10th Global Conference on Sustainable Manufacturing
Sponsored by the International Academy for Production Engineering (CIRP)

Proceedings:
10th Global Conference on Sustainable Manufacturing

Towards Implementing Sustainable Manufacturing

Istanbul, Turkey
31st October – 02nd November 2012

Günther Seliger
S. Engin Kılıç
Editors

Berlin Institute of Technology, Berlin, Germany
Middle East Technical University, Ankara, Turkey

Editor
Günther Seliger
Department of Machine Tools and Factory Management
Technische Universität Berlin, Germany
Pascalstr. 8-9, 10587 Berlin
Germany
seliger@mf.tu-berlin.de

S. Engin Kılıç
Department of Mechanical Engineering,
Middle East Technical University,
Ankara, Turkey
engink@metu.edu.tr

ISBN-978-605-63463-1-6

Prof. Dr.-Ing. Günther Seliger
Department of Machine Tools and Factory Management
Technische Universität Berlin, Germany
Pascalstr. 8-9, 10587 Berlin
Germany
seliger@mf.tu-berlin.de

Issued in Ankara/ Turkey October 16, 2012

17.10 Study of Waste, Air Emissions, and Sustainability Initiatives in West-Australian Small-Medium Manufacturing Industries

F. Latunij [1,2], M. Rosano [1], B. J. Mullins [3]

[1]Sustainable Engineering Group, Curtin University, GPO Box U1987, WA 6845, Australia

[2] Department of Chemical Engineering, Institut Teknologi Indonesia, Tangerang 15320, Indonesia

[3] Health, Safety, and Environment and Curtin Health Innovation Research Institute, School of Public Health, Curtin University, GPO Box U1987, WA 6845, Australia

Abstract

Small and medium-sized Industries represent approximately 40% of Australian industry [1], however are estimated to be responsible for 70% of industrial pollution [2,3,4]. Despite this, environmental regulations to which large companies must comply with are often not applicable to SMEs.

This study examines wastes and air emissions generated by SMEs in the Western Australian manufacturing sector. The study consisted of (1) face-to-face surveys of 42 SMEs in Perth, Western Australia; (2) detailed waste and energy audits for a sub-group of the above; and (3) exploring innovative sustainability approaches for SMEs to reduce wastes and air emissions.

A relatively small number of initiatives to reduce wastes and emissions undertaken by the SMEs were found such as investing in improved technologies or equipment, and utilising waste streams as inputs for other business operations. A decrease in the uptake of sustainability initiatives was evident compared to previous studies in the region.

The paper presents an overview of the findings of the study, as well as the barriers to the uptake of sustainability initiatives among the SMEs for reducing their wastes and air emissions.

Keywords:

Cleaner Production, Small-MediumSized Enterprises (SMEs), Waste, Waste Exchange, and Western Australia

1 INTRODUCTION

Small-Medium Sized Industries (SMEs) constitute about 40% of business in Australia and 96.5% of industries in Western Australia are defined as small and medium industries [1]. However, it has been estimated that 70% of pollution is produced by SMEs [2,3,4]. While IGES [5] estimated that 50% of pollution in the Asia-Pacific region was due to SMEs.

It is therefore clear, that while SMEs contribute positively to economic and social systems, SMEs may have a significant environmental impact.

This study aims to examine wastes and air emissions generated by SMEs in the manufacturing sector and investigate how they can reduce air emissions by implementing sustainability initiatives such as: Cleaner Production (CP) and Industrial Symbiosis (IS); and to investigate the degree of adoption of such initiatives by Small–Medium Sized Manufacturing Industries (in Western Australia.

2 SUSTAINABILITY INITIATIVES TO IMPROVE ENVIRONMENTAL PERFORMANCE IN SMES

From the SME's viewpoint, reducing environmental impacts frequently requires a high capital investment, which is indeed the case with "end-of-pipe" treatment methods, which only consider the pollutant rather than the process, which created it.

