Establishing an Eco-efficiency Analysis program for the North Aegean region: a case study on mineral water packaging systems

Kyriaki Glyptou [1], Nicholas Kondakis[2], Aegean Eco-efficiency Group [1]

[1] Department of Financial and Management Engineering, University of the Aegean, Greece
[2] Institute for Sustainable Development, SUNY SB, USA

This paper is part of the 03ED375 research project, implemented within the framework of the "Reinforcement Programme of Human Research Manpower" (PENED) and co-financed by National and Community Funds (25% from the Greek Ministry of Development-General Secretariat of Research and Technology and 75% from E.U.-European Social Fund).

Abstract

Eco-efficiency reflects the management philosophy which encourages environmental improvements that yield parallel economic benefits. Keeping always at the core of the assessment the benefit of the customer, the Eco-Efficiency Analysis of BASF considers the life cycle economic and environmental effects of a product or process, giving them equal weighting. The relevance of each environmental category, as well as economic versus environmental impacts, is evaluated using national emissions and economic data. The Laboratory for Physical and Computational Sciences of the Financial and Management Engineering Department of the University of the Aegean in collaboration with BASF and the Institute for Sustainable Development SUNY SB USA aims to apply the concept of eco-efficiency in the North Aegean reality. The scientific goals of the collaboration first relate to the adoption and adjustment of the methodology to the reality and the specific characteristics of the North Aegean region. In this regard, all relevance and weighting indicators as well as assessment factors are modified appropriately along with regional economic and environmental parameters which are quantified to complement the study. An example on mineral water packaging systems is developed to illustrate the potential of the methodology in the North Aegean region. Taking into account, data throughout the life cycle of the packaging production process, the assessment identifies the best alternative system in terms of eco-efficiency. The paper concludes by suggesting some areas of particular interest and importance for the regional community as potential application areas, where Eco-Efficiency Analysis could serve as tool towards sustainable decision-making.

Keywords: Eco-efficiency, Sustainable Decision Making, Life-Cycle Assessment (LCA), North Aegean Region

1. Introduction

Since its introduction at the Rio Earth Summit in 1992, the concept of eco-efficiency has been internationally recognised as the way that business can contribute to the sustainable development of the society [15]. As defined by WBCSD, eco-efficiency entails '*the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity*'[20]. Eco-efficiency is strongly supported by those who envisage the production of economically valuable goods and services while reducing the ecological impacts of production [19]. In other words, it means producing more with less and its main objective is to combine the achievement of economic and environmental viability in a single process.

The key component of a concrete eco-efficiency analysis is the adoption of practices and processes that simultaneously create economic growth opportunities while reducing environmental impacts [4]. In this way, it promotes the creation of a competitive advantage for businesses while maintaining a commitment to the principles of sustainable development. At present, the most complete version of a methodology that encompasses the above objectives is the Eco-efficiency Analysis developed by BASF.

BASF Corporation adopted an analytical tool to help identify products and production processes that consume less energy, produce fewer emissions and less waste than alternatives, while maintaining or improving the products' commercial value [2]. The Eco-Efficiency Analysis, first introduced by BASF AG (NYSE: BF) in Germany in 1996, assesses the life cycle of a product or manufacturing process from the "cradle to the grave'', aiming to give its customers a total picture of both the economic and ecological impact of a particular product or process[14]. Therefore, the main asset of this methodology is that it is customer oriented and developed around one single concept, the customer benefit.

The region of the North Aegean Sea consists of a unique ecosystem in terms of functions and products. Unfortunately, the development of the region during the last decades has frequently jeopardised the natural system in the name of economic growth. However, in this race for competitiveness and achievement of market demands, the businesses of the region should not overlook their responsibility to preserve and protect the environment for future generations.

This is why the concept of eco-efficiency appears as the ultimate solution for these regional medium-scale businesses, to develop a competitive edge on markets increasingly characterized by customer demands for improved environmental and performance attributes, while at the same time securing their economic viability [5,7]. Bearing this in mind, the Laboratory for Physical and Computational Sciences of the Financial and Management Engineering Department of the University of the Aegean initiated a collaboration with BASF and the Institute for Sustainable Development SUNY SB USA in the framework of the ENTER program, having as main objective the application of the concept of eco-efficiency in the North Aegean reality.

