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An Exploratory Evaluation of Economic and Environmental Efficiency of Solid Waste Management in Welsh Small and Medium-sized Enterprises

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An Exploratory Evaluation of Economic and Environmental Efficiency of Solid Waste Management in Welsh Small and Medium-Sized Enterprises

Joseph Sarkis[1] and Jeroen Dijkshoorn

Abstract

This paper provides an efficiency analysis of practices in Solid Waste Management of manufacturing companies in Wales. We apply data envelopment analysis (DEA) to a data set compiled during the National Waste Survey Wales 2003. We explore the relative performance of small and medium sized manufacturing enterprises (SME; 10-250 employees) in Wales. We determine the technical and scale environmental and economic efficiencies of these organizations. Our evaluation focuses on empirical data collected from companies in a wide diversity of manufacturing industries throughout Wales. We find significant differences in industry and size efficiencies. We also find correlations that exist among environmental and economic efficiencies. These variations show that improvements can be made using benchmarks from similar and different size industries. Further pursuit of an investigation of possible reasons for these differences is recommended.

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[1] This work was completed while Joseph Sarkis was a Visiting Scholar at the BRASS Institute at Cardiff University and Supported by ESRC Grant No. M568285001

About the BRASS Centre

In 2001, Cardiff University won £3.1 million in research funds from the Economic and Social Research Council to develop a Research Centre for Business Relationships, Accountability, Sustainability and Society (BRASS). The Centre is a joint venture between the University's Schools of Business, City & Regional Planning and Law. It brings together the three Schools' existing research expertise on issues of sustainability, business ethics, company law, corporate reporting and business communication.

The Centre started work in October 2001 under the leadership of Professor Ken Peattie of the Business School, Professor Terry Marsden of the Department of City and Regional Planning and Professor Bob Lee of the Law School. The funding of the Centre covers an initial five-year period, but this should just mark the beginning of BRASS' contribution to creating more sustainable and responsible businesses locally, nationally and globally.

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Introduction

Resources for essential environmental programs are in short supply in most small and mediums sized manufacturing enterprises (SMEs). Competitiveness is vital for businesses and most SMEs can't afford to invest time or money to assess their environmental performance, let alone improve it. In many cases SMEs put resources targeted for environmental purposes into activities relating to environmental compliance; a reactive approach. Businesses can manage better in these environments if they can become aware of, and learn how well they are managing environmental and economic factors in their organisations. Benchmarking processes can aid in this process and Data Envelopment Analysis (DEA) can help in the benchmarking process for environmental and economic efficiency assessment. This paper deals with providing such an analysis in solid waste management efficiency using DEA techniques, providing some evidence of variations in environmental and economic efficiencies of solid waste management among SMEs within Wales. An assessment of these performance characteristics in a broad-scale study helps both policy makers and organizations understand some characteristics of SME efficiencies with some general guidance on comparative benchmarking directions.

With this goal in mind, we provide an analysis of economic and environmental efficiency in solid waste management over a number of industrial sectors among SMEs in Wales. This analysis can be used to raise the awareness for various industrial sectors and organisations that under-perform in this field. Also, more broadly, the findings of this study can contribute to the literature by providing further insights on how industries are performing, especially among the somewhat neglected SME organizational sector. Industrial sectors and organizations that perform well can arrive at conclusions that they are 'on the right track' and continue to progress. DEA can, to a certain extent, explain possible reasons for these efficiency or inefficiency results by examining industrial and organizational size characteristics and influences. We also investigate the general relationship between economic and environmental efficiency, or whether 'win-win' exists in this situation. In addition, an examination of scale economies (returns to scale) can provide insights into whether SMEs should be growing their efforts in this area by investing additional resources to make further environmental or economic gains. We find that environmental and economic efficiency, and indeed inefficiency, is related to the size of the company or the industrial environment.

In presenting our study and findings we begin with a general discussion of the regulatory and environmental context that these organizations face. This issue is important since it lays the foundation on why these studies have become increasingly relevant to SMEs. We then provide details on the study methodology including discussion of data acquisition, the modelling approach used and its execution to arrive at our results. A presentation of the results then follows with implications discussed in this and later sections.

The Regulatory and Environmental Context

In Wales, the UK and throughout the European Union (EU), the issue of solid waste arisings has received continuous attention from policymakers, legislators, communities, and industry. EU legislation (see Table 1 for regulatory policies from the EU, UK and Wales that influence solid waste management practices), the prime source for approximately 75% of UK environmental regulations, is the principle driving force behind current changes to achieving sustainable waste management in the United Kingdom (UK). Since the early 1990s, the EU has undertaken a proactive course of passing a number of new directives relating to management of solid waste. The main challenge is the de-coupling of economic growth and rising waste output i.e. to maintain the quality of life for current and future generations with continuing economic growth and at the same time decreasing waste output, in other words economic and environmental sustainability. The EU's environment policy is based on the win-win belief that high environmental standards stimulate innovation and business opportunities. Waste is one area where such economic and environment benefits may be achievable. This is partly due to the range of materials involved, but also to the scale of the waste problem in Europe. For example, a total of 1.3 billion tonnes of waste is disposed annually within the EU, 40 million tonnes of this waste is hazardous. The EU plans to achieve a 20% reduction in waste for final disposal between 2000 and 2010, increasing to 50% by 2050 (European Commission, 2002), but materials will still be available for recycling and treatment through other methods.

Currently, in the UK. landfilling is the preferred method of waste disposal. However, landfilling not only takes up valuable land space, it also causes air, water and soil pollution, discharging greenhouse gases such as carbon dioxide (CO2) and methane (CH4) into the atmosphere and toxic leachate into the earth and groundwater. A comprehensive summary of environmental implications of solid waste for a variety of situations is shown in Table 2. Landfilling is not a sustainable option; once in the ground the wastes or resources are mostly lost. In addition, economically, UK landfill in tax is set to rise on an annual basis (excluding gate fees up to £35 by 2010) but with an annual increase of just £3 per tonne it will remain in most cases the cheapest option. It remains to be seen if the tax rise will cause 'waste to be pushed up the waste hierarchy' as envisaged by central government.

Localized waste management requirements

In response to these solid wastes based issues, legislation from the EU has included an avalanche of regulations. In addition, England and Wales waste regulations deriving from Part II of the Environmental Protection Act 1995, control many aspects of how the environment is protected and regulated in daily life. This Act provides the main statutory waste framework. There are current and pending regulations under consideration to implement the harmonisation requirements of the EU directives (see table 1). Wales is also implementing its own 'secondary' legislation. Wales does not have any primary legislative powers but it can and does pass secondary legislation. The Welsh Assembly Government however is bound Central UK Government. This can restrict the options available in Wales in how to tackle waste issues. For example, as the Welsh Assembly Government has no tax raising powers, it cannot increase the Landfill Tax if it felt that in Wales the level of taxation was still too low. Altogether though, it is obvious that with these new regulations the cost of compliance and proper waste management is set to rise and drive up the cost of running a business (e.g. pre-treatment of all hazardous wastes, compliance with packaging regulations). Environmental efficiency (resource efficiency, process control, waste reduction) is the way to contain or even reduce the rising cost of waste disposal and thus becomes economic efficiency.

Wales Waste Strategy and Industrial Pressures

The Welsh waste strategy recognises that *"waste is Wales' biggest environmental problem*[2]*"* and that Wales has to improve how it manages waste. The Assembly Government's intention for the waste strategy is:

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[2] Welsh Assembly Government, Wise about Waste: The National Waste Strategy for Wales, Part One, June 2002, v

> "*…to move Wales from an over-reliance on landfill to a position where it will be a model for sustainable waste management…it will achieve this by adopting and implementing a sustainable, integrated approach to waste production, management and regulation…that minimises the production of waste and its impact on the environment, maximises the use of unavoidable waste as a resource….* (pg. vii)"

Wales is the only country in Europe where the devolved government has a duty (under section 121 of the Government of Wales Act 1998) to promote sustainable development in the exercise of its functions. Thus the Welsh waste strategy sets stricter targets (see Table 3) than those set in the UK Waste Strategy. More significantly, it also sets targets for the commercial and industrial sector. Some of these targets are classed as 'secondary targets'. To meet the targets, the Assembly Government is relying not solely on how companies will respond to the pressures from current European waste directives, but also from a package of incentives and assistance to encourage Welsh businesses to adopt sustainable waste management practices. The UK Waste Strategy encourages business to aggregately achieve these reductions.

