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Environmental management — Integrating environmental aspects into product design and development

Management environnemental — Intégration des aspects environnementaux dans la conception et le développement de produit

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Contents

Foreword ... iv
Introduction ... v
1 Scope ... 1
2 Normative references ... 1
3 Terms and definitions ... 1
4 Goal and potential benefits ... 3
5 Strategic considerations ... 3
5.1 General ... 3
5.2 Organizational issues ... 4
5.3 Product-related issues ... 4
5.4 Communication ... 4
6 Management considerations ... 5
6.1 General ... 5
6.2 Management role ... 5
6.3 Proactive approach ... 6
6.4 Support from existing management systems ... 6
6.5 Multidisciplinary approach ... 6
6.6 Supply-chain management ... 7
7 Product considerations ... 7
7.1 General ... 7
7.2 Product-related environmental aspects and impacts ... 8
7.3 Basic issues ... 9
7.4 Strategic product-related environmental objectives ... 12
7.5 Design approaches ... 13
8 Product design and development process ... 13
8.1 General ... 13
8.2 Common issues ... 13
8.3 Product design and development process and integration of environmental aspects ... 14
8.4 General review of the product design and development process ... 20
Bibliography ... 22

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Foreword

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TR 14062 was prepared by Technical Committee ISO/TC 207, *Environmental management*.

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Introduction

All products, that is, all goods or services, have some impact on the environment, which may occur at any or all stages of the product's life cycle: raw material acquisition, manufacture, distribution, use and disposal. These impacts may range from slight to significant; they may be short-term or long-term; and they may occur at the local, regional or global level (or combination thereof).

The interest of customers, users, developers and others in the environmental aspects and impacts of products is increasing. This interest is reflected in discussions among business, consumers, governments and non-governmental organizations concerning sustainable development, eco-efficiency, design for the environment, product stewardship, international agreements, trade measures, national legislation, and government or sector based voluntary initiatives. This interest is also reflected in the economics of various market segments that are recognizing and taking advantage of these new approaches to product design. These new approaches may result in improved resource and process efficiencies, potential product differentiation, reduction in regulatory burden and potential liability, and costs savings. In addition, globalization of markets, shifts in sourcing, manufacturing and distributing all influence the supply chain, and therefore have an impact on the environment.

More organizations are coming to realize that there are substantial benefits in integrating environmental aspects into product design and development. Some of these benefits may include: lower costs, stimulation of innovation, new business opportunities, and improved product quality.

Anticipating or identifying the environmental aspects of a product throughout its life cycle may be complex. It is important to consider its function within the context of the system where it will be used. A product's environmental aspects must also be balanced against other factors, such as the product's intended function, performance, safety and health, cost, marketability, quality, and legal and regulatory requirements.

The process of integrating environmental aspects into product design and development is continual and flexible, promoting creativity and maximizing innovation and opportunities for environmental improvement. As a basis for this integration, environmental issues may be addressed in the policies and strategies of the organization involved.

Early identification and planning enables organizations to make effective decisions about environmental aspects that they control and to better understand how their decisions may affect environmental aspects controlled by others, i.e. at the raw material acquisition or end-of-life stages.

This Technical Report is intended for use by all those involved in the design and development of products, regardless of organization type, size, location and complexity, and for all types of products whether new or modified. It is written for those directly involved in the process of product design and development and for those responsible for the policy/decision making process. The information provided by this Technical Report may also be of interest to external stakeholders who are not directly involved in the product design and development process.

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Environmental management — Integrating environmental aspects into product design and development

1 Scope

This Technical Report describes concepts and current practices relating to the integration of environmental aspects into product design and development, where “product” is understood to cover both goods and services.

This Technical Report is applicable to the development of sector-specific documents.

It is not applicable as a specification for certification and registration purposes.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14050, *Environmental management — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14050 and the following apply.

3.1
process
set of interrelated or interacting activities which transforms inputs into outputs

NOTE 1 Inputs to a process are generally outputs of other processes.

NOTE 2 Processes in an organization are generally planned and carried out under controlled conditions to add value.

[ISO 9000:2000, 3.4.1]

3.2
product
any goods or service

NOTE 1 The product can be categorized as follows:

— services (e.g. transport);

— software (e.g. computer program, dictionary);

— hardware (e.g. engine mechanical part);

— processed materials (e.g. lubricant).

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NOTE 2 Services have tangible and intangible elements. Provision of a service can involve, for example, the following:

— an activity performed on a customer-supplied tangible product (e.g. automobile to be repaired);

— an activity performed on a customer-supplied intangible product (e.g. the income statement needed to prepare a tax return);

— the delivery of an intangible product (e.g. the delivery of information in the context of knowledge transmission);

— the creation of ambience for the customer (e.g. in hotels and restaurants).

Software consists of information and is generally intangible and can be in the form of approaches, transactions or procedures.

Hardware is generally tangible and its amount is a countable characteristic. Processed materials are generally tangible and their amount is a continuous characteristic.

NOTE 3 Adapted from ISO 14021:1999, 3.1.11.

3.3
design and development
set of processes that transforms requirements into specified characteristics or into the specification of a product, process or system

[ISO 9000:2000, 3.4.4]

NOTE 1 The terms “design” and “development” are sometimes used synonymously and sometimes used to define different stages of the overall process of turning an idea into a product.

NOTE 2 Product development is the process of taking a product idea from planning to market launch and review of the product, in which business strategies, marketing considerations, research methods and design aspects are used to take a product to a point of practical use. It includes improvements or modifications to existing products or processes.

NOTE 3 The integration of environmental aspects into product design and development may also be termed Design For Environment (DFE), eco-design, the environmental part of product stewardship, etc.

3.4
environment
surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation

NOTE Surroundings in this context extend from within an organization to the global system.

[ISO 14001:1996, 3.2]

3.5
environmental aspect
element of an organization's activities, products or services that can interact with the environment

NOTE A significant environmental aspect is an environmental aspect that has or can have a significant environmental impact.

