Application of an environmental valuation approach that incorporates externality costs in sustainability decision-making of the metallurgical sector

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Synopsis

Consideration of the economic, environmental, and social impacts associated with the life-cycle of a technology is of increasing importance for decision-making in industry. It has been suggested that economic assessment of technology deployment projects requires the translation of associated environmental effects into monetary values. This paper introduces an approach for identifying and evaluating environmental damage in monetary terms. The approach groups the environmental impacts associated with a technology life-cycle system into four main criteria: air, water, land, and mined abiotic resources. The valuation of the impacts on the resources consists of an economic cost benefit analysis (CBA) procedure that comprises four steps: the compiling of an impact inventory, a monetary valuation of the inventory, discounting, and a risk/uncertainty analysis. The monetary valuation step for impacts on air resources is primarily based on published externality costs for Europe and the United States, which are adopted and converted to reflect the South African context. Local opportunity costs are utilized for the other resource criteria. The damage costs are transformed into South African Rand at 2005 prices. The paper demonstrates how the approach may be applied in the assessment of projects in the metallurgical industry. Shortcomings in the approach are identified. For example, not all of the aspects that are considered necessary to assess environmental performances comprehensively can be valued in monetary terms. Also, certain values, specifically those pertaining to opportunity costs, need to be determined on a case-by-case basis. Furthermore, the uncertainties associated with the indicators obtained may strongly influence the usability of the results of an environmental performance assessment, e.g. future damage costs will change with fluctuations in the markets. It is concluded that although such an approach has merit in increasing the understanding of the potential financial implications of a technology's environmental performance, further research is required to improve the approach described if it is to be used further in the South African metallurgical industry. Damage cost estimates that are specific to South Africa need to be developed to reduce uncertainty, and the combination of both quantitative and qualitative approaches is recommended for comprehensive sustainability decision-making.

Introduction

Environmental legislation has become more stringent in compelling metallurgical organizations to take responsibility for the impacts of their activities on the environment. This responsibility is erected from a cradle-to-grave perspective, i.e. over the entire-life cycle of their operations[1]. It has further been suggested that if a proposed project may cause environmental harm, the total cost of damages needs to be included in the economic appraisal of the project[2]. Therefore, economic analyses carried out to ascertain the viability of projects in the metallurgical sector should also take into account all the costs and benefits generated by the projects, including positive or negative environmental impacts, from commissioning, through the operational life cycle phases, to decommissioning[2]. Other researchers have argued that in the past the environmental impacts of projects were not considered as part of economic assessment practices, making projects appear artificially more attractive than they were. Some of the reasons for not incorporating externality costs in the economic assessments of projects included a lack of appropriate methodologies to set a value on either the effects[3] or the environmental issues viewed as a constraint on business[4].

Published research relevant to the South African metallurgical industry that deals with environmental monetary valuation is limited. Most studies dealing with environmental valuation issues have been conducted in developed countries for other sectors, e.g. the energy sector in the European Union[5]. The study summarized in this paper[6] set out to answer the research question: can a monetary valuation approach that has been developed for the manufacturing sector[7,8] be applied in the metallurgical sector? The objective was to identify potential environmental indicators and consider their monetary valuation in a South African context.

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Table I

Environmental criteria and definitions

Criteria	Definition
Environmental sustainability	The environmental dimension concerns an organization's impacts on the environment due to an introduced technology. It has an external focus and addresses impacts on air, water, land and mined abiotic resources.
Air resources	Air resources assess a technology's contribution to regional air quality effects (e.g. visibility, smell and noise levels) as well as to global effects such as global warming and stratospheric ozone depletion.
Water resources	Water resources assess the availability of clean and safe water by focusing on a technology's impacts on the quantity and quality of water.
Land resources	Land resources assess the impacts a technology has on the quantity and quality of land resources, including aspects such as biodiversity, erosion, transformation and rehabilitation ability.
Mined abiotic resources	Mined abiotic resources assess a technology's contribution to the depletion of non-renewable mineral and energy resources.

