UNITED NATIONS

EP

UNEP(DTIE)/Hg/OEWG.2/7/Add.1

Distr.: General
14 July 2008

Original: English

United Nations Environment Programme

Ad Hoc Open-ended Working Group on Mercury
Second meeting
Nairobi, Kenya
6–10 October 2008
Item 3 of the provisional agenda*

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

Report on the major mercury-containing products and processes, their substitutes and experience in switching to mercury-free products and processes

Note by the secretariat

Addendum

The annex to the present addendum contains the full text of the report referenced in UNEP(DTIE)/Hg/OEWG.2/7.

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

K0841199 160908

Annex

Global Report on Mercury Use in Products and Processes, Level of Substitution, Technology Change-over, and Available Substitutes

Prepared for:

United Nations Environment Programme

Table of Contents

Executive Summary

At its twenty-fourth session in February 2007, the Governing Council of the United Nations Environment Programme (UNEP) adopted decision 24/3 IV, recognising that further long-term international action was required to reduce the risks posed by mercury to human health and the environment. The Council established an ad hoc open-ended working group (OEWG) of Governments, regional economic integration organizations and stakeholder representatives to review and assess measures to address the global issue of mercury. The first meeting was held from November 12 to 16, 2007 in Bangkok, Thailand and agreed on a program of inter-sessional work to be undertaken by the secretariat in order to further discussions at the Working Group's second meeting to be held from October 6 to 10, 2008.

This report provides information on use and relative quantities of mercury in major mercury containing products and processes, the level of substitution of such products and processes, and experiences with technology changeover and alternatives, including mercury use and substitution at the country level in geographic regions throughout the world.

In an effort to effectively collect mercury data, UNEP circulated a request for information to countries. This request included estimated mercury demand, level of substitution, and experience with non-mercury alternatives for six product categories (measuring and control devices, batteries, dental use, electrical and electronic devices, lamps/lighting, and other uses) and three process categories (vinyl chloride monomer production, chlor-alkali production, and small scale/artisanal gold mining). The level of substitution for products and processes was grouped into three categories as indicated below.

Table ES1: Level of Substitution Categories

Level of Substitution	Description
2	Substitutes available in market and commonly used
1	Substitutes available in market but minimally used
0	No available substitutes in the market

Responses were received from thirty-three countries. Information presented for each of the products and processes includes:

- For mercury containing products and processes: Description of product/process, purpose of mercury in the product/process, quantity of mercury used per unit of product/process, representative manufacturers and processors, retail pricing, and estimated annual demand for mercury at the country level.

- For mercury-free alternatives: Description of product/process, representative manufacturers/processors, retail pricing, advantages and disadvantages of these substitutes as compared to mercury containing products/processes, level of mercury substitution, and experience with alternatives.

In addition, a summary is provided for each product and process, including the key findings for demand and substitution. This section also describes whether transition success to the non-mercury alternative was achieved. Transition success is considered demonstrated if the following two conditions are met:

1) Greater than 50% of respondents indicate that substitutes are available and commonly used, and no negative experiences with the alternatives were reported..
2) Two or more respondents had an annual demand of zero tons of mercury or have implemented a product/process ban that will lead to zero tons of mercury in 2009.

The use of mercury in products/processes and its substitution was then categorized based on transition results from a global perspective. This categorization included the following three groupings:

- Transition Success Demonstrated: This grouping includes products and processes where alternative technologies are available and transition success has been demonstrated in some responding countries. Products and processes in this grouping would be considered most readily substitutable on a global basis.

- Alternatives Available – Challenges Identified: This grouping includes products and processes where alternative technologies are available, but there are economic, technical, social, and/or institutional challenges identified that remain before the alternatives can be fully implemented on a global basis. Products and processes in this grouping would require an intermediate or longer transition time depending upon the magnitude of the challenges identified.

- Site Specific Feasibility: This grouping includes products and processes where economic, technical, social, and/or institutional factors that impact the feasibility of implementing the non-mercury alternatives vary significantly from site to site.

Transition Success Demonstrated

Based upon the responses provided, several products and processes have alternative technologies available, and have demonstrated transition success to these non-mercury alternatives. These products and processes are listed below:

- *Thermometers*: Several alternative technologies such as liquid, dial, and digital were identified. Fifty-three percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Further, five countries reported zero demand for mercury containing thermometers. However, four countries reporting a level of substitution of "1" indicated that the costs were higher for the non-mercury alternatives.

- *Sphygmomanometers:* Two major alternative technologies, aneroid and electronic, were identified. Sixty-nine percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Three countries reported zero demand for mercury containing sphygmomanometers.

- *Thermostats:* Two major alternative technologies, mechanical and electronic, were identified. Eighty-two percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Five countries reported zero demand for mercury containing thermostats.

- *Batteries (non-miniature):* Paste-type zinc-manganese cylinder batteries, paperboard type zinc-manganese cylinder batteries, alkaline zinc-manganese cylinder batteries, and mercuric oxide batteries have commercially available alternatives such as alkaline manganese. Seventy-six percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Six countries reported zero demand for mercury containing non-miniature batteries.

- *Switches and relays*: Numerous alternative technologies were identified for the various types of mercury containing switches and relays. Seventy percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Further, four countries reported zero demand for mercury containing switches and relays.

- *High Intensity Discharge (HID) Automobile Lamps:* Automobile manufacturers use mercury-containing high-intensity discharge (HID) headlamps for use on some high-end luxury or performance automobiles but mercury-free halogen lamps are currently used for the majority of automobiles. Headlamp design and type is determined by the automobile manufacturer and typically cannot be changed by the consumer. HID headlamps cost more than halogen headlamps but they provide certain benefits including improved nighttime visibility, smaller size, longer life, and better efficiency. Automobile manufacturers that want performance benefits similar to HID headlamps now have the option to select from two recently developed mercury-free headlamp technologies: HID headlamps that use zinc iodide as a substitute for mercury, and LED headlamps.

- *Chlor-alkali Production*: Many countries around the world with mercury cell chlor-alkali plants have significantly reduced mercury consumption by closing mercury cell chlor-alkali facilities, reducing their mercury release through improved operations, or have successfully converted from the mercury cell process to the membrane cell process. In addition, there is industry commitment to close or convert mercury chlor-alkali facilities in Europe and India. Although conversion from a mercury cell process to membrane cell process is technically feasible, the conversion costs vary from site to site. Significant factors that affect conversion costs include the need for increased capacity, energy costs, and maintenance costs associated with the age of the mercury cell facility. The benefits reported from completing a conversion of mercury cells to membrane cells include reduced energy consumption, reduced need for maintenance, and elimination of mercury management issues. Approximately 89% of RFI responses for chlor-alkali production were rated at a substitution level of “2”, and there were no negative responses provided for the transition to the non-mercury alternatives. Also, ten countries reported estimated mercury demand of zero.

Alternatives Available – Challenges Identified

The following products and processes have alternative technologies available, but there are economic, technical, social, and/or institutional challenges identified that remain. These challenges must be addressed before the alternatives can be fully implemented on a global basis.

- *Silver oxide, zinc air, alkaline and mercuric oxide miniature batteries*: Mercury free miniature batteries are available as alternatives to these mercury containing products. However, these alternatives have limited availability, and are not available to meet the demands of many miniature battery applications. Despite this, product bans at the state level in the United States for all uses of these products go into effect by 2011, allowing enough time for manufacturers to develop mercury free miniature batteries for most applications.

- Dental amalgam: Mercury-free alternatives to dental amalgam include composite and glass ionomer materials. The alternatives can be matched to the tooth color and are widely used where aesthetics are important. They also have the advantage of not requiring special handling of waste generated during cavity filling. The alternatives cost more, take longer to place, and often have lower resistance to fracture and wear. Three countries (Denmark, Norway and Sweden) determined that the alternatives were adequate replacements for amalgam and, in 2008, imposed bans on dental amalgam. Eight countries, representing fifty percent of the responses received relating to this mercury use, indicated that substitutes are available and commonly used in those countries. Despite the fact that transition success has been demonstrated in some countries, the higher cost of the alternatives is a challenge that is preventing the further transition away from dental amalgam. Four countries commented on the higher cost of alternatives.

- *Liquid Crystal Display (LCD) backlight units*: LCD displays with mercury-free light-emitting diode (LED) backlights are currently available in both laptop computers and televisions. The LED backlight technology has certain performance advantages over the widely-used cold-cathode fluorescent backlights, including longer life, higher contrast ratio, and the potential for decreased power consumption. LED backlight technology is still evolving, has a higher cost, and a successful transition may require the redesign of the products that use LCD displays.

- *Linear and compact fluorescent lamps*: LED lamps are currently available as alternatives to both linear and compact fluorescent lamps but these LED lamps are suitable only for limited types of applications due to lower light output and high cost. LED lamps have the potential to become a feasible alternative to fluorescent lamps due to their long life and energy-efficiency but further technological advancements are required for this potential to be realized.

- *HID lamps (non-automobile)*: Mercury-free alternatives to HID lamps are not currently available, with a few exceptions. However, several mercury-free lamp technologies were identified that are potential alternatives to mercury-containing HID lamps, including: LED lamps, metal halide lamps using zinc iodide as a substitute for mercury, and mercury-free high-pressure sodium lamps.

- *Artisanal and small-scale gold mining:* Mercury-free alternatives to the amalgam gold mining process are available and currently in use. However, a successful transition away from mercury use is likely to require: large-scale training and education efforts; initiatives

to overcome cultural, logistical and economic barriers; and a reduction in the supply of low-priced mercury.

Site Specific Feasibility

The following process was determined to require a site-specific analysis before the economic feasibility of implementing a non-mercury process could be assessed:

- *Vinyl chloride monomer (VCM) production*: VCM manufacturers in nearly every country, with the exception of China and Russia, have converted to the mercury-free ethylene-based process because of lower energy requirements and lower raw material costs. In China, the production of VCM with mercury using the acetylene-based process continues to be economically favorable due to factors including inexpensive coal and limited availability of ethylene for the ethylene-based process. The use of mercury for VCM production is expected to increase as China expands its VCM production with additional facilities using the acetylene-based process.

Limitations on the information provided were considered in this analysis. Many responses contained data gaps for certain categories of products and processes. Further, the estimated mercury demand responses provided often contained data from various years, with some responses providing data as far back as 2001. Therefore, it was not possible to use these responses as a basis to extrapolate aggregate mercury demand estimates on a regional or a global basis.

Introduction

Background

At its twenty-fourth session, in February 2007, the Governing Council of the United Nations Environment Programme (UNEP) adopted decision 24/3 IV, in which the Governing Council concluded that further long-term international action was required to reduce the risks posed by mercury to human health and the environment. By the same decision the Council established an ad hoc open-ended working group (OEWG) of governments, regional economic integration organizations, and stakeholder representatives.

The first meeting of the OEWG to review and assess measures to address the global issue of mercury was held from November 12 to 16, 2007 in Bangkok, Thailand. The participants at this meeting included representatives of ninety-one governments, one regional economic integration organization, seven intergovernmental organizations and twenty-nine civil society organizations. The OEWG agreed on a program of inter-sessional work to be undertaken by the secretariat in order to further discussions at the Working Group's second meeting. The second meeting of the OEWG will be held from October 6 to 10, 2008.

Objective

The objective of this study is to accomplish the following:

- Identify alternative technologies available for mercury containing products and processes
- Report the use and relative quantities of mercury in such products and processes, the level of substitution of such products and processes, and experiences with technology changeover and alternatives.
- Provide comprehensive insight into mercury use, substitution, and experience with substitution at the country level in geographic regions throughout the world.
- Provide the necessary information to the second meeting of OEWG for the discussion of increased efforts and/or additional measures to reduce risks from mercury in products and mercury used in processes.

Methodology

The primary sources of information for this report include:

- Responses to the UNEP Request for Information (RFI)
- Responses to the UNEP Mercury Inventory Toolkit (MIT) project
- Manufacturers of mercury containing products
- Manufacturers of alternative products
- Trade associations
- Government and non-governmental organizations
- Retailers of mercury containing products
- Retailers of alternative products
- Other published sources of information, such as: UNEP Global Mercury Assessment report (2002), UNEP guidance document on Mercury Use and Release (2006), UNEP Mercury Inventory Toolkit (2006), UNEP report on Supply, Trade, and Demand Information on Mercury (2006), The Nordic Council of Ministers report on the "Mercury Substitution Priority Working List".

In addition this report references data from the Northeast Waste Management Officials Association's (NEWMOA) Interstate Mercury Education & Reduction Clearinghouse (IMERC) database on mercury in products. The IMERC database presents information submitted to the IMERC-member states on the amount and purpose of mercury in consumer products. The information in this database was submitted through IMERC by or on behalf of product manufacturers in compliance with laws in the states of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.

In total, UNEP received responses from thirty-three countries, including responses from countries in North America, South America, Europe, Asia, and Africa. The table below lists the information received from each of the thirty-three countries that provided a response.

Table I1: Mercury Use Information Provided by Country

Country	Region	RFI Provided	MIT Provided	Other Documentation Provided
Argentina	South America	✓		
Bangladesh	Asia			One page response
Belarus	Europe	✓		
Brazil	South America	✓		
Cambodia	Asia	✓	✓	
Canada	North America			Cover letter, a three page response, and a five page response
Chile	South America	✓	✓	
China	Asia			Eight page response
Denmark	Europe	✓		
Ecuador	South America	✓		
France	Europe	✓		
Germany	Europe	✓		Mercury report and battery report
Iran	Middle East	✓		
Japan	Asia	✓		
Mauritius	Africa	✓		Mercury report
Mexico	North America			Two page response
Netherlands	Europe	✓		
Norway	Europe	✓		
Pakistan	Middle East			Twelve page mercury inventory, and PowerPoint presentation
Panama	Central America	✓		
Philippines	Asia		✓	PowerPoint presentation
Poland	Europe			Three page response
Qatar	Middle East			Two page response
Romania	Europe	✓		
Slovenia	Europe	✓		
Sweden	Europe	✓		References to additional reports
Switzerland	Europe	✓		
Syria	Middle East	✓		
Trinidad and Tobago	Caribbean			Three page response
United Kingdom	Europe	✓		Six page mercury report
United States	North America	✓		Twenty-one page response
Uruguay	South America			Four page response
Yemen	Middle East			PowerPoint presentation

Report Format

The findings section of this report is organized with a format that is consistent with the structure of the RFI with one chapter for products and one chapter for processes as outlined below.

Chapter A: Findings – Products Containing Mercury

1. Measuring and control devices
2. Batteries
3. Dental use
4. Electrical and electronic devices
5. Lamps/lighting
6. Other products

Chapter B: Findings – Processes Using Mercury

1. Chlor-alkali production
2. Small scale/artisanal gold mining
3. Vinyl chloride monomer production

The format for each of the products and processes in the findings section of this report is as follows:

- ***Product/Process Overview***: This section provides an overview of each mercury containing product/process category studied for this project, which includes the following:
    - Description of the product/process.
    - Purpose of mercury in the product/process.
    - Quantity of mercury used per unit of product/process.
    - Product/process performance requirements related to mercury content.
    - Retail prices, or price ranges, for mercury containing products: Information on pricing is subject to the public availability of data. Sources of pricing information include internet sources, product brochures, and other publicly available information.
    - Manufacturers and Processors: For products, this section identifies representative manufacturers of each product category and the location of their headquarter facilities. For processes, this section identifies representative processors and the location of the processing facilities.
    - Mercury-free alternatives including: product and process descriptions, retail prices or price ranges, manufacturers and processors, as well as the advantages and disadvantages of these substitutes as compared to mercury containing products/processes.
- ***Demand and Use of Mercury:*** This section quantifies and tabulates the estimated mercury demand for each product/process category. The primary data source for this section is the responses to the UNEP Request for Information (RFI) and the Mercury Inventory Toolkit (MIT) results. The mercury use data provided by countries was rounded to the nearest kilogram of mercury. Some countries responded with a range for their estimated demand. In these cases, the range and midpoint values are provided in the tables. Comparative data is presented from other published sources as appropriate.
- ***Level of Mercury Substitution and Experience with Alternatives:*** This section identifies the degree to which substitute products have replaced, or are available to replace, mercury containing products. This section also summarizes the key information provided from the

RFI regarding the positive and negative experiences with switching to mercury-free alternatives. The primary data source for this section is the responses to the RFI.

- ***Summary:*** This section includes the key findings for product/process demand and substitution as well as a summary table with the following columns:

  Alternative Technologies Identified: A positive response is provided if at least one commercially available alternative product and manufacturer was identified for the particular product category, or at least one commercially available alternative process was identified for a particular process category.

  Transition Feasibility: The use of mercury in products/processes and its substitution was then categorized based on transition results from a global perspective. This categorization included the following three groupings:

  - Transition Success Demonstrated: This grouping includes products and processes where alternative technologies are available and transition success has been demonstrated in some responding countries. Products and processes in this grouping would be considered most readily substitutable on a global basis. Transition success is considered demonstrated if the following two conditions are met:

    1) Greater than 50% of RFI respondents provided a level of substitution of "2", and did not provide a negative response for the transition to the alternative. This indicates that substitutes are available and commonly used in the majority of countries that provided mercury demand information.

    2) Two or more RFI respondents that either had an annual demand of zero tons of mercury, or have implemented a product/process ban that will lead to a mercury demand of zero tons in 2009.

  - Alternatives Available – Challenges Identified: This grouping includes products and processes where alternative technologies are available, but there are economic, technical, social, and/or institutional challenges identified that remain before the alternatives can be fully implemented on a global basis. Products and processes in this grouping would require an intermediate or longer transition time depending upon the magnitude of the challenges identified.

  - Site Specific Feasibility: This grouping includes products and processes where economic, technical, social, and/or institutional factors that impact the feasibility of implementing the non-mercury alternatives vary significantly from site to site.

A. Findings: Products Using Mercury

A.1 Measuring and Control Devices

A.1.a Thermometers

Thermometers are devices that are used to measure temperature. There are many types of thermometers that may contain mercury including:

- Refrigerator, dishwasher, oven, candy, and meat thermometers
- Thermometers used to measure indoor and outdoor temperature
- Laboratory thermometers
- Fever thermometers
- Basal thermometers used to measure the basal metabolic temperature
- Thermometers used in industrial applications

This section covers mercury thermometers and three non-mercury alternatives including: liquid thermometer, dial thermometer, and digital thermometer.

Mercury Thermometer
Product Overview
Mercury thermometers commonly consist of mercury inside a thin glass tube that rises and falls with corresponding changes in temperature. The Nordic Council of Ministers report states that the price of non-mercury alternatives are higher than the price of medical thermometers, and the price of non-mercury alternatives are approximately the same price as other glass thermometers used for laboratory, educational, and other purposes. (Maag, 2007)

The mercury content of thermometers reported as a range to IMERC by manufacturers for mercury thermometers was in one of the following two ranges: 100 to 1,000 milligrams per device or greater than 1,000 milligrams per device. Some manufacturers reported exact amounts to IMERC, and these amounts varied from 0.5 to 54 grams per thermometer. (NEWMOA, 2008) The UNEP Toolkit provided examples of mercury content for medical thermometers (0.5 – 1.5 grams in the European Union), household thermometers (0.5 – 2.25 grams in the European Union), and laboratory thermometers (1.4 – 48 grams in Russia). (UNEP, 2005)

The mercury content reported by digital thermometer manufacturers to IMERC was either 0 to 5 milligrams per device, or 5 to 10 milligrams per device. However, the mercury content reported was for the mercury contained in the miniature button battery that was used inside the digital thermometer.

Representative Manufacturers and Products
The following are representative manufacturers of mercury thermometers:

Table Al.1: Representative Manufacturers of Mercury Thermometers

Manufacturer	Location	Website	Model	Pricing (USD)
Caretek Medical	Wenzhou, China	www.cnmeditek.com	CRW Series	Not readily available.
Changzhou Ruiming Thermometer Factory of China	Changzhou, China	www.china-lanxi.com	LX Series	Not readily available.
Medline Industries, Inc.	Mundelein, Illinois, USA	www.medline.com	Oral Glass	$4.90, (Nextag, and Vitality)
SoFine Group Co. Ltd.	Ningbo, China	www.sofine-medical.com	DT-TO1-02	$2.00, (Supplierlist)
Sper Scientific Ltd.	Scottsdale, Arizona, USA	www.sperscientific.com	736060	$1.50, (Technika)
Taylor Precision Products	Oak Brook, Illinois, USA	www.taylorusa.com	Dishwasher Thermometer	$17.03, (Nextag)
Vee Gee Scientific	Kirkland, Washington, USA	www.veegee.com	80102	$2.70, (Novatech)

Alternative 1: Liquid Thermometer

Product Overview

Liquid thermometers consist of a cylindrical tube containing a liquid that expands and contracts with increasing and decreasing temperature. Liquid thermometers use common organic liquids such as alcohol, kerosene, and citrus extract based solvents that are dyed blue, red or green. In addition, "galinstan" type liquid thermometers consist of silvery liquid in a glass tube. The liquid is a mixture of gallium, indium, and tin that expands with temperature to provide a reading.

"Galinstan" type liquid thermometers are comparable in function to mercury, because it consists of a glass tube containing a silvery liquid that rises in a column with increasing temperature. However, the toxicity of the gallium-indium-tin mixture is not well understood. The liquid thermometer is the most common replacement for the mercury thermometer.

Representative Manufacturers and Products

The following are representative manufacturers of liquid thermometers:

Table Al.2: Representative Manufacturers of Liquid Thermometers

Manufacturer	Location	Website	Model	Pricing (USD)
Changzou Ruiming Thermometer Factory of China	Changzhou, China	www.china-lanxi.com	LX Series	Not readily available.
RG Medical Diagnostics	Southfield, Michigan, USA	www.rgmd.com	Geratherm Series, Rectal Mercury Free	$5.38, (Amazon)
Sper Scientific Ltd.	Scottsdale, Arizona, USA	www.sperscientific.com	735384,	$1.50, (Technika)
Vee Gee Scientific	Kirkland, Washington, USA	www.veegee.com	80501, Spirit filled,	$2.30, (Novatech)

Alternative 2: Dial Thermometer

Product Overview

Dial thermometers typically use a bimetal coil that consists of two dissimilar metals bonded together. The metals have different coefficients of expansion, and rotate the coil when exposed to a temperature change. Dial thermometers can be used for applications in industrial settings, and operate in wide temperature ranges. For example, the Ashcroft CI model can be used in temperatures ranging from -50 degrees C to 500 degrees C.

Representative Manufacturers and Products

The following are representative manufacturers of dial thermometers:

Table Al.3: Representative Manufacturers of Dial Thermometers

Manufacturer	Location	Website	Model	Pricing (USD)
Ashcroft Inc.	Stratford, Connecticut, USA	www.ashcroft.com	CI, EI, EL, and FT Series	Not readily available.
Comark Ltd.	Hertfordshire, United Kingdom	www.comarkltd.com	CD400 and MT200 Series, 1inch pocket	$5.00, (QAsupplies)
Taylor Precision Products	Oak Brook, Illinois, USA	www.taylorusa.com	8212	$19.00, (Miller)
Vee Gee Scientific	Kirkland, Washington, USA	www.veegee.com	81070	$4.90, (Novatech)

Alternative 3: Digital Thermometer

Product Overview

Digital thermometers use temperature sensors such as thermistors or thermocouples. Thermistor operation is based on the principle that electrical resistance of the thermistor material changes as its temperature changes. Thermocouples are comprised of two wire strips of dissimilar metals. The metal wires are joined at one end, and the voltage is measured at the other end. A circuit measures these resistance or voltage changes and converts them into a temperature reading. The digital thermometer provides several advantages such as shorter time to obtain a temperature reading, and the digital thermometer can beep to signal when the peak temperature is reached. A disadvantage is that the digital thermometer often uses miniature button batteries that may contain mercury.

Representative Manufacturers and Products

The following are representative manufacturers of digital thermometers.

Table Al.4: Representative Manufacturers of Digital Thermometers

Manufacturer	Location	Website	Model	Pricing (USD)
American Diagnostic Corp.	Hauppauge, New York, USA	www.adctoday.com	ADTEMP IV	$5.62, (Nextag)
Becton Dickinson and Company	Franklin Lakes, New Jersey, USA	www.bd.com	52 Series, Rapid	$8.59, (Nextag)
Omron Healthcare Inc.	Kyoto, Japan	www.omronhealthcare.com	MC Series, 20 Second Flexible,	$10.43, (Vitality)
Taylor Precision Products	Oak Brook, Illinois, USA	www.taylorusa.com	1400 Series, Instant Read	$11.99, (Nextag)

A.1.b Sphygmomanometers

Sphygmomanometers measure systolic and diastolic blood pressure. Blood pressure measurement devices typically use an air filled cuff to temporarily block blood flow through the artery, and then apply a particular technique to obtain blood pressure data while the cuff deflates. The two most common techniques for pressure measurement are the auscultatory and oscillometric techniques. The auscultatory method involves the listening for characteristic blood flow sounds, and the oscillometric technique uses a pressure transducer. Sphygmomanometers are available in different styles such as wall unit, mobile unit, pocket unit, and desk model.

This section covers the mercury sphygmomanometer and the two non-mercury alternatives: the aneroid and electronic sphygmomanometer.

Mercury Sphygmomanometers

Product Overview

The mercury sphygmomanometer uses the auscultatory method to measure blood flow. The clinician determines systolic and diastolic blood pressures by listening for Korotkoff sounds, or sounds that characterize different stages of blood flow during cuff deflation. At certain points in the sound pattern, the clinician reads the pressure level. The mercury sphygmomanometer uses a column of mercury (manometer) to provide the pressure readout. The precise expansion and contraction of mercury in response to pressure are very suitable for pressure indication. The manometer typically reads from 0 to 300 millimeters of mercury.

When manufacturers reported the mercury content of sphygmomanometers to IMERC as a range, the amount was greater than 1,000 milligrams per device. Some manufacturers reported exact amounts to IMERC, and these amounts varied from 50 to 140 grams per sphygmomanometer. (NEWMOA, 2008) The UNEP Toolkit provided examples from Denmark and the European Union where sphygmomanometers contained 70 and 85 grams of mercury per sphygmomanometer respectively. (UNEP, 2005)

Representative Manufacturers and Products

The following are representative manufacturers of mercury sphygmomanometers:

Table Al.5: Representative Manufacturers of Mercury Sphygmomanometers

Manufacturer	Location	Website	Model	Pricing (USD)
American Diagnostic Corp.	Hauppauge, New York, USA	www.adctoday.com	972	$281, (Nextag)
Caretek Medical	Wenzhou, China	www.cnmeditek.com	MT-3 Series	Not readily available.
GF Health Products Inc.	Atlanta, Georgia, USA	www.grahamfield.com	Labtron Series, 03-225	$59.95, (Promed)
MDF Instruments	Agoura Hills, California, USA	www.mdfeurope.com	MDF 800	$67.07, (Healthy)
Rudolf Riester GmbH	Jungingen, Germany	www.riester.de	R-12-605	$113.84, (Healthy)
W. A. Baum	Copiague, New York, USA	www.wabaum.com	Numerous models.	Not readily available.
Wenzhou Wuzhou Group Co. Ltd.	Zhejiang, China	wuzhou.en.alibaba.com	Standard Desk Type	Not readily available.

Alternative 1: Aneroid Sphygmomanometers

Product Overview

Aneroid sphygmomanometers also use the auscultatory method to measure blood flow. An aneroid gauge consists of a dial that reads in units of 0 to 300 millimeters of mercury and a thin brass corrugated bellows that is responsive to changes in pressure. To assess the level of accuracy of aneroid sphygmomanometers, the Mayo Clinic in the United States conducted an assessment of 283 aneroid sphygmomanometers. The study found that virtually 100% of the values from the aneroid sphygmomanometers were within the 4 millimeters of mercury range recommended by the Association for the Advancement of Medical Instrumentation. The study concluded that aneroid sphygmomanometers provide accurate pressure measurements when a proper maintenance protocol is followed. (Canzanello, 2001) An example of a maintenance protocol from the Welch Allyn aneroid sphygmomanometer service manual is: during normal operation if the pointer is inside the oval/square then the instrument is likely in calibration. However, if the pointer is outside the oval/square with zero pressure applied, then the device should be recalibrated. Further, the device should be recalibrated on an annual basis even if the pointer is inside the oval/square. (Welch Allyn)

Representative Manufacturers and Products

The following are representative manufacturers of aneroid sphygmomanometers:

Table Al.6: Representative Manufacturers of Aneroid Sphygmomanometers

Manufacturer	Location	Website	Model	Pricing (USD)
A&D Medical	San Jose, California, USA	www.andmedical.com	UA-200	$39.95, (Promed)
American Diagnostic Corp.	Hauppauge, New York, USA	www.adctoday.com	Diagnostix 703	$66, (Nextag)
BV Medical Standard	Barrington, Illinois	www.bvmedical.com	BV-115M	$20.93, (Healthy)
GF Health Products Inc.	Atlanta, Georgia, USA	www.grahamfield.com	Labtron Series, 03-202S	$39.95, (Promed)
MDF Instruments	Agoura Hills, California, USA	www.mdfeurope.com	MDF808B,	$41.08, (Healthy)
Omron Healthcare Inc.	Kyoto, Japan	www.omronhealthcare.com	115M,	$22.04, (Healthy)
Trimline Medical Products Corp.	Raritan, New Jersey, USA	www.trimlinemed.com	Numerous Models	Not readily available.
W. A. Baum	Copiague, New York, USA	www.wabaum.com	Pocket Series	$49.98, (AllHeart)
Welch Allyn Tycos	Skaneateles, New York, USA	www.welchallyn.com	Pocket Aneroid	$117.98, (AllHeart)

Alternative 2: Electronic Sphygmomanometers

Product Overview

The electronic sphygmomanometer uses the oscillometric technique. The electronic sphygmomanometer utilizes a pressure sensor and a microprocessor instead of the human ear and simple gauge. During cuff deflation, a pressure sensor transmits an electric signal to a microprocessor that translates the signal to systolic and diastolic blood pressure.

In addition to systolic and diastolic blood pressure, this type of device can display more comprehensive information about blood pressure patterns, which can be useful for diagnostics.

Representative Manufacturers and Products
The following are representative manufacturers of electronic sphygmomanometers:

Table Al.7: Representative Manufacturers of Electronic Sphygmomanometers

Manufacturer	Location	Website	Model	Pricing (USD)
A&D Medical	San Jose, California, USA	www.andmedical.com	UA-766-PV	$89.95, (Promed)
Homedics	Commerce Township, Michigan, USA	www.homedics.com	BPA-300	$99.95, (Promed)
Omron Healthcare Inc.	Kyoto, Japan	www.omronhealthcare.com	HEM-711DLX	$99.95, (Promed)

A.1.c Thermostats

Thermostats are devices that are most often used to automatically measure room temperature and control equipment to maintain a desired room temperature. Thermostats control room temperature by starting and stopping the heating and cooling equipment when the room temperature falls outside a specified temperature range or differential. For example, if the thermostat turns the heating equipment on at 70 degrees F and turns the heating equipment off at 74 degrees F, then the differential is 4 degrees F. Anticipator control is an advanced function used by thermostats to turn off the heating equipment before the room temperature actually reaches the high temperature shut off point.

The two major components of a thermostat are the temperature sensor and the temperature switch. For example, when the room temperature falls below a certain temperature, the thermostat sends an electrical signal to turn the heating equipment on. This section includes thermostats with a mercury switch, and the two non-mercury alternatives: thermostats with a mechanical switch, and electronic thermostats. There are numerous considerations that influence the ultimate selection of a thermostat, such as cost, product quality, product reliability, product accuracy, on-time delivery, customer service, technical support, ease of use, electrical rating, number of heating/cooling stages, environmental concerns, and energy efficiency.

Energy efficiency is often a very important thermostat attribute for thermostat selection. As a thermostat turns heating/cooling equipment on and off, the room temperature will vary above and below the desired temperature. The range of the room temperature variations is called “temperature swing”. The U.S. EPA requires a “temperature swing” of 4 degrees F or less to achieve an Energy Star rating for electronic programmable thermostats. However, temperature swing data is not commonly available from the various thermostat manufacturers. Consequently, for this report a thermostat is considered energy efficient if it offers both a differential of 4 degrees F or less and has additional thermostat control functions such as anticipator control. A thermostat with these characteristics has a reasonable likelihood of maintaining a temperature swing of less than 4 degrees F if properly installed and calibrated. Thermostat models with a differential of 4 degrees F or less and anticipator control are available for mercury thermostats, thermostats with a mechanical switch, and electronic thermostats.