Some approaches introduced to SMEs are Environmental Management System (EMS) or also known as ISO 1400 [6], Eco Efficiency [7], Energy Efficiency or Savings [8], Total Quality Environment Management (TQEM) [9].

One approach which typically offers 'win-win' solutions to environmental and economic issues is Cleaner Production (CP) which is believed to improve the environmental and economic performance of industry generally and SMEs in particular [10]. By application of the cleaner production principles, companies can improve both their environmental and economic performance simultaneously.

In addition to the CP methodology, which is intra-plant/facility, Industrial Symbiosis is a complimentary inter-plant methodology, which forms part of Industrial Ecology. Industrial Symbiosis is industrial collaboration in exchanging products, by-products, and wastes to reduce environmental impacts. Furthermore, the links built up among the firms in an industrial area constitute an "Industrial Ecosystem" or "Industrial Symbiosis" [11].

2.1 Cleaner Production (CP) Approach

One approaches to deal with environmental concerns is Cleaner Production [10], which describes a preventive approach to environmental management [12], defined as *"the continuous application of an integrated preventive environmental strategy to processes, products and services to increase overall efficiency, and reduce risks to humans and the environment"* [12]. This definition has been adopted by Environment Australia [13] and Australia's National Cleaner Production Strategy [14].

Furthermore, CP aims to make more efficient use of natural resources (raw materials, energy, and water) and to reduce the generation of wastes and emissions at the source [10]. The most common means of achieving this is through the five prevention practices [10]:

- **Modification of the product**: changing the product design in order to reduce the product's environmental impact in manufacturing process, use, and/or disposal.
- **Substitution of input materials**: using environmentally friendly (e.g. renewable) materials in products and processes.
- **Modification of technology**: changing the equipments and technology to make the process more efficient and to reduce waste and emissions.
- **Good housekeeping**: adopting standardised /improved operation and maintenance procedures to avoid waste and emission, such as leaks, spills, etc. This may include improved worker training.
- **On-site recycling**: recovery and reuse of waste materials, water and heat at the company where they are generated.

2.1.1 Benefits of Cleaner Production

A case study review of cleaner production opportunities for small to medium sized enterprises conducted by Van Berkel [10] using five SMEs cases studies within Australia presented that investment in cleaner production is generally attractive both economically and environmentally. These benefits were gained through firstly, *reduction of expenditures on input materials, energy and water*; secondly, *reduction of expenditures on waste (water) treatment*; thirdly, *increase of production revenues*; fourthly, *better product quality*.

2.1.2 Barriers to Cleaner Production Implementation

Some common barriers in implementing CP among SMEs have been previously identified. Lack of Knowledge was a principal barrier found in India [15], South Africa [16], Canada [17], Netherland [18], Spain [6] and Australia [19]; as well as Lack of Skill and Expertise found in India [15], Netherlands [18], Australia [19], and Zambia [20]; Cost and Financial resources was an issue in Zambia [20], India [15], China [21], and Australia [19]; and finally Lack of Appreciation and Incentives found in Lebanon [22], India [15], and South Africa [16].

2.1.3 Drivers of Cleaner Production Implementation

Some researchers have identified drivers that could motivate and stimulated small-medium industry to implement cleaner production. Drivers identified in many countries include **marketing benefit** [18, 17], **economic benefit** [23,17], **value and commitments of management** [24, 25, 10], **networking and case studies** [26, 27, 23], **outside assistance** [28, 29, 17, 7], **and government regulations** [20, 30].

2.2 Industrial Symbiosis or Waste Exchange Approaches

Industrial Symbiosis is industrial collaboration in exchanging products, by-products, and waste to reduce environmental impacts. Furthermore, the links built up among the firms in an industrial area transform an "Industrial Ecosystem" or "Industrial Symbiosis". Chertow [11] states: *"Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity".*

Especially in Australia, products that are captured in Industrial Symbiosis can be divided into two categories, i.e [31]:

- **By-Products Synergies**: the use of by-product generated by an industry as an input by other industries.
- **Utility Synergies**: utility share among the industries in the area such as power generation, water resource facility, and waste treatment.

