Smart ecoDesign

Eco-design Checklist

For Manufacturers of Printed Wiring Boards

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1. Introduction

This document is intended to help manufacturers of printed wiring boards (PWBs) meet the ever increasing demand from customers for eco-friendly components. This demand is being fuelled by both legislation that is appearing in many countries of the world and increased consumer awareness of the negative impact products are having on the environment around them.

The document is split into three main sections:

1. Legislation/Customer Requirements Checklist.
2. Eco declarations Checklists.
3. Eco-design checklists for printed wiring board manufacturers.

Each of the sections starts with a checklist. It is followed by background information and more detailed advice. If this is the first time you are reading this report then it is recommended that you read the information and advice first before going through the checklist. After this you will probably only have to refer to the checklists, which is why they have been put first.

Any feedback or comments on the checklist are welcomed.

2. Legislation/Customer Requirements

Legislation/Customer Requirements Checklist	
Checklist Item	**Answer**
Has the responsibility to collect and document customer and legislation responsibilities been assigned to an individual(s)	
Does that person(s) have clear reporting responsibilities to top management?	
Do you have a system/tool(s) to keep you up to date with the latest legislation	
Do you have a documented system in place to generate a single requirements document that covers all your customers and legislation requirements?	
Is there a system in place to regularly review the above document and keep it up to date?	
Where there are any non-conformances to legislation or customer requirements, is urgent action in place to rectify the situation?	
Has the customer been informed of any non-conformances and has it been documented?	
If the answer to any of the above is no, put in place a documented plan to address the issue(s) with target completion dates.	

Background

Printed Wiring Boards have a significant environmental impact and are likely to receive much more attention from product manufacturers as they try to improve the environmental performance of their products to meet the requirements of the EuP.

There is likely to be much more pressure to move towards cleaner manufacturing processes, to non-halogenated PWBs and possibly the acceleration of some of the emerging technologies where circuits are formed by inkjet printing rather than disposition and etching away of copper as done now.

The need for good environmental data from suppliers is steadily increasing as more and more environmental product legislation is passed by different countries. Companies not able to address these needs are likely to loose significant market share. For this reason you should have a robust system in

place that monitors new requirements and implements any changes needed to meet them.

Most printed wiring board companies have at least ISO9000, and a substantial number also now have ISO14001 or EMAS. Use whatever management system you have to control the above monitoring system, with identified resources and responsibilities. Putting this system within a documented management system ensures it does not become a one off exercise

Monitoring Legislation

seeba Website
The seeba website (www.cfsd.org.uk/seeba) contains a lot of global legislation on electronics products. It is free to use. The resource centre on the website contains slide presentations on a number of the important pieces of legislation.

BuyUSA
This is a free US government website and contains a lot of information on environmental product legislation. (www.buyusa.gov/)

ERA Technologies
Subscription magazine. (http://www.era.co.uk/news/pr0217.asp) Updates on environmental product legislation.

PlesTech Ltd.,
Software/web and subscription. Substance database with legislation summaries and text, and minimum overall thresholds. (www.plestech.co.uk)

Raymond Communications
Subscription site, with overviews of most environmental product legislation, and reporting of new legislation. (www.raymond.com/)

Legislation Overview

Directive 2005/32/EC:

The EuP Directive was published in the European Union official journal on the 22nd July 2005. Member States are supposed to transpose it into national law by the 11th August 2007. It is based on article 95 so the requirements should be identical for all member countries. It creates a framework for the integration of various environmental aspects, such as energy efficiency, hazardous substances, water consumption or noise emissions, into the design of energy using products.

The EuP directive came about because it was estimated over 80% of all product-related environmental impacts are determined during the product design phase. The EuP directive states in the introduction:

‘*Action should be taken during the design phase of EuPs since it appears that the pollution caused during a product’s life cycle is determined at that stage, and most of the costs involved are committed then.’*
Energy using products account for a large proportion of the consumption of natural resources and energy used within the EU.

The directive applies to products that use electricity, fossil fuels or renewable energy sources during its use stage of the life cycle. It also applies to products used for generation, transfer or measurement of energy, and parts dependent on energy input supplied to end-users as individual parts if they can be assessed for environmental performance. Component and sub-assembly manufacturers may under the implementing legislation have to supply material composition and energy/material consumption data to the EuP producer.
There are some exemptions. They are:

- Transportation vehicles for people or goods. E.g. cars, trucks, ships, aeroplanes and rail.
- It is not clear whether the above includes agricultural and construction equipment that can move.

The EuP is a framework directive. The framework sets a template for legislation on specific product groups. The specific product groups will follow the parts of the template that are applicable to those groups. The framework will then allow the rapid implementation of legislation on products under the scope of the EuP in a standardised manner. It should be noted the EuP Directive will not directly create legal obligations and requirements for manufacturers. This will happen only when the implementing measures are adopted.

There will be 2 types of implementing measure requirements called specific and generic requirements. Specific requirements will have specific measurable targets set which companies will have to meet. This could be for example a value for maximum energy consumption on standby mode, or a maximum threshold set for a hazardous substance.

Generic requirements have no targets but a company is expected to demonstrate they have addressed it in their product launch process. These requirements will be taken from the complete list of generic requirements in the EuP.

