soldertec

THE SOLDERING TECHNOLOGY CENTRE

SECOND EUROPEAN LEAD-FREE SOLDERING TECHNOLOGY ROADMAP

February 2003

and

FRAMEWORK FOR AN INTERNATIONAL LEAD-FREE SOLDERING ROADMAP

December 2003

Second European Lead-free Soldering Technology Roadmap
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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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Contact
Kay Nimmo
SOLDERTEC at Tin Technology Ltd
Kingston Lane
Uxbridge
Middx UB8 3PJ
UK

Tel: +44 (0)870 458 4265
Fax: +44 (0)870 458 4273
Email: kay.nimmo@tintechnology.com
Websites: http://www.lead-free.org and http://www.tintechnology.com

Second European Lead-free Soldering Technology Roadmap

February 2003

INTRODUCTION

Following the publication of the first European Lead-free Technology Roadmap in 2002[1] this second version has now been prepared which incorporates additional information, and, an International Roadmap framework.

Section 1 of this document introduces the framework for an International Lead-free Roadmap that has been agreed with JEITA (Japan Electronics and Information Technology Industries Association). This International Framework will be used as a basis for further development and international co-operation in the field of lead-free technology.

Section 2 contains more detailed information on current European attitudes.

Any roadmap can describe the current situation, the options available for moving forward, and, indicate in which direction industry appears to be aiming. In lead-free soldering there are many choices to be made, for example, what are the timescales for removing lead from products, which alloys will be preferred, and, how assembly processes may need to be altered to achieve lead-free production in the future. This Second European Lead-free Soldering Technology Roadmap indicates some changes in attitude over the last year, current industry opinion, and, guidelines for future activity. The use of this roadmap will allow any person in industry to compare their plans and beliefs on lead-free with those of the 'average' as represented by these survey results. For example, evidence of significant differences from this average can indicate areas requiring further work.

Lead-free technology roadmaps are produced and updated for the USA by the IPC[2] (first version released in 1999), and for Japan by JEITA[3] (version 2.1 released in 2002). Soldertec has undertaken work on roadmapping for Europe on a voluntary basis. Undoubtedly this work is of limited scope as a result of funding restrictions but it is hoped that the process 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 EU Directives on Waste Electrical and Electronic Equipment (WEEE)[4] and Restriction of Hazardous Materials (RHS)[5] came into force on 13.2.2003 and confirm that any product, of the affected categories, sold in the European market will have to be **lead-free from 1 July 2006**. Full texts of the Directives are available from internet sources[6]. This document 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.

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 however, evidence of much greater activity has been seen over the past year. This is expected to escalate up to the legislative 2006 deadline.

The 2002 version of this EU Roadmap contains original information that is still relevant today and should be referred to in addition to this update[1].

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1. SOLDERTEC European Lead-free Technology Roadmap, Version 1, February 2002 available from http://www.lead-free.org
2. IPC Roadmap: A guide for assembly of lead-free electronics from http://www.leadfree.org
3. JEIDA (now JEITA): Challenges and efforts towards commercialisation of lead-free solder, version 1.3, August 2000, and, version 2.1, 2002 from http://tsc.jeita.or.jp/TSC/COMMS/7_EASM/english/index.htm
4. Directive 2002/96/EC of the European Parliament and Council on waste electrical and electronic equipment (WEEE)
5. Directive 2002/95/EC of the European Parliament and Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RHS)
6. Soldertec website http://www.lead-free.org

EUROPEAN INDUSTRY SURVEY

Questionnaire
Opinions were obtained from European industry through the use of a survey questionnaire. Many of the questions and available answers can be seen and are discussed in Section2. The JEITA data discussed in this document arises from a survey undertaken of Japanese industry with effectively identical questions. Graphs of EU data are shown with a yellow background, and, graphs of Japanese data are shown with a blue background.

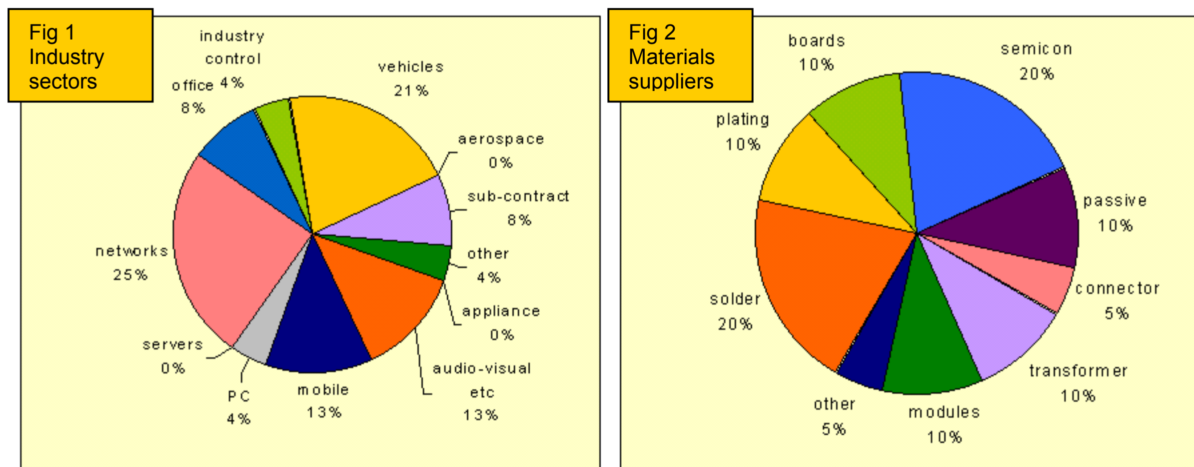
Survey results discussed in this document represent the opinion of companies who replied to the questionnaire, and do not directly represent the opinion of Soldertec, however, various comments and clarifications have been added by the author.

Information on Respondents
Responses were received from 52 organisations across 11 European countries; Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, Norway, Portugal, Sweden, UK. However, a significant number were reporting the policy of a global corporation (68%).

A cross section of company sizes ranked by employee numbers took part in the survey. Numbers of employees ranged from < 50 to >1000 but overall SME's, categorised as having less than 250 employees represented 23% of the industry survey data.

Overall, 46% of replies came from assemblers, either manufacturing their own product or sub-contracting. The product categories represented can be seen in Figure 1. This represents a cross-section of industry although no information was available from manufacturers of household appliances (such as refrigerators), aerospace, toy and server manufacturers.

A large number of responses (50%) were received from component, chemicals and materials manufacturers and suppliers according to the split seen in Figure 2.



EU Member States
For information, it may be useful to note current and future members of the EU. It should be remembered that by 1 July 2006 when the requirement for lead-free product comes into effect, the EU is due to have 25 member states.

The following 15 countries are currently members of the EU;
Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK
The following 10 countries are due to join the EU in 2004;
Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia

The following 2 countries are due to join the EU in 2007;

Bulgaria, Romania

Turkey is likely to join the EU after 2007.

Figure 3 illustrates the current and potential member states of the EU.

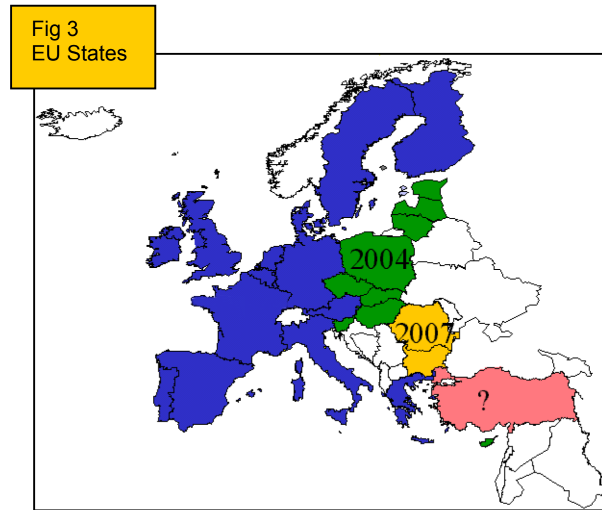


Fig 3
EU States

SECTION 1

FRAMEWORK FOR AN INTERNATIONAL LEAD-FREE SOLDERING ROADMAP

December 2003

Introductory Statement

An International Framework recommending timescales and actions for achieving co-ordinated introduction of Lead-free Soldering processes was agreed in December 2002 as a result of the 2nd Lead-free World Summit meeting held in Tokyo at that time. Soldertec and JEITA (Japan Electronics and Information Technology Industries Association) established the International Lead-free Soldering Roadmap Framework as a guidance document to be recommended to those in the electronics industry wishing to implement lead-free production processes in a timely manner.

The Framework (on the following page) details the recommended timescales for electronic components manufacturers and electronic assemblers to initiate, and complete, the transition to lead-free, with the aim of developing products that will comply with imminent European legislation.

The basis for the recommendations of the International Roadmap document are also described over the following pages in parts 1.1 to 1.5. Opinions were obtained from European industry through the use of a survey questionnaire. The full list of questions and available answers can be seen in Annex 1. The JEITA data discussed in this document arises from a survey undertaken of Japanese industry with effectively identical questions. Graphs of EU data are shown with a yellow background, and, graphs of Japanese data are shown with a blue background.

