European Lead-free Technology Roadmap

Ver1: February 2002

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About SOLDERTEC

Soldertec is the Soldering Technology Centre of Tin Technology Ltd. It is a membership-based organisation through which members receive a unique package of benefits that aims to provide access to leading-edge lead-free research and information within a community of key electronics industry technologists. The current research portfolio tackles key focus areas in lead-free technology and there are opportunities for collaborative projects between the multi-level industry partners within the membership. Soldertec also aims to bring lead-free information directly to its members, with delivery mainly through the www.lead-free.org website.

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INTRODUCTION

Research into the replacement of tin-lead solder in the electronics industry has been underway for at least 15 years, however, implementation has been slow and industry infrastructure has not yet fully adapted to the requirements of this new technology. While products using lead-free solder are already available, predominantly in the Japanese market and particularly for consumer goods, these are generally manufactured by companies that are leading industry activity. Lead-free production is not yet widespread in Europe.

While lead-free technology roadmaps are produced and updated for the USA by the IPC[1] (first version released in 1999), and for Japan by JEITA[2] (version 1.3 released in 2000) there has been no attempt to summarise activity in Europe as a whole. This is somewhat surprising considering that one of the main causes driving the change to lead-free are the draft EU Directives on Waste Electrical and Electronic Equipment (WEEE)[3] and Restriction of Hazardous Materials (RHS)[4]. However, unlike the USA or Japan there is no Europe wide industry organisation to assume responsibility for this activity.

At the request of certain member companies, and organisations preparing roadmaps information for the Japanese industry, Soldertec has undertaken a survey of European company opinions on lead-free via questionnaire. Results from this survey are summarised in the following document. Undoubtedly the survey was of limited scope as a result of funding restrictions but it is hoped that this initial work will encourage further participation by other industry groups in order to extend any future work and ensure an effective and cost effective transfer to lead-free technology.

The survey has made it possible to summarise the average target dates for lead-free implementation by European companies and also summarise opinions on specific technical issues. It some cases it has also been possible to compare EU opinion to that of those Japanese companies that have already made significant progress towards lead reduction targets. Those companies who participated in this activity will be able to compare their opinions to the average, to obtain an estimate of their relative progress on lead-free implementation, and, to note any areas where significant differences may represent further requirement for activity.

Categories used in this Soldertec survey reflect to a greater or lesser extent some of the questions of the JEITA roadmap and the ZVEI[5] lead-free technological assessment of German industry in 1999 and allow a degree of comparison

The current proposed dates for lead phase-out in electronics in the EU via the RHS Directive is either January 2006 or by January 2007 at the latest. This remains under review and companies should keep up-to-date with the legislative deadlines via more regularly revised information sources such as the internet[6]. The document also assumes a reasonable background knowledge of the subject by the reader, however, other downloadable information is available from the same source if required. Effects of the WEEE Directive are not addressed.

Survey results, of course, represent the opinion of companies who replied to the questionnaire, and do not directly represent the opinion of Soldertec, however, various comments and clarifications have been added.

1. OUTLINE

As a voluntary activity by Soldertec the document cannot hope to address any topic in detail but is aimed at providing general benchmarking information to European companies that will be affected by the impending EU legislation.

The document has been prepared in the various sections listed below;

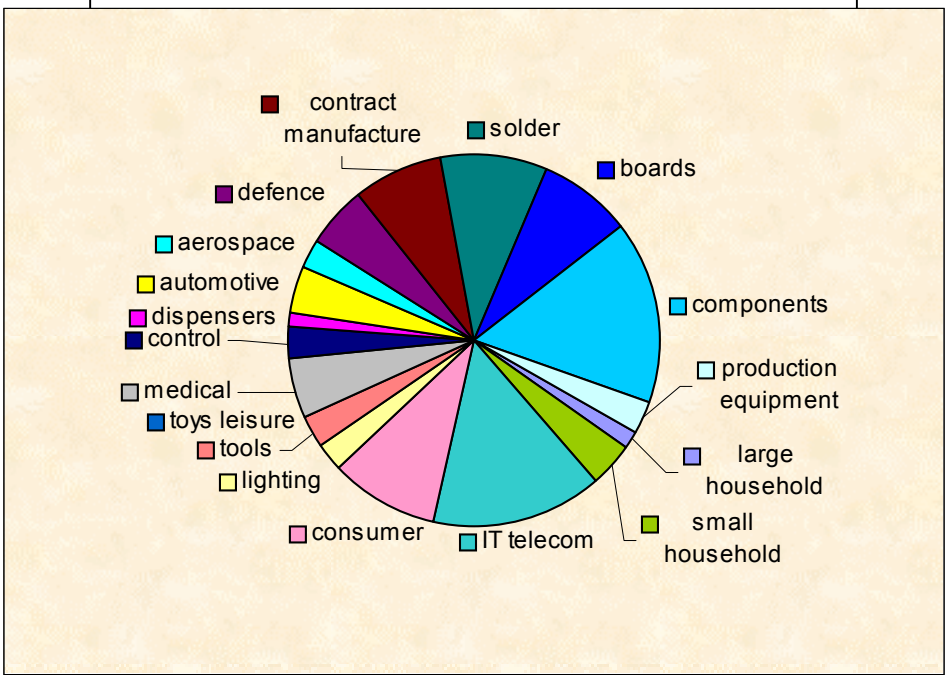
1. Outline
2. Information on respondents
3. Targets and progress towards lead-free information
4. Survey of general opinion
5. Technical, cost and status evaluation
6. Recommendations
7. Suggestions for working groups and future pan-European activity
8. Annex 1: questionnaire used to obtain feedback on the general issues described in section 4
9. Annex 2: tabular questions used to obtain feedback for section 5

2. INFORMATION ON RESPONDENTS

Responses were received from 48 organisations in a range of EU countries; France, Germany, Netherlands, Norway, Sweden, UK as well as corporations operating and expressing views on a general European (41%) or Global (41%) basis. Most responses were from individual companies although 3 were received from trade associations or research organisations. A limited number of small and medium sizes enterprises (SME's) participated but some responses were received.

Information was obtained from manufacturers of products in all categories covered by the WEEE Directive apart from toy manufacturing. Responses were also obtained from companies in all other categories listed (automotive etc). Company interest is not limited to one product category and overall 40% noted an interest in some aspect of component manufacture, this for instance includes plating chemical suppliers. This component classification was the highest percentage of interest, followed by 37% who indicated their involvement in IT and telecom. Further information on the breakdown of company interests is shown in Figure 1 below.

Figure 1: Information on participating company interests



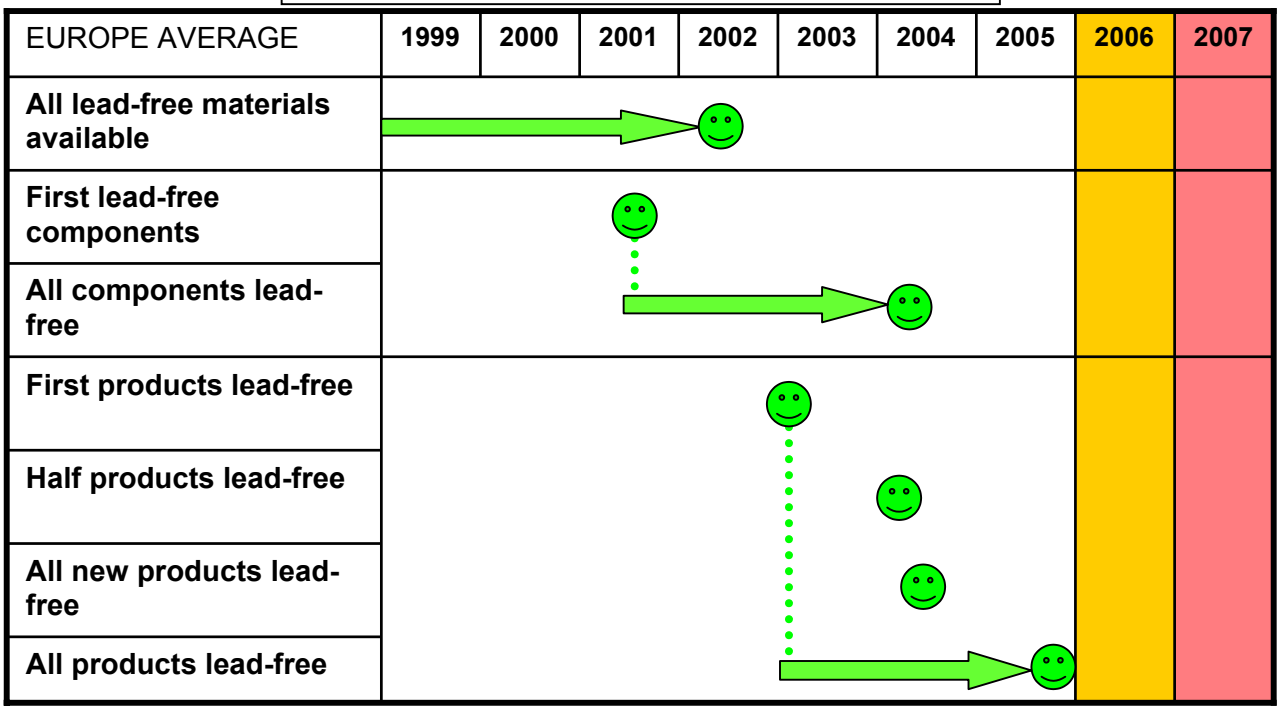
3. TARGETS AND PROGRESS TOWARDS LEAD-FREE IMPLEMENTATION

Companies were requested to provide as much information as possible on the number of lead-free products already in the market, when the first product was/would be introduced and a range of indicators up to full lead-free implementation. The data in this section represents an average indication of target dates. In effect, the data can be compared to indicators of 'market match' situations as described in other roadmaps such as that of the IPC. Information on 'market leader' and 'market follower' companies was obtained during this work but is not included in this summary for reasons of confidentiality. It was clear from the responses obtained that it was not appropriate to summarise target dates across all companies involved; analysis according to three categories (materials, components, assemblers) has been carried out.

