USE OF ECO-DESIGN PRINCIPLES IN CHEMICAL PRODUCT INNOVATIONS

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Abstract

Corporate social responsibility in accordance with the concept of sustainable development plays an increasingly important role in the existing business and competitive environment. This trend together with more strict environmental legislative requirements forces companies to implement various activities in the environmental field of corporate social responsibility. One of the voluntary preventive tools of company environmental policy is use of eco-design techniques within product development. The paper presents the findings of a qualitative study focused on possibilities of eco-design implementation within medium sized Czech chemical company, a producer and distributor of chemical compounds. The survey was conducted through personal interviews with company employees, especially with people on manager and technologist positions. Various types of potential innovations for improvement of environmental product profile are discussed. At the same time, perceived benefits are shown together with potential barriers for eco-design implementation within these companies. The contribution of this paper lies in the detail analysis of eco-design application within Czech chemical company in the form of case study.

Introduction

The growing interest in environmental issues led companies to address the issues of sustainable development, sustainable consumption and sustainable production. One way in which companies could improve their environmental profile is to adopt eco-efficiency approaches[1]. External drivers for environmental innovations include for example customer demand, government regulations or industrial sector initiatives[2]. There are also internal drivers for environmental innovations, such as possibilities for innovation and market development opportunities[2] or implemented environmental management systems or corporate social responsibility. Innovations could be approached by different ways on different levels. To reduce the impact of a business on the environment, the systematic monitoring of progress, not only in the field of business (where the key is to follow development of Best Available Techniques or Technologies) but also in management practices, standards, certifications are important. Nearly all future environmental impacts of a product are destined already in the design stage[1]. An analysis of the different ways of protecting the environment showed that the most effective methods are based on the systematic and precautionary approach, i.e. focus on reducing the causes of having a negative impact on the environment, not on the consequences (damage or waste removal). Enterprises are also realizing that the use of the integrated environmental protection compared to end-of-pipe technologies is of great importance not only for business itself but also for its surroundings and society as a whole[3]. Sustainability becomes a new functional requirement and functional operation of the product is viewed not only during its lifespan but encompass its entire lifecycle[2].

Eco-design, an environmental management tool, is the systematic integration of environmental aspects into product design and development, with the aim to reduce environmental impacts of the product throughout its whole life cycle[4,5]. When designing and developing a product the attention is not paid only to the product but to the whole lifecycle. This results in both better environmental profile of the product and the better economic efficiency. It is connected also with terms such as DfE – design for environment, or broader sustainable design, or with green design (predecessor - the designation of handmade products, and later for the products in harmony with nature), etc. Product life cycle could consist of following stages: raw material acquisition, manufacture, distribution, use and disposal[6]. The aim of choosing the best design and product development is to achieve a balance between environmental and other qualitative, safety and economic, etc. aspects of business operations and products.

The process of integration of eco-design can generally be divided into the same stages as the traditional way of product development. It primarily differs in determination of product environmental profile and the selection such eco-design strategy, in which negative impact on the environment is reduced. Introducing eco-design lies not only in the technical changes but it has its social (human and organizational) part[7]. Process of eco-design involves several different departments of a company[2]. The success of the eco-design project will depend both on cooperation between different departments of the company – the risks could lie in the inter-functional conflicts, it requires multifunctional implementation team with top management support, and goal setting[8],

initiatives like awareness raising and training, use of pilot projects, combining creativity and motivation, action learning could be important factors for successful eco-design integration[8], and also on the mutual sharing of information between the company and its stakeholders[9], customer input is required during incorporation of environmental issues into product design[10] and the cooperation within whole value chain is also necessary. Rossi et al.[11] brings summary of the main eco-design barriers and strategies retrieved from literature review.

