, p21 with the kind permission of the National Research Council

Lead [Pb), already the most abundant industrial chemical - Lead or heavy metals) feature in all but one (Dzerzhinsk) of the Blacksmith Institute's "World's Most Polluted Places": 1. Linfen, 2. Tianying, China. 3. Sukinda, India. 4. Vapi, India. 5. La Oroya, Peru. 6. Dzerzhinsk, Russia. 7. Norilsk, Russia. 8. Chernobyl, Ukraine. 9. Sumgayit, Azerbaijan. 10. Kabwe, Zambia (Walsh, 2007). With lead mine production increasing annually (ABARE 2008), the amount of lead "out there" (variously dispersed into the environment or still in use), or "cumulative lead mine production" now well exceeds 300 million metric tons (NRC, 1993), all of which needs to be managed for the rest of our time on the planet.

Much of this lead has been distributed in everyday items: 2.5 billion people live in countries where there is no limit on lead in new house paint sold today. 275 million people in 14 countries are still exposed to leaded petrol for road vehicles. Leaded AvGas (aviation fuel for propeller driven aircraft) is used everywhere. Leaded petrol contains up to 2g/l of lead compared to as much as 0.013g/l for unleaded petrol and 0.017g/l for diesel though some countries apply further limits (0.005 g/l in most European countries). Most combustible material with biological origins (coal, biomass, dung) has trace levels of lead. Electronic equipment also contains lead and while lead's use is being reduced even in the EU [European Union] special exemptions continue to allow its use in objects such as solar panels.

The phasing out of lead petrol in most countries has seen a consistent worldwide fall in average blood lead levels (Mexico's SOH 2005, Singh & Singh 2005) but more than a dozen countries have yet to phase out leaded petrol (Taylor 2009) and the lead deposited by petrol combustion in fine particulate dust over decades, remains a cause for concern even where leaded petrol has been phased out (Laidlaw & Filippelli 2008). Japan, the first country to phase out leaded petrol, has average blood lead levels under 4ug/dL (Miyaki 2009) and now receives much of its airborne lead pollution from continental Asia (Bellis 2004). The situation is much worse in large portions of the developing world. In Karachi, Pakistan as recently as 2002, 80.5% of children had blood lead levels of more than 10 μg/dL (Kadir 2008 p711). In a meta-analysis by Wang and Zhang (2004), more than one third (33%) of the children in China were found to have blood lead levels greater than 10 μg/dL. Recent reductions in Indian blood lead levels have still left the children of five cities with average blood lead levels of 12.1 μg/dL (Singh & Singh 2005). Lead levels above WHO's cause for concern are extremely common.

The costs of reducing blood lead levels have been shown to lead to huge economic benefits. In the US, Grosse et al (2002) compared children of the late 1970s to children of the late 1990s and estimated that the latter's lowered blood lead levels and consequent raised IQ and lifelong earnings create an economic benefit for each year's cohort of 3.8 million 2-year-old children, ranging from $110 billion to $319 billion (US year-2000 dollars). Gould (2009) demonstrated that for every (US) dollar spent on controlling lead paint hazards, between **$17 and $221** is returned in benefits to society, not only in increased earnings and tax revenue, but also in reduced costs of healthcare, special education, attention deficit–hyperactivity disorder and crime.

Loss leads to Gain / Gain leads to Loss etc GRID

The central conclusion of this presentation is that climate change has massive impacts on the potential exposure of individuals to lead, both through distribution and by climate change solutions increasing the demand for lead acid batteries ie a gain or improvement for climate change leads to a loss for lead management (GW&CV Gain→Loss Pb mgt). This grid provides a way of conceptualizing the relationships between global warming and climate variability (GW & CV) and lead management. Gains and losses in lead management arise from policies that affect climate change but the reverse is true only to a small degree, unless you count the dumbing down of the planetary population due to the "Mistake of the 20th Century" (lead in petrol) as a major cause of the "Age of Stupid" we find ourselves in. Only a drastic reduction in the production of newly mined lead and massive expenditure on reducing and containing existing lead mining, smelting and combustion wastes, can prevent additional distribution of lead into the environment if US hurricane damage doubles (predicted at around a 3°C temperature rise) or if a billion people are trapped in arid, dusty conditions, another billion experience massive flooding increases and a significant number experience both (at 4°C). If widespread flooding spreads lead contamination and plants take up more lead, it will be difficult to limit lead exposure from biomass combustion during wild fires (at 4°C). Massive falls in crop yields (at 3-4°C for the developing world, 5-6°C in the developed world) will enable a much higher uptake of lead in humans due to iron and calcium deficiencies. Nothing we can do will negate these effects completely. Concentrating a multitude of small scale battery recycling and processing works into fewer large scale facilities, will have a small impact on global warming once increased SO2 capture (98% at modern facilities) is taken into account and decreases in atmospheric lead pollution may reduce cloud formation raising temperatures to a tiny degree. Limiting or reducing the rate of climate change must be a primary lead control strategy.

Not all quadrants of the grid are equally important but the consistent pattern has been explained above. Dealing with climate change has significant benefits for lead management, principally in reduced atmospheric lead from combustion but the reduction in GHG from restricting the burning of wastes containing lead are much lower (Quadrant One) The slight losses to GW from lowering atmospheric lead is dwarfed by the implications of massive increases in lead quantities and associated waste created in reducing GW through increased power or transport energy storage(Quadrant 2). The loss to lead management (and health) from increased lead availability is massive but results in significant impacts on global warming. By contrast, gains to lead management from continued GW such as decreased flood contamination due to aridity are marginal and two edged, reducing water for hygiene .(Quadrant 3). In Quadrant 4 the pattern recurs with marginal GW losses from poor management of lead processing being insignificant compared to the massive impact on lead dispersion of losing the struggle to slow GW, already explained. By contrast there are a wide range of options that are beneficial to either lead or GW that have no mutual or antagonistic impact such as nutrient supplementation for the under nourished to reduce vulnerability to lead contamination or reducing non-carbon rural GHG for GW ie. reduction in rural methane and N2O emissions. We must now look at the elephant in the room and determine much climate change is likely to occur.

Quadrant 1. Gain➔Gain **Pb mgt Gain➔Gain GW&CV** Good for lead management and for reduction in GW&CV • Reduced combustion (less travel & goods) & regulations controlling particulate emissions from all fuel & waste burning. • Up-scaling battery recycling reduces GHG **GW&CV Gain➔Gain Pb mgt** Efforts to reduce GW&CV which can also enhance lead management • When ceiling insulation is going to be installed, ceiling dust should be removed first, and recycled for its lead content.	**Quadrant 2. Gain➔Loss** **Pb mgt Gain➔Loss GW&CV** Improving the mgt of lead but exacerbating GW&CV • The reduction of lead in the atmosphere (with its many health benefits) may have a slight tendency to increase global temperatures. **GW&CV Gain➔Loss Pb mgt** Reducing GW&CV worsens lead management • as more storage is required for alternative power sources such as solar- or electric-powered vehicles, more lead acid batteries will hit the recycling black market where lead poisoning rates are already highly concerning in less well-regulated countries. • Veganism reduces methane emissions but if the diet is insufficient in iron and calcium, blood lead levels go up
Quadrant 3. Loss➔Gain **Pb mgt Loss➔Gain GW&CV** Bad for lead managementt but better for reducing GW&CV • if more lead is mined, there will be more lead available cheaply for alternative energy storage **GW&CV Loss➔Gain Pb mgt** GW&CV is worsened but lead management is improved • If there are more droughts there will be less water-borne lead contamination from flooding	**Quadrant 4. Loss➔Loss** **Pb mgt Loss➔Loss GW&CV** Poor lead management exacerbates GW&CV • continuing to sell leaded petrol means catalytic converters can't be used to reduce GHGs. If the price of newly mined lead and lead acid batteries remains low, the uncontrolled growth of ebikes and vehicles will be encouraged, thus worsening GHG emissions **GW&CV Loss➔Loss Pb mgt** Worsening GW&CV exacerbates lead poisoning • blood lead levels will rise if temperatures increase and more droughts, windstorms and wildfires increase exposure to lead contamination and reduce availability of water for cleaning and personal hygiene

Climate Change Outcomes

There is no indication the Bali conference cuts will be achieved on a worldwide basis The Kyoto protocol has not resulted in any real change to the upward trend of carbon dioxide or nitrous oxide in the atmosphere (NOAA 2009). China and India have rejected absolute cuts while America has offered a conditional 17% (<16% including agriculture) based on 2005 (rather than 1990) levels. Without these three countries, who represent 40% of carbon emissions now, a predicted > 50% in 2030 (Garnaut 2008 p65) and > 85% of projected increases in coal fired power by 2030 (EIA 2009), required cuts are unlikely be achieved. Should greenhouse emissions peak at or after 2020, an effective Kyoto scale cut would be required every year to reach the 2050 targets.