Material supply companies (such as solder, plating chemicals and board suppliers) have been manufacturing lead-free product for sometime and are dependant on customer request for further increases in percentages supplied. Therefore the possibility of obtaining 'all lead-free materials' dates from before 1999 and should be possible by mid-2002 if demand exists. Remaining development work of new technology is concentrated particularly on lead-free plating chemistries, but, obviously, development of other consumables e.g. solder pastes, will continue as it has in the past with tin-lead.

Data from component manufacturers indicated that on average the first lead-free and lead-free compatible products were introduced in the market in mid-2001, and, overall all components are expected to be lead-free by early 2004. It should be noted that the 'component manufacturers' category includes semiconductor companies and a range of others such as connector or passive component suppliers.

Figure 2: Average targets for lead-free implementation



The first lead-free products from assembly companies are, on average, expected to be on the market at the end of 2002. Of course, this does not indicate the very first introduction and it should be noted that market leading companies already have lead-free products in the European market and have had for several years. It can also be seen that all newly designed products are expected to be lead-free during mid-2004. This compares with the JEITA

roadmap for Japan that suggests, in general, all new products should be lead-free during 2002; approximately 2 years in advance of the EU. Complete conversion to lead-free technology is anticipated at the end of 2005 just in time for the introduction date of the expected EU legislation. A very small number of companies indicated that they would not be able to meet the 2006 deadline but in these cases products were not of the types affected by the WEEE/RHS Directives e.g. defence. In both the EU and Japan, companies are at different stages of lead-free implementation, with some far in advance of others.

It is clear that introduction of lead-free assembly will take place in advance of full availability of lead-free components. This reflects the situation faced and successfully dealt with in the Japanese market during the initial implementation of lead-free in that region. The difficulties associated with use of mixed lead containing and lead-free technology have been well documented and should by considered by companies facing this situation.

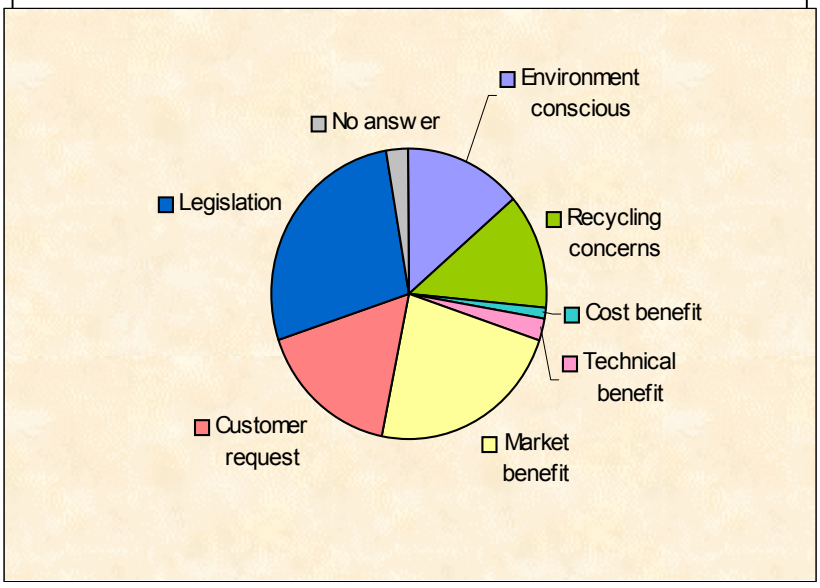
4. SURVEY OF GENERAL OPINION

The questionnaire used to obtain feedback on the general issues below can be found in Annex I. In most cases it was possible to provide more than one answer to each question and total percentages may therefore add to more than 100% in each category. The graphical representation for each question indicates the relative popularity of the possible answers from those that replied to that specific question only. Exact percentage figures are noted and explained in the text where appropriate.

QD: What do you consider to be the main drivers for lead-free activity?

Unsurprisingly, most companies who replied (78%) felt that legislation was a driving factor towards the introduction of lead-free processes. However, not all companies agreed, and it was noticeable that those with a Japanese base did not feel that legislation was relevant. Some form of market benefit (64%) was on average considered the secondary driving force behind legislation, followed by customer request (46%). Concerns over ease of recycling (36%) and 'environmental consciousness' (39%) were also evident. Around 6% of respondents did not provide a reply to this question.

Figure 3: Relative importance of drivers for lead-free technology



QE: What is your opinion of the EU proposed legislation banning lead in electronics?

Overall the proposed legislation was welcomed by the vast majority of companies (70%), of which it was accepted either in the current form (62%) or with small changes to the detail of

the proposals (38%). However, concerns over cost, timescales and environmental benefit were sometimes raised.

13% of companies were opposed to the introduction of legislation for one of more reasons; cost (75%), technological reasons (75%) or other concerns (100%) usually relating to doubt over environmental improvement. It was evident that these opinions were more strongly held by companies with a significant US base.

Around 17% of respondents did not provide a reply to this question, or, did not have an opinion either way.

QF: What do you believe will be the effects of legislation on European manufacturing competitiveness?
The proposed legislation was expected to have little effect on European competitiveness by 50% of companies that replied. Another 39% believed that the legislation would actually create some competitive advantage, while only 11% were concerned about a potential disadvantage.

Around 7% of respondents did not provide a reply to this question.

QG: Please provide a rough estimation of the following lead-free production targets to be achieved for your company in Europe, or your industry sector (if an association), or for your particular product (e.g. components) if not an assembly company;
QH: How do you feel progress towards lead-free implementation in your company/sector compares with others?
Information obtained for the two questions above have been dealt with in a earlier section (3) on target timescales for lead-free introduction.

QI: Which alloys will be used for soldering?

REFLOW SOLDERING

Figure 4 illustrates industry support for the use of SnAgCu solder for lead-free reflow processes. Certain companies propose to use more than one alloy for future production and in fact 100% of those who replied will use SnAgCu to a greater or lesser extent. The other alloys noted are a second option for various applications. The SnAg was favoured by around 27% of respondents, SnAgCuBi and SnZnBi equally by around 9%, and others by 4%. Other alloys suggested included; SnZn, SnSb, BiSnAg. Notably, the SnCu and SnAgBi alloys were not thought suitable for this soldering process.

Around 27% of respondents did not provide a reply to this question.

WAVE SOLDERING

Overall results can be seen in Figure 5. Around 95% of respondents planned to use either the SnAgCu or the SnCu alloy for wave soldering, with a roughly equal split between their popularity. SnAgCuSb was seen as the first choice by a limited group of companies, but not popular overall. The SnAg was also seen as a good option by around 23% of respondents. Apart from those indicated no other alloy types were directly suggested. As expected, the SnZnBi type alloys were not thought suitable for this soldering process.

Around 27% of respondents did not provide a reply to this question.

HAND SOLDERING

Around 88% of companies planned to use SnAgCu as one of the alloys suitable for hand soldering processes. Additionally, the two binary eutectic solders SnAg (33%) and SnCu (33%) were also relatively popular as choice options. Limited use of the SnAgCuBi solder

was suggested in some cases but not popular overall. No other alloys were thought suitable for the hand soldering process. This information I represented in Figure 6.

Around 40% of respondents did not provide a reply to this question, which suggests that more uncertainty remains over the choice of alloy for this process than others.