Table II

Economic CBA procedure

Step	Description
Step 1 Inventory	Costs and benefits that are imposed by a company (as a by-product of its economic activity) on third parties are identified.
Step 2 Monetary valuation	*Cost approaches:* Cost approaches assess actual costs or hypothetical expenditures aimed at reducing or eliminating impacts. *Benefit approaches:* Benefit approaches, analyze how changes in environmental and social quality affect income or wealth generation in society. One technique that is used is to calculate the opportunity costs of preserving an asset, e.g. relocating an industrial plant to secure an ecologically sensitive area.
Step 3 Discounting	Environmental damage present actions will occur many years from now. The higher the discount rate, the lower the value that will be attached to these damages. The discount rate for externalities is strongly debated, and is addressed in the case study of this paper.
Step 4 Risk/Uncertainty	Case probabilities can be assigned to the likelihood that an event (industrial accident) will occur, or little is known about future impacts.

Defining appropriate environmental criteria and indicators

A number of integrated frameworks and proposed criteria to assess the sustainability of a deployed technology have been reviewed in the literature[9]. The environmental impacts associated with a technology life-cycle system have been grouped into the four main criteria of air, water, land, and mined abiotic or non-renewable resources[7,8,9,10] (see Table I).

A method has subsequently been developed for the manufacturing sector[7,8], and specifically for technology management purposes[10], to calculate the impacts in monetary terms as quantitative indicators. The monetary valuation method, based on the economic cost benefit analysis (CBA) procedure[11,12], is summarized in Table II and described in the sections below.

Method to determine monetary values of impacts for South Africa

Published externality monetary values for Europe and the United States were adopted and converted to reflect the South African context[3,7,8,10]. In the case of environmental impacts on a global scale, e.g. the release of gases that contribute to climate change, no adjustments to published values are required for South Africa. For local and regional impacts, the following assumptions were made:

- Damage costs to health vary in direct proportion to income[13];
- Damage costs to crops vary with market prices[3]; and
- Damage costs to buildings are reflected in restoration costs[10].

On the basis of these assumptions, a relationship for damage transfers across space was suggested[13,14], and modified to cater for transfer across time using consumer price indices (CPI) provided by Statistics South Africa, according to Equation [1][15]:

$$C_{SA} = C_{EU/US} \times \left[\frac{PPP(\chi)_{SA(1995)}}{PPP(\chi)_{EU/US(1995}}\right]^{\gamma} \bullet \left[\frac{CPI_{2005}}{CPI_{1995}}\right]^{0.1} \quad [1]$$

Where: C_{SA} = Unit cost in South Africa.
$C_{EU/US}$ = Unit cost in European Union / United States.
PPP = Purchasing Power Parity Index.
χ = GDP/capita or Price Level Index.
CPI = Consumer Price Index.
γ = Income elasticity.

An income elasticity (γ) of between 0.3 and 1.1 has been cited for goods that could reduce risk to life[16]. In order to ensure conservative benefit estimates for South Africa, an income elasticity of 1.0 was assumed for the main resource criterion.

Impacts of air pollution

Table III summarizes the atmospheric pollution damage cost estimates that were identified[14,17]. These were transformed into a South African unit of 'ZAR/kg pollutant at 2005 prices'.

Table III

Atmospheric damage cost estimates for South Africa in 2005 (adapted from Spadaro and Rabl[17])

