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**THE EFFECTS OF GOVERNMENT ENVIRONMENTAL POLICY ON COSTS AND
COMPETITIVENESS -- IRON AND STEEL SECTOR**

This document will be considered by the Steel Committee at its meeting on 13-14 November 1997.

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SUMMARY

Background

At its meeting on 12-13 June 1997, the Steel Committee requested the Secretariat to explore ways that the Committee could build on the work being done on environmental issues in other fora [DSTI/SI/SC/M(97)1, paragraph 24]. This, it was noted, could include examining the effects on trade of different national environmental regulations.

In support of this work, a document has been prepared on *The Effects of Governmental Policy on Costs and Competitiveness -- Iron and steel sector*. The report, which was prepared by consultants¹, provides a framework for analysing the effects of environmental regulation on the competitiveness of steel producers. The report:

- identifies elements of government policy which affect production costs and competitiveness;
- proposes a methodology for analysing the effects of governmental environmental policies on production costs and competitiveness, on a cross-country basis;
- differentiates environmental costs from other production costs; and
- raises issues for further discussion.

Please note that the dollar amounts referred to in the report are US dollars. The report has been edited by the Secretariat, but in no way which alters the information, arguments or conclusions contained in the original draft.

Report conclusions

The report concludes that it is not possible to link environmental regulation and competitiveness directly or clearly. Any attempt to link the two must consider environmental regulation in the context of other critical factors which affect the ability of a business to respond to pressures in an innovative, efficient and adaptable manner. These include:

- the institutional and political relationships between policymakers and industry;
- the quality and consistency of environmental policy and regulation; and
- the approach of companies in responding to environmental regulation.

1. Dr. Alison E. Simpson and Mr. Edmund Mangan.

The report provides estimates of the costs for controlling the different types of pollutants generated in steelmaking. These are as follows:

- *Air borne pollutants:*
 - *Particulate matter (such as heavy metals).* The capital and operating costs for different types of particulate removal technologies can vary by up to a factor of 18. Average particulate abatement costs are estimated at \$18 per tonne of pollutant removed.
 - *Gases [principally sulphur-oxides (SOx) and nitrogen-oxides (NOx)].* In most countries gaseous emissions are controlled by careful selection of fuels and raw materials. Where additional controls are required, due to strict standards, costs for the needed technologies can be costly. Indicative capital costs range from \$300 to \$700 per tonne of pollutant removed for sulphur-oxide gases, and from \$100 to \$200 per tonne of pollutant removed for nitrogen-oxide gases.
- *Wastewater pollutants.* The cost of pollution controls depends on wastewater flows, which can be twenty times higher in developing countries due to poor water management. Indicative costs for treatment \$1 500 per m³/h for larger plants, but these costs may increase ten-fold for secondary and tertiary treatment. Discharge fees can also be a significant contributor to overall costs.
- *Solid waste.* Costs depend on classification systems and landfill costs.

Particulate and wastewater treatment generally contribute to the main cost of environmental compliance. In the OECD area, direct environmental costs are believed to account for one to five per cent of production costs, but this figure does not take indirect costs or savings.

Recommendations for further work

The report recommends that further work be undertaken to examine how environmental costs can be reliably quantified and accurately related to production costs, and to examine how a weighting system could be incorporated into the methodology to provide a scoring system which accurately reflects comparative costs and cost-effectiveness.

ACTION

The report is for consideration at the 13-14 November 1997 meeting of the Steel Committee.

RELATED DOCUMENTS

DSTI/SI/SC/M(97)1, paragraph 24.

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THE EFFECTS OF GOVERNMENT ENVIRONMENTAL POLICY ON COSTS AND COMPETITIVENESS -- IRON AND STEEL SECTOR

EXECUTIVE SUMMARY

1. Sustainable development depends on a balance between environmental effectiveness and economic competitiveness. This paper takes a preliminary view of this balance, to determine the relationship between environmental policies, regulations and standards and environmental performance, production costs and business competitiveness in the iron and steel sector. It proposes an outline methodology for comparative analysis of the costs and cost-effectiveness of environmental compliance.

2. For the purposes of this paper, and because of the globalisation of the iron and steel market, competitiveness is related to overall production costs, and is taken to encompass success on the domestic as well as the international market. Competitiveness is maximised where production costs are minimised, and is determined by the ability of a business to respond to changing circumstances in an efficient, innovative and adaptable manner.

3. Despite considerable study, it has not been possible to directly or clearly link environmental regulations and competitiveness. Any attempt to correlate environmental regulations and production costs must consider environmental regulations in the context of other critical factors which affect the ability of a business to respond to pressures in an innovative, efficient and adaptable manner. These include: institutional and political relationships between policy makers and industry; the quality and consistency of environmental policy and regulations; and the approach of the business in responding to environmental policy.

4. Traditional iron and steel processes, which account for the bulk of production in developing and developed countries, use the blast furnace for pig iron production, and the basic oxygen furnace or electric arc furnace for steel making. These processes are technologically complex and have the potential to significantly impact the environment if wastes and emissions are not managed effectively.

5. Because of the multitude of potential pollution sources and pollutants associated with iron and steel processes, it is necessary to focus on those which have significant environmental impact, and will comprise a major portion of environmental protection costs. These are particulate matter (including heavy metals), sulfur-oxides (SO_x) and nitrogen-oxides (NO_x) emissions to air; wastewater treatment; and hazardous solid waste. Particulate control and wastewater treatment generally contribute to the main cost burden of environmental compliance.

6. Pollution control methodologies adopted in response to the introduction of environmental regulations and standards related to each of these sources and pollutants, include direct retrofit of end-of-pipe controls, and the introduction of process changes to minimise waste at source. The first option represents one of maximum cost and least value-added, and is frequently adopted in developing countries. The second option is increasingly used in developed countries. It is more cost-effective, but requires innovation, efficiency and adaptation.

7. The choice of pollution control technology depends on the degree of removal required and waste stream characteristics. Different technologies involve different costs, and achieve different levels of environmental performance. A technical and financial analysis of pollution control technologies shows how environmental standards can dictate the selection of the control technology, and thus the costs of control.

8. Capital and operating costs of different forms of particulate removal technologies vary by up to a factor of 18, relative to those for cyclones². Where environmental regulations are lenient or unenforced, cyclones can be used instead of more costly bag filters, wet scrubbers and electrostatic precipitators, with significant cost advantage. Average particulate abatement costs for the iron and steel sector are estimated to be \$182/tonne pollutant removed.

9. In most countries, NO_x and SO_x emission levels are controlled by careful selection of fuels and raw materials. In addition, low emission burners and modern combustion systems can be used to control NO_x emissions. Where stricter standards apply, the need for additional pollution control technologies can present considerable cost disadvantage. Indicative capital costs for SO_x and NO_x removal are \$300-700 and \$100-200/tonne pollutant removed, respectively.

10. Current wastewater technologies are established. Costs depend on wastewater flows. Because of poor water management in developing countries, wastewater flows may be 20 times higher per tonne of product than the industry norm. Technology depends on the level of treatment required, which will in turn depend on the receiving environment (sewer vs surface water body). Technology therefore also determines costs. Indicative costs for standard treatment plant are \$1 500 per m³/h for larger plants, but these costs may increase ten fold for secondary and tertiary treatment. Discharge fees may be a significant contributor to overall costs.

11. Differentials in solid waste management costs arise where there are different hazardous waste classifications (and therefore regulated controls) and landfill costs.

12. Using as a focus those pollution sources and pollutants which are most likely to impact on environmental costs in the iron and steel sector, environmental standards can be set in the context of other critical factors to be used as a comparative tool in determining potential costs and cost-effectiveness of environmental compliance.

13. A comparison of the environmental standards applicable to the United Kingdom, Egypt and the World Bank for the significant pollution sources and pollutants indicates the relationship between regulations, technologies and costs. The stringency of standards is an important criteria in considering the environmental control technology required to meet compliance, and the costs of compliance.

14. A cross country comparison of environmental standards will therefore provide a semi-quantitative comparison of potential costs of compliance. However, actual costs will be influenced by the innovation, efficiency and adaptability of the business response to the standards imposed. This in turn will depend on general aspects of government environmental policy and quality of business strategy.

15. The outline methodology combines semi-quantitative and qualitative analysis to consider the impacts of environmental standards on costs and cost-effectiveness of environmental protection, within the context of the three critical success factors for balancing environmental effectiveness with business

2. Cyclones are the most common and least costly technology employed to remove particulates from fluid streams.

competitiveness: institutional and political factors of government environmental policy, the potential quality of industry response to this policy, and the potential quality of regulatory tools.

16. The methodology comprises six steps:

- semi-quantitative comparison of costs of compliance for different technology options, based on a comparison of regulatory standards for significant sources and pollutants and technologies required to meet these regulatory standards;
- qualitative assessment of strategy of government environmental policy;
- qualitative assessment of potential of business to be innovative, efficient and adaptive in response to environmental policy;
- qualitative assessment of potential for regulatory factors to promote innovation;
- qualitative comparison of the position of each facility with respect to innovative potential, costs of compliance and cost-effectiveness of expenditure;
- combination of semi-quantitative and qualitative analysis to compare costs and cost-effectiveness of environmental protection, within the context of the critical success factors for balancing environmental effectiveness and economic competitiveness.

17. Absolute environmental costs are difficult to define, measure and compare because of universal uncertainties surrounding environmental cost accounting. This restricts quantitative comparisons of environmental costs and cost-effectiveness, which in turn restricts the accuracy of correlating environmental costs to overall production costs and competitiveness.

18. Production costs are determined by a number of contributory factors. The impact of a change in any one factor on overall production costs will be determined by the ability of the business to redress the balance between factors. In OECD, direct environmental costs are believed to account for 1-5 per cent of production costs, but this figure does not consider indirect costs or savings. Relative to costs of labour, materials, energy and financial expenses, environment costs are expected to be lower determinants of overall business viability and competitiveness.

19. Competitive advantage depends on how effectively money is spent and not on how much money is spent. Effectiveness depends on the ability of the business to minimise loss of shareholder value caused by environmental costs. There is a positive correlation between environmental cost effectiveness and business competitiveness.

20. The methodology developed is not considered definitive. Rather, it should be a starting point to initiate further study and development of an effective tool which can be used by the OECD steel group for cross country analysis.

21. It is recommended that a case study be used during the further development stage, in order to ensure that a practical and useable methodology is developed. This case study should involve the active analysis of two or more iron and steel facilities in different countries. The aim will be to create a manual for determining how environmental policies, regulations and standards in each country potentially affect the production costs and competitive position of the facilities; standardise an accounting procedure for cost comparisons; and evaluate what policies and regulations might be appropriate for different countries.

1. INTRODUCTION

22. More and more, business sustainability depends on a balance between enhancing competitiveness and meeting environmental demands, particularly where competitors abroad operate within different governmental environmental policy regimes. The relationship between environmental policy and business competitiveness is one which has been little understood by both policy makers and the business community, but is receiving increasing focus as the issue of sustainable development is addressed.

23. In their quinquennial meeting in 1996, OECD Environment Ministers identified the links between globalisation and environmental policies as a research priority. This research should entail a deeper examination of the connections between environment and competitiveness, employment, investment, trade and technology.

24. With respect to the current work, OECD wishes to gain insight into the effect of government environmental policies on competitiveness in the iron and steel sector. This paper takes a preliminary view of how different environmental policies affect industry response to environmental performance improvement, production costs, and ultimately competitiveness. It aims to:

- review elements of government environmental policy which impact production costs and business competitiveness;
- identify an appropriate methodology for comparative analysis of the effects of government environmental policy on production costs and business competitiveness in the iron and steel sector;
- differentiate between environmental costs and other production costs;
- raise issues for further discussion and study.

25. The paper hereafter is set out as follows:

- section 2 defines competitiveness in the context of the iron and steel sector, and relates this to production costs;
- section 3 considers the relationship between environmental policy and business competitiveness, to define critical factors which link the two;
- section 4 reviews iron and steel production processes and considers which aspects of environmental regulations can be used as a comparative tool in determining potential costs of environmental protection in this sector;
- section 5 proposes an outline methodology to compare the costs of environmental compliance of iron and steel facilities in different countries, by considering selected aspects of environmental regulations in the context of general environmental policy and business strategy;
- section 6 considers how environmentally-related costs and cost-effectiveness are related to business competitiveness;

- section 7 provides conclusions;
- section 8 identifies areas for further study.

2. BUSINESS COMPETITIVENESS

26. Competitiveness is the ability of a business to sell in competition to foreign competitors. Theoretically, it should refer to exported products only. However, since the iron and steel market is globalised, and the price of iron and steel sold locally, even in developing countries, is generally based on international prices, it is assumed that, in the iron and steel sector, the term competitiveness can be applied to total production.

27. For current purposes, then, because of the globalisation of the iron and steel market, competitiveness is related to overall production costs and profitability. It is taken to encompass success on the domestic as well as international market, and reflects costs of production against sales. Lower unit-specific production costs are assumed to enhance profitability and competitiveness, while higher production costs will reduce profitability and hinder competitiveness.

28. The competitive position of a business is determined by its overall performance with respect to various contributory factors, such as capital depreciation, labour, energy, material inputs, and environmental demands.

29. Competitiveness can be broken into three components: efficiency, innovation and adaptation³. Efficiency involves directing resources where they are valued most. Innovations involve the search for better products, and better ways of producing existing products. Adaptation is the speed of imitation of superior techniques developed elsewhere. All three components are essential if the competitive position of a business is to be maximised.