This would effectively lock in a 3°C rise (or around 550 ppm CO2 equivalent). This is the maximum target of the Stern and Garnault review and the level both felt was achievable (Stern 2007 p.iii, xi-xv, Garnaut Ch 12 p.277-298). Both raised the idea we can overshoot our desired target and return to lower atmospheric greenhouse concentration, though Stern (Stern 2007 p.xi) was more guarded than Garnaut (Garnaut Ch 12 p.277-298): a dangerous assumption. Even when greenhouse gas levels stop rising it may take centuries for temperatures to moderate from new highs (Monastersky et al 2009), especially if there has been a reduction in the carbon sinks that can be used for storage (Anderson & Bows 2008 p3865, Fung et al 2005, Le Quere et al 2009).This would mean declining crop yields, increasing aridity, food shortages notably in Africa & W. Asia, , a 30% decline in the amount of water run-off in the Mediterranean and southern Africa, a decline of the Amazon rainforest due to extended dry seasons and a doubling of the cost of hurricanes in the USA (Stern. 2007 p.v). Lenton provides a rare bright spot by pointing to possible greening of the Sahel/Sahara at these temperatures at the cost of the west African monsoon, boreal forest dieback and greater El Nino intensity (Lenton et al 2009). Massive declines in rainfall and food availability coupled with a doubling of extreme weather damage and even larger increases in heavy rainfall events cannot but have massive impact on lead distribution when so much waste is stored as dry tailings or in open waste ponds. Even accomplishing this uncomfortable limit is based on some very doubtful assumptions .

Real Cuts

The cuts recommended after the Bali conference are based on three assumptions: that allowing for oceans acting as a heat sink most of any inherent temperature rise has already been realised, that all GHG sources are of equal value apart from the emissions themselves and regional impacts will not negate emissions cuts. First we may already have experienced a warming of as much as 2.4°C but ~1.3°C has deflected by atmospheric pollution (particularly SO2 related aerosols) and ~0.5 ° C is currently gradually warming very deep oceans (Ramanathan & Feng 2008). Secondly not all GHG emitters are equal. Coal fired power stations emit large quantities of carbon dioxide but, in most cases, even larger quantities of SO2 which negates CO2's GW impact (Ramanathan & Feng 2008, 2009). Therefore most coal fired power (over 16% of global GHG emissions (Stern 2007 annex 7.b)) and water transport (1.4% (Stern 2007 annex 7.c)) have little or no short term impacts and should not be counted for short term GHG cuts (Ramathan and Feng 2009 p47, Berntsen & Fuglestvedt 2008 p19157 fig 3). This is not to deny a stronger influence on a hundred year scale. Agriculture (14%) is currently excluded from most schemes as it is essential, emissions are difficult to measure, can be costly to address and methods to modify them uncertain (Rochette 2008, SSSA 2008, SSSA2009.).

Finally regional impacts. The arctic is warming at 2-3 times the rate of the rest of the planet (Chylek 2009) and is beginning to thaw long before the 2°C target is reached (Sommerkorn and Hossel 2009). Current ice losses exceed the worst projections of three years ago (Laurel 2009). This is important to climate change as the arctic is currently a carbon sink storing more terrestrial carbon than tropical and temperate regions combined: twice the amount of carbon in the atmosphere (Canadell and Raupach 2009 p73). In the immediate future it is likely to convert to a GHG emitter of unknown magnitude (Brook 2008 p421, Canadell and Raupach 2009 p74). It can currently generate methane equivalent to ~10% of CO2 emissions [x25 conversion used] in 2004 from fossil fuel (Canadell and Raupach 2009 p75, Wikipedia 2009) or ~5.8% of anthropogenic GHG in 2004. As the region thaws this should comfortably double and may be much higher (Brook 2008 p423-426). In addition up to the equivalent of 3600 of such years may be stored frozen in permafrost and to a small degree in tundra while offshore deposits in the East Siberian Arctic shelf alone may comfortably exceed this. It would be unwise to assume that normal arctic GHG emissions (mostly methane) once the thaw is firmly established would be less than ~6% of global anthropogenic GHG since the arctic total is likely to be bolstered by rising CO2 emissions (Canadell and Raupach 2009, Lenton 2009 p1791) and the IPCC standard conversions understate methane's short term impacts (Smith 2008 slides 14-27). Cuts (from under 68% of emissions) would need to be adjusted upwards by 9% to compensate for this and would be subject to ongoing review. So in conjunction with the previously listed exclusions and allowing a small margin (2-3% depending on the scale of cuts) for other minor exclusions to have a reasonable chance of limiting temperature rises to 3° the real cuts by 2020 would have to be approximately 44-65% of 1990 levels and at least 78% by 2050. Of the nations attending Copenhagen only the European nations have even offered 30% cuts from 1990 levels, and then mostly conditionally. The USA is currently offering a real cut of 16% of 2005 levels or around 3% of 1990 levels (AAP 2009) (various sources calculate it as between 0-7% of 1990 levels). It is a fraction of the total required to limit warming to **3°C**. The current policy settings are a cause for concern.

It is unlikely that temperature rises can be kept to a minimum (Anderson & Bows 2008, Monastersky et al 2009, Hamilton, C 2009). While chemical (eg biochar) or biological sequestration may hold promise, it is dangerous to place significant faith in technological fixes yet to be demonstrated on a commercial scale. We need to accept that in a world ~2°C colder than the average of the last 35 million years (Haines 2000) we may have only be able to regulate the speed of the change we have initiated, not necessarily the magnitude or end point. We need to be prepared for a significant increase in global temperatures and accordant regional climate pattern changes.

Increased Precipitation

[GW&CV Loss➔Loss Pb mgt – Quadrant 4 of the GRID]

Climate modelling is an inexact science and specific predictions must be treated with caution. However current modelling tends to agree on some broad trends. The most important are increased climatic variability (including increased risk of hurricanes, typhoons, floods, droughts and associated phenomena such as avalanches, mudslides and dust storms) and changes in precipitation and evaporation (Bates et al 2008. p15-81, Bader et al 2008 p51-84). There is strong evidence that these effects have already been occurring in the past two decades (IPCC 2007 Ch 2). There is strong evidence that much modelling underestimates the variability in precipitation (Allen & Sodden 2008, Bader et al 2008 p79- 82, Williams 2009) and that if precipitation occurs in short intense bursts a climate can become more arid even as rainfall and flooding increase (Bates et al 2008 p26-30). Both have significant impact on the distribution and release of dangerous chemicals in the environment and the severity of health effects. In addition, efforts to ameliorate climate change through reduced carbon combustion will change the quantities of such materials available to be released into the environment

Regional precipitation may increase the distribution of lead contamination both in volume and the area affected. Unfortunately while this aspect is of key importance it is also technically complicated as it relates to waste storage and its management and contaminant dispersal. The fact that lead's ability to pass into water can vary over 10 times depending on the compound it has formed, the surrounding chemistry and acidity make this a specialised field (Palumbo-Roe 2009). Lead is certainly less soluble in alkaline conditions and any increased carbon content in the water will make the water more acidic (Palumbo-Roe 2007).

Increased Aridity

[GW&CV Loss➔Loss Pb mgt – Quadrant 4 of the GRID]

Increased regional aridity can also significantly increase human exposure to lead. Laidlaw and Filippelli (2008) have recently demonstrated that in US cities greater than 50% of the seasonal changes in blood lead levels of children (who are particularly vulnerable to lead's neurological impacts) can be predicted from weather patterns. Over 50% of such variations can be explained by monthly soil moisture, PM10 (fine particulate pollution), wind speed and temperature. In situations where ambient moisture is low, soil (particularly the finer grained soil most likely to be contaminated by gasoline lead in the past 90 years) becomes resuspended in the atmosphere, making up over 50% of fine particle pollution. Soil re-suspension can contribute over 40% (and as much as 75%) of atmospheric lead content after leaded gasoline has been phased out (Laidlaw & Filippelli 2008).

Atmospheric lead is far more efficiently absorbed by the body through the lungs than ingested lead through the digestive tract (Patrick 2006). One of the least-known "sinks" for lead air pollution is building cavity dust which accumulates (often from decades of air pollution fallout) especially in the ceiling void and sits on top of the ceiling until events such as hail storms or heavy snowfall damage the roof and ceiling and allow the dust to get into the living/working space. Over half of the lead in house dust may be from external sources and three quarters of the dust in ceiling voids may be soil or plant matter (Laidlaw & Filippelli 2008).