Domain	Pollutant	Impacts	Costs, (€/kg_{poll})[a]	Converted costs, (ZAR/kg_{poll})[b]
Global	**CO_2-eq**	Global warming	0.0246	0.221
Local and regional	**PM_{10}** (primary)	Mortality, morbidity	15.4	90.7
(Health)	**SO_2** (primary)	Crops, materials, mortality	0.3	1.77
	SOx (via sulphates)	Mortality, morbidity	9.95	58.6
	NOx (primary)	Mortality, morbidity	small	Small
	NOx (via nitrates)	Mortality, morbidity	15.7	92.4
	NOx (via O3)	Crops, mortality, morbidity	1.5	8.83
	VOC (via O3)	Crops, mortality, morbidity	0.9	5.3
	CO (primary)	Morbidity	0.002	0.0118
Local and regional	**SO_2**	Buildings	0.3	9.59
(Buildings and crops)	**NO_2**	Crops	0.35	11.5
	VOC	Crops	0.2	6.43

a The damage costs assume an average population density of 80 persons/km^2, in 1995 prices.

b The damage costs converted to South African circumstances, in 2005 prices.

Table IV

Damage costs per hectare of selected land use types (adapted from Constanza *et al.*[20])

Type of Land[a]	Value per hectare (US$/ha/year), 1997	Value per hectare (ZAR/ha/year), 2005
Forests	302	1 022
Grass/rangelands	232	785
Wetlands[b]	14 785	50 018
Lakes/rivers[b]	8 498	28 749
Cropland	92	311

a The values of these specific land types are extremely regionally bound.

b The high damage costs of these affected land types are due to the scarcity of these natural assets in the specific regions where the study was conducted.

Impacts on water resources

The Department of Water Affairs and Forestry[18] regulates effluents stringently. It was assumed that steady-state releases to water resources are of minor importance in terms of environmental costs. The only externality considered with respect to water resources was the quantity of water used in the evaluated system. This is expressed as the difference between the price and the true opportunity cost of water, i.e. the cost of depriving the next best user of the use of that water[3]. The externality cost of water for all inland regions of South Africa was estimated in 2002[6,19] to be R2.67/m^3.

Impacts on land resources

The consequences of land use are changes in biodiversity; erosion; transformation; and rehabilitation ability[9]. The damage costs associated with the occupation or use of land were adopted from Constanza *et al.* (see Table IV)[20]. Estimates of the economic costs of biodiversity loss for South Africa were obtained by making adjustments to the adopted values for regional differences in ecological sensitivity:

➤ Land pollution: It is assumed that solid waste is managed according to the Department of Water Affairs and Forestry guidelines[21]. The impact of land pollution attributable to these types of operation is considered negligible.

➤ Land rehabilitation: The Department of Minerals and Energy of South Africa has drafted guidelines[22] for calculating closure and rehabilitation costs for mines and processing plants; and these are adopted and used in calculating closure and rehabilitation costs.

Impacts on mined abiotic resources

Mangena and Brent[23] have argued that the impact of the minerals extraction sector on mined abiotic resources is directly associated with the productivity of the sector. A reduction in the impact on non-renewable resources would therefore constitute a reduced economic contribution from the sector. It is proposed to exclude the environmental costs of the burden of the mineral extraction industry, which is highly dependent on supportive mining activities, in terms of non-renewable resource depletion.

Integrating the indicator externalities into technology assessment

For the purpose of an economic evaluation that is performed in the metallurgical sector, a cash flow analysis and associated net present values (NPV) are normally calculated. An expected project life of 20 years is often applied. Currently there is no consensus on the discount rate for externalities[3,11,12], and to consider externalities in an economic evaluation a sensitivity analysis on the discount rate is subsequently suggested (see discussion below). The total potential external costs are then deducted from the projected cash flows. Figure 1 illustrates how damage costs are integrated to the economic evaluation, which Brent *et al.*[7,8] have described in detail. The application of the approach for incorporating externalities into project financial analyses is demonstrated by the case study below.

Case study in the minerals beneficiation industry

The case study is based on the production of steel in the South African metallurgical industry[6]. Direct production of steel from iron ore has an environmental impact on all natural resources. The case study is intended to improve the understanding of possible practical obstacles to the environmental valuation approach.