The implementation of industrial symbiosis in Australian SMEs has not yet been documented; however, industry parks elsewhere containing a large number of SMEs have successfully implemented industrial symbiosis, including Burnside Industrial Park in Dartmouth, Nova Scotia, Canada [32]; Rantasalmi Eco-Industrial Park, Finland [33]; Landskorna, Sweden [34]; Uimaharju Industrial Park, Eastern Finland [33]; Harjavalta Industrial Eco-park, Finland [33].

3 METHODOLOGY

To reveal the extent of CP and WE/IS adopted by SMEs in Western Australia, a face-to-face survey was performed in three major industrial areas in three suburbs of Perth (Canning Vale, Welshpool, and Osborne Park), Western Australia.

Approximately 60% of companies surveyed were involved in fabrication as their primary business.

103 companies were approached, 42 companies were interviewed (success rate 41%). 33 (of the 42) were manufacturing companies (propeller and marine, ventilation, steel fabrication, coating, fastener, gear motor, auto, furniture, cement, window cover, plastic packaging, and aluminium fabrication; with 9 "other" industries (bakery, laundry, auto body repair, and printing).

In Canning Vale, 19 of the companies interviewed were manufacturing and 4 were others. In Welshpool, 13 were manufacturing companies and 2 were "other". While in Osborne Park, 3 companies were manufacturing and 1 was other.

All companies surveyed were classified as SMEs, with 3 to 150 workers. Based on ABS [1], these companies are grouped as micro, small, and medium enterprises at 4.8%, 43.1%, and 52.1% respectively.

All companies undertook a face to face structured interview. The interviewee was the person judged most suitable to respond (company environmental manager, production manager, or general manager). The interview questions covered company identification, profile, operations, managerial structure, employee numbers, company turnover and associated data, input output data, knowledge of waste and emissions generated and quantity, knowledge of sustainability approaches and barriers to implementation. Semi-structured follow up questions were used to gain further information as needed.

3.1 Wastes Discharged by SMEs

3.1.1 Solid Waste

Figure 1 shows the solid waste reportedly discharged by SMEs in WA. Ferrous scrap and packaging were the most common wastes discharged. The y-axis plots the number of SMEs with reported discharging the particular waste.

It was found that waste generation was proportional to company size: Only 5% was micro enterprises, 46.3% was small enterprises produced, and 48.7% was medium companies. Data from figure 1 was summed for each company size and converted to a percentage of whole dataset.

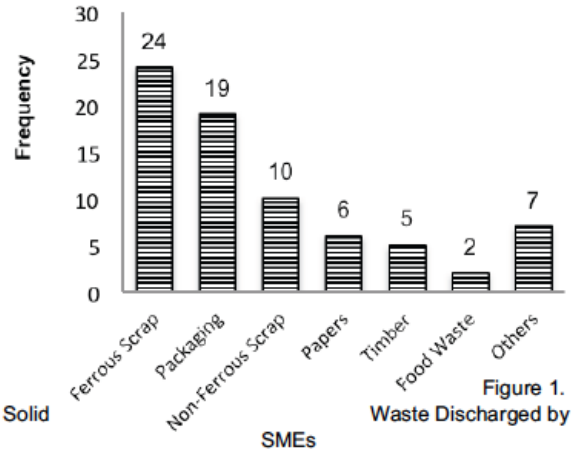

Figure 1. Solid Waste Discharged by SMEs

3.1.2 Liquid Waste

Figure 2 shows liquid waste discharged by SMEs (not including general wastewater from toilet or office, etc.). Wastewater is the common waste generated from manufacturing processes; and then oil which was typically from machines used for the process operation. While, machining fluid (coolant) used to cool machines was the least waste revealed by SMEs.