Lead soldering materials have been widely used in electronics equipment to attach components to circuit boards, in integrated circuits and other electronic components. However, in recent years the environmental impact of lead has come under scrutiny. The transition from use of tin-lead to lead-free solder affects companies on a global basis and any delays in parts of the supply network, or in some regions of the world, can have a serious effect on lead-free implementation as a whole. For the transition of assembly and packaging manufacturers to lead-free, it is necessary for assembly manufacturers to deal with such issues as improving the heat resistance of electronic components and achieving lead-free connections within, and to, these components. For this reason, a harmonized approach is essential.

To realize the elimination of lead across the increasingly global electronics supply chain, an internationally promoted initiative is imperative. International co-operation through the Lead-free Soldering Roadmap Framework will ensure an orderly conversion process over the next few years and Soldertec and JEITA will be pro-actively recommending these international guidelines to industry. Further discussions will continue to develop this important international communication strategy, and, extend the scope of the initial Framework Roadmap.

Framework of International Lead-free Soldering Roadmap
December 2002

1) General View of "Lead-free"

There is a recognized need to have a definition for lead-free. There is still some debate over the exact value. However, there is a general view that European legislation and the JEITA roadmap will use a target of 0.1weight percent.

2) Milestones in Lead Elimination

The following schedule has been set as *an average* for manufacturers.

Components: Commenced supplies of lead-free components/lead-free terminal components: by the end of 2001
Complete line-up of lead-free terminal components: by the end of 2003
Complete line-up of lead-free components: by the end of 2004

Assemblies: Commence manufacturing of lead-free soldering assemblies: by the end of 2002
Complete lead elimination from products: by the end of 2005

Leading manufacturers will achieve these results one year ahead of this schedule, other manufacturers two years later.

3) Lead-free Solder Alloy Selection

The type of solder composed of Sn-Ag-Cu is recommended for board assembly.

4) Compatibility with Existing PWBs

Lead-free solder technology has been shown to be compatible with existing PWBs.

5) Identification of Lead-free Material Contents

Identification of material contents is needed for rework and/or recycling; further work is required to develop a recommended system for labelling.

1.1 GENERAL VIEW OF 'LEAD-FREE'

Lead level

It is clear that some guidance is urgently required on a global basis regarding the criteria for Pb level in electronic products. Several 'limits' have been under discussion within the industry for several years although 0.1wt% and 0.2wt% are most commonly mentioned.

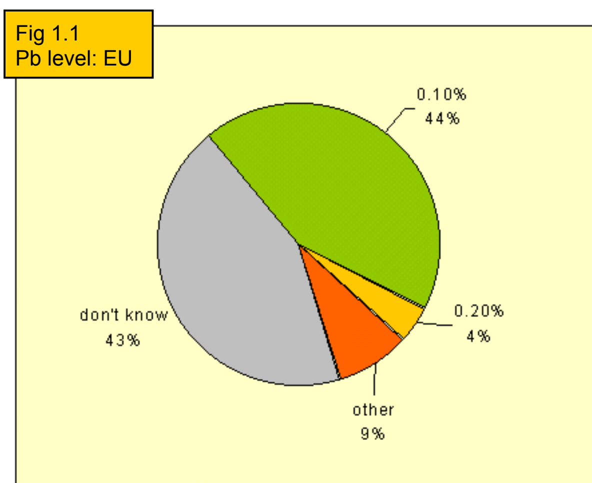
In 2002, EU industry responses indicated that many companies (53%) appeared unsure about the actual figure to be used as a Pb content threshold, but, of those that did reply, a large majority (79%) favoured the use of 0.1%Pb rather than (21%) a higher limit of 0.2%Pb.

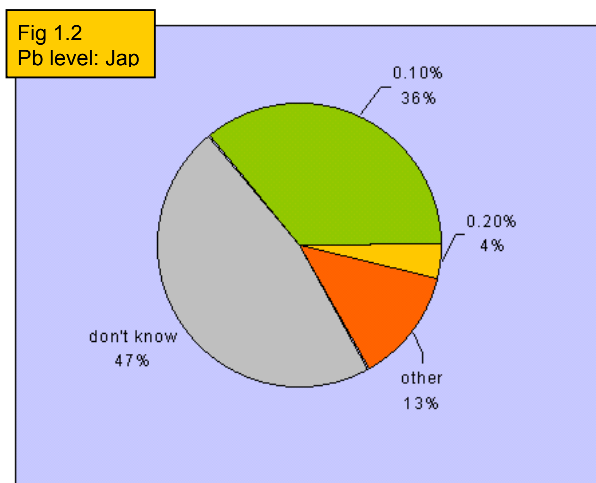
In 2003, the relative percentage supporting the use of 0.1% had risen to 92% and those using a limit of 0.2% had fallen to just 8%. Overall data for 2003 is shown in Figure 1.1. Voluntary EU company guidelines so far published generally refer to the use of a 0.1% specification.

A large proportion of those questioned replied that they did not have an opinion or would follow whatever limit is set by legislation. However, it should be remembered that although the RHS Directive has now been approved, detailed technical questions such as the acceptable level of impurities in each material are still under discussion. A final legislative agreement on this may not be available until 2004 and it is therefore imperative to move forward with a limit that is likely to be accepted by the legislative bodies. It should be noted that the limit on acceptable Pb in vehicles (excluding solder) has already been set by the EU End of Life Vehicle Directive at 0.1wt%[7]; this may be taken as an indication of what may be introduced in the requirements of the RHS Directive.

The level of 0.1wt% has also been accepted by the 2002 JEITA roadmap. The equivalent survey results for Japan can be seen in Figure 1.2.

The limit of 0.2% received poor support in both the EU and Japan. A lead level of 0.1weight% was therefore agreed as a limit above which the presence and specific content of Pb should be declared.





Level definition

It is not only important to promote a generally acceptable limit for Pb, but it is also necessary to define how such a limit is being measured.

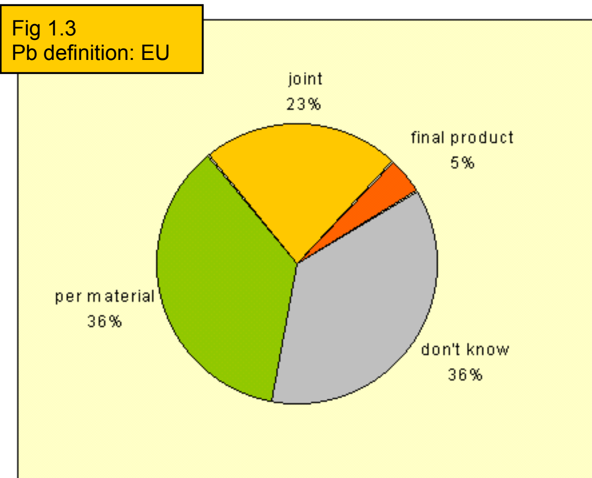
In 2002 a slight majority (56%) of those in the EU preferred lead content to be defined in each individual material used rather than in any alternative way. In 2003, this result remained identical and the data can be seen in Figure 1.3. Support for definition of Pb content by total final product weight received very poor support. Definition by Pb content of the total solder joint in an assembly was also though to be a possibility by 36% of those that replied although it is not clear how such a definition would be implemented.

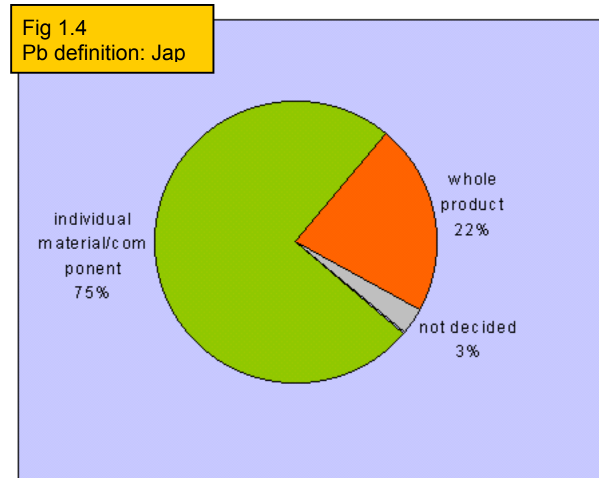
[7] Directive 2000/53/ EC end of life vehicles of 18.9.2000 and amendment 2002/525/EC from 27.6.2002

For reference, it should be noted that the Pb content defined by the EU End of Life Vehicles Directive is taken to be the limit in each individual homogeneous material, **not** by total product, board or component weight.

In the JEITA survey of 2002 calculation of Pb content by individual material or component was also that favoured by a significant majority of those that replied to the survey although no specification has been included in the Japanese roadmap. Data can be seen in Figure 1.4.

Although no firm agreement was reached in the International Roadmap it seems to be most appropriate to define Pb content as 0.1% by weight of each individual material within each individual constituent of the final assembly and product.