On the positive side there are more droughts there will be less water-borne lead contamination from flooding (but more air lead pollution and less water available for hygiene and cleaning so this is an arguable gain). [**GW&CV Loss➔Gain Pb mgt – Quadrant 3 of the GRID]**

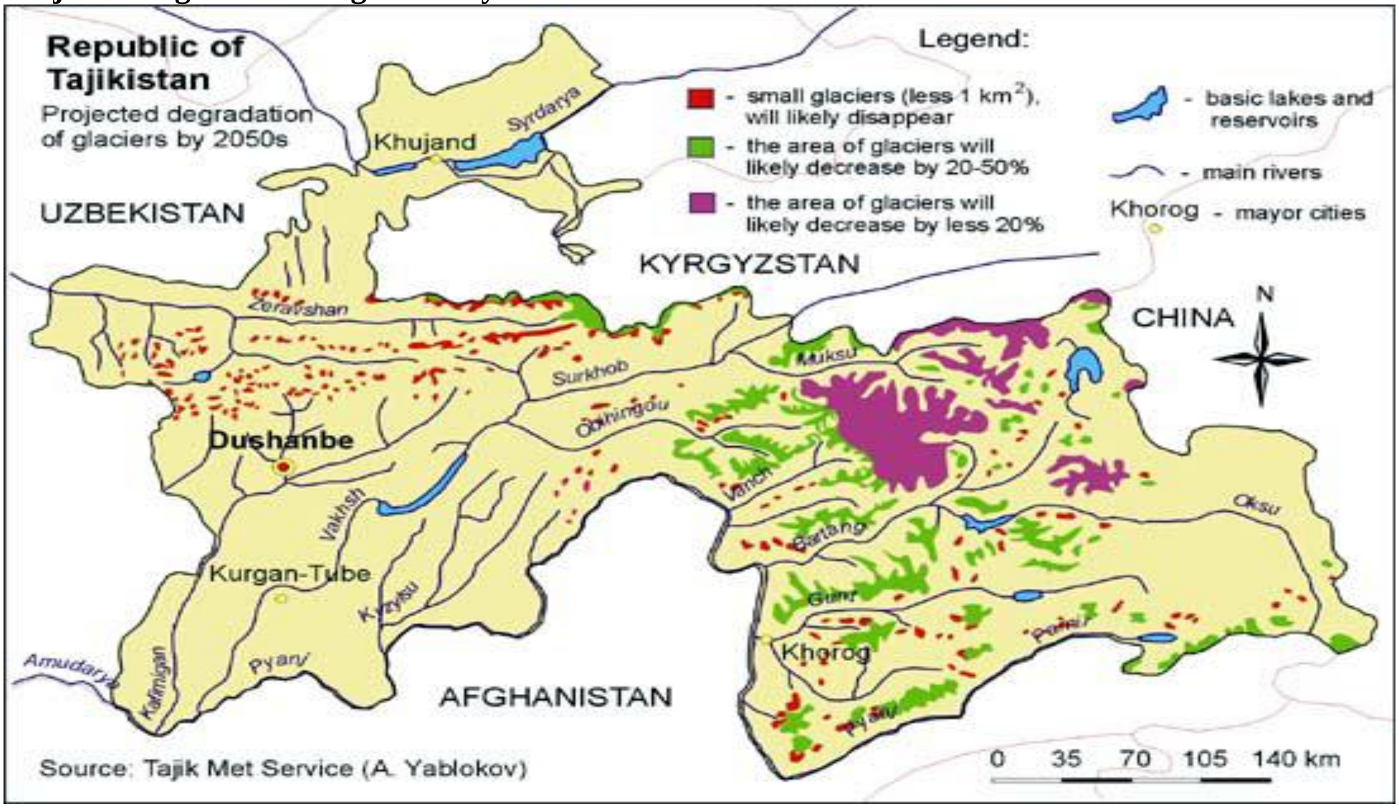
Central Asia : Leaded petrol, mining waste, melting glaciers, flash floods and lowland aridity

[GW&CV Loss➔Loss Pb mgt – Quadrant 4 of the GRID]

The level of lead in the air falls markedly once leaded petrol is no longer in use (Mexico's SOH 2005 p30), so it is of some concern that central Asian countries which are already dry and dusty continue to use leaded petrol. Leaded petrol is still legal in Tajikistan and Uzbekistan (UNEP PCFV 2009) and may be available in neighbouring countries (OECD 2007 p62). While rainfall projections in this region are uncertain as the globe warms (Bates et al 2008 VI fig 2.1, Perelet, 2008 page 10) at least significant ongoing aridity can be expected so a clear priority is to complete the global elimination of leaded petrol. Unfortunately, this region is also heavily polluted with lead from Soviet era enterprises with the Ferghana Valley (shared by Uzbekistan, Tajikistan, and Kyrgistan) being a good example.

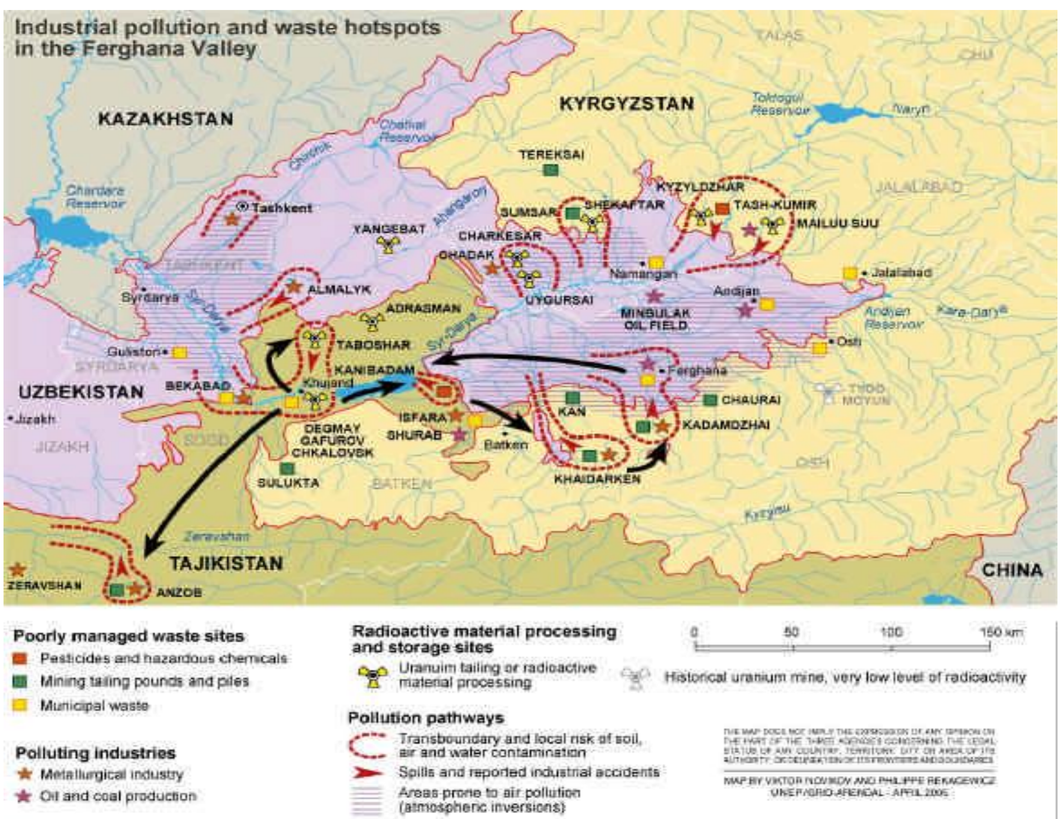
Case study: The Ferghana Valley is home to over 8 million people including 27% of Uzbekistan's population even though it represents 4.3% of its area. The Adrasman lead-silver ore extraction site in Tajikistan and enrichment plant in northern Tajikistan contains an estimated 18,000 tons of lead waste in tailings (ENVSEC Tour 2005). The region is already seismically unstable and prone to flash floods (ENVSEC Report 2005 p25, 35). There was already a major contamination event in 2005 exposing lead waste to direct run off (ENVSEC Tour 2005). There was also a lead treatment facility in the Sumsar Valley. An ENVSEC governmental environment meeting in Dushanbe was informed that the waste from this site was unowned, unmonitored and allowed to wash away during downpours. The waste tailings are located near the banks of the Sumsar River near residential areas that use the river for drinking water. There is no record of any follow-up action (ENVSEC 2006). If rainfall events become more intense as global models predict, the risk to such deposits intensify, so efforts must be made to store the lead waste in a more manageable form. The combination of glacier-fed rivers with heavy mountain precipitation (for the moment falling as snow) leading to seasonal flooding combined with an arid, dusty lowlands (UNEP 2007 fig 6,7,8 p14-15) offers a "perfect storm scenario" for the distribution of a toxic substance like lead in a period of global warming. The following maps indicate the scale of vulnerability.