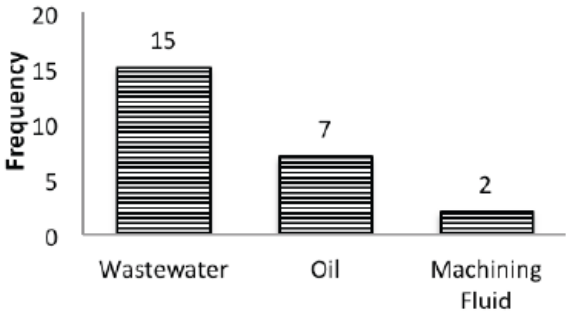

Figure 2. Liquid Waste Discharged by SMEs

Related to the company sizes, as with solid waste, the larger the company, the more liquid waste generated. Medium companies produced 55%, small companies discharged about 40%, and micro companies generated about 5% of liquid waste.

3.1.3 Air Emissions

Most SMEs do not, nor are they required to, conduct air sampling. However, SMEs reported emissions that were generated by their processes, included Particulate Matter (20 SMEs), VOCs (6 SMEs), CO/CO2 (6 SMEs), NOx (2 SMEs), and SOx (1 SMEs). These are based on qualitative knowledge of emissions. Particulate Matter was the most common emissions reported; it could be because particulate matter was the very visible emission. Other emissions were not answered by most SMEs because most of them did not measure and monitor their emissions, so it was hard for them to indicate type of emissions they discharged.

3.2 Awareness of Sustainability Initiative Approaches

This survey also revealed the awareness (or lack thereof) of sustainability initiative approaches among SMEs such as Environmental Management System (EMS), Cleaner Production (CP), Eco Efficiency (EE), Energy Savings (ES), Total Quality Environmental Management (TQEM).

From Figure 3, the most popular approach was Energy Efficiency/Savings (ES) which was recognised by 17 SMEs; the second popular was EMS, recognised by 15 companies; the third was Eco Efficiency was known by 11 companies; 10 SMEs recognised Total Quality Environmental Management (TQEM), and Cleaner Production (CP) was recognised by 7 SMEs. This revealed that Cleaner Production has not been more popular than other approaches to improve environmental performance among SMEs in Western Australia.

Out of those approaches above, some companies also mentioned other approaches that they aware such as Best Practice for Dust, BOD reduction scheme, OHS standard, Risk Assessment, Self Assessment, Skylights program, and Waste & Recycling Management. However, only 1 company mentioned each of them.

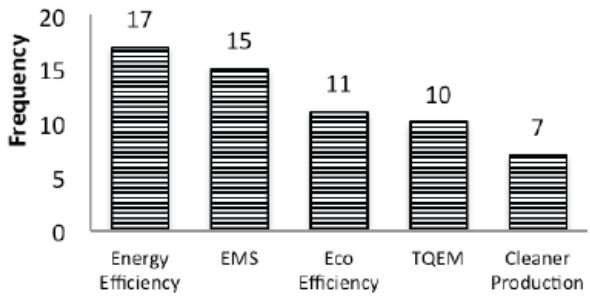

Figure 3. Awareness of Specific Sustainability Initiative Approaches

3.3 Implementation of Sustainability Initiative Approaches

The implementation of sustainability initiatives was also explored in this study, shown in Figure 4 below. 55.6% of companies reported implementation of some strategies. Individual companies had implemented up to 3 approaches.

The common results of implementation identified by SMEs' managers above were firstly, environmental benefits. They said companies could be part of saving the environment programs such as reducing environmental impacts and resources efficiency (energy and water savings).

Secondly, marketing benefits was one of the results for many companies. They could use environmental improvement implementation as promotion to their clients. Thirdly, business productivity was improved in line with environmental performance. Fourthly, work environment became safer and cleaner. However, there was a failed result reported by a company; and some other implementations were still ongoing so that the results had not yet identified.

