ECOLIFE II
ECO-efficient LIFE-cycle Technologies
From Products to Service Systems

Summary Report

State-of-the-Art Technology in the Electronics Industry Innovation System

Dialogue, Strategies and Tools towards Sustainable Development

Contract N°

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CONTENT

1. Conceptual Framework

1.1. Background of the Approach

Following a comprehensive “Innovation System Approach” ECOLIFE II focuses on the product-service life cycle of electr(on)ic products, and reflects the fact that in an Innovation System key players in all of the various stages of the product-service life cycle – component suppliers, product manufacturers, service and logistic providers, processing industry etc -- are involved in the innovation process.

The shift from environmental sound technologies to sustainable growth requires the co-operation of most of these actors in the Innovation System. The WEEE and other elements of the legislative context (IPP, EuP, RoHS, etc.) have proven to be key drivers for this movement. But complexity of innovation has increased over time. In the past, mainly as the result of the announced WEEE directive, single technologies such as separation technologies, (semi-)automated disassembly devices have been developed to take care of selected problems at the End-of-Life of electr(on)ic products.. Today, we are talking about systems innovations, involving all key actors, requiring parallel R&D processes, setting up new business models, and experimenting with new property rights models (like leasing), especially in the main area of ECOLIFE II, the so called “Product-Service-Systems”.

1.2. Technologies addressed in the report

With this background several aspects of the Electronics Industry Innovation System are crucial for ECOLIFE II as far as “technologies” to move towards sustainability are concerned:

- The methodologies, tools and technologies have to be compatible with the challenges of sustainable growth through improving design and use of renewable / recyclable resources;
- They have to increase the functionality and service value of electr(on)ic products, to reduce material intensity in the whole life of products and to reduce time-to-market of new high quality goods and services;
- They have to extend the life and optimal operation of products through new maintenance, repair and refurbishment schemes;
- They have to improve disassembly, recovery of waste (including new treatment processes), re-utilisation and safe disposal of waste as an integral part of a life-cycle approach;
- Finally they have to focus on the provision of flexible, interoperable supply-production-distribution-End-of-Life systems for quality and customer-driven product design and manufacturing.

Regarding these requirements, ECOLIFE II refers to “Technologies for sustainable Development in the Electronics Industry Innovation System” by defining them as

all measures, instruments and (management) tools, both hardware and software, helping to move the Electronics Industry Innovation System towards sustainable growth, i.e. meeting the requirements of the triple bottom line of economic, ecological and social improvements in the Electronics Industry.

A brief analysis of the main characteristics of the present situation within the Electronics Industry Innovation System shows that 3 categories of “technologies” are to be differentiated:

- **Dialogue**

In a knowledge-based economy, innovation is a result of a constant flow of both formal and tacit knowledge within an innovation system. It strongly depends on the effective organization of learning processes by facilitating trusted contacts and interrelations between the innovation players. Especially the genesis and implementation of sustainable innovation requires an extensive co-operation and calls for an intensive Dialogue and an open communication platform between the players involved.

With this background the first category of technologies to focus on are instruments of Dialogue. With these instruments the Electronics Industry Innovation System will overcome the problems of co-operation barriers by facilitating interactive learning among different innovation actors.

- **Strategies**

In a complex innovation system, many incentives (that are also referred to as “key drivers of innovation”) play an important role to move the innovation actors in a certain direction, and to encourage them to develop certain economic, technological or social measures. Needless to say the key drivers of innovation in the Electronics Industry Innovation System are formed at the legislative or regulatory context (i.e. the WEEE, the RoHS, IPP, EuP, but also the upcoming European Chemistry Legislation, The Product Liability Laws, Norms, Standards, etc). But also intrinsic incentives (i.e. to make profit) are present, accelerating or strengthening the incentive impacts of the regulatory context, of market demands, or even of the technology push phenomena of the innovation actors.

Since there is always a broad spectrum of solutions to comply with extrinsic regulatory drivers or to put intrinsic drivers into practise, the players of the innovation system (re-) act by making plans, and by setting up strategies to gain primarily economic and competitive advantages. With new ideas coming up as the result of an intensive discussion about “Greening the Industry” following the Brundlandt Report, huge environmental accidents with hazardous substances (Brent Spa etc.) exposed to the environment etc., industry also started with cognitive innovations (thinking green) and experimenting with double dividend projects by putting eco-efficiency into practise.

In this context , the second major category of technologies to report on are instruments of strategy, methodologies and plans to keep in line with sustainability requirements like de-materialization, de-toxification, and de-energization. Strategies in this respect are more than the application of a software tool; it is also the organizational and institutional setting in which the application of tools take place.

- **Tools**

The third category of technologies is the most visible ones, the instruments covering a certain scope of problems of sustainability like evaluating the eco-efficiency of a certain process. These normally have a limited scope as it is clear that a tool to support decisions on economic, technological, ecological or social measures cannot cover the complexity of the interdisciplinary context. So it is obviously that the Electronics Industry Innovation System needs a toolbox with manifold instruments in place to help innovation actors to move towards sustainability. This toolbox may also be the most critical one as the outcome of decision tools are very important to produce reliable and valid information on the road to sustainability.

Since ECOLIFE II focuses on the whole life cycle of electronic products, these three main categories

- Dialogue
- Strategy
- Tools

will be explicitly embedded into the main stages of the life cycle of an electronic product, i.e.

- Design
- Manufacturing
- Use
- End-of-Life
- Management

understanding “management” as a horizontal task throughout the life cycle.

Figure 1 gives an overview of the conceptual framework used as the basis for this report:

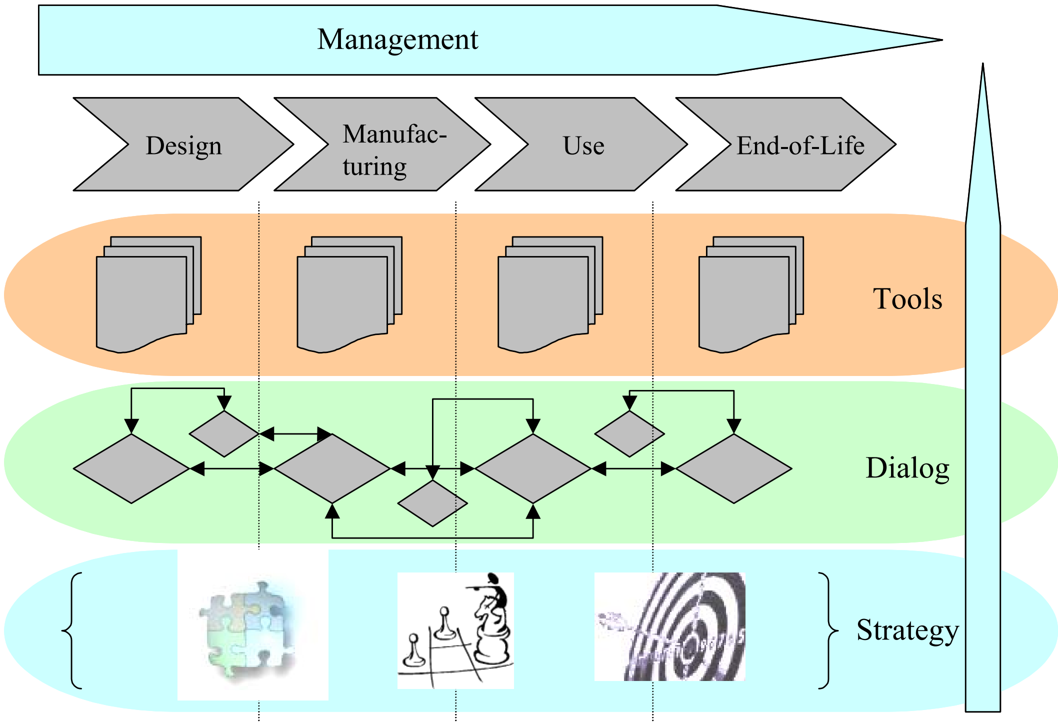

Figure 1: Conceptual Framework of D7

To evaluate the technologies in view of sustainable development in the Electronics Industry, a Sustainability STS Scorecard (STS Approach) is used.

2. Technology evaluation methodology

STS is based on a technometric approach as a method to determine primarily the technological and economic performance of technologies, and to define, ascertain and process performance indicators of technologies. While traditional technometric methods primarily aim at comparing national economies on the basis of technological parameters and the scope is restricted to contribute to the early recognition off the technological and economic potential of such technologies, the STS approach in ECOLIFE II is used to evaluate the State-of-the-Art of the technologies (dialogue, strategies, tools) with respect to their contribution to sustainable growth in the Electronics Industry Innovation System. Therefore additional indicators are used beyond technological performance indicators to describe, whether the technology indicates a move towards sustainability (see chapter 2.2.2.).