Mercury Thermostats

Product Overview

Thermostats with mercury switches typically use a bimetal material, such as brass and steel, to sense temperature changes. Bimetal temperature sensors change shape in response to temperature. The bimetal sensor is usually coil shaped to activate the mercury switch based on angular rotation. Mercury switches consist of a glass bulb filled with an inert gas and a small pool of mercury. The glass bulb is fastened to the moveable end of the bimetal, so that it can rotate based on the movement of the bimetal. When the bimetal rolls the glass bulb to a new position, the pool of mercury connects or disconnects the electric flow to control heating and cooling equipment. The Nordic Council of Ministers report states that the price of non-mercury alternatives is approximately the same price as mercury containing thermostats. (Maag, 2007)

The mercury content reported to IMERC as a range by manufacturers for mercury thermostats was in one of the following two ranges: 100 to 1,000 milligrams per device or greater than 1,000 milligrams per device. Some manufacturers reported exact amounts to IMERC, and these amounts varied from 1 to 3 grams per thermostat. (NEWMOA, 2008)

Representative Manufacturers and Products

The following are representative manufacturers of mercury thermostats:

Table Al.8: Representative Manufacturers of Mercury Thermostats

Manufacturer	Location	Website	Model	Pricing (USD)
Honeywell	Minneapolis, Minnesota, USA	www.honeywell.com	Numerous models.	Not readily available.
Invensys Controls (Robertshaw)	Carol Stream, Illinois, USA	www.robertshaw stats.com	988-1	$20.50, (Electric)
Lux	Mt. Laurel, New Jersey, USA	www.luxproducts.com	Numerous models.	Not readily available.
White-Rodgers	St. Louis, Missouri, USA	www.white-rodgers .com	1F56-301	$24.99, (AZ)

Alternative 1: Thermostats with Mechanical Switches

Product Overview

Thermostats with mechanical switches often use a bimetal material to sense temperature changes. The bimetal sensor activates a mechanical snap switch that connects or disconnects the electric flow to control heating and/or cooling equipment. Thermostats with mechanical or mercury switches are often similar in specifications other than the switching mechanism.

Representative Manufacturers and Products

The following are representative manufacturers of thermostats with mechanical switches:

Table Al.9: Representative Manufacturers of Thermostats with Mechanical Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Honeywell	Minneapolis, Minnesota, USA	www.honeywell.com	Numerous models	Not readily available.
Invensys Controls (Robertshaw)	Carol Stream, Illinois, USA	www.robertshaw stats.com	200-401	$23.00, (Electric)
Lux	Mt. Laurel, New Jersey, USA	www.luxproducts.com	Numerous models	Not readily available.
White-Rodgers	St. Louis, Missouri, USA	www.white-rodgers .com	1E50N-301	$32.75, (Protherm)
			1C20-102	$11.79, (AZ)

Alternative 2: Electronic Thermostats

Product Overview

Electronic thermostats often use thermistors or other integrated circuit sensors to sense temperature changes. Thermistors provide a low-cost temperature measurement solution as well as provide large signal outputs and fast response to temperature changes.

Electronic thermostats can either be programmable or non-programmable. Both types often provide a light-emitting diode (LED) display for enhanced readability, and can be set to maintain a single temperature set point. However, the programmable thermostat enables the heating/cooling program to be altered by the user as desired. For example, the programmable thermostat can be programmed by the user to automatically set back the temperature at predetermined times and days to reduce energy consumption.

Representative Manufacturers and Products

The following are representative manufacturers of programmable electronic thermostats:

Table Al.10: Representative Manufacturers of Programmable Electronic Thermostats

Manufacturer	Location	Website	Model	Pricing (USD)
Honeywell	Minneapolis, Minnesota, USA	www.honeywell.com	LineVoltPRO 8000	$49.00, (Nextag)
Invensys Controls (Robertshaw)	Carol Stream, Illinois, USA	www.robertshaw stats.com	Model 9701	$139.95 (Air)
Lux	Mt. Laurel, New Jersey, USA	www.luxproducts.com	PSP 511	$33.00, (Thermostat)
White-Rodgers	St. Louis, Missouri, USA	www.white-rodgers .com	1F78H-151,	$33.95, (Protherm)

The following are representative manufacturers of non-programmable electronic thermostats:

Table Al.11: Representative Manufacturers of Non-programmable Electronic Thermostats

Manufacturer	Location	Website	Model	Pricing (USD)
Honeywell	Minneapolis, Minnesota, USA	www.honeywell.com	TH5220D	$49.95, (Nextag)
Invensys Controls (Robertshaw)	Carol Stream, Illinois, USA	www.robertshaw stats.com	9400 Model	$44.95 (Air)
Lux	Mt. Laurel, New Jersey, USA	www.luxproducts.com	PSD100,	$38.50, (Thermostat)
White-Rodgers	St. Louis, Missouri, USA	www.white-rodgers .com	1F86-241,	$38.95, (Protherm)

A.1.d Other Measuring and Control Devices

There are numerous other types of measuring and control devices that contain mercury including: barometers, manometers, psychrometers, hygrometers, hydrometers, flow meters, flame sensors, and pyrometers. Responses from four countries were received with estimated mercury for these other measuring and control devices. These responses are outlined in the following Demand and Use of Mercury section.

Demand and Use of Mercury

Thirteen countries reported their estimated mercury demand for measuring and control devices in the following sub-categories: thermometers, sphygmomanometers, thermostats, and other. Therefore, the mercury demand data is presented in four separate tables, one for each of these subcategories.

However, two countries reported their estimated mercury demand for measuring and control devices as one value with no breakdown by product type. Canada reported an estimated demand of 0.35 metric tons of mercury in 2003, and the United Kingdom reported an estimated demand of 2.37 metric tons of mercury in 2005.

Thermometers

The following table contains the mercury demand data for thermometers provided by countries in their responses to the UNEP Request for Information (RFI) or from other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT). Thirteen countries provided estimated mercury demand information for thermometers. The range of responses was 0 to 179.3 metric tons of mercury per year, with three countries reporting no mercury demand for thermometers. The estimated mercury demand responses provided data from various years, including information as far back as 2004.

Table A1.12: Mercury Demand for Thermometers (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
China	Other	200.9 (2005)* 179.3 (2004)
Russia	Other	25.579 (2002)**
Chile	RFI, MIT	1.433 (0.743 – 2.123)
Romania	RFI	1.588 (2006, 2007)
Belarus	RFI	0.73
Japan	RFI	0.59 (2005)
United States	RFI	0.5 (2004)***
Philippines	MIT	0.132 (0.066 – 0.198)
Argentina	RFI	0.05
Cambodia	MIT	0.006 (0.003 – 0.009)
Sweden	RFI	0.001
France	RFI	0
Netherlands	RFI	0
Norway	RFI	0

* Information obtained from Natural Resources Defense Council, Research Analysis Report on Mercury Use in China 2003 – 2005 – The Measuring Devices Industry of China, May 2007.

** Information obtained from an ACAP report titled: "Assessment of Mercury Releases from the Russian Federation". (ACAP, 2004)

*** Lab and fever thermometers only

The reported levels of mercury demand per capita fall within the following three distinct groups:

1. Russia (0.180) and China (0.152) reported the highest level of mercury demand per capita in grams of mercury per person per year. This may be attributed to the manufacture of mercury containing thermometers in Russia and China. In 2005, 200.9 tons of mercury was consumed by medical thermometer manufacturers in China. Of this amount, 40.3% was exported. OJSC Termopribor is the only manufacturer of mercury thermometers in Russia, and manufactured thermometers containing 25.579 metric tons of mercury in 2002.
2. Three countries (Chile, Romania, and Belarus) reported levels of annual mercury demand per capita between 0.074 to 0.086 grams.
3. The other nine countries each reported annual mercury demand per capita of equal to or less than 0.005 grams.

The Mercury Inventory Toolkit (MIT) recommends collecting actual data on mercury levels in the particular thermometers. However, if this information is not available, then the following default mercury input factors are recommended to be used for various types of thermometers:

Table A1.13: Default Input Factors for Thermometers

Thermometer Type	Mercury Content (grams mercury/item)
Medical	0.5 – 1.5
Ambient air temperature	2 - 5
Industrial and special application	5 - 200
Miscellaneous glass thermometers	1 - 40

These input factors are then multiplied by the total quantity of mercury containing thermometers for each thermometer type. The three countries used the Mercury Inventory Toolkit process in the following manner:

Table A1.14: Mercury Inventory Toolkit Parameters Used for Mercury in Thermometer Demand

Country	Medical Thermometers		Environmental Thermometers	
	Quantity	Factor Used (grams mercury per item)	Quantity	Factor Used (grams mercury per item)
Cambodia	6,141	0.5 – 1.5	Not included	Not included
Chile	1,058,013	0.5 – 1.5	107,138	2 - 5
Philippines	131,765	0.5 – 1.5	Not included	Not included

Sphygmomanometers

The following table contains the mercury demand data for sphygmomanometers provided by countries in their responses to the UNEP Request for Information (RFI) or from other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT). Eight countries provided estimated mercury demand information for sphygmomanometers. The range of responses was 0 to 94.9 metric tons of mercury per year, with three countries reporting no mercury demand for sphygmomanometers. The estimated mercury demand responses provided data from various years, including information as far back as 2004.

Table A1.15: Mercury Demand for Sphygmomanometers (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
China	Other	94.9 (2004)
Japan	RFI	1.89 (2005)
United States	RFI	1 (2004)
Argentina	RFI	0.006
Sweden	RFI	< 0.001
Belarus	RFI	0
Netherlands	RFI	0
Norway	RFI	0

The reported levels of mercury demand per capita for sphygmomanometers fall within the following two distinct groups:

1. China reported the highest level of annual mercury demand per capita of 0.72 grams of mercury demand per person per year. This may be attributed to the manufacture of mercury containing sphygmomanometers in China.
2. The other seven countries reported annual mercury demand per capita equal to or less than 0.015 grams.

The Mercury Inventory Toolkit does not provide any default input factors for sphygmomanometers. However, the toolkit does provide two examples of sphygmomanometers, one with 70 grams of mercury per item, and one with 85 grams of mercury per item. There was no estimated mercury demand provided using the Mercury Inventory Toolkit as the source of data.

Thermostats

The following table contains the mercury demand data for thermostats provided by countries in their responses to the UNEP Request for Information (RFI) or from other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT). Eight countries provided estimated mercury demand information for thermostats. The range of responses was 0 to 65.5 tons of mercury per year, with five countries reporting no mercury demand for thermostats.

Table A1.16: Mercury Demand for Thermostats (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
Philippines	MIT	65.5
United States	RFI	12.8
Canada	Other	0.88
Denmark	RFI	0
Japan	RFI	0
Netherlands	RFI	0
Norway	RFI	0
Sweden	RFI	0

The reported levels of mercury demand per capita fall within the following three distinct groups:

1. The Philippines reported an extremely high level of annual mercury demand per capita of 0.738 grams. This could be attributed to the high number of mercury thermostats identified in the inventory process. The inventory may reflect total installed thermostats, rather than annual demand.
2. The United States reported the next highest level of annual mercury demand per capita of 0.042 grams of mercury per person per year. This could be attributed to the manufacture of mercury thermostats in the U.S, where at least four manufacturers were identified.
3. The other six countries reported annual mercury demand per capita equal to or less than 0.027 grams.

The Mercury Inventory Toolkit includes thermostats in the same section as electrical switches and relays. The Mercury Inventory Toolkit recommends collecting actual data on mercury levels in the

particular thermostats. However, if this information is not available then the following default mercury input factor range can be used to estimate use for all electrical switches and relays:

Input factor: 0.02 – 0.25 grams mercury per inhabitant per year

Since thermostats are only one type of product included in this input factor range, it may not be an appropriate input factor range to estimate mercury use in thermostats. The Mercury Inventory Toolkit does provide an example of a tilt switch used in a thermostat that contains 3 grams of mercury per switch. The toolkit further states that thermostats frequently contain 2 – 6 tilt switches.

The Philippines used the MIT to estimate their mercury demand for thermostats. The Philippines identified a quantity of 10,920,000 thermostats. Using the assumptions in the MIT, this quantity was multiplied by 6 grams of mercury per unit, resulting in a total demand of 65.5 tons of mercury.

Others

The following table provides a summary of the demand data provided in the RFI and MIT responses for other types of measuring and control devices.

Table Al.17: Other Types of Measuring and Control Devices

Country	Source of Data	Product Description	Estimated Mercury Demand/Quantity Used (metric tons/year)
Denmark	RFI	Other measuring and control devices	0
Norway	RFI	Other measuring and control devices	0
Philippines	MIT	Barometers	0.052 – 0.104
United States	RFI	Barometers and manometers	1.3

The Mercury Inventory Toolkit (MIT) does not provide any default input factors for barometers. However, the toolkit does provide two examples of barometers, one with 40 to 1,000 grams of mercury per item, and one with 590 to 2,200 grams of mercury per item.

The Philippines identified a quantity of 173 barometers, and used a factor of 300 to 600 grams of mercury per unit. This resulted in an estimated mercury demand range of 0.052 to 0.104 metric tons of mercury.

All Measuring and Control Devices

A report prepared by the Northeast Waste Management Officials' Association (NEWMOA) provides a breakdown of various measuring and control devices sold in the United States in 2004. This information provides an understanding of the relative quantities of mercury used for the various products within the United States only. The results are provided in the following table. (NEWMOA, 2008)

Table A1.18: Mercury Content of Products Sold in the United States (2004)

Product Category	Mercury Sold in U.S. (Metric Tons)	Percentage of all Measuring and Control Devices
Thermometers	2.06	11.5%
Sphygmomanometers	1.01	5.6%
Thermostats	13.61	75.9%
Manometers	1.16	6.5%
Barometers	0.11	0.6%
Psychrometers and other measuring equipment	0.001	< 0.1%
Total	17.94	100.0%

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries on their experiences with the technology changeover or alternatives associated with substituting mercury measuring and control devices with available alternatives. The information contained in the tables is derived from the responses to the UNEP Request for Information (RFI), Mercury Inventory Toolkit (MIT), or other source of information. In some cases, the tables contain an abbreviated or revised version of the response included in the RFI.

Table A1.19: Countries Responding with a Level of Substitution of "2"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" Substitutes Available and Commonly Used
Belarus	RFI	*Sphygmomanometers:* There are no mercury-containing sphygmomanometers on national market.
Brazil	RFI	*Thermometers and Sphygmomanometers:* Substitutes are available. Since 2006, promoted voluntary substitution of thermometers and sphygmomanometers in São Paulo State. At present, 94 clinics and hospitals have already substituted thermometers and sphygmomanometers.
Denmark	RFI	*All Devices:* Denmark has not experienced any problems in relation to the introduction of the mercury product ban. The first version of the Order was introduced in 1998.
France	RFI	*Thermometers:* Thermometer ban in place since 1998.
Germany	RFI	*All Devices:* A rating of 1 – 2 was provided. Positive experience for thermometers, sphygmomanometers, and thermostats.
Iran	RFI	*All Devices:* A rating of 1 – 2 was provided. Ministry of Health is considering the possibility of minimizing or eliminating material in products that contain mercury or mercury compounds.
Japan	RFI	*Thermometers and Sphygmomanometers:* Thermometers and sphygmomanometers with mercury are still manufactured, but electronic types are now the main products. *Thermostats:* No experience data provided for this rating.
Netherlands	RFI	*All Devices:* Positive experience, and since 1998 it is prohibited to bring mercury containing products onto the market.

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" Substitutes Available and Commonly Used
Norway	RFI	*Thermometers and Sphygmomanometers:* Norway has a general ban on the use of mercury in products since January 2008. No negative experiences with alternatives for thermometers and sphygmomanometers. *Thermostats:* No experience data provided for this rating.
Slovenia	RFI	*Sphygmomanometers and Thermostats:* Sphygmomanometers and thermostats containing mercury are not produced in Slovenia.
Sweden	RFI	*Thermometers:* Positive experience with technology change-over to digital and other alternatives. Covered by a national ban since 1992 (medical thermometers) and 1993 (other thermometers). Dispensation from the national ban for some special measurements according to standardized methods, especially oil industry. Costs have not been a major obstacle for substitution. Mercury-containing fever thermometers may not be placed on the EU market according to a decision in 2007 (Dir. 76/769/EC). *Sphygmomanometers:* Positive experience with technology change-over. Covered by a national ban since 1993. For sphygmomanometers the substitution is complete. For strain gauges plethysmographic devices the main use will be phased out in two years following a decision 2007 (dispensation rejected for these applications). Some minor applications in research and for special measurements of blood flow were granted dispensation to allow time for evaluation of available alternatives. *Thermostats:* Positive experience with technology change-over. Covered by the national ban since 1993. No applications for exemption from the ban, and no indication of any economic problems when implementing it.
Switzerland	RFI	*Thermometers (Level 2) and Sphygmomanometers (Level 1 – 2)*: Mercury containing products are banned, and are only permitted in monitoring and control instruments and medical devices used in laboratories.

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" Substitutes Available and Commonly Used
United States	RFI	*Thermometers:* Positive experience. Non-mercury alternative thermometers are reliable and reasonable in cost. Some states have banned sales of mercury thermometers. Most retail outlets now sell non-mercury alternatives, even in states that have not banned mercury thermometers. Most hospitals are switching to non-mercury thermometers, spurred by the Hospitals for a Healthy Environment (H2E) Program, a voluntary partnership initiative between USEPA and non-profit health care organizations. *Sphygmomanometers:* Positive experience. Non-mercury alternative blood pressure cuffs are reliable and reasonable in cost. Most hospitals are switching to non-mercury blood pressure cuffs, spurred by the Hospitals for a Healthy Environment (H2E) Program. *Thermostats:* Positive experience. Mercury thermostats are still widely sold, but electronic programmable and non-programmable thermostats are cost-effective and more energy-efficient alternatives. The domestic market for mercury thermostats continues to decrease. A recent study reports that in 2002 non-mercury alternatives accounted for 84 percent of the thermostat market in North America (Abt Associates: Market Study: Mercury-Containing Thermostats, November 2007). The sale of mercury thermostats is already banned in some states, and other states are proposing legislation to phase out sales of mercury thermostats. States, USEPA and non-governmental organizations are actively encouraging the use of non-mercury digital alternatives for both new and replacement thermostats. *Other - Barometers*: Mercury barometers typically cost upwards of $500. Current non-mercury alternatives include aneroid, digital, and non-mercury liquid-filled barometers. These alternative products are just as accurate as the mercury barometer and are generally less expensive.

Table A1.20: Countries Responding with a Level of Substitution of "1"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "1" Substitutes Available and Minimally Used
Argentina	RFI	*Thermometers and Sphygmomanometers:* Partnership USEPA and NGO Healthcare without Harm in Buenos Aires, La Rioja, Córdoba, Río Negro and Tierra del Fuego hospitals.
Belarus	RFI	*Thermometers:* High price of electronic thermometers.
Chile	RFI	*All Devices:* Negative experience. The alternatives have not been diffused, and the alternatives without mercury cost more.
Ecuador	RFI	*Thermometers:* It is most common to find digital strip which is used especially for children. The cost is higher ($7 US) than the conventional thermometers ($1 US). Level 1 reported for clinical thermometers, and Level 0 reported for industrial thermometers.

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "1" Substitutes Available and Minimally Used
Mauritius	RFI	*Thermometers:* • Less exposure to health hazards (for both alcohol and digital thermometers) • Higher cost of digital thermometers (MRU 1500 compared to MRU 175 for alcohol and mercury thermometers) • Alcohol thermometers are less accurate • Larger temperature range for digital thermometers • Digital thermometers more fragile *Sphygmomanometers:* • Higher cost for digital sphygmomanometers (3 times) • Digital sphygmomanometers are more fragile
Panama	RFI	*Thermometers:* No experience data provided for this rating.
Slovenia	RFI	*Thermometers:* Thermometers containing mercury are not produced in Slovenia.

Table A1.21: Countries Responding with a Level of Substitution of "0"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "0" No Available Substitutes
Panama	RFI	*Sphygmomanometers:* No experience data provided for this rating. *Thermostats:* No experience data provided for this rating.

Table A1.22: Countries with No Response for Level of Substitution

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Cambodia	MIT	*Thermometers:* Of the 6,141 thermometers distributed to health facilities throughout Cambodia in 2007, most of these thermometers were mercury, but some of them were alcohol and digital type thermometers.
Canada	Other	*Sphygmomanometers*, *Thermometers*, *Other:* Measuring devices, sphygmomanometers, manometers, barometers, psychrometers, hygrometers, hydrometers, flame sensors, flow meters, pyrometers, and thermometers, have viable alternatives that, in many cases, offer cost savings or improved performance. *Thermostats:* Mercury-containing thermostats can be viably substituted by digital thermostats. In most cases, a programmable digital thermostat can also encourage energy savings. Presently some manufacturers have programs to take back old mercury-containing thermostats in order to reuse components in new products.
Mexico	Other	*All Devices:* Letter of agreement in place with two national health institutes for the elimination of mercury and the planned 100% substitution.
Syria	RFI	*Thermometers:* Alcohol and digital electronic thermometers.
United Kingdom	RFI	*All Devices:* Electronic devices in use, but mercury instruments still required as 'gold standard', for validation of non-mercury instruments and in certain medical cases.
Uruguay	Other	*Thermometers and Sphygmomanometers:* The delivered cost of digital thermometers is 56 Uruguayan pesos plus tax. There is a plan to replace 9,600 thermometers and 120 blood pressure cuffs with digital technology at the University Hospital.

Eleven countries reported a substitution level of "2" for one or more categories of measuring and control devices, and two countries, Germany and Iran, reported a substitution level of "1-2". Several of these countries (i.e. Sweden) have instituted a ban for one or more categories of measuring and control devices. There were not any negative experiences reported by any of these thirteen countries for the transition to the mercury free alternatives.

Seven countries reported a substitution level of "1" for one or more categories of measuring and control devices. Four of these countries (Belarus, Chile, Ecuador, and Mauritius) reported that the non-mercury alternatives are more expensive than the mercury containing products.

Summary – Measuring and Control Devices

The following table shows a quantitative breakdown of the RFI responses for the level of substitution for thermometers and sphygmomanometers.

Table A1.23: Country Responses for Level of Substitution for Thermometers

Level	Number of Responses (Thermometer)	Percentage of Responses (Thermometer)	Number of Responses (Sphygmomanometer)	Percentage of Responses (Sphygmomanometer)
2	9	52.9%	11	68.8%
1 - 2	2	11.8%	1	6.2%
1	6	35.3%	3	18.8%
0	0	0%	1	6.2%

The following table shows a quantitative breakdown of the RFI responses received from eleven countries for the level of substitution for thermostats.

Table A1.24: Country Responses for Level of Substitution for Thermostats

Level of Substitution	Number of Country Responses	Percentage of Responses
2	9	81.8%
1 - 2	0	0%
1	1	9.1%
0	1	9.1%

Greater than 50% of RFI responses for thermometers, sphygmomanometers, and thermostats were for a level of substitution of "2", and there were not any negative experiences reported by these countries for the transition to the mercury free alternatives.

This indicates that substitutes are available and commonly used in the majority of countries that provided mercury demand information. Also, more than two countries reported estimated mercury demand of zero for each of the three product categories. Therefore, alternative technologies were identified and transition success to mercury free alternatives was demonstrated for each of the three product categories.

Table A1.25: Measuring and Control Device Substitution Summary

Measuring and Control Device	Alternative Technologies Identified	Transition Feasibility
Thermometers	Yes	Transition success demonstrated
Sphygmomanometers	Yes	Transition success demonstrated
Thermostats	Yes	Transition success demonstrated

A.2 Batteries

The batteries section is divided into two major classifications of mercury containing batteries: 1) miniature batteries and 2) non-miniature batteries. In general, the miniature batteries contain a small amount of mercury (except for mercuric oxide miniature batteries) and have limited non-mercury alternatives available for substitution. The mercury containing non-miniature batteries have significant amounts of mercury and have readily available non-mercury alternatives.

Miniature Batteries

Miniature batteries are used in a variety of products that require compact sources of electrical power. Miniature batteries are often used for supplying electrical power for toys, hearing aids, watches, calculators, and other portable devices. Miniature batteries are typically coin or button shaped. The four common technologies used for miniature batteries are: silver oxide, zinc air, alkaline, and lithium. The lithium miniature batteries contain no intentionally added mercury. However, there is typically 0.1% to 2.0% mercury content in most silver oxide, zinc air, and alkaline miniature batteries. The UNEP toolkit provides mercury content for miniature batteries in the European Union as outlined in the following table. (UNEP, 2005)

Table A2.1: Mercury Content in Miniature Batteries

Battery Type	Kilograms of Mercury Per Metric Ton of Batteries
Mercury oxide	320
Zinc air	12.4
Alkaline	4.5 - 10
Silver oxide	3.4 - 10

The function of the mercury is to inhibit corrosion inside the miniature battery cell. Corrosion can cause electrolysis in the electrolyte and initiate the production of hydrogen gas. Gas buildup inside the cell could lead to bulging and potentially result in leakage of battery cell materials, as well as impair the ability of the battery to continue functioning.

Several alternatives to mercury-containing miniature batteries were identified. There are mercury-free models commercially available for silver oxide, zinc air, and alkaline miniature batteries. In addition, lithium miniature batteries, which do not contain mercury, are sometimes considered as a potential alternative to mercury containing miniature batteries.

Original equipment manufacturers (OEMs) need to evaluate numerous design considerations when selecting the best miniature battery for their end product. The most important considerations for OEMs appear to be cost, nominal voltage, capacity, physical size/shape, and discharge profile. Other considerations for OEM's include: type of discharge, shelf life, energy density, operating temperature, replacement availability, and leakage resistance. The level of importance for each of these considerations can vary greatly depending upon the requirements of each particular end product. Thus, the suitability for replacing one miniature battery technology with another miniature battery technology must be determined on a case-by-case basis by OEMs based upon the particular requirements of their products.

The International Electrotechnical Commission (IEC) has published standards for batteries. The IEC nomenclature scheme for batteries is based on the electrochemical system as well as the size and shape of the battery. The following table indicates the IEC nomenclature for batteries relevant to this study.

Table A2.2: Standard Battery Nomenclature

IEC Letter Code	Battery Type	Nominal Voltage
B	Lithium (with carbon monofluoride	3
C	Lithium (with manganese dioxide	3
L	Alkaline manganese dioxide	1.5
P	Zinc air	1.4
S	Silver oxide	1.55

The IEC uses the letter "R" to identify round batteries. The IEC uses many numerical designations to indicate the acceptable minimum and maximum dimensions for battery diameter and height. The following table provides some examples:

Table A2.3: Battery Dimensions

IEC Designation	Minimum Diameter (mm)	Minimum Height (mm)
R44	11.25 – 11.6	5.0 – 5.4
R64	5.55 – 5.8	2.4 – 2.7
R1620	15.7 - 16	1.8 – 2.0
R2032	19.7 - 20	2.9 – 3.2

Battery manufacturers often base the model numbers for their miniature batteries on the IEC nomenclature. The following example is provided to illustrate the IEC nomenclature for miniature batteries:

- The IEC nomenclature for a lithium manganese dioxide miniature battery with a diameter of 20 millimeters and a height of 3.2 millimeters would be: CR2032.

There are two basic markets for batteries:

1) *Original equipment market*: This includes products that are sold with embedded miniature batteries such as toys, watches, calculators, and hearing aids. Manufacturers of these products are commonly referred to as original equipment manufacturers (OEMs).

2) *After market/retail market*: This includes the purchase of miniature batteries by end-users to replace expired batteries that are embedded in products from the original equipment market. These replacement batteries can be purchased from various local retailers, mail order operators, and Internet based suppliers.

The pricing information in this report is provided for the after market/retail market. Retail pricing is provided for representative manufacturers for certain miniature battery technologies such as alkaline, silver dioxide, lithium, and zinc air. However, there are numerous factors that should be considered that affect the retail price of miniature batteries including:

- *Battery technology* – The materials are different for the various miniature battery technologies and some raw materials are more expensive than others.

- *Battery capacity* – The capacity of a battery varies greatly and can have an impact on pricing.

- *Battery manufacturer* – The price for batteries manufactured by different manufacturers may vary due to brand name recognition, scale of production, and other market factors.

- *Retail pricing versus OEM pricing* – The pricing available for retail customers purchasing replacement miniature batteries is often higher than the pricing provided to OEMs that incorporate miniature batteries into their end products.

- *Quantity of batteries purchased* – The retail price per battery often decreases as the quantity of batteries purchased increases.

Silver Oxide Miniature Batteries

Product Overview

Silver oxide miniature batteries are used for numerous products such as watches, miniature clocks, calculators, electronic games, and cameras. The voltage of the silver oxide miniature battery is 1.55 Volts. The cathode of a silver oxide battery contains monovalent silver oxide (Ag_2O), and the anode contains powdered zinc.

Silver oxide miniature batteries provide long shelf and operational life. Most silver oxide batteries are designed to operate watches for five years without leakage. Battery test data indicate that storage up to ten years is possible at 21 degrees C. Silver oxide batteries come in a variety of shapes and sizes. For example, the SR41 battery is button shaped with a diameter of 7.8 mm and a height of 3.6 mm. The SR1116 battery is coin shaped with a diameter of 11.6 mm and a height of 1.65 mm. The mercury content of the silver oxide miniature battery is often between 0.2% and 1.0% of total battery weight.

Representative Manufacturers and Products

The following are representative manufacturers of silver oxide miniature batteries containing mercury:

Table A2.4: Representative Manufacturers of Silver Oxide Miniature Batteries Containing Mercury

Manufacturer	Location	Website	Model	Pricing (USD)
Energizer	St. Louis, Missouri, USA	www.energizer.com	387S,	$3.06, (Nextag)
Maxell	Tokyo, Japan	www.maxell.com.jp	SR616SW	$0.60, (Nextag)
Renata	Itingen, Switzerland	www.renata.com	399R,	$2.29, (Batteries)

The following are representative manufacturers of silver oxide miniature batteries that do not contain mercury:

Table A2.5: Representative Manufacturers of Silver Oxide Miniature Batteries that do not Contain Mercury

Manufacturer	Location	Website	Model	Pricing (USD)
Seiko Instruments Inc.	Chiba, Japan	www.sii.co.jp	Seizaiken SR621SW, SR626SW,	$2.95, (MicroBatt)
Sony	Tokyo, Japan	www.sony.net	SR series	Not readily available.

Zinc Air Miniature Batteries

Product Overview

Zinc air miniature batteries are mostly used for hearing aids, but can also be used for other applications such as pagers, behind-the-ear speech processors, and cochlear (inner ear) implants. Zinc air miniature batteries use oxygen from ambient air as the cathode material, and use granulated zinc powder as the anode material. The ambient air enters the battery through a hole on the positive terminal.

The zinc air miniature battery has a voltage of 1.4 Volts. Zinc air miniature batteries are mostly button shaped; however there are some commercially available coin-shaped batteries. Zinc air miniature batteries are excellent candidates for continuous, low-discharge applications, and they also provide good leakage resistance. The mercury content of the zinc air miniature battery is usually between 0.3% and 2.0% of total battery weight.

Representative Manufacturers and Products

The following are representative manufacturers of zinc air miniature batteries containing mercury:

Table A2.6: Representative Manufacturers of Zinc Air Miniature Batteries Containing Mercury

Manufacturer	Location	Website	Model	Pricing (USD)
Energizer	St. Louis, Missouri, USA	www.energizer.com	AC10EZ,	$1.38, (Batteries)
Rayovac	Atlanta, Georgia, USA	www.rayovac.com	Hearing Aid Series, Size 10	$1.00, (Walgreens)
Renata	Itingen, Switzerland	www.renata.com	Maratone 312	$0.92, (Batteries)

The following are representative manufacturers of zinc air miniature batteries that do not contain mercury:

Table A2.5: Representative Manufacturers of Zinc Air Miniature Batteries that do not Contain Mercury

Manufacturer	Location	Website	Model	Pricing (USD)
Energizer	St. Louis, Missouri, USA	www.energizer.com	AC series	Not readily available.
Rayovac	Atlanta, Georgia, USA	www.rayovac.com	Proline Mercury Free	Not available until end of 2008

Alkaline Miniature Batteries

Product Overview

Alkaline manganese dioxide miniature batteries are used in numerous products including: calculators, toys, key chains, tire gauges, remote controls, and photographic products. The cathode consists of electrolytic manganese dioxide, and the anode material is powdered zinc.

