ECOLIFE II

ECO-efficient LIFE cycle Technologies.

From Products to Service Systems

State-of-the-Art Technology in the Electronics Industry Innovation System
Dialogue, Strategies and Tools towards Sustainable Development

GREEN BOOK

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1 Introduction

In the European Union, 2.2 million people are employed in the manufacturing of electrical and electronic products. The annual value of these products is about 450 billion EUR, almost 30% of the global market. Inevitably, this large-scale economic activity has several impacts on the environment: one of the most important of these is the 10 million tons of electrical and electronic equipment (EEE) that reaches its end-of-life each year and is disposed of as waste. Waste from electrical and electronic equipment (WEEE) represents the fastest growing waste stream in the EU, and, unless preventive action is taken, the amount is expected to double within the next decade. WEEE contains substances which, if they are not treated properly at end-of-life, are hazardous.

ECOLIFE II focused on the product-service life cycle of electr(on)ic products, and involves key players in the electronics and automotive industries in all of the various stages of the product-service life cycle –from component suppliers and product manufacturers, to service and logistic suppliers and the end-of-life processors. The main activities of the Network focused on the environmental and economic aspects of product design, functional innovation and service-system innovation.

The ECOLIFE II consortium has 29 partners, of which 22 are companies and 7 research organisations. The partners come from 10 countries - 9 EU Member States and 1 associated country. They play leading roles in European branch organisations (e.g. ORGALIME, EICTA, EECA, ECTEL, CECED, CAPIEL), national branch organisations (FEI, BITKOM, FEEI), international standardisation bodies (ISO, ECMA, DIN) as well as other networks (CARE Electronics, UNEP, WBCSD, IRC). The value of these connections is of major importance for transferring the best practice results of ECOLIFE II to large numbers of SMEs and other relevant bodies.

The ECOLIFE II network co-ordinated not only at least 27 RTD projects at EU level, but also 23 national as well as 8 regional projects representing total costs close to 100 MEUR.

The European Commission (through a series of Directives – WEEE, RoHS, EEE and IPP), Member States and industry in Europe are currently addressing a series of major environmental challenges to minimise waste and resource consumption, restrict the use of hazardous substances, and offer more and better products and services to users of electr(on)ic products. ECOLIFE II will make a major contribution to this process. It will advance the development of eco-efficient electronics and sustainable services. It will strongly support the creation of about 450.000 new jobs in the sector, as well as the re-training of about 100.000 existing employees, and the furthering of the Internal Market. It will lead to safer and healthier products and accelerate the development of product-service systems.

ECOLIFE II facilitated the co-ordination of EU and national RTD in the field of eco-efficient electr(on)ics and sustainable services which leads to a rationalisation in, and decrease of, RTD costs. It engages in the exchange of information between researchers in the EU and beyond, provide easy access to state-of-the art RTD developments, and reduces the duplication

of studies on identical topics at the EU and national levels. It contributes to the development and implementation of EU environmental and electr(on)ic policies, including standardisation, concerning products and product-services.
ECOLIFE II advances economic growth because it result in increased levels of technology and service development, maximise the use of emergent eco-efficient technologies and sustainable services, and promote – via the dissemination of best practice case studies – the wider adoption (especially by SMEs) of these technologies and services. Additionally it decreases the overall life-cycle costs of electr(on)ic products which enhances the competitiveness of enterprises and offer better value, and new and different products and services to consumers. In order to achieve these targets a one stop shop was implemented, which provides complete aspects of design, production, operation/use and re-use until the end of the operative life, at both technical and organisational levels.

Within this one-stop-shop special attention was given to:
Modernisation of the electr(on)ics industry and adaptation to the new economy by introducing more flexibility and capability to respond in real time to customer needs.
Enhancing the participation of SMEs with their specific needs and roles in the supply chain in order to create and maintain jobs in Europe.
Integration of the new and future EU Member States.
Improving substantially (20-30% in the short-term) the overall quality within the value chain (‘quality’ = value for and timely satisfaction of customer needs at the lowest cost)
Minimising waste, use of hazardous substances and resource consumption in such a way, that the overall “life cycle” impact will be drastically reduced by the new electr(on)ic “product – service” systems.

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

This section “State-of-the-Art Technologies in the Electronics Industry Innovation System” provides information on technologies to manage and evaluate the design, manufacturing, (re-)use and recycling of Electronic goods from cradle to grave. It not only describes single technologies such as “Lead-free soldering”, but also management tools and other measures to set up for new business opportunities to meet the triple bottum line of economic, ecological and social improvements. Since ECOLIFE II in this respect refers substantially to the problems of sustainable development in the Electronics Industry, a broad definition of “technologies” was chosen to provide a comprehensive framework describing measures of dialogue between the actors of the innovation system, instruments of strategy-making and operational tools or techniques, all referred to as “technologies”.

2.1 Conceptual Framework to evaluate the “State-of-the-Art”

Following a comprehensive “Innovation System Approach” ECOLIFE II focusses 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.
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 bottum line of economic, ecological and social improvements in the Electronics Industry.
To evaluate the technologies in view of sustainable development in the Electronics Industry, a kind of technometric approach called “Sustainability STS Scorecard (STS Approach)” is used:

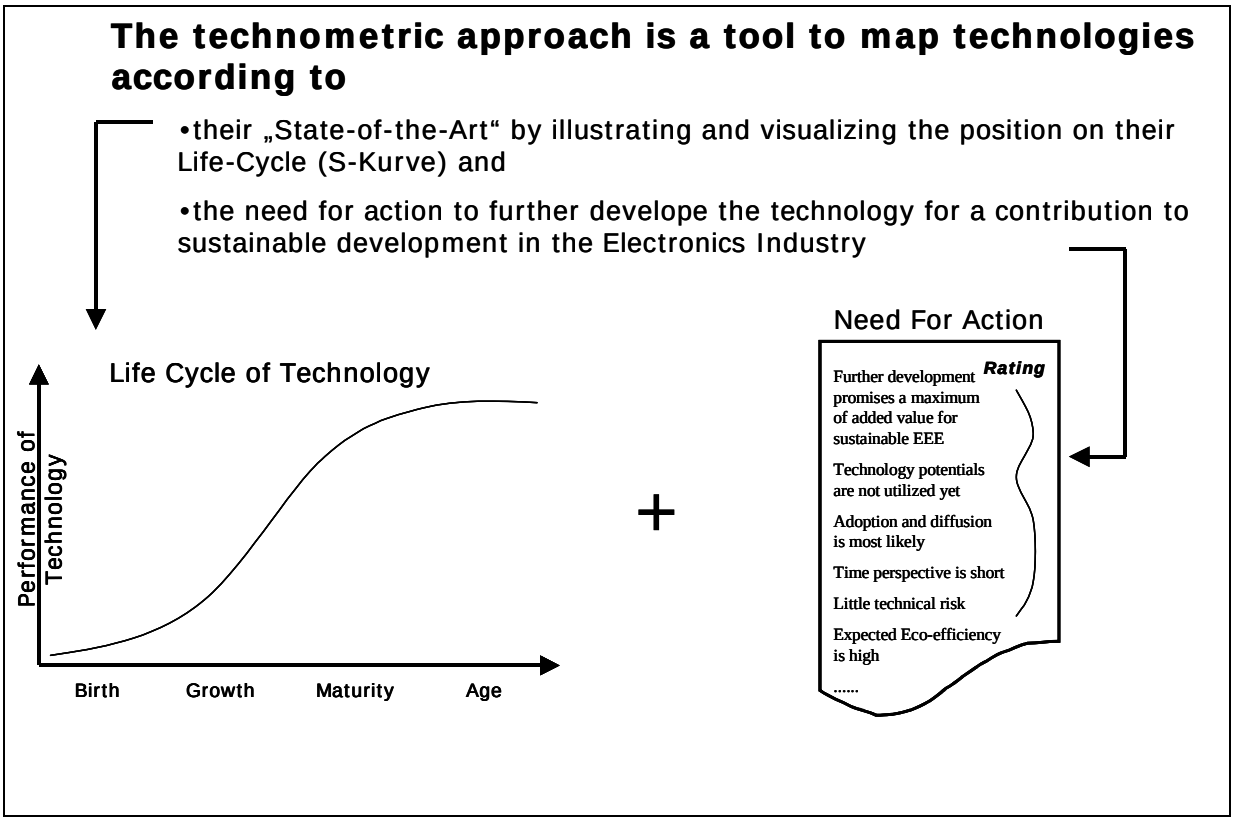


Figure 1: S-curve thinking in technometric approach

The evaluation goes along two axises:

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....

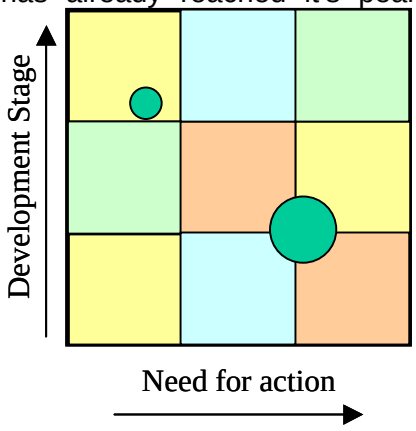


Figure 2: Principal Portfolio Matrix of STS Approach in ECOLIFE II

Putting these elements of evaluation together, the ECOLIFE II STS Approach allows for a descriptive visualization of the State-of-the-Art of Technologies with respect to the need for further development of these technologies in the context of sustainable development in the Electronics Industry Innovation System:
As can be seen from the criteria and indicators used, the evaluation procedure may be called “qualitative” since ECOLIFE II uses a non-metric scale for these indicators. As a result, the representation of the evaluation of technologies may be called an “estimation” based on the experiences of a balanced mix of expertise from industrial and research actors of the Electronics Industry Innovation System.

2.2 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 stud-

ies 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 II and will be presented in this first Technology.
First 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 (Eco-design and Dialogue). 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.

2.2.1 Evaluation of the different technologies in Design and Dialogue

Figure 3 Summarises the discussion concerning technologies of Dialogue / Design, which concentrates on three main issues: (1) Eco-design within the supply chain, (2) Management of eco-cost reduction and (3) Information dissemination to SMEs:

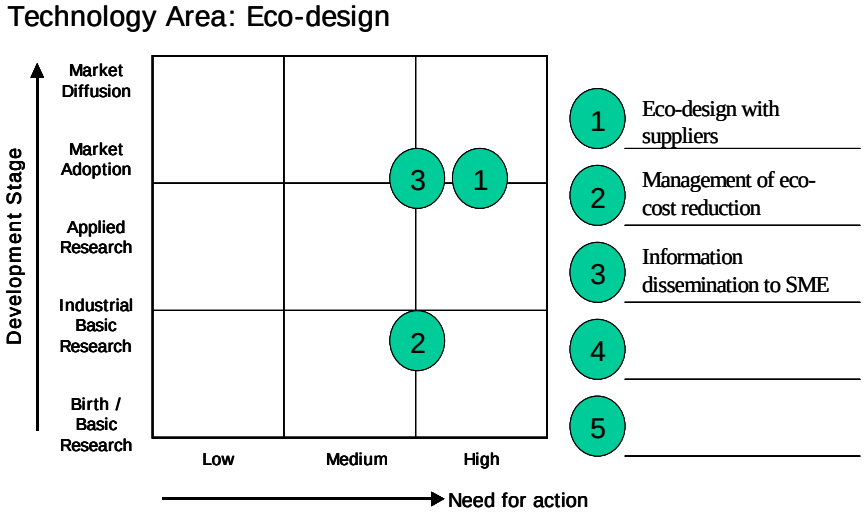


Figure 3: STS Evaluation of Dialogue Technologies in the Area of Eco-design

2.2.2 Eco-design with suppliers

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.
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.

Management of eco-cost reduction

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.

Information dissemination to SMEs

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.

2.2.2.1 Evaluation of different strategies for Design

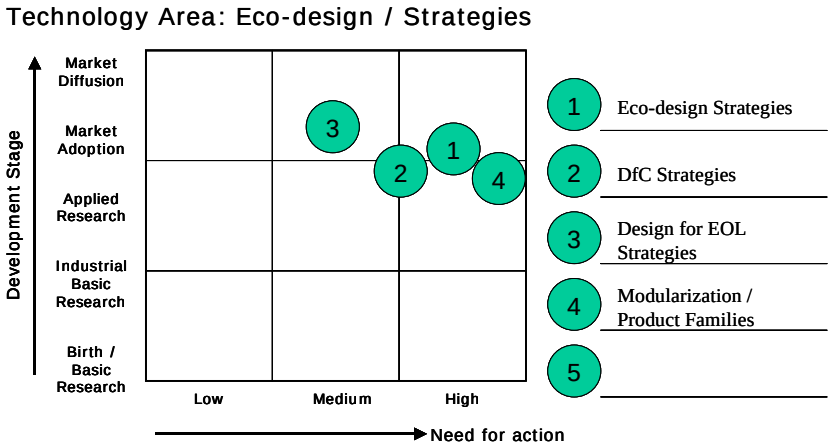


Figure 4 depicts the portfolio of Strategies within the design phase of the Electronics Industry innovation process:

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

2.2.2.2 Eco-design Strategies

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 1* 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.
As far as level 3 and 4 methodologies are concerned – these are still in an early industrial adaptation stage: 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.
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.

2.2.2.3 Design for chemical content

For **Design for chemical content** the 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.

2.2.2.4 Design for END-OF-LIFE / disassembly

For **Design for END-OF-LIFE / disassembly** the 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.

Modularisation

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.

2.2.3 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 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. An overview is depicted in the following figure:

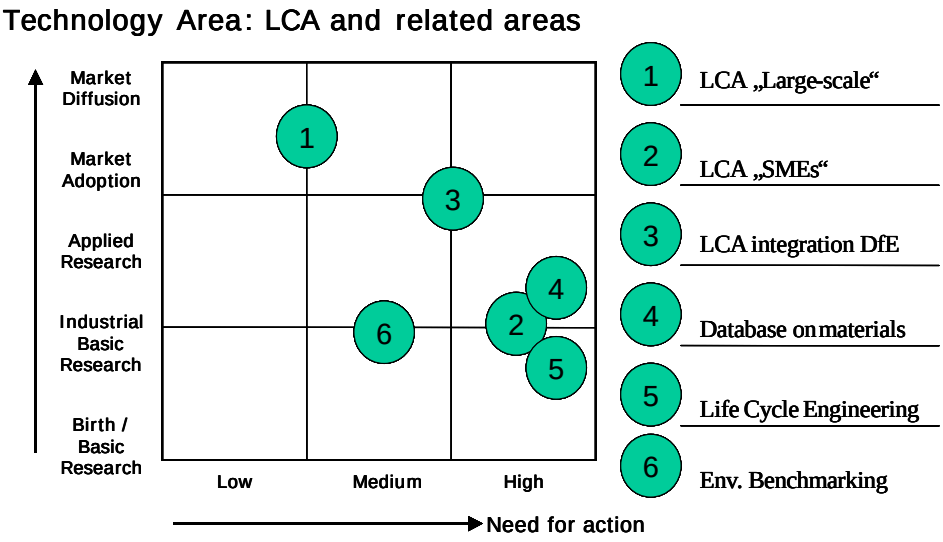


Figure 5: STS Evaluation of LCA/LCE and related areas

2.2.3.1 Need for simplified LCA in SMEs

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.
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.
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.

2.2.3.2 Implementing LCA into DfE

The methodology of DfE integrates the environmental aspects directly into the internal design process. 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.
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. For "Implementing LCA into DfE" the need for action is still medium to high a poor linkage of these tools.

2.2.3.3 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.
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.

2.2.3.4 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.
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.

2.2.3.5 Environmental Benchmarking

From experience in industry it is obvious that environmental benchmarking results in a tremendous increase in awareness in the organization, particularly because it focuses on comparing performance with that of the competition, rather than on focussing or absolute environmental score. Simultaneously, it is instrumental in generating in a straightforward manner environmental improvement options that are to be analysed in terms of environmental, business, customer and societal benefits.
Multiple environmental benchmark data analysis (MEBDA), however, is still the subject of academic discussion since there are ongoing debates on methodological questions.The need for action is to be described as follows:

- 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.

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.

2.2.4 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 breakthrough 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'.

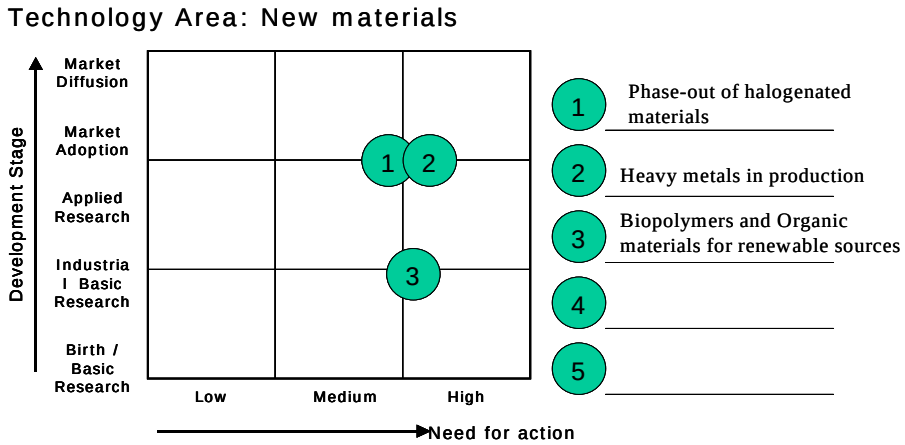


Figure 6: STS Evaluation of Materials

2.3 Manufacturing

Figure 7 depicts the areas of Manufacturing that had been tackled under the ECOLIFE II and their evaluation with respect to their "State-of-the-Art":

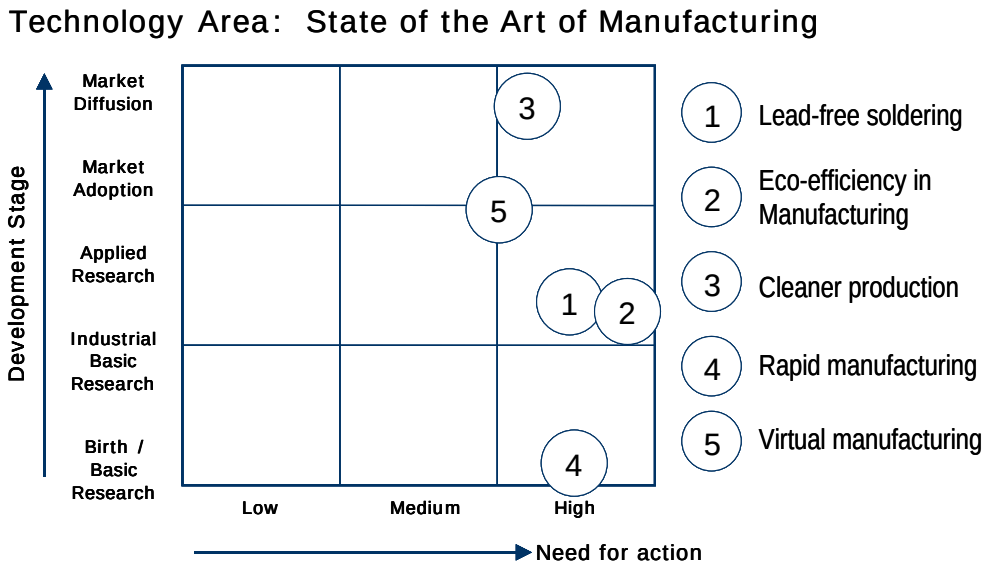


Figure 7: Technology Area: Manufacturing

2.3.1 Lead-free soldering

The RoHS Directive 2002/95/EC (Restriction of certain Hazardous Substances in electrical and electronic equipment) establishes that, from 1 January 2006, new electrical and electronic equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE).
There is no doubt that the electronic goods manufactured or used within the European Union will soon have to be assembled using lead-free solder. At the very latest, manufacturers will have to switch to lead-free assembly by the middle of 2006. Although the principal legislation driving the move to lead-free soldering has originated in Europe, there has already been much work carried out by major Japanese companies to enable them to convert their production to lead-free. Some Japanese manufacturers have already changed to lead-free assembly on many of their products and others have announced plans to convert well in advance of the European legislative deadline. European and North American manufacturers still have some way to go and it is important, in view of the many issues which must be addressed during such a conversion, that manufacturers do not wait too long to begin the changeover.
A number of lead-free electrical and electronic equipment (e.g. mobile phones) are already on the market. Lead-free technology roadmaps are being drawn up in the EU as well as in Japan/USA.
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.