Figure 4: Alloys for reflow soldering

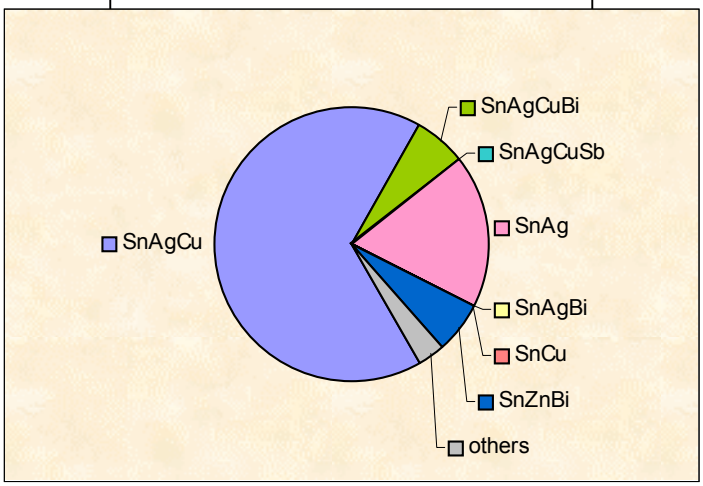


Figure 5: Alloys for wave soldering

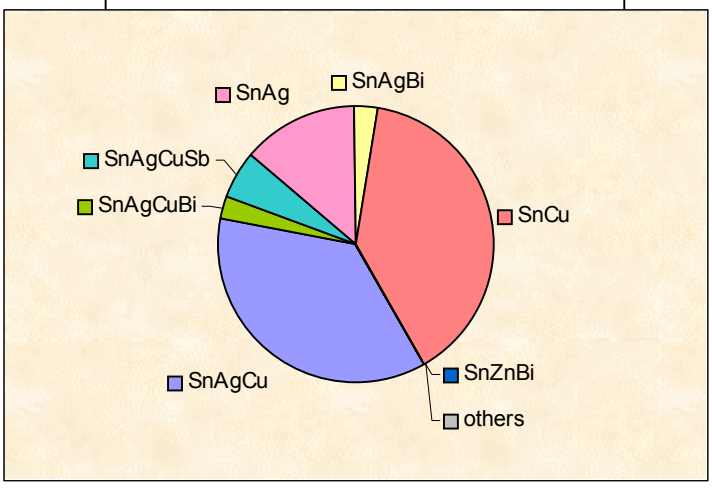
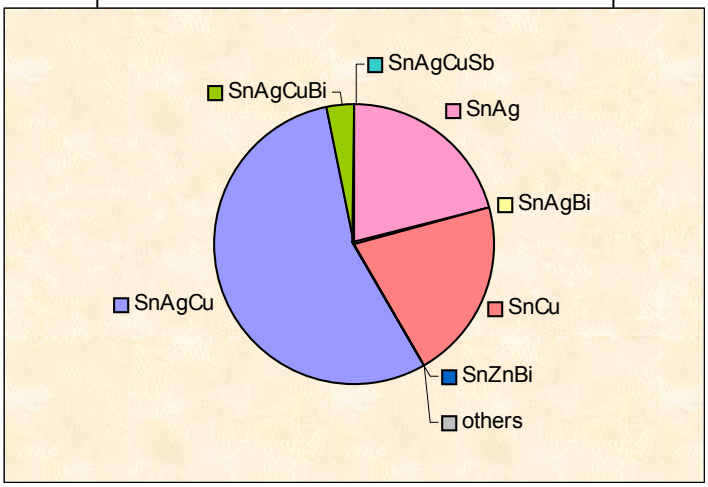
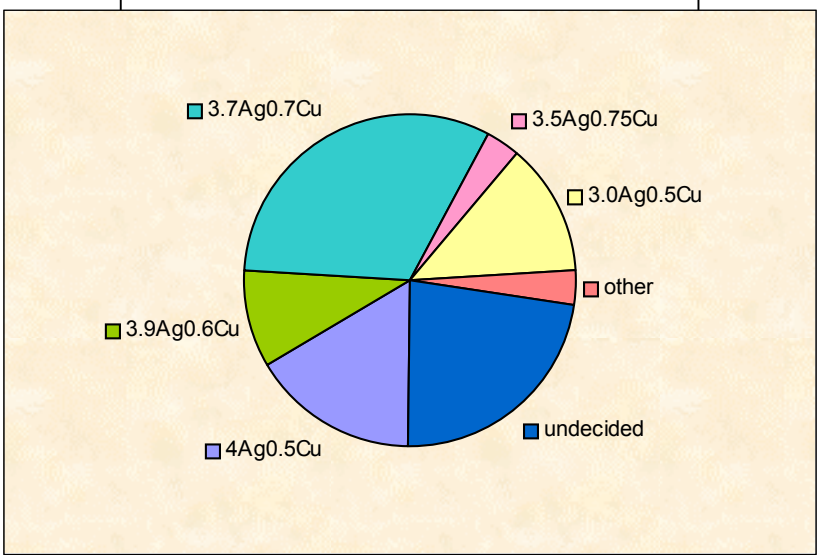


Figure 6: Alloys for hand soldering



QJ: What is your preferred SnAgCu solder composition?
Around 40% of companies did not reply to this question, or, were undecided about which alloy would be selected. Of those who did note a preference the greatest percentage (40%) supported the Sn-3.7Ag-0.7Cu solder (which also includes selection of Sn-3.8Ag-0.7Cu if noted). Another 32% supported higher silver content alloys; either the Sn-4Ag-0.5Cu or the Sn-3.9Ag-0.6Cu. Around 20% supported lower silver alloys such as the Sn-3.5Ag-0.75Cu or the Sn-3.0Ag-0.5Cu. It should also be noted that 22% selected more than one alloy composition. Other compositions specifically indicated included examples such as Sn-3.4Ag-0.8Cu.

Figure 7: Popularity of SnAgCu compositions



QK: How do you plan to deal with the issue of lead level definition?
A large number of companies did not reply to this question (7%) or were undecided about what labelling systems would be favoured (40%). Of those that did reply, 44% wished to see lead content defined as a percentage of the total product including an average of the lead levels in all materials used, whereas 56% preferred lead content to be defined in each individual material used.

Many companies (53%) also appeared unsure about the actual figure to be used as a lead content threshold. Of those that did reply a large majority favoured the use of 0.1%Pb (79%) rather than the higher limit of 0.2%Pb (21%).

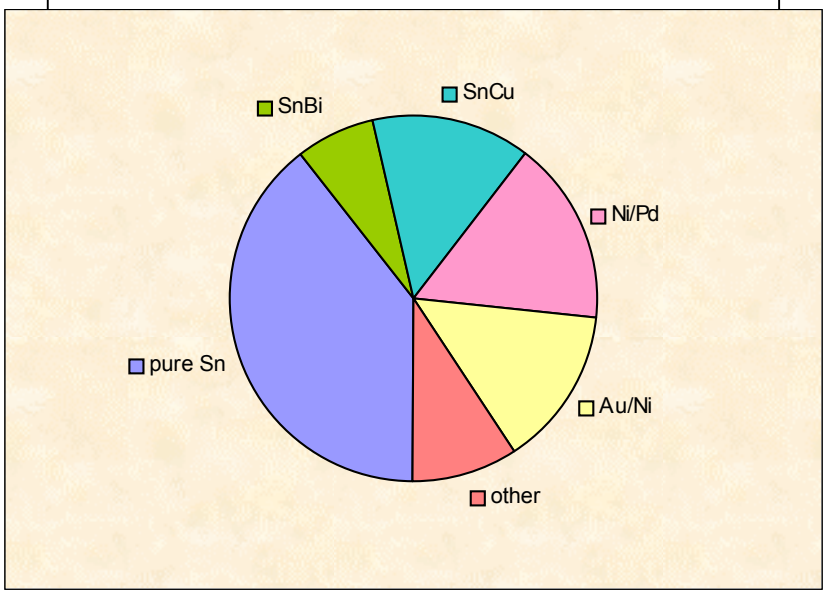
QL: Which best summarises your planned use of 'lead-free' labelling?
It appeared that a great deal of uncertainty remained regarding the issue of labelling. When questioned about the use of labelling to provide information on 'lead-free' products to the consumer 53% of companies did not reply or were undecided about their intended actions. When questioned regarding introduction of material labelling for recycling information 60% of companies did not reply or were undecided.

Of those companies that noted a decision regarding this issue the majority (57%) favoured a company standard label rather than an industry standard label (43%) for providing information to the consumer. However, when labelling for recycling was considered the majority favoured an industry wide standard (58%) rather than individual company labels (42%).

QM: What component coating finishes are preferred?
The use of one or more tin based finishes was favoured by 86% of companies who replied to this question. Of these, pure Sn was by far the favourite (90%) followed by SnCu (32%) and SnBi (16%). The use of SnAg was also suggested by some companies and is included in the 'other' category that also includes proposed coatings such as CuNiAg. Around 59% of the total survey suggested use of Ni/Pd or Au/Ni, but, of assembly companies the majority favoured the use of tin based coatings with only around 25% planning on the use of Ni/Pd or Au/Ni.