30. Improved competitiveness is generally correlated to improved productivity. Productivity may be defined as the efficiency of transforming inputs into outputs⁴, and is usually a determinant of real income. Productivity growth implies increased output with the same input.

31. The following discussion therefore considers the relationship between environmental policy and business competitiveness, where production costs are used as an indicator of competitiveness, and competitiveness is determined by factors which affect business efficiency, innovation and adaptation.

3. ENVIRONMENTAL POLICY AND BUSINESS COMPETITIVENESS

32. This section considers the relationship between environmental policy and business competitiveness, to define critical factors which link the two. Since environmental policy often manifests itself in environmental regulations, many researchers have tried to identify a direct relationship between regulations and competitiveness. As the text below verifies, this has not proved possible. Rather, the

3. Economic Council of Canada, *Competitiveness and the Design of Regulations*, December 1992.

4. Robert Repetto, Dale Rothman, Paul Faeth and Duncan Austin, *Has Environmental Protection Really Reduced Productivity Growth: We Need Unbiased Measures?* World Resources Institute, 1996, ISBN 1-56973-101-2.

consultant proposes that any attempt to correlate environmental regulations and business competitiveness must consider environmental regulations in the context of those aspects of general environment policy which affect the ability of a business to respond to pressures in an innovative, efficient and adaptive manner.

Environmental regulations and business competitiveness

33. The implementation of government environmental policies and regulations alters the commercial conditions for industry. In the 1970's and 1980's, it was generally believed that environmental regulations were imposing excessive costs on industry, thereby reducing the competitiveness of industry in OECD countries, where environmental regulations were increasingly stringent by comparison to developing countries. The effect of reduced competitiveness was believed to be most severe for environmentally sensitive industry sectors, such as the iron and steel sector⁵. Especially among OECD countries, concerns over competitive disadvantage have manifested themselves in numerous policy initiatives, including attempts to harmonise environmental standards.

34. Opposing economic thought suggests that, under certain conditions, where industry responds creatively, environmental regulations can actually promote growth and competitiveness. This hypothesis builds on the fact that, in today's global marketplace, the ability to innovate, adapt and use resources efficiently is a greater determinant of business success than traditional factors of comparative advantage (such as the availability of low cost resources or labour). A combination of tough regulations and informed and continuous dialogue between industry and policy makers can stimulate the development of superior technologies and improved corporate performance. These benefits may outweigh some or all the costs of increased standards and may enhance competitiveness or minimise loss of competitiveness.

35. Alternative revisionist views of environmental regulations have emerged in the 1990's. These views accept that environmental regulations continue to require large and continuous investments in environmental protection, but that there is no direct, clear or consistent link between environmental regulations and competitiveness. Environmental regulations alone neither restrict competitiveness nor adversely impact trade and investment flows. Nor do stricter environmental regulations actually improve competitiveness.

5. According to an unpublished paper by Satish Joshi of the John Heinz School of Public Policy and Management, Carnegie Mellon University, Pittsburgh (1995), the debate has been particularly heated in the US steel industry. Between 1973 and 1992, intense regulatory activity coincided with a drop in steel production from 150 million tonnes to 93 million tonnes, a drop in steel capacity of 40 million tonnes, and reduced employment from over 500 000 to 140 000 people.

36. Recent findings by international organisations include the following:

- Economists of the World Resources Institute⁶ have found little evidence that costs of environmental protection have affected the competitiveness or profitability of US firms or reduced the number of jobs in the economy. Industrial facilities with poor environmental records are no more profitable than cleaner ones in the same industry, even after normalisation for size, age and technology.
- International economists from schools at John Hopkins and Harvard Universities, have found no evidence to suggest that environmental regulations have measurable adverse effects on: net imports, relocation of industry (from highly regulated to less regulated countries), investment decisions (in highly regulated countries as opposed to less regulated countries), and productivity⁷. Environmental regulation would only increase production costs if technologies, products, processes and customer needs are fixed⁸.
- Investigations on behalf of OECD conclude that pollution control costs are a small portion of total costs in most sectors, and that environmental regulations have not been the source of significant manufacturing cost differentials among OECD countries, having minimum effects on overall trade between OECD and non-OECD countries or on relocation of industry from developed to developing countries⁹.
- Investigations by the World Bank have found no self-evident or systematic relationship between regulatory standards and competitiveness. A report¹⁰ reviewed trends in world trade between 1970 and 1990, in products from industries which spend most to comply with environmental regulations (including the iron and steel industry). It concluded that higher environmental standards in developed countries do not tend to reduce their international competitiveness in these environmentally sensitive goods.
- According to the CBI¹¹, costs incurred in response to environmental regulations are unlikely in themselves to shift competitive advantage significantly, as they comprise only a small

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6. Robert Repetto, Jobs, Competitiveness and Environmental Regulation: *What are the Real Issues?* World Resources Institute, 1995, ISBN 1-56973-030-X.
 7. Adam Jaffe, Steven Peterson, Paul Portney, Robert Stavins, Environmental Regulation and International Competitiveness: *What Does the Evidence Tell Us?* Washington DC, Resources for the Future Discussion Paper, 1993.
 8. Michael Porter and Claas van der Linde, Green and Competitive: *Ending the Stalemate, Business and the Environment*, Ed Richard Welford and Richard Starkey, Earthscan Publications, 1996, ISBN 1-859383-301-0.
 9. Candice Stevens, Synthesis Report, *Environmental Policies and Industrial Competitiveness*, Paris, OECD, 1993.
 10. Patrick Low and Alexander Yeats, *Do Dirty Industries Migrate?* International Trade and the Environment, Washington DC, World Bank, 1992.
 11. Confederation of British Industry, Environment Costs: *The Effects on Competitiveness of Environment, Health and Safety*, 1994, ISBN 0-852071-444-9.

portion of business turnover (1-2 per cent)¹². Rather environmental costs are a contributory factor to general business health and are part of a cumulative burden¹³ which can weaken competitiveness. The CBI's survey of UK industry concluded that environmental legislative pressures do not significantly increase costs; only in a small number of cases have they led to process or plant closure; and very seldom did they result directly in a loss of jobs or market share.

37. The view that there is no clear link between environmental regulations and competitiveness stems from the fact that countries have adopted a great diversity of attitudes and approaches to environmental policy and regulation. There are fundamental differences in philosophy between countries, which are related to the political climate on environmental issues, and result in differences in the details of setting standards and implementing them. These differences in turn have the potential to create a range of commercial environments which either enhance or restrict competitiveness. As a result, even where regulations are identical in two different countries, the function and effect of these on the costs and competitiveness of industry may be completely different.

38. Since the relationship between environmental regulations and competitiveness is unclear and complex, debate internationally has been refocused to understand rather how:

- government environment policy can be reformulated to enhance sustainable development. Obviously, government policies are critical in determining whether environmental regulations will, on the one hand, trigger innovation, adaptation and efficiency, which would lower the cost of the product, thereby offsetting environmental costs, reinforcing business success and increasing competitiveness or, alternatively, conflict with overall business strategies and restrict economic growth;
- industry can respond to changes in policies in a cost-effective (or least-cost) manner, thereby balancing environmental effectiveness and economic competitiveness -- this requires an integrated strategy either for seizing environmental opportunities to enhance business success, or at least to manage unavoidable costs of regulation.

39. In summary, based on current economic thinking, the contention developed further in this paper is that:

- considered in isolation, changes in environmental regulations are not clearly linked to changes in production costs, profitability and competitiveness;
- the effect of environmental regulations on production costs, profitability and competitiveness must be evaluated in the context of certain critical success factors of overall environment policy and industry response.

12. This is an average estimate. For environmentally sensitive sectors, costs incurred to meet compliance with environmental regulations will be higher. For example, these are estimated to be less than 5 in the iron and steel sector in the USA, which are comparable with costs percentages in the sector in other countries.

13. According to the CBI, negative effects of environmental regulation are most likely where a business faces existing competitive weaknesses such as high labour costs, low capital investment, traditional technologies, or is competing primarily on price or in local markets.

Critical success factors in achieving environmental effectiveness and economic competitiveness

40. Critical success factors for industry to achieve the balance between environmental effectiveness and economic competitiveness are:

- institutional and political relationships between policy makers and industry;
- quality and consistency of environmental policy and regulations;
- approach of business in responding to environmental policy.

41. The combination of these factors determines whether environmental policy is a source of conflict or not, and whether environmental regulations are associated with cost burdens or technical progress, efficiency and innovation¹⁴.

42. Thus, an assessment of the comparative competitive advantages that different environmental policies offer to iron and steel producers must consider environmental regulations in the context of:

- the nature of the relationship between policy makers and industry, and whether this promotes effective policy, and open and honest dialogue while maintaining the political independence of policy making from industry;
- the characteristics of regulatory mechanisms and schedules, and their ability to accommodate innovation, improved efficiency and adaptation, encourage least-cost solutions, and enhance competitiveness;
- the capacity and readiness of the business to measure market expectations, and seize opportunities which improve business efficiency, while managing environmental risks and compliance.

43. For each of the three critical success factors, Table 1 provides a list of elements which positively or negatively impact the potential of a business to be innovative, efficient and adaptable, thereby influencing the costs of environmental protection, production costs and the ability of the business to be competitive. These elements also represent significant differences in the approaches by governments and businesses to environmental issues, both in developing and developed countries.

44. The methodology developed in Section 5 for assessing the effect of environmental policy on production costs views environmental regulations within the context of these three critical success factors, and their subelements listed in Table 1.

14. In *Environmental Policy and Industrial Innovation, Strategies in Europe, the US and Japan*, Royal Institute of International Affairs, Earthscan Publications, 1995, ISBN 1-85383-288-X, Wallace argues that innovation is the key to achieving the balance between environmental effectiveness and economic competitiveness. Where innovation is stifled, costs become higher than necessary. Innovation is broadly defined to encompass any change in technology, production process or organisational and management structure and technique.

Table 1. **Critical Success Factors and Impact on Competitiveness**

Critical Success Factor and Element	Good for Competition	Bad for Competition
Institutional and Political Factor		
Policies and regulatory instruments	<ul style="list-style-type: none"> • Policies flexible, with personal approach • Clear, stable and consistent policy framework and goals, with long-term credibility and low commercial risk • Policies consistent with those in competitive countries and based on market information • Combined use of traditional, economic and voluntary instruments • Use of market incentives to highlight resource inefficiencies and promote resource productivity • Use of voluntary agreements which devolve responsibility to industry, increase dialogue, increase innovation, lower costs, and lower opposition to policy 	<ul style="list-style-type: none"> • Policies rigid and legalistic approach, with tedious and stifling rules • Inconsistent, unpredictable and reactive policy, unclear goals, with high commercial risk • No harmonisation with policies in competitive countries • Instruments limited in range, inflexible • Rigid application of command and control instruments • Industry not allowed to set own goals and use resources to innovate or effect change in a manner which suits them
Dialogue and relationship	<ul style="list-style-type: none"> • Open, informative and honest between stakeholders on policy, commercial and technical issues • Environmental goals determined by lengthy consultation with industry and interest groups • Integration of industry into policy making, policy in line with capacity of industry to change and innovate • Trusting political climate • Advice and assistance to firms with genuine difficulties • Regulators understand the economics of the industry they regulate and the nature of decision making in the industry • Regulators are informed of technologies and developments, competent and knowledgeable 	<ul style="list-style-type: none"> • Limited dialogue and power-based negotiations, no formal channels of information exchange • Imposition of goals and ineffective consultation • Industry isolated from adversarial decision-making process • Opposing views and mutual distrust • No support for small businesses • Regulators are insensitive to industry needs • Regulators are technically ignorant
Political independence	<ul style="list-style-type: none"> • Policy making is independent of politics • Environmental costs are reflected in decision -making 	<ul style="list-style-type: none"> • Policy makers are not politically independent • Environmental goals are compromised by industry interests

Table 1. **Critical Success Factors and Impact on Competitiveness** (cont'd)

Critical Success Factor and Element	Good for Competition	Bad for Competition
Regulatory Factor		
Quality of regulatory tools	<ul style="list-style-type: none"> • Focus on outcomes, not methods or technologies • Stress pollution prevention • Promote investment, new ideas, innovative responses and technological progress • Based on achievable limits of existing technologies within realistic time scales • Scope to relax standards if technical progress does not meet expectations • Devised by technically competent regulators in consultation with industry and other groups • Flexibility at local level • Even implementation and strict enforcement • Scheduled introduction tied to industry capital investment cycles 	<ul style="list-style-type: none"> • Constrain the choice of technology, or prescribe treatment technologies • Stress end-of-line measures • Increase risk of innovation • Based on expected achievements of developing technologies • Fixed, inflexible, inappropriate and expensive • Drafted independently by non-technical regulators in a formula, procedure-driven process • National control which does not consider local conditions • Inconsistent or no enforcement, lax regulation • Forced hasty implementation, requiring expensive solutions
Business Factor		
Business environment and corporate strategy	<ul style="list-style-type: none"> • Good internal and external communication • Technological competence to be continuously innovative in reducing costs, ahead of regulation • Effective project planning and control, integration of environment issues into business planning • Positive attitude to quality, business efficiency, and continuous improvement • Effective market orientation and customer relations • Committed, dynamic and competent key individuals to manage change • Risk and liability management strategy to avoid sudden financial costs 	<ul style="list-style-type: none"> • Poor communication and reception of new ideas • Management resistant to change • Bad management and control of projects, with no consideration of environment in business strategy • Inefficient production tools, poor quality control, ineffective operation • Unaware of customer needs and market shifts • Inflexible management, unresponsive to change and unwilling to take risk • Business growth and development is potentially undermined by poorly managed risks and liabilities

Sources: Michael Porter and Claas van der Linde, Green and Competitive: *Ending the Stalemate, Business and the Environment*, Ed Richard Welford and Richard Starkey, Earthscan Publications, 1996, ISBN 1-85383-301-0. David Wallace: *Environmental Policy and Industrial Innovation, Strategies in Europe, the US and Japan*, Royal Institute of International Affairs, Earthscan publications, 1995, ISBN 1-85383-288-X. Confederation of British Industry, *Environment Costs: The Effects of Competitiveness of Environment, Health and Safety*, 1994, ISBN 0-85201-444-9 and consultant analysis..