2.3.1.1 Eco-efficiency in Manufacturing

Since the early 80th, academic attention has been directed towards eco-efficiency, defined as double dividend effects of improving the resources consumption in industrial manufacturing processes. The win-win situation of reducing the amount of resources (water, energy, input material etc.), closing loops to avoid or reduce waste streams with the result of abating waste and emissions and reducing costs is supposed to be the key to a market driven environmental orientation of industrial processes. EU legislation on WEEE, RoHS and IPPC will accelerate and strengthen these incentives though the dissemination on the level of SMEs is still an open question and will be time consuming.
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 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.

2.3.1.2 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.

2.3.1.3 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.

2.3.1.4 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.

2.4 Use

2.4.1 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 develop-

ment, 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.

2.4.2 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 (see fig. 8):

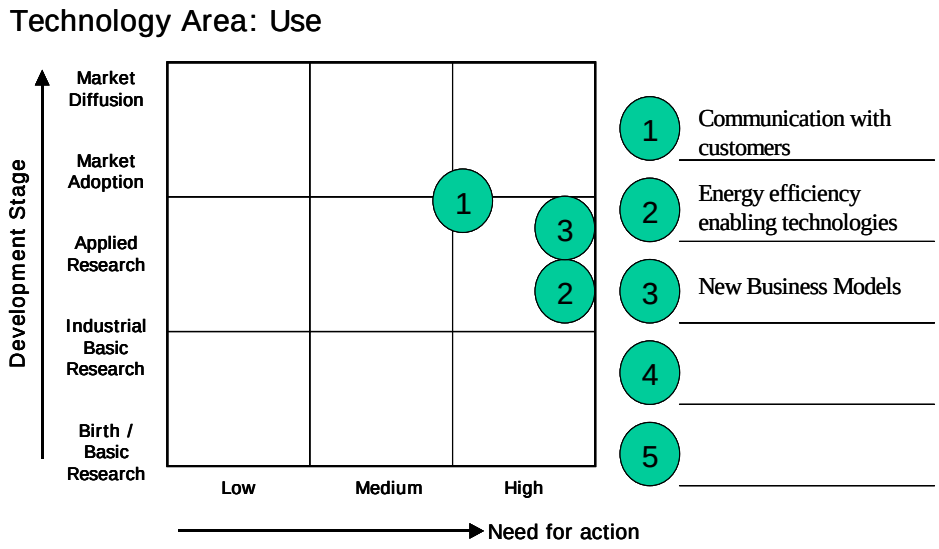


Figure 8: STS evaluation of the area "Use"

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.
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 II 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.

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.

2.5 Recovery and End-of-Life

2.5.1 Evaluation of Recycling

The evaluation of Recycling is depicted in *Figure 9,10 and 11.* 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:

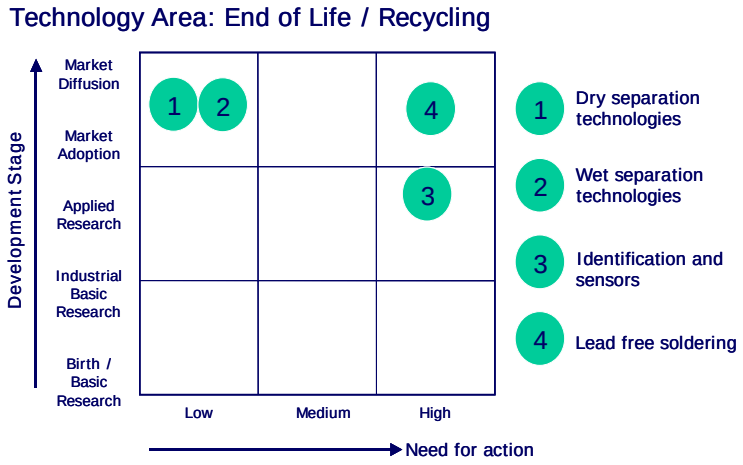


Figure 9: STS evaluation of recycling technologies (1)

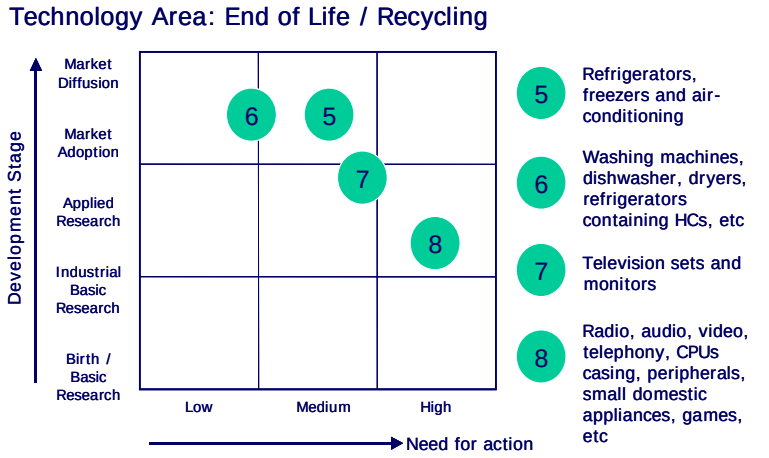


Figure 10: STS evaluation of recycling technologies (2)

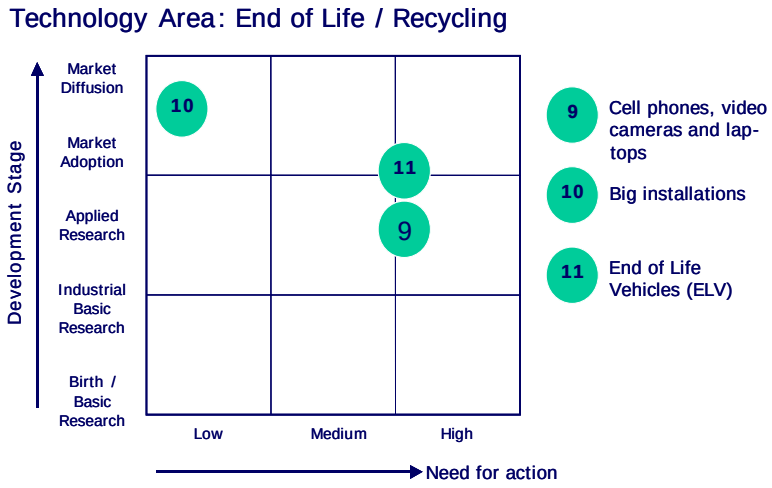


Figure 11: STS evaluation of recycling technologies (3)

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 hu-

man 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.

2.5.2 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.

2.6 Management

2.6.1 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 preconditions 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.

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.

2.6.2 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 12* due to a lack of competences and capacity. As a result the issues presented in *Figure 12* 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:

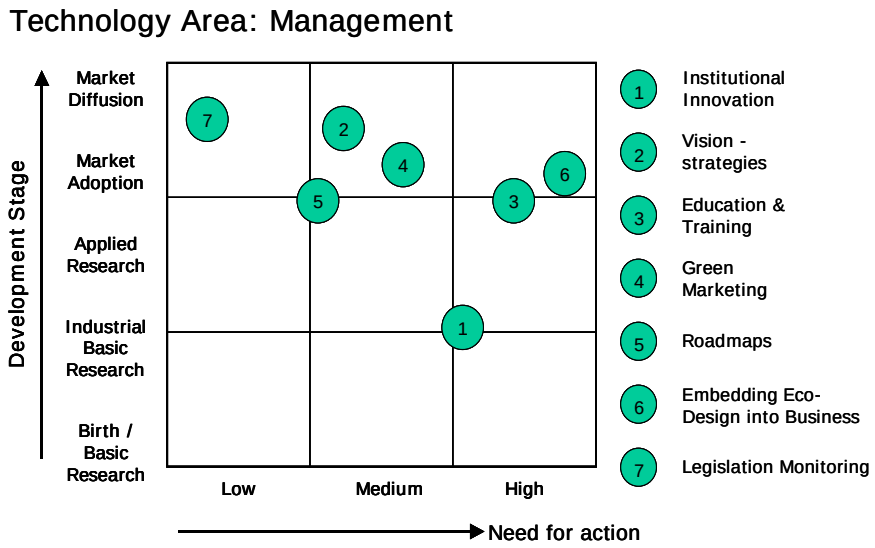


Figure 12: STS Evaluation in the Area of Management

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 ap-

proach 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.

3 Best Practice Guide on Eco-efficiency of Electronic Products

3.1 Concept of eco-efficiency

Eco-efficiency can be defined as a route to maximise environmental and economic benefits, while simultaneously minimising both environmental and economic costs. The concept promotes the integration of environmental considerations directly into business functions such as manufacturing, product design and purchasing.
Economic efficiency refers to the economic benefits (like service provided by goods or profit generated) achieved per unit of invested economic cost (e.g. labour cost, capital cost).
Ecological efficiency, which is less easily quantified, relates environmental benefits to environmental costs. It is interesting to note that environmental benefits (e.g. habitat protection, ecological integrity, site remediation) are often overlooked in environmental impact evaluations, which tend to focus on assessing environmental costs (air, soil and water pollution and other natural resource impacts and other impacts such as land disruption and loss of biodiversity).
Eco-efficiency was developed, and is now used, as a means by which organisations can contribute to the sustainability objectives of society. Therefore, it is useful to situate eco-efficiency within the greater context of sustainable development. The World Resources Institute has provided a useful figure that considers to what extent eco-efficiency addresses the three dimensions of sustainable development (see Figure 13). It is clear from the figure that eco-efficiency relates to the area of synergy between the economic and environmental dimensions of sustainable development. Unlike sustainable development, eco-efficiency does not directly address social performance. Related to this is the fact that eco-efficiency is mute to who pays and who benefits; issues of social equity and meeting of human needs are captured in sustainable development, but outside eco-efficiency.

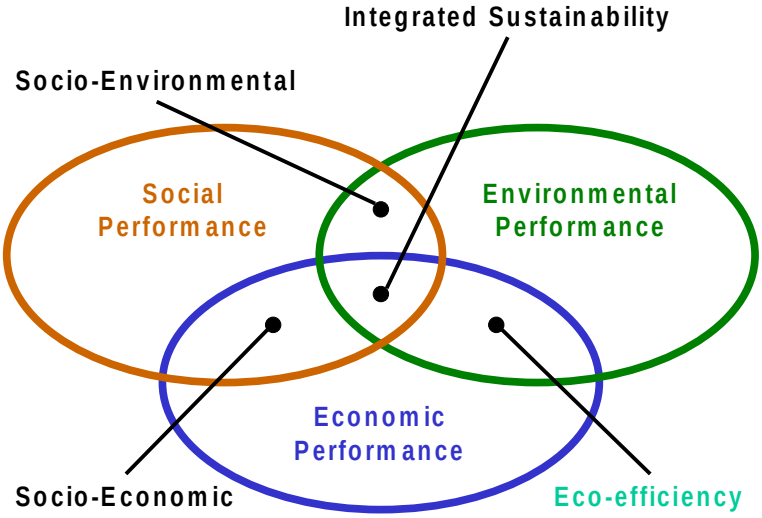


Figure 13. Relationship of social, environmental and economic spheres of sustainability

3.2 Actions related with eco-efficiency

The identification of actions for eco-efficiency and benefits of eco-efficiency, taken from WBCSD (World Business Council for Sustainable Development):
Actions for eco-efficiency:

Benefits of eco-efficiency

Attending to design aspect related with Eco-efficiency and sustainability it is possible to distinguish between:

- Environmental technologies: cleaning and filtering measures to reduce emissions and environmental impact
- Green design: focus on single factors such as recycling and energy efficiency
- Eco-design: a radical life-cycle perspective where the most significant environmental impacts are reduced, from “the cradle to the grave”
- Sustainable design: includes eco-design and emphasise long term, radical, system innovations and an ethical approach and a shift in focus towards service instead of products

The eco-efficiency related with materials at

is taken from “Eco-Efficiency and Materials: Foundation Paper, by Five Winds International”, International Council on Metals and the Environment (ICME), Ottawa, Ontario (Canada), April 2001, ISBN 1-895720-34-6

A. Component Level	**1. Selection of low-impact materials**	1.1 Cleaner materials 1.2 Renewable materials 1.3 Lower energy content materials **1.4 Recycled materials** **1.5 Recyclable materials**
	2. Reduction of material quantity	2.1 Reduction in weight 2.2 Reduction in (transport) volume
B. Product Structure Level	3. Optimisation of production techniques	3.1 Cleaner production techniques 3.2 Less production steps 3.3 Lower/cleaner energy consumption 3.4 Less production waste 3.5 Fewer/cleaner production consumables
	4. Optimisation of distribution system	4.1 Less/cleaner/reusable packaging 4.2 Energy-efficient transport mode 4.3 Energy-efficient logistics
	5. Reduction of impact during use	5.1 Lower energy consumption 5.2 Cleaner energy source 5.3 Fewer consumables needed 5.4 Cleaner consumables 5.5 No waste of energy/consumables
C. Product System Level	6. Optimisation of initial lifetime	6.1 Reliability/durability 6.2 Easier maintenance and repair 6.3 Modular product structure 6.4 Classic design 6.5 Strong product–user relation
	7. Optimisation of end-of-life system	**7.1 Reuse of product** **7.2 Remanufacturing / refurbishing** **7.3 Recycling of materials** **7.4 Safer incineration**
D. New Concept Development	8. New concept development	8.1 Dematerialization 8.2 Shared use of the product 8.3 Integration of functions 8.4 Functional optimisation of product (components)

Table 2. Eco-efficiency related with materials

3.3 Terminology related with eco-efficiency

The terminology referred to the sustainability and Eco-efficiency is very extensive as we can see in these previous definitions. Defining some terms or vocabulary would be useful in order to understand the ideas and methodology of the Eco-design, Eco-efficiency etc. Next some of these terms are defined to make easy the understanding of the concepts.

- **Cost:** a loss or sacrifice; an expenditure of time, effort or resources. The focus is usually on economic, environmental and resource impacts; however, the concept can be extended to other areas of negative impact, like social costs.
- **Design for Disassembly (DfD):** Design allowing easier disassembly of a product.
- **Design for Energy Efficiency (DfEE):** Design of a product for low energy consumption.
- **Design for Environment (DfE):** DfE is a concept where the environment is one of the relevant criteria integrated during product design, as well as cost, quality and performance. It results from the decision of some companies to establish for designers specific environmental objectives for products. It is a way of taking into account environmental constraints as early as possible during the design process. It is also a way to decrease the harmful effects of a product during the design process and the harmful effects of a product during its life cycle in a continuous manner.
- **Design for Recycling (DfR):** Design allowing easier recovery of a product at the end of its lifetime.
- **Down-cycling:** recycling of a material into a lower grade material for use in a less demanding application.
- **Eco-design:** The word Eco-design will soon replace the phrase “design for environment”, although the latter is still used in some organisations. Eco-design reflects life cycle thinking, as opposed to the greening of designs, which might only involve one stage of the life cycle. Other largely synonymous terms are Environmentally Conscious Design and Manufacture (ECDM) and Environmentally Sensitive or Superior Design (ESD).
- **Eco-efficiency:** the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity, through the life cycle, to a level at least in line with the Earth’s estimated carrying capacity. Source: World Business Council for Sustainable Development (WBCSD) (2000).
- **Efficiency:** productivity with minimum waste or effort. Efficiency is generally measured as the ratio of benefits to costs.
- **Energy Efficiency:** A sustainable system is characterised by its ability to deliver required services without exhausting resources. The efficient use of all resources is necessary both in an environmental and economic sense. Using energy inefficiently creates waste in all the world's economies and has environmental impacts with local, regional and global implications. The steps to create a sustainable energy system begin with the sensible use of resources, and continue with increased use of renewable resources and controlled use of non-renewable one in advanced technology. Energy efficiency is a top priority in moving to a sustainable energy system. Many technical developments have fostered more and more sophisticated equipment, which provides increased service with less use of energy. Much

of the challenge in creating a sustainable energy system lies in how technological achievements can be put to use faster, be more broadly disseminated and how the behaviour of energy users adapts.

- **Environmental management:** the part of the overall management system that includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy (ISO 14001).
- **Environmentally Conscious Design and Manufacture (ECDM):** ECDM is the most recent approach to the design for environment concept. It covers both, the design of products and the design of processes. The main idea behind ECDM is that designers are conscious that negative environmental effects will invariably take place during the life cycle of the product and that they should try to include some constraints in their design to decrease these effects.
- **EOL:** End-of-life
- **Life cycle assessment (LCA):** compilation and evaluation of the environmental inputs, environmental outputs and the potential environmental impacts of a product throughout its life cycle.
- **Life Cycle Costing (LCC):** Life Cycle Costing is the economic assessment of all money flows that are caused by the existence of a product.
- **Life Cycle Design:** Life Cycle Design is defined as a life cycle systematic approach with the objective to give the most complete environmental profile of a product or service. The idea behind the LCD concept is that taking into account the complete life cycle of a product should help designers to develop products, for which the main potential environmental impacts are identified, minimised, and not simply displaced, as could happen in environmental engineering or pollution prevention. For example, the reduction of waste production during the manufacturing phase can generate an increase in waste in the overall life cycle.
- **Life Cycle Management (LCM):** "LCM aims at integrating environmental concerns into industrial and business operations by considering off-site, or supply chain, impacts and costs. LCM seeks to increase the competitiveness of new, and existing, products by examining advantages, and business risks, associated with the environmental and social aspects of a product, throughout its life cycle.
- **Material Eco-efficiency:** an Eco-efficiency strategy intended to maximise the benefit/cost ratio of the material stock.
- **Material stock:** valuable substances that are used by society to make the products or provide the services it needs.
- **Model:** any tool, approach or set of principles.
- **Process Eco-efficiency:** an Eco-efficiency strategy at the operational level. Process eco-efficiency addresses the reduction of real and potential environmental impacts, including the management of risk. It covers issues of process energy and process material efficiency at the unit-process level in production and manufacturing, to minimise polluting emissions and other ecological disturbances, to maximise product outputs, and to manage risk associated with facilities and processes.
- **Product cycle:** goods and services, including their associated design, production, use and end-of-life.

- **Product Eco-efficiency:** an Eco-efficiency strategy intended to maximise the benefit/cost ratio of the product cycle.
- **Resource Eco-efficiency:** an Eco-efficiency strategy intended to maximise the benefit/cost ratio and integrity of the resource stock.
- **Resource stock:** natural substance that is in or on the Earth, which presents opportunity for use by society.
- **Sustainable development:** "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987).
- **Utility:** usefulness, profitable.
- **Value:** the worth, desirability or utility of a thing. In general, and in this paper, value is evaluated as the difference between benefit and cost.
- **Value-added:** increase in value. Note: Here, value-added is presented from a societal perspective.
- **WEEE:** Waste from Electrical and Electronic Equipment

3.4 Selected case studies related with eco-efficiency

Recommendations for eco-efficient materials and processes for electronic products are derived from the analysis of a group of selected case studies that were transfer into the harmonised template shown at *Table 3* for their analysis. Practical product and PSS (product service system) case studies collected were both in B2B and B2C levels.