[ISO 14001:1996, 3.3]

3.6
environmental impact
any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services

[ISO 14001:1996, 3.4]

3.7
life cycle
consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to the final disposal

[ISO 14040:1997, 3.8]

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3.8
product system
collection of materially and energetically connected unit processes which performs one or more defined functions

[ISO 14040:1997, 3.15]

3.9
supply chain
those involved, through upstream and downstream linkages, in processes and activities delivering value in the form of products to the user

NOTE 1 In practice, the expression “interlinked chain” applies from suppliers to those involved in end-of-life processing.

NOTE 2 In practice, the expressions “product chain”, “value chain” are often used.

4 Goal and potential benefits

The goal of integrating environmental aspects into product design and development is the reduction of adverse environmental impacts of products throughout their entire life cycles. In striving for this goal, multiple benefits can be achieved for the organization, its competitiveness, customers and other stakeholders. Potential benefits may include:

— lower costs by optimizing the use of materials and energy, more efficient processes, reduced waste disposal;

— stimulation of innovation and creativity;

— identification of new products, e.g. from discarded materials;

— meeting or surpassing customer expectations;

— enhancement of organization image and/or brand;

— improved customer loyalty;

— attraction of financing and investment, particularly from environmentally conscious investors;

— enhancement of employee motivation;

— increased knowledge about the product;

— reduction in liability through reduced environmental impacts;

— reduction of risks;

— improved relations with regulators;

— improved internal and external communications.

5 Strategic considerations

5.1 General

This clause describes some of the common strategic considerations that organizations take into account when integrating environmental aspects into product design and development. It is useful to consider the goal (see Clause 4) within the context of the organization's existing policies, strategies and structure. These existing policies or strategies can provide valuable direction to integrating environmental aspects into product design and development.

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5.2 Organizational issues

It is important to consider strategic issues such as those mentioned below, because they may have economic and environmental implications for the organization. The overall objectives of the organization influence the extent to which these strategic issues are relevant:

— competitors' activities;

— customer needs, requirements and demands;

— supplier activities;

— relationships with investors, financiers, insurers and other stakeholders;

— organization's environmental aspects and impacts;

— activities of regulators and legislators;

— activities of industry and business associations.

5.3 Product-related issues

Organizations that integrate environmental aspects into product design and development commonly consider the following product-related issues:

a) early integration, i.e. addressing the environmental aspects early in the design and development process;

b) product life cycle, i.e. analysis from raw material acquisition to end of life (see Figure 1);

c) functionality, i.e. how well the product suits the purpose for which it is intended in terms of usability, useful lifetime, appearance, among others;

d) multi-criteria concept, i.e. consideration of all relevant environmental impacts and aspects;

e) trade-offs, i.e. seeking optimal solutions.

These issues are discussed in more detail in 7.3.

5.4 Communication

A communication strategy is an integral part of the process of incorporating environmental aspects into product design and development. An effective strategy addresses both internal and external communication.

Internal communication could involve providing information to employees on

— the organization's policy,

— product-related environmental impacts,

— training courses on environmental issues, programmes and tools,

— successful projects or products,

— site-specific impacts on the environment.

Such communication can also involve mechanisms that obtain feedback from employees on product design and development issues.

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External communication can be an opportunity for enhancing the value and benefits of integrating environmental aspects into product design and development. This communication can be to stakeholders, such as customers and suppliers, and can include information on

— product properties (performance, environmental aspects, etc.),

— proper use and end-of-life handling of products.

There are various national and international standards for external communication. For example, the ISO 14020 series provides principles, examples and requirements for environmental labelling.

6 Management considerations

6.1 General

This clause describes the role of top management and the importance of its commitment to a programme of integrating environmental aspects into product design and development. The decisions taken by management determine the framework and targets of the programme, the level of support the work will receive and the degree of optimization the programme will achieve.

6.2 Management role

The process of integrating environmental aspects into product design and development can be initiated either by management (top-down) or by designers and product developers (bottom-up). In practice, both approaches can take place simultaneously. Regardless of which business function initiates the process, top management level support is needed to have a significant effect on an organization's product design and development activities.

Top management actions are needed to enable effective implementation of procedures and programmes. This includes the allocation of sufficient financial and human resources and time for the tasks involved in integrating environmental aspects into product design and development. An effective integration programme engages actors involved in the product design and development process, such as product developers and designers, experts from marketing, production, environment, procurement, service personnel and customers or their representatives.

In general, management may formalize its commitment to the programme by establishing particular goals within the following processes:

— continual environmental improvement of products;

— management of the supply chain;

— active participation in the programme by employees engaged in product design and development; and

— fostering the creation of new ideas and innovation.

Management establishes and maintains the basic framework within which the organization operates. When integrating environmental aspects into product design and development, elements of this framework may include:

— defining the environmental vision and policy;

— defining objectives and targets to

  — ensure legal compliance,

  — reduce adverse environmental impacts of products;

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— allocating resources;

— assigning responsibilities, tasks and accountabilities;

— defining, supporting and monitoring product design and development programmes;

— defining and instituting programmes for review of the product design and development process;

— organizing/structuring environmental functions and processes for product design and development;

— identifying recruitment and training needs for implementing the programmes;

— defining measurement and performance indicators;

— following up and providing feedback on environmental performance.

6.3 Proactive approach

Integration of environmental aspects into product design and development seeks to prevent adverse environmental impacts before they arise. It provides a systematic opportunity to anticipate problems and their solutions along the whole product life cycle. Organizations that take proactive actions in this regard may increase their chances to benefit from this approach.

6.4 Support from existing management systems

The integration of environmental aspects into product design and development can be supported by existing management systems (e.g. quality and environmental management systems or product stewardship programmes). On the other hand, the existing management system may be activated by these integration activities. ISO 14001 and ISO 14004, for example, describe and give guidance to establishment of environmental management systems that can be used in connection with product design and development.

Help box No. 1

Links with environmental management system

For many organizations, the environmental impact of their products is related to a significant environmental aspect. Therefore it is often relevant for them to consider products in the environmental policy, objectives and targets of their environmental management system, e.g. ISO 14001.