1.2 MILESTONES IN LEAD ELIMINATION

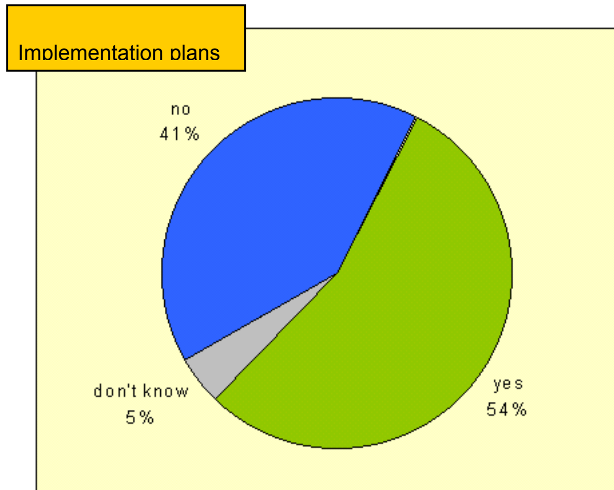
One of the main aims of the lead-free roadmapping activity is to describe the current trends in the technology and to provide clear indications of average timescales for transition away from the use of Pb. This allows companies to make comparison with their own performance in the area and to keep up with the average if desired.

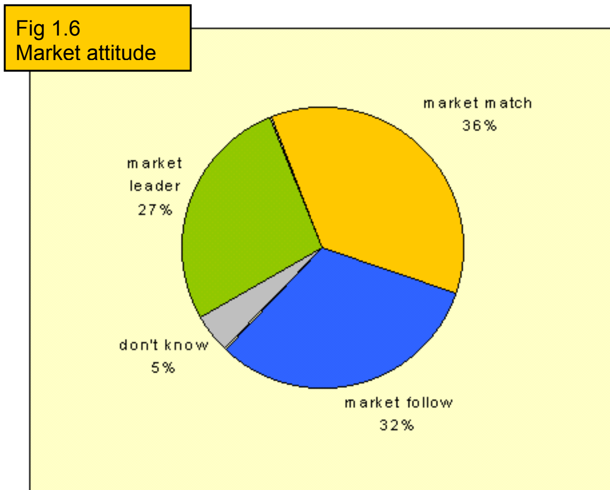
Despite the fact that there are only around 3 years until the EU Directive deadline for sale of lead-free product it was clear that many companies in the EU had not yet made firm plans for dealing with this requirement. While 54% of respondents had produced a plan or targets for conversion to Pb-free technology, a further 41% of companies had not yet made any firm plans and an additional 5% were not aware of company plans even if they existed; see Figure 1.5. This lack of planning is a serious concern. Even if production trials are not yet underway it is essential to begin discussions with suppliers and customers regarding Pb-free requirements as soon as possible.

The EU industry survey also demonstrated (Figure 1.6) that while around one quarter of companies hoped to be market leaders in this field, 36% were content with implementing Pb-free on average timescales, and, a significant 32% were planning to follow what other companies had achieved at a later date.

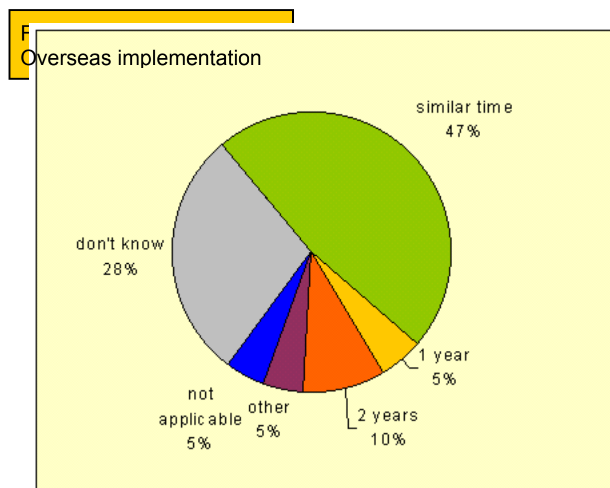
Analysis of company voluntary plans by JEITA produced the conclusion that leading manufacturers are generally 1 year ahead of the average, and market followers are generally 2 years behind. This was found to be true for both component manufacturers and product assemblers. This spread of deadline targets was taken into account in the discussions of the International Roadmap and the following conclusion accepted.

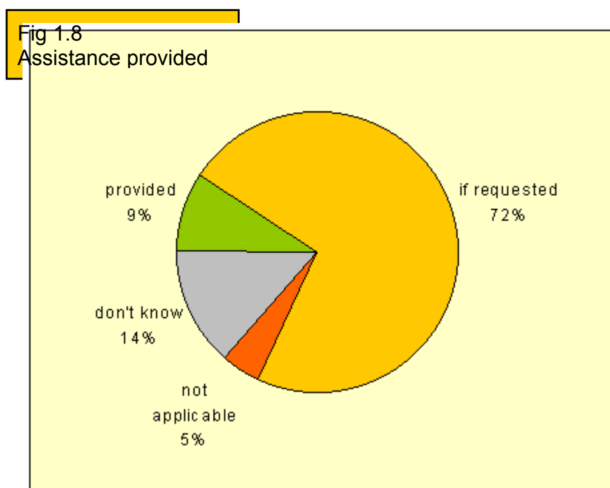
Leading manufacturers will achieve these results one year ahead of the quoted average schedule, trailing manufacturers two years later.





The 2003 EU survey also asked whether associated sites overseas would be expected to meet the same implementation targets as the main company sites in Europe. The results (Figure 1.7) showed that 47% would be expected to follow the same deadlines, and only 15% would be permitted a delay of up to 2 years. In most cases (72%), the main technology site would provide guidance if requested to do so but only 9% would do so proactively, as a matter of course (as shown in Figure 1.8).





The JEITA 2002 roadmap suggests the following guidelines;

Components

- Start supplying components to withstand heat resistance/Pb-free terminal components; end 2001
- Complete supply of Pb-free terminal components; end 2003
- Complete supply of Pb-free components; end 2004

Assemblies

- Start introducing lead-free solder; 2002-2003
- Totally adopt lead-free solder into new products; end 2003
- Complete lead-free adoption; end 2005

These are for average manufacturers, leaders are 1 year ahead and followers 2 years behind.

The EU 2003 roadmap provides an indication of the current target dates being used by European manufacturers for implementation of lead-free materials sales, component production and assembly for products affected by RHS legislation. Figure 1.9 indicates dates when first lead-free products are available, when half will be lead-free and, when all products will be lead-free. The overall average

target is shown by the ☺ symbol, and the range of early to late dates for market leaders and followers is shown by the coloured bar. In this case average is classed as the most common result.

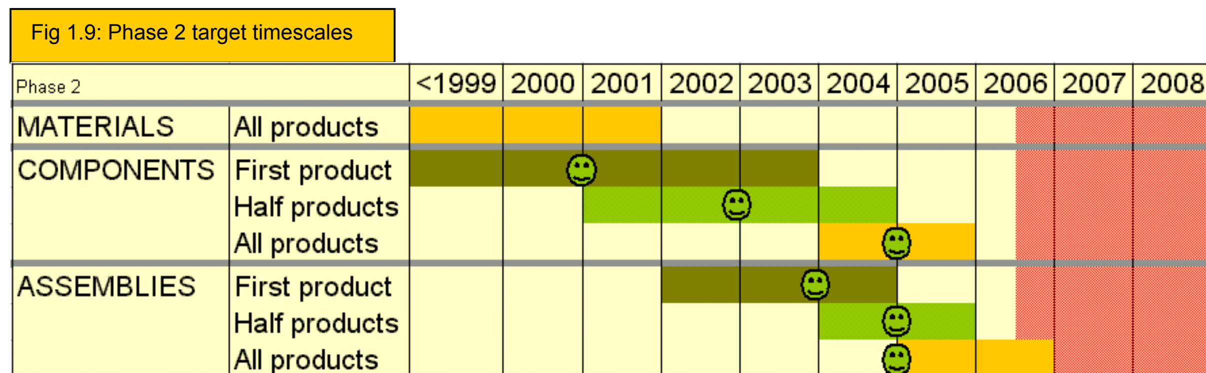


Fig 1.9: Phase 2 target timescales

On average, component manufacturers will be able to supply all products as lead-free compatible by the end of 2004, and, on average, all assemblies affected by RHS legislation are planned to be Pb-free soldered by the end of 2004. This refers to 'phase 2' implementation which eliminates Pb from the majority of the materials, but where Pb may still be present in, for example, high temperature solders that are provided with an exemption from the RHS Pb ban. Further information on definition of phases and additional average EU target dates can be seen in section 2.4 of the EU Lead-free Soldering Roadmap.

The importance of adhering to average timescales as far as possible is clear. Market followers involved in the assembly industry with slow reaction to the impending legislation are at risk of missing the deadline by around 6 months.

EU and JEITA recommendations have been taken into account when producing the guidelines of the International Roadmap Framework shown below.

The following schedule has been set as an average for manufacturers.

Components:
Commenced supplies of lead-free components/lead-free terminal components: by the end of 2001
Complete line-up of lead-free terminal components: by the end of 2003
Complete line-up of lead-free components: by the end of 2004

Assemblies:
Commence manufacturing of lead-free soldering assemblies: by the end of 2002
Complete lead elimination from products: by the end of 2005

1.3 LEAD-FREE SOLDER ALLOY SELECTION

The favoured alloys already used, or, expected to be used for reflow, wave and hand soldering can be seen in the Figures below – both for the EU (yellow background) and Japan (blue background). The SnAgCu ternary remains the most popular for all soldering processes and in both regions. There appears to have been no significant change in expectation since the previous EU survey reported in 2002.

