Energy efficient and environmentally sound industrial technologies in Asia

Part I: Assessment of the economic viability of technological options

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Abstract
This article describes some technological changes that could be introduced in energy-intensive and polluting industries in China, India, the Philippines and Sri Lanka. Among the factors that need to be considered when a new energy efficient and environmentally sound industrial technology is chosen are the state of existing technologies, up-front costs, operating costs, efficiency of the equipment, and the level of in-house skill available. To make sure a new technology is economically viable, a number of external factors also need to be considered: the presence of rational energy pricing, whether there are appropriate environmental regulations and incentive regimes in place, the general financial environment, the transparency of the economic system, etc.

Résumé
L'article décrit quelques-unes des modifications qui pourraient être apportées aux industries polluantes et énergivores de la Chine, de l'Inde, des Philippines et du Sri Lanka. Avant de choisir une nouvelle technologie industrielle économe en énergie et respectueuse de l'environnement, il convient de considérer l'état des technologies existantes, la mise de fonds initiale, les coûts d'exploitation, l'efficacité de l'équipement, et le niveau de qualification du personnel. Pour qu'une nouvelle technologie soit économiquement viable, il faut aussi prendre en compte certains facteurs externes : l'existence d'un système rationnel de fixation des prix de l'énergie, l'existence de règlements environnementaux et de mesures incitatives adéquates, le contexte financier général, la transparence du système économique, etc.

Resumen
Este artículo describe algunas modificaciones tecnológicas que podrían aplicarse a las industrias de alta producción energética y muy contaminantes de China, India, Filipinas y Sri Lanka. Los factores a tener en cuenta para elegir una nueva tecnología de ahorro energético y optimización medioambiental, son: el estado de la tecnología vigente, los costes derivados y operativos, la eficacia del material disponible y el grado de competencia interna. Para cerciorarse de la viabilidad económica, también hay que observar si el precio de la energía es el adecuado, si existen reglamentos sobre medio ambiente e incentivos, cual es el entorno financiero general, si el sistema económico es propicio, etc.

Part II will appear in the next issue.

Introduction

This article summarises the outcome of a research project conducted using the Case Study Approach in three energy intensive and environmentally polluting industrial sub-sectors identified in four Asian countries, namely China, India, the Philippines and Sri Lanka. The industries selected were iron and steel, cement, and pulp and paper.

The objective of the research project was to enhance the synergy among the four countries in their efforts to grasp the mechanism and various aspects related to the adoption and propagation of energy efficient and environmentally sound industrial technologies (E^{3}STs). The results of this study should be useful to other developing countries, as it covers countries of different sizes, with different political systems and at different stages of development.

The article includes discussion of E^{3}STs retained for appraisal in the three industrial sub-sectors, their cost-benefit analysis, and an inter-country comparison of their performance. The purpose of this comparison is to identify the causes of variations in the economic performance of the same technology/process in different countries and to learn from the success or failure of technology adoption in some cases.

Methodology

Following visits to selected plants and familiarization with the existing set-ups in the four countries, one or two E^{3}STs that had already been adopted and one potential candidate for implementation (out of over 30 E^{3}STs identified for consideration from three sectors selected) were shortlisted from each industry in consultation with plant personnel. All actors belonging to the enterprise and the external actors who influence the process of E^{3}ST selection, and are involved in its successful adoption, were identified during the study. Discussion with them has allowed assessment of the role they play in the technology adoption process. The manner in which this task was accomplished, with the involvement of personnel from the enterprise as well as the external actors, is schematized in Figure 1.

Cost-benefit analysis of selected E^{3}STs

Cost-benefit analysis of an E^{3}ST is important for its adopters as well as for potential financing agencies. Such an analysis permits assessment of the economic viability of a specific technology in a country's prevailing socio-economic environment. Though the complexity of a given technology remains the same in all the countries, several intervening factors determine its adoption, some associated with the internal dynamism of the adopter and some with external parameters over which the adopter has practically no control. If adoption of the technology does not make economic sense in the first place, however, it is unlikely to be accepted unless there are other compelling reasons.

Most often, the cost-benefit analysis of an E^{3}ST only deals with the direct cost of a project and its direct benefits to the adopter, including total investment in the project, benefit from energy efficiency improvements, reduced waste emission fees, increased productivity, etc. With greater awareness of the adverse impacts of human activities on the natural environment, it has become necessary to incorporate some indirect costs and benefits in a project. These include additional costs associated with pollution prevention, benefits in the form of environmental and natural resources conservation, and avoided cost of additional investment in waste treatment facilities and energy supply enhancement.