Eco-design is necessarily reflected in the policy and strategy of a company. Organizations in creating processes and procedures leading to the implementation of a structured and integrated eco-design can make use of international and national standards for eco-design, ČSN 01 0962 (based on: ISO/TR 14062) and ČSN EN ISO 14006 that also includes relevant information from other international standards. Eco-design is also subject to mandatory legislation with requirements for products; see Directive 2009/125/EC, implemented in the Czech Republic Act no. 406/2000 Coll., or in decree no. 337/2011 Coll., applicable to product groups, namely consuming energy. Important role within development of a new product plays use of Life Cycle Assessment[12] that provides valuable information and critical points for environmental performance improvement of a product. It should be applied as soon as possible even if only been partially results about a new or similar product are obtained[13, 14].

Areas of application of eco-design in the design and product development in terms of the various stages of the product life cycle can be divided into parts: A new concept of a product or its parts, considered should be for example dematerialization, common usage, replacement product by a service[13]; Optimizing the performance of a product, finding solutions that will increase reliability and product lifetime, optimizing its functionality, over dimensioned, or combining several different product features in one product; The choice of materials and components, weighing renewable, recycled or recyclable materials, materials with lower energy requirements during production and usage, with lower harmful substances; reducing the volume or size of product, etc.; Optimization of the production process, reducing environmental impacts of the product during its production, following the principles of cleaner production, reduction of waste; Optimizing distribution of the product, aiming at economically as well as environmentally efficient transportation[15], to minimize or optimize packaging materials and better capacity utilization of the vehicle, optimizing transport; Optimizing the procedures at the end of life of the product, supporting renovation, modernization and re-use of the product or its components or easier recycling.

Integration of eco-design principles in the very early stages into the product realization process offers very important flexibility to make changes and improvements to products[12]. By implementation of eco-design within business innovation, enterprise can run a number of advantages. Economic benefits are e.g. maintaining competitiveness, reducing production costs[1], and increasing efficiency of production, reducing product operation costs, improving environmental performance, potential savings on insurance premiums. Marketing benefits are: inclusion of the needs and requirements of customers in the development and product design and with doing so increasing values for customers, strengthening the company image both among the public and customers, increased customer awareness about the appropriate use of the product and its impact on the environment. Other stakeholders benefits are e.g. improved relations with environmental inspections and smooth implementation of the requirements of the environmental legislation, improved relationships and attractiveness of the company in the eyes of financial, insurance and investment institutions, prevention in the area of safety and health of employees, and environmental aspects, elimination of the risks associated with product, improved communication within the enterprise and other stakeholders, higher perception of corporate social responsibility in the eyes of stakeholders. The same benefits are referred in ISO 14006. However, it also points out that the effects of the introduction of eco-design may not be realized simultaneously or within a short period and it may be obtained by various types of organizations[6].

Research methodology

The analysis was performed in the form of a qualitative survey through the method of individual in-depth interviews with employees of the company management supplemented with analysis of internal documents provided by the company. The survey was conducted in a Czech medium sized chemical company being both producer and distributor of chemicals. It assessed already realized or potential application of the eco-design principles in the process of a product design and development within the company innovation system that could lead to the reduction of the negative impacts of the product on the environment. The general methods of analysis, comparison and synthesis were applied and combined with case study presentation of the analysis results.

Discussion and result analysis

Environmental profile of the company

The company, in which the research was conducted, is the manufacturer of so called “compounds” i.e. semi product that is further used to manufacture plastic products. The company is also a distributor of an extensive portfolio of specialty chemical products. These products are mainly used by customers for improvement of properties of their constructions and painting materials, for modification of rubber products, for water treatment and for the plastics production.