Projected degradation of glaciers by 2050



Source: Tajikistan 2002: State of the Environment Report UNEP, 2003

Industrial pollution and waste hotspots in the Ferghana Valley



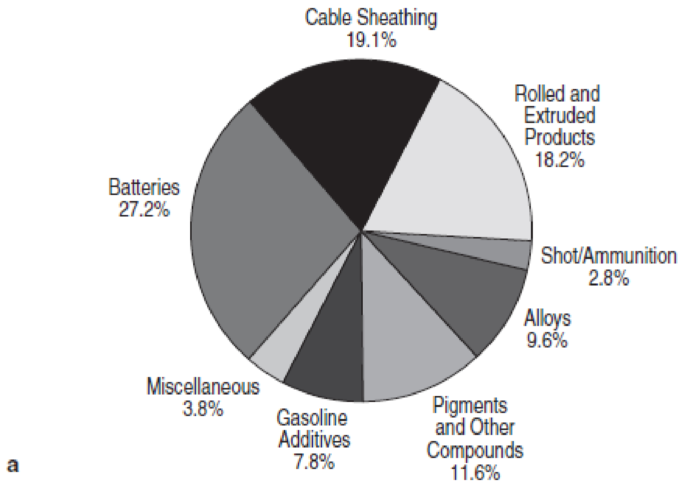
Source: UNEP April 2005 from Ferghana Valley Environmental Media Tour 5 - 10 June 2005"

Lead In Batteries

[GW&CV Gain➔Loss Pb mgt – Quadrant 2 of the GRID]

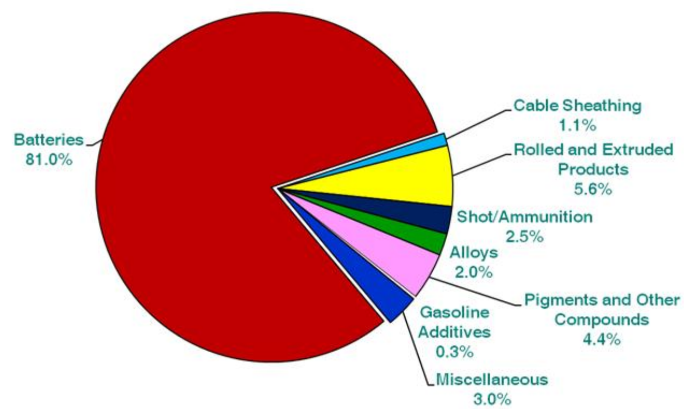
Measures to limit global warming also present severe challenges to lead policy and management. At the present time, lead acid batteries are the predominant form of energy storage with lead acid batteries making up the bulk of installed capacity for the car and small scale static use (such as home-based wind or solar) though exact figures are elusive partially due to battery recycling. The following charts showing global lead use in 1960 compared to 2008 and growth of lead use in lead-acid batteries gives a good idea of the scale of the problem.

The End Uses of Lead 1960



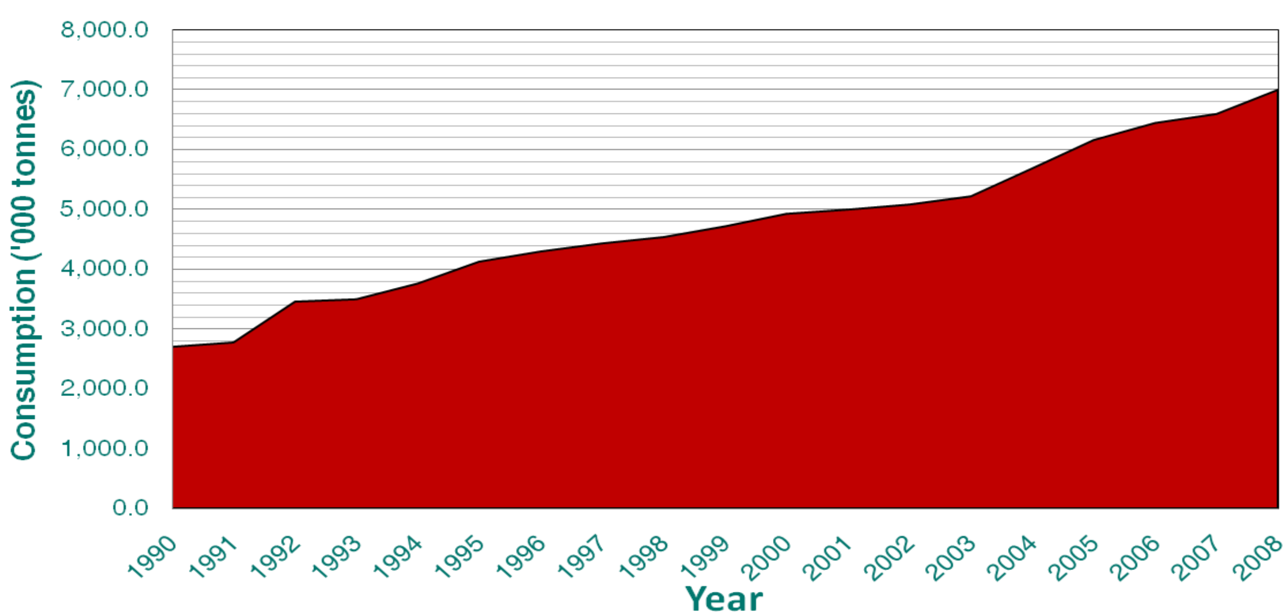
From "Overview Lead: Non-Battery Applications - Beyond Batteries: Other Trends in the Demand for Lead" Wilson, 2006 with the kind permission of David Wilson

The End Uses of Lead 2008



Lead For Batteries 1990-2008 Use

From ""The Effects of Carbon Emissions Reduction and the New Energy Economy on Demand for Lead-Acid Batteries" Wilson, 2009 with the kind permission of David Wilson



From ""The Effects of Carbon Emissions Reduction and the New Energy Economy on Demand for Lead-Acid Batteries" Wilson, 2009 with the kind permission of David Wilson

Addressing climate change is not always a win-win proposition. Acting against climate change can increase the amount of lead in circulation. It is necessary to understand the relationships between diverse and complex systems before creating policy initiatives.

Given a lack of regulations and enforcement in many countries, a major problem with the amount of lead acid batteries in circulation is that their lead content is readily diverted to other uses, particularly when the battery is exhausted. Lead from used batteries has been recycled for use in cosmetics, folk medicine, in illegal drugs, spices or foods to increase weight or add colour : one study from India indicates that over 99% of local turmeric may be lead contaminated possibly due to colouring agents (Girimaji 2004). It is also fashioned into bullets, fishing sinkers, jewellery, craftworks and lead arsenate pesticide. At least one Iranian has died from sampling the lead adultered opium he was selling (Moharari et al 2009). Globally, more than 375,000 people are killed each year by small arms (IANSA, 2009):- how many of these weapons are using ammunition made out of diverted battery lead?

Grid based energy production – Lead from coal, natural gas and biomass

[GW&CV Loss➔Loss Pb mgt – Quadrant 4 of the GRID]

One of the most widely reported greenhouse gas contributors is coal. Since the phasing out of lead petrol in most industrialised countries, coal-based power production has been a significant contributor to atmospheric lead pollution. Coal produced 12% of atmospheric lead emissions in the European Union in 2004 (Diaz-Somoano 2005). Spectrographic analysis of particulates in Shanghai indicated that up to 45% of lead may come from coal burning, and may well have exceeded petrol as a source if not for the phasing out of leaded petrol (Zhang et al 2009). In addition to airborne emissions, there is also significant lead in fly ash waste product stored in waste ponds (EIP 2008). There have been two major US fly ash spills from storage ponds recorded in the past decade: Martin County in October 2000 (released 1.16 billion litres of waste) and the Kingston Fossil Plant (released 4.2 billion cubic meters) in December 2008 (Sourcewatch 2009). Coal combustion, in all forms produced 41% of CO2 emissions in 2005 but can produce 77% of all SO2 emissions. SO2 related aerosols can offset the warming caused greenhouse gasses by reflecting heat into space. Thus, coal fired power production may have no effect on global warming except in jurisdictions that have significantly reduced its SO2 emissions, eg in OECD countries, particularly in Europe (Ramanathan & Feng 2009 p47, 2008 p14248). It is not necessary to totally accept Ramanathan & Feng's upgrading of the impacts of aerosols for this to be true as on a 20 year basis the inhibitory impact of SO2 is only slightly lower than CO2's warming potential according to the IPCC itself (Smith 2008 slide 27).