Application of an environmental valuation approach

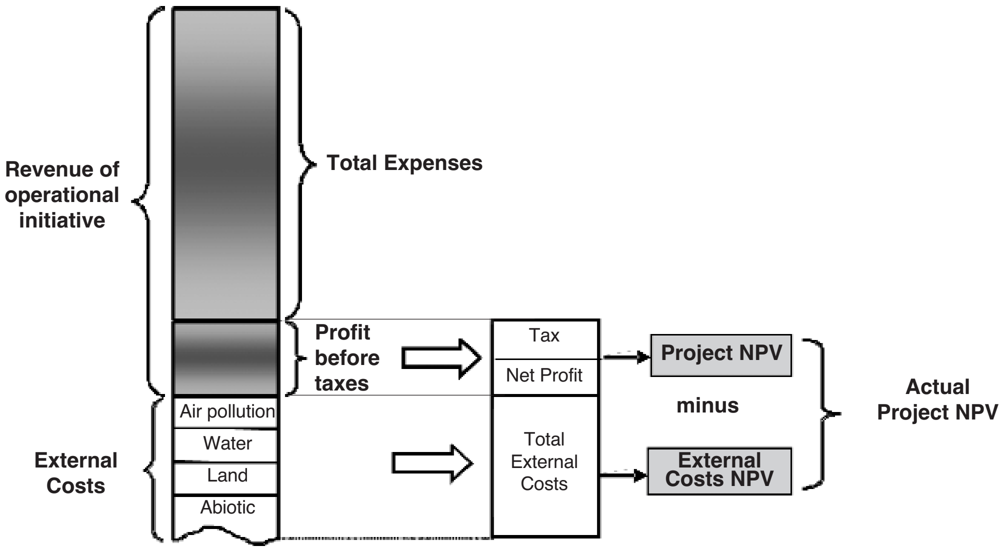

Figure 1—Schematic model for incorporating externalities into an economic analysis of a project (from Brent *et al.*[7])

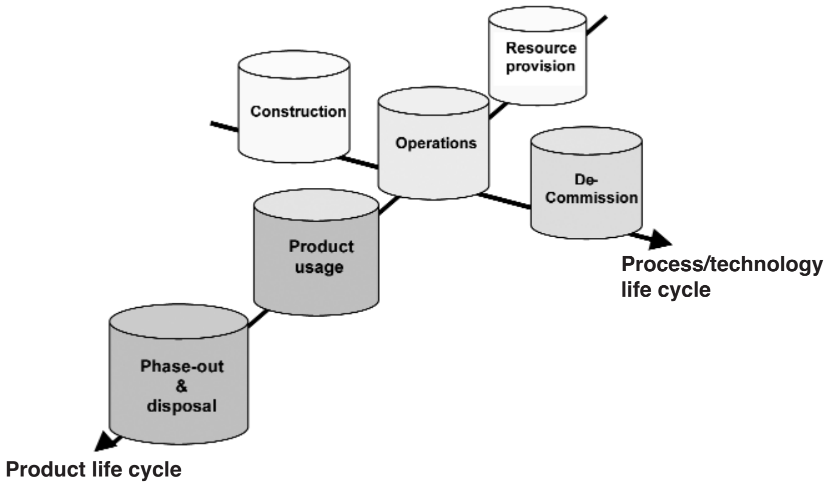

Figure 2—Life cycle phases of a deployed technology (from Brent *et al.*[8])

The functional unit

A functional unit is imperative for environmental life cycle assessment (LCA) studies[23]. It provides the reference in terms of all impacts are translated. For this study[6], the functional unit 1.0 tonne of steel produced was chosen.

System boundaries

The environmental impacts resulting from a deployed technology can be attributed to two distinct life-cycles[24]:

- ➤ Life-cycle of the technology or the physical asset; and
- ➤ Life -cycle of the product (or service) that arises from the implemented technology or physical asset.

Figure 2 illustrates the integration of these two life-cycles in a technology for the process industry.

For the purposes of this case study, only the environmental impacts associated with process or technology life-cycle phases were considered. To simplify the undertaking, the impacts resulting from resource provisioning, product usage, phase-out and disposal were not assessed. (This type of LCA is referred to as a gate-to-gate analysis)[23].

