

State of RoHS compliance in small and medium sized enterprises

- Technical, Economic and Environmental Evaluation of the Transition Process -

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Key Words: RoHS, small and medium sized enterprises, legal compliance, green electronics

1. Introduction

The RoHS Directive has been effective since 1st July 2006, restricting the use of six hazardous substances in the manufacture of electronic and electrical equipment including lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs) and legally forces electrical and electronic industry to take full responsibilities towards “Green Electronics” worldwide. Manufacturers need to understand the requirements of the RoHS Directive to ensure that their products and components comply with the Directive.

In order to support enterprises, especially small and medium sized enterprises (SMEs), with relevant processes and techniques to comply with the requirements of the Directive and produce electronic equipment free of hazardous substances with guaranteed quality and reliability, a 3-year project called GreenRoSE (Removal of Hazardous Substances in Electronics) funded by the European Union was launched mid 2004.

According to one of the working packages of the project GreenRoSE, an investigation based on a questionnaire was conducted in October 2006, three months after the RoHS deadline. The intention was to evaluate the RoHS transition process in SMEs and the achieved status. The target respondents of the investigation are 40 electronic enterprises in Poland, 85 % of them are SMEs with less than 250 employees. Their business scopes include end producers, producers of sub-assemblies / components / materials to producers of soldering equipment. Some of them are running multiple sectors. The relationship between the size and business sectors of enterprises is shown in Table 1.

Business sectors in electronics industry	<10 employees	10-50 employees	50-250 employees	>250 employees
End producers	5.0 %	27.5 %	30.0 %	15.0 %
Producers of components or materials	2.5 %	30.0 %	15.0 %	5.0 %
Producers of soldering equipment	2.5 %	12.5 %	5.0 %	5.0 %
Producers of others equipment	2.5 %	0 %	0 %	0 %

Table 1: Business sectors and sizes of respondents in electronics industry

Change of mature technology inevitably brings technical, economic and management problems. This paper mainly focuses on demonstrating the influence of the RoHS implementation, evaluating the transition processes and revealing critical issues to make contributions to solving difficulties along with the EU project GreenRoSE. The evaluation will be addressed in five aspects: the general status of implementation before and after RoHS, management of transition process, technical issues, economics as well as environmental impacts.

2. Evaluation of the Transition Process

2.1. General Implementation Status of Pre-RoHS and Post-RoHS

2.1.1 Status of Implementation

Among the RoHS-6 substances, lead in general is the most widely used one, which is confirmed also by the replies shown in Figure 1.

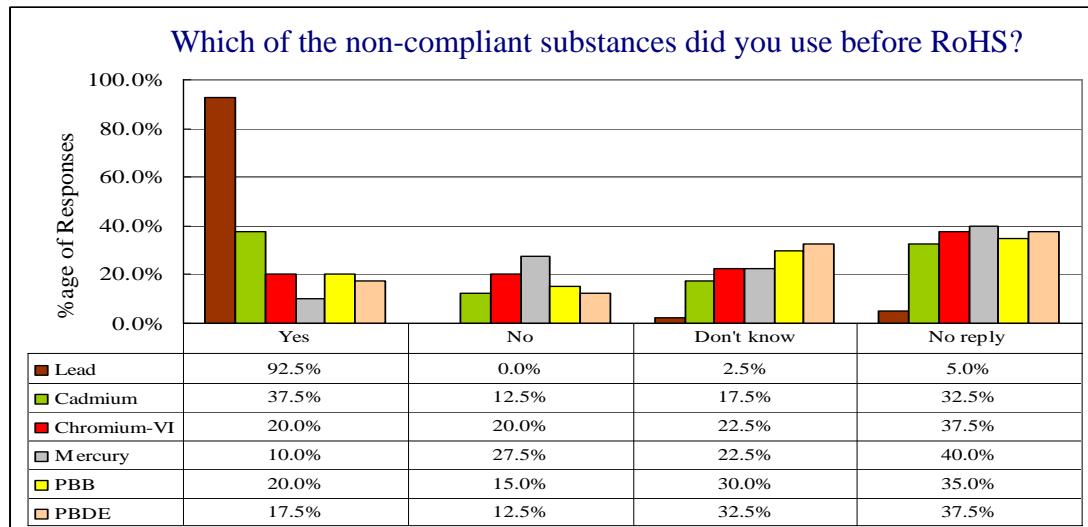


Figure 1: Use of non-compliant substances prior to RoHS

The investigation showed that 37 in those 40 enterprises (92.5 %) used lead either within internal working processes or/and in materials from external suppliers before RoHS came into force. Among the rest of the enterprises, one simply responded that they “don’t know” if their products contain lead, while the other two had no response to the question. On the contrary, for the other five different hazardous substances banned in RoHS, only minority enterprises are able to give a straightforward answer whether such kind of non-compliant substances were used in their products or not. About 18 to 33 % directly answered “don’t know”, and more than one-third even had no reply.

