



Department of the Environment and Heritage

Hazard Status of Waste Electrical and Electronic Assemblies or Scrap

**Guidance Paper
October 1999**



Mixed Electronic Scrap



Computer Scrap

Environment Australia has prepared a number of information papers and guidance papers to provide a resource to people and organisations concerned with the export or import of hazardous waste under the Australian Act.

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INTRODUCTION

1. Environment Australia is responsible for the implementation and administration of the *Hazardous Waste (Regulation of Exports and Imports) Act 1989* ('Act'). The Act implements Australia's obligations under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal ('Basel Convention').

2. This paper has been prepared by Environment Australia on the basis of advice from the Hazardous Waste Technical Group, which has been established under the Act to provide advice to Environment Australia on the operation of the Hazardous Waste Act and related issues arising from Australia's implementation of the Basel Convention. This paper is current as at October 1999, however, the concentration cut-off levels for lead, which were revised by Worksafe Australia in 1999, were updated in this paper in May 2001.

3. If you require further information on the operation of the Act, or about this guidance paper, please phone 02 6274 1411, facsimile 02 6274 1164 or email hwa@ea.gov.au.

PURPOSE

4. Exports and imports of waste electrical and electronic assemblies or scrap may require a permit under the Act. The purpose of this guidance paper is to provide advice on the circumstances under which a permit is, or is not, required. It is assumed that the reader is familiar with the other information papers on the operation of the Act, including the papers on distinguishing wastes from non-wastes and setting concentration cut-offs for hazardous constituents of wastes.

5. This paper presents a brief overview of the ways in which waste electrical and electronic assemblies or scrap are disposed of. It then describes the requirements of the Basel Convention followed by a detailed review of particular hazardous or non-hazardous constituents. Lastly, a comparative analysis of the positions adopted by selected jurisdictions is discussed.

SUMMARY

Exports and imports of waste electrical and electronic assemblies or scrap require a permit under the Hazardous Waste Act unless they do not contain hazardous components such as nickel-cadmium batteries, mercury switches and glass from cathode-ray tubes. They must not be contaminated with constituents listed in Annex I of the Basel Convention such as cadmium, mercury, lead, or polychlorinated biphenyl. Waste or scrap consisting of printed circuit boards (even if accompanied by other waste or scrap) requires a permit unless:

- the boards contain less than 0.5% (w/w) of lead and leach less than 1 (mg/L) of lead in a TCLP leachate test (and are free of other hazardous constituents); or
- the material is destined for recovery operations in an OECD country.

Note that boards containing lead solder will usually leach more than 1 mg/L lead and fail the TCLP test.

Waste or scrap consisting of other materials does not require a permit if printed circuit boards are present but only as an incidental constituent.

The definition of waste covers anything that is to be disposed of, even if someone else is willing to pay for it. Disposal operations include both final disposal (eg by incineration or landfill) and recovery (eg by recycling or reclamation). A permit is therefore required for all exports and imports of waste electrical and electronic assemblies or scrap (unless they are free of hazardous constituents), including computers destined for disassembly followed by re-use, recycling, recovery or final disposal of their components.

Export and import of used computers for sale and continued use as computers does not require a permit under the Act if they are in working order or require only minor repairs to restore them to working order before sale. The term minor repairs includes replacement of broken parts or motherboards, or upgrading of chips. It does not encompass reconstruction of single units from multiple units and a permit is required for exports and imports for this purpose.

DISPOSAL OF WASTE ELECTRICAL AND ELECTRONIC ASSEMBLIES OR SCRAP

6. The need to dispose of discarded electrical and electronic equipment is a result of the continued decommissioning of obsolete electronic and electro-mechanical equipment. These old products represent the “high technology” of the previous two decades, and in many cases reliability of the electrical connections between different functional units and high product performance was achieved through the use of components containing small, but significant, levels of “exotic” materials.

7. In particular, the multi-pin connectors used to physically link computer and telecommunication modules contained significant levels of gold, palladium and other noble metals. These inert (but expensive) metals were (and still are) alloyed with

copper in order to increase resistance to corrosion at the contacts, or coated directly onto the pins.

8. In older mainframe computers and switching gear significant quantities of high quality copper cable and power supply components are also present. Modern personal computers (PC's) require less robust connections, and consequently the connectors are smaller and contain less noble metal. Nevertheless a substantial fraction of annual gold production (around 5%) is used in the electronics industry, primarily in electrical connectors.

9. In recent years, obsolete PC's have begun to be discarded, and, due to the comparative cheapness of new equipment and consequently a small secondhand market, this is expected to increase. These old computers and other electronic devices (eg fax machines, TV sets and telephone sets) often contain, in addition to the printed circuit boards on which the important chips and other components are mounted, components such as nickel-cadmium and other batteries, disk drives and integral power supplies containing transformers and electrolytic capacitors. Old PC's are usually accompanied by a visual display unit (VDU or monitor) containing a cathode ray tube (CRT) which is also discarded.

10. Apart from the small quantities of copper and precious metals in the circuitry there is little of material value in the discarded PC's and overall there appears to be far more scrap value in older equipment - particularly old mainframes and telecommunications switching gear.

11. Usually the valuable metal and other components of electronic equipment are enclosed within metal or plastic cases, or are mounted on steel frame racks. Consequently it is necessary to undertake a good deal of manual disassembly to separate valuable components before attempting recovery procedures. Similarly, while old motors and transformers contain significant amounts of copper, the windings are tightly associated with iron armatures, stators etc, and significant effort is required to separate the valuable copper from the other components.

