NATURAL EMISSIONS, GLOBAL CHANGE AND THE GLOBAL MERCURY CYCLE – A 2-DAY WORKSHOP.

Venue: Department of Earth Sciences, University of Oxford, UK, 24-25 May 2011.

Organised by: The IKIMP project: Integrating Knowledge to Inform Mercury Policy
http://www.mercurynetwork.org.uk/

Briefing Notes.

In preparation for the workshop, here are some brief notes which summarise current estimates of natural and anthropogenic mercury emissions; some scenarios for future energy use and a synopsis of legislation and other agreements relating to mercury.

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Annual global natural and anthropogenic emissions, and natural reservoirs for mercury.

Here is a recent summary of the global mercury inventory: the first, from a synoptic paper by Pirrone et al., (ACP, 2010), is a tabulation of global natural and anthropogenic emissions in 2007-2008.

Global Mercury Emissions, Natural Sources	Mg/yr	%	Global Anthropogenic Mercury Emissions	Mg/yr	%
Oceans	2682	*52*	Coal and Oil combustion[1]	810	*35*
Lakes	96	*2*	Non-ferrous metals	310	*13*
Forests	342	*7*	Pig iron and steel production	43	*2*
Grasslands+Tundra	448	*9*	Cement production	236	*10*
Desert, Metalliferous & unvegetated land	546	*10*	Caustic soda production	163	*7*
Agricultural land	128	*2*	Mercury production	50	*2*
Evasion after mercury-depletion	200	*4*	Artisanal gold mining	400	*17*
Biomass burning	675	*13*	Waste disposal	187	*8*
Volcanoes/Geothermal	90	*2*	Coal bed fires	32	*1*
			Vinyl Chloride Monomer production	24	*1*
			Other	65	*3*
Total	**5207**			**2320**	

1 – considerable variance in this estimate; quoted as 1422 Mg/yr in Pirrone and Mason (2009).

In addition, the global emissions budget is summarised as two box models of reservoirs and exchange fluxes in the GEOS-Chem chemical transport model (Selin et al., 2008): the first being an estimate of the pre-industrial mercury cycle; the second, being the present day.

Sources.

N. Pirrone and R. Mason (eds, 2009), Mercury fate and transport in the global atmosphere: emissions, measurements and models. Springer, 637 pp. doi:10.1007/978-0-387-93958-2

N. Pirrone et al., (2010), Global mercury emissions to the atmosphere from anthropogenic and natural sources Atmospheric Chemistry and Physics, 10, 5951–5964. www.atmos-chem-phys.net/10/5951/2010/ doi:10.5194/acp-10-5951-2010

N.E. Selin et al., (2008), Global 3-D land-ocean-atmosphere model for mercury: present-day vs. pre-industrial cycles and anthropogenic enrichment factors for deposition, *Global Biogeochemical Cycles,* 22, GB2011, doi:10.1029/2007GB003040.

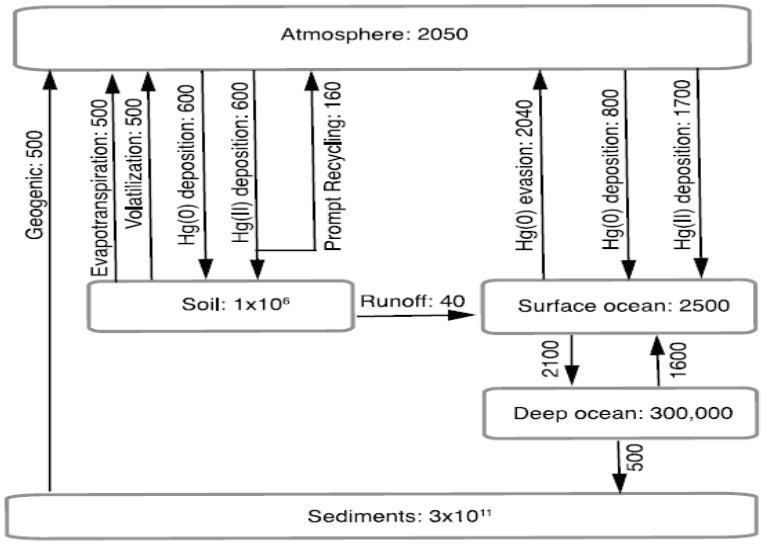

Figure 1. Global preindustrial biogeochemical cycle of mercury in GEOS-Chem. Inventories are in Mg and rates are in Mg a^{-1}. All reservoirs are in steady state.

