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Review and assessment of options for enhanced voluntary measures and new or existing international legal instruments

Report on the current supply of and demand for mercury, including the possible phase-out of primary mercury mining

Note by the secretariat

Addendum

The annex to the present addendum contains the full text of the report referenced in UNEP(DTIE)/Hg/OEWG.2/6.

* UNEP(DTIE)/Hg/OEWG.2/1.

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Annex

UNITED NATIONS
ENVIRONMENT PROGRAMME
CHEMICALS

Meeting projected mercury demand without primary mercury mining

requested by
the Ad Hoc Open-Ended Working Group on Mercury

July 2008

Executive summary

1. Rationale for this study

The UNEP Governing Council established the Ad Hoc Open-Ended Working Group on mercury (OEWG) to, review and assess options for enhanced voluntary measures and new or existing international legal instruments to deal with global mercury problems. One of the highest priorities is reducing the supply of mercury to the global market, with a special focus on phasing out the production of new mercury (i.e., from mercury mines) because this mercury increases directly the total quantity of mercury circulating in the economy. In November 2007, the OEWG requested the UNEP secretariat to study whether future mercury demand could be met if mercury mining were to be phased out, in particular consideration of mercury mining for export, currently carried out only in Kyrgyzstan.

2. Mercury from primary mining

Kyrgyzstan is the only country currently mining significant quantities of mercury for export. China mines mercury for its own needs and does not export liquid mercury, while mercury mines in Spain and Algeria have closed, and no longer supply mercury to the global market (see table below).

Major mercury mine production, 2000-2005

Mercury mining (metric tonnes)	***2000***	***2001***	***2002***	***2003***	***2004***	2005
Spain	236	523	727	745	0	0
Algeria	216	320	307	234	90	0
China	203	193	495	612	700-1140	800-1094
Kyrgyzstan	590	574	542	397	488	304

3. Global mercury consumption

The following table shows the consumption of mercury by major uses in 2005, as well as projections of future consumption through 2015. Two future scenarios are described. The first scenario represents the highest future consumption, reflecting trends, legislation and modest initiatives that are already in place. The second scenario[1] reflects lower levels of mercury consumption in products containing mercury. These targets will depend to some extent on more progressive measures such as new political initiatives, special funding or other encouragement that has not yet been confirmed.

[1] Developed by the UNEP Global Mercury Partnership within the Reduction of mercury in product partnership area.

Global mercury consumption, 2005-2015

Application	Consumption range 2005 (tonnes)	Conservative "status quo" projections to 2015	More progressive UNEP Product Partnership targets for 2015
Artisanal mining	650 - 1000	no significant change	not applicable*
VCM/PVC	715 - 825	increase to 1250, followed by gradual decrease	not applicable*
Chlor-alkali	450 - 550	reduction of 30%	not applicable*
Batteries	260 - 450	reduction of 50%	reduction of 75%
Dental amalgam	300 - 400	reduction of 10%	reduction of 15%
Measuring & control devices	300 - 350	reduction of 45%	reduction of 60%
Lamps	120 - 150	reduction of 10%	reduction of 20%
Electrical & electronic devices	170 - 210	reduction of 40%	reduction of 55%
Other applications	200 - 420	reduction of 15%	reduction of 25%
Total consumption	3,165 - 4,365		
Recycled & recovered mercury	(650 - 830)	increase from 20% of consumption to about 28%	not applicable*
Net consumption	2,500 - 3,500		

* not covered within the products partnership

In most cases mercury consumption through 2015 is expected to decline. However, a reduction of mercury consumption in artisanal gold mining cannot be expected without a focused effort to address this use of mercury. Likewise, despite initial steps taken by the Chinese government, the consumption of mercury in the production of vinyl chloride monomer (VCM) and polyvinyl chloride (PVC) is expected to increase further before it decreases.

4. Future mercury consumption vs. mercury supply

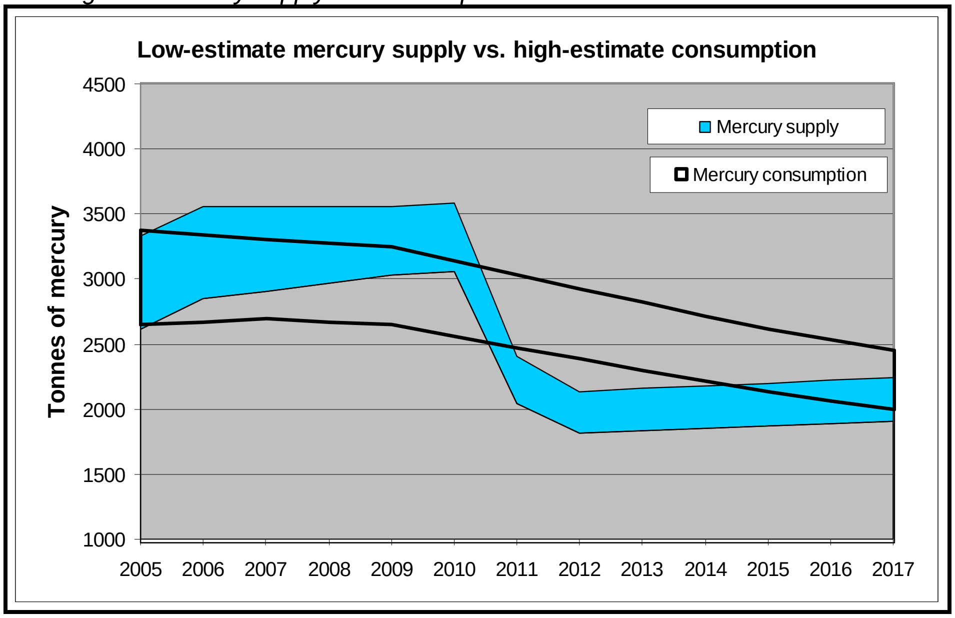
With regard to the next 10 years, this report assumes three major disruptions to mercury supplies. Most importantly, the a ban on the export of mercury from the European Union will enter into effect in 2011. This will remove from the global supply mercury mainly recovered from the EU chlor-alkali industry, as well as mercury from smelting of ores and natural gas cleaning.

The second disruption to supply is the potential phase-out of mercury mining in Kyrgyzstan. It is assumed, merely for the purpose of this analysis which requested consideration of the effects of closing all primary mercury mines, that mine production would cease in 2011. It is noted that the reserves available in Kyrgyzstan for commercial development will support production at current levels for only another 8 to 10 years, with a subsequent reduction in production even without a policy decision to close the mine.

The third disruption, included to ensure that this analysis considers the "worst case" mercury supply scenario, assumes a decline in Chinese mercury mine production from 2012, based on limited mine reserves.

These disruptions, which have an additive effect, are reflected in the following graph of future mercury supply and consumption, comparing the lower estimates of mercury supplies with the higher estimates of mercury consumption in order to visualize the "worst-case" scenario.

Future global mercury supply vs. consumption



Reflecting the various supply disruptions, this figure reveals a sharp reduction in mercury supply in 2011-2012.

However, even if this "worst case" scenario were to occur, the cumulative deficit in mercury supply compared to consumption for the entire period 2005-2017 is only 1500-1600 tonnes, or one-half of the global consumption in 2005. In the mercury marketplace, over a 10-year period, it is normal for mercury surpluses generated in some years to be stored and later retrieved when there is an insufficient supply.

Nevertheless, in the event that further mercury supplies might be required, there are other sources available to meet the deficit. Additionally, there would be some flexibility in the potential closure date of the Kyrgyzstan mine, should it be considered essential.

5. Alternative sources of mercury

There are a number of sources of mercury – other than mining – that are typically exploited to satisfy demand. The most important of these is mercury from the chlorine industry. There is a large quantity of mercury at the bottom of the production "cells" that is necessary for the mercury process to function properly. When a "mercury cell chlor-alkali" facility is closed or converted to a mercury-free process, the mercury is removed from the cells.

While not a "source" of mercury in the same sense, mercury recycled or recovered from products (thermometers, dental fillings, fluorescent lamps, batteries) and other manufacturing processes also reduces the need for newly mined mercury. Likewise, mercury may be recovered from sludges and wastes such as those generated by the chlor-alkali industry.

The largest inventory of commercially available mercury held by a single organisation is in Spain. This inventory has been accumulated over a number of years from various sources, and continues to be sold as needed to many of the long-time customers of the now-closed mercury mine.

Zinc, copper, lead and other non-ferrous ores often contain trace concentrations of mercury. Due to the high temperatures of the smelting process, trace mercury is typically emitted to the atmosphere unless it is intentionally captured before release. Because of the enormous quantities of ore processed globally, the mercury potentially available from these "by-product" sources is significant. Likewise, most natural gas contains mercury in trace quantities that is typically removed when the gas is "cleaned."

The quantities of mercury supplied by these sources are quite variable from one year to the next. Because they are so diverse, they are able to respond relatively rapidly to changing demand. At the same time, however, their diversity also makes these sources more difficult to monitor with any precision.

The following table summarises the main sources of mercury as described above. The key sources at present are mined mercury and mercury recovered from the chlor-alkali industry.

Global mercury supply, 2005

Key sources	Mercury supply (metric tonnes)
Mercury mining	1150-1500
By-product mercury from other ores, including natural gas cleaning	410-580
Recycled Hg from Hg-added products & processes	a)
Mercury from chlor-alkali cells (after decommissioning)[b)]	700-900
Stocks and inventories	300-400
Total	**2560-3380**

Notes:
a) Included in previous table to determine "net" mercury consumption.
b) "Mercury from chlor-alkali cells" is elemental mercury removed from cells after they have stopped operating.

In some cases the cost of mobilising additional mercury sources would be a major consideration. In other cases, the cost has less relevance. For example, since recycling is an increasingly viable waste treatment option, mercury recovered from waste is typically already paid for by the organisation that sends mercury waste to a recycler. On the other hand, if one were to install equipment to remove mercury from industrial flue gases for the sole purpose of increasing the mercury supply, the cost would be prohibitive.

The following table suggests that substantial additional mercury may be recoverable from various sources at an equivalent cost of up to $US 50/kg, which is considered to be close enough to the present mercury price that these sources may be considered as viable additional resources. The table also indicates further quantities of mercury that may be available at 4-5 times the present price. An increase of this magnitude occurred between the middle of 2003 and the middle of 2005, and may be seen again under expected circumstances of tightening supplies around 2011-2012.

Additional mercury recoverable from major sources at reasonable cost (tonnes/year)

Enhanced recovery of mercury from:	Mercury consumption	Already recovered as metallic mercury	Additional Hg recoverable at < $50/kg Hg	Additional Hg recoverable at $50-100/kg Hg
Artisanal mining	650-1000	~0	400-500	100-200
VCM/PVC production	715-825	350	100-150	150-200
Chlor-alkali industry	450-550	100-120	80-100	80-100
Dental amalgam	300-400	50-80	0	0
Other mercury-added products, and "other" applications	1050-1580	150-250	100-200	100-200
By-product (non-ferrous metal mining, natural gas) sources	1100-1400	400-600	50-100	100-150
Coal combustion emissions	~1500	minimal	0	0
Total			**750-1000**	**550-800**

6. Key observations

There are two key observations that stand out in particular as a result of this analysis. First, apart from the present situation in China, mercury mining is not essential. The contributions of Kyrgyzstan to the global mercury supply over many years have been important but not indispensible. The recent experience in closing both Spanish and Algerian mining operations, which represented a much larger part of the global mercury supply than does Kyrgyzstan's mine, have demonstrated that mercury demand can readily be met without primary mercury from Kyrgyzstan.

Second, experience has also demonstrated that the various elements of global mercury markets work effectively according to basic market principles. The closure of the important mercury mine in Spain, closely followed by the mine in Algeria, in 2003 and 2004 were followed by sharp mercury price increases. As a result, global mercury consumption in products decreased, while a variety of non-mining sources of mercury scrambled to meet demand. Once a new supply-demand equilibrium was achieved, the price of mercury eased somewhat, although it remained several times higher than its pre-2003 level.

As a result of the volatility surrounding these market adjustments, a greater variety and greater quantities of mercury waste are now treated for recovery than previously, more mercury-containing products are separated from the waste stream, more by-product mercury is generated, and more mercury is now held in storage to deal with future supply disruptions. In other words, the global supply of mercury has become more diverse, while the elevated mercury price (not to mention increasing awareness of environment and health concerns) continues to add pressure on mercury users to further reduce consumption and shift to viable mercury-free alternatives.

The challenge of meeting mercury demand without mercury mining

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TABLES

1 Background

1.1 Global objective

The overall global objective of the UNEP Mercury Programme is to reduce the risk to human health and the environment from mercury. The Global Mercury Assessment[2] concluded that this objective can only be achieved by decreasing the "mercury burden" in the biosphere.

The UNEP Governing Council (in Decision 24/3) determined that the following are among the priority measures for reducing the risk to human health and the environment from mercury:

- reducing the global mercury demand related to use in products and production processes;
- reducing the global mercury supply, including considering curbing of primary mining and taking into account a hierarchy of sources.

1.2 Regional responses

1.2.1 Reducing mercury demand

Numerous measures are underway, both nationally and internationally, to reduce mercury demand and to encourage mercury-free alternatives for a range of product and process applications.

To take only the example of mercury in products, large amounts of mercury are used globally in the manufacture and use of numerous products, representing almost one-third of the global mercury demand. Yet for most products there are viable alternatives available. The most obvious exception is mercury containing energy-efficient lamps, where mercury-free alternatives are still limited or quite expensive. Reducing and, if possible, eliminating mercury in products is important because any reduction in the use of mercury ultimately reduces releases of mercury to the air, land or water and reduces the potential for human exposure and environmental impact. Addressing mercury use in products will reduce the global demand for mercury and help to ultimately break the cycle of mercury being transferred from one environmental medium to another.

The major effort presently in place to coordinate activities aiming to reduce mercury in products is the Mercury-Containing Products Partnership Area (MCPPA) within the UNEP Global Mercury Partnership.[3] The MCPPA is coordinating and supporting a variety of initiatives that promote substitution where feasible and that develop mercury-free alternatives where none currently are available; that identify, reduce, and eliminate global mercury releases to air, water, or land that are associated with the manufacture of mercury products; that provide economic and educational benefits to partners and the general public by promoting commercially competitive and environmentally responsible solutions for reducing the use of mercury-added products; that identify where mercury is used in products and manufacturing sectors, implement effective strategies for promoting the use of feasible alternatives to mercury-added products, track reductions in mercury use; etc.

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2 UNEP, 2002.

3 Reference website.

1.2.2 Reducing mercury supply

A number of initiatives have also been undertaken with the aim of reducing the overall supply of mercury to the marketplace, with a special focus on phasing out the production of primary mercury (from mercury mines) because primary mercury increases directly the total quantity of mercury circulating in the economy.

Mercury mining in recent decades has been dominated by three nations mining mercury for export (Spain, Kyrgyzstan and Algeria), and a fourth nation (China) that has mostly provided for its own domestic consumption. However, both Spain and Algeria have during the last several years terminated their mercury mining operations, which accounted for well over half of the primary mercury produced each year. Their reasons for doing so involved a combination of economic, technical and political factors, but their decisions have coincided with increased international scrutiny of primary mercury mining sites, and a growing consensus that primary mining is no longer desirable, and perhaps unnecessary.

The only major mercury mine still exporting mercury is the Khaidarkan mining complex in Kyrgyzstan. Despite logistical and technical challenges, including relative inaccessibility and difficulty obtaining spare parts, this mine is important to the local economy and continues to operate. A project to develop an action plan to address primary mercury mining in Kyrgyzstan has been initiated with the support of the governments of Switzerland and the United States of America.

In recent years the People’s Republic of China has restricted mercury imports and increased domestic production of mercury to provide for its substantial domestic needs. China has not historically exported much mercury, and does not appear to have the capacity or desire to do so. However, because China is such a large mercury consumer, and because of the rapid increase in mercury demand for certain sectors, China may need to look again to mercury imports in the near term unless other measures are taken to dampen demand.

Broader measures to reduce the circulation and availability of mercury include such initiatives as the proposed EU and USA mercury export bans. In the case of the EU, the export ban is coupled with a requirement for storage of “surplus” mercury coming from the chlor-alkali industry, among others. In the USA, the federal government has decided to put government inventories of mercury into long-term storage rather than to sell them on the open market. All such measures have the effect of restricting the mercury supply, putting upward pressure on mercury prices, and contributing to reduce mercury demand.

