Design for Environment

Integrating Environmental Aspects into Product Design and Development
The new ISO TR 14062 – Part 2: Contents and Practical Solutions

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DOI: http://dx.doi.org/10.1065/ehs2003.03.006

DOI: http://dx.doi.org/10.1065/ehs2003.02.005
DOI: http://dx.doi.org/10.1065/ehs2003.03.007

Abstract. The new ISO TR 14 062 offers a manifold of examples how to integrate environmental aspects into product design and development. With some selected examples it is demonstrated what can be done and how. In every company a consequent and logical way from the business strategy to the organizational changes and integration of the aspects has to be derived – depending on the existing way of business. Therefore the form of a Technical Report can only offer a list of options for selection. However, a skilled manager can easily adopt the already existing, corresponding management system. Strategic and business thinking is nevertheless necessary for application.

Although the Technical Report offers several options there are often very limited opportunities for a specific company due to two reasons: Firstly, integration has to be achieved into the existing company specific framework of management and product development. Secondly, in this paper information is only provided about the addition of environmental aspects and tools for this purpose, but many other influences like social acceptance or competition have also to be taken into consideration. In reality, product systems are very complex and inter-linked. Tools for the description of such complex systems are existing but for a design and development engineer there is a missing link to the level of his needs for detailing to his product.

Keywords: Product design and development; development scheme; environmental aspects; environmental tools; ISO 9001; ISO 14001; ISO TR 14062; management systems; organization; product related environmental protection; strategy; system analysis

1 Introduction

Today, there are in most companies organization charts, management systems or product development schemes and strategies. In this context, ISO TR 14062 can act as a reminder or a checklist for environmental subjects. The user of ISO TR 14062 should be familiar with the management components. However, not every subject is as self-declaring as a simple checklist.

Many elements of ISO TR 14062 need not to be described here because they were only a necessary but well known environmental 'add on' from other standards like the ISO 14 040 series (Life Cycle Assessment). As the integration seems often to be very simple a concentration to those examples was made where the situation can be very complex. This is the case with strategic elements where the standard at first glance provides simple recommendations. In addition, this paper is not repeating the detailed contents of the Technical Report as it is publicly available. Instead, we follow the structure and explain the ideas behind the Technical Report using selected examples. Besides the introductory chapters like definitions, goal and potential benefits, the structure follows the subjects in **Table 1**. Especially with the subject of strategy, the structure seems a bit confusing and needs explanation. Also the role of existing management systems can be explained in more detail.

2 Strategy Development

As the development of strategies was not the target of the Technical Report and only necessary inputs from the environmental view should be provided, the order within the chapters 5 and 7 does not follow the way normally a strategy is developed. (Reason for this structure was to keep product related subjects together). But recommendations are made for a company strategy, a product strategy and a design strategy. This is the hierarchy for the strategy development to be kept in mind reading these chapters.

There is no need to reflect company strategies here because company strategies are nowadays published in many environmental reports. Also business and product strategies can be very simple. Some companies for example have a green product family in addition to the standard products and want to address a special market sector. But to become really successful, the strategy must be based on market data that help to identify for which properties the customer is willing to pay. In the same sense the strategy cannot be based on the change of just a few materials, a strategic concept must be integrated into all stages of the product development.

2.1 Business strategy and design strategies

Business strategies can include approaches where the own, traditional product is broadened by links to other product systems, or even substituted by service approaches (e.g. offering mobility without selling the product vehicle – car renting companies, organizing car sharing schemes, etc.). Therefore, product in the sense of the ISO TR 14062 means 'any goods or service' and includes also software. Service contains the chance to substitute hardware partly or totally with often less environmental impact. Therefore, in an analysis of the product and its application, a business planner should check whether instead of hardware also alternative, better environmentally compatible services are possible. Such a check will also lead to new business chances because many companies look at their traditional product alone. Here, *software* can provide significant opportunities. As an example the remote control of plants or vehicles can be mentioned. This idea to improve maintenance created new products like in sensor technology and in the software development. Results are the saving of unnecessary service, i.e. costs. Other examples where software can reduce environmental impacts are provided in **section 2.2**.