The alkaline manganese dioxide miniature battery has a voltage of 1.5 Volts. Alkaline manganese dioxide miniature batteries are most commonly available in button shapes. The mercury content of the alkaline manganese dioxide miniature battery is usually 0.1% to 0.9% of total battery weight.

Representative Manufacturers and Products
The following are representative manufacturers of alkaline miniature batteries containing mercury:

Table A2.6: Representative Manufacturers of Alkaline Miniature Batteries Containing Mercury

Manufacturer	Location	Website	Model	Pricing (USD)
Duracell	Bethel, Connecticut, USA	www.duracell.com	LR44	$1.08, (Nextag)
Maxell	Tokyo, Japan	www.maxell.com.jp	LR44	$1.46, (Nextag)
Toshiba	Tokyo, Japan	www.toshiba.com.jp	LR43	$3.59, (Lowcost)

The following are representative manufacturers of alkaline miniature batteries that do not contain mercury:

Table A2.7: Representative Manufacturers of Alkaline Miniature Batteries that do not Contain Mercury

Manufacturer	Location	Website	Model	Pricing (USD)
Chung Pak	Hong Kong, China	www.chungpak.com	Vinergy, L1154F, L1142F, L626	Not readily available.
Leopro Battery	Hong Kong, China	www.leopro-battery.com	L736H	Not readily available.
New Leader Battery Industry Ltd	Hong Kong, China	http://newleader.smeitrade.com	LR series	Not readily available.
Super Energy (Taishan) Battery Industries Co. Ltd	Hong Kong, China	www.superenergy.com.hk	Megaton LR44XS	Not readily available.

Mercuric Oxide
Mercuric oxide miniature batteries can be used for various applications such as hearing aids, watches, calculators, and cameras. Mercuric oxide miniature batteries are produced with a cathode material consisting of either mercuric oxide or a combination of mercuric oxide and manganese dioxide. This results in a high concentration of mercury within the battery. Mercuric oxide batteries can be produced with either a potassium hydroxide or a sodium hydroxide electrolyte. Current manufacturers of mercuric oxide miniature batteries were not easily identified.

The mercury content of the mercuric oxide miniature battery is approximately 32% of total battery weight. Mercuric oxide miniature batteries are typically replaced with either alkaline, silver oxide, or zinc air miniature batteries. These batteries also contain mercury, but at a much smaller

concentration. For example, the PX13 mercuric oxide miniature battery can be replaced by an S625X silver oxide miniature battery, the LR9 alkaline miniature battery, or the MRB 625 zinc air miniature battery. (Small Battery, 2008, MD Battery, 2008)

Other Mercury-Free Miniature Battery Technologies

Lithium miniature batteries do not contain mercury, and can be considered a potential alternative to mercury containing miniature batteries. Lithium miniature batteries have a much higher nominal voltage and a different physical shape (typically flatter and wider - coin shaped) than the other three miniature battery technologies, and therefore cannot easily be substituted in existing products.

Lithium miniature batteries are commonly used in products such as electronic games, watches, calculators, car lock systems, electronic organizers, and garage door openers. The two primary lithium miniature battery chemistries both use lithium as the anode material but use different cathode materials: 1) lithium/manganese dioxide, and 2) lithium/carbon monofluoride. Lithium metal can react vigorously with water, and as a result must be used with non-aqueous electrolytes. Another consideration is that there is the potential for fire when lithium batteries are collected.

Lithium miniature batteries have a voltage of 3.0 Volts. Lithium miniature batteries are commercially available in a wide range of capacities, from 25 to 1,000 mAh, and are mostly available in coin-shaped batteries. However, there are some lithium battery models available in button shapes. Lithium miniature batteries have excellent storage characteristics, and also provide excellent leakage resistance. Lithium miniature batteries can be used for a wide range of operating temperatures, from about –20 degrees C to 55 degrees C.

Representative Manufacturers and Products

The following are representative manufacturers of lithium miniature batteries:

Table A2.8: Representative Manufacturers of Lithium Miniature Batteries

Manufacturer	Location	Website	Model	Pricing (USD)
Duracell	Bethel, Connecticut, USA	www.duracell.com	DL2032B	$2.99, (AtBatt)
Energizer	St. Louis, Missouri, USA	www.energizer.com	ECR-1220BP	$2.99, (AtBatt)
North American Battery Company	San Diego, California, USA	www.nabcorp.com	UL2325	$2.95, (Nextag)
Renata	Itingen, Switzerland	www.renata.com	CR2430	$2.25, (AtBatt)

Non-Miniature Mercury Containing Batteries

There are four methods of producing non-miniature mercury containing batteries (NRDC, 2006):

- *Paste-type zinc-manganese cylinder batteries*: Mercuric chloride is used as a corrosion inhibitor and is mixed with other materials to create a paste that is deposited between the battery outside layer and the inner anode. Most batteries of this type are “D” sized cylinder batteries.

- *Paperboard type zinc-manganese cylinder batteries*: The mercury containing paste is applied to laminated paper for corrosion control for these types of batteries. Batteries using this technology can be used for D, C, AA, and AAA sized cylinder batteries. (Xiaodong, 2008)

- *Alkaline zinc-manganese cylinder batteries*: Zinc powder is used as the anode material in this type of battery. Mercury is used as a corrosion retardant in the zinc powder material.

- *Mercuric oxide batteries*: This type of battery contains mercuric oxide as the cathode material, and mercury containing zinc powder as the anode material.

Alkaline manganese cylinder batteries without intentionally added mercury are readily available to meet the various size and power requirements for the various cylinder battery applications. For example, cylinder batteries without intentionally added mercury are available in AA, AAA, C, and D standard battery cell types. The Nordic Council of Ministers report states that the price of non-mercury alternatives are approximately the same price as each of the mercury containing non-miniature battery types listed above. (Maag, 2007)

Demand and Use of Mercury

The following table contains the mercury use data for batteries provided by countries in their responses to the UNEP Request for Information (RFI) or other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT). Eighteen countries provided estimated mercury demand information for batteries. The range of responses was 0 – 154 metric tons of mercury per year, with two countries reporting no mercury demand for batteries. The estimated mercury demand responses provided data from various years, including information as far back as 2004.

Table A2.9: Mercury Demand for Batteries (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
China	Other	154
Cambodia	MIT	4.34 (0.203 – 8.476)
Chile	MIT	2.838
United States	RFI	2.3
Japan	RFI	1.83
Germany	RFI	1.4
France	RFI	1
United Kingdom	RFI	1
Canada	RFI	0.5 (2004)
Belarus	RFI	0.136
Sweden	RFI	0.126
Switzerland	RFI	0.02 (2004 – 2006)
Argentina	RFI	0.01
Brazil	RFI	0.008
Norway	RFI	0.002
Slovenia	RFI	< 0.001
Mauritius	RFI	0
Netherlands	RFI	0

The reported levels of mercury demand per capita for batteries fall within the following two distinct groups:

1. China, Cambodia, and Chile reported high levels of mercury demand per capita of between 0.117 to 0.303 grams of mercury per person per year. For China, this could be attributed to the significant domestic manufacture of mercury containing batteries. A detailed breakdown of China's battery manufacturing industry is provided below. For Cambodia and Chile, the high levels could be attributed to the assumptions made while using the Mercury Inventory Toolkit. A detailed description of Cambodia and Chile calculations are provided below.
2. The remaining fifteen countries reported mercury demand per capita of equal to or less than 0.017.

China has a significant battery manufacturing industry that annually produces billions of batteries. The following table provides a detailed breakdown of the 154 metric tons of mercury reported by China in 2004 that were used for the production of various battery types.

Table A2.10: Mercury Use for Battery Manufacturing in China, 2004 (Source: NRDC, 2006)

Battery Type	2004 Output (millions of units containing mercury)	Estimated Mercury Consumption (metric tons)
Paste type zinc manganese cylinder batteries	9,349	34.65
Paperboard zinc manganese cylinder batteries	3,580	10.35
Alkaline manganese cylinder batteries	0.134	5.358
Alkaline manganese button cell batteries	8,000 – 10,000	98.65
Silver oxide button cell batteries	81	0.02778
Zinc air button cell batteries	Not Available	4.32
Mercuric oxide batteries (miniature and non-miniature)	0.245	0.147

The battery industry in China reportedly used over 800 metric tons of mercury in 1999 (Feng, 1999). Therefore, the 154 metric tons reported in 2004 is a reduction of approximately 80% over the five year period from 1999 to 2004. The usage of mercury in the Chinese battery industry should diminish significantly as China and more countries around the world adopt battery regulations banning the use of mercuric oxide batteries and cylindrical batteries with the intentional addition of mercury. For example, China has implemented a policy for zero-mercury alkaline batteries. Under this policy, the production of batteries containing more than 0.0001% mercury by weight is banned as of January 1, 2005, and the sales of batteries containing more than 0.0001% mercury by weight is banned as of January 1, 2006. (CCRC, 2005)

The Mercury Inventory Toolkit provides the following default input factors to use in cases where source-specific data about mercury content in batteries are not available.

Table A2.11: Mercury Inventory Toolkit Default Input Factors for Batteries

Battery Type	Mercury Content (kilograms of mercury per metric ton of batteries)
Mercury oxide (all sizes)	320
Zinc air miniature	12
Alkaline miniature	5
Silver oxide miniature	4
Alkaline, non miniature	0.25

The following table depicts the battery type, quantities, and input factors used by Cambodia to estimate their annual mercury demand of 0.203 to 8.476 metric tons.

Table A2.12: Battery Type, Quantity, and Input Factors Used by Cambodia

Battery Type	Quantity (metric tons of batteries)	Input Factor Used (kg mercury per ton of batteries)
Cylindrical batteries	635.599	0.25 - 10
Other batteries (includes button batteries)	13.251	3.4 - 160

The following table provides the battery type, quantities, and input factors used by Chile to estimate their annual mercury demand of 2.838 tons.

Table A2.13: Battery Type, Quantity, and Input Factors Used by Chile

Battery Type	Quantity (metric tons of batteries)	Input Factor Used (kg mercury per ton of batteries)
Mercury oxide	1.71	Not identified
Zinc-air	2.13	Not identified
Silver oxide button cells	13.24	Not identified
Alkaline other than button cells	2,212	Not identified

If the default factors recommended by the mercury toolkit were used by Chile, then the total annual mercury demand for batteries in Chile would be calculated to be 1.179 tons, not 2.838 as reported.

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries on their experiences with the technology changeover or alternatives associated with substituting mercury-containing batteries with available alternatives. The information contained in the tables is derived from the responses to the UNEP Request for Information (RFI), Mercury Inventory Toolkit (MIT), or other source of information. In some cases, the tables contain an abbreviated or revised version of the response included in the RFI.

Table A2.14: Countries Responding with a Level of Substitution of "2"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" Substitutes Available and Commonly Used
Argentina	RFI	Import, manufacturing and assembly of batteries with more than 0.005% of mercury content are banned. Certification of battery imports is required.
Brazil	RFI	Regulated since 1999. Maximum limit of mercury for zinc-manganese and alkaline-manganese batteries is 0.010%, and for button batteries the maximum concentration allowed for mercury is 25 mg.
Denmark	RFI	No experience data provided for this rating.
France	RFI	EU ban in effect since 2000 (with exemptions).
Germany	RFI	Positive experience.
Iran	RFI	In some major cities, collection and recycling of batteries has been started.
Japan	RFI	Mercury in primary cells, especially in manganese dry cells and alkali dry cells has been used to prevent oxidation and as a corrosion inhibitor. Owing to the improvement of battery cell structure to avoid the oxidation by ambient air, the adoption of impurity-free refining method, and the introduction of alternative substance to prevent oxidation, the use of mercury was stopped voluntarily by the manufacturers in the early 1990s. Although mercury button batteries were mostly used in hearing aids, the Japanese manufacturers urged to replace the usage of mercury button batteries by air zinc batteries, and the production of mercury button batteries was discontinued around 1996. There are three types of batteries that still use mercury: alkali button batteries, silver oxide cells and air zinc batteries. Among these batteries, since the silver oxide cell without any added mercury was developed using corrosion inhibitors and hydrogen adsorbents, mercury free substitution has progressed. Provided a "0" level rating for hearing aid batteries.
Mauritius	RFI	Alternatives are cheaper and there is less exposure to health and environmental hazards.
Netherlands	RFI	There are no mercury containing batteries produced in the Netherlands. Provide a level of substitution of "1 – 2".
Norway	RFI	Follow the EU-directive on batteries.
Panama	RFI	No experience data provided for this rating.
Slovenia	RFI	New technology.
Sweden	RFI	Since 2000 the marketing of batteries containing >0.0005 % Hg by weight is prohibited in the EU, including in those cases where these batteries are incorporated into appliances. Button cell batteries containing < 2 % mercury by weight are exempted from the ban. Positive experience with technology change-over. No indication of any economic problems when implementing the restriction. According to the Swedish Battery Association the estimated mercury level in button cell batteries on the market is about 1% mercury by weight.
Switzerland	RFI	A level of substitution of "2" provided for mercury oxide, alkaline cylindrical, and zinc manganese batteries (paste and paper types). Provided a level of substitution of "0" for alkaline, zinc air, and silver oxide miniature batteries.

Table A2.15: Countries Responding with a Level of Substitution of "1"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "1" Substitutes Available and Minimally Used
Belarus	RFI	No experience data provided for this rating.
Chile	RFI	Negative experience. The alternatives have not been diffused. The costs are similar for both products.
Ecuador	RFI	No experience data provided for this rating.

Table 2.16: Countries with No Response for Level of Substitution

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Canada	Other	Commercially viable replacements for alkaline-manganese and zinc-carbon mercury-containing batteries are currently available. However, the few mercury free replacements for button cell and zinc oxide batteries that are commercially available are generally considered to have reduced performance at a significant cost increase. The use of large mercuric oxide batteries is expected to decline rapidly as older hospital and military equipment become obsolete while smaller mercuric oxide batteries can be replaced by alternative battery types.
Poland	Other	Button cell batteries cannot have mercury content higher than 2% by weight.
United Kingdom	RFI	Various alternatives available and in use.
United States	RFI	Positive experience. In 1996 Congress passed The Mercury-Containing and Rechargeable Battery Management Act, which prohibits or limits the sale of certain types of mercury-containing batteries in the United States: • Prohibits sale of mercury-containing alkaline-manganese batteries, except for button cells containing up to 25 mg mercury. • Prohibits sale of zinc-carbon batteries that contain intentionally-added mercury. • Prohibits sale of button cell mercuric-oxide batteries. • Prohibits sale of other mercuric-oxide batteries unless the manufacturer follows stringent requirements to provide purchasers with information on recycling or proper disposal. Major manufacturers produce mercury-free alternatives for both silver-oxide and alkaline-manganese button cells. However mercury-free zinc-air button cells are currently not widely available in the United States. Congress prohibits the sale of mercuric-oxide batteries (other than button cell) unless the manufacturer follows stringent requirements to provide purchasers with information on recycling or proper disposal. Previously used in hearing aids, these batteries are now used only for military and medical equipment where stable electrical current and long service life are essential requirements.

Additional information available about addressing mercury in miniature batteries is available for the United States. During March 2006, National Electrical Manufacturers Association (NEMA) provided the following statement: "The U.S. battery industry is announcing a commitment to eliminate added mercury from button cell batteries by June 30, 2011". (NEMA, 2006) At that time, NEMA members included dry cell battery manufacturers Duracell Inc., Eastman Kodak Company, Energizer Holdings, Inc., Panasonic Battery Corporation of America, Rayovac Corporation, Renata SA, Saft America, Inc., and Wilson Greatbatch, Ltd. Also in the United States, the states of Maine and Connecticut have recently passed legislation to ban the sale of miniature batteries containing mercury by June 2011. The implementation of this product ban was delayed until 2011 to provide manufacturers with enough time to develop mercury free button batteries for most applications.

Summary - Batteries

The following table shows a quantitative breakdown of the RFI responses received from seventeen countries for the level of substitution provided.

Table A2.17: Country Responses for Level of Substitution

Level of Substitution	Number of Country Responses	Percentage of Responses
2	13	76.5%
1 - 2	1	5.9%
1	3	17.6%
0	0	0%

Overall, the results of the RFI meet the criteria for transition success because greater than 50% of RFI responses provided a level of substitution of "2", and more than two countries reported estimated mercury demand of zero tons for batteries. The RFI provided multiple lines for entering different data for products such as measuring control devices and electrical and electronic devices. However, the RFI had only one line allocated for input data for all types of batteries. This limited the RFI respondents to provide one level of substitution rating for all battery types. There are two major categories of batteries from a mercury substitution standpoint:

Category 1: The batteries with readily available non-mercury substitutes: mercuric oxide non-miniature, and the various zinc manganese cylinder batteries.

Category 2: The various miniature batteries without readily available non-mercury substitutes.

For the majority of RFI responses, a level of substitution of "2" was provided. The responses often did not indicate what particular battery type(s) that this response was intended to address, but it appears this response was intended for Category 1 batteries if there was no clarifying language provided. There were responses received that indicate the overall level of substitution for Category 1 batteries was "2", and the overall level of substitution for Category 2 batteries was "0". For example, Switzerland provided level of substitution of "2" provided for mercury oxide, alkaline cylindrical, and zinc manganese batteries (paste and paper types), and provided a level of substitution of "0" for alkaline, zinc air, and silver oxide miniature batteries.

Another example is Japan reported that the overall level of substitution for batteries was "2", with the exception of providing a level of "0" for zinc air miniature batteries. This concept is further substantiated by the efforts underway in the U.S. for Category 1 batteries where prohibitions have been in place for mercuric oxide and alkaline-manganese batteries since 1996. For Category 2 batteries, the U.S. states of Maine and Connecticut have recently passed legislation to ban the sale of miniature batteries containing mercury; however, the implementation of this product ban was delayed until 2011 to provide manufacturers with enough time to develop mercury-free button batteries for most applications.

Based upon this assessment, transition success was achieved for Category 1 batteries, but not for Category 2 batteries.

Table A2.18: Battery Substitution Summary

Battery Type	Alternative Technologies Identified	Transition Feasibility
Paste type zinc manganese cylinder	Yes	Transition success demonstrated
Paperboard type zinc manganese cylinder	Yes	Transition success demonstrated
Alkaline zinc manganese cylinder	Yes	Transition success demonstrated
Mercuric oxide – non miniature	Yes	Transition success demonstrated
*Mercuric oxide miniature	Yes	Alternatives available – challenges identified
Silver oxide miniature	Yes	Alternatives available – challenges identified
Zinc air miniature	Yes	Alternatives available – challenges identified
Alkaline miniature	Yes	Alternatives available – challenges identified

*Transition success has been demonstrated for mercuric oxide miniature batteries to low mercury content miniature batteries such as silver oxide, zinc air and alkaline. However, there are remaining challenges to move to mercury free miniature battery technologies.

A.3 Dental Use

Mercury is used to produce dental amalgam, which is a material that dentists use for tooth restorations. There are two types of dental restorations: direct restorations and indirect restorations. A direct restoration is a filling that a dentist places directly in a prepared cavity of the tooth. The placement of a direct restoration requires only one dental appointment. Materials for direct restorations include: amalgam, glass ionomers, resin ionomers and composites.

Indirect restorations are fillings (inlays, onlays, veneers, crowns and bridges) that are made in a dental laboratory and therefore require two or more visits to the dentist. Materials for indirect restorations include: gold, ceramics and composites. The focus of this section is on dental amalgam and alternative filling materials for use in direct restorations.

Mercury Dental Amalgam

Product Overview
Dental amalgam is a material used for dental fillings composed of a mixture of elemental liquid mercury and a silver, tin and copper alloy powder. Small quantities of zinc, palladium, or indium may also be present in the alloy powder.

Historically, dentists made their own amalgam on-site by mixing the liquid mercury and alloy powder ingredients. While this practice of mixing amalgam on-site still exists in some countries, most amalgam is sold in capsules containing pre-measured quantities of mercury and alloy powder. Amalgam capsules are available in a variety of sizes, and three common sizes are 400, 600, and 800 milligrams. The mercury is contained in a thin plastic film wafer (pillow pack) within the capsule. Prior to use, the capsule is placed in an amalgamator which ruptures the pillow pack and mixes the mercury with the alloy powder.

Amalgam has several characteristics that make it a popular choice for direct restorations in posterior teeth. It is durable and withstands the biting forces of posterior teeth. It is relatively easy to work with and has a low cost. Amalgam fillings typically last approximately 12 years. (Johnstone, 2008)

Amalgam also has limitations. It has a silver color that darkens with age and is therefore primarily used for restorations in posterior teeth for cosmetic reasons. Amalgam is not bonded to the tooth but rather held in place by being packed into pockets created within the cavity. Dentists must remove some healthy tooth material in order to create these pockets. Amalgam also requires special handling and an amalgam separator should be used to reclaim amalgam scrap from the wastewater.

The mercury content of amalgam ranges from 43 percent to 54 percent by weight. The amount of mercury used when a dentist fills a tooth cavity with amalgam varies with the size of the cavity and the amalgam capsule size (e.g., 400, 600, or 800 milligrams) used. The mercury content reported by U.S. manufacturers to the Interstate Mercury Education & Reduction Clearinghouse (IMERC) for mercury amalgam capsules was in the range of less than 100 milligrams up to 1,000 milligrams.

Representative Manufacturers and Products
The following are representative manufacturers of dental amalgam containing mercury.

Table A3.1: Representative Manufacturers of Dental Amalgam Containing Mercury

Manufacturer	Location	Website	Model	Pricing (USD)
Dentsply International	York, Pennsylvania USA	www.dentsply.com	Dispersalloy, Regular Set, Single Spill, 50% Hg	$59.00 400mg, Qty 50 (Net32)
Ivoclar Vivadent Group	Liechtenstein	www.ivoclarvivadent.com	Valiant PhD Sure-Caps, Single Spill	$54.81 400mg, Qty 50 (Net32)
Kerr Corporation	Orange, California USA	www.kerrdental.com	Tytin FC Caps, Regular Set, Single Spill	$99.00 400mg, Qty 50 (Net32)
SDI Limited	Australia	www.sdi.com.au	Permite Caps, Fast Set, Single Spill	$57.50 400mg, Qty 50 (Net32)

Alternative 1: Composites

Product Overview

Composites are tooth-colored fillings composed of a mixture of acrylic resin and powdered glass or silica filler. Composites are available in either bulk syringes or one dose capsules and are either self-curing or light-curing. Composite materials are applied to the tooth cavity in layers (approximately 2mm thick) with each layer being cured before the subsequent layer is applied.

The incremental filling technique used for composites generally requires more time than the filling technique used for amalgam. This increased restoration time, combined with higher material costs, typically results in composite fillings costing more than amalgam fillings. There are a number of other factors that affect the cost of a filling, including: insurance coverage, location where the procedure is performed, size of filling, and type of filling material. Given these various factors, it is difficult to quantify the difference in price a patient must pay for a composite filling versus an amalgam filling. A review of several U.S. dental websites indicated that composite fillings are generally 1.2 to 2 times the cost of amalgam fillings. (About Cosmetic Dentistry, 2008; Cost Helper, 2008)

One distinct advantage that composite fillings have over amalgam is that they closely match the tooth color and, for this reason, they are often the preferred choice for anterior teeth or where aesthetics is important. Another advantage is that composite fillings can be chemically bonded to the tooth cavity, which can result in a stronger tooth structure because fillings that are bonded to the tooth require less healthy tooth material to be removed when preparing the cavity.

The American Dental Association states that composite “is a relatively strong material, providing good durability in small to mid sized restorations” but composite fillings may require more frequent replacement than amalgam, particularly when subject to heavy biting forces or in large fillings. Composite fillings are typically expected to last five to seven years. (Johnstone, 2008)

The use of micro and nano technologies has opened the door to new opportunities for improving the performance of composite materials, including strength, fracture resistance, wear, aesthetics, and handling characteristics. Many composite manufacturers, including those listed in the following table, currently offer products that incorporate micro and nano materials in the filler materials of some composites. The use of micro and nano materials is a relatively new development and further advancements are likely.

One type of composite material, compomer, is a hybrid between a composite material and a glass ionomer. One of the advantages of compomer materials is that the wear rate is approximately three times better than composite materials. Compomers can also contain fluoride which is slowly released over time to help prevent additional decay of the tooth.

Representative Manufacturers and Products
The following are representative manufacturers of composite fillings.

Table A3.2: Representative Manufacturers of Composite Fillings

Manufacturer	Location	Website	Model	Pricing (USD)
3M	St. Paul, Minnesota USA	http://solutions.3m.com/wps/portal/3M/en_US/3M-ESPE/dental-professionals/	Filtek Z250 Restorative Refill Capsules	$51.01 Qty 20 (Net32)
Dentsply International	York, Pennsylvania USA	www.dentsply.com	Herculite XRV Refill Compules	$32.60 Qty 20, 0.25g compules (Net32)
Ivoclar Vivadent Group	Liechtenstein	www.ivoclarvivadent.com	Tetric EvoCeram Cavifil Refill	$67.00 Qty 20, 0.2g cavifils (Net32)
Kerr Corporation	Orange, California USA	www.kerrdental.com	Prodigy Unidose Refills	$49.99 20 tips, 0.2g (Net32)
SDI Limited	Australia	www.sdi.com.au	Ice Complet Refills, Light Cure	$68.75 Qty 20, 0.25g (Net32)

Alternative 2: Glass Ionomer

Product Overview
Glass ionomers are natural looking, tooth-colored materials made of a mixture of acrylic acids with fine glass powders that are used to fill cavities. Glass ionomers have relatively low resistance to fracture and are therefore used primarily on small, non-load bearing fillings, such as those on the root surfaces of teeth. Glass ionomer materials are available in different delivery forms including: dispensers, capsules, and powder/liquid.

One distinct advantage that glass ionomer fillings have over amalgam is that they closely match the tooth color and, for this reason, they are often used for anterior teeth or where aesthetics is important. Another advantage is that glass ionomers chemically bond to the tooth cavity, which can result in a stronger tooth structure because fillings that are bonded to the tooth require a smaller quantity of the healthy tooth material to be removed when preparing the cavity. Glass ionomer fillings also contain fluoride which is slowly released over time to help prevent additional decay of the tooth.

Disadvantages of glass ionomer fillings include higher cost and a longer time required for placement. From a durability standpoint, they have a lower resistance to fracture and are more likely to wear than either amalgam or composites. (Colgate, 2008) The cost of dental fillings is subject to a variety of factors and it is therefore difficult to quantify the difference in price a patient

must pay for a glass ionomer filling versus an amalgam filling. The American Dental Association stated that the costs for glass ionomer fillings are comparable to composite fillings but higher than amalgam fillings.

Representative Manufacturers and Products
The following are representative manufacturers of glass ionomer dental restoration materials.

Table A3.3: Representative Manufacturers of Glass Ionomer Materials

Manufacturer	Location	Website	Model	Pricing (USD)
3M ESPE	St. Paul, Minnesota USA	http://solutions.3m.com/wps/portal/3M/en_US/3M-ESPE/dental-professionals/	Ketac Molar Aplicap Refill Capsules, Self Cure	$189.00 Qty 50 (Net32)
3M ESPE	St. Paul, Minnesota USA	http://solutions.3m.com/wps/portal/3M/en_US/3M-ESPE/dental-professionals/	Photac-Fil Quick Aplicap Refill Capsules, Dual Cure	$209.00 Qty 50 (Net32)
GC America, Inc.	Alsip, Illinois, USA	http://www.gcamerica.com/	Fuji II LC Refill Capsules, Light Cure	$108.95 Qty 50 (Net32)
SDI Limited	Australia	www.sdi.com.au	Riva Light Cure Refill Capsules	$136.55 Qty 50 (Net32)

Other Alternatives

Resin Ionomers
Resin inomers and resin-modified glass ionomers (RMGI) are a mixture of acrylic acids and acrylic resin with a glass filler. They are tooth-colored and can release fluoride over time to help prevent further tooth decay. Like glass ionomers, resin ionomers bond to the tooth cavity and require a smaller amount of the healthy tooth material to be removed when preparing the cavity. Resin ionomers outperform glass ionomers in certain mechanical properties including strength and coefficient of thermal expansion.

Resin ionomers have a low to moderate resistance to fracture and experience high wear when used on chewing surfaces. For these reasons, the use of resin ionomers is typically limited to small, non-load bearing fillings or short term fillings in primary teeth. The cost of resin ionomer fillings is similar to composite filling but more than amalgam fillings.

Gold, Ceramic and Porcelain
Gold alloy, ceramic and porcelain are typically used for indirect restorations and therefore were not considered to be alternatives to amalgam, which is primarily used for direct restorations. These materials require two or more dentist visits and typically involve the placement of a temporary filling.

Polycarboxylate Cement
Polycarboxylate cement is used for temporary fillings and as a cementing medium for cast alloy and porcelain restorations. It is not considered to be an alternative to amalgam because the fillings are temporary. (www.free-ed.net, 2008)

Zinc Oxide

Zinc oxide is used for a variety of dental purposes including temporary fillings. It is often used in combination with eugenol, a liquid derived from the oil of cloves, and acts to relieve pain and is slightly antiseptic. It is not considered to be an alternative to amalgam because the fillings are temporary. (www.free-ed.net, 2008)

Demand and Use of Mercury

The following table contains the mercury demand data for dental amalgam provided by countries in their responses to the UNEP Request for Information (RFI) or other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT).

Table A3.4: Country Mercury Use for Dental Amalgam (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
United States	RFI	27.6 (2004)
Germany	RFI	20
Philippines	MIT	17.741 (2006)
United Kingdom	RFI	6.6 (2006)
China	Other[1]	6
Canada	Other[2]	4.665 (2007)
Syria	RFI	4.125
Netherlands	RFI	1.6 (2007)
Denmark	RFI	1.2 (1.1 – 1.3) (2001)
Russia	Other[3]	0.8 (2001)
Argentina	RFI	0.614
Japan	RFI	0.15 (2005)
Sweden	RFI	0.103
Cambodia	MIT	0.086 0.008 – 0.163 (2007)
Norway	RFI	0

The Mercury Inventory Toolkit (MIT) recommends a default range of 0.05 - 0.20 grams of mercury per year per inhabitant for estimating total demand of amalgam. (UNEP 2005) Three countries (Germany, Denmark and Syria) provided use quantities above the MIT range. The Philippines calculated mercury use utilizing the higher end of the Mercury Inventory Toolkit range (0.20 grams of mercury per year per inhabitant). Four other countries provided use numbers that fell within the MIT range (Canada, United Kingdom, Netherlands, and United States). The remaining seven countries provided use numbers below the MIT range.

Use of dental amalgam is likely affected by a number of factors including: government policies, level of dental care available, level of personal hygiene, and availability and cost of alternatives. For example, the low use in Sweden was likely caused, in part, by the policy implemented in 1999 of excluding amalgam restorations from health insurance coverage. The Cambodia Mercury Inventory Toolkit Report attributes the low use number to the low frequency of dental restorations combined with the widespread use of alternative filling materials.

[1] SEPA, 2005.
[2] Canadian information to support intersessional work of the ad hoc open-ended working group on mercury, January 31, 2008.
[3] ACAP, 2004

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries on their experiences with the technology changeover or alternatives associated with substituting mercury dental amalgam with other filling options. The information contained in the tables is derived from the responses to the UNEP Request for Information (RFI). In some cases, the tables contain an abbreviated or reworded version of the response included in the RFI.