Economic Issues

In the last two decades Wales has undergone an economic transformation and today has an economy based on a wider range of business sectors than was the case in the 1970s and early 1980s. The transformation has included an aim to attract foreign owned corporations via inward investment. Currently in Wales, manufacturing and construction employ about 28% of the workforce and represents over 28% of GDP in Wales, and therefore has a substantial impact on the amount of waste generated. However, manufacturing in Wales is undergoing decline and any opportunity to retain material (waste) value in Wales, and to support businesses designed to use such wastes as secondary materials would help support the economy, as well as meeting environmental targets.

As many management researchers have argued (e.g. van der Linde and Porter, 1995) waste quantities are influenced by how efficiently resources are used in production and by the quantities of goods produced and consumed. Waste is ultimately a reflection of the loss of materials and can be a tangible representation of inefficient production practices and unsustainable consumption and production. It imposes both economic and environmental costs on society for its collection, treatment and disposal. A report published by the

Environment Agency in 2003 indicated that British manufacturing could increase profits by as much as £2 - £3 billion per year from resource productivity.

Current Welsh practices of disposing waste to landfills are unsustainable, and landfill capacity is declining (one anecdotal argument is that with 'lots' of holes from the Welsh mining industry, this was not an issue, until very recently). There are currently no landfill sites left in Wales that accept hazardous wastes, resulting in higher management cost (transport, supply and demand imbalance). The majority of Welsh companies continue to dispose of large quantities of waste to landfill (see Table 4) and as a result, Wales is near the bottom of the European list of solid waste disposal best practice. At the heart of current waste policies is the need for businesses to recognise that resource efficiency is a central issue in the sustainability challenge. The impetus is to enhance competitiveness through the better use of physical, human and financial resources, thereby creating equal value with less impact.

SMEs' Environmental Impacts

The EU defines SMEs as organizations between 10 and 250 employees, companies with less than 10 employees are defined as micro-enterprises. Corporate environmental research on SMEs, even though it continues to grow in recent years, still lacks the research involving larger and multinational organisations, and in many ways has been largely overlooked (Lefebvre et al., 2003; Williamson and Lynch-Wood, 2001; Worthington and Patton, 2005). Investigation of environmental and economic efficiencies and some of the characteristics of SMEs has been virtually non-existent.

It has become increasingly apparent that the environmental implications of SMEs can no longer be ignored or 'fall through the cracks' of regulatory policy, especially in the UK. There are approximately 3.7 million businesses in the UK, of which only about 7000 are larger than 250 employees. SMEs represent about 38% of the UK's Gross Domestic Product and estimates are that they represent 70% of the pollution generated (Williamson and Lynch-Wood, 2001). According to the UK government's Small Business Services department, in 2001 in Wales, 67% of employment and 61% of revenue was generated by SMEs, with over 25% of the contribution derived from manufacturing SMEs. These figures are quite significant because large numbers of SMEs that generate waste in aggregate terms pose challenges to management resolution at policy as well as company level. In addition to policy issues, SMEs also feel 'greening' pressures from industrial customers in their supply chain to improve their environmental performance. Further understanding of SMEs and their environmental efficiencies can benefit the SMEs, regulators, and researchers.

'You can't manage what you can't measure'

Efficiency evaluation through benchmarking and comparative evaluation of SMEs on economic and environmental performance can prove valuable to SMEs in understanding how to improve their own operations. Such evaluation may also help policy makers to identify issues when developing environmental business support required to assist SME environmental performance. It is important to choose the most appropriate benchmarks for each industrial sector in which SMEs operate. Also, realising that a relationship exists between environmental and economic efficiencies can help further motivate SMEs to adopt practices that can be both environmentally and economically beneficial to these organizations. This result may encourage proactive, not just reactive, reasons for the adoption of environmentally sound practices.

Study Methodology

In the methodology discussion we shall first discuss the approach used to gather the data. Then the methodological approach to calculate the performance and efficiency is broadly presented.

Survey and Data Acquisition Methodology

In 2003 the BRASS Centre conducted the National Waste (Commercial and Industrial) Survey Wales on behalf of the Environment Agency Wales (EAW). The EAW has a statutory duty to report waste data statistics to the EU and also provides other stakeholders with waste data.

The survey instrument was organized into three parts, part I required general information from the company including confirming SIC code and full time employment equivalent (FTE). Part II of the questionnaire noted the waste details, particularly:

- Types of waste (EWC Code);
- Quantity (either by weight or container type, size and quantity;
- Whether waste was special;
- The physical form of the waste;
- The waste management option;
- The waste contractor;
- Initial and final destination of the waste; and
- The cost of or income from the disposal.

Part III of the questionnaire asked the company questions about its general approach to management of environmental issues.

After full agreement by facilities to be involved in this study, data was acquired by a team of 13 surveyors who went through an intensive two-week training program. The training program provided guidance into the survey, the data within the survey, and standardization of the data collection process, and the data integrity process. This standardization reduced the errors and bias that might occur with multiple surveyors gathering data. The surveys were completed by the surveyors with observations (site inspections) made to confirm waste stream data. Site inspection details are presented in Appendix A.

Data integrity was included in the follow-up to data acquisition from the facilities. The project manager in the BRASS Centre carried out rigorous quality assurance on the data and requested additional information where discrepancies in data were identified.

A stratified sampling procedure was designed drawing a random sample provided by the British Office of National Statistics (ONS) interdepartmental business register database. The data for this study was collected using broad-based site visits throughout Wales, using a short survey questionnaire. To ensure consistency in data collection the data collected was based on a series of predetermined categories:

- Standard Industrial Classification (SIC95) codes were used to identify business sectors;
- European Waste Catalogue codes (EWC) were used to identify waste type;
- A standard set of conversion factors were developed by the EAW to calculate weight from volume data;
- Standard lists were developed to define -
  - waste management options;
  - skip and container types;
  - waste form (solid, liquid, sludge, etc.);
  - hazardous/non hazardous;
  - waste contractor and waste carrier names; and
  - initial and end destination local authority names.

The waste survey sample was designed to include 2210 companies. In this project it was decided that sectors with a high economic impact on the Welsh economy would be highlighted. The survey methodology used a stratified random sampling approach based on SIC codes and number of employees (size) of a company. Each company within a survey cell (SIC Code/size sub-sample) was randomly chosen. The ONS were provided with the sample categorizations and were requested to provide the necessary randomly generated populations, in this instance a total of 2210 companies. The sample was also proportioned to each region within Wales. This breakdown allowed the sample to be representative of Wales as it reflected the Welsh economy.

To ensure no bias appeared in the survey, the randomness of company selection had to be maintained throughout the life of the survey. As a result, all companies had to be approached in the order provided by the ONS. With a target of 2210 companies to be surveyed, a sample of 7237 companies were randomly allocated by the ONS. Only the companies on the first list of live 2210 companies, identified by appropriate coding could be approached first. The remaining companies could only be approached in the necessary order determined by the 'Replacement company' process. This was either to 'Abandoned', 'Refused' or 'Uncontactable'. An explanation of these terms is as follows:

1. Abandoned companies were classified as those companies that had ceased to exist.
2. Duplicate companies were those companies who appeared more than once.
3. Uncontactable companies were not accessible by phone or postal.
4. Refusals – either due to unavailability of people or time frame of study or other reasons.