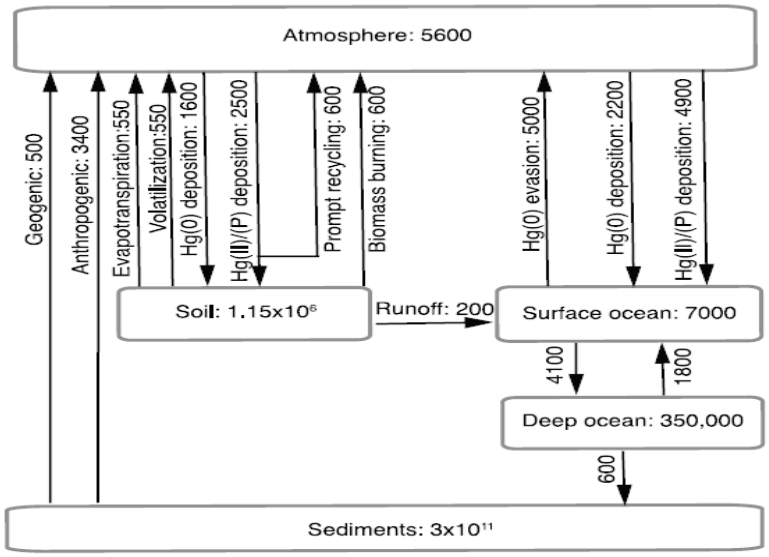

Figure 4. Global present-day biogeochemical cycle of mercury in GEOS-Chem. Inventories are in Mg, and rates are in Mg a^{-1}.

Projections of Energy Use to 2050

In its 'Energy Technology Perspectives 2010' report (http://www.iea.org/techno/etp/etp10/English.pdf) the International Energy Agency examines two scenarios for the future development of energy supply and demand:

- **The baseline scenario:** in which governments introduce no new energy and climate policies
- **The BLUE Map scenario:** the BLUE Map scenario (with several variants) is target-oriented: it sets the goal of halving global energy-related CO_2 emissions by 2050 (compared to 2005 levels) and examines the least-cost means of achieving that goal through the deployment of existing and new low-carbon technologies.

By 2050, radically different energy futures emerge between these two scenarios as summarised in the following table.

Baseline Scenario	BLUE Map Scenario
Energy-related CO_2 emissions roughly double	Energy-related CO_2 emissions reduced by 50 %
Primary energy use rises by 84 %; carbon intensity of energy use increases by 7 %	Primary energy use rises by 32 %; carbon intensity of energy use falls by 64%
Liquid fuel demand rises by 57 % requiring significant use of unconventional oil and synthetic fuels; primary coal demand increases by 138 %; gas demand is 85 % higher	Liquid fuel demand falls by 4 % and biofuels meet 20 % of total; coal demand drops by 36 %; natural gas falls by 12 %; renewables provide almost 40 % of primary energy supply
CO_2 emissions from power generation more than double; CO_2intensity of power generation declines slightly to 459 g/kWh	CO_2 emissions from power generation are cut by 76 %; its CO_2 intensity falls to 67 g/kWh
Fossil fuels supply more than two-thirds of power generation; the share of renewable energy increases slightly to 22 %	Renewables account for 48 % of power generation; nuclear provides 24 % and plants equipped with CCS 17 %
Carbon capture and storage (CCS) is not commercially deployed	CCS is used to capture 9.4 Gt of CO_2 from plants in power generation (55 %), industry (21%) and & fuel transformation (24 %)
CO_2 emissions in the buildings sector, including those associated with electricity use, nearly double	CO_2 emissions in buildings are reduced by two-thirds through low-carbon electricity, energy efficiency and the switch to low- and zero-carbon technologies (solar heating and cooling, heat pumps and CHP)
Almost 80% of light-duty vehicles (LDVs) sales rely on conventional gasoline or diesel technology; petroleum products meet more than 90% of transport energy demand	Almost 80 % of LDVs sales are plug-in hybrid, electric or fuel-cell vehicles; the share of petroleum products in final transport demand falls to 50 %
CO_2 emissions in industry grow by almost half, as industrial production increases	CO_2 emissions in industry fall by around a quarter mainly thanks to energy efficiency, fuel switching, recycling, energy recovery and CCS
Total investment in energy supply and use totals USD 270 trillion	Investment is USD 46 trillion (17 %) more than in Baseline; cumulative fuel savings are USD 112 trillion higher than in Baseline
Non-OECD countries are responsible for almost 90 % of growth in energy demand and account for nearly three-quarters of global CO_2 emissions	Non-OECD countries achieve CO_2 emissions reduction of around 30% compared to 2007; OECD countries account for less than one-quarter of global CO_2 emissions, having reduced emissions by 70 % to 80 % below 2007 levels