Within the UNEP Global Mercury Partnership, some activities aimed at limiting global mercury supply have been initiated. For example, focused action to assist Kyrgyzstan to address the possible transition of the Khaidarkan Mercury Mine has been recognised as a priority within the international community. Further work under this partnership area is under consideration.

1.3 Rationale for this analysis

The UNEP Governing Council established the *Ad Hoc* Open-Ended Working Group on mercury (OEWG) to review and assess options for enhanced voluntary measures, and new or existing legally binding instruments on mercury.[4]

The first meeting of the Open-Ended Working Group was held in Bangkok, Thailand from 12 to 16 November 2007. The meeting requested the UNEP secretariat to undertake a range of work in preparation for the second meeting of the OEWG. Among other tasks, the

4 See Decision 24/3, paragraph 29.

secretariat was requested to prepare "an assessment of whether projected [mercury] demand could be met if primary mining was phased out and to provide, based on information that is available, a brief summary of major sources of mercury releases by country, or if unavailable, by regions, using *inter alia* the atmospheric emission study, and covering the following areas: emissions from coal-fired power plants, industrial emissions (e.g. waste combustion, non-ferrous metals, cement production), artisanal gold mining use and emissions, and use of mercury in products and processes."

As mentioned above, significant mercury mining operations have been phased out in recent years, and global demand for mercury is still being met, although the market price of mercury has increased during this period. The purpose of this analysis is to assess the feasibility of further reducing the global supply of primary mined mercury, i.e., by more closely investigating the feasibility of phasing out production in Kyrgyzstan. Assuming the supply of primary mercury is further reduced, the critical question examined here is whether there will remain sufficient Hg supply to meet expected demand. That is the focus of the analysis and future supply-demand scenarios presented in the balance of this report.

It should be mentioned that this analysis is only a small part of a much more extensive impact assessment – including full consideration of the economic welfare of the local population – that should be undertaken before any substantive action is taken with regard to Kyrgyzstan's mining operations.

2 Global mercury consumption 2005-2017

2.1 Background

2.1.1 Mercury "consumption"

From the beginning it must be stressed that, for the purpose of consistency, mercury "consumption" is defined here in terms of regional consumption of mercury in products and processes rather than overall regional "demand."

For example, although most measuring and control devices are produced in China (reflecting Chinese regional "demand" for mercury), a large number of these products are exported, "consumed" and disposed of in other countries.

2.1.2 "Gross" mercury consumption

It must also be pointed out that, unless noted otherwise, mercury consumption will be considered to be "gross" consumption, i.e., before any recycling and recovery operations.

This is an important distinction because, for those industries that are able to carry out significant recycling of mercury wastes or discarded products, the industries' "net" consumption of mercury may be much lower than its "gross" consumption. In the following analysis gross mercury consumption will be assessed first, followed by a general discussion of mercury recycling in all key sectors.

2.1.3 Base year 2005

2005 has been chosen as the "base year" for mercury consumption in this analysis. In order to carry the analysis 10 years into the future from the present date, mercury consumption has been forecasted to 2017. Much of the baseline assessment may be found in the UNEP Trade Report.[5] However, the following discussion has revised those baseline figures where new information has come to light since the publication of the Trade Report.

2.1.4 World regions

This analysis refers to different parts of the world as "regions." The regions selected, including the countries listed in Appendix I, are generally consistent with United Nations classifications of world regions, typically reflecting geographic proximity and/or similarities.

2.1.5 Mercury flows south and east

While continuing its long-term decline in most higher income countries, consumption of mercury remains relatively robust in many lower income economies, especially South and East Asia (significant mercury use in products, vinyl chloride monomer (VCM) production and artisanal gold mining), and Central and South America (especially mercury use in artisanal and small scale gold mining). The main factors behind the decrease in mercury consumption in higher income countries are the substantial reduction or substitution of mercury content in regulated products and processes (paints, batteries, pesticides, chlor-alkali, etc.), increasing regulation of hazardous wastes and a gradual shift of mercury product manufacturing operations (thermometers, batteries, etc.) from higher income to lower income countries. The major mercury applications are discussed individually below.

2.2 Major mercury applications

Unless otherwise noted, the main sources for this chapter are the UNEP Trade Report, which presents a general overview of mercury uses globally; an extensive analysis and paper by Cain *et al.* focused on USA mercury uses; and a draft analysis in progress for the European Commission detailing EU mercury applications.[6]

2.2.1 Artisanal gold mining

Artisanal and small-scale gold mining (ASM) remains the largest global user of mercury, reportedly continues to increase with the upward trend in the price of gold, is the largest source of releases, and is inextricably linked with issues of poverty and human health

According to the UNIDO/UNDP/GEF Global Mercury Project, at least 100 million people in over 55 countries depend on ASM – directly or indirectly – for their livelihood, mainly in Africa, Asia and South America.[7] ASM is responsible for an estimated 20-30% of the world's gold production, or approximately 500-800 tonnes per annum. It involves an estimated 10-15 million miners, including 4.5 million women and 1 million children. This type of mining relies on rudimentary methods and technologies, and is typically performed by miners with little or no economic capital, who operate in the informal economic sector, often illegally and with little organization. Due to inefficient mining practices, mercury amalgamation in ASM results in the consumption and release of an estimated 650 to 1000 tonnes of mercury per annum.[8]

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[5] UNEP, 2006.

[6] UNEP, 2006; Cain, 2007; DG ENV, 2008.

[7] It should be noted that not all artisanal/small scale gold miners use mercury. Some use cyanide, permitting more gold to be recovered than when using mercury. Others use gravimetric methods without mercury or cyanide.

[8] UNEP, 2006.

In Section 2.4, regional estimates of mercury use in ASM have been derived from country estimates based on personal communications with a number of experts directly involved in the UNIDO/UNDP/GEF Global Mercury Project.[9]

2.2.2 VCM production

The large and increasing use of mercuric chloride as a catalyst in the production of vinyl chloride monomer (VCM), mostly in China, is another area of major concern. Investigations in China confirmed the consumption of an estimated 610 metric tonnes of mercury for this application in 2004. This use of mercury has been increasing 25-30% per year as the Chinese economy booms, and as Chinese demand for PVC end-products increases. It was estimated as high as 700-800 tonnes of mercury in 2005.[10]

Limited consumption of about 15 tonnes of mercury for the same purpose was reported by Treger in the ACAP study of the Russian chemical industry.[11] Further uses in the CIS region are believed to exist but have not been specifically identified.

It is reported in China and Russia that less than half of the mercury consumed for VCM is later recovered from the spent catalyst. The rest of the mercury goes mainly into the hydrochloric acid by-product, from where mercury can also be recovered, with some air and wastewater emissions that are typically quite low.

2.2.3 Chlor-alkali production

The chlor-alkali industry is the third major mercury user worldwide. Many plant operators have phased out this technology and converted to the more energy-efficient and mercury-free membrane process, others have plans to do so, and still others have not announced any such plans. In many cases governments have worked with industry representatives and/or provided financial incentives to facilitate the phase-out of mercury technology. Recently governments and international agencies have created partnerships with industry to encourage broader industry improvements with regard to the management and releases of mercury.

The range for global mercury consumption[12] presented in Section 2.4 is based on previous studies. EU and USA mercury consumption are based on industry figures, as are those of India, Brazil and Russia. Mercury consumption estimates for Mexico and other countries are based on individual plant capacities as provided by various industry actors, together with representative mercury consumption factors as identified for different world regions.[13]

2.2.4 Batteries

The use of mercury in batteries, while still considerable, continues to decline as many nations have implemented policies to deal with the problems related to diffuse mercury releases related to batteries.

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9 See Telmer, 2008. It should be noted that in a very recent paper (Telmer and Veiga, 2008) the authors have suggested to use the range 640-1350 tonnes mercury consumption in the ASM sector, and refer to ASM activity in 70 countries.

10 NRDC, 2006; Tsinghua, 2006.

11 ACAP, 2005.

12 The convention here is to calculate mercury "consumption" before any recycling of wastes, with the knowledge that, as in many industries, some waste is recycled in order to recover the mercury, while most mercury waste is sent for disposal.

13 UNEP, 2006; EEB, 2006; Euro Chlor, 2007; WCC, 2006; SRIC, 2005.

While mercury use in Chinese batteries was confirmed to have been high through 2000, most Chinese manufacturers have reportedly now shifted to lower mercury designs, following international legislative trends and customer demand in other parts of the world. However, there are still vast quantities (tens of billions) of batteries with relatively low mercury content produced in China, and lesser quantities in other countries as well. Moreover, trade statistics suggest that there continues to be a reduced, but still significant, trade in mercuric oxide (HgO) batteries, some produced in mainland China, and many more apparently produced in Customs-free trade zones on Chinese territory.[14]

There also remain a large number of button cell batteries manufactured in many different countries, containing up to 2% mercury. These will eventually be replaced by mercury-free button cells,[15] but for the moment these batteries, also produced in the tens of billions, consume significant amounts of mercury. Therefore, the global consumption of mercury in batteries still appears to number in the hundreds of metric tonnes annually.

The draft study for the European Commission has recently made an estimate of mercury in batteries for the EU25. This EU estimate does not fully account for trade statistics suggesting significant consumption of (mostly larger than button size) HgO batteries, since physical evidence of such consumption levels has not yet been produced. Dr. Cain and colleagues have recently made an estimate of mercury in batteries for the USA, which this study has extrapolated to Canada. Other regional estimates of mercury consumed in batteries are assumed to be correlated with regional economic activity, as described in Section 2.3 below.

2.2.5 Dental applications

Among others, Denmark, Finland, Japan, Norway and Sweden have implemented measures to greatly reduce the use of dental amalgams containing mercury.[16] In these and some other higher income countries (e.g. the USA) dental use of mercury is now declining. The main alternatives are composites (most common); glass ionomers and compomers (modified composites). However, the speed of decline varies widely, so that mercury use is still significant in most countries, while in some countries (Sweden, Norway) it has almost ceased. In many lower income countries, changing diets and better access to dental care may actually increase mercury use temporarily.

Regional consumption of mercury for dental use is presented in Section 2.4, based on draft work for the European Commission and industry estimates. The North American estimate used in Section 2.4 is consistent with IMERC data, and includes Canada as well.[17]

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14 This paragraph makes reference to NRDC (2006). For just one type of battery, the D-size "paste battery," the known Chinese production in 2004 was 9.349 billion batteries. The authors estimated mercury chloride consumption for these batteries at 47.11 tonnes, with an estimated mercury content of 34.91 tonnes. The battery label claims less than 250 ppm mercury content.

15 The National Electrical Manufacturers' Association in the USA has called for a phase-out of all mercury in button cell batteries in the USA by 2011.

16 Norway has introduced a general ban on Hg in products. Sweden intends to introduce a similar ban of Hg in products before the end of 2008.

17 Industry communications; the Interstate Mercury Education & Reduction Clearinghouse (IMERC) was established by state environmental officials in the USA to help them implement laws and programs aimed at getting mercury out of consumer products, the waste stream, and the environment. IMERC and its database are a program of the Northeast Waste Management Officials' Association (NEWMOA).

2.2.6 Measuring and control devices

There is a rather wide selection of mercury containing measuring and control devices, including thermometers, barometers, manometers, etc., still manufactured, although thermometers and sphygmomanometers dominate with regard to mercury use. As market awareness has improved, most international suppliers now offer mercury-free alternatives. European legislation, among others, is being implemented to phase out such equipment and to promote mercury-free alternatives since the latter are available for nearly all applications.

In Section 2.4, the global range for mercury consumption in these applications is based heavily on Chinese production of sphygmomanometers and thermometers, for, which Chinese authorities calculated over 270 tonnes of mercury used in the production of only these two devices in 2004,[18] although Chinese production likely represents 80-90% of world production of these two products. Likewise, thermometers and sphygmomanometers are considered to represent around 80% of total mercury consumption in this sector.

The EU25 estimate in Section 2.4 is drawn from the draft study for the European Commission that confirms significant reduction in EU Hg use in these applications in recent years. The North America estimate, based on Cain, pays special attention to the quantities of mercury consumed in dairy manometers, industrial and other thermometers, sphygmomanometers, etc. Other regional estimates of mercury consumed in measuring and control devices are assumed to be correlated with regional economic activity, as described in Section 2.3 below.

2.2.7 Lamps

Mercury containing (fluorescent tubes, compact fluorescent, high-intensity discharge – HID, etc.) lamps remain the standard for energy-efficient lamps, where ongoing industry efforts to reduce the amount of mercury in each lamp are countered, to some extent, by the ever-increasing number of energy-efficient lamps purchased and installed around the world. There is no doubt that mercury-free alternatives such as light emitting diodes (LEDs) will become increasingly available, but for most applications the alternatives are still quite limited and/or expensive.

In retrospect, the UNEP Trade Report underestimated global mercury consumption in lamps. The range used in Section 2.4 takes better account of significant Hg use in backlighting of liquid crystal displays (LCDs) of all sizes – from electronic control panels to computer and television monitors. The lower part of the range used in the UNEP study has therefore been raised. For China alone, mercury used in the production of mostly fluorescent tubes and CFLs was estimated at 64 tonnes for 2005,[19] and Chinese production has increased since then. Many of these lamps were exported, so it may be noted that the mercury consumption of China's own domestic market is somewhat lower.

The EU estimate in Section 2.4 includes significant Hg use in small lamps for backlighting of LCDs. The North America estimate for lamps presented by Cain did not include backlighting of LCDs. Other regional estimates of mercury consumed in lamps are assumed to be correlated with regional economic activity, as described in Section 2.3 below.

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18 SEPA, 2008.

19 Lennett, 2007.

2.2.8 Electrical and electronic devices

Following the implementation of the European Union's Restriction on Hazardous Substances (RoHS) Directive, and similar initiatives in Japan, China and California, among others, mercury-free substitutes for mercury switches, relays, etc., are being actively encouraged,[20] and mercury consumption for these applications has declined substantially in recent years. At the same time, the USA-based Interstate Mercury Education and Reduction Clearinghouse (IMERC) database[21] demonstrates that mercury use in these devices remains significant.

In Section 2.4, the global range of mercury consumption in this sector has been reduced from that estimated for UNEP, based on improved data from both the EU and the USA. At the same time, the lower range of that estimate has been raised because Cain's paper shows higher than previously estimated mercury consumption in this category, including thermostats, wiring devices, switches and relays. The EU25 estimate in Section 2.4 recognises significant reduction in Hg use in these applications in recent years as a result of RoHS legislation, confirmed by the draft assessment for the European Commission. Other regional estimates of mercury consumed in electrical and electronic devices are assumed to be correlated with regional economic activity, as described in Section 2.3 below.

2.2.9 Other applications of mercury

This category has traditionally included the use of mercury and mercury compounds in such diverse applications as pesticides, fungicides, laboratory chemicals, in pharmaceuticals, as a preservative in paints, traditional medicine, cultural and ritual uses, cosmetics, etc. However, there are some further applications that have recently come to light in which the consumption of mercury is also especially significant.

In particular, the continued use of mercury in the production of artificial rubber is one such use that is rather widespread.[22] Likewise, the use of significant quantities of mercury in some technical devices has until recently escaped special notice.

In Section 2.4, the global range of mercury consumed in "other applications" is significantly higher than that estimated previously for UNEP, based on the draft study for the European Commission that identifies substantial Hg consumption in compounds used as chemical intermediates and catalysts (other than VCM/PVC production), as well as elemental mercury still used in significant quantities in research and testing instruments, not to mention lesser uses for routine maintenance of lighthouses, etc.

The North American estimate in Section 2.4 of mercury consumed in "other applications" relies on evidence that this region has most of the same applications as those identified in the EU. Other applications in other regions vary widely, including cultural/ritual uses in

[20] For California, see www.dtsc.ca.gov/HazardousWaste/EWaste/.
For Korea's RoHS/WEEE/ELV-like legislation called "The Act for Resource Recycling of Electrical/Electronic Products and Automobiles," see www.europeanleadfree.net/pooled/articles/BF_NEWSART/view.asp?Q=BF_NEWSART_195645.
For Japan, see www.jeita.or.jp/index.htm;
and farnell.com/jsp/bespoke/bespoke8.jsp?bespokepage=farnell/en/rohs/rohs/facts.jsp.