Table 3. Template for the collection of sustainable case studies

Criteria	Description
Case No.	Serial numeration
Organisation	Name of company acting as initiator of the case study
Partners	Partner companies
Project Title	Denomination
Sector	Electr(on)ics industry
Product/Service	Product serving as basis for utilisation of the service in question Description of the product-service system (offer, pricing, marketing, etc.)
Classification	Product-oriented, use-oriented, result-oriented
Duration	Limited duration? Past or still ongoing?
*Background**	Initial motivation and objectives (economical, ecological, social)
*Benefits, success**	Question for measurement criteria (operationalisation): Numerical assessment of economical benefits and ecological economisations.
*Investments**	Tools applied, resources spent (money, personnel, time, etc.)

Problems	Risks, obstacles
Methods of resolution	Improvement potentials and methods of resolution taken in order to solve the problems appeared in implementation.
Results	Results in economical, ecological and social terms: Lessons learned for other PSS-cases (SWOT-analysis for economic, ecological and social areas)
Conclusions and future Prospects	Future strategies concerning the project: Further development and implementation, modifications or termination.
Contact	Contact details for obtaining further information

*Critical research elements

Table 4 summarises the collected case studies including their title and the names of organisations involved in its development.

Table 4. Collected case studies 1/2

Case No.	Project Title (Organisation and Partners)
01-SAT	"IT on demand" - Towards an Environmental Conscious Service System in Vienna (SAT, Municipality of Vienna, ECOTRONICS, TU Vienna)
01-GAIKER	Eco-designed DAISALUX Hydra Auto test emergency luminaries (DAISALUX, IHOBE)
02-GAIKER	Eco-designed FAGOR F-536 washing machine (FAGOR, IHOBE)
03-GAIKER	Eco-design as a tool for the development of a more environmentally respectful pad mounted compact transformer CTIN (INCOESA TRAFODIS, IBERDROLA)
04-GAIKER	Design for Environment: A Case Study of the Power Mac G4 Desktop (APPLE COMPUTER)
01-IKP	Automotive LCA Case Study: Starter Generator vs. Conventional System (IKP - University of Stuttgart, CONTINENTAL, MOTOROLA)
02-IKP	Simulation and Optimization of Metal Cutting Processes in the Automobile Industry (IKP - University of Stuttgart, PE Europe, SINIS Umwelttechnik)
01-FEBE	EcoSirio (Telecom Italia Lab, Telecom Italia)
02-FEBE	--- (ABB Sace)
03-FEBE	--- (EMAK)
04-FEBE	PNEUMA (Pneumatic Uninterruptible Machine) System: Uninterruptible Pneumatic Power Generator (MAGNETEK, TELEFÓNICA MÓVILES ESPAÑA, University of Florence, FEBE EcoLogic, ENEA)
01-BTU	Successful Design and Marketing of Eco- and Sustainable Goods (Agency for Sustainable Design Cologne, Federal Ministry for Education and Research)
02-BTU	The Eco Bable (29th Annual Environment and Energy Symposium)
03-BTU	JIEP EcoDesign Tomorrow (FUJIKURA)
04-BTU	Eco-design, a new challenge for engineers (ENSAM)
05-BTU	DfE Tools – A Way for Application of LCA in Product (PE PRODUCT ENGINEERING)
06-BTU	Eco-design and human-powered products (O2 France, PES Research Group, Delft University of Technology)
07-BTU	Increasing Credibility of LCA (SETAC Europe)
08-BTU	Weyerhaeuser - Pulp – It's part of our nature (World Business Council for Sustainable Development)
01-RHEMEL	Environmentally Conscious PC (TOSHIBA)
02-RHEMEL	Green Procurement (NEC)
03-RHEMEL	Electronic Equipment Manufacturer Benefits from Cleaner Design (Varian Medical Systems, ENVIROWISE)

04-RHEMEL	Examples of Cleaner design from Industry (Ericsson Corporation, ENVIROWISE)
01-IVF	Case study at a truck company (Atlet, customers companies, IVF Industrial Research and Development Corporation)
01-TASK-1.1	ETMUEL. Eco-design Training for Manufacturing Use and "End-of-Life" for SMEs program (C&W, CfSD)
02-TASK-1.1	Remote vehicle security keyless entry unit (CONNAUGHT ELECTRONICS)
03-TASK-1.1	Applying EcoDesign to Softstarts (PROACTUS, Saftronics 2S)
04-TASK-1.1	ETMUEL. Eco-design Training for Manufacturing Use and "End-of-Life" for SMEs program (CH&K, CfSD)
05-TASK-1.1	Project aimed at increasing the drying efficiency of a tumble dryer (General Domestic Appliances, Aston University).
06-TASK-1.1	Increased awareness and design for environment at AMP (AMP, partner companies)
07-TASK-1.1	EcoVision / Green Flagship (Philips Consumer Electronics, partner companies)
08-TASK-1.1	Eco re-design of Accelerator Pedal (ProActus, Birkby's Plastics)
09-TASK-1.1	Energy+ (Electrolux Major Appliances)
10-TASK-1.1	Integration Cooker (Electrolux)
11-TASK-1.1	Development of Disassembly friendly and Recyclable Rail Vehicles (ALSTOM LHB, Hamburger Hochbahn, AGIMUS, European Union)

3.5 Handling information from collected case studies

Some of the research elements have analysed in order to compare all the case studies and evaluate the current tendency in the Eco-design and Eco-efficiency. Figure 14, Figure 15, Figure 16 and Figure 17 represent the different aspects compiled at Table 5, Table 6, Table 7 and Table 8 and the tendency in case studies.

The analysis of Case Studies by classification, Figure 14 and Table 5, shows that product-oriented type predominates over use-oriented and result-oriented types 78%, 11% and 11% shares respectively.

- The product-oriented Case Studies predominate since they are straightforward (it is always clear the improvement of a product version compared with the new one) and easy to identify.
- The use-oriented Case Studies are less direct and many times are mixed with product-oriented.
- The result-oriented Case Studies are development of methodologies and tools to be applied on products (mainly on goods and less on services).

The final result is usually the release of an improved or new product (good or service). Relevant problems like lack of tools, lack of data for calculations, lack of suppliers of desired materials or inter departmental co-ordination are usually not included because only successful Case Studies are collected.

The analysis of Case Studies by background, Figure 15 and Table 6, shows that environmental 47% and economic 34% drivers predominate over social 19% drivers.

- Environmental protection, via resource conservation (minimisation of material used) and/or climate change prevention (via increase of energy efficiency and use of renewable resources), together with economic development, via wealth and/or job generation, predominate over social progress for increasing the quality of life, by allowing a better education and/or health care.
- Some Case Studies contribute to more than one concept: less use of raw material or change to non-hazardous materials mean wealth generation or improvement of working conditions.
- The motivation differs from Case Study to Case Study but can be originated both in **external factors** like legislation (RoHS, WEEE…), competitors or market demands and **internal factors** like enterprise policies.

The objectives are different from Case Study to Case Study but can be classified on reduction of impacts (environmental), reduction of costs (economic) and other miscellaneous very specific like inform to the users, give support to take-back systems for recycling or allow access to knowledge (social).

The analysis of Case Studies by benefits, Figure 16 and Table 7, shows that environmental 45% and economic 41% benefits predominate over social 14% benefits. This picture is very similar to the previous ones since benefits come directly from objectives, the slight variation in percentages is related with the easier identification of economic benefits.

- The environmental benefits identified are the reduction of environmental impact in different life cycle phases, the improvement in product quality and features, the reduction of waste, the reduction of energy consumption, the reduction of material consumption or the improvement in reciclability.
- The economic benefits are mainly the reduction of costs in manufacture or use phase.
- The social benefits again very specific and usually combined with others. The identification of social benefits under common general denominations is still a matter of debate.

The analysis of Case Studies by investment, Figure 17 and Table 8, shows that tools 47% predominate over direct money 28% and personnel 25%. Nevertheless, all categories can be related with money. Investment is related with manpower, software or market survey. This item is generically expressed and difficulties a detailed analysis

Table 5. Classification of Case Studies

Case Study	Classification		
	Product -oriented	Use -oriented	Result -oriented
01-SAT	0	1	0
01-GAIKER	1	0	0
02-GAIKER	1	0	0
03-GAIKER	1	0	0
04-GAIKER	1	0	0

01-IKP	1	0	0
02-IKP	1	0	0
01-FEBE	1	0	0
02-FEBE	1	0	0
03-FEBE	1	0	0
04-FEBE	0	1	0
01-BTU	1	0	0
02-BTU	1	0	0
03-BTU	1	0	0
04-BTU	0	0	1
05-BTU	1	0	0
06-BTU	1	0	0
07-BTU	1	0	0
08-BTU	1	0	0
01-RHEMEL	1	0	0
02-RHEMEL	0	0	1
03-RHEMEL	1	0	0
04-RHEMEL	0	0	1
01-IVF	0	1	0
01-TASK-1.1	0	0	0
02-TASK-1.1	1	0	0
03-TASK-1.1	1	0	0
04-TASK-1.1	1	0	0
05-TASK-1.1	1	0	0
06-TASK-1.1	1	1	1
07-TASK-1.1	1	0	0
08-TASK-1.1	1	0	0
09-TASK-1.1	1	0	0
10-TASK-1.1	1	0	0
11-TASK-1.1	1	0	0
TOTAL	**28**	**4**	**4**

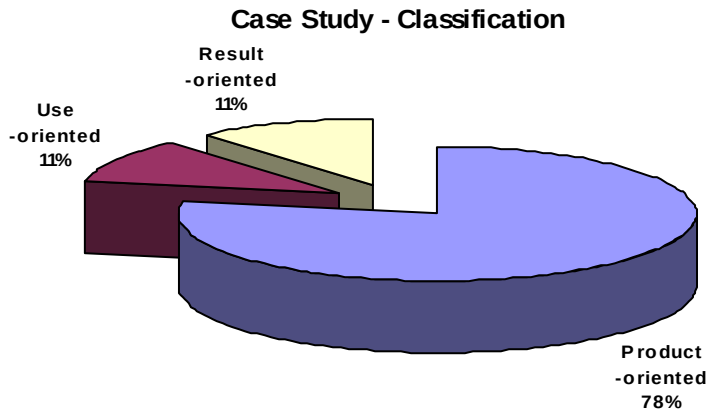


Figure 14. Classification of Case Studies

Table 6. Background of Case Studies

Case Study	Background		
	Environmental	Economic	Social
01-SAT	1	0	1
01-GAIKER	0	1	1
02-GAIKER	1	1	1
03-GAIKER	1	1	0
04-GAIKER	1	1	1
01-IKP	1	0	0
02-IKP	1	1	0
01-FEBE	1	1	0
02-FEBE	1	1	0
03-FEBE	1	1	0
04-FEBE	1	1	0
01-BTU	1	1	0
02-BTU	0	0	0
03-BTU	0	0	0
04-BTU	1	1	0
05-BTU	1	0	0
06-BTU	1	0	0
07-BTU	0	0	0
08-BTU	1	0	0
01-RHEMEL	1	0	0
02-RHEMEL	1	0	0
03-RHEMEL	1	1	1
04-RHEMEL	0	1	0
01-IVF	0	0	1
01-TASK-1.1	1	1	1
02-TASK-1.1	1	0	0
03-TASK-1.1	1	1	0
04-TASK-1.1	1	1	0
05-TASK-1.1	0	1	0
06-TASK-1.1	1	0	0
07-TASK-1.1	1	1	1
08-TASK-1.1	1	1	1
09-TASK-1.1	1	0	1
10-TASK-1.1	1	1	1
11-TASK-1.1	1	0	0
TOTAL	**28**	**20**	**11**

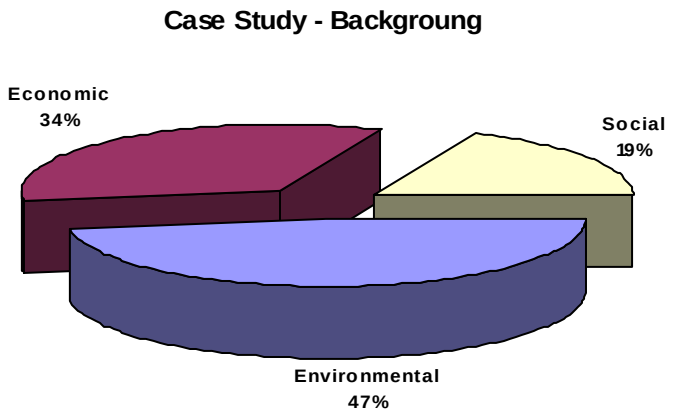


Figure 15. Background of Case Studies

Table 7. Reported Benefits of Case Studies

Case Study	Reported Benefits		
	Environmental	Economic	Social
01-SAT	1	1	0
01-GAIKER	1	1	1
02-GAIKER	1	1	1
03-GAIKER	1	1	1
04-GAIKER	1	1	1
01-IKP	1	0	0
02-IKP	1	1	0
01-FEBE	1	1	0
02-FEBE	1	0	0
03-FEBE	1	1	0
04-FEBE	1	1	0
01-BTU	0	1	1
02-BTU	0	0	0
03-BTU	0	0	0
04-BTU	0	0	0
05-BTU	0	0	0
06-BTU	0	0	0
07-BTU	0	0	0
08-BTU	1	1	0
01-RHEMEL	1	1	0
02-RHEMEL	0	1	0
03-RHEMEL	1	1	1
04-RHEMEL	1	1	0
01-IVF	1	1	0
01-TASK-1.1	1	1	0
02-TASK-1.1	1	1	0
03-TASK-1.1	1	1	0
04-TASK-1.1	0	1	1
05-TASK-1.1	0	1	0
06-TASK-1.1	1	0	0
07-TASK-1.1	1	1	0
08-TASK-1.1	1	0	0
09-TASK-1.1	1	0	1
10-TASK-1.1	1	1	0
11-TASK-1.1	1	0	0
TOTAL	**25**	**23**	**8**

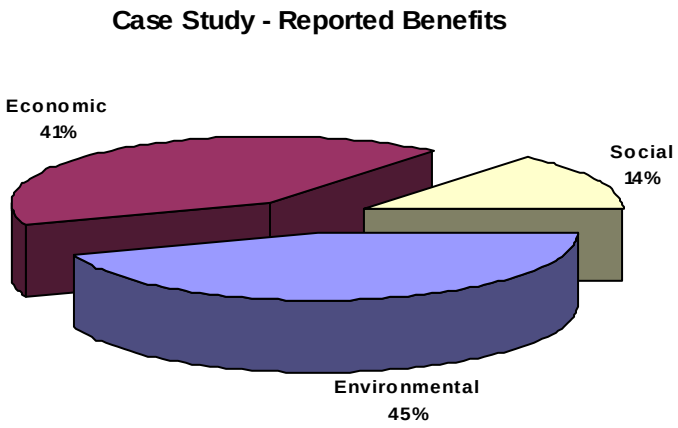


Figure 16. Reported Benefits of Case Studies

Table 8. Required Investments of Case Studies

Case Study	Required Investments		
	Tools	Money	Personnel
01-SAT	1	1	1
01-GAIKER	1	0	1
02-GAIKER	1	0	0
03-GAIKER	1	0	0
04-GAIKER	1	0	0
01-IKP	1	0	1
02-IKP	1	0	1
01-FEBE	0	0	0
02-FEBE	1	1	0
03-FEBE	1	1	0
04-FEBE	0	1	1
01-BTU	0	0	0
02-BTU	0	0	0
03-BTU	0	0	0
04-BTU	0	0	0
05-BTU	0	0	0
06-BTU	0	0	0
07-BTU	0	0	0
08-BTU	0	0	0
01-RHEMEL	1	1	0
02-RHEMEL	0	0	0
03-RHEMEL	1	1	1
04-RHEMEL	1	0	0
01-IVF	0	0	1
01-TASK-1.1	1	0	0
02-TASK-1.1	0	1	0
03-TASK-1.1	0	0	0
04-TASK-1.1	1	0	0
05-TASK-1.1	0	1	1
06-TASK-1.1	0	0	0
07-TASK-1.1	0	0	0
08-TASK-1.1	0	0	0
09-TASK-1.1	0	0	0
10-TASK-1.1	0	0	0
11-TASK-1.1	1	1	0
TOTAL	**15**	**9**	**8**

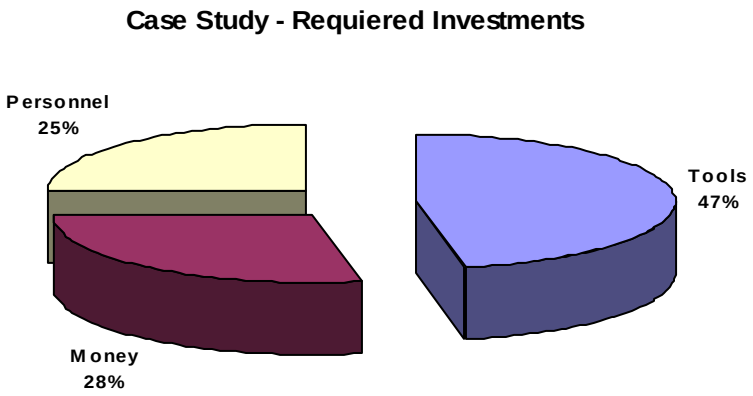


Figure 17. Required Investments of Case Studies

Table 9 summarises all the case studies and the issues which have improved in each ones. The actions are divided in the different parts of the Life cycle of the product and are:

Actions for Eco-efficiency

1 Reduction of the material requirements for goods and services
2 Reduction of energy intensity of goods and services
3 Reduction of toxic dispersion
4 Enhancement of material recyclability
5 Maximisation of sustainable use of renewable resources
6 Extension of product durability
7 Increase of the service intensity of goods and services

The benefits are considered taking account the global cycle.

Benefits of Eco-efficiency

A Reduced operating costs
B Improved production processes
C Reduced liability and risk
D Enhancement brand image
E Increased employee morale
F Increased opportunities for innovation
G Increased opportunity for revenue generation
H Better supplier management
I Better relationships with customers

Table 9. Identification of issues improved and benefits

	CASE STUDIES	ISSUES IMPROVED																											
		ACTIONS																				BENEFITS							
		Manufacturing Phase							Use Phase							End of Life Phase														
		1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	A	B	C	D	E	F	G	H	I
1	01-SAT	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2	01-GAIKER	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
3	02-GAIKER	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	03-GAIKER	1	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0
5	04-GAIKER	1	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	1
6	01-IKP	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	02-IKP	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
8	01-FEBE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
9	02-FEBE	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
10	03-FEBE	1	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
11	04-FEBE	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	01-BTU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	02-BTU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	03-BTU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	04-BTU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	05-BTU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	06-BTU	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	07-BTU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	08-BTU	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
20	01-RHEMEL	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0
21	02-RHEMEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
22	03-RHEMEL	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	0	0	0	0
23	04-RHEMEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
24	01-IVF	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1
25	01-TASK-1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
26	02-TASK-1.1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
27	03-TASK-1.1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
28	04-TASK-1.1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0
29	05-TASK-1.1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0
30	06-TASK-1.1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
31	07-TASK-1.1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	0	1
32	08-TASK-1.1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
33	09-TASK-1.1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
34	10-TASK-1.1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
35	11-TASK-1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	TOTAL	**10**	**7**	**8**	**2**	**0**	**0**	**0**	**5**	**13**	**6**	**0**	**1**	**6**	**1**	**2**	**1**	**3**	**10**	**1**	**0**	**0**	**10**	**5**	**3**	**12**	**2**	**6**	**0**	**3**	**7**

3.6 Conclusions and summary

The initial objectives for the activity “Eco efficient materials and processes” were focused on the identification, collection and analysis of application to electr(on)ic industry of (1) eco-efficient materials and (2) eco-efficient processes. The revised objectives broaden the activity to the sustainability level covering: (1) eco-design, (2) eco-efficiency along the whole life cycle and (3) sustainability including economic - ecological - social dimensions.