An organization can identify the significant environmental aspects of its products and establish procedures to identify and track developments in environmental, legal and other requirements applicable to its products. It can also define, design, initiate and maintain appropriate training programmes to ensure employees adhere to established and developing environmental standards or practices.

In addition, the product design and development process is usually part of an existing management system, such as ISO 9001, through which the environmental aspects and product-related activities could be incorporated according to the stages of the process.

6.5 Multidisciplinary approach

The success of integrating environmental aspects into product design and development in an organization is enhanced by involvement of relevant disciplines and organizational functions such as design, engineering, marketing, environment, quality, purchasing, service delivery, etc. These competencies often involve several people, depending on the size of the organization.

The aim is to ensure that all relevant business functions contribute and commit to environmental improvement in the earliest stages of the design and development process and stay involved throughout the process, up to and including market launch and product review. The key tasks and participants (shown below in brackets) from the business functions involved in integrating environmental aspects into product design and development may include:

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— researching and implementing creative solutions in product design and development (product planners, developers and designers);

— investigating and documenting environmental aspects and impacts of and providing alternatives for existing and planned technologies, e.g. acquisition and use of raw materials, components/subassemblies and materials, and waste management (environmental personnel);

— communicating with suppliers, retailers, customers, recyclers and disposers (environmental personnel);

— collecting and documenting data on materials and components/subassemblies and informing suppliers about the organization's environmental requirements (purchasing managers);

— investigating and providing information on the technical feasibility of alternative designs, manufacturing, materials or processes;

— checking technical feasibility of supplier's production or the end-of-life processes (management, engineers and technicians);

— establishing baseline environmental measurement systems based on previous product generations, competitors' products, etc. (management);

— increasing environmental awareness through training and education (environmental and training personnel);

— considering and tracking new developments in legislation, environmental regulations, competitors' activities and customers' needs, and providing strategic information on the direction of product development and pricing of the end product (regulatory affairs, marketing or brand managers).

6.6 Supply-chain management

Supply-chain management deals with interactions with suppliers, carriers, customers, retailers, waste managers and end-of-life actors. These interactions are likely to vary upstream and downstream, depending on the influence the organization can have on the supply chain. Effective communication can enhance cooperation, reduce misunderstandings and influence actions taken by organizations in the supply chain. Other tasks that may be associated with supply-chain management are:

— increasing environmental information and awareness among suppliers and customers;

— specifying and discussing environmental requirements for organizations within the supply chain (e.g. the use of supplier standards or environmental measurement systems);

— assessing suppliers' environmental performance;

— redesigning products on the basis of customers environmental preferences;

— establishing programmes in relation to reuse and recycling of packaging, materials, components/sub-assemblies or the whole product;

— involving suppliers in environmental programmes.

7 Product considerations

7.1 General

This clause gives an overview of product-related environmental aspects and impacts, basic issues and strategic environmental objectives, as well as examples of design approaches.

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7.2 Product-related environmental aspects and impacts

Products may have a range of environmental aspects (e.g. emissions generated, resources consumed) that result in environmental impacts (e.g. air, water and soil pollution, climate change).

A product's environmental impacts are largely determined by the material and energy inputs and outputs generated at all stages of a product's life cycle. If the product is a service, these impacts are generally related to the physical products used to deliver the service. Environmental impacts can be greatly influenced by the actions of organization(s) and individual(s) using the product. Figure 1 shows some environmental impacts associated with the product's life cycle.