[21] All suppliers of mercury containing products to the northeastern United States are required to file annual reports, as described in http://www.newmoa.org.

[22] Mercury "catalysts" (basically hardening or curing agents) are sometimes used in the production of polyurethane elastomers, used as artificial "rubber" for roller blade wheels, etc., in which the catalysts remain in the final product.

Latin America and the Caribbean, traditional uses in Chinese medicine, cultural/religious uses in India, cosmetic uses such as skin-lightening creams in many countries, etc. Lacking more precise data, other regional estimates of mercury consumed in "other" applications are assumed to be correlated with regional economic activity, as described in Section 2.3 below.

2.3 Estimating mercury consumption where data is inadequate

The diverse uses of mercury have been rather well studied in the EU and North American regions, and in various countries such as Russia, Malaysia, etc. Apart from specific applications, however, mercury use for most other regions has been only roughly estimated, and the UNEP Trade Report presented the best overview available at the time.[23] This analysis will further refine previous estimates by correlating mercury consumption in products (especially batteries, lamps, measuring & control, electrical & electronic, and "other"), for regions and applications where better data is not available, with regional economic activity expressed in terms of purchasing power parity (PPP).[24]

Table 2-1 below shows the population for the defined regions in 2005, the percentage of the regional population that is urban (relevant with regard to the use and disposal of mercury containing products), the GDP per capita and per region, and the regional share of global economic activity as expressed by each region's total "purchasing power."

Table 2-1 Regional population and economic activity

	Population, total (millions) [1]	**Urban population (% of total population)** [2]	**GDP per capita, PPP (2005 international $)** [3]	**Regional economic activity, GDP total, PPP (2005 international $ - billions)**	**Share of world economic activity, GDP total, PPP (%)**
East and Southeast Asia	2063	44%	8185	16882	27.6%
South Asia	1493	29%	3174	4738	7.8%
European Union (25 countries)	460	74%	27706	12760	20.9%
CIS and other European countries	334	63%	9306	3110	5.1%
Middle Eastern States	237	66%	8943	2126	3.5%
North Africa	152	54%	5542	844	1.4%
Sub-Saharan Africa	757	35%	1997	1511	2.5%
North America (excl. Mexico)	332	81%	41062	13637	22.3%
Central America and the Caribbean	180	68%	9001	1623	2.7%
South America	372	82%	8412	3131	5.1%

23 UNEP, 2006.

24 The purchasing power parity (PPP) theory uses the long-term equilibrium exchange rate of two currencies to compare their purchasing power for a given basket of goods. The PPP can be useful to compare living standards among nations because PPP takes into account the relative cost of living and the inflation rates of different countries, as contrasted with a gross domestic product (GDP) comparison.

Australia New Zealand and Oceania	26	84%	28872	756	1.2%

Notes:

1- UN (United Nations). 2007e. World Population Prospects 1950-2050: The 2006 Revision. Database. Department of Economic and Social Affairs, Population Division. New York. Accessed July 2007.

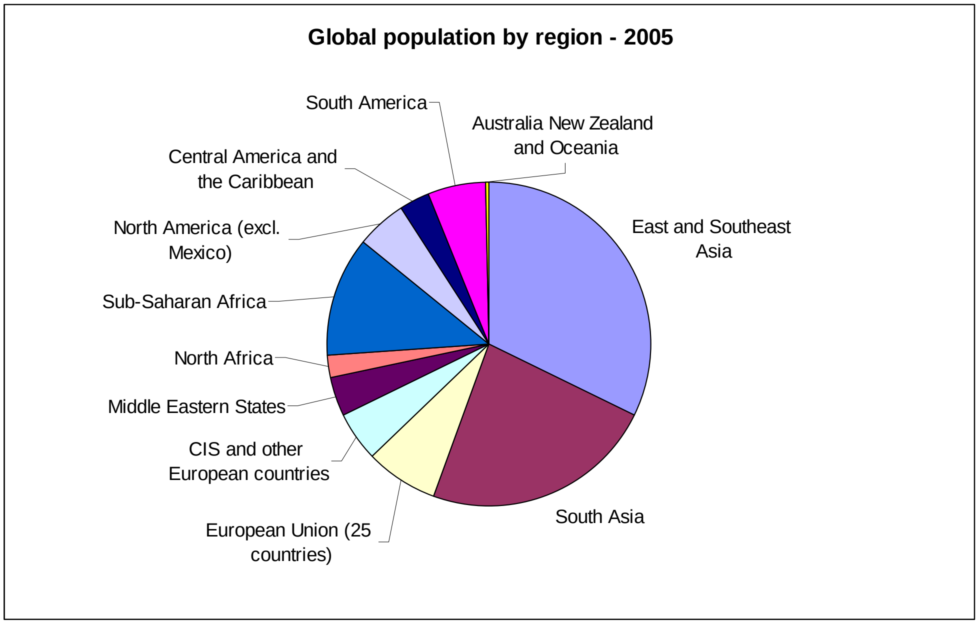
2- UN (United Nations). 2006. World Urbanization Prospects: The 2005 Revision. Database. Department of Economic and Social Affairs, Population Division. New York.

3- World Bank. 2007b. World Development Indicators 2007. CD-ROM. Washington, D.C.; aggregates calculated for HDRO by the World Bank.

Source: Data available in UNDP Human Development Reports; http://hdrstats.undp.org/indicators/indicators_table.cfm

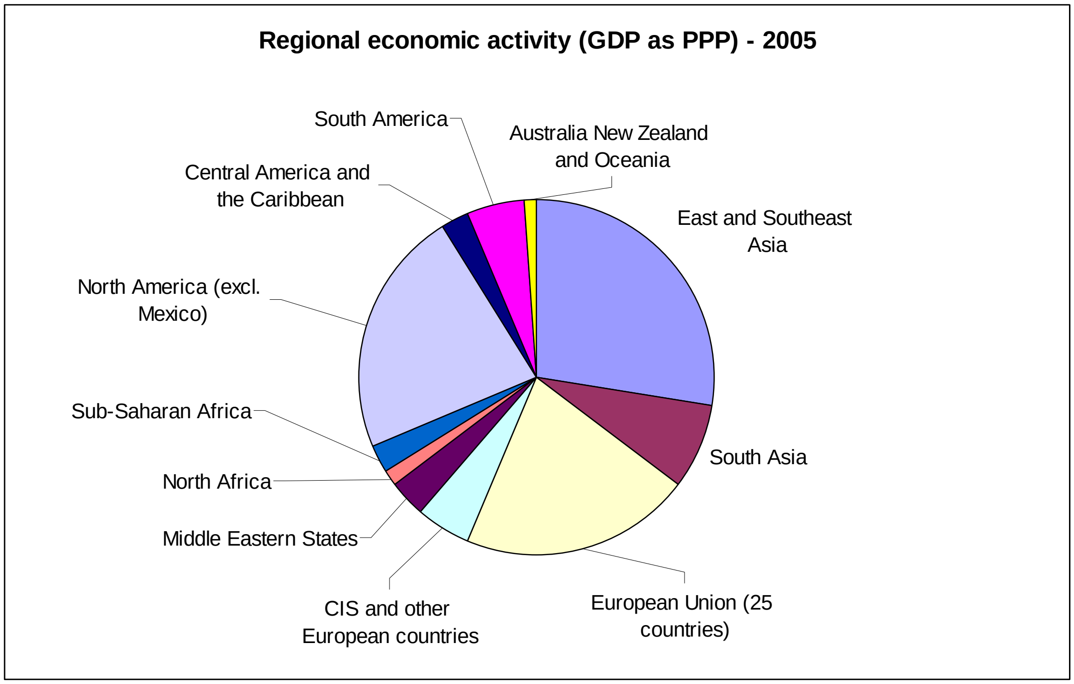
As can be seen in Figure 2-1, some two-thirds of the global population reside in East & Southeast Asia, South Asia and Sub-Saharan Africa.

Figure 2-1 Global population by region - 2005



On the contrary, Figure 2-2 shows that some two-thirds of global economic activity takes place in East & Southeast Asia, North America and the European Union. While there are some major differences in regional consumption as regards various mercury containing products, it is evident that these three regions (together with South America, as described below), and predominantly East & Southeast Asia, are responsible for much of the mercury consumed in products and processes around the world.

Figure 2-2 Regional economic activity - 2005



2.4 Regional mercury consumption in 2005

In cases where useful statistics are lacking, the above approach takes account of the relative economic wellbeing of different regions to permit the correlation of a region's purchasing power with its consumption of mercury containing products.

Based on the assumptions discussed in Section 2.3, this approach has been applied to those regions and major uses of mercury where data is scarce, completing Table 2-2 on the following page.

Table 2-2 Total mercury consumed[1] worldwide by region and by major application

Elemental mercury 2005 (metric tonnes)	**Artisanal gold mining**			**VCM production**			**Chlor-alkali production**			**Batteries**		
	min	*MAX*	*ave*	*min*	*MAX*	*ave*	*min*	*MAX*	*ave*	*min*	*MAX*	*ave*
East & Southeast Asia	408	520	464	700	800	750	5	10	8	180	300	240
South Asia	3	10	7	0	0	0	35	40	38	20	45	33
European Union (25 countries)	3	5	4	0	0	0	152	197	175	10	25	18
CIS & other European countries	18	40	29	15	25	20	100	115	108	8	15	12
Middle Eastern States	1	3	2	0	0	0	50	58	54	5	10	8
North Africa	0	10	5	0	0	0	7	10	9	2	4	3
Sub-Saharan Africa	59	118	89	0	0	0	1	2	1	4	7	6
North America	2	4	3	0	0	0	55	65	60	17	20	19
Central America & the Caribbean	15	25	20	0	0	0	15	18	17	4	7	6
South America	141	260	201	0	0	0	30	35	33	8	14	11
Australia, New Zealand & Oceania	0	5	3	0	0	0	0	0	0	2	3	3
Total per application	**650**	**1000**	**825**	**715**	**825**	**770**	**450**	**550**	**500**	**260**	**450**	**355**

Elemental mercury 2005 (metric tonnes)	**Dental applications**			**Measuring and control devices**			**Lamps**		
	min	*MAX*	*ave*	*min*	*MAX*	*ave*	*min*	*MAX*	*ave*
East & Southeast Asia	70	86	78	122	136	129	44	50	47
South Asia	22	32	27	34	38	36	13	15	14
European Union (25 countries)	80	100	90	5	15	10	11	16	14
CIS & other European countries	10	12	11	22	25	24	8	10	9
Middle Eastern States	15	23	19	15	18	17	5	7	6
North Africa	4	6	5	6	6	6	1	2	2
Sub-Saharan Africa	5	9	7	11	13	12	3	4	4
North America	33	45	39	45	55	50	23	30	27
Central America & the Caribbean	20	27	24	12	13	13	4	5	5
South America	38	55	47	23	25	24	7	9	8
Australia, New Zealand & Oceania	3	5	4	5	6	6	1	2	2
Total per application	**300**	**400**	**350**	**300**	**350**	**325**	**120**	**150**	**135**

Elemental mercury 2005 (metric tonnes)	**Electrical and electronic devices**			**Other[2]**			**Regional totals**		
	min	*MAX*	*ave*	*min*	*MAX*	*ave*	*min*	*MAX*	*ave*
East & Southeast Asia	55	65	60	44	66	55	1628	2033	1831
South Asia	16	20	18	10	20	15	153	220	187
European Union (25 countries)	1	2	2	43	174	109	305	534	420
CIS & other European countries	10	13	12	8	12	10	199	267	233
Middle Eastern States	7	10	9	5	8	7	103	137	120
North Africa	3	4	4	2	3	3	25	45	35
Sub-Saharan Africa	5	7	6	4	6	5	92	166	129
North America	55	65	60	70	110	90	300	394	347
Central America & the Caribbean	5	7	6	4	6	5	79	108	94
South America	11	14	13	8	12	10	266	424	345
Australia, New Zealand & Oceania	2	3	3	2	3	3	15	27	21
Total per application	**170**	**210**	**190**	**200**	**420**	**310**	**3165**	**4355**	**3760**

Note 1 Regional mercury "consumption" is defined here in terms of regional market demand for mercury products. For example, although most measuring and control devices are produced in China, many of them are exported and subsequently "consumed" in other regional markets.

Note 2 “Other” applications include uses of mercury in pesticides, fungicides, catalysts, paints, chemical intermediates, laboratory and clinical applications, research and testing equipment, pharmaceuticals, cosmetics, maintenance of lighthouse lenses and other equipment, traditional medicine, cultural and ritual uses, etc.

Figure 2-3 shows graphically the predominance of China and its East and Southeast Asia neighbours with regard to overall mercury consumption, although it should be noted that most of this region's consumption is in certain economic sectors – artisanal mining, VCM/PVC production, batteries and measuring & control devices. It should be noted as well that this figure presents gross mercury consumption, i.e., before any recycling or recovery is counted.

Figure 2-3 Global mercury consumption by application and by region

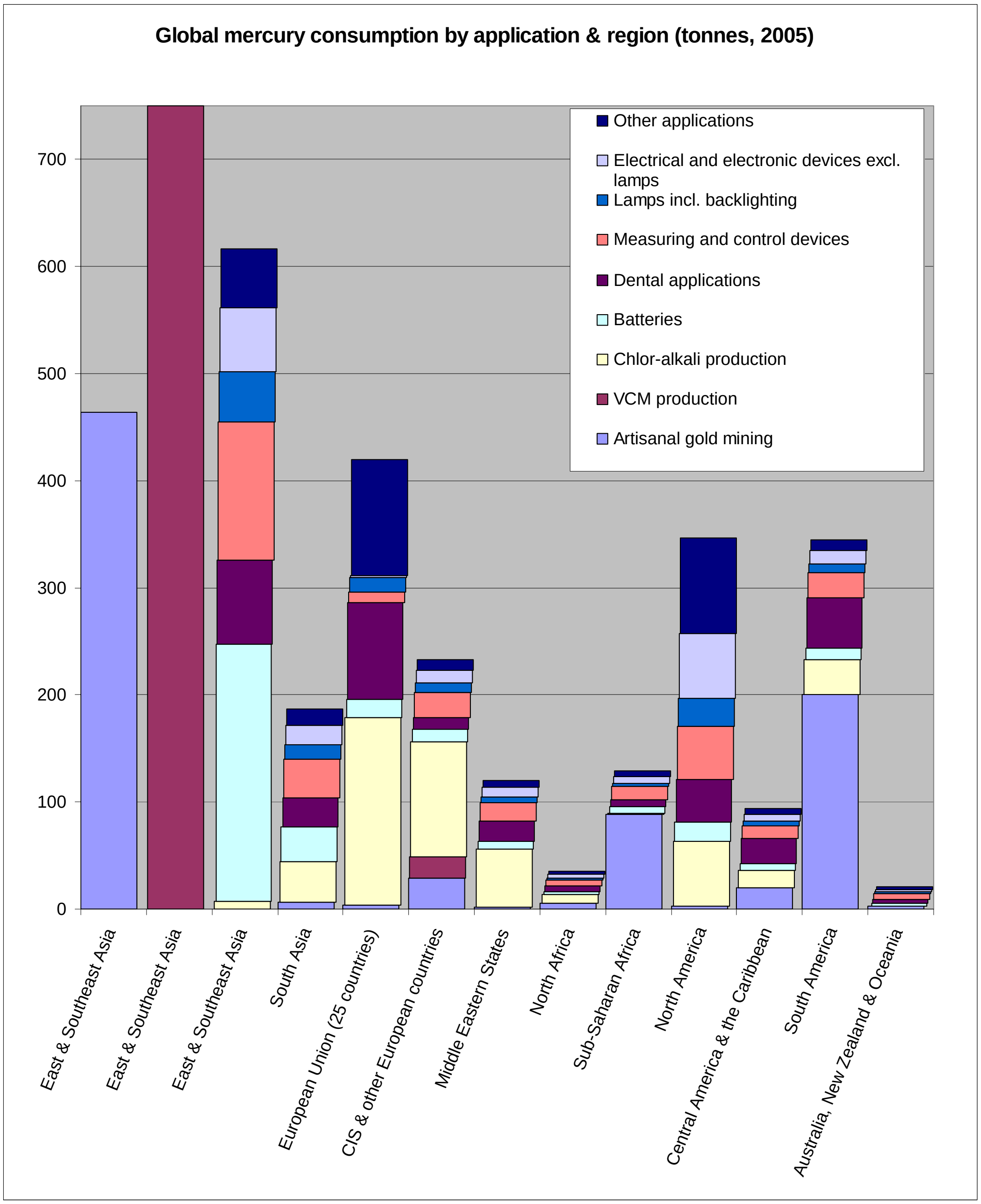
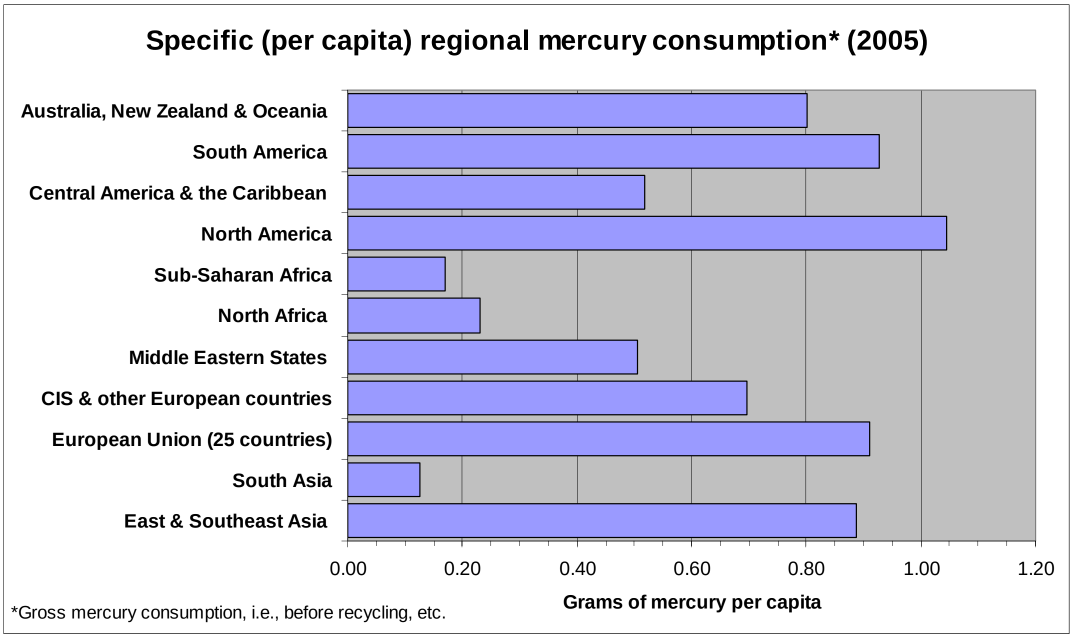