Natural gas is a cleaner energy source than coal, producing about 60% less carbon dioxide emissions and about 80% less nitrous oxide emissions (Naturalgas.org 2004) per unit of energy, and contains minimal lead concentrations. A possible downside is the impact of fugitive methane emissions from natural gas production and storage, which for Canada amounted to 8% of all carbon emissions in 2007 (equivalent to about 33% of the emissions of the transport sector) (Hamilton, T 2009). It also produces almost no SO2 to offset its atmospheric carbon impact so its global warming impact may be considerably higher than coal (Ramanathan & Feng 2008 p14248). Oil-fired power produces 80% of coal's CO2 emissions and considerable SO2 but also considerable black carbon. Whether it is better or worse than gas for global warming purposes depends on estimation of the impact of black carbon (Ramanathan & Feng 2008 p14248). It certainly can produce significant lead emissions with burning of a specific heavy oil fraction producing 17.9% of industrial lead emissions in Cairo in 1999 (Labib 2000).

Biomass combustion is an emerging technology that has received significant interest from governments. The most widespread example is the use of ethanol in cars but preliminary research has been done on using it in conjunction with or instead of coal or petroleum products for base load power. Traditionally most biomass is used in household furnaces and in appliances up to 5 MW. The widespread use of biomass combustion inside houses for cooking and heating in the third world is not only a significant CO2 source but produces a range of pollutants (Smith, 2009). Biomass combustion can be more polluting than fossilised carbon (Smith, 2009), though its trace heavy metal content can vary widely (Hasan et al 2009). In Northern Ireland, biomass and coal combustion produced most of the 42% of lead emissions produced from domestic sources (NAEI, 2009). In combination with forest burning (for new agriculture), home-based biomass combustion is the primary source of black carbon pollution (Smith, 2009). Black carbon warms the atmosphere and is responsible for snow and ice melting due to changed albedo (reflectivity of sunlight and heat) and temperature at altitude but reduces temperatures at sea level (Ramanathan & Feng 2009 p 44). Claims for a major role in the retreat of arctic sea ice (Ramanathan & Feng 2009 p 44) need to be balanced with the role of thermohaline ocean currents, which move warmer water from the Atlantic to the arctic (Chylek 2009).

Grid based energy production – Lead implications of nuclear, solar, wind, geothermal and other.

Gains in global warming and climate variability lead to losses in lead management.

[GW&CV Gain➔Loss Pb mgt – Quadrant 2 of the GRID]

There are over two dozen types of nuclear reactors now operating. But regardless of type they contribute less greenhouse gas emissions per watt of output (including manufacturing, construction, maintenance and running related emissions) than any of the alternative energy sources: 70% of the greenhouse gas cost of wind and as low as 25% greenhouse gas cost of solar (Kulkinski 2004). The problems are fuel security, toxic waste, plant security, meltdowns and risk management. The new types of reactors, building on the lessons of the past, will reduce waste production and risk. However, one new type of reactor is lead-bismuth cooled, which should of course be discouraged and avoided. During the world's worst environmental disaster, the Chernobyl meltdown, from 27 April to 5 May 1986, more than 30 military helicopters flew over the burning reactor in a failed attempt to smother the fire with 2,400 tonnes of lead and 1,800 tonnes of sand. (Chernobyl.info, undated). Greenpeace (p67, 2006) reports that compared to 1985, anaemia rates in some local regions increased 7-fold during the first 3 years after the accident, apparently correlated to the level of radioactive contamination, however, lead pollution may have been a confounding factor in the study.

Hydroelectric power probably has insignificant impact on lead emissions or waste (though it can increase lead levels in sediments behind the dam) but a variable impact on greenhouse gasses. Major hydroelectric schemes are able to produce significant methane. The electricity produced in tropical regions thereby releases more than twice the greenhouse gases produced by oil combustion, compared with as little as 2% in boreal regions (Tremblay et al, 2004). Tropical conditions are set to expand as the temperature warms.

Geothermal energy has almost no greenhouse impact beyond construction, and its lead impact is limited to the risk of leaks of lead contaminated steam. While it produced 0.4 % of the world's energy in 2004 (IEA, 2007) it is geographically restricted requiring suitable locations and is not projected to grow much in the next 21 years (EIA, 2009). The primary lead impact of solar, wind and similar alternate power generation is storage to deal with the variability of electricity production where inadequate immediate grid demand exists or where there is no reliable grid connection (ie. local or household electricity production or backup). The degree to which they can contribute to our energy future is the subject of fierce debate (Brook, 2009, Trebilcock, 2009) frequently with doubtful scholarship (Giberson 2009). In addition solar panels use powerful greenhouse trace gasses in their production notably nitrogen triflouride, a substance with an estimated 17,000 times the greenhouse impact of carbon dioxide (Coniff 2008).

The lead waste generated by electricity storage can be considerable where lead acid-batteries are the most convenient form of storage. Each computer distributed in the developing world can add 0.9-1.6 kg of lead waste to the environment, due to the unreliability or absence of mains power supply, (Cherry & Gottesfeld, 2009). In the United States lead acid batteries generate over 1.8 pounds (0.8 kg) of lead waste per person. However, little enters the waste stream as 99.2% of lead-acid batteries are recycled (Miller 2009). This is not true of many developing counties. In Uganda in 2000 for example, less than 10% of batteries used for solar systems were returned to the distributor, located in the capital of a country with limited transport and lacking the capacity to reprocess batteries even if they had been returned (Sandgren, 2001).

The competitiveness of lead-based electronic storage in an industry where (unlike transport) battery size and weight is not a major concern is likely to be given a massive boost by the development of lead-carbon batteries that can use the same recycling technology as lead-acid batteries. Preliminary tests of some commercial designs indicate they compete comfortably with Lithium-ion technology for performance, and are likely to be considerably cheaper (Petersen, 2009). Venture capital companies (US military backed) are also developing a foam-based alternative (3D, 3D2) to enhance lead acid battery performance, with claims of improved size/weight ratios for transport applications.

Energy for transport – Lead exposure from petrol, gas and electric cars

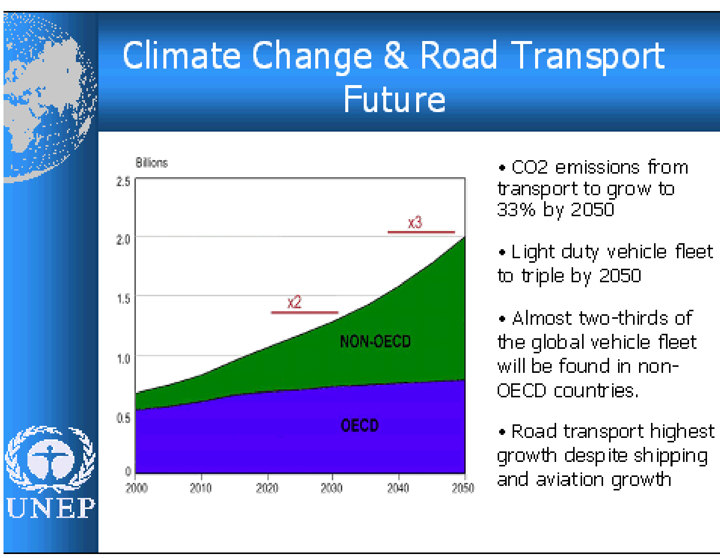
[Pb mgt Loss➔Gain GW&CV - Quadrant 3 of the GRID]

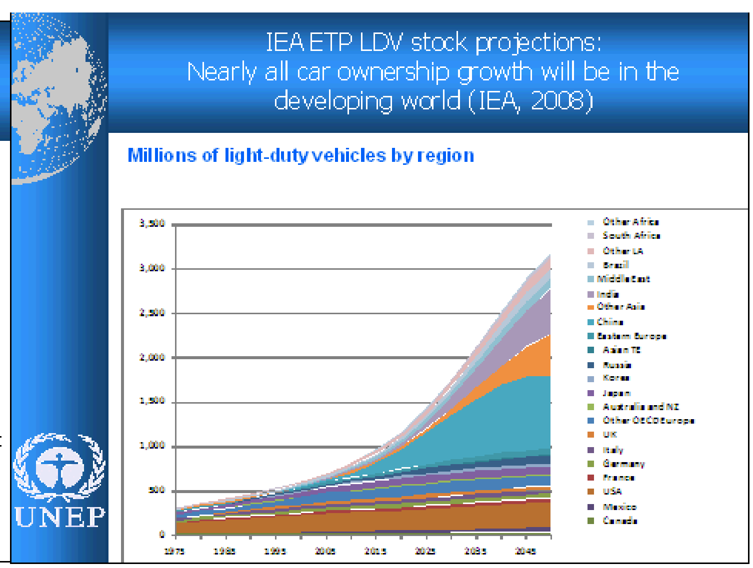
Transport contributes 14 % of global carbon emissions. 45% of this is generated by cars or vans used predominantly for personal transportation. Transport is projected to be the second fastest growing carbon emission sector (Stern, 2007). Hydrocarbon-powered vehicles have the largest impact on global warming of any element of transportation and one that grows over time (Bernsten & Fuglestvedlt, 2009).