Table A3.5: Countries Responding with Level of Substitution of "2"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" – Substitutes Available and Commonly Used
Brazil	RFI	No experience data provided for this rating.
Denmark	RFI Other[4]	The usage of amalgam has declined from 37% of all fillings in 2000 to 28% in 2005. Different kinds of plastics have been dominating the market during the last years supplemented by glass ionomers. Dentists will no longer be allowed to use dental amalgam after April 1, 2008.
Germany	RFI	Germany reported a substitution level of 1- 2. Positive experience.
Japan	RFI	Dental amalgam usage declined from 5 metric tons in 1970 to 0.15 metric tons in 2005 as a result of concerns with ingestion of mercury through deterioration, decay and inhalation of vapor generated by heat from mastication. Alternatives include gold-silver-palladium alloy, ceramic and composite resin.
Netherlands	RFI	A decrease in use of mercury of approximately 15% per year is estimated, due to the decrease in tooth decay and the increased usage of alternative dental fillers. Since mid-1980's, dental amalgam use has decreased from 3,500 grams per dentist per year to 260 grams per dentist per year.
Norway	RFI	No negative experiences with alternatives. Norway's ban on the use of mercury in products, including dental amalgam, became effective in January 2008.
Slovenia	RFI	No experience data provided for this rating.
Sweden	RFI Other[5]	Positive experience. Mercury used for dental amalgam has been reduced by 90% between 1997 and 2003. About 98% of total fillings on adults are made with alternative materials, mostly composites. On children the corresponding figure is 99.95%. Health insurance stopped paying for amalgam restorations in 1999. A ban on mercury in dental amalgam took effect on January 1, 2008.
Switzerland	RFI	Technically no problem, but may be an issue due to higher cost of alternative materials.

[4] PR Newswire, 2008.
[5] PR Newswire, 2008.

Table A3.6: Countries Responding with Level of Substitution of "1"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "1" – Substitutes Available and Minimally Used
Argentina	RFI	No experience data provided for this rating.
Chile	RFI	Negative. The availability of the alternatives is limited and the cost of the alternatives is higher than amalgam.
France	RFI	No experience data provided for this rating.
Iran	RFI	Dental amalgam is still used, although many dentists are using composite resin as an alternative. The consumption of mercury in dentistry has decreased significantly since 1998.
Panama	RFI	No experience data provided for this rating.
United Kingdom	RFI	Composites and glass ionomers both used. Decline in mercury amalgam from 9 metric tons (2004) reflects improvements in the oral health of the population. Use of amalgam is expected to continue to decline to around 2 metric tons of mercury per year by 2011.
United States	RFI Other[6]	Negative. Non-mercury alternatives to dental amalgam are expensive, and cost is not covered by private or governmental medical insurance. Dental treatment products are regulated by the federal government, and states cannot independently ban the use of dental amalgam. Insurance plans typically cover most or all of the cost of an amalgam filling but only 50% to 80% of composite fillings.

Table A3.7: Countries with No Level of Substitution Response

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Cambodia	MIT	Filling materials used include amalgam, composite, glass ionomer cement, polycarboxylate cement, zinc oxide and ceramic. Dental clinic patients prefer composites rather than amalgam while wealthy people prefer zinc oxide and ceramic materials.
Canada	Other[7]	Alternatives include cast gold, bonded amalgam, ceramics and composite resins. There are concerns regarding the alternatives including higher costs and lack of suitability for certain procedures. Amalgams are also very durable, relatively fast and easy to place, and can often be repaired.

Eight countries reported a substitution level of "2" for dental amalgam and one country, Germany, reported a substitution level of "1-2". A level "2" response indicates that substitutes are available and commonly used in those countries. Of these nine countries, seven are European. Three of the European countries (Denmark, Norway, and Sweden) have bans on the use of dental amalgam. Brazil and Japan also reported a substitution level of "2".

[6] www.aboutcosmeticdentistry.com

[7] Canadian information to support intersessional work of the ad hoc open-ended working group on mercury, January 31, 2008.

Seven countries reported a substitution level of "1" for dental amalgam, which indicates that substitutes are available and minimally used in those countries. Two of these countries are in South America, two in Europe, one in Western Asia, one in Central America and one in North America.

Overall, thirteen countries provided written comments regarding experiences with alternatives to dental amalgam. Four comments included statements about the cost of alternatives being higher than the cost of dental amalgam while only one country expressed concern about the performance characteristics of the alternatives.

Summary – Dental Use

Dentists consider a variety of factors when deciding on the type of filling material to use for a direct restoration including: health of patient, aesthetics, location of filling, biting force, length and number of visits, durability, and cost. (ADA, 2008) In certain cases, alternatives to amalgam are clearly the best choice. For example, tooth-colored composites are typically used for cavities in anterior teeth for cosmetic reasons. Glass ionomers or resin ionomers are typically the preferred choice for small cavities on the necks or roots of teeth, and small cavities in primary teeth.

The application of micro and nano technologies is resulting in improved physical performance and aesthetic qualities of the alternative materials. RFI responses from several countries indicate that the alternatives are suitable replacements for amalgam with respect to performance. The higher price of the alternatives was identified by several countries as a barrier for transitioning away from the use of amalgam.

Three countries, Norway, Sweden and Denmark, have bans on the use of mercury amalgam for dental fillings that took effect in 2008. These countries viewed composites as adequate replacements for amalgam. (PR Newswire, 2008)

The following table shows a quantitative breakdown of the level of substitution for mercury in dental uses based on the RFI responses from sixteen countries.

Table A3.8: Country Responses for Level of Substitution

Level of Substitution	Number of Country Responses	Percentage of Responses
2	8	50%
1-2	1	6%
1	7	44%

The information provided in this section indicates that there are alternative technologies available for dental amalgam, and some countries have been successful in transitioning away from the use of dental amalgam. Fifty percent of RFI responses indicated that substitutes are available in the market and commonly used. One country (Norway) estimated its dental use of mercury at zero and the 2008 ban on dental amalgam for Sweden and Denmark will likely drive their use numbers to zero in 2009.

Despite the transition success in these countries, challenges were identified that are preventing transition success on a global basis. The most significant barrier to transition success, based on the RFI responses, is the higher cost of alternatives. Other factors that may affect the transition to

mercury-free dental fillings include: insurance coverage of alternatives, training of dentists, government regulations, and concern about hindering dental care in developing countries. (Maag, 2007)

Table A3.9: Dental Use Substitution Summary

Dental Use	Alternative Technologies Identified	Transition Feasibility
Dental amalgam	Yes	Alternatives Available – Challenges Identified

A.4. Electrical and Electronic Devices

The "Electrical and Electronic Devices" section is comprised of two major product subgroups: electrical switches and relays. In the first subsection "A.4.a Electrical Switches", information is provided for the four major switch types: float, tilt, pressure, and temperature. This section includes information for both the mercury switch and the non-mercury alternatives for each of the four types of switches. In the second subsection "A.4.b Relays", information is provided for the two types of mercury relays (mercury displacement and mercury wetted reed) and the six non-mercury relay alternatives (dry magnetic reed, other electro-mechanical, solid state, silicon controlled rectifiers, and hybrid).

Switches and relays are used in thousands of different products and applications with use in many areas such as residential, industrial, medical, agricultural, municipal, and commercial. There are many design parameters that affect the specification and selection of a switch or relay for a particular product or application. The switch or relay design and product options can vary widely by manufacturer.

The design requirements have a significant impact on product model selection and ultimate product cost. The following are some of the more critical design parameters: number of switch points, type of level detection, switch/relay accuracy, reliability, type of liquid environment (for float switches), mounting style, type of enclosure, output contact rating, switch/relay life expectancy, regulatory approval required, electrical load type, operating parameters, environmental conditions, input power requirements, and type of switch/relay.

A.4.a Electrical Switches

Tilt Switches

Tilt switches are capable of sensing changes in position or rotation, and are then able to actuate a switch based upon these changes. The tilt switch can be used to activate alarms, controls, lights, or other equipment.

Tilt switches are useful components that are used to meet the needs of hundreds of different products and applications. The table below lists some examples of products and applications that use tilt switches.

Table A4.1: Tilt Switch Applications

Type of Application	Examples
Industrial	Processing equipment, conveyor controls, extruders, speed controls, foot pedals, coal level monitoring, construction vehicles, cranes, hoists, chutes, scissor lifts, static platforms, etc.
Agriculture	Tractors, conveyor controls, food processing, bins, silos, grain level monitoring, etc.
Marine	Rudder controls, deep sea manipulators, salt water platforms, ship & barge leveling etc.
Medical equipment	X-ray machines, MRI scanners, position controls, wheelchairs, etc.

Mercury Tilt Switches

Product Overview
Mercury tilt switches are typically comprised of small tubes with electrical contacts at one end of the tube. As the tube is raised, the mercury pools at the lower end, providing a conductive path to complete the switch circuit. When the switch is tilted back the circuit is then disconnected.

A mercury tilt switches has high reliability and long operational life because they have few components and are not subject to arcing. The results of life cycle testing have reported an operational life of over one million cycles. Mercury tilt switches can handle a high inductive load, and have a quiet operation. However, mercury in tilt switches is less desirable for many applications including the food and beverage industry. Also, there is a potential cost for removal of mercury switches at the end of life of the product, such as removal of trunk switches from automobiles.

The mercury content reported to IMERC by manufacturers as a range for mercury tilt switches was in the following three ranges: 50 – 100 milligrams, 100 – 1,000 milligrams, and greater than 1,000 milligrams. Some manufacturers reported exact amounts to IMERC, and these amounts varied from 0.05 to 5 grams per tilt switch. (NEWMOA, 2008)

Representative Manufacturers and Products
The following are representative manufacturers of mercury tilt switches.

Table A4.2: Representative Manufacturers of Mercury Tilt Switches

Manufacturer	Location	Website	Model	Pricing (USD)
American Terminal Supply Company Inc.	Wixom, Michigan, USA	www.american-terminal.com	AT-MS-4	$4 - $12 (SJ, Amazon)
Celduc Relais	Sorbiers, France	www.celducrelais.com	IB600099 Series	Not readily available.
Comus International	Tongeren, Belgium	www.comus-intl.com	Numerous models	Not readily available.
Well Buying Industrial Company	Taipei, Taiwan	www.wellbuying.com.tw	M5 Series	Not readily available.

Alternative 1: Potentiometer Tilt Switches

Product Overview
Potentiometers consist of a curved conductive track with a connection terminal at each end of the track. A moveable wiper is connected to a third terminal. As the shaft of the potentiometer is rotated, the length of the electrical path and resistance proportionally changes. Potentiometers can be used to detect linear motion, single turn rotation, or multiple turn rotation.

Potentiometers are inexpensive and reliable. Potentiometers have a long operational life, often greater than 20 million cycles. Potentiometers are also available in miniature size for space saving design requirements.

Representative Manufacturers and Products
The following are representative manufacturers of potentiometers.

Table A4.3: Representative Manufacturers of Potentiometers

Manufacturer	Location	Website	Model	Pricing (USD)
ETI Systems	Carlsbad, California, USA	www.etisystems.com	EUP and SP series	Not readily available.
Precision Electronic Components Ltd.	Weston, Ontario, Canada	www.precisionelectronics.com	R Series	Not readily available.
Taiwan Alpha Electronic Co, Ltd	Taoyuan, Taiwan	www.taiwanalpha.com	9 MM	$1 - $35, (Mouser)
Tokyo Cosmos Electric Co. Ltd.	Kanagawa, Japan	www.tocos.com	GF and RJC Series	Not readily available.
Vishay Intertechnology Inc.	Malvern, Pennsylvania, USA	www.vishay.com	P9 Series	$3 - $6, (Mouser)

Alternative 2: Metallic Ball Tilt Switches

Product Overview

A rolling metallic ball, typically made of steel, is used to make the actual electrical connection. The metallic ball moves based on the movement of the tilt switch housing, or can be moved by actuator magnets.

Metallic ball tilt switches are suited for applications subject to high levels of electromagnetic interference or high stress applications that require a robust switch. The metallic ball tilt switch can have a long life if it is only used for small rated loads. Metallic ball tilt switches are not suitable for applications that may experience significant levels of shock or vibration because it can cause false contacts due to bounce. Also, the metallic ball may become welded to the electrical contacts due to overheating or arcing. Another disadvantage of metallic ball tilt switches is that they cannot handle loads greater than two amps without experiencing arcing issues.

Representative Manufacturers and Products

The following are representative manufacturers of metallic ball tilt switches.

Table A4.4: Representative Manufacturers of Metallic Ball Tilt Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Assemtech Inc.	United Kingdom	www.assemtech-inc.com	THS-SP and DHS- SP series	Not readily available.
Comus International	Tongeren, Belgium	www.comus-intl.com	Numerous models	Not readily available.
Magnasphere Corporation	Waukesha, Wisconsin, USA	www.magnaspherecorp.com	NM Series	Not readily available.

Alternative 3: Electrolytic Tilt Switches

Product Overview
Electrolytic tilt switches contain electrodes and are filled with an electrically conductive fluid. As the switch tilts, the surface of the fluid remains level due to gravity. The conductivity between the electrodes is proportional to the length of electrode that is immersed in the fluid. Different electrolyte material can be used to vary conductivity and viscosity to meet different design parameters.

Electrolytic tilt switches provide excellent repeatability, stability, and accuracy. The switch is often designed for high accuracy tilt angle measurements over short angular ranges. Electrolytic tilt switches are rugged and can be used in environments of extreme temperature, humidity, and shock.

Representative Manufacturers and Products
The following are representative manufacturers of electrolytic tilt switches.

Table A4.5: Representative Manufacturers of Electrolytic Tilt Switches

Manufacturer	Location	Website	Model	Pricing
Fredericks Company	Huntingdon Valley, Pennsylvania, USA	www.frederickson.com	Series 07X	Not readily available.
Spectron Glass and Electronics Inc.	Hauppauge, New York, USA	www.spectronsensors.com	SP, AU, RG, CG, and SH series	Not readily available.

Alternative 4: Mechanical Tilt Switches

Product Overview
Mechanical tilt switches are snap or micro-switches that are actuated in a variety of methods. A common actuation method is that the lever arm is actuated by a metallic rolling ball. The ball changes position based upon gravity and the changing position of the switch housing.

Mechanical tilt switches have high reliability, long operational life, and can handle high inductive loads. Mechanical tilt switches are often rated to have an operational life in excess of one million cycles. Mechanical tilt switches require a small amount of pressure to actuate the switch action.

Representative Manufacturers and Products
The following are representative manufacturers of mechanical tilt switches.

Table A4.6: Representative Manufacturers of Mechanical Tilt Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Binmaster	Lincoln, Nebraska, USA	www.binmaster.com	BM-T Series	Not readily available.
Monitor Technologies LLC	Elburn, Illinois, USA	www.monitortech.com	TC Series	Not readily available.
Omron Corporation	Kyoto, Japan	www.omron.com	D7E-3	$5 - $11, (Digikey)

Alternative 5: Solid-State Tilt Switches

Product Overview
Solid-state tilt switches are often referred to as inclinometers or accelerometers depending upon the application. Solid-state tilt switches can use a Hall effect integrated circuit sensor, a highly stable silicon micro-machined capacitive inclination sensor element, force balance accelerometer technology, or inertial instrument torquers.

Solid-state tilt switches provide high resolution, accuracy, fast response, and maintain accuracy over a wide temperature range. Solid-state tilt switches have a long operational life, often greater than ten million cycles. The solid-state tilt switch can be used in strong vibration and shock environments.

Representative Manufacturers and Products
The following are representative manufacturers of solid-state tilt switches.

Table A4.7: Representative Manufacturers of Solid-state Tilt Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Jewell Instruments, LLC	LC Series	www.jewellinstruments.com	LC Series	Not readily available.
Omron Corporation	Kyoto, Japan	www.omron.com	D6BN Series	$2 - $4, (Digikey)

Alternative 6: Capacitive Tilt Switches

Product Overview

Capacitive tilt switches utilize a capacitive based sensor that produces output directly proportional to the relative tilt. The capacitive tilt switch sensor is typically two hermetically sealed capacitive domes containing high dielectric constant fluid that fills the space between the domes.

Capacitive tilt switches provide high accuracy, high long-term stability, and low power requirements. Capacitive tilt switches are suitable for applications requiring high measurement accuracy, and for measuring large inclination angles.

Representative Manufacturers and Products

The following are representative manufacturers of capacitive tilt switches.

Table A4.8: Representative Manufacturers of Capacitive Tilt Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Measurement Specialties Inc.	Hampton, Virginia, USA	www.schaevitz.com	Accustar II DAS Series	Not readily available.
Seika Kempten	Germany	www.seika.de	NG2, NG3, and NG4 Series	Not readily available.

Float Switches

Float switches are used for monitoring the level of various liquids. The types of liquids that can be monitored include: water, sewage, wet sludge, oil, chemicals, grease, and liquid nitrogen. Float switches can be used for monitoring liquid levels in tanks, wells, chambers, drillings, and other containers. Float switches are used to actuate alarm and control circuits to provide controlled responses to varying liquid levels. There are two basic types of operation for float switches. The first method is that a float switch can be located in a buoyant float housing and can be actuated based upon rising and falling liquid levels. The second method is that a float switch can be stationary and can be actuated by the presence or absence of liquid.

A float switch is a versatile component used to meet the needs of hundreds of different products and applications. A float switch can be incorporated into a product, such as bilge pump, or can be purchased as a component to be used in a customer specific application. The table below lists some examples of products and applications that use float switches.

Table A4.9: Float Switch Applications

Type of Application	Examples
Industrial/manufacturing	Processing liquids, waste treatment, air conditioners, semiconductor manufacturing, automatic plating machinery, etc.
Residential	Sump pumps, septic tanks, hot water heaters, automatic plumbing fixtures, etc.
Marine	Bilge pumps, shower pumps, ocean liner sewage disposal, balance tank on ships, etc.
Municipal	Pumping stations, waste water treatment, sewage plants, etc.

Mercury Float Switches

Product Overview

Mercury float switches are usually located inside a buoyant float housing and are actuated based upon the rising and falling liquid levels. Mercury float switches typically contain a small tube with electrical contacts at one end of the tube. As the tube rises, the mercury collects at the lower end, providing a conductive path to complete the circuit. When the switch lowers back, the circuit is then broken.

The advantage of mercury float switches is that they have high reliability and long operational life because they have few components and are not subject to arcing. Life-cycle testing has been reported for more than one million cycles. Mercury float switches can handle a high inductive load, and have quiet operation.

Mercury float switches require a swing area to properly operate. For applications in a tight location with limited space for a swing area, a magnet reed float switch may be a more appropriate selection. Since the mercury float switch contains mercury, a toxic chemical, it is becoming less desirable for many applications such as the food and beverage industry. The Nordic Council of Ministers report states that the price of non-mercury alternatives are approximately the same price as mercury containing float switches. (Maag, 2007)

The mercury content reported by manufacturers to IMERC as a range for float switches was either 100 to 1,000 milligrams per switch or greater than 1,000 milligrams per switch. Some manufacturers reported exact amounts to IMERC, and these amounts varied from 0.1 to 70 grams per float switch. The UNEP Toolkit provides an example from Denmark where mercury float switches can contain between 6.8 – 13.6 grams of mercury. (UNEP, 2005)

Representative Manufacturers and Products

The following are representative manufacturers of mercury float switches.

Table A4.10: Representative Manufacturers of Mercury Float Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Comus International	Tongeren, Belgium	www.comus-intl.com	Numerous models	Not readily available.
Conery Manufacturing Inc.	Ashland, OH, USA	www.conerymfg.com	2900 series	Not readily available.
Mercury Displacement Industries	Edwardsburg, Michigan, USA	www.mdius.com	A, B, C, D, and E series	Not readily available.
Zoeller Pump Co.	Louisville, Kentucky, USA	www.zoeller.com	10 Series	$90 - $95, (Dean)

Alternative 1: Mechanical Float Switches

Product Overview

Mechanical float switches are usually located in a buoyant float housing and are actuated based upon the rising and falling liquid levels. Mechanical switches can be a snap switch or micro-switch and are actuated using a variety of methods. A common actuation method is that the lever arm is actuated by a metallic rolling ball that changes position based upon gravity and the resultant position of the buoyant float housing.

Mechanical float switches have high reliability, long operational life, and can handle high inductive loads. Mechanical switches are often rated to have an operational life in excess of one million cycles. The mechanical float switch can use one float for both on and off functions. Mechanical float switches typically need a swing area to properly operate. However, this is not required for mechanical float switches that use magnets in a vertical stem to activate the micro-switch.

Representative Manufacturers and Products

The following are representative manufacturers of mechanical float switches.

Table A4.11: Representative Manufacturers of Mechanical Float Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Automation Products Group Inc.	Logan, Utah, USA	www.apgsensors.com	Ft-100 series	Not readily available.
Dwyer Instruments, Inc.	Michigan City, Illinois, USA	www.dwyer-inst.com	L8 series	$66, (Dwyer)
Kari-Finn Oy	Lahti, Finland	www.kari-finn.fi	Kari Float Switch Series	Not readily available.
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	NGS series	Not readily available.
Mercury Displacement Industries	Edwardsburg, Michigan, USA	www.mdius.com	G, H, K, N, and P series	Not readily available.
MJK Automation	Naerum, Denmark	www.mjk.com	7030 series	Not readily available.
Nivelco Process Control Co.	Budapest, Hungary	www.nivelco.com	Nivofloat and NivoMag series	Not readily available.
SOR	Lenex, Kansas, USA	www.sorinc.com	100, 1710, 200, and 300 series	Not readily available.

Alternative 2: Magnetic Dry Reed Float Switches

Product Overview
Magnetic reed switches are embedded in a vertical stem of the float switch device. Permanent magnets are mounted in the float housing that move vertically along the tubing or stem. The magnets activate the reed switches in the stem at pre-determined levels to enable control or alarm functionality.

The magnetic dry reed switch is desirable for use in small or narrow enclosures. Magnetic dry reed switches have a long operational life. A disadvantage of the magnetic dry reed switch is that it cannot handle a high inductive load, and therefore has a low contact rating. Also, the magnetic dry reed switch must be used in a clean environment, because debris collected on the stem will impair proper functioning.

Representative Manufacturers and Products
The following are representative manufacturers of magnetic dry reed switches.

Table A4.12: Representative Manufacturers of Magnetic Dry Reed Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Comus International	Tongeren, Belgium	www.comus-intl.com	Numerous models	Not readily available.
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	L10 series	$66, (Dwyer)
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	NC series	$18, $39 (Lesman)

Alternative 3: Optical Float Switches

Product Overview
Optical float switches utilize optical principles to detect the presence or absence of a liquid as compared with a gas such as air. The sensor in the optical float switch contains a small infrared light-emitting diode (LED) and a phototransistor light receiver to detect the presence of liquid.

Optical float switches are unaffected by liquid color or density. Further, optical float switches provide very slight hysteresis, high repeatability, and are highly chemical resistant.

Representative Manufacturers and Products
The following are representative manufacturers of optical float switches.

Table A4.13: Representative Manufacturers of Optical Float Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	OLS series	$70, (Dwyer)
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	OPT series	Not readily available.

Alternative 4: Conductivity Float Switches

Product Overview
Conductivity float switches utilize electrodes to measure conductivity in a liquid and can therefore sense the presence or absence of a liquid. Conductivity float switches rely on the conducting properties of liquids to complete an electrical circuit between electrodes, or between an electrode and the metal tank.

Conductivity float switches do not have any moving parts and are therefore very reliable, and they can be used in vessels with moving equipment that may damage other types of float switches. Conductivity float switches can also sense the presence of different types of liquids. For example, conductivity float switches can detect gas, oil, and diesel fuel in bilge water applications that can trigger an automatic shutdown of the pump. A disadvantage of the conductivity float switch is that it must be used in a conductive liquid for proper operation.

Representative Manufacturers and Products
The following are representative manufacturers of conductivity float switches.

Table A4.14: Representative Manufacturers of Conductivity Float Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	DPL110	$345, (Dwyer)
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	NES, NEK series	Not readily available.
Nivelco Process Control Co.	Budapest, Hungary	www.nivelco.com	NivoCont series	Not readily available.

Alternative 5: Sonic/Ultrasonic Float Switches

Product Overview
Sonic/ultrasonic float switches utilize a sensor that contains a piezoelectrical crystal. The crystal generates oscillations, allowing the liquid level to be measured by oscillation frequency. Sonic/ultrasonic float switches are highly accurate and can be used for non-conductive and highly viscous liquids. Also, the sonic/ultrasonic float switch sensor can be quickly removed for cleaning as required by the food, beverage, and pharmaceutical industries. A disadvantage of the sonic/ultrasonic switch is that it needs to be rigidly mounted for proper operation.

Representative Manufacturers and Products
The following are representative manufacturers of sonic/ultrasonic float switches.

Table A4.15: Representative Manufacturers of Sonic/Ultrasonic Float Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	MULS Series	$180 (Dwyer)
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	Numerous models	Not readily available.
MJK Automation	Naerum, Denmark	www.mjk.com	Numerous models	Not readily available.
Siemens	Munich, Germany	w1.siemens.com	ULS series	$700 (L172)
SOR Inc.	Lenex, Kansas, USA	www.sorinc.com	701 series	Not readily available.

Temperature Switches

Temperature switches convert a temperature change into an electrical switching function. Temperature switches use a temperature responsive sensor to actuate a mercury switch, solid state, micro-switch, or snap switch. Thermocouples, thermistors, integrated circuits, and resistance temperature detectors are examples of temperature sensors commonly used in temperature switches.

A temperature switch is a versatile component used to meet the needs of hundreds of temperature monitoring/control products and applications. A temperature switch can be incorporated into a product (e.g. food warming trays, hot water boilers, etc.), or can be purchased as a component to be used in a customer specific application (e.g. plastics injection molding process). Other examples of products and applications that use temperature switches include: refrigerating equipment, ventilating equipment, alarm systems, generators, conveyors, motors, presses, mixers, appliances, and vending machines.

Mercury Temperature Switches

Product Overview

Temperature switches use a temperature-responsive sensor to actuate a mercury switch. The temperature-responsive sensor used is typically either a thermocouple, resistance temperature detector (RTD), or gas actuated bourdon tube.

Mercury temperature switches have high reliability and long operational life because they have few components and are not subject to arcing. Life cycle testing has been reported for more than one million cycles. A mercury temperature switch can handle a high inductive load, and has a quiet operation. However, a mercury temperature switch contains mercury, which is less desirable for many applications including the food and beverage industry. The mercury content reported by manufacturers to IMERC for temperature switches was in the range of greater than 1,000 milligrams.

Representative Manufacturers and Products

The following table lists a representative manufacturer of mercury temperature switches.

Table A4.16: Representative Manufacturers of Mercury Temperature Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	M51 Series	$258, (Dwyer)

Alternative 1: Mechanical Temperature Switches

Product Overview
Mechanical temperature switches use a temperature-responsive sensor to actuate a mechanical switch. Mechanical temperature switches use temperature-responsive sensors such as thermocouples, bulb and capillaries, resistance temperature detectors, welded alloys, or gas actuated bourdon tubes.

Mechanical temperature switches have high reliability, long operational life, and can handle high inductive loads. The reliability and accuracy of a mechanical temperature switch is largely dependent on the type of sensor used. The mechanical temperature switch provides functionality similar to the mercury temperature switch.

Representative Manufacturers and Products
The following are representative manufacturers of mechanical temperature switches.

Table A4.17: Representative Manufacturers of Mechanical Temperature Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	DA7035	$345, (Dwyer)
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	TBS Series	Not readily available.
SOR Inc.	Lenex, Kansas, USA	www.sorinc.com	NN and RN Series	Not readily available.
United Electric Controls	Watertown, Massachusetts, USA	www.ueonline.com	100 Series	Not readily available.

Alternative 2: Solid-State Temperature Switches

Product Overview
Solid-state temperature switches use temperature coefficient thermistors, resistance temperature detectors, or integrated circuits to sense temperature. A semiconductor is used for the switching output. Solid-state temperature switches provide improved accuracy, repeatability, and reliability as compared with mechanical or mercury temperature switches. Solid-state temperature switches operate with low power consumption. Solid-state temperature switches usually have a higher initial cost than mechanical or mercury temperature switches.

Representative Manufacturers and Products
The following are representative manufacturers of solid-state temperature switches.

Table A4.18: Representative Manufacturers of Solid-state Temperature Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	TDD Series	Not readily available.
United Electric Controls	Watertown, Massachusetts, USA	www.ueonline.com	One Series	Not readily available.

Pressure Switches

Pressure switches convert a pressure change into an electrical switching function. The pressure change can be measured as pressure, vacuum, or differential between two pressure inputs. Pressure switches use a sensor responsive to pressure to actuate a mechanical switch, mercury switch, or transistor. Diaphragms, pistons, bellows, and flex circuits are examples of pressure responsive sensors used in pressure switches.

A pressure switch is a versatile component used to meet the needs of hundreds of pressure monitoring/control products and applications. For example, pressure switches can be used in various heating, ventilation, air conditioning, industrial, medical, automotive, appliance, and safety applications.

Mercury Pressure Switches

Product Overview

Mercury pressure switches often use a pressure sensitive sensor such as a piston, diaphragm, or bellows to actuate the mercury switch. Mercury pressure switches offer high reliability and long operational life because they have few components and are not subject to arcing. Life cycle testing has been reported for more than one million cycles. Mercury float switches can handle a high inductive load, and have quiet operation. The mercury pressure switch contains mercury, a toxic material, which is less desirable for many applications including the food and beverage industry. The Nordic Council of Ministers report states that the price of non-mercury alternatives are approximately the same price as mercury containing pressure switches. (Maag, 2007) The mercury content reported by manufacturers to IMERC for pressure switches was in the range of greater than 1,000 milligrams. (NEWMOA, 2008)

Representative Manufacturers and Products

The following is a representative manufacturer of mercury pressure switches.

Table A4.19: Representative Manufacturers of Mercury Pressure Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	DA31	$212, (Dwyer)

Alternative 1: Mechanical Pressure Switches

Product Overview
Mechanical pressure switches use a piston, diaphragm, or bellows as the pressure sensitive sensor. The mechanical pressure switch is either directly actuated; or a pushrod, lever, or compression spring can be used to actuate a snap-acting micro-switch.

Mechanical pressure switches have high reliability, and a long operational life. Mechanical pressure switches can provide high accuracy when used with a diaphragm type pressure sensor. These switches can also provide good resistance to shock and vibration when they use a diaphragm and a negative rate Belleville spring.

Representative Manufacturers and Products
The following are representative manufacturers of mechanical pressure switches.

Table A4.20: Representative Manufacturers of Mechanical Pressure Switches

Manufacturer	Location	Website	Model	Pricing (USD)
Dwyer Instruments, Inc.	Michigan City, IL, USA	www.dwyer-inst.com	DA7031	$199, (Dwyer)
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	KPH Series	Not readily available.
Schneider Electric (Square D)	Cedex, France	www.schneider-electric.com	9013 Series	$57 - $315 (Schneider)
Tecmor Corporation	Mentor, Ohio, USA	www.tecmarkcorp.com	Series 3000P	Not readily available.
United Electric Controls	Watertown, Massachusetts, USA	www.ueonline.com	100 Series	Not readily available.

Alternative 2: Solid-State Pressure Switches

Product Overview
Solid-state pressure switches contain one or more strain gauge pressure sensors, a transmitter, and one or more switches. In addition to actuating the pressure switch circuit, they can provide a proportional analog or digital output. The pressure sensors used are often diffused silicon piezoresistive sensors or thin-film strain gauges. A microprocessor is used to process the strain gauge sensor information and actuate the switching element which is typically a transistor. Solid-state pressure sensors can be provided with a built-in keypad and display to simplify setup and ongoing field adjustments.

Solid-state pressure switches provide a higher degree of accuracy than mechanical switches. They can achieve long life at rated loads that can often be ten million cycles or greater. Solid-state pressure switches can also provide a wide range of set-point and dead-band adjustment. However, they are usually restricted to low-level direct current voltage applications. High temperatures or transient pressure spikes can cause damage to a solid-state pressure sensor.

Representative Manufacturers and Products
The following are representative manufacturers of solid-state pressure switches.

Table A4.21: Representative Manufacturers of Solid-state Pressure Switches

Manufacturer	Location	Website	Model	Pricing
Kobold Messring GmbH	Taunus, Germany	www.kobold.com	PDD Series	Not readily available.
Schneider Electric (Square D)	Cedex, France	www.schneider-electric.com	XMLE Series	$362 -$460 (Schneider)
SOR Inc.	Lenex, Kansas, USA	www.sorinc.com	SGT Series	Not readily available.
United Electric Controls	Watertown, Massachusetts, USA	www.ueonline.com	One Series	Not readily available.