4. ENVIRONMENTAL REGULATIONS IN THE IRON AND STEEL SECTOR

45. By reviewing technical, economic and regulatory aspects of pollution control in the iron and steel sector, this section considers which aspects of environmental regulations can be used as a comparative tool in determining potential costs of environmental protection. These aspects can then be set in the context of general environment policy of different countries to provide a tool for comparative analysis of impacts on production costs and competitiveness.

Iron and steel production processes

46. Steel is produced by one of two significant methods:

- integrated iron and steel manufacturing, in which pig iron is produced from iron ore in the blast furnace, and converted to steel in the basic oxygen furnace¹⁵;
- direct production of steel from scrap and directly reduced iron in an electric arc furnace (EAF), typically in minimills.

The main difference between the two significant methods is that in integrated iron and steel manufacture, coke-making and iron-making precede steel-making.

47. After manufacture, steel is finished by a series of processes, which include continuous casting, hot rolling and forming, cold rolling, wire drawing, coating, scarfing and acid pickling.

48. Figure 1 is a block diagram of the common steel making processes, showing inputs and outputs at each stage. Materials recycled within the process are not shown.

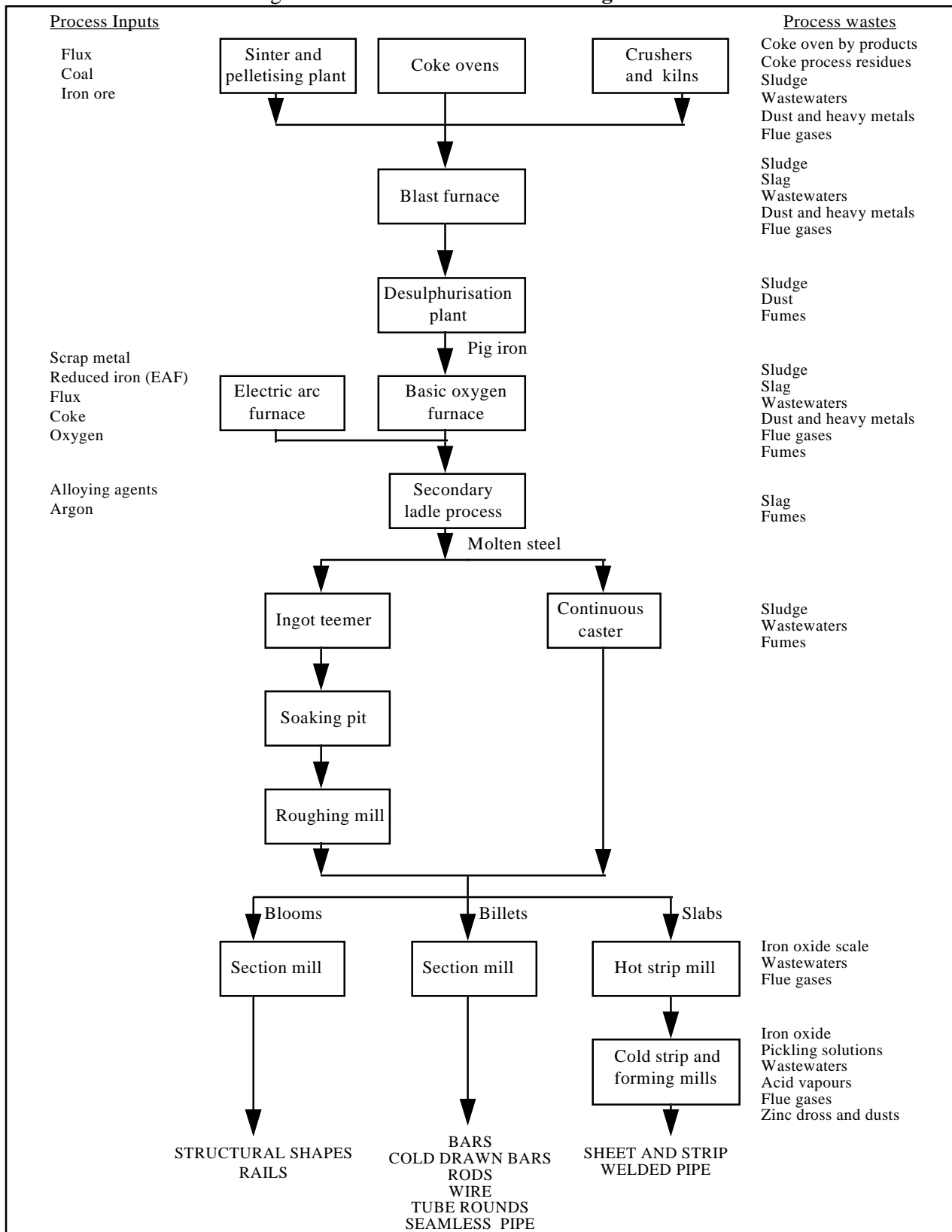
49. Current research in the steel industry is mainly directed at improving the costs and efficiency of iron production. Major focus has been to develop methods:

- to inject coal directly into the blast furnaces, thereby reducing (but not eliminating) the need for coke;
- which produce solid or liquid iron directly from ores in a single step¹⁶.

15. The open hearth furnace, and acid and Bessemer processes are steel making processes which also use molten iron as a charge material. The open hearth furnace has largely been replaced by the basic-oxygen furnace, while the other two processes have almost disappeared.

16. Alternative processes include reduction to liquid iron by processes such as Corex, Hismelt and Direct Iron Smelting, which produce iron for use in the basic oxygen process. Many alternative liquid processes (with the exception of Corex, first operating at ISCOR in Pretoria, South Africa) do not yet have operational plant. Alternative processes also include reduction as a solid by processes such as Midrex, HYL and Fastmet, which produce a solid product for use in electric arc furnaces. Such processes are most common in countries such as South Africa and India, where there is poor availability of natural gas but adequate supplies of low cost coal. Many other processes have been actively promoted since the 1970s but most are not commercially available.

Figure 1. Common Steel Making Processes



50. The focus of this paper is on the traditional processes of blast furnace for pig iron production, and basic oxygen process and EAF for steel making. These account for the bulk of production world-wide (in developed and developing countries).

Waste/emission profiles

51. Iron and steel processes are technologically complex, and have the potential to significantly impact the environment if wastes and emissions are not managed effectively. Solid wastes, wastewater and air emissions are released from each process stage, and contain regulated pollutants which require effective control.

52. For the common unit operations in Figure 1, Table 2 presents typical profiles for point source wastes and emissions. There are a multitude of potential pollution sources and pollutants. Untreated waste and emission characteristics will vary with each industrial facility, according to characteristics such as raw material quality, age of plant, technology, process design, operational efficiency, working practices, and maintenance. Thus, data in Table 2 are representative only.

53. Experience in developing countries suggests that untreated point source wastes and emissions have high flows and high pollutant loads, compared to those generated in developed countries. In addition, significant pollution arises from fugitive or diffuse sources. The differences in waste characteristics between facilities in developed and developing countries are because, in developing countries:

- production technologies are often outdated and equipment is old;
- processes are ineffectively managed and poorly monitored, with little or no regard to resource conservation or process optimisation;
- preventative measures, including scheduled maintenance, are neglected;
- waste and emissions streams are unmeasured, unmonitored and therefore largely unmanaged.

Table 2. Iron and Steel Processing: Waste and Emission Characteristics

Waste and Process	Components	Amount	Comment	
Solid wastes				
Coking	Total	1 kg/t coke**	Almost all classified as hazardous wastes	
	Coal tar recovery	0.1 kg/t coke		
	Tar decanter	0.2 kg/t coke		
	Tar storage	0.4 kg/t coke		
	Light oil processing	0.2 kg/t coke		
	Wastewater sludge	0.1 kg/t coke		
	Naphthalene recovery	0.02 kg/t coke		
	Tar distillation	0.01 kg/t coke		
Blast furnace	Slag	300-600 kg/t steel	Depends on impurity content of raw materials; contains 40 % CaO 35 % SiO ₂ - 10 % Al ₂ O ₃ - 8 % MgO	
Basic oxygen furnace/ EAF	Slag	70-170 kg/t steel	Depends on impurity content of raw materials; contains 47 % CaO 17 % Fe, 13 % SiO ₂ - 2 % Al ₂ O ₃ - 5 % MgO	
Finishing	Iron oxide scale	up to 50 kg/t steel	- From galvanising From pickling	
	Zinc dross/ash	-		
	Ferrous sulphate	-		
Wastewater treatment	Sludges	-	Pollutants collected as sludge will not be released in wastewater	
Gas cleaning	Particulate matter*	Depends on efficiency of gas cleaning equipment	Pollutants collected as solid waste from gas streams will not be released to air	
Liquid wastes				
Coking	Benzene	0.04 kg/t coke	10 mg/l	Total flow is 0.3-4 m ³ /t coke**
	BOD	4 kg/t coke	1,000 mg/l	
	COD	6-24 kg/t coke	1 500-6 000 mg/l	
	Suspended solids	0.8 kg/t coke	200 mg/l	
	Phenol	0.3-12 kg/t coke	150-1 200 mg/l	
	PAH	0.1 kg/t coke	30 mg/l	
	NH ₃ (as N)	0.1-2 kg/t coke	30-600 mg/l	
	CN	0.1-0.6 kg/t coke	30-1.8 mg/l	

Table 2. **Iron and Steel Processing: Waste and Emission Characteristics** (cont'd)

Waste and Process	Components	Amount		Comment
Liquid wastes (cont'd)				
Iron making (sintering and blast furnace)	Organic carbon	2.5-5 kg/t steel	100-200 mg/l	Total flow is 25 m ³ /t steel, 0.3-5 m ³ /t steel is discharged (80-99 % recycle); Also contains phenols, F, P, dissolved solids, Cl, sulphates, and other traditional contaminants
	Suspended solids	175 kg/t steel	7 000 mg/l	
	CN	0.4 kg/t steel	15 mg/l	
	F	25 kg/t steel	1 000 mg/l	
	COD	23 kg/t steel	500 mg/l	
	Zn	0.9 kg/t steel	35 mg/l	
Steel making (basic oxygen furnace)	Suspended solids	220 kg/t steel	4 000 mg/l	Total flow is 55 m ³ /t steel, 0.5-11 m ³ /t steel is discharged (80-99 % recycled) Also contains dissolved solids, Cl, sulphates and other traditional contaminants
	Pd	0.4 kg/t steel	8 mg/l	
	Cr	0.3 kg/t steel	5 mg/l	
	Cd	0.02 kg/t steel	0.4 mg/l	
	Zn	0.8 kg/t steel	14 mg/l	
	F	1.1 kg/t steel	20 mg/l	
Gaseous wastes				
Material handling	Particulate matter*	0.001 per cent of material stored		Depends on suppression and containment facilities
Sintering/pelletising	Particulate matter*	20-35 kg/t steel	1-17 g/Nm ³	Other pollutants include CO ₂ - O ₂ - CO - N ₂ - F and Cl; HM include Zn, Pb, Cd, Mn; SOx emissions may represent up to 38 % of total SOx emissions from a typical factory 85 % of particulate matter may be less than 5 µm
	SOx	1.5 kg/t steel	0.2-1 g/Nm ³	
	NOx	0.5 kg/t steel	0.4 g/Nm ³	
Coking	Particulate matter	0.7-7.4 kg/t coke**		Other pollutants include benzene
	SOx	0.2-6.5 kg/t coke		
	NOx	1.4 kg/t coke		
	NH ₃	0.1 kg/t coke		
	Volatile organics	3 kg/t coke		
Flux preparation	Particulate matter	-		Pollutants include fines of limestone, lime dolomite, etc.
Blast furnace	Particulate matter*	10-40 kg/t steel	10-40 g/Nm ³	Other pollutants include hydrocarbons, SiO ₂ , dioxins, HF; HM include Fe (40-50 %), Zn, Pb, Mn; 75 % of particulate matter may be less than 5 µm

Table 2. **Iron and Steel Processing: Waste and Emission Characteristics** (cont'd)

Waste and Process	Components	Amount	Comment
Gaseous wastes (cont'd)			
Desulphurisation	Particulate matter	10 kg/t steel	Other pollutants include SO
Basic oxygen process	Particulate matter*	15-60 kg/t steel	Other pollutants include SiO ₂ - CaO - S - P - CO ₂ - O ₂ - CO - NO _x ; 75 % of particulate matter may be less than 5 µm
	Fe	up to 40 kg/t steel	
	Cr	2 g/t steel	
	Cd	0.2 g/t steel	
	Pb	0.06 g/t steel	
EAF	Particulate matter*	5-25 kg/t steel	Other pollutants include S - Cl - F - CaO - Na ₂ O - Al ₂ O ₃ HM also include Ni, Cr, Mn, Hg; 90 % of particulate matter may be less than 5 µm
	Fe	1.8-9 kg/t steel	
	Zn	0.8-4 kg/t steel	
	Pb	0.1-0.4 kg/t steel	
	SiO ₂	0.3-1.3 kg/t steel	
Hot rolling	Combustion gases	-	Depends on fuel used in preheating and annealing furnaces SO _x emissions may represent up to 35 % total SO _x and 45 % of NO _x emissions from factory
Cold rolling and forming	Acid vapours	-	Acid vapours from pickling
	Combustion gases, CO, O, CO, NO _x	-	Depends on fuel used in annealing and tempering furnaces
	Metallic fumes	-	Zn and ZnCl ₂ from galvanising

* Contains heavy metals.