For many years leaded petrol provided the primary atmospheric lead pollutant. A significant but declining number of countries continue to use leaded gasoline. The use of leaded petrol prevents the use of catalytic converters which reduce the presence of tropospheric ozone, the second most significant greenhouse gas produced by road transport (Fuglestvedt, 2008). Unfortunately this is not the only consideration as even three way catalytic converters produce NO2, being blamed for a doubling of transport emissions of NO2 in Britain from 1990 to 2006 (EEA 2009). They also produce the toxic substance hydrogen sulphide (reducing sulphur dioxide production) and ammonia (which can be a nitrous oxide precursor) (NAEI 2009 pvi). The greenhouse impact of catalytic converters is difficult to assess.

Unleaded hydrocarbon fuels and brake pads still provide a small proportion of atmospheric lead emissions: an estimated 5-8 % of lead emissions in the EU (Gon & Appelman, 2009). UK figures vary from 1% in Wales to 9% in Northern Ireland. (NAEI, 2009 p72-80). Hydrocarbon-powered vehicles are divided by their fuel source (petrol, diesel or gas).

Although the growth in human population has had a significant impact on climate change, the rate of growth of the vehicle population has been even faster, and projections are that the number of vehicles is set to triple to two billion by 2050 with CO2 emissions from transport set to grow to 33% of all emissions by 2050. More recent projections put the car population as high as three billion by 2050, with nearly all car ownership growth expected to be in the developing world. Every car requires a new battery every 3-5 years throughout its life.





Source: de Jong, Rob, United Nations Environment Program (UNEP)

Diesels have the bulk of the vehicle market in Europe and major shares of the heavy vehicle market in Australia and America. Diesel engines are 30-50% more fuel efficient than petrol engines, produce less CO2 but far more particulate matter. In spite of having less than 3% of new car and light vehicle sales and 56% of one ton trucks in the US, diesels produced 67% of black carbon emissions in Pittsberg (Huebner & Sáez, 2006, Lambe et al, 2009). Over 19% of black carbon emissions come from the transport sector, almost all from diesel or two stroke engines (Cross 2009).

Gas powered vehicles have the reputation for reasonably clean burning. Tests carried out earlier this decade found that light vehicles powered by gas rather than gasoline, achieved significant emission reductions while emitting little trace or particulate pollution: CO 90% reduction, CO2 20%, NO >35%, Hydrocarbons >50%. Comparable statistics for heavy vehicles were halved particulate production, CO2>25% reduction, NO and hydrocarbons >50%, at the cost of increased methane production (US DOE). This means vehicle gas combustion still produces significant quantities of greenhouse gases though it is the hydrocarbon least likely to contain naturally-occurring metal trace elements such as lead. As mentioned in the power section fugitive emission can be massive.

Hydrogen powered cars are being developed. Their GHG impact will depend on the method used to produce the hydrogen. They should produce emissions that are lead and GHG free.

Electrical vehicles and hybrid vehicles are emerging but lead-acid batteries face significant competition from alternate battery technology and to date little lead has been used in these markets. The major niche seems to have been the electric bicycle/ tricycle market in Asia particularly China. Using cheap lead-acid batteries they provide convenience in congested cityscapes. According to the ILA (International Lead Association) >7% of current lead used in batteries is used in Chinese electric bicycles/tricycles and this is likely to grow (Wilson 2009). Batteries used to power electric vehicles have shorter lives than those used as ignition batteries due to the number of recharges they undergo, and must be replaced more frequently. The main problem is that in 2006 only 31% of batteries were recycled in China. An equal number were believed to be recycled through a battery black market with poor control and safety standards. Given that even the official recycling lost up to 30% of recycled lead to the environment, Cherry estimated each 10 Kilo battery produced 6.9 kilos of lead waste, so of the 700,000 tonnes of lead used in electric bikes last year, as much as 483,000 tonnes escaped into the environment (Cherry, 2007, Wilson, 2009). Clearly, this rate of loss is alarming.

Rural contributions to climate change and lead levels

[GW&CV Gain→Loss Pb mgt – Quadrant 2 of the GRID]

Rural industries contribute three major greenhouse gasses to the atmosphere: carbon dioxide, methane and nitrous oxide. According to Mohr (2005): "The conclusion is simple: arguably the best way to reduce global warming in our lifetimes is to reduce or eliminate our consumption of animal products. Simply by going vegetarian (or, strictly speaking, vegan), we can eliminate one of the major sources of emissions of methane, the greenhouse gas responsible for almost half of the global warming impacting the planet today." As long as veganism assures adequate iron and calcium in the diet, lead absorption rates will not increase on a vegan diet. Mohr (2005) also states: "Because ruminant livestock produce far more methane than non-ruminant livestock, reductions in agricultural methane can also be achieved by shifting consumption away from cows and sheep in favor of chickens and pigs. However, the benefits of such shifts are not simple; for example, in the U.S., manure from pigs produces more than five times as much methane as manure from beef cattle." Red meat is a superior source of iron for people prone to iron deficiency.

[GW&CV Loss➔Loss Pb mgt – Quadrant 4 of the GRID]

CO2 is the rural GHG with the most significance for lead management. CO2 is predominantly created by the burning of forested areas for farmland, providing about 18% of global carbon emissions (Stern, 2007 p171). Larson & Koenig (Annual Review of Public Health, 1994) reported that lead particles in wood smoke ranged from 0.1 to 3.0 mg per kg of wood burned. Burning 3 tonnes of wood could therefore result in between 0.3 and 9 g of lead emissions, an enormous range. More significantly for the individual is the location where the biomass is consumed. A significant amount of biomass (including dung) is used for domestic cooking and heating. In poorly ventilated buildings, such as huts, it can be a major source of exposure to heavy metals (Kang 2009). The impact depends on the exposure the vegetation (including that in dung) has had to lead. One impact of increasingly intense precipitation will be to increase the range and diversity of vegetation exposed to lead including food crops.

Tranformations

[GW&CV Loss➔Loss Pb mgt – Quadrant 4 of the GRID]

Now to examine transformations in one of the most publicised areas, power generation. Yet even energetic measures may have less impact than may be imagined.

Europe has targeted 20% of energy from renewable sources (double its current level) by 2020 (BBC 2009) at significant cost, yet this will not reduce its carbon dependence. It will retire some coal fired power generation replacing it with a greater amount of gas fired capacity which may lower emissions while possibly increasing the greenhouse impact (EIA 2009). The region has substantial diversity in power generation, with significant and increasing holdings in wind, solar, gas and nuclear, yet it still uses carbon combustion (including biomass) as its primary electricity generator at 55.1% in 2006 (Eurostat, 2009).

Immediate reduction in the construction of coal-fired power plants would have immediate positive health benefits (including significant reductions in lead emissions) but would have little short-term climate change impact: contrary to popular imagination coal combustion is only a major climate change driver if it is comparatively "clean" (Ramanathan & Feng 2009). Converting to nuclear would eventually eliminate lead and other emissions from coal fired power stations but at the (remote) risk of a nuclear disaster spreading radioactive lead if it occurred. A nuclear power station takes between 7 and 15 years (WNA 2009) to build making its impact too late for the 2020 deadline though it may have a role to play thereafter once the new Gen IV reactors can be evaluated . Of the other possible replacements hydroelectricity and geothermal are limited by suitable sites and environmental objections while variable alternate energy sources (wind, solar etc) are limited by the need for co-generation of power or massive electrical storage.

The central problem is that owing to the capital and material intensive nature of their construction only a small proportion of major power plants, which remain in operation for 30-50 years, can be replaced in any given year. While focusing on power generation, as many government and environmental organizations have done, may have its rewards it does little to deal with the need to reduce GHG emissions in a 6-11 year time frame.