Since 2002, the company obtained and repeatedly meets The Responsible Care Certification. At the same time, the company has also certified integrated system of quality and environmental management according to ISO 9001: 2008 and ISO 14001: 2004 certified by “Lloyds Register Quality Assurance” company. The corporate environmental policy is based on principles of the Responsible Care program. The main environmental objectives of the company are improvement of the grounds maintenance company, improvement of management of chemical substances and additives (beyond the current legislation). There were two main reasons for the introduction of the environmental management system according to ISO 14001, primarily the requirements from customers and secondly the formation of a good company image. The main perceived benefit of this system is improvement of the environmental profile of the company, which leads to the reduction in energy consumption, to the reduction of potential risks of business operations, to financial savings, to the elimination of fines and decreasing the insurance payments against potential damages/accidents and to the saving further costs connected with legislation implementation. The company regularly provides information about the environmental aspects of its activities through forums and publishing annual reports on environmental impacts and health and safety. In recent years, there were no events in the company's activities that could be considered as accident with impact on environment.

The company's product, compound, or in other words granulate mixture, is made from various blends according to customer requirements on the properties of the final product. Production takes place at the so-called “compound line”. For compound production, the formulation of a detailed customer requirements is very important, because the final characteristics and quality of the supplied granulate determines the quality of final plastic products made by end consumers. These products must also comply with series of regulations very often. The products are mainly used in the automotive industry, in the production of electronic parts, furniture industry etc. Environmental aspects of production operation are closely related: to the product itself, which has an impact on the environment; to exhaust emissions due to operation of company cars or potential fire; to water pollution; water consumption; electricity consumption; to waste production; to leakage of hazardous chemicals during handling of chemicals; to waste production during the compound production process.

A significant portion of the development and design of new products is carried out in the company laboratory, which is also monitoring quality of produced compound, e.g. deviations of colour tone, impact strength, tensile strength etc. Every year, many new compound formulations are proposed that improve the properties of final products. Environmental aspects in accordance with the principles of eco-design are also considered at other departments.

Activities applied within product design related to the eco-design principles

To survey activities implemented in the company in accordance with the principles of eco-design the system boundaries were defined as follows: purchase of raw materials, compound production, transport and distribution of various compounds and the use of various compounds by the customer. Inputs include: energies (consumption of electricity, gas and water), the raw material (polymers, recycled polymers, additives) and auxiliary materials (lubricants). Outputs include: waste (scrap, waste materials, waste packaging materials, waste water), product (granulate).

- **Optimization of the utility value of the product**

Increased reliability and lifetime of granulate: The properties of the produced granulate defined by a type of used polymer and added additives (colorants, fillers (glass fibres)) affect the performance and durability of a plastic product which is manufactured from granulate by a customer. Following requirements play the significant role during production e.g. for health safety, resistance to climatic and weather conditions, reduction of flammability, increase of hardness or replacement of other more expensive and less durable materials, improved UV stability, strength or colour stability and so on. In relation to the climatic conditions, into which the finished plastic product is intended, company together with customer must choose correct quantity of added UV stabilizers, must choose suitable type of polymer for the granulate production according to atmospheric influences, for particular hardness requirements will include such polymers and additives to increase the hardness. **Reduction of chemicals consumption**: In terms of proposals for reduction of chemicals

consumption, instruments of environmental legislation, including REACH, are perceived as strict. Therefore in this area of eco-design, the company is primarily focused on their fulfilment. **Usage of recycled materials**: The company also produces compounds from recycled materials, so-called regranulates. Regranulates are manufactured from assorted plastic waste, whose advantage is low price. However, regranulates also cause certain problems, crushed regranulates sometimes contain impurities that cause clogging of screens in compounding line. To replace the old screens with new ones, the line must be stopped and the machine head must be dismantled. During disassembly some components may be contaminated by molten plastic. Consequently, these parts must be cleaned to prevent their deterioration and potential problems when reassembling, or must be replaced. Such problems lead to time losses, higher consumption of components, loss of raw materials and higher scrap with every new start of compound line and generation of additional waste. Another disadvantage of the compounds production from regranulates is worse properties of the final product. The change of the polymer chemical structure occurs with each processing cycle (melting) and its quality gradually decreases. Esthetical properties of produced polymers also deteriorate with each processing cycle (polymers turn yellow). Therefore compound made of regranulates are delivered to customers who producing plastic products, which are not subject to esthetical requirements.