SnAgCu is available in many compositions around the ternary eutectic. No additional information on the favoured composition has been obtained for the EU following the 2002 noted preference for Sn3.8Ag0.7Cu. The work of JEITA with Japanese industry shows a preference for Sn3.0Ag0.5Cu. No specific compositional recommendations are made in the International Roadmap.

Various recommendations on SnAgCu compositions have been published over the past few years;

- Trials on the solder by the EU sponsored IDEALS research project 1996-1999 were based on the Sn3.8Ag0.7Cu alloy

- Soldertec made a recommendation of an alloy range of Sn(3.4 to 4.1)Ag(0.45 to 0.9)Cu[8] in October 1999
- The JEITA roadmaps of 2000 and 2002 favour a Sn3.0Ag0.5Cu alloy
- NEMI issued a recommendation of Sn3.9Ag0.6Cu also in the year 2000

The Sn-Ag-Cu solder is recommended for general use in board assembly.

Reflow

Figure 1.10 shows alloys favoured in the EU, and Figure 1.11 those preferred in Japan. The most significant difference is the noted use of alloys such as SnZnBi in Japan which are not yet considered in the EU.

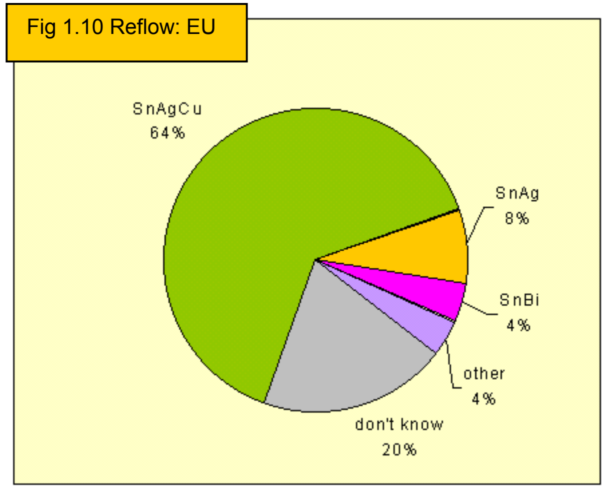


Fig 1.10 Reflow: EU

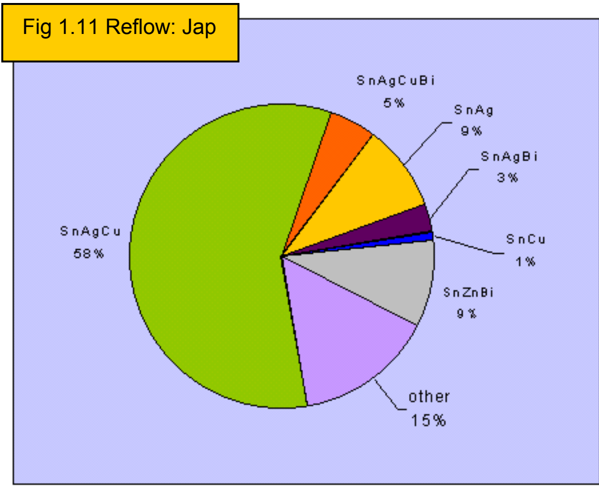


Fig 1.11 Reflow: Jap

Wave solder alloys

Figure 1.12 shows alloys favoured in the EU, and Figure 1.13 those preferred in Japan. A preference for SnAgCu solder for wave soldering is still seen in both regions but the SnCu eutectic and modified alloys is also popular for this manufacturing process.

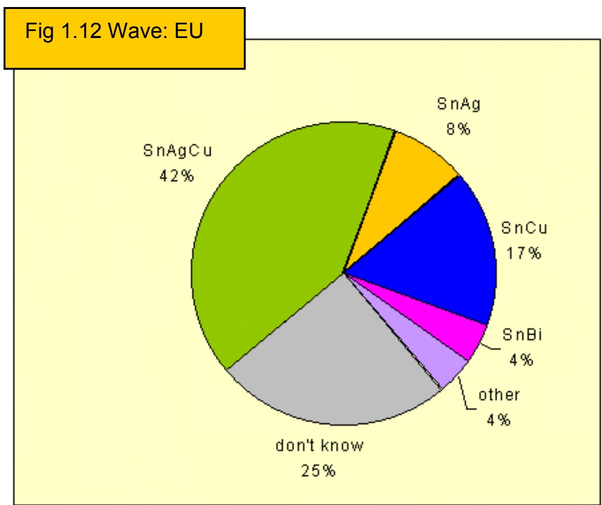


Fig 1.12 Wave: EU

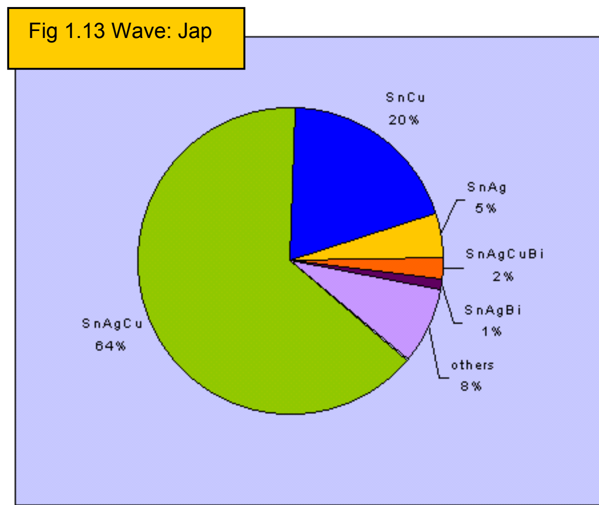
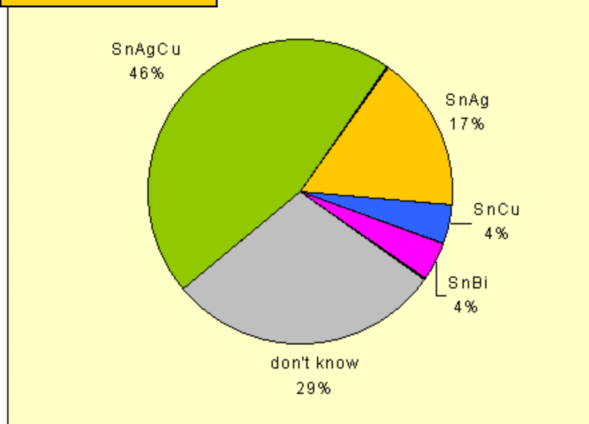


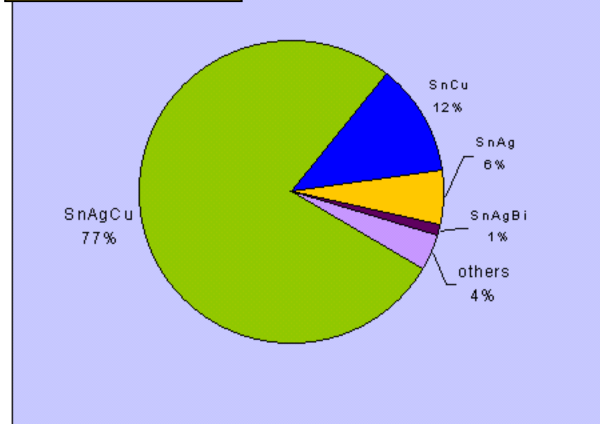
Fig 1.13 Wave: Jap

Hand solder alloys

Figure 1.14 shows alloys favoured in the EU, and Figure 1.15 those preferred in Japan. Whle SnAgCu remains the solder favoured by the majority, the SnAg eutectic is seen as the secondary alternative in the EU while the SnCu eutectic is seen as the most common alternative in Japan.