12. Recovery of the high value materials is technically feasible, although the economics are such that there has been little recycling within Australia. The labour costs associated with dismantling the old equipment and separating those components containing the valuable materials appear to be a barrier. However, a facility in Melbourne is conducting tests on the treatment of circuit boards with bath smelting technology. The processing and recovery of metallic components in an environmentally sound manner has been proven. If the process can be proven to be commercially viable Australia will have an in-country option for the processing of circuit boards.

13. Disposal of end-of-life electrical and electronic products imposes costs on the environment in terms of resource consumption and waste generation. These have been examined in detail in a report entitled "*Short Circuiting Waste from Electrical and Electronic Products*", written by John Gertsakis, Chris Ryan and Clare Hoy and published by the National Centre for Design at RMIT in 1996. This report concluded

that more activity was urgently needed in Australia, not only because there are substantial environmental gains to be achieved, but also because this is an area of significant market change with implications for the competitive future of Australian marketing.

14. Although there is little reprocessing or recovery of value from electronic scrap in Australia today, there is a market for export of old equipment to Asia. Some old computers and electronic and electrical equipment, if reasonably free of metal or plastic cases, steel frames and so on, may fetch up to \$500 per tonne when exported. Export to Asian countries is presumably predicated on low labour costs and available infrastructure which allow for repair and refurbishment of some old PC's for resale, and recovery of useful materials - particularly those containing valuable metals - from the remainder of the electronic equipment.

15. Even when old computers are refurbished, it is reasonable to assume that certain of the original components would be disposed of (ie become wastes), and these may either enter the recycling stream for the recovery of valuables or, if they contain no recyclable materials, be disposed of to local landfills. Similarly, even when material is clearly destined for recycling most of the equipment associated with the valuable portions is of low value or worthless - eg plastic cases, cable insulation, glass from monitors and steel frames etc, and would be sent to final disposal. Consequently, regardless of whether some of the exported used equipment is refurbished or repaired or not, all should be regarded as actual or potential waste.

16. Given this situation, the question arises as to whether waste electrical and electronic assemblies and scrap possess hazardous characteristics and require a permit under the Act when exported or imported. This may be answered, in the first instance, by reference to the Basel Convention's requirements.

WHICH MATERIALS ARE CONTROLLED UNDER THE BASEL CONVENTION AND THE HAZARDOUS WASTE ACT?

17. The Basel Convention places a responsibility on exporting countries to ensure that any hazardous wastes exported are going to be treated in an environmentally sound manner in the importing country, and that the importing country knows that the hazardous wastes are being imported and which facilities are receiving the materials. The Convention also requires that countries dispose of their own hazardous wastes where possible, and ensure that the transboundary movement of hazardous wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes. The Convention is implemented in Australia by the Act.

18. Annex I of the Basel Convention lists the hazardous waste regulated by the Convention and, in consequence, by the Act. This Annex is quite general and is further elaborated by Annexes VIII and IX. Annex VIII (also known as list A) is a list of wastes covered by the Convention, Annex IX (also known as list B) is a list of wastes not generally covered by the Convention. Wastes are placed in Annex VIII if they belong to a category contained in Annex I and typically possess one or more of the hazardous characteristics listed in another Annex, Annex III. Wastes are placed in

Annex IX if they do not belong to a category contained in Annex I, or if they typically lack hazardous characteristics.

19. The Organisation for Economic Cooperation and Development (OECD) has its own special rules for shipments of wastes for recovery. Waste is put onto three lists according to the degree of overall environmental risk posed: red list waste poses high environmental risk, amber list waste poses environmental risk and green list is considered to pose no environmental risk when moved within the OECD for recovery.

20. Waste electrical and electronic assemblies or scrap have been assigned to both Annex VIII and Annex IX of the Basel Convention. That is, they have been assigned both to list A of hazardous wastes controlled under the Convention (Annex VIII) and to list B of non-hazardous wastes not controlled under the Convention (Annex IX). The difference depends on whether the particular material contains hazardous components or constituents and the full text of the relevant entries reads as follows:

Annex VIII, A1180. Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included on List A, mercury switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (eg cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (see B1110). (Note this entry does not include scrap assemblies from electrical power generation).

Annex IX, B1110. Waste electrical and electronic assemblies:

- Electronic assemblies consisting only of metals or alloys.
- Waste electrical and electronic assemblies or scrap (including printed circuit boards) not containing components such as accumulators and other batteries included on List A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or not contaminated with Annex I constituents (eg cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III (see A1180). (Note this entry does not include scrap assemblies from electrical power generation).
- Electrical and electronic assemblies (including printed circuit board, electronic components and wires) destined for direct re-use, and not for recycling or final disposal.

21. This paper provides guidance on the precise characteristics that separate the Annex VIII and Annex IX entries. It considers first the two short list B entries, for electronic assemblies consisting only of metals or alloys and for electrical and electronic assemblies destined for direct re-use. The paper then discusses in detail the List A entry and its mirror-entry on List B, working through the various hazardous

constituents in turn. Note that in this paper the term PCB is used only for polychlorinated biphenyls: it is not used for printed circuit boards.

22. Scrap assemblies from electrical power generation are excluded from A1180 and B1110. They have their own entry B1040 which refers to: "Scrap assemblies from electrical power generation not contaminated with lubricating oil or PCB or PCT to an extent to render them hazardous". There is no specific entry for scrap assemblies from electrical power transmission.

23. The OECD green list contains two entries that are relevant. GC010 refers to "Electrical assemblies consisting only of metals or alloys". GC020 refers to "Electronic scrap (eg printed circuit boards, electronic components, wire, etc) and reclaimed electronic components suitable for base and precious metal recovery". There are no relevant entries on the OECD red or amber lists.