A harmonised template was developed as basis for the collection of case studies in the fields of eco-design, eco-efficiency and sustainability and was extended to products and product-service systems (PSS). A combined analysis of case studies was done taking in account the different actions for eco-efficiency identified in the Manufacture, Use and End-of-Life phases and their benefits over the product (good or service).

Specific and general actions by phase were detected from case studies. Reduction of toxic dispersion seems to be important action and common in all phases. Reduction of energy intensity is more important action at the use phase, less important at the manufacture phase and testimonial at end of life phase. Action for reduction of material requirements is particular of the manufacture phase, action for extension of product durability is particular of the use phase and action for material recyclability is particular of the end of life phase.

Specific and general benefits were detected from case studies. Thought some benefits like enhancement of brand image or increase opportunity for innovation are usually found, reduction of operating costs was identified as predominant.

4 From Products to Services: Threats and Opportunities

Product Service Systems have been studied for several years. Trials have been launched to drive the environmental improvement and to reduce resource consumption by addressing and changing the use phase. Although many analyses, case studies and guidelines have been published and Product Service Systems are already established in the business to business arena a real shift in the consumer market has not been reached so far. Difficulties have been experienced turning the trials into successful business cases.
The Ecolife II project has studied the current status of Product Service Systems and discussed the motivation and the lessons learned from case studies and company transitions. A special focus has been put on the Information and Communication Technology. Our motivation on the Green Paper has been driven by consolidating and structuring the Product Service System Research and Development, by providing an extraction of lessons learned and the key factors to consider.
Starting with a short history on Product Service Systems this Green Paper provides a common understanding and characterization. Examples are used to illustrate the different types of Product Service Systems and to show the huge variety of solutions. The Green Paper helps classifying current and future work, delivers the first steps how to start developing Sustainables Service Systems and identifies the most promising and risky issues in that area.

4.1 What are Product Service Systems (PSS)?

4.1.1 History of PSS - Business to Business (B2B)

Functional sales have become very common in business to business (B2B) transactions. One of the pioneers in this field is the Xerox Corporation. Xerox closely guarded the technology and the ownership of the copying machines remained with the company, with users being charged on the basis of cost per copy (pay-per-use e.g. PPU). Installation and maintenance remained under the control of Xerox, and users were not allowed to open the machines. With a monopoly on this copying process Xerox rapidly grew into a huge multinational company dominating the market in this sector.

When the patents started to run out, other manufacturers moved into this business arena and the business became much more price competitive, with the ownership of the majority of copiers moving to the user. Xerox moved into other areas such as scanners and fax machines. In 1992 the company noted:
“As we move into this systems world, we aren’t just making and selling boxes anymore. Increasingly we are working with customers to design and redesign their basic business processes. In the future, Xerox won’t just sell copiers. It will sell innovative approaches for performing work and for enhancing productivity … it’s a partnership [with the customer] in which we take a more consultative approach.” (Howard,1992)
Overall service momentum in ICT industry is coming from customers mainly. Customers have been asking for an enhanced supplier partnership focusing on:

- security,
- safety, and
- reliability of systems.

Service has been seen as business growth and customer satisfaction initiative. Most services have been developed in a close cooperation with the customer. However service is mainly seen as product enhancement mostly and provided from the OEM or its licensed partner directly. Reasons for that have been seen in brand protection and in required system knowledge. A lot of B2B services are supporting testing, optimization, management and maintenance of systems.
The history of IBM’s development to a service provider shows the long and hard way of transition. IBM started in 1993 as it was nearly out of business. The initial thinking was to sell computing and not computers. The service started in business groups, than moved into an own sector and has now been developed as a separate sector with own lines. The IBM Service has now its own global brand and is not only based on IBM products. IBM strategy is to be an end-to-end service provider starting from consulting, system engineering, planning and design, implementation, installation to maintenance what ever system the customer uses.

4.1.2 History of PSS - Business to Consumer (B2C)

The business to consumer (B2C) market is heavily influenced by fashion and culture. During the 1950s products using new technologies started to become available in the Western World. However many of these products were much too expensive for the average individual to afford. As a result it became common to wash clothes in launderettes, and to rent televisions, telephones and other products in some countries. As the Western World became more affluent, ownership became a sign of success within a competitive world and that preference for ownership lasts up to this day. As a result of this functional sales are now almost exclusively restricted to niche markets within the developed nations of the world.
These niche markets are:

- Amongst people not wealthy enough to buy a particular product.
- For expensive products only needed for occasional use.
- For people living short term away from their normal place of residence.

There are however other areas of PSS which matured into large markets. Most of these require a complex infrastructure for delivery of the function. An example is downloading of music over the web. The first MP3 player was developed by Fraunhofer IIS in the early 1990s. MP3 was mainly used for illegally downloading music off the web. The music industry refused the sales via internet as they attempted to protect their existing business models of selling CDs through shops. When Apple launched the iPod the landscape changed and it suddenly became the fashion item to own and sales went through the roof. iTunes users are now downloading one and a quarter million songs per day, which is an annual run rate of almost half a billion songs per year. Erik Wilde of the Swiss Federal Institute of Technology (ETH) wrote in a paper entitled 'When Business Models Go Bad: The Music Industry's Future'
'While the music industry is mainly concerned with protecting their traditional sources of income, the record sales, other companies concentrate on new business models. Apple's iTunes was the first online music distributor to become rather popular, and one of the reasons is that the concept is modelled around user-friendliness rather than the goal to protect old business models. The online distribution of music still is in its infancy, but it seems to be able to support a business, given the business is designed to work within the new world rather than against it. Users are willing to pay for a real alternative to P2P, if they can choose among titles of major labels, in user-friendly formats, without copy protection and for Windows and Apple platforms. Business models with copy restrictions or proprietary formats are less attractive and less successful.'

4.2 Current definition of PSS

A 'Product Service System' (PSS) is an academic term for a product that consists of both hardware and a function or a service rather than just a physical product (hardware). In practice there is no such thing as a pure product or pure service. Many companies provide combinations of products and services as part of mainstream business development without recognising the PSS terms. Even within academia the boundaries are not always clear.
The common understanding of the Ecolife II network of a PSS has been established with the following term:

A Product Service System consists of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs.

Product Service Systems can be classified into four types:

- **Product-oriented service:** service integration (adding products or functionality), product extension (providing upgrades, maintenance)
- **Use-oriented service:** product owned by the service provider who sells the function not the product or software e.g. leasing and rental
- **Result-oriented service (product substitution):** e.g. virtual answering service replacing answering machine, web-based information replacing directories
- **Result-oriented service (vertical integration):** e.g. production transferred to user.

In terms of sustainability, a PSS is expected to fulfill the following criteria:

- Economical
  - Improvement of efficiency
  - Improvement of productivity
- Ecological
  - Reduction of material intensity
  - Reduction of energy intensity
  - Reduction of toxic/harmful material or materials of concern
- Social
  - Improvement of health and safety for employees and consumer/society
  - Improvement of workplace quality
  - Improvement of education and learning society

4.3 Forecast of future development of PSS

4.3.1 PSS Oportunities in B2B

The PSS market in B2B is already well established. The most important and challenging issue seems to be the provision of **flexible and scalable services** designed to:

- fulfill customer standards and requirements,
- enhance user experiences with common service quality, and

- ensure interoperability with many types of access.

The following success factors have been summarized and underline the observation of the Ecolife II PSS case studies:

- Creating value for clients, by adding quality and comfort.
- Customizing offers or delivery of offers to clients.
- Creating new functions (new functionality can create new market demand and thus commercial success).
- Making smart and unique combinations of different functions.
- Decreasing the threshold of a large initial or total investment sum for customers, by sharing, leasing or hiring.
- Decreasing environmental load.
- Increasing the quality of contacts with clients (e.g. earlier in process, more frequent or personal or durable).

New oportunities are likely to be generated by:

- The emergence of new technologies.
- The increasing need to manage outsourcing on a global scale.
- Meeting the increasing burden of product legislation within the EU.

There seem to be considerable business opportunities for PSS software solutions by providing industry with remote servers for their thin client terminals, so they can pay-per-use (PPU) of software rather than buying it. This could be very attractive for all sizes of companies, since it would have the following benefits:

- The requirement for sophisticated IT support is removed.
- Companies would have access to a very large number of software packages but only have to pay for time of use e.g. PPU.
- Software used would always be up to date.
- For small companies in particular a higher level of data security may be realized.

Companies running the remote servers would then be able to offer other services such as document control, specification libraries, supply chain management systems etc.

4.3.2 PSS Oportunities in B2C

The future trends in B2C functional sales are more difficult to predict because history has shown that consumer taste depends on many variables, last but not least perceptions (true or false), fashion and culture. There is also the barrier resulting from consumers wanting to own. Reviewing existing PSS in terms of B2C, it seems to be successful to focus on younger people, which are not so emotional linked with an owned product and use behaviours are still dynamic, with higher education and income level. The number of persons in the household has no influence on the acceptance. Single households have an economic benefit due to the reason of a lower utilisation, shared usage allows more social contacts. Households with more family members are already familiar with a shared usage. However communication of advantages, like time, money and/or space savings is very important.
One conclusion drawn from the Ecolife II Task 2.1 study of technology shift within the electronics industry is that technology shift can play a role in the evolution from products to product service systems, but there is no evidence that technology shift plays a major role.
The most revolutionary aspect of the technology is that it creates new economies of scope and integration that change the economics of content distribution (Picard, 2000). New technologies permit the combination and integration of the other existing means of communications and allow readers/viewers/listeners more control and choice. It provides different methods for participating in and receiving communication. These changes create a significantly different relationship than exists between users and traditional media. It is ignorance or misunderstanding of this essential demand element that has made it so difficult for many firms to find ways to profitably exploit the potential of the new information and communications technologies and associated products and services (Picard, 2000).
For a product service system to be beneficial in an overall sense, all actors throughout both the product and service element's value chains must find the product service setup to be superior compared to an alternative consumption pattern:

- Customers must find an economic benefit or find the setup to include properties they find sufficiently exiting and willing to pay the extra premium. An important barrier in this sense is the lacking visibility of the total cost of ownership of a product, compared to procuring a service. Transportation service by taxi may be considered as expensive when seen in isolation, but may also be cheap compared to the equivalent trip using a personal car with all the indirect costs associated with the ownership broken down to total cost per km.
- Product Service deliverer must find economic benefit in delivering the setup, either through cost savings (economies of scale), or through delivering excitement properties that create advantages facing competitors and therefore become preferable towards customers.

- Society as a whole including the environment must find the product service setup beneficial through reduced materials consumption, reduced energy consumption and elimination of toxic or other hazardous substances.

In this setting, technology shift plays a role through improving efficiency in different ways, e.g.

- through energy efficiency of a PSS compared to a traditional product setup,
- through improved company internal efficiency in product management resulting in reduced cost for the customer compared to total cost of ownership of the traditional product setup,
- through improved efficiency in total life cycle material handling by distinct ownership throughout the product life cycle resulting in a clear benefit of closing material loops.

The following two PSS areas were identified to make a big impact in the consumers market:

- e-Newspapers, Magazines and Books
- Network Home Services

4.3.3 Cooperation forms for PSS

PSS are likely to be organized by cooperating entities. A network of companies can be characterised and differentiated by various characteristics. A short description of several of the most common network types is ment to differentiate the various forms of networks established. The given examples show some of the best known networks that exist.

Cluster

A cluster usually starts with a natural advantage or an advantage of location, leading to a collaboration among companies within this location. As a result, there is a pool of companies working in the same branch in order to establish a regional platform of experts. From this cluster, collaborations between single members can be initiated to realise short-term projects (example: AC - Automobile Cluster).

Consortium

A consortium is a cooperation of independent companies to realise short-term projects. Often there is a pool of companies working in the same branch, from which those who are interested

in can pick out partners and establish a consortium to work on a special task. The partners are mostly unchanging (example: Toll Collect).

Franchising

Franchising is a method for the distribution of products and services. The franchisor allows the franchising partner to duplicate the business format, in which he has proved to be sussessful. The franchising partners have to pay a fee and must fulfill the franchisor editions without getting payed for it. In return they achieve the high profile of the trade mark and become linked to a already organised network (example: McDonalds).

Joint Venture

A Joint Venture is an arrangement where two or more individuals or companies join forces to develop one particular product or service. A Joint Venture is based on contracts. Every time a new partner joins, already existing contracts must be canceled and new ones have to be placed (example: Samsung-Sony).

Keiretsu

A Keiretsu is a group or family of affiliated Japanese companies that form a tight-knit alliance to work for the mutual success. A Keiretsu is involved in many different sectors and consists of a variety of subcontractors (example: major japanese banks).

Outsourced partner

Outsourcing is a strategy to settle the claim of transforming important, non-core business processes to supplying partners and ensuring that a maximum value from resources is focused on core processes. This organisation needs a high level of organisation and communication because the consolidation of the single goods must be done just in time to be competitive on the market (example: Automotive Industrie).

Strategic Alliances

Strategic Alliances are long term collaborations between two or more independent parties, who share a variety of resources to gain significant strategic advances. Strategic Alliances are common within multinational organisations. These alliances allow companies to be active in sectors or places, in which they normally have no capacities. In return the companies take care of their partner businesses in sectors or places they are active in (example: Google-Lycos).

SCM

Supply Chain Management describes the practice of coordinating the flow of goods, information, services and finances across the entire supply chain starting from the raw materials supplier to the OEM or the consumer. SCM aims on the reduction of stocks in the supply chain and at the same time on securing the production of the OEM (example: Automotive Industrie).

Stable Virtual Enterprise

A stable virtual enterprise is a network of already existing enterprises which outsource all of their competences except their core competences. This allows the enterprises to be more flexible and convenient, because they do not have to deal with processes they can not handle well enough. These networks show one face to the customer and are considered to be one enterprise by their customers. Stable virtual enterprises are long term collaborations dominated by the core enterprise (example: Nike).

Dynamic Vitual Enterprise

Dynamic virtual enterprises are determinable networks of companies for the rapid, joint use of temporarily existing market niches. Such networks joint together only in order to fill the market niches and break up when work is done. The temporarily union is based on a well organised consolidation of all required competences for the performance of the issue (exemple: TelePad Corp.).

Which PSS are already known in the ICT-Industry?

In recent years several case studies have been collected and studied to identify success factors and barriers, to define suitable development methods, to understand consumer behaviour and business models, and to evaluate social, environmental and economic benefits. A few samples have been structured to illustrate the PSS type in the ICT industry:

Product-oriented service

- Added functionality and upgrades for PC.
- Remote maintenance management (reliability prediction, ...).
- Supply chain controlling systems (object tracking, ...).
- Environment and operation condition monitoring (operation, temperature, vibration, ...).

Use-oriented service

- Leasing of ICT hardware (B2B).

- Facility management.
- Energy management systems.
- Online control and accounting system for pay on demand.
- Online control of use intensity and capacity.
- Hardware is paid for on usage.

Result-oriented Service: Hardware substituted by ICT PSS

- Electronic books.
- Unified messaging.
- Voice over IP.
- Virtual answering machine (e.g. T-Net box).
- Internet provider hosting webpages.
- Location based service.
- Online banking.
- Customer relationship management (consumer pattern).

4.4 Which are the Critical Factors for Success?

4.4.1 Lessons learned

The development of PSS seems to be successful in areas with:

- Increased competition.
- Globalized markets, opportunity to create new service concepts by globalization.
- Liberalization and deregulation.
- New IC-technologies.
- Increased risk for success.
- High customer expectations.
- Demand for systematic and continuous innovation management.
- Innovative product technologies offer a good chance for integrated solutions.
- Strategies, which consist of a combination of industrial made products and services.
- New services form a decisive factor of competition.
- Increased risk for success.

Lessons learned from previous research projects and PSS pilots detected a lack in systems analysis and understanding the system dynamic, which is an important factor to be successfull in the market and develop a PSS as life long component for consumers and leads to longer relationships.
Service is not a simple growth strategy, it is a transition. It requires significant changes to market strategy, organization, business processes and cultures. The commitment of the CEO is needed, and changes in executives and supply chain partners are often required. For example IBM changed its incentive system, flipped the power from the region to the global brand and functions, as well as changed the money flow accordingly. IBM used its strong core competency in integration. The success of service depends on the understanding of customer demand, the right combination of the offer, pricing and infrastructure.
Another critical success factor is cooperation: A network implies many chances and risks. At the end everything depends on the organisation. The organization of the cooperating companies has shown to be dependend on various factors. To be successful in networking and retain an efficient PSS it is important to consider some aspects of the cooperation. Although every network has to be planned and supervised with its specific characteristics, there are some factors for success that have to be realized:

- Definition of comand structure.
- Determination of responsabilities.
- Definition of offered services and products.
- Agreement on goals to achieve.
- Analysis of customer topologies.
- Appliance of quality control and supervision.
- Structure for data exchange and information flow.
- Agreement on contracts.
- Consolidation of know-how benefits and capacities.

The decision to establish or join a network can evolve from different motivations. Small and medium-sized enterprises or single persons are dependent on the core competences of other enterprises or persons, because they may not be experts in all aspects and areas of the activity they are involved in. They need to band together in order to cover all those sectors, their business is in need of. Multinational enterprises are forced to outsource competences, because they can not make the effort to treat businesses they do not control well enough in the face of competition. In the supplier/customer relationship it is recommendable to create a network with all parties which are involved to better the communication in the supply chain. Furthermore companies join forces in order to create new products or services, the single company would not be able to, because a single company may not have the required resources, production facility or sales potential.

On this basis chances by working within a network can be realized such as:

- Access to new markets.
- Broadening of the assortment of products and services.
- Increase in productivity by shifting non core-competences to partners.
- Increase of flexibility.
- Increase of innovation.
- Sharing of responsibilities.

Risks by working within a network:

- Dependency of others.
- Hand-over and loss of know-how.

- Reduction in the quality standard.
- Restrictions in future planning.
- Rising complexity of workflow, IT and legal issues.

ICT functionality can be also used to enable and enhance sustainable PSS supporting the following essential task within a PSS:

- Connection of actors.
- Exchange of information.
- Provision of security and safety.
- Access to product or service.
- Monitoring actions and conditions.
- Capacity management.
- Enable payment on usage.
- Administrative work.

Investigation of the Ecolife II network on a pay-per-use shared computer service in community buildings in combination with social interactions have been conducted. From the user point of view this concept seems more convenient for corporate customers, for private customers only with restrictions feasible (service hours, prices, etc.). The degree of information needed for assessing the offer is much higher than for a product purchase. The test of such systems is highly appreciated to be considered as an alternative. There is always an assumption that the concept is very difficult to realise. Customer must not be subject to comprising liabilities and duties (e.g. in replacement of components). The following requirements have been extracted from the response of the consumer:

4.4.2 Product and Service requirements

- Clear definition of scope of services and basic equipment of software.
- Adequate price-performance-ratio.
- Individual, sufficient and satisfying services (Customising).
- Affordability, even for young persons with low income.
- Good quality, fair price.
- Functionality.
- Stability.

- Good service, always on current state of technology.
- Complete functionality and modern products.
- Guarantee of pre-defined level of technology, clear defined service- and replacement-intervals.
- High quality, environmentally friendly and realistic price.
- Environmentally sound and durable.
- No antiquated appliances.
- Higher performance, maintenance, upgrade of components.
- Reliability of 100%.
- Quick and reliable service and updates.
- Adaptation to personal requirements and environmentally adequate production.