[8] Lead-free alloys – the way forward, 10.99, available from http://www.lead-free.org features archive

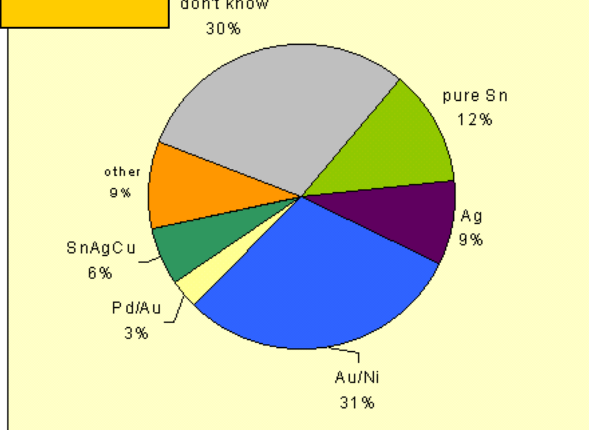


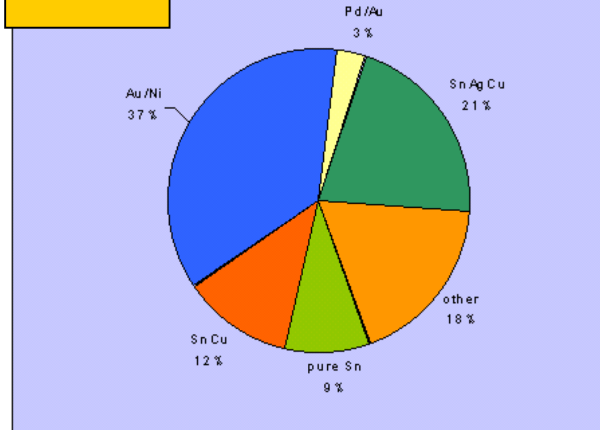


1.4 COMPATIBILITY WITH EXISTING PWBS

It is well known that many circuit board finishes in use today with SnPb solder processes are Pb-free. It appears that there are no significant compatibility issues with the use of these common surface finishes and Pb-free solders. The graphs below illustrate the approximate distribution of preferred alternative finish types for circuit boards in the EU (Figure 1.16) and Japan (Figure 1.17). Au/Ni is generally most popular. The category 'other' includes organic solderability preservatives. The use of SnCu as a board finish is noted in Japan but is not yet noted in the EU.

Lead-free solder technology has been shown to be compatible with existing circuit board finishes.

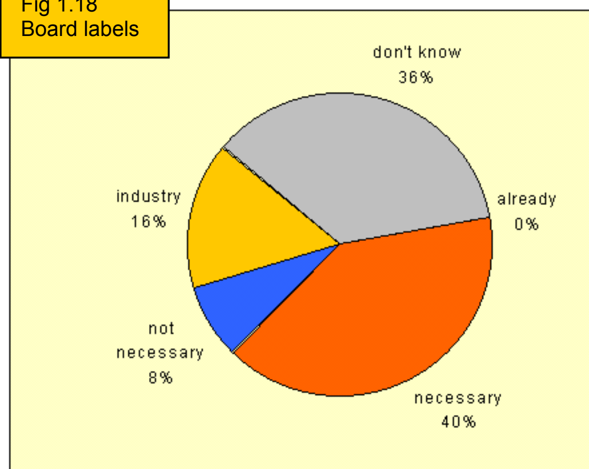


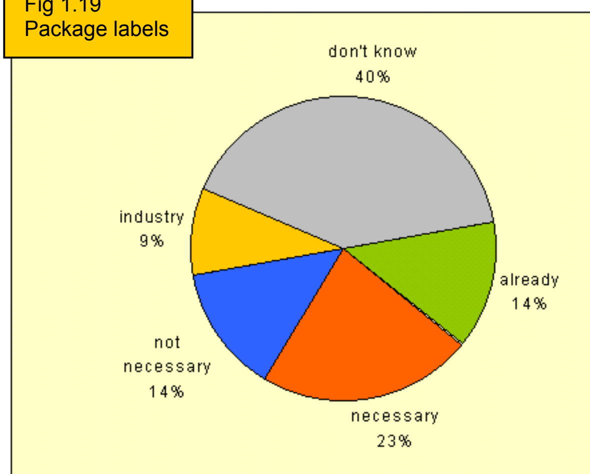


1.5 IDENTIFICATION OF LEAD-FREE MATERIAL CONTENTS

In the previous survey of EU opinion it was established that many companies, 60% of respondents, had made no decision about labelling strategies. This has been reduced in 2003 and now only 35-40% of companies remain undecided. Some companies stated that labelling is already used to indicate a Pb-free material or product and the majority felt that some form of labelling would be required. However, it remains unclear whether companies prefer to develop their own labelling system or use an industry standard format.

Examples of opinion on board labelling can be seen in Figure 1.18 and package labelling in Figure 1.19. The category 'industry' indicates a preference for an industry standard.





There are concerns over inventory management of mixed Pb containing and Pb-free systems. It is also possible to reduce issues related to rework, repair and recycling if material content is more easily recognised through labelling.

Some component manufacturers have introduced coding systems to differentiate Pb and no-Pb packages. For example, letters such as 'Z' or 'G' are added to the part coding system. Some form of differentiation is recommended.

Guidelines have been issued by the EMS Forum regarding package labelling[9];

- All components should have the outer packaging boxes and inner package material (tray, tube, reel) marked with some form of traceable information that indicates that no Pb is present in the components. This must also appear on the package where there is room for such a marking.
- All lead-free area array packages, and other lead-free components which are not backward compatible, should have new supplier P/N's assigned. Suffix or prefix additions to existing P/N structures are acceptable.
- Device datasheets should clearly indicate the termination solder composition, maximum component temperature rating, recommended & absolute reflow profile limits, and the moisture sensitivity rating. If this information is not present on the datasheet, there should be a clear reference as to where it can be located.

The JEITA roadmap of 2002 plans to promote the industrial standardisation of lead-free labelling. Further work on this issue will be carried out as part of the development of the International Roadmap.

Identification of material contents is needed for rework and/or recycling; further work is required to develop a recommended system for labelling.

[9] EMS Forum guidelines available from http://www.lead-free.org

SECTION 2

EU LEAD-FREE SOLDERING ROADMAP VERSION 2: February 2003

INTRODUCTION

Following the publication of the first European Lead-free Technology Roadmap in 2002[10] this Second Version 2003 indicates some changes in attitude over the last year, current industry opinion, and, guidelines for future activity. The use of this roadmap will allow any person in industry to compare their plans and beliefs on lead-free with those of the 'average' as represented by these survey results. For example, evidence of significant differences from this average can indicate areas requiring further work. Information on the companies who participated in this survey, product type and size, can be found in the overall introduction in the section titled European Industry Survey.

The 2002 version of this EU Roadmap contains further information that is still relevant today and should be referred to in addition to this update.

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.

SUMMARY OF EU ROADMAP 2003

1. The EU 2003 roadmap provides an indication of the current target dates being used by European manufacturers for implementation of lead-free materials sales, component production and assembly (in regard to product types affected by RHS legislation). Companies should compare their own activity to the average summarised in this document and adjust their implementation schedule accordingly. It is essential to match the guidelines in phase 2 introduction in order to comply with the RHS Directive. Consumable and component manufacturers should already have lead-free product available. Assemblers should be well on the way to introducing their first lead-free product which should be achieved by the end of 2003. All companies should already be actively participating in implementation activities.

2. It is important to clarify company plans for implementation of Pb-free in order to inform suppliers of the planned timescales for Pb-free procurement. The uncertainty in the supply chain demonstrated by these results could be a potential stumbling block in the introduction of Pb-free soldering processes.

3. Companies should be prepared to introduce Pb-free components into their current SnPb production process.

4. Companies should be aware that the continued availability of Pb-containing materials and components is not guaranteed. If availability is continued for a limited number of years following introduction of RHS legislation then this may be at additional expense. Companies should plan for such an eventuality.

5. 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.

6. Reference should be made to Version 1 of the EU Roadmap 2002 in order to evaluate the relative importance of specific technical concerns. These mainly 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

[10] SOLDERTEC European Lead-free Technology Roadmap, Version 1, February 2002 available from http://www.lead-free.org

maintaining a practical process window. Process development may also produce benefits such as reduced energy consumption.

7. Additional participation from companies in certain market sectors, in other EU member states and small companies in all countries should be actively encouraged i.e. all sectors of industry and the supply network. Specific emphasis will be necessary on small company involvement.

8. Work will continue to develop further comparative roadmap data from the EU, Japan and other regions to assist in development of the International Roadmap framework document described in section 1.

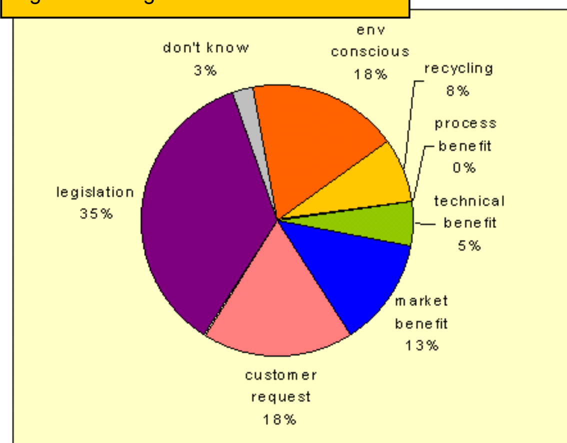
Comments on this document are welcome. Anyone willing to participate in further surveys or discussions related to the development of European and Global Roadmaps should contact the author.