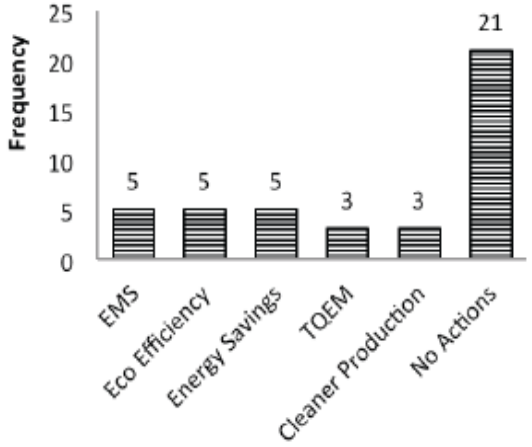

Figure 4. Implementation of Sustainability Initiatives by SMEs

3.4 Barriers to Implement Sustainability Initiative Approaches

Figure 5 shows the barriers when SMEs implemented the approaches. The main barrier, indicated by 14 SMEs, mentioned in the interview was lack of knowledge to undertake the assessment and formulate improvement initiatives. This includes how hard to find technical support (6.3%) to conduct the implementation either from other institutions (government and non-profit institutions).

When SMEs perform implementation themselves, they faced financial issues and have difficulty finding financial support to overcome the costs. 11 SMEs faced financial issues such as re-investing or replacing new equipment. The cost to undertake environmental assessment and consultancy with the experts also became a problem as SMEs often have insufficient additional capital.

Inflexible improvement programs - mentioned by 3 companies - sometimes also made implementation fail.

Some SMEs could not see any clear benefits (2 SMEs) of the implementation of sustainability initiative approach. These SMEs probably have a lack of knowledge or just see the benefit in term of money or profit in a very short time.

Another important barrier, revealed by 2 SMEs, was habits or mindset of the employees in SMEs. Typical status quo employees existed in some SMEs, which make change-implementation or management difficult.

In some cases, identified sustainability solutions would require shutdown of plant for extended periods of time to allow major changes, which was found not to be economical.

3.5 Awareness and Implementation of Waste Exchange (WE)

When SMEs were asked if they were aware of the concept of Waste Exchange, 30 companies answered Yes and 12 companies No. A further 2 companies stated they were aware when the concept was explained to them.

Figure 6 shows the wastes usually exchanged with other companies. Metals, oil, packaging and wood are the most commonly exchanged. Waste exchange was correlated with value of the waste.