The ECOLIFE II STS Approach is based on a S-curve thinking for the evaluation of a technology performance:

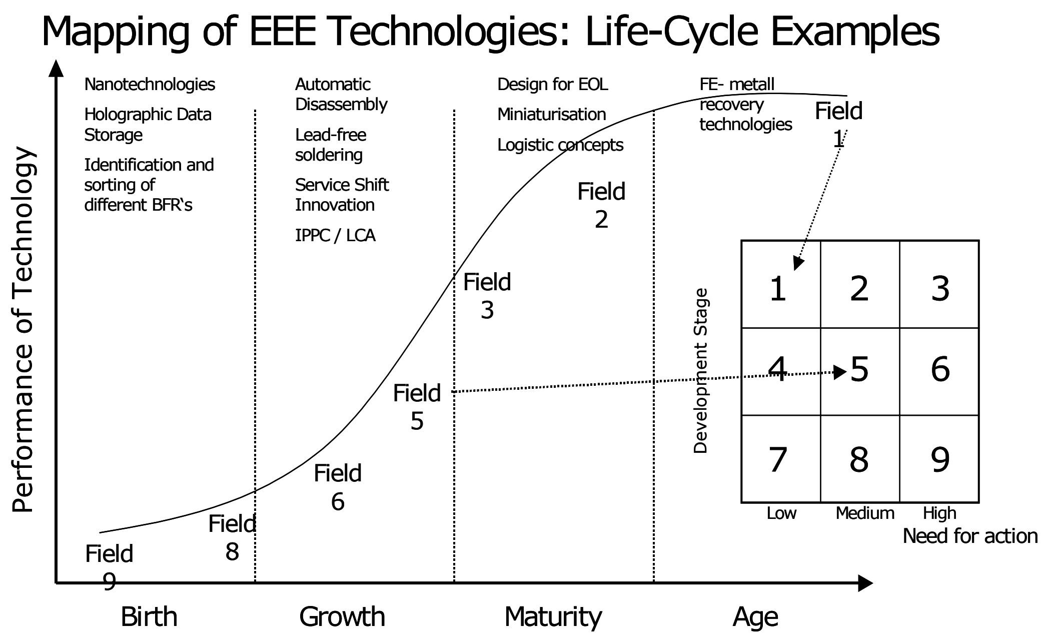

Figure 2: Examples of EEE Technologies according to the S-Curve

To illustrate the position of a technology, portfolio matrixes are used with two evaluation axis:

1st axis: Life Cycle of the technology according to performance and related to

- Birth (is the technology only to be found in scientific basic research?)
- Growth (is the technology yet in industrial or applied research?)
- Maturity (is the technology almost adopted and/or diffused in industry?)
- Age (has the performance of the technology almost reached it‘s peak?)

2nd axis: Need for action (NfA) to further develop the technology to contribute to sustainable development (SD)

- High NfA: the technology promises to contribute to SD very much, adoption of industry is most likely; eco-efficiency is high....
- Medium NfA: technology potentials are not clear by all means, expected eco-efficiency is medium....
- Low NfA: existing technology that has already reached it‘s peak, expected eco-efficiency of new technology is low....

2.1. Indicators to evaluate the Need for Action to further develop a technology towards sustainability

Since the positioning of a certain technology on the S-Curve may be an easy task to do, the evaluation of the Need for Action with respect to sustainable development might be ambiguous because the actors involved may not share the same norms and culturally based systems of interpretation, and may use different systems of evaluation reference according to their interests. Thus intensive discussion is needed to evaluate the contribution of a certain technology to sustainable development.

In the ongoing debate of indicators for sustainable development a consensus on indicators is not in sight, except for agreement on very abstract principles not directly applicable for a specific Innovation System like the Electronic Industry supply chain. These principles are often referred as to the Brundtland principles

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

A specific innovation system like the Electronics Industry needs a certain break-down of these principles into specific and operational indicators. These indicators are manifold and have at least to provide information on the three areas of sustainable development:

- economic improvement
- ecological improvement
- social improvement

This is also referred to as the triple bottom line (TBL) of sustainable development. ECOLIFE II also refers to this TBL as the mandatory rule to evaluate technologies with respect to their contribution to sustainability.

Obligatory indicators used in ECOLIFE II with respect to the mandatory TBL are:

Economic improvement

- Efficiency of the Technology, i.e. a certain positive relation of costs and benefits in monetary terms)
- Productivity of the Technology, i.e. a certain positive relation of output and input in quantitative terms)

Ecological improvement

- De-Materialization, i.e. a certain positive relation of output and input in quantitative terms like resource efficiency (materials, water…)
- De-Toxification, i.e. a certain decrease in the amount of hazardous substances
- De-Energization (or de-carbonization), i.e. improvement in the energy-efficiency

Social improvement

- Encouragement of learning and education in the society
- Improvement of the job security of employees involved
- Improvement of their health security of employees involved.

Within the hierarchy of indicators there are in addition several **recommended indicators** to put the obligatory indicators into practice. These indicators may differ from each other according to their application area.

Since ECOLIFE II does not work scientifically on the further development of indicator systems for sustainable development, the above mandatory and obligatory indicators are used more qualitatively to address the problems of sustainable development in the Electronics Industry. In this context, it should be stressed that the ECOLIFE members who worked on the State-of-the-Art report Technologies agreed on the fact that the indicators used to evaluate the technologies served primarily as a catalyst for discussion within the network, and not as a stringent scientific framework.

3. Design

In June 2002 a comprehensive Eco-design Guide was published as the result of the previous Thematic Network ECOLIFE I: "Closing the loop of electr(on)ic products and domestic appliances. From product planning to End-of-Life technologies". This guide contains 24 case studies from the European Electronics Industry illustrating general eco-design principles (like life-cycle thinking, eco-design process, tools and methods, strategies, Dialogue and partnership). The guide is publicly accessible and can be downloaded from the website http://www.ihrt.tuwien.ac.at/sat/base/ecolife/index.html.

In addition ECOLIFE I provided deep insights into Eco-design related tasks, mainly the design implications of End-of-Life processing and the role of components as significant elements toward a final realisation. As a result of ECOLIFE I additional questions arose which were picked up in ECOLIFE 2 and will be presented in this first Technology.

In the area of Dialogue, special attention is paid to the Eco-design relationships to suppliers asked how to secure design requirements within the supply chain of the Electronics Industry Innovation System. For the Strategy section, the state-of-the-art of DfX is described (X stands for X=Environment, X=chemical content, X= disassembly) as well as strategies to integrate DfX into conventional management systems and into the product development process. On the level of "materials", some issues of hazardous materials and renewable materials are tackled. Finally in the Tools section, the actual developments in LCA and LCE, databases, teaching curricula, environmental benchmarks, new substrates for PCB, halogen-free and new flame retardants are described.

3.1. STS evaluation of the different technologies Design/Dialogue

All of the supply chain work has identified a core of key issues related to the implementation of eco-design within the supply chain:

- Many companies are not aware of the forthcoming legislation, and for those who are it is not well understood
- Suppliers are beginning to communicate the requirements of these directive and general issues related to eco-design but only to those high up in the supply chain (1st or 2nd tier).
- Supply chain pressure is more of a driver than legislation at the current time.
- Information exchange is key to the success of eco-design along the supply chain.
- Easy to use tools and information are needed if eco-design is to become a feature of everyday design and manufacture.

There are a number of initiatives within the European Electronics Innovation System that are furthering eco-design in the supply chain. Those that have already been completed have shown potential but those that are current underway or planned would seem to offer better opportunities to demonstrate the business advantages of eco-design.

With this background for the positioning of **"Eco-design with suppliers"** within the STSs matrix the following issues seem crucial:

According to the **stage of development** the "technology" as indicated by the principal measures of Dialogue to suppliers, and embedded tools for the benchmarking of suppliers has already reached industrial application (first adoption within case studies) although a broad diffusion of the technology has not yet happened.

The **need for action** to further develop the technology for sustainable development in the electronics supply chain however proves to be high:

What is needed are more good, industrially relevant case studies on eco-design supply chain management: case studies that not only show the results of eco-design activities but also case studies that document the steps that were taken and the tools that were used to achieve theses results. At this time there is a lack of good industrial examples but this should change within the next 2 years. With the deadlines for legislation coming closer regulation will begin to play a more important part in eco-design, but at this stage the supply chain is still the most effective driver.

Large companies need to be engaging their suppliers and customers in forward thinking projects that offer support, information exchange and the chance to network. To develop truly 'eco-designed' products it is essential that all players within the supply chain are involved. We are not yet at this stage but things will change in the near future.

The key needs to develop and promote eco-design in the supply chain are:

- Better communication between customers and suppliers
- The development of eco-design standards and requirements along the supply chain
- Eco-design requirements to become part of the standard supply chain agreements and contracts
- Easy to use tools and methods that do not require specialist expertise and that especially integrate the supplier's environmental performance to his turnover
- Clear, industrially relevant case studies on Eco-design supply chain management

Improvement of Dialogue and tools in the area of Eco-design with suppliers will substantially improve the greening of the entire supply chain, especially if a linkage between environmental performance and purchase turnover will be implemented within tools or benchmarks that will move the supply chain towards sustainability. High eco-efficiency effects will be attainable because a reduction in the environmental load of parts and components will correlate with a price reduction in purchased goods. A feasible value-added for sustainable EEE will be realized, at least within the two dimensions of economics and ecologics. Because of the double dividend aspects, a broad diffusion seems to be possible within a relatively sizable timeframe. Social improvements may occur if reduction of material resources within the supply chain also includes hazardous material, which is clear for all material tackled by the RoHS.

The **stage of development** of the technology **"Management of eco-cost reduction"** is more or less to be located in theory and in basic research. Applicable tools are not yet developed. The need for action is to be scored as medium to high, since it makes sense to spread the idea of double dividend mechanisms throughout the supply chain by linking the resources consumption in manufacturing processes to the corresponding environmental load with purchase negotiations. Problems may occur in data accuracy and reliability according to the mass balance of suppliers necessary to evaluate the amount of resources decrease possible and the corresponding potential of cost reduction. Thus the chances for implementation of such tools may be ambiguous. In this field, additional research and case studies seem to be necessary.

For **"Information dissemination to SMEs"** the stage of development should be classified as "Market Adoption", since a lot of tools (either web-based or "classic information and decision support systems) are available, though they might be far away from a broad diffusion to, and continuous recognition by, SMEs. The need for action may be qualified as high, since a more intensive recognition of environmental related information through SMEs is crucial. From the experiences with eLCA it seems that further development necessary for dissemination does not definitely mean more information but tailor made information according to the special situation of SMEs.