LEAD-FREE IMPLEMENTATION – LEGISLATION AND DEADLINES

2.1 What do you consider to be the main factors driving lead-free implementation?

- Environmentally conscious manufacturing
- Recycling and end of life treatment concerns of
- hazardous material use
- Process or other cost benefit
- Technical and/or performance benefit
- Market related benefit
- Customer request
- Legislation
- Don't know

Fig 2.1: Driving forces

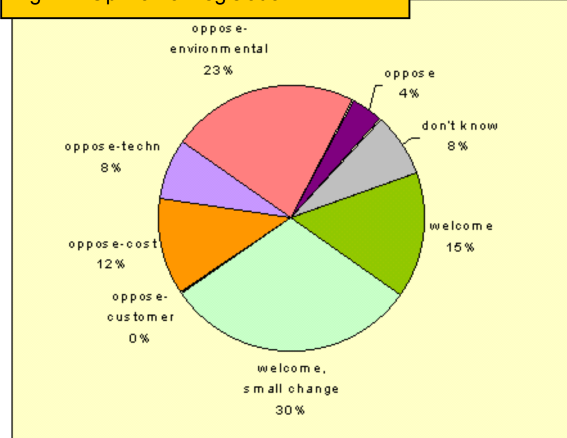


Similar results were obtained in 2003 as had been seen in 2002 although there appeared to be a slight increase in general 'environmental consciousness' and 'technical benefits' at the expense of a smaller influence from potential 'market benefit'.

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

- Welcome the legislation and the overall environmental aims
- Welcome the legislation but wish to see some change in detail (materials issues only)
- Oppose the legislation due to poor customer acceptance
- Oppose the legislation for cost reasons
- Oppose the legislation for technological reasons
- Oppose the legislation due to doubt over environmental benefit
- Oppose the legislation for other reasons
- Don't know

Fig 2.2: Opinion on legislation



The data above shows that there was an even split between companies opposing the RHS legislation and those welcoming it. This illustrates greater opposition than was found in the 2002 survey – possibly due to the greater number of smaller companies participating this year. Cost and environmental concerns were the main cause of the opposition.

2.3 What do you believe will be the effects of the RHS legislation and lead ban on European manufacturing competitiveness?

- Provide an advantage
- Create a disadvantage
- Cause little overall change
- Don't know

Despite opposition to the RHS legislation noted in response to question 2, the majority of companies believed that competitiveness would not be affected, or, that some advantage was to be gained from it for European manufacturers.

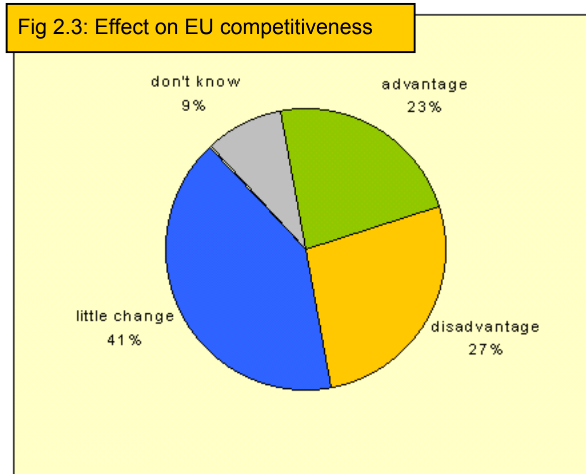


Fig 2.3: Effect on EU competitiveness

2.4 Company implementation plans

Company attitudes to the market, and implementation plans, are discussed in the International Lead-free Roadmap Framework in section 1.2. Figure 1.9 in that section shows planned target dates for Phase 2 introduction of Pb-free as this refers to the elimination of Pb from the majority of the materials, but where Pb may still be present in, for example, high temperature solders that are provided with an exemption from the RHS Pb ban. Phase 2 therefore relates to compliance with the EU Directive. Data is also available on phase 1 and phase 3 Pb-free implementation which is explained below.

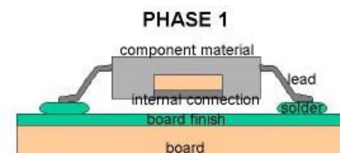
Phase 1 represents the initial stages of transition to Pb-free technology with the following definitions for components and assemblies. This represents a change in solder but little else.

In the assembly process the following must be lead-free;

- solder paste, wave solder baths, board finishes

Components must be capable of withstanding heat requirements of Pb-free soldering, but Pb can be used in components in;

- termination finishes, internal connections, in modules, component materials

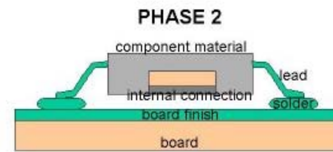


The average target timescales for EU industry and RHS affected product types are shown in the Figure. This indicates dates when first lead-free products are available, when half will be lead-free and, when all products will be lead-free. The overall average target is shown by the symbol, ☺ and the range of early to late dates for market leaders and followers is shown by the coloured bar. In this case average is classed as the most common result.

Phase 1		<1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
MATERIALS	All products										
COMPONENTS	First product										
	Half products										
	All products										
ASSEMBLIES	First product										
	Half products										
	All products										

It can be seen that phase 1 assembly is planned to be completed on average by the end of 2004. The importance of adhering to average timescales as far as possible is clear. Extreme market followers involved in the assembly industry with slow reaction to the impending legislation are at risk of missing the deadline of RHS by around 6 months. For all manufacturers phase 1 typically involves an extensive lead-in period of a few years during which time technology and know-how is being developed.

Phase 2 represents Pb elimination from the majority of materials within a product and most closely represents compliance with the RHS Directive. Changes to solder, board and components are required.



In the assembly process the following must be lead-free;

- solder paste, wave solder baths, board finishes, and component terminations

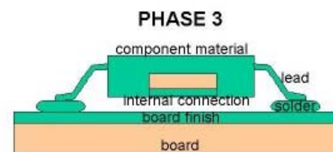
Pb can be used in components in the following areas;

- for internal connections, in modules, component materials

Phase 2		<1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
MATERIALS	All products										
COMPONENTS	First product										
	Half products										
	All products										
ASSEMBLIES	First product										
	Half products										
	All products										

For phase 2, component manufacturers will be able to supply all products as lead-free compatible by the end of 2004, and, on average, all assemblies are also planned to be lead-free solder by the end of 2004. Although this is the same overall final end-2004 date as in phase 1, it is clear that there is a shorter lead-time to achieve these targets. In particular, activities of market leaders and market match companies appear to merge in the final category of achieving all products Pb-free.

Phase 3 represents Pb elimination from all materials within a product and exceeds the demands of the RHS Directive. Changes to solder, board and components are required including to the internal connections of components and modules.



In the assembly process the following must be lead-free;

- solder paste, wave solder baths, board finishes, component terminations, connections, modules and materials

Pb cannot be used in any areas

PHASE 3		<1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
MATERIALS	All products										
COMPONENTS	First product										
	Half products										
	All products										
ASSEMBLIES	First product										
	Half products										
	All products										

For phase 3, the deadline for achieving Pb-free in all assembled products is the end of 2005. Again the lead-in times have been shortened with activities of market leaders and market match companies merging for both categories half and all products. This is also seen for the category of all components to be Pb-free, with the market followers extending past the July 2006 legislative deadline for the first time. However, it should be remembered that there is currently an exemption in the RHS Directive for high temperature solders of the sort used for die attach/internal component connections.

> The EU 2003 roadmap provides an indication of the current target dates being used by European manufacturers for implementation of lead-free materials sales, component production and assembly. Companies should compare their own achievements to these averages in order to determine how urgent any required action could be. It is essential to match the guidelines in phase 2 introduction in order to comply with the RHS Directive.

2.5 What are your company requirements for procurement of lead-free compatible materials/components from suppliers?

This applies to components, units such as (magnetic disk, CPU module, LCD unit etc), and OEM equipment procurement

- Immediately
- 1 year later
- 2 years later
- Other
- Not applicable
- Don't know

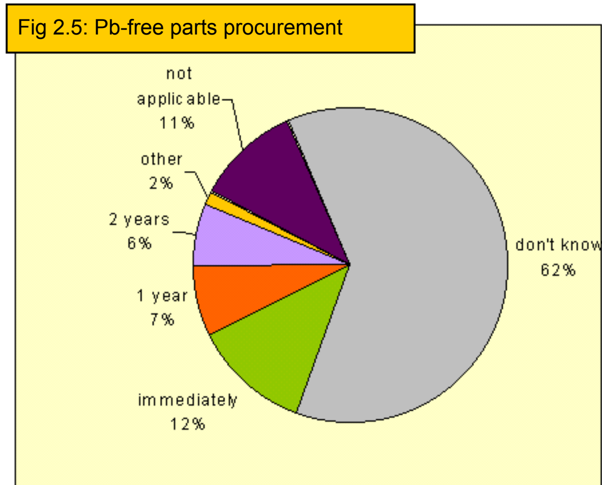


Fig 2.5: Pb-free parts procurement

Surprisingly, it appeared that many companies were unsure about their requirements for Pb-free components and the timescales in which these would need to be procured. In the case of component procurement, 22% required Pb-free parts immediately, and 43% within 2 years with the remainder undecided.

> It is important to clarify company plans for implementation of Pb-free in order to inform suppliers of the planned timescales for Pb-free procurement. The uncertainty in the supply chain demonstrated by these results could be a potential stumbling block in the introduction of Pb-free soldering processes.

2.6 Do you currently use lead-free leaded components with tin-lead solder assembly process, or plan to do so in the future?