How did the situation change with enforcement of RoHS? 30 % of all respondents unambiguously declared that they had achieved the standard of RoHS-compliance, which means that their components were within the limit of maximum concentration values (MCVs) in RoHS, while 34 % had less confidence of giving a positive answer, just chose “probably yes”. However, 28 % of the respondents still failed to reach the bottom line of RoHS-compliance in due time. One-third of them could be in the exemption list of RoHS based on their final products. It means that nearly 20 % of the whole respondents violated the RoHS Directive. In addition, 8 % have no comments on the question at this moment.

2.1.2 Critical issues

Furthermore, respondents should identify the level of understanding and familiarity with the clauses such as definitions and scopes regarding the Directive. More than one-third of the respondents are still unclear of definitions and scopes in RoHS even three months after the enforcement of RoHS (Table 2). As for the “No reply”, only one respondent is exempt because its business is out scope of RoHS. For the others, there is no reason but they do not dare to admit their violation of the Directive. In short, a very good understanding of the legislation is the indispensable prerequisite for the whole transition process. The common standpoint that the achievement of RoHS-compliance was merely hampered by technical or economic aspect is incomplete. It gave a negative signal for the fact that some enterprises did pay less importance to the RoHS Directive.

	Fully understood	Still unclear	No reply
Understanding of definitions	57.5 %	35.0 %	7.5 %
Understanding of scopes	52.5 %	37.5 %	10.0 %

Table 2: Understanding of clauses in the RoHS Directive

2.2. Evaluation of Transition management

2.2.1 Status

Three core management issues urgently derive from the transition of the RoHS legislation, preparation, verification of compliance, and supply logistics.

For those, 7.5 % of the overall respondents had started to prepare their programs by taking RoHS terms into account at least three years before the deadline. However, still one-third of them admitted not meeting the RoHS Directive until the survey in October 2006. 10 % commenced their preparation in 2004, nearly half (47.5 %) in 2005, and 35 % in the first half of 2006. A sufficient preparation leads to successful and smooth transition. Actually, those who began to prepare the implementation of RoHS in 2006 are those which are still RoHS non-compliant in due time. The results demonstrated that the initiatives are necessary and the transition process will not simply be finished without a wearing period due to complicated influence of multiple factors.

The enterprises were asked to describe where they got the general, logistics and technical information and which were their favourite sources of assistance for RoHS, which are listed in Figure 2.

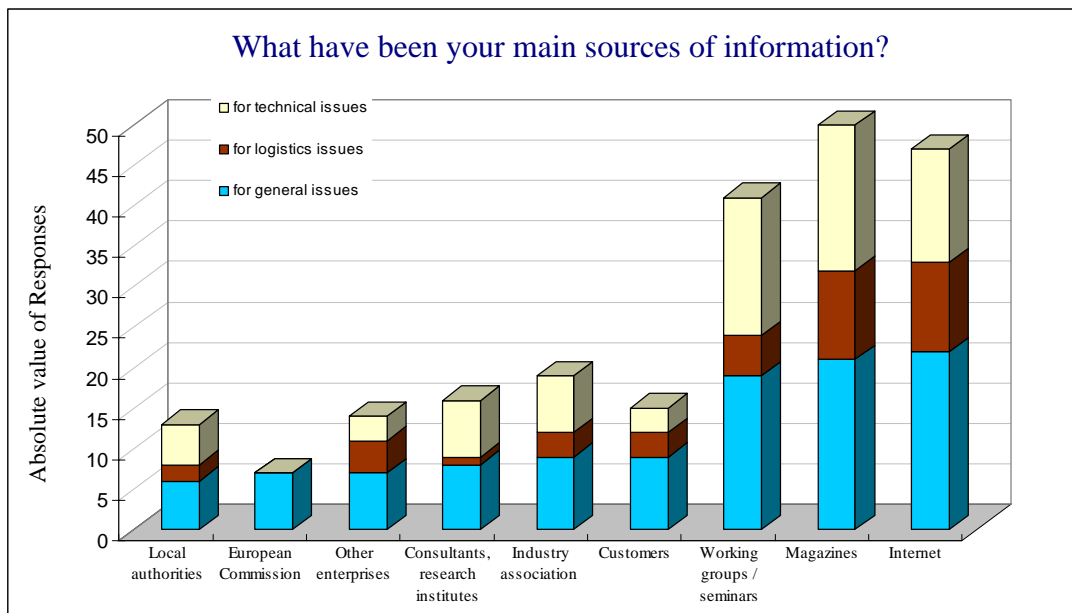


Figure 2: Sources of preparation for RoHS transition

Generally, internet, magazine and working groups/seminars are the most widely used top-3 channels of getting information. The results of the first two have a similar pattern with nearly equal percentage on the general, logistics and technical information. The logistics issues from the third channel were relatively weak, corresponding with the assistance from the channel “Other enterprises”. The RoHS transition process in general was also a question of missing information and misunderstandings: Information sourcing has been simplified by some networking projects but still was a difficult undertaking. Being asked through which channel the enterprises would have liked to get more information, respondents choose sequentially consultants or research institutes (20 %), internet (17.1 %), European Commission (11.4 %) and magazines (11.4 %).