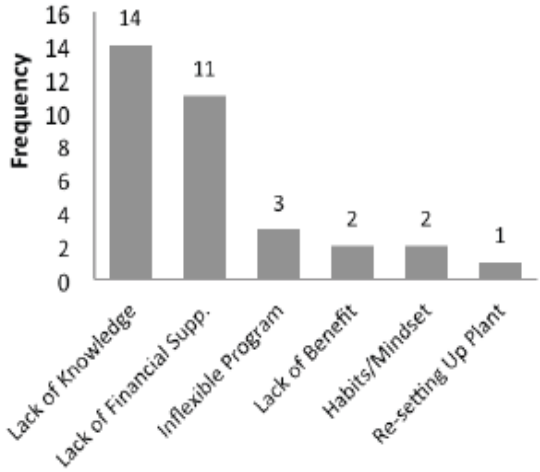

Figure 5. Barriers Faced by SMEs to Implement the Approaches

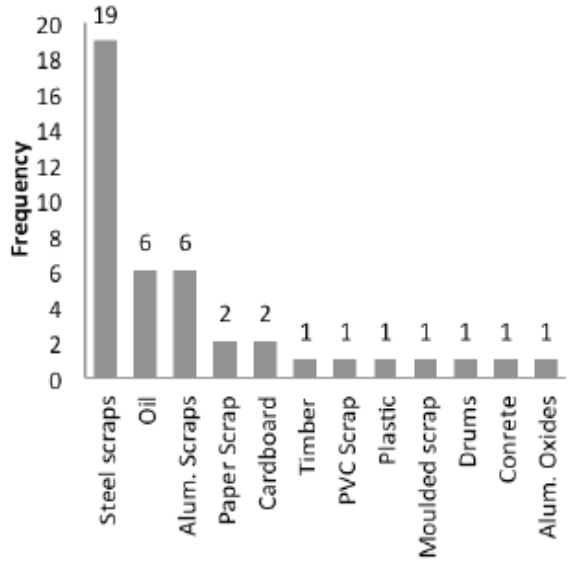

Figure 6. Wastes that are Usually Exchanged by SMEs

Furthermore, the implementation of Waste Exchange among the SMEs was also explored and is shown in Figure 7. Only few of these activities can be classified as waste exchange based on Chertow [11] or Bossilkov [31] definition.

When SMEs were asked how they implemented Waste Exchange (WE), then their answers first were selling the waste for recycling to recycling company or agent is 22 companies; most of the company sell their waste to a recycling company and get additional revenue (Cost Positive) as the benefits; then the recycling company will process the waste to be raw materials. This activity usually happens for steel off cut or scraps waste in steel and aluminium fabrication industries.

The second popular implementation is giving the waste to recycling companies (9 companies); SMEs do not get any additional revenue or spend cost (Cost Neutral/CNeu.) for this initiative. This activity is usually happened for cardboard, plastic, and PVC wastes. The third activity regarding to waste is SMEs pay the recycling company to take away their waste

(2 companies) such as oil waste. In this case, SMEs have to spend cost (Cost Negative/CNeg.) to manage their waste. The fourth waste activity is giving away (Cost Neutral/CNeu.) to people (1 company) such as timber scrap from Furniture Company.

The last two waste activities are a little bit different than the others; one cement industry sent their concrete waste directly to paving grey block companies as a raw material for paving block (1 company). The other industry is newspaper printing sent their waste paper and paper scrap to house Insulation Company as a raw material for insulation product (1 company). The benefit of this initiative is environmental protection as there is neither concrete nor paper waste sent to landfill, and in this case, resources saving are performed; there is no additional revenue or cost (Cost Neutral/CNeu.) for this.

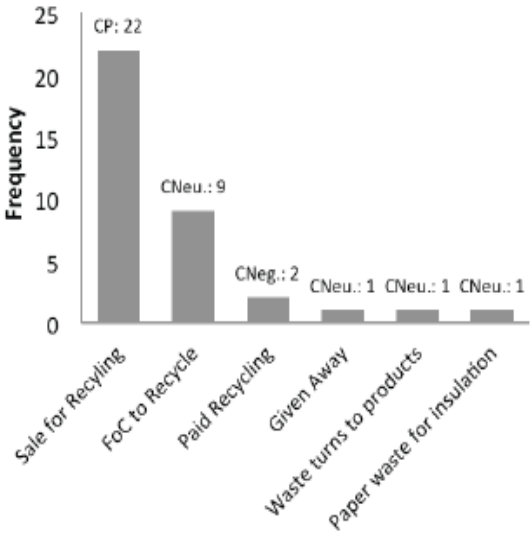

Figure 7. Waste Exchange (WE) Implementation

Most WE implementations above are dependent on a 3rd party organisation to reprocess or use the waste. Only two companies implemented WE with exchanging their waste as raw materials directly to other companies; this is the very close implementation to the definition of WE or IS in the article written by Chertow [13] about exchanging waste and by-product among industries.

4 COMPARISON WITH PREVIOUS WA STUDIES

A study undertaken by Graham and van Berkel [19] in Western Australia (WA) evaluated three key components of Cleaner Production implementation – **awareness, management,** and **implementation** - among small-medium enterprises (SMEs). This study used a semi quantitative scoring system which gave a maximum score of 100 for each of 3 components when SMEs could indicate certain features.