A range of products have already been identified for priority action on introducing implementation measures. Preparatory study groups have been formed. The products impacted are:

- Heating and water heating equipment
- Electric motor systems
- Lighting
- Domestic appliances
- Office equipment
- Consumer electronics
- Heating ventilating air conditioning system (HVAC)

Separate implementation measure reducing stand-by energy use for a range of products will also be introduced. The target products have not yet been specified. The commission will introduce implementing measures after consultation for the above listed products most probably in 2007.

The current preparatory study groups for the above list are using what is called standardised data. For PWBs there is a standardise data set which is multiplied by the board weight to give the environmental impact of the PWB. This data set covers energy, emission to air and water, hazardous and non-hazardous waste, and water use. The number of types of PWB covered is at present very limited, but the EU has commissioned a group to develop a much better standardised data set.

The following lifecycle phases, where they relate to design will be required to look at:

- Raw material selection and use
- Manufacturing
- Packaging, transport and distribution
- Installation and maintenance
- Use
- End of life (e.g. end of its first use – reuse- recycling - until final disposal.)

PWB manufacturers could be impacted by all of the items on the above list except the use phase, where the third item in this case refers to the packaging and transport of the parts.

All EuPs covered by an implementing measure will require a documented ecological profile. It is a description with physical measurable values of the inputs and outputs as outlined in the implementing measure. It can include for example material content, energy, emissions and waste for those parts of the life cycle which have a significant environmental impact. The implementing measure may require the ecological profile to be made available to consumers along with the benefits of eco-design.

Each EuP covered by an implementing measure will require having a technical documentation file to demonstrate conformance. The file will cover the both the ‘generic’ and ‘specific’ eco-design requirements. Member States will assume an EuP bearing a CE marking conforms to any implementing measure on that EuP. This file will need to contain supplier part data either directly or as links to the relevant documents on the supplier’s website.

EuPs will come under CE marking and companies will have to make a declaration of conformity before their products can be put on the market. Checks on compliance will be required by member states, with samples of products subjected to compliance checks. Member states must provide a means for other interested parties to submit observations on non-compliance of products. This could result in competitors reporting on each other. Manufacturers will have to re-call any non-compliant product from the market. Member states must state the grounds on which non-compliance is based.

Under the EuP legislation, part manufacturers for the first time in any legislation will have a legal obligation to supply data to the manufacturers of EuPs so that manufacturer can meet the requirements of the EuP. At the minimum this will be the PWB weight and the inclusion of any hazardous substances. This is likely to meet the requirements if standardised part data is used, but some manufacturers may wish to use more accurate data to meet the requirements set out in the implementation measure on their product. This will be covered more fully under the next section.

Directive 2002/96/EEC:

The 'Waste from Electrical and Electronic Equipment' (WEEE) directive calls for information to be given to treatment centres on the location of hazardous substances, and for manufacturers to give information to users on how to dispose of dispose of the product. Documented evidence to demonstrate this is likely to be required for relevant products in the technical documentation file. Component manufacturers will need to provide information so this can be achieved. In the case of PWBs these will have to be removed from the product for separate treatment if they are over $10cm^2$ in area. The inclusion of metals that have restrictions on their disposal such as lead, nickel etc should be declared. Many PWBs use Tetrabromobisphenol-A (TBBA) as a flame retardant in substantial quantities. Sweden is looking at banning TBBA, and many companies such as Sony-Ericsson have or are in the process of phasing it out. Where TBBA is used, it should be declared.

Directive 2002/95/EC:

The 'Restriction of the Use of Certain Hazardous Substances in EEE' (RoHS) Directive bans with some exemptions the use of cadmium above a threshold 0.01% of homogeneous material and above 0.1% of homogeneous material for lead, mercury, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE). For impacted products the product technical documentation file will need to demonstrate that these requirements have been met. Information is required from PWB suppliers to meet these requirements.

Directive 76/769/EEC:

The directive 'Restrictions on marketing and use of certain dangerous substances and preparations' contains a large number of restricted or banned components. The product technical documentation file will almost certainly require data to show these requirements have been met. This directive along with its many daughter directives is often overlooked by many companies. However this is not likely to last long once the technical documentation file comes into general use under the EuP process.

Directive 67/548/EEC:

The directive on the 'Classification, Packaging and Labelling of Dangerous Substances' will need to be taken into account when selecting materials and their use reduced to a minimum. This will need to be documented in the technical documentation file.

REACH:

REACH is the acronym for Registration, Evaluation and Authorisation of CHemicals. The REACH proposal requires industry to register all existing and future new substances with a new European Chemicals Agency. This legislation which will come into force in 2007 and will considerably impact the PWB industry. It will require downstream users to report on the uses of different substances, and authorisation will be required to use substances of very high concern

Management Methods for Controlling Pollution by Electronic Information Products Order No. 39 China: Bans same substances as per RoHS plus it requires special labelling on the presence of RoHS substances whether they are exempted or not. The labels also indicate whether the product is recyclable and its safe working life. The labelling applies to all products, sub assemblies and parts coming under the scope and takes effect from March 2007. All products put on the market that are put in the catalogue will have to be tested by licensed laboratories. The catalogue has not yet been published.