** Up to 0.9 tonne coke may be used to produce 1 tonne steel product at some integrated steel mills, depending on iron content of iron ore, coke dosing rate etc.

Sources: United Nations Environment Programme (UNEP), *Environmental Aspects of Iron and Steel Production, An Overview*, 1984, ISBN 92-807-078-8. Her Majesty's Inspectorate of Pollution (HMIP), *Pollution Control for Integrated Iron and Steel Processes*, Report N°DoE/HMIP/TT/93/022; World Bank, *Pollution Prevention and Abatement Handbook*, draft report, July 1995 and March 1997; and consultant analysis.

54. In order to make comparisons between countries, and because of the multitude of potential sources and pollutants in iron and steel production, it is necessary to focus on those sources and pollutants which have significant environmental impact, and will comprise the major portion of environmental protection costs:

- For existing facilities in both developing and developed countries, expenditure on air emission control and wastewater treatment represents the main portion of the cost burden of environmental protection. Typically, retrofitting of air emission control is the most urgent problem, and most costly¹⁷. Solid waste handling and disposal costs are typically much lower than air emission control and wastewater treatment.
- For air emission control, pollutants of most significance are particulate matter (which includes heavy metal dusts), SO_x and NO_x¹⁸.
- For wastewater treatment, pollutants of most significance are suspended solids, toxic substances (heavy metals, phenol, cyanides), and waste acid.
- Hazardous solid wastes requiring treatment before disposal, which include wastewater sludges and coke residues.
- Principal sources of the significant pollutants are the coke ovens, sinter plant, blast furnace, basic oxygen process, EAF, boilers and preheating furnaces.

55. The discussion below focuses on technical, economic and regulatory aspects related to the significant sources and pollutants identified here.

Pollution control methodologies

56. For existing industrial facilities, the introduction of new environmental regulations requires businesses to:

- invest in end-of-line treatment facilities, or
- introduce process changes which minimise or eliminate waste.

It is generally accepted that the option of directly retrofitting environmental control equipment onto existing processes (i.e. end-of-pipe) is one of maximum cost, and least value-added, while in-process changes can decrease costs and increase the cost-effectiveness.

17. As an example, a recent study of three iron and steel facilities in a developing country indicated that, to meet compliance with new environmental regulations, a minimum of \$80 million investment is required, of which 66 per cent is for air emission control, 30 per cent for water reticulation and wastewater improvements and 4 per cent of solid waste handling and other minor investments.

18. In the example from the footnote above, the control of particulate emissions (and associated heavy metals) accounted almost exclusively for total expenditure related to air emission control.

57. In most of the developed countries, businesses are increasingly responding to more stringent regulatory measures by placing emphasis on pollution prevention and waste minimisation as a means of waste and emission control. Environmental management systems, clean technologies and in-process improvements are increasingly used to meet compliance. End-of-pipe approaches are considered costly and cost-ineffective, and are applied as a last resort to treat unavoidable wastes and emissions.

58. Experience of iron and steel production processes in developing countries indicates that, as a generalisation:

- pollution control, where it exists, is based on end-of-pipe treatment, with little or no appreciation of the value of management systems and in-process controls for waste minimisation;
- existing pollution control equipment is poorly designed, and inoperational or malfunctioning, with little or no regard to maintenance and optimisation;
- poor resource productivity results in high flow waste streams and high pollutant loads, compared to those generated in developed countries -- typically these remain unmonitored, and untreated or partly treated;
- under pressures for environmental improvement, innovative, adaptable and efficient business response is stifled by a poor knowledge and experience of environmental management systems, clean technologies and in-process controls;
- for improved environmental performance, businesses resort to high cost, low value-added pollution control equipment, usually end-of-pipe -- disadvantages are amplified by the additional costs required to control high flow, high load streams¹⁹.

59. Thus, the methodology with which industrial facilities in developing countries currently approach pollution control restricts their ability to implement cost-effective pollution control technologies compared to developed countries.

Pollution control technologies

60. This section overviews commonly used pollution control technologies for addressing the significant sources and pollutants defined in the section above, and their performance achievements and cost implications.

19. Recently a wastewater treatment plant has been installed in an integrated iron and steel mill in a developing country. This plant is designed to treat 30 m³/tonne steel, a safety factor of 50 per cent on existing wastewater flows of 20 m³/tonne steel. World Bank guidelines for developing countries suggest that a wastewater production rate of 1 m³/tonne steel should be achievable. Because the business failed to reduce wastewater flows by in-process controls, the treatment plant is hugely oversized, capital costs for treatment are excessive, water and wastewater pumping costs are excessive, and wastewater treatment plant operational costs are excessive. Finally, the design criteria for the treated wastewater do not meet the applicable discharge standards.

Particulate emissions

61. The control of particulate emissions from iron and steel processes is possibly one of the most important environmental issues facing the sector. This is not only because of substantial levels of emissions (by flow and load), but also because of the potential hazardous nature of these emissions -- they contain a multitude of toxic materials (including heavy metal and silica dusts) and respirable particles²⁰.
62. The main sources of particulate emissions from iron and steel processes are the sintering plant, blast furnace, basic oxygen furnace and electric arc furnace. Concentrations in untreated streams range from 0.5 to 40 g/Nm³, and individual sources may each generate up to 2 000 000 Nm³/h. At an integrated iron and steel works, indicative unit-specific flows of particulate laden air streams from the main sources are 15 000-25 000 Nm³/tonne steel.
63. Typically 65 to 90 per cent of particulates from these sources are less than 10µm in size and are therefore respirable dusts.
64. Technology options for particulate removal include centrifugal separation, electrostatic precipitation (ESP), fabric filtration, and wet scrubbing. Table 3 compares different designs of the technology options currently used in the iron and steel sector, along with a summary of the technical and economic advantages and disadvantages of each.
65. The choice of particulate removal technology depends on the degree of removal required, the particulate size and chemical composition, and the flow and temperature of the waste air stream. For effective control of particulates below 10 µm, bag filters and ESPs are the technologies of choice in the iron and steel sector.
66. Cyclones will not achieve the high reductions of particulates required by modern regulatory standards, as they are ineffective on the small particulate size emissions from iron and steel processes. Wet scrubbers are commonly used for particulate removal from blast furnace off-gases. They will achieve high levels of particulate removal, but application is restricted to flow rates of less than 2 000 m³/min.

20. The critical size of dust and aerosol particles is 0.5-7 µm since these can deposit and accumulate in the respiratory bronchioles and alveoli.

Table 3. Guide to Selection of Particulate Control Technologies

Particle Size Range (μm)	Type of Control	Pressure Drop (m bars)	Collection Efficiency (% at μm)	Maximum Temperature ($^{\circ}\text{C}$)	Condition of Air	Dew Point Sensitivity	Effect of Particle Density	Capital Costs (relative to cyclone)*	Operating Costs (relative to cyclone)
>150	Settling chamber	<2.5	50 at 150-300 95 at >300	500	Dry	Fairly sensitive	Efficiency rises with density	0.8	0.5
>10	Cyclones	2.5-10	40 at 0-5 70 at 5-10 80 at 10-20 90 at >50	500	Dry	Sensitive to plugging and corrosion	Efficiency rises with density	1	1
>5	Irrigated cyclones	5-20	50 at 0-5 80 at 5-10 95 at 10-20 97 at >50	350	Wet	Not sensitive	Efficiency rises with density	2	2
>3	Low pressure drop washers	5-18	50 at 3-5 98 at >5	350	Wet	Not sensitive	Little effect	2.6	1.8
>0.5	Low pressure drop venturi scrubbers	15-30	90-95	350	Wet	Not sensitive	Little effect	2.9	3.5
>0.3	High pressure venturi scrubbers	35-190	96-99	350	Wet	Not sensitive	Little effect	3.5	18
>0.3	Medium pressure flooded disc scrubber	30-100	97-99	350	Wet	Not sensitive	Little effect	3.4	15
>0.1	Shaker bag filter	8-18	95-99	220 **	Dry	Very critical	Little effect	8	2
>0.1	Pulse jet bag filter	8-18	95-99	220 **	Dry	Very critical	Little effect	10	2
>0.01	High efficiency dry ESP	0.6-2	90-99	350	Dry	Critical	Little effect	8	0.6
>0.01	Wet ESP	0.6-4	86-99	350	Wet	Not sensitive	Little effect	12	0.8

* Typical cyclone capital costs are around \$0.6 per Nm^3/h . World Bank, *Pollution Prevention and Abatement Handbook*, draft report, July 1995.

** Special material.

Source: Her Majesty's Inspectorate of Pollution (HMIP), *Pollution Control for Integrated Iron and Steel Processes*, Report N^oDoE/HMIP/RR/93/022.

67. Table 4 summarises particulate removal technologies commonly in use to control the main sources of particulate matter in the iron and steel sector. This table also gives performance achievements of each.

Table 4. **Technologies for Particulate Removal from Main Air Emission Sources**

Operation	Common Technology	Achievable Limits (mg/Nm ³)
Sintering		
Primary emissions	Dry ESP	60-80
Secondary dust collection	Bag filter or ESP	50
Blast furnace		
Fuel cleaning	Dust catcher and wet scrubber	10
Secondary dust collection	Bag filters, or ESPs	10 25
Basic oxygen furnace		
Primary emissions	Wet scrubber or ESP	50-80
Secondary dust collection	Bag filters or ESPs	10 30
EAF		
Primary emissions	Bag filters	20
Secondary dust collection	Bag filters	20

Source: Her Majesty's Inspectorate of Pollution (HMIP), *Pollution Control for Integrated Iron and Steel Processes*, Report N°DoE/HMIP/RR/93/022.

Conclusions are:

- Capital and operating costs are determined by flow, rather than load.
- Where high percentages of respirable dusts need to be removed, bag filters, wet scrubbers and ESPs are the only suitable technology options -- bag filters and ESPs have comparable capital and operating costs, while high and medium pressure scrubbers have relatively low capital costs but high operating costs.
- Cyclones have significant cost advantages over bag filters, wet scrubbers and ESPs. However, they will only be applicable in countries with very lenient standards, or in where standards are not enforced.
- Capital costs of particulate emission control equipment may be significant. There are economies of scale for large plant. For bag filters and ESPs, capital costs may range up to \$6 per Nm³/h for relatively small plant (600 000 Nm³/h) to \$3 per Nm³/h for relatively large plant (2 000 000 Nm³/h). Indicative costs for an installation to treat primary emissions of 2 000 000 Nm³/h from a single large basic oxygen furnace are \$6.5 million, while those for a smaller secondary dust collection system of 600 000 Nm³/h are \$3.5 million.
- Indicative average abatement costs are \$182/tonne particulates removed²¹.
- Overall operating costs are dependent on operating costs of pollution control equipment and charges (taxes) for releases to atmosphere.

21. Raymond Hartman, David Wheeler and Manjula Singh, *The Cost of Pollution Abatement*, World Bank Research Grant No. 67781, December 1994.

68. Thus, in comparing cost implications for two facilities, differentials for particulate emission control may be significant where:

- there are significant differences in production scale (and volumetric flow rates of waste air streams);
- cyclones can be used instead of other pollution control technologies (where particulate emissions of 500 mg/Nm³ or higher are acceptable). In this case capital costs could be as low as 10 per cent, and operating costs between 5 and 100 per cent, of other high performance technologies;
- there are significant differences in charges (taxes) for releases to atmosphere.

SOx and NOx

69. Table 5 shows typical sources of SOx and NOx in an iron and steel factory. The reheating furnaces (used in finishing) and the boilers are the main sources of NOx, while the sinter plant, boilers and reheating furnaces are the main sources of SOx.

Table 5. **Main SOx and NOx Emission Sources**

Source	% of Total NOx	% of Total SOx
Coke ovens	9.7	7
Sinter plant	0.7	38
Boilers	32	18
Blast furnace	9	-
Reheating furnaces	45	35
Other	3.6	2

Source: Her Majesty's Inspectorate of Pollution (HMIP), *Pollution Control for Integrated Iron and Steel Processes*, Report N°DoE/HMIP/RR/93/022.

70. Untreated SOx emission concentrations depend on the sulphur content of fuel and raw materials, and are estimated to range between 200 and 2 000 mg/Nm³ for significant sources (sinter plant, boilers and reheating furnaces). Untreated NOx emission concentrations depend largely on fuel type, combustion temperature and burner design, and are estimated to range between 100 and 1 500 mg/Nm³ for significant sources (boilers and reheating furnaces).

71. In most countries, NOx and SOx emission levels are controlled by careful selection of fuel and raw materials. In addition, low emission burners and modern combustion systems can be used to control NOx emissions. Pollution control technologies are not common, but could include scrubbers (wet and dry) for SOx and reduction (catalytic, non-catalytic and adsorption) for NOx. Costs of this equipment is very site specific, and depends on the design specifications and degree of removal required. Indicative capital costs are \$300-700/tonne SOx removed²² and \$100-200/tonne NOx removed²³.