A.4.b Relays

Relays are electrically controlled devices that open or close electrical contacts to effect the operation of other devices in the same or another electrical circuit. Relays are often used to switch large current loads by supplying relatively small current loads to a control circuit. Relays are versatile devices used to meet the needs of hundreds of varied products and applications. Relays can be incorporated into a product, or can be purchased as a component to be used in a customer specific application. The table below lists some examples of products and applications that use relays.

Table A4.22: Relay Applications

Type of Application	Examples
Industrial	Cable testers, circuit testing, injection molding machines, kilns, ink heating, vacuum forming, soldering systems, semiconductor processing, programmable logic controllers, etc.
Aerospace	Master power switches, motor control switching, heavy current load switching, instrument panel, generator switching, alternator power switching, antenna changeover, channel selection, etc.
Food & Beverage	Food processing, deep fryers, pizza ovens, baking ovens, electric grills, dishwashers, etc.
Healthcare	Surgical equipment, X-ray machine control, energy management systems, surgical lighting, etc.
Telecommunications	Trunk switching, test panels, telecomm circuit boards, load switches, radio base stations, ground start, input/output cards, control panel exchanges, antenna switches, loop current test, etc.

Mercury Displacement Relays

Product Overview

Mercury displacement relays use a metallic plunger device to displace mercury. The plunger is lighter than mercury and floats on top of the mercury. The plunger also contains a magnetic shell that can be pulled down into the mercury with a magnetic field. Mercury displacement relays are

often used in high current, high voltage applications such as industrial process controllers and power supply switching.

Mercury displacement relays can cycle faster than a mechanical relay, and have low contact resistance. They have quiet operation and have long life because they contain only one moving part. They last on average between one and ten million cycles. Mercury displacement relays need to be mounted in a specific orientation to function properly. Mercury displacement relays can burst, causing a hazardous waste problem, if the relay is overheated due to rapid cycling or if the load is short-circuited. The Nordic Council of Ministers report states that the price of non-mercury alternatives are approximately the same price as mercury displacement relays. (Maag, 2007)

The amount of mercury in mercury displacement relays can vary greatly based on the number of poles, current rating, termination requirements, and other factors. The mercury content reported by manufacturers to IMERC for mercury displacement relays was in the range of greater than 1,000 milligrams. (NEWMOA, 2008) The UNEP Toolkit provides an example from Canada where mercury displacement relays can contain up to 400 grams of mercury. (UNEP, 2005)

Representative Manufacturers and Products
The following are representative manufacturers of mercury displacement relays.

Table A4.23: Representative Manufacturers of Mercury Displacement Relays

Manufacturer	Location	Website	Model	Pricing (USD)
American Electronic Components, Inc.	Elkhart, Indiana, USA	www.aecsensors.com	DURA Series	$44 - $82, (MOR)
Chromalox	Pittsburgh, Pennsylvania, USA	www.chromalox.com	HGR Series	Not readily available.
Mercury Displacement Industries Inc.	Edwardsburg, Michigan, USA	www.mdius.com	Numerous models	Not readily available.
Tempco Electric Heater Corporation	Wood Dale, Illinois, USA	www.tempco.com	RLY Series	$34 - $362, (Tempco)

Mercury Wetted Reed Relay

Product Overview
Mercury wetted reed relays are a type of electro-mechanical relay that employs a hermetically sealed reed switch. They are comprised of a glass encapsulated reed with its base immersed in a pool of mercury and the other end capable of moving between two sets of contacts. Mercury flows up the reed by capillary action and wets the contact surface of the reed and the stationary contacts. Wetted mercury reed relays are typically small circuit controls used in electronic devices for switching or signal routing functions. Reed relays are often used in test, calibration, and measurement equipment applications.

Magnetic reed relays offer a life span in excess of one billion operations. They operate in the millisecond range, which is slower than solid-state relays, but sufficiently faster than other electro-mechanical relays and therefore can be used in high-speed switching applications. Mercury wetted reed relays offer the following advantages over a dry reed relay: no contact bounce, longer life, and lower contact resistance. The Nordic Council of Ministers report states that the price of non-

mercury alternatives are approximately the same price as mercury wetted reed relays. (Maag, 2007)

The mercury content reported by manufacturers to IMERC for mercury wetted reed relays was in the following four ranges: 10 – 50 milligrams, 50 – 100 milligrams, 100 – 1,000 milligrams, and greater than 1,000 milligrams. The UNEP Toolkit provides an example from Denmark where mercury relays used for electronics can contain between 0.001 and 0.01 grams of mercury per relay. (UNEP, 2005)

Representative Manufacturers and Products
The following are representative manufacturers of mercury wetted reed relays.

Table A4.24: Representative Manufacturers of Mercury Wetted Reed Relays

Manufacturer	Location	Website	Model	Pricing (USD)
American Relays, Inc.	S.F. Springs, California, USA	www.americanrelays.com	Numerous open frame and axial models	Not readily available.
Computer Components, Inc.	East Granby, Connecticut, USA	www.relays-unlimited.com	Numerous models	Not readily available.

Alternative 1: Dry Magnetic Reed Relays

Product Overview
Dry magnetic reed relays consist of a pair of flattened reeds that are hermetically sealed into a glass tube with a controlled atmosphere. They are typically small circuit controls that are used on printed wiring boards. Dry magnetic reed relays are primarily used in test, calibration, and measurement equipment applications.

Dry magnetic reed relays have long operational life, fast cycling time, and can be mounted in any position for proper operation. They experience similar effects from electromagnetic interference as the mercury wetted reed relay, and exposure to high voltage may cause the contacts to weld together. However, dry magnetic reed relays have a shorter operational life than mercury wetted reed relays.

Representative Manufacturers and Products
The following are representative manufacturers of dry magnetic reed relays.

Table A4.25: Representative Manufacturers of Dry Magnetic Reed Relays

Manufacturer	Location	Website	Model	Pricing (USD)
American Relays, Inc.	S.F. Springs, California, USA	www.americanrelays.com	Numerous models	Not readily available.
Celduc Relais	Sorbiers, France	www.celducrelais.com	D31, D32, and D71 series	Not readily available.
Computer Components, Inc.	East Granby, Connecticut, USA	www.relays-unlimited.com	Numerous models	Not readily available.
Magnecraft	Northfield, Illinois, USA	www.magnecraft.com	528 Series	$2 - $35, (Mouser)

Manufacturer	Location	Website	Model	Pricing (USD)
Meder Electronic, Inc.	Wareham, Massachusetts, USA	www.meder.com	Numerous models	Not readily available.
NTE Electronics, Inc.	Bloomfield, New Jersey, USA	www.nteinc.com	R42, R44, R56, and R57 Series	Not readily available.

Alternative 2: Other Electro-Mechanical Relays

Product Overview

There are several classifications of electro-mechanical relays including mercury displacement, mercury wetted reed, and dry reed. This section focuses on other electro-mechanical relays that include general purpose, definite purpose, heavy duty, and printed circuit board mounted relays. These electromechanical relays are driven electro-magnetically, by passing a current through a coil and generating a magnetic flux. The magnetic flux then causes an armature to move to open and close electrical contacts.

Other electro-mechanical relays are often selected because of their low initial cost, when electrical interference is likely to be present, or when low heat dissipation is required. Other electro-mechanical relays will typically wear out within several hundreds of thousands of cycles. This is a shorter operational life than for mercury or solid-state relays. Other electro-mechanical relays also have a slow cycle time and provide limited control of equipment.

Representative Manufacturers and Products

The following are representative manufacturers of other electro-mechanical relays.

Table A4.26: Representative Manufacturers of Electro-mechanical Relays

Manufacturer	Location	Website	Model	Pricing (USD)
Carlo Gavazzi	Steinhausen, Switzerland	www.carlogavazzi.com	RCP Series	Not readily available.
Chromalox	Pittsburgh, Pennsylvania, USA	www.chromalox.com	CONT Series	Not readily available.
Hongfa	Jimei, China	www.hongfa.com	HF Series	Not readily available.
IDEC	Osaka, Japan	www.idec.com	RY2S	$9, (Newark)
Omron Electronics	Kyoto, Japan	www.omron.com	MY2IN	$7 (Drillspot)
Tyco Electronics (Potter & Brumfield)	Berwyn, Pennsylvania, USA	www.tycoelectronics.com	KRP	$46, (Newark)

Alternative 3: Solid-State Relays

Product Overview

Solid-state relays are semiconductor-based, electronic switching devices that operate a load circuit without the use of physical mechanical contacts. Solid-state relays contain an input circuit, an opto-coupler chip, and an output circuit. They provide very long operational life, immunity to electromagnetic interference, low power consumption, high operating speeds, low level control signals, small package size, and multi function integration. The solid-state relay is also more immune to physical shock, vibration, and damage.

Some solid state relays use silicon controlled rectifier as a switch that can rapidly turn power on or off in a variety of applications. Silicon controlled rectifiers consist of four layers of semiconductor material. Silicon controlled rectifiers are an extremely fast switch that can be cycled in milliseconds. Silicon controlled rectifiers provide improved response time, closer process control, and extended life of controlled equipment.

Representative Manufacturers and Products

The following are representative manufacturers of solid-state relays.

Table A4.27: Representative Manufacturers of Solid-state Relays

Manufacturer	Location	Website	Model	Pricing (USD)
Carlo Gavazzi	Steinhausen, Switzerland	www.carlogavazzi.com	RHS, RP, RX, RS, and RD Series	Not readily available.
Celduc Relais	Sorbiers, France	www.celducrelais.com	SC, SLA, SPA, XK, and SK Series	Not readily available.
Chromalox	Pittsburgh, Pennsylvania, USA	www.chromalox.com	SSR Series	Not readily available.
Comus	Tongeren, Belgium	www.comus-intl.com	WG Series	Not readily available.
Crouzet Automatismes	Valence, France	www.crouzet.com	GNR Series	$40 - $155, (Mouser)
Crydom SSR Ltd.	Dorset, United Kingdom	www.crydom.com	CMX Series	$20 - $27, (Mouser)
Hongfa	Jimei, China	www.hongfa.com	HFS Series	
Magnecraft	Northfield, Illinois, USA	www.magnecraft.com	W, Series	$17 - $61, (Mouser)
Mercury Displacement Industries	Edwardsburg, Michigan, USA	www.mdius.com	SS20AE	$30, (MDI)
NTE Electronics, Inc.	Bloomfield, New Jersey, USA	www.nteinc.com	RS Series	Not readily available.
Omron	Kyoto, Japan	www.omron.com	G3M Series	$3 - $9, (Mouser)
Temp Inc.	Fairmont, West Virginia, USA	www.temp-inc.com	SE Series	$21 - $96, (Temp)

Alternative 4: Hybrid Relay (Electro-mechanical and Solid-State)

Product Overview
Hybrid relays combine electromechanical and solid-state relay technologies. The switching of hybrid relays is controlled by a microprocessor, and utilizes both solid-state elements and electromechanical relay contacts. Hybrid power relays are designed to cycle power on and off for a variety of applications including heating, ventilation, air conditioning and lighting.

Hybrid relays eliminate the internal heating caused by current flow through electronic power components. This feature eliminates the need for integrated heat sinks and also reduces the physical size of the relay. Hybrid relays provide a long operation life, often greater than five million cycles. They also have a virtually silent operation, enabling the relay to be used in noise-sensitive areas.

Representative Manufacturers and Products
The following are representative manufacturers of hybrid relays.

Table A4.28: Representative Manufacturers of Hybrid Relays

Manufacturer	Location	Website	Model	Pricing (USD)
Crouzet Automatismes	Valence, France	www.crouzet.com	RHP	$47, (Newark)
Watlow Electronic Manufacturing	St. Louis, Missouri, USA	www.watlow.com	E-Safe Relay	Not readily available.

Demand and Use of Mercury

The following table contains the mercury use data for electrical and electronic devices provided by countries in their responses to the UNEP Request for Information (RFI) or other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT). Ten countries provided estimated mercury demand information for electrical and electronic devices. The range of responses was 0 to 46.9 metric tons of mercury per year, with four countries reporting no mercury demand for electrical and electronic devices.

Table A4.29: Mercury Demand for Electrical and Electronic Devices (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
United States	RFI	46.9 (2004)
Philippines	MIT	11.97 (1.77 – 22.17)
Chile	MIT	2.196 (0.325 - 4.067)
United Kingdom	RFI	1 (2005)
Canada	Other	0.772
Slovenia	RFI	0.0022 (< 0.001 – 0.004)
Japan	RFI	0
Netherlands	RFI	0
Norway	RFI	0
Sweden	RFI	0

The reported levels of mercury demand per capita fall within the following three distinct groups:

1. The United States reported the highest level of mercury demand per capita of 0.155 grams of mercury per person per year. This could be attributed to the manufacture of mercury switches and relays within the United States. Representative manufacturers from the United States that produce mercury containing tilt switches, float switches, temperature switches, pressure switches, displacement relays, and wetted relays were identified.
2. The Philippines and Chile reported the second and third highest levels of mercury demand per capita of 0.135 and 0.132 grams of mercury per person per year, respectively. These high levels could be attributed to the assumptions made while using the Mercury Inventory Toolkit. The calculations used to derive these estimates are provided below.
3. The remaining eight countries reported of mercury demand per capita of equal to or less than 0.023.

The Mercury Inventory Toolkit recommends collecting actual data on mercury levels in the particular switches and relays in use. However, if this information is not available then the following default mercury input factor range can be used to estimate use for all electrical switches and relays:

Input factor: 0.02 – 0.25 grams mercury per inhabitant per year.

Chile used the above input factor and multiplied it by 16,267,278 inhabitants. The Philippines also used the above input factor and multiplied it by 88,700,000 inhabitants.

A report prepared by the Northeast Waste Management Officials' Association (NEWMOA) provides a breakdown of various electrical and electronic devices sold in the United States in 2004. This information provides insight into the relative quantities of mercury used for products within the electrical and electronic devices category for the United States only. The results are provided in the following table. (NEWMOA, 2008)

Table A4.30: Mercury Sold in Electrical and Electronic Devices in U.S. (2004)

Product Category	Mercury Sold in U.S. (Metric Tons)	Percentage of all Measuring and Control Devices
Relays	16.91	36.4%
Tilt switches	3.25	7.0%
Float switches	6.31	13.6%
Other switches (e.g. reed switches, vibration switches, flame sensors)	19.97	43.0%
Total	46.44	100.0%

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries on their experiences with the technology changeover or alternatives associated with substituting mercury electrical and electronic devices with available alternatives. The information contained in the tables is derived from the

responses to the UNEP Request for Information (RFI), Mercury Inventory Toolkit (MIT), or other source of information. In some cases, the tables contain an abbreviated or revised version of the response included in the RFI.

Table A4.31: Countries Responding with a Level of Substitution of "2"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" Substitutes Available and Commonly Used
Denmark	RFI	Denmark has not experienced any problems in relation to the introduction of the ban. The first version of the Order was introduced in 1998.
Iran	RFI	A level of 1 – 2 was reported for switches and relays. Switches and electronic pieces of worn out automobiles are recycled.
Japan	RFI	No experience data provided for this rating.
Netherlands	RFI	Positive experience, since 1998 it was prohibited to bring mercury containing products onto the market. Now this is prohibited through EU ROHS directive.
Norway	RFI	Norway has a general ban on the use of mercury in products from January 2008.
Slovenia	RFI	Mercury containing switches and relays are not produced in Slovenia.
Sweden	RFI	According to the EU RoHS Directive on hazardous substances in electrical and electronic equipment, electrical and electronic equipment placed on the EU market may not contain mercury. Positive experience with technology change-over. These products were covered by the national ban since 1993. No indication of any economic problems when implementing it.
Switzerland	RFI	Mercury banned, only permitted in monitoring and control instruments and medical devices used in laboratories.

Table A4.32: Countries Responding with a Level of Substitution of "1"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "1" Substitutes Available and Minimally Used
Chile	RFI	Negative experience. The alternatives have not been diffused, and there is a higher cost of alternatives without mercury.

Table A4.33: Countries Responding with a Level of Substitution of "0"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "0" No Available Substitutes
Panama	RFI	No experience data provided for this rating.

Table A4.34: Countries with No Response for Level of Substitution

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Canada	Other	Alternatives for mercury-containing switches and relays vary in relative cost and performance, however viable replacements can be found for most applications.
United States	RFI	Positive experience. Alternative switches and relays are reliable and reasonable in cost. Some states have banned the sales of mercury switches and relays.

Seven countries reported a substitution level of "2", and one country, Iran, provided a level of substitution of "1 – 2" for electrical and electronic devices. Six of the seven countries that reported a substitution level of "2" are from Europe. Three of these countries (Denmark, Netherlands, and Sweden) had implemented bans for electrical and electronic devices in the 1990s. Also, in February 2003 the Restriction on the use of certain Hazardous Substances (RoHS) Directive was enacted in Europe (Directive 2002/95/EC) that restricted the use of mercury and five other hazardous materials in electrical and electronic equipment. This directive covers electrical and electronic equipment placed on the market beginning July 1, 2006. This directive is a further driver for reducing mercury in electrical and electronic devices sold in Europe.

Chile was the only country that reported a substitution level of "1" for electrical and electronic devices. Chile reported that there was a higher cost associated with the non-mercury alternatives.

Summary – Electrical and Electronic Devices

The following table shows a quantitative breakdown for the RFI responses received from ten countries for the level of substitution for electrical and electronic devices.

Table A4.35: Country Responses for Level of Substitution

Level of Substitution	Number of Country Responses	Percentage of Responses
2	7	70%
1 - 2	1	10%
1	1	10%
0	1	10%

Greater than 50% of RFI responses for electrical and electronic devices were for a substitution level of "2", and did not report any negative experiences with the transition to non-mercury alternatives. This indicates that substitutes are available and commonly used in the majority of countries that provided mercury demand information. Also, more than two countries reported estimated mercury demand of zero. Therefore, alternative technologies were identified and transition success to mercury-free alternatives was achieved for electrical and electronic devices in these countries.

Table A4.36: Electrical and Electronic Device Substitution Summary

Electrical and Electronic Device	Alternative Technologies Identified	Transition Feasibility
Tilt switch	Yes	Transition success demonstrated
Float switch	Yes	Transition success demonstrated
Temperature switch	Yes	Transition success demonstrated
Pressure switch	Yes	Transition success demonstrated
Displacement relay	Yes	Transition success demonstrated
Wetted reed relay	Yes	Transition success demonstrated

A.5 Lamps/Lighting

One of the unique properties of mercury is that light can be produced by passing an electrical current through mercury vapor. This efficient method of producing light is used in a variety of lamps including fluorescent lamps, high-intensity discharge (HID) lamps, and some neon lamps. These mercury-containing lamps are used in a wide variety of applications including: residential, commercial and industrial lighting; outdoor lighting and street lamps; automobile headlamps; and backlighting for liquid crystal displays (LCDs).

Linear Fluorescent Lamps

Product Overview
Linear fluorescent lamps utilize phosphor-lined glass tubes containing mercury vapor with electrodes at either end. An electrical current is passed through the mercury vapor, which excites the mercury atoms causing them to give off ultraviolet light. The ultraviolet light then causes the phosphor to fluoresce, producing visible light.

Linear fluorescent lamps are available in various lengths, diameters and levels of light output. The lamps can be straight, circular or U-shaped. They are used for general illumination and for special applications such as tanning lamps, black lights, and germicidal lamps. They are available in a variety of color temperatures including: warm white, cool white, and daylight white. This section focuses on straight linear fluorescent lamps and the mercury-free alternatives used for general illumination.

The primary advantages of linear fluorescent lamps are that they are more efficient than other lamp technologies, which means that for a given amount of energy input, they produce more usable light and less heat. Fluorescent lamps have a longer service life than incandescent lamps. Typical fluorescent lamps have an average life of 10,000 to 20,000 hours while the life of a typical incandescent lamp is only 750 to 1,500 hours.

Linear fluorescent lamps have several disadvantages. They contain mercury and therefore should be recycled and special care should be taken when cleaning up broken lamps. Fluorescent lamps sometimes produce a light that flickers and the light quality is not suitable for all applications. Fluorescent lamps have reduced light output in cold temperatures. Linear fluorescent lamps are not dimmable and frequent switching will shorten their life.

The mercury content reported by manufacturers to the Interstate Mercury Education & Reduction Clearinghouse (IMERC) for fluorescent lamps was in one of the following five ranges: greater than 0 to 5 milligrams, greater than 5 to 10 milligrams, 10 to 50 milligrams, 50 to 100 milligrams, and 50 to 100 milligrams per lamp. A 2008 Northeast Waste Management Officials Association (NEWMOA) report states that the average mercury content of a 4 foot lamp was 8 milligrams in 2001. The mercury content of specialty lamps is at least fifty percent more than that of equivalent sized general illumination lamps.

A 2007 Natural Resources Defense Council (NRDC) report on the use of mercury in China's lighting industry estimated that the production of straight fluorescent tube lamps consumed an average of 40 milligrams of mercury per lamp in 2005. (NRDC, 2007)

Representative Manufacturers and Products
The following are representative manufacturers of linear fluorescent lamps.

Table A5.1: Representative Manufacturers of Linear Fluorescent Lamps

Manufacturer	Location	Website	Model	Pricing (USD)
General Electric Company	Connecticut, U.S.A.	www.ge.com	14811 F40SPX41/RS/WM 34 Watt, 48 inch, T12 Cool White, Medium Bi-pin Base, Life: 20000 Hours.	$5.69 (lightingonthe net. com)
Osram GmbH	Munich, Germany	www.osram.com	24588 F40CW/SS 34 Watt, 48 inch, T12 Cool White, Medium Bi-pin Base, Life: 20000 Hours.	$5.69 (lightingonthe net. com)
Royal Philips Electronics	Netherlands	www.philips.com	F34T12/841/EW/ALTO 34 Watt, 48 inch, T12 Cool White, Medium Bi-pin Base.	$3.49 (bulbs.com)

Alternative 1: Linear LED Lamps

Product Overview

Linear light-emitting diode (LED) lamps are a relatively new lighting option that uses LED technology as a drop-in replacement for linear fluorescent lamps. LED's are solid state semiconductor devices that emit light when electricity is passed through them. The linear LED lamps utilize a series of LEDs arranged in a tube, which is the same size as the equivalent linear fluorescent lamp.

There are several advantages that linear LED lamps have over linear fluorescent lamps. They do not contain mercury and therefore do not require special end-of-life treatment. The lamps have a durable construction and do not contain fragile glass like the fluorescent lamps or fragile filaments like incandescent lamps. They can be used in cold temperatures without a decrease in light output. The light from LEDs does not flicker like the light from some fluorescent lamps. Linear LED lamps are available in a range of color temperatures, from warm white to daylight white.

Manufacturers of linear LED lamps state that their products are 10-20% more efficient than equivalent fluorescent lamps and they expect the efficiency to improve significantly over the next five years. LEDs are available with additional energy savings or convenience features including built-in motion sensing, remote control, adjustable color temperature, and technology that reduces light output when ambient natural light levels increase. The long life of LEDs translates into a lamp life of 50,000 hours or more. The life is not shortened by frequent on-and-off switching.

The primary disadvantages of linear LED lamps are that they are a new, unproven technology, they have limited availability, and they have a high cost. The lamps are available in a limited number of sizes including 2-, 3- and 4-foot lengths. Online retailers listed 2-foot lamps for $47.60 (LED Liquidators, 2008) and 4-foot lamps for $92.00 (EdisonLED, 2008). These online retailers did not list the manufacturers of these lamps so this information was not included in the following Representative Manufacturers and Products table.

Representative Manufacturers and Products

The following are representative manufacturers of linear LED lamps.

Table A5.2: Representative Manufacturers of Linear LED Lamps

Manufacturer	Location	Website	Model	Pricing (USD)
AlbEO Technologies, Inc.	Boulder, Colorado, U.S.A.	www.albeotech.com	T8LED Troffer Retrofit Kit	Not readily available.
Ilumisys, Inc.	Troy, Michigan, U.S.A.	www.ilumisys.com	MK1 Fluorescent Tube Replacement	Not readily available.
LEDdynamics, Inc.	Randolph, Vermont, U.S.A.	www.EverLED.com	Ever-LED TR, E25T8-48-S2, 48 inch, Warm White	$149.00 (LED dynamics)
Shenzhen Dicolor Optoelectronics Co. Ltd.	Shenzhen, China	www.dicolor.cn	LED Replacement Tube Light (T8 Socket, 2400LM)	Not readily available.

Compact Fluorescent Lamps

Product Overview

Compact fluorescent lamps (CFLs) produce light using the same technology as the linear fluorescent lamps described above. The difference is that CFLs are designed to be drop-in replacements for incandescent lamps and therefore approximate the size and shape of incandescent light bulbs. This is achieved by configuring the glass tubes in a spiral or folded configuration. Many CFLs utilize a screw base (i.e., Edison base) and integrate the ballast into the base of the lamp.

Compact fluorescent lamps are available in many of the same configurations as incandescent lamps including: twist shapes to replace standard incandescent bulbs; decorative globe and candelabra shapes; and, reflector configurations for spotlights and floodlights. Some models are designed for outdoor use or for use with dimming switches.

CFLs have many of the same advantages as linear fluorescent lamps. They use approximately 75 percent less energy than equivalent incandescent lamps and they generate significantly less heat than incandescent or halogen lamps. CFLs last up to thirteen times longer than incandescent lamps. (General Electric, 2008)

CFLs have several disadvantages. They contain mercury and therefore should be recycled and special care should be taken when cleaning up broken lamps. The life of CFLs is reduced when the lamps are subject to frequent on and off switching. GE Lighting recommends leaving CFLs on for a minimum of fifteen minutes before turning them off. Fluorescent lamps sometimes produce a light that flickers and the light quality is not suitable for all applications. Fluorescent lamps have reduced light output in cold temperatures. Many CFLs are not compatible with dimmer switches, electronic timers, photocells or motion detectors. CFLs should not be used in locations subject to vibration, high humidity or extreme temperatures.

The mercury content reported by manufacturers to IMERC for compact fluorescent lamps ranged from greater than 0 up to 50 milligrams per lamp. A 2006 NEWMOA report states that sixty-six percent of CFLs sold by National Electrical Manufacturers Association (NEMA) member companies in 2004 had between 0 and 5 milligrams of mercury per lamp. Ninety-six percent of CFLs had ten milligrams or less. (NEWMOA, 2006)

A 2007 NRDC report on the use of mercury in China's lighting industry estimated that the production of compact fluorescent lamps consumed an average of 8 milligrams of mercury per lamp in 2005. (NRDC, 2007)

Representative Manufacturers and Products
The following are representative manufacturers of compact fluorescent lamps.

Table A5.3: Representative Manufacturers of Compact Fluorescent Lamps

Manufacturer	Location	Website	Model	Pricing (USD)
General Electric Company	Connecticut, U.S.A.	www.ge.com	13 Watt Energy Smart Soft White Spiral T3 Light Bulb	$12.88 Package of 3 (Amazon.com)
			R-30 Flood, 15 Watt, 120 Volt, Dimmable, Life: 6,000 Hours, 60W Incandescent Equivalent	$13.50 (Energy Federation, Inc.)
Osram GmbH	Munich, Germany	www.osram.com	CF13ELMTWSTCVP 13 Watt, 120 Volt, Warm White, Medium Base CFL	$21.22 Package of 12 (Amazon.com)
			BR30 Reflector Flood, 15 Watt, 120 Volt, Dimmable, Life: 6,000 Hours, 65W Incandescent Equivalent	$19.75 (Energy Federation, Inc.)
Royal Philips Electronics	Netherlands	www.philips.com	El/MDT 18W 18 Watt, 120 Volt, Warm White CFL Bulb, 75W Incandescent Equivalent, Energy Star Approved	$5.49 (bulbs.com)
			R40 Dimmable Marathon Flood, 20 Watt, 120 Volt, Life: 8,000 Hours	$17.75 (Energy Federation, Inc.)

Alternative 1: Incandescent Lamps

Product Overview
Light is produced by an incandescent bulb when an electric current passes through a thin tungsten filament, heating it until it incandesces. Incandescent lamps are viewed as being old technology and are significantly less efficient than fluorescent lamps and LEDs. Approximately 90 percent of the energy used is given off as heat.

While incandescent lamps do not contain mercury, their life-cycle mercury emissions often exceed those of equivalent CFLs. (Ramroth, 2008) This is because coal- and oil-fired power plants release mercury emissions when generating this electricity and incandescent lamps consume more electricity than CFLs.

General Electric announced in February 2007 that it was developing high efficiency incandescent lamps, which would be two to four times as efficient as current incandescent bulbs. General Electric expects the new technology to be as efficient as CFLs but with a lower price. The light quality and instant-on convenience would be the same as current incandescent lamps. These high efficiency lamps would be replacements for 40 to 100 watt household incandescent lamps. They are expected to reach the market by 2010.

Alternative 2: LED Lamps

Product Overview

Light-emitting diodes (LEDs) are solid-state semiconductor devices that emit light when electricity is passed through them. This technology is now being used to produce lamps for general lighting applications, including alternatives to certain compact fluorescent lamps. The LED lamps covered in this section are alternatives to CFLs with the screw-type Edison base, in either the twist- or reflector-type configuration.

An individual LED does not produce sufficient light for typical applications so LED lamps incorporate multiple LEDs. These LEDs produce a light that is directional, unlike compact fluorescent lamps that emit light in all directions. To achieve the desired light dispersion, LEDs are placed in specific patterns on the lamps. Some LED lamps also incorporate diffusers and lenses to disperse the light.

Advantages of the LED lamps include: long life (50,000 hours), warm light color similar to incandescent lamps, low heat generation, and the ability to work with dimming switches in certain lamps. LED lamps are energy-efficient and have the potential to be more efficient than CFLs for some applications. They do not emit ultraviolet or infrared light.

The disadvantages of LED lamps are that they are currently expensive and available for only limited applications. Light output of the available lamps is typically low which limits the use to applications such as task lighting, accent lighting or low level ambient lighting.

Representative Manufacturers and Products

The following are representative manufacturers of LED Lamps.

Table A5.4: Representative Manufacturers of LED Lamps

Manufacturer	Location	Website	Model	Pricing (USD)
Altech LED	Japan	www.altechled.com	LED PAR 38 High Power Bulb, 12 Watt, 120 Volt, Life: 15,000 Hours, 20° Narrow Flood	$74.99 (lightingonthenet.com)
C. Crane Company, Inc.	California, U.S.A.	www.ccrane.com	GeoBulb LED Light Bulb, 8 Watt, 120 Volt, Warm White, 800 Lumens, Life: 30,000 Hours, 60W Incandescent Equivalent	$119.95 (C. Crane)
			CC Vivid PAR 38 LED Spotlight Bulb, 3.75 Watt, 120 Volt, 200 Lumens	$44.95 (C. Crane)
Super Bright LEDs, Inc.	Missouri, U.S.A.	www.superbrightleds.com	E27-G50-W6 Edison Base Bulb with 3x2 Watt SSC P4 White LEDs, 120 Volt, 250 Lumens	$36.95 (Super Bright LEDs)
			PAR 20 x36 LED Bulb Medium Base with 36 Super Bright 5mm LEDs, 120 Volt, Glass Housing, 25 Degree Beam Pattern	$11.95 (Super Bright LEDs)

Alternative 3: LED Downlight Lamps

Product Overview
Light-emitting diode (LED) downlights are a replacement for CFL reflector lamps used in recessed light fixtures. The LED downlights covered in this section include not only the lamp but also the recessed lighting trim. These products are intended for new construction or remodeling where new recessed light fixtures will be installed. They are compatible with standard recessed housing fixtures.

Advantages of the LED downlights include: long life (50,000 hours), warm light color similar to incandescent lamps, low heat generation, and they are dimmable. LED downlights are energy-efficient, and in some cases, they consume less energy than equivalent CFL lamps. LED lamps do not emit ultraviolet or infrared light.

LED lamps emit light in a specific direction and this directional light is well suited for downlight applications. Fluorescent and incandescent lamps are bulb shaped and emit light in all directions and, in the case of downlight applications, as much as 50 percent of the light is emitted back into the fixture and lost.

LED downlights are a relatively new technology and therefore prices are high and availability is limited. Another potential disadvantage is that a light failure may require the replacement of the entire unit, which is much more costly than replacing a CFL lamp.

Representative Manufacturers and Products
The following are representative manufacturers of LED downlights.