Around 27% of companies did not reply to this question.

Figure 8: Relative popularity of component finishes



5. TECHNICAL, COST AND STATUS EVALUATION

The document used to request input into this evaluation of technical, cost and implementation status section can be seen in Annex II. The categories included for assessment ranged from assembly design and materials required, through the types of soldering process, to test issues and end-of-life treatment. They are listed below in more detail. The definition of these categories and responses has been adapted from those originally devised by the ZVEI Zentralverband Elektotechnik und Elektronikindustrie e.V., Germany, 1999. Information on results of this German work is available on the internet[5].

- Assembly design
- Solder alloys (SnPb eutectic replacement)
- Solder alloys (high lead solder replacement)
- Solder pastes
- Fluxes
- Component design
- Component lead finish
- Component heat resistance (to 260°C)
- Board finish
- Board substrate
- Paste printing
- Component insertion/placement
- Reflow process
- Reflow equipment

- Wave process
- Fillet lifting
- Wave equipment
- Rework/repair
- Inspection
- Process energy consumption
- Long-term reliability
- Materials property database
- Assembly dismantling
- Materials recycling/disposal
- Standardisation
- Test method development

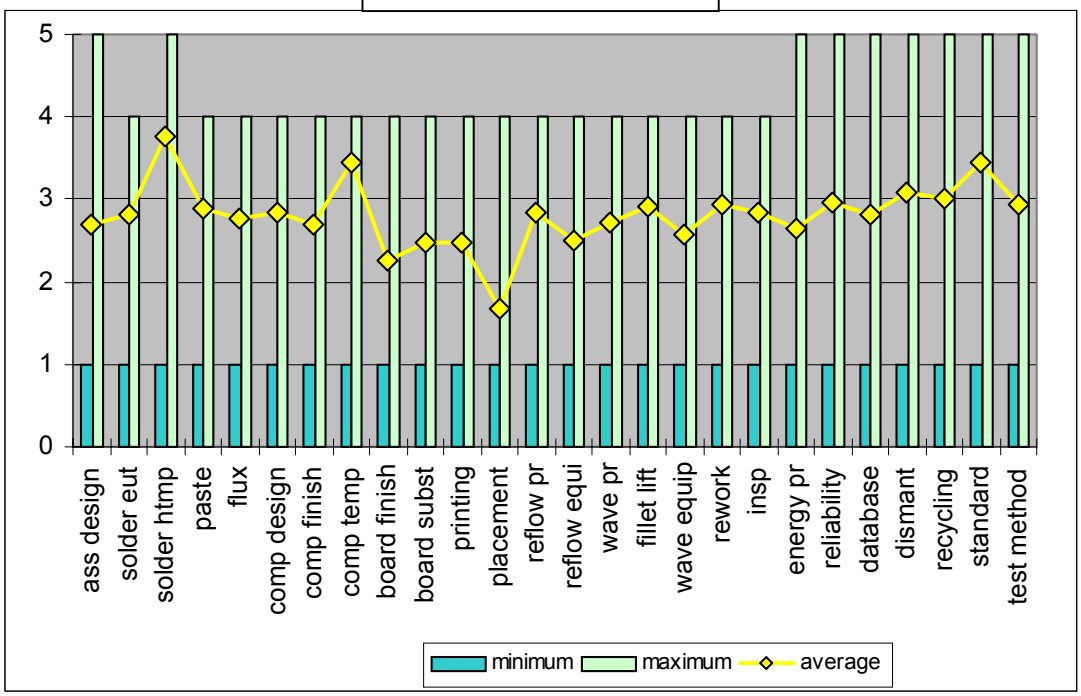
Suggested responses were provided for each question and the values obtained have been used to calculate an average over all companies that replied. This average can be indicated graphically for each question and the maximum (most pessimistic) and minimum (most optimistic) response also noted.

Technical issues
This section was used to identify the greatest concerns remaining over specific technical issues involved with changes of materials, the soldering process, test and recycling. The suggested responses are shown below and the resulting graph in Figure 9.

1. no changes required
2. well tested solutions exist
3. moderate technical problems
4. considerable technical problems
5. strategy undefined

Least concern was noted over component placement, and board related issues such as finish, substrate and printing.

Figure 9: Technical issues



The most significant concerns were expressed regarding the use of alternative materials to high lead, high temperature solder, the generation and updating of industry standards, and, the manufacture of components of increased temperature resistance suitable for use in lead-free manufacturing processes. Of course, although much work has been carried out to find an alternative material or process for high lead solder this has not been widely successful and it should be noted that current EU proposals provide an exemption for the use of lead in this application.

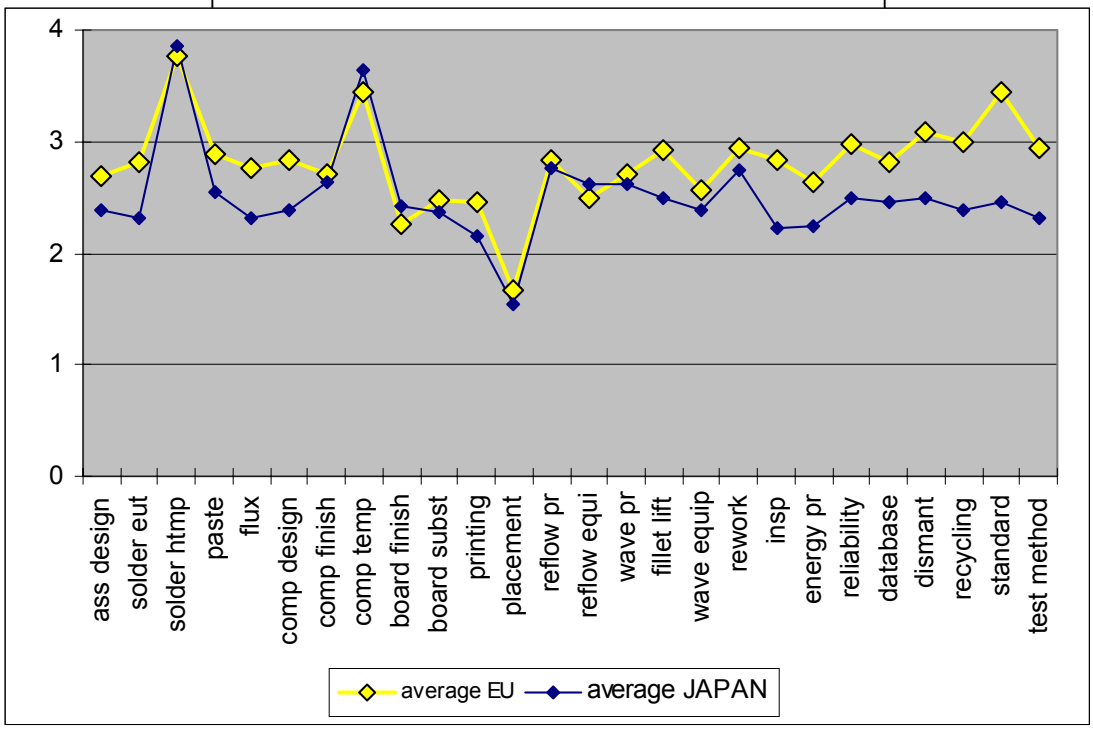
Overall, for all issue categories, the average level of concern was calculated as 2.81 i.e. between the opinion that well tested solutions exist, and concern over moderate technical problems.

In looking at the extreme responses (graphical bars) in all categories at least one company felt that no further changes would be required. It is evident from more detailed examination of the information that this opinion is commonly received from companies at the forefront of lead-free implementation with one or more products in the market.

Several companies noted undefined strategies to deal with issues such as assembly design, product dismantling and recycling indicating that the requirements of the WEEE Directive proposals had perhaps not yet been fully considered. A greater degree of uncertainty on how to deal with process energy reduction also indicated that a majority of companies had not yet reached the stage of lead-free implementation where this issue is seen to be of importance. Additionally, undefined strategies were also noted for standard development, materials database generation and development of suitable test methods. These topics may not be directly relevant to all and this is understandable. Comments regarding unresolved reliability issues generally reflected lack of lead-free product test data.

An identical survey has also been very recently initiated of a number of companies involved with lead-free soldering issues within JEITA (Japan Electronics and Information Technology Industries Association). The results of this work have not been published but a comparison can be made with information from Europe (Figure 10).