In the overall study a total 2122 surveys were completed after site visits to SMEs in a broad variety of industries and organisations. There were 1198 SMEs who did not participate in the survey with 2122 respondents, a response rate of 64% (2122/3320). Of these 1198 non-participants, 82 were abandoned because the companies did not exist, 76 were duplicates of other companies already included in the sample, 368 were uncontactable for various reasons and 672 companies refused to participate. By removing the abandoned, duplicate, and uncontactable companies from the sample size, the response rate only including those that either responded or refused to respond for the total sample was 85%. That is, the overall initial sample from this included a broad variety of companies and sizes, including non-manufacturing and service organisations.

Since we wished to study manufacturing oriented companies we narrowed down our SIC coded respondent companies (from the total survey respondents of 2122) to those organizations that had between 10 and 250 employees. Using the EU designation companies from 10-50 employees were defined as small, while those that ranged from 51-250 employees were medium sized companies. We also eliminated companies that had reported zero costs or wastes from our analysis. This reduced the total number of SMEs in our sample to 299 companies.

A breakdown of the totals of respondent companies and response rates for each SIC and Size category is shown in Table 5. In Table 5 we see that for the population we are considering, the total actual sample that was originally selected was for 543 small companies and 345 medium sized companies. The overall response rate for these samples were 394 (73%) for the small companies and 276 (82%) of medium sized companies, for a total of 670 responding companies. The individual SIC/Company response rate ranged from 100% at the upper end to 47%. After further elimination of companies with missing data we arrived at our final sample sizes. These included 178 small companies (33% of the originally designated small enterprise sample population) and 121 medium-sized enterprises (37% of the medium enterprise population). An evaluation of the final eliminated companies with some missing data showed that their percentage of reported waste was only 3% of the total responding companies 97% of the waste is accounted for in the 299 reporting companies. These eliminated companies averaged 64 employees, a similar average size to the remaining data set we use in our investigation.

Environmental and Economic Efficiency Models

The evaluation of the solid waste practices by Welsh SMEs will first require that we examine the performance of these organizations by determining their environmental and economic efficiencies. We will complete this process using DEA, a multifactor productivity evaluation tool. The DEA methodology is useful here since we can determine relative efficiencies of organizations by aggregating multiple factors of performance into one measure of relative performance. It is also a valuable methodology in that it allows a comparison of whether productivity characteristics exhibit varying returns to scale. Detailed descriptions of the DEA methodologies are in the Appendix. (For a more detailed discussion of applying DEA for environmental efficiency see Dyckhoff and Allen, 2001; Sarkis and Talluri, 2004). What we shall describe here are the factors and relationships we will be using to describe environmental and economic efficiency.

The relative efficiency scores will first require that we determine input and output factors that will be evaluated in a relative fashion amongst the various facilities we will be investigating. DEA attempts to find weights that will maximize a given facility's productivity ratio making it look as good possible when compared to the productivity ratios of other facilities. We shall now describe the multi-factor productivity ratios for the environmental and economic efficiency scores.

Environmental Efficiency Model

In this study we have defined environmental efficiency on how well a facility or organization can manage its wastes on a per employee basis. To do this we use a multifactor environmental productivity model. For the multifactor environmental productivity model we will utilize one input (employees) and two outputs. One output is what we define as a ‘desirable’ output which is material that has been handled using environmentally sound approaches. This output we describe as ‘recycled’ material. In the survey we inquired about the waste management option organisations used and how much waste was recycled, recovered, or reused. Other, less environmentally sound waste management options included incineration and landfilling (either on site or off-site treatment). Thus, in our model recycling practices are more preferable than the other disposal techniques, based on the ‘waste management hierarchy’.

The second output for the environmental efficiency ratio is total waste generated, but is an ‘undesirable’ output. To incorporate total waste as an output we will take its inverse value (i.e. now the larger value is more preferable as should be the characteristics of all outputs, (see Ball et al. (1994) and Dychoff and Allen (2001), for various measures to deal with undesirable outputs). Thus the environmental efficiency model is how effective they are at managing their operations based on a per employee basis. We did not use other inputs, e.g. costs, product units, or revenues due to the variations that exist among organizations and facilities. For example, revenues may not be appropriate since some facilities were stand alone facilities, while other facilities were subdivisions of larger organizations and revenues would have been difficult to estimate for these types of organizations. Other environmental factors may have been utilized, but since our study is focused on the management of solid wastes, we focused on these aspects for our study.

Thus, the multifactor environmental productivity ratio to be evaluated is:

$$Env_k = \frac{v_{k1}^{env} \dfrac{1}{W_k} + v_{k2}^{env} R_k}{u_{k1}^{env} EMP_k} \qquad (1)$$

Where:

Env_k is the environmental efficiency score for facility k;

W_k is the total waste generated for facility k;

R_k is the total amount of waste treated in an environmentally sound way by facility k;

EMP_k is the input of labor (number of employees) for facility k;

v_{k1}^{env} = the weight to be assigned to environmental ratio output factor 1 by facility k.

v_{k2}^{env} the weight to be assigned to environmental ratio output factor 2 by facility k.

u_{k1}^{env} = the weight to be assigned to environmental ratio input factor 1 by facility k.

Economic Efficiency Model

We have defined economic efficiency in our study as the capability to manage the wastes generated and their management in a cost effective manner. Thus, an organization is being economically efficient if it can manage its wastes on a low per unit cost measure. Costs were arrived at by asking how much the facility spent on managing its solid waste streams. Thus, these costs include only direct waste management expenses. This was the only input factor. Three output factors were used, total waste generated, total waste recycled, and hazardous waste generated. We do not view total waste generated as an undesirable factor since we want to see how efficient they are on a waste (by weight) per unit cost. In this situation the more waste they can manage on less cost the more economically efficient they are. We also include more proactive management items like recycled wastes. We include hazardous wastes as an output factor so that companies that deal with these types of waste are not penalized because their cost structures may cause them to pay more per unit. Incorporating hazardous wastes could actually benefit those organizations who are cost efficient in managing these wastes.

Thus our multifactor economic productivity ratio to be evaluated is:

$$Eco_k = \frac{v_{k1}^{eco} W_k + v_{k2}^{eco} R_k + v_{k3}^{eco} H_k}{u_{k1}^{eco} Cost_k} \qquad (2)$$

Where:

Eco_k is the economic efficiency score for facility k;

W_k is the total waste generated for facility k;

R_k is the total amount of waste treated in an environmentally sound way by facility k;

H_k is the total hazardous waste generated for facility k;

$Cost_k$ is the input of waste management costs for facility k;

v_{k1}^{eco} = the weight to be assigned to economic ratio output factor 1 by facility k.

v_{k2}^{eco} the weight to be assigned to economic ratio output factor 2 by facility k.

v_{k3}^{eco} the weight to be assigned to economic ratio output factor 3 by facility k.

u_{k1}^{eco} = the weight to be assigned to economic ratio input factor 1 by facility k.

Descriptive statistics, mean and standard deviations, for the input and output factors used in this study are shown in Table 6. We show the statistics for the overall sample in our study (between 10 to 250 employee number range) as well as the statistics for each group of medium and small sized companies. The values for all three groups are presented due to investigations within each full set of groups. We decided to also consider groupings of smaller and medium sized groups, since DEA results may be sensitive to various issues such as heterogeneity of data (e.g. widely different sizes of organizations). Thus, our first test will be to determine if size differences (i.e. small versus medium organizations) are related to efficiency differences.

Results and Discussion

In the results portion of this study we will focus on three primary results relating to industry/size comparisons, a returns to scale evaluation, and an overview of the relationships between economic and environmental efficiency performance. Some major implications from our results are further divulged in our discussion section.