Techno-economic comparison

Inter-country comparisons are not always straightforward, as they are undertaken or considered in different countries at different times. Therefore, presenting costs and benefits in the same time scale is not easy as it involves the use of exchange rates as well as inflation rates of the local currency.

The following section provides an overview of E³STs selected for assessment in three industrial sub-sectors, with respect to their investment and financial returns, before making an inter-country comparison.

The cement industry

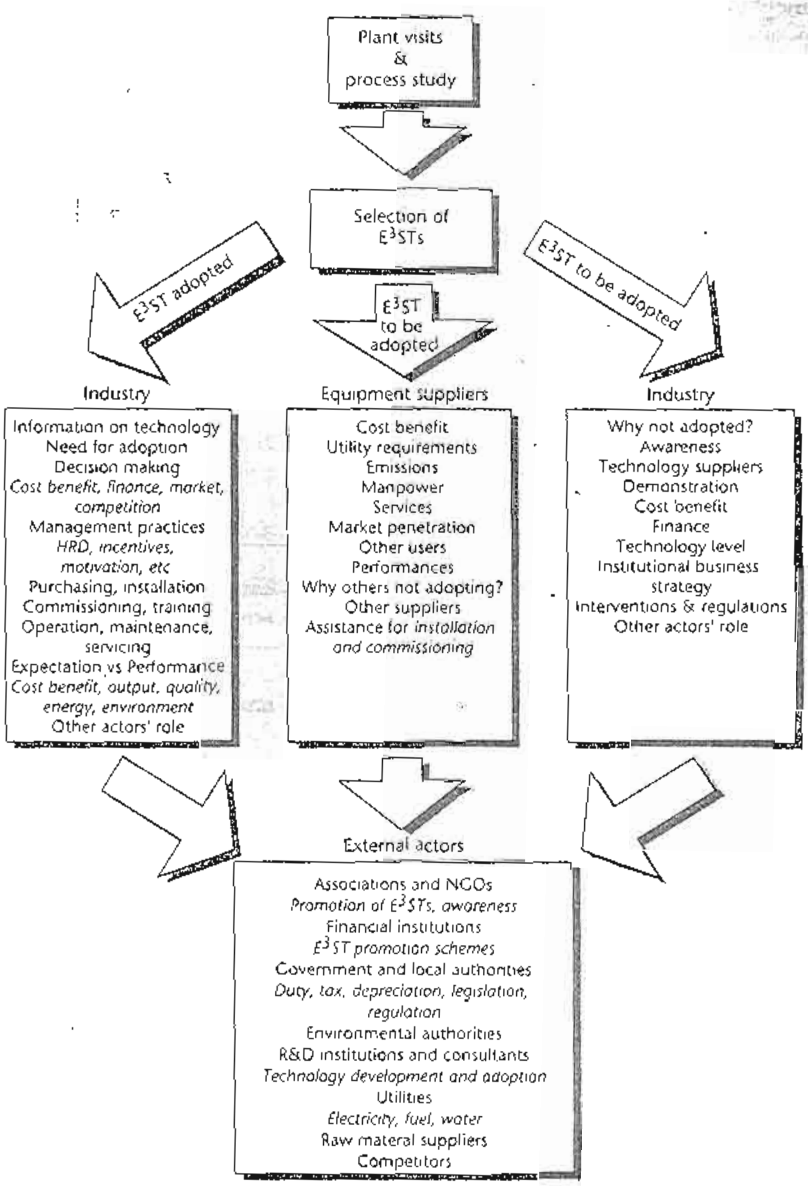
Some of the E³STs analysed in the cement industry contribute to both energy conservation and environmental depollution (e.g. wet to semi-wet process conversion, wet to dry process conversion, five-stage pre-heating with pre-calcination, replacement of ball mill by a vertical E-mill and of ball mill by a vertical roller mill). Some measures are taken purely for energy conservation (e.g. clinker cooler efficiency improvement, replacement of the tube mill with vertical roller mill and ball mill, and closed loop milling instead of open loop) or environmental protection (use of bag filters or electrostatic precipitators). Some technologies require marginal investments in the range of US$ 50,000, while others require investment in the range of US$ 5 to 10 million. One project in China, involving complete retrofitting of the process in a large factory (conversion from wet to dry process), requires an investment of US$ 132 million. In general, the higher the investment the higher are the associated financial benefits. These range from as low as US$ 24,000 up to US$ 19 million per year, leading to pay-back periods of less than a year up to 17 years. Since indirect benefits are not quantified in this analysis, the E³STs involving purely environmental gains have led to an increase in the production cost.