Electronic assemblies consisting only of metals or alloys

24. This list B entry refers to electronic assemblies from which all potentially hazardous materials are absent. It may apply to the particular case of power supplies and associated "lump" components which contain transformers and smoothing chokes - both containing windings of copper wire - together with capacitors and solid state rectifiers. In some cases these power supplies could conceivably be reused in "new" computers, but if not it is likely that the copper would be salvaged and sent to a copper refinery, with the remainder of the material going to landfill.

Electrical and electronic assemblies (including printed circuit boards, electronic components and wires) destined for direct re-use, and not for recycling or final disposal

25. This list B entry refers to used equipment that is exported or imported for continued use for its original purpose, most commonly computers which are destined for continued use as computers. Such movements are not controlled under the Act although computers often require minor repairs to restore them to working order before sale. Such repairs include replacement of broken parts or motherboards, or upgrading of chips. These are not considered to be waste recovery operations and the computers are not considered to be wastes. Note, however, that the term minor repair is not considered to encompass reconstruction of single units from multiple units. All used computers exported for disassembly followed by re-use, recycling and recovery of their components are classified as a waste destined for recycling/reclamation of metals and metal compounds and other materials.

Annex VIII, A1180. Waste electrical and electronic assemblies or scrap containing (hazardous) components, etc

Annex IX, B1110. Waste electrical and electronic assemblies or scrap not containing (hazardous) components, etc

Accumulators and other batteries included on list A

26. Batteries included on list A (at A1170) will usually have been made with lead, mercury or cadmium, and sometimes with other Annex I constituents such as Y42, organic solvents. Because these batteries are generally enclosed within the equipment and may be physically attached to circuit boards or other components, it may be difficult to be sure that equipment does not contain them unless and until that equipment has been disassembled.

Mercury switches

27. Mercury switches and mercury relays may also be enclosed and physically attached to circuit boards or other components. If present, they must be removed before the material can be considered non-hazardous.

Glass from cathode-ray tubes (CRTs) and other activated glass

28. It is unlikely that old monitors and the associated CRTs would be re-used in newly constructed equipment, and there appears to be little potential in Australia for recovery of glass or other materials from the tubes. In Europe there appears to be some market for adding the glass from old CRTs (after removal of phosphors) to ceramic melts - presumably due to the relatively high content of barium and strontium (face plates) and of lead in the cone glass.

29. Although the face plates of the monitors are made of high quality glass, remelting of this glass for production of new face plates would be a very risky procedure because there could not be adequate control of the melt composition and this is extremely important for this application. The only realistic recycling option would be to remove the face plates from the old tubes, and to "resolder" them to new neck assemblies (using low melting point glass). Obviously this would be a labour intensive activity.

30. A facility is being developed in Sydney which, if successful, will recycle CRT components including:

- (a) polymers
- (b) circuit boards
- (c) power supplies
- (d) side glass
- (e) face plates

It is intended to remove the activated coatings on the screens for disposal at a secure landfill site.

31. In all probability CRT's exported from Australia as components of electronic scrap would end up in landfill. Although the glass in the cathode ray tubes contains significant content of metals such as barium, strontium or lead (face plate) and lead (in the solder glass used for joining the necks to the face plates), these metals would be expected to leach from the glass matrix at a slow rate and some glass may pass a Toxicity Characteristic Leachate Procedure (TCLP) test. It is then necessary to consider whether glass that passes the TCLP test may be regarded as lacking hazardous characteristics.

32. In the OECD lists of wastes (see Information Paper No 4, *Guide to Controlled and Other Wastes under Australia's Hazardous Waste Act*), glass waste from cathode ray tubes and other activated glass is placed on the amber, or hazardous, list (AB040) and all other glass is placed on the green, or non-hazardous, list (GE010). An amendment to the green list entry, agreed by the OECD Waste Management Policy Group meeting in April 1998, has clarified the hazard status of these wastes by inserting the words "with coatings" and the next amendment to the lists of wastes will include the following amended entry:

GE010 Cullet or other waste and scrap of glass except for glass from cathode-ray tubes and other activated (with coatings) glasses.

33. The effect of this change is to make it clear that for glass waste from cathode-ray tubes, it is not sufficient to pass the TCLP test for lead or other Basel constituents. The phosphor coating must also have been removed from the glass before it is considered non-hazardous. When cathode-ray tubes are recycled the fluorescent substances that make up the phosphor coating, and which represent only up to 0.04 percent by weight of the whole tube, are removed by a mechanical dry procedure and held as a mixture in a closed box in the filter system before being sent to secure landfill. The amended entry is helpful because it indicates that the principal concern is with the activating phosphor coatings, most of which are metal salts: when these are removed the glass may be placed on the green list if it passes a TCLP test.

PCB-capacitors

34. Older equipment is likely to contain capacitors and other equipment that contains polychlorinated biphenyls (PCBs) in excess of the Basel Convention limit of 50 mg/kg, set in Annex VIII entry A3180.

35. The Australian and New Zealand Environment and Conservation Council (ANZECC) adopted a Polychlorinated Biphenyls Management Plan in November 1996. The Plan divides materials and wastes into four categories according to the concentration of PCB they contain:

- (a) concentrated PCB contains more than 10 % PCB;
- (b) scheduled PCB contains more than 50 mg/kg PCB;
- (c) non-scheduled PCB contains more than 2 mg/kg PCB; and
- (d) PCB-free materials or wastes contain less than 2 mg/kg PCB.