Figure 2-4 presents overall regional mercury consumption in a different manner, where it may be seen that mercury consumption per capita does not vary greatly among four major economic regions. Estimated mercury consumption per capita in East & Southeast Asia, North America (greatest consumption in chlor-alkali, measuring & control, electrical & electronic devices, and "other" uses), South America (relatively heavy consumption in artisanal gold mining) and the European Union (most significant consumption in chlor-alkali, dental and "other" uses) varies from approximately 0.9 g/capita to around 1.05 g/capita. The per capita mercury consumption of these four regions appears to be nearly an order of magnitude greater than the per capita mercury consumption of South Asia as presented in this analysis.

Figure 2-4 Specific mercury consumption per capita, by region



2.4.1 The case of China

Global Hg demand reflects the strong influence of China's domestic consumption and production of mercury products. However, because China's Hg supply is mostly sourced domestically, China's mercury supply vs. demand situation does not seriously affect the supply vs. demand equilibrium of the rest of the world. Likewise, just as domestic mercury mining has increased in response to Chinese demand in the past, it may be assumed that as China works to reduce its mercury consumption, then its domestic mercury supply will decline in parallel.

Table 2-3 provides a rough estimate of China's overall mercury demand. It should be noted that this table presents all uses of mercury in China, before any recycling or recovery is counted, and including mercury used to manufacture goods that are later exported (especially batteries, lamps and measuring devices). This special presentation for China is intended to facilitate later comparison with China's overall sources of mercury supply.

Table 2-3 Mercury consumption in China

	Base year for calculation or estimate	Hg consumption (metric tonnes)	Recent trend (2000-2005)
Batteries	**2005**	**150-250**	**– – –**
VCM/PVC	**2005**	**700-800**	**+++**
Lamps	**2005**	**60-70**	**+**
Measuring devices	**2005**	**280-310**	**++**
Small-scale gold mining	**2000**	**120-240**	**?**
Other (Hg compounds, etc.)	**2005**	**40-80**	**+**
Total		1400-1750	++

Key: **–** **small decline** **+** **small increase**
– – **medium decline** **+ +** **medium increase**
– – – **large decline** **+ + +** **large increase**

Sources: UNEP, 2006; NRDC, 2006; CRC, 2007

2.5 Future Hg consumption by sector

This section describes the “status quo” evolution of (gross) global mercury consumption between 2006 and 2015. The status quo projection of future mercury consumption may be thought of as a “business-as-usual” case, reflecting evident trends, legislation and modest initiatives that are already in place. It does not reflect more progressive measures that may be dependent on new political initiatives, special funding or other uncertain ingredients.

During the next five years, the rate of decline in mercury consumption will depend primarily upon reductions in the battery, electrical product, and measuring device manufacturing sectors; dental use; and chlor-alkali facilities. These sectors represent the greatest potential for near-term declines because the alternative mercury-free technologies or products are readily available, they are of equal or better quality and prices are mostly competitive. For these sectors, the challenges are not technical, but are rather related to the extent of encouragement offered by countries or regions through financial assistance, and legal or voluntary mechanisms.

In comparison, reducing mercury consumption in small-scale gold mining presents a major challenge during the next 5-10 years, and further challenges even beyond that time-frame. Finally, reducing mercury consumption in VCM manufacturing is more appropriately a mid- to long-term challenge, although net mercury consumption can already be further reduced through more aggressive recycling.

Nevertheless, these predictions of future mercury consumption can only be seen as educated guesses. Uncertainties are further discussed in section 4.2.

It should be mentioned that UNEP is involved in a number of partnerships and other initiatives – many dealing with reducing the consumption of mercury in products – that may be hoped to push future mercury consumption considerably lower than these estimates.

In many commodity markets, the difficulty of projecting future demand is complicated by the influence of the commodity price on demand. In this case, however, the cost of Hg is generally a small percentage of the overall cost of the process or device in which it is used, and the demand for Hg therefore varies relatively little with price variations – at least within the ranges of US$5-25/kg that have been seen since 2000. Even in the case of artisanal and small-scale gold mining (ASM), which is more sensitive to Hg price and supply constraints, the cost of Hg consumed is a small fraction of the value of the gold typically recovered.

Some projections of future mercury consumption were developed for the UNEP Trade Report.[25] The following discussion includes new information that has come to light since the publication of the Trade Report, for which the sources are footnoted.

2.5.1 Artisanal gold mining

The heavy use of mercury for artisanal gold mining in many parts of the world is showing no signs of abating. In the near term, high gold prices are expected to draw more miners into the ASM sector and increase mercury consumption in artisanal mining. At the same time, high gold prices may also be expected to stimulate activities of larger (non-ASM) mines and related by-product mercury production.

Otherwise the informal mining sector does not lend itself to easy predictions. While ASM activity appears to be increasing, there are signs that the high price of mercury has already encouraged some miners to seek ways to use mercury more efficiently, or not at all. Based upon experience during the last five years, if the mercury market price is above USD 25/kilogram, there will be more serious ASM efforts to use mercury more efficiently; if the mercury market price is below USD 10/kilogram, there will be less attention devoted by the miners to such measures, unless UNIDO and other major field programs redouble their efforts. At present the mercury price is USD 15-20/kg. If it stays in that range for the foreseeable future, one might expect that over the next 10 years total mercury use in ASM may not increase much above its present high level, nor can it be expected to decline significantly.

2.5.2 VCM production

China is home to the vast majority of manufacturers that use a mercuric chloride catalyst for VCM production. Market demands, together with the availability of cheap coal in China, have combined to rapidly expand VCM production, and the mercury catalyst process is being used for much of that production. NRDC estimated that mercury consumption for VCM production in China may have increased from 700-800 metric tonnes in 2005 to over 1,000 metric tonnes in 2007.[26]

[25] UNEP, 2006.
[26] NRDC, 2006.

Figure 2-5 A VCM production plant in China

After some further increase into 2009, it may be expected that there will be increasing pressure from outside China, along with increasing efforts within China, to encourage investment in Hg-free alternatives and to further increase mercury recovery. European competitors have begun to voice concern that China is producing VCM/PVC for export at a very low cost using a process that is no longer "acceptable" – for environmental reasons – in other regions of the world.

2.5.3 Chlor-alkali production

The mercury consumed in a chlor-alkali facility has been shown to follow many pathways to air and water emissions, into chemical products, into solid wastes, and to "unexplained" losses.[27] Meanwhile, some of the wastes are retorted or recycled to recover the mercury.

Around 10 million metric tonnes of mercury cell chlorine capacity in 2005 may be expected to decrease to less than 4 million metric tonnes capacity by 2020. Therefore, around 500 metric tonnes of total mercury consumption during 2005 may be expected to decrease to some 350 metric tonnes of mercury by 2015. The reductions are not proportional because, globally, the average mercury plant that stops operating will probably consume less mercury per tonne of production capacity than the average facility that continues operating elsewhere in the world.

2.5.4 Batteries

The consumption of mercury in batteries in 2005 has been estimated at 260-450 tonnes. A large amount of the mercury now used in this sector is for button cell battery production, although there are open questions about the ongoing production and use of mercuric

[27] Also referred to as "difference-to-balance" by Euro Chlor, the European chlor-alkali manufacturers association.

oxide batteries as well.[28] Thus, the pace of the transition to mercury free button cells will influence the reduction of mercury use in this sector. With U.S. manufacturers already committed to producing only mercury free button cells by 2011 (reference), a major question is when manufacturers in other regions will do the same. Given the highly competitive nature of battery manufacturing, the implementation of Chinese and other legislation to further reduce the mercury content of batteries,[29] and the further regulatory pressures that will be placed on this sector, one might predict that the major battery manufacturers will make this transition by 2015, probably reducing annual mercury consumption for this sector to less than 200 tonnes, although these numbers depend to some extent on further information that may be obtained on mercuric oxide batteries.

2.5.5 Dental applications

Composite and other materials are now widely available as substitutes for mercury-containing "silver" amalgam dental fillings. Advances in mercury-free dental care and reductions in mercury use in many countries may be offset by improved dental care with greater treatment of cavities in others, including some increased use of low-priced mercury amalgam fillings, at least in the near to medium term. One must also keep in mind that diets are changing in much of Asia and Africa, sometimes accompanied by an increased consumption of sugar, which could also lead to an increasing number of citizens seeking dental treatment. While aesthetic considerations argue for whiter fillings, and new and cheaper materials will gradually come on the market, it is possible that the global reduction in dental mercury use by 2015 may be no more than 10%. On the other hand, this trend may be further accelerated by the change in policy at the US Food and Drug Administration, which has recently conceded that amalgams may not be entirely safe.[30]

2.5.6 Measuring and control devices

Consumption of mercury for measuring and control devices in 2005 has been estimated at 300-350 tonnes, based on a recent report on extensive production of thermometers and sphygmomanometers in China.[31] As reliable mercury-free alternatives are widely available, the EU has prohibited the marketing and use of some of these mercury devices, and is studying further restrictions. Likewise, some states in the United States are taking measures to prohibit the manufacture and sale of certain measuring and control devices. The health care sector is where NGOs are most active with regard to measuring devices, and where they have achieved the greatest success in Hg reductions. Some experts are projecting a reduction in mercury use of 60-70% during the next ten years.[32] Nevertheless, a more conservative "status quo" forecast of mercury consumption in this sector would rather appear to be a 40-50% reduction by 2015.

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28 As mentioned in the UNEP trade report (UNEP 2006), there remains unanswered questions with regard to batteries that are entered in the Comtrade database as "mercuric oxide batteries." The database shows world imports of more than 3,000 tonnes of these batteries for 2005, each battery weighing an average of 65 – therefore most of them are not button cells. Even if one assumes that many of these batteries may have been traded several times during the year, they represent several hundred tonnes of mercury. In conclusion, the full extent of mercury in batteries will not be fully known until this international trade in "mercuric oxide batteries" is better understood.

29 NRDC, 2006.

30 FDA, 2008.

31 CRC, 2007.

32 USEPA, 2008.

2.5.7 Lamps

Consumption of mercury for lamps in 2005 has been estimated at 120-150 tonnes. With China, Japan and other countries adopting or considering similar legislation to that in the European Union (EU) RoHS Directive, the limits on mercury content in lamps imposed by the EU could be adopted much more widely. However, any reduction of the amount of mercury per lamp, at least over the next 3-5 years, may be offset by a greatly increased demand for mercury-containing compact fluorescent lamps (CFLs) as various countries propose phasing out traditional filament lamps[33] in favour of CFLs. In other words, as the mercury per lamp decreases, the number of mercury lamps installed will increase.

Mercury-free alternatives to energy-efficient lamps are appearing, but the range of applications remains limited.[34] As a wider range of affordable light-emitting diodes (LEDs) and other energy-efficient mercury-free lamps come onto the market, one could conceive of a net and continued reduction in mercury use in this sector at 5-10 years in the future.

Overall, therefore, while there will certainly be fluctuations in the global total, a 10% reduction in mercury consumption toward the end of the 10-year time frame may be possible.

2.5.8 Electrical and electronic devices

Consumption of mercury in electrical and electronic devices in 2005 has been estimated at 170-210 tonnes. As above, one may assume that the European Union Restriction on Hazardous Substances (RoHS) Directive, which bans the use of mercury in electrical and electronic devices after 1 July 2006, is influencing the global market. Among other national initiatives, China is implementing RoHS legislation,[35] and Korea has made its own proposal. The EU RoHS Directive is also starting to influence state laws in the United States, where it is expected to gradually spread to other states as well.

Due to the gradual global standardisation of typical legislation that deals with widely traded goods such as electrical and electronic equipment, a “status quo” forecast of mercury consumption in this sector might assume a 40% reduction by 2015. While that result may be achieved by a somewhat faster reduction during the next five years (as new legislation takes effect), followed by a somewhat slower reduction in years six to ten, for purposes of this analysis the assumption of a straight-line reduction over the 10-year period is adequate.

2.5.9 Other applications of mercury

Consumption of mercury in 2005 for such miscellaneous uses as paints, pesticides, fungicides, catalysts (other than those for VCM production), chemical intermediates, laboratory reagents, research and testing instruments, maintenance of lighthouses and mercury vacuum pumps, pharmaceuticals, traditional medicine, cultural and ritual uses, and many other applications has been estimated at 200-420 tonnes.

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[33] Referred to as “incandescent” lamps within the lighting industry.

[34] The use of LED backlights instead of mercury lamps for “notebook” computers, for example, has been growing and is set to increase in 2008. Sony has used LED backlights on some of its higher-end slim VAIO notebooks since 2005. Fujitsu introduced notebooks with LED backlights in 2006. In 2007 Asus, Dell and Apple also introduced LED backlights into some of their notebook models, and other companies like HP will be marketing LED-backlit notebooks in the near future (Wiki 2008).

[35] China enacted RoHS-type legislation that became effective on March 1, 2007. However, the scope of the Chinese RoHs was developed entirely independent of the EU RoHS. Further, although there is substantial overlap between the European and Chinese RoHS, many product types that are not within the scope of EU RoHS are within the scope of Chinese RoHS (*see* http://www.chinarohs.com/faq.html).

General trends indicate that some of these uses of mercury will continue to decrease gradually, but past experience has demonstrated that new uses for mercury sometimes appear, and other uses that have been going on for many years may be newly identified, as in the draft study for the European Commission.[36]

One might assume that the more international attention devoted to mercury awareness and reduction in general, the more reduction of mercury in these "other uses" may also be expected. Furthermore, legislation banning the sale of newly developed products containing mercury has been introduced in Norway. Sweden is expected to adopt a similar measure later in 2008, and other countries will increasingly consider such initiatives as well. These uses are too diverse to predict large reductions over 10 years, but a more modest "status quo" reduction of 10-20% is very likely.