This paper highlights briefly the necessary adjustments to be made in order to address the Eco-efficiency Analysis of BASF to the North Aegean reality and the specific characteristics of the area (regional indicators, weighting/relevance factors). In addition, some suggestions are presented on potential developments of the methodology, mainly regarding the inclusion of the socio-cultural and regional dimension of sustainable development. Following, a case study on a mineral water packaging system is used to demonstrate the different features of the method and to serve as a pilot study for the region. Finally, several areas that reflect practices of particular interest for the local businesses and society are chosen as application candidates of the Aegean Eco-efficiency Analysis. The paper concludes with a brief discussion on the added-value of eco-efficiency analysis as a tool towards sustainable decision-making.

2. Eco-efficiency Analysis in the Aegean Region

The Eco-efficiency Analysis provides a quantitative basis for the comparison of the levels of sustainability on products and processes. A detailed presentation of the methodological tool developed by BASF is described by Saling *et al.,* (2002)[14]. The well defined and pragmatic approach ensures high quality of results in short times, as well as low project costs. The flexible modular framework of the method enables the valuation of ecological and economic impacts in all the cases and facilitates validation and plausibility of the system [16]. Finally, the approach is end-user friendly since it allows the easy and clear communication of results and thus, opens fields for further discussion.

In order to adapt the suggested methodology of BASF in the North Aegean region, the economic and ecological profile of the processes at stake need to be developed. In regard to the economic profile, everything is developed around the customer benefit which is defined appropriately to the needs of the inhabitants of the specific region. Thus, the base case and the alternatives proposed for assessment are developed to depict the regional reality and to respond to the specific needs of the inhabitants/customers.

The ecological profile of the North Aegean region is developed considering those components per environmental category (Raw Material Consumption, Energy Consumption, Air, Water & Soil Emissions) that are identified to be of most impact in the region. These components are identified through public and expert interviews, regional statistical resources and all other available databases and literature. The selection of these region-specific components of interest results in the specialization of the evaluation method into the ecological profile of the region. For practical reasons, the Risk and Toxicity Potential of the ecological profile were calculated based on the Risk phrases of BASF [10], which depend on perceived seriousness of the different risk phrases. Thus, in this stage of the project there was no need of further methodological adaptation to the characteristics of the North Aegean region.

The selection of regional data is not always easy; this is why, in some cases, the calculation of relevance and normalization factors is based on the available national data[11]. Even though this is not completely correct, it is considered acceptable[12] since in the end it is a comparative assessment, where the differences of the area specific-components are considered adequately highlighted by the factors calculated based on the national standards (country profiles from EUROSTAT) [6].

As for the weighting factors assigned per each environmental category, these are calculated specifically for the North Aegean region in communication with experts of the regional reality. The values are assigned in a way to represent the relative importance of each environmental category comparatively to the others and thus, reflect these differences to the regional ecological profile. The relative importance of the environmental categories considered in this study is as follows: Raw Material Consumption 10%, Energy Consumption 30%, Emissions 40%, Toxicity potential 10% and Risk potential 10%. The total value of environmental emissions is composed 30% by the effect of air pollutants, 40% of water pollutants and 30% by soil pollutants.

The scientific review and the experience gained throughout the first applications of the adopted methodology in the North Aegean region is expected to highlight other areas of particular interest for the region, and consequently extend the methodology towards new directions. At next stage, specific interest will be paid to the societal, cultural and regional aspects in order to build up the social-cultural profile of the region. The end result of this effort will be a three-dimensional model that produces holistic assessments based on all economic, environmental and socio-cultural interests. This version of the model will have the potential to serve as a decision support system that produces integrated assessments and allows sustainable decision making and management planning through a process of assigning relative weights to each category according to the interest *per se* [13].