Design-strategies like 'design for recycling' (cf. VDI 2243) are influenced by market opportunities like 'easy to disassemble modules' for a better serviceability. The success of such a 'limited' strategy can be compromised if not other rules like energy saving, etc. are included. Within the overall strategy development such a detailed decision might not be appropriate. But in combination with the special product design process and the defined overall properties such a strategy can be **one** good solution for the set of environmental parameters in the product profile.

The following example is taken from VDI 2243. It describes how such a general concept influences all stages from product to material level (**Table 2**).

It is possible to have such an intensified look to only **one** environmental aspect of a product, but usually much more aspects are relevant like energy consumption, hazardous substances, resources consumption , etc. There are issues with both approaches: either being very strict in following one demand for e.g. recyclability without compromising with other environmental aspects or looking at all different environmental aspects in a multi-criteria approach.

One problem is that some occurring environmental aspects can have contradictory effects: A lightweight, but more toxic material could save more energy than a less toxic but heavier material. Looking at different possible combinations of aspects it is obvious that several good solutions can exist also in combination with cost evaluation. Possible alternatives must be compared and their overall environmental impact has to be evaluated with (simplified) Life Cycle considerations together with cost estimation. Before doing a time consuming detailed LCA a selection of preferred technical solutions should be derived with the introduction of the aspects into a Quality Function Deployment scheme. This scheme always includes the other product requirements like functionality or costs. In the end, we should never forget that a manufacturer has to plan and design for consumers accepting the product or service!

> Looking at the examples of vehicle catalytic converter there is the trade-off of consuming precious metals (resource depletion, high energy consumption by mining) versus significantly reducing vehicle tailpipe emissions versus slightly increasing fuel consumption. Reducing the necessary amount of precious metals and improving the efficiency of the catalytic converter can solve technically the trade-off.
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> Trade-offs between environmental and cost aspects can be addressed by looking at the environmental efficiency (what alternative provides the highest environmental improvement for the lowest cost).

2.2 The complexity problem and interdependence

In reality the products are applied in systems which are more complex and cannot be described completely by the tools available at the moment. Neither by scenario techniques nor by Life Cycle Assessments. The effects, not only environmental, caused from such systems are much more far reaching. For example by e-business the numbers of transports and packages are very much increased or by e-governance the behavior of people could change dramatically because of loosing the social contacts. The influence of the software is not evaluated and the influence of the clients , etc. The opportunities of a manufacturer who will be able to investigate such complex systems and gets more detailed experience in environmental improvements can be very high.

> **A complex example:** Looking for example at *the Internet system*, the problems how to define the correct system and all of its environmental impacts and consequences become evident: At first glance the Internet system only consists of hardware, software and a limited number of users. It is easy to calculate the energy consumption of the numbers of clients (hardware like PC), the number of servers and their resulting environmental impact. Also a general *strategic target* could easily be derived: Keep the energy consumption of the overall system constant also if the performance is increased. (It cannot be estimated here whether such a target in the future can be realistic!) From the view of a manufacturer of flat screens, the strategy also will be simple because the energy consumption is about 60% of the CRT monitors. His contribution to the target is very high and a good argument for advertising. In a similar way all other manufacturers and customers can contribute. It seems to be clear that the dimension of the individual targets and strategies can only be estimated over the application of the products in this system and over the whole life cycle.

This example shows that nearly every manufacturer can contribute and calculate roughly his contribution by designing his product according to such a system. This example also proves that the problem of many companies can be solved at this level even if customers do not seem to be interested in environmental aspects. The value-added becomes evident at the system level.

To achieve improvements in a system some conditions seem to be necessary in contrast to the view to only a single product:

- It has to be accepted that resources are limited and many participants in the system have to contribute in the same direction to get an effect
- The reduction targets must be designed to keep the system sustainable (which can mean constant) and the cost reduction evident. Only a very innovative product or service can achieve a high level target
- A system planning using scenarios can achieve the long-term societal and consumer acceptance.

Effective improvements are very sensitive to the specific base conditions and the acceptance and suitability of the proposed measures cannot be described by a general standard.