36. All scheduled PCB solid or liquid waste must be treated and must not go to landfill. Non-scheduled PCB waste must be disposed of in accordance with approved methods and liquid wastes must not go to landfill. The plan provides for all equipment containing concentrated PCB material to be removed from service in priority areas (defined as areas that require a particularly high level of protection, such as water catchment areas, schools, hospitals and aquatic spawning areas). Elsewhere, equipment containing concentrated or scheduled PCB materials must be removed from service or subjected to *in-situ* treatment to less than the threshold concentration of 50 mg/kg. Materials that contain less than 50 mg/kg PCB are not considered hazardous under the Basel Convention, whether they are wastes or not.

37. When equipment is retrofilled or treated *in situ*, management requirements shall be based on the PCB concentration in the diluent, measured after at least one month of normal operation following retrofilling or treatment. PCB waste derived from retrofilling or *in situ* PCB shall be disposed of in accordance with the Plan.

Annex I constituents (e.g. cadmium, mercury, lead, polychlorinated biphenyl), especially lead in printed circuit boards

38. This category overlaps to a large extent with the previous categories covering batteries, mercury switches and PCB capacitors, and the principal remaining uncertainty concerns the hazard status of the printed circuit boards. These boards, ubiquitous in modern electronic equipment, are fire retardant epoxy plastic masses interlaced with copper circuitry. The important semiconductor chips and other components (resistors and capacitors etc) are mounted on these boards, and are usually connected to the copper circuitry by high quality solder. Usually multi-pin connectors are also mounted enabling connection to other boards or electronic modules. The metal in these boards - particularly in the connectors that usually contain some gold and/or platinum group metals - represents the major potential for recovery and recycling.

Recovery of copper and precious metals from printed circuit boards

39. Because of the robust construction of the circuit boards it is likely that mechanical separation and recovery of the copper would not be economical, and in most cases the connectors only would be salvaged for recovery of the precious metal values. However, in more sophisticated recycling facilities, the boards may be shredded prior to comprehensive hydrometallurgical leaching processes, or possibly incinerated to destroy the plastic prior to hydrometallurgical treatment of the resultant ash for metals recovery. On this point it should be noted that the plastic used in circuit boards is inherently fire retardant, and usually contains heavily brominated polymer resins. Given the nature of the material, complete destruction via

incineration would require high temperatures, and incomplete combustion may lead to the production of dioxins.

40. A common hydrometallurgical process involves shredding or incineration followed by leaching in an aerated alkaline cyanide solution to dissolve the noble metals. The pregnant leach solution is then separated from the solid residues and further processed for recovery of the gold and platinum metal values. Both incineration and the use of cyanide imply an element of hazard in the processing of printed circuit boards, but detailed information is not available.

41. Another type of facility processes precious metal-bearing material into two forms, molten metal or ingots, and fine powder or “prepared sweeps”. This material is then sampled and assayed so that its composition, weight and recoverable precious metal content are known. The ingots and prepared sweeps are then sold to non-ferrous smelters for final reclamation of gold, silver, platinum, palladium and copper.

42. The initial processing step is to either burn the material in a furnace, or to shred it into small pieces and burn a representative ten percent sample or, if there is no organic content, to dry it. Material which has been dried, or ash from the portion of a batch which has been burned, is collected and milled. The product of the mill is screened to divide it into two fractions: a fine powder which is tumbled to a high state of homogeneity and retained pieces of metal which are melted to homogeneity. These two fractions are sampled and assayed separately for onward sale to non-ferrous smelters.

43. The furnaces used to burn the material are typically equipped with pollution control equipment including venturi and acid gas scrubbers and a baghouse, and stack testing is carried out for emissions of metals, VOCs and dioxins. The mills are equipped with dust ventilation control and baghouses, and the melting furnaces have fume ventilation control and baghouses. Ground water is monitored through on-site monitoring wells. Precious metal ash from incineration of printed circuit boards is included both in Annex VIII (A1150) and Annex IX (B1160) of the Basel Convention: it is controlled as a hazardous waste if it contains Annex I material to an extent causing it to exhibit an Annex III characteristic.

44. Particular attention must be paid to controlling emissions of lead during waste disposal operations. For example, if the boards are incinerated, metals such as lead will be concentrated in the flyash. If the boards are treated in a smelter the lead will be fumed off with high efficiencies and would be collected in the baghouse filtration system. Either system (incinerator or smelter) will need an efficient gas handling system as well as an effective way of handling the solid product safely after removal of particulate matter. The presence of lead as fume in the system will require measures to prevent lead entering the atmosphere. Even if the boards are sent to landfill, the presence of lead above leachable limits will require that they may not be sent to uncontrolled landfill sites.

Do waste printed circuit boards belong to Annex VIII or Annex IX?

45. The Annex IX entry for electronic scrap refers explicitly to “Waste electrical and electronic assemblies or scrap (including printed circuit boards)”, etc. This suggests that printed circuit boards are considered to be non-hazardous but the entry then imposes a condition, that they are “not contaminated with Annex I constituents (eg cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III”.

46. A number of printed circuit boards have been subjected to independent chemical analysis and TCLP leachate tests in Australia recently. Concentrations of lead in the boards varied from 9,640 to 35,400 mg/kg and all of them generated high concentrations of lead in leachate, from 142 to 1,325 mg/L. Concentration cut-off values for lead in wastes have been established in Australia for concentrations of lead in materials and in leachate from those materials. A concentration of 1% (w/w) of lead has been set on the basis of the value for occupational exposure set by Worksafe Australia: most of the circuit boards tested exceeded that value. A value of 1.0 mg/L has been set for lead in leachate from a TCLP test, based on the practice of State and Territory governments in controlling disposal of wastes to landfill: all the circuit boards tested exceeded this value by at least two orders of magnitude.