Figure 3 Summarises the discussion concerning technologies of Dialogue / Design:

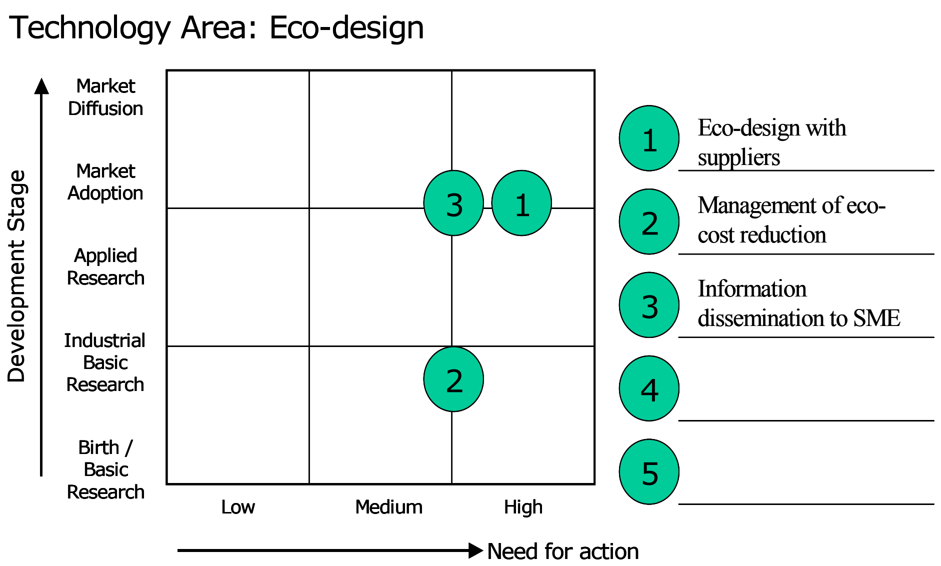

Figure 3: STS Evaluation of Dialogue Technologies in the Area of Eco-design

3.2. STS evaluation of different strategies for Design

In the table below the various items of Eco-design have been positioned with respect to awareness and the perspectives of the new green circle:

Perspective / Item	Awareness	Organisation of processes, engineering	Company / Business perspective	Consumer perspective	Societal perspective	Overall score
Eco-design level 1, 2	+++	+	++	0	++	1.6
Eco-design level 3, 4 (Paradigm shifts)	++	+	+	0	+	1.0
Supplier integration	+	0	0	0	0	0.2
Green marketing and sales	++	+	+	0	0	0.8
Quality/ reject	0	0	0	0	0	0.0
Overall score	1.6	0.6	0.8	0	0.6	–

Table 1: Where do we stand and where to go

In *Table 5* indications have the following meaning:

+++ = well addressed
++ = sufficiently addressed
+ = insufficiently addressed
0 = not addressed

The overall score is an average of the various columns.

Table 1 show that only awareness about Eco-design is on level 1 and 2 is well addressed. Awareness that level 3, 4 should be addressed as well as that green marketing and sales are an integral part of Eco-design is still sufficient. The supplier aspects ("chain management") score insufficient in terms of awareness, whereas it is not realized at all that Eco-design can be an important issue when combined with quality.

In terms of the overall score, only awareness and Eco-design on level 1, 2 have currently developed in such a way that it can be said that these are just sufficient.

In all other cases there is still a long way to go. Eco-design level 3, 4; green marketing and sales, organization of processes/engineering, company/business perspective and societal perspective got off the ground but have still to be developed much further. Supplier integration, and consumer perspective are still in their infancy.

In terms of STS evaluation, **Eco-design** – as far as level 3 and 4 methodologies are concerned – is obviously in an early industrial adaptation stage. A rough estimation of what has to be done to further develop Eco-design as referred to the basic indicators described above leads to a high score for “Need for Action”, since an in-depth embedding into the business of OEMs and the innovation processes along the supply chain will increase ecological and social benefits and – as long as the double-dividend effects are still to be expected – economic benefits.

For **Design for chemical content** the STS evaluation is based on the fact that controlling chemical content will become more and more decisive for the electronics industry supply chain facing the RoHS, the EU white paper on a Strategy for a Future Chemicals Policy, PVC bans etc. Again, the suppliers and customers perspective is supposed to be in an early adaptation stage, and the Need for Action accordingly high, since an elimination of hazardous chemicals out of the supply chain will dramatically increase ecological and social benefits.

For **Design for END-OF-LIFE / disassembly** the STS evaluation depicts a slightly different diagnosis: tools are well developed and are located in an advanced adoption stage. The medium score for Need for Action is not justified with respect to more industrial research but with respect to practical implementation efforts to be done. According to the mandatory sustainability indicators, design for END-OF-LIFE is still to be evaluated. Manual disassembly is very costly, and can therefore be applied only to a limited number of product categories. Furthermore, disassembly in most cases has to be subsidized or even cross-subsidised, which might be difficult in competitive recycling markets. Finally the in-depth disassembly might not gain environmental benefits, since the energy to be spent on the disassembly process might exceed a reasonable amount.

For **modularisation** the STS evaluation leads to the following picture:

Modularization and Product family strategies are widely applied in many industries. Manufacturers of standard desktop PCs are all using a modularized product architecture comprising standard components that fit together through interface standards. Car manufacturers have for a long time been utilizing product family strategies to utilize components and sub-assemblies for different car models with a streamlined production using standard components resulting in a variety of models in the marketplace.

The basis behind product family strategies is to combine and balance industry's external need and to satisfy customers demand for tailor-made products with industry's in-house need for efficient manufacturing using standard components. No environmental focus is originally present in this strategy. However, a product family strategy will apparently increase the probability for standard components and sub-assemblies to be included in a closed loop material flow, depending on how collection and reverse logistics are routed, introducing environmental focus as a major focus among the product family benefits.

The research community is currently looking into identifying generic characteristics that are valid for all industries. This includes methodologies and tools that identifies and estimates the degree of commonality and variety within a product and a family of products. Thus, modularisation and product family development is plotted on the applied research/market adoption development stage with a high need for action.

Figure 4 depicts the portfolio of Strategies within the Design phase of the Electronics Industry innovation process:

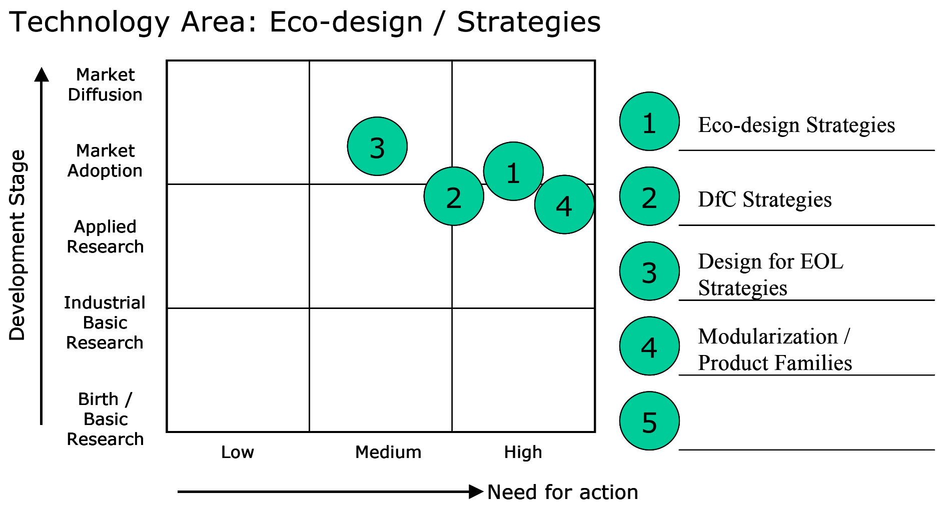

Figure 4: STS Evaluation of Strategy Technologies in the Area of Eco-design

3.3. STS evaluation of LCA/LCE and related issues

LCA is no longer an academic issue today. Many large companies conduct LCA studies to analyze their systems/products and let their results influence new developments. Nevertheless, of the thousands of electrical and electronic products that have been put on the market in Europe to date, only a tiny percentage have had any form of LCA of LCC carried out as part of their design and development. The use of LCA from SMEs is still quite rare, but due to the pressure from OEMs, future directives, (e.g. the EuP) and the fact that high quality background data will become more and more available on a broad basis and relatively low priced, LCA will become increasingly accepted.

For the STS evaluation LCA for SMEs will therefore be distinguished from LCA for large-scale companies, as the diffusion of SME compatible LCA is far away from a broad application, whereas LCA in large-scale companies is supposed to have been adopted. .

On the other hand, the **need for action** to further develop LCA can be described more or less precisely:

Need for simplified LCA

Several constraints are to be tackled in future research and development to improve the applicability of LCA especially in SMEs. Current work on LCA has shown that for many companies the reasons that LCA or LCC is not widely used are:

- Lack of understanding – companies are not sure what LCA really is and what it can be used for
- Lack of data – LCA data is not available for many materials
- Complexity – the expertise needed is not readily available to smaller companies
- Time – complete LCAs take a very long time. In many cases the product is on the market before the LCA is actually completed
- Cost – many companies find the high costs of LCA prohibitive
- Presentation of results – sometimes these can be very complex

Some of these drawbacks, such as complexity and the amount of needed resources, can be eliminated by using simplified LCA, which would also allow SMEs to run competitive studies using LCA methodology. However, many companies are interested in the principles of LCA and will undertake simplified studies. The main advantage is that they take less time, cost less money and use techniques that are more readily available to smaller companies. These simplified studies normally use standardized data sets, which reduce cost and complexity, and present the results in a much simpler way. A number of independent consultancies offer these simplified studies.