3 Integration into Management Systems

Usually the product development scheme is already integrated in ISO 9001, whereas environmental politics , etc. are usually included in ISO 14001. In many companies there is only **one** handbook with both systems, also the two management systems are harmonized since the year 2000. There are also initiatives to include worker's health and safety management system into a combined management system. The processes are now often defined, implemented and applied in one comprehensive management system instead of referring to various independent handbooks and descriptions according to organizational functions; they include also the product development (Rocha and Brezet 1999), (Cramer 1997). In such an open management system a discussion about the integration of additional management systems or the 'correct' management system can be avoided. It is obvious that people can only live with one solution in practice. The ISO TR 14062 describes the processes, the tools, and the reviews that can easily be transferred to each of the existing systems. In **Table 3**, product related environmental subjects were integrated into ISO 9001 and ISO 14001 where it seemed possible.

It is obvious that ISO 9001 is more precise for an integration of product related environmental protection. Besides some changes in the development scheme the essential processes have to be defined. This can include either changes of existing processes (like the purchasing process which becomes an environmental supply chain management process) or the establishment of new processes like the take back process till disposal. Some other examples for these processes are: Analysis and environmental evaluation, strategy development, innovation, take back and recovery, documentation of environmental information, etc. Most of these processes are missing, completely or partly, in both aforementioned management systems and have to be described individually. In quality management according to ISO 9001, processes end with the supply to the customer. ISO 14001 implementation is often focused on the production. Both together fit very well! Processes missing can be quickly identified after the business strategy is fixed. Customer satisfaction and environmental improvements have also to be brought together. Instead of trying to keep the systems divided, the *link* is created with the environmentally compatible product design! This integration of management systems should be reflected by the integration of tools (v Ahsen 1999).

4 Integration of Environmental Aspects into the Design and Development Scheme

By describing the integration of environmental aspects into the development phases we focus only on the integration area (stages of the design and development process) and the name of the integrated environmental aspect. Several solutions and decisions are reasonable and applied in practice. Market analysis can be done within the strategy, marketing or sales phase or at the end of the development. Also for the aspects several solutions are possible because we have to find compromises between several sometimes contradictory environmental aspects. For example energy consumption and weight of materials have to be balanced with the costs, etc. Decision making tools like a cost/benefit analysis can be applied to chose the best alternative.

The planning phases are the most effective for improvements. Review steps have to be integrated. Managers who want to keep everything the same by only adding some properties will not be successful. For every product the planning process has to be optimized again. ISO TR 14062 describes from the beginning till market launch examples for inputs and outputs for each phase and for tools applicable. The descriptions in the technical report are very precise so that everyone should be able to add the necessary elements to the existing system. In **Table 4**, the typical stages in the design and development process are described.

It is not the intention of ISO TR 14062 to establish a certifiable system because the elements to be integrated might differ depending on the kind of business, but the manifold of examples given are sufficient for a practical selection.

In **Table 5**, a simplified possible solution is selected derived from the rules in the Siemens standard SN 36 350 part 1. In these rules the environmental aspects like resources consumption are not used directly but in the way it contributes to a design activity. The indirect way is applied as it is known that e.g. the easiness of disassembly contributes to reuse/recycling while reuse/recycling to reduction of resources consumption. To make it easy for a design engineer such a translation can be made from the management in the planning of the management system.

In the beginning of a new development, an analysis should be started with the identification of possible environmental impacts caused by the product from inputs like materials and energy till outputs like air emissions, water effluents, waste and others. If this information is available the correlation between the impacts and the aspects can be drawn. But such an analysis from the very beginning is not possible with every new development. A standard list of possible remedies seems to be a good choice.

There are many examples in the Technical Report which need not to be repeated in this article. But there is no example for a complex product dealing with the whole life cycle and showing the manifold of improvements (in: Quella 1998) further examples from all life cycle phases are demonstrated). We have selected an example which won the Siemens Environmental Award in the category of products in the year 2000 and is also for the engineers still a best practice example.

5 Tools

In this Technical Report the necessary or possible tools have been provided for every design and development phase. Examples for application have been described.

These include tools for *strategy* development that are often very complex and time consuming as well as tools for the product design that are less sophisticated. However, the focus of this paper is product design and development. Therefore those engineering tools are of interest where the linkage between the above mentioned management systems is reflected. Looking at business practice, those tools are in particular helpful if suitable for non-experts or even directly linked, combined or merged with existing, classical product development tools. Examples include quality management tools like QFD (the translation of customer wishes into technical properties) if broadened to the environmental dimension – see also a detailed example for E-FMEA. The authors recommend to built up own guidelines and tools adopted to company specific product development tools that then can be more easily accepted and used by development engineers. The application of ISO TR 14062 and the feedback from applicants can help to fill in the missing information about useful tools.