47. Some national authorities (for example, the US EPA) consider whole used circuit boards to be scrap metal. This implies that the lead content is not considered to be in an available or dispersible form and the material is not controlled, regardless of the concentration of lead or other metals. Many scrap metals on Annex IX are considered non-hazardous not because they lack an Annex I constituent, but because that constituent is unlikely to be available, through leaching or other means, when the metal is in massive form. The same metal is considered hazardous if in dispersible form, when it may be exposed to chemical or physical conditions that convert it to water soluble salts which can disperse into the environment. It is necessary, therefore, to decide whether lead and other Basel metals are present in circuit boards in massive or dispersible form.

48. For Basel Annex I metals such as lead and cadmium, the meaning of the term “massive form” is clarified by the entry on Annex IX, which specifies “clean, uncontaminated metal scrap, including alloys, in bulk finished form (sheet, beams, rods, etc)”. Lead and other metals on printed circuit boards do not fall within this Annex IX definition. They are not clean and uncontaminated because they are attached to the board, and they are certainly not in bulk finished form such as sheets, beams or rods. Other metallic wastes in similar physical form and containing leachable lead or other Annex I metals would certainly be regarded as Annex VIII hazardous wastes: an inconsistency would be created if printed circuit boards were not treated in the same way.

49. It has been argued by industry that the reference to “contaminated” in the Annex VIII and IX entries implies that the scrap or assemblies have come in contact with some new material that is not part of the original design and increases the risk

associated with managing the assembly or scrap. On this argument, scrap or assemblies that contain small amounts of Annex I constituents such as lead, intentionally by design, should not be viewed as “contaminated”. This would lead to the conclusion that the Parties to the Basel Convention determined that circuit boards, which contain lead as part of their overall design and manufacture, do not present risks sufficient to warrant classification as a hazardous waste in the absence of hazardous components.

50. A major difficulty with this argument is that, while its interpretation of “contamination” may be appropriate to equipment that is still being used as designed, it is not appropriate once that equipment becomes waste. Lead, and perhaps other Annex I constituents, are unwanted contaminants in any waste management operation involving printed circuit boards, if present in concentrations sufficient to exhibit Annex III characteristics. In the context of waste and scrap, the term contamination must be interpreted in relation to the hazards (and not the risks) that Annex I constituents present during waste disposal operations.

51. Turning to the question of what the Parties to the Basel Convention agreed, it is necessary to examine the construction of the Annex VIII and IX entries in some detail. The starting point for B1110 appears to be OECD green list entry GC020 “Electronic scrap (eg printed circuit boards, electronic components, wire, etc) and reclaimed electronic components suitable for base and precious metal recovery”. This entry must be read in the context of the chapeau to the green list, which reads “Regardless of whether or not wastes are included on this list, they may not be moved as Green Tier wastes if they are contaminated by other materials to an extent which (a) increases the risks associated with the waste sufficiently to render it appropriate for inclusion in the amber or red lists, when taking into account the criteria in Annex 2, or (b) prevents the recovery of the waste in an environmentally sound manner”.

52. It is significant that the Parties to the Basel Convention did not adopt the OECD wording, but added two exclusions “not containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB capacitors” or “not contaminated with Annex I constituents (eg cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the characteristics contained in Annex III”. The Parties also adopted a chapeau to Annex IX that is significantly different to the chapeau on the OECD green list. The Annex IX chapeau reads “Wastes contained in this Annex will not be wastes covered by Article 1, paragraph 1(a) of this Convention unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic”.

53. These arguments point to three conclusions.

- (a) The member countries of the OECD have adopted entry GC020 from which one may infer that when printed circuit boards are destined for recovery operations in an OECD country, the risks associated with the waste are such that the material may be moved as a green-listed waste. Competent authorities may impose stricter controls by invoking the green-list chapeau when appropriate.
- (b) The Parties to the Basel Convention have adopted entries A1180 and B1110 from which one may infer that printed circuit boards are hazardous if they are contaminated by Annex I constituents including lead to an extent that they possess Annex III characteristics. They have also adopted a chapeau to Annex IX which does not refer to contamination, but uses the phrase “unless they contain Annex I material”.
- (c) There is sufficient ambiguity in the use of the word “contaminated” to enable different Parties to interpret these entries in different ways.

54. Based on these conclusions, waste printed circuit boards containing lead or other Annex I constituents in Annex III amounts should be assigned to Annex VIII entry A1180 as hazardous wastes. They are therefore controlled under the Act if they contain more than 0.5% (w/w) of lead or generate more than 1.0 mg/L lead in a TCLP test: similar considerations apply to other Annex I constituents. The only exception is that no permit is required for printed circuit boards that are assigned to OECD green-list entry GC020 and are exported to or imported from an OECD country for recovery operations.

Are waste printed circuit boards controlled by other jurisdictions?

55. This conclusion may be compared with the positions of four other jurisdictions which have issued detailed written guidance on the status of electronic scrap, as described in Appendix A to this paper. They are Austria, Switzerland, the United States and the Australian State of New South Wales.

56. All four jurisdictions regard shredded circuit boards as hazardous wastes subject to controls when exported. The United States exempts internal movements but only if they are properly stored in containers that would be adequate to prevent a release to the environment prior to recovery. According to the US Federal Register of 12 May 1997, these materials are still subject to manifesting, export and speculative accumulation requirements.