Data gathering

Data sources included reports from pilot tests and mass balance software calculations in the steel industry, personal discussions with production personnel and other experts, the findings published in the literature and project-specific reference materials[6].

Overview of monetary indicators for the case study

The monetary impact indicators for the three resource groups (of Table I) considered applicable to the case study are summarized in Table V[6].

Environmental accounting

By applying the monetary indicators (Table V) the influence of the externalities on the current project NPV was determined (Table VI) for different discount rates for externalities (Table II).

Discussion

The dimensions of negative impacts on the environment, if accounted for in monetary terms, has a considerable

Table V

Damage costs of selected environmental indicators[6]

Main criteria	Sub-criteria	Indicator	Cost ($ZAR_{2005/tonne\ steel}$)
Air	Local and Regional pollution	Impacts on human health due to:	
		SO_2	R4.60
		NO_x	Negligible
		PM_{10}	R474.36
		Photochemical ozone	R86.02
		Impacts on buildings due to:	
		SO_2	R24.93
		Impacts on crops (in R_{2005}/kg_{poll}) due to:	
		Photochemical ozone	R104.36
	Global pollution	Impacts (in R_{2005}/kg_{poll}) due to	
		Greenhouse Gases (equivalent CO_2)	R94.81
Water	Water use	Difference between opportunity costs and water price	R1.60
	Water pollution	Remedy costs	Negligible
Land	Land use	Opportunity costs for the total area affected	R4.03[a]
	Land pollution	Remedy costs	Negligible
	Site rehabilitation	Remedy costs	R1.34[b]

a The production plant occupies 3 hectares of land.
b An operational life of 20 years at 100 000 tons per annum has been assumed.

Table VI

Environmental accounting results discounted at various rates for the case study

Step	Year	2005 (ZAR)	2005 (ZAR)	2005 (ZAR)	2005 (ZAR)
1	Project NPV	105,483,405	105,483,405	105,483,405	105,483,405
2	External Costs discount rate	4%	8%	12%	15%
3	Atmospheric Pollution	(103,826,505)	(77,892,279)	(61,454,160)	(53,150,245)
4	Water Use	(226,426)	(169,870)	(134,020)	(115,910)
5	Land Use	(216,320)	(162,288)	(128,038)	(110,737)
6	Site Rehabilitation	(367,640)	(172,828)	(83,508)	(50,170)
7 = 3+4+5+6	Total Environment	(104,636,891)	(78,397,965)	(61,799,726)	(53,427,063)
8 = 1-7	Actual Project NPV	846,514	27,085,440	43,683,678	52,056,542
	Year when positive cash flows is experienced	Year 2016	Year 2022	OK	OK

influence on the economic viability of the project. The monetary evaluation approach identifies atmospheric pollution as the greatest environmental impact associated with the case study. Site rehabilitation costs are incurred, as it is a Department of Minerals and Energy regulatory requirement. Together with land use during the operational life cycle phases, these account for the second highest externality costs. Additionally, water is a scarce resource in South Africa[25]; hence the externality cost of water usage is also of significance.

Externality costs are very sensitive to the discount rate used for estimating the present value of future damage costs applying to a long-term perspective. The choice of discount rate is much debated in the literature[3]. Conway-Schempf[26] argues that high discount rates, e.g. rates matching the cost of capital, are inappropriate for promoting sustainable development. The Department of Environmental Affairs and Tourism[27] recommends between 6%–10%[28] for South Africa. However, it has been proposed[3,8,10] that for a country like ours which has a mixture of First and Third World conditions, a discount rate of 4% should be adopted. As no clear recommendation exists on the appropriate environmental discount rate for South Africa, several rates, ranging from 1%–16%, were tested for sensitivity (see Figure 3). The implication of lower discount rates is that higher net present damage costs are obtained, owing to the greater weighting of the present values of long-term impacts, and vice versa.