Graham and van Berkel's [19] study was conducted in 2001 via telephone survey to 140 SMEs from most manufacturing sectors in Western Australia (WA) (50%), Queensland (25%), and South Australia (25%). While, the current study, undertaken in 2010, interviewed (face to face) 42 SMEs from most manufacturing sectors in Perth (WA). Most of the SMEs interviewed were therefore not the same as in Van Berkel's study (only few were involved in the previous study). As the current study was face to face and more detailed, the level of confidence of the current study is expected to be higher than the previous study.

Based on these two studies, a comparison can be undertaken to analyse the progress of sustainability initiatives implementation in Western Australia. This comparison was undertaken by using the same scoring system and the same questions-answers such as awareness, management, and implementation. The result of this comparison can seen in Table 1.

Table 1. Comparison with WA study using Semi-Quatitative Scoring System (Scores/100)

COMPONENTS	Van Berkel's Study (2001)	This Study (2010)
Awareness	22	19
Management	60	12
Implementation	55	7

It is clear that the uptake of CP has declined between 2001 and 2010. The reasons for this are likely to be the same as those discussed in this paper.

5 SUMMARY

Sustainability initiatives have not been widely implemented amongst small-medium manufacturing industry in Western Australia. Sustainability initiative adoption appears to have declined over the past decade.

More effort is required with respect to sustainability initiatives, promotion and building networks between government, consultants, and financial institutions to support SMEs and to resolve the main barriers such as lack of knowledge (technical skill), lack of financial support, and lack of government regulations. It is evident that a more strategic approach is required.

Most of SMEs were still difficult to identify their types of waste, especially air emissions as they never measure and monitor emissions.

6 ACKNOWLEDGMENTS

The authors are grateful to Directorate General of Higher Education, Indonesia Ministry of National Education for funding this research; and also to the environmental officers from Air Quality Management Branch, Department of Environment and Conservation, Western Australia for assistance and supporting fund to conduct this research.

7 REFERENCES

[1] Australian Bureau of Statistics 2002, Small business in Australia, cat. no. 1321.0, ABS Canberra.

[2] Hillary, R. 2004, Environmental Management Systems and The Smaller Enterprise, Journal of Cleaner Production, vol. 12, issue 6, pp. 561-569.

[3] Pimenova, P. and van der Vorst R. 2004, The Role of Support Programmes and Policies in Improving SMEs Environmental Performance in Developed and Transition Economies, Journal of Cleaner Production, vol. 12, pp. 549-559.

[4] Schaper, M. 2001, Environmental Attitudes and Practices Amongst Small Business Owner/Managers in the Western Australian Community Pharmacy Sector, Working Paper Series 2001: no. 2001-3, Curtin University, School of Management.

[5] Institute for Global Environment Strategies (IGES) 2006, *AEIS RISPO: Strategic policy options database*.

[6] Heras, I. and Arana, G. 2010, Alternative models for environmental management in SMEs: the case of ekoscan vs. ISO 14001, Journal of Cleaner Production, vol. 18, pp. 726-735.

[7] Côté, R., Booth, A., and Louis, B. 2006, Eco-efficiency and SMEs in Nova Scotia, Canada, Journal of Cleaner Production, vol. 14, pp. 542-550.

[8] Cagno E., Trucco P., Trianni A., and Sala G. 2010, Quick scan: a methodology for the energy scan of SMEs, Energy, vol. 35, pp. 1916-1926.

[9] Curkovic S. and Sroufe R. 2007, Total quality environmental management and total cost assessment: an exploratory study, International Journal of Production Economics, vol. 105, pp. 560-579.

[10] Van Berkel, R. 1999, Cleaner production opportunities for small to medium sized enterprises, Waste and Recycle Convention, Perth, Western Australia.

[11] Chertow R. C. 2000, Industrial symbiosis: literature and taxonomy, Annual Review Energy Environment, vol 25, pp. 313-337.

[12] UNEP 2001, Cleaner production – key elements, United Nations of Environment Programmes, Paris, France.

[13] Environment Australia 2000, Best practice environmental management in mining: cleaner production, Department of Environment and Heritage, Australia.