57. Two jurisdictions, Austria and the United States, do not regard whole used circuit boards as hazardous wastes subject to controls when exported for recovery operations. In the case of Austria, this conclusion is based on the assumption that such boards do not need to be controlled when destined for recovery operations in OECD countries: no specific provision appears to be made for exports to non-OECD countries because Austria does not export such wastes to non-OECD countries.

58. In the case of the United States, the conclusion is also based on the assumption that the boards will be recycled: they would be controlled if destined for final disposal. This assumption is not consistent with the requirements of the Basel Convention.

59. Switzerland imposes controls but these are imposed whether or not the boards contain specified harmful substances such as nickel-cadmium batteries, switches containing mercury, capacitors containing PCB, heat insulation containing CFC and cathode ray tubes.

60. New South Wales requires that printed circuit boards destined for landfill be subject to a leachate test for lead and other metals.

61. As concluded at the end of the previous section, printed circuit boards that contain hazardous concentrations of lead or other controlled metals, either as composition by weight or after a TCLP leachate test, will be subject to control under the Act. This position is consistent with the control regimes operated by New South Wales and Switzerland. It is stricter than the requirements of Austria and the United States but those requirements are based on an assumption of legitimate recycling that may be consistent with an interpretation of the (“risk-based”) OECD control system, but which is not consistent with the requirements of the (“hazard-based”) Basel Convention.

Are waste electrical and electronic assemblies or scrap considered hazardous if they contain printed circuit boards?

62. Having concluded that waste printed circuit boards that contain hazardous constituents are controlled under the Act, the question then arises whether any piece of equipment that contains a printed circuit board is also to be considered hazardous. Because the boards are ubiquitous in modern electronic equipment, the potential scope of such controls could be very wide indeed. For example, power supplies may be removed from computer equipment and sold for the value of the (non-hazardous) scrap metal that they contain. Should these power supplies be controlled as hazardous waste if they contain small internal printed circuit boards that are difficult to remove? Or are they similar to, for example, modern motor vehicles, which contain printed circuit boards that are simply shredded along with the rest of the vehicle when it is scrapped?

63. For the purposes of the Act, a distinction may be drawn between wastes in which the printed circuit boards are an important and valuable constituent and those in which the boards are only an incidental inclusion. The first category would include scrap computers, for example, where the printed circuit boards and back-planes are easily demountable or detachable and constitute a major proportion of the value of the waste. The second category would include a wide variety of wastes, including motor vehicles and some whitegoods, in which the printed circuit boards are integrated into the material, are difficult to remove and are only incidental to the value of the waste. The first category would be controlled under the Act. The second category would not unless some other hazardous constituent is present.

GENERAL CONCLUSION

64. Waste electrical and electronic assemblies or scrap will be controlled as Annex VIII waste (A1180) unless they are free of hazardous components such as nickel-cadmium batteries, mercury switches and glass from cathode-ray tubes, or constituents listed in Annex I of the Basel Convention such as cadmium, mercury, lead, or polychlorinated biphenyl.

65. Waste or scrap consisting of printed circuit boards (even if accompanied by other waste or scrap) requires a permit unless the boards contain less than 0.5% (w/w) of lead and leach less than 1 mg/L of lead in a TCLP leachate test (and are free of other hazardous constituents) or unless the material is destined for recovery operations in an OECD country. Waste or scrap consisting of other materials does not require a permit if printed circuit boards are present but only as an incidental constituent.

66. Some countries do not control printed circuit boards destined for recycling until they have been shredded, but the absence of controls is generally based on an assumption that the boards are destined for environmentally sound recycling in an OECD country. Outside the OECD this assumption is not consistent with the requirements of the Basel Convention.

67. A list of some common components of computer and electrical scrap, their placement on Basel Annexes VIII and IX and the typical means of disposal may be found in Appendix B.

APPENDIX A: CONTROL OF ELECTRONIC SCRAP, PARTICULARLY PRINTED CIRCUIT BOARDS, BY OTHER JURISDICTIONS

Austria

A.1. Austria has produced detailed national explanations concerning the green list of the EU waste shipments regulation (Federal Ministry of Environment, Youth and Family Affairs, 1997). Under GC020: Electronic scrap etc, several wastes are described as an integral part of the green list including:

- (a) Disassembled or partly disassembled printed circuit boards and frames, without components which contain harmful substances, bare printed circuit boards and copper laminates. (This refers to printed circuit boards and frames without batteries, components containing mercury, larger condensers such as electrolytic capacitors, components containing PCB and without LCD displays).
- (b) Printed circuit board assemblies without components containing harmful substances (eg printed circuit boards assemblies without components containing harmful substances (eg. printed circuit boards bearing resistors and integrated circuits).

A.2. Waste which are excluded from the green list because they are hazardous include:

- (a) Condensers containing PCBs;
- (b) Batteries (eg button cells, lithium batteries, lead-acid batteries, nickel cadmium batteries);
- (c) Printed circuit boards, equipped with components that contain harmful substances;
- (d) Glass wastes from cathode-ray tubes and other activated glass;
- (e) Physically intact picture tubes of the cathode ray tube type;
- (f) Gas-discharge lamps, fluorescent tubes and other lamps containing mercury, as cullet and in physically intact form;
- (g) Components containing mercury (eg mercury switches);
- (h) Electrical and electronic devices and components with ecologically important quantities of parts or constituents that contain harmful substances (eg night storage heaters containing asbestos, oil radiators, cooling and air conditioning devices and/or refrigerated systems with the following pollutants: chlorofluorocarbons, fluorocarbons, and hydrocarbons such as propane/butane, other refrigerants such as ammonia);
- (i) Carbonisation cables, electrical and electronic scrap material to be ground (including shredded printed circuit boards), precious-metal-bearing ashes from the incineration of printed circuit boards.