Californian Bills Numbers: SB 20, SB50 and Bill 2202 USA: The first 2 bills Ban the same substances as RoHS on video devices greater than 4 inches diagonally. They also require data and improvement targets for recyclate use and designing for recycling. New bill going through extending scope to the same products as RoHS.

Bill 2202 which was passed in June 2006 extends the scope of the first 2 bills to the same scope covered by the EU RoHS directive.

Japanese J-Moss
Requires a label to be put on the product and packaging, plus details on the web if cadmium above a threshold 0.01% of homogeneous material and above 0.1% of homogeneous material for lead, mercury, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE). Some but not all the exemptions listed under the European RoHS are allowed.

3. Eco-declarations Checklists

Minimum Declaration Requirements Checklist	
Checklist Item	**Answer**
Do you publish the weight of your products?	
Do your products meet the RoHS requirements, and do you have documented evidence: • Less than 0.01% cadmium of homogeneous material • Less than 0.1% lead of homogeneous material • Less than 0.1% mercury of homogeneous material • Less than 0.1% hexavalent chromium of homogeneous material. • Less than 0.1% PBB of homogeneous material • Less than 0.1% PBDE of homogeneous material Note put exempt where applications has applicable exemption(s)	
Do you declare to your customers that you meet the RoHS requirements?	
Do you document and declare quantity and location of any occurrences of the above substances that are exempt under RoHS?	
Do you monitor whether you have any other substances in the product that are banned or restricted by other applicable legislation, and report occurrences to your customers?	
Have you colligated all the customer reporting requirements and are you reporting them?	
If the answer to any of the above is no, put in place a documented action plan to address the issue(s) with target completion dates.	

The above declaration is considered the minimum declaration a PWB manufacturer should give so their customers can satisfy current legislation and there internal needs.

Recommended Level of Declaration Checklist	
Checklist Item	**Answer**
Do you publish the weight of your products?	
Do your products meet the RoHS requirements, and do you have documented evidence: • Less than 0.01% cadmium of homogeneous material • Less than 0.1% lead of homogeneous material • Less than 0.1% mercury of homogeneous material • Less than 0.1% hexavalent chromium of homogeneous material. • Less than 0.1% PBB of homogeneous material • Less than 0.1% PBDE of homogeneous material Note put exempt where applications has applicable exemption(s)	
Do you declare the average materials and substances for available types of PWB/cm^2 in percent (or ppm) of part weight?	
Do you monitor whether you have any other substances in the product that are banned or restricted and taking action to eliminate any occurrences?	
For PWBs containing substances listed in Annex I to Directive 67/548/EEC on Classification and Labelling of Dangerous Substances do you produce a Materials Safety Data Sheet	
Have you colligated all the customer reporting requirements and are you reporting them?	
If the answer to any of the above is no, put in place a documented action plan to address the issue(s) with target completion dates.	

Following the above checklist should satisfy most customer requirements and supply sufficient information for companies to meet the requirements of the new environmental legislation that are coming into force around the world. An example of a materials declaration for PWBs can be found under the umbrella specs at ZVEI. It combines the data from 3 companies.

Market Leader Level of Declaration Checklist	
Checklist Item	**Answer**
Do you publish the weight of your products?	
Do your products meet the RoHS requirements, and do you have documented evidence: • Less than 0.01% cadmium of homogeneous material • Less than 0.1% lead of homogeneous material • Less than 0.1% mercury of homogeneous material • Less than 0.1% hexavalent chromium of homogeneous material. • Less than 0.1% PBB of homogeneous material • Less than 0.1% PBDE of homogeneous material Note put exempt where applications has applicable exemption(s)	
Do you declare the following for families of PWBs in percentage (or ppm) of the PWB weight per cm^2? • Materials and substances composition • Energy GER, feedstock, and electricity • Air emissions in GWP, AD, VOC, POP, HM, PAH, and PM • Water emissions of heavy metals and EUP. • Hazardous and non-hazardous waste generation • Water use for process and cooling	
Do you monitor whether you have any other substances in the product that are banned or restricted and taking action to eliminate any occurrences?	
For PWBs containing substances listed in Annex I to Directive 67/548/EEC on Classification and Labelling of Dangerous Substances do you produce a Materials Safety Data Sheet	
Have you started preparing for REACH by gathering data on how substances are used as recommended by cefic	
Have you colligated all the customer reporting requirements and are you reporting them?	
If the answer to any of the above is no, put in place a documented action plan to address the issue(s) with target completion dates.	

Minimum Declaration Requirements Overview

Many PWB companies are just making a statement that they are RoHS compliant. However most countries in the EU require readily available documented evidence to show a manufacturer has practiced due diligence under RoHS. If this is not available then there are risks that customers will be lost.

In China it looks like their version of RoHS, which covers not only products but also parts as well, will require reporting of all substances over the thresholds, even those that are exempt. If you also consider that REACH will probably require these chemicals to be tracked and reported then reporting the presence and location of these substances within a part becomes essential.