Table A5.5: Representative Manufacturers of LED Downlights

Manufacturer	Location	Website	Model	Pricing (USD)
Cree LED Lighting Solutions, Inc.	Morrisville, NC USA	www.creells.com	LED 6” Recessed Light: LR6 – 120V, Incandescent Color (2700K), Edison Base, 650 lumens	$92.99 (lightingonthenet.com)
Gallium LED Lighting Systems	Fayetteville, Georgia, U.S.A.	www.galliumlighting.com	GS6-CXRE 6” Square LED Downlight	Not readily available.
Permlight	Tustin, California, U.S.A.	www.permlight.com	ENBC6F 6” Fixed Recessed Trim	Not readily available.

High-Intensity Discharge Lamps

Product Overview

High-intensity discharge (HID) lamps represent a category of lamps that includes metal halide, high-pressure sodium, and mercury vapor lamps. These lamps are used in a wide variety of applications where high levels of light output, long life and high efficacy are required. Examples of HID lighting applications include: warehouses, stadiums, street lamps, and retail and industrial buildings.

HID lamps produce light when a current is passed between two electrodes in a gas-filled tube, which energizes a metallic vapor causing it to produce visible radiant energy. HID lamps operate with high gas pressures inside the tube and they generate high temperatures. The gas-filled tube in most HID lamps contains mercury, either xenon or argon gas, and another element such as sodium or a metal halide.

The mercury content reported by manufacturers to IMERC for HID lamps varied significantly with the type of lamp. The HID lamp mercury content ranges are summarized in the following table.

Table A5.6: HID Lamp Mercury Content Ranges

Lamp Type	Amount of Mercury in Lamp (mg)	Percent of Lamps with Specified Mercury Amount
Metal Halide	>10-50	24%
	>50-100	40%
	>100-1,000	35%
Ceramic Metal Halide	0-5	17.6%
	>5-10	46.8%
	>10-50	35.6%
High-Pressure Sodium	>10-50	97%
Mercury Vapor	>10-50	58%
	>50-100	29%
	>100-1,000	12%
Mercury Short Arc	>100-1,000	65%
	>1,000	23%
Mercury Capillary	>100-1,000	100%

Source: NEWMOA 2006.

A 2007 NRDC report on the use of mercury in China's lighting industry estimated that, in 2005, the production of metal halide lamps consumed an average of 20 milligrams of mercury per lamp, and the production of high pressure sodium lamps consumed 60 milligrams per lamp. (NRDC, 2007)

Representative Manufacturers and Products

The following are representative manufacturers of high-intensity discharge lamps.

Table A5.7: Representative Manufacturers of High Intensity Discharge Lamps

Manufacturer	Location	Website	Model	Pricing (USD)
General Electric Company	Connecticut, U.S.A.	www.ge.com	MVR100/U/MED M90 100 Watt Metal Halide Lamp, Clear, Medium Base.	$28.62 (Dyna-Brite Lighting)
Osram GmbH	Munich, Germany	www.osram.com	M1000/PS/U/BT37 M141/E 1000 Watt Metal Halide Lamp, Reduced Color Shift, Pulse Start, Clear	$44.62 (Dyna-Brite Lighting)
Royal Philips Electronics	Netherlands	www.philips.com	MH400/U/ALTO 400 Watt General Lighting Metal Halide Lamp, Clear, Mogul Base	$15.35 (Dyna-Brite Lighting)

Alternatives

Product Overview

Alternatives to HID lamps are very limited. HID lamp applications require long lamp life, high light output and high efficiency. Mercury-free technologies have not yet achieved these performance requirements. Potential mercury-free technologies include metal halide lamps using zinc iodide as a substitute for mercury, LEDs and mercury-free high-pressure sodium lamps.

Zinc-based metal halide lamps are available for HID automobile headlamps (see below) but information was not found on their use in general lighting applications. LED lamps, with their long life and high efficiency, may eventually be an alternative to HID lamps but information was not found on lamps suitable for replacing HID lamps. A Philips Lumileds case study highlighted the use of LED lamps for street lighting in Lansing, Michigan, where they replaced mercury vapor lamps. The case study involved the use of custom-made lamps that are not available in the market but it illustrated the potential for LEDs as replacements for HID lamps.

Representative Manufacturers and Products

The only mercury-free HID lamps identified were high-pressure sodium (HPS) lamps produced by Osram Sylvania. Sylvania offers three LUMALUX HgF mercury-free HPS lamps ranging from 70 watts to 150 watts, with light output of up to 13,200 lumens.

High-Intensity Discharge Automobile Headlamps

Product Overview

High-intensity discharge (HID) automotive headlamps are metal halide lamps that produce light when an electrical arc is initiated between two electrodes, vaporizing the metallic salts, mercury and xenon. The rapid vaporization of the xenon gas allows the lamps to provide adequate light immediately after being turned on and reduces warm up time. Light is emitted by the plasma discharge formed between the two electrodes.

HID headlamps produce a distinctive blue-white light. The color temperature of light produced by HID headlamps approximates the color temperature of sunlight at noon. HID headlamps provide improved nighttime visibility over halogen headlamps since they illuminate a wider area in front of the vehicle and the bright light stimulates reflective paints used for highway signs and road

markers. They are currently available on a limited number of automobile models with their use typically being limited to luxury or performance models.

HID headlamps are more efficient than halogen headlamps since they produce more than three times the lumens per watt. In addition to using less power, they also produce less heat and allow for smaller headlamp designs. Small headlamps are typically favored by auto designers seeking to improve aerodynamics.

HID headlamps are significantly more expensive than halogen headlamps. HID headlamps are not drop-in replacements for halogen headlamps since they require different electrical components including a ballast and ignitor. One complaint about HID headlamps is that they produce glare that is visible to oncoming traffic. HID headlamps that contain mercury must be removed at the vehicle's end of life.

The mercury content reported by manufacturers to IMERC for HID automobile headlamps was in one of the following two ranges: greater than 0 to 5 milligrams per lamp and greater than 5 to 10 milligrams per lamp. HID headlamp manufacturer Osram stated that the mercury content of the lamps is 0.55 milligrams.

Representative Manufacturers and Products
The following are representative manufacturers of HID automotive headlamps.

Table A5.8: Representative Manufacturers of HID Automotive Lamps

Manufacturer	Location	Website	Model	Pricing (USD)
Royal Philips Electronics	Netherlands	www.philips.com	D2R	Not readily available.
Osram GmbH	Munich, Germany	www.sylvania.com	D2R HID Bulb	$129.99 (AutoZone)http://www.autozone.com
PIAA Corporation	Oregon, U.S.A.	www.piaa.com	D2R HID Bulb	$359.95 Package of 2 eAutoWorks.com

Alternative 1: Mercury-Free HID Headlamps

Product Overview
Mercury-free HID headlamps are very similar to HID headlamps described in the previous section except they use zinc iodide as a substitute for mercury and the amount of xenon gas is increased. An additional benefit of the mercury-free HID headlamp is that the color stability was improved. (Osram, 2008)

The chemistry and geometry of the HID headlamp was changed in order to remove the mercury but the light output and color temperature remained the same. Mercury-free HID headlamps have different electrical requirements and are therefore not interchangeable with HID lamps containing mercury.

Representative Manufacturers and Products
The following are representative manufacturers of mercury-free HID automobile headlamps.

Table A5.9: Representative Manufacturers of Mercury-free HID Automobile Headlamps

Manufacturer	Location	Website	Model	Pricing (USD)
Osram GmbH	Munich, Germany	www.osram.com	D3	Not readily available.

Alternative 2: Halogen Headlamps

Product Overview

Halogen headlamps use a tungsten filament in a quartz or high silica bulb containing inert gas and a trace amount of halogen vapor. The use of halogen in tungsten filament lamps results in more lumens per watt, which has resulted in the widespread use of halogen lamps for automotive headlamps. The color temperature is typically in the warm white range.

While halogen headlamps are significantly less expensive than HID headlamps, they are less energy-efficient and have a shorter life than HID lamps. Halogen lamps do not produce the glare that is common with HID lamps but HIDs are viewed as providing better nighttime visibility.

Representative Manufacturers and Products

The following are representative manufacturers of halogen automobile headlamps.

Table A5.10: Representative Manufacturers of Halogen Automobile Headlamps

Manufacturer	Location	Website	Model	Pricing (USD)
Osram GmbH	Munich, Germany	www.sylvania.com	H11	$14.99 (AutoZone)
Royal Philips Electronics	Netherlands	www.philips.com	LMP 9003NGS2	$41.99 Package of 2 (NAPA)

Alternative 3: LED Headlamps

Product Overview

In 2008, automobile manufacturers Audi, Lexus and Cadillac each introduced one automobile model that featured light-emitting diode (LED) headlamps. LED's are solid state semiconductor devices that emit light when electricity is passed through them.

LED headlamps are up to 55 percent thinner than HID or halogen headlamps and they can be installed as multiple small segments, giving automotive designers greater design flexibility. LED headlamps produce an intense white light that provides good illumination. They are an efficient source of light with lower power consumption than HID headlamps. LED headlamps are an emerging technology and additional advances in reducing power consumption are expected.

LED headlamp suppliers state that LED lamp life is 10,000 to 50,000 hours, which is significantly longer than HID or halogen lamp life. With this long service life, LED headlamps have the potential to outlast the vehicle they are installed in.

LED headlamp model information and pricing was not available because these lamps are designed for and sold to the automobile manufacturers. One published price estimate was that they are eight

times the cost of HID headlamps. (Woodyard, 2006) Prices are expected to come down as demand increases.

Representative Manufacturers and Products
The following are representative manufacturers of LED headlamps.

Table A5.11: Representative Manufacturers of LED Headlamps

Manufacturer	Location	Website	Model	Pricing (USD)
Koito Manufacturing Company, Ltd.	Tokyo, Japan	www.koito.co.jp/english/	Not available.	Not available.
Hella KGaA Hueck & Company	Lippstadt, Germany	www.hella.com	Not available.	Not available.
Visteon Corporation	Michigan, U.S.A.	www.visteon.com	Not available.	Not available.

Backlight Units for LCD Displays

Product Overview
Cold-cathode fluorescent lamps (CCFLs) are currently used to illuminate most liquid crystal displays (LCDs) used in televisions, desktop computer monitors, and laptop computers. CCFLs produce light by passing an electrical current through mercury vapor, similar to other fluorescent lamps. Advantages of CCFLs include low power consumption, and a bright white light.

Disadvantages of CCFLs include: limited choice of color temperature, a warm-up period is required, and the life is in the range of 10,000 to 50,000 hours. Cold temperatures reduce the light output and vibration can reduce the life expectancy. Another disadvantage is that the light intensity cannot be adjusted – it is either on or off. The CCFLs contain mercury and therefore they must be removed from the monitors and televisions prior to disposal.

The mercury content reported by manufacturers to IMERC for LCD televisions and computer monitors using CCFL backlight units was in one of the following three ranges: greater than 0 to 5 milligrams, greater than 5 to 10 milligrams, and greater than 10 to 50 milligrams per lamp.

Representative Manufacturers and Products
The following are representative manufacturers of laptop computers and televisions with LCD displays using cold-cathode fluorescent lamps.

Table A5.12: Representative Manufacturers of Laptop Computers and Televisions with LCD displays using Cold-cathode Fluorescent Lamps.

Manufacturer	Location	Website	Model	Pricing (USD)
Apple Inc.	California, U.S.A.	www.apple.com	Laptop Computer: MacBook Pro with 17-inch Widescreen Display	$2,799.00 (Apple)
Dell Inc.	Texas, U.S.A.	www.dell.com	Laptop Computer: XPS M1330 with Standard Display with 2.0 Megapixel Webcam	$ 1,249.00 (Dell)
Samsung Electronics Co., Ltd.	Seoul, South Korea	www.samsung.com	Television: LN40A650 40 inch, 1080p LCD HDTV	$1,999.99 (Crutchfield)

Alternative 1: LED Backlight Units

Product Overview

LED backlights are commonly used for small, inexpensive LCD displays and are now beginning to be incorporated into the larger LCD displays used for computers and televisions. Computer laptops and monitors using LED backlights are now available from multiple manufacturers including Apple and Dell. LCD televisions with LED backlights are available from Samsung.

One advantage of LED backlights is their long life, which can be 50,000 hours or more. This is a significant improvement over CCFLs, which may require replacement in certain LCD applications including LCD televisions. The solid state technology used in LEDs is relatively robust and not subject to vibration, which is a distinct advantage for laptop applications.

Other advantages of LED backlight include: the ability to adjust light intensity, a higher contrast ratio, and the elimination of “image ghosting” that occurred in some LCD televisions. LED backlight technology can also result in reduced power consumption of the LCD. Samsung states that their 40, 46, 52 and 57 inch televisions with LED backlight technology consume up to 30 percent less energy.

An LCD with LED backlight technology may produce a brighter picture and more color. Samsung states that the LED-based DLP technology used in its television produces a 40 percent brighter picture with 40 percent more color than CCFL-based models.

The price gap between LED backlight-based and CCFL backlight-based televisions and laptop computers has narrowed recently. The premium for LED backlight technology is in the $100 - $200 range for several models of both televisions and laptop computers.

Representative Manufacturers and Products

The following are representative manufacturers of laptop computers and televisions with LCD displays using LED lamps.

Table A5.13: Representative Manufacturers of Laptop Computers and Televisions with LCD Displays using LED Lamps

Manufacturer	Location	Website	Model	Pricing (USD)
Apple Inc.	California, U.S.A.	www.apple.com	Laptop Computer: MacBook Pro with 17-inch Hi-Resolution Glossy LED Widescreen Display	$2,899.00 (Apple)
Dell Inc.	Texas, U.S.A.	www.dell.com	Laptop Computer: XPS M1330 with Slim and Light LED Display with VGA Webcam	$ 1,399.00 (Dell)
Samsung Electronics Co., Ltd.	Seoul, South Korea	www.samsung.com	Television: LN-T4081F 40 inch, 1080p LCD HDTV with LED Backlight	$2,199.99 (Crutchfield)

Other Mercury-Containing Lamps

Mercury is used in several other categories of lamps including mercury short-arc and neon lamps. These lamps are used for special applications and are produced in smaller quantities but typically contain more mercury per lamp than fluorescent lamps.

Mercury short-arc lamps are filled with low pressure argon and mercury vapor. An intense light is created by an arc between two closely positioned electrodes. Applications for these lamps include search lights, specialized medical equipment, photochemistry and UV curing. These lamps typically contain between 100 and 1,000 milligrams of mercury but often contain more than 1,000 milligrams. (NEWMOA, 2006) Mercury-free alternatives for mercury short-arc lamps were not identified.

Neon lamps are similar to fluorescent lamps in that each end of the lamp's glass tube contains metal electrodes. The tube is filled with a mixture of gases at a low pressure. The color of the neon light is determined by the mixture of gases, the color of the glass tube and other lamp characteristics. Red neon lamps are the only color of light that does not utilize mercury. All other neon lamps use mercury with noble gases including krypton, argon, and helium. The mercury content of neon lamps varies but is estimated to be between 250 and 600 milligrams per lamp. (NEWMOA, 2006) Mercury-free alternatives for neon lamps were not identified.

Demand and Use of Mercury

The following table contains the mercury demand data for lamps/lighting provided by countries in their responses to the UNEP Request for Information (RFI) or other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT).

Table A5.14: Country Mercury Use for Lighting (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
China	Other	47 (2000)[8] 63.94 (2005)[9]
Philippines	MIT	25.7
United States	RFI	17.6
Russia	Other	7.5 (2001)[10]
Japan	RFI	4.72 (2005)
Canada	Other	1.839[11]
Germany	RFI	1 (tubes only)
Argentina	RFI	0.725
France	RFI	0.525 (0.4 – 0.65)
Belarus	RFI	0.412
United Kingdom	RFI	0.320 (2012)
Sweden	RFI	0.121 (2004)
Netherlands	RFI	0.04 (2007)
Norway	RFI	0.01
Romania	RFI	0.0074 (2007)

China reported the highest total demand of 47 metric tons per year which may be attributed to the manufacture of mercury-containing lamps in China. A 2007 study by NRDC estimated China's mercury use for lighting at 63.94 metric tons in 2005. (NRDC, 2007)

The Philippines reported a demand of 25.7 metric tons per year which was the second highest demand reported. This figure was calculated using assumptions about the number of fluorescent lamps per school, household, hospital, government building, and manufacturing facility and then multiplying the estimated number of lamps by 40 milligrams of mercury per linear fluorescent lamp and 15 milligrams per compact fluorescent lamp. It is not clear whether the number of lamps represents annual consumption or existing inventory. The Philippines' mercury content figures were at the high end of the range provided as preliminary default input factors in the 2005 UNEP Mercury Inventory Toolkit. The mercury content ranges listed in the Toolkit were 10 - 40 milligrams of mercury per linear fluorescent lamp and 5 – 15 milligrams of mercury per compact fluorescent lamp.

There are a variety of factors that could influence a country's mercury demand for lamps/lighting including: the size and economic status of the country, the extent to which fluorescent lamps have replaced incandescent lamps, the number of mercury-containing lamps being produced for export, and the average amount of mercury in the lamps.

[8] Strategy Proposal for International Actions to Address Mercury Problem - Mercury Situation in China, 2008.
[9] Survey and Research on the Status of Use of Mercury in China's Electric Light Source Industry, Chemical Registration Center of State Environmental Protection Administration of China, Natural Resources Defense Council, 2007.
[10] ACAP, 2004
[11] Canadian information to support intersessional work of the ad hoc open-ended working group on mercury, January 31, 2008.

It should be noted that the countries reported mercury demand for lamps/lighting as one line item and therefore mercury demand for specific lamp types was not reported. The one exception was the United States, which provided the breakdown of mercury demand by lamp type shown in the following table.

Table A5.15: United States Mercury Demand for Lamps/Lighting

Lamp Type	Mercury Demand
Fluorescent tubes	6.2 metric tons
Fluorescent compact bulbs	0.9 metric tons
High-intensity discharge lamps	1.7 metric tons
Short arc lamps	0.0018 metric tons
Neon and other miscellaneous lighting	0.0227 metric tons

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries on their experiences with the technology changeover or alternatives associated with substituting mercury-containing lamps with other lighting options. The information contained in the tables was derived from the responses to the UNEP RFI. In some cases, the tables contain an abbreviated or reworded version of the response included in the RFI.

Table A5.16: Countries Responding with Level of Substitution of "2"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" – Substitutes Available and Commonly Used
Brazil	RFI	In March 2008, the National Environmental Commission (CONAMA) established a Working Group to discuss regulation aimed to decrease the mercury content in lamps, and management of waste mercury.
Denmark	RFI	It is assumed that this usage has declined rapidly during the past 5 years due to pressure from consumers for having non-mercury solutions, as well as the EU bans in the RoHS directive.
Germany	RFI	Positive experience.
Iran	RFI	Iran has not banned the use of mercury in products yet.
Norway	RFI	Follows the EU-RoHS directive.
Panama	RFI	No experience data provided for this rating.
Sweden	RFI	Sweden reported a substitution level of 0-2. The use of mercury in lamps is exempted from the mercury ban in the EU Directive on hazardous substances in electrical and electronic equipment. The Directive sets out maximum permitted content of mercury in certain fluorescent lamps. Mercury-free alternatives are becoming available for some applications. From a technical view it is possible to lower the mercury content in some lamps.

Table A5.17: Countries Responding with Level of Substitution of "1"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "1" – Substitutes Available and Minimally Used
Argentina	RFI	The National Saving Energy Plan implemented in December 2006 promotes the substitution of incandescent lamps with fluorescent tubes and CFLs.
Belarus	RFI	Lamps with lower amounts of mercury are commonly used.
Chile	RFI	Negative experience. The alternatives have not been diffused. Alternatives without mercury have a higher cost.
Netherlands	RFI	No experience data provided for this rating.

Table A5.18: Countries Responding with Level of Substitution of "0"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "0" – No Available Substitutes
France	RFI	This does not take into account incandescent and halogen lamps as substitutes.
Japan	RFI	Mercury content in a fluorescent lamp was 50 mg in 1974, but decreased to 7.5 mg in 2005. Mercury reduction has been achieved with advances in the inclusion technique (change from direct inclusion to pellet inclusion) and the spread of high efficiency three band fluorescent lamps. Production increases in laptop computers and large liquid crystal televisions has increased the demand for mercury for backlights. LEDs without mercury are being used as backlights. Costs of alternatives, such as LED or non-mercury fluorescent lamps are much higher at present.
Slovenia	RFI	No experience data provided for this rating.
Switzerland	RFI	No experience data provided for this rating.
United Kingdom	RFI	Alternatives are currently expensive and do not provide the same sort of light as a CFL, but we expect the technology to improve over the coming years.
United States	RFI	Negative experience for fluorescent tubes, CFLs, and neon lights.

Table A5.19: Countries with No Level of Substitution Response

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Canada	Other[12]	Alternatives for fluorescent and HID lamps are currently not available in the domestic marketplace. In some cases LED lights can be used to replace neon signs; however LED lights are more costly and cannot be used as direct substitutes for all applications.

[12] Canadian information to support intersessional work of the ad hoc open-ended working group on mercury, January 31, 2008.

Six countries reported a substitution level of "2" for lighting and one country, Sweden, reported a substitution level of "0-2". A level "2" response indicates that substitutes are available and commonly used in those countries. Of these seven countries, four are European. Three of the European countries mentioned the European Union's Restriction of Hazardous Substances (RoHS) Directive as a driver for reduced mercury use for lighting. RoHS set limits on the amount of mercury allowed in linear fluorescent lamps and CFLs.

Four countries reported a substitution level of "1" for lighting, which indicates that substitutes are available and minimally used in those countries. Six countries reported a substitution level of "0" for lighting, which indicates that substitutes are not available in those countries.

Overall, fourteen countries provided written comments regarding experiences with alternatives to mercury-containing lighting. Four countries mentioned that mercury use for lighting has decreased due to a reduction of the mercury content in some lamps. Four countries stated that alternatives are available for limited applications and four stated that alternatives cost more than mercury-containing lamps.

Summary – Lighting

The following table shows a quantitative breakdown of RFI responses from seventeen countries of the level of substitution for mercury in lamps and lighting. It should be noted that the countries reported the level of substitution for lamps/lighting as one line item and therefore level of substitution for specific lamp types was not reported.

Table A5.20: Country Responses for Level of Substitution

Level of Substitution	Number of Country Responses	Percentage of Responses
2	6	35%
0-2	1	6%
1	4	24%
0	6	35%

Thirty-five percent of the RFI responses stated that substitutes for mercury-containing lamps are available in the market and commonly used and another thirty-five percent stated that substitutes are not available in the market. One possibility for the discrepancy in these responses is that some countries may have viewed incandescent and halogen lamps as alternatives while other countries may have viewed them as old technology and discounted them as alternatives. Another possibility for the discrepancy is that some countries may have considered the availability of substitutes for mercury in all categories of lamps, while others may have based their response on substitutes for a specific application or lamp type.

Mercury-containing lamps are among the most energy-efficient lamps available and the high cost of energy is driving increased demand for compact fluorescent lamps and other energy-efficient lighting technologies. The governments of some countries, including Argentina and the U.S.A., are promoting the use of fluorescent tubes and CFL lamps to reduce energy consumption.

While the demand for fluorescent lamps is increasing, the amount of mercury used for lamps/lighting is not increasing at the same rate. Many of the fluorescent lamps being produced today have significantly less mercury than equivalent lamps produced in previous years. Japan stated in its RFI that the mercury content of fluorescent lamps has been reduced from 50 milligrams in 1974 to 7.5 milligrams in 2005. Advancement in manufacturing technology, including the use of mercury-containing pellets in lieu of liquid mercury, was the reason cited for this reduction in mercury use. Regulations are also being passed that set maximum content levels of mercury in fluorescent lamps. Sweden stated in its RFI that the EU RoHS Directive established a maximum permitted content of mercury in certain fluorescent lamps.

China is a leading manufacturer of mercury-containing lamps and reported the highest use of mercury for lighting. In 2005, it produced more than 30 billion units using nearly 64 metric tons of mercury. Eighty-percent of the manufacturers of fluorescent lamps in China use liquid mercury in the manufacturing process (drip method). The production of lamps using liquid mercury results in a significantly higher use of mercury than methods using mercury pellets or amalgam. Upgrading the manufacturing facilities with systems using less mercury per lamp and releasing less mercury to the environment will require a significant investment. Higher mercury prices and mercury content limits set by the RoHS Directive have reportedly motivated manufacturers to reduce mercury use in recent years. (NRDC, 2007)

The following table provides a lighting substitution summary. Alternative technologies were identified for all types of mercury-containing lamps with the exception of HID lamps. While one manufacturer is producing a mercury-free high-pressure sodium HID lamp, it was considered an alternative for only a limited number of HID lamp applications.

Transition success for the lamp/lighting product category has not been achieved since only thirty-five percent of respondents provided a level of substitution of “2” and no respondent had an annual demand of zero metric tons of mercury. The table below shows that transition success has not been achieved for any individual type of lamp with the exception of HID Automobile Headlamps. Only a small number of high-end automobiles utilize mercury-containing HID headlamps. Mercury-free halogen headlamps are much more common and mercury-free HID and LED headlamps are becoming available. For these reasons, transition success was considered to be achieved. A 2007 TemaNord report identified HID headlamps as a “mercury use which may be most readily substitutable in a global perspective.” (Maag, 2007)

The high cost and limited availability of alternatives for linear and compact fluorescent lamps and HID lamps where identified as challenges that must be addressed before transition success is achieved. Alternatives using LED technology are becoming available but significant advances in efficiencies and product development are predicted as the technology evolves over the next five years.

The transition to mercury-free LCD backlight units will likely depend on the success of current products in the marketplace that utilize mercury-free LED backlights. The number of computers and televisions with mercury-free LED backlights will likely increase each year given the distinct advantages that this technology has over CCFL backlights.

Table A5.21: Lighting Substitution Summary

Lighting	Alternative Technologies Identified	Transition Feasibility
Linear Fluorescent Lamps	Yes	Alternatives available – challenges identified
Compact Fluorescent Lamps	Yes (limited applications)	Alternatives available – challenges identified
HID Lamps	No	Alternatives available – challenges identified
HID Automobile Headlamps	Yes	Transition success demonstrated (halogen only)
LCD Backlight Units	Yes	Alternatives available – challenges identified

A.6 Other Products

The following table provides a listing of the estimated mercury demand reported by countries in their RFI response, Mercury Inventory Toolkit (MIT) report, or other supporting documentation.

Table A6.1: Estimated Mercury Demand for Other Products

Country	Source of Data	Product Description	Estimated Mercury Demand/Quantity Used (tons/year)
Canada	Other	Tire balancers	0.744 (2000 – 2004)
Chile	RFI	Laboratory chemicals	0.004
Ecuador	RFI	Laboratory chemicals	0.02 (2004)
Japan	RFI	Vermillion inks	1.6
Japan	RFI	Reagents	0.1 (2005)
Mauritius	RFI	Jewelers recovery of waste gold	0.007
Philippines	MIT	Lighthouse	22.8
Slovenia	RFI	Vaccine	< 0.001
Slovenia	RFI	Chemicals for laboratory use	0.7
Sweden	RFI	Pharmaceuticals, vaccine preservative	0.002
Syria	RFI	Pharmaceuticals	0.325
United States	RFI	Preservatives and reagents	0.4
United States	RFI	Piston pack sensors, firearm accessories, pressure transducers, film, transceivers, and scanning electrodes.	2.0

Lighthouses

Mercury is used in some older lighthouses to float the heavy glass Fresnel lens, which magnifies the light to produce a powerful light signal. Beginning at the end of the 19th century, lighthouse light assemblies were designed to float on a trough filled with mercury in order to reduce the amount of force required to rotate the lens. The amount of mercury used to construct a lighthouse light assembly varied with the size of the lens. A larger lens required more mercury in order to float the lens. Early designs required as much as 1,088 kilograms of mercury while later designs with smaller lenses required significantly less mercury. (Shultz, 2005)

Current lighthouse designs no longer use a mercury float for the lens. The lamps currently used in lighthouses (mercury vapor and xenon lamps) are significantly more powerful than previous generations of lamps and heavy glass lenses are no longer required. Many existing lighthouses have been upgraded since the 1970s to use the current lamp design, eliminating the use of mercury. (Baird, 2008)

The Philippines estimated their mercury use for lighthouses to be 22.8 metric tons per year. They stated in their MIT that there are 57 lighthouses in the country and it was estimated that each lighthouse uses 400 kilograms of mercury.

Tire Balancers

Mercury containing tire balancers are composed of mercury filled tubes that are fitted to rotating mechanical parts such as tires. These balancers can be used in a variety of components, but in Canada they are mostly used in trucks, cars, motorhomes, motorcycles, jetskis, and ultralites. During the time period 2000 – 2004, approximately 744 kilograms of mercury was used in tire balancers in Canada. It is estimated that each mercury-containing tire balancer contains approximately 99 grams of mercury. (Jacovella, 2008) Tire balancers are installed on a vehicle's wheels during the tire balancing process and usually remain in service until the tire is rebalanced or replaced, or until the wheel or vehicle is retired from use.

Tire balancers do not typically wear out but they can become dislodged when a vehicle is jarred or during sudden velocity changes. Factors such as improper installation and damage from contact with curbs or other objects can also cause these weights to become dislodged. There two common methods for attaching tire balancers to wheels are either clipping the weight to the rim of the wheel, or affixing the weight to the wheel using an adhesive. For both tire balancer applications, a small weight size is desirable because it is less visible and to prevent interference with other vehicle components, such as the brakes. Therefore, density of the tire balancer material directly influences the size of the wheel weight, and is a key physical characteristic that affects the desirability of alternatives. Since adhesive weights are mounted to curved surfaces of the wheel, it is also desirable for tire balancers to be relatively soft and malleable so the curvature of the weight can be adjusted during installation to match the curvature of the wheel. Tire balancers must also be corrosion resistant due to the harsh environment which includes exposure to moisture, high temperatures and road salt.

Lead is a commonly used material for tire balancers; however, lead has significant adverse human health effects such as being a probable human carcinogen, and can cause adverse neurological, reproductive, and development symptoms. Other tire balancers are commercially available that use less toxic materials such as copper, steel, tin, and zinc. (TURI, 2006)

B. Findings: Processes Using Mercury

B.1 Chlor-Alkali Production

Chlorine and sodium hydroxide are typically co-produced using one of three basic cell processes: diaphragm, mercury, and membrane. The co-production of chlorine and sodium hydroxide is based on the electrolysis of sodium chloride solutions where the solution is electrolytically decomposed to chlorine at the anode of the cell, and sodium hydroxide at the cathode of the cell. In 2001, these three co-production processes accounted for about 95% of total world chlorine capacity. Other less commonly used processes include the electrolysis of hydrogen chloride, by-products of metal production, and co-product of potassium nitrate production.

Mercury Cell Process

Process Overview

The mercury cell (Castner-Kellner cell) process was introduced in 1892. The mercury cell process consists of two cells, the primary electrolyser (brine cell) and the decomposer. In the primary electrolyser, brine containing sodium chloride flows through an inclined trough that contains a shallow film of mercury on the bottom. Electric current in the cell decomposes the brine to chlorine gas at the anode and metallic sodium at the mercury cathode. At the cathode a liquid amalgam with mercury is formed. The amalgam then flows from the primary electrolyser to the decomposer where it reacts with water and a catalyst to form sodium hydroxide and hydrogen gas. The sodium-free mercury is then returned to the primary electrolyser for reuse. A major disadvantage of this process is the environmental release of mercury.

Representative Processors:

The following are representative chlor-alkali processors using the mercury cell process.

Table B1.1: Representative Chlor-alkali Processors Using the Mercury Cell Process

Processor	Location	Website
Akzo Nobel	Oulu, Finland	www.akzonobel.com
Solvay	Bussi, Italy	www.solvay.com

Alternative 1: Diaphragm Cell Process

Process Overview

The diaphragm cell (Griesheim cell) process was introduced in 1885. The reactions of the diaphragm cell process occur within one cell. A diaphragm is used to separate the chlorine at the anode and the hydrogen and caustic soda produced at the cathode. A disadvantage of the diaphragm cell process is that the diaphragm is usually made of the toxic material asbestos; however, operation is possible with non-asbestos diaphragms.

Representative Processors:

The following are representative chlor-alkali processors using the diaphragm cell process.