Such analysis comprehends a scientific study of the entire lifecycle of a product or process with an evaluation of all facets of costs, energy use, use of raw materials, environmental, safety and (at next stage) societal issues related to manufacturing, storage and transportation, health impacts, and emissions. This is why the role of industry is essential during all the stages of the study.

The main difficulties arising when plotting this study are related to the collection of case specific data, in order to address the problem realistically and produce accurate results. In most of the cases small size businesses like the ones under study are not able to provide specific quantitative data during all the stages of their production processes since in most cases there is no adequate monitoring. In these cases, the assessment is based on data from studies on relevant businesses, statistical resources and also expert opinions.

The study also takes into account that, due to the size and the range of the businesses, the whole life cycle of a product or process is not realized inside the same company. This means that a number of material or sub-products are imported and thus, the business can not account for those system cycles. In these cases, the study focuses on the specifically defined steps inside the system of each alternative, trying to compare those steps that differ.

In order to compensate for this problem, the acquisition of a life cycle inventory database is considered essential, to complement this lack of information. The main data source selected for this purpose is The Life Cycle Inventory Data (Ecoinvent Data), V 1.3 for the year 2006 of the Swiss Centre for Life Cycle Inventories [17]. The data provide information on the specific eco-profiles of the construction materials, and on the resources assessed in the studies, for all the environmental categories of interest. The data refer to the whole European region with specific national profiles being used when available.

3. Application Study on Mineral Water Beverage Packaging

This section presents an application of the adapted methodology of Eco-efficiency Analysis. As it has been discussed before in this report, the selection of case study topics is made based on the unique criterion of importance and interest for the North Aegean community. The product under study is the Mineral Water Beverage Packaging. With three product options available in the market, the analysis performed identifies the most eco-efficient alternative.

The case study includes a short description of the product or process being analyzed, a definition of the system boundaries and of the functional unit (customer benefit), followed by descriptions of data sources, model assumptions, key results, and interpretation.

The lack of high-quality natural potable water is one of the main problems that a big part of the North Aegean community faces daily. As a response to this increasing concern, the bottled water and in particular the mineral water consumption has significantly raised during the last years. Due to its increasing importance, an eco-efficiency analysis was conducted to compare the main alternative packaging systems for bottled mineral water that exist in the regional market.

The customer benefit for this study is defined as the marketing of 1000lt of mineral water in a distance of 300 km from the production site. Three alternative packaging systems of the regional market are considered in this study:

(1) PET bottle, 1.5lt each, packaging crate of 6 bottles, use once and not returned nor recycled
(2) PET bottle, 0.5lt each, packaging crate of 24 bottles, use once and not returned nor recycled
(3) Glass bottle, 1lt each, packaging crate of 12 bottles, reusable with refundable deposit per bottle, bottle return rate of 80% considered for this study.

The system boundaries were constructed similarly for each option, based on the production process described in the example performed by BASF [2]. Each alternative considers extensively all the impacts (economic and environmental) related to the production, use and recycling/disposal of all the materials (terephthalate (PET, bottles), polypropylene (PP, caps), wood (pallets), paper (labels), low-density polyethylene (LDPE, film), high-density polyethylene (HDPE, bottle cases), detergent (bottle cleaning) and processes (filling, packaging, distribution, return transport, sorting, cleaning and refilling). Finally, the recycling of the PET, PP, LDPE, HDPE, and wood components are considered when possible. Similar life cycle stages are defined for the other alternative packaging systems, with appropriate changes to reflect the differences between the options.

Figure 1 presents the calculation of the costs of all the studied alternatives throughout the whole life cycle of the system. Cost calculation includes the production of adequate packaging of 1000lt of mineral water depending on the alternative, transfer from production site and if possible recycling / reuse of materials. As it can be seen in *Figure 1*, the main differences in costing arise from the consumption of material during the production process (Raw materials category), the production process itself (Pre-form production & bottles blowing category for PET bottles), the packaging and transfer requirements of each alternative. What strikes to the eye, are the costs for the retailer which represents a percentage of the total expenses up to that point (40% in this case study) and functions additively to the final cost of the product for the consumer. Normally then, the higher the production and transfer expenses, the higher the percentage of the retailer and thus, the higher the final price of the product.