It is often overlooked by companies that RoHS is not the only legislation restricting the use of substances. PWB manufacturers should ensure their products meet all the legislation. In many cases failure to meet legislation can result in a product having to be withdrawn from a market, and in some cases it can even go as far as imprisonment of company personnel. Most, but not all, of these substances are in the Level A list in the Joint Industry Guide which can be obtained from http://www.eia.org/new_policy/jig_download.phtml This guide however should not be used as a means of keeping up to date on legislation since a few substances are missing that are banned in Germany and also because changes have to be agreed by many companies making up the associations, and new legislation on substances will take its time to get into the guide.

Many multinational companies have their own reporting requirements. If retention of this customer is important, their requirements should be included in the declarations made.

Recommended Level of Declaration Overview

Companies have been reluctant to make full material declarations. The reasons given are:

- It gives away information to the competitors.
- There are too many types PWBs for materials declaration to be practical.

The first on the list does not stand up to careful scrutiny. If a competitor wants to know the material content he will just carry out a material analysis on the product.

The second on the list is a more understandable concern because each PWB is normally different for every application. The trick to overcome this is to report by families of PWBs per square centimetre of board, and let the customer adjust the values for area etched away and vias. Try to split them

into families so the error never exceeds +/-10% and for hazardous substances the maximum is reported. The reported data for this would be:

- PWB base material such as FR1, FR2, FR4, FR4 filled, FR4 halogenfree, BT, or Arimid
- Number or layers
- Thickness
- Surface such as HAL (Sn/Pb), HAL (leadfree), nickel/gold, OSP, immersion tin, or immersion silver
- Soldermask
- Impact of number of vias/cm^2 on copper content

An example from the ZVEI umbrella specs sites for a FR4, 1.6mm thick, 4 layer PWB of 100cm^2 area having a surface treatment of Ni-Au (ENIG) and using a solder mask is:

Construction element	**Material group**	**Materials**	**CAS if applicable**	**Material mass[g]**	**Material analysis [%]**	
				Average	**from**	**to**
Basematerial	FR4 Standard	Brominated epoxy resin		11.28	38.84	31.53
		E-glass fabric		15.56	49.84	47.23
Surface	Metal	Copper	7440-50-8	4.70	10.17	19.17
		Nickel	7440-02-0	0.07	0.15	0.30
		Gold	7440-57-5	0.01	0.01	0.08
Surface	Soldermask	Acrylate/Novolak		0.43	1.00	1.70
			Sum in total	32.07	100	100

The above table shows the main problem of combining data from different manufacturers. That is the wide spread in the data. Gold for instance has a spread of a factor of 8. Although the quantities are small it does have a large impact on both energy use and recyclability. The above data also does not give a correction factor for vias.

The inclusion of the above information is likely to become a valuable market advantage for a PWB manufacturer. This information will also need to be given on Material Safety Data Sheets when they are required under REACH. These should be generated if the part contains any of the substances listed under 67/548/EEC on Classification and Labelling of Dangerous Substances. (http://ec.europa.eu/environment/dansub/home_en.htm)

Market Leader Level of Declaration Overview

The indications are at the moment that for the EuP, standardised data will be used to analyse products. For PWBs this means that a standard sets of data probably can be used for these parts. The data covers:

- Primary gross energy requirement (GER) , feedstock (energy from incineration), and electricity usage of the total energy.
- Air emissions:
    - Greenhouse gases (GWP)

    - Acidifying agents (AD)
    - Volatile organic compounds (VOC)
    - Persistant organic pollutants (POP)
    - Heavy metals (HM)
    - Polycyclic Aromatic Hydrocarbons (PAH)
    - Particulate matter (PM)
- Water emissions of heavy metals and Eutrophication (EUP).
- Hazardous and non-hazardous waste generation
- Water use for process and cooling

In principle the above would mean that PWB manufacturers would only have to supply the PWB weight and area to their customers. However some of the multinational companies may wish to gather real data from their suppliers so they can use it to help meet EU set targets for their products. In addition some suppliers may wish to drive performance improvements to help them get a larger market share. All the above parameters can be declared for families of products as per material content. (See appendix 1 for detail definition of parameters)

Table . Life Cycle Impact (per unit) of Products

Nr	Life cycle Impact per product:	Date	Author
0	Products	0	vhk

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			0			0	0	0	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			0			0	0	0	0
4	Non-ferro	g			0			0	0	0	0
5	Coating	g			0			0	0	0	0
6	Electronics	g			0			0	0	0	0
7	Misc.	g			0			0	0	0	0
	Total weight	g			0			0	0	0	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	0	0	0	0	0	0	0	0	0
9	of which, electricity (in primary MJ)	MJ	0	0	0	0	0	0	0	0	0
10	Water (process)	ltr	0	0	0	0	0	0	0	0	0
11	Water (cooling)	ltr	0	0	0	0	0	0	0	0	0
12	Waste, non-haz./ landfill	g	0	0	0	0	0	0	0	0	0
13	Waste, hazardous/ incinerated	g	0	0	0	0	0	0	0	0	0
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	0	0	0	0	0
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	0	0	0	0	0	0	0	0	0
17	Volatile Organic Compounds (VOC)	g	0	0	0	0	0	0	0	0	0
18	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	0	0	0	0	0
19	Heavy Metals	mg Ni eq.	0	0	0	0	0	0	0	0	0
	PAHs	mg Ni eq.	0	0	0	0	0	0	0	0	0
20	Particulate Matter (PM, dust)	g	0	0	0	0	0	0	0	0	0
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	0	0	0	0	0	0	0	0	0
22	Eutrophication	g PO4	0	0	0	0	0	0	0	0	0
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

Standardised data being used by the preparatory study groups.