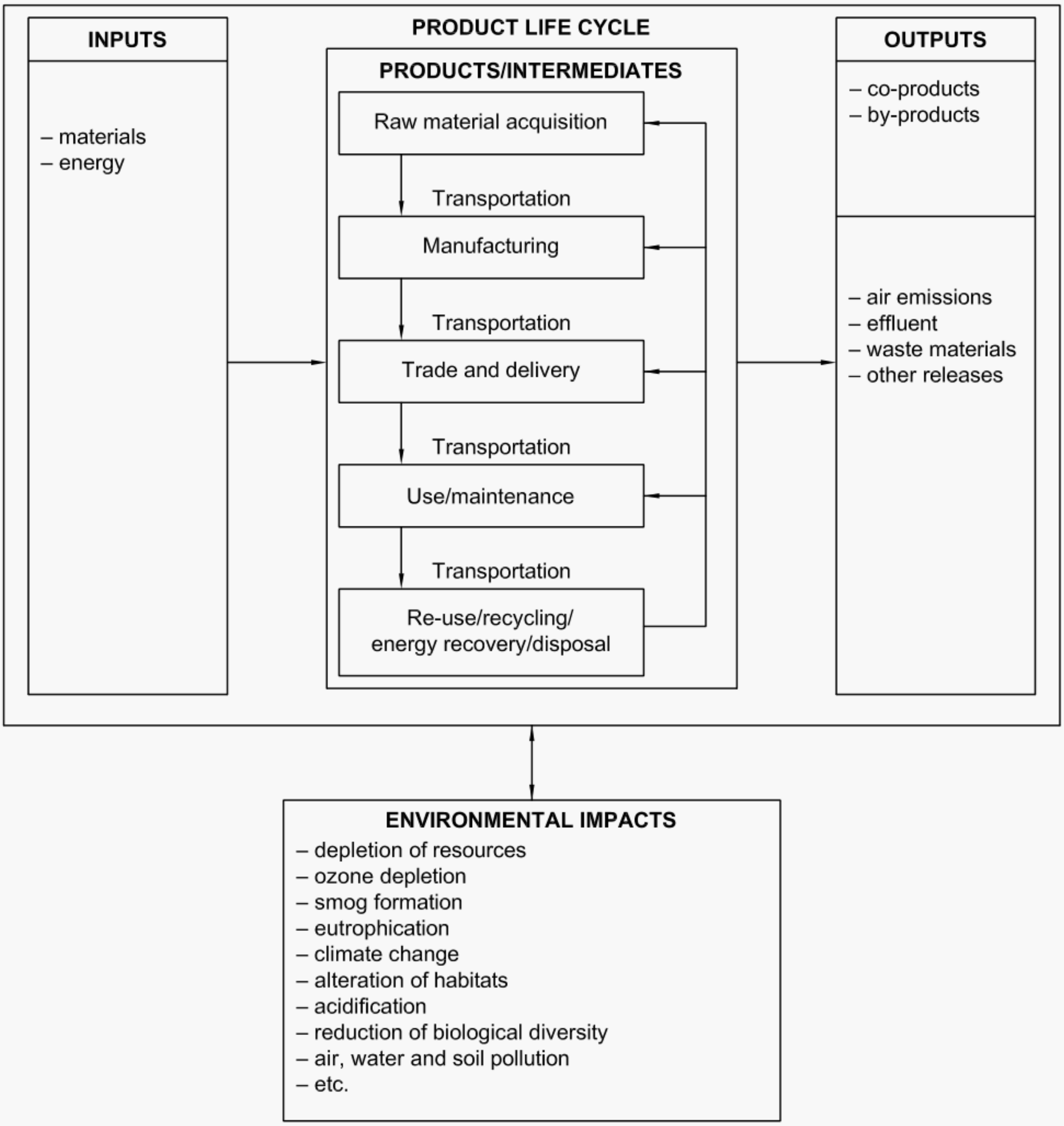

Figure 1 — Inputs and outputs and examples of environmental impacts associated with a product life cycle

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Inputs generally fall into two broad categories: material and energy.

Material inputs are associated with a variety of environmental aspects, for example, use of resources, exposure of humans and ecological systems to contaminants, emissions to air, water and soil and the generation of waste materials and their accumulation.

Energy inputs are required at most stages of a product's life cycle. Energy sources include fossil and biomass fuels, waste materials, nuclear, hydropower, geothermal, solar and wind energy. Each type of energy source has identifiable environmental aspects.

Outputs generated during a product's life cycle fall into several categories: the product itself, intermediates, co-products, by-products and other outputs as described below.

— Air emissions comprise releases of gases, vapours and particulate matter into the air. These releases may adversely affect ecosystems, people, materials, etc. or contribute to other adverse environmental impacts such as acidification, ozone depletion and climate change. These releases can occur, as point or diffused emissions, under normal or accident conditions.

— Effluent discharges comprise discharges of substances to either surface or groundwater. These discharges can be either point sources or non point sources. An example of the latter is agricultural runoff. Like air emissions, these discharges vary in character and can adversely affect the environment, e.g. through eutrophication.

— Waste can be generated during each stage of a product's life cycle. Waste products can become inputs to other processes or can be treated, recycled, used as energy sources, incinerated or land-filled.

— Other releases can include noise, radiation, electromagnetic fields, etc..

— Substances can migrate through materials or material layers into air, water, soils or other material.

For design and development, it may be useful to describe inputs and outputs in terms that are measurable and comparable.

7.3 Basic issues

7.3.1 General

Organizations integrating environmental aspects into product design and development commonly consider the following basic issues.

7.3.2 Early integration

Integration of environmental aspects as early as possible into the product design and development process offers the flexibility to make changes and improvements to products. In contrast, waiting until later stages of the process may preclude the use of desirable environmental options, because all the major technical decisions have already been made.

7.3.3 Product life cycle

A life cycle approach is used to identify the relevant environmental aspects and impacts during the entire product life cycle, thus helping to define design approaches. It is important to take into account all stages of the product's life cycle, as shown in Figure 1, and to recognize how products can affect the environment at different stages.

Organizations should be aware of the limitations and subjectivity involved when designing to reduce the impacts of a product on the environment. Considering the product's entire life cycle can help to ensure that

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— materials are not arbitrarily excluded,

— all the environmental characteristics of a product are taken into account,

— the most relevant environmental impacts during the product's life cycle are identified,

— consideration is given to impacts generated by intermediate products or auxiliary materials that are associated with manufacture, but are not present in the finished product,

— consideration is given to a component or element arbitrarily considered as being minor that may turn out to have significant environmental impact,

— focus is not only on the environmental impact of the product itself, but also on the system in which the product will perform,

— environmental impacts are not shifted from one life cycle phase to another or from one medium to another.

Help box No. 2

Examples of impacts on life cycle related to the product design

Water or energy consumption during the “use stage” of a home appliance may generate the greatest environmental impact of any stage of the product's life. Improving the efficiency of water or energy use as part of product design and development can reduce the environmental impacts of these products.

The use of metals in glass or windows can improve the energy efficiency of a building, through better insulation, but may reduce the possibility of recycling of the glass after use.

Changing any single input (e.g. altering a material used) or influencing a single output (e.g. reducing specific emissions or making provisions for reducing hazardous wastes) may affect other inputs or outputs. Therefore, it is important to ensure that any emphasis on a single stage of a product’s life cycle does not unintentionally alter the environmental impacts at other stages or result in additional impacts on other elements of the local, regional or global environment.

The life cycle approach may also be applied to services including, but not limited to, the tangible products employed in their delivery. Services generally consist of the following three elements: use of tangible products, application of knowledge and skill, and human labour or activity. Services also create environmental impacts by influencing the behaviour of people and organizations to which the services are delivered.

7.3.4 Functionality

When developing products, there may be considerable value in thinking in terms of functionality (how well the product suits the purpose for which it is intended in terms of usability, useful lifetime, appearance, etc.) rather than in terms of a specific technical solution. It is therefore important to take a broad approach when searching for new options and to highlight the functionality required to fulfil customer or user demands and needs.

Help box No. 3

Extending a product's lifetime

When defining the product’s lifetime as part of its function, increasing the durability and extending the services associated with the product can reduce adverse environmental impacts. It can also be beneficial to achieve a balance between the product’s technical lifetime and its useful lifetime (i.e. how long a product is considered useful, before it is obsolete or no longer needed by the user). If for instance the product has a relatively short useful lifetime but is designed to have a long technical lifetime, this may result in larger than necessary environmental impacts. Designing a lasting aesthetic can help to improve the useful lifetime of the product. Some products are discarded before they are physically worn out or are technically superseded because their design is out of fashion or inappropriate to changed circumstances. A balance is also necessary between extending a product's lifetime and applying the latest technological advances that may improve the environmental performance during use by taking into account possible upgrading during product development.