4.4.3 PSS Provider requirements

- Competent technician, good service.
- Cooperation.
- Reliability, possibility of making use of the services of technician even beyond office-hours.
- Competent consultancy.
- Satisfying customer service (consultancy by telephone, replacement service).
- Customer friendliness.
- Flexibility concerning contract duration and choice of components.
- Competence, flexibility and friendly service.
- Adequate prices.
- Competent employees.
- On-site service, information about possibilities concerning upgrades.
- Quick handling of customer needs.
- Good service, fair prices, consideration of privacy.
- Adequate information in advance.
- Possibility of personal supervision.

- Quick service in the case of defects.

As system understanding is the key to develop a sustainable service and especially in the business to consumer market understanding of consumer needs, motivation, decision making process and behaviour, their relationships and dependencies are essential, the Ecolife II project studied the consumer needs and investigated a lot of effort for a successful implementation of PSS. The following section gives an overview on consumer needs and social drivers.

4.4.4 Consumer needs

4.4.4.1 Physiological/Basic Needs

- Need for satisfying hunger, thirst.
- Need for sleep.
- Need for avoiding pain.
- Need for realising one's sexual instinct.
- Need for an adequate home (e.g. a clean apartment, heating) (depends on standard of living).
- Need for physical health and well-being (i.e. no injuries).
- Need for mental health and well-being (i.e. no stress).

Need for safety/security

- Need for a safe job.
- Need for financial independence (e.g. a high income, shares).
- Need for order/organisation.
- Need for individual time management (i.e. organise my day).
- Need for phases of recreation.
- Need for phases of work.
- Need for control.
- Need for retraction and isolation (e.g. anonymity).

- Independence from others (i.e. no need to be dependent from persons and their services).

Need for comfort

- Need for low physical (and/or mental) stress (e.g. no hard or monotonous work).
- Need for enough time for own interests (e.g. hobbies, friends).
- Need for (simple) communication and information acquisition (e.g. use a mobile phone).
- Need for permanent availability of information, goods and services (e.g. adequate infrastructure in surroundings like shops, banks etc.).
- Need for mobility (e.g. by using a car or public transportation).
- Need for entertainment (e.g. TV, books, theatre).

Need for socialisation

- Need for human contact and interaction (e.g. friendships, colleagues).
- Need for exchanging ideas with others (e.g. intellectual development and suggestion).
- Need for acceptance.
- Need for social affiliation (e.g. need for acceptance by society, being member of a social group).
- Need for responsibility.
- Need for helping others.
- Need for admiration.
- Need for love (e.g. family, relationship).

Need for self-actualisation

- Need for autonomy (i.e. to decide autonomously on something).
- Need for independence and freedom (e.g. financial independence).
- Need for freedom from pressure of opening hours (e.g. flexible closing time of shops).
- Need for individuality (e.g. design your own T-shirt).

- Need for creation (e.g. being an architect) and implementing one's creativity (e.g. painting a picture, writing a book).
- Need for power over and influence on other people (e.g. being member of political party).
- Need for status and prestige.
- Need for respect.

Need for change/alternation

- Need for broadening one's horizon (e.g. learning a new language, travelling, job-related development).
- Need for eagerness for knowledge (e.g. questioning new things, need for knowledge and understanding).
- Need for entertainment (e.g. visiting a concert, watching TV).
- Need for satisfying one's play instinct (e.g. playing computer games, parlor games).

Need for esteem

- Need for achievement, accomplishment, activity.
- Need for competition.
- Need for impressing.
- Need for avoiding/minimising failures/flops.

The challenge for PSS is of course how to fulfill these consumer needs by providing more value for money using tangible products and intangible services jointly. Considering already existing PSS as described before it attracts attention that PSS – depending on the particular design and implementation regarding critical success factors – may obviously fulfill consumer needs more efficient and effective while meeting the ‘zeitgeist’ and well detecting major shifts in consumer behaviours. Also it strikes that some PSS, while providing solutions for a basic need to take centre stage also generates surplus to fulfill additional needs described in the list above (see examples in chapter 3).

4.4.5 Information Flow

During the work of the Ecolife II project the investigation of both the state-of-the art of information flow and the information flow needed in a service system have been carried out.
These investigations made clear that the current development in the information flow leads to a system that will involve not only part suppliers, but end-of-life treatment service providers, logistic companies (including reverse logistics) and also users.
This is the result of

- on one hand: the regulatory and policy instruments of the European Union, which forces the producers
  - to include end-of-life strategies into their product life cycle model with extended producer responsibility (WEEE Directive, EuP Directive Draft, etc.), and
  - to improve their communication within the supply chain (RoHS Directive).
- on the other hand: the market forces (eco-labelling, green procurement, etc.), corporate culture and environmental management, which leads to a better management of the product life-cycle, including the improvement of communication as well.

As an example the **EuP** Draft summarises the need for information in all phases of the life-cycle:

- Manufacturers should know the environmental profile of the components they are incorporating into their products.
- Designers should examine life cycle impacts of their choices and have easy access to existing lifecycle data and methodologies to do so.
- Producers should pass on information down the product chain to consumers and buyers in an easily accessible form.
- Retailers, consumers and buyers should recognise, which are greener products.

The main problem is that up to now the use phase of a product life cycle is a black box for the producers. Product use has never been tracked, repair shops are usually third parties, not collecting or supporting data on the product characteristics during the use phase for producers. For extended producer responsibility and especially for service based systems tracking the "real use" of a product is a key issue. In case of PSS, even payments are sometimes linked to this in the pay-per-use model. Improving information flow within the use phase is an important issue in case of a product system, and a very critical issue in a service system.
As a result of all the aforementioned issues, we have to draw the conclusion that the current needs for information within the product life-cycle require that all life-cycle phases should be

covered to improve sustainability and to fulfill customer needs. Gathering, storing and processing the information became a highly significant part of marketing, as it improves the market position of the producer through the improvement of customer satisfaction. Improving satisfaction through joint services for products drives the companies from the "traditional producer" position automatically to a "service provider" position, which can be the basis of a service based economy. Thus "all life-cycle phases should be covered" prerequisite is the same as in a service based life-cycle.
Information flow in the service system can be a critical point not only for reaching sustainability of the service but for success, too. Critical factors for success from the information flow point of view can be the followings:

- The information flow should cover all phases of the product life-cycle.
- Highly efficient methods and techniques should be developed and operated to involve users into the information flow as user (especially private customers) can be considered as the weak points in the information flow.
- Well defined communication techniques (protocols) should be used in the information flow towards the members of the information flow.
- All members should receive all information that is important for them.
- Information for users should not be more complex in order to help understanding.

4.4.6 Social trends

New social drivers deliver new opportunities and target markets for innovative services:

- working mothers,
- people working and living in a foreign country,
- growing elderly population,
- longer life expectation,
- single households,
- home offices,
- more leisure time etc.

Some of the drivers and their influence on the success of the implementation of PSS within the electr(on)ics sector have been detailed below:

Elderly more active consumers (generation 50+)

The share of population of senior people feels psychologically young and disposes of sufficient purchasing power in order to satisfy its generally high requirements. This group of people is growing super proportionally. The share of population of the above-60-year-olds amounts to approximately 20% currently. The income of this group of persons lies above the average of the younger generations and they are willing to pay more for comfort and safety, fitness and health. Desires and needs of senior people have to be considered more thoroughly, products and advertisements have to be adjusted according to their requirements.
Special accentuation requires the fact that seniors do not want to be addressed over the criterion of age (e.g. „seniors fair“, etc.), but over innovative product ideas and solutions, which are explicitly adjusted to their needs and requirements. They want to be addressed as persons, who do have still a lot of plans during their future life.

Responsibility for the environment

The responsibility of consumers for society and for preservation of healthy living spaces is continually growing. At the same time, the quantity of people is climbing, who are prepared to increase their quality of life via contributing to environmentally friendly measures and actions. Population is increasingly open and interested in information and details concerning production, usage and finally disposal of products. Generally speaking, women exhibit tendential a greater ecological awareness than man. Parents with children under 6 years old are more environmental oriented than other groups.

Avocation from every-day-life

On the run from every-day-stress, one can recognise a stronger orientation on leisure and adventure. This orientation represents a major consumption- and shopping-adventure for a major part of the population. Henceforward, the purchase is not any longer only an act of procurement, but becomes a part of this world of adventure. The customer claims for the offered selling environment and atmosphere and on the compliance with a certain level of creativity (demand for the extraordinary) are rising erratically. Furthermore the demand for continuant change in order to affirm the variety from every-day-life even stronger grows.

Growing health consciousness

This trend manifests itself in a deeper nutrition and body consciousness. Increasingly consumers take matters into their own hands (e.g. self-medication). The growing health consciousness of consumers will find expression in the according choice of products, but also in the need for serious communication and information in these matters. These companies which are in a position to provide trustworthiness on sides of their customers and bind them in a long term, by implementation of means like authenticity and honest information’s policy, will succeed.

The critical and demanding consumer

Through comprising education as well as through permanent availability of information, the consumer is acting more price-sensitive and more demanding. The aura of brands will suffer losses for the benefit of an objective freedom of evaluation. Increasingly the consumers are going to resist against mass products and services. Moreover one will not any longer be prepared to let oneself squeeze into the consistent organisational framework of a company, but will growingly expect that price and product features, as well as the selling environment during the act of purchase will be adjusted to one's needs and desires (by means of information, service, delivery, montage, installation, etc.). Real quality and worthiness of products are demanded more strongly.

Growing individuality

The personal strive for self-development, self-realisation and the desire to distinguish from others, represents a central need complex at the moment. This trend will prolong and cumulatively grow. The addiction to exclusive desires increases, which can be limited to certain spheres of living. In the long-term, the customer will not be satisfied with only being treated as consistent consumer-number, but will expect that firms will consider his individuality and accept him/her as a person with different needs and desires. This represents a special challenge for companies to make real use of all of its IT-resources in order to generate detailed knowledge about preferences and behaviours of its customers (modern customer databases, individualised communication).

Change in the size of households

The development in regard of continuing shrinking the size of households (single-household) represents a fact even today. The average size of households will continue to decline, after the turn of millennium a trend to the opposite direction is expected.

Design

Design will become one prerequisite for mass production, as there exists a strong development in regard of democratisation of design. Product categories, like textiles, cars, furniture and interior will be especially affected. Design is not just perceived as a question of price any longer, but is also experienced as wellness-component. This development has in any case consequences for an adequate presentation of design within sales policy.

The new role of women

The influence of women within purchase decisions will grow and exceed – with limitations – the influence of men. Women will step in typical male markets and vice versa. Preconceptions

about traditional role allocations have to be abolished. In this sense, one has to pay special attention to penetrability through differenced communication in advertising.

Culture, the leisure-activity of the future

Within the next years, leisure time one can dispose of will continually grow. Especially cultural consumption will gain on importance, at the expense of sports- and mass-events. Leisure time will mainly be used for permanent education. The reason for this development can be due to the common desire of customers to have more time for oneself and the personal search for the sense of life.
The connection between economy and culture must not lose itself in undifferentiated cultural sponsoring, but opens a wide range for creative connections in advertising and event-marketing. In particular, the demand for ideas which concentrate on new ways and alternatives (to the current very striking advertising) in order to present services and products of a company in a more subtle way will be highly demanded. Furthermore, the consumer is searching for possibilities which enable him to express individual ideas in a creative way and develop himself culturally. Major part of this development is the growing interest of consumers for educational contents.

Cocooning

Individual and social "Cocooning“ are on their way. Habitation and social gathering within own reference groups will gain on significance. This will lead to a retraction from the undifferentiated mass back to small groups of like-minded people. Specialists do have chances for success, if they perceive themselves not only as contributors of a small product segments, but also as meeting-points and platforms for communication with people with likewise bedded interests.

4.5 Conclusion

The motivation of developing and offering Product Service Systems is as much different as company cultures are. Additionally the characteristics of a Product Service System are as much as different as market and customers needs differs. The success of a service depends on the understanding of customer demand, the right combination of the offer, pricing and infrastructure.
The Ecolife II network analyzed gaps and forecast of future technologies, products and services and reported and provided trends. New social drivers deliver new opportunities and target markets for innovative services:

- working mothers,
- people working and living in a foreign country,
- growing elderly population,
- longer life expectation,
- single households,
- home offices,
- more leisure time etc.

It is very difficult to create general, widely applicable Product Service Systems. Product Service Systems are very much specialized, depending on the product characteristics, organizational structure, chain actors network support and infrastructure in place as well as the type of customers. In general a Product Service System development has to follow traditional market and product development approaches. e.g. scenario planning, market research, requirements definition, alternative concept design, value assessment etc. However PSS are more complex systems, more partners might be involved, balancing cost and revenues along the value chain and the life time is quite sensitive. Mistakes in service execution can lead to value destruction.
Lessons learned from previous research projects and Product Service System pilots detected a lack in systems analysis and understanding the system dynamics, which is an important factor to be successfully in the market and develop a PSS as life long component for consumers and leads to longer relationships. Many companies underestimate the significant changes to market strategy, organization, business processes, and cultures required to be successful in service delivery.
This Green Paper gave insights into the shift from environmental sound technology to sustainable service systems. Meeting the triple bottom line of sustainable services in ICT means (1) economic growth by improving efficiency and productivity, (2) reducing the environmental impact by reducing material and energy intensity and the use of toxic /harmful material or materials of concern and (3) social improvements of health and safety for employees and consumer/society, of workplace quality and of education and learning society.
An innovative Product Service System may meet these requirements if the critical success factors described in this Green Paper are taken into consideration, although only basic hints have been presented. In that sense, this guide provides initial information to set up efficient Product Service System meeting also ecological and social requisites – accomplishing and structuring this challenging task is up to the innovator!

5 *Examples of successful business models for sustainable Services in the Electr(on)ics Industry*

5.1 Mobile telephone product service systems

The first commercial use of mobile telephones was launched by Bell Laboratories in 1946. In 1947 the reuse of radio frequencies among hexagonal "cells" was conceived, leading to today's cellular communications. However at that time the number of frequencies available was very limited in the US allowing only up to 23 simultaneous phone conversations to be held in the same cell area. This position did not change until 1968.
Motorola in 1973 was the first to incorporate the technology into portable device that was designed for other than the use in police cars. It was not until 1981 that the first commercial cellular telephone system began operation in Tokyo. A year later the FCC in the US gave authorisation for the first commercial US service.
In 1982, the Conference of European Posts and Telecommunications (CEPT) began the process of creating a digital cellular standard that would allow users to roam from country to country in Europe. By 1987, the GSM standard was established and was the only communication standard that could provide data services such as email, fax, internet browsing, and intranet/LAN wireless access.
Since the late 1980s mobile telephones have gone from being rare and expensive product used almost exclusively by businesses to a low-cost personal item. In many developed countries, mobile phones now outnumber land-line telephones. Mobile phone penetration is also increasing dramatically in the developing countries, where there is little existing fixed-line infrastructure.
The mobile phone has now become a fashion item, and its use is being extended to become smart phones which can adopt the roles of Internet browser, game console, personal music player, and personal digital assistant. As the PSSs in the mobile telecommunications industry develop the business models are adapted. However most of them in the developed world work are based on the 'Bait & Hook' business model with the mobile phone being either given away free or at a very low price (bait) and the income comes from the line rental, call charges, and other data services (hook). Some fall under the subscription business model (pay as you go) although this type is more common in the developing countries.
In most cases the user owns the phone and product service therefore falls under the class of PSS called Product-oriented services. However with new models having extended use as a

camera, music player etc the product service system is rapidly moving into Result-oriented service (product substitution) category.
The European mobile telecommunications market is very fragmented. Pan-European mobile telecommunications services are not available, nor are fixed-mobile converged services. This has resulted in many differences in the business models between member states.
Within the mobile telecoms industry there are a number of different types or organisation involved in bringing the PSS to the user. These are:

- Mobile phone producers.
- Retailers
- Service Provider

Often the service providers own retail outlets and also handle sales and replacement phones directly. The mobile phone manufacturers are normally independent organisations from the service providers. Since the service provider put together the complete PSS package that organisation is a key driver of the PSS.
In general the mobile phone manufacturers are multinational and offer the features on a mobile rather than the content. The latter is normally handled by the service provider, although this picture is becoming more complex as new features are introduced. As an example Motorola has teamed up with Apple to produce a mobile that can download music from the iTunes music store. Sony Ericsson on the other hand has joined forces with online music service Napster to develop a service for mobiles.
From the above the question is raised on who is the initiator of the product service system? Whilst it is the service provider that puts the PSS together along with the revenue generation model it is the mobile phone manufacturer that seems to be in most cases the PSS initiator and they are now showing the ability to initiate PSSs with content providers other than the service providers.
Since there appears to be a multitude of different business models it is difficult to make an overall judgement on sustainability. Certainly the drive by manufacturers to offer more features to retain high sales levels results in short product life. If those manufacturers had a revenue stream from content rather than almost exclusively from the sale of the phone then a much more sustainable business model would probably evolve. This however is unlikely to occur. On the plus side the move to include other features such as camera, PDAs and music players[5] reduces the number of devices a user requires and saves on material resources. Within the developing world the mobile phone is allowing communications structures to come into place where landlines are not available and helping those countries to develop faster.

5.1.1 Example of Mobile Communications

Mobile Communication – “Simyo”
What is the product service system Simyo offers mobile voice-telecommunication and SMS.
Who is the key driver Simyo was launched in June 2005 by E-plus, a major player in the German market in.
What are the different elements Simyo offers only cheap telecommunications, not hardware. The service uses any existing unlocked mobile phone for its services.
Who is the customer Customers are normally young people/children using prepaid cards, or people who already have an existing mobile phone contract and want to use a cheaper alternatives.
Basic needs and drivers Accessibility of communication, the need to be available and peer-group pressure.
The initiator of the product service system E-plus in order to attract new costumers.
Financial flow through the product service system Simyo works as a prepaid system: Prepaid cards are available from 10 to max 200€ and are valued for 6 months. Talking via a mobile phone is charged at 19cents per minute to all numbers within Germany on the prepaid card. SMSs are charged at 14cent each. 
Sustainability of the business model Mobile phones no longer used and out of date get the chance of a second lifetime in a reuse phase. There is for example no Multimedia Messaging (MMS) possibility via Simyo so older models can still use the services. Newer mobile phones are often equipped with two sim-card slots, so customers who want to use the (in some cases cheaper) Simyo services can switch back and forth between their standard network and Simyo. Extra value is provided to the existing mobile phone.
Collaborators within the product service system No known collaborators
Costumer/provider relationship All customer contacts are either over the web or through a call centre, including the ordering of a starter package.
Marketing tactics Under the brand “Simyo” E-plus is able to offer “no-frills” services for costumers. E-plus is able to skim the market in a different market segment.

Details
www.simyo.de

5.2 Downloadable music, films and radio

In the mid-1980s, at the Fraunhofer Institut in Erlangen, Germany, work began on a high quality, low bit-rate audio coding with the help of Dieter Seitzer, a professor at the University of Erlangen. In 1989. Fraunhofer was granted a patent for MP3 in Germany and a few years later it was submitted to the International Standards Organization (ISO), and integrated into the MPEG-1 specification. The first MP3 player was developed by Fraunhofer in the early 1990s. MP3 was mainly used for illegally downloading music off the web. Portable players did not take off in a big way, because the higher quality sound from a portable CD player was preferred by consumers and the refusal of the music industry to sell over the internet as they attempted to protect their existing business models of selling CDs through shops.
When Apple launched the iPod the landscape changed and it suddenly became the fashion item to have one and sales went through the roof. Erik Wilde of the Swiss Federal Institute of Technology (ETH) wrote in a paper entitled 'When Business Models Go Bad: The Music Industry's Future'
'While the music industry is mainly concerned with protecting their traditional sources of income, the
record sales, other companies concentrate on new business models. Apple's iTunes was the first online music distributor to become rather popular, and one of the reasons is that the concept is modelled around user-friendliness rather than the goal to protect old business models. The online distribution on music still is in its infancy, but it seems to be able to support a business, given the business is designed to work within the new world rather than against it. Users are willing to pay for a real alternative to P2P, if they can choose among titles of major labels, in user-friendly formats, without copy protection and for Windows and Apple platforms. Business models with copy restrictions or proprietary formats are less attractive and less successful.'
Apple reported that since its inception, customers have purchased and downloaded more than 250 million songs from the iTunes Music Store. iTunes users are now downloading one and a quarter million songs per day, which is an annual run rate of almost half a billion songs per year. The iTunes Music Store is now available in fifteen countries, which together represent more than 70 percent of the global music market.
The downloading of complete films via the internet is at an even earlier stage of development. There are two major road blocks preventing it becoming a large commercial market. These are:

- As with the music industry the desire of the Hollywood studios to protect their existing revenue stream model.
- Lack of fast enough broadband connections to the majority of households.