REACH Industry Preparation Letter No 3 from cefic states for both manufacturers/Importers (Registrants) and downstream Users they should start preparing now the following:

- Produce your own company inventory of individual chemical substances and preparations.
- Define for each substance or preparation your own status from the perspective of REACH (M/I, distributor, DU, legal entity) and your "position" in the supply chain.
- Define for each substance or preparation your own status from the perspective of REACH (M/I, distributor, DU, legal entity) and your "position" in the supply chain.
- Establish whether individual substances and preparations fall into the following categories:
  - Manufactured by your company within the EU
  - Imported by your company into the EU
  - Purchased by your company from a supplier established within the EU

PWB manufacturers use a lot of substances during the manufacturing process and starting the preparation now will make the whole task more manageable.

Declaration Tools

RosettaNet
RosettaNet (www.rosettanet.org/) is a standard for the electronic exchange of materials and substance data between companies that uses XML.

IPC 1752
IPC have developed a PDF electronic form for materials declaration. It can handle a full materials and substance declaration. It is XML based so could be automatically populated. (http://members.ipc.org/committee/drafts/2-18_d_MaterialsDeclarationRequest.asp)

The GoodBye Chain Group
Material Declaration Wizard 3.0 is a software package for declaring materials to the 'Joint Industry Guide' levels A, B, and C.
(www.smta.org/declaration_software.html)

PlesTech
REACH, EuP, WEEE, RoHS (EU/Chinese), 'Joint Industry Guide' levels A, B, and C declarations. Software/database with web based documentation, and database updates (www.plestech.co.uk)

Synapsis
web-based Environmental Material Aggregation and Reporting System for WEEE, RoHS and ELV.
(www.synapsistech.com/Products_Environmental_Compliance.asp)

Eco-design checklists for printed wiring board manufacturers

The following checklist does not include items already covered in previous lists, and should be used in conjunction with those lists.

Eco-design Requirements Checklist	
Checklist Item	**Answer**
Do you have sufficient person(s) that have received training in eco-design?	
Is eco-design an integral part of the management system for product launch?	
Are their company metrics and targets for eco-design, which are reviewed by top management?	
Is eco-design included in design and product launch reviews together with price, quality, milestones etc?	
Does the corrective action system include product environmental issues?	
When choosing materials for processes and the PWBs do you consider alongside price and quality the environmental impacts of producing the PWB for: • Hazardous material content? • Energy use? • Waste generation (hazardous and non-hazardous)? • Water use? • Water emissions? • Air emissions?	
Where applicable and can be influenced by design do you consider and try to reduce the environmental impact of the part on: • Product assembly? • Product Use? • End-of-life disposal/recycling of the product?	

Checklist Item	Answer
Where applicable have you compared the environmental impact of using different technologies and processes for producing the PWB taking into account (See appendix for more details): • Hazardous material content? • Energy use? • Waste generation (hazardous and non-hazardous)? • Water use? • Water emissions? • Air emissions?	
Does marketing use your strengths in eco-design in a similar manner to those in cost and quality? • Material selection? • Use of clean technologies? • Advantages to customers?	

Checklist Item	Answer
Have you investigated the overall environmental impact and associated costs of using reusable packaging with selected customers?	
Have you designed the PWB packaging for minimal environmental impact including: • Absence of hazardous substances? • Minimal weight? • Minimal volume? • Economical to recycle at end-of-life? • Least number of different materials?	
If the answer to any of the above is no, put in place a documented plan to address the issue(s) with target completion dates.	

Background

Eco-design is in the process of making the same sort of step change that was seen in the 1970/80s with the establishment by the Japanese of integrated quality control and in 1986 by the Six Sigma methodology pioneered by Bill Smith at Motorola. The latter manages process variations that cause defects, defined as unacceptable deviation from the mean or target; and to systematically work towards managing variation to eliminate those defects. Many companies not embracing these changes went out of business or lost market share. Prior to these changes quality was considered peripheral to the main business activity just as eco-design is for many companies today.

What is causing this change? It is the fast growing public awareness of the environmental damage being done by products to their quality of life and that of their children plus the growing body of legislation emerging in many countries to try and limit that damage. As an example a poll carried out by Zogby International in the US (A country not generally seen as strong on environmental issues) stated: "*Nearly three of every four (general public) – 74% – are more convinced today that global warming is a reality than they were two years ago*" In addition "*The survey also indicated there is strong support for measures to require major industries to reduce their greenhouse gas emissions to improve the environment without harming the economy – 72% of likely voters agreed such measures should be taken.*"

As a result of the above PWB manufacturers can expect to see the following trends coming very quickly from their customers:

- Request for more environmental information.

- Demonstration of capability to integrate eco-design into product launch
- Reduction in environmental Impacts from parts used in their products.
- Product redesigns resulting in changes to types of parts used in products.