2.5.10 Status quo projections vs. UNEP targets

Table 2-4 below summarizes the status quo forecasts described above, and contrasts them with the more progressive, but certainly achievable, target reductions agreed with NGOs in the joint USEPA-UNEP Mercury-Containing Products Partnership Area Business Plan. The Business Plan presents percentage reduction targets for mercury consumption in each main product area.[37] The status quo forecasts are not quite as optimistic as the UNEP targets because it is evident that the latter depend to some extent on NGO initiatives, political support and funding that may be uncertain.

Table 2-4 Global mercury consumption forecasts for 2015

Application	Consumption range 2005 (tonnes)	Status quo reduction by 2015 (%)	UNEP product partnership target reduction by 2015 (%)
Artisanal mining	650 - 1000	0%	not applicable
VCM/PVC	715 - 825	increase to 1250, followed by gradual decrease	not applicable
Chlor-alkali	450 - 550	30%	not applicable
Batteries	260 - 450	50%	75%
Dental amalgam	300 – 400	10%	15%
Measuring & control devices	300 – 350	45%	60%
Lamps	120 - 150	10%	20%
Electrical & electronic devices	170 - 210	40%	55%
Other applications	200 - 420	15%	25%

36 DG ENV, 2008.
37 USEPA, 2008.

2.6 *Global mercury consumption 2005-2017*

2.6.1 Gross mercury consumption 2005-2017

Table 2-5 below summarises the previous forecasts of global mercury consumption by application sector through 2015, and extends the trends to 2017. It should be noted that this table does not include the effects of recycling, and therefore does not (yet) represent the net mercury consumption that needs to be met by mercury supply.

Table 2-5 Global gross mercury consumption (status quo) in tonnes

	Artisanal gold mining	**VCM production**	**Chlor-alkali production**	**Batteries**	**Dental applications**	**Measuring and control devices**	**Lamps**	**Electrical and electronic devices**	**Other applications**	**Annual totals (GROSS Hg consumption)**
	(Average values given for clarity of presentation)									
2005	825	770	500	355	350	325	135	190	310	**3760**
2006	825	910	485	337	347	310	134	182	305	**3835**
2007	825	1050	470	320	343	296	132	175	301	**3911**
2008	825	1150	455	302	340	281	131	167	296	**3946**
2009	825	1250	440	284	336	267	130	160	291	**3982**
2010	825	1200	425	266	333	252	128	152	287	**3868**
2011	825	1150	410	249	329	237	127	144	282	**3753**
2012	825	1100	395	231	326	223	126	137	277	**3639**
2013	825	1050	380	213	322	208	124	129	273	**3524**
2014	825	1000	365	195	319	193	123	122	268	**3410**
2015	825	950	350	178	315	179	122	114	264	**3295**
2016	825	900	335	160	312	164	120	106	259	**3181**
2017	825	850	320	142	308	150	119	99	254	**3066**

2.6.2 Mercury recycling and recovery

The first column of Table 2-6 summarises the situation in 2005 for mercury recycled or recovered from products and manufacturing processes to which mercury is intentionally added. It does not include by-product mercury or other sources that are discussed in Section 3. The second column below makes business-as-usual assumptions about future recycling for the status quo scenario. The third column below presents potential recycling targets that could be achieved with some modest extra effort and, in some cases (e.g. mercury use in artisanal mining), a much broader effort and a substantial budget.

Table 2-6 Status quo and realistic potential mercury recycling

Sector	Recycling in 2005	Status quo projected recycling rates to 2015	Progressive recycling rates to 2015
ASM	There is some recycling and cleaning of Hg that takes place at ASM locations, but the Hg consumption estimated in Section 2.2.1 represents the total quantity of Hg lost after taking account of such activities. For such an industry, this is the only realistic way of trying to account for mercury use.	Since the industrial mining community (represented by the International Council on Mining and Metals – ICMM) is firmly behind taking specific measures with regard to ASM,* it may be safely assumed that at least a 5-10% reduction of Hg consumption will be achieved by 2015. * Telmer, 2008.	Widespread retorting and recycling of ASM mercury could potentially reduce consumption by 32%. Hg cleaning and/or reactivating could potentially reduce Hg consumption by a further 25%.* While it will take significant time and funding (see Section 0) to reach these potential goals, these efforts are so important to human health and the environment that it would not be unrealistic to aim for 50% of those goals (i.e., an overall 25-30% reduction in Hg consumption) by 2015. * Telmer and Veiga, 2008.
VCM/PVC	According to the Chinese State Environmental Protection Administration (SEPA), 95% of spent catalyst was recycled in 2004. There are reports of informal recyclers (perhaps with limited environmental safeguards) who are willing to pay even more for the spent catalyst than formal recycling operations. Since the mercury content of the spent catalyst is depleted to less than 50% of the original mercury content, total recycling could amount to about 350 t Hg for 2005. Russia is reported to recycle about 8 t Hg in its VCM facilities.	If close to 95% of the spent catalyst is already recycled, one could not expect this rate to go higher. One would need to look mainly to contaminated process hydrochloric acid for additional mercury recovery. However, the costs and technical challenges in this area are uncertain.	The logical step is to encourage a range of measures to phase out this technology in favour of mercury-free alternatives. Implementing such a strategy will take many years, but the authorities could already ban the construction of any new facilities using the mercury process. In the meantime, one could target at least 10-20% additional mercury recovery from the hydrochloric acid process stream by 2015.
Chlor-alkali	The USA chlor-alkali industry in 2005 recycled about 50 t of Hg (over 80% of its Hg consumption) from chlor-alkali wastes, the EU about 35 t (less than 20% of its Hg consumption) and other countries an estimated 15-35 t, totalling 100-120 t worldwide. This is just over 20% of industry gross Hg consumption.	Mercury recovery is becoming an increasingly attractive alternative to waste disposal. More US, EU and Indian facilities will stop using the mercury process. But there may be little official encouragement for recycling. It may be assumed that at least another 10% of mercury consumption will be recovered by 2015.	Considering this industry's total gross Hg consumption approaching 500 t worldwide in 2005, and the USA showing how much mercury can be recovered, one might assume that with adequate encouragement an additional 20-25% above the 2005 recycling rate could be recovered worldwide by 2015.

Sector	Recycling in 2005	Status quo projected recycling rates to 2015	Progressive recycling rates to 2015
Mercury in products and “other” applications	In 2005 the EU recovered about 80 t of Hg from Hg-added products and related manufacturing wastes, compared to EU consumption of about 320 t Hg in these product categories during the same year. It is estimated that the rest of the world recovered no more than 10-15% of the total 1410 t of Hg that they consumed in products in 2005. Globally this amounts to over 250 t Hg recovered from products, compared to about 1730 t Hg consumed in products, or just under 15% rate of recovery.	Considering the extent of international interest in reducing mercury circulating in the economy, the anticipated rise in the price of Hg with the EU export ban in 2011, further increases in hazardous waste disposal costs, etc., it may be assumed that by 2015 recycling and recovery of Hg from products will increase to at least 20-25% of the Hg consumed in products.	With focused additional effort, the recycling rate could exceed 30% of the Hg consumed in products by 2015.
Products and processes combined (average values cited)	Combining the above recycling information, in 2005 a total of nearly 750 t of Hg was recovered from mercury products and processes, compared to nearly 3800 t Hg consumed in products and processes, for an overall recovery rate of about 20%.	Combining the projected recycling information for products and processes above, by 2015 there will be about 910 t Hg recovered, compared to roughly 3300 t Hg consumed in products and processes, for an overall recovery rate of approximately 28%.	The assumptions above would push the overall Hg recovery and recycling rate to just above 40%.

2.6.3 Net mercury consumption 2005-2017

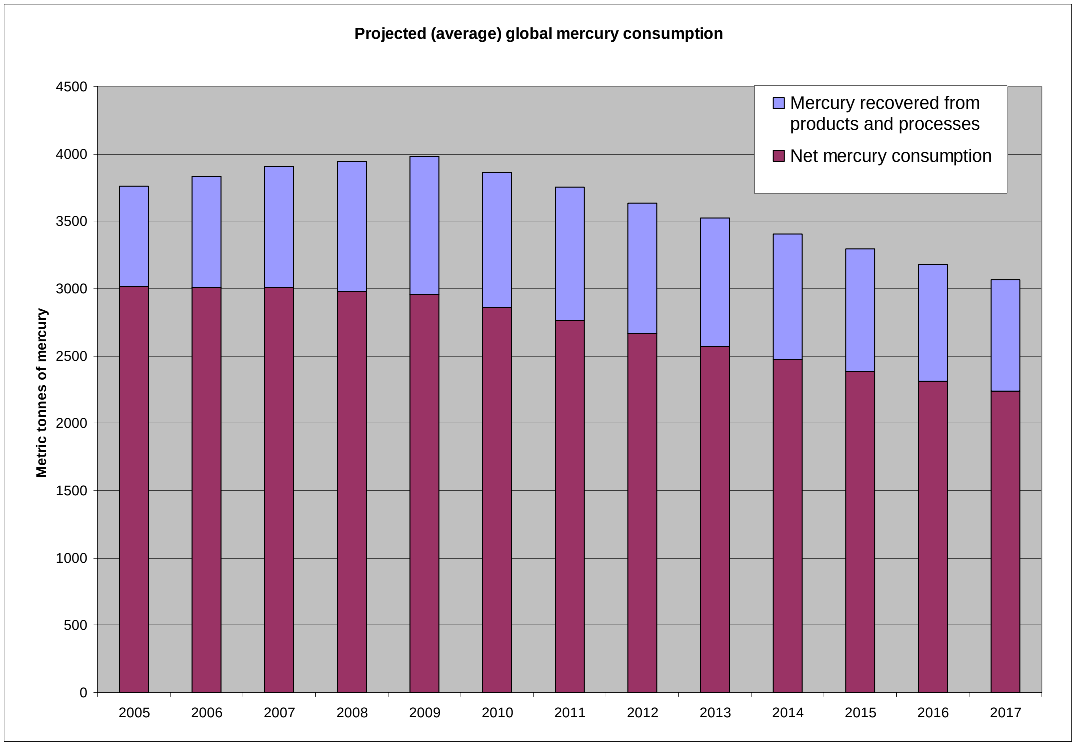
After subtracting recycled and recovered mercury from (gross) mercury consumption, Table 2-7 and Figure 2-6 present projections for net mercury consumption for products and processes. Net mercury consumption represents the quantity of mercury in any given year for which sources will need to be assured.

Table 2-7 Global mercury consumption (status quo), 2005-2017 (tonnes)

	Gross mercury consumption	Recovered Hg from Hg-added products and processes	Net mercury consumption
2005	3760	741	3018
2006	3835	824	3011
2007	3911	906	3005
2008	3946	967	2980
2009	3982	1026	2956
2010	3868	1010	2857
2011	3753	993	2760
2012	3639	974	2665
2013	3524	955	2570
2014	3410	934	2476
2015	3295	912	2383
2016	3181	871	2310
2017	3066	830	2236

The status quo assumptions indicate that for the period up to 2017 one could anticipate mercury recovery of about 800-1000 tonnes per year, and net mercury consumption of just over 3000 tonnes in 2005, declining to just over 2200 tonnes in 2017.

Figure 2-6 Global mercury consumption and recovery (status quo), 2005-2017 (tonnes)



3 Global mercury supply 2005-2017

3.1 Major sources of Hg supply

Apart from mercury recovered from products and processes, which has been discussed above, there are four main sources of mercury "supply":

1. Mining and processing of primary mercury ores;
2. Collection of process mercury from decommissioned mercury cell chlor-alkali plants (MCCAPs);
3. By-product mercury from the refining of some ferrous and most non-ferrous metals; and from the cleaning of natural gas;
4. Stocks of mercury accumulated from previous years (typically the original source would have been mercury mine or by-product, chlor-alkali decommissioning, or other large sources).

3.1.1 Primary mercury mining

Spain

At Almadén (Spain), the mining of primary mercury ores stopped in 2003, and processing stopped in 2004. However, the company continues to store mercury and sell it in the global marketplace. Table 3-1 shows how much the primary mercury supply was reduced when this mine was closed.

Table 3-1 Annual mercury mine production (metric tonnes) in Spain, 2000-2005

Mercury mine production (metric tonnes)	2000	2001	2002	2003	2004	2005
Spain	236	523	727	745	0	0

Source: MAYASA communications.

Algeria

Algeria closed its mercury mine at the end of 2004 in light of continuing technical problems and a relatively low production level. Since about 2000, Algeria rarely produced more than 200 metric tonnes/year. However, the coincidental timing of the closure, around the same time as the Almadén closure, made the market impact of these two events much greater, contributing to the sharp increase in the market price of mercury.

China

Chinese mercury imports in 2004 were reported as 354 tons, with no exports reported then or since. Concurrently with increased mercury consumption, domestic production has also increased. According to the Non-Ferrous Industry Yearbook, China's mercury mine production was 1140 tons in 2004, the highest since 1990. However, the Chemical Registration Center (CRC) of the State Environmental Protection Administration of China was unable to verify such an increase, so it estimated production at 700 tons, a value more consistent with prior years. In 2005, mine production was reported at 1094 tons and imports at 180 tonnes. In 2006 no imports were reported, and it is evident that the authorities are strictly limiting imports.[38]

Table 3-2 Annual mercury mine production (metric tonnes) in China, 2000-2005

Mercury mine production (metric tonnes)	2000	2001	2002	2003	2004	2005
China	203	193	495	612	700-1140	800-1094

Sources: CRC (2007), showing the uncertainty in recent years, and not including a modest amount of mercury said to come from "informal" mining operations, i.e., by small groups of miners not necessarily respecting the regulations to protect the health of workers.

It should also be mentioned that only one mercury mine in China currently produces more than 100 tons per year. In 2004, this mine produced 312.54 tons of mercury. Due to limited reserves, this mine may have an estimated remaining lifespan of only 5-6 years. Likewise, if the total mine output remains in the range of 1000 tons per year, it is

[38] SEPA, 2008; CRC, 2007.

anticipated that China's mercury mines may be able to maintain that level for only about 10 more years.[39]

As the dominant mercury producer and consumer, China's 2004 and 2005 mercury supply may be roughly estimated as in Table 3-3.

Table 3-3 Mercury supply (metric tonnes) in China, 2004-2005

Source	2004	2005
Legal mining	700-1140	800-1094
Imports	233	180
Catalyst recycling	290	350
Informal mining*	0-200	0-200
Total	**1220-1860**	**1330-1830**
* Informal or artisanal mining is typically carried out by individuals or small groups outside the normal commercial and legal system; as such, it is very difficult to obtain good information on the extent of these activities.		

Sources: Derived from NRDC (2006) and CRC (2007).

Kyrgyzstan

Kyrgyzstan has the world's third largest resources of mercury after Spain and China. There are about 400 mercury deposits, two of them comprising large fields (Chonkoi and Khaidarkan with more than 20 thousand tonnes) and one medium-sized field (Zardobuka with 1500 tonnes). The remaining deposits are relatively small. The Khaidarkan Mercury Combine, the only mercury producer in Central Asia, is based in the Batken region of southern Kyrgyzstan. Miners of mercury ore at Khaidarkan, the main source of ore for the Combine, are increasingly going after deep deposits. Moreover, the resource base is now confined to the western end of the district, with an average ore grade of 0.4% Hg (compared to over 3% for high-grade cinnabar ores at the Almadén mine in Spain). Such factors may help to explain why the Combine has not been able in recent years to come close to its rated processing capacity of around 600 tonnes Hg per year. Proven reserves available for commercial development will support production at current levels for only another 8 to 10 years.[40]

Kyrgyzstan exports its entire mine output, as shown in Table 3-4, and has also in the past accepted antimony-mercury mine concentrates from Russia for refining. Mine output in 2006 has been estimated at 350 tonnes of Hg.

Table 3-4 Mercury mine production (metric tonnes) in Kyrgyzstan, 2000-2005

Mercury mine production (metric tonnes)	2000	2001	2002	2003	2004	2005
Kyrgyzstan	590	574	542	397	488	304

Sources: UNEP awareness raising workshop, Kiev, Ukraine (UNEP 2004); personal communications.