22. IEA Coal Research, *IEA Statistics, Energy Prices and Taxes*, 1993, 4Q, Gemini House, 10-18 Putney Hill, London, SW15 6AA.

72. Japan is one of the few countries where SO_x and NO_x emissions are controlled because of the strict regulations regarding these compounds²⁴. Here absorption processes have been installed after ESPs to remove SO_x, NO_x and fluorides. These systems are expensive to erect and operate. In particular they consume huge quantities of electricity, providing little net benefit once extra energy and SO_x generated at the power stations are taken into consideration²⁵.

73. Conclusions are:

- in most countries, in-process controls generally suffice in reducing SO_x and NO_x concentrations to acceptable levels;
- capital and operating costs for end-of-pipe SO_x and NO_x removal equipment are determined by level of removal required and are very site-specific;
- capital costs of control equipment may be significant -- indicative costs are \$300-700/tonne SO_x removed and \$100-200/tonne NO_x removed;
- overall operating costs are dependent on operating costs of control equipment and charges (taxes) for discharge.

74. Thus, in comparing cost implications for two facilities, differentials for NO_x and SO_x control may be significant where:

- stringent environmental regulations exist, which cannot be met by in-process control;
- in such cases, there are significant differences in concentrations and flows;
- there are significant differences in charges (taxes) for releases to atmosphere.

Wastewater

75. The current methods of wastewater treatment are established and can be modified or adapted to meet new regulations. Suspended solids are removed with little technical difficulties using settlement and clarification. Toxic chemicals may be removed from segregated streams by a combination of secondary and tertiary systems. Sludges are filtered and dewatered.

23. Raymond Hartman, David Wheeler and Manjula Singh, *The Cost of Pollution Abatement*, World Bank Research Grant N° 67781, December 1994.

24. For SO_x, national legislation sets emission standards according to a formula (*k-value*) which includes factors such as stack height, output and local climate. This introduces flexibility which allows emission limits to vary according to source and location. For NO_x, small variations in the limits are intended to account for equipment capacity, fuel type and location. The current national standards set a limit of 60 ppmv (about 120 mg/m³) for stack emissions from new, large natural gas fired boilers, and 110 ppmv for existing facilities.

25. Her Majesty's Inspectorate of Pollution, *Pollution Control for Integrated Iron and Steel Processes*, Report N° DoE/HMIP/RR/93/022.

76. Most treatment plants achieve satisfactory levels of wastewater quality. Some processes may require additional stages if there is a demand for increased standards, but this does not present particular problems. It is generally assumed that if wastewater is of good enough quality to discharge to a river, it is good enough to be reused in the process. Thus the principle of zero discharge should be applied.

77. Wastewater flows are typically 1-5 m³/tonne steel, but because of poor water management, can range up to 20 m³/tonne steel in developing countries.

78. Conclusions are:

- Since wastewater treatment processes are standard, capital and operating costs will largely be determined by wastewater flows.
- The level of treatment required on-site will depend on the receiving environment (surface water body or municipal sewer). Primary treatment will be sufficient for discharges to sewers, but secondary and tertiary treatment may be required for discharges to rivers (or complete recycle).
- Capital costs of wastewater treatment may be significant. There are economies of scale for large plant. Indicative costs for standard treatment plant (balancing, neutralisation, sedimentation, filtration) are \$1,500 per m³/h for larger flows. The need for an activated sludge plant may increase capital costs (per m³/h) ten-fold.
- Overall operating costs are dependent on wastewater treatment plant operating costs and fees for discharge. Indicative operating costs for standard treatment plant are \$200-500 per annum per m³/h. Fees for discharge will vary considerably with country, region and receiving environment.

79. Thus, in comparing cost implications for two facilities, differentials for wastewater treatment may be significant where:

- wastewater flows (per unit of production) are significantly different;
- stringent environmental regulations exist, which require treatment additional to standard processes;
- there are significant differences in discharge fees.

Solid Wastes

80. The principal solid wastes are slags from the blast furnace and steel conversion processes. These amount to between 400 and 800 kg/tonne steel. They can be sold as a building material, but the marketability depends on local demand. In many developing countries, this material is stock piled.

81. Coal residues (1 kg/tonne coke) and wastewater treatment sludges may be classified as hazardous because of their content of leachable heavy metals. Environmental management costs will be related to regulations governing disposal.

82. Thus, in comparing cost implications for two facilities, differentials for solid waste management may be significant where:

- hazardous waste classifications (and therefore regulated controls) differ;
- there are significant differences in landfill costs.

Environmental regulations and regulated pollutants

83. The above sections have identified significant sources and pollutants in the iron and steel industry, technology options for their control, and indicative costs of control.

84. To what extent, and under what conditions, can environmental regulations concerning these pollutants dictate the selection of control technology and costs of control? Do environmental regulations provide a tool for the cross country comparison of compliance costs?

85. To answer the first question, the consultant has compared three sets of environmental regulations for the iron and steel industry: the United Kingdom, Egypt and World Bank. These examples have been chosen to include the requirements of a developed country, a developing country and an international financing institution focusing on industrial upgrade in developing countries.

86. The Annex to this document contains details of environmental policies, regulations and guidelines for the United Kingdom, Egypt and the World Bank.

87. Regulations have some common aspects. Usually, some form of site licensing system constitutes the main element of the regulatory regime for local pollutants. National or local authorities set specific standards for types of equipment, handling of pollutants, absolute levels of emissions or concentrations of pollutants in waste streams. These same authorities then ensure that industries comply with the standards.

88. Generally however, environmental regulations are not easily comparable between countries for the following reasons:

- Environmental regulations commonly encompass a broad range of qualitative as well as quantitative conditions, many of which are not measurable or comparable.
- Even quantitative conditions are not comparable, as regulations are based on a range of instruments:
 - Direct or command and control instruments:
 - engineering standards, which regulate the technology;
 - performance standards, which regulate the operation of plant and emission ratios;
 - quantity limits, which regulate overall emission levels by quota;
 - ambient standards, which regulate the receiving environment quality;

- prohibitions/sanctions, which preclude certain activities of use of certain materials.
- Economic instruments:
 - emission charges, which is a tax applied per unit of pollution;
 - product charges, which is a tax on products used in or resulting from a polluting activity;
 - marketable permits, which are emission permits that can be used, sold or leased;
- Voluntary agreements, which are negotiated settlements between regulators and the regulated industry.
- Even where two countries use a similar direct regulatory instrument for a certain pollutant, comparison is difficult as the required levels may be based on average or instantaneous values. Averages are often further quoted over a fixed period which varies from country to country, and with allowances for excursions during certain periods.
- Regulations often make allowance for the fact that the retrofit of environmental protection equipment to existing processes is often excessively expensive, and sometimes impractical. Thus, to provide realistic targets for pollution control, environmental standards within any one country are often differentiated for old and new processes.
- Environmental regulations are not always strictly enforced.
- The emphasis of regulations and regulated pollutants often depends on national priorities, and varies with country.
- The iron and steel sector faces emission constraints on a diverse range of pollutants, which varies from country to country.

89. However, using as a focus those pollution sources and pollutants which are most likely to impact on environmental costs in the iron and steel sector, there are a few clear regulatory factors which become potential tools in comparing technology options and economic implications of meeting compliance.

90. Table 6 is a summary of certain aspects of the Annex. For those significant air and wastewater sources and pollutants in the iron and steel sector, it lists, for comparison, regulated standards applicable to the United Kingdom, Egypt and the World Bank.

91. With respect to each of the significant sources and pollutants, Table 7 summarises the relationship between regulations, technologies and costs. Analysis of the data suggests that for most of the significant pollutants, the stringency of the standards is an important criteria in considering the environmental control technology required to meet compliance. Furthermore, the choice of this technology is often a significant determinant of costs of compliance.

Table 6. Summary Comparison of Regulated Standards for the Iron and Steel Sector

Pollutant	Unit	United Kingdom		Egypt		World Bank
Air emissions						
Particulate matter	mg/Nm ³	25-100 (depending on source)		200 (existing processes) 100 (new processes)		50
SOx	mg/Nm ³	2 000*		4 000 (existing processes) 2 500 (new processes)		500
NOx	mg/Nm ³	650*		3 000 (existing processes) 300 (new processes)		750
Pb	mg/Nm ³	2		20		-
Cd	mg/Nm ³	1		10		-
Heavy metals	mg/Nm ³	-		25		-
Fluoride	mg/Nm ³	10		20		5
Wastewater						
		Sewer**	River***	Sewer	River	General
Suspended solids	mg/l	30	-	500	30	50
COD	mg/l	800	-	700	40	250
Phenol	mg/l	-	-	0.005	0.002	0.5
Cd	mg/l	1	0.05	-	0.01	0.1
Cr	mg/l	0.5	-	-	0.05	0.5
Zn	mg/l	-	-	-	1	2
Pb	mg/l	1	-	-	-	0.2
Hg	mg/l	0.5	-	-	-	0.1

* General EU standard for combustion processes

** Indicative, set by individual water companies

*** Only one official standard is set. Other standards are determined on a site-specific basis according to environmental quality objectives

92. To answer the second question, we must consider the limitations of the analysis in Table 7. While this analysis illustrates the possible effect of regulations on technology choice and cost, its application is limited for the following reasons:

- In reality, actual costs for a facility to meet compliance will be influenced largely by site-specific factors:
 - final choice of pollution control technology, and waste flows and concentrations, which depend on local management and the business efficiency, innovation, and adaptability (and may include in-process solutions such as changes in technology, processes, raw materials and products);
 - other cost elements unrelated to technology, such as charges, fees, incentive and penalty systems, which depend largely on central and local government policy.
- It considers costs of the most pressing production-related pollution control issues. Other issues which contribute to overall environment costs are not considered. These include issues such as developing and maintaining environmental management systems, remediation of contaminated soils and groundwaters, compensation, transport and storage, etc., the comparative costs of which cannot be as easily related to regulations.

Table 7. Relationship Between Regulations, Technologies and Costs

Source/Pollutant	Regulations	Technologies	Indicative Capital Costs	Indicative Operating Costs
Particulate emissions	<ul style="list-style-type: none"> Standards compared vary from 25 mg/Nm³ in the United Kingdom for point source emissions from roof extraction and general collection to 200 mg/Nm³ for all existing point source emissions in Egypt Where standards exist for particulate emission control in developed and developing countries, most fall within this range 	<ul style="list-style-type: none"> Restricted by nature of emissions and particle size Cyclones are applicable where acceptable emissions exceed 500 mg/Nm³ Bag filters, wet scrubbers and ESPs are required to reach below 200 mg/Nm³ 	<ul style="list-style-type: none"> \$0.6 per Nm³/h \$3- 6 per Nm³/h 	<ul style="list-style-type: none"> 100 % Bagfilters 200 % Scrubbers 300-1 800 % ESPs 60-80 %
SOx	<ul style="list-style-type: none"> Standards compared vary from 500 mg/Nm³ for World Bank to 4 000 mg/Nm³ for existing sources in Egypt Where standards exist for SOx emissions in developed and developing countries, most fall within this range 	<ul style="list-style-type: none"> Control by careful selection of raw materials suffices in most countries End-of-pipe treatment includes wet and dry scrubbers 	<ul style="list-style-type: none"> NA \$300-700 tonne removed 	<ul style="list-style-type: none"> Differential in raw material costs is site specific Site specific, use of electricity significant
NOx	<ul style="list-style-type: none"> Standards compared vary from 300 mg/Nm³ for new processes in Egypt to 3 000 mg/Nm³ for existing processes in Egypt Japanese standards are lower (as low as 120 mg/Nm³), but where standards exist for NOx emissions in other developed and developing countries, most fall within this range 	<ul style="list-style-type: none"> Control by low emission burners, fuel type, and modern combustion systems suffices in most countries End-of-pipe treatment includes reduction 	<ul style="list-style-type: none"> Site specific High relative cost, usually combined with SOx removal 	<ul style="list-style-type: none"> Site specific, low by comparison to end-of-pipe Site specific, use of electricity significant
Wastewater	<ul style="list-style-type: none"> Depends on sewers or surface discharges Not directly comparable, but World Bank requirements lie between those for sewer and surface water discharge of the United Kingdom and Egypt Where standards exist, in developed and developing countries, they cover traditional pollutants and specific pollutants of national concern, but are of similar orders of magnitude 	<ul style="list-style-type: none"> Standard technologies applicable to comply with most standards Mechanical treatment on-site for sewer discharge Biological and chemical treatment for surface water discharge 	<ul style="list-style-type: none"> \$1 500 per m³/h Site-specific, but up to 10 fold higher 	<ul style="list-style-type: none"> \$200-500 per annum per m³/h Site-specific
Solid waste	<ul style="list-style-type: none"> Hazardous waste classifications, and therefore stringency of control vary 	<ul style="list-style-type: none"> Secure landfill is generally acceptable 	<ul style="list-style-type: none"> NA 	<ul style="list-style-type: none"> Disposal costs are country specific

93. In summary, therefore:

- environmental standards influence technology choice and ultimately costs;
- a cross country comparison of environmental standards for the main sources and pollutants (particulates, SO_x, NO_x, wastewater and hazardous solid waste) will provide a semi-quantitative comparison of potential costs for meeting compliance;
- actual costs for meeting compliance will be influenced by the innovation, efficiency and adaptability of the business response to environmental standards -- this in turn will depend on general aspects of government environmental policy and quality of the business strategy, as described in Section 3;
- in developing a methodology for comparative analysis of the effects of government environmental policy on production costs in the iron and steel sector, environmental standards for significant sources and pollutants are a basic indicator which must be considered in the context of business and policy issues.