In addition, the cost advantages of reusing and refilling the bottles can be seen when comparing the PET bottle alternatives with the Glass bottle option. Despite the increase in the collection, transfer and recycling expenses (recycling plant was considered back to the production point in this study), it is still obvious that the reduced need to purchase new glass bottles to satisfy the customer benefit results in decreased expenses compared to the PET alternatives. It is also noticeable that the Glass bottle option is the only one where the collection logistics guarantee a return income and thus, the total system cost is further minimized.

In total, the economic assessment shows that the cost of the PET 6_1,5lt alternative is quite comparable with that of the Glass 12_1lt option. Even though the production costs for PET bottles are higher, the glass bottles option still has to account for the collection, cleansing and rinsing of the bottles. However, when it comes to the comparison of the different bottle size effect (comparing PET 6_1,5lt and PET 24_0,5lt alternatives), it turns out as expected that a larger bottle size reduces expense costs. Even if the quantity of the raw material necessary is smaller (almost half of the quantity required for the big PET bottles), the amount of energy used remains the same (in small and large bottle option), resulting, in reference to the total quantity of water, in higher energy consumption and thus, higher cost.

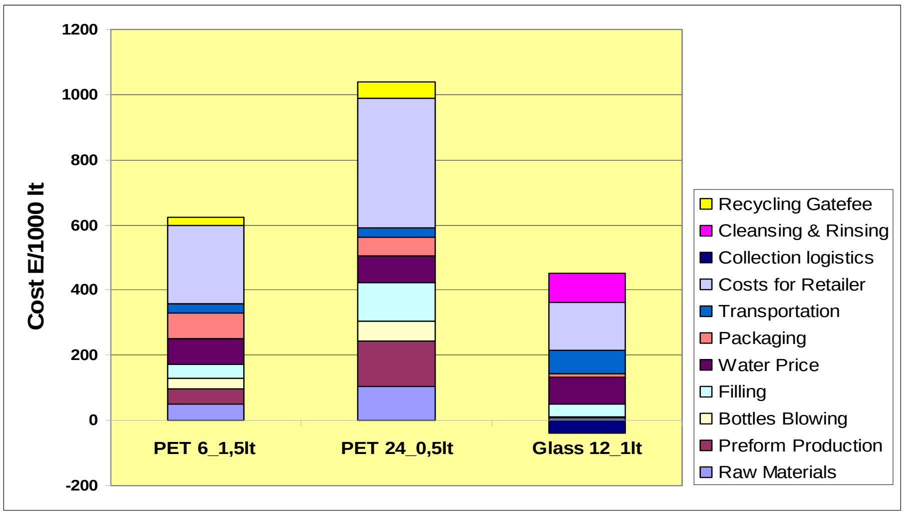

Figure 1. Life Cycle Cost Calculation of alternative mineral water beverage packaging systems.

Following the economic evaluation of the system, the environmental assessment is summarized in a special plot, the Environmental Fingerprint. The categories composing the environmental profile are a) Raw Material Consumption (e.g. aluminium, bauxite, dolomite, feldspar, nickel), b) Energy Consumption (e.g. coal, oil, lignite, gas, hydroelectric power), c) Emissions (air, water, soil), d) Toxicity potential and e) Risk potential. As mentioned in section 2 of this paper, particular attention is paid to the emission category, so as to reflect the main pollutants in the region (AOX, Cr, Cl and HMs for the water emission, aluminium and lead for the solid wastes).

Figure 2 represents the comparative graphical depiction of the relative environmental advantages and disadvantages of the three studied alternative systems. The alternative assigned the value 1 (values at these stage of the methodology are already weighted and normalized) is located the further outward in the plot, and represents the choice with highest negative impact. The axes of the polygon represent the environmental categories considered in the methodology, which are mutually independent and thus, allow the identification of those environmental impact drivers which are responsible for the good or bad environmental performance of each alternative.