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Such thinking to address functionality may eventually lead to a practical solution that has a reduced environmental impact overall, as in the case of a shift from providing tangible goods to offering services.

Help box No. 4

Shifting from selling products to offering services

If the user's need is to produce photocopies, he/she may not need to own a copier (and to be responsible for maintenance, repair, etc. of the machine). A service provider can offer leasing of photocopiers or photocopying services, solutions that fulfil the customer's need with high reliability and at the least possible cost. This approach relates to product design and development (e.g. design of durable parts) and could improve the end-of-life handling of the product (e.g. reuse of parts); this solution makes it easier to control the reuse and the recycling of the equipment and puts focus for the user on the number of copies made (which might lead to minimized use of paper and toners).

7.3.5 Multi-criteria concept

In addition to traditional design criteria (e.g. performance, quality, cost, etc.), a variety of environmental criteria can be taken into account. This generally involves considering a range of different potential environmental impacts (see Figure 1) through a multi-criteria concept.

Considering a broad range of potential impacts and environmental criteria, and exercising caution when excluding such criteria, helps ensure that the reduction of one impact does not result in an increase in another impact.

The organization may recognize that different interested parties (scientific community, government, environmental groups, customers, etc.) may have varying perceptions of the importance of environmental issues. These different perceptions can have relevance for product design and development.

Help box No. 5

Use of a multi-criteria concept

Using the life cycle considerations in 7.2.3, different approaches may be applied, such as

— reduction in product mass or volume,

— improvement in energy efficiency,

— lengthening of product life,

— choice of materials and processes used.

Applying and combining these criteria may reduce environmental impacts of the product. For example:

— A reduction in product mass or volume may be the result of optimizing material use, thereby reducing impacts associated with resource depletion. The reduced product mass or volume could decrease shipping mass or volume, thereby reducing emissions associated with transport.

— Improving energy efficiency, both during the use of the product and in standby mode, is important, particularly in domestic electrical appliances.

— A longer product life may decrease requirements for resources. Extending product life can however delay the implementation of technological advances that may improve the environmental performance.

— Designing products to facilitate disassembly can extend product life through reuse of product parts and can encourage recycling.

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7.3.6 Trade-offs

An integrated perspective to the different life cycle stages and environmental aspects can help ensure that adequate solutions are found for dealing with the trade-offs associated with most design decisions. There are three types of trade-off:

— trade-offs between different environmental aspects, e.g. optimizing a product for mass reduction might negatively affect its recyclability. The comparison of potential environmental impacts associated with each option can help decision-makers to find the best solution;

— trade-offs between environmental, economic and social benefits. These can be tangible (e.g. lower cost, waste reduction), intangible (e.g. convenience) and emotional (e.g. image). For example, making a product more robust increases the lifetime and as a result may benefit the environment by reducing long-term resource use and waste, but may also increase initial costs. This may have social as well as economic effects;

— trade-offs between environmental, technical and/or quality aspects, e.g. design decisions related to use of a particular material might negatively impact the reliability and durability of a product, even though it produces environmental benefits.

Experience has shown that the best solutions are specific to the product and the organization's characteristics. Products are complex and diverse, knowledge and techniques evolve rapidly, and new experience improves the ability to apply novel solutions. It is therefore important to find an appropriate strategy for the integration of the environmental aspects into the product design and development process.

7.4 Strategic product-related environmental objectives

7.4.1 General

The integration of environmental aspects into product design and development involves setting strategic product-related objectives. As discussed in 7.3.4, the objective is to reduce the product's environmental impact while maintaining or improving its functionality. Two main product-related environmental objectives are described below.

7.4.2 Conservation of resources, recycling and energy recovery

This objective is to optimize the use of resources required for the product (material and energy) without having an adverse effect on its performance, its durability, etc. Decreasing the quantity and hazardousness of materials used also can minimize the creation of waste during manufacturing and disposal. Product design and development can incorporate features that make the product more suitable for subsequent reuse, recycling, or for use as a source of energy.

7.4.3 Prevention of pollution, waste and other impacts

Using end-of-pipe means such as sewage treatment, particulate filters, incinerators, etc. can reduce pollution and other impacts generated by a product during its life cycle. These means cannot be the ultimate for the abatement of pollution, waste and other impacts because they can generate other sources of pollution or waste, such as sewage sludge, ashes, slag, etc. Greater environmental improvements can be achieved by using measures that prevent pollution, waste or other impacts. Such approaches deal with problems at their source, considerably reducing the cause of the environmental impact and the cost associated with the end-of-pipe treatment.

Help box No. 6

Pollution prevention

When using a solvent-based paint for surface treatment of a product, an analysis to prevent the emission of volatile organic compounds can lead to different solutions, such as development of a product using a material that does not require a surface treatment, use of another paint system, etc.

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7.5 Design approaches

By considering the goals of the organization, economic and social aspects, and the product type, the organization may decide upon a combination of design approaches to meet the strategic environmental objectives (see 7.4). Examples of possible design approaches are:

— improvement of materials efficiency: checking if environmental impact can be reduced e.g. by minimal use of materials, use of low impact materials, use of renewable materials, and/or use of recovered materials;

— improvement of energy efficiency: considering total energy use throughout the product's life cycle (including use phase), check if environmental impact can be reduced, e.g. reduction of energy use, use of low impact energy sources, use of energy from renewable sources;

— sparing use of land: particularly to be considered when land-consuming infrastructure or materials are utilized in the product system;

— design for cleaner production and use: using cleaner production techniques, avoiding use of hazardous consumables and auxiliary materials and using an overall systems perspective to avoid decisions based on a single environmental criterion;

— design for durability: considering the product's longevity, reparability and maintainability; considering environmental improvements emerging from new technologies;

— design for optimizing functionality: considering opportunities for multiple functions, modularity, automated control and optimization; comparing the environmental performance to that of products tailored for specific use;

— design for reuse, recovery and recycling: considering opportunities to ease disassembly, reducing material complexity, and the use of recyclable materials, subassemblies, components and materials in future products;

— avoidance of potentially hazardous substances and materials in the product: checking for human health, safety, and environmental aspects, lower impact of materials and transportation.