An 'Environment-FMEA' is a way to integrate environmental considerations into existing product development and management systems. A Failure Mode Effect Analysis (FMEA) is a well known and applied quality tool to identify potential failures in achieving the targeted functions of a new design, process / machinery or concept / system (Design-, Process-, Machinery-, Concept or System-FMEA). Systematically, the following steps are conducted:

- potential classes of failures to achieve the targeted function are checked (no, partial, unintended, intermitted function),
- effects of the failure are described and weighted for 'severity',
- root causes of the failures are identified and assessed regarding their 'occurrence',
- existing detection methods are mentioned and valued according to their ability to detect the failure before an effect can take place,
- measures to reduce the identified risks are agreed focusing on those that have the highest importance (e.g. severity, occurrence),
- a new assessment of the improved situation is done.

In companies where FMEAs are applied to the development of all new products, an Environment-FMEA is the natural fit of environmental tools. The Environment-FMEA (Schmidt 2001) follows exactly the same process with the following differences:

- not failures to achieve technical functions but failures to achieve environmental objectives are checked,
- the definition of the severity (and detection likelihood) is tailored to environmental effects (and detection methods available for environmental considerations),
- the designer is encouraged to look at the life cycle to avoid a problem shifting when evaluating the effects and most important the targeted new situation.

The Environment-FMEA can be conducted separately or ideally just in the same FMEA sessions as traditional FMEAs. The format and software for both are identical. In the case of Ford Motor Company even the training manual and FMEA support cards contain both types of FMEAs. Consequently, the applied quality and environmental tools are merged – following the integration of environmental considerations in one management system.

4 Integration into Organization and Information Flow

There are several companies who had accomplished projects for integrating environmental aspects into the design. However, due to their pilot character, these projects often did not succeed to systematically and permanently integrate ecological aspects into product development (Rocha & Brezet 2000). One reason is that the availability of tools (see above) is not enough. Cramer & Schot (1993) argue that companies have to make 'drastically changes to the way they address environmental product development and its management' to get to a real integration. Gouldson & Murphy (1998) suggest three interrelated perspectives for the integration of environmental aspects in the product development: a technological (see above), strategic (chapter 2), and an organizational view.

Usually there are existing process owners for the different steps of the design and development scheme. After the integration of environmental considerations has been finished the owners of the processes get and accept additional tasks. This may include decisions on new or restructured resources. In the beginning a coordinator for the overall integration can be helpful but after some time of application the development of environmentally compatible products must become the daily job of the development engineers.

Commitment of all affected management levels and reinforcement is necessary as in every other management system. The biggest task with environmental product management is to install a real supply chain management or even Life Cycle stakeholder management which means to achieve an information flow internally, up- and downstream.

Therefore, *communication* to many stakeholders has to be organized. A systematic communication is necessary for an increase of acceptance. This communication has to enable all life cycle stakeholder to improve the overall environmental effectiveness and efficiency of the product system. For the example of the Life Cycle Stakeholder Involvement Strategy developed by Ford the roles and responsibilities of the life cycle stakeholders are described in **Table 4**. The communication flow includes aspects like

- the International Material Data System (Substance and Material Information along the supply chain), Design for Environment Training for own and supplier's training, supplier forums, knowledge sharing, communicating environmental targets
- supporting consumers in using vehicles with even better fuel economy than homologated (Ford Eco-Driving improves on average the fuel economy by additional 25%).
- communicating ways to dismantle products (for vehicles via the International Dismantling Information System, IDIS).

Anyway, behind all these many new tasks are many opportunities to reduce costs, sell services, new products or improve the competitive situation. If not today the investment may pay off within some years.

Prevention is assumed to be highest in the hierarchy of environmental improvements. The manufacturer can contribute to prevention by avoiding materials with high impact for the environment, by reducing the consumption of resources or by recycling, etc. This original task of the manufacturer and must be fulfilled. But it has to be mentioned that for many products the highest environmental impact is caused during the product use (exemptions include for example food products). In the Technical Report the chapter of Communication from the manufacturer to the customer about environmental improvements is therefore very important (see also **Table 6**).