5. METHODOLOGY FOR COMPARATIVE ANALYSIS OF COMPLIANCE COSTS

94. This section proposes an outline methodology for the comparative analysis of the costs of environmental compliance of iron and steel facilities in different countries. It considers selected aspects of environmental standards for significant pollutants in the context of government environmental policy and business strategy.

Outline of proposed methodology

95. The methodology considers the impact of environmental standards on costs and cost-effectiveness of environmental protection, within the context of the three critical success factors for balancing environmental effectiveness and economic competitiveness: institutional and political factors of government environmental policy, the potential quality of industry response to this policy, and the potential quality of regulatory tools.

96. The methodology involves a combination of semi-quantitative and qualitative analysis ... :

- *Semi-quantitative analysis.* Regulatory standards for significant pollutants are used to compare potential costs of compliance (based on end-of-pipe systems) of industrial facilities.
- *Qualitative analysis.* These potential costs of compliance are then placed in the context of the ability of each industrial facility to be innovative, efficient and adaptable in meeting compliance, to compare probable levels of cost and cost effectiveness.

... and comprises six steps:

- Semi-quantitative analysis:
 - semi-quantitative comparison of costs of compliance for different technology options, based on a comparison of regulatory standards for significant sources and pollutants and technologies required to meet these regulatory standards.
- Qualitative analysis:
 - assessment of strategy of government environmental policy;
 - assessment of potential of business to be innovative, efficient and adaptive in response to environmental policy;
 - assessment of potential for regulatory factors to promote innovation;
 - qualitative comparison of the position of each facility with respect to innovative potential, costs of compliance and cost-effectiveness of expenditure;
 - combination of semi-quantitative and qualitative analysis to compare costs and cost-effectiveness of environmental protection, within the context of the critical success factors for balancing environmental effectiveness and economic competitiveness.

97. For developing countries, where businesses are unlikely to differ significantly with regard to business environment and corporate strategy, Step 3 may be omitted. Only environmental policy and regulatory issues are then considered in the analysis.

98. The outline of the proposed methodology for the comparative analysis of environmental compliance costs is shown in Figure 2.

Semi-quantitative analysis of potential compliance costs

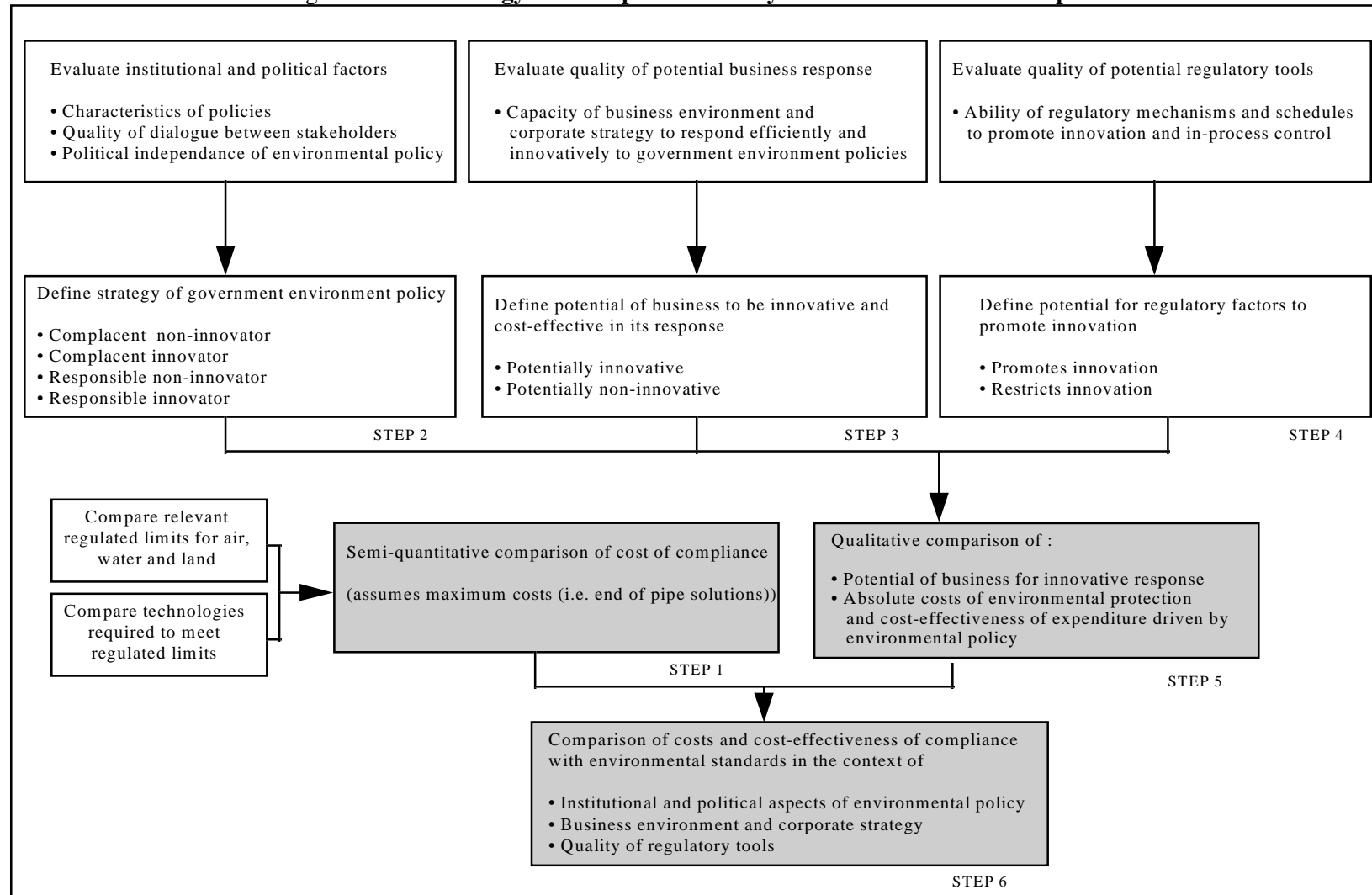
99. For pollution sources and pollutants which are significant in terms of environmental impact and potential costs of control, regulatory standards are examined to provide a semi-quantitative comparison of technology options and potential costs for compliance.

Step 1: Compare potential compliance costs for significant sources and pollutants

Aim: To identify where differences in technology options required to achieve regulated standards may impact costs of control

100. This step builds on the discussion in Section 4. It assumes that environmental standards can influence the choice of technology option and therefore the potential cost of compliance, but expresses caution that actual costs of compliance may be influenced by business and policy factors.

Figure 2. Methodology for Comparative Analysis of Environmental Compliance Costs



Worksteps

- For each facility under consideration, identify regulated standards for significant pollution sources and pollutants:
 - particulate emissions;
 - NO_x and SO_x;
 - wastewater;
 - hazardous solid waste classification and control;
- Using Table 7 identify differences in standards that could impact choice of technology and costs of compliance.
- Where standards for significant sources and pollutants differ, consider the technology options which would be most appropriate in achieving these standards;
- Identify cost implications of different technologies to allow a semi-quantitative comparison of possible compliance costs;
- Consider other significant cost issues associated with environmental protection and compliance (charges, fees, environmental soil and groundwater liabilities, etc.).

Qualitative analysis of costs and cost-effectiveness

101. Each industrial facility under consideration is examined in terms of the three critical success factors for balancing environmental effectiveness and economic competitiveness: institutional and political factors of government environmental policy, the potential quality of industry response to this policy, and the potential quality of regulatory tools. This analysis provides an indication of the potential for each industrial facility to be innovative in meeting compliance, thereby providing a qualitative comparison of potential absolute costs for environmental protection and cost-effectiveness of expenditure.

Step 2: Define strategy of government environmental policy

Aim: To characterise the strategy of government environment policy in terms of institutional and political factors, and assign countries to one of four environmental policy strategy categories differentiated by overall costs for environmental protection as well as the cost-effectiveness of environmental expenditure.

102. This step is based on a graphical tool developed by Wallace²⁶ to allow strategic management of the interface between industry and environment policies, and which considers the critical role of

26. David Wallace, *Environmental Policy and Industrial Innovation, Strategies in Europe, the US and Japan*, Royal Institute of International Affairs, Earthscan Publications, 1995, ISBN 1-85383-X.

innovation in reducing costs of compliance, increasing cost-effectiveness, and enhancing profitability and competitiveness.

103. For this paper, Wallace's tool has been further developed to produce a matrix which correlates cost and cost-effectiveness with government environment policy. By considering institutional and political factors of environmental policy, each country can be assigned to one of four cost/cost-effectiveness categories.

Description of Wallace's Graphical Tool

104. Wallace's tool comprises an industry-regulator matrix which represents the possible relationships between policy makers and industry on environmental issues. Relationships are characterised by two factors: political independence of environmental policy makers and quality of dialogue between stakeholders. Together these determine the effectiveness of environmental policy making and its impact on industrial innovation, efficiency and adaptability. This matrix is therefore based on the first critical success factor for enhancing profitability and competitiveness, identified in Section 3 and expanded in Table 1²⁷.

105. Based on the industry-regulator matrix, Wallace has proposed four emergent governmental environmental strategies, each of which influences competitiveness in a different way. These strategies are characterised by high and low political independence of environmental issues (termed responsible and complacent respectively) and high and low quality of dialogue (which leads to possible innovative and non-innovative approaches to meeting environmental objectives). The characteristics of the four emergent strategies are listed in Table 8.

106. Wallace's tool provides insight into the environmental strategies for developing countries (DCs), and how these may develop to influence industry competitiveness in these countries in the future. In DCs, economic liberalisation is causing rapid economic growth. Limited institutional capacity restricts effective regulation, and government policy promotes industrialisation. Industries are politically linked to their governments. Regulatory delays and uncertainties face private investors in these countries. Environmental aspects of production are neglected, expenditure for environmental improvement is generally low, and is cost-ineffective. Typical strategies are complacent non-innovators, which are associated with a continuously increasing risk of pressure for reform. The effect of future environment policy reforms on costs and competitiveness will depend on the transition of the current strategy. Two routes are possible, from complacent non-innovator to:

- *Responsible non-innovator*. This regime may be forced on DCs if pressure for environmental improvement is resisted until it becomes unstoppable. Such a shift would result in an uncertain regulatory system, which concentrates on clean-up and not prevention, and mandates specific technologies. Furthermore, rapid transition would restrict the development of high quality dialogue and sever industry-state relations. The overall result

27. Table 8 lists three elements under institutional and political factors: policies and regulatory instruments; dialogue and relationships; and political independence. However, the matrix is constructed from two of these three elements: dialogue and political independence. The matrix does not directly consider the third element (policies and regulatory instruments) since the characteristics of the two matrix elements determine overall effectiveness of policy.

would be inflexible and costly impositions on industry, with potential loss of competitiveness;

- *Responsible innovator*. This is a more desirable route, which would retain or enhance competitiveness. However, it could only be achieved if the government sets out a clear environmental agenda, creates an effective dialogue with industry, while politically distancing itself from industry, and uses flexible regulatory mechanisms which enhanced innovation. The danger lies in the possible cementing of industry-policy makers relationship, leading to a complacent innovator strategy, which is subject to political risk if pressures for environmental improvement increase.

Table 8. **Characteristics and Effects of Strategies for Government Environment Policy**

Strategy for Policy	Characteristics	Effects
Complacent innovator	High quality dialogue Politically dependent	<ul style="list-style-type: none"> • For countries with low level of environmental concern • Favours lowest-cost, innovative responses • Avoids loss of competitiveness • Disadvantage of political risk if environmental issues assume political importance
Responsible innovator	High quality dialogue Politically independent	<ul style="list-style-type: none"> • Favours cost-effective, innovative responses • Avoids loss of competitiveness • Avoids political risk • Disadvantage of high costs in maintaining dialogue
Responsible non-innovator	Low quality dialogue Politically independent	<ul style="list-style-type: none"> • Creates high-cost responses, with no innovation • Restricts competitiveness • Frequent policy swings from deregulation to crescendos • Disadvantages of rule-bound and costly regulatory approaches
Complacent non-innovator	Low quality dialogue Politically dependent	<ul style="list-style-type: none"> • Possibly successful strategy for less developed countries where benefits of industrialisation outstrip environmental damage • Disadvantage under pressure, can lead to inflexible and costly impositions on industry strategy (i.e. to responsible non-innovator); or lack of political independence (i.e. to complacent innovator)

Adaptation of Wallace's Graphical Tool

107. For the purposes of current work, Wallace's matrix can be adapted to show qualitative trends in costs of environmental protection and cost-effectiveness of environmental expenditure. Overall environmental protection costs are likely to increase with political independence, while cost-effectiveness of environmental expenditure will increase with quality of dialogue.

108. It is assumed that government environmental policy is most effective for the responsible innovator category, where there is political independence in policy making and high quality dialogue. As defined in the first row of Table 8, effective government environmental policy will be characterised by:

- flexibility, with a personal approach;
- clear, stable and consistent framework and goals, with long-term credibility and low commercial risk;
- consistency with policies in competitive countries and are based on market information;
- use of market incentives to highlight resource inefficiencies and promote resource productivity;
- use of voluntary agreements which devolve responsibility to industry, increase dialogue, increase innovation, lower costs, and lower opposition to policy.