These design approaches are instrumental to generate design options that can be checked against the feasibility and potential benefits for customers, the organization and stakeholders. When applying these approaches, individually or in combination, the design options can be checked against the basic concepts outlined in 7.3.

8 Product design and development process

8.1 General

The purpose of this clause is to describe in more detail how environmental aspects are commonly integrated into the various stages of the product design and development process.

8.2 Common issues

There are common issues in the product design and development process regardless of its nature, the product or sector. These issues are also relevant when integrating environmental aspects into the product design and development process. Some of these are the following:

— **iterative nature of the product design and development process:** Results and information from each stage of the product design and development process can be evaluated and fed back to designers and developers in an iterative way to refine the product. The iterative nature of the process seeks to address significant environmental aspects, alternative design options, and review considerations to verify opportunities for environmental and other improvements;

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— **research:** Research functions in an organization often support the product design and development process. In particular, research can help to provide more details about the environmental and feasibility issues identified in the early design stages. Results of such investigation can be applied to products under development or to future product generations;

— **information and data management:** Information and data management is an essential element of the integration of environmental aspects into product design and development. Decision-making is supported and improved by collection, exchange and management of information and data from both internal (e.g. manufacturing processes, service delivery) and external (e.g. customers) sources and organizations. In particular the quality of data is important for assessing the product and for decision-making. The data to be gathered are defined by the organization's measurement system and the nature of the project. The scope of such data can vary from a material inventory of the product to a full life cycle assessment. The credibility of the results from an evaluation of the environmental impacts of a product is increased through efficient information management, data management software, open and agreed data formats and traceability of the underlying data;

— **evaluation:** Product development involves periodic evaluation of the product and the process itself. From an evaluation of the product's environmental aspects and impacts, it is possible to evaluate progress of the development process against baselines. This evaluation may occur at appropriate milestones before product launch. Efficient evaluation of the product's environmental properties or performance can be done through measurements using various types of indicators. The indicators can be selected by considering the purpose of the evaluation or the design process;

— **communication:** The design and development of products with respect to the environment involves communication. The points of view of the different participants along the supply chain (designers, production and environmental engineers, customers, suppliers, service providers, etc.) can be taken into account. Internal and external information exchange, dialogue and collaboration are important to improve the decision-making behind design and development. Communications can be established and conducted on the basis of accurate and careful information to the product development team;

— **supply-chain management:** As a result of globalization and a trend towards outsourcing, supply-chain management is becoming more important. Suppliers are being involved in the product design and development process, as well as in environmental programmes. An organization can translate its internal environmental requirements into criteria for purchased materials, components, sub-assemblies and services.

8.3 Product design and development process and integration of environmental aspects

8.3.1 General

The product design and development process varies between products and organizations. Figure 2 shows a generic model of product design and development with its typical stages and possible actions to integrate environmental aspects into the process.

8.3.2 Models of the product design and development process

In practice, companies use a combination of approaches and tools to design and develop their products. Accordingly one standard approach to integrate environmental aspects is not reasonable. In large companies the product design and development process might be a formalized approach with fixed milestones and gateway management, whereas in small companies one or several people, working in an informal and more intuitive manner can carry out product development. Many different participants may be involved (e.g. designers, engineers, scientists, suppliers, marketing and service providers). The design and development process for software or services may consist of the same steps as described in Figure 2.

Introduction of environmental aspects as early as possible in the product design and development process increases the opportunity for designers and developers to consider environmental requirements and balance these with other requirements.

The following clauses describe the actions related to integrating environmental aspects in each phase of the product design and development process. The inputs and outputs of each phase are also described, along with possible tools where relevant.

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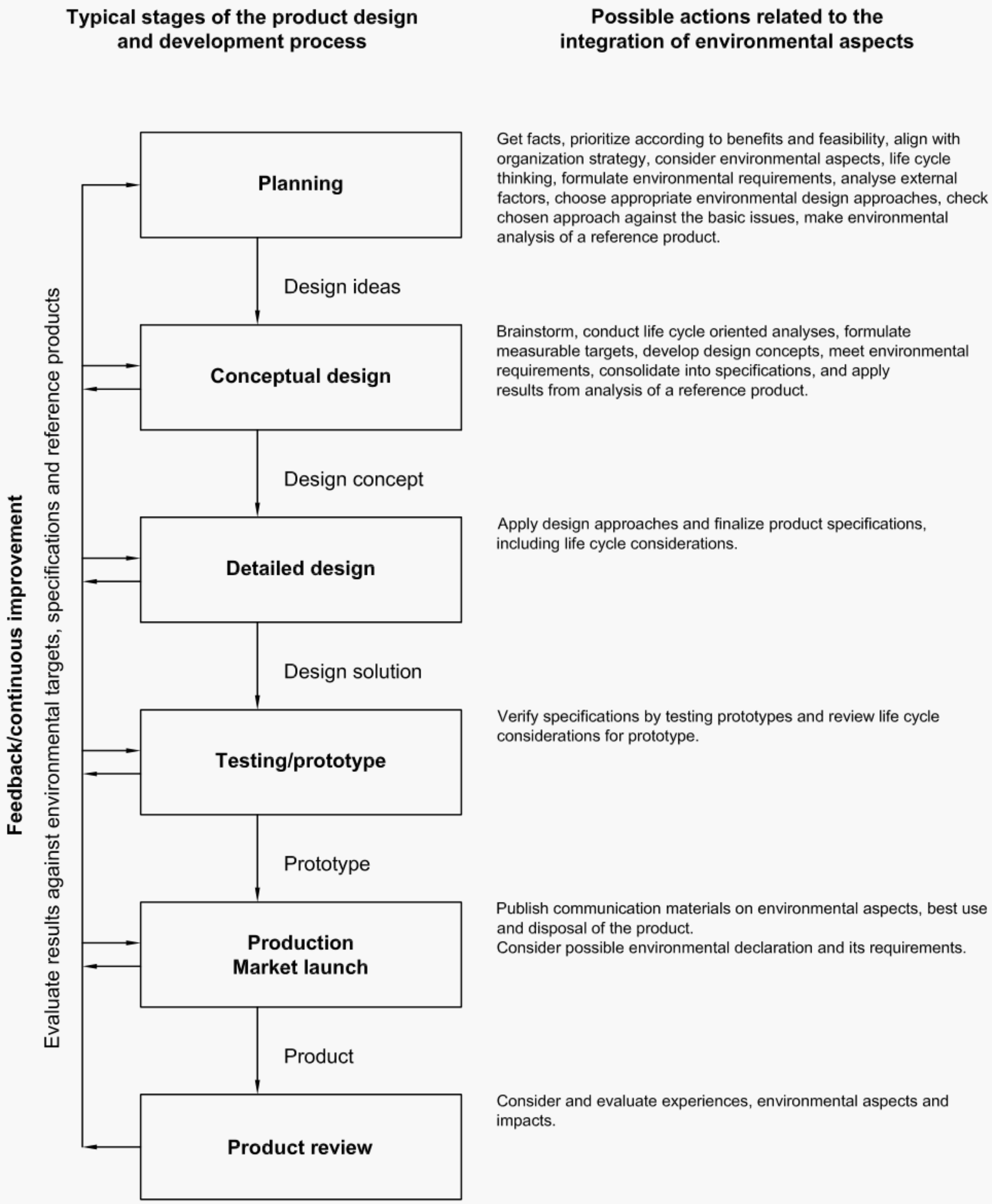