Applying Eco-design

When starting with eco-design either hire or train an individual to take overall control of its implementation. That person should then be overall responsible for:

- Constructing an implementation plan with dates and costs.
- Getting top management buy in for the implementation plan
- Establishing measurable and appropriate metrics.
- Putting in place the resources, and organisation.
- Training of staff
- Documented procedures and auditing of them.

Once the organisation is in place, determine for the company products, what environmental impacts can be influenced by design. For instance a manufacturer of PWBs normally can not impact very much the energy used by the products during the use phase. However part weight, choice of materials, manufacturing processes, part packaging and data declarations are all very important.

The environmental performance of parts is likely to become much more important in the marketing of products, since it is an area a company can demonstrate it is better than its competitors, and something that customers will increasingly want as the EuP and other legislation comes into force. For this reason ensure the marketing/sales departments are fully involved and environmental data required by the customer base is easily available from the web.

What is the first thing a company should do once the system is in place? Understand what is currently being sold. This includes:

- Part and packaging weights
- Material composition and identification of hazardous substances in parts and packaging.
- Energy used to produce products and packaging including idle time energy. Include overheads (offices)
- Waste and hazardous waste generated.
- Any emissions to air and water during production.
- Recyclability of packaging including any return and reuse activities.

The above can be used as a starting point to drive future improvements. One of the things many companies are surprised over is that often by doing this exercise they can make substantial cost savings. Few companies know exactly where the energy is being consumed and often most of it is consumed doing nothing (Sometimes up to 90%). If a company has multiple factories it is

not unusual to find large variations in energy use between them. In addition to the above further saving can often be made by reductions in the use of materials especially packaging. In summary a well planned exercise with improvements implemented can result in:

- Reduced costs
- More environmentally friendly products.
- Good customer satisfaction
- A clear marketing advantage.

Eco-Design Tools

There are many eco-design tools available, however check that they will do at least the following before investing in one:

- It uses a database to store the parts. Most PWB manufacturers deal with 100s or thousands of different part numbers and a database system is essential for handling them.
- Ensure similar parts can be generated so that only a few fields have to be changed for each part.
- Can import and export records in at least XML, ODBC, and Excel.
- Handle EuP standardised data, and the EuP standardised data records are kept up to date.
- Can generate materials composition, EuP data and RoHS compliance reports
- Can it handle both product and packaging.
- Can be used by current staff of the company, and expertise not in the company is not required?
- Does it fit in well with how products are launched by the company?
- Is the tool user friendly?
- Does the tool also address other environmental product legislation requirements such as REACH?
- Is it affordable for the company?

The following links can be used as a starting point.

Product Eco-design Tools:

- Eco Scan http://www.ind.tno.nl/en/product/ecoscan/
- EDT http://www.plestech.co.uk
- Idemat http://www.io.tudelft.nl/research/dfs/idemat/index.htm

Life Cycle Analysis:

- Boustead http://www.boustead-consulting.co.uk/
- GaBi http://www.gabi-software.com/
- Sima Pro http://www.pre.nl/simapro/default.htm
- TEAM http://www.ecobilan.com/uk_team03.php

Appendix: EuP Environmental Indicators and Scope for Improvements

Gross Energy Requirement (GER)

Gross energy requirement (GER) which is defined by IFIAS (1974) as: "*... the amount of energy source which is sequestered by the process of making a good or service ...*". The GER of a product is the sum of all energy sources which are required for the making of the product or service.

The EuP values are given below for PWBs of 10x10cm:

PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
11 MJ	10 MJ	17MJ

It can be seen from the above results that substantial energy is required to produce PWBs. Actions that can be taken to these figures, are:

- Reduce board size by better design or component integration.
- Maximise panel use.
- Use thinner boards
- Use a direct metallization process for through holes as this reduces energy use mainly because of the faster cycle time. (See table below for a comparison table.)
- Energy consumption can be up to 80% less for immersion silver surface finish compared to that for HASL.
- Organic solderability preservative (OSP) surface finish uses less energy because process temperatures are lower.
- Direct write technologies such as use of ink jets for printed wiring boards are progressing rapidly. They offer the chance to substantial reduce energy consumption by their reduced size, and much lower energy processes. Embedded passive components are already possible at +/-5% tolerance, and considerable development work is taking place on embedding active components and optical interfaces.

It should be noted that implementing any of the above energy reduction methods will not reflect in any improvements in the figures generated by the use of the EuP standardised data. It is therefore far better manufacturers used actual material composition and process data to demonstrate the improvements made. Reducing energy costs, besides improving the environmental performance also can substantially reduce manufacturing costs.