Figure 10: Technical issues comparison EU-Japan



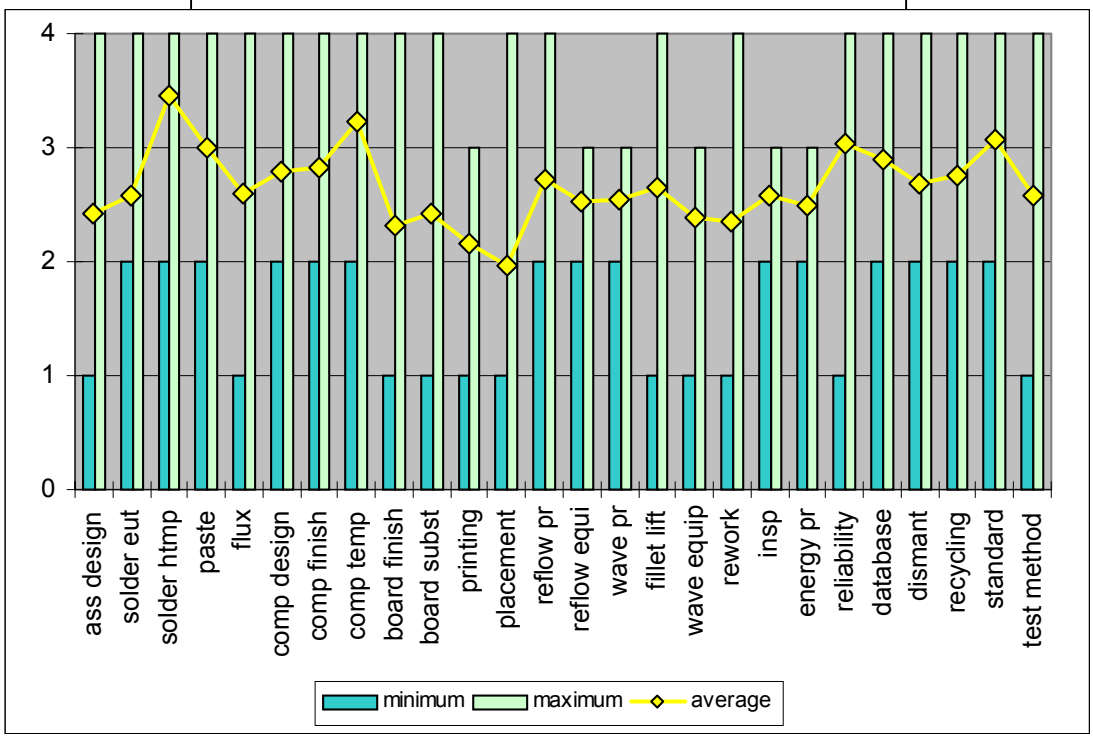
While there is a good overall general agreement it can be seen that in general the concern over technical issues in Japan is lower than the concerns noted by European companies. For instance, concerns over reliability and process energy are significantly lower. Exceptions to this include the concerns over high lead solder replacement, component temperature rating and finish, and, the reflow process itself. Overall, for all issue categories, the average level of concern was calculated as 2.50. Data from component companies and assemblers is available separately. Notable differences between the 2 groups are evident but this is not presented in this document.

Need for action by relevant companies
This section was used in order to identify issues where the most research or development activity was still though to be necessary for implementation of lead-free production. The suggested responses are shown below and the resulting graph in Figure 14.

1. no specific action required
2. some continued observation
3. further research and development required
4. considerable research and development required

The results from this section showed a perceived requirement for considerable research and development in several areas. Again, high temperature solder replacement is a concern but this may be dealt with through legislative exemption. Component temperature resistance was also noted and significant research is already being carried out regarding this issue. Standardisation is noted to be of high concern; this has also been recognised and is being dealt with in some cases although process related standards may require further development. Solder paste development also rates relatively highly and it may be that paste development is related and linked to the success of further process development and standardisation and must therefore progress on a continuous basis (as has always been the case with tin-lead).

Figure 11: Need for additional research or other activity



Reliability is noted as a priority area for considerable research, but, it is also interesting to remember that reliability was rated as an area of only moderate technical concern in section 5: technical issues. Therefore, although further research may be required the resulting data is not expected to highlight particular technical problems.

Overall, for all issue categories, the average level of concern was calculated as 2.65 i.e. that continued observation is certainly required, together with additional research and development in many areas.

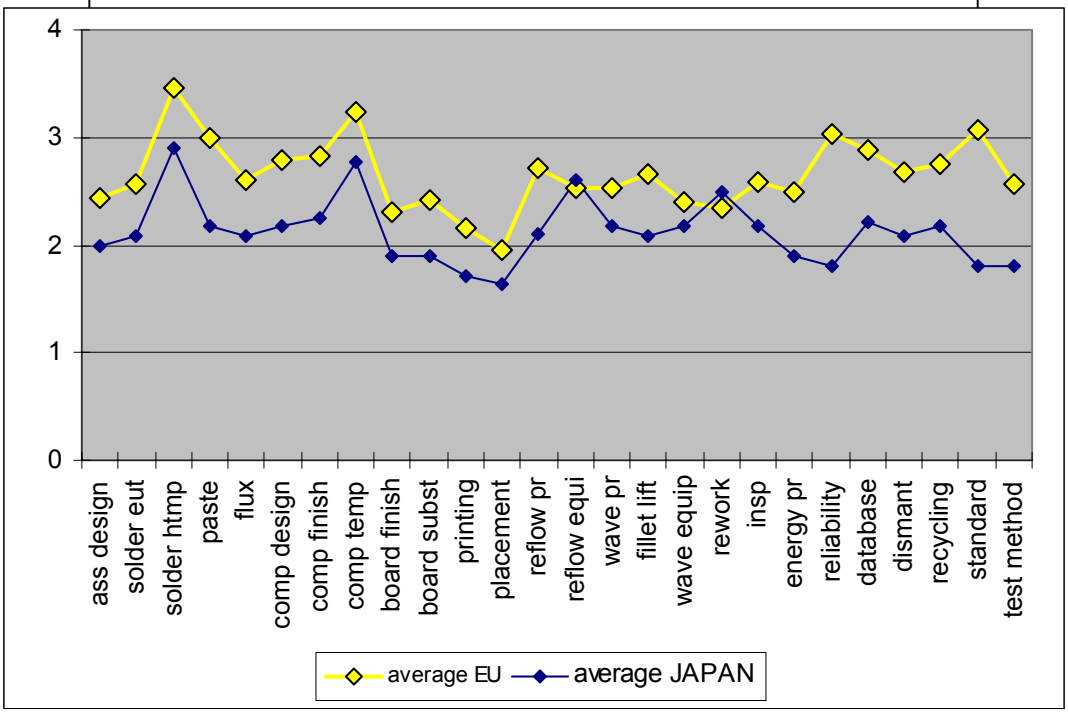
The extreme responses (graph bars) indicate that some companies envisage 'no action' necessary in slightly less than half of the issue categories, and 'considerable R&D' in over half the categories. In some cases, this extreme variation was seen regarding the same topic.

Again it is most interesting to compare the European data with draft information from JEITA (Figure 12). In almost all categories the expectation for further research requirement was significantly lower than the data obtained from European companies. An approximate average of 2.12 across all categories indicates that in most cases only observation of the issues will continue but that little further research would be required. This is a reduction from the average of 2.65 obtained from European industry and is an indication of the degree that Japan is in advance of Europe with implementation of lead-free technology (approximately 2 years according to information in section 3).

Particularly noticeable is the result for reliability that obtained a ranking of just above 3 (further research required) in Europe but less than 2 (observation) from the draft JEITA survey. The information on the reflow process and rework stand out as the only categories where the Japanese felt that a similar level of research would be required to Europe.

Overall the issues where more research and development was anticipated were most obviously; high lead solder replacement, component temperature resistance, reflow equipment modification and rework.

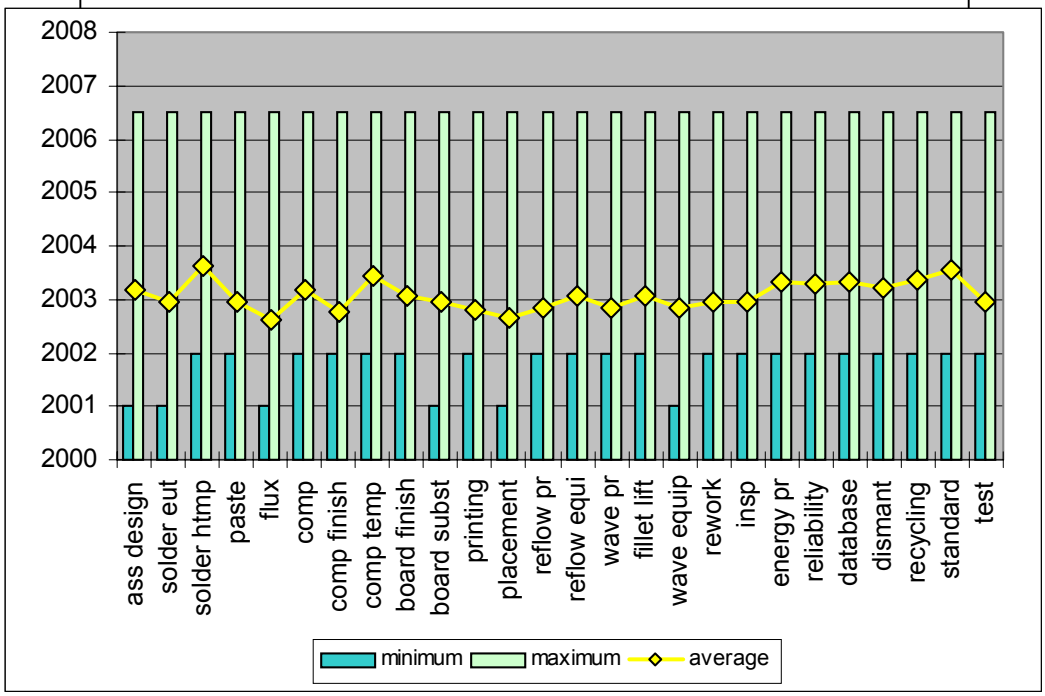
Figure 12: Need for research and development EU-Japan comparison