Many enterprises have incorporated RoHS compliant alternatives in their products, but it is not sufficient enough for regulatory requirements. Enterprises must demonstrate evidences to prove their

compliance. Hence, for the purpose of ensuring the legal compliance the enterprises ought to have the ability to track material, control process, and record product inventory. Enterprises may be asked for providing the evidence to verifying their RoHS-compliant products by customers, similarly, enterprises may also ask their suppliers to reveal the similar evidence, which ensures that they were neither purchasing non-compliant components nor putting non-compliant products into the market. In light of these two roles of enterprises, Figure 3 compared five evidences by which enterprises intended to control such compliance management.

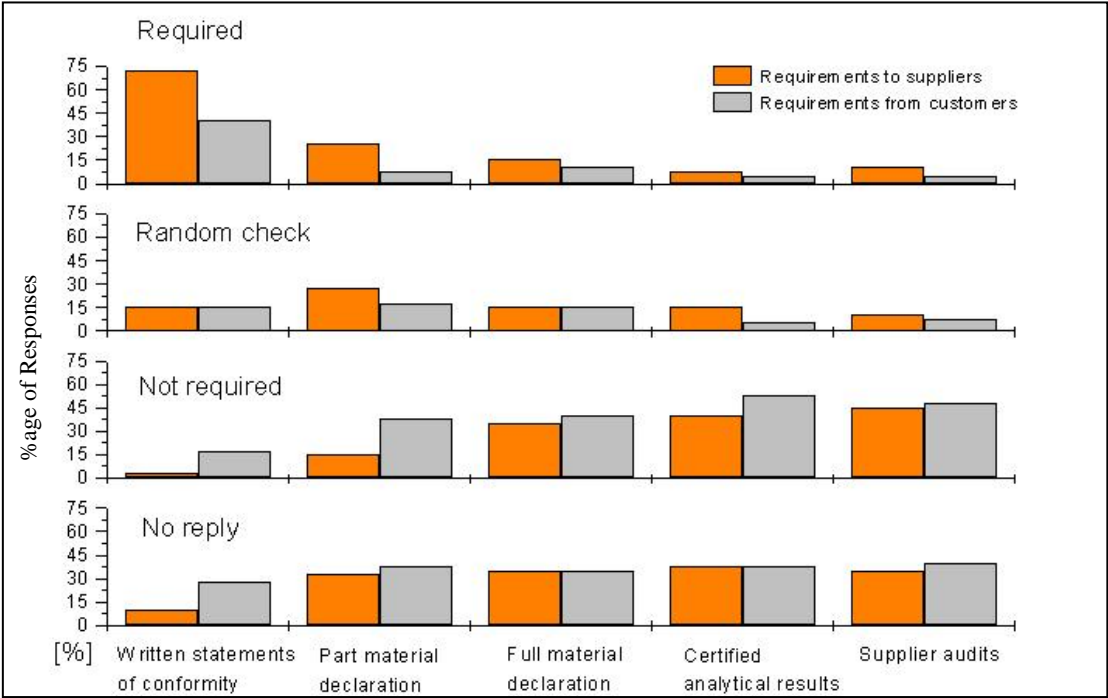


Figure 3: Demonstration of RoHS-compliance

A majority of respondents (close to 73 %) indicated that a written statement of conformity was commonly used to meet the requirement of their suppliers. The same method was also dominated by the requirement of customers (40 %). In addition, about one-quarter of the respondents require from their suppliers to provide a part material declaration for the ban of six hazardous substances in RoHS or/and a random check of sample. Regardless of each role of respondents, a full material declaration, certified chemical analytical results, and supplier audits seemed not to be adopted broadly. This might reflect the situation that 85 % of the respondents were SMEs, which might naturally choose the cost-effective and practical methods to demonstrate RoHS-compliance. Actually, as the lack of existing standards, enterprises have to evaluate the potential risk of inadequate evidence associated with the enforcing market surveillance. Possibly, this trend would be varied with standardization of an ad hoc approach verifying the RoHS-compliance.