The table below shows how direct metallization compares to Electroless Copper Overall? It comes from a report by EPA called Alternative Technologies for Making Holes Conductive

Alternative	Worker Health Risks *see Question 3*		Environmental Concerns *see Questions 3 and 6*			Performance *see Question 4*	Production Costs *see Quest. 5*
	Inhalation Risk *# chemicals of concern*	Dermal Risk *# chemicals of concern*	Water Use (gal/ssf)	Energy Use (Btu/ssf)	# Chemicals with High Aquatic Toxicity		($/ssf)
Electroless Copper-Non-conveyorized (BASELINE)	10	8	12	573	11, including copper sulfate	Performance for all technologies varied among test sites	0.51
Electroless Copper-Conveyorized	★★	=	★★	★★	=	Comparable or superior	★★
Carbon	★★	★★	★★	=	=	Comparable or superior	★★
Conductive Polymer	★★	★★	★★	★★	★	Comparable or superior	★★
Graphite	★★	★★	★★	★★	=	Comparable or superior	★★
Non-Formaldehyde Electroless Copper	★	★	★★	★★	=	Comparable or superior	★
Organic Palladium-Non-Conveyorized	★★	★	★★	★★	★	Comparable or superior	★★
Organic Palladium-Conveyorized	★★	★	★★	★★	★	Comparable or superior	★★
Tin Palladium-Non-Conveyorized	★	★	★★	★★	=	Comparable or superior	★★
Tin Palladium-Conveyorized	★★	★	★★	★★	=	Comparable or superior	★★

★★ Greatest improvement over the baseline.
★ Some improvement over the baseline.
= Little or no improvement over the baseline.

Hazardous and Non-hazardous Waste

Waste has been defined as the solid waste that is not reused or recycled. Hazardous waste refers to the substances listed in RoHS plus others non-defined. For the Excel ecodata spreadsheet of standardised values the definitions given in the waste directive 75/442/EEC appear to have been used. For the 3 types of PWBs considered above the waste generated in grams per 10x10cm PWB are using the EuP standardised data:

	PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
Hazardous	65 grams	85 grams	85 grams
Non-hazardous	98 grams	47 grams	183 grams

Besides reducing PWB weight, the board technology and production process are the largest influence on these figures. The amount of waste, both hazardous and non-hazardous is considerable. In the worst case the above shows that over 4 times the PWB's weight can be generated as hazardous waste and the same for non-hazardous waste.

Consider:

- Reducing size of PWB.
- More efficient use of panel sizes
- Using metal recovery equipment
- Use sodium borohydride or dithio carbamate instead of ferrous sulfate in waste treatment as they will generate less sludge.
- Use reusable polymer membrane filters instead of paper filters for filtering copper and zinc from the wastewater of mechanical wet scrubbing operations.
- Consider use of direct write technology. This would substantially reduce the generation of hazardous and non-hazardous waste.

Water Use (Process and Cooling)

Process water usage is the one of primary importance between the two indicators. It is the water used in the process of the material or PWB that is then normally disposed of into the sewage system. A secondary indicator is cooling water which can be taken from a river or lake then returned to them slightly warmer. Only the first is really normally of any concern for PWBs. The process water usages for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
6 litres	8 litres	22 litres

The following actions can be taken to reduce water usage:

- Use thinner boards
- Reduce the size of the PWB
- More efficient use of panel sizes
- Use analysis results rather than a schedule to replace process baths (documented process)
- Use leak detection and overflow sensors and alarms
- Have in place a preventative maintenance system.
- Avoid dripping outside of tanks from boards by using some of the following:
    - Air knife to remove liquid over tank
    - Allowing more time over baths
    - Use of drip tanks
    - Lower viscosity with wetting agents
    - Use drip shields
- Minimise water used for rinsing by using some of the following
    - Use a counterflow rinse system
    - Recycling rinse water
    - Use spray rinses
    - Use basket rinsing instead of rack rinsing
    - Use sensors to control rinse
    - Remove and reclaim water remaining on board

- Consider changes in technology
    - Use direct write technology. This would substantially reduce water usage.
    - Use dry polishing technique for levelling insulation material surfaces of printed wiring boards instead of the wet scrubbing process.
    - Use a closed loop hot deionized (DI) water system to clean boards instead of chemical-based cleaning systems.
    - Use Organic Solderability Preservative (OSP) instead of other surface finishes. Uses half the water of HASL.

Water Emissions (Heavy metals and EUP)

The 2 main pollutants to water by energy using products are heavy metals and eutrophication (EUP). The first are metals such as lead and mercury and the amount is expressed as mg of equivalent mercury/20.

The second is eutrophication, which is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth such as algae. This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die. This can be caused by pollutants and in particular phosphorus, nitrogen, and carbon. This is expressed as one value in terms of mg of phosphorus (PO_4) equivalent. The metal and EUP impact for the 3 types of PWBs of size 10x10cm are:

	PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
Metal (mg Hg/20eq)	0.6	7	6
EUP (mg PO_4 eq.)	138	57	110

Metal plating is a large source of both metal and EUP emissions. In addition the board epoxy material can generate high levels of EUP.