Deadlines for resolution

Companies were also requested to indicate by what date they believed the technical changes required and described in the above sections would be resolved. Figure 13 illustrates the average opinion on the range of issues discussed. On one extreme, several companies felt that some issues had already been resolved, however on another extreme at least one company suggested that it would take until 2006 to resolve each of the issues. However, on average, all issues are expected to be resolved by 2004 i.e. when all newly designed product is expected to be lead-free. Resolution of the high lead solder replacement question was defined as finalised exemption from legislation.

Figure 13: Deadlines for resolution of technical problems



Specific costs for change over period only

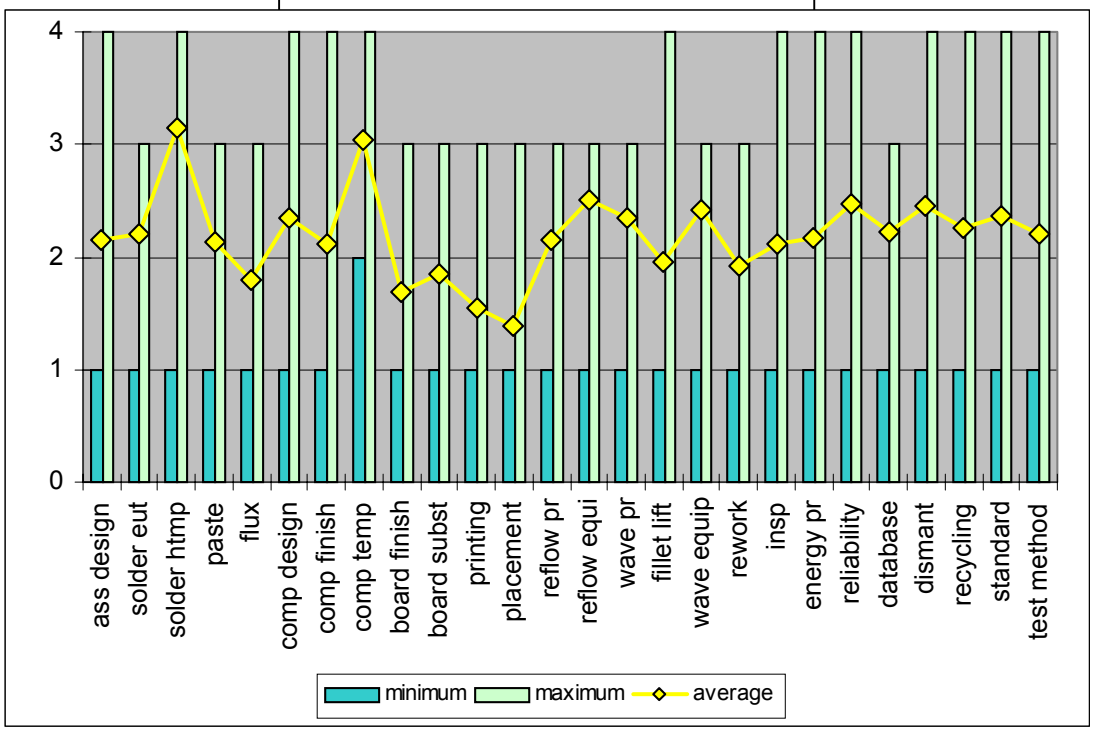
This section was used in an attempt to provide some information on the issues expected to cause the greatest relative cost increases during the introduction of lead-free technology. This would cover, for example, costs of upgrading process equipment or other one-off expenditures. The suggested responses are shown below and the resulting graph in Figure 14.

1. no cost
2. moderate
3. considerable
4. not currently estimable, significant development still required

The most significant concerns were expressed regarding the cost of alternative materials to high lead, high temperature solder, and, the manufacture of components of increased temperature resistance suitable for use in lead-free manufacturing processes. These cost concerns reflect to a great extent the technical concerns described in the above section although, in general, there is greater variation evident across different process stages.

The least concern over cost was evident with regard to board materials, flux, and standard solder paste printing and component placement.

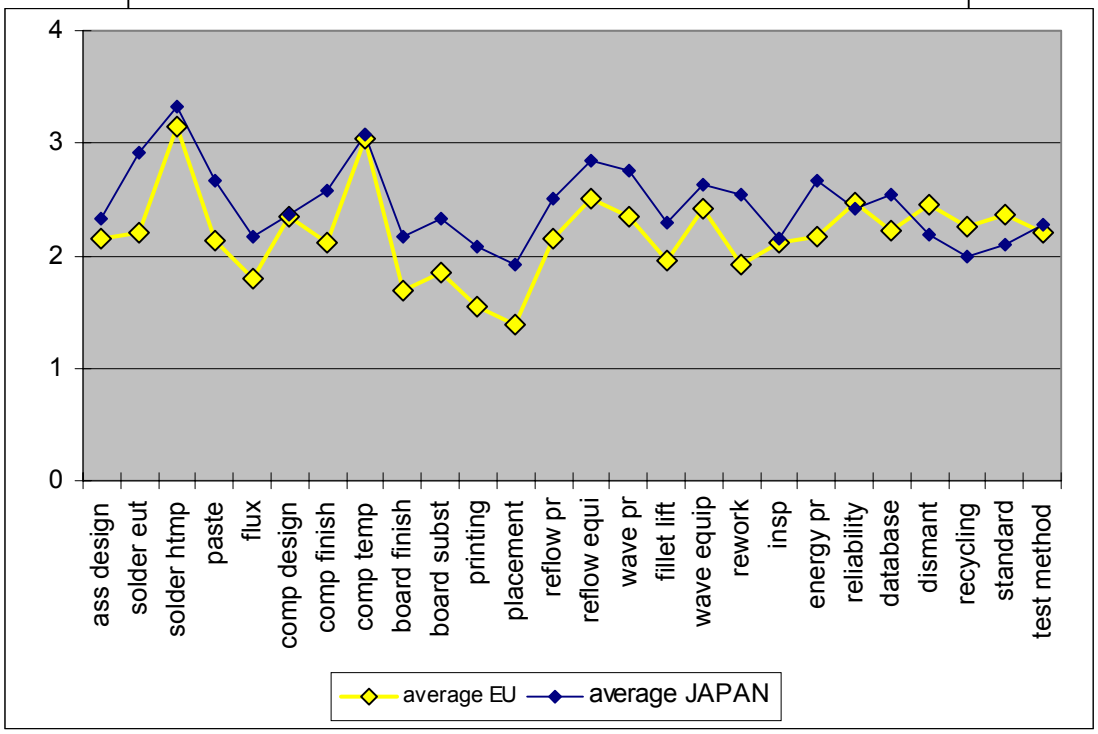
Figure 14: Costs of process change over



Overall, for all issue categories, the average level of concern was calculated as 2.19 i.e. close to a general expectation that moderate cost increases could be anticipated across many parts of the design, production and recycling stages during the implementation phase.

In looking at the extreme responses (graphical bars) at least one company felt that all issues surrounding component manufacture (design, finish and temperature rating) had not yet been resolved to an extent where cost increases could be estimated. This was also the case for certain process issues (fillet lifting, inspection, process energy consumption) and also end-of-life issues (dismantling and recycling).

Figure 15: Process change over costs EU-Japan comparison



Through comparison with draft information from JEITA clear overall agreement was seen in most cases (Figure 15). Overall the costs of change over are considered higher in Japan across most of the process, but, costs of recycling, dismantling etc for lead-free are considered lower. The overall average for Japan is 2.45, compared to that of Europe of 2.19. This may reflect differences in relative regional opinion on the qualitative answers 'moderate' or 'considerable' and/or additional implementation experience in Japan.