The Environmental Fingerprint of the mineral water packaging study shows a clear superiority of the PET 6_1,5lt alternative to the one of the PET 24_0,5lt in terms of environmental performance. In all the environmental categories under consideration it turns out that the choice of a bigger packaging results in smaller environmental impact. As it was explained in the economic assessment part, this is due to the fact that despite the smaller amounts of raw materials used per unit (bottle), the number of units necessary in the case of PET 24_0,5lt are triple than the PET 6_1,5lt. In addition, during the production process there is no significant differentiation in the amounts of energy utilized regarding the size of the bottle. As expected, bigger amounts of raw material and energy consumption result in higher environmental emissions. This is why in the three categories (Raw Material Consumption, Energy Consumption, Emissions) of the Environmental Fingerprint, PET 24_0,5lt bottles score twice as high, comparatively to PET 6_1,5lt. Toxicity potential depends primarily on the quantity of the raw material and energy consumed and consequently, follows the pattern of the other environmental categories.

In comparison to the Glass 12_1lt alternative, it appears that environmental impact is smaller in terms of energy and material consumption, as well as overall emissions due to the impact of recycling and reusing of the bottles. However, it scores the outermost values in the category of Toxicity potential, due to the higher initial amount of raw material utilized and it's processing.
No Risk Potential data was collected for this case study, since none of the products was considered to possess any special properties that indicate significantly higher risk potential than the others.
Thus, in order to define the most or least favourable of the alternatives in terms of environmental impact, one should prioritize the impact categories. In this study, all three packaging systems were considered to have the same risk potential and this is why they all fall around the same value in *Figure 2*.

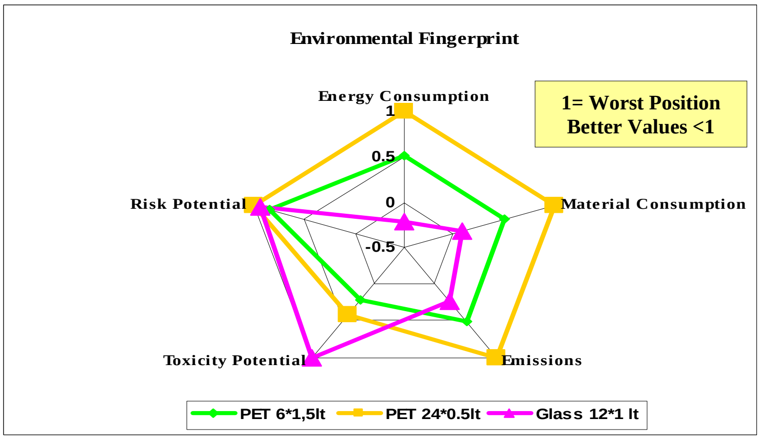

Figure 2. Environmental Fingerprint for the Mineral Water Packaging System study.

Under these results of the separate assessments, the Eco-efficiency portfolio for the bottled water packaging system study, presented in *Figure 3,* combines and compares the direct production costs and the life cycle environmental impacts for each alternative.