In order to reduce non-compliance risks, some enterprises will change their supply chains to meet RoHS requirements. In this survey, 25 % of respondents claimed to change several of their suppliers. Another 20 % changed only 1 or 2 of their suppliers; however 47.5 % tended to get materials, components, sub-assemblies still from exactly the same suppliers.

2.2.2 Critical issues

Several issues which could be ranked as “critical” by respondents in view of transition management were addressed in the questionnaire. For the evaluation the issues having a sum of options “Very critical” and “Critical” over 30 % are shown in the graph below. Results of “Very critical” and “Critical” were illustrated in a same column which differed in two sorts of patterns as shown in Figure 4. In total six aspects were addressed as “Very critical” by at least 20 % of respondents and “Critical” by 5 to 10 %. However, it is reported that all “Critical” and parts of “Very critical” issues have been successfully solved during the transition process. In the other part of unsolved and very critical issues,

18 % of respondents were still struggling to the availability of components while 43 % claimed to have solved them without problems. Furthermore, other unsolved and very critical issues at that time are the research capabilities (15 %), the last-time-buy problem (13 %), the availability of auxiliaries (13 %), compliance management workflow (13 %) and internal part logistics (10 %) respectively.

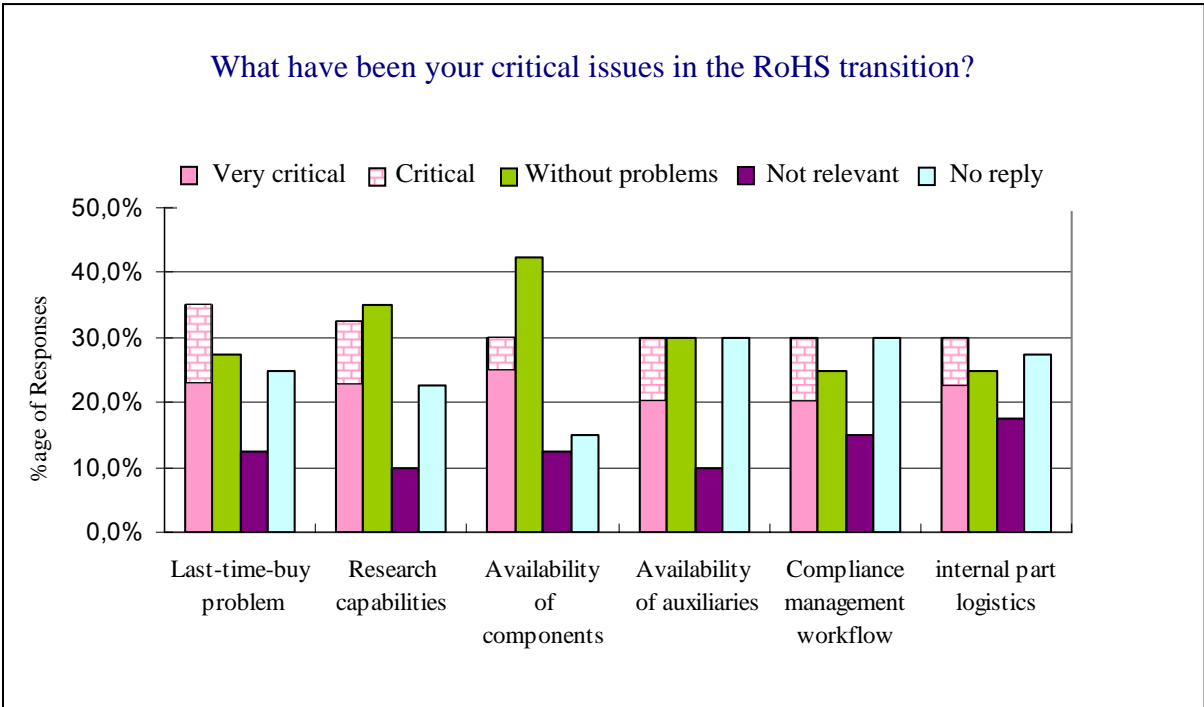


Figure 4: Critical issues for RoHS-compliance

2.3. Technical Evaluation

2.3.1 Status

For enterprises, the first concern on RoHS transition is the technology changes. However, how to deal with the non-compliant components on stock should be more pressing need and more urgent matter beyond this transition, since according to the survey the inventory are relatively large. According to reference 2004/2005, 30 % of respondents reflected that 90 % of purchased parts have been non-compliant with RoHS and are subject to the transition process. 37 % stated that 10 to 90 % of their bought-in parts contained any of the RoHS-6 substances and only 25 % of respondents had less than 10 % non-compliant bought-in parts. This statistical evidence leads to the fact that a massive effort was needed to cope with the legislation. Figure 5 indicates how the respondents handle the non-compliant components still on stock now after the deadline. The non-compliant components are used by 65 % of respondents in products out of scope of RoHS, which means some enterprises might maintain two separate product lines due to the different customers' demands. It seems that the non-compliant and compliant components would coexist over a quite long period of time.