- We do/will use lead-free components with tin-lead solder
- We do/will not use lead-free components with tin-lead solder
- We do/will use lead-free components, but dependent on the composition of terminal plating, or the solder ball
- Don't know

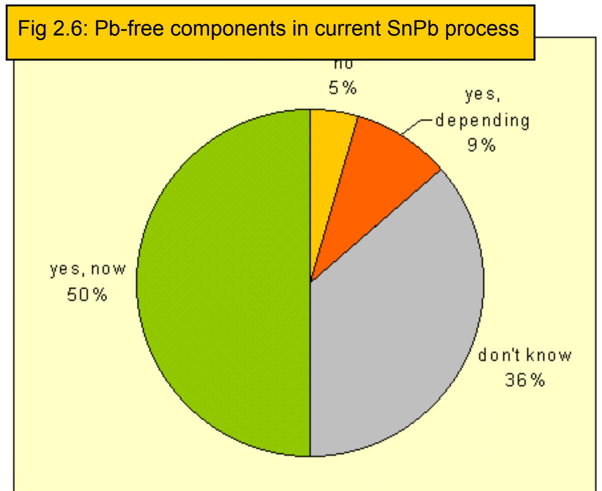


Fig 2.6: Pb-free components in current SnPb process

The backward compatibility of Pb-free components has sometimes been raised as a concern In the majority of cases companies already use Pb-free component terminations or would be using them in the future in combination with the present SnPb soldering production process.

> Companies should be prepared to introduce Pb-free components into their current SnPb production process.

2.7 Will you continue to supply lead containing products for sometime after much of the transition has been made in order to support other applications or repair requirements?

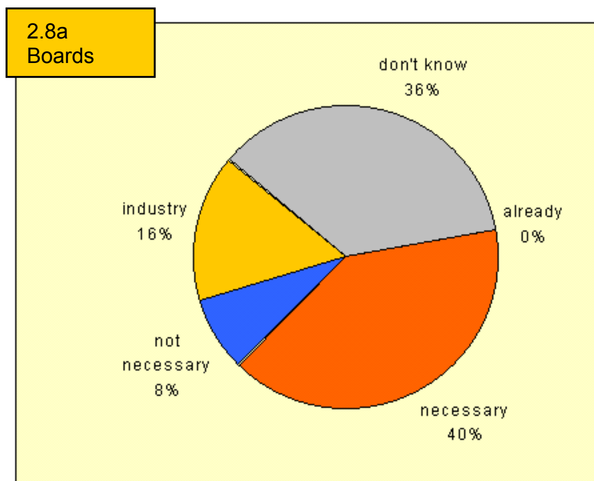
Many companies (68%) plan to continue manufacture of Pb containing materials and components for sometime in order to support repair, unaffected industry sectors and for other reasons. However, it was sometimes noted that Pb containing products will inevitably become more costly due to reduced production quantities. It was also noted that although continued production is planned this may be only for 1 or 2 years following the majority of implementation activities. In addition, 14% of companies were planning to cease production of Pb containing materials as soon as possible.

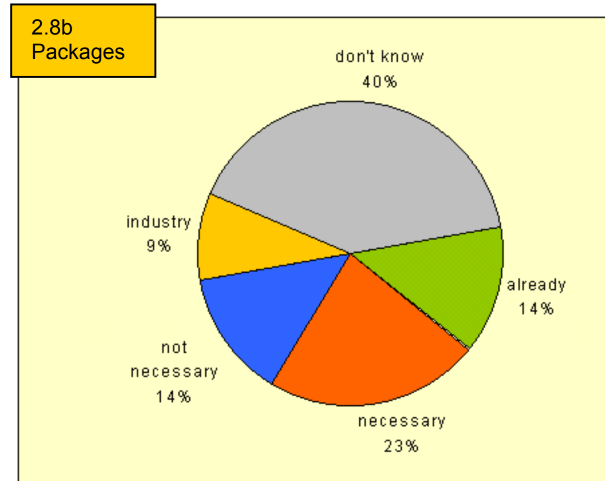
Companies should be aware that the continued availability of Pb-containing materials and components is not guaranteed. If availability is continued for a limited number of years following introduction of RHS legislation then this may be at additional expense. Companies should plan for such an eventuality.

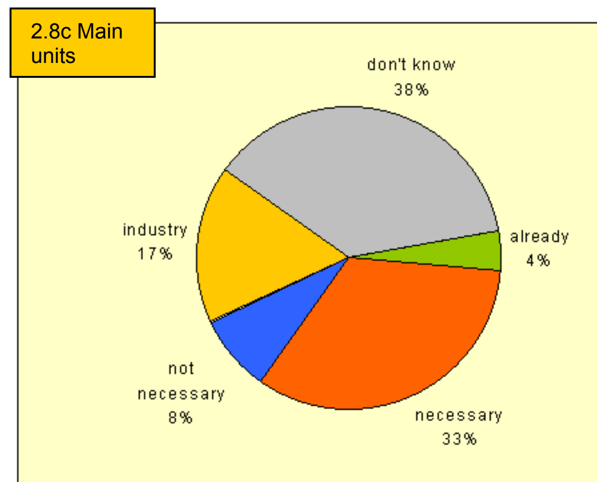
2.8 Regarding labelling of lead-free products

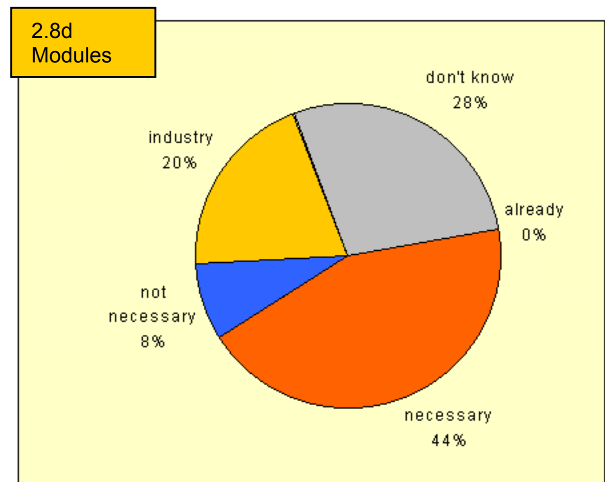
When lead-free is introduced it may be necessary to indicate this either to the consumer, industry customer, or, to assist in the recycling and material recovery process. It was asked whether boards, modules, main units, and packages were already labelled or would be in the future.

- Already labelled now
- Labelling will be necessary
- Labelling not necessary
- An industry-wide label is required
- Don't know









Additional comments on labelling can be found in Section 1.5 of the International Roadmap agreement. The importance of labelling is illustrated by the Figures above where the response 'labelling not necessary' did not gain much support. Around half of those companies who thought that labelling would be required appeared to prefer an industry standard label. Work on this issue will continue.

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.

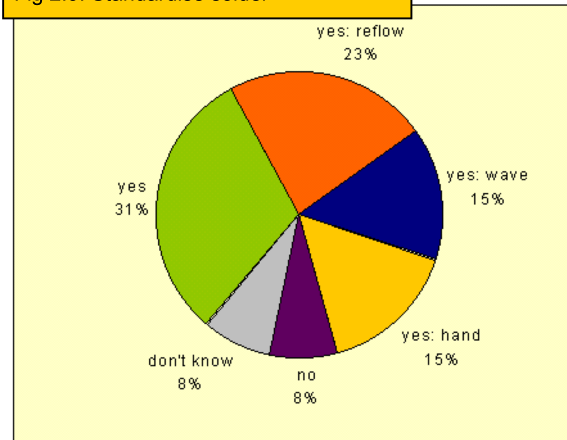
LEAD-FREE IMPLEMENTATION – TECHNICAL INFORMATION

2.9 Do you hope that an industry standard lead-free solder is agreed?

Data on solder alloy composition can be seen in section 1.3 of the International Roadmap framework. Few significant changes to the data obtained in 2002 was observed although there was a fall in support for SnCu for wave and hand soldering applications. The ternary SnAgCu remains the main solder to be used for all applications.

Overall, the majority of respondents favoured establishing a standard solder alloy composition for both reflow and wave soldering but there was no general consensus on what that alloy should be.

Fig 2.9: Standardise solder



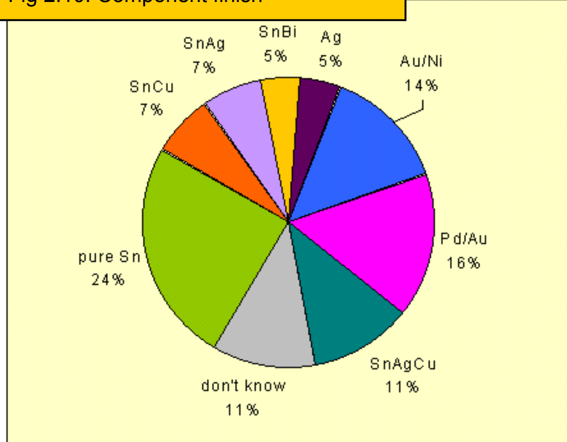
2.10 What are your preferred component termination materials?
This question was asked in reference to component terminations, solder ball materials and board finish. Data on board finish can be found in section 1.4 of the International Roadmap framework.

For solder ball material, 48% of responses indicated that SnAgCu would be used, followed by pure Sn (13%) and SnAg (9%) although the remainder were undecided.