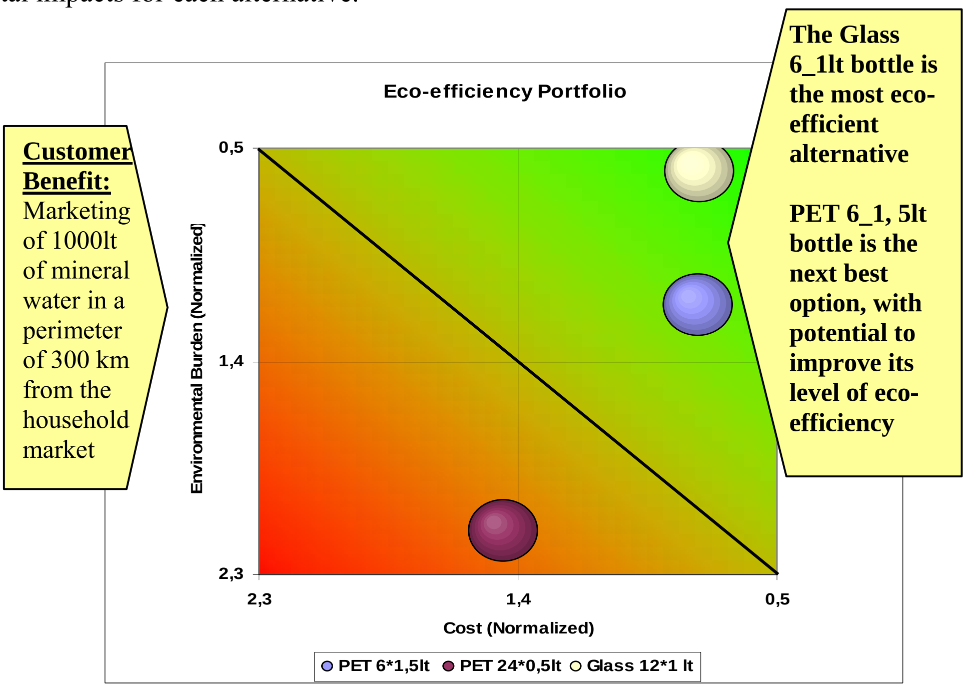

Figure 3. Eco-efficiency Portfolio for the Mineral Water Packaging System study.

Following the trend of the costs, environmental impact differences are also very large, especially when it comes to the small size PET bottles (24_0,5lt). The consumption of more materials and resources results in higher environmental impact values. As for the other two options, the effects of the return rate are seen when comparing the two alternatives. Even though direct production costs are almost comparable, the environmental advantages of collection and reuse in the case of Glass bottles are significant. This last point gives the impression that once a recycling system for the PET bottles is established, decreasing both the environmental impact and the direct production costs, it will be possible to talk about two comparable eco-efficient alternatives for the mineral water beverage packaging system.
This study is useful to both policy makers and producers of bottled mineral water in order to encourage production and marketing strategies that reduce costs and decrease environmental impacts over the entire life cycle.

4. Discussion

The study performed in this report introduces Eco-efficiency Analysis as a tool for the identification of both economic and environmentally responsible systems in applications related to the North Aegean region. The case study of mineral water packaging systems was established as a discovery tool for the regional reality and therefore it will serve as a pilot for future studies and areas of applications. The experience gained will help to create a constructive tool that improves the existing methodological steps and builds up on new aspects fully adjusted to the local environment.
The specialization and adaptation of the methodology to the reality of the region lies, on one hand, on the parameters that define the customer benefit. Under different circumstances (distance from production point, more alternative systems, existence of recycling plant) the economic profile of the study would be altered. On the other hand, as it was highlighted throughout this paper the selection of indicators for each environmental category was made in accordance to the main (identified) pollutants of the region. A different selection of environmental indicators could result in a more or less burdened environmental profile of the process. Both the economic and environmental profile compose the base for the normalization and relevance factors, which thus, become region specific. The profile that varies mainly though, depending on the region, is the socio-cultural aspect, included here only through the calculation of the weighting factors and expressed as relative importance of each environmental category for the specific region. Further research could reveal a number of region-specific socio-cultural indicators.
Another point stressed here is the capacity of the Eco-efficiency methodology to assess complete life cycles of products but also specific stages of processes or production lines. In this way, it overcomes the arising problem of the availability of data one has to deal with once working with small and medium scale companies. The Eco-efficiency Analysis Methodology is a comparative tool, so once the system boundaries of the study are well-defined, it can be utilized to assess the system in the desired depth and extent.
In this regard, the methodology can provide the medium size North Aegean businesses with a valuable insight when seeking the competitive market advantage which minimizes the environmental burden resulting from their processes. Moreover it can highlight the hot-spots of the production lines by quantifying expenses and ecological impacts and thus, suggest sustainable directions of improvement.
The case study on mineral water packaging systems initiated the adaptation of the methodology based on the Aegean region standards. Currently several other studies are being developed on businesses of general interest for the community. Two of them include the assessment of segments of the production lines of the Chios Mastic Growers Association and the local beverage company Kampos. In both cases some changes on the current systems are suggested to improve the level of eco-efficiency. Another application of the methodology under development is the study of renewable energy production systems that will cover the needs of the Department of Financial Engineering and Management of the University of the Aegean, as alternatives to the existing power plant.