Table B1.2: Representative Chlor-alkali Processors Using the Diaphragm Cell Process

Processor	Location	Website
Anwil	Wloclawek, Poland	www.anwil.pl
Norsk Hydro	Rafnes, Norway	www.hydro.com

Alternative 2: Membrane Cell Process

Process Overview

The membrane cell process was introduced in 1970, and the first industrial membrane plant was installed in Japan in 1975. The membrane is typically fluoropolymer based and it separates the anode and cathode. The brine solution flows through the anode compartment and produces chlorine gas. The sodium ions pass through the membrane to the cathode compartment and form a caustic soda solution.

Advantages of the membrane cell process include the production of a very pure caustic soda solution, and less energy requirements than the other two processes. A disadvantage is that the brine feedstock must be of high purity, and often requires costly purification steps prior to electrolysis.

Representative Processors:

The following are representative chlor-alkali processors using the membrane cell process.

Table B1.3: Representative Chlor-alkali Processors Using the Membrane Cell Process

Processor	Location	Website
Donau Chemie	Bruckl, Austria	www.donau-chemie.at
Solvin	Jemeppe, Belgium	www.solvinpvc.com

Alternative 3: Independent Production of Chlorine and Sodium Hydroxide

The mercury, diaphragm, and membrane cell processes typically co-produce chlorine and sodium hydroxide. Another non-mercury alternative to the mercury cell process is to independently produce chlorine and sodium hydroxide. For example, hydrogen chloride can be converted to chlorine through the process of either electrolysis or oxidation. Also, when potassium chloride is electrolyzed, the products include chlorine, hydrogen, and potassium hydroxide.

Sodium hydroxide can also be independently produced. For example, the lime soda process takes place when an aqueous solution of sodium carbonate reacts with calcium oxide to form sodium hydroxide.

Demand and Use of Mercury

The following table contains the mercury use data for chlor-alkali production provided by countries in their responses to the UNEP Request for Information (RFI) or other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT).

Twenty countries provided estimated mercury demand information for chlor-alkali production. The range of responses was 0 to 17.468 metric tons of mercury per year, with ten countries reporting no

mercury demand for chlor-alkali production. The estimated mercury demand responses provided data from various years, including information as far back as 2004.

Table B1.4: Mercury Demand for Chlor-alkali Production (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
Romania	RFI	17.468
France	RFI	16.5 (2004 - 2006) (Range: 14 – 19)
Pakistan	Other	16.1
United States	RFI	11 (2006)
Syria	RFI	10
Philippines	MIT	4.46 (Range: 0.525 – 8.4)
Argentina	RFI	4.184
United Kingdom	RFI	1
Switzerland	RFI	0.95
Sweden	RFI	0.05
Belarus	RFI	0
Cambodia	MIT	0
Chile	MIT	0
China	Other	0
Denmark	RFI	0
Ecuador	RFI	0
Japan	RFI	0
Netherlands	RFI	0
Norway	RFI	0
Trinidad and Tobago	Other	0

The Mercury Inventory Toolkit recommends collecting site specific data to determine mercury usage in chlor-alkali plants. However, if this information is not available then the following default mercury input factors are used for chlor-alkali production:

Input Factor: 25 to 400 grams of mercury per ton of chloride produced.

The Philippines used the above input factor and applied it to a capacity of 21,000 tons chloride per year to determine their annual mercury demand for chlor-alkali production of 0.525 – 8.4 tons.

A global estimate of mercury consumption by chlor-alkali production was reported by UNEP in a November 2006 report titled: “Summary of Supply, Trade, and Demand Information on Mercury”. The mercury consumption estimates from this report are provided in the table below.

Table B1.5: Mercury Cell Process – Mercury Consumption (2005)

Country/region	Mercury Total Net Consumption (metric tons)	Mercury Recycled and Recovered From Waste (metric tons)	Mercury Total Consumption (metric tons)
Europe	147	25 – 40	175 - 190
United States	9	35 – 60	45 – 70
Brazil	10 - 15	0 - 5	11 - 25
India	20 - 28	0 - 5	20 – 35
Russia	25 - 45	0 - 5	25 – 50
Other	120 - 180	10 - 40	140 - 210
Total	350 - 430	90 - 140	450 - 550

Source: UNEP, 2006

For the United States, there is similarity between the mercury consumption values provided in this report (9 tons in 2005), and the value provided in the RFI response (11 tons in 2006). There were no RFI responses provided from Russia, India, and Brazil to compare to the UNEP estimates.

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries about their experiences with the technology changeover or alternatives associated with substituting mercury chlor-alkali production with available alternatives. The information contained in the tables is derived from the responses to the UNEP Request for Information (RFI), Mercury Inventory Toolkit (MIT), or other source of information. In some cases, the tables contain an abbreviated or revised version of the response included in the RFI.

Table B1.6: Countries Responding with a Level of Substitution of "2"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" Substitutes Available and Commonly Used
Argentina	RFI	Two chlor-alkali production plants began to change mercury technology to diaphragm technology in 2006. Mercury technology is still used in about 37% of total chlor-alkali production.
Brazil	RFI	There are eight chlor-alkali plants in Brazil. For new chlor-alkali plants, chlorine production is prohibited using mercury cells and asbestos diaphragms.
France	RFI	Fifty percent of chlorine is produced with alternative techniques.
Germany	RFI	Provided a level of substitution of "1 – 2". Positive experience.
Japan	RFI	The mercury cell process was replaced by ion-exchange membrane method in all caustic soda manufacturing factories in Japan by 1986.

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" Substitutes Available and Commonly Used
Netherlands	RFI	Since 2006, chlor-alkali production in the Netherlands adapted to best available mercury free techniques.
Norway	RFI	No use of mercury in this industry in Norway.
Sweden	RFI	One mercury-cell chlor-alkali plant in operation with approximately 200 tons of mercury in the cells. This plant will convert to membrane cells in 2010. One plant converted from mercury cells to membrane cells in the 1980's with good experiences. The initial investment cost is high, but membrane cells are more energy efficient than mercury cells and conversion to membranes is therefore economically favorable.
Switzerland	RFI	No experience data provided for this rating.

Table B1.7: Countries with No Response for Level of Substitution

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Bangladesh	Other	Mercury is used to produce chlorine and sodium hydroxide in a paper mill at Karnaphuli.
Chile	MIT	The chlor-alkali company Occidental Chemical Chile replaced its mercury cell production process with the membrane process in 1991.
Denmark	RFI	One industry plant previously existed in Denmark, but it closed due to safety problems (use of chlorine in the middle of a big city) twenty years ago.
Ecuador	RFI	The only company that manufactures chlor-alkali uses the membrane cell technology.
Iran	RFI	Implementation of a plan has been determined by Ministry of Oil and Petroleum to establish a new chlor-alkali plant with membrane technology. The old chlor-alkali plants (3 units) will be phased out soon after the new site is ready for operation.
Pakistan	Other	Eighty percent of chlor-alkali capacity uses membrane cell technology, and the remaining twenty percent of capacity uses the mercury cell process.
Slovenia	RFI	New technology (membrane process).
Syria	RFI	Uses mercury-free technique.
United Kingdom	RFI	Membrane technologies are well developed, successful and have lower running costs than mercury technology. However the capital cost of conversion from mercury to membrane technology is so high that conversion can only be commercially viable for mercury technology plants that are essentially life-expired. The EuroChlor 2020 deadline recognizes that the majority of mercury technology plants will be approaching end of life by that date.
United States	RFI	As a result of a voluntary commitment to mercury reduction made by the U.S. Chlorine Institute under the Great Lakes Binational Toxics Strategy, the chlor-alkali industry has made significant progress in reducing its mercury use since 1995. The U.S. Chlorine Institute's Tenth Annual Report to EPA showed a 92 percent reduction between 1995 and 2006 in mercury used in the U.S. production of chlorine and caustic soda.

Eight countries responded with a level of substitution of "2", and one country, Germany, responded with a level of substitution of "1 - 2" for chlor-alkali production. These countries did not report any negative experiences with the transition to non-mercury alternatives. No countries responded with a level of substitution of "1" or "0".

In addition to the country-specific responses about mercury substitution provided above, there is available information about the aggregate European use of mercury substitution in the chlor-alkali industry. More than 20 million tons of chlorine, caustic soda, and hydrogen were produced by the European chlor-alkali industry in 2007. Forty three percent of this production was accomplished using mercury cells, 40% by membrane cells, 14% by diaphragm cells, and 3% by other technologies. These figures apply to Euro Chlor member companies in eighteen countries. Further, all European chlor-alkali producers are committed to voluntarily close or convert their mercury cell plants as soon as practicable, but by a date no later than 2020. (Euro Chlor, 2008, Andersson, 2008) Also, in India there is an active government supported voluntary agreement with industry to close the remaining mercury cell chlor-alkali facilities by 2012.

Summary – Chlor-alkali Production

Many countries around the world with mercury cell chlor-alkali plants have significantly reduced mercury consumption by closing mercury cell chlor-alkali facilities, reducing their mercury release through improved operations, or have successfully converted from the mercury cell process to the membrane cell process. These conversions have either been full or partial conversions depending on the requirements of the individual facility. Technical changes are typically required, for example, because the membrane cell needs purer brine than the mercury cell process, a secondary brine purification step may be needed. In addition to the mercury reduction successes already achieved for this industry, there is industry commitment to close or convert mercury chlor-alkali facilities in Europe and India.

Although conversion from a mercury cell process to membrane cell process is technically feasible, the conversion costs vary from site to site. Significant factors that affect conversion costs include the need for increased capacity, energy costs, and maintenance costs associated with the age of the mercury cell facility. A report published by the European Commission in 2001, reported the conversion costs for a number of facilities located in Europe, United States, and Japan. The conversion costs were converted to Euros and normalized to the chlorine capacity of the plants. The conversion costs ranged from 213 to 700 Euros (approximately 336 – 1,104 USD) per ton of annual chlorine production. The benefits reported from completing a conversion of mercury cells to membrane cells include reduced energy consumption, reduced need for maintenance, and elimination of mercury management issues. (EC, 2001)

The following table shows a quantitative breakdown of the level of substitution for chlor-alkali production provided by nine countries in their RFI response.

Table B1.8: Country Responses for Level of Substitution

Level of Substitution	Number of Country Responses	Percentage of Responses
2	8	88.9%
1 - 2	1	11.1%
1	0	0%
0	0	0%

More than 50% of RFI responses for chlor-alkali production were rated at a substitution level of "2", and there were no negative responses provided for the transition to the non-mercury alternatives. This indicates that substitutes are available and commonly used in the majority of countries that provided mercury demand information. Also, more than two countries reported estimated mercury demand of zero. Therefore, transition success to mercury-free alternatives was demonstrated for chlor-alkali production.

Table B1.9: Chlor-alkali Substitution Summary

Chlor-alkali Production	Alternative Technologies Identified	Transition Feasibility
Mercury cell process	Yes	Transition success demonstrated

B.2 Artisanal and Small Scale Gold Mining

Artisanal and small-scale mining (ASM) is the term used when referring to all small- and medium-sized, informal, legal and illegal mining operations that use rudimentary processes to extract gold and other minerals from secondary and primary ores. (Veiga, 2006) In this section, ASM was used to refer specifically to artisanal and small-scale gold mining.

It is estimated that 15 million people are involved in ASM operations in more than 50 developing countries in Asia, Africa and South America. (UNIDO, 2007) By definition, ASM operations are not organized into corporate structures, and therefore, this section does not identify representative processors for ASM gold mining.

ASM miners use a wide variety of processes to extract gold from ore depending on the type of ore, local traditions, equipment availability, water availability, and other factors. This section covers mercury amalgamation and the following three categories of non-mercury alternatives: gravity separation, cyanidation and chlorination.

Mercury Amalgamation

Process Overview

Mercury amalgamation is the method most commonly used by ASM miners because it is a simple, inexpensive process for extracting gold from ore. Mercury and gold have an affinity for each other, and therefore, fine particles of gold are drawn to the mercury, forming an amalgam. Amalgam is then separated from the sand and gravel. Once separated, the amalgam is placed in a cloth and the excess mercury is squeezed out and collected for reuse. The remaining amalgam is typically 60% gold and 40% mercury. This amalgam is then heated to vaporize the mercury, leaving sponge gold, which contains approximately 5% residual mercury and other impurities. ASM miners typically sell the sponge gold to gold dealers who then smelt it into pure gold.

Amalgamation only works with ore containing free gold. It is not effective on refractory ores, e.g. ores where the gold particles are trapped by sulfide minerals. ASM miners typically use mercury amalgamation in combination with other screening or separation processes. For example, mercury is added to the riffles and troughs of sluices. The dense amalgam sinks and is trapped, while the sand and gravel are washed away. Mercury is also added during panning to facilitate the collection of fine gold flakes.

The amount of mercury used in ASM operations varies greatly with factors such as the type of ore, the separation process used, cost of the mercury, and knowledge of the miners. The highest rate of mercury usage occurs when miners add liquid mercury directly to the whole ore. Whole ore is ore that has not been processed and contains very low concentrations of gold, typically less than 10 grams per metric ton. Examples of whole ore amalgamation methods include: mixing Hg with whole ore in a pump box; adding Hg during a grinding or milling process; or introducing Hg to a sluice. (Veiga, 2006) The gold recovery efficiencies of whole ore amalgamation are typically low since significant quantities of amalgam are not recovered and discarded with the tailings.

The more efficient use of mercury amalgamation is using it with ore concentrate. Ore concentrate is generated when whole ore passes through one or more screening processes (e.g., gravimetric separation or sluice) resulting in ore with concentrated levels of gold. Amalgamation is achieved by mixing liquid mercury with the concentrates in blenders, barrels or other separation equipment. Miners then separate the amalgam from other heavy minerals by panning with water.

The ratio of "mercury consumed" to "gold extracted" is greater than 3:1 for whole ore amalgamation and can be as high as 100:1. (Veiga, 2006) The ratio with the amalgamation of ore concentrates is approximately 1:1. (UNEP, 2005) The use of a retort to recover mercury vapors can significantly reduce the amount of mercury consumed.

Alternative 1: Gravity separation

Process Overview
Gravity separation includes all processes that separate gold from ore based on density. Gravity separation processes include: sluices, centrifuges, vibrating tables, and hand screening. These processes can be applied to either whole ore or ore concentrate depending on the equipment used. Mercury amalgamation is frequently used in conjunction with gravity separation but this section covers gravity separation without the use of mercury.

Sluices
The most commonly used gravity separation process by ASM gold miners is the sluice or sluice box. Sluices are long boxes or troughs sloped at an angle with riffles in the sluice floor. A steady stream of ore slurry pours into the top of the sluice and higher density particles (i.e., gold) settle out of the slurry and are trapped by the riffles.

Sluices are popular with ASM miners because they do not require electricity, they are easily constructed, simple to operate and are effective at concentrating gold. Sluices can be designed for use with either whole ore or ore concentrates. The best recovery rates are achieved when the sluice design is matched to the type of ore and particle size. Factors that affect performance are: slurry flow rate; the ratio of water to ore; the length, width and slope of the sluice; and, the particle size of the ore.

Sluices are often fabricated locally but are also available for purchase from companies such as Keene Engineering located in the U.S.A. Keene sells their A52 model for approximately $100 USD. This model is 25 cm wide by 129 cm long, it weighs 5 kg, and it can process up to 5 metric tons per hour of ore. (Veiga, 2004)

Centrifugal Separators
Centrifugal separators typically incorporate a ribbed cone that rotates, creating increased gravitational force. A slurry of 20 – 40% ore in water is fed into the cone and the high gravitational force causes the dense gold particles to concentrate in the outer layer of the slurry and accumulate in the riffles of the separator. Water is injected into the cone to create a counter flow, which helps to reduce compaction and allows the gold particles to penetrate the concentrate layer.

Centrifugal separators have been used in gold mining for decades, in both large and small operations. One manufacturer of centrifugal separators is Knelson Gravity Solutions in British Columbia, Canada.

Disadvantages of centrifugal separators are that they are expensive, they require electricity, they consume a significant amount of clean water, and they require skilled operators.

Cleangold sluice
The Cleangold sluice is manufactured by the Cleangold LLC, located in Oregon, U.S.A. Cleangold sluices are designed for ASM miners and available in three sizes. They are intended for recovery of gold from concentrates or for use in low flow streams.

The Cleangold sluice differs from other sluices in that polymeric magnetic sheets are inserted into the floor of the sluice. The magnetic sheets attract the mineral magnetite from the ore, which forms a corduroy-like surface on the floor of the sluice. The magnetite surface is very effective in recovering fine gold flakes. The gold is collected by scraping the gold-bearing magnetite into a pan and separating it using a magnet. The gold that remains in the pan is of a high purity and ready for smelting. The results of a field test in Guyana indicated that the Cleangold sluice has the potential to replace mercury amalgamation as a final cleanup method. (Vieira, 2006)

Prices for the Cleangold sluices range from $40 USD for a small 20.3 centimeter by 20.3 centimeter size to $250 USD for a 40.6 centimeter by 40.6 centimeter size. (www.cleangold.com, 2008)

Gemini Table
A Gemini Table is a type of shaking table used for the final cleanup of concentrates. The recovered gold is of high purity and suitable for smelting. A Gemini Table consists of tilting fiberglass deck supported by a steel frame. An electric motor produces a shaking movement that has a variable speed controller. The tables require a constant supply of clean water (0.7 cubic meters per hour) at a steady pressure. The gold-bearing concentrate is fed to the table at a constant rate, along with the water, and the gold is collected in the ridges of the table. The Gemini Table model GT60 Mk2 has a capacity to process up to 27 kilograms per hour of concentrate. It has a price of $8,000 USD. (Vieira, 2006)

Extrac-TEC
IE-TEC Marketing sells a line of gravimetric separators and their smallest unit, the Extrac-TEC HPC-10, is being marketed to ASM miners. This gravity separator utilizes a multi-stage separation process. In the first stage, whole ore is gravity fed into a screening trommel where it is washed with water and classified. Oversized material is separated out and the remaining material is fed onto a spiral concentration belt, which separates the heavy particles from the lighter particles. The heavy particles are fed to a sluice for further concentration. The resulting concentrate is of such low volume and high concentration of gold that the final classification can be hand-panned by one person.

The HPC-10 has a 0.5 hp electric motor and requires the use of a water pump and 120 liters per minute of water. Ore can be fed using a mini excavator or a team of 2 – 6 miners with shovels. The price of the HPC-10 is $28,300 USD, excluding the required electrical generator and water pump. (Oppenheimer, 2008)

Disadvantages of the Extrac-TEC HPC-10 are that it is expensive and it requires electricity and a significant amount of clean water.

Alternative 2: Cyanidation

Process Overview
Cyanidation is the most common method of gold extraction used by large-scale mining operations. Cyanidation is also used by ASM miners, often in combination with mercury amalgamation.

The cyanidation process involves three steps: leaching, concentration and refining. In the leaching step, cyanide is added to a slurry of gold ore. The gold is leached out of the ore as it reacts with cyanide and oxygen. The concentration step involves removing the gold from the slurry by absorbing it with activated carbon, which is often made from coconut shells. The refining step can

be achieved in a variety of ways. ASM miners typically use a simple refining process that involves screening and burning.

The advantage of the cyanidation process is that it dissolves the gold contained in refractory ore and achieves a high gold extraction rate. In addition, the process is relatively easy for the ASM miners to use and equipment costs are low. The primary disadvantage of cyanidation is that cyanide is toxic and therefore puts the health of the miners at risk. However, unlike mercury, cyanide is biodegradable and is not bioaccumulative.

Unfortunately, ASM miners often use cyanidation on ore concentrate that was previously processed with mercury amalgamation. The cyanide reacts with the mercury, making it more soluble and therefore increasing the potential of methylation. The use of mercury amalgamation on whole ore prior to cyanidation also typically results in a decrease in gold recovery. The reason for this is that the gold-mercury amalgam is disintegrated into small droplets (floured mercury) during the mixing or pumping processes. This gold-containing floured mercury is not easily recovered and typically discarded with the tailings.

Alternative 3: Chlorination

Process Overview

The origin of the chlorination process dates back to 1848, before the use of cyanidation. The process uses diluted hydrochloric acid and chlorine to dissolve the gold. The gold is then precipitated using sodium metabisulfite, oxalic acid, zinc or other agents.

Mintek, a mineral technology research body of the government of South Africa, has developed a chlorination process called the iGoli process. This process has been designed specifically for ASM miners and therefore it uses inexpensive equipment and chemicals that are commonly available such as swimming pool acid (diluted HCl), bleach (NaOCl) and sugar. This process applies only to ore concentrates so miners must use a form of gravity separation on the whole ore before using this process.

The process involves the following steps: leaching the ore concentrate with diluted hydrochloric acid and bleach; filtering out the solids; precipitating out gold powder from the solution; and, compressing the powdered gold into a disk.

Advantages of the iGoli process are that it can produce gold with a purity level of 99%. This is a significant improvement over amalgamation, which produces sponge gold that contains approximately 5% residual mercury along with other impurities. This process also has an advantage over amalgamation in that it can be applied to both ore containing free gold and refractory ore, while amalgamation only works with ore with free gold. As a result, the miners recover more gold from the ore and the gold that is recovered has greater value.

Hydrochloric acid and bleach are toxic and must be handled with care but they are chemicals that are commonly used for cleaning and pool maintenance and represent significantly less risk to the miners than mercury or cyanide. The chlorine is converted to salt during the process, which can be safely released to the environment.

Mintek does not protect the intellectual property of the process and a guide to developing the process is freely available. Mintek will also test samples and provide designs for the process to

small-scale miners. Mintek has demonstrated this process to ASM miners in Mozambique, Peru, and Tanzania.

Demand and Use of Mercury

The following table contains the mercury demand data for artisanal and small-scale gold mining provided by countries in their responses to the UNEP Request for Information (RFI) or other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT).

Table B2.1: Country Mercury Use for ASM Gold Mining (sorted by Estimated Mercury Demand)

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
China	Other	200 - 250[13]
Philippines	MIT	56.04
Ecuador	RFI	5
Cambodia	MIT	0.61 (0.035 – 1.182) (2008)
Argentina	RFI	0
Denmark	RFI	0
France	RFI	0
Germany	RFI	0
Iran	RFI	0
Japan	RFI	0
Netherlands	RFI	0
Norway	RFI	0
Sweden	RFI	0
Switzerland	RFI	0
Trinidad and Tobago	Other	0
United Kingdom	RFI	0
United States	RFI	0

Two countries reported ASM gold mining mercury use in their Mercury Inventory Toolkit (MIT) reports. The Philippines estimated an annual gold production in 2006 of 18,680 kilograms and used the default input factor of 3 kilograms of mercury per kilogram of gold from the MIT to estimate mercury use of 56.04 metric tons. Cambodia also reported a use number in its MIT report but based their estimate on mercury use by the 175 miners they interviewed. The 175 miners used a total of 0.0345 metric tons of mercury and Cambodia used this figure as the minimum demand. The maximum demand of 1.182 metric tons was calculated by multiplying the average use of the 175 miners (0.197 kilograms per miner) by the estimated number of ASM gold miners (6,000).

In an October 2006 UNIDO report titled "Global Impacts of Mercury Supply and Demand in Small-Scale Gold Mining", it was estimated that ASM gold mining represents 20-30% of the world's production of gold and results in the release of 650 – 1,000 metric tons of mercury per year. The report also estimated, by country, the release of mercury to the environment due to ASM gold mining activities.

The report defines the quantity of mercury released as the total amount used less the amount that is recycled and it states that the demand is equal to the quantity released, assuming constant

[13] UNIDO, 2006.

production levels and no change in technologies used. Therefore, it is assumed that the estimate of mercury released by ASM mining is equal to the estimated mercury demand for ASM mining. The following table summarizes these estimates.

Table B2.2: Mercury Demand for ASM Gold Mining

Country	Estimated Mercury Demand for ASM Gold Mining (metric tons/year)
China	200 - 250
Indonesia	100 - 150
Bolivia	10 - 30
Brazil	10 - 30
Columbia	10 - 30
Ecuador	10 - 30
Ghana	10 - 30
Peru	10 - 30
Philippines	10 - 30
Venezuela	10 - 30
Tanzania	10 - 30
Zimbabwe	10 - 30

The Philippines estimate of 56.04 metric tons using the default Mercury Inventory Toolkit input factor was significantly higher than the 10 – 30 metric ton estimate in the UNIDO report. Ecuador provided a use of 5 metric tons of mercury in their RFI compared to the 10 – 30 metric ton estimate in the UNIDO report. The discrepancies in the numbers are likely due to different estimation methods, different time periods, and other unknown factors.

In the Arctic Council Action Plan to Eliminate Pollution of the Arctic (ACAP) 2004 report of mercury releases in Russia, mercury consumed for amalgamation in ASM gold mining was estimated at 3-8 metric tons in 2001. This estimate was based on ASM miners producing 20 - 40 metric tons of gold with the quantity of mercury consumed being approximately 10% - 20% of gold production.

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries about their experiences with the technology changeover or alternatives associated with substituting mercury amalgamation in ASM gold mining with other methods. The information contained in the tables is derived from the responses to the UNEP Request for Information (RFI). In some cases, the tables contain an abbreviated or reworded version of the response included in the RFI.

Table B2.3: Countries Responding with Level of Substitution of “2”

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level “2” – Substitutes Available and Commonly Used
Japan	RFI	No experience data provided for this rating.

Table B2.4: Countries Responding with Level of Substitution of "1"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "1" – Substitutes Available and Minimally Used
Brazil	RFI	Mercury use is permitted only in licensed (authorized) mining.
Chile	RFI	Alternatives that don't contain mercury cost more.
Ecuador	RFI	Approximately 40% of production is still done by mercury amalgamation and 60% by cyanidation. Of the miners who still use amalgamation, 50% use a retort to reclaim mercury vapors but the other 50% vaporize the mercury in the open air.
Panama	RFI	No experience data provided for this rating.

Table B2.5: Countries with No Level of Substitution Response

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Argentina	RFI	No small/artisanal gold mining registered.
Cambodia	MIT	Most miners in Ratanakiri use mercury to extract gold from (whole) ore while miners in the other provinces use mechanical methods or other chemicals.
Denmark	RFI	Never been an industry.
France	RFI	Mercury use is banned but illegal use is still reported.
Iran	RFI	Mercury is not used in artisanal gold mining.
Netherlands	RFI	Not applicable.
Norway	RFI	Not applicable.
Philippines	MIT	Mercury use for gold mining is banned but miners continue to use it.

One country, Japan, reported a substitution level of "2" for ASM gold mining, which indicates that substitutes are available and commonly used in Japan. Four countries reported a substitution level of "1", which indicates that substitutes are available and minimally used in those countries.

Overall, eight countries provided written comments regarding experiences with alternatives to ASM gold mining. Two countries stated that mercury use is banned for gold mining but ASM miners continue to use it. One country stated that mercury-free alternatives cost more.

Summary – Artisanal and Small-Scale Gold Mining

The following table shows a quantitative breakdown of the level of substitution for mercury in ASM gold mining based on the RFI responses from five countries.

Table B2.6: Country Responses for Level of Substitution

Level of Substitution	Number of Country Responses	Percentage of Responses
2	1	20%
1	4	80%
0	0	0%

Thirteen countries stated that mercury demand for ASM mining was zero. It should be noted that many of these countries do not have ASM mining operations. Zero demand should not be interpreted as a successful transition to alternative processes. Japan was the only country to state that substitutes are available in the market and commonly used. Japan also stated that mercury was not used for ASM mining (demand = 0). This would indicate that a transition to alternative processes has been achieved.

The country responses indicate that alternatives to mercury amalgamation in ASM gold mining are available in the market but are not yet commonly used. While mercury-free gold extraction technologies do exist that are potentially viable for ASM miners, the transition to these technologies will likely require a longer timeline.

The challenges for this transition are not limited to the availability of feasible alternatives. A major challenge is that a successful transition would require that the estimated 15 million AMS miners, located in 50 different countries, change the process they use in their daily efforts to provide for their families. Another significant challenge is that low-priced mercury is readily available so ASM miners are not seeking out mercury-free alternatives on the basis of economics. History has shown that increases in the price of mercury result in reduced mercury use by ASM gold miners. (Maag, 2007) A successful transition is likely to require: large-scale training and education efforts; initiatives to overcome cultural, logistical and economic barriers; and a reduction in the supply of low-priced mercury.

Table B2.7: ASM Gold Mining Substitution Summary

ASM Gold Mining	**Alternative Technologies Identified**	**Transition Feasibility**
Mercury amalgam process	Yes	Alternatives available – challenges identified

B.3 Vinyl Chloride Monomer Production

Vinyl chloride monomer (VCM) is the primary feedstock material for polyvinyl chloride (PVC) production. The first commercial vinyl chloride monomer (VCM) production process was the acetylene-based process which uses mercuric chloride as a catalyst to react acetylene with hydrogen chloride. Today, nearly every country has converted VCM production to a mercury-free ethylene-based process, with the exceptions of China and Russia. (Doa, 2007)

Acetylene-Based Vinyl Chloride Monomer Production

Process Overview

The acetylene-based VCM production process typically uses coal and limestone as raw materials to produce calcium carbide, which is then mixed with water to make acetylene. VCM is produced when acetylene is reacted with anhydrous hydrogen chloride using mercuric chloride as a catalyst.

High raw material costs and high energy use has rendered this technology obsolete except in China. This technology is economically feasible in China because all of the raw materials are available domestically, material and energy costs are low due to the availability of inexpensive coal, capital costs are lower, and the process can be easily integrated with PVC production.

Acetylene-based VCM production is energy intensive and it is highly polluting, including mercury that is released along with reaction gases. In addition, there are concerns that expansion of acetylene-based production in China will result in electric power shortages given that China's electricity generating capacity is already strained. (ICIS, 2008)

The UNEP Mercury Inventory Toolkit (MIT) default input factor for mercury use in VCM production is 100-140 grams of mercury per metric ton of VCM produced. This estimate was based on 2002 data from the Russian Federation where 16 metric tons of mercury where used to produce 130,000 metric tons of VCM. (UNEP, 2005)

Representative Processors

The following are representative acetylene-based vinyl chloride monomer processors.

Table B3.1: Representative Acetylene-based Vinyl Chloride Monomer Processors

Manufacturer	Location	Website
Ningxia Yinglite Chemical Co., Ltd.	Shizuishan City, Ningxia, China	www.yinglitechem.com/en/main_en.htm
Shenyang Chemical Co	Shenyang, Liaoning, China	http://www.sychem.com/en/index_en.asp

Alternative 1: Ethylene-Based Vinyl Chloride Monomer Production

Process Overview

The ethylene-based VCM production process uses ethylene as the primary feedstock. Ethylene is reacted with chlorine to make ethylene dichloride (EDC). EDC can be produced either through direct chlorination using pure chlorine, or through oxychlorination using hydrogen chloride. Thermal cracking is then used to produce VCM from EDC. Hydrogen chloride is produced as a by-product and is recycled using the oxychlorination process.

Beginning in the 1960's, high production costs of the acetylene-based process resulted in the conversion of VCM production to ethylene-based processes. Approximately thirty-five percent of

VCM production in China and nearly all VCM production outside of China currently utilize ethylene-based processes.

A PVC production facility using the ethylene-based process would need approximately 3,500 kilowatt-hours of electric power to produce one metric ton of PVC, which is significantly less than the 6,500 – 7,000 kilowatt-hours required to produce a metric ton of PVC using the acetylene-based process. (ICIS, 2003)

Representative Processors
The following are representative ethylene-based vinyl chloride monomer processors.

Table B3.2: Representative Ethylene-based Vinyl Chloride Monomer Processors

Manufacturer	Location	Website
The Dow Chemical Company	Midland, Michigan, U.S.A.	www.dow.com
Formosa Plastics Corporation	Taipei, Taiwan	www.fpc.com.tw/enfpc/suba1-1.htm
INEOS	Lyndhurst, Hampshire, UK	www.ineoschlor.com

Alternative 2: Ethane-Based Vinyl Chloride Monomer Production

Process Overview
The ethane-based process produces VCM through direct chlorination of ethane. This process has the advantages of lower feedstock costs and utilization of a relatively simple chemical reaction. Ethane costs are approximately one third of the costs of ethylene. The primary disadvantage is that high reaction temperatures are needed. Reaction temperatures above 500^{o}C cause corrosion problems. A number of companies have attempted to develop an ethane-based process but development of a process with reaction temperatures below 500^{o}C has been a challenge. (cheresources.com, 2008)

One company, INEOS ChlorVinyls, has developed a process that maintains a reaction temperature below 400^{o}C, and for several years, it has operated a 1,000 metric ton per year pilot plant in Wilhelmshaven, Germany. The INEOS ethane-based process achieved a 30% reduction in energy consumption compared to an ethylene-based process. INEOS does not currently have plans to build a commercial scale operation because of problems encountered with by-product formation at the pilot plant. (Littlewood, 2008)

Representative Processors
Commercial-scale production of ethane-based VCM does not yet exist.