Other "mining" activities

Other mercury "mining" activities may take place in a few other countries, but they are very small and typically informal. In the largest of these by far, at the site of a silver mine that has been inactive for many years, mercury has been extracted from silver mine tailings in

39 CRC, 2007; SEPA, 2008;.

40 Masters, 2007.

Zacatecas in the Mexican municipalities of Guadalupe and Veta Grande. A total of 60.63 metric tons of mercury were reported to have been recovered during 1998,[41] although more recent data are unavailable. Therefore one might estimate 50-100 tonnes of mercury mined worldwide in locations not included in the previous discussion.

Total mined mercury

For 2005 the total mined mercury – both legal and informal (as defined in Table 3-3) – described above adds up to 1154-1498 tonnes. During the next 10 years, assuming "business as usual" (status quo scenario), primary mercury mining may decline about 20% after year 6 due to a fall-off in Chinese mining. On the other hand, alternative mining sources may be opened in China to make up the shortfall, as in the past. Otherwise, there should be no other significant changes other than the obvious impact if a country such as Kyrgyzstan should decide to phase out its mining operations.

3.1.2 Residual mercury from the chlor-alkali industry

Apart from the mercury waste generated by chlor-alkali facilities, there is a large quantity of process mercury at the bottom of the electrolytic "cells" that is necessary for the mercury process to function properly. When a mercury cell facility is closed or converted to the membrane process, the process mercury may be removed.

In 2005, there remained about 5.8 million metric tonnes of mercury cell chlorine capacity operating in the EU-25.[42] During 2005-2007, the closing or conversion of some one million metric tonnes of this chlorine capacity were announced by industry, including plants in Italy, Poland, etc.

Globally, outside the EU-25, there remained in 2005 approximately four million metric tonnes of mercury cell chlorine capacity, including about 1.1 million metric tonnes in the United States of America, 428 thousand metric tonnes in India, 430 thousand metric tonnes in the Russian Federation, 341 thousand metric tonnes in Brazil, and 1.5-2.0 million metric tonnes in other parts of the world.[43] In these regions as well, mercury cell chlor-alkali facilities are increasingly decommissioned, and mercury-free facilities are constructed, reflecting a long transition away from the mercury cell process. Among other progress in this industry, India is reported to be working toward a 2012 mercury cell phase-out date. Apart from an expansion of the mercury cellroom at the Bandahar facility in Iran a few years ago, no new mercury cells have been put into operation since the early 1990s.

When a mercury cell chlor-alkali facility stops operating (also called "decommissioning"), the process mercury may be reused within the industry, or it may be sold outside the industry on the international market. Between now and 2020, most of the remaining European mercury cell facilities are expected to decommission. This will liberate up to 11,000 metric tonnes of mercury in the cells, and more mercury from other parts of the plants. Euro Chlor, the European industry trade association, has an agreement that all mercury not needed by the European chlor-alkali industry should be sold to MAYASA, the Spanish trading (and former mining) company, which then sells it on the world market. The European Commission has recently reached political agreement on legislation that

[41] CEC, 2001.
[42] Euro Chlor, 2005.
[43] WCC, 2006.

will ban such mercury exports and require mercury from decommissioned chlor-alkali plants to be sent to long-term "safe storage" as of 31 March 2011.[44]

Based on the phase-out schedule in Table 3-5, it may be estimated that an average of about 1000 tonnes of Hg per year will become available from decommissioned chlor-alkali facilities, of which an average of 760 tonnes (minus all mercury transferred for ongoing use within the European Union chlor-alkali industry) will be required by European Union law to go to long-term storage after March 2011. Therefore, beginning in 2011 the non-EU chlor-alkali contribution to global mercury supply may be assumed to average some 240 tonnes per year.

Table 3-5 Mercury liberated by chlor-alkali facility decommissioning, 2005-2015

Country or region	Chlorine capacity (t/yr)	Probable capacity (t/yr) reduction 2006-2015	Hg recovered from cells 2006-2015 (tonnes)	Hg available (tonnes - annual average)	
European Union	5.8 million	3.8 million	7,600	760	
USA	1.1 million	500,000	1,000	100	
India	428,000	300,000	600	60	
Brazil	341,000	50,000	100	10	
Russian Federation	430,000	80,000	160	16	
Other	1.5 - 2 million	300,000 - 500,000	600 - 1,000	80	
Total			~10,300	~1,000	

For 2005, it was estimated that some 700-900 tonnes of mercury were made available from this source.[45]

3.1.3 By-product mercury

3.1.3.1 Non-ferrous metal ore processing

The processing of zinc, copper, lead, gold, nickel, and other non-ferrous metals is likely to release mercury because these ores typically contain trace concentrations of mercury, and because thermal methods are used to process them.

The mercury content of an ore is dependent on the particular geology of the mineral deposits. "Belts" of high mercury deposits are known to occur in the Mediterranean region, the Western US and Canada, Eastern Australia, certain areas of central China, and Peru[46]. Many of these geographic areas also produce much of the world's gold: four of the five largest gold producers in 2004 were Australia, the USA, China and Peru[47] (South Africa was the largest producer). These high-mercury areas also correspond to major zinc producing regions: in 2004, China alone accounted for about a quarter of all world zinc mining, and Australia, Peru, Canada and the US together accounted for another 40 percent. It is important to keep in kind, however, that high mercury content has been

44 The text of the proposed legislation, COM(2006) 636 final, may be consulted at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52006PC0636:EN:HTML
45 UNEP, 2006.
46 Rytuba, 2003.
47 USGS Minerals Yearbook, 2005 for Gold.

documented in ore deposits in other parts of the world as well,[48] and that mercury content can vary dramatically even within a geographic area.

Mercury that occurs in various ores as a trace metal is typically emitted to the atmosphere during smelting, unless it is removed from the process before it can be emitted. Mercury releases may be trapped by activated carbon or other techniques, and is frequently disposed of as a hazardous waste. Alternatively, if certain removal techniques are used and the mercury content is high enough, it may be economically feasible (or required by the operating permit, as in Finland) to recycle the mercury wastes and recover the mercury.

According to officials of the main company selling advanced mercury removal technology, their equipment could be installed on zinc, copper, lead, gold and other smelters to reduce mercury emissions. However, aside from gold production facilities using thermal pre-treatment and electro-refining to recover by-product mercury (especially in North and South America),[49] primarily the zinc smelters, and only some of the larger ones, have chosen to make the necessary investment to keep their mercury emissions out of the atmosphere.[50]

Zinc ores

In an effort to estimate mercury in zinc smelting wastes, Boliden officials calculated mercury by-product production based upon the design capacity of the units, the amount of gas managed in the units, and the typical mercury content of the gas. Globally, they estimated about 260 tons of mercury in calomel produced (some of which was then recycled, and some sent for disposal) at zinc smelters annually, plus or minus 50% given uncertainties about individual plant operations, unit operating status, etc. The 22-24 tons of mercury produced at the Finland smelter in 2005, using another process, was added to the first estimate to calculate the global potential mercury recovery from zinc ores.[51] It should be noted that this is merely the potential from presently installed mercury removal equipment.

Gold ores

With regard to recovery of by-product mercury from industrial gold mining (as opposed to artisanal and small-scale gold mining), the main sources of recovered mercury are South America and the United States of America. In the aggregate, there are five gold mines in South America recovering mercury – three in Peru, one in Chile (an especially large operation), and one starting up in Argentina. Not counting the Argentina operation (because it is too early to estimate), the total amount of mercury recovered from these four mines is 80-100 metric tonnes annually.

NRDC (2006) has discussed this sector in some detail and, recalling that the United States (mostly the state of Nevada) presently recovers at least 100 metric tonnes of mercury from its own gold mining operations (Brooks and Matos, 2005; Jones and Miller, 2006), provided the basis for an estimate of around 200 metric tonnes of mercury recovered in 2005 from gold mining operations worldwide. A significant motivation for mercury recovery is said to be companies' increasing concern about their environmental

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[48] UNEP, 2005.

[49] Hylander, 2008.

[50] In particular, the Boliden-Norzink process, now owned by Outokumpu Oy, produces a calomel (mercurous chloride) waste that may be recycled for mercury recovery.

[51] UNEP, 2006.

image, which suggests that mercury recovery is a practice that will likely become more common in the smelting industry.

Other ores

The mercury content of lead and copper ores is much lower, on average, but the quantities processed are quite high. In addition, by-product mercury is recovered from an antimony-mercury mine in Tajikistan, from some mining operations elsewhere in the Russian Federation, etc.[52]

Based on data concerning mercury content of non-ferrous ores provided in the UNEP mercury "Toolkit,"[53] it has been roughly estimated that some 1,000-1,500 metric tonnes of mercury are released every year from various ores by refining processes.[54] Most of that mercury goes to the atmosphere, but much is captured and recovered, as described above, or disposed of. Adding the various non-ferrous sources as in Table 3-6 gives an estimated 400-500 metric tonnes of mercury recovered globally from smelting in 2005.

3.1.3.2 Natural gas cleaning

At the UNEP mercury workshop in Bangkok,[55] the Malaysian delegate drew attention to the possibly very significant gas-field related emissions of mercury in her country, mainly due to gas flaring.

Most natural gas contains some mercury in trace quantities. In many regions of the world, depending on geology, such as the Netherlands, North Sea, Algeria, Croatia, etc., the mercury concentrations are high enough to cause serious equipment problems during processing.[56] Pirrone and colleagues reported that "a reduction of mercury to below 10 $\mu g/m^3$ has to be obtained before the gas can be used," although mercury is sometimes removed from gas even at far lower concentrations.[57] It is estimated that 25-30 metric tonnes of mercury are recovered yearly from natural gas wastes in the European Union alone.[58] In 2005 the Netherlands exported for recycling in Germany an estimated 55 tonnes of Hg in gas-cleaning wastes, although these were not all accumulated in one year.[59] The UNEP Trade Report estimated mercury recovered globally from natural gas at 30-40 tonnes per year, although this may be a slight underestimate.[60]

3.1.3.3 Global production of by-product mercury

Table 3-6 below summarises the main points of the previous discussion, and estimates a global total of some 400-600 tonnes of mercury recovered annually from by-product sources. This is significantly less than half of the estimated total mercury content of the raw materials listed in the table.

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52 UNEP, 2006.
53 UNEP, 2005.
54 Maxson, 2006.
55 UNEP Workshop to Reduce Mercury Use and Release in Products for the Asia Pacific, Bangkok, Thailand, 17-19 May 2007.
56 Specifically, mercury condenses as liquid mercury on the inside of piping and equipment, or it amalgamates with aluminium (most problematic) or other metals (except iron), gradually corroding and weakening the metals, which has resulted in serious industrial accidents.
57 Pirrone, 2001.
58 Maxson, 2006.
59 Netherlands, 2008.
60 UNEP, 2006.

Table 3-6 Global by-product mercury production (2005)

By-product source	Primary metal production (tonnes)	Total mercury content (tonnes)	Metallic mercury recovered (tonnes)
Zinc ores	9 million	500-650	80-120
Lead ores	3.5 million	20-30	0
Copper ores	14 million	200-270	20-40
Gold ores	2.4 thousand	220-250	180-220
Other mine by-product	not applicable	not applicable	100-150
Natural gas	not applicable	no estimate available	30-50
TOTAL		1000+ to 1200+	410-580

Sources: "Primary metal production" estimated from NRDC (2007); "total mercury content" from consultant estimates; "mercury recovered" estimated as described in the text.

3.1.3.4 Status quo projection to 2015

As noted above, the mercury content of ores and natural gas is very dependent not only on the geographic region, but also on the specific ore seam or gas field in question. For example, there is some indication that the quantity of mercury recovered from the Yanacocha gold mine in Peru has decreased during 2006 and 2007 due to mining of different deposits, even though they are geographically close to the deposits mined previously.[61]

Nevertheless, it is expected that mercury recovery from by-product sources could easily increase to 50% or more of the mercury content by 2015. In parallel, it may be anticipated that total demand for these resources will increase by at lease 30% by 2015, in light of impressive economic growth especially in China and India.

3.1.4 Mercury stocks or inventories

In the past, reserve stocks of mercury held by governments or their proxies have been traded on the world market. The sale of such stocks has contributed significantly to the supply of mercury exported from the United States of America and from the former Soviet Union, although accurate information is sometimes difficult to obtain.

Mercury sales from the US Government were suspended in 1994 in response to environmental concerns.[62] In 2006 it was decided that the remaining US mercury stocks would be consolidated at a single site in Nevada. These include an inventory of 4436 tonnes of mercury under the responsibility of the US Defense Logistics Agency, and another 1306 tonnes of mercury held by the US Department of Energy.

Despite information in 2005 from a major European mercury broker that stockpiles of mercury in the former Soviet Union had been depleted, about 500 tonnes of mercury, said to have originated in Kyrgyzstan, were made available by Russian dealers in 2006 and 2007.[63] In 2008 it has been rumoured that Russian dealers are again stockpiling mercury, perhaps new mercury purchased from Kyrgyzstan.

The largest inventory of commercially available mercury held by a single organisation is in Spain. Based on an on-site inspection, stocks of elemental mercury held by MAYASA at

61 Masters, 2008.
62 USGS, 2006.
63 Masters, 2008.

Almadén in 2005 were estimated at 1,000-2,000 metric tonnes,[64] although a well-informed European broker has estimated more than twice that quantity.[65] This inventory has been accumulated over a number of years from previous mining activities at Almadén, mercury purchased from Kyrgyzstan, deliveries of mercury from decommissioned chlor-alkali facilities in Europe, etc.

Other than some stocks held on-site in storage rooms by chlor-alkali producers, it is likely there are other stocks remaining as well, especially in light of increased speculation by brokers, fuelled by the volatility of mercury prices since 2004. Lambert Metals has had mercury storage facilities at the ports of Antwerp and Rotterdam.[66] Likewise, the largest Indian mercury broker has been especially active in recent years, and logically maintains stocks in Mumbai, although there is no precise information regarding quantities.

Mercury inventories, in general, are an important variable in mercury supply and demand, for a number of reasons:

- The overall quantities are not well known, but are thought to be at least 4000 to 6000 tonnes.
- The mercury is often held in Customs-Free Zones, either for ease of transhipment, or for avoiding administrative formalities of shipments in and out of countries.
- If an inventory is not presently in a Customs-Free Zone, it could easily be shipped to one, for example shortly before the EU mercury export ban takes effect. It is anticipated that remaining EU inventories will be moved out of the EU before 2011.[67]
- Finally, these inventories are instrumental in helping to balance mercury supply and demand during periods of transition or market disruption – for example, if a primary mining operation were to close, or when the EU export ban takes effect.

However, for all of the above reasons as well, the annual contribution of such inventories to the market are virtually impossible to predict. For 2005, it was estimated that 300-400 tonnes of mercury from the inventory at Almadén were put on the market.[68] Based on best available information, it is very likely that a similar quantity (on average) could be made available from various stocks and inventories through the next 10 years.

3.1.5 Global mercury supply in 2005

Summarising the previous discussion, Table 3-7 presents all of the major sources of mercury supply in 2005.

[64] Maxson, 2006.
[65] Masters, 2008.
[66] Fialka, 2006.
[67] Masters, 2008.
[68] UNEP, 2006.

Table 3-7 Global mercury supply, 2005

Sources of mercury supply (2005)	Mercury supply (metric tonnes)
Primary mercury mining	1150-1500
By-product mercury incl. natural gas cleaning	410-580
Recycled Hg from Hg-added products & processes	a)
Mercury from chlor-alkali cells (after decommissioning)[b)]	700-900
Stocks[c)]	300-400
Total	**2560-3380**

Notes:
a) Included in previous calculation of "net" mercury consumption
b) "Mercury from chlor-alkali cells" is elemental mercury removed from cells after they have stopped operating.
c) Mainly from Almadén, not including Hg previously received from decommissioned chlor-alkali facilities.

These global sources of mercury in 2005 may be compared to the calculation of global net mercury consumption (average value slightly over 3000 tonnes) as presented in Table 2-7 previously.

3.1.6 Impacts of the European Union mercury export ban

As mentioned previously, the European Union mercury export ban, which takes effect from 31 March 2011, most importantly bans the export of "surplus" mercury coming from the chlor-alkali industry, and bans the export of calomel (mercurous chloride, or Hg_2Cl_2) – most commonly produced as a mercury waste from smelting operations – and other by-product mercury wastes. This will have the following main impacts on the previous calculations of mercury supplies:

- the average 760 tonnes of mercury recovered from chlor-alkali facilities in the EU, some of which is presently reused by the chlor-alkali industry and the remainder put on the open market, after March 2011 will no longer be available to any users outside the EU chlor-alkali industry;
- the roughly 60-100 tonnes of by-product mercury recovered annually from mining, smelting and natural gas production in the EU will no longer be available to any users inside or outside the EU.