The following actions can be taken to reduce water emissions:

- Reduce board size by better design or component integration.
- Maximise panel use.
- Use direct write technology.
- Use thinner boards to reduce EUP

Air Emissions (GWP, AD, VOC, POP, HM, PAH and PM)

Some of the air pollutants can be removed by air scrubbers. However the process only moves the unwanted substances from the air into a solid paste or powder form. Often this is then put into landfill. In general it is best to minimise the generation of air pollutants in the first place. The following are definitions of the different air emissions included under the EuP standardised data:

- **GWP:** Is the 'Global Warming Potential' from gas emissions, or sometimes call greenhouse gases. It is a relative scale which compares the gas in question to that of the same mass of carbon dioxide (whose GWP is by definition 1). The standardised data is expressed in terms of equivalent kilograms of carbon dioxide (CO_2). GWP is tied to energy use, so reductions can be made simply by reducing the energy used to manufacture the PWB. The values for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
0.4 kg CO_2 eq	0.4 kg CO_2 eq	0.7 kg CO_2 eq

  Consider the following to reduce the emissions of AD:
  - Reduce board size by better design or component integration.
  - Maximise panel use.
  - Use direct write technology.
  - Use thinner boards to reduce AD
  - Recommend avoidance of precious metals such as gold or silver that use a lot energy (e.g. use OSP)

- **AD:** These are 'Acidifying Agents' that cause what is commonly known as acid rain. They mainly form during fossil fuel combustion. When emissions of sulphur dioxide and nitrogen oxides come in contact with water, they become sulphuric acid and nitric acid. The standardised data is expressed in terms of equivalent grams of sulphur dioxide (SO_2). The values for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
8 gm SO_2 eq	4 gm SO_2 eq	17 gm SO_2 eq

  Consider the following to reduce the emissions of AD:
  - Reduce board size by better design or component integration.
  - Maximise panel use.
  - Use direct write technology.
  - Use thinner boards to reduce AD

- **VOC:** These are 'Volatile Organic Compounds' which are emitted as gases from certain solids or liquids. Many organic compounds are known to cause cancer in animals; some are suspected of causing, or are known to cause, cancer in humans. The main source of VOC for PWBs is the epoxy in the board. The standardised data is expressed in terms of mg of VOC. The values for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
0.09 mg	0.001 mg	0.05 mg

  Consider the following to reduce the emissions of VOC:
  - Reduce board size by better design or component integration.
  - Maximise panel use.
  - Use thinner boards to reduce VOC

- **POP:** These are 'Persistent Organic Pollutants' which are a set of chemicals that are toxic, persist in the environment for long periods of time, and bio-magnify as they move up through the food chain. They include polychlorinated biphenyls (PCBs), which were used as plasticizers in paints, plastics, and rubber products and dioxins and furans, which are produced unintentionally from most forms of combustion. Dioxins comprise of polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The standardised data is expressed in terms of ng I-Teq. This is a rather complex measurement which is the summation of individual (Toxicity Equivalents) TEQs for a mixture of PCDDs and PCDFs and is termed the International Toxicity Equivalent or I-TEq of the mixture. The values for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer 3.75kg/m^2	PWB 6 layer 2kg/m^2	PWB 6 layer 4.5kg/m^2
0.1 ng i-TEQ	0.06 ng i-TEQ	0.2 ng i-TEQ

  Consider the following to reduce the emissions of POP:
  - Reduce board size by better design or component integration.
  - Maximise panel use.
  - Use thinner boards to reduce POP
  - Recommend use of non-halogenated boards (e.g. nitrogen/phosphorous) that do not generate dioxins when incinerated at end-of-life.

- **HM:** Stands for heavy metals. The 3 particularly harmful metals are cadmium, lead and mercury, which are covered by the 1998 Heavy Metals Potocol. Parties agreed to reduce their emissions for these three metals below their levels in 1990. The standardised data is expressed in terms of mg of equivalent nickel. The values for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer $3.75kg/m^2$	PWB 6 layer $2kg/m^2$	PWB 6 layer $4.5kg/m^2$
1.4 mg Ni eq	0.7 mg Ni eq	3.2 mg Ni eq

  Consider the following to reduce the emissions of HM:
  - Reduce board size by better design or component integration.
  - Maximise panel use.
  - Use thinner boards to reduce HM
  - Recommend use of Organic Solderability Preservative (OSP) instead of a surface finish with electroless nickel.

- **PAH:** These are 'Polycyclic aromatic hydrocarbons' and are chemical compounds that consist of fused aromatic rings. Some of them are known or suspected carcinogens. They are formed by incomplete combustion of carbon-containing fuels. PAHs have been grouped with the heavy metals under directive 2004/107/EC so under the standardised data it is expressed in terms of mg of equivalent nickel as above. The values for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer $3.75kg/m^2$	PWB 6 layer $2kg/m^2$	PWB 6 layer $4.5kg/m^2$
0.13 mg Ni eq	0.07 mg Ni eq	0.31 mg Ni eq

  Consider the following to reduce the emissions of HM:
  - Reduce board size by better design or component integration.
  - Maximise panel use.
  - Use thinner boards to reduce HM

- **PM:** Stands for particulate matter. It is a complex mixture of extremely small particles and liquid droplets made up of a number of components, including acids (such as nitrates and sulphates), organic chemicals, metals, and soil or dust particles. The standardised data it is expressed in terms of grams of PM. Airborne particulate matter is generated by machining operations during board preparations. The values for the 3 types of PWBs of size 10x10cm are:

PWB 1/2 layer $3.75kg/m^2$	PWB 6 layer $2kg/m^2$	PWB 6 layer $4.5kg/m^2$
0.2 gm	0.12 mg Ni eq	1.7 mg Ni eq

Consider the following to reduce the emissions of HM:

- Minimise machining of boards
- Recommend use of surface mounted parts rather than through hole.
- Reduce board size by better design or component integration.
- Maximise panel use.
- Use thinner boards to reduce HM