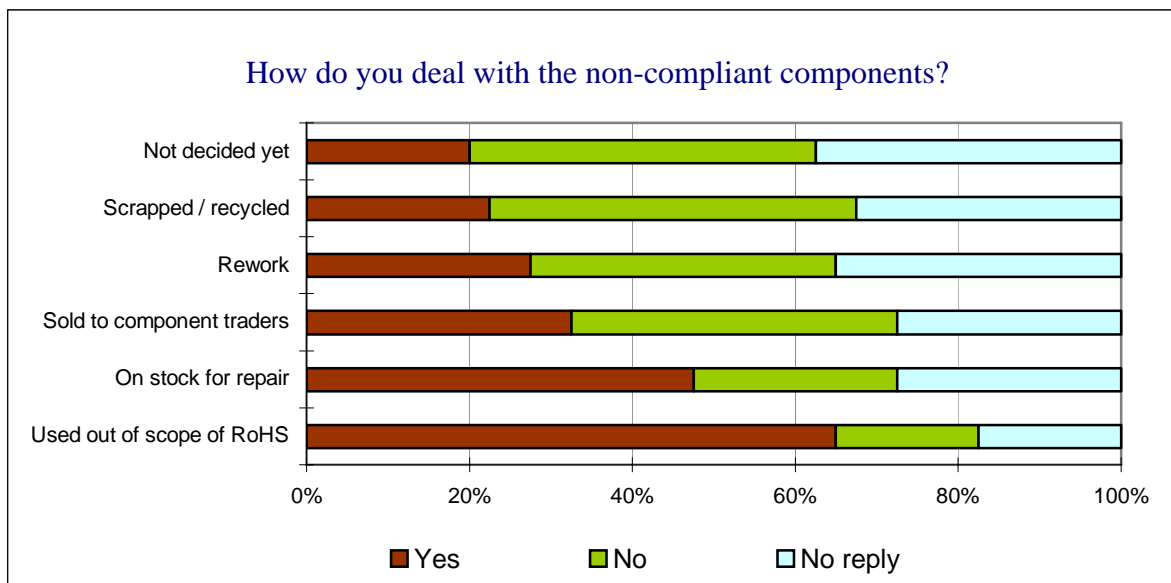


Figure 5: Use of non-compliant components after RoHS

Early half the respondents (48 %) stated to use non-compliant components for repair. Excessive stock of non-compliant components was also sold to other traders. Moreover, 28 % of respondents reworked certain non-compliant components in order to reach the requirements, which involved a high demand of technologies. To work out an effective method is determined by costs and suitable technologies. If there were no available alternatives, it would better dispose them simply through scrap or recycling which has been done by 20 % of respondents. Unfortunately, 20 % still stayed in the middle of nowhere.