Mercury concentrations in oil and natural gas

Another work package within the IKIMP initiative is currently reviewing published data on the mercury content of oil and natural gas. Recognising that this review is not yet complete, it has revealed some information of relevance to the workshop.

The concentration of mercury in crude oil and natural gas varies by many orders of magnitude, with measurements ranging from 0.1 to 20,000 ppb in crude oil (Wilhelm et al, 2007) and from 0.05 to 4,400,000 μg/Nm^3 in natural gas (Carnell et al, 2005). By way of illustration, Table 1 presents information on the mercury contents of crude oil from different countries processed in the US in 2004 (from Wilhelm et al, 2007). The high concentration of mercury in crude oils from Thailand and Vietnam are of particular note.

Table 2 from Carnell et al, 2005 presents average mercury levels in natural gas from different regions. Levels from individual wells can be much higher.

References

Carnell, P., Foster, A., and Gregory, J., 2005. "Mercury matters". Hydrocarbon Engineering, December 2005. http://www.jmcatalysts.com/ptd/pdfs-uploaded/Mercury%20matters%20Dec%2005.pdf

Wilhelm, S., Liang, L., Cussen, D., and Kirchgessner, D., 2007. "Mercury in crude oil processed in the United States (2004)". Environmental Science and Technology, Vol. 41, No. 13, pp 4509-4514. http://pubs.acs.org/doi/pdf/10.1021/es062742j

Table 1: Mercury in oil processed in US in 2004: breakdown by country

Extracted from: Wilhelm, S., Liang, L., Cussen, D., and Kirchgessner, D., 2007: Table 2

Country / region	Mercury concentration Country average (µg/kg)
Africa	
Algeria	13.3
Angola	1.6
Chad	1.2
Gabon	0.5
Guinea	0.3
Ivory Coast	0.3
Nigeria	1.8
Asia	
Australia	0.8
Thailand	593.1
Vietnam	66.5
North America	
Canada	2.1
USA	4.3
Mexico	1.3
Europe	
Norway	19.5
Russia	3.1
UK	3.6
Middle East	
Iraq	0.7
Kuwait	0.8
Saudi Arabia	0.9
South America	
Argentina	16.1
Brazil	1.1
Columbia	3.4
Ecuador	1.8
Venezuela	4.2

Table 2: Regional average level of mercury in natural gas

From: Carnell, P., Foster, A., and Gregory, J., 2005: Table 1

Location	Elemental mercury concentration mg/m^3
South America	69-119
East Asia	58-193
North Africa	0.3-130
Northern Europe	0.01-180
Middle East	1-9
Eastern US pipeline	0.019-0.44
Midwest US pipeline	0.001-0.10
North America	0.005-0.040

European Union legislation related to mercury

IKIMP seeks to bring together the scientific and technical knowledge base to ensure relevant and appropriate information is used to inform public policy.