[14] Australian and New Zealand Environment and Conservation Council (ANZECC) 1998, Towards sustainability: achieving cleaner production in Australia, 16th Meeting, Hobart, Tasmania.

[15] Rathi, A. K. A. 2006, Promotion of cleaner production for industrial pollution abatement in Gujarat (India), Journal of Cleaner Production, vol. 11, pp. 583-590.

[16] Government of the Republic of South Africa 2004, National cleaner production strategy: draft for comment-regional and national workshop, Government of the Republic of South Africa.

[17] Tylor, B. 2006, Encouraging industry to assess and implement cleaner production measures, Journal of Cleaner Production, vol. 14, pp. 601-609.

[18] Van Hemel, C. and Cramer, J. 2002, Barriers and stimuli for ecodesign in SMEs, Journal of Cleaner Production, vol. 10, pp. 439-453.

[19] Graham, A. H. and Van Berkel R. 2007, Assessment of cleaner production uptake: method development and trial with small business in Western Australia, Journal of Cleaner Production, vol. 15, pp. 787-797.

[20] Siaminwe, L., Chinsembu K. C., and Syakalima M. 2005, Policy and operational constraints for the implementation of cleaner production in Zambia, Journal of Cleaner Production, vol. 13, pp. 1037-1047.

[21] Shi, H., Peng, S., Liu, Y., and Zhong, P. 2008, Barriers to implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspective, Journal of Cleaner Production, vol. 16, pp. 842-852.

[22] Massoud, M. A., Fayad, R., El-Fadel, M., and Kamleh, R. 2010, Drivers, barriers, and incentives to implementing environmental management systems in the food industry: a case of Lebanon, Journal of Cleaner Production, vol. 18, pp. 200-209.

[23] Altham, W. 2007, Benchmarking to trigger cleaner production in small businesses: drycleaning case study, Journal of Cleaner Production, vol. 15, pp. 798-813.

[24] Net. Regs 2003, SME-nvironment 2003: northern Ireland, Environment and Heritage Service Commonwealth House, Belfast.

[25] Narayanaswamy, V. and Stone, L. 2007, From cleaner production to sustainable production and consumption in Australia and New Zealand: achievement, challenges, and opportunities, Journal of Cleaner Production, vol. 15, pp. 711-715.

[26] Gunningham, N. and Sinclair, D. 1997, Barriers and motivators to the adoption of cleaner production practices, The Australian Centre for Environmental Law, The Australian University, Canberra.

[27] Visvanatahan C. and Kumar, S. 1999, Issues for better implementation of cleaner production in Asian small and medium industries, Journal of Cleaner Production, vol. 7, pp. 127-134.

[28] Gardstorm, T. and Norrthon, P. 1994, Implementation of cleaner production in small and medium-sized enterprises, Journal of Cleaner Production, vol. 2, pp. 201-205.

[29] Gombault, M. and Versteege S. 1999, Cleaner production in SMEs through a partnership with (local) authorities: success from the Netherlands, Journal of Cleaner Production, vol. 7, pp. 249-261.

[30] Pimenova, P. and van der Vorst R. 2004, The role of support programmes and policies in improving SMEs environmental performance in developed and transition economies, Journal of Cleaner Production, vol. 12, pp. 549-559.

[31] Bossilkov A., Van Berkel R., and Gorder G. 2005, Regional Synergies for sustainable resource processing: a status report, Centre for Sustainable Resource Processing, Perth, WA, Australia.

[32] Côté R. and Hall J. 1995, Industrial parks as ecosystems, Journal of Cleaner Production, vol. 3, no. 1-2, pp. 41-46.

[33] Saikku L. 2006, Eco-industrial parks: a background report for the eco-industrial park project at Rantasalmi, Publication of Regional Council of Etela-Savo 71, Finland.

[34] Starlander J. E. 2003, Industrial symbiosis: a closer look on organisational factors. Master Thesis, The International Institute for Industrial Environmental Economics, Lund, Sweden.