There is also no clear choice of preferred component termination as can be seen from the adjacent data. Pure Sn was the most popular material, certainly from the range of Sn based plating available, although concerns over the possibility of tin whiskering remain. Precious metal finishes such as Au/Ni also appear popular with a significant proportion of the industry.

It is perhaps the case that termination finish will vary according to component type. Pure Sn may be more usual for connector or passive finishes, whereas manufacturers of active components may opt for other alternatives. A detailed analysis of termination finish by component type was carried out by JEITA and illustrated this type of trend.

Fig 2.10: Component finish

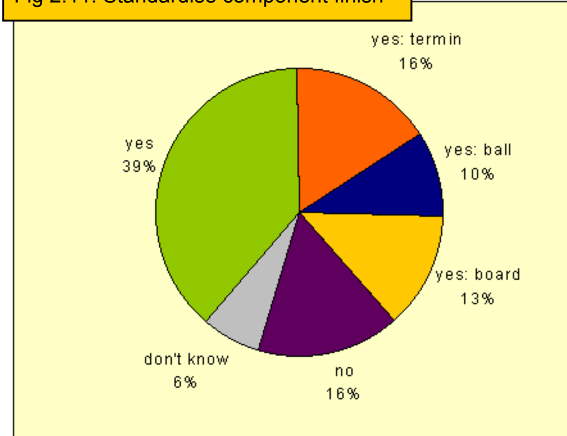


Due to uncertainty surrounding this issue no guidelines have yet been agreed in the International Roadmap.

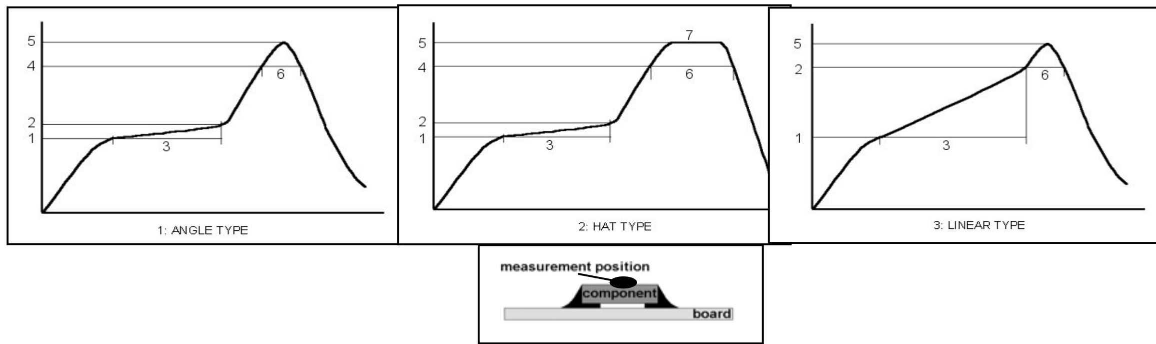
2.11 Do you hope that an industry standard lead-free component termination is agreed?

Overall, establishing a standard termination finish would be supported by the majority of companies who replied to the survey, although, this did not appear to be the case for solder balls or board finishes.

Fig 2.11: Standardise component finish



2.12 Three typical thermal profiles are shown below. In order to define preferred reflow profiles please select the most commonly used within your company for lead-free production.



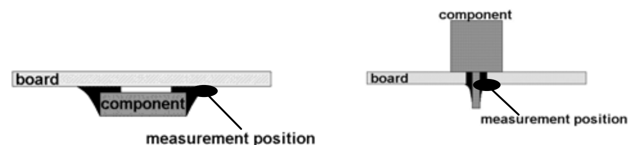
The linear type 3 profile was found to be the one most commonly used in current Pb-free production by 37% of respondents. This was followed by 29% of companies utilising the angle type 1. No current production appeared to be using the hat type 2 profile.

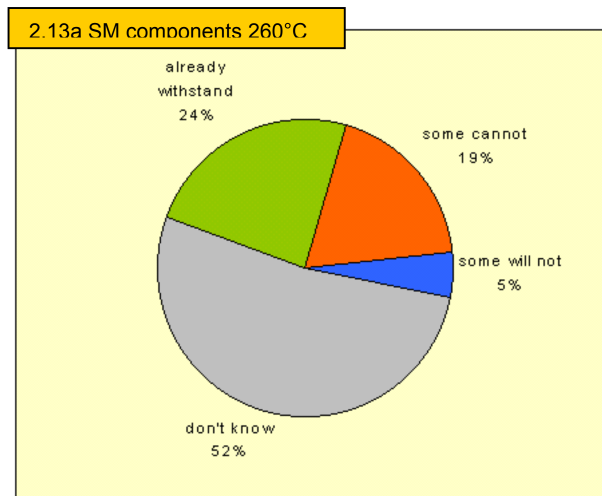
The average profile conditions for each type are shown below;

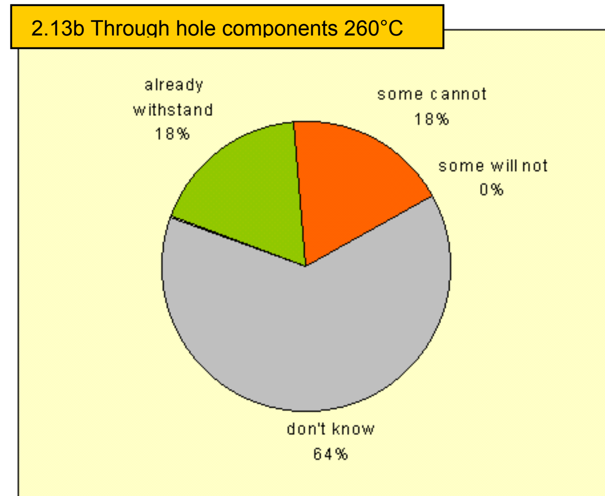
Linear profile	**Angle profile**
Pre-heat 25 to 215°C, 190 s	Pre-heat 120 to 155°C, 100 s
Peak 246°C, 30 to 90 s above melting	Peak 250°C, 40 to 60 s above melting
Most reflow in air	Most reflow in air

2.13 Do components meet wave solder process temperature conditions assuming temperature of 260°C for up to 10 seconds?

- Components already withstand 260°C/10s
- Some components cannot withstand 260°C/10s
- Components will not be able to withstand 260°C/10s
- Don't know







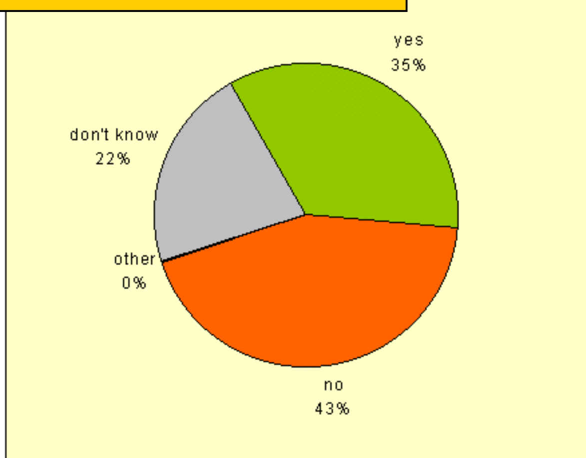
The majority of companies did not appear to be sure whether components would be able to withstand 260°C for 10 seconds. Of those that did reply, around half felt that components would be able to achieve this, and half believed that some would not. It is recommended that further clarity on this issue is obtained from component suppliers.

2.14 Do you believe that assembly equipment will need to be changed due to lead-free introduction (in addition to routine equipment replacement)?

While 43% of respondents did not believe that assembly equipment would need to be changed for the implementation of Pb-free processes, 35% of companies did think so. The remainder did not know.

Requirement for equipment changes is dependent on process and product types, however, at least some small changes will be beneficial to practically all assembly equipment when changing to Pb-free.

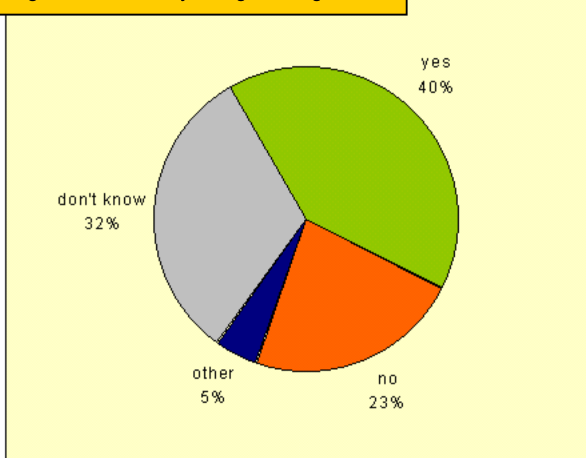
Fig 2.14: Assembly equipment change

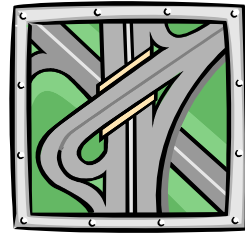


2.15 Do you believe that assembly or component design will need to be changed specifically for lead-free introduction (in addition to normal procedures)?

There was a greater uncertainty over this question with 32% of companies unsure of the answer. However, overall the majority (40%) felt that some design changes would be required.

Fig 2.15: Assembly design change





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