These impacts are shown in more detail in Table 3-8 below, specifically in terms of mercury that will not be available to the global market due to the EU export ban. Average values have been used in this table. Uncertainties will be further explored in section 4.2.

Table 3-8 Mercury unavailable to the global market after the 2100 EU export ban

Year	**Mercury from the EU chlor-alkali industry unavailable from 2011***				**EU by-product mercury unavailable from 2011***			**Total Hg removed from the global market by the EU export ban (tonnes)**
	EU chlorine capacity (tonnes chlorine)	Average Hg recovered in EU from decommis-sioning (tonnes)	Hg normally available for global use other than EU chlorine (tonnes)	Hg removed from the global market by export ban (tonnes)	Average EU by-product mercury recovered (tonnes)	Hg normally available for global use (tonnes)	Hg removed from the global market by export ban (tonnes)	
2005	5800000	760	608	0	80	80	0	0
2006	5480000	760	617	0	82	82	0	0
2007	5160000	760	626	0	84	84	0	0
2008	4840000	760	635	0	86	86	0	0
2009	4520000	760	644	0	88	88	0	0
2010	4200000	760	653	0	90	90	0	0
2011	3880000	760	662	662	92	92	92	754
2012	3560000	760	671	671	94	94	94	765

2013	3240000	760	680	680	96	96	96	776
2014	2920000	760	689	689	98	98	98	787
2015	2600000	760	698	698	100	100	100	798
2016	2280000	760	708	708	102	102	102	810
2017	1960000	760	717	717	104	104	104	821

* Average values have been used in order to facilitate the presentation

3.2 Global mercury supply 2005-2017

From the previous analysis, Table 3-9 summarises the global mercury supply during 2005-2017, including the impacts of Chinese primary mine production declining from 2012, and the effects of the EU mercury export ban from 2011, while including primary mercury mine production from Kyrgyzstan.

Table 3-9 Global mercury supply (status quo) with Kyrgyzstan contribution

	Primary mercury mining (<u>including</u> Kyrgyzstan mining)	By-product mercury incl. natural gas cleaning	Mercury from chlor-alkali cells (after decommis-sioning)	Stocks or inventories	Total sources before the export ban	Total Hg removed from the global market by EU export ban	Total sources after the EU export ban
2005	1325	495	800	350	2970	0	**2970**
2006	1325	526	1000	350	3201	0	**3201**
2007	1325	556	1000	350	3231	0	**3231**
2008	1325	587	1000	350	3262	0	**3262**
2009	1325	617	1000	350	3292	0	**3292**
2010	1325	648	1000	350	3323	0	**3323**
2011	1325	678	1000	350	3353	754	**2599**
2012	1060	709	1000	350	3119	765	**2353**
2013	1060	739	1000	350	3149	776	**2373**
2014	1060	770	1000	350	3180	787	**2392**
2015	1060	800	1000	350	3210	798	**2412**
2016	1060	831	1000	350	3241	810	**2431**
2017	1060	861	1000	350	3271	821	**2450**

The Table 3-9 results may be compared with those in Table 3-10, which keeps all of the same assumptions except that Kyrgyzstan mine production is excluded after 2010. It is assumed that even if alternative economic opportunities could be provided relatively smoothly, the Kyrgyzstan mine production of 350-400 tonnes of mercury would probably not stop until after 2010.

Table 3-10 Global mercury supply (status quo) without Kyrgyzstan contribution

	Primary mercury mining (<u>excluding</u> Kyrgyzstan mining)	By-product mercury incl. natural gas cleaning	Mercury from chlor-alkali cells (after decommis-sioning)	Stocks or inventories	Total sources before the export ban	Total Hg removed from the global market by EU export ban	Total sources after the EU export ban
2005	1325	495	800	350	2970	0	**2970**
2006	1325	526	1000	350	3201	0	**3201**
2007	1325	556	1000	350	3231	0	**3231**
2008	1325	587	1000	350	3262	0	**3262**
2009	1325	617	1000	350	3292	0	**3292**
2010	1325	648	1000	350	3323	0	**3323**
2011	950	678	1000	350	2978	754	**2224**
2012	685	709	1000	350	2744	765	**1978**
2013	685	739	1000	350	2774	776	**1998**
2014	685	770	1000	350	2805	787	**2017**
2015	685	800	1000	350	2835	798	**2037**
2016	685	831	1000	350	2866	810	**2056**
2017	685	861	1000	350	2896	821	**2075**

4 Global (net) mercury consumption vs. supply 2005-2017

4.1 Status quo (net) consumption vs. supply

From the previous analysis, Table 4-1 summarises the global mercury supply during the period 2005-2017, as compared with the net mercury consumption summarised in Section 2.6.3. This is a critical period for the mercury markets, as several key events coincide to disrupt the market.

Table 4-1 (Net) mercury consumption vs. supply without Kyrgyzstan contribution

	Total sources after the EU export ban	Net consumption (status quo)	Supply minus consumption
	(average values shown for clarity of presentation)		
2005	2970	3018	-48
2006	3201	3011	189
2007	3231	3005	226
2008	3262	2980	282
2009	3292	2956	336
2010	3323	2857	465
2011	2224	2760	-537
2012	1978	2665	-686
2013	1998	2570	-572
2014	2017	2476	-459
2015	2037	2383	-347
2016	2056	2310	-254
2017	2075	2236	-161
Cumulative	33662	35226	-1564

Unsurprisingly, this table reveals the sharp reduction in mercury supply in 2011-2012 due to the start of the EU mercury export ban, the hypothetical phase-out of primary mercury production in Kyrgyzstan, and an assumed reduction in Chinese mine production. This could be considered a rather pessimistic supply scenario since the Chinese mercury supply has been largely separate from the rest of the world in recent years, as domestic mercury supplies increase with domestic demand.

With regard to net mercury consumption, it should be recalled that the status quo scenario represents no significant effort to reduce consumption or to increase recycling. It does not even go as far as the UNEP Product Partnership targets for reducing mercury consumption as summarised in Table 2-4. Therefore it could also be considered a rather pessimistic (upper end) view of the future of mercury consumption.

However, even accepting these pessimistic forecasts for the sake of modelling something like a "worst case," the cumulative deficit in mercury supply compared to net consumption for the entire period 2005-2017 is only 1500-1600 tonnes, or one-half of the net consumption in 2005. In the mercury marketplace, over a 10-year period, one could expect the mercury surpluses in some years to be stored and later retrieved when there is a supply deficit.

Nevertheless, in the event that the above does not represent the worst case that mercury does not come out of storage to meet the supply deficit, etc., one might consider alternative non-primary (i.e., not coming from mercury mines) sources that might be available to meet the deficit. These are discussed in section 5.

4.2 Accounting for uncertainties

The main uncertainties in this analysis have been discussed above. Others should be mentioned, but their probability of occurring is about the same as their probability of not occurring. Overall, as seen in Table 4-2, the weight of uncertainties does not weigh heavily in one direction or the other.

Table 4-2 General impact of other uncertainties

Uncertainty	**Impact on the supply vs. consumption equilibrium**
China may not face a reduction in its mine output.	+ +
China may face a reduction in its mine output, as assumed, but then it may decide to import mercury to cover the supply deficit.	included in this analysis
Primary mine production in Kyrgyzstan may continue due to a lack of alternative support for the local economy.	+ +
Phase-out of primary mine production in Kyrgyzstan may take place, but somewhat later than assumed.	+
The future contribution to the mercury supply by Kyrgyzstan's mine may have been greater than assumed in this analysis.	included in this analysis, since it is assumed that the Kyrgyzstan contribution becomes zero.
Future recycling rates may be greater than assumed.	+ to + +
Future recycling rates may be lower than assumed.	– to – –
Targeted reductions in mercury consumption may be greater than assumed.	+ to + +
Targeted reductions in mercury consumption may be lower than assumed.	– to – –
The USA may implement a mercury export ban somewhat similar to that in the EU. This has not been discussed above because its passage is uncertain. However, such a ban would probably have little net impact on global mercury supplies because US production (mostly by-product from gold mines) is in rough balance with consumption. It would, however, alter international trade flows of mercury by-product and wastes that now come into the US for cleaning or recycling, and which are then re-exported.	– to +
Key: – slightly reduced supply or increased consumption; – – significantly reduced supply or increased consumption; – – – greatly reduced supply or increased consumption; + slightly increased supply or reduced consumption; + + significantly increased supply or reduced consumption; + + + greatly increased supply or reduced consumption	

5 Additional "sources" of Hg that could be mobilised

If one needed to mobilise additional sources of mercury in order to temporarily meet demand while phasing out primary mercury mining, the main targets, in order of the quantity of mercury potentially available, would include:

- enhanced recycling of mercury used in artisanal mining,
- better separation, collection and recycling of mercury products, dental amalgams, blood pressure devices, thermometers, etc.
- enhanced recovery of mercury used in VCM/PVC production,
- enhanced recovery of mercury from mining and smelting processes,
- enhanced recovery of mercury from chlor-alkali waste,
- enhanced recovery of mercury from natural gas cleaning wastes,

- enhanced recovery of mercury from incinerator, coal combustion and crematorium flue gases.

Nevertheless, whatever the potential quantity available, the cost of mobilising additional mercury sources would be a major consideration. These costs are discussed further below, but first it is useful to have a better idea of the full range of options available when balancing mercury supply with demand.

5.1 Supply-side vs. demand-side options

The sources of additional mercury mentioned above may be referred to as "supply-side" options because they are all aimed at increasing the available mercury supply. But one should also keep in mind "demand-side" options, such as any measures that would reduce consumption of mercury. A reduction of mercury consumption could be thought of as merely another kind of mercury "source."

The difference supply-side and demand-side options may appear trivial, but is quite important because:

To increase the mercury supply, you need to pay every year;
but if you decrease mercury demand, you pay only once.

This becomes clear if one takes a simple example such as mercury in thermometers. If one selects a supply-side option in order to increase the overall mercury supply, it might take the form of an aggressive thermometer collection and recycling programme in one's city. One could design and carry out such a programme so that mercury thermometers are routinely collected and recycled, and the mercury recovered. If one added together all of the costs (organisation, information diffusion, thermometer collection, transport, recycling, etc.), just for the sake of this example, one might discover that the cost of the mercury recovered was $US 1000 per kg.

Alternatively, if one decided to pursue a demand-side programme in order to decrease overall mercury demand, it might take the form of a massive information campaign to convince the public that mercury-free thermometers are better for health and the environment, to persuade shops not to stock mercury thermometers any longer, and perhaps even to work with manufacturers to encourage them to phase out production of mercury thermometers. If one eventually calculated the cost of this programme, again for the sake of example, one might discover that the cost of every kilogramme of mercury consumption eliminated was $US 2000.

The great difference between these two approaches, as suggested above, is that the cost of increasing the mercury supply needs to be spent again and again, year after year, for every kilogramme of mercury "produced." The cost of decreasing mercury demand, on the other hand, while greater per kilogramme of mercury, was spent only once and eliminated forever the need for an ongoing mercury supply.

As a result, in order to have a better comparison between such different approaches, it may be reasonable to spread the cost of any demand-side measure over 10-15 years.[69] If so, the equivalent cost of this demand-side example would be considerably less than $US 200 per kg mercury, or less than one-fifth of the supply-side cost of meeting the same

[69] There is an economic justification for such an approach, in that the farther into the future an annual supply-side cost is considered, the less "present value" that cost will have. Depending on the discount rate chosen, the "present value" of a cost 10-15 years in the future would be so small as to no longer significantly influence the cost calculation.

market objective (ignoring, for the moment, any benefits related to human health or environmental considerations).

This example does not, by any means, imply that only demand-side programmes should be pursued. But it does demonstrate that one needs to be very careful when comparing costs of different options.

5.2 Cost of mobilising additional Hg

While phasing out primary mining of mercury is an objective that has broad support, if it requires other mercury sources to meet some of the demand, then the cost of further exploiting those sources must be considered. A detailed analysis of such costs is beyond the scope of this paper, since it would include an assessment of the accessibility of different sources in various geographical locations, an assessment of the various recovery techniques that may be available, etc. Nevertheless, the following discussion aims to give a general impression of the range of costs involved in the main options for balancing supply and demand, if necessary.

5.2.1 Enhanced recycling of ASM mercury

Although one should not underestimate the challenges of implementing such a large and geographically diverse program, the cost of a viable program to seriously reduce Hg consumption in ASM has been unofficially estimated at some $20 million,[70] and if one includes a broad range of related contributions, perhaps as high as $30 million all-inclusive, in order to achieve a reduction in Hg consumption of some 400 tonnes (per year). If one assumed the investment might take place over a maximum of 10 years, and might achieve an average of 200 tonnes per year reduction in mercury consumption over that period of time, this would calculate to an average of some $15 per kilogramme of Hg consumption eliminated during those 10 years. This is a very simplified calculation, and ignores that after those 10 years ASM mercury consumption would still be 400 tonnes lower than at present. Nevertheless, it gives an idea of the maximum cost involved in reducing ASM mercury demand.

5.2.2 Enhanced recovery of mercury used in VCM/PVC production

Judging from the high rate of recycling of VCM/PVC catalyst (Hg content 4-5%) in China, and the fact that the informal sector seems eager to take part, it is evident that the cost of recycling spent catalyst is lower than the market price of mercury.

The cost of recovering additional mercury from the process hydrochloric acid has not been reported, although it is known that some of this mercury is recovered in the Russian installations.[71] Therefore modest additional recycling is assumed at a reasonable cost.

5.2.3 Enhanced recovery of mercury from chlor-alkali waste

The chlor-alkali industry worldwide now recovers some 100-120 tonnes of mercury from a total of 300-400 tonnes of mercury in wastes. Some of the recovery is done on-site and some at off-site recycling facilities. In the USA the chlor-alkali industry is legally obligated to recover all mercury from waste with an elevated mercury content, and has shown that a high rate of recovery is possible. Precise numbers are not available, but it is estimated that for waste with a mercury content of more than 10%, the mercury can generally be recovered for less than $US 50 per kg of mercury recovered.

70 Telmer, 2008.
71 ACAP, 2005.

For a comparative calculation, various sources have estimated that the cost of converting a typical chlor-alkali facility[72] to a mercury-free process would be on the order of $US 30-50 million. Such a conversion would eliminate the consumption of 2-20 tonnes of mercury consumption every year – depending on the efficiency of the facility – and permit the recovery of at least 200 tonnes of Hg from the process cells.

Based on the suggestion in section 5.1 that an investment eliminating mercury demand is worth at least 10 times the cost of increasing the mercury supply, this $US 30-50 million investment would "supply" mercury at the equivalent unit cost of $US 100-150 per kg. Compared to other examples, this investment may not be quite as attractive in terms of supplying a "source" of mercury. However, if one were to take account of the overall economic and social benefits of conversion as well, this option would be considerably more interesting.[73]

5.2.4 Enhanced separation, collection and recycling of dental amalgams, mercury products, etc.

In a recent report to the US House of Representatives, the complete cost of installing and maintaining amalgam separators, collecting and recycling the mercury from the amalgam was estimated at about two US dollars per filling, or $US 4000 per kg of mercury recovered.[74] This could be compared with the overall cost of increasing the rate of recycling of dental mercury collected in chairside traps at dental clinics, estimated at some $US 240 per kg of mercury recovered.[75]

Recyclers have provided costs for recovering Hg from various sorts of Hg waste. In most cases the recycling cost depends on the quantity of waste, the recovery technique used, and the chemical nature of the waste, and has little to do with the mercury content of the waste.

In order to have an overall mercury recovery cost, one needs to also include the cost of collection and delivery of the waste to the recycler. The overall cost per kg of Hg recovered therefore depends heavily on the Hg content of the waste, since low mercury content implies greater quantities of waste to handle per kg of mercury content.