Industry-Size Comparisons

There are a series of results which we will consider in this study. We utilize the GTR method of DEA (see Appendix B for further discussion) to determine the initial efficiency scores for the complete data set of 299 companies. We complete a comparison of these initial results to determine whether significant differences in efficiency score occur between the small and medium sized enterprises sub-samples. To complete this initial analysis, we use the Mann-Whitney U-test since DEA data is considered to be non-parametric (Brockett and Golany, 1996). These results are shown in Table 7. We can see that there are significant differences in the efficiency scores among small and medium sized enterprises for both environmental and economic efficiencies. Thus, we will do much of our testing using the overall data set, as well as separate data sets for small and medium sized organizations to control for various size influences in our data set. In these initial results we also find that smaller size organizations seem to be more efficient than larger organizations (larger average ranks represent higher efficiency scores) in both relative efficiency measures. The mean efficiency scores for environmental efficiency seem to be larger than those for economic efficiency. This result signifies that SMEs are actually closer to best practice when it comes to environmental efficiency per person employed. The smaller the average score, the further away from the 'most efficient' unit the average unit is. One other observation to make at this point is that even though the mean economic efficiency score for small companies is less than the medium-sized companies (-0.955 versus -0.950, respectively), the mean ranks clearly show better (higher) average rank scores for smaller companies.

A second analysis involves evaluating industrial variations in environmental and economic efficiency scores. Mean efficiency score results, by industry (SIC code) are shown in Table 8. For each industry we report six scores, the means of the environmental and economic efficiency scores for all size enterprises (EVA, ECA), small-sized enterprises (EVS, ECS), and medium-sized enterprises (EVM, ECM) industries. The rankings for each industry, using Kruskal-Wallis mean rank scores[3] are shown in Table 9. As we can see from these tables SIC 19 performed the best overall in almost all categories. But, in this data sample the industry only included 2 enterprises. The industry with a substantial number of companies in the cells (greater than 5) that consistently did well on mean rank scores was the *Other Non-Metallic Minerals* (SIC 26) industry. Two industries, with a significant number of respondents per cell, that performed relatively poorly in the various efficiency scores were the *Food Product and Beverages* (SIC 15) and the *Rubber and Plastic* (SIC 25) industries. A reason for this may lie in the fact that both these sectors produce large quantities of wastes that are difficult to reduce or recycle and costly to manage. Landfill is often the only option for these wastes.

Most industries and sizes seemed to be performing somewhat consistently in terms of their relative environmental and economic rankings, no matter the size of the company or sample set. Yet, counter examples do exist. For example *manufacture of wood and wood products* (SIC 20) arrived relative results showing they were doing better in environmental performance for medium sized enterprises but poorly in economic performance for their medium sized enterprises. The small companies in SIC 20 seemed to be more balanced in their relative rankings when compared to other industries. Yet another industry, *manufacture of fabricated metal products* (SIC 28) seemed to be doing relatively poorly

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[3] We use Kruskal Wallis mean rank scores to do a relative evaluation across industries because determination of differences across industries will be evaluated using the Kruskal-Wallis non-parametric test.

on its small company environmental and economic performance, but relatively better than average in its medium sized companies. *Manufacture of radio, television and communication equipment* (SIC 32) was also enigmatic in that it did best on the average ranks of its economic performance for medium sized companies, but relatively poorly in economic performance for its small sized companies (it performed just the opposite for environmental where it was one of the best for small and relatively worse for medium-sized companies). A reason for this might be the fact that although a lot of the waste is recycled, the output quantities are of such low volume that the companies cannot generate any income from these wastes.

These results show that there might be benchmarking and learning opportunities not only between industries, but also within industries among different sized organizations. Given the scores and rankings for each industry, we will now determine if these differences are significant. To determine whether significant differences occur for non-parametric DEA data among a group of industries we apply the Kruskal-Wallis non-parametric test. The results for each of the various efficiency scores of the three samples are shown in Table 10. In all cases we see that there are significant overall industry differences when it comes to economic performance. Yet, no overall statistically significant industry differences occur for the environmental efficiencies. Even though paired comparisons between best and worst industries in each do show significant differences.

Returns to Scale

The next set of results that were calculated focus on the returns to scale for each of the model categories. DEA-based returns to scale calculation procedures are described in Appendix B. The results are shown in Table 10. Here we see that the preponderance of the facilities in our study exhibit decreasing returns to scale, ranging from 86.5% of facilities for the small company environmental efficiency evaluations, to 98.3% of facilities for the small company economic efficiency evaluations.

When looking at the average size of the companies with each of these characteristics (the final column of Table 11), we see that for the environmental efficiency evaluations in each of our model categories (i.e. all companies, small only, medium only) the average size of the companies that exhibit increasing returns to scale are smaller than the average size of all companies in that model category. This result implies that smaller companies may actually wish to expand to take advantage of their economies of scale related to improving their environmental performance based on a per employee basis. The returns to scale for the economic efficiency evaluations are more dispersed for the 'all companies' model category, but clearly show an increasing returns to scale for larger when looking at small and medium sized organizations. Here true economics of scale exist when organizations seem to reach the upper ends of the scale (only 3 companies for each, but at the extreme end of the size of the companies for these size categories). This result implies that there is a threshold level where companies may start to take advantage of economically efficient returns to scale and these levels are at the upper ends of the small and medium sized company categories.

Correlations between Economic and Environmental Performance

To evaluate the relationship between the economic and environmental performance of companies within our investigation we calculated the Kendall's–Taub rank correlation coefficient for the various environmental and economic efficiency scores. Positive and significant correlations were found in all three samples; the full sample (.321 correlation statistic, significant at .01 level), the medium-sized enterprise sample (.140 correlation statistic, significant at the .05 level), and the small-sized enterprise sample (.156 correlation statistic, significant at the .01 level). These positive relationships support the propositions that the relationship between good environmental and economic performance is real and occurs, even within SMEs.

Discussion

Our first point of discussion is on the result that there are size differences in efficiency and more interestingly, in both cases of environmental and economic efficiency, that smaller organizations performed better. This result is consistent with results that show a decreasing returns-to-scale for a vast majority of enterprises in our study, where these larger enterprises are not taking advantage of their size.

A couple possible reasons for this occurrence may provide clues. The first is that smaller enterprises may not have as complex a set of waste streams as medium sized enterprises.

Trying to manage a diversity of streams, many of which are not large enough to maintain economically effective control of these streams, may be an ineffective strategy. However, because some SMEs dispose of most their wastes through the Local Authority through municipal trade / commercial waste routes, their costs are in fact far lower than for those companies who use commercial waste disposal routes, meaning that such results may offer a rather artificial picture of economic efficiency. Another reason may be evident if we observe the descriptive statistics in Table 6. We see that the medium-sized enterprises have to manage almost 25 times as much hazardous waste tonnage, on average, than smaller organizations. This additional consideration may make them less economically efficient due to the larger costs of managing hazardous wastes, but may also make them less environmentally efficient since their worries are focused on managing the hazardous wastes and not necessarily the total waste or introducing recycling type programs (the two measures that were used for environmental efficiency). The other ratios of the statistics were approximately at 4 or 5:1 medium to small sized ratio (for size, costs, total wastes, recycled wastes measures). This is one area of study that needs to be advanced, but will be left for future investigation.

Other, operational, explanations may also exist. For example smaller-sized enterprises typically have less complex production processes and less diverse raw material input resulting in less start-up/close down (set-up costs) waste, less maintenance down time, easier to control resources management, all together providing an environment that produces less waste. Also, smaller organizations tend to be operated as ‘job-shops’ that focus on low output high value products, where raw materials and waste may be substantially more valuable and thus managed more closely.