Demand and Use of Mercury
The following table contains the mercury demand data for vinyl chloride monomer production provided by countries in their responses to the UNEP Request for Information (RFI) or other documents, including reports generated using the UNEP Mercury Inventory Toolkit (MIT).

Table B3.3: Mercury Demand for Vinyl Chloride Monomer Production

Country	Source of Data	Estimated Mercury Demand/Quantity Used (metric tons/year)
China	Other	264 – 352 (2000)[14] 610 (2004)[15]
Russia	Other	15.5 (2002)[16]
Chile	RFI	0
Denmark	RFI	0
France	RFI	0
Germany	RFI	0
Japan	RFI	0
Netherlands	RFI	0
Norway	RFI	0
Philippines	MIT	0
Sweden	RFI	0
Switzerland	RFI	0
United Kingdom	RFI	0
United States	RFI	0

The Chemical Registration Center (CRC) of China's State Environmental Protection Administration estimated that 610 metric tons of mercury were used to produce VCM in 2004 and that almost 50% of this mercury was reclaimed and recycled for further use in China. The estimated net mercury consumption for VCM production in China in 2004 was 320.4 metric tons. Gross mercury use is expected to increase to over 1000 metric tons by 2010. (NRDC, 2006)

In a report prepared for the Arctic Council Action Plan to Eliminate Pollution of the Arctic (ACAP), four VCM producers located in Russia were identified as using the acetylene-based process in 2002. The gross mercury consumption for these four facilities was 15.5 metric tons. It was estimated that, of this total, 0.1% is released as air emissions, 0.1% is released with wastewater, 30% is reclaimed from the spent catalyst, and about 70% remains in the hydrochloric acid. Approximately 8 metric tons of mercury is reclaimed from the hydrochloric acid. The remaining mercury containing hydrochloric acid is sold for other applications including use in the oil and gas industries to treat wells. (ACAP, 2004)

Level of Mercury Substitution and Experience with Alternatives

The following tables contain information provided by countries about their experiences with the technology changeover or alternatives associated with substituting vinyl chloride monomer production using mercury with mercury-free production alternatives. The information contained in the tables is derived from the responses to the UNEP Request for Information (RFI), Mercury Inventory Toolkit (MIT), or other source of information. In some cases, the tables contain an abbreviated or revised version of the response included in the RFI.

[14] SEPA, 2005.
[15] NRDC, 2006.
[16] ACAP 2004.

Table B3.4: Countries Responding with a Level of Substitution of "2"

Country	Source of Data	Experience with Technology Changeover/ Alternatives Level "2" – Substitutes Available and Commonly Used
France	RFI	All facilities use the mercury-free process based on ethylene.
Germany	RFI	No experience data provided for this rating.
Iran	RFI	Iran reported a Level of Substitution of 1-2. All units are obliged to maintain their discharge at environmental criteria and standard level promulgated by the DoE.
Japan	RFI	No mercury catalyst processes are now used to manufacture VCM. The carbide-acetylene process had been used to manufacture VCM with mercuric chloride as a catalyst until the 1960's when the processes were converted to the ethylene dichloride method and the oxychlorination method due to the rise in electricity costs.
Netherlands	RFI	VCM is produced with ethylene and hydrogen chloride or ethylene dichloride. These ethylene-based processes do not use mercury as a catalyst.
Norway	RFI	No use of mercury in this industry in Norway.
Sweden	RFI	One plant using the ethylene route in operation since 1970 replacing a plant using the acetylene process (mercuric chloride based catalyst). The experience of changing to mercury free process is good both economically and environmentally.

Table B3.5: Countries with No Response for Level of Substitution

Country	Source of Data	Experience with Technology Changeover/ Alternatives No Response for Level
Cambodia	MIT	No activities related to the intentional use of mercury in industrial processes in Cambodia.
Chile	MIT	Doesn't apply to Chile.
Denmark	RFI	Never been an industry.
Germany	RFI	Not relevant
Switzerland	RFI	Process does not take place in Switzerland.
United States	RFI	No acetylene-based vinyl chloride monomer production activities in the U.S.

Six countries reported a substitution level of "2" for VSM production and one country, Iran, reported a substitution level of "1-2". A level "2" response indicates that substitutes are available and commonly used in those countries. Of these seven countries, five are European. Four of these countries reported that all VSM production is achieved using mercury-free processes.

Summary – Vinyl Chloride Monomer Production

China is the largest PVC producer with 32% of the global market in 2007. Sixty-five percent of China's PVC is produced from acetylene-based VCM using mercuric chloride as a catalyst. (KGI, 2008) There were an estimated 80 VCM plants in China in 2006. Seventy-one of the plants used

the acetylene-based process to produce an average of 85,000 metric tons per plant per year. (Chemsystems.com, 2008)

In recent years, China has built additional acetylene-based VCM production facilities due to increased demand for PVC and economic factors that favor acetylene-based production over ethylene-based production. VCM production capacity using acetylene has increased as fast as or faster than production capacity using ethylene. China has an abundance of inexpensive coal, which is the primary raw material for acetylene production. The supply of ethylene in China is limited, which also contributes to economic factors favoring acetylene-based production.

There are indications that the acetylene-based process may be losing some of its economic advantage over the ethylene-based process. The price of coal in China increased substantially from 2007 to 2008. Ethylene prices have recently dropped due to expanded production capacity in the Middle East. The Chinese government is also making efforts to reduce the export of high-energy-consuming, high-polluting, and low-value-added products and, in 2007, it cut the PVC export tax rebate from 11% to 5%. (KGI, 2008)

The following table shows a quantitative breakdown of the level of substitution for mercury in vinyl chloride monomer production.

Table B3.6: Country Responses for Level of Substitution

Level of Substitution	Number of Country Responses	Percentage of Responses
2	6	86%
1-2	1	14%
1	0	0%
0	0	0%

Eighty-six percent of the RFI responses stated that substitutes are available in the market and commonly used with respect to the use of a mercury catalyst in VCM production. These responses, combined with the fact that, globally, most VCM is produced using a mercury-free process, indicated that transition success has been achieved. Further transition to a mercury-free process will depend on factors in China including: availability and cost of raw materials, energy costs, and government regulations.

Table B3.7: Vinyl Chloride Monomer Substitution Summary

Vinyl Chloride Monomer Production	**Alternative Technologies Identified**	**Transition Feasibility**
Acetylene-based process	Yes	Site specific feasibility

Conclusions:

The conclusions provided in this report are primarily based on the Request for Information (RFI) and Mercury Inventory Toolkit (MIT) responses received from thirty-three countries. These responses provided valuable mercury demand data at a product/process level and on a country by country basis throughout North America, South America, Europe, Africa, and Asia. The RFI requested responses in a specific format for demand and substitution information. This consistent format was helpful for consolidating and analyzing the data provided by many countries. The MIT was helpful in that it provided consistent guidelines for countries to estimate their mercury demand for various product and process categories.

However, of the thirty-three responses received, many of them contained data gaps for certain categories of products and processes. For example, ten out of the thirty-three responses contained demand information for electronic and electrical devices, and eight out of thirty-three responses contained demand information for thermostats. Further, the estimated mercury demand responses provided in the RFIs often contained data from various years, with some responses providing data as far back as 2001. Therefore, it was not possible to use the RFI responses from countries as a basis to extrapolate aggregate mercury demand estimates on a regional or a global basis.

The estimated mercury demand reported in the RFI responses had similar characteristics for measuring and control devices, batteries, electrical/electronic devices, and lamps/lighting. For these product categories, the highest were received 1) from countries with high levels of domestic manufacturing for a particular mercury containing product or process, or 2) from countries that utilized the Mercury Inventory Toolkit as a basis for deriving their estimated mercury demand.

Alternative technologies were identified for the vast majority of products and processes covered in this report. Alternative technologies were considered "identified" if at least one commercially available alternative product and manufacturer was identified for the particular product category, or at least one commercially available alternative process was identified for a particular process category.

For the purposes of this report, transition success was considered "demonstrated" if greater than 50% of RFI respondents provided a level of substitution of "2" (substitutes available and commonly used) with no negative transition experiences reported, and two or more RFI respondents that either had an annual demand of zero tons of mercury, or have implemented a product/process ban that will lead to a mercury demand of zero tons by 2009.

Transition Success Demonstrated

Based upon the responses provided, several products and processes have alternative technologies available, and have demonstrated transition success to these non-mercury alternatives. These products and processes are listed below:

- *Thermometers*: Several alternative technologies such as liquid, dial, and digital were identified. Fifty-three percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Further, five countries reported zero demand for mercury containing thermometers. However, four countries that reported a level of substitution of "1" indicated that the costs were higher for the non-mercury alternatives.

- *Sphygmomanometers:* Two major alternative technologies, aneroid and electronic, were identified. Sixty-nine percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Three countries reported zero demand for mercury containing sphygmomanometers.

- *Thermostats:* Two major alternative technologies, mechanical and electronic, were identified. Eighty-two percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Five countries reported zero demand for mercury containing thermostats.

- *Batteries (non-miniature):* Paste-type zinc-manganese cylinder batteries, paperboard type zinc-manganese cylinder batteries, alkaline zinc-manganese cylinder batteries, and mercuric oxide batteries have commercially available alternatives such as alkaline manganese. Seventy-six percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Six countries reported zero demand for mercury containing non-miniature batteries.

- *Switches and relays*: Numerous alternative technologies were identified for the various types of mercury containing switches and relays. Seventy percent of the respondents indicated that these alternatives are available in the market and commonly used without any negative experiences reported. Further, four countries reported zero demand for mercury containing switches and relays.

- *High Intensity Discharge (HID) Automobile Lamps:* Automobile manufacturers use mercury-containing high-intensity discharge (HID) headlamps for use on some high-end luxury or performance automobiles but mercury-free halogen lamps are currently used for the majority of automobiles. Headlamp design and type is determined by the automobile manufacturer and typically cannot be changed by the consumer. HID headlamps cost more than halogen headlamps but they provide certain benefits including improved nighttime visibility, smaller size, longer life, and better efficiency. Automobile manufacturers that want performance benefits similar to HID headlamps now have the option to select from two recently developed mercury-free headlamp technologies: HID headlamps that use zinc iodide as a substitute for mercury, and LED headlamps.

- *Chlor-alkali Production*: Many countries around the world with mercury cell chlor-alkali plants have significantly reduced mercury consumption by closing mercury cell chlor-alkali facilities, reducing their mercury release through improved operations, or have successfully converted from the mercury cell process to the membrane cell process. In addition, there is industry commitment to close or convert mercury chlor-alkali facilities in Europe and India. Although conversion from a mercury cell process to membrane cell process is technically feasible, the conversion costs vary from site to site. Significant factors that affect conversion costs include the need for increased capacity, energy costs, and maintenance costs associated with the age of the mercury cell facility. The benefits reported from completing a conversion of mercury cells to membrane cells include reduced energy consumption, reduced need for maintenance, and elimination of mercury management issues. Approximately 89% of RFI responses for chlor-alkali production were rated at a substitution level of “2”, and there were no negative responses provided for the transition to the non-mercury alternatives. Also, ten countries reported estimated mercury demand of zero.

Alternatives Available – Challenge Identified

The following products and processes have alternative technologies available, but there are economic, technical, social, and/or institutional challenges identified that remain. These challenges must be addressed before the alternatives can be fully implemented on a global basis.

- *Silver oxide, zinc air, alkaline and mercuric oxide miniature batteries*: Mercury free miniature batteries are available as alternatives to these mercury containing products. However, these alternatives have limited availability, and are not available to meet the demands of many miniature battery applications. Despite this, product bans at the state level in the United States for all uses of these products go into effect by 2011, allowing enough time for manufacturers to develop mercury free miniature batteries for most applications.

- Dental amalgam: Mercury-free alternatives to dental amalgam include composite and glass ionomer materials. The alternatives can be matched to the tooth color and are widely used where aesthetics are important. They also have the advantage of not requiring special handling of waste generated during cavity filling. The alternatives cost more, take longer to place, and often have lower resistance to fracture and wear. Three countries (Denmark, Norway and Sweden) determined that the alternatives were adequate replacements for amalgam and, in 2008, imposed bans on dental amalgam. Eight countries, representing fifty percent of the RFI responses, indicated that substitutes are available and commonly used in those countries. Despite the fact that transition success has been demonstrated in some countries, the higher cost of the alternatives is a challenge that is preventing the further transition away from dental amalgam. In their responses to the RFI, four countries commented on the higher cost of alternatives.

- *Liquid Crystal Display (LCD) backlight units*: LCD displays with mercury-free light-emitting diode LED backlights are currently available in both laptop computers and televisions. The LED backlight technology has certain performance advantages over the widely-used cold-cathode fluorescent backlights, including longer life, higher contrast ratio, and the potential for decreased power consumption. LED backlight technology is still evolving, has a higher cost, and a successful transition may require the redesign of the products that use LCD displays.

- *Linear and compact fluorescent lamps*: LED lamps are currently available as alternatives to both linear and compact fluorescent lamps but these LED lamps are suitable only for limited types of applications due to lower light output and high cost. LED lamps have the potential to become a feasible alternative to fluorescent lamps due to their long life and energy-efficiency but further technological advancements are required for this potential to be realized.

- *HID lamps (non-automobile)*: Mercury-free alternatives to HID lamps are not currently available, with a few exceptions. However, several mercury-free lamp technologies were identified that are potential alternatives to mercury-containing HID lamps, including: LED lamps, metal halide lamps using zinc iodide as a substitute for mercury, and mercury-free high-pressure sodium lamps.

- *Artisanal and small-scale gold mining:* Mercury-free alternatives to the amalgam gold mining process are available and currently in use. However, a successful transition away from mercury use is likely to require: large-scale training and education efforts; initiatives

to overcome cultural, logistical and economic barriers; and a reduction in the supply of low-priced mercury.

Site Specific Feasibility

The following process was determined to require a site-specific analysis before the economic feasibility of implementing a non-mercury process could be assessed:

- *Vinyl chloride monomer (VCM) production*: VCM manufacturers in nearly every country, with the exception of China and Russia, have converted to the mercury-free ethylene-based process because of lower energy requirements and lower raw material costs. In China, the production of VCM with mercury using the acetylene-based process continues to economically favorable due to factors including inexpensive coal and limited availability of ethylene for the ethylene-based process. The use of mercury for VCM production is expected to increase as China expands its VCM production with additional facilities using the acetylene-based process.

Future follow-up with responding countries to address data gaps by providing additional mercury demand and substitution data would be helpful to validate and potentially enhance the findings and conclusions of this report. In addition, follow-up with non-responding countries to provide an initial response to the RFI would provide further insight into the use of non-mercury alternatives on a global basis.

Sources

Introduction and Methodology:

United Nations Environment Programme, Request for Information of Mercury in Products and Processes, Quantities Used, Demand, Level of Substitution, Technology Change-over, Available Substitutes, December 2007.

United Nations Environment Programme, Report of the Ad hoc Open-ended Working Group on Mercury on the work of its first meeting, November 28, 2007.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Measuring and Control Devices:

ACAP, Assessment of mercury releases from the Russian Federation. Russian Federal Service for Environmental, Technological and Atomic Supervision and Danish Environment Protection Agency for Arctic Council. December 2004.

Air & Water, Inc., www.air-n-water.com, April 2008.

AllHeart, www.allheart.com, April 2008.

Amazon, www.amazon.com, April 2008.

AZ Partsmaster, www.azpartsmaster.com, April 2008

Canzanello, Vincent, et al., Are Aneroid Sphygmomanometers Accurate in Hospital and Clinical Settings?, Archives of Internal Medicine, Vol. 161, No. 5, March 12, 2001.

Electric Supplies Online, www.electricsuppliesonline.com, April 2008

Global Village of Beijing, Market Research Report on Chinese Mercury-free Thermometers and Sphygmomanometers, November 22, 2007.

Healthy Heart Help, www.healthyhearthelp.com, April 2008.

KemI, Report No. 7/05 Mercury-free blood pressure measurement equipment – Experiences in the Swedish Healthcare Sector, 2005.

Lassen, Carsten, and Maag, Jakob, “Alternatives to Mercury- containing Measuring Devices”, Environmental Project No. 1102, 2006.

Lowell Center for Sustainable Production, A Review of Thermostat Energy Efficiency and Pricing, May 12, 2003.

Lowell Center for Sustainable Production, An Investigation of Alternatives to Mercury Containing Products, January 2003.

Lowell Center for Sustainable Production, Sustainable Hospitals Project, www.sustainablehospitals.org, April 2008.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541)

Manufacturer location, product, and pricing information: See manufacturer website listed in the representative manufacturer tables.

Miller Thermometer Company, www.millerthermometer.com, April 2008.

Natural Resources Defense Council, Research Analysis Report on Mercury Use in China 2003 – 2005 – The Measuring Devices Industry of China, May 2007.

Nextag, www.nextag.com, April 2008.

Northeast Waste Management Official's Association (NEWMOA), IMERC Database, www.newmoa.org/prevention/mercury/imerc, April 2008.

Northeast Waste Management Official's Association (NEWMOA), Trends in Mercury Use in Products: Summary of IMERC Mercury-added Products Database, June 2008.

Novatech, www.novatech-usa.com, April 2008.

Promed Products, www.promedproducts.com, April 2008.

Prothermostats, www.prothermostats.com, April 2008.

Supplierlist, www.supplierlist.com, June 2008.

Thermostat Shop, www.thermostatshop.com, April 2008.

QA Supplies, www.qasupplies.com, April 2008.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Vitality Medical, www.vitalitymedical.com, April 2008.

Welch Allyn, Service Manual Aneroid Sphygmomanometers, 95P504 Rev. D.

Batteries:

AtBatt, www.atbatt.com, April, 2008.

Batteries.com, www.batteries.com, April 2008.

China Chemicals Registration Center, State Environmental Protection Administration, "China Mercury-related Information Analysis Report", April 2005.

Feng, Xinbin, Mercury Pollution in China – An Overview, Table 3. In: Pirrone, N., Mahaffey, K. (Eds.), Dynamics of Mercury Pollution on Regional and Global Scales: Atmospheric Processes, Human Exposure Around the World. Springer Publishers, Norwell, MA, USA, pp. 657-678.

Lowell Center for Sustainable Production, An Investigation of Alternatives to Miniature Batteries Containing Mercury, December 17, 2004.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541)

Manufacturer location, product, and pricing information: See manufacturer website listed in the representative manufacturer tables.

MD Battery, Varta V625U, PX625A, Lr9, 1.5V Alkaline Battery, www.mdbattery.com, June 2008.

Microbattery, http://shopping.microbattery.com, April 2008.

National Electrical Manufacturers Association (NEMA), Press Release, NEMA Announces Battery Industry Commitment to Eliminating Mercury in Button Cells, March 2, 2006, http://www.nema.org/media/pr/20060302a.cfm.

National Resources Defense Council (NRDC), NRDC Submission to UNEP In Response to March 2006 Request for Information On Mercury Supply, Demand, and Trade, www.chem.unep.ch.

Nextag Comparison Shopping, www.nextag.com, April 2008.

Northeast Waste Management Official's Association (NEWMOA), IMERC Database, www.newmoa.org/prevention/mercury/imerc, April 2008.

Northeast Waste Management Official's Association (NEWMOA), Trends in Mercury Use in Products: Summary of IMERC Mercury-added Products Database, June 2008.

Radioshack, Mercuric Oxide Batteries, http://support.radioshack.com, April 2008.

Small Battery Company, Mercury Replacement Battery Catalogue, http://www.smallbattery.company.org.uk/sbc_mercury_catalogue.htm, June 2008.

State of Maine, Maine Revised Statutes, http://janus.state.me.us/legis/statutes/38/title38sec1661-C.html.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Walgreens, www.walgreeens.com, April 2008.

Xiaodong, Jian, China Ministry of the Environment, email communication, May 20, 2008.

Dental Use:

About Cosmetic Dentistry, www.aboutcosmeticdentistry.com, accessed on May 19, 2008.

ADA, American Dental Association, Dental Fillings Facts, www.ada.org, accessed on April 16, 2008.

Atlanta Dental, http://www.atlantadental.com/default.aspx

Christensen, GJ, Compomers vs. Resin-reinforced Glass Ionomers, *J Am Dent Assoc* 1997;128;479-480.

Colgate-Palmolive Company, Oral & Dental Health Basics – Types of Fillings, http://www.colgate.com/app/Colgate/US/OC/Information/OralHealthBasics/CheckupsDentProc/Fillings/TypesOfFillings.cvsp, accessed on May 13, 2008.

Cost Helper, How Much Does a Cavity Filling Cost?, www.costhelper.com/cost/health/cavity-filling.html, accessed on May 19, 2008.

Dentsply Caulk, http://www.caulk.com/Index.html

www.free-ed.net, Fundamentals of Dental Materials, http://www.free-ed.net/sweethaven/medtech/dental/dentmat/lessonMain.asp?iNum=fra0105, accessed on May 13, 2008.

Holt Dental Supply, Inc., http://www.holtdentalsupply.com/

Johnstone, Greg, Let's Talk Dental Fillings, Consumer Guide to Dentistry, www.yourdentistryguide.com/, accessed on May 19, 2008.

KemI, Report No. 4/04. Mercury – Investigation of a General Ban, 2004.

Manufacturer location, product and pricing information: See manufacturer and retailer websites listed in the representative manufacturer tables.

Mitra, Sumita B. et al, An Application of Nanotechnology in Advanced Dental Materials, *J Am Dent Assoc* 2003; 134; 1382-1390.

Net32, http://www.net32.com/, accessed on May 14, 2008.

Northeast Waste Management Official's Association (NEWMOA), IMERC Database, www.newmoa.org/prevention/mercury/imerc, April 2008

Pearson Dental, http://www.pearsondental.com/

Pediatric Dental Health, Should Children Have White Dental Fillings?, November 1, 2001, www.dentalresource.org/topic33whitefilling.htm, accessed on May 13, 2008.

PR Newswire, Dental Mercury Use Banned in Norway, Sweden and Denmark Because Composites Are Adequate Replacement, January 3, 2008, http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/01-03-2008/0004729824&EDATE, website accessed May 13, 2008.

SEPA, China Chemicals Registration Center, State Environmental Protection Administration, "China Mercury-related Information Analysis Report", April 2005.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541)

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Electrical and Electronic Devices:

Amazon, www.amazon.com, April 2008.

Dean Bennett Supply, www.aermotorwindmills.com, April 2008.

Digikey, http://parts.digikey.com, April 2008.

Drillspot, www.drillspot.com, April 2008.

Lesman Online, Lesman Online Pressure, Temperature, Level, Flow, Analytical Products, www.lesman.com, April 2008.

Lowell Center for Sustainable Production, An Investigation of Alternatives to Mercury Containing Products, January 2003.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541)

Manufacturer location, product, and pricing information: See manufacturer website listed in the representative manufacturer tables.

MOR Electric Heating Association, www.heatersplus.com, April 2008.

Mouser, Mouser Catalog, www.mouser.com, April 2008.

Newark, Electromechanical and Industrial Control, www.newark.com, April 2008.

Northeast Waste Management Official's Association (NEWMOA), IMERC Database, www.newmoa.org/prevention/mercury/imerc, April 2008.

Northeast Waste Management Official's Association (NEWMOA), Trends in Mercury Use in Products: Summary of IMERC Mercury-added Products Database, June 2008.

SJ Greatdeals, www.sjgreatdeals.com, April 2008.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Lamps/Lighting:

AlbEO Tecnologies, Inc., www.albeotech.com, June 2008.

Amazon.com, Inc. www.amazon.com, June 2008.

Apple Inc., www.apple.com, June 2008.

AutoZone Inc., www.autozone.com, June 2008.

Bulbs.com, www.bulbs.com, June 2008.

C. Crane Co. Inc., www.ccrane.com, June 2008.

Crutchfield Corp. www.crutchfield.com, June 2008.

eAutoWorks.com, www.eautoworks.com, June 2008.

EdisonLED.com, www.edisonled.com, June 2008.

Energy Federation Inc., www.energyfederation.org, June 2008.

EverLED, www.everled.com, June 2008.

Dell Inc., www.dell.com, June 2008.

General Electric Company, www.ge.com, June 2008.

Hasek, Glenn, On the Horizon and Here Today: LED Alternatives to Linear Fluorescents, Green Lodging News, www.greenlodgingnews.com, March 4, 2008.

Ilumisys, Inc., www.ilumisys.com, April 2008.

LEDdynamics, Inc., www.EverLED.com, April, 2008.

LED Liquidators, Inc., www.ledliquidatorsinc.com, June 2008.

Lightingonthenet.com, www.lightingonthenet.com, June 2008.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541)

Manufacturer location, product and pricing information: See manufacturer and retailer websites listed in the representative manufacturer tables.

National Automotive Parts Association (NAPA), www.napaonline.com, June 2008.

Natural Resources Defense Council (NRDC), Survey and Research on the Status of Use of Mercury in China's Electric Light Source Industry, Chemical Registration Center of State Environmental Protection Administration of China, 2007.

Northeast Waste Management Official's Association (NEWMOA), IMERC Database, www.newmoa.org/prevention/mercury/imerc, April 2008

Northeast Waste Management Official's Association (NEWMOA), Mercury Use in Lighting, http://www.newmoa.org/prevention/mercury/imerc/factsheets/lighting.pdf, June 2006.

Northeast Waste Management Official's Association (NEWMOA), Trends in Mercury Use in Products: Summary of the Interstate Mercury Education & Reduction Clearinghouse (IMERC) Mercury-added Products Database, June 2008

Osram Sylvania, www.sylvania.com, June 2008.

Ramroth, Laurie, Comparison of Life-Cycle Analyses of Compact Fluorescent and Incandescent Lamps Based on Rated Life of Compact Fluorescent Lamp, Rocky Mountain Institute, February 2008.

Samsung Electronics Co. Ltd., www.samsung.com, April, 2008.

Shenzhen Dicolor Optoelectronics Co. Ltd., www.dicolor.cn, June 2008.

Super Bright LEDs Inc., www.superbrightleds.com, June 2008.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.netl.doe.gov/ssl/publications/publications-factsheets.htm, June 2008.

Woodyard, Chris, Healy, James R., Car buyers to see the light in LEDs, USA Today, November 1, 2006.

Other Products:

Baird, David M., Lighthouses, The Canadian Encyclopedia, www.thecanadianencyclopedia.com, accessed on July 15, 2008.

Jacovella, France, Canadian Information to Support Intersessional Work of the OEWG, January 31, 2008.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541).

Shultz, Denise and Paul Shultz, Pharology 101 – Mercury Float, Lighthouses of Australia Inc. Monthly Bulletin, May/June 2005 – Vol 8 No. 3.

Toxics Use Reduction Institute (TURI), Five Chemical Alternatives Assessment Study, June 2006.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Chlor-alkali Production:

Andersson, Caroline, Counsellor Regulatory and Environmental Affairs, Euro Chlor, email communication, May 27, 2008.

Berthiaume, Sylvie, et. al., SRI International, Chemical Economics Handbook, Chlorine/Sodium Hydroxide, 2000.

Euro Chlor, Position Paper on Mercury, February 12, 2008.

Eur Chlor, Chlorine Plants January 2005, http://www.eurochlor.org/plants.

European Commission, Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques in the Chlor-Alkali Manufacturing Industry, December 2001.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541).

United Nations Environment Programme, Draft Business Plan of the Reductions from the Chlor-Alkali Sector Partnership Area, February 26, 2008.

United Nations Environment Programme, Summary of Supply, Trade, and Demand Information on Mercury, November 2006.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Small Scale/Artisanal Gold Mining:

ACAP, Assessment of mercury releases from the Russian Federation. Russian Federal Service for Environmental, Technological and Atomic Supervision and Danish Environment Protection Agency for Arctic Council. December 2004.

Cleangold, LLC, www.cleangold.com, June 2008.

Gunson, A.J., Veiga, M.M., Mercury and Artisanal Mining in China, *Environmental Practice*, 2004, 6:109-120.

Hylander, Lars D., et al, Comparison of Different Gold Recovery Methods with Regard to Pollution Control and Efficiency, *Clean*, 2007, 35(1), 52-61.

IE-TEC Marketing Limited, www.extrac-tec.com, May 2008.

Knelson, www.knelson.com, June 2008.

Maag, Jakob et al., Mercury substitution priority working list: An input to global considerations on mercury management. Nordic Council of Ministers, Copenhagen, Denmark., 2007. (TemaNord 2007:541)

Minerals Council of Australia, www.minerals.org.au, accessed on May 21, 2008.

Mintek, www.mintek.co.za, June 2008.

Oppenheimer, Greg, IE-TEC Marketing Limited, email correspondence, May 21, 2008.

UNIDO, Global Mercury Project, Report to the UNEP Governing Council Meeting, Nairobi, February 2007, Global Impacts of Mercury Supply and Demand in Small-Scale Gold Mining, October 2006.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.

Veiga, Marcello, Global Mercury Project, Equipment Specification for the Demonstration Units in Zimbabwe, March 2004.

Veiga, Marcello M., et al, Origin of Mercury in Artisanal and Small-scale Gold Mining, *J. Cleaner Prod.* 2006, 14, 436-447.

Vieira, Rickford, Mercury-free Gold Mining Technologies: Possibilities for Adoption in the Guianas, *J. Cleaner Prod.* 2006, 14, 448-454.

Vinyl Chloride Monomer Production:

ACAP, Assessment of mercury releases from the Russian Federation. Russian Federal Service for Environmental, Technological and Atomic Supervision and Danish Environment Protection Agency for Arctic Council. December 2004.

Chemsystems.com, PERP Program – Acetylene-Based VCM, http://www.chemsystems.com/about/cs/news/items/PERP%200506S4%20Acetylene%20Based%20VCM.cfm, accessed on June 3, 2008.

Cheresources.com, VCM from Ethane Becomes Profitable, http://www.cheresources.com/vcm.shtml, accessed on April 4, 2008.

Doa, Maria, Commodity-Grade Mercury Global Supply, Demand, and Movement, Commodity-Grade Mercury Stakeholder Meeting, May 8, 2007, http://www.epa.gov/mercury/stocks/20070508.htm, accessed on June 3, 2008.

The Dow Chemical Company, Product Safety Assessment Vinyl Chloride Monomer, January 2007.

European Commission, Integrated Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques in the Large Volume Organic Chemical Industry, February 2003.

ICIS, Impact of Costs Shrugged Off, December 15, 2003, http://www.icis.com/Articles/2003/12/16/542742/impact-of-costs-shrugged-off.html, accessed on June 2, 2008.

ICIS, Vinyl Chloride Monomer (VCM) Prices and Pricing Information, accessed at http://www.icis.com/v2/chemicals/9076567/vinyl-chloride/pricing.html, on April 4, 2008.

ICIS, Vinyl Chloride Monomer (VCM) Uses and Market Data, accessed at http://www.icis.com/v2/chemicals/9076568/vinyl-chloride/uses.html, on April 4, 2008.

KGI, http://research.kgieworld.co.th/recom.nsf/0/56FB5A0B162894F74725741100068AD9/$file/Short+Report_TPC_2008_03_19_e_th.pdf, accessed June 2, 2008.

Linak, Eric et. al., "Vinyl Chloride Monomer (VCM),"Chemical Economics Handbook Product Review, SRI International, October, 2003.

Littlewood, Andrew, INEOS ChlorVinyls, email correspondence, June 3, 2008.

National Resources Defense Council (NRDC), NRDC Submission to UNEP In Response to March 2006 Request for Information On Mercury Supply, Demand, and Trade, www.chem.unep.ch.

SEPA, China Chemicals Registration Center, State Environmental Protection Administration, "China Mercury-related Information Analysis Report", April 2005.

United Nations Environment Programme, Toolkit for Identification and Quantification of Mercury Releases, Pilot Draft, November 2005.