IKIMP has worked closely with the UK Department for Environment, Food and Rural Affairs (Defra) as this UK government department has responsibility for all matters relating to mercury policy. As an independent body IKIMP has also briefed the European Commission which recently made mention of IKIMP in a communication to the European Parliament and Council: "Action 14: …..*The EU and its Member States are members and participants in several international fora where the mercury issue is discussed. Initiatives have also been taken at individual Member State level, such as* ***IKIMP*** *(Integrating Knowledge to Inform Mercury Policy), a 3-year knowledge exchange initiative dedicated to mercury issues in the UK*." [com2010_0723en01][1]

As an executive body of the European Union the European Commission is responsible for proposing legislation which is presented to the European Parliament and Council for approval. *Regulations* are immediately enforceable as law in all member states simultaneously, whereas *Directives* require member states to achieve a result through their own procedures and legislative instruments. Within the EU there are a number of legislative acts which make reference to mercury.

Regulations

Regulation (EC) No 1907/2006; amended by Regulation (EC) No 552/2009	the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation bans the sale of mercury-containing measuring devices (e.g. manometers, barometers, sphygmomanometers, thermometers).
Regulation (EC) No 689/2008	establishes prior informed consent (PIC) concerning the export and import of mercury compounds.
Regulation (EC) No 1102/2008	bans the export of metallic mercury and certain mercury compounds and mixtures and concerns the safe storage of redundant metallic mercury.

Directives

Directive 82/176/EEC	sets limit values and quality objectives for mercury discharges by the chlor-alkali electrolysis industry.
Directive 84/156/EEC	sets limit values and quality objectives for mercury discharges by sectors other than the chlor-alkali electrolysis industry.
Directive 89/369/EEC	onthe prevention of mercury pollution from new municipal waste incineration plants.
Directive 89/677/EEC	places restrictions on the marketing and use of certain dangerous substances and preparations e.g. anti-fouling paints containing mercury.
Directive 91/188/EEC	prohibits the placing on the market and use of plant protection products containing certain substances such as mercury.

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0723:FIN:EN:PDF

Directive 99/31/EC	on the landfill of wastecontaining mercury compounds.
Directive 2000/53/EC	bans mercury in materials and components of vehicles.
Directive 2000/60/EC	establishes a framework for Community action in the field of water policy (Water Framework Directive) which incorporates mercury discharge limits.
Directive 2002/95/EC	An annex to the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS Directive) significantly reduces the limit values for mercury in light bulbs.
Directive 2002/96/EC	The Directive on waste electrical and electronic equipment (WEEE) sets provisions for collection and treatment of light bulbs.
Directive 2006/66/EC	stipulates the maximum allowed content of mercury in batteries and accumulators and waste batteries and accumulators
Directive 2007/51/EC	relates to restrictions on the marketing of certain measuring devices containing mercury.
Directive 2008/1/EC	Integrated Pollution Prevention and Control (IPPC) is a key legal instrument for reducing mercury emissions.
Directive 2008/98/EC	amalgam from dental waste is characterised as hazardous so subject to the Waste Framework Directive.
Directive 2008/105/EC	stipulates environmental quality standards in the field of water policyfor certain priority substances including mercury and its compounds.
Directive 2009/161/EU	establishes a list of indicative occupational exposure limit values for workers who may be exposed to mercury.

Mercury Policy

Legislation to protect air quality is not a new phenomenon; in 1273 the use of coal was prohibited in London as it was "prejudicial to health" [2]. The clean air act of 1956 was brought in to deal with smog incidents in London and introduced smoke control areas, controlled chimney heights and prohibited emission of dark smoke from chimneys. However, specific legislation to control Hg in the environment is a more recent development driven by a realisation of the degree of toxicity of this element and the introduction of technologies to measure and monitor it. Below we summarise some of the legal instruments by which Hg is currently controlled in the environment. These were put together in part from previous compilations[3,4].

[2] *H.C. Routledge and J.G. Ayres, 2005, Air Pollution and Health, Occupational Medicine, 55, 439-447. doi:10.1063/occmed/kqi136*

[3] Noelle Eckley Selin and Henrik Selin; Global Politics of Mercury Pollution: The Need for Multi-Scale Governance, Review of European Community & International Environmental Law, 15(3), 258–269, doi: 10.1111/j.1467-9388.2006.00529.x

[4] Lesley Sloss; Economics of mercury control, IEA Clean Coal Centre Reports [IEA Clean Coal Cent. Reports]. no. CCC/134, 60 pp. 6 Jan 2008.