Figure 4 shows the influence of the discount rate on the economic viability of a project: at a rate of 4% the project NPV is just above break-even point, whereas at 8% the project NPV is above R27 million. This underlines the importance of the choice of discount rate for decision-makers, because it can influence the long-term economic viability of a deployed technology considerably.

The monetary valuation procedure reveals three limitations. Firstly, it is not possible to express the concept of environmental sustainability in monetary terms in a comprehensive manner because not all of the aspects that are

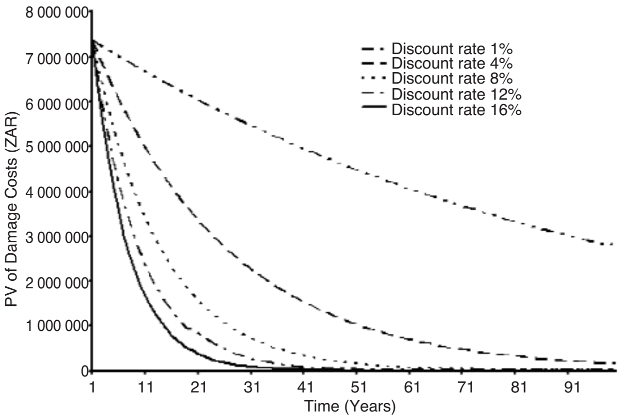

Figure 3—Effect of discount rate on present value of damages associated with the case study

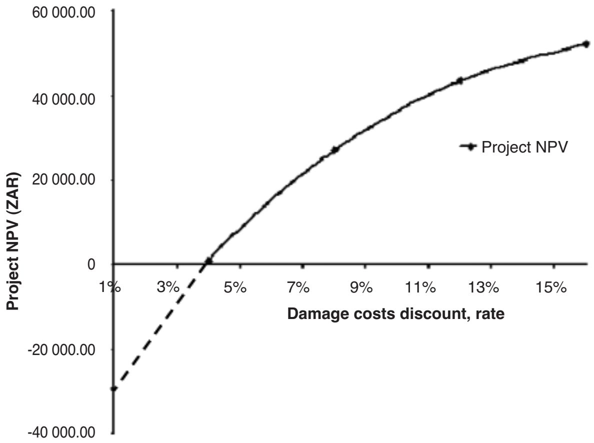

Figure 4—Effect of discount rate on the net present value of damages associated with the case study

Table VII

Damage costs confidence intervals for the case study (adapted from ExternE[5])

Receptors	Indicator	68% Confidence Interval		Geometric Factor Use
		Minimum $ZAR_{2005/tonne\ steel}$	Maximum $ZAR_{2005/tonne\ steel}$	
Human Health	SO_2	22.35	162.92	Total geometric standard deviation, factor 2.7
	NO_x	34.23	249.54	
	PM_{10}	33.58	244.77	
	CO	0.0044	0.0318	
	VOC	1.96	14.30	
Buildings	SO_2	2.82	32.59	Factor 3.4[a]
Crops	VOC	1.89	21.85	Factor 3.4
Crops	NO_2	3.37	39.01	Factor 3.4
Global	CO_2	0.0886	0.5535	Factor 2.5[b]
Water resources	Water use	0.47	5.44	Factor 3.4
Land resources	Land use	1.19	13.70	Factor 3.4

a Economic valuation geometric standard deviation.
b Global warming geometric standard deviation.

considered relevant to assess environmental performances can be measured quantitatively. Secondly, values used by the different indicators, specifically those pertaining to opportunity costs, have to be evaluated on a case-by-case basis. Thirdly, the uncertainties associated with the indicators obtained may strongly influence the usability of the results of an environmental performance assessment, e.g. future damage costs will change with fluctuations in the markets. The European Union's ExternE project[5] attempted to handle uncertainty on the basis of geometric standard deviations[5]. The project yielded a wide spread of values that should be taken into account when applying the environmental indicators (see Table VII).