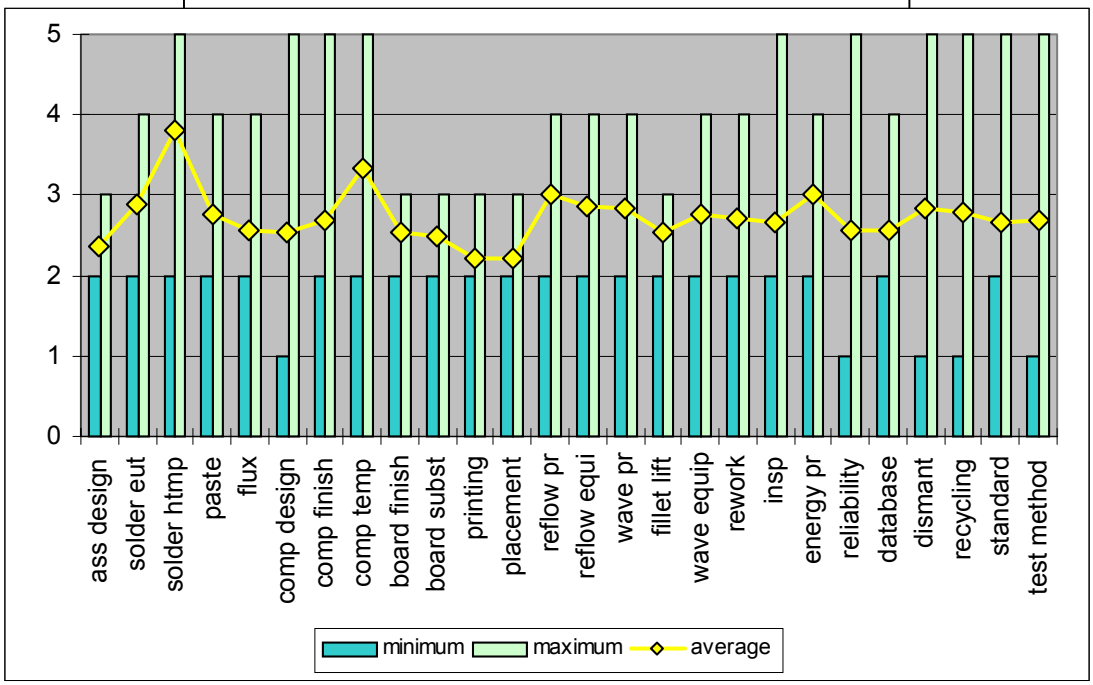
On-going running costs
This section was used in an attempt to provide an estimate of the greatest continuing costs of operating lead-free production in the future. This would cover, for example, solder price increases or similar material related issues, not one-off equipment or process changes. The suggested responses are shown below and the resulting graph in Figure 12.

1. reduction
2. no change
3. rise in some individual part of process
4. considerable increases
5. not currently estimable

The data shows that on average the most significant changes to running costs can be expected again from the requirement for components of higher temperature resistance. All parts of the process and materials supply appeared to indicate an approximate cost increase fairly close to the average. Overall, for all issue categories, the average level of concern was calculated as 2.73 i.e. between the belief that no changes were seen and the expectation that moderate cost increases could be anticipated across some cost rise in some individual part of the process.

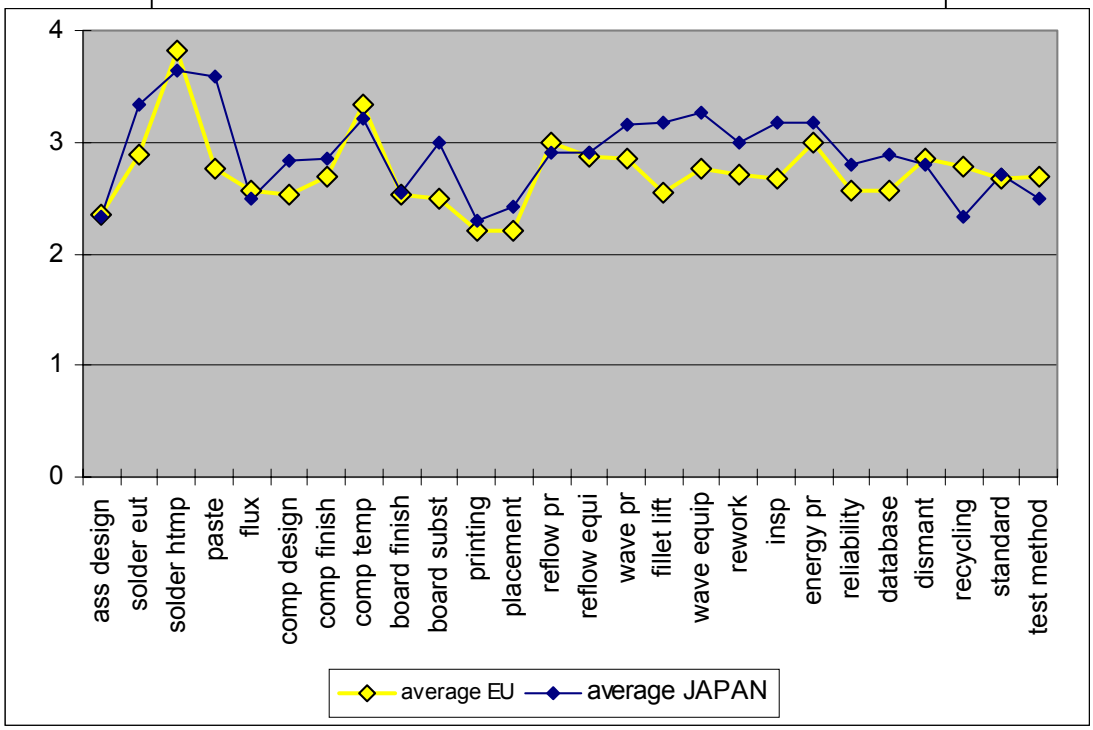
Extreme responses can be examined and used to illustrate some expectation of cost reductions with lead-free, notably the dismantling and recycling processes. However, high or indefinable costs were also associated with these categories by some companies, and, additionally with categories such as reliability and inspection.

Figure 16: On-going running costs of lead-free processes



Of most interest is the possibility of comparison with the same draft survey carried out by JEITA (Figure 17). It is particularly noticeable that the cost of standard solder and paste, and also board substrate is thought to contribute a significant amount to increased costs in Japan. There is also a generally higher overall process cost. Contrary to these increases, no change in recycling cost is anticipated in Japan in contrast to some rise expected in Europe. The overall average value for Japan was 2.9 compared to 2.7 in Europe. Again this may reflect differences in relative opinion on the qualitative answers 'moderate' or 'considerable' and/or additional implementation experience in Japan.

Figure 17: Process running costs EU-Japan comparison



6. SUMMARY AND RECOMMENDATIONS

1. Target timescales should be defined and agreed for each industry sector. Companies should compare their own activity to the average summarised in this document and adjust their implementation schedule accordingly. Consumable and component manufacturers should already have lead-free product available. Assemblers should be introducing their first lead-free product by the end of 2002 and already be actively participating in implementation activities.

2. The roadmap should be regularly updated in order to asses progress being made and identify expected changes to technical and cost issues of concern. Such differences are already evident through comparison of EU industry data with that from Japan where additional implementation experience exists.

3. Lead levels for 'lead-free' product should be defined by individual material composition within the specified product. 'Lead-free' should be defined as 0.1%wt Pb or below.

4. Companies should devise individual labelling systems to notify consumers of the availability of lead-free/reduced hazardous material content product. An industry wide

standard label may be developed if required but is unlikely to achieve widespread use.

5. An industry wide labelling system for product recycling purposes should be proposed in order to indicate material type, hazardous substance location etc.

6. The roadmap should aim towards more specific alloy composition definition than that already available, and, address similar issues such as favoured component finish.

7. Research efforts should be directed towards the areas of concern indicated. This could also be addressed by some method of increased data and information sharing.

8. Many technical concerns surround higher process temperatures. Activity to resolve this can take 2 complementary approaches, the first to raise component temperature rating when necessary and deal with relevant issues, and, the second, to develop the soldering process further in order to limit temperature increases while maintaining a practical process window. Process development may also produce benefits such as reduced energy consumption.

9. Efforts could be made to address identified areas of greatest cost concern.

10. Future roadmaps should present summarised information on environmental matters such as recycling (although only that relevant to the RHS Directive and not the WEEE Directive), and life cycle analysis of production using lead-free solders.

11. Additional participation from companies in certain market sectors, in other EU member states and small companies in all countries should be encouraged i.e. all sectors of industry and the supply network. Specific emphasis will be necessary on small company involvement and documents such as an EU roadmap will assist with this objective.

12. Some system of further co-ordination should be considered, for example, through the formation of a European Lead-free Solder Committee with specific groups responsible for certain areas of concern; components, process, standards, research etc.

13. Work should continue to develop further comparative data from the EU, USA and Japan (through co-operation with IPC and JEITA) and assist in development of global agreement on lead-free.