According to the developments that will be brought to light with the completion of these new cases studies, further improvements will be made in the existing model, with the intention of turning it into a standardized tool of analysis, that will bring together indicators of economic, environmental and social nature. In this way, hopefully, an important contribution will be made to the shortening of the long road that still separates us from a truly sustainable development.

References

1. Atkinson, G. and Hamilton, K. (1996) Accounting for progress: indicators for sustainable development. *Environment* 1996; 38(7):16e20
2. BASF Eco-Efficiency group (2007) BASF's Eco-Efficiency Analysis Method Training Seminar - lecture handouts: March 13-14, 2007
3. BASF Eco-Efficiency group homepage http://www.sustainability.basf.com/en/sustainability - (last access December 2007)
4. Cramer, J. (2000) Early warning: integrating eco-efficiency aspects into the product development process, *Environmental Quality Management,* Winter 2000, 1 – 10.
5. DeSimone, L. and Popoff, F. (1997) Eco-efficiency: The Business Link to Sustainable Development. *MIT Press: Cambridge, MA.*
6. EUROSTAT- http://epp.eurostat.ec.europa.eu- (last access December 2007)
7. Hinterberger, F., Bamberger, K., Manstein, C., Schepelmann, P., Schneider, F. and Psangerberg, J. (2000) Eco-efficiency of regions. How to improve competitiveness and create jobs by reducing environmental pressure. Vienna: *Government of Carinthia, Austrian Ministry of Agriculture, Forestry, Environment and Water, SERI*
8. Huppes, G. and Ishikawa, M. (2005a) Eco-efficiency and its terminology. *J. Ind. Ecol.* 9 (4), 43–46.
9. Huppes, G. and Ishikawa, M. (2005b) A framework for quantified eco-efficiency analysis. *J. Ind. Ecol.* 9 (4), 25–41.
10. Landsiedel, R. and Saling, P. (2002) Assessment of Toxicological Risks for Life Cycle Assessment and Eco-efficiency Analysis. *Int J LCA* 7 (5) 261–268.
11. Melanen, M., Seppälä, J., Myllymaa, T., Mickwitz, P., Rosenstrőm, U., Koskela, S. et al. (2004) Measuring regional eco-efficiency the case of Kymenlaakso: Key results of the ECOREG project. *The Finnish environment 735en. Helsinki: Finnish Environment Institute*
12. Mickwitz, P., Melanen, M., Rosenstrőm, U. and Seppälä, J. (2006) Regional eco-efficiency indicators – a participatory approach, *Journal of Cleaner Production* 14 (2006) 1603-1611.
13. *Organisation for Economic Co-operation and Development (OECD)* Paris (1998): Eco-efficiency
14. Saling, P., Kicherer, A., Dittrich-Kraemer, B., Wittlinger, R., Zombik, W., Schmidt, I., Schrott, W. and Schmidt, S. (2002) Eco-efficiency Analysis by BASF: The Method. *Int J LCA* 7 (4) 203–218.
15. Schmidheiny, S. (1992) Changing Course: A Global Business Perspective on Development and the Environmnetnt. *The MIT Press, Cambridge*
16. Shonnard, D., Kicherer, A. and Saling, P. (2003) Industrial Applications Using BASF Eco-Efficiency Analysis: Perspectives on Green Engineering Principles. *Int Environmental Science &Technology* 37 (23) 5340-5348
17. Swiss Centre for Life Cycle Inventories; The Life Cycle Inventory Data, Version 1.3, Year 2006
18. UNEP and WBCSD (1998) Cleaner Production and Eco-efficiency, Complementary Approaches to Sustainable Development
19. Verfaillie, H.A. and Bidwell, R. (2000) Measuring Eco-Efficiency—A Guide to Reporting Company Performance. World Business Council for Sustainable Development
20. World Business Council for Sustainable Development WBCSD (2000) Eco-Efficiency: creating more value with less impact, Geneva, Switzerland - www.wbcsd.org (last access December 2007)