If the use of LCA is to become more widespread then:

- More LCA database need to be made available
- Sector specific guidelines must be developed
- Better documented and simplified tools and methods are required
- More training and awareness raising is important
- Supply chain initiatives for the development and sharing of Life Cycle data should be developed

The industry needs to develop more easily accessible life cycle data and the future of LCA and LCC for SMEs is definitely in the simplified and abridged studies. The diffusion of LCA among SMEs still has a long way to go, and more efforts need to be invested if the methodology can be used by companies.

Implementing LCA into DfE

The methodology of DfE integrates the environmental aspects directly into the internal design process. Therefore DfE should serve as an environmentally fast decision support system for products under development. DfE is a methodological framework for environmental decision support which has to be adapted to the specific needs of its application field. Thus, a DfE tool for the electronics industry cannot be the same as a DfE tool in other branches such as the automotive, building or ship industry.

Because of its integration to specific applications, DfE uses the system structure and the wording of the designer. As the designer normally focuses on special parts, components or subassemblies of a product, the DfE tool should not treat him with modelling the life cycle of the product or the calculation of material and process inventories as required in a LCA. Therefore DfE tools offer a user interface that is related to the designers' daily work. The calculation of the environmental consequences of changes in design are calculated by using data sets and methodologies which are already stored in the DfE database that is derived from LCA data. Achieving this implementation into the designers' daily workflow the designer is able to asses the environmental consequences of different design alternatives without being a LCA expert.

Because of the usage of already developed data sets and high aggregated models, the transparency of environmental impact related DfE results is not as high as the transparency in LCA. The modules of components or processes under the designers' consideration certainly reflect the environmental profiles, but at a very high level of aggregation. Therefore, a detailed investigation for the main drivers of the overall impact of those single 'black box' modules is not possible. However, this detailed analysis is usually not in the scope of the designer but more in the interest of the environmental expert. As the designer needs material data as well as the environmental loads of production processes, cradle to gate date of materials and manufacturing processes are connected between LCA and DfE. Thus, it is part of LCA to create the cradle to gate material or manufacturing process data and then transfer them by programmed interface from the LCA/LCE software to the DfE tool.

DfE must be able to deal with technical parameters that consider the dependencies of design choices, of the manufacturing phase, of the use phase, of the End-of-Life phase and of dependencies between these phases. To cope with these requirements DfE needs more criteria than LCA, for example the product structure (e.g. for assembly and disassembly dependencies), kinds of joints of parts and components, as well as their effects on End-of-Life.

Many projects and approaches are dealing with developing DfE tools. But currently there is not a tool available, that fully covers the described features, also allows the consideration of the not yet discussed points, such as reducing toxic dispersion or increasing the service intensity of goods and services.

Improving databases for LCA

Instead of having a national initiative of collecting life cycle data and normalizing it, European industry is focusing more on identifying relevant indicators to reduce the amount of data, and then collecting product and company specific data. The challenge is to fill the most interesting data gaps, which will be identified by industry, and after then defining a strategy for future LCI data collection.

Beside actual LCA software tools(that, for example, provide graphical interfaces and display, database interface, calculation procedures, modelling options, user interfaces, impact calculations, parameter implementation and variation, analysts etc.), the more important part of the LCA application-software is the **database and data sets**.

The general quality of data requires information about the time relation (e.g. how is a database developed), geographical coverage and technical coverage. This information and its documentation rely on the precision, completeness, representativeness, consistency and the reproducibility of a study. **Appropriate** data depends on the reliability and trustworthiness of a study and its results. **Availability** of data depends on the feasibility of conducting a study and on the details of modelling. **Homogeneity** of data depends on the balance of the results. In particular, background data (e.g. data for energy provision, material processing or transports) and foreground data (data for the focus of the study, e.g. data from an assembly line, if the focus is on assembling a product) of a study are often misbalanced, which means that the focal issues are analysed too much in detail, but the background data are averaged or even estimated.

Life Cycle Engineering: integration of economical and social indicators into LCA

The implementation of cost aspects into LCA -- the LCE approach --is state of the art and some LCA software tools already offer this functionality. Against the background of sustainability assessments, social implications are a future oriented requirement for LCA and

LCE. As the quantification of social impacts is quite difficult to cope with, and as there is no common agreement among experts, authorities and other interested parties, about which social criteria to consider, a commonly accepted solution is not yet developed. The way to define a method and criteria for sustainability assessment will be crucial.

The GaBi4 version offers a first step in this direction through the implementation of Life Cycle Working Time (LCWT) that quantifies selected social aspects. This quantification is in relation to the system modelling, the functional unit (work time per process step) and follows similar lines to LCE, and the conditions, structure and modelling of LCA.

Environmental Benchmarking

The hypotheses of RF and RDA metrics to contribute to improvements in eco-design are at the present subject of basic industrial research.

Need for action: The testing of the hypotheses in table 10 will be an important part of future research regarding the use of MEBDA metrics. Apart from this, further work on the MEBDA metrics will include:

Further use of examples for fine-tuning of RF and RDA;

- Investigation of additional, potentially meaningful metrics;
- Interviews with prospective users of MEBDA metrics (environmental managers, strategic management) to find out what type of metric and representation has the most appeal;
- The elaboration of the Band Width Indicators in the future.
- The applicability of these, and other, benchmark metrics, especially in relation to their potential to communicate the intended message.

Positioning in the STS portfolio

LCA makes a relevant contribution to sustainable development not only because of its typical "Life cycle thinking" approach in terms of scientific results, but also because of its systematic approach to environmental burdens. The effect of an action taken to face one single problem (for example replacing one material because of its level of emission during the END-OF-LIFE treatment) can lead to worse problems in other phases (for example higher energy needed for the production of the new material). The LCA gives the possibility to look at the overall picture and make the best choice. Also, there are efforts today to integrate other issues and impact categories in the LCA such as economical and social issues.

The development stage of LCA for large-scale companies can be considered as being in the phase between "Growth", as we have evidence of both industrial and applied research, and "Market Adoption". For SMEs, industrial application is far behind and additional research and development problems have to be solved. So the need for action can be defined as High for SMEs, as the potential is not exploited yet, and the diffusion of this methodology for SMEs is still difficult. At the same time, expected improvements of the mandatory sustainability indicators are very high since a broad application of LCA also within SMEs will dramatically shift the orientation of designers towards DfE and will show up in resources reduction as well as improved energy efficiency of products, etc.

For “Implementing LCA into DfE” the need for action is still medium to high a poor linkage of these tools. The issue “Database on materials” is depicted as high need for action since a reliable database is crucial for the further dissemination of LCA tools.

LCE as referred to a full integration of technical, economical and social criteria into LCA is still an issue of basic research: the need for action is evaluated as “high”, assuming that a breakthrough in solving the related problems will dramatically increase sustainability in the Electronics Industry.

In view of the STS portfolio, MDBA environmental benchmarking is defined as being at a basic research stage, the need for action is medium, since there are expected to be further methodological problems that will hinder the application and diffusion of environmental benchmarking.

Technology Area: LCA and related areas

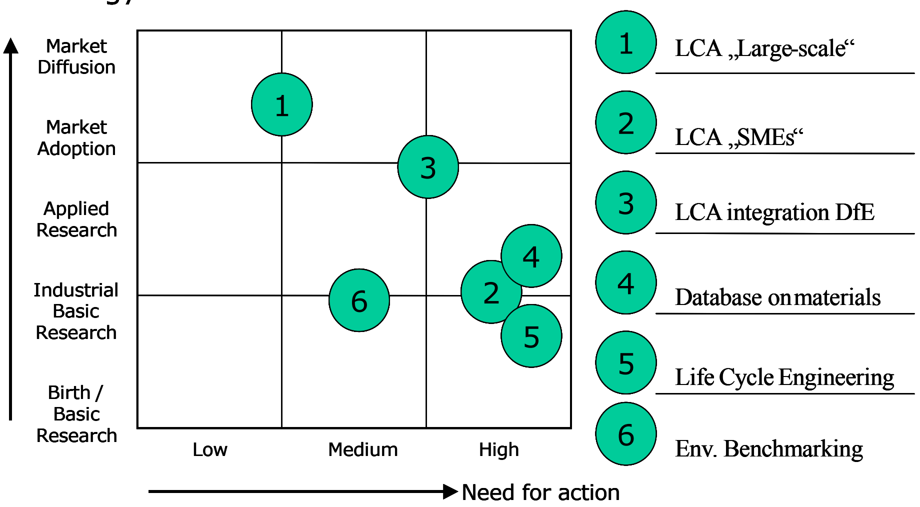

Figure 5: STS Evaluation of LCA/LCE and related areas

3.4. STS evaluation of New Substrates and Renewable Materials

Alternatives to the traditional FR4 laminate exist. The alternative laminates have slightly different technical properties, but causes few or no problems when used in the electronics products. However, the long-term experiences from using the new laminates are still missing. Some producers have started to use the new laminates in certain products, but the major break-through is still to come. Therefore the stage of development can be classified as ‘Market adoption’. The major obstacle today is perhaps the price difference compared to the traditional laminate. The need for action is therefore to be classified as being ‘Medium-high’, primarily related to a need for increase of volumes and associated reduction the prices of the laminates

Efforts are currently underway to eliminate hazardous substances in production, primarily elimination of lead. There is no doubt that multinational electronic manufacturers are currently aiming at introducing lead-free solders. SMEs, on the other hand, find this shift in technology as being relatively hard to pursue. Many companies consider the new materials and the new combinations of existing materials as a challenge to manage. Therefore the development stage can be stated as ‘Market adoption’, considering that the large companies are striving to eliminate lead at least for certain products. The need for action would still be characterized as ‘Medium-high’ as there is a need to support SMEs adopting the new lead-free solders.