A.3. Whole devices with ecologically important quantities of dangerous constituents are, in the absence of an entry for electronic scrap on the amber list, to be included in the red list control procedure if no definite allocation of the ecologically important part (eg CFC or glass wastes from cathode ray tubes) to a designation on the amber list is possible.

A.4. The Austrian authorities have advised that their green and amber listings of intact and shredded printed circuit boards are based upon two considerations. The first consideration is that the various hazardous components of intact printed circuit boards are regarded as constituents of the waste, not as contaminants. Since the chapeau (or heading) to the OECD green list refers to wastes that are not “contaminated by other materials”, Austria considers that its listing of specified hazardous components goes beyond the requirements of the green list. This means that only those materials specifically referenced in the Austrian list are subject to control.

A.5. Once the boards are shredded, they are classified as amber-listed wastes partly because of the risk that hazardous components were not removed before shredding and partly because the shredded boards are more easily dispersed into the environment.

A.6. The second consideration is that the OECD lists are valid only for shipments of wastes destined for recycling operations within the OECD, these are considered to present a low risk even if the material contains hazardous materials. In Austria’s view there is a great difference between the so-called “risk-based” approach of the OECD and the “hazard-based” approach of the Basel Convention. Austria does not export such wastes to non-OECD countries.

A.7. These two considerations are not directly relevant to the Australian situation. First, Australia’s primary concern is with exports to non-OECD countries under the Basel Convention definitions. The chapeau to Annex IX does not refer to “contaminants”, “components” or “constituents”, but simply states that materials are excluded from the non-hazardous list if “they contain Annex I material to an extent causing them to exhibit an Annex III characteristic”.

A.8. Second, Austria interprets the chapeau to the OECD green list in the German language. In English it is more difficult to argue that the printed circuit boards are not “contaminated by other materials”. The Macquarie Dictionary defines “contaminate” as “to render impure by contact or mixture”, and “impure” as “not pure; mixed with extraneous matter, especially of an inferior or contaminating kind”. As argued above, lead solder may not be a contaminant in electronic equipment that is still operating as designed, but it is a hazardous contaminant when that equipment is subjected to waste disposal operations.

Switzerland

A.9. Switzerland has introduced an ordinance on the return, taking back and disposal of electrical and electronic appliances. The ordinance requires the owner of an appliance to dispose of it by returning it to a retailer, manufacturer or importer, or to a disposal facility. Retailers, manufacturers and importers must accept appliances (but not their electronic components) and dispose of them.

A.10. Under the ordinance, a person who disposes of appliances shall guarantee that the disposal be carried out in an environmentally tolerable way, according to state-of-the-art technology; in particular:

- (a) components which contain harmful substances such as nickel-cadmium batteries, switches containing mercury, capacitors containing PCB, and heat insulation containing CFC should be disposed of separately;
- (b) cathode ray tubes and metal-containing components such as diodes, metal casings, metal frames, cables with a high proportion of metal and plug devices which are primarily of metal, should be recycled, insofar as this is commercially acceptable;
- (c) organic chemical components which are not recycled such as plastic casings, cable insulation or epoxy plates, shall be incinerated in the appropriate installations.

A.11. Export of appliances for disposal also requires a permit. There must be evidence that the planned disposal is environmentally tolerable, in particular by a written contract with the disposal facility and documentation from which it follows that the disposal facility is in accordance with the regulations of the import country. Note that Switzerland, like most OECD countries but unlike Australia, may impose national export and import controls on wastes regardless of whether they possess hazardous characteristics.

United States

A.12. In 1992 the US EPA established that whole used circuit boards destined for recycling could be considered scrap metal and therefore exempt from regulation under the Resource Recovery and Conservation Act (RCRA). This exemption did not apply to boards which contain mercury switches, mercury relays, nickel-cadmium batteries or lithium batteries.

A.13. Shredded circuit boards do not meet the definition of scrap metal because the shredded material contains fines which are too small to qualify as scrap metal. Shredded circuit boards with economically recoverable quantities of precious metals were eligible for conditional exemption from many RCRA regulatory provisions but were still subject to manifesting, export and speculative accumulation requirements.

A.14. In 1997 the US EPA excluded shredded circuit boards from regulation on condition that the boards were free of mercury switches, mercury relays, nickel-cadmium batteries and lithium batteries, and were properly stored in containers that would be adequate to prevent a release to the environment prior to recovery. Open bulk shipments of board by rail, truck or barge are not within the scope of the exclusion, and the shredded circuit boards are still subject to manifesting, export and speculative accumulation requirements.

A.15. The US EPA has confirmed that the classification of whole circuit boards depends on their destination. They are classified as solid wastes if destined for final disposal: exports of both whole and shredded boards are controlled provided they exhibit toxicity characteristics, including leachate testing. They are treated as scrap metal, however, if destined for recycling.

A.16. This distinction does not make it possible to ensure that exports are truly for legitimate recycling as opposed to “sham” recycling or final disposal. For this reason, it is likely that any implementation of the Basel Convention would require legislative authority over exports that might not be environmentally sound or not done according to the exporter’s plans.