Practically, medium-sized enterprises should observe what makes smaller-sized enterprises (both internally and external to their industries) are doing to manage these streams. If simplification and removal of waste streams is the reason, then making some of these streams disappear (through prevention programs) may be both environmental and economic opportunities. If it is the hazardous waste difference, then prevention programs focusing on these types of waste streams should take precedence, e.g. regeneration and/or substitution of mineral oils, solvents and paints.
Using inter-industry benchmarks is an improvement exercise that should also be pursued for environmental performance management. There are clearly industries that have top

practices and some that do not perform so well. This situation occurs for both environmental and economic efficiencies. That there are industrial differences is not truly a surprising finding, yet, given that these companies are in the same situation with the pressures they face from regulatory policy and size limitations/resources, they should benchmark each other to see what operational and strategic characteristics may be transferable from one industry to the other. For example, the availability of private or public programs to aid industries in managing wastes may be available to a particular industry and not to another. If we return to our hazardous waste argument, manufacturing the materials rubber and plastics requires numerous hazardous chemical ingredients. This may be the reason for the poor performance of this (SIC 25) industry. Another operational factor that has a great influence on environmental as well as economic performance is the residual value, the desirability or the recyclability of the wastes in question. For example, an engineering company that uses significant amounts of aluminium will perform better than a similar sized engineering company that uses mild steel as their main ingredient because the income from residual wastes materials is higher. On top of that more valuable material will motivate organisations to implement resource recovery programs and thus balance their waste management costs.

We have also found that intra-industry differences also exist in a number of circumstances. Industries have shown that they may perform better in some circumstance on environmental performance, while poorly for economic performance. This situation may also vary depending on whether we are considering smaller or larger organizations in the same industry. One aspect to consider and research is why some industries are consistently good performers (or bad performers) across the board. This may be a systemic issue faced for all industry members and gets to the core of industrial differences (rather than organizational differences). Industries that show variations in performance based on size or whether they perform better on economic or environmental measures clearly have room for improvement based on intra-industry comparisons. Thus, they may be able to control their performance more effectively through management of operational resources (e.g. management implementing an auditing system) that these enterprises can control. One aspect of operational and strategic decision making, with industrial ecology implications, is the proximity and location of facilities. Some companies are so rurally located that transport cost made by recyclers or by themselves drive down the resale value of the recyclate, often making it cheaper to landfill the waste. If this is the case, these companies should actively try to prevent these wastes from being generated.

Another situation, that may be beyond the control of specific enterprises focuses on infrastructural and regulatory policy that may influence the performance of organizations. One of the bad performing industries, the food business, generates large quantities of biodegradable waste. Apart from composting, for which the packaging would have to be removed, there are no other true re-use or recycling, potentially profitable routes. Traditionally this material would have been used as animal feed but this route is closed since the foot and mouth crisis of a few years ago in the U.K.

Either way, it is clear that further investigation into the characteristics of good performers and poor performers (whether they are industry or organizational-size based), would provide additional insights into what good and bad operational and strategic practices exist. The initial information from this study can be used to further evaluate data for determination if certain programs (e.g. environmental management system implementation) may help or hinder performance from both an environmental or economic perspective.

One final finding in this study that supports the 'win-win' propositions is the apparent and strong significance of the relationships between organizations that did well environmentally and those that did well economically. There isn't a direct relationship, with numerous counter-examples, but there is a definite statistically significant pattern. This is encouraging to both policy makers and industries who may wish to encourage solid waste management improvements. Yet, within some industries (and this may be due to a sample size issue) the relationships may not be as strong. To tease out this information on why it may hold for some industries, and varying size organizations, while not holding for other industries is something that should also be investigated.

Summary and Conclusion

Solid waste management is an important issue in most of Europe, the United Kingdom, and especially Wales, which has had a history of poor performance in environmental management. The negative impact of SMEs on solid waste management has not gone unnoticed. A comparative evaluation of environmental and economic efficiencies using industry and organizational-size characteristics for an initial investigation provides initial policy and managerially valuable findings that can be used to improve the solid waste management performance of SMEs. To explore these issues we used a sub-sample of a broad-based study from Wales on waste management practices for SMEs. We applied DEA to arrive at relative environmental and economic performance scores. Results showed that various differences existed between small- and medium-sized enterprises, various industries (but not as much as we initially thought would occur) and a significant correlation between environmental and economic efficiencies. We also provided a number of potential reasons based on operational, organizational, industry and regulatory reasons for these differences. Teasing out these differences and relating them to other organizational practices and programs is an avenue for furthering this exploratory research.

There are some limitations in our research that need to be recognized. Even though we had a broad-based sample from a wide variety of industries, many industries had only a few representative enterprises in our sample. These smaller sizes may bias the results. In addition, in our evaluation of the DEA models the selection of inputs and outputs that are used to determine the efficiency scores can cause significant variations in the results. We only used a small set of factors for inputs (e.g. cost and/or number of employees), additional factors such as capital equipment investment, general environmental program investments, not just costs of waste elimination, number of employees focused on environmental issues, and other factors, may provide a more accurate, or at least variable picture of the efficiencies. The same argument can be made for the output measures, where other measures of environmental performance (emissions to air or water, for example) could have been used. Investigating variations in input and output measures is open for future research as well.

This research contributes to the body of literature to more fully understand the role that SMEs play in the broader environmental management landscape.

References

Ball VE, Lovell CAK, Nehring RF, Somwaru A. (1994) Incorporating undesirable outputs into models of production: An application to U.S. agriculture. Cahiers d'Economique et Sociologie Rurales 31: 59-73.

Banker, R.D., Charnes, A., and Cooper, W.W., (1984), “Some models for estimating technical and scale inefficiencies in data envelopment analysis,” *Management Science*, Vol. 30, pp. 1078-1092.

Brockett, P.L., and Golany, B., (1996), “Using rank statistics for determining programmatic efficiency differences in data envelopment analysis,” *Management Science*, Vol. 42, No. 3, pp. 466-472.

Charnes, C., Cooper, W.W., and Rhodes, E., (1978) “Measuring the efficiency of decision making units,” *European Journal of Operational Research*. Vol. 2, pp. 429-444.

DEFRA, (2005), “Recycling and Waste” homepage http://www.defra.gov.uk/environment/waste/index.htm.

Dyckhoff, H. and Allen, K. 2001. “Measuring ecological efficiency with data envelopment analysis (DEA).” European Journal of Operational Research, vol. 132, No. 2, pp. 69-82.

European Commission, (2002), *Choices for a greener future – the European Union and the environment*. European Commission, Brussels, Belgium.

Lefebvre, E., Lefebvre, L.A., and Talbot, S., (2003), “Determinants and Impacts of Environmental Performance in SMEs,” *R&D Management*, Vol. 33, pp. 263-283.

Porter, M.E., and C. van der Linde (1995) ‘Green and Competitive: Ending the Stalemate’, *Harvard Business Review*, Vol. 75, No. 3, pp. 120-134.

Sarkis, J., and S. Talluri, (2004), "Ecoefficiency Measurement Using Data Envelopment Analysis: Research and Practitioner Issues," *Journal of Environmental Assessment Policy and Management*, Vol. 6, No. 1, pp. 91-123.

Seiford, L.M., Zhu, J., (1999a), "An investigation of returns to scale in data envelopment analysis," *OMEGA*, Vol. 27, No. 1, pp. 1-11.

Seiford, L.M., Zhu, J., (1999b), "Profitability and narketability of the top 55 U.S. commercial banks," *Management Science*, Vol. 45, No. 9, pp. 1270-1288.

Williamson, D., and Lynch-Wood, G., (2001), "A new paradigm for SME environmental practice," *The TQM Magazine*, Vol. 13, No. 6, pp. 424-432.

Worthington, I., and Patton, D., (2005), "Strategic intent in the management of the green environment within SMEs," Long Range Planning, Vol. 38, pp. 197-212.

Appendix A: Site Inspection and Observation Protocol

The purpose of the site inspection is to ensure that all waste producing activities and waste streams are identified and quantified and Part 2 of the form is completed accurately. The visit would usually consist of an administrative part in which Parts I and III of the survey were completed. Also at this moment in the survey there would be an initial discussion about all possible waste streams, supported by available paperwork such as Duty of Care (waste transfer) notes, waste management bills and permits and licences. The following site inspection should then:

a) Ensure that all waste is accounted for;
b) Act as a check of the data (e.g. number of containers, waste types, size of containers);
c) Assess the composition in percentage of mixed waste streams;
d) Identify all wastes associated with the waste producing activities;
e) Identify all wastes associated with non-producing activities;
f) Identify all one-off wastes that may have arisen once within that year (for example refurbishment/new computers).