Figure 2 — Example of a generic model of integrating environmental aspects into the product design and development process

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8.3.3 Planning

This stage of the product design and development process encompasses planning and formulation of product requirements while considering the time frame and budget available. This process may start with analysing the external factors influencing the planned product, for example:

— customer needs and expectations: basic analysis of the function to be provided by the product — technical performance, functionality, convenience, quality, price, changes in consumer behaviour and environmental consciousness of customers, etc.;

— market situation: profitability, image of the organization and its products;

— competitors: profile of competing products including environmental criteria;

— environmental requirements: efficient and sparing use of resources, protecting human health and the environment with respect to hazardous substances, environmentally relevant emissions and waste;

— expectations of the public/media: awareness of relevant aspects by the general public, image of the organization and its products;

— legal requirements: present and future development, e.g. national and international environmental policy, regulations, legislation, such as product take-back, producer responsibility, waste management, etc.;

— product system: the system in which the future product will perform its function.

These external factors may be considered in relation to the internal resources available to the organization when making decisions within the product design and development process.

In addition, some internal factors can be considered:

— positioning of the product in the organization's line-up;

— knowledge and expertise of staff;

— availability of external expertise;

— need for/availability of relevant intellectual property;

— financial resources;

— availability of sub-assemblies, components and materials (including recovered materials and materials from renewable sources);

— production technologies, capability or need for new processes;

— manufacturing capacity, location;

— scope of influence of the organization;

— availability of data;

— suppliers' capabilities.

Development and improvement of products can be made either at the level of product components, the product as a whole or the product system. Participants in new-product development can ask fundamental questions regarding customer or user needs.

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There are a variety of tools to assist designers and developers. These can assist in the development of measurement systems, analysis of environmental performance, decision-making, fostering creativity, and integration with business and economic factors. Examples of such tools are:

— qualitative decision-making tools, such as matrices, checklists, Pareto diagrams, SWOT analysis (Strengths, Weaknesses, Opportunities, Threats), spiderweb diagrams, and portfolio diagrams;

— benchmarking based on physical quantities (e.g. kilograms, seconds, watts);

— QFD (Quality Function Deployment) and FMEA (Failure Mode and Effects Analysis) techniques and tools derived from quality management, e.g. transfer of environmental aspects into product properties;

— environmental analyses of existing products, e.g. LCA (Life Cycle Assessment) as described in the ISO 14040 series;

— life cycle costing;

— hazard and risk assessment;

— stakeholder benefits and feasibility analysis.

When selecting which tools to use, it is helpful to consider the basic product-related concepts for integrating environmental aspects into product design and development as described in 7.3.

Help box No. 7

Environmental benchmarking

Environmental benchmarking is the measurement of properties of a product that are related to environmental impacts during its lifecycle. The measurements can be compared to a baseline of a previous product or a competitor's product, both with similar functionality.

Properties to be measured could include:

— energy consumption: during operation and standby mode;

— materials application: mass of main materials and component categories applied;

— packaging: ratios of packaging mass to product mass and volume of packaged product to volume of product;

— transportation: distance transported;

— substances: amounts of potentially hazardous substances;

— disassembly: number of screws and other fixtures.

To advance benchmarking over time, it may be worthwhile to validate periodically the choice of properties against the results of a more detailed analysis.

The planning phase to a large extent determines

— the functionality of the product,

— the main environmental aspects related to the product's function,

— the main environmental impacts expected.

Outputs of the planning phase are a number of qualified design ideas and a list of requirements that form the basis for the next stages.

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8.3.4 Conceptual design

The goal of this stage is to realize the requirements for the product, based on the insights gained in the planning stage and the approaches selected. The design ideas and requirements as developed in the planning stage ideally give indication as to the environmental goals for the product and focus on its environmental aspects.

There are some general techniques that can be used to support the conceptual process, e. g.:

— creativity techniques (brainstorming, unorganized thinking);

— innovation methods (systematic explorations);

— system analysis (scenario techniques).

Specific tools to support the integration of environmental aspects at this stage can be

— guidelines and checklists, e.g. regarding environmental impacts of materials, assembly/disassembly, and recycling,

— manuals, e.g. compatibility lists, generic design rules to describe strengths and weaknesses of design concepts,

— material databases.