The first issue is already disappearing since some of movie producers are in both the film and music business and are starting to find the digital music business model a lucrative business to be in. Warner Music in 2005 reported digital revenues climbed substantially, reaching $44

million, or 6 percent of overall company revenues. That percentage is likely to increase even further as overall CD sales continue to decline. In addition in the US, Sony, Warner Bros., Paramount, MGM and Universal have created a joint company called Movielink from which movies at a cost of between $3.99 and $4.99 per film can be downloaded. The films can be watched while they are being downloaded although there are only about 450 titles currently available.
Apple are now moving into streaming of radio programmes to the iPod. This has been called podcasting and is gaining in popularity at a tremendous rate. It is being embraced by conventional radio companies and amateur broadcasters. Both the BBC and Virgin Radio are 2 conventional companies pushing podcasts. Virgin's breakfast show is being downloaded 85,000 times a month through Apple's iTunes. Colleges are using podcasting to make lectures available to students and a vicar in the UK is podcasting his sermons which have been downloaded by over 2400 people.
Podcasting is not without its problems. There is a big fear though that it will destroy the conventional business model for commercial radio in that the podcast audience will stop listening to advertisements by skipping them. In addition there is the digital rights issues on how to legally include music in podcasts. The solution to the latter may not however be insurmountable. Adam Klein, executive vice-president for strategy and business development for EMI stated:

'We've all become a lot more sophisticated about how to create business models that could meet a broad range of interests. Everybody's trying to work out what's a responsible way to do this.'

The downloading of music, films and podcasts falls into the PSS category of 'Result-oriented service' since the films and music replace cassettes and CD/DVDs. The normal business model used is the 'Bit Vendor' model. Apple for instance charges in the US 99 cents per tune. For each tune downloaded a royalty is paid to music producers. Some companies use the subscription business model where you pay a monthly fee for downloads.
The downloading of music and films at first glance would seem to be an ideal way of reducing the environmental impact of the industry. In truth the actual situation is much more complex. ICT Digital Europe has issued a booklet called 'Making the Net Work.[8] Steps to a sustainable networked world' It is a summary of two years of research on the effects of ICT on sustainable development. It showed that downloading music can result in less than half the environmental impact of purchasing from a shop, if the consumer uses a broadband connection and does not burn the music to a CD. However a narrowband user who does burn the music can have an environmental impact of over three times that from the shop. Furthermore a user that down loads the same piece of music over broadband more than twice again has a larger environmental impact than purchasing a CD. This shows how complex the analysis of PSS in ICT can become. The study did not touch on the impact of transferring music to MP3 players or the increase in market resulting from such a PSS.
The social impacts are similarly complex. Certainly it is of social benefit for people that can not easily leave the house because they are infirmed, but it also adds to financial pressures within town and city centres which are already suffering from many retail businesses closing down. Furthermore most of the business for this PSS is within the developed world as few countries in the developing world have broadband connections available to a significant proportion of their population.

5.2.1 Example of Downloadable Music

Downloadable Music – Chello Musiczone
What is the product service system Chello Musiczone offers under www.chello.at music for legal download and streaming. A search button is used to find songs under different categories such as country; dance; folk; jazz; klassik; poprap/hip hop; rock; world; deutschpop.
Who is the key driver The key driver is Chello Musiczone.
What are the different elements Chello Musiczone offers two listing modes. The user can either listen to the music online via a music-stream, or can download the music and burn it on to CD-ROM or flash for an MP3 player.
Who is the customer Customers are persons having access to the internet and wanting to listen to legal MP3-music.
Basic needs and drivers Customers have the advantage of availability of up to date music as well as oldies without spending too much time on searching (for example in music stores). The user is attracted by the convenience of fast access, without the need to go to a retail outlet.
The initiator of the product service system Chello: Offer new products to the customer and to enrich the service of a standard provider.
Financial flow through the product service system Chello Musiczone offers three different credit-packages: o 500 Pack: Price 4.99€, 30 hrs online music, 4 downloaded songs + 0.99€ each further song. o 1600 Pack: Price 14.99 €, 100 hrs online music, 11 downloaded songs + 0.94€ each further song. o 2800 Pack: Price 24.99 €, 180 hrs online music, 2 downloaded albums + 0.89€ each further song. o 6000 Pack: Price 49.99 €, 400 hrs online music, 4 downloaded albums + 0.83€ each further song. The packages have to be paid by credit cards online.
Sustainability of the business model The download of music from the internet would at first glance suggest it is more sustainable than purchasing CDs. However research by Digital Europe has shown that this is not necessarily the case since it depends on many factors including modem versus broadband, whether the songs are burnt on to a CD or how often a song is streamed or downloaded.
Collaborators within the product service system The existence in the different laws regarding online music acts as a framework for music industry, provider and customers.
Customer/provider relationship

Customers only have contact with the provider via internet. The bill is paid online via credit card. Support contact details are published on the webpage of the provider.
Marketing tactics Provider offers free trial membership or the download of 50 songs for free from time to time in order to overcome potential customers inhibitions of buying products in this manner. Long time customer relationship is supported through special offers for members purchasing specific credit-packages. The bigger the credit-package – the cheaper the download is (per song).

5.3 Mobile navigation systems

Mobile navigation systems have developed out of the concept of using global positioning satellites to determine the exact position of missiles for accurate targeting at enemy positions. The first concepts were developed in the late 1960s. In December 1973, the proposal for a GPS system was approved by the Defence System Acquisition and Review Council (DSARC). In 1989, the Magellan Corporation introduced the first hand-held GPS receiver. Development in commercial applications was held back by the decision to reduce the location accuracy for non-military applications from 15-25 metres to about 100 metres. This limitation was lifted in May 2000. The European Union is building its own global navigation satellite system called Galileo, currently projected to be operational in 2008.

Commercial navigation systems are mainly used for navigation of road vehicles. The largest organisation providing the maps for such systems is Navteq. They have formed partnerships with most of the manufacturers of such systems. Over the last couple of years mobile navigation systems often combined with a PDA have started to become very popular. Navteq provides the maps for most of those devices as well.

The PSS for mobile navigation systems mainly falls under the category result-oriented service since the service replaces the use of maps. Payment is normally either on a subscription basis or pay-per-use. The navigation hardware is either sold or included in the subscription. Like the downloading of music it is now starting to be integrated into the mobile phone services.

Mobile navigation systems are seen as an important tool in reducing the environmental and social impact of road congestion. This has been recognised within the EU Commissions report ‘Intelligent Transport Systems’ and is a key element within that initiative. Such systems have the potential to reduce congestion, time, money and energy use on the roads if used on the majority of vehicles on the road. There has though been little detailed research into the subject and there is a lack of real data to quantify the overall benefits. These systems are expected to become an integral part of long term plans for road pricing within Europe.

5.3.1 Example of a Mobile Navigation System

Mobile Navigation System – “A1 Navi”

What is the product service system
GPS based routing and navigation system for mobile phones.

Who is the key driver
A1 Navi was introduces by the “Mobilkom”, a provider of mobile communication in Austria.

What are the different elements
A1 Navi offers navigation from the current position of the user to a specific target. The current location of the user is based on GPS. To navigate the user is directed with the help of maps and/or arrows and voice (several voice modes are available). The service can be used via a mobile phone. Its application is therefore not just limited to use in cars. It can be used on bikes and motor bikes as well as by walkers. A1 Navi offers European wide maps and special support in the case of searching for “points of interest” like hotels, railway stations etc.

Who is the customer
Business men and private customers with a focus on travelling.

Basic needs and drivers
A1 Navi was launched to meet the growing demand for navigation systems. With increasing global mobility people are travelling more into areas they do not know and such products assists them in their travels and helps them to save time.

The initiator of the product service system
Mobile communication providers looking to satisfy market demand and offer new services.

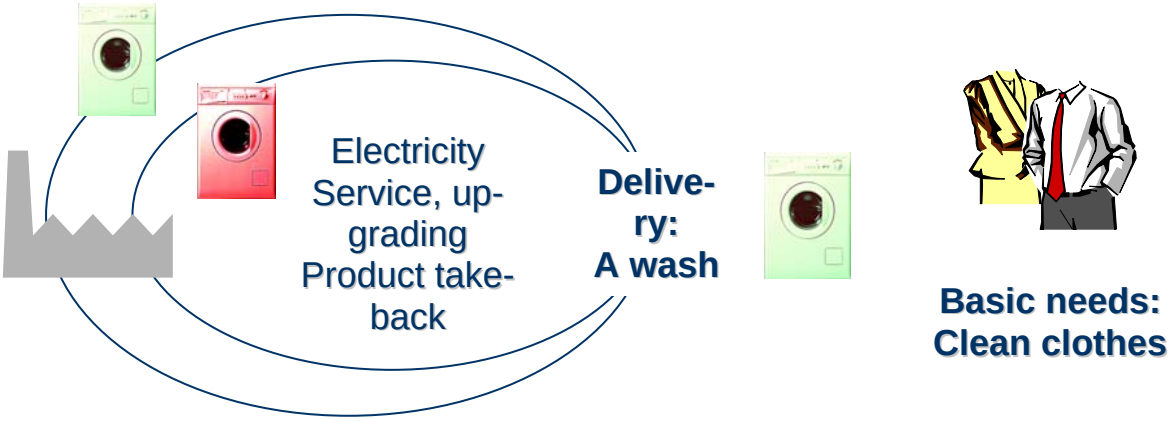
Financial flow through the product service system
Two different structures of payment are available. The “A1 Navi Basis” rate is a classic pay per use-system. The customer has to pay 1€ for each day the navigation system is used (excluding UMTS and GPRS charges). “A1 Navi Package” offers a monthly package for 6€ (5€ if you pay for a whole year). With this base fee the using of A1 Navi is covered for the whole month (excluding UMTS and GPRS charges). In both cases using A1 Navi outside the domestic country costs an additional 1.9€ per day of use. Payment is charged with the monthly cost statement of the Mobilkom.

Sustainability of the business model
The purchase of extra (and expensive) navigation system is not necessary. The A1 Navi system is very flexible and can be used in most situations without the dependency of standard navigation systems. The mobile phone replaces the hardware of the normal navigation

systems.
Collaborators within the product service system Hardware producers are interested in bringing capable products to market, which allow the use of a product in various ways and mark their products off from competitors with less capable products.
Customer/provider relationship As per the normal mobile network supplier, since the A1 Navi is an add-on accessory.
Marketing tactics A1 Navi gives the Mobilkom the chance to introduce new products for existing costumers and to foster the growth of the company in the mature mobile phone market in Austria.
Details: www.a1.net

5.4 Electrolux pay per wash trial

Electrolux completed a pilot scheme based on a pay-per-use system with washing machines[10] during 1999/2000 in Gotland, Sweden. Instead of selling or renting out the appliances they were paid by the consumers according to how much the appliances are used. When the project was started, 7.000 smart meters were installed, mainly around the city of Visby. Since the EU has calculated up to 90% of the environmental impact can be attributed to the use stage of a washing machine, the pay-per-use method would give a financial incentive to do fewer washes. In addition Electrolux chose their most energy efficient machine for the trial.
The business model included providing a washing machine to the consumer, and charging approximately €1 per wash at 1kWh/wash cycle, rather than charging for the washing machine. The machine remained the property of Electrolux, although the consumer paid for the installation that was about €45. A 24-hour service and repair was guaranteed as well as new machine after 1000 wash cycles. The intention was then to refurbish the used machines at the Electrolux refurbishment facility. The basic process is shown below:



The partners in the project were Vattenfall a major electricity production/distribution company, GEAB the local electricity company based in Gotland and one Electrolux Home store on Gotland. The usage of the washing machine was monitored by a smart electricity meter installed in the washers, and connected to the electricity and telephone networks. Each month the households received a bill listing the washing expenses as part of their regular electricity bill from GEAB.
The PSS for this business model is a 'Use-oriented service' since the washing machine remains the property of the manufacturer. This is one of the main reasons this project failed to take off as a viable business since most of the targeted market preferred to own the equipment in their house rather than that ownership being retained by the manufacturer. This is a cultural issue that has to be taken into account when setting up a business model. It could change with time, but currently to be successful in the consumer market compelling advantages of not owning the equipment must be apparent to the consumer. These could be:

- The product is needed for a task or tasks but is very expensive and not used that often. (e.g. Marquee for a wedding reception)
- It is a product the consumer wants but there is no other manufacturer currently offering this product for sale. (e.g. Initially time slip hard drives for television programmes were only available on a monthly lease)
- A product or system which offers many advantages to the consumer but requires central technical support to operate it. (e.g. The networked home may fall into this category)

In the case of the Gotland project users were able to purchase washing machines from local stores on hire purchase, where the monthly payments were lower than the costs of pay per wash for the Electrolux machines.
What could give the cultural shift required to make pay-per-use attractive to the consumer? The debt mountain could be one factor. The consumer debt in the Western world is now so huge that many are predicting that it is not sustainable and the bubble will soon burst. This could result in consumers moving from hire purchase to pay-per-use over the next few years.
Whilst this example was not a commercial success, it does point the way to how producers can take a more responsible environmental approach within a business model. As the home becomes more integrated and dependent on electronic communication systems this approach could become much more commercially viable.

5.4.1 Example of the Lease of White Goods

Lease instead of buy: “Extra-Rent”

What is the product service system
Extra-Rent offers white goods for rent. On a 5 year basis the newest generation of electrical equipment is available for a calculated monthly fee. All maintenance costs are covered through the rental fee. In case of a breakdown the product will be repaired by a service technician of the company for free. The offer comprises fridges, washing machines, tumble-driers, cookers, microwaves, dishwashers, vacuum cleaners and freezers. The retailer delivers the products onsite for free, performs the setting up and checks the functionality. The Extra-Rent service is a ready to run system.

Who is the key driver
Siemens in conjunction with local electrical service centres and retailers.

What are the different elements
The rental service comprises of high quality products, with no cash down payment or repair charges.

Who is the customer
Private households as well as companies.

Basic needs and drivers
Allows customers to own modern white goods who lack the funds to buy the equipment.

The initiator of the product service system
Siemens introduced the rental service with the help of its retailers.

Financial flow through the product service system
The rental contract lasts 5 years, with monthly payments of:

fridge: 16.70€	washing machine: 17.00€/22.50€ (2 types available)
tumble-drier: 14.30€	cooker: 11.00€
microwave: 14.70€	dishwasher: 19.10€/21.90€
vacuum cleaner: 4.90€	freezer: 16.70€
oven: 14.50€	

Sustainability of the business model
The average life of white goods is normally between 10 to 12 years. Since the rental period is over 5 years and after that a new product is supplied such a PSS could impact negatively on the environment. A lot will depend on what Siemens does with the equipment at the end of the 5 years.

Collaborators within the product service system
Retailers and maintenance companies

Customer/provider relationship
The service is the core of the customer relationship. The following services are included: Consultation, delivery to the customer, implementation of the product in the individual

household, waste management, on-site instructions by specialised stuff as well as via hot-line repair within the rental period for free.
Marketing tactics The marketing idea is based on: o A premium line of goods o No cash down payment o No repair charges o State of the art equipment o On a rental basis with small amounts. o rental period for free.
Details: http://www.extraklasse.at/BSH/www/frontdoor.aspx?CURI=cms-DE_277_O_pf%3dln_6406

5.5 Online games

It is believed the first true online game was released in 1969 for the Plato gaming platform. In 1972 the same platform supported a game called 'Empire' that allowed 32 simultaneous online players. In 1984 Atari put Plato on its 8-bit computer. It had a $5/hour connect fee. During 1986 MUD2 launched in the UK as a pay-for-play service. In 1993 the Mosaic web browser was launched giving a graphical interface to the internet for the first time. Sony launched a PlayStation with broadband capabilities in 2001. However with connection speeds still being very low many games depended on the graphics being on a CD-ROM for multi-player online games. As broadband appeared along side software developments such as 'Flash' which uses a native Vector graphics animation format to deliver crisp, stunning graphics in very small files, the need for the CD-ROM has started to diminish.
Today there are many companies offering online games. They usually entice new customers with free games, or a free trial period. The following are typical example of pricing structures available:

- Completely Free: No software or subscription fees are involved to play these games.
- Free Trial: New players are able to try these games for a limited time before paying.
- Free Software: The player does not have to purchase the software to play these games, although subscription fees may apply.
- Free Subscription: The player does not have to pay a subscription fee to play these games, although the software may not be free.
- Pay Software: The player must purchase the software to play these games.
- Pay Subscription: The player must pay a periodical subscription fee to play these games

Another interesting part of the revenue model is the mixture of software purchase and sub-scription. The purchase part is in general for games that require the graphics to run on the machine rather than from a server on the internet. However it does get a revenue stream from those users that do not wish to pay a regular subscription.

In addition to online games available on the web, many games are sold on CD or DVD for playing over the web. The product part of the PSS consists of:

- The initial software package, delivered on CD or DVD, which has to be purchased
- Web-based content to allow the customer to interact with other customers using message boards and/or chats
- The game server(s) to which the software connects to and on which the customer plays the game
- The update server(s) that ensures that all customers have the same version of the software at any given time

The service part of the PSS consists of:

- A web based account management system that enables the customer to view/modify the data of their purchased game account(s), which is maintained by a dedicated team of web designers, administrators and accountants
- A dedicated bulletin board for technical support and general customer information, which is maintained by customer support staff
- In-game 24/7 customer service, provided by a team of customer service representatives
- A dedicated hotline, active on weekdays, maintained by customer support staff
- A team of developers to create new game content (Industry standard would be to release major content updates as purchasable expansion, provided either as retail package or as digital download)
- A dedicated operations team to maintain the server infrastructure required to play the game
- A team of public relations specialists that ensures sufficient advertising for the product is done

An online game is offered by a software publisher, which is in most cases also the focal leader (i.e. the publisher decides when to release game expansions, and the development studio that creates the game content will make the requested changes to the product). Please note that nowadays most game development studios are owned by the publishing company.
The customer base is owned by the publishing company, which also provides all accounting services.
The customer base for most online games begins to evolve years before the actual public release of the product, since the publishing company would start advertising for the product way ahead of schedule.
Additionally, before the initial release the publishing company will usually enable the customer base to have a “sneak preview” of the game in the form of a so called “beta test” (for which the customer doesn't need to purchase the game and/or a game subscription) allowing the company to evaluate the product before its actual release, and to have a very successful method of advertising.