Comments on this document are welcome

Anyone willing to participate in further surveys or discussions related to the development of European and Global Roadmaps should contact the author. Some working group topics have been suggested by participating companies. These are shown below. Participants and leaders of such groups would be required from industry.

- Overall co-ordination
- Definition of common timeline for lead-free implementation (with conversion by 1.1.2004) (components and assembly)
- Component temperature resistance
- Component finishes and whisker tests
- Recommended industry reflow process requirement
- Board finishes
- Upgrade of current process technology to lead-free

- Technology, materials and process study
- Environmental impact of lead-free study
- Standardisation
- Test method development
- Labelling

Additional comments or questions for further consideration
Additional questions of interest have also been indicated by some companies and these are shown below for further discussion.

- What are the European member states governments opinions on lead-free and what support will thy provide
- Backward and forward compatibility of lead-free technology
- Slow take-up of lead-free components in the market will further delay implementation
- Specific detailed questions to reflect changes in process, materials, inspection, reliability data etc that the customer has obtained, or expects to need
- Significant participation from involved companies and dissemination to major electronics magazines
- Contention surrounding environmental benefits
- Poor awareness of the topics complexity, especially among decision makers, may lead to unrealistic timescales

Further work
More detailed roadmaps could be developed which study various issues in more depth and provide information below. However, it is not clear how such activity could be organised or achieved without widespread industry co-operation.

- Comparison of EU member state attitudes
- Comparison of EU and global activity
- Present situation, expectation in 2 years, 5 years, 10 years
- Regular monitoring of opinion
- Regular monitoring of progress of implementation of RHS Directive requirements (assessment of implementation within imported goods may not be possible)

7. REFERENCES

1. IPC Roadmap: A guide for assembly of lead-free electronics, http://www.ipc.org or http://www.leadfree.org
2. JEIDA (now JEITA) Roadmap: Challenges and efforts towards commercialisation of lead-free solder, version 1.3, August 2000
3. WEEE Directive proposal, European Commission
4. RHS Directive proposal, European Commission
5. ZVEI website http://www.zvei.org/bleifrei
6. Soldertec website, http://www.lead-free.org

ANNEX I: Questionnaire used for feedback on general issues

*****Please mark ALL relevant answers, as many as may apply, and add **additional comments anywhere required********

QA: This response is from an;

1. Industry Association
2. Company representative
3. Other ……

QB: Which regions are represented by this response?;

1. Europe
2. Individual European State

   Please name…….
3. Global company policy
4. Other …….

QC: Which product groups are being represented in this response?

Those covered by WEEE/RHS;

1. Large household appliances
2. Small household appliances
3. IT & Telecommunication equipment
4. Consumer equipment
5. Lighting equipment
6. Electrical and electronic tools
7. Toys, leisure and sports equipment
8. Medical devices
9. Monitoring and control instruments
10. Automatic dispensers

Other industry sectors;

11. Automotive
12. Aerospace
13. Defence
14. Contract manufacturing in general

Constituent products;

15. Solder and related materials
16. Boards and related finishes
17. Components and related finishes
18. Production equipment manufacturer
19. Other…….

QD: What do you consider to be the main drivers for lead-free activity?

1. Environmentally conscious manufacturing
2. Recycling and end of life treatment concerns of hazardous material use
3. Process or other cost benefit
4. Technical benefit

5. Market related benefit
6. Customer request
7. Legislation

QE: What is your opinion of the EU proposed legislation banning lead in electronics?

1. Welcome the legislation and the overall environmental aims
2. Would wish to see some change but only in detail (materials issues only)

Or, Oppose the legislation for reasons of ;

3. Poor customer acceptance
4. Cost concerns
5. Technological reasons
6. Others……

QF: What do you believe will be the effects of legislation on European manufacturing competitiveness?

1. Provide an advantage
2. Create a disadvantage
3. Cause little overall change

QG: Please provide a rough estimation of the following lead-free production targets to be achieved for your company in Europe, or your industry sector (if an association), or for your particular product (e.g. components) if not an assembly company;

1. Current number of lead-free products manufactured in Europe by your company

……

2. Estimated date of introduction of first lead-free product in Europe

……

3. Estimated date for introduction of lead-free for approximately half products in Europe

……

4. Estimated date for introduction of lead-free for all newly designed products in Europe

……

5. Estimated date for introduction of lead-free for all products in Europe

……

6. Is this information company confidential ? Yes…..... No……. .
7. Are these unofficial guidelines?……..or official policy, regional…..... ..or global…....?

QH: How do you feel progress towards lead-free implementation in your company/sector compares with others?

1. Aims to be a technology leader
2. Aims to match published Japanese timescales for implementation e.g. by 2003
3. Aims to match proposed phase out deadlines of WEEE/RHS i.e. by 2007
4. Requires increased technical knowledge before implementation is considered
5. Other ……..

QI: Which alloys will be used for soldering?

	Reflow	Wave	Hand
1. SnAgCu			
2. SnAgCuBi			
3. SnAgCuSb			
4. SnAg			
5. SnAgBi			
6. SnCu			
7. SnZnBi			
8. Other……..			

QJ: What is your preferred SnAgCu solder composition?

1. Sn-4.0Ag-0.5Cu
2. Sn-3.9Ag-0.6Cu
3. Sn-3.7Ag-0.7Cu
4. Sn-3.5Ag-0.75Cu
5. Sn-3.0Ag-0.5Cu
6. Other……..
7. Undecided or don't know

QK: How do you plan to deal with the issue of lead level definition?

1. By total product lead content
2. By individual material component lead content
3. Undecided or don't know

Has any level been defined by your company/organisation?

4. 0.1%Pb?
5. 0.2%Pb?
6. Other….

QL: Which best summarises your planned use of 'lead-free' labelling?

1. Undecided or don't know

Labelling for consumer information

2. Company standard label preferred
1. Industry standard label preferred

Labelling for recycling information

1. Company standard label preferred
2. Industry standard label preferred

QM: What component coating finishes are preferred?

1. Pure Sn
2. SnBi
3. SnCu
4. NiPd
5. Au/NiAu
6. Other ……..

QN: Are you currently involved in any external research projects on lead-free technology?

1. With Universities or other academic bodies
2. As part of a collaborative industrial project
3. Other ……

If possible please name any University contacts. The recently formed European Lead-free Network (ELFNET) is currently surveying the scope of academic research on lead-free within European Institutions. Further details available on request from Jeremy@lead-free.org

……

QO: Do you have any suggestions for additional questions to be added to any future surveys? Or any other comments?

Please include contact details here or on email;

1. Name
2. Company/organisation
3. Address
4. Email

I am interested in further participation in EU roadmap development. YES……. NO…...

I am interested in participating in a working group to address specific issues YES……. NO…...

Working Group topics of concern……

Annex II: TECHNICAL, COST AND STATUS EVALUATION

Specific technical issues are summarised in the final table in this document. It would be extremely helpful if this could also be completed wherever possible using the response categories listed below in order to identify the most serious technical roadblocks. The definition of these categories and responses has been adapted from those originally devised by the ZVEI Zentralverband Elektotechnik und Elektronikindustrie e.V. , Germany, 1999

Suggested Responses for; ***Technical issues***

1 no changes required
2 well tested solutions exist
3 moderate technical problems
4 considerable technical problems
5 strategy undefined

Suggested Responses for; ***Specific costs for change over period only (e.g. individual equipment upgrade)***

1 no cost
2 moderate
3 considerable
4 not currently estimable, significant development still required

Suggested Responses for; ***On-going running costs (e.g. increased solder cost)***

1 reduction
2 no change
3 rise in some individual part of process
4 considerable increases
5 not currently estimable

Suggested Responses for; ***Need for action by relevant manufacturers***

1 no specific action required
2 some continued observation
3 further research and development required
4 considerable research and development required

Suggested Responses for; ***Expected deadline for resolution***

Insert a relevant date if possible

Please add any suggestions, or further categories and comments as required for addition to this or future versions of the roadmap.

Technical, Cost and Status Evaluation (Required response categories defined on previous page)

Ref	Category	Technical issues	Costs		Need for Action	Expected deadlines for resolution
			Change over only	On-going running cost		
1	Assembly design					
2	Solder alloys (SnPb eutectic replacement)					
3	Solder alloys (high lead solder replacement)					
4	Solder pastes					
5	Fluxes					
6	Component design					
7	Component lead finish					
8	Component heat resistance (to 260°C)					
9	Board finish					
10	Board substrate					
11	Paste printing					
12	Component insertion/placement					
13	Reflow process					
14	Reflow equipment					
15	Wave process					
16	Fillet lifting					
17	Wave equipment					
18	Rework/repair					
19	Inspection					
20	Process energy consumption					
21	Long-term reliability					
22	Materials property database					
23	Assembly dismantling					
24	Materials recycling/disposal					
25	Standardisation					
26	Test method development					