5 Conclusion and Outlook

ISO TR 14062 is a very valuable guide for all who are interested or involved in the design and development of environmentally compatible products. It is recommended to transfer the general standard to the company-specific management systems, tools and cultures. Nevertheless practical experience is necessary to identify its limits in each case. As this Technical Report is the first global one the feedback from applicants in the different regions of the world will be interesting. Every company can easily integrate many elements and thus achieve an improvement for the environment.

The future development of this Technical Report to a management system standard may not be difficult – and even necessary as shown in the paper. The problem occurs in the variety of opportunities to be implemented. Again, the integration shall be tailored to the existing management systems, in particular ISO 9000/14001. In addition, the design engineer needs the freedom of choice. If there for example could only be written sentences like "in this phase measures have to be taken to assure ...." the information would stay vague because nobody will know what to do. In form of a TR one can explain by examples. On the other hand, the detailed description of the measures does often not make sense because one would lose the aforementioned opportunities.

Therefore, a solution for this difficulty is necessary before starting a new standardization step.

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Received: February 7th, 2003
Accepted: March 15th, 2002
Online: March 17th, 2003

Appendix: Table 1-6

Table 1: Structure of ISO 14062

Subject	Contents
Strategic considerations like Company, business/product and design strategy	Chapter 5.1–5.4 with General, Organizational issues, Product-related issues and Communication Chapter 7.3 Concepts Chapter 7.4 Strategic product related objectives Chapter 7.5 Design approaches
Management considerations	Chapter 6 (General, Management role, Proactive approach, Support from existing management systems, Multi disciplinary approach, Supply chain management)
Product considerations	Chapter 7.1–7.2 (General, Product related environmental aspects and impacts)
Product design and development process	Chapter 8

Table 2: Design for Recycling Concept according to VDI 2243

Levels and degree of detailing	Overall structure	Connections	Materials
General	Recycling concept	Detachability	Recyclability
Product level	Modular construction	Types and range of connections	Compatibility for use
Component level	Accessibility	Dismantling level, dismantling time	Multiplicity of materials
Material specific level	Separability	Dismantling time	Material selection, compatibility

Table 3: Possibilities for the integration of product related subjects into ISO 14001 and ISO 9001, a comparison

Management Step	ISO 9001 (selected stages)	Examples for environmental inputs in ISO 9001	ISO 14 001	Examples for inputs in ISO 14001
Strategy	5.2 Customer focus 5.3 Quality policy 5.4 Planning 5.4.1 Quality objectives 5.4.2 Quality management system planning	Environmental requirements Input in strategy Integration of environmental product targets Implementation of new processes like take back, Information of customers, recycling, etc.	4.2 Environmentally policy 4. 3 Planning 4.3.1 Environmental aspects 4.3.2 Legal and other requirements 4.3.3 Objectives and targets 4.3.3 Environmental management programmes	Input for products Product specific aspects Product specific legislation Product specific targets Development of new products (better in ISO 9001 chapter 7)
Planning	7. Product realization 7.1 Planning of product realization	Implementation of new processes like take back, information of customers, recycling, etc.		
	7.2 Customer related processes 7.2.1 Determination of requirements related to the product 7.2.2 Review of requirements related to the product 7.2.3 Customer communication	Inputs from environmental legislation, standardization, customer, competition Information about environmental properties of product	4.3.2 Legal and other requirements 4.4.6 Operational control	Procedures related to environmental aspects
Design and Verification	7.3 Design and development 7.3.1 Design and development planning 7.3.2/3 Design and development inputs and outputs 7.3.4–7 Review, verification, validation	Inputs of environmental aspects Planning of review steps		
Market	7.4 Purchasing 7.4.1 Purchasing process 7.4.2 Purchasing information	Environmental requirements for suppliers	4.4.6 Operational control	Requirements to suppliers and contractors
Production	7.5 Production and service provision 7.5.3 Identification and traceability 7.5.5 Preservation of product	Environmental aspects Disassembly, take back Product marking Conformity to legislation		
Product Review	8. Measurement	Evaluation of the environmental properties of the product, customer satisfaction with environmental properties		

Table 4: Typical stages of the design and development process (stages are inter-linked)