Reduction of Hg emissions			
International	(UNEP) Global Mercury Partnership	2005	Reduce Hg emissions to air, water and land, main areas of interest are: • Artisanal and small scale gold mining • Mercury cell chlor alkali production • Mercury air transport and fate research • Mercury in products • Mercury releases from coal combustion • Mercury waste management • Mercury supply and storage http://www.chem.unep.ch/mercury/partnerships/new_partnership.htm
European	UNECE-LRTAP TF Convention on Long-Range Transboundary Air Pollution	1979	Legally binding instrument to deal with problems of air pollution on a broad regional basis • *Aims to cut emissions of Hg from industry, combustion and waste and lower emissions from products* http://www.unece.org/env/lrtap/welcome.html
Baltic Region	HELCOM Declaration on the Protection of the Marine Environment of the Baltic Sea Area	1988	Reduce Hg discharges to the Baltic sea • Initial aim was a 50 % reduction by 1995 – while this target was not met since then a number of binding recommendations have been introduced to work towards lowering Hg emissions http://ec.europa.eu/environment/water/marine/helcom.htm
European	OSPAR Convention for the protection of the Marine Environment of the North-East Atlantic	1998	Started as Olso convention against dumping from ships/aircraft in 1972. Aims to reduce marine Hg concentrations to near background levels and cease discharges, emission and losses by 2020 Includes specific decisions/recommendations covering: • Chloralkali plants • Pollution from Hg products • Release from dentistry • Release from crematoria (in the UK a burden sharing scheme, CAMEO, aims to achieve a 50 % reduction in Hg emissions from this source) http://www.ospar.org/
European	Barcelona Convention	1976	Part of the Convention for the Protection of the Mediterranean Sea Against Pollution • Goal is reduction of pollutants transported to the Mediterranean sea http://www.unepmap.org/index.php?module=content2&catid=001001004
Northern America	NARAP	1995	North American Regional Action Plan on Mercury • Involves Canada, the United Mexican States and the USA • Aim is to reduce mercury fluxes. http://www.cec.org/Page.asp?PageID=1325&SiteNodeID=312
US/Canada	Great Lakes Binational Toxics Strategy	1997-2006	Canada and the USA have a project for cleaning up substances, including mercury, in the Great Lakes Basin Area • Establishes reduction challenges • Aim for 50 % reduction in US Hg emissions o Between 1990 and 1999 US Hg emissions decreased 45 % • Aim for 90 % reduction in Ontario Hg emissions o Between 1988-2002 Ontario Hg emissions decreased 84 % http://www.epa.gov/reg5oair/mercury/binational.html
European	Water Framework Directive	2000	Integrated river basin management for Europe • Covers water in lakes, streams, rivers, estuaries, coasts and aquifers

			• Aims to achieve good water quality in terms of chemistry and ecology • Mercury is one the "priority hazardous substances" which should be phased out from EU waters by 2020 http://ec.europa.eu/environment/water/water-framework/index_en.html

Monitoring/research			
International	GEO: Global Monitoring Plan for Atmospheric Mercury	2009-2011	Part of the Group of Earth Observations (GEO), in the Health section "monitoring and prediction systems for health" sub-task no. HE-09-02d Aims to: • Develop a global observation system for mercury and its compounds in air, atmospheric deposition, water, soil, sediments, vegetation and biota • Encourage data sharing • Support Modelling, establish baselines and changes http://isprs-wg8-2.unm.edu/working-group-correspondence/geo-health-tasks/he-09-02d.pdf/view
EU funded, international project	Global Mercury Observation System	2010-2015	GMOS is EU contribution to HE-09-02d but also involves key contributors in US, Canada, Japan and Korea as "external GMOS partners" on the steering board Aims to: • Develop global monitoring system for Hg • Measurements in permanent terrestrial stations, cruises and troposphere campaigns, validate models http://www.gmos.eu/
International	Global Experts Scientific Aspects of Marine Environmental Pollution (GESAMP) Working group 37, Hg and its compounds	2006	Scientific review of mercury and its compounds covering: • Sources • Transport • Fate • Pathways • Toxicity • Monitoring and Evaluation • Special considerations http://www.gesamp.org/work-programme/workgroups/working-group-37
European	MEPOP	1997-2002	Study of atmospheric cycling of Hg and POPs specifically • Atmospheric cycling of mercury and persistent organic pollutants http://www.helmholtz-muenchen.de/eurotrac/publications/et2_fin_rep/fr_10_mepop.pdf
Arctic	Arctic Monitoring and Assessment Programme (AMAP)	1991	The Arctic Council's Environmental Protection Strategy includes mercury • Monitoring and assessment of Hg in the arctic and production of assessment reports http://www.amap.no/Resources/HgEmissions/