These tools may be generic or specifically developed for the organization or its products.

It is reasonable at this stage to obtain an overview of the significant aspects over the product life cycle and to consider and decide upon

— analytical tools to be used to gain necessary information (e. g. LCA or LCA-oriented analyses, decision theory tools, risk assessments, benchmarking against best available techniques),

— access to relevant data (internal and external),

— the integration between environmental management and the product design and development process.

An important task of the conceptual design stage is the iterative evaluation of the design concepts against each other and in comparison with existing solutions on the market. The result of the conceptual design stage is the selection of one or more possible concepts that best meet all requirements. It is common that a product design specification, describing targets and requirements, is created in preparation for the detailed design phase.

8.3.5 Detailed design

In this stage, the concept(s) is(are) developed further to meet the product design specification and to specify the product prior to production or introduction into service. Depending on the complexity of the design and development process, the number of participants (and their areas of expertise) involved in this stage can vary. Often, designers, engineers, production planners, service providers and marketing personnel work together to refine the design concept to meet the design specification.

Project-specific priorities appropriate to the organization’s business strategies are used to refine the design solution and the product details. These priorities may similarly be aligned and integrated with the organization's environmental goals and requirements. Various design approaches can be used in this stage (see 7.5).

Developing the chosen design concepts further may need detailed information and data related to the whole product life cycle and possible environmental impacts. Such data can be systematically collected from both internal and external sources. A database may be established and maintained to provide detailed

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environmental data during the product design and development process. In addition to design and product development personnel, other relevant experts and external partners could be involved to enable the acquisition of data. External partners can be

— organizations that extract and produce (raw) material,

— organizations that produce components,

— organizations that produce capital goods and consumer products,

— recyclers and waste disposal contractors,

— organizations that use products as components of other products or services they market or provide.

It is important to ensure that the collected data is valid, relevant and adequate (see the ISO 14040 series).

Tools typically employed at this stage may encompass

— software and modelling tools, e.g. to estimate efficiency during use,

— material databases,

— design tools for assembly/disassembly,

— production and process optimization tools,

— substance lists.

8.3.6 Testing/prototype

Prototype evaluation and testing is an opportunity to check the detailed design against environmental targets and other specifications. This stage includes important milestones in the product development process, and is an opportunity to interact with production planning and detailed process engineering. Prior to and parallel to prototype evaluation, testing can occur on multiple levels, including material properties, wear resistance, functionality, quality, lifetime, as well as on different elements, such as processes and components.

For services, testing and evaluation can be carried out against expected outcomes as described in the service specification. Testing may include verifying tools/products, physical tasks and their sequence and appropriate training.

Checking the product's environmental requirements can proceed in a similar manner. The product's environmental aspects can be evaluated at this stage and decided upon at the milestone. This goes along two lines:

— to check whether a realistic implementation of environmental requirements has been achieved;

— to allow for adaptations and changes in the design if necessary.

The environmental performance of the product can be assessed with respect to use, mass, production scrap, material and energy efficiency, disassembly properties, recyclability, etc. In addition, testing and prototyping is often the first occasion that major sub-assemblies, materials and production processes can be evaluated with respect to economic and environmental performance against given criteria (particularly important if services, parts and sub-assemblies are purchased from suppliers).

Review of life cycle assessment results can be conducted at this stage. The review can also be used

— to improve detailed design;

— to improve production processes;

— to indicate a need to change suppliers.

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The information gained during this stage can be used for communicating the environmental aspects of the product prior to and during marketing.

8.3.7 Market launch

Market launch involves the delivery of the product to the marketplace. This stage includes presenting and communicating information on the product's features and benefits to encourage customers to purchase or procure the product.

At market launch, the product's relevant environmental aspects can form the basis of a marketing approach. Within the approach, environmental communications can make use of various instruments and media. A product-related environmental communications programme could be developed that is consistent with the positioning of product groups or brand families. To develop clear environmental information it can be helpful to follow international and national guidelines (e.g. ISO 14020 series).

A separate category of market communication assists the user in minimizing the product's environmental impact during the use and disposal phases. Such communication can be provided at the point of sale or in the instructions supplied with the product.

8.3.8 Product review

After market launch, the organization can conduct a review intended to find out whether the expectations of the organization, customers, etc. have been met.

Feedback and criticism from customers and other stakeholders are an important information source for the organization to improve its current or future products, as well as the design and development process. Therefore, a review of the environmental aspects of the organization's products and services on the market can be helpful. Insights from practical experiences and new environmental knowledge can feed back into the planning process for product revision and the development of new products (see Figure 2).

8.4 General review of the product design and development process

It is normal practice for an organization to review periodically its product design and development process and its results to assess performance and identify opportunities for improvement. The review of the product development process and its results can cover

— functionality of the product,

— environmental benefits (prevention/reduction of adverse impacts),

— cost effectiveness and benefits,

— appropriateness of selected tools,

— data sources, data collection methods and data quality.

Participants in such reviews generally include those individuals involved in product design and development. The outcome of the reviews and subsequent actions are recorded to improve management performance and the environmental performance of the products.

This iterative process addresses relevant factors in the product design and development process, including

— evaluating and exchanging information on the environmental issues connected with the product,

— designing specific measures to reduce adverse environmental impacts,

— testing alternative solutions,

— applying the resulting experience to further development.

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Measurements of the results obtained from these processes form the basis for

— generating ideas,

— improving actions,

— testing alternative solutions,

— developing products with reduced adverse environmental impact.

Improvement of the product design and development process can be achieved by

— evaluating performance in relation to environmental requirements,

— recognizing problems and proposing follow-up actions,

— information management, improved tools and techniques, training of staff.

The iterative process of continual improvement in product design and development can also be described by the PDCA (Plan, Do, Check, Act) approach (see the management systems standards ISO 9001, ISO 9004, ISO 14001, ISO 14004 and ISO 14031). This approach also provides a means of dealing with changing legal, organizational, economic and environmental requirements.

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