Stages	Activities during Design and Development Process
Planning	Environmental analysis, benchmark, determine aspects and requirements, define targets
Conceptual Design	Develop design concepts, analyse reference and alternative products
Detailed Design	Apply design approach and tools
Testing/Prototype	Verify compliance to specification
Production/Market Launch	Communication about material, best use, take back, disposal
Product Review	Evaluate experiences (market success, environmental impacts)

Table 5: Example for the application of design rules (corresponding to aspects) and their consequences over the whole life cycle

Life cycle phase	**Activities**	**Result for the Siemens Mobile Phone Base Station BS 241**
Marketing, Planning, Conceptual and Detailed Design	Integrate expectations of customers Estimate impact over life cycle Derive development targets like - reduced energy consumption - reduced hazardous substances	A new cooling (-33% cost) system avoiding an active cooling by air and new patent cooling with membrane filter (= no heat exchanger)
Procurement, Production**	Reduce material Reduce weight	- New subrack: 1 part/1 material, ca. -80% cost, 25% more space; former rack: 66 parts, 4 materials - Front: pure steel with structured surface, laser inscription, 100% recycling possible
*Sales and Service **	Information about disposal Documentation for customers	Service call by software and remote control (= less service costs)
*Use/ application**	Information about long useful life and product use in environmental favorable way	Power consumption was reduced by –35% Sensitivity was increased by +2dB (corresponding power reduction in cellular phones –37%)
Disassembly, Disposal**	Ease of disassembly	Packaging (now plug & play from factory); materials only wood, multi-use Total product: Nearly 100% recycling possible.
* Planning happens during 'planning and development' phase		

Table 6: Role of life cycle stakeholder to improve environmental performance of products and services (Schmidt 2002)

	Role of industry (manufacturers and suppliers)	**Role of consumer (users / end-users)**	**Role of companies in the disposal / recycling business**
Up-stream in the life cycle	- Influencing the environmental performance processes of suppliers directly (e.g. Ford Motor Company is requesting ISO 14001 certification for all suppliers by July 2003 and is offering training), banning the usage of certain targeted substances in the supply - Share knowledge, provide supplier training - Creating a green supply market by demanding competitive, environmentally favourable materials, technology, and design solutions that provide a better environmental performance, - Establishing an information flow, creating supplier forums, etc.	- Purchasing materials, technology, and design solutions that provide significant better environmental performance even when priced at a premium. - Feedback to manufacturers, as to what (environmental) issues have priority for them. - Rewarding companies that are leading in environmental performance and punishing those who don't (e.g., purchase behaviours, personal investment portfolio, word of mouth)	- Providing information to end-users where to leave products at the end of their life
Own life cycle stage	- Improving own environmental performance of manufacturing (cleaner production, waste, & energy management, ISO14001, etc.) - Choosing materials and design options (use of recycled or renewable materials, use of materials that are supported by Design for Environment tools - Educating staff and cooperating suppliers in environmental aspects - Innovating / improving the product, Develop cleaner fuels, more efficient product, better fit between fuel and product/machine - Infrastructure and incentive alignment between competitors (e.g. for future fuels)	- Following recommendations on environmentally responsible product use (e.g. Eco-Driving). - Switching off stand-by devices to avoid unnecessary environmental impacts, etc. - Looking for further usages / functions of products as well as use-cascades (e.g. old computer processors for other purposes) - Intelligent combinations of products (inter modality using the different mobility and communication opportunities)	- Improving environmental performance (cleaner production, waste & energy management, ISO14001, improved yield, etc.) - Ensuring high quality / competitiveness of recycled materials / products (same or lower price, same or higher quality compared to virgin materials/products)
Down-stream in the life cycle	- Educating retail locations (e.g., dealers) and including environmental aspects in contracts (e.g. Ford) - Informing and training customers about environmental aspects of the products (for example Ford's environmental and safety label) and environmentally-conscious use of the products (for example Ford's Eco-Driving, dosing recommendations to measure out washing agents, etc.) - Enabling and providing information for product dismantling and recycling / recovery (IDIS, IMDS) - Raising awareness among consumers of critical environmental issues and product impacts	- Directing products and materials to the appropriate collection / disposal / recycling facilities.	- Communicating to manufacturers how to improve Design for Recycling / Dismantling Providing high quality / competitive recycled materials / products