A.17. The separate consideration of whole and shredded boards reflects a concern about dispersible lead particles, hence the requirement for proper containerisation. There is no separation based on particle size definition although the definition of scrap metal is somewhat descriptive of this: “Bits and pieces of metal parts (eg bars, turnings, rods, sheets, wire) or metal pieces that may be combined together with bolts or soldering (eg radiators, scrap automobiles, railroad box cars), which when worn or superfluous can be recycled”.

A.18. In general, the US EPA position is based on assumptions of environmentally sound recovery that are appropriate at a domestic level, but which do not accommodate the requirements of the Basel Convention, that exports to other countries be managed in an environmentally sound manner.

New South Wales

A.19. It is difficult to be sure of the position adopted by Australian State and Territory jurisdictions because it is unusual for electronic scrap to be presented in bulk for disposal. Detailed guidance has been prepared by the New South Wales EPA, however, and Table 1 sets out acceptable disposal methods for electronic scrap. Note that in New South Wales waste and scrap consisting of printed circuit boards is controlled unless the boards contain less than 1% (w/w) of lead and leach less than 5 mg/L of lead in a TCLP test (and are free of other hazardous constituents).

TABLE 1. Acceptable disposal methods for electronic scrap in New South Wales.

Item	Contaminants	Disposal Requirements
1. Printed circuit boards	heavy metals	<p>1. Assess circuit boards for suitability for recycling in Australia</p> <p>2. Recycle circuit boards if suitable, otherwise dispose of circuit boards to landfill with EPA approval, including TCLP test meeting TCLP2 requirements for heavy metals as specified in Technical Appendix 1 of the Waste Guidelines.</p>
2. Computer Monitors (cathode ray tubes)	heavy metals	<p>1. Assess glass for suitability for recycling in Australia</p> <p>2. Recycle plastics, metals, and glass if suitable, otherwise dispose of glass to landfill with EPA approval, including TCLP test meeting TCLP2 requirements for heavy metals as specified in Technical Appendix 1 of the Waste Guidelines.</p>
3. Nickel Cadmium Batteries	nickel, cadmium	<p>1. Arrange if possible with an Australian company with access to nickel-cadmium battery recycling facilities overseas to recycle, otherwise</p> <p>2. If not possible, dispose of to landfill with EPA approval including treatment to immobilise contaminants which results in the treated waste meeting TCLP2 requirements for nickel and cadmium as specified in Technical Appendix 1 of the Waste Guidelines.</p>
4. Lead-acid Batteries	lead, cadmium	<p>1. Recycle or recover metals and plastic in Australia if suitable, otherwise</p> <p>2. Dispose of non-recyclables to landfill with EPA approval including treatment to immobilise hazardous contaminants which results in the treated waste meeting TCLP2 requirements for lead as specified in Technical Appendix 1 of the Waste Guidelines.</p>

APPENDIX B: COMPONENTS OF ELECTRONIC SCRAP

B.1. The following table lists some common components of computer and electrical scrap, the relevant entry on the Basel lists and the typical means of disposal. A list entry prefixed with an A means that the material is placed on list A, or Annex VIII of the Basel Convention, the list of hazardous wastes controlled under the Convention and the Act. A list entry prefixed with a B means that the material is placed on list B, or Annex IX of the Basel Convention, the list of non-hazardous wastes not controlled under the Convention and the Act. A list entry prefixed with a C means that the material has not yet been placed on list A or list B and advice on its status should be sought from Environment Australia.

Component	List entry	Typical means of disposal
PVC coated copper wire	C1	Process in granulation plant, sell metallic copper as scrap, dispose of PVC.
Aluminium	B1010	Disassemble, clean up and sell as feedstock.
Magnets	B1010	Disassemble, clean up and sell for re-use.
Motors	B1010	Disassemble, clean up and sell as scrap.
Power supplies	B1110	Disassemble, clean up and sell as scrap, but includes difficult-to-remove circuit boards. Circuit board content estimated to be less than 1 % by weight.
Circuit boards	A1180/B1110	Disassemble, clean up and accumulate for precious metals recovery if suitable, otherwise dispose of circuit boards to landfill after TCLP test.
Computer monitors (cathode ray tubes)	A2010	Recycle plastics, metals, and glass if suitable, otherwise dispose of glass to landfill after determining whether phosphor coatings have been removed and if they have been, after TCLP test also.
Nickel cadmium batteries	A1170	Export to nickel-cadmium battery recycling facilities overseas to recycle, otherwise, dispose of to landfill after treatment to immobilise contaminants which results in the treated waste passing a TCLP test.
Lead-acid batteries	A1160	Recycle or recover metals and plastic.
Data and telecommunications cable	C1	Disassemble, clean up and sell as scrap. Copper content about 20-45 %.

Peripherals including printers	A1180/B1110	Disassemble for removal of identifiable circuit boards, accumulators, mercury switches and copper wire. Sell balance as scrap.
ACSR Aluminium cable steel reinforced	B1010	Sell as scrap aluminium cable (comprises about 65 % aluminium).
Covered aluminium Plastic coated aluminium	B1010	Sell as scrap aluminium cable (comprises about 60 - 65 % aluminium).
Electrical transformers: power distribution – less than 100 KVA	B1010	Sell as scrap transformers in steel casing including copper windings and silicon steel core. Drain oil, test for PCB contamination, dispose of in accordance with legal requirements.
Electrical transformers: power distribution – greater than 100 KVA	B1010	Remove steel casing, separate copper and aluminium windings, sell as silicon steel, copper windings and aluminium windings.
Electrical meters and time clocks	B1010	Sell as scrap.
Bare copper wire	B1010	Cut into lengths, sell as scrap.