109. A responsible innovator strategy will best balance environmental effectiveness and business competitiveness. While environmental regulations may be stringent and absolute costs for environmental protection may be high, expenditure is cost-effective, resulting in benefits which off-set high costs.

110. The least desirable categories are those of:

- responsible non-innovator, where ineffective policy results in high costs, low value-added, and an imbalance between environmental effectiveness and business competitiveness;
- complacent non-innovator, where there is little or no consideration of environmental effectiveness.

Worksteps

- Data collection:
 - quality of dialogue between stakeholders at all stages on all issues;
 - industry involvement in policy making;
 - level of trust between industry and policy makers;
 - technical and commercial competency of regulators;
 - level of assistance to individual companies;

- political independence of policy making;
- consideration of environmental costs in decision-making.
- Data analysis:
 - based on existing country benchmarks, countries under consideration are rated with respect to political independence of environmental policy makers and quality of dialogue between stakeholders;
 - countries are ranked (responsible innovator, complacent innovator, complacent non-innovator, responsible non-innovator), to provide a qualitative comparison of potential absolute costs of environmental protection and cost effectiveness of expenditure.

Step 3 Define ability of business to be innovative, efficient and adaptable

Aim: To characterise business environment and corporate strategies, to define the potential for individual businesses to respond to environmental policy in an innovative, efficient and adaptable manner.

111. This step considers the comparative positions of individual businesses based on their ability to respond to changes in environmental policy in a cost-effective manner. It is based on the assumption that a business with the internal capacity to be innovative, efficient and adaptable in the face of change will have significant cost-advantage.

112. Where the cross country comparison is between two developing countries, it may be safe to assume that businesses will rank evenly in this step. Since neither business then will be at a significant cost-advantage over the issue of business environment and corporate strategy, this step may be omitted.

Worksteps

- Data collection:
 - effectiveness of internal and external business communication;
 - technological competence;
 - effectiveness of integrated planning and control;
 - commitment to business efficiency, quality and improvement;
 - effectiveness of market orientation and assessment of customer needs;
 - management and key individual competence;
 - effectiveness of risk and liability management systems.

- Data analysis:
 - rank businesses into two categories (innovator, non-innovator) according to the potential quality of the business environment and corporate strategy.

Step 4: Define ability of environmental regulations to promote innovative business response

Aim: To characterise the innovative potential of business response in the context of the quality of the regulatory tools used to implement environment policy.

113. This step considers the comparative quality of regulatory tools used by government to implement policy. It is based on the assumption that high quality tools encourage an innovative, efficient and adaptable response to change by business.

Worksteps

- Data collection:
 - focus of regulatory tools (performance vs technology; pollution prevention vs end-of-line; locally determined vs nationally determined);
 - achievability of standards and scope for relaxation;
 - history of implementation and enforcement;
 - appropriateness of implementation schedules.
- Data analysis:
 - rank regulatory tools into one of two categories (promotes innovation, restricts non-innovation) according to their potential quality and ability to promote innovation, efficiency and adaptability.

Step 5: Qualitative comparison of costs and cost-effectiveness

Aim: To provide qualitative comparison of the overall innovative potential of the business response to environment issues, and costs and cost-effectiveness of environmental expenditure.

114. This step combines the results of Steps 2, 3 and 4, to define for each facility an overall innovation potential which considers government environmental policy strategy, business strategy and regulatory tools.

115. As illustrated in Figure 3, the most desirable combination is:

- responsible innovator government environmental policy strategy;
- innovative business strategy;
- regulatory tools which promote innovation.

Under this combination, environmental improvement may be related to increased growth and productivity. The combination of tough but stable regulations, political independence and informed and continuous dialogue between industry and policy makers will encourage companies to re-engineer their technologies in a way which causes a process to pollute less, operate at lower costs and produce higher quality products. These benefits outweigh some or all the costs related to increased standards and environmental protection.

Figure 3. **Desirability and Cost-effectiveness of Combinations of Government Environmental Policy Strategy, Business Strategy and Regulatory Tools**

Desirability Cost effectiveness High ↓ Low	Government Environmental Policy Strategy	Business Environment and Corporate Strategy	Characteristics of Regulatory Tools
		Responsible innovator Complacent innovator Complacent no innovator Responsible non-innovator	Innovator Non innovator

Worksteps

- Characterise each facility by government environmental policy strategy, business strategy and regulatory tools.
- Using weighted scores for each of the three elements, calculate overall score.
- Correlate overall score to costs and cost-effectiveness and compare scores for the different facilities.

Step 6: Comparison of potential compliance costs and cost effectiveness

Aim: To provide comparison of the influence of regulatory standards on potential compliance costs and cost-effectiveness, within the context of the critical success factors for balancing environmental effectiveness and economic competitiveness.

116. This step sets the semi-quantitative comparison of potential compliance costs based on regulated standards (Step 1) within the context of the qualitative comparison of costs and cost effectiveness (Step 5).

Worksteps

- Evaluate how significant differences in potential costs of technologies required to meet selected environmental standards (Step 1) could be affected by the ability or disability of the business to be innovative, efficient and adaptable.

- Rank each facility in terms of the likely costs of environmental compliance.

117. Note that if Step 3 is omitted (in cases where business environment and corporate strategy are similar), the analysis will be based on a comparison of government environmental policy, standards and regulations only. The final outcome will therefore be a comparison of countries in terms of the likely costs of environmental compliance.

6. COSTS, COST-EFFECTIVENESS AND COMPETITIVENESS

118. The outline methodology above provides a qualitative comparison of the effect of environmental policies, regulations and standards on the costs and cost-effectiveness of environmental protection. The current section considers how these environmentally-related costs and cost-effectiveness can be correlated to business competitiveness by reviewing:

- methods of environmental cost accounting;
- the link between environmental costs, production costs and business competitiveness;
- the link between environmental cost-effectiveness and business competitiveness.

Environmental cost accounting

119. The components of environmental costs include:

- direct costs, associated with pollution abatement equipment:
 - investment costs: plant and equipment; buildings; land; upgrade; loss of output during transition/installation;
 - operating costs: labour; energy; materials; services (monitoring, auditing, and training); rents; maintenance; fees/fines/penalties;
- indirect costs, which arise from in-process adjustments and input changes.

120. Absolute environmental costs are difficult to define, measure and compare, because of uncertainties surrounding environmental cost accounting:

- there is no universal way to define environmental costs;
- in many businesses, environmental expenses are not calculated in absolute terms. Rather they are rolled into overheads, often to avoid prohibitively expensive environmental cost accounting systems;
- where they exist, environmental cost accounting methods are business-specific, and are often incompatible or incomparable between businesses;

- conventional accounting systems are flawed as they have no means to record and value a transaction which has no value (e.g. wastes);
- conventional accounting systems do not measure and record impacts on resources, property or interests external to the entity. Thus they cannot account for environmental benefits or degradation²⁸.

121. The absence of reliable environmental cost accounting systems tends to restrict quantitative comparisons of environmental costs and cost-effectiveness. This in turn restricts the accuracy in correlations of environmental costs to overall production costs.

Environmental costs and production costs

122. Section 2 links production costs for the iron and steel sector to competitiveness. Because the market for this sector is globalised, maximum competitive advantage will be derived where businesses operate with minimum production costs. But what is the relationship between environmental costs and production costs?

123. Environmental costs are just one of a range of factors which influence relative production costs and business competitiveness. Other significant factors include costs of labour, energy, materials and financial expenses (depreciation and interest). The actual costs of each factor vary significantly from country to country, and between facilities in the same country. Overall production costs for any one business reflect actual costs of each contributing factor and the combined effectiveness with which each is managed and balanced. A change in any one factor will create a change in the composition of overall production costs. The quality of the business response to redress this change will determine overall production costs. This process of redressing the balance between factors is particularly critical in the iron and steel sector, where highly competitive businesses are plagued by overcapacity and relatively low margins.

124. Country-average production costs in the iron and steel sector for February 1997 are summarised in Table 9. Average country costs range from \$415/tonne steel shipped in Mexico to \$554/tonne in Germany. Germany's competitive disadvantage is related to highest labour costs (twice that of some countries per tonne steel), and high material costs. Mexico's advantage is related to lowest material costs and low labour costs. Material costs vary from 30 per cent of pretax cost in Germany to 42 per cent in CIS. Labour costs vary from 15 per cent of pretax cost in Brazil to 31 per cent in Germany. Financial expense is highest in Brazil at 18 per cent of pretax cost, and lowest in CIS at 6 per cent.

125. To what extent can environmental costs influence production costs? Realistically, responding to environmental challenges brought about by environmental regulations is a complicated and costly

28. Robert Repetto, Dale Rothman, Paul Faeth and Duncan Austin, *Has Environmental Protection Really Reduced Productivity Growth: We Need Unbiased Measures?* World Resources Institute, 1996, ISBN 1-56973-101-2. This study issues caution about current methods of assessing cost advantages and disadvantages of environmental improvements which result from regulations. Conventional accounting systems are often used, which consider the higher input costs resulting from regulation, but fail to account for concomitant environmental savings/benefits which result from lower environmental emissions.

proposition for industry, especially where environmental costs outpace inflation and economic growth²⁹. It is estimated that, over the period 1973 to 1989, capital expenditures in the US steel industry averaged \$3.8/tonne of steel, while operating expenditures averaged \$10.2/tonne³⁰. Expenditures peaked in 1979/1980. These expenditures on direct pollution control were estimated at less than 5 per cent of steel production costs throughout the period, and comparable to expenditures in other countries. These estimates do not consider indirect costs (additional costs incurred in adjustments to production process and optimal input combinations) or indirect cost benefits (increased productivity).

Table 9. **World Production Cost Comparisons**
(\$/tonne steel shipped, February 1997)

Item	USA	Japan	Germany	UK	France	Canada
Material cost	177	172	169	167	156	169
Labour cost	155	144	170	119	144	140
Financial expense	38	82	60	31	68	37
Pretax cost	513	538	554	462	518	490
Item	Australia	South Korea	Chinese Taipei	Brazil	Mexico	CIS
Material cost	159	155	160	158	144	186
Labour cost	137	89	125	71	91	70
Financial expense	49	77	64	84	57	27
Pretax cost	477	471	505	461	415	442

Source: PaineWebber from World Steel Dynamics. Plant comparisons do not reflect different steel qualities. Cost figures range from well above to well below average costs in a number of countries.

126. Thus:

- production costs are not determined by any one cost factor, but by the balance of a number of contributory factors;
- the impact of a change in any one factor on overall production costs will be determined by the ability of the business to redress the balance between factors;
- a change in cost of any one factor may therefore cause increased or decreased production costs, and the change in production costs may not be proportional to the original change in factor costs;
- in OECD countries, direct environmental costs are believed to account for 1 to 5 per cent of production costs, but this figure does not consider indirect costs or savings;

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29. Noel Wally and Bradbley Whitehead, *It's Not Easy Being Green*, Business and the Environment, Ed Richard Welford and Richard Starkey, Earthscan Publications, 1996, ISBN 1-85383-301-0.
30. Satish Joshi, unpublished paper, *Impact of Environmental Regulations on the US Steel Industry*, John Heinz School of Public Policy and Management, Carnegie Mellon University, Pittsburgh, 1995.

- relative to costs of labour, raw materials and financial expenses, environment costs are expected to be far lower determinants of overall business viability and competitiveness;
- the lack of reliable and standard environmental cost accounting systems complicates the issue of quantitatively relating environmental costs to overall production costs.

Environmental cost-effectiveness and business competitiveness

127. The matrix approach adopted to provide comparative analysis of the effect of environmental regulations on costs and cost-effectiveness is based on the premise that innovation is the key to long-term sustainable competitiveness, and that flexible government policy and stable, consistent regulation promotes innovation. Within a given environmental policy regime, it is the manner in which companies respond to environmental challenges that determines whether or not environmental spending will achieve real, sustainable competitive advantage. Thus, while there are costs associated with compliance, there may also be productivity benefits which off-set these costs.

128. Competitive advantage therefore depends on how effectively money is invested in environmental controls and not necessarily on how much money is invested. This is because production costs are minimised where the most cost-effective solution, and not necessarily the least-cost option, is chosen.

129. For any given business, different environmental initiatives will bring different levels of cost-effectiveness. An innovative business will not always or indefinitely generate positive financial return from environmental expenditures, thereby creating value through environmental enhancements. However, an innovative business will seek to minimise the loss of shareholder value caused by environmental costs. This in itself will bring competitive advantage over another business which is subjected to similar environmental demands, but which is restricted in its innovation.

130. Thus, there is a positive correlation between environmental cost-effectiveness and business competitiveness. Again, however, the lack of reliable and standard environmental cost accounting systems means that this correlation is not easily quantified.

7. CONCLUSIONS

131. Because of the globalisation of the iron and steel market, competitiveness can be related to overall production cost and profitability.

132. Production costs are determined by the overall performance of the business against a number of cost factors including environment, labour, energy, materials and capital depreciation. Maximum competitive advantage is achieved at minimum production cost. Production cost is minimised where cost-effectiveness of environmental expenditure is maximised.

133. There is no clear or direct relationship between environmental regulations and business competitiveness.

134. However, there is a relationship between the innovation, efficiency and adaptability of business response to environmental demands and business competitiveness. The quality of the response will

determine whether or not environmental spending will be cost-effective and enhance competitiveness, or at worst minimise loss.

135. The ability of business to respond in an innovative, efficient and adaptable manner to environmental demands is determined by government environmental policy strategy, the quality of the regulatory tools, and business environment and corporate strategy.