The potential environmental gain of introducing biopolymers seems considerable. The application within the electronics industry is, however, currently limited. Therefore the development stage is to be characterized as ‘Industrial/basic research’. As the environmental potential seems considerable, but the potential for application in electronics products is still unclear, the need for action can be characterized as ‘Medium-high’.

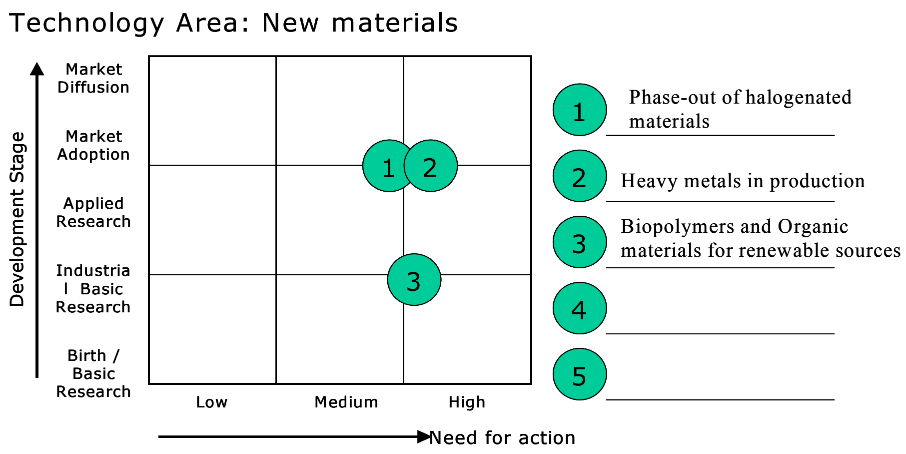

Figure 6: STS Evaluation of Materials

4. Manufacturing

This section describes the STS evaluation of the Manufacturing area of the Ecolife II project. The **strategy section** describes the state-of-the-art within manufacturing strategy innovation system including new strategies for manufacturing gaining competitive advantage. The **new innovative manufacturing technology section** describes promising manufacturing technologies that can significantly contribute to a future sustainable manufacturing practice in the electronic industry. In the **tools section**, innovative developments in different tools for analyses and improvements of manufacturing systems (both individual subsystems and as a whole) are described.

4.1. Definitions

Intelligent manufacturing

Intelligent manufacturing is the intelligence built into the manufacturing system, e.g. measuring points that contribute to uncover obstacles in daily production.

Manufacturing technology

Manufacturing technology is technology and tools used in the production.

Material flow

The material flow is the flow of materials, semi-manufactured goods, standard parts, components and products through a company from supplier to customer.

Manufacturing systems

Manufacturing systems include the people, organizational and technical structure as well as the interface and connections to the environment.

Simulation in production

Simulation is the technique of using representative or artificial data to reproduce in a model various conditions that are likely to occur in the actual performance of a system. This includes the planning and organising of the manufacture of the product and the operating environment of the product

4.2. STS evaluation

Impacts of EU legislation on manufacturing

In terms of STS evaluation, the WEEE and RoHS directives have recently been implemented. The deadlines for follow up are:

- Directives commence – 27 July 2004
- Producer Responsibility – 13 August 2005
- Meet collection target – 31 Dec 2006
- Meet recycling targets – 31 Dec 2006

The practical consequences for the electronic industry are presently unknown, but will become visible during the following months and years. Consequently the impacts of EU legislation on manufacturing are plotted in applied research/market adoption with a high need for action. Investigative actions are needed to understand the consequences of WEEE and RoHS for the electronic manufacturing industry, and to verify their consequences according to their intentions.

Lead-free soldering

Lead-free soldering has been on the basic research agenda for some years, and seems overall to be solved in a theoretical way. The theoretical results are being implemented into industrial use in the electronic manufacturing industry. Although the results seem promising, the consequences on e.g. efficiency in industrial application are not known.

Thus, lead-free soldering is plotted on the applied research development stage with a high need for action.

Eco-efficiency in Manufacturing

Eco-efficiency has also been on the basic research agenda for some years. Several definitions of the interpretation of the concept of eco-efficiency have been made. However, there seems to be a lack of common understanding of eco-efficiency as an operational strategy for manufacturing. Furthermore, there is also a lack of agreement on how to measure eco-efficiency as an indicator and I n its interpretation. Some of the eco-efficiency initiatives are being developed and tested in industrial application, and the number of initiatives is growing.

Thus, eco-efficiency in manufacturing is plotted on the Industrial basic research/applied research development stage with a high need for action.

Cleaner production

Cleaner production is a rather mature theoretical concept. Cleaner production in a manufacturing context is a strategy for continuous improvement of in-house manufacturing processes and activities with the goal to reduce a manufacturing facility's overall environmental load. Such initiatives are being promoted to industry and strategies and are being disseminated around the industrialized world, as well as in developing countries.

Thus, cleaner production is plotted on the Market adoption/Market diffusion development stage with a high/Medium need for action.

Rapid manufacturing

Rapid manufacturing of finished products is a technology that is currently at the birth stage. Industrial applications have been made within the area of rapid prototyping. Thus the technology is applied to the manufacture of prototypes during product development. Large scale manufacture of tailor made products is not industrialized.

Thus, Rapid manufacturing is plotted on the Birth/basic research development stage with a high need for action.

Virtual manufacturing

Virtual manufacturing is a well proven technology with a growing adoption in all areas of the manufacturing industry. The development of the technology follow the development of computing power of the PC industry where more powerful PCs give room for more complex and demanding (simulation) models. The development trend is to include new aspects in the model making the model behavior converge towards the behavior of real objects.

Thus, virtual manufacturing is plotted on the Market adoption development stage with a high/medium need for action.

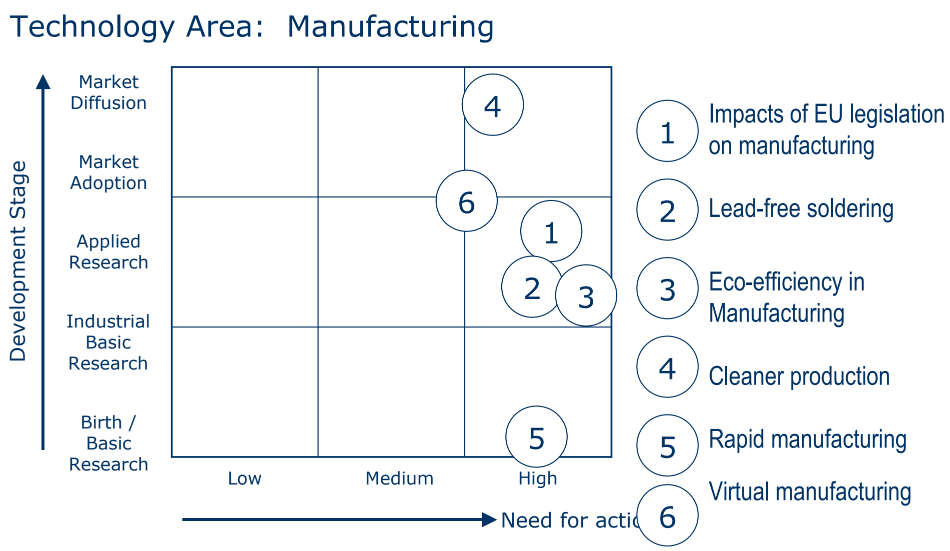

Figure 7: Technology Area: Manufacturing

5. Use

5.1. A New Paradigm for the Electronics Industry Innovation System

In the life-cycle of electronic products energy consumption – depending on the type of product - counts for 50%-80% of the environmental impact, only 10%-40% is caused by material and parts, approximately 10% by packaging and transport and a maximum of 5% by End-of-Life treatment.

These figures demonstrate that the consumer has to be addressed extensively as a key actor in the electronics industry innovation system when raising the issues of sustainable development, since the susceptible settings of decreasing energy consumption are supposed to depend on the behavioral attitudes of the consumer, and on the fact, that technology enables the consumer to save energy resources.

As a matter of fact, the communication with consumers plays an important role to improve his knowledge of sources for energy saving, his experience in daily energy efficient handling of electronic products, and his insights into the circumstance that he himself might contribute to sustainability to a considerable amount with his consumption behavior.

- At the same time, the principal relationships between the Electronics Industry and its customers have to be re-defined.

With this background, the main topics in this section are customer information and education on usage, communication of product impacts to the consumer, energy efficiency in use and new business models.

5.2. STS evaluation of technologies in the area of "Use"

Customer information, communication of product impacts, enabling technologies for energy saving and new business models are by no means crucial issues to encourage consumers to move towards sustainable behaviour in the Electronics Industry.

Improving the effectiveness of the above mentioned tools and strategies will lead to a substantial contribution to sustainable development in the Electronics Industry Innovation System.

However the maturity and need for action of the different approaches are to be scored differently:

- **Customer information & communication of product impacts**: apart from general information campaigns as described in the report. The information policy of industry has to be improved substantially. There are only a few large-scale companies in the

Electronics Industry who provide sustainability reports on a regular basis, e. g. industrial application is at an early adoption stage at most. The need for action is very high, especially in view of a desirable dissemination of information and reporting to customers in the sector of SMEs.