The consequences of increased demand for lead

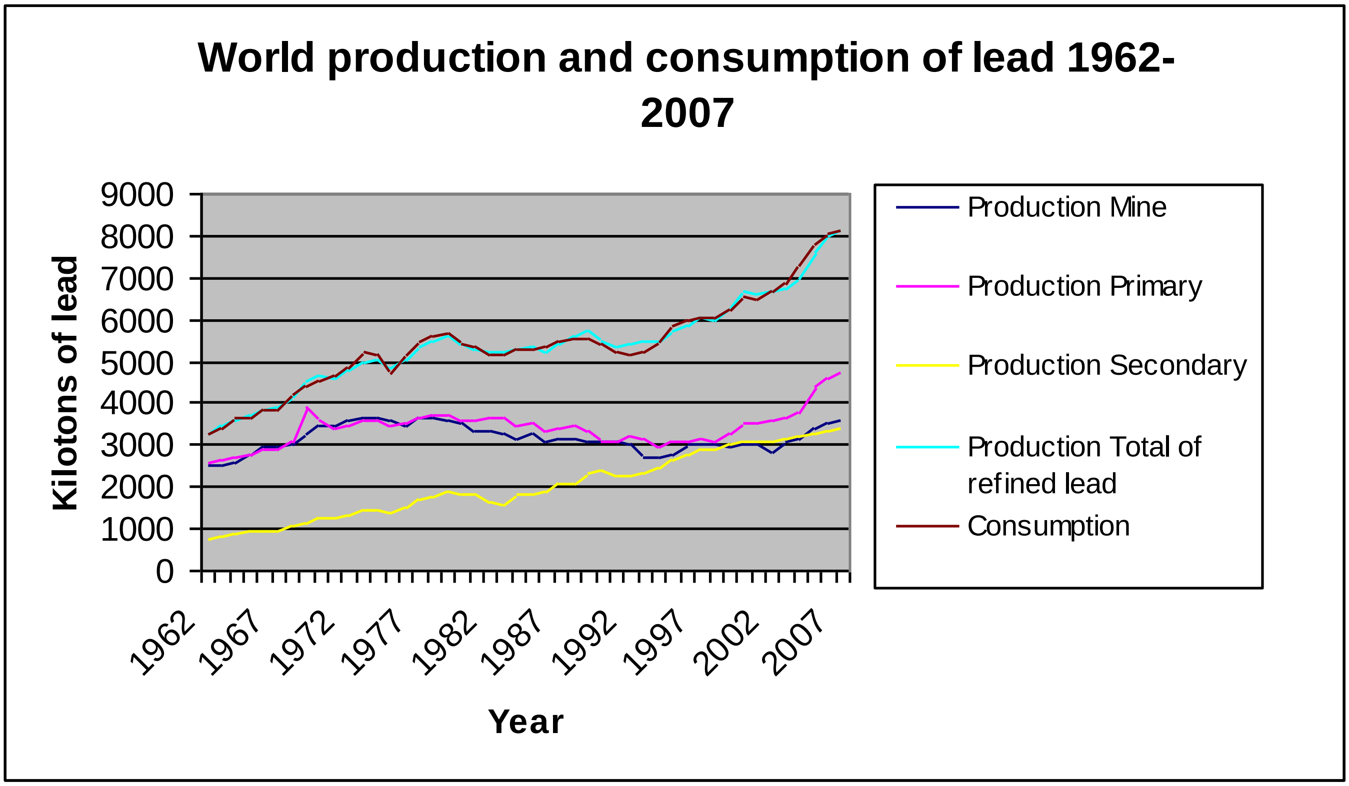
[GW&CV Gain➔Loss Pb mgt – Quadrant 2 of the GRID]

Source: AP Photo/Rebecca Blackwell

Some calculations have less than 22 years global supply of lead remaining which could be profitably mined at current prices (Garnault, 2008 p71) and prices and volumes are bound to rise as carbon reduction strategies take effect, increasing the demand for lead acid batteries. Such a rise is already underway as the graph below indicates.

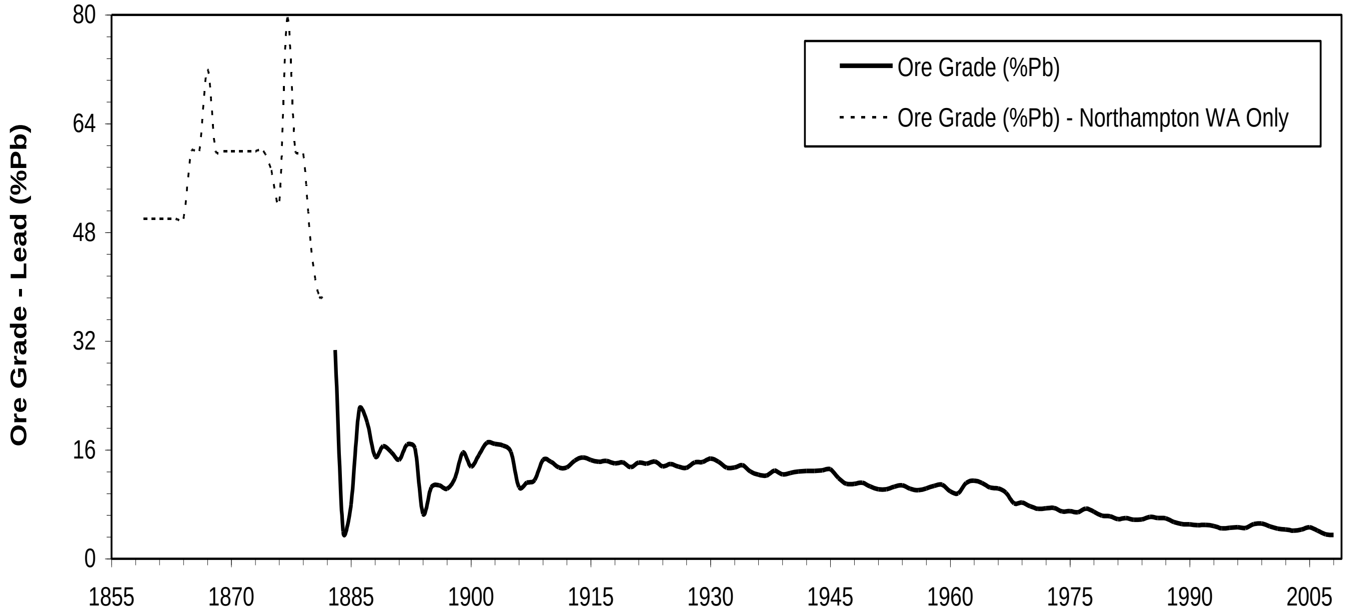
The danger is that if lead prices rise there will be more incidences like Thiaroye Sur Mer, Senegal where 18 children died and an entire town was lead poisoned.

A lead merchant offered the townspeople 60 cents a kilo for lead sifted from a blacksmithing site where batteries had been turned into sinkers for fishing nets, lead poisoning all who took part, and through releasing dust with high lead concentrations into the air, the entire town (Vogt, 2009).



Source of data: ABARE 2008, graphed by The LEAD Group.

Over time and as the price of lead rises, higher tonnages of lower-grade ores are mined, thus increasing the tonnage of waste per tonne of lead or zinc mined. From the following graph, there is currently approximately 4% of lead and 8.5% of zinc being extracted from each tonne of lead-zinc-silver ore in Australia (the world's biggest lead exporter), presumably leaving approximately 87.5% waste rock.The actual tonnage of mine waste per tonne of newly mined lead is around 29 tonnes of lead for an underground mine and 87 tonne for an open pit. Lead and zinc smelting produces around 9.3-9.6 kg waste per kg of lead.



Source: Mudd, 2009 “Sustainability of mining in Australia” Reprinted with the kind permission of Gavin Mudd

Recommendations

Greenhouse gas related recommendations

[Gain GW&CV ➔ Pb mgt Gain – Quadrant 1 of the GRID]

The first point is the need to focus on measures that have short term impacts. Measures that produce long term reduction are worthwhile but the first set of targets must be met in less than 11 years. Black carbon stands out as it life span in the atmosphere is measured in weeks rather than years.

The primary policy could be immediate hefty increases in taxes on hydrocarbons for transport and the immediate cessation of direct and indirect government hydrocarbon subsidies current in many countries. In spite of the fact that fuel is relatively cost insensitive (Stern, 2007), unlike major power generation, other transport modes, car technologies and uptake can radically shift in an 11 year lifecycle. Fuel use in the USA (responsible for 37% of transport emissions (Stern Transport 2007 annex 7.c) fell in 2008 due to a combination of high fuel prices and the economic recession (Intertanko, 2009). Reduction in fuel use would directly reduce lead emissions. It should be accompanied by an abandonment of subsidies and mandates for most biofuels, given most biofuels increase global warming by forest clearing in the developing world or increasing nitrogen oxide release from farming (Crutzen et al 2007, Melillo et al 2009). An immediate priority is to complete the global elimination of leaded petrol. This can be readily accomplished as only one global petrochemical manufacturer is now supplying all the world’s lead–petrol additive.