Inspection of operational and non-operational areas and waste storage areas is necessary to identify and obtain key information on associated waste streams.

The site inspection also assisted the surveyor to determine the type and composition of waste streams, which had already been identified. It was to ensure that all wastes were identified and if the surveyor saw or expected a waste type from the activity, they could then discuss with the company as to whether they did produce this waste type and if so what they did with it.

The surveyors were also encouraged to look into mixed waste containers and with the company representative assess the five main components with a percentage value. In addition, where no container size was available, they were required to measure the container.

After the site visit, the surveyor had to confirm all details required from Part II, particularly expected wastes types that had not been identified by the company representative. This also provided an opportunity for the company to ask any questions and if assistance was required, passing on the relevant contact details for the EA Regional Officers. Finally, if any data were missing, requests were made for the surveyor to make arrangements to obtain the data in the future by e-mail or telephone follow-up.

In the ‘How to Complete a Site Visit’ guidance manual, the surveyors were provided with a list of wastes commonly overlooked and were informed to ensure that they always asked about these waste types.

After completion of the site visit and the data integrity procedure a computer generated waste stream report of the collected data is sent to participating companies.

Appendix B: DEA Models and Extensions

Basic Ratio-Based Technical and Scale Efficiency DEA Models

DEA productivity models for a given decision-making unit (DMU) can use ratios based on the amount of outputs per given set of inputs. The definition of a DMU can vary greatly, from individuals to countries, as long as the unit can be modeled with input and output values. The definition in our case is a facility or company surveyed in our study. DEA allows for the simultaneous analysis of multiple inputs to multiple outputs, a multi-factor productivity approach. The general efficiency measure used by DEA is best summarized by equation (B1).

$$E_{ks} = \frac{\sum_y O_{sy} v_{ky}}{\sum_x I_{sx} u_{kx}} \qquad \text{(B1)}$$

where:

(E_{ks}) is the efficiency or productivity measure of DMU s, using the weights of test DMU k;
(O_{sy}) is the value of output y for DMU s;
(I_{sx}) is the value for input x of DMU s;
(v_{ky}) is the weight assigned to DMU k for output y; and
(u_{kx}) is the weight assigned to DMU k for input x.

In the basic DEA ratio model developed by Charnes, Cooper, and Rhodes (1978) (CCR), the objective is to maximize the efficiency value of a test DMU k from among a reference set of DMUs s, by selecting the optimal weights associated with the input and output measures. The maximum efficiencies are constrained to 1. The formulation is represented in expression (B2).

maximize $$E_{kk} = \frac{\sum_y O_{ky} v_{ky}}{\sum_x I_{kx} u_{kx}}$$

subject to:

$$E_{ks} \leq 1 \qquad \forall \quad \text{DMUs} \quad s \qquad \text{(B2)}$$
$$u_{kx}, v_{ky} \geq 0$$

This nonlinear programming formulation (B2) is equivalent to formulation (B3) (see Charnes et al. (1978) for a complete transformation explanation):

$$
\begin{array}{lll}
\text{maximize} & E_{kk} = \sum_{y} O_{ky} v_{ky} & \\
\text{subject to:} & & \\
 & E_{ks} \leq 1 \qquad \forall \quad \text{DMUs } s & \\
 & \sum_{x} I_{kx} u_{kx} = 1 & \text{(B3)} \\
 & u_{kx}, v_{ky} \geq 0 &
\end{array}
$$

The transformation is completed by constraining the efficiency ratio denominator from (B2) to a value of 1, represented by the constraint $\sum_{x} I_{kx} u_{kx} = 1$.

The result of formulation (B3) (the CCR formulation) is an optimal simple or technical efficiency value (E_{kk}*) that is at most equal to 1 (this formulation has also been defined as the constant returns to scale formulation). If E_{kk}* = 1, then no other DMU is more efficient than DMU k for its selected weights. That is, E_{kk}* = 1 has DMU k on the optimal frontier and is not dominated by any other DMU. If E_{kk}* < 1, then DMU k does not lie on the optimal frontier and there is at least one other DMU that is more efficient for the optimal set of weights determined by (B3). The formulation (B3) is executed s times, once for each DMU.

The dual of the CCR formulation (also defined as the envelopment side) is represented by model (B4):

$$
\begin{array}{lll}
\text{minimize} & q & \\
\text{subject to:} & & \\
 & \sum_{s} l_{s} I_{sx} - q I_{sx} \leq 0 \qquad \forall \ \text{Inputs } I & \\
 & \sum_{s} l_{s} O_{sy} - O_{ky} \geq 0 \qquad \forall \ \text{Outputs } O & \text{(B4)} \\
 & l_{s} \geq 0 \qquad \forall \ \text{DMUs } s &
\end{array}
$$

The CCR model has an assumption of constant returns to scale for the inputs and outputs. To take into consideration variable returns to scale, a model introduced by Banker, Charnes, and Cooper (1984) (BCC) is utilized. The BCC model aids in determining the scale efficiency of a set of units (which is a technically efficient unit for the variable returns to scale model). This new model has an additional convexity constraint defined by limiting the summation of the multiplier weights (λ) equal to one, or:

$$\sum_{s} \lambda_s = 1 \qquad \text{(B5)}$$

The use of the CCR and BCC models together helps determine the overall technical and scale efficiencies of the DMU respondents and whether the data exhibits varying returns to scale.

A DEA-based model that can help discriminate among efficient and inefficient units is one proposed by Rousseau and Semple (1995), which focuses on preservation of a unit's classification (e.g., changes required to input and output values to maintain a unit's classification as efficient or inefficient). This approach is based on determining a unit's sensitivity to changes in the data values. The formulation used here to evaluate the data set is the generalized Tchebycheff radius of classification preservation (GTR) model (B6).

$$\text{minimize} \quad \alpha^+ - \alpha^-$$

subject to:

$$\begin{aligned}
&\sum_{s\neq k} \lambda_s I_{sx} - \alpha^+ I_{kx} + \alpha^- I_{kx} - I_{kx} \le 0 \qquad \forall \ \text{Inputs } I \\
&\sum_{s\neq k} \lambda_s O_{sy} + \alpha^+ O_{ky} - \alpha^- O_{ky} - O_{ky} \ge 0 \qquad \forall \ \text{Outputs } O \qquad \text{(B6)} \\
&\sum_{s\neq k} \lambda_s = 1 \\
&\lambda_s, \alpha^+, \alpha^- \ge 0
\end{aligned}$$

where α^+ is the distance of an efficient unit from the Pareto frontier and α^- is the distance of an inefficient unit from the Pareto frontier.

Unlike the other DEA models discussed above, the optimal value for this formulation can be either negative (inefficient unit) or positive (efficient unit). The magnitude of the objective value is also significant because it defines the robustness of the unit's score. Magnitudes of objective values can serve as good measures to discriminate among units with similar classifications, and thus to rank the various units either efficient or inefficient. Whereas the RCCR model is based on the CCR formulation, the GTR model is underpinned by the BCC formulation.

Returns to Scale Identification

Returns to scale refers to increasing or decreasing efficiency based on size. We will use the basic model from expression (B4) the envelopment side of the CCR model to help us define whether there are increasing, decreasing or constant returns-to-scales for some of the facilities. The returns-to-scale classification for a facility is identified as constant return to scale if $\sum_s l_s = 1$, increasing returns-to-scale if $\sum_s l_s < 1$, and decreasing returns-to-scale $\sum_s l_s > 1$, for the optimal solution to formulation B4. Managerially, the returns-to-scale can be interpreted by stating that facility would be in a more favorable position for expansion if it exhibits increasing returns to scale, compared to a facility with decreasing or constant returns to scale (see Seiford and Zhu, 1999a; 1999b for a discussion of the practical and theoretical implications of returns-to-scale).