- **Energy-efficiency** providing "enabling technologies": this topic represents one of the main issues to be tackled by future research and dissemination activities. According to the present state-of-the-art a high potential for energy saving enabling technologies exists, which has not been fully exhausted yet. Mainstreams as for instance the switch to LCD technology, improvements in fuel cells, the generation and storage questions for solar cells and human power, improvements for portable sources of energy as a substitution for Li-Ion Batteries, further miniaturization and the implementation of nano-technologies etc are not solved concerning their corresponding problems. The need for action is very high since a substantial improvement of energy efficiency is one of the utmost urgent activities to spread in the Electronics Industry Innovation System.

- **New Business Models**: The evolution and diffusion of new business models for sustainable service systems in the Electronics Industry depends on radical changes in economic paradigms and requires a change in the perception and in the behaviour of all actors involved in the innovation system.

  What is the new economic paradigm?

  For the dissemination of new business models in the electronics industry like life cycle extension, durable products, product-service shifts etc., new incentive systems have to be implemented to shift earning possibilities from "old economy strategies" (earnings as a result of shortening the innovations cycle) to "new sustainable economy strategies" (earnings as a result of life time extension, energy minimization, intelligent services etc.).

  The value added in new sustainable economy strategies is located in new service systems providing life time extension via repairing, maintenance, service for energy minimization etc. Furthermore, value-added may be created by multi generation product planning, time dependent product innovation systems with cascades of product use, re-manufacturing and refurbishment options. The consequences for production, distribution and marketing are tremendous. The whole innovation process from R&D to distribution and sales needs to be revised

  The success factor "time to market" is strongly connected with the old paradigm where innovation cycles are short and pressure is high for new product launches. To gain early advantages and first mover profits it is indispensable to push technology, and shorten

R&D cycles to realize a fast product launch. The whole innovation system is adjusted to this economic paradigm, a paradigm that equals earnings with throw-away behaviour.

In a new economic paradigm, the innovation system should be detached from "time-to-market" as the key issue of economic strategy. That does not mean that there are no first mover advantages to beat the competitors. There is just another strategic orientation of the business model: it is set up to earn money with intelligent services around a product over the life cycle. It requires an alternation of

- R&D, which has to be adjusted to longer life cycles
- Production, which has to be adjusted to multi modules of products to be assembled for customisation
- Distribution and marketing, which have to be adjusted to selling services and further benefits for the customer (functions) instead of selling a product or technology.

In the categories of the STS approach in ECOLIFE 2 for "new business models" and related innovation in Product-Service Systems the highest score for complexity has to be considered since a change in paradigms requires the change of attitudes from at least all actors in the innovation system. The consumer has to give up property rights (a new way of thinking about ownership structures and self understanding of consumers), the manufacturer has to build up coalitions with service providers and maintenance providers, new concepts of multi-generation products and re-use have to be developed etc.

ECOLIFE 2 will conduct further research on these topics within the ongoing project. A first estimation of "New Business Models" – subject to a further differentiation, however, leads to the statement of "high needs for action" and a fairly poor maturity.

The STS evaluation for the area "Use" is summarized in *Figure 8*:

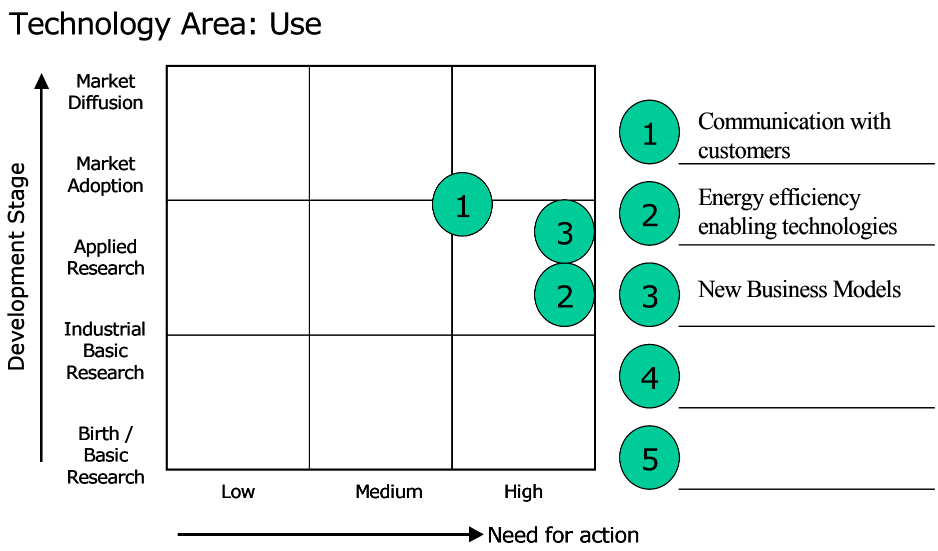

Figure 8: STS evaluation of the area "Use"

6. Recovery and End-of-Life

6.1. Introduction: The END-OF-LIFE Hierarchy

There has been ongoing innovation on the part of the actors involved in the product flow of (used) electrical appliances since the mid-1980s, especially after the debate on an electrical scrap ordinance in 1991 in Germany. It was first directed at developing solutions to improve opportunities for disposal and recycling at the End-of-Life phase. A large number of R&D projects have naturally been initiated to solve problems in identifying, separating or fractioning off materials and components, processing and recycling, removing pollutants and disposing of residues. This affects more or less all product groups, materials and components, although with differing emphasis.

A data survey on 187 R&D projects conducted in the European Union on WEEE issues conducted in ECOLIFE 1 depicts the following figures:

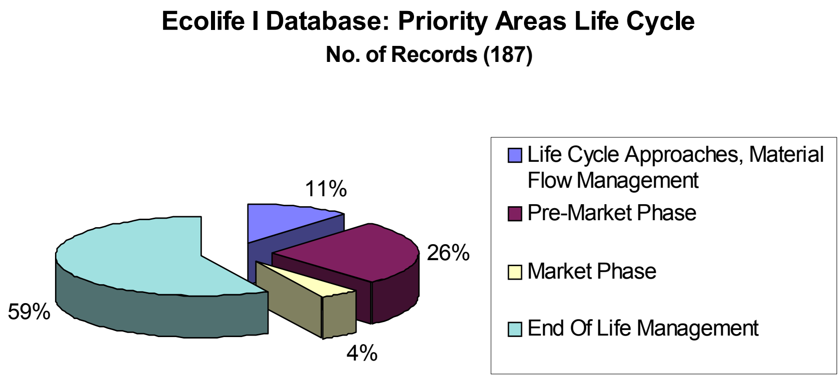

Figure 9: ECOLIFE 1 database: priority areas life cycle

Approximately 59% of the research projects conducted within the last 20 years in the area of WEEE have been focussed more or less on End-of-Life problems of WEEE. The major part of this research has been directed to the problems of separation of hazardous substances (15%), sorting (10%), identification (7%), preparation (10%), recycling and re-use (8%) and at least waste disposal (3%).

Much has been achieved with these activities (e.g. sophisticated technology with in-depth disassembling, separation, shredding, recover) although, however, not necessarily leading to sustainability benefits as far as the eco-efficiency of these measures is concerned (see Stevels).

ECOLIFE 1 already reported on the state-of-the-art of certain End-of-Life technologies, beginning with identification technologies and separation, as well as touching upon health and safety aspects. The work also summarises financial aspects (covering collection and processing implications) and strategies for re-use and upgrade of discarded electronic products. Finally, new management strategies have been discussed in order to meet future requirements in the End-of-Life sector. The future needs, defined in ECOLIFE 1 have been taken up in ECOLIFE 2. The state-of-the-art of these technologies is presented in the chapters of the report.

6.2. STS Evaluation of Recycling

The STS evaluation of Recycling is depicted in *Figure 10.* As may be noticed, there are sufficiently available technologies already in the market diffusion phase (i.e. separation technologies, recycling of white goods and big installations) without any further necessity for research.

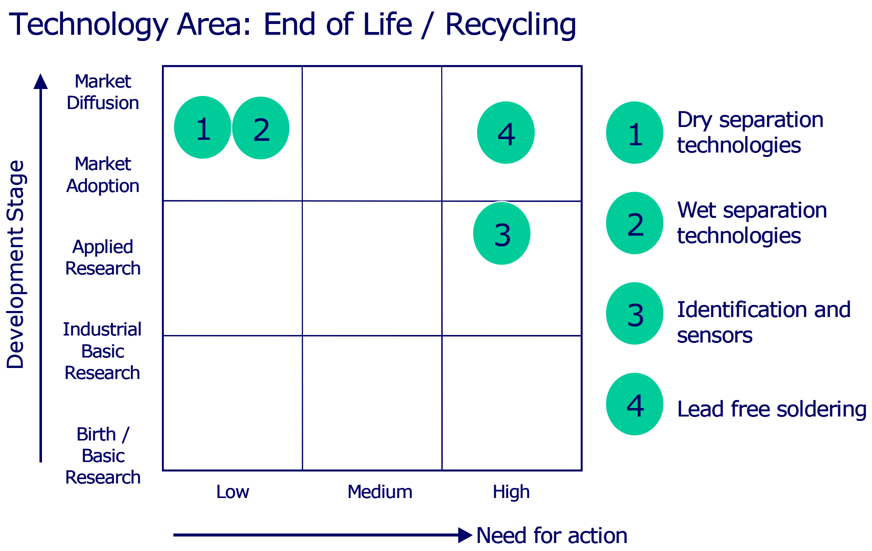

Figure 10: STS evaluation of recycling technologies (1)