Conclusions

This paper introduces a modified environmental valuation approach for the conversion of potential external impacts into monetary values for the appraisal of a technology deployment project in the metallurgical sector. For the sector three main environmental criteria are proposed for which environmental cost indicators are identified, i.e. emission cost indicators (SO_X, NO_X, PM_{10}, CO and CO_2, and VOC) and opportunity cost indicators (land and water resources usage). Monetary values are placed on the selected indicators by translating into the South African context damage costs which have been proposed in other countries. A case study in the metallurgical sector is used to demonstrate the application of this procedure. Certain limitations are pinpointed through the case study. It is concluded that although such an approach has merit in increasing the understanding of the potential financial implications of a technology's environmental performance, further research is required to improve the approach if it is to be used in the South African metallurgical industry. The following recommendations are suggested:

- Further damage cost estimates specific to South Africa need to be developed. As discussed, the uncertainty of data is considered the main problem for using the outcome of the monetary valuation procedure in decision-making.
- A combined quantitative and qualitative valuation of environmental indicators is proposed. Damage costs for some selected environmental indicators, e.g. damage to land resources, are not fully reflected by monetary valuation. Further qualitative analyses may be necessary, possibly by integrating monetary valuation outcomes with multi-criteria decision-analysis techniques.

References

1. SWART, E. *A regulatory framework for mining environmental management within South Africa*. Department of Minerals and Energy, website: http://www.dme.gov.za/minerals/pdf/New_Act.pdf, accessed on 17 May 2006.

2. SILVA, P. and PAGIOLA, S. A review of the valuation of environmental costs and benefits in World Bank projects. *Environmental Economic Series*, 2003, Paper 94, website: http://econwpa.wustl.edu:80/eps/othr/papers/0502/0502007.pdf, accessed on 17 May 2006.

3. VAN ERCK, R.P.G. *Monetary evaluation of business sustainability, Case Study: GTL fuel production in South Africa*. Master's thesis, Technical University of Eindhoven, and Department of Engineering and Technology Management, University of Pretoria, 2003.

4. WINGARD, C.H. *Financial performance of environmentally responsible South African listed companies*. Doctoral thesis, University of Pretoria, 2001.

5. ExternE Core Project. *Maintenance, Improvement, Extension an Application of the ExternE Accounting Framework*. European Union Contract No. JOS3-CT95-0002, 1997, website: http://externe.jrc.es/meth2.pdf, accessed on 17 May 2006.

6. NYOKA, M. *Internalising environmental costs: A case study of the minerals extraction industry in South Africa.* Master's project, Department of Engineering and Technology Management, University of Pretoria, 2005.

7. BRENT, A.C., VAN ERCK, R.P.G., and LABUSCHAGNE, C. Sustainability Cost Accounting: Part 1—A monetary procedure to evaluate the sustainability of technologies in the South African process industry. *South African Journal of Industrial Engineering*, 2006, vol. 17, no. 2, pp. 35–51.

8. BRENT, A.C., VAN ERCK, R.P.G., and LABUSCHAGNE, C. Sustainability Cost Accounting: Part 2—A case study to demonstrate and assess the introduced monetary procedure to evaluate the sustainability of technologies in the South African process industry. *South African Journal of Industrial Engineering*, vol. 18, no. 1, pp. 1–17.

9. LABUSCHAGNE, C., BRENT, A.C., and VAN ERCK, R.P.G. Assessing the sustainability performances of industries. *Journal of Cleaner Production*, 2005, vol. 13, no. 4, pp. 373–385.

10. BRENT, A.C., VAN ERCK, R.P.G., and LABUSCHAGNE, C. A sustainability cost accounting methodology for technology management in the process industry. *14th Conference of the International Association of Management of Technology (IAMOT)*, Vienna, Austria, 2005.

11. BLIGNAUT, J.N. *Environmental Accounting in South Africa*. Doctoral thesis, University of Pretoria, 1995.

12. VAN PELT, M.J.F. Ecologically sustainable development and project appraisal in developing countries. *Ecological Economics*, 1993, vol. 7, pp. 19–42.