- **Production process optimization**

Reduction of production energy requirements: In order to reduce the energy demands of production, the compound line was thermally insulated. Following consequences were achieved due to this measure: reduction of energy consumption, reduction of time required for the warm-up to operating temperature, increase of labour productivity and increase of the production process efficiency. **Waste Reduction**: The production of compounds produces wastes in the form of scrap, dripping polymers from the machine, waste water and waste packaging materials. Most often, waste is generated during beginning of the production. When the production is running most of waste is generated in the form of scrap, if the production is interrupted, it is necessary to replace some parts of the compound line. The amount of waste in production is influenced by the experience of the line operator, so the company aims to personally stabilize this position. Another waste results from the mixing of individual raw materials of polymers and additives, where may occur material losses between the steps of weighing, mixing and moving to vibration unit. The innovation of the storage bin was proposed in the form of an increase of its walls, which can reduce the space, where the losses occur during material transfer. Similarly, to move finished products from production to packaging according to customer requirements the size of filling reservoir was increased and filling into final packages was improved by a suction device. Therefore waste was minimized and replacement cycle of finished granules container was prolonged. Waste packaging materials from the raw materials are sorted and then sold to a recycling company. **Reduction of consumption of auxiliary materials**: the lubricity of production line was increased by means of special additives and the lubricant lifetime was prolonged. Therefore the production is less frequently interrupted and consequently higher efficiency of the production process (see above) and lower consumption of lubricants are achieved.

- **Product distribution optimization**

Regarding distribution activities of the company, up to 90% of chemical products are bought and sold away as unchanged, while the transport is carried out by external carriers. The main environmental aspects of distribution activities are primarily related to the storage and handling of the chemical products.

Selection of a recycled and returnable packaging: Company offers products in plastic recyclable bags with 25 kg of granulate suitable for handling without the use of lifting equipment. These packages are designed accurately for the product in order to minimize the quantity of packaging material. The company also pack its products in large-returnable "big bags", which can be filled with 600 kg and 900 kg of granulate. **Company activities focused on limitation of negative environmental impact related to logistics of products and commodities**: The company is engaged in the supervision within the Product Stewardship - Responsible Care product. Therefore company accept back used products and provide customers safety data sheets together with the product. The company has and complies with internal guidelines for handling product before offering the market in compliance with the REACH legislation. Packaging for their products is selected and used with regard to their safety and subsequent disposal possibility. Customers are provided with comprehensive information and advices, such as guidelines for the handling of products and their packaging, information on possible side effects when used improperly and instructions for safe disposal of the product and packaging in an environmentally friendly manner. The company has secured the performance of the safety adviser for loading, unloading and transport. The company also participates in voluntary transport accident system information (TRINS). The company arranged a professionally trained person who regularly organise trainings of workers involved in the loading, unloading and arrangement of transport and handling of dangerous chemicals. All dangerous substances and additives imported, stored or dispatched from the distribution company are

labelled, packed and stored in accordance with applicable legal requirements. During transportation company follows relevant national and international regulations for transportation of dangerous goods by road and rail. In order to reduce the environmental impact of distribution activities the company made investments in building of new warehouses. This measure among other things also reduced number of trucks entering residential areas and limit potential risks during transportation of chemical products. The reliability of storage is improved by regular inspections of the warehouses (own and leased) in terms of their physical condition as well as stored chemical compounds. The company also set out eligible requirements for external carriers to implement SQAS system and ISO 14001 and compliance with ADR regulations. **Energy efficiency of logistics**: Energy-efficient transportation is considered, sea or river transport supposed to be preferred to railway transport and railway transport preferred to the road transport. River transport would appear as a convenient way of transport for the products distribution to Germany, if navigability of the Elbe from the company site would be permitted. The railway transport is considered for any product. However the road transport is mostly preferred due to following reasons: customer requirements, poor infrastructure of railway network, small flexibility, bad compliance with Just in Time system, poor quality of services for existing railway carrier, a higher level of risk due to handling between several modes of transport. On the other hand, it should be pointed out that with respect of Just in Time deliveries required by customers, the company must address only partial (not 100%) utilization of the truck capacity of in order to increase the environmental efficiency of transport.