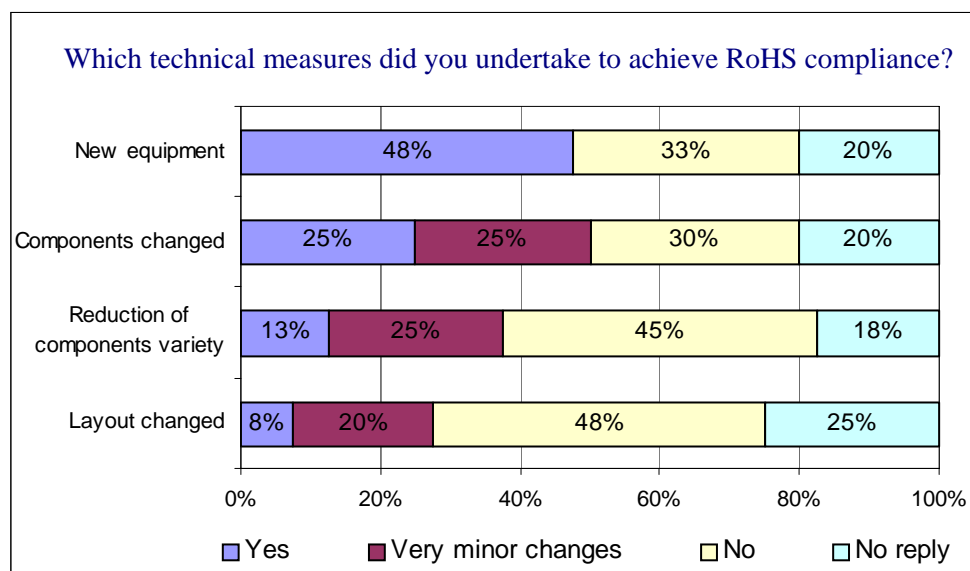


Figure 6: Technical measures due to RoHS transition processes

Similarly, a series of new technologies should be applied and improvement actions should be taken inevitably in order to produce compliant products, for example, replacing lead solders with lead-free, adding a product line to satisfy customers' requirement, upgrading equipments, redesigning layout and so on. At the same time, such improvement solutions are mutually influenced by each other. Using lead-free solder means it will be processed at 40 degree temperature higher than that of lead solder, hence the process window narrows, which compels enterprises not only to adjust old procedures but to improve the rigidity of other components and equipments. It was expected that the different respondents' characteristics lead to various strategies. Yet, almost half of respondents (48 %)

purchased new equipment – which shows also the importance of establishing demonstration lines as undertaken e.g. in the GreenRoSE project. 50 % of the respondents changed components, which goes hand in hand also with reduction of component variety, leading to leaner component management. A remarkable number of enterprises changed the layout, although most of them introduced only minor changes (see Figure 6).

2.3.2 Critical Issues

When being asked the question about the “very critical” technical issues, 40 % of respondents named processes and 23 % deemed product reliability. On the other hand, respondents who considered these issues as “critical” were 10 %, and 13 % respectively. It is worthy to point out that present unsolved issues in view of “very critical” are product reliability (18 %) and process regarded (15 %). Only one large enterprise claimed not to solve the technical issues regarding the process whereas the others stem from SMEs. As a summary, the finding highlights the three technical issues are controvertible barriers for SMEs to master the technologies complying with RoHS.

2.4. Economic Evaluation

2.4.1 Status

A prevailing opinion that the general running cost increased was defined by 62.5 % of respondents (see Figure 7). 17.5 % claimed that there was no significant economic change between before- and afterwards of RoHS. The remaining 20 % had no reply. Further for the percentage of the cost increase, 45 % of respondents said that it was up 1 to 15 % and 18 % respondents estimated that would be 16 to 30 % increase.

As for the detailed factors, it is noted in Figure 7 that the massive cost impact from the use of consumables covered 70 % of respondents. Once the enterprises are mandatory in the scope of RoHS, non-compliant consumables such as auxiliaries and operating materials have to be replaced by compliant and compatible substitutes, for instance, using tin/silver/copper instead of conventional tin/lead solder or nickel/gold instead of lead for printed circuit board coating. Without regard to the precious metals, the base metals such as nickel, copper and tin are at least sevenfold more expensive than lead, which is the cheapest base metal. Obviously materials have a significant impact on costs.

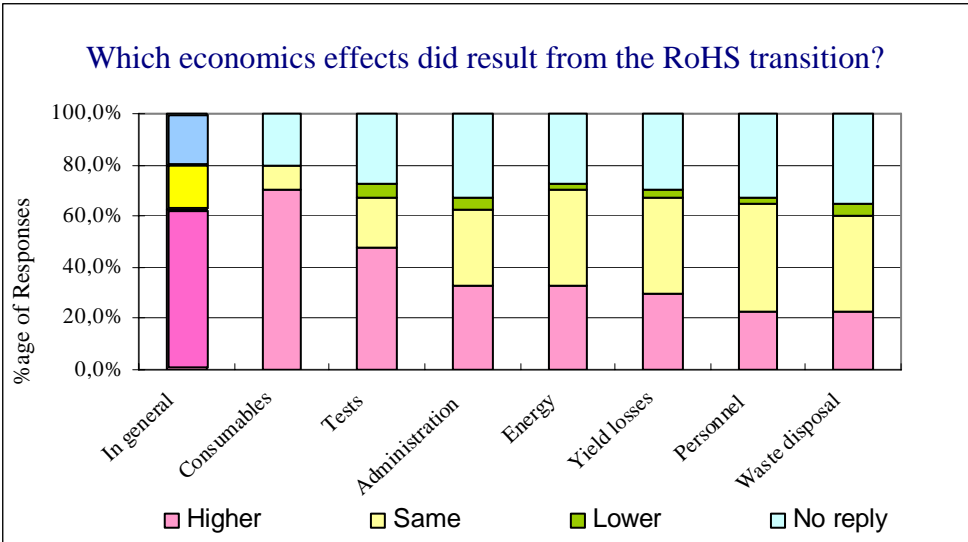


Figure 7: Costs change due to RoHS transition processes

Another significant effect of RoHS on costs results from the transition management. Nearly half of respondents (48 %) said that compliance assessments, tests for product reliability and process control, made costs higher. Additionally, the administration issues like proving RoHS compliance, the energy consumption as well as yield losses also took responsibility for the negative impacts on about one-third of enterprises. However not all respondents are influenced by the negative impact in economic