The simple recycling of dental amalgam after delivery to the recycler has been estimated at some $US 15-25 per kg of mercury recovered, while the recycling of mercury in other products such as thermometers and blood pressure devices, which have a lower average mercury content, has been estimated at some $US 100-200 per kg of mercury recovered.[76]

Complete programmes (i.e., all costs included) to collect mercury thermometers in Sweden cost $US 950-1200 per kg of mercury recovered. By comparison, programmes to replace mercury thermometers in Minnesota cost anywhere from $US20 to 2000 per kg of mercury consumption eliminated.[77]

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72 That is, approximately 100 thousand tonnes annual chorine production capacity.

73 See Maxson (2006), which presents the argument for governments that may consider providing financial assistance to industry in order to achieve the broad socioeconomic benefits of such conversions.

74 Bender, 2008.

75 Hylander, 2008.

76 DG ENV, 2008; personal communications.

77 Hylander, 2008.

Programmes to collect mercury and mercury compounds in school and university laboratories in Sweden and Minnesota ranged from $US20 to 1400 per kg of mercury recovered.[78]

5.2.5 Enhanced recovery of mercury from mining and smelting processes

Mining and smelting processes may produce a range of mercury-containing wastes, depending on the production processes, including calomel, filtercake, activated carbon wastes, sludges, etc.

Some experienced zinc smelting operators have reported that recovering Hg from calomel (over 70% mercury content) is a "break-even" operation for them, suggesting that it costs them no more than $US 10-20 to recover one kilogram of Hg from calomel using on-site equipment.[79] The need for other facilities to ship the wastes some distance could add significantly to the cost, partly explaining why much calomel is presently sent for disposal.

Recovery of mercury from flue gas emissions is much more expensive, as noted in section 5.2.7 below.

5.2.6 Enhanced recovery of mercury from natural gas cleaning wastes

All natural gas that contains mercury that may damage the gas processing system is cleaned in some manner, leaving primarily wet sludges, dry sludges and contaminated catalyst as mercury wastes. Information from recyclers about the costs of removing mercury from such wastes are inconclusive. However, indications of a cost of over $US 50 per kg mercury removed for only the recycling phase of some of these wastes suggests that in general the mercury recovery cost would likely be greater than $US 100 per kg mercury.

5.2.7 Enhanced recovery of mercury from flue gases

There are three main categories of cost involved in recovery of mercury from incinerator, coal combustion, crematorium and other flue gases:

1. following system design, the cost of installing flue gas cleaning devices;
2. the cost of activated carbon or other materials to capture the mercury; and
3. the cost of recycling the filter cake, activated carbon or other materials in which the Hg has been captured.

In the first case, the argument could be made that some industries in some regions are already installing such devices, so the equipment installation cost should not be included in the overall cost of mercury recovered from this source.

Due to the low mercury content of the waste, recycling (not including activated carbon cost, transport, etc.) of contaminated activated carbon (less than 1% mercury content) costs the equivalent of $US 200-400 per kg of Hg recovered.[80]

The recycling (not including filter material cost, transport, etc.) of contaminated filtercake from flue gas cleaning (less than 0.1% mercury content) costs the equivalent of $US 2000-4000 per kg of Hg recovered.[81]

[78] Hylander, 2008.
[79] Personal communications with Boliden officials.
[80] DG ENV, 2008; personal communications.
[81] DG ENV, 2008; personal communications.

Total mercury recovery costs for a range of technologies to remove Hg from waste gases have elsewhere been reported at $US 465, and far higher, per kg of mercury recovered.[82]

Due to the generally high cost of recovering mercury in this manner, these sorts of wastes are commonly disposed of if a reasonable cost disposal option is available, such as deep underground disposal in former German salt mines.

5.2.8 Summary of cost-effective additional sources

Due to the lack of detailed information on many of the sources discussed here, and the necessarily general nature of the analysis, the summary provided in Table 5-1 should be considered no more than indicative. Nevertheless it suggests how much additional mercury may be recoverable from major sources at an equivalent cost of up to $US 50/kg, which is deemed to be close enough to the present mercury price that these sources may be considered as viable additional resources. Table 5-1 then suggests further mercury sources that may be available in the range of $US 50-100/kg, which may also be viable if the mercury price increases to 4-5 times the present price under expected circumstances of tightening supplies around 2011.[83]

Table 5-1 Additional mercury recoverable from major sources (tonnes/year)

"Additional" source	Mercury consumption or releases	Already recovered as metallic mercury	Additional Hg recoverable at < $50/kg Hg	Additional Hg recoverable at $50-100/kg Hg
ASM	650-1000	~0	400-500	100-200
VCM/PVC production	715-825	350	100-150	150-200
Chlor-alkali industry	450-550	100-120	80-100	80-100
Dental amalgam	300-400	50-80	0	0
Other mercury-added products, and "other" applications	1050-1580	150-250	100-200	100-200
By-product (non-ferrous metal mining, natural gas) sources	1100-1400	400-600	50-100	100-150
Coal combustion emissions	~1500	minimal	0	0
Total			**750-1000**	**550-800**

Finally, it should be kept in mind that despite the apparent high cost of some of these sources, many of them will expand in any case. Such a development could result from legislation regulating disposal of hazardous waste (as in the case of dental amalgam waste), and/or because recycling may be available at a lower cost than hazardous waste disposal (as in the case of natural gas cleaning wastes).

6 Observations

The global consumption of mercury has not much decreased during the last five years. This would appear to be due largely to significant increases in mercury consumption in the ASM and VCM/PVC sectors, while the use of mercury in most product applications is declining markedly. Another reason may be that with closer study, certain mercury applications are coming to light that were less in evidence before.

Since the mercury mines in Spain and Algeria ceased production in 2003 and 2004, followed by sharp price increases, and accompanied by increased attention to regulating mercury emissions and wastes, the global supply of mercury has become more diverse. A greater variety and greater quantities of mercury waste are being treated for recovery than

82 Hylander, 2008.

83 While a mercury price increase of 4-5 times sounds extreme, in fact a similar increase occurred between the middle of 2003 and the middle of 2005 (see UNEP, 2006).

previously, more mercury-containing products are being separated from the waste stream and far more by-product mercury is being generated.

Reduction of the quantity of mercury circulating in society was agreed to be a high priority by governments, as reflected in the Governind Council decision 24/3. Parallel reductions in mercury supply and mercury demand lead to a decrease in mercury circulating in society without major disruptions on one side of the balance or the other. Major reductions in mercury demand for paints and batteries were followed by pressure to phase out supplies coming from the Spanish mines. More recent efforts to reduce mercury in electrical applications and measuring devices have been followed by a closer examination of the need for primary mercury from Kyrgyzstan.

This analysis has concluded that the Kyrgyzstan role in global mercury supply (some 10-15%) has been important but is not essential. When this source of supply is phased out, it is likely to increase efforts to reduce consumption. The recent experience in closing both Spanish and Algerian mining operations, which represented a much larger part of the global mercury supply, along with this analysis, have demonstrated that mercury demand can readily be met without primary mercury from Kyrgyzstan.

This analysis has also demonstrated that in the event that mercury demand temporarily exceeds supply after a phase-out of the Kyrgyzstan mercury mine, other non-primary sources are available, including increased recovery from products, additional by-product sources and various stocks or inventories.

Finally, with regard to achieving a market equilibrium between mercury supply and demand, while this analysis concentrates largely on mercury supply options, one must not underestimate the great(er) value of reducing demand, and addressing this by exploring a broad range of international initiatives.

References

ACAP (2005) – *Assessment of Mercury Releases from the Russian Federation*. Arctic Council Action Plan to Eliminate Pollution of the Arctic (ACAP), Russian Federal Service for Environmental, Technological and Atomic Supervision & Danish Environmental Protection Agency. Danish EPA, Copenhagen. See http://www.mst.dk/homepage/default.asp?Sub=http://www.mst.dk/udgiv/Publications/2005/87-7614-539-5/html/helepubl_eng.htm

Bender (2008) – M Bender, Facing Up to the Hazards of Mercury Tooth Fillings – A Report to the US House of Representatives Government Oversight Subcommittee on Domestic Policy to Assess State and Local Regulations to Reduce Dental Mercury Emissions, Mercury Policy Project/Tides Center, July 8, 2008.

Cain (2007) – A Cain, S Disch, C Twaroski, J Reindl and CR Case, "Substance Flow Analysis of Mercury Intentionally Used in Products in the United States," *Journal of Industrial Ecology*, Volume 11, Number 3, copyright Massachusetts Institute of Technology and Yale University.

CEC (2001) – "Preliminary Atmospheric Emissions Inventory of Mercury in Mexico," Final Report, Acosta y Asociados Project CEC-01, prepared for the Commission for Environmental Cooperation (CEC), May 30, 2001

CRC (2006) – *Research Report on Mercury Production and Use in China*, Chemical Registration Center (CRC) of State Environmental Protection Administration of China (SEPA) and Natural Resources Defense Council (NRDC), 2006.

CRC (2007) – *Research Analysis Report on Mercury Use in China 2003 – 2005 - The Measuring Devices Industry of China*, Chemical Registration Center (CRC) of State Environmental Protection Administration of China (SEPA) and Natural Resources Defense Council (NRDC), May 2007.

DG ENV (2008) – *Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society*, COWI AS and Concorde East/West Sprl for the European Commission, draft 11 April 2008, Brussels.

EEB (2006) – *Status report: Mercury cell chlor-alkali plants in Europe*, Concorde East/West Sprl for the European Environmental Bureau, Brussels, October 2006.

EEB (2007) – *Mercury in Dental Use: Environmental Implications for the European Union*, Concorde East/West Sprl for the European Environmental Bureau, Brussels, May 2007.

Euro Chlor (2007) – Chlorine Industry Review 2006-2007, Euro Chlor, Brussels, August 2007. See www.eurochlor.org.

European Commission (2005) – *Communication on the Community Strategy Concerning Mercury*. Brussels, 28.01.2005 COM(2005) 20 final {SEC(2005) 101}.

FDA (2008) – US Food and Drug Administration, Center for Devices and Radiological Health, CDRH Consumer Information, refer to website http://www.fda.gov/cdrh/consumer/amalgams.html

Fialka (2006) – J Fialka, "Backfire: How Mercury Rules Designed for Safety End Up Polluting," *Wall Street Journal*, New York, NY, 20 Apr 2006.

Hylander (2008) – LD Hylander and RB Herbert, Global Emission and Production of Mercury during the Pyrometallurgical Extraction of Nonferrous Sulfide Ores, *Environmental Science and Technology*, in publication, July 2008.

Lawrence (2008) – Personal communication with B Lawrence, Bethlehem Apparatus recycling, Hellertown, PA, USA.

Lennett (2007) – Mercury use in the developing world, presentation by D Lennett, NRDC, Bangkok, November 2007

Masters (2007) – H Masters, "Mercury," *Mining and Minerals Journal*, 2007.

Masters (2008) – H Masters, Lambert Metals, personal communication, March 2008.

Maxson (2006) – *Mercury flows and safe storage of surplus mercury*, Concorde East/West Sprl for the European Commission – Environment Directorate, August 2006. Available at http://ec.europa.eu/environment/chemicals/mercury/pdf/hg_flows_safe_storage.pdf

Netherlands (2008) – Netherlands information provided to the European Commission, DG Environment, in response to a request for quantitative data on mercury, January 2008.

NRDC (2006) – “Submission to UNEP in response to March 2006 request for information on mercury supply, demand, and trade,” Natural Resources Defense Council, Washington, DC, May 2006. http://www.chem.unep.ch/mercury/Trade-information.htm

NRDC (2007) – “Mercury Releases from Industrial Ore Processing,” Natural Resources Defense Council, Washington, DC, June 2007.

NRDC (2008) – Personal communication, David Lennett, NRDC consultant on mercury in China.

Pirrone (2001) – N Pirrone, J Munthe, L Barregård, HC Ehrlich, G Petersen, R Fernandez, JC Hansen, P Grandjean, M Horvat, E Steinnes, R Ahrens, JM Pacyna, A Borowiak, P Boffetta and M Wichmann-Fiebig. *EU Ambient Air Pollution by Mercury (Hg) - Position Paper*. Office for Official Publications of the European Communities, 2001. Available on http://europa.eu.int/comm/environment/air/background.htm#mercury).

Rytuba (2003) – J Rytuba, Mercury from mineral deposits and potential environmental impacts. *Environmental Geology 43*:326-338.

SEPA (2008) – “Strategy Proposal for International Actions to Address Mercury Problem - Mercury Situation in China,” State Environmental Protection Administration of China (SEPA), submitted to UNEP 28 January 2008.

SRIC (2005) – *Chlorine/Sodium Hydroxide*, E Linak, S Schlag and K Yokose, CEH Marketing Research Report, SRI Consulting, Zurich, August 2005.

Telmer (2008) – Personal communications with experts Telmer (School of Earth and Ocean Sciences, University of Victoria, Canada), Veiga and Spiegel (both with the Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Canada) – all involved in the UNIDO/UNDP/GEF Global Mercury Project.

Telmer and Veiga (2008) – K Telmer and M Veiga, “World emissions of mercury from artisanal and small scale gold mining and the knowledge gaps about them,” Final draft, paper prepared for UNEP FT, Rome, 23 May 2008.

Tsinghua (2006) – “Improve the Estimates of Anthropogenic Mercury Emissions in China,” Tsinghua University, October 2006.

UNEP (2002) – *Global Mercury Assessment (GMA).* United Nations Environment Programme (UNEP), Chemicals Programme. Inter-Organisation Programme for the Sound Management of Chemicals. December, 2002.

UNEP (2005) – *Toolkit for identification and quantification of mercury releases* - pilot draft of November 2005. United Nations Environment Programme, Chemicals Branch, Geneva, 2005. Available in English at http://www.chem.unep.ch/mercury/Guidance-training-materials.htm.

UNEP (2006) – *Summary of supply, trade and demand information on mercury.* Analysis requested by UNEP Governing Council decision 23/9 IV, United Nations Environment Programme – Chemicals. Geneva, November 2006.

USEPA (2008) – Mercury-Containing Products Partnership Area Business Plan, US Environmental Protection Agency in coordination with UNEP, Washington DC, 1 July 2008.

USGS (2006) – 2005 Minerals Yearbook: Mercury, US Geological Survey, US Department of the Interior, August 2006.

WCC (2006) – World Chlorine Council Submission [to UNEP] on Global Mercury Partnership for the Reduction of Mercury in the Chlor-alkali Sector, World Chlorine Council, undated, no address, see http://www.worldchlorine.com

Wiki (2008) – Wikipedia, http://en.wikipedia.org/wiki/Backlight, accessed May 2008.

Appendix 1

Regional country groups, roughly as defined by the United Nations

Region	Countries grouped in each region
East and Southeast Asia	Brunei Darussalam, Cambodia, China and Taiwan, China-Hong Kong SAR,[1] China-Macao SAR,[1] Democratic People's Republic of Korea, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Mongolia, Myanmar, Papua New Guinea, Philippines, Republic of Korea, Singapore, Thailand, Viet Nam
South Asia	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka
European Union (EU-25)	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom
Commonwealth of Independent States(CIS) and Other Europe2	Albania, Andorra, Armenia, Azerbaijan, Belarus, Bosnia Herzegovina, Bulgaria, Croatia, Georgia, Gibraltar, Iceland, Kazakhstan, Kyrgyzstan, Norway, Republic of Moldova, Romania, Russian Federation, Serbia and Montenegro, Switzerland, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkmenistan, Ukraine, Uzbekistan
Middle East	Bahrain, Cyprus, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Occupied Palestinian Territories, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen
North Africa	Algeria, Egypt, Libya, Morocco, Tunisia
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, Saint Helena, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
North America	Canada, Greenland, United States of America
Central America and the Caribbean	Anguilla, Antigua, Barbuda, Aruba, Bahamas, Barbados, Belize, British Virgin Islands, Cayman Islands, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Aruba, Nicaragua, Panama, Saint Kitts, Nevis, Anguilla, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, US Virgin Islands
South America	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela
Australia, New Zealand and Oceania	Australia, Christmas Islands, Cocos Islands, Cook Islands, Fiji, French Polynesia, Federated States of Micronesia, Kiribati, Marshall Islands, North Mariana Islands, Nauru, New Caledonia, New Zealand, Niue, Norfolk Islands, Palau, Pitcairn, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna Islands

Notes:

1- *"SAR" is an abbreviation for "Semi-Autonomous Region."*

2- *In order to treat the European Union as a single region, the decision was made to include EEA countries such as Switzerland and Norway and other neighbouring countries in the "CIS and Other Europe" region.*