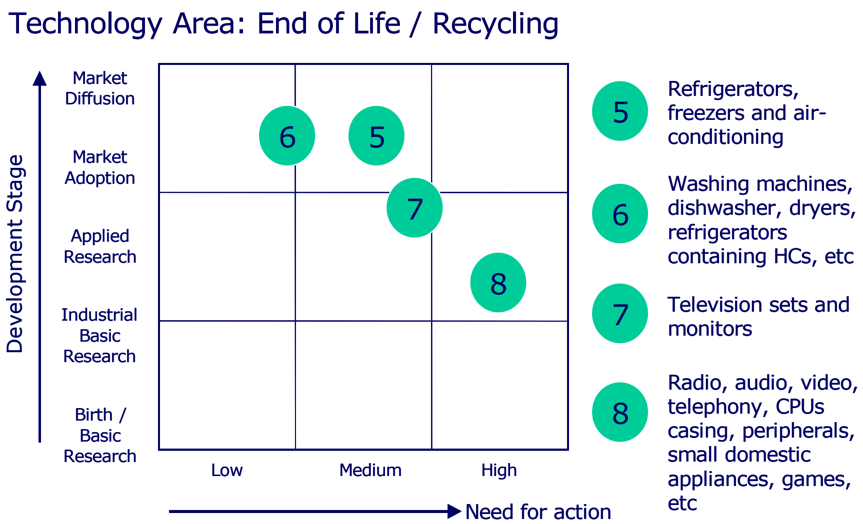

Figure 11: STS evaluation of recycling technologies (2)

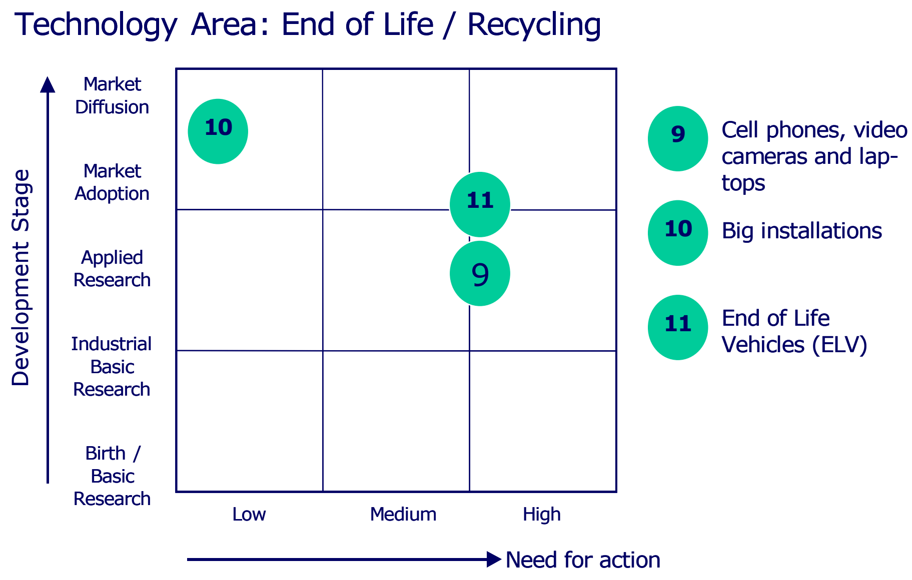

Figure 12: STS evaluation of recycling technologies (3)

In other areas however a specific need for action necessary to contribute more substantially to sustainability:

(1) Lead-free soldering:

This technology is at the MARKET DIFUSSION level. Actions required are the complete industrial implementation of lead-free soldering technologies at large and, specially, at small and medium enterprises and also the industrial availability, more in Europe and America than in Japan, of the suitable solders, specific boards and particular components that supports the lead-free soldering practices. Additionally, the advances in quality assurance of lead-free soldering processes (ranging from solders themselves to components and products) at low cost, and the definition of the lead-free solder standard alloy or alloys are desirable. Complementary, the definitive confirmation of the diminution of negative effects on environment and human health of the lead-free solders when compared with the traditional lead containing solders and restrictive legislation on restriction of use of lead and lead compounds will be helpful.

(2) Identification and Sensors:

This technology is at the MARKET ADOPTION level. Main actions required are cost decrease and implantation at industry. Additionally, the increase of speed of on-line recognition (by diminution of both analysis and identification times), the enhancement of hybrid sensors, that integrate different specific sensors, for recognition of diverse material families (polymers, metals and inorganic additives, organic additives, halogens and halogenated substances…) are desirable. Complementary, the advance in dark polymer recognition and overcome of recognition faults due to dirt, external impurities or labels and the building and refining of libraries with reference materials will be helpful.

(3) Television sets and monitors:

This technology is at the MARKET ADOPTION level. Main actions required are the need to migrate from manual separation and cleaning of funnel and panel to more automated operations and the development of specific processes for handling of these CRT containing equipment (that represents around 60% by weight) including the cleaning and grading of several types of glasses. Additionally, the search of high value applications for glasses from CRTs and the market development for plastic housings and the alternative uses for wood in old television sets are attractive. Complementary, adaptation of the transport and storage systems in order to avoid undesired breakage of CRTs or market alternatives for glasses from B&W television sets that have poorer qualities are recommended. In the future this technology is called to extinguish, television sets and monitors will change from CRTs to LCDs, TFTs or plasma displays.

(4) Radio, Audio, Video, Telephony, CPUs, Peripherals, Small domestic appliances, Games, etc.:

This technology is at the APPLIED RESEARCH level. Main actions are related with the equipment characteristics (small size and large diversity, presence of Ni/Cd batteries, presence of LCDs, plastic and iron predomination, level of copper under the accepted by copper smelters and absence of valuable metals or components). Actions need are the improvement of separations of complex mixtures of materials, like mixed plastics, or their combined reprocessing if shredding is used and the treatment of LCDs and treatment of PWBs and PCBs generated if partial dismantling is used. Since full manual dismantling is prohibitive, the search of alternatives for lowering manpower and energy requirements, by incorporation of automatic disassembling operations based in robots and/or active disassembling operations based on the responses of active devices included in products, is needed to reach recycling and recovery set by legislation. Additionally the introduction by manufacturers of design for recycling in new products, that will overcome cross contamination and material incompatibilities in the recycling phase and the up-scale of existing pilot lines for the automatic disassembling based in robots and/or active devices are necessary.

(5) Cell phones:

This technology is at the APPLIED RESEARCH level. Main actions are related with the equipment characteristics (very small size due to integration, extremely short life due to fast technology changes, presence of batteries, presence of LCDs, presence of plastics and relatively high contents of valuable metals and components). Actions need are similar to the ones summarised for other small equipment, special emphasis is required on non destructive automatic disassembling operations based in robots for reuse of valuable components and specific selective recycling schemes for the separation of the valuable metals.

(6) End-of-Life Vehicles:

This technology is at the MARKET ADOPTION level. Action needed is related with the adoption of legal texts that have forced the increase of recycling and recovery levels of EVLs. If the actual scheme is maintained, since the particular recycling and recovery of the metallic materials are almost complete, any increase of the global numbers for ELVs means the improvement of the treatment of ASR. The benefit of the ASR will be increased only via development of separations for complex mixtures and collective reprocessing alternatives, especially for plastics and rubbers. If a new scheme based on dismantling is preferred, effort in design for recycling, to favour previous decontamination operations and the selective (manual or automatic) separation of parts and materials is need from car manufacturers.

6.3. Take-back schemes and logistical concepts concerning the collection of used electronics

The take-back and recycling of white and brown goods have been discussed in Europe for many years. The four main reasons to address this subject are:

- Reduction of waste volume going to landfill -- the underlying reason is the lack of landfill space in densely populated areas.
- Promoting recycling of materials – closing the loop, use of less resources
- Better control of potentially toxic substances - reducing environmental risk
- Promote better design for recycling – a subject which had not been addressed earlier by producers

In order to address this situation, different principles have been introduced by the authorities:

(1) The producers responsibility principle. This principle extends the responsibility of producers beyond the traditional boundaries of the factory gates and includes, for example, responsibility for products discarded by consumers,

(2) The polluter pays principle : This is the financial translation of the responsibility as defined under 1.

(3) The cost internalisation principle. The extra costs resulting from the responsibilities 1) and 2) have to be absorbed in the cost prices of the product, thus ensuring, for edxample, better design for recycling.

The transformation of these principles into laws and regulations has led to lengthy discussions in most countries in Europe, and the EU, that are still.

The debate about producers' responsibility is both about scope and time. As regards scope the big question is whether producers can be realistically held responsible for issues on which they have little or no influence (e.g. the disposal behaviour of consumers, collection of discarded products). The time issue is whether the responsibility is for products still to be put on the market (future waste) or also for products already in the market/historic waste (retroactive activity). The question 'who pays the bill' (application of the polluters pays principle) is directly connected to the responsibility issue. Although the cost internalisation principle is basically correct, it will lead – even in case of good design for recycling – to higher cost prices. A major question is whether this cost increase can be recouped in the very competitive markets for white and brown goods.

When the debate about the principles is combined with a debate about the ambition the take-back and recycling system should have (collection target, recycling targets, targets about level of toxic control to be achieved) differences in opinion among stakeholders increase even more and agreement is far away.

The report presents the current state of play for the Netherlands, Hungary, and Spain and further addresses eco-efficiency aspects of take back and recycling.

7. Management

7.1. Institutional innovation of management systems in the Electronics Industry

Observations in the Electronics Industry Innovation System suggest that changing the rules in management systems, of embedding "Green" into the innovation process, and considering sustainability requirements in all actions taken by management is one of the crucial pre-conditions to accelerate progress towards sustainable development. Empirical proof might be the fact that innovation in management systems takes place above all in the following:

- *Changes in external communications:* as well as continuous environmental reporting, major manufacturers are nowadays conducting detailed environmental and regulation monitoring, and participating in committees and in the drafting of regulations. In this context, environmental policy is not government driven (a top-down approach), but the result of negotiation (partnership). Many large companies codify these environmental goals, for example, in guidelines, containing commitments to building up environmental organisations, devising environmental targets or setting up an internal regulation management.