terms. Examining cost factors in personnel and waste disposal, it seems that there are relatively moderate impacts since majority respondents inclined to choose the category “Same”. The reasons for both sporadic positive and little impact in some costs factors are listed as follows. One thing is that the wastes have become more valuable than before with the shift away from lead so that it would be likely more worthy to recycle them. The other thing is that some enterprises pass the incremental price of RoHS from transition to their customers. This has been proved in the previous sections of this survey. Nearly 13 % of respondents definitely declared that they entirely put incremental costs onto customers, while 28 % stated that they would transfer in part. 38 % of respondents said they would take the full responsibility for the cost increase by themselves. For those who declined comments, it is estimated that the impacts of extra costs are still unknown because of inefficient management of RoHS transition. Contrastively, certain enterprises were not fully ready for compliance, and hence it was impossible for them to estimate the extra costs under this situation.

2.4.2 Critical Issues

As for the question about the expenses of dealing with non-compliant components since July 2006, the response rate is low: 14 out of 40 enterprises quantified their costs. Besides two SMEs, one components manufacturer and the other final producer, indicated that no costs resulted from disposal of non-compliant parts. The remaining respondents from the sectors final products such as computers, mobile or handheld devices, household equipments etc. spent between 3,000 and 300,000 Euro on disposal whereas manufacturers in soldering and electronic components sectors spent 1,000 to 200,000 Euro. In fact, how to deal with obsolete components is one of the critical issues. According to various customers affected by RoHS or excluded from RoHS, enterprises have to energize inventory and transition management in order to improve capabilities on minimizing risks from upcoming outdated products.

In order to discover the concrete costs impact from the practical implementation of RoHS, respondents should also state their annual turnover and estimate initial costs for the whole transition process such as human resources to get the process managed, equipment investment, research and development for compliant products, external assistance and so on. Table 3 highlights the link between initial time for preparation and initial costs percentage of annual turnover. It indicates that the earlier effective and reliable measures are taken, the less the costs will be spent. Some enterprises taking no action until the last minute might put maximum 15 % of their annual turnover on the conversion. These figures lead to the impression, that late action is significantly more costly than preparation in due time, showing also the importance of projects such as GreenRoSE, which assisted enterprises in timely preparation for the deadlines.

Start of transition	Ratio of initial costs / annual turnover [%]
2004 and before	0.2 % - 4.3 %
I-II 2005	0.8 % - 5.0 %
III-IV 2005	0.3 % - 6.0 %
I-II 2006	2 % - 15 %

Table 3: Correlation between initial preparation’s time and costs

Generally speaking, evaluating the economic impact is not an easy task, because it not only involves explicit and visible costs mentioned above associated with material, management and research investment but also implicit and latent costs. First, the increasing demand on metals has been accompanied by climbing prices in markets. According to the London Metals Exchange [LME 2006], nickel and copper prices jumped almost twofold in end September 2006 compared with the same period of last year. Second, the component market is moving: the availability of RoHS-compliant parts and “old” parts for exempted applications is partly critical, because either the component suppliers didn’t shift to compliant parts in time or shifted to lead-free components fully leaving the trouble of shortages in SnPb components to market segments, which are not affected by RoHS directly. This leads to highly speculative prices for some components. On the other hand, this transition leaves component suppliers also with a remarkable logistic effort, documentation and testing requirements leading very likely to rising component prices. Another cost factor is the principle risk of non-compliance. Finally, China RoHS which will come into force on 1st March 2007 is similar to EU

RoHS, even somewhat stricter than EU RoHS. The economic impact from China RoHS must be gradually attacking European market since China is one of the biggest markets in the world. Basically, compared with large enterprises, SMEs are more vulnerable to the cost effects under RoHS because of their small-scale production.

2.5. Environmental Evaluation

The vital objectives of the RoHS Directive are very clear: firstly to restrict the use of hazardous substances which is baseline for electronics industry, and then to compel enterprises to take environmental issues into considerations when designing and manufacturing products.

As shown in Figure 8, considering the four factors with severe impacts on environment, unsurprisingly energy consumption was the most frequent stated one. More than half of respondents (52.5 %) agreed on the close connections between the increasing demand of energy and improvements of manufacturing process for RoHS-compliance. One-quarter declared that they had been experienced little impact, since the businesses of them are different from the previous respondents'. Those who primarily focus on manufacturing the materials and components have to alter the non-compliant materials or/and auxiliaries to new substitutes with a higher thermal profile, which consequently leads to the increasing energy consumption. In addition, reworking and repairing of components are inevitable processes for converting the non-compliant components and consumes extra energy. As for the amount of production waste and waste water, half of the respondents considered to be slightly influenced by the RoHS transition, and 18 % regarded the influence as incremental while 8 % as decreasing. This divergence might have connections with product design, operation efficiency and recycling strategy for reducing production of the waste. Moreover, as it is already mentioned in economic evaluation, the waste has become more valuable than before because of the replacement of the hazardous substances, hence the higher the recycling rate, the lower the environmental impact from waste.