Table 1. Current and Pending Legislation effecting Wales Corporate solid waste management practices*:*

Batteries Directive (1991/157/EEC)
Consultation on proposed Landfill (England & Wales) Regulations 2005
Directive on Integrated Pollution Prevention and Control (1996/61/EC)
ELV- end of life vehicles Directive (2000/53/EC)
End of Life Vehicles Regulation 2003, SI 2635
Environmental Protection (Duty of Care) (Amendment) (Wales) Regulation 2003, SI 1720
Environmental Liability Directive (2004/35/EC)
Hazardous Waste Directive 91/689/EC (‘HWD’)
Hazardous Waste Regulations (2005)
Landfill Directive (1991/31/EC)
Landfill (England & Wales) Regulation 2002, SI 1559
Packaging (Essential Requirements) Regulation 2003, SI 1941
Packaging Directive (94/62/EC)
Producer Responsibility Obligations (Packaging Waste) (Amendment) (Wales) Regulation 2003, SI 3238
The European Waste Catalogue (2000/532/EC)
The Restriction of Hazardous Substances in Electrical and Electronic Equipment (ROHS) Directive (2002/95/EC)
Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/ EC)
Waste Framework Directive (75/442/EEC)
Waste Incineration Directive (2000/76/EC)
Waste Incineration (England & Wales) Regulation 2002, SI 2980
Waste Management Licensing (Amendment) (Wales) Regulation 2004, SI 70
Waste Statistics Regulation (2150/2002/EC).

Table 2: Impact of solid waste management activities on various media and geography[4]

		Solid Waste Management Activities				
		Landfill	**Composting**	**Incineration**	**Recycling**	**Transportation**
Media and Geography	**Air**	Emission of CH_4	Emission of CH_4, CO_2 odours	Emission of SO_2, Nox, HCI, HF, CO, CO_2, N_2O, dioxins.	Emission of dust	Emission of dust Nox, SO_2, release of hazardous substances from accidental spills
	Water	Leaching of salts, heavy metals, biodegradable and persistent organics to ground water		Deposition of hazardous substances on surface water	Waste water discharges	Risk of surface water and ground water contamination from accidental spills
	Soil	Accumulation of hazardous substances in soil		Landfilling of potentially hazardous slags, fly ash and scrap	Landfilling of final residues	Risk of soil contamination from accidental spills
	Landscape	Soil occupancy; restriction on other land use	Soil occupancy; restriction on other land use	Visual intrusion; restriction on other land uses	Visual intrusion	Traffic
	Eco-systems	Contamination and accumulation of toxic substances	Contamination and accumulation of toxic substances	Contamination and accumulation of toxic substances		Risk of contamination from accidental spills
	Urban Areas	Exposure to hazardous substances		Exposure to hazardous substances	Noise	Risk of exposure to hazardous substances from accidental spills, traffic

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[4] Adapted from the Directorate-General Environment, Nuclear Safety and Civil Protection, European Commission, EU focus on waste management , 1999, 9

Table 3: Wales Strategic Targets for Waste Minimization by the Public Sector

Wales primary target: Waste minimisation target for public sector:

- By 2005, achieve a reduction in waste produced equivalent to at least 5% of the 1998 arisings figure;
- By 2010, achieve a reduction in waste produced equivalent to at least 10% of the 1998 arisings figure.
- Secondary target: Businesses are encouraged to join the public sector to meet or exceed these targets.

Wales secondary target: Diversion of commercial and industrial waste from landfill:

- By 2005 to reduce the amount of waste sent to landfill by 85% of that landfilled in 1998;
- By 2010 to reduce the amount of waste sent to landfill by 80% of that landfilled in 1998.

Wales secondary target: Diverting commercial and industrial biodegradable waste from landfill:

- By 2005 to reduce biodegradable waste sent to landfill to 85% of that landfilled in 1998;
- By 2010 to reduce biodegradable waste sent to landfill to 80% of that landfilled in 1998.

Table 4: Waste Management and quantities in Wales 1998/99 (source: DEFRA, 2005)

Waste category	**Arisings**		**Waste management method (1000t)**			
	Tonnage (1000t)	**% Of total**	**Re-used & recovered / recycled**	**Landfilled**	**Other treatment**	**Transfer & unknown**
Industrial - mineral wastes & residues	2654	25	2148	506	0	0
Industrial - all other	2335	22	921	1144	244	28
Total industrial	4989	47	3069	1650	244	28
Commercial	1141	11	206	781	34	121
Household	1331	12	69	1262	0	0
C&D	3285	30	2467	818	0	0
TOTAL	10746	100	5811	4511	278	149

Table 5: Sample characteristics of industries and survey respondents

SIC	SIC Classification Name	Total Sample Size		Response Rate		Final Sample Size		
		Small Enterprises	**Medium Enterprises**	**Small Enterprises**	**Medium Enterprise**	**Small Enterprises**	**Medium Enterprises**	**Total per SIC**
15	Food Products and Beverages	65	43	49 (75%)	39 (91%)	26 (40%)	20 (47%)	46
17	Textiles	18	10	13 (72%)	10 (100%)	6 (33%)	3 (30%)	9
18	Wearing Apparel Manufacture	8	5	5 (63%)	5 (100%)	1 (13%)	3 (60%)	4
19	Tanning and Dressing Leather	4	0	3 (75%)		2 (50%)		2
20	Wood Products	41	4	31 (76%)	4 (100%)	10 (24%)	2 (50%)	12
22	Pulp and Paper	36	13	21(58%)	12 (92%)	8 (22%)	4 (31%	12
24	Publishing and Printing	32	31	29 (91%)	22 (71%)	14 (44%)	12 (39%)	26
25	Rubber and Plastic	23	33	21 (91%)	28 (85%)	10 (43%)	16 (48%)	26
26	Other Non-Metallic Minerals	37	15	22 (59%)	11 (73%)	11 (30%)	6 (40%)	17
27	Basic Metals	26	22	21 (81%)	18 (82%)	7 (27%)	7 (32%)	14
28	Fabricated Metal (no machinery)	84	46	63 (75%)	36 (78%)	27 (32%)	18 (39%)	45
29	Machinery and Equipment	61	20	37 (61%)	14 (70%)	18 (30%)	5 (25%)	23
30	Office Machinery/Computers	3	3	2 (67%)	3 (100%)	1 (33%)	2 (67%)	3
31	Other Electrical Machinery	16	22	12 (75%)	16 (73%)	6 (38%)	3 (14%)	9
32	Radio, Television and Communication	8	7	8 (100%)	4 (57%)	4 (50%)	3 (43%)	7
33	Medical, Precision, Optical	14	12	11 (79%)	8 (67%)	5 (36%)	3 (25%)	8
34	Motor Vehicles, Trailers	15	14	7 (47%)	12 (86%)	4 (27%)	5 (36%)	9
35	Other Transport	12	9	9 (75%)	7 (78%)	3 (25%)	1 (11%)	4
36	Furniture and other	40	36	30 (75%)	27 (75%)	15 (38%)	8 (22%)	23
	Total Number of Companies	543	345	394 (73%)	276 (82%)	178 (33%)	121 (37%)	299

Table 6: Descriptive Statistics of Input and Output Factors for Various Organizational Size Samples in DEA Runs

Employee Size Ranges (N= Employee #)		Employees (# FTE)	Costs (£)	Total Wastes (Tons)	Recycled Wastes (Tons)	Hazardous Wastes (Tons)
10<=N<=250	Mean	61.8	12930.8	3289.9	402.3	44.1
	Std. Dev.	*54.9*	*34297.2*	*33525.3*	*2780.6*	*232.5*
10<=N<=50	Mean	25.9	5506.5	1452.9	167.9	4.5
	Std. Dev.	*11.8*	*14172.0*	*15024.4*	*1151.4*	*15.8*
50<N<=250	Mean	114.5	23852.5	5992.3	747.2	102.4
	Std. Dev.	*50.9*	*49322.0*	*49549.7*	*4136.2*	*358.5*