The publisher needs the following suppliers or partners in order to offer the PSS:

- A game development studio that has the know-how to create and maintain game content
- A data-centre with a sufficient connection to host the server infrastructure, sufficient bandwidth capacities usually are in the 5 to 10 g bit range.
- A company to print the initial software package on CD or DVD in order for the publisher to deliver it to the retailers
- An advertising company to handle the initial advertising of the product and/or to provide staff in order to train personnel the publisher can use to do the advertising by themselves

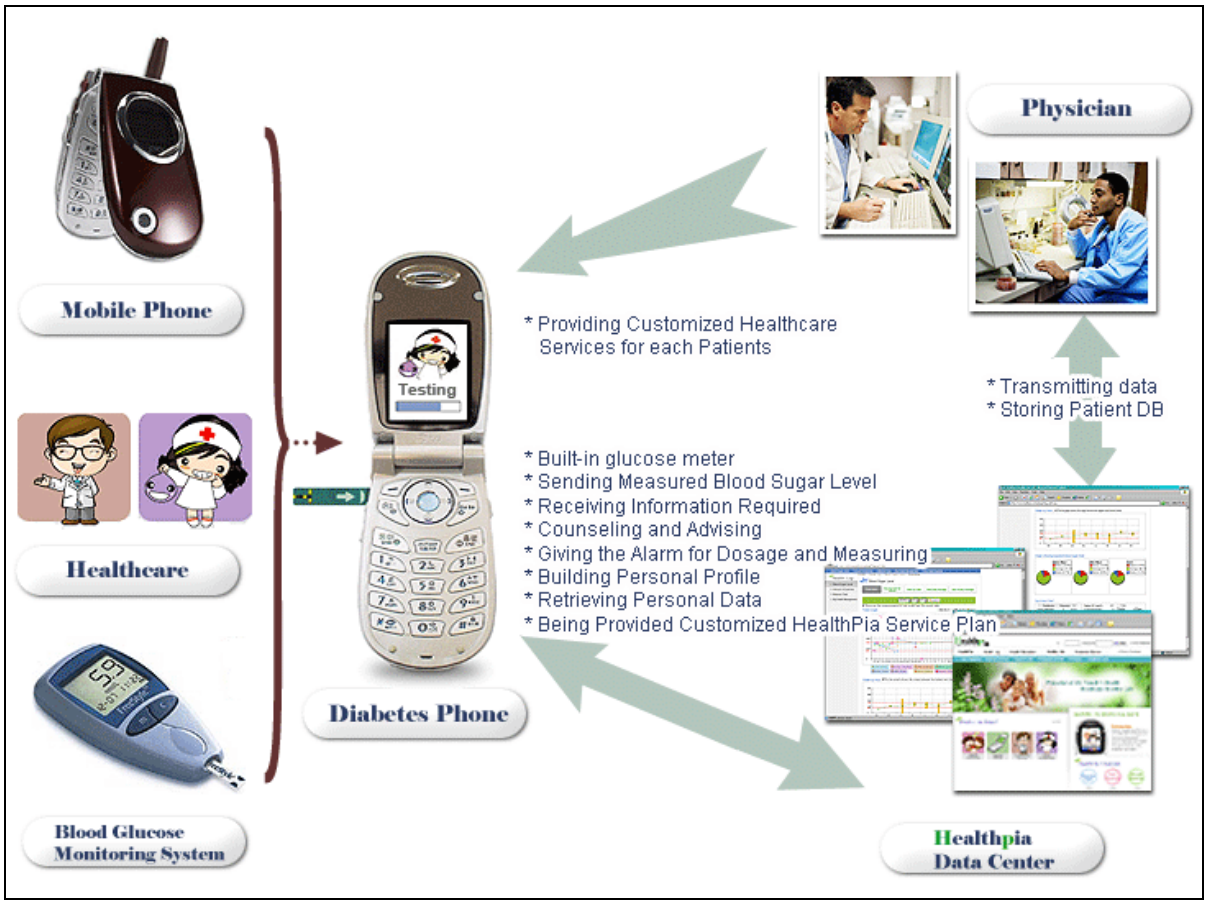
In a typical online game the product requires, in order for the customer to play it, a monthly subscription fee, additionally to having the customer purchase the initial product package (the program CD/DVD). Subscription fees are paid to the publishing company. Additionally the publishing company will usually offer extra services related to the game which create an additional income, though these services are optional. Such services could be special in-game abilities or rewards which are only available to the customer if purchased.
The publishing company has to pay for the development of the game, staffing and advertising and the technical infrastructure required to offer the product, not to mention office space running costs.
An initial investment was made to create the technical infrastructure to run the game platform, including the development and distribution of the software package and tools needed later on by the customer service department in order to maintain the product. Further investments had to be made into advertising and web content development in order to introduce the product to the customer base.
The basic need to be satisfied is the long term entertainment of the customer base.
Because of the competitive nature of an online game, these online environments offer a way for the customer to “escape real life” and to experience something interesting out of the normal world. An online game offers the customer a unique experience in which they can “grow” and learn by doing, while interacting with a vibrant community.
Additional innovation drivers would be the game development studios. These companies employ a multitude of dedicated, highly creative staff that create game content based on their ideas. Example: A current online game was created after the development studio presented their ideas to the publisher that owns the development studio.
Another very important factor is the customer base that provides feedback based on their experience with earlier online games. The industry responds to this feedback in order to create a product that suits the needs of most of the customer base.
In order to realize the PSS a highly redundant and adaptive technical infrastructure is needed. As online games consist of multiple “areas” in which a lot of customers can play together at the same time, the architecture needs to be clustered and “load balanced”, allowing the system to scale if more/less performance is needed.
Also, media creation technology is needed to create game content. Especially complex voice and sound recording/editing as well as the rendering of 3D cinematics are key technologies for any successful online game.
The PSS is initiated by the customer base, which displays an interest into this type of game.
Feedback and requests are made to game development studios which then consider ways of creating game content to fulfil the needs of the customer – The game development studio will

set up a concept and propose it to the publisher, which then makes the call to develop the game or to cancel the project.
The common problem with online games is new content. If asked nowadays, customers would most likely respond that the content in any given (current) online game is repetitive and lacks innovation.
In order to satisfy the customers need the development studios must to come up with new, fresh ideas and implement them into the games, then again it is not guaranteed that the customer base will respond well to all of those ideas. In the worst case, a lack of innovation can cause a PSS to fail completely, which has happened multiple times in the past.
To avoid such a scenario, it should be ensured that the development studios that are creating the game content show a lot of talent and creativity with their work, and keep a close connection with the customer base in order to receive constant, valuable feedback (free of charge!).
In order for an online game to develop quickly the publishing company has to ensure that the game is distributed quickly among the customers.
To do so, contracts with Internet Service Providers are not unusual. The ISP offers a way to download the latest game information and/or content updates from their own web presence, while being able to advertise for their own products on the very same website. The publisher company in return benefits from reduced load on their own infrastructure (reducing the costs required to maintain the platform) and increased advertising for their product.
Further thought is often given to expositions, such as the Games Convention in Leipzig, which offer a convenient way to introduce new products and/or make existing products more attractive.
All online games currently on the market have a dedicated “community management team”. This team is the point of communication between the customer base and the publisher/game developer, and ensures that the community is always up to date with the latest product related information.
Additionally the community management team maintains the product's bulletin boards and creates content to be published on the product web presence.
The community management team are the ears and eyes of the publisher and developers, allowing them to learn the current mood and trends in the customer base, to adjust the product to the needs of the customer if warranted. Also, they are usually the company employees to introduce the product at expositions and talk to the press.
The community management team usually consists of former online game players, that know how the customer can feel in certain situations, and how to respond to issues where excessive customer criticism and/or frustration shows.
Additionally to standard ways of marketing (put the product in a store and advertise in the media), an online game draws a lot of its customers from web advertisement. For that purpose, contracts with companies that offer game related content are signed, so that the publisher may advertise on their web space.
Furthermore the community (customer base) is provided with “sneak previews” of game content prior to its release, which usually raises the interest in the game. This can happen several years before the actual product release without risking a loss of customer interest.
A new way of selling the product are online stores. For that purpose the publisher company would create a store on their web presence, allowing the customer to purchase a “product key” for the game, instead of having to go to a local retailer and purchase the software package.

Once the product key has been purchased, the customer may then directly set up their game account and download the software from the publisher company's web presence. All these services are offered through the game's web portal.
One of the main social issues arising out of online games is addiction. Both Korea and China are in the midst of a campaign to address the issue of online addiction, and are working with game operators on systems to discourage compulsive behaviour. The online game sector is growing explosively in Asia, worth an estimated $1.1 billion last year with annual growth set to average 19 percent through 2008. Reuters reported
'the industry's rapid growth gives rise to a new generation of addicts, like the South Korean man who died of heart failure after playing a game called "StarCraft" for 50 hours at an Internet cafe. The 28-year-old Korean had quit his job to spend more time playing games, and left his seat only to go to the toilet and take brief naps, according to media reports.'
Little is known about the environmental impact of online gaming, but it probably has a far greater impact than the downloading of music or other media as users tend to be online longer, and often a CD still has to be purchased.

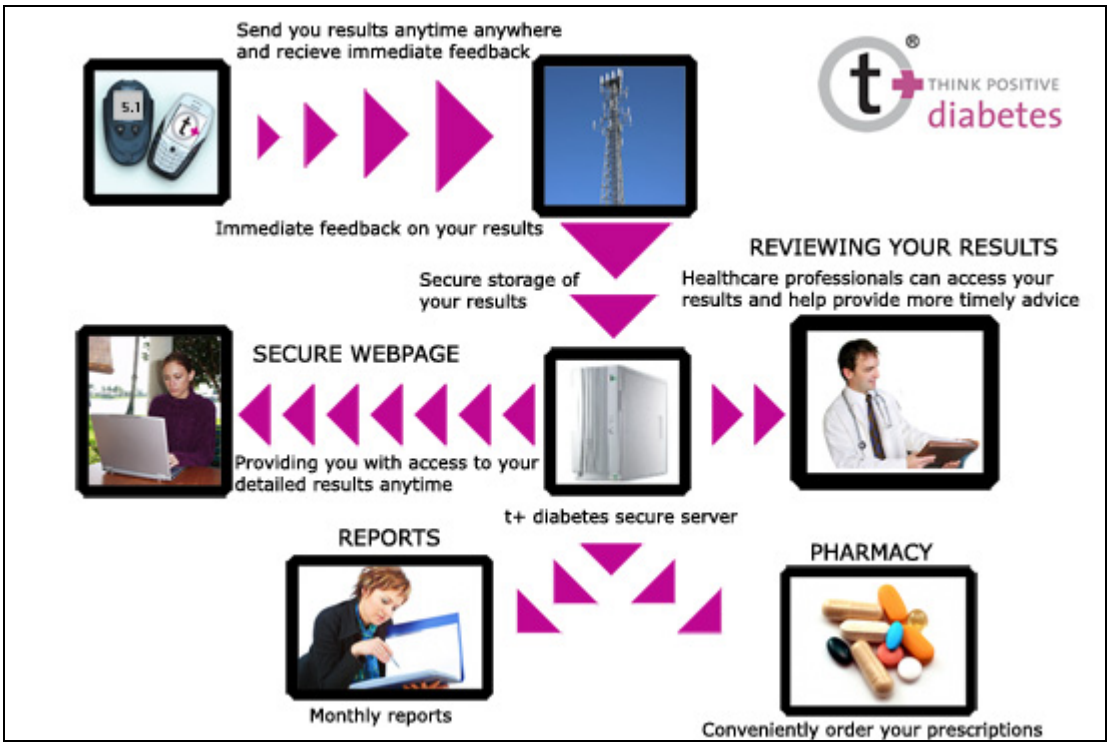
Remote Disease Control

The remote management of chronic illnesses is a relatively new area for PSS[12]. There are two main systems coming on to the marketplace that uses a mobile phone to monitor and manage illnesses. The first to market was from Healthpia in Korea with their diabetes phone. This was followed in January of this year by e-San Ltd in the UK with the t+ diabetes system.
Healthpia who have carried out trials in Korea will shortly be putting their system on the marketplace in the US again for diabetes. Other health-care handsets in development are diet phones which will contain devices which can measure human-body fat and beauty phones which will be incorporated with a massaging function as well as equipment to gauge skin humidity level. The diabetes system is shown in the figure below:



It is expected that Healthpia will charge a subscription for the service side of the system. The CDMA KP8400 handset used was co-developed with LG, and sells for the equivalent of about US$380 in LG's home market of Korea.

The t+ diabetes system product consists of a GPRS mobile phone, a One Touch Ultra meter and a Blue Tooth cradle. As soon as the reading is taken, the phone display provides immediate feedback represented as a bar chart or scatter graph, whilst also sending data to a secure server where it is stored with previous readings. The results are further processed and sent out as a printed monthly report to the diabetes sufferer. Readings can also be viewed via a secure web page. The business model for this system is similar to the first one in that the main revenue model is by subscription. The phones are standard phones with Bluetooth, but the sensor and sensor cradle is thought to be paid for out of the subscription. The figure below shows how the system works:



Both products from the systems' provider point of view fall under the PSS category called Result-oriented service since they both provide a remote service. With the Healthpia system the system could be seen to fall under Product-oriented services from LG's point of view as they are adding functionality to their mobile phones.
Whilst such systems probably don't have a very large environmental impact they do have a considerable social impact, in that it provides continuous remote monitoring of patients. These sort of systems are likely to grow, and potentially in the long term could be used beneficially in the developing world for remote communities.

5.6 Comparisons of Examples

5.6.1 Type of Product Service system

Many of the PSS looked at often fall under more than one type of product service system. See table below. This shows the difficulty of trying to describe a PSS particularly when digital media is involved. Industry in fact seldom attempts to distinguish between products and product service systems.

Product Service System	**Product-oriented services** e.g. service integration (adding products or functionality), product extension (upgrades, maintenance)	**Use-oriented service** (product owned by the service provider who sells the function not the product) e.g. leasing and rental	**Result-oriented service (product substitution)** e.g. product substituting service (e.g. web database replacing telephone directories)
Mobile Telephone Services	User owns phone	Service provider retains ownership	Digital services
Downloadable music, films and radio	Specific equipment required to play media		PSS replaces CDs / DVDs
Mobile Navigation Systems	If specific hardware needed for this PSS		Direct replacement of maps
Pay-per-use White Goods		Provider retains ownership	
Online Games	Where CD is sold PSS partly falls in this category.		Falls in this category fully when PSS is completely online.
Remote Disease Control	Sensor system is purchased	Sensor system is leased	Self monitoring and remote analysis

5.6.2 Different Elements of the PSS

Most of the cases looked at had many elements that was brought together by the service provider

Product Service System	Hardware	Service	Delivery Mode
Mobile Telephone Services	Mobile phone, accessories	Voice and data services	GSM, CDMA
Downloadable music, films and radio	MP3 players	Supply of audio/visual media	Internet
Mobile Navigation Systems	Navigation device	Current position & electronic format maps	Satellite, GSM and internet
Pay-per-use White Goods	White goods and meters	Installation, repair, removal at end-of-life	Internet and/or phone
Online Games	CDs	Servers to connect on-line gamers.	Internet
Remote Disease Control	Sensor system	Results analysis	GSM, internet

5.6.3 Basic needs and drivers

The following table gives a summary of the needs and drivers for each case looked at:

Product Service System	Time & Convenience	Unique Product	Too expensive to buy	Fashion Item
Mobile Telephone Services	Yes	No	Sometimes	Sometimes
Downloadable music, films and radio	Yes	No		Sometimes
Mobile Navigation Systems	Yes	Yes		
Pay-per-use White Goods	Sometimes	No	Yes	No
Online Games		Yes		Sometimes
Remote Disease Control	Yes	Yes		No

5.7 Sustainable Consumption: Definition and Situation review

The term sustainable consumption is defined in parallel to the Brundtland definition for sustainable development as: providing products and services which cover basic needs and improve the quality of life, while minimising the use of natural resources and toxic materials as well as emissions of wastes and pollutants throughout the life cycle of the service or the product without jeopardising the needs of future generations. (Lafferty, M., W. 2001).
This definition remains open to different interpretations because the assessment of what is sustainable is site and problem specific. It depends on social and political decisions on acceptable level of risks as well as substitution between natural capital and man made human and social capital. (Omar, P., J. 2002).
For instance, there is a general consensus for industrialized countries that implies a reduction in the throughput of resources. This requires a shift from a linear economy to a circular economy so that inputs (virgin raw material and energy) and outputs (in the form of waste) enable a decline of disposal. This approach is increasingly recognized in public policy and already established in countries such as Germany (through its Closed Substance Cycle and Waste Management Act) and Sweden for a long period of time (through the work of its Eco-cycle Commission) (Cooper, T. 2005). Thus local authorities must lead the way in an active effort to promote consumption patterns that are compatible with natural resources and ecological carrying capacity. (Lafferty, M., W. 2001).
However, sustainable consumption is unlikely to be achieved as long as the quantity of household waste generated in industrial nations continues to rise (Cooper, T. 2005). To avert this predicament, the OECD Environmental directorate's 1999-2001 programme on sustainable consumption was designed to provide a comprehensive exploration of key household consumption patterns in OECD countries, related environmental burdens and policy measures to promote sustainable patterns (Omar, P., J. 2002).
Thus sustainable consumption should encompass consuming less, consuming differently, consuming efficiently and having an improved quality of life as well as sharing between the rich and the poor (Bentley, M. 2004).
Policy dialogue on sustainable consumption, however, has been poorly focused and muddled, largely because of the ambiguous nature of core concepts and the problem of how to draw boundaries around the discussion (Cohen, M et al. 2001).
In this light, The UNEP sustainable consumption programme, (complementary to the OECD Environmental directorate's 1999-2001 programme on sustainable consumption) was launched in 1999 to better understand the forces that drive consumption and use the findings to inspire Governments, businesses and NGOs to take action bearing in mind the core principle that consumers need information, products, services, price incentives, legal frameworks and infrastructure in order to be inspired to change their consumption choices (Bentley, M. 2004).

As main strategy for a future sustainable consumption four different ideas are possible:

- increase the individual benefit of sustainable consumption

- minimize the benefit of the consumption of common goods
- minimize costs for sustainable consumption
- increase the costs for the consumption of common goods

This all should be moved within the framework of the knowledge that individual action has essential impacts on the whole system.

What is sustainable consumption?

Sustainable consumption does not mean that people have to consume less, it refers more to consume in a different way. The target of sustainable consumption is an efficient use of resources with the same or higher standard of living. The consumption shall be based on the natural reproduction possibilities of the environment. A sustainable consumption of wood for instance should not exceed the growing trees at the same time. The target is a balanced consumption of resources.

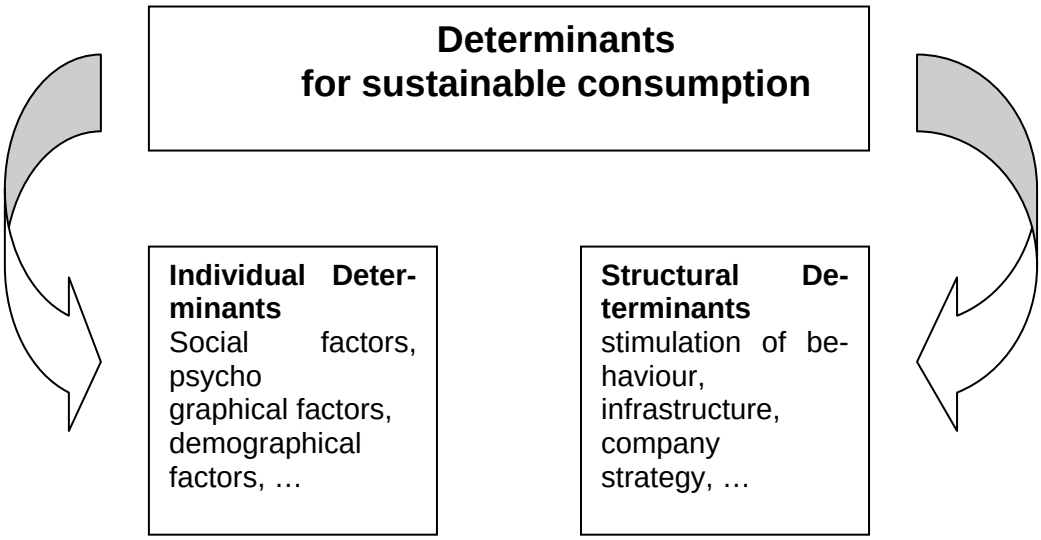
A general definition of sustainable consumption is based on the idea to find a balance between the rights as free consumers and the responsibility towards others and the earth.