136. The actual business response to environmental demands will be to invest in end-of-line treatment facilities, or introduce process changes which minimise or eliminate waste.

137. Environmental standards may influence the methodology and technology option chosen for pollution control. This in turn will influence costs. A cross country comparison of environmental standards for the main sources and pollutants (particulates, SO_x, NO_x, wastewater and hazardous solid waste) will therefore provide a semi-quantitative comparison of potential costs for meeting compliance.

138. However, a comparative analysis of cost advantages that different environmental policies offer to iron and steel producers must consider environmental standards in the context of:

- the nature of the relationship between policy makers and industry, and whether this promotes effective policy, and open and honest dialogue while maintaining the political independence of policy making from industry;
- the characteristics of regulatory mechanisms and schedules, and their ability to accommodate innovation, improved efficiency and adaptation, encourage least-cost solutions, and enhance competitiveness;
- the capacity and readiness of the business to measure market expectations, and seize opportunities which improve business efficiency, while managing environmental risks and compliance.

139. Therefore, the outline methodology proposed provides a qualitative comparison of the impact of environmental standards for significant pollution sources and pollutants on the costs and cost-effectiveness of environmental protection, within the context of environmental policy strategy, the quality of the regulatory tools, and business environment and corporate strategy.

140. The methodology ranks businesses (or countries) according to the potential for innovative, efficient and adaptable responses and thus the likely costs and cost-effectiveness of environmental compliance.

141. This work has aimed to provide a preliminary view of the relationship between environment policy and competitiveness in the iron and steel sector. It has also aimed to raise issues for further discussion. The methodology developed is not considered definitive. Rather, it should be a starting point to initiate further study and development of a effective tool which can be used by the OECD Steel Group for cross country analysis.

8. RECOMMENDED AREAS OF FURTHER STUDY

142. The outline methodology proposed here needs further development of the detail in order to provide OECD with an effective and useful comparative tool.

143. It is recommended that this development be focused on quantitation:

- how environmental costs can be reliably quantified and accurately related to production costs (and hence competitiveness);
- how a weighting system can be incorporated into the methodology to provide a scoring system which accurately reflects comparative costs and cost-effectiveness -- this weighting system needs to be incorporated at each step and for each variable.

144. It is recommended that a case study be used during the further development stage, in order to ensure that a practical and useable methodology is developed. This case study should involve the active analysis of two or more iron and steel facilities in different developing countries. The aim would be to predict how environmental policies, regulations and standards in each country potentially affect the production costs and competitive position of the facilities.

145. It is envisaged that the outline methodology proposed here will be used as a basis of comparison, and that this will be further developed into a detailed list of relevant issues, questions, scores and weightings. The scores and weightings will reflect the potential of each issue to influence production costs. This development stage will result from interviews with policy makers and facility staff, a policy evaluation, and an environmental review of the facilities themselves to develop and test cost data for upgrade to be compliant with relevant standards.

146. Deliverables would include:

- a step-by-step guide, which will allow the use of this model as a tool for practical purposes, to provide some quantification of how different environmental policies, regulations and standards can affect production costs;
- a simplified uniform method for environmental cost accounting, to enable two facilities to be compared;
- some insight into how environmental policies, regulations and standards could be developed in a manner more appropriate to the developing world, which would stimulate maximum environmental effectiveness while producing minimum loss of competitiveness.

**ANNEX: REVIEW OF ENVIRONMENTAL POLICIES, REGULATION AND GUIDELINES
IN THE IRON AND STEEL SECTOR FOR THE UNITED KINGDOM,
EGYPT AND THE WORLD BANK**

United Kingdom

1. British legislation is based on environmental objectives set at the level of the European Union (EU). In accordance with EU policy, EU Member States are free to develop their own programmes for achieving these objectives. In doing so, Member States should consider general EU policy which stresses that, while environmental protection is a challenge for industry, industrial facilities need to use environmental protection as an opportunity to improve competitiveness through optimisation of resources.

2. In the United Kingdom, the government has developed a series of sector-specific guidance notes for prescribed processes. Operators are required to reduce the generation of waste at source and select a combination of primary process and pollution abatement techniques which constitute best practicable environmental option (BPEO). Specific conditions also relate to the use of best available techniques not entailing excessive economic cost (BATNEEC) to prevent or minimise and render harmless any release of prescribed substances and for rendering harmless any other substances which may cause harm.

3. For the iron and steel sector, performance standards are used to define release levels for air and environmental quality objectives define release levels of wastewater. Requirements for releases to land are determined for individual processes. Table A1 summarises performance standards for air and water. Guidance notes also specify operational practices and monitoring requirements. These are also listed in Table A1.

4. British standards for the iron and steel sector are not equivalent with other countries in the EU, because each country has different priorities, and different target pollutants. As an indication, Table A2 compares how air emission standards vary across the EU. These data are not directly comparable, but are given as an illustration of differences only.

Egypt

5. With the creation of the new Environmental Affairs Agency and the ratification of Law 4 of 1994 on the environment, the government of Egypt has shown commitment to a stronger position on industrial pollution. Law 4 and its regulations have consolidated environmental law, and revised and extended regulated standards. For example, they introduce for the first time point source air emission standards. The process of developing the law has involved consultation with industry. Industry has until February 1998 to comply with the standards, apply for a two-year extension, or risk being closed down.

Table A1. **British regulations for iron and steel sector**

Regulation	Specification
Release levels to air	Particulate matter - EAF direct extraction, sinter plant, desulphurisation 100 mg/m ³ - Basic oxygen process (converters), sinter dedusting, scarfing, general extraction, auxiliary foundry operations 50 mg/m ³ - Combined collection systems, roof extraction systems 25 mg/m ³ Lead and compounds (as Pb) 2 mg/m ³ Cadmium and compounds (as Cd) 1 mg/m ³ Fluoride (as HF) 10 mg/m ³
Release levels for water	Total Cadmium and its compounds 0.05 mg/l Discharges to controlled waters and sewers set according to individual facility. Discharges to controlled waters are regulated by maximum load and concentration to safeguard receiving water quality standards
Abatement techniques	Process selection should be least polluting and waste should be minimised by recycling Release levels to air are based on efficient use of bag filters and electrostatic precipitators to control dusts; cyclones are encouraged for reducing loads prior to subsequent cleaning plant; hot and aggressive gases should be controlled by venturi scrubbers or impeller disintegrators; arrestment equipment should be available at all times Fluorides should be removed by water scrubbing HF is removed by contact with lime upstream of a bag filter Mercury in water is removed by reaction with sodium sulphide, followed by flocculation, settlement and filtration Cadmium in water is precipitated using lime or caustic, followed by flocculation, settlement and filtration
Sampling and monitoring	For air: continuous sampling and monitoring where appropriate; for compliance purposes, tests are carried out according to the main procedural requirements of that standard For water: continuous and flow proportional, according to specified methods

Source: Her Majesty's Inspectorate of Pollution (HMIP), *Pollution Control for Integrated Iron and Steel Processes*, Report N°DoE/HMIP/RR/93/022.

Table A2. Performance standards for air pollutants from iron and steel sector in the EU (mg/Nm³)

Pollutant	Denmark	Germany (steel)	Sweden (steel)	Italy (steel)	Spain (steel)	United Kingdom (steel)
Particulate matter	20	20 converters 50 sinter plant 50 blast furnace	10 converters (150 g/tonne)	100 sinter plant 150 blast furnace	250 new sinter plant 400 old sinter plant 100 new blast furnace 200 old blast furnace	100 desulphurisation 100 material handling 100 sinter plant 100 blast furnace 100 EAF 50 converters 50 sinter(secondary emissions) 50 general process emissions 25 roof extraction
SO _x	500	500 (general)	-	-	-	-
NO _x	500	400	-	400	-	-
VOC	500	-	-	-	-	-
Cu	5	5 (general)	-	-	-	-
Pb	1-5	5 (general)	-	10	-	2
Hg	0.1-0.5	0.2 (general)	-	0.4	-	-
Cd	-	0.2 (general)	-	-	-	1
Zn	5	-	-	-	-	-
F	-	-	-	-	-	10

Source: Her Majesty's Inspectorate of Pollution (HMIP), *Chief Inspector's Guidance to Inspectors, Industry Guidance Note IPR 2, Metal Industry Sector*, 1993, ISBN 0-11-752409-3.

6. The policy of the Environmental Affairs Agency is not to restrict development, but to find a compromise on environmental performance and economic growth. Although a nation-wide enforcement network is being created, the Agency will encourage self-monitoring as an alternative to official inspection.

7. Law 4 specifies a series of explicit standards for discharges of industrial wastes to air and water. For significant pollutants from the iron and steel sector, Table A3 summarises these standards.

Table A3. Selected Performance Standards for Iron and Steel Sector in Egypt

Regulation	Specification
Point source air emissions	<ul style="list-style-type: none"> - Particulate matter (steel) <ul style="list-style-type: none"> Existing processes 200 mg/Nm³ New processes 100 mg/Nm³ - SO_x <ul style="list-style-type: none"> Existing processes 4,000 mg/Nm³ New processes 2,500 mg/Nm³ - NO_x 300 mg/Nm³ - Pb 20 mg/Nm³ - Cd 10 mg/Nm³ - Heavy metals 25 mg/Nm³ - Fluorine 20 mg/Nm³
Discharges to controlled surface water bodies	<ul style="list-style-type: none"> - pH 6-9 - Suspended solids 30 mg/l - COD 40 mg/l - Phenol 0.002 mg/l - Cd 0.01 mg/l - Total Cr 0.05 mg/l - Zn 1 mg/l - Oil and grease 5 mg/l - Fluoride 0.5 mg/l
Releases to land	Disposal of wastes to land should not threaten human health or environment

World Bank

8. The World Bank has developed standards for each industry which are:

- based on USA legislation;
- to be used by Bank staff and consultants in project assessments.

9. In adapting US legislation for their own purposes, the World Bank has produced comprehensive guidelines for the iron and steel sector, which cover pollution prevention and control, target pollutant loads, treatment technologies, emission levels, and monitoring and reporting. Table A4 summarises these guidelines.

Table A4. **World Bank Guidelines for Iron and Steel Sector**

Guideline	Specification
Pollution prevention and control	A number of specific in-process measures for improved efficiency in iron and steel making
Target pollutant loads	<u>For wastewater:</u> <ul style="list-style-type: none"> - Reuse 90 per cent of wastewater - Discharge less than 5 m³/tonne steel, and preferably less than 1 m³/tonne steel
	<u>For solid wastes:</u> <ul style="list-style-type: none"> - Generate blast furnace slag at a rate less than 320 kg/tonne iron - Generate basic oxygen process slag at a rate between 70 and 170 kg/tonne steel - Recycle 65 per cent of basic oxygen process slag as building materials - Consider zinc recovery
Treatment technologies	<u>For air emissions:</u> <ul style="list-style-type: none"> - Particulate matter (PM 10) 100 g/tonne product for blast furnace and basic oxygen furnace; 300 g/tonne from sinter plant Arrest using scrubbers, baghouses and electrostatic precipitators (99.9 per cent removal efficiency for latter two technologies) - Sulphur oxides 1,200 g/tonne for sinter plant (500 mg/Nm³) Arrest with scrubbers (90 per cent removal efficiency) - NOx 500 g/tonne (200 mg/Nm³) Use low NOx burners or other combustion modifications - Fluoride 1.5 g/tonne (5 mg/Nm³)
	<u>For wastewater:</u> <ul style="list-style-type: none"> - Treatment should include sedimentation to remove suspended solids, physical chemical treatment to precipitate heavy metals, and filtration - Blast furnace - 0.1 m³/tonne steel Zn - 0.6 g/tonne steel Pb - 0.15 g/tonne steel Cd - 0.08 g/tonne steel - Basic oxygen process - 0.5 m³/tonne steel Zn - 3 g/tonne steel Pb - 0.75 g/tonne steel

Table A4. **World Bank Guidelines for Iron and Steel Sector** (cont'd)

Guideline	Specification
	<p><u>For solid waste:</u> Solid wastes containing heavy metals must be stabilised before disposal</p>
Emission levels	<p>- Must be established on a project-by-project basis based on the following guidelines</p> <p><u>For air emissions:</u></p> <ul style="list-style-type: none"> - Particulate matter 50 mg/Nm³ - SOx 500 mg/Nm³ - NOx 750 mg/Nm³ - Fluorides 5 mg/Nm³
Emission levels c/t	<p><u>For wastewaters:</u></p> <ul style="list-style-type: none"> - pH 6-9 - Suspended solids 50 mg/l - COD 250 mg/l - Phenol 0.5 mg/l - Cd 0.1 mg/l - Total Cr 0.5 mg/l - Pb 0.2 mg/l - Hg 0.01 mg/l - Zn 2 mg/l - CN (free) 0.1 mg/l - CN (total) 1 mg/l <p><u>For sludges:</u></p> <ul style="list-style-type: none"> - Heavy metals should be stabilised to ensure that leachates from sludges do not exceed the limits presented for wastewater
Monitoring and reporting	<p><u>For air emissions:</u></p> <ul style="list-style-type: none"> - Continuous monitoring for air emissions after control device for particulate matter; annually for fluoride, SOx and NOx <p><u>For wastewater:</u></p> <ul style="list-style-type: none"> - Daily for listed parameters (except metals) - Metals on a quarterly basis

Source: World Bank, *Pollution Prevention and Abatement Handbook*, draft report, July 1995 and March 1997.