From the developing world perspective the priority should be reducing forest clearing as not only does it produce an average of 18% of GHG emissions (Stern 2007) but over 5% of black carbon emissions (Smith 2009). Again some decline in lead emissions would ensue, though difficult to quantify. Priority must also be given to replacing or modifying biomass and coal combustion from home cooking or heating in the developing world since this produces over 50% of black carbon emissions and exposes individuals to arrange of trace metals including lead. Programmes such as Respire which aims to improve stove construction (Smith 2009) or project Surya which replaces biomass with solar or gas (Ramanathan & Feng 2009 p48). with must be expanded and better funded**.**

Adding thermal insulation to a building will reduce the need for energy for both heating and cooling but when ceiling insulation is going to be installed, ceiling dust should be removed first, and recycled for its lead content (O'Brien and Roberts, 2009b).

Industry is comparatively price sensitive (Stern 2007) and produces a significant amount of black carbon (about 8%, mostly from iron and steel production which also produces significant lead emissions). Price incentives should be based on the need to rapidly reduce black carbon emissions and carbon emissions with little ancillary atmospheric pollution. While removing ancillary pollution may have positive health impacts, from some pollutants (notably SO2) the price of their elimination will be accelerated climate change (Ramanathan & Feng 2008). Lead impacts would vary.

In the long term the ability to sequester greenhouse gasses will become a priority particularly if pollution levels are reduced for health reasons. Burying carbon dioxide (geosequestration) has been an attractive proposition for politicians but 13 years after it was first used and 6 years after the Bush administration pledged enormous funds to Futuregen it has produced the pilot Mountaineer project which removes less than 4% of carbon dioxide emissions from the power complex to which it is attached (James 2009, Garber 2009). Equally importantly, clean coal technology is unlikely to be available till well after 2020 (Pearce 2008). The cost, scale, capital intensiveness and risks make it unlikely to be effective except as a political chimera **(**Thomson 2009**).** Biosequestration may well be more attractive since it is not capital intensive, can be initially implemented on a small scale and can therefore be trialled in a number of forms with different tie-ins. It is also more immediate. The idea of using algae to purify power station emissions and then to use the algae for biofuel or feedstock for animals or fish is at the point of trial commercial application (Biotech Patent News 2008) and early results show some promise though it must be emphasised that current carbon reductions seem modest (Ben-Amotz 2008), especially if most of its product is burned as biofuel.. Specifically designed greenhouse gas storage mechanisms (such as biochar) are in development and may have subsidiary benefits for wider applications for control of toxics. The fact that one biochar product may be able to absorb lead is promising (Cao et al, 2009).

Lead management recommendations

One of the most important recommendations is the need to modify the way we handle waste that contains significant quantities of lead. Mining or smelting operations traditionally use ponds or dry tailings. Such stores will be vulnerable to increasing heavy precipitation events predicted worldwide. It is vital we develop cheap ways of extracting toxics such as lead from wastes and storing them in more compact and controllable form. Current experiments with biological wastes like pectin (Baleria, 2008) or brewer's yeast (Parvathi, 2007) need to be expanded and better resourced. Chemical treatments to make lead less mobile or bioavailable also need industry and government support.

We need to reduce the amount of lead entering the environment through mining, smelting, manufacturing into dispersed products, and during recycling, particularly due to the growing demand for lead acid batteries. The USA shows this is possible, where over 80% of lead is used in batteries (Shoenung, 2003) but only 0.8% of this is not delivered for recycling (Miller, 2009). A government tax on newly-mined lead and mandatory deposit or re-purchase schemes on lead acid batteries can be implemented through those organisations that distribute lead-acid batteries, and through certification of recycling facilities.

While this may not be wholly achievable in the developing world, a number of Indian initiatives show that matters can be significantly improved. The initiative in India was developed jointly by Occupational Knowledge International (OK Intl), Development Alternative (DA), NRCLPI and other stakeholders such as a major battery manufacturing unit and various Governmental bodies. It succeeded in the outcome of Better Environmental Sustainability Targets (BEST), which received global recognition at the recent UNEP meeting in Bangkok.

Good case examples need to be promoted in other countries. In India, a couple of major players in battery manufacturing units have already signed up for the certification program where eco labelling of their batteries will be made available. This has already resulted in the reduced impact of lead on the environment. The average blood lead levels have come down amongst their employees. Small battery manufacturing units have signed up for improving the safety of their production of lead acid batteries. This initiative is recommended by QCI.

It is also essential that governments enforce any regulations that they have against the use of lead (usually taken from the lead acid battery black-market) for potentially fatal uses such as in food, cosmetics, toys, jewellery, fishing sinkers, folk medicines and illegal drugs.

One option is to tax new vehicles applying the tax differentially to encourage cars that are more easily recycled, have lower GHG footprints for their manufacture, burn less hydrocarbons and that do not use lead acid batteries for power or ignition. European car now conform to an end of life vehicle standard which makes them more easily recycled while cars from Germany, France and Sweden have lower carbon footprints owing to most the electricity being produced from nuclear, hydroelectric and wind power so under this scheme cars from this region would be less heavily taxed. Other strategies may be divided into long term and short term strategies Short term strategies are those that will have a significant impact quickly and need priority. These are mostly related to personal vehicle usage: subsidising car share schemes, increased parking cost, pay as you drive pricing, and pricing for road use. The other is long term and requires significant lead time to allow for infrastructure: improving public transport (particularly given buses are frequently not a preferred transport mode), improving bike and walking access, reforming planning to "encourage" higher dwelling density and smart growth policies to integrate land use within a locality. These have lower priority because of the difficulty of implementing them to a major degree in a 5-11 year time frame.

Dr Perry Gottesfeld of OK International recommends converting such operations to battery-collection and concentrating battery recycling into larger regulated facilities to gain efficiencies that would reduce their GHG emissions (although this might be somewhat offset by increased SO2 capture). More importantly, it would improve occupational health and safety for the workers and limit access of third parties, notably children to lead and lead contaminated waste.

Leaded AvGas should be banned globally

The aspects most likely to be addressed first by governments are those that involve minimal change and minimal expenditure. The cheapest policy option is arguably education. The experience of the USA and India demonstrates that lead education can be highly cost effective. The National Referral Center for Lead Poisoning in India (NRCLPI) with the help and assistance from the Quality Council of India (QCI) has successfully initiated and launched the Lead Educators program (Lead-er) in ten states of India training over 6,000 school teachers on awareness about the impact of lead on our environment and health. Each of these school-teachers who had participated in a one day workshop could reach out to over 500 school students within six months. This has resulted in reduced exposure to lead and lead based materials. (Thuppil, 2008).

The next cheapest option is likely to be to support the priority of the Copenhagen Initiative in providing nutritional supplements (Vitamin C and trace minerals) to the poorest individuals. In particular, individuals who are iron and calcium deficient are far more susceptible to lead exposure, so the provision of these supplements to deficient individuals immediately reduces risk at minimal cost. Community studies in India showed that children who were anaemic, when provided with iron supplements, were found to have lower blood lead levels after exposure to environmental lead (Herman et al, 2003, Vishwanath et al, 1988)

Both measures also have the advantage of being useful even if climate change does not occur (unlikely but possible). Both can be accomplished by private means if governments are disinterested.

It is strongly recommended that research be conducted into the tertiary prevention of lead poisoning. Since lead poisoning health effects are worsened by higher temperatures, and lead stored in bone returns into the blood during ageing, finding a treatment which can remove lead (and other toxic heavy metals) before the lead causes widespread health issues, will reduce the burden of ageing populations with lead induced slow reaction times, poor memory and hearing, balance problems, increased irritability, osteoporosis, Alzheimers and mental decline.

Conclusions

[GW&CV Gain➔Gain Pb mgt – Quadrant 1 of the GRID]

This paper has identified relationships and correlations between climate change and lead poisoning, giving researched examples of each of the gain/loss combinations. Exposure to lead and occurrences of poisoning will be increased by climate change and also by efforts to mitigate climate change unless mitigation strategies are considered for gain/loss with other health and environmental issues.

Priority strategies to counter global warming and climate variability need to overcome the scenarios in the **Loss➔Loss** quadrant and be selected from the **Gain➔Gain** quadrant in their relationship with lead toxicity.

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