Table 7: Statistical Results of Differences in Environmental and Economic Efficiency Scores by Size of Company Category

Efficiency Type	Size	Number of Companies	Mean Score	Mean Rank	Sum of Ranks	M-W Test Statistic	Significance
Environmental Efficiency using GTR	Small	178	-0.498	209.4	37270	199	.000**
	Medium	121	-0.874	62.6	7580		
Economic Efficiency using GTR	Small	178	-0.955	172.4	30692	6777	.000**
	Medium	121	-0.950	117.0	14158		

*Significance levels (two-tailed): ** = .05 or better*

Table 8: Environmental and Economic Mean Efficiency Scores of Small and Medium Enterprises Categorized by Industry SIC codes

SIC		EVA[+]	ECA	EVS	ECS	EVM	ECM
15	Mean	-0.693	-0.980	-0.500	-0.879	-0.538	-0.992
	Std. Dev.	*0.290*	*0.050*	*0.379*	*0.367*	*0.226*	*0.014*
17	Mean	-0.538	-0.970	-0.377	-0.743	-0.313	-0.990
	Std. Dev	*0.399*	*0.028*	*0.399*	*0.519*	*0.232*	*0.002*
18	Mean	-0.700	-0.952	-0.135	-0.815	-0.421	-0.995
	Std. Dev.	*0.379*	*0.091*	*	*	*0.276*	*0.004*
19	Mean	-0.177	-0.557	-0.177	-0.533	**	**
	Std. Dev	*0.597*	*0.388*	*0.597*	*0.401*	**	**
20	Mean	-0.544	-0.951	-0.485	-0.903	-0.325	-0.998
	Std. Dev.	*0.250*	*0.087*	*0.227*	*0.090*	*0.366*	*0.001*
22	Mean	-0.616	-0.987	-0.479	-0.923	-0.474	-0.994
	Std. Dev	*0.290*	*0.009*	*0.260*	*0.089*	*0.276*	*0.002*
24	Mean	-0.665	-0.903	-0.482	-0.791	-0.379	-0.813
	Std. Dev.	*0.269*	*0.361*	*0.242*	*0.318*	*0.260*	*0.528*
25	Mean	-0.765	-0.991	-0.541	-0.984	-0.535	-0.990
	Std. Dev	*0.234*	*0.009*	*0.245*	*0.010*	*0.174*	*0.013*
26	Mean	-0.492	-0.743	-0.419	-0.615	-0.189	-0.529
	Std. Dev.	*0.411*	*0.573*	*0.226*	*0.639*	*0.594*	*0.779*
27	Mean	-0.666	-0.969	-0.453	-0.945	-0.495	-0.960
	Std. Dev	*0.300*	*0.038*	*0.294*	*0.048*	*0.285*	*0.056*
28	Mean	-0.655	-0.969	-0.513	-0.894	-0.361	-0.962
	Std. Dev.	*0.260*	*0.032*	*0.248*	*0.225*	*0.206*	*0.044*
29	Mean	-0.602	-0.971	-0.526	-0.952	-0.357	-0.954
	Std. Dev	*0.244*	*0.035*	*0.219*	*0.048*	*0.234*	*0.073*
30	Mean	-0.790	-0.992	-0.565	-0.988	-0.521	-0.989
	Std. Dev.	*0.197*	*0.004*	*	*	*0.183*	*0.005*
31	Mean	-0.616	-0.972	-0.481	-0.566	-0.486	-0.990
	Std. Dev	*0.287*	*0.030*	*0.254*	*0.439*	*0.384*	*0.006*
32	Mean	-0.597	-0.904	-0.379	-0.976	-0.443	-0.675
	Std. Dev.	*0.329*	*0.156*	*0.258*	*0.024*	*0.257*	*0.434*
33	Mean	-0.688	-0.966	-0.552	-0.888	-0.562	-0.958
	Std. Dev	*0.209*	*0.025*	*0.121*	*0.106*	*0.073*	*0.059*
34	Mean	-0.724	-0.967	-0.522	-0.954	-0.414	-0.932
	Std. Dev.	*0.214*	*0.047*	*0.147*	*0.073*	*0.195*	*0.107*
35	Mean	-0.828	-0.988	-0.787	-0.979	-0.746	-0.983
	Std. Dev.	*0.083*	*0.002*	*0.014*	*0.010*	*	*
36	Mean	-0.655	-0.969	-0.536	-0.871	-0.384	-0.976
	Std. Dev	*0.254*	*0.080*	*0.239*	*0.418*	*0.217*	*0.035*
Total	Mean	-0.650	-0.950	-0.494	-0.864	-0.437	-0.931
	Std. Dev.	*0.285*	*0.188*	*0.269*	*0.313*	*0.260*	*0.261*

[+]**EVA** – Environmental Efficiency Score for all SME's; **ECA** – Economic Efficiency Score for all SME's.
EVS - Environmental Efficiency Score for small SME's; **ECS** – Economic Efficiency Score for small SME's.
EVM - Environmental Efficiency Score for medium SME's; **ECS** – Economic Efficiency Score for medium SME's.
* Only 1 company in this category
**No companies in this category.

Table 9: Industry Results of Sample Industries using Kruskall-Wallis Mean Ranks (higher numbers represent better performing ranks)

SIC Code	EVA Rank	ECA Rank	EVS Rank	ECS Rank	EVM Rank	ECM Rank
15	131	93	77	64	46	30
17	176	177	104	110	82	64
18	115	105	157	155	66	35
19	251	292	130	162	**	**
20	197	159	98	113	79	15
22	164	139	96	106	55	42
24	147	164	95	103	71	78
25	107	106	81	50	48	47
26	184	198	108	114	74	81
27	142	176	97	97	51	76
28	154	178	86	98	75	80
29	178	167	88	88	74	76
30	103	108	93	41	52	65
31	165	172	98	131	50	58
32	162	194	120	61	62	105
33	146	192	90	123	48	75
34	131	153	96	62	68	73
35	98	147	10	61	8	84
36	155	129	81	63	72	62

Table 10: Kruskal-Wallis Tests for Statistically Significant differences Among Industry

Efficiency Score$^+$	c^2 statistic	Degrees of Freedom	Significance
EVA	25.36	18	0.115
ECA	53.29	18	0.000*
EVM	17.45	17	0.424
ECM	42.73	17	0.001*
EVS	16.77	18	0.539
ECS	40.07	18	0.002*

$^+$**EVA** – Environmental Efficiency Score for all SME's; **ECA** – Economic Efficiency Score for all SME's.
EVS - Environmental Efficiency Score for small SME's; **ECS** – Economic Efficiency Score for small SME's.
EVM - Environmental Efficiency Score for medium SME's; **ECS** – Economic Efficiency Score for medium SME's.
* Statistically Significant difference at < .005 level

Table 11: Number and Percentage of Companies Exhibiting Various Returns-to-scale Results of (CCR) Constant Returns-to-scale Model for Environmental and Economic Efficiencies for Model Groupings

Model Category	Efficiency Type	Returns-to-scale*	Number of Companies	Average Size of Company
All Companies	Environmental (EVA)	IRS	37	20.6
		DRS	260	67.7
		CRS	2	50.5
	Economic (ECA)	IRS	31	50.2
		DRS	262	62.7
		CRS	2	125.5
Small-size Companies Only	Environmental (EVS)	IRS	22	11.8
		DRS	154	28
		CRS	2	21.5
	Economic (ECS)	IRS	3	50
		DRS	175	25.5
		CRS	0	--
Medium-size Companies Only	Environmental (EVM)	IRS	5	55.4
		DRS	113	118.4
		CRS	3	65.3
	Economic (ECM)	IRS	3	244.7
		DRS	118	111.2
		CRS	0	--

*IRS = Increasing Returns-to-scale
DRS = Decreasing Returns-to-scale
CRS = Constant Returns-to-scale

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