Transport/Storage of Hg			
International	Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	1992	Aims to protect health and environment from use/movement of waste to developing countries/eastern Europe • Hg contaminated waste may not be exported from the EU or OECD for disposal, recovery or recycling in other countries. http://www.basel.int/
International	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	2004	Prevents the export of specified chemicals and pesticides cannot take place without prior informed consent of the importing country • At present this procedure covers mercury compounds used as pesticides, but mercury and its compounds intended for industrial use are not. http://www.pic.int/home.php?type=s&id=77
European	Mercury export ban and its safe storage	2008	• Obligation to store mercury waste "in a way that is safe for human health and the environment" before eventually being disposed of. • Export ban on elemental Hg, other mercury compounds as e.g. cinnabar ore, mercury chloride and mercury oxide. • Compounds for research and development, medical or analytical analysis purposes are not covered by the prohibition. http://www.europarl.europa.eu/sides/getDoc.do?language=en&type=IM-PRESS&reference=20080520IPR29477
US	Mercury Export Ban Act	2008	• Mercury exports and long-term mercury management and storage • Export of Hg prohibited from the US 2013 http://www.epa.gov/mercury/regs.htm#ban
European	Integrated pollution prevention and control: (IPPC) Directive	2008	Permit system for industry and agriculture http://ec.europa.eu/environment/air/pollutants/stationary/ippc/index.htm
European	European Pollutant Release and Transfer Register (EPRTR)	2006	Register for the use and release of Hg. • Publicly accessible electronic database http://prtr.ec.europa.eu/

Products			
US	Mercury-Containing and Rechargeable Battery Management Act	1996	Phases out the use of mercury in batteries http://www.epa.gov/osw/laws-regs/state/policy/p1104.pdf
European	Mercury From Chloroalkali Process Directive	1982	Includes a number of daughter directives to limit emissions from mercury chloralkali cells. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31982L0176:EN:HTML
US	Reduction of Toxic Air Pollutants from Mercury Cell Chlor-Alkali Plants	2003	Calls for reduction in mercury emissions from mercury cell chlor-alkali plants http://www.epa.gov/ttn/atw/hgcellcl/hgcellclpg.html
European	Hazardous waste directive 91/689/EEC	1991	States that where the discharges of hazardous waste take place, the waste shall be recorded and identified http://ec.europa.eu/environment/waste/hazardous_index.htm
European	Directive 2006/66/EC on batteries and accumulators	2006	Limit the amount of Hg permissible in batteries to 0.0005 % by weight or 2 % by weight for button cells http://ec.europa.eu/environment/waste/batteries/index.htm
European	Directive 94/62/EC on Packaging and packaging waste	1994	Limits amount of mercury in packaging http://www.speciation.net/Database/Links/European-Legislation-Council-Directive-9462EC-on-Packaging-and-packaging-waste-;i1808
European	End of life vehicles (ELV) directive (2000/53/EC)	2000	Restricts the use of mercury in vehicles on sale after 2003 http://ec.europa.eu/environment/waste/elv_index.htm
European	Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (2002/95/EC)	2002	Restricts use of Hg in electrical and electronic equipment from 2006 Exceptions for certain lamps http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0095:en:HTML
European	Waste electrical and electronic equipment (WEEE) directive (2002/96/EC)	2002	WEEE must be treated with the best available treatment and recycling techniques components of electronic goods such as mercury containing switches must be removed from WEEE and Hg must be removed from gas discharge lamps http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002L0096:en:HTML http://ec.europa.eu/environment/waste/weee/index_en.htm