- *Changes to internal innovation management and strategic planning:* manufacturers show modifications to their innovation management in order to include more environmental orientation. This is generally operationalised by additional testing at all phases of innovation. The environmental needs thus embodied result, as a rule, in far-reaching changes to the organisation of innovation, which may be expressed in restructuring the product development teams to include an Environment Officer. Also at a product's specification, targets are set regarding environmental aspects.

- *Changes to organisational planning instruments:* the so-called Green Books and environmental guidelines, summarise product development from an environmental perspective, and generally contain the corresponding requirements for design, assembly, dismantling, packaging, etc. in each product group. Developing such environmental handbooks is often a learning process, which usually starts at a purely technical level, and gradually comes to include other areas, such as environmental accounting or management. Beyond these guidelines, there are now also so-called Red Listings for many areas -- detailed lists of requirements for each product group drawn up from various sources, principally customer feedback (including prescriptions for materials) and legal requirements such as proscribed materials.

- *Introducing construction principles or Design for Environment (DFE):* as described in Chapter 3, there are now numerous DFE software tools available for analysing the environmental stress arising during the product life-cycle – from production, through distribution and transport, to use and disposal. Their databases contain all the technical information on materials and processes, usually with LCA-based software and benchmark studies. The "1996 Electronics Industry Environmental Roadmap" already lists 40 such software tools[1], today there are even more available. Despite their availability, problems arise in making use of these substance flow management tools, which essentially points to a further, considerable need for research to generate the required knowledge.

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1 cf. MCC Technical Report MCC-ECESM-001-96, p. 45.

– *Introducing internal environmental incentive systems:* another phenomenon now frequently observable is the modification of existing internal incentive systems to reward environmentally friendly behaviour. This includes environmental prizes for particularly outstanding development, and also – in isolated cases – including an environmental component in performance related pay structures.

– *Changes in marketing:* the “global players” in the electronics industry regularly conduct marketing and consumer research, in order to develop and assess their marketing strategies. However, chances for successful advertising using “green” arguments had already peaked in the late 90ties, as consumers expected products to be environmentally well-designed. Willingness to pay a premium seems to be only evident where a direct benefit for the consumer exists.

– *Introducing new training programmes*: manufacturers are conducting a variety of programmes for organising training seminars in environmental management, which generally involve every department of a company.

7.2. STS evaluation of the area Management

The STS evaluation for management presented here includes in its scope large manufacturing organizations, but does not take into account SMEs. As a general judgement it should be stressed that SMEs in principal are suffering from a backlog demand on all issues presented in *Figure 13* due to a lack of competences and capacity. As a result the issues presented in *Figure 13* have to be located somewhere in between Industrial Basic Research and Applied Research with an extremely high Need for Action. Of course it is indispensable to further differentiate the specific needs of SMEs in these topics, since their special prerequisites and capacities often require simple and adapted solutions.

However the state of the art of management issues in the scope of large manufacturers commentated below are:

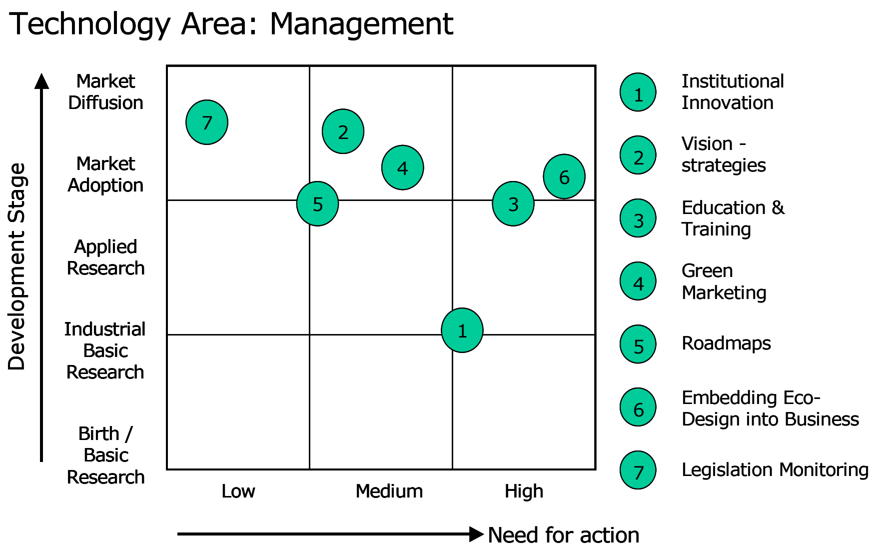

Figure 13: STS Evaluation in the Area of Management

The development stage of environmental management in large manufacturing organizations can be considered being in the phase of "market diffusion". Most organizations develop environmental reports (lately, also sustainability reports, including economic, social and environmental performance).

Institutional Innovation: Institutional innovation starts to leap from the research field and to be adopted by firms. Furthermore, organizations seem to be afraid of changing their current way of managing the business, meanwhile institutional innovation requires big changes. At the same time, considering sustainability requirements in all actions taken by management is a crucial condition to accelerate progress towards sustainable development. Therefore, the need for action scores medium/high and it can be translated on diffusion of knowledge. For SMEs the situation is more difficult: solutions for institutional change developed for large manufacturers are not applicable on a 1:1 basis to SMEs because the procedures may be too formalistic and presume expertises and competences as well as infrastructures usually not existent in SMEs. On the other hand, SMEs are not constrained as much by organizational settings and institutional frameworks like large-scale organizations, assuming that SMEs may be more flexible and adaptable to changing environments. However the Need for Action in institutional innovation may be scored as high for SMEs, as research activities start to move from basic to applied concepts.

Vision: Large organizations start to include environmental (sustainability) elements on their long-term strategic vision of the business so as to ensure its continuity. In order to achieve full cross-functionality of environmental management at all levels of the organization, it is necessary that top-management commits and supports it. It is a necessary but not sufficient condition to end up with high rates of eco-designed products launched to the market. Vision scores medium at the Need for Action section of the STS scorecard, each organization may define its own vision according to company culture. For SMEs it is important to, firstly, understand that an environmental vision and orientation towards sustainability does not necessarily place a one-sided burden on costs; it is perceived, as a result of environmental obligations compliance, that it may open opportunities of new business, especially due to a high demand on the side of large manufacturers to re-organize their supply chain and mechanisms of product use etc. This new thinking is in its very beginning in the wider area of SMEs, but obviously is also present on the side of innovative SMEs in the area of special services providers. So it is a matter of putting more incentives for a broad diffusion of this new thinking into SMEs.

Education and training: activities are underway around Europe related to education and training on eco-design issues and techniques. Furthermore, a lack of awareness on the forthcoming Directives and lack of understanding of the implications in product development, suggest that action is needed on this area, both in industry and at the academic level (greening of curricula) with specific needs especially for adapted solutions for SMEs.

Green Marketing: the role of ‘green’ in product creation processes and in business has been repositioned. This has lead to new strategies in which green brand image and benefits from the perspective of the consumer play a key role. Experience shows that green does not sell by itself, what appeals to consumers is convenience and self-interests. The action needed in this area may be a strategic shift from “appeal to feelings” to “appeal to self-interest”, promoting consumer’s benefits when acquiring an eco-designed product (less energy consumption, safety, etc.). In other branches green marketing has also successfully been implemented by selected SMEs with the aim to differentiate the product against the large-scale competition (for instance in the furniture industry). It would be of interest to investigate the conditions of a transfer of these marketing strategies to SMEs in the Electronics Industry Innovation System.

Roadmaps are partly based on corporate programmes and targets, and can be defined as the corner stone for operationalization of sustainability in the business. Roadmaps are based on corporate goals and strategies, and help to define steps towards the desired goal in the mid- to long-term. Need for action scores low-medium on the STS. Action related to this topic can be defined as diffusion of knowledge on the design of roadmaps. For SMEs **the** need for action scores high, since existing roadmaps have been elaborated primarily with the participation of large manufacturing companies. For SMEs it is not only the diffusion of existing knowledge but again the adaptation of roadmap principles to their specific needs.

Embedding Eco-design into the business: Eco-design does not merely rely on technological and technical aspects in order to achieve higher efficiency on eco-designed products. Creativity and originality are key elements to end up with innovative solutions. The challenge (need for action) is to ensure that eco-design is present on a daily basis within the product development process, and not to handle it as a separate discipline from regular activities. This is harder to diffuse in SMEs. Today's incentives to embed eco-design into SMEs regular businesses are predominantly the result of obligations placed on the manufacturers at the end of the supply chain, shifted back to the SME suppliers. These shifts may increase in the coming years as the WEEE, RoHS and other Directives come into force. The decisive issue for SMEs in this context will be to switch from a re-active position into an active role within the supply chain.

Legislation monitoring: environmental management started as a defensive approach towards legislative requirements. Today it can be said that organizations take a proactive approach towards environmental issues, but legislative requirements are still a main driver for managerial activities. Legislative monitoring is at a very mature stage and most organizations use a methodological approach to ensure a continuous update of environmental legislation that may affect the business. Since this is true for large organizations the opposite may be stated for SMEs : most small companies in the supply chain of the Electronics Industry Innovation System are not aware of the huge changes in environmental legislation and are processing data and information on these changes on a regular basis. Today, recognition of legislation is mainly caused by information channels within the supply chain. To conceive legislation and changes within the regulation framework as an opportunity for new businesses SMEs have to develop – as mentioned above – a more active information management and monitoring system. The need for action is scored as very high.