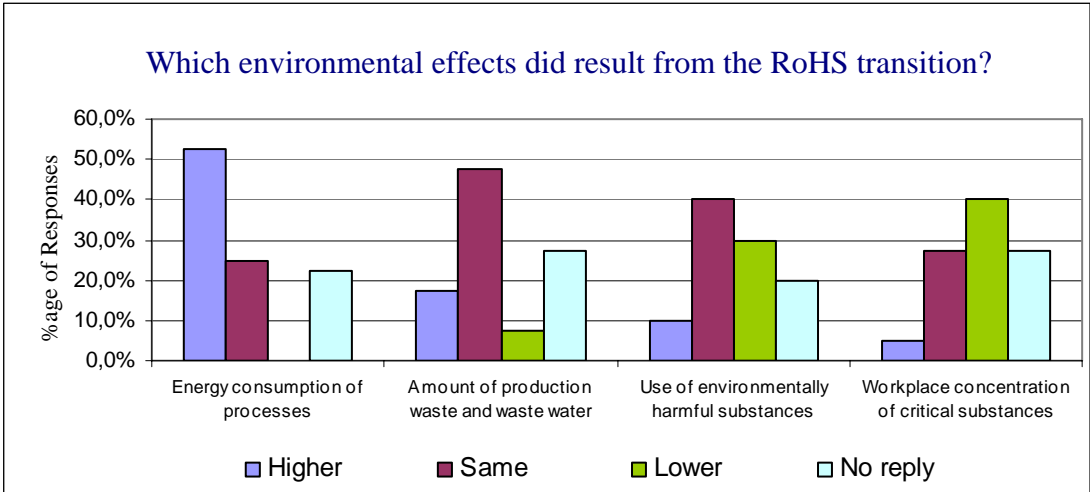


Figure 8: Environmental impacts due to RoHS

The use of environmentally harmful substances and workplace concentration of critical substances is linked to each other to certain extent. For example flux is used during soldering in order to avoid the oxidation of the surfaces and molten solder joints, and to benefit solder spreading. However, the flux usually contains critical additives or even toxic chemicals. In terms of the different physical features, the flux is substituted correspondingly with the new containing more severe additives in order to guarantee the reliability of the compliant solder alloy. This could be the reason why 10 % of respondents consider the use of harmful substances more serious than before. Similarly, if the fume produced during the heat of flux is not online extracted and cleaned, the concentration of critical substances at workplace will become higher too. For over 30 % of respondents indicating the positive impact, there is no denying that the negative environmental impact can be indeed diminished through use of clean flux and protection action as well as restriction of the six hazardous substances.

It is essential to point out that the questions of environmental issues in this survey are designed from the enterprises' understanding point of view. A precise environmental evaluation ought to be drawn with professional methods.

Furthermore, not included are the end-of-life aspects of the products themselves – which has been the major motivation for the RoHS legislation.

3. Conclusions

First and foremost, the analysis provided in this paper is a frank status report, giving reflections on the difficulties with the RoHS transition process. Numerous problems on various levels had to be solved. There are various reasons for these delays in the transition process, among them an under estimation of the general task and challenges in correlation with starting too late with transition activities. It has been found that the transition process is more arduous and longer than it was estimated. General supply chain and logistics problems are another issue.

Furthermore, another virtual finding is that a certain number of respondents' customers are located in the adjacent countries of Poland, such as Russia which is non-EU country and therefore is beyond the control of the RoHS Directive. This questionnaire lacking of information about the customers location (EU or non-EU) is exactly the shortage of this investigation, which can be one of the future tasks in the course of the GreenRoSE implementation.

Additionally, it is worth noting that the evaluation of another similar survey which has been conducted in December, 2006 in Slovenia has also been finished. 271 questionnaires were distributed, and only 16 responses were received. The response rate is merely 6%. Although these two investigations are carried out in the different time period, the status of RoHS transition process in Slovenia does not differ significantly from the analysed status of the Polish industry. Surely, in the progress of two months, the general status in Slovenia is slightly more advanced than that in Poland.

Finally, the GreenRoSE project undertook numerous efforts and activities to support SMEs in transition management – and the enterprises appreciated the various resources for information and assistance -, however, this could not solve the transition problems fully.

For some success stories, how pro-active Polish enterprises such as the PCB board manufacturer ELDOS managed the transition and the specific problems they faced, see the project website of GreenRoSE.

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