13. MARKANDYA, A. and BOYD, R. *Economic valuation of environmental impacts and external costs*. Metroeconomica Consultants, Ltd, Bath, UK, 2000.

14. SPADARO, J.V. *Monetary values*. Riskpoll (Version 1.04), 2005, website: http://www.arirabl.com, accessed on 17 May 2006.

15. PARK, S.P. *Fundamentals of engineering economics*. Prentice Hall, Upper Sadle River, NJ, 2004.

16. PEARCE, D.W. and HOWARTH, A. *Technical report on methodology: Cost Benefit Analysis and policy responses*. RIVM report 481505020 commissioned by the Environment Directorate-General of the European Commission, Brussels, 2000, website: http://europa.eu.int/comm/environment/enveco/priority_study/methodology.pdf, accessed on 17 May 2006.

17. SPADARO, J.V. and RABL, A. Air pollution damage estimates: the cost per kilogram of pollutant. *International Journal of Risk Assessment and Management*, 2002, vol. 3, no. 1, pp. 75–97.

18. Department of Water Affairs and Forestry (DWAF). *Water Quality Management in South Africa*. 2001, website: http://www.dwaf.gov.za/dir%5Fwqm/wqm%5Fwastedispland.htm, accessed on 17 May 2006.

19. NIEUWOUDT, W. *Water Market Institutions In South Africa, Lessons From Colorado*. Department Of Agricultural Economics, University Of Natal, Pietermaritzburg, 2002.

20. CONSTANZA, R., D'ARGE, R., DE GROOT, R., FARBER, S., GRASSO, M., HANNON, B., LIMBURG, K., NAEEM, S., O'NEILL, R.V., PARUELO, J., RASKIN, R.G., SUTTON, P., and VAN DER BELT, M. The Value of the World Ecosystem Services and Natural Capital. *Nature*, 1997, vol. 387, no. 15, pp. 253–260.

21. Department of Water Affairs and Forestry (DWAF). *Minimum requirements of the handling, classification and disposal of hazardous waste*. Second edition, CTP Book Printers, Cape Town, 1998.

22. Department of Minerals and Energy (DME). *Guideline document for the evaluation of the quantum of closure-related financial provision provided by a mine*. Official guideline as contemplated in Regulation 54(1) to the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002). Rev 1.6, 2004, Available from: http://www.dme.gov.za.

23. MANGENA, S.J. and BRENT, A.C. Application of a Life Cycle Impact Assessment framework to evaluate and compare environmental performances with economic values of supplied coal products. *Journal of Cleaner Production, 2006*, vol. 14, no. 12–13, pp. 1071–1084.

24. LABUSCHAGNE, C. and BRENT, A. C. Sustainable Project Life Cycle Management: The need to integrate life cycles in the manufacturing sector. *International Journal of Project Management*, 2005, vol. 23, no. 2, pp. 159–168.

25. LEIMAN, A. and STANDISH, B. Privatisation in the water industry of South Africa: Identifying relevant issues. *Trade and Industry Monitor*, 2001, vol. 17, no. 3, pp. 6–10.

26. CONWAY-SCHEMPF, N. Full Cost Accounting: *A course module on incorporating environmental and social costs into traditional business accounting systems*. Carnegie Mellon University, Pittsburgh, 1998, website: http://www.p2pays.org/ref/21/20348.pdf, accessed on 17 May 2006.

27. Department of Environmental Affairs and Tourism (DEAT). *Cost Benefit Analysis*. Information Series, 2004, website:http://www.environment.gov.za/Documents/Publications/2005Jan7/Book3.pdf, accessed on 17 May 2006.

28. Conningarth Economists. *A manual for cost benefit analysis in South Africa with special reference to water resource development*. WRC Report GT177/02, Water Research Commission, Pretoria, 2002. ◆