The iron and steel industry

All E³STs analysed in the iron and steel industry contribute to significant energy saving. Except E³STs such as O_2 lancing, top pressure recovery turbine and blast furnace gas recovery, all others help in environmental depollution in terms of SO_x and NO_x emissions. They differ significantly in terms of capital investment requirements, from practically zero to as high as US$ 160 million, depending on plant capacities. Similarly, the financial returns range from a negligible amount to as high as US$ 26 million per year, leading to pay-back periods of up to six years. In spite of the fact that many of these E³STs have a relatively short pay-back period of less than three years, they are still under consideration for adoption.

Replacement of the alternate-current arc furnace (AC-EAF) by a direct-current EAF in China and India shows vast differences in capital

Figure 1
Methodology followed to assess the technology adoption process



outlay, financial returns and energy saving. Though the Chinese system appears to be twice as energy efficient as the Indian one, its financial return is not as high due to the low cost of energy in China.

The pulp and paper industry

All E³STs selected from this sub-sector contribute to significant energy saving (thermal as well as electrical) and environmental gains in terms of CO, SO_x and NO_x emissions. Most of the E3⁵Ts lead to relatively short pay-back periods of less than three years. One exception is the black liquor chemical recovery project in Sri Lanka, where the expected pay-back period was 15 years. However, as far as the factory is concerned, this attempt was a failure due to the wrong choice of technology. A similar technology was successfully adopted almost ten years later in China with nearly one-fourth the capital outlay and a pay-back period of less than nine years. (The details are given in Table 2.) The cogeneration project, which requires nearly the same capital outlay in India and China, results in significantly different financial returns. This could be mainly attributed to the major differences in energy pricing.

The next section compares the economic performance of the same E³ST in two different countries, in order to identify important factors influencing project viability.

Inter-country comparison of E³STs

In order to identify differences in the techno-economic performances of E³STs, an attempt has been made to compare two countries at a time in detail. Due to the differences in the time of implementation, level of existing technology, and general socio-economic settings and backgrounds, the same E³ST can lead to very different economic results in different countries. Although a perfect comparison cannot be made due to varying local conditions in different countries, this at least allows identification and highlighting of some major factors contributing to the differences, as

Table 1
Continuous casting in the iron and steel industry (India vs. Sri Lanka)

Country	India	Sri Lanka
Project	Five machines with 1.5 million tonnes of annual capacity	One machine with 12,000 tonnes of annual capacity
Status	Adopted in 1985	Adopted in 1996
Total investment (million US$)	28.57	0 36
Discount rate (%)	12	12.5
Interest rate (%)	15	24
Raw material price (US$/tonne)	72	136
Finished product selling price (US$/tonne)	139	545
Energy price (US$/GJ)	0.82	4.9
Energy savings (GJ/tonne)	0.7	0 7
Productivity increase (%)	9.1	5
Benefit* (million US$)	3.81	0.221
Pay-back time (years)	7.5	1 6
Specific cost of installation (US$/tonne)	19	30
Share in benefit (%)		
Productivity increase	64	88
Energy savings	36	12

* This is over and above the benefit derived from the existing system

Table 2
Black liquor chemical recovery in the pulp and paper industry (China vs. Sri Lanka)

Country	China	Sri Lanka
Project	Black liquor 50 tpd	Pulp 35 tpd
Status	Adopted in 1987	Adopted in 1978, but abandoned due to technological failure
Adopter	Capacity: Pulp 15,000 tpy, Paper 30,000 tpy	Capacity: Pulp 10,500 tpy, Paper 15,000 tpy
Total investment (million US$)	5.63	20.2
Discount rate (%)	12	12.2
Interest rate (%)	15	24
Purchase price of NaOH (US$/tonne)	650	645
Steam price (US$/tonne)	3.98	
Recovery cost (US$/tonne of alkalai)	120	6,756
Percentage of recovery	50