The following should to be noted:

- The expansion of consumption has left about a fifth of the world's people out;
- Consumption is environmentally damaging. Thus the consumption of some harms the well-being of others, in both present and future generations;
- Consumption growth and patterns have social impacts that deepen inequalities and social exclusion; and
- Consumer rights to information and product safety are difficult to defend in the context of the global consumer market.

Determinants for sustainable consumption

Two different core determinants for sustainable consumptions can be identified: Individual Determinants and Structural Determinants.



Individual determinants refer to the influence of the personality of each consumer.
The consumer will buy his/her products according to his/her subsistence-perspective, whereas in the case of the structural determinants the social environment has a significant impact on costumer's behaviour.

Product Service Systems
The UNEP in its report "The role of product service systems in a sustainable society" defines a product service system as "…a competitive system of products, services, supporting networks and infrastructure. The system includes product maintenance, parts recycling and eventual product replacement, which satisfy consumer needs competitively and with lower environmental impact over the life cycle" (UNEP: The role of product systems in a sustainable society)
An example of product service: a consumer might hire a firm to clean his carpet / rent a vacuum cleaner instead of purchasing a new vacuum cleaner.
A Product Service System can be defined as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands.

Basic facts on Product Service Systems
One of the more interesting ideas to emerge in industrial ecology is the notion that environmental impacts can be reduced by moving from a focus on the physical possession of products to functional needs that can be met by their use. This idea is variously called the functional economy (Stahel), product service combinations

(Manzini), product-to-service (McDonough), servicing (the Tellus Institute), or product service systems (PSSs) (Dutch Ministry of the Environment) (Reid, L. 2000).
Another possibility is that manufacturers may review the potential for leasing products rather than selling them, and choose to sell services as distinct from products. This has long been proposed by advocates of product service systems, defined as "a marketable set of products and services capable of jointly fulfilling a user's needs" and would represent a move from today's "fast replacement system" to the "optimal utilisation" of products, characterised by an extension of their life spans (Cooper, T. 2005).
In recent years services have become increasingly important in western economies. Thus, Product Service Systems are recognised by the Dutch Policy Document on Environment and Economy, to offer favourable prospects for sustainable economic growth in the medium and long term (Mark, J. et al. 1999).
Thus Product Service Systems can prove advantageous to the environment in combination with creating new businesses with key factors of success, similar in many cases, such as:

- Creating value for clients, by adding quality, customisation and comfort.
- Creating new functions, or making smart or unique combinations of functions.
- Decreasing the threshold of an investment by sharing, leasing, or hiring.
- Decreasing environmental load. Often this will bring additional and perceived eco-benefits.
- Product Service Systems: Assessing the environmental and economic aspects of dematerialisation.

(PRé Consultants: http://www.pre.nl/pss/default.htm.)

Application of Product Service Systems to consumer durables, however, may not always have a high environmental payoff. As many LCAs will attest, the most environmentally damaging stage of the life cycle of a durable product is often its use or consumption phase. But if the environmental impacts of the production and disposal phases are relatively trivial compared to those of the consumption phase, then industrial ecologists could be chasing the wrong target (Reid, L. 2000).
Accordingly, a more dramatic change in marketing strategy would be from selling product "hardware" to selling the services that products provide. Such a change in the product-service mix has been proposed on the grounds that it may increase resource efficiency (Cooper, T. 2005).

Three main business approaches to Product Service Systems can be seen as promising in terms of their win-win potential (systemic eco-efficiency) as:

- Services providing added value to the product life cycle
- Services providing "final results" for customers
- Services providing "enabling platforms" for customers

When applying this approach, a company is providing additional services to guarantee functionality and durability (i.e. product life extension) of the product, which is sold to the consumer or customer. A typical service contract would include maintenance, repair, up-grading and

substitution services over a specified period of time. When the contract period is over, the PSS provider may take back the product, deciding about its possible sale or disposal (Manzini, E and Vezzoli, C. 2002).
In effect, Product Service Systems are really a cluster of related concepts; some researchers (e.g., Meijkamp) are particularly attentive to the behavioural dimensions of these novel ways of meeting human needs. In some cases, it is argued that the environmental gains from behavioural gains are at least as important as the changes in the product itself (Reid, L. 2000).

6 Challenges for the electronics industry in the next 10 years

6.1 Future studies, a way to prepare for what might come

There is no way to know what will happen in the future, but by applying systematic measures in analysing different possible developments a better preparation for what might come can be achieved.
Future studies are sometimes made to create strategies for a large set of more or less probable future situation, answering “what will we do if”, giving a the opportunity to be prepared in advance. This has been successfully used by several large industries who are dependant on politic developments on a global level.
Another reason for future studies is to give the necessary knowledge and preparation to influence development in a desired direction.

6.1.1 Methodologies for future studies

Since futurology in itself and by definition can’t become an exact science, there are many different methods applied for different situation and purposes. The perhaps most common and accepted methods are “Delphi studies” and “Scenario studies”. Other methods might produce more challenging results but with a high dependence of the background of the team performing the study.

Delphi studies
The Delphi method was originated by Rand Corporation during the Second World War. The main characteristic is to create a consensus opinion from a large number of chosen experts by repeated questionnaires with feedback on the previous rounds of questions in between. The questionnaires are based on statements, which the experts are asked to judge if the will come true and in such case when.
The Delphi studies may not discover the more unexpected future developments, but are good for acquiring a holistic view of the more foreseeable developments.

Scenario studies
Scenario studies are mostly used to generate a set of answer on “What if”. When doing a scenario study a set of parameters are varied, and the situation in all the boxes of the upcoming matrix are analysed. In most cases the number of parameters allowed to vary are very few, thus creating a few scenarios. In some cases also large parameter rooms are used, with special software to help in the analyses.
The scenarios are effective in the sense that the experts are supposed to be able to relieve themselves from their own believes on what is the most probable scenario, thus creating a more objective result. The judgement on which of the scenarios to use and act upon is left to the user.

Expert panels
Many of the large national foresights are based on expert panels, meaning a large set of experts from different disciplines are brought together to discuss and analyse the future. Many of these efforts are high profiled operations, generating are large interest for discussing the future, but there is a risk that the results are a bit to much a reflection of the major existing strategies.
In a previous Eureka project, “Informan”, which was intended to combine the result from several “Expertpanel Studies”, it was found that several of them lacked explanations of the logic and reason behind the statements, to make them comparable.

Trend studies and trend babies
Studies of a more predictive nature are often based on studies of existing trends and the prerequisites that made the trends advancing from a possibility to a trend. Applying this logic to new “trend babies” it is possible to make some judgements on what might become new trends.
These types of methods are highly dependant of the experts performing them and are naturally not as reliable as other methods, but often generate more challenging predictions than the methods based on a consensus process.

Science fiction
Artist and writers have often generated very challenging thoughts and pictures about the future from more or less pure fantasy. In some cases the ideas become true after quite some time, often hundreds of years. Just think of Jules Verne who wrote about submarines hundred of years before they were invented.
The value as a prediction is obviously not very high, but the value as a driver for development can be significant.

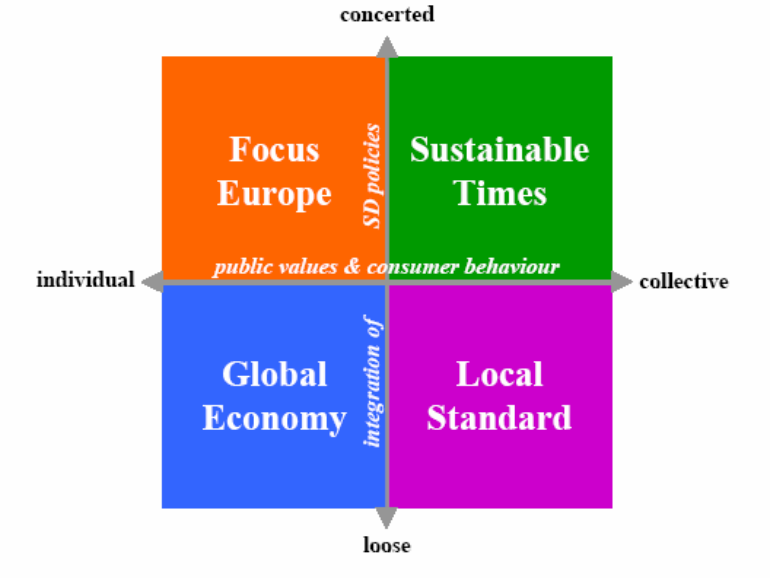
Ecolife II activities on future studies.
As part of the Ecolife II project, it is stipulated to make a future study on how to achieve a sustainable development of electronics in Europe. Since there have been a number of different European studies on the future as input to the preparation of the Seventh Framework Program, the Ecolife II project took a decision to investigate whether any of the previous studies could be used as a base for the upcoming study. The following studies were investigated:

ManVis (Manufacturing Visions)
ManVis was a very large Delphi on the very broad scope of manufacturing in Europe, performed in 23 European countries. The study was finished at the end of 2005 and the results were presented on a conference in Bled, Slovenia in October 2005. The project was managed by Fraunhofer ISI. More information on the study can be found on ***www.manufacturing-visions.org***.
The nature of ManVis, covering a lot of issues on manufacturing in Europe, makes it less useful for Ecolife II purposes, although some of the results can be applied to Ecolife.
In ManVis it was clearly identified that most of the 3500 experts did not think that more strict legislation in Europe on environment and sustainability should drive industrial activities out of Europe. It was even identified that Europe could create a competitive advantage by leading in environmental concern.

Manufuture
Manufuture is an ongoing "Technology Platform" with a lot of participation from European industry. Manufuture has developed a "Vision document", which very efficiently indicates the developments necessary for European industry to stay competitive. The sustainability issues are of course covered as an important part of competitiveness and a very important issue for quality of life. The level of detail and the nature of the study make it not fully applicable for the purposes of Ecolife, apart from stressing the importance of sustainability.
Manufuture is currently (June 2006) finalizing the "Strategic Research Agenda", which describes the necessary research topics and goals, to achieve the vision. The work on the implementation plan has just recently started.
More information on: **www.manufuture.org**

The Fistera Delphi on the social dimensions of the Information Society
http://les.man.ac.uk/PREST/fistera/delphi_results.htm
The Fistera Delphi was reported during 2005 and was followed by workshops aiming at defining a strategic research agenda.
The Fistera study was aiming at the use of IT and the necessary steps to create a successful Information Society. Although ICT and electronics are clearly linked, the study was not on the technical aspect, and therefore not useful for the Ecolife study, other than as background material.

FUTMAN
Futman, a scenario study focussing on measures to achieving a sustainable Europe, was finished in 2003. More information on the project can be found on:
http://ec.europa.eu/research/industrial_technologies/articles/article_410_en.html .
The project made a scenario based on the two parameters "integration of Sustainable Development politics" and "Public Values and Consumer behaviour", thus creating the 4-cell matrix below.



The FUTMAN scenarios

The characteristics for the FUTMAN scenarios in general is described below, as a general background to the mapping of sustainable electronics development against the scenarios which will follow.

Global Economy

In the scenario Global Economy, there is no integration of environmental legislation between the different regions and nations. The consumers are driven by highly individualistic preferences, thus generating a world based on fierce competition.

Sustainability has to be created through the market forces, by generation of demand for sustainable products. There is always the risk that competitors, especially from other regions, will try to make shortcuts offering less sustainable solutions for a lower price.

Shortage of resources will probably be a strong driver for more sustainable solutions, but with a risk of coming late when the cost for the resource is high enough to make other solutions viable.

Collective transport will have to compete against private transport on a value for money base.

Local Standard

In the scenario Local Standard, the integration between regions is weak or nonexistent, while it is common with strong consumer groups focusing on different subjects on sustainability.

In such a society it can be expected to find sustainability islands with different focuses. The industry might face different and incompatible demands from different regions, making life for the large global firms complicated.

Local industries and small scale solutions might be the outcome, with loss of some of the advantages of large scale production.

The communication and transportation systems are at risk of not being integrated, making travels and global communications less fluent than today.

The infrastructure linking the regions might suffer, due to unclear responsibility.

Energy will be produced in lot of different regional systems, some regions preferring wind and solar, while others rely on nuclear power and so on.

Focus Europe

In this scenario, the consumers are acting according to the highly individualistic values and patterns we are used to today, while the European Union has created a strong integrated legislation for sustainability all over Europe.

Europe is trying to take the lead in the sustainable direction, which can create a substantial advantage in the long run, but with the risk of loosing in the competition against regions with less concern for the environment initially.

Transport over Europe will be well integrated, based on governmental support making public transport systems able to compete against individualistic systems.

European products might be based on other specifications than products used in the rest of the world, making trade outside the region suffer.

Global Integrated Legislation

The scenario called “Sustainable Times” by FUTMAN and “Global Integrated Legislation” by Ecolife, is the situation where all governments globally agrees on the same common measures for sustainability and are strongly supported by the consumers, all acting in the same direction.

The industry has become a “globally responsible citizen”, putting sustainability before absolute competition.

We will have public transportation as the dominating alternative, and lots of resources will be put into creating energy systems which are truly sustainable.

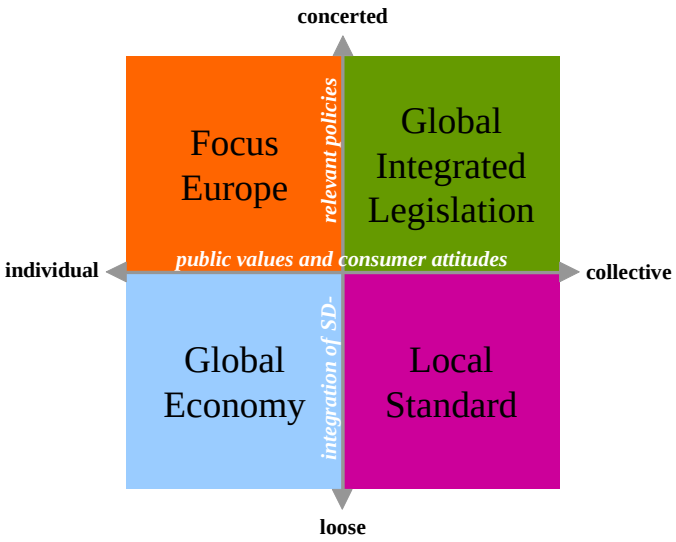
It might be feared that such a global society will offer fewer alternatives, and with limitations to the will for competition, negative effects on the speed of development might occur.

6.2 Ecolife II Visions

In Ecolife II, we have used the basic structure from FUTMAN, and have made an exercise to create future visions for the future of electronics and the electronics industry under the different scenarios. The results from this exercise are intended to give ideas about a possible future, and as in all future studies, these are only to be considered as ideas or visions, but with at least some structured logic behind.

The above structure was in Ecolife II considered as a very suitable framework for the study on development on a sustainable European electronics industry.

During the Ecolife II workshops on the subject, there was some criticism on the choice of name made by FUTMAN for the upper right quadrant; Sustainable Times which name in some sense indicate this to be only societal system which can create a sustainable society. For the work of Ecolife, it was decided to use the name “global integrated legislation”, to make the name less leading. The Matrix will then be:



When developing visions, based on political legislation and consumer preferences, it is also necessary to cover important expected developments which are not directly dependant on the axes in the matrix. To avoid misunderstandings coming from different emphasis of such expected developments in the different visions, we start by presenting a “baseline” of expected developments which are almost independent of the scenarios ore common for all the scenarios.

6.2.1 Base-line of future developments

Global warming

Most experts agree on a continued rise of the global temperatures due to previous emissions. The speed of the warming can off course be influenced by legislations and consumer actions, but the process will continue for a long time even wit zero emissions.

Shortage of fossile energy

According to most experts, the world is very close to “peak oil”, the production is declining. The discovery of new large oil reserves has declined rapidly, even if higher price make some large

reserves like the Canadian oilfields worth to explore. It is highly probable with a continued increase of the price for oil, which makes it necessary for the world to explore other more sophisticated sources of energy.
The situation will according to most sources become accelerated due to expected elevation of the living standard in large regions like China and south East Asia, generating an increase of the demand.

Demographics

Most of the European nations are facing a very troublesome age distribution in the population (this has been covered to great detail in a previous Ecolife report). The general life expectancy is currently increasing with several months/year, due to better health care and better living standards. Combined with longer education before entry into working life, the net sum is that fewer people active in working must support an increasing number of people in education and in retirement.
Due to the increasing need for care of elderly will even further reduce the workforce available for production.

A rapid advancement of technology

The speed and direction of technological developments will off course be affected by both political measures and consumer preferences, but with the pace set, the developments will continue. The empirical laws, Moores law and the fibre law seems to be valid still for a number of years.

A global competition due to unlimited communication

Independently on which scenario/vision applied, the explosion of communication capacity from networks and telecommunication opens up the possibility to make instant comparisons globally. This will always make the consumers aware of alternatives.

Changes in factor costs

With the ongoing automation, manual labor is getting more and more expensive in comparison with the costs for physical products. In societies with an expanding need for services, this will generate a complex challenge for the political systems.

6.2.2 Comparison between the Ecolife II Visions

The visions presented are each based on one person's ideas of the future with special emphasis on the environment and on a sustainable electronics industry, thus making strict comparisons on each of the subjects covered in the visions an overestimation of the stringency. Making predictions on the future is never an exact science, and there must be room for the imagination of the authors.
When making scenarios, it is always a problem to be able to stick to the prescribed prerequisites for the specific scenario, and in this case we also had to deal with the issue of how far out on the axis the vision should reflect.
As a comparison between the visions, we have instead tried to list the strong and weak elements of each vision in the aspect of achieving a sustainable world with preserved environment.

6.2.2.1 Globally Integrated Legislation

Strong elements

- Focus on environment from all, governments, consumers and industry
- A possibility for the less developed regions to catch up
- Radical reduction of exploitation of scarce resources
- Radical reduction of pollution

Weak elements

- A very radical change of the global political system, never achieved before
- Limitations on competition, with a risk for reduced efficiency in business and innovation
- Severe reduction of traveling and other activities seen as human rights
- Decisions taken very far from the people, by a remote global government

6.2.2.2 Local control

Strong elements

- Very environmentally engaged citizens
- Opportunities to benchmark between many different solutions
- Local small industry may prosper

Weak elements

- Closed local economies, acting in under-critical size
- Lack of integration, making infrastructure suffer
- The big global environmental challenges are not taken care of, sub-optimization

6.2.2.3 Focus Europe

Strong elements

- Common legislation in a region large enough to make a difference
- Competition preserved under strong legislation
- Legislation made by an accepted “super government”
- Strong focus of research towards sustainability
- Other regions might be influenced by Europe and follow the same pattern towards sustainability

Weak elements

- Legislation may not be accepted by the consumers
- Other regions might win the business race, by offering cheap, not sustainable solutions
- The industry may disappear to other parts of the world, to operate in a less strict environment

6.2.2.4 Global Economy

Strong elements

- Competition drives innovation
- Cheap products due to stiff competition
- Environmentally friendly solutions must be economically advantageous to survive, but can then succeed on their own merits

Weak elements

- There will always be actors who try to take the easiest road, disregarding the environment
- A strong dependency on development of a globally common environmental conscience
- Over-utilization of scarce resources until the price goes up due to acute shortage