- **Reduction of impacts during product usage**

As mentioned above, the granulate properties affect the characteristics and durability of the final product manufactured by a customer, therefore the preparation of granulate formula is conducted closely with detailed requirements of the customer. **Reduced energy consumption**: compound granulates are sold in the form of cylindrical granules. The size of the individual granules is about 3x3 mm (this minimal size is determined by used technology of compounding line). Such size maximizes the granules surface, which interacts with heat during melting. If the granules size would be bigger, the surface exposed to heat would be smaller and electrical energy consumption required for melting of granulate would increase. The Chosen size optimized electricity consumption of the company.

Conclusion

Research has examined whether the principles of eco-design are applied in product design and development in the company whose business is the distribution of chemicals and production of polymer compounds. Based on personal interviews were identified areas, in which they have been implemented eco-design principles, although the company did not implemented eco-design in accordance with ISO 14006 norm.

Eco-design options were very limited in the distribution area, since the company buys and sells goods that is in 90% unchanged. Besides compliance with national and international legislation the company mostly considers appropriate type of transport, optimized size and suitable type of packaging for the transport. The company uses Just in Time method for distribution activities as a competitive advantage therefore it must meet customer requirements for type of transport. More intensive use of rail transport has certain limitations. Unsatisfactory infrastructure, low flexibility and low quality of services of existing carrier does not meet conditions of Just in Time system and therefore the majority of products are transported by road transport.

In the production of various compounds, raw materials for manufacturing of plastic products, following ways of eco-design application were found: optimization of utility parameters of a product, process optimization, and optimization of distribution. Optimizing the performance of a product can be achieved by various additives which enhance the properties of the resulted plastics, such as hardness, product lifetime etc. Production process optimization was carried out using innovations resulted in reduction of energy consumption and reduction of waste amount. Recycled material (regranulate) was also used as production input. To optimize distribution, company used containers, which are either recyclable or returnable. It must be pointed out that with every recycling cycle the properties of the novel final product deteriorate. Therefore it is important to look for such applications of plastic products made from recycled materials, where worse properties are still acceptable.

Eco-design is considered as a useful tool for reduction of the environmental impacts of the product. The surveyed company is located in middle of value chain, and therefore sees its possibilities of eco-design application as narrower. Its activity is dependent on the demand from companies that design and develop final products. Company managers validate eco-design potential benefits in terms of increased competitiveness only if applied methods of eco-design would lead to cost reductions. It is not common according to their opinion that competitiveness of the company would increase through greater customer interest in environmentally friendly products. Most of the customers are not willing to pay a higher price for the product that was

manufactured with less negative impact on the environment. Appropriate product quality is expected by default and the customer decides in most cases based on product price. Due to the perceived negative impacts of chemical production on the environment by society generally, it should be noted the increasing quality and development of new types of plastics, which can lead to substitution of other types of materials. Plastics meet many of eco-design requirements of the product. They support modular structure of the product, interchangeability of individual product components and therefore prolong lifetime of the product. Low weight of plastics can lead to reduction of environmental impacts during transport and they can be further recycled once their lifetime ends. Given that competition in the market for the products of the company is largely based on the final price of the product, the company had to implement such eco-design activities that led both to the benefits of economic efficiency and to reduce environmental impacts. Ways that would lead only to reduction of environmental impacts and increase the costs of the company are not implemented because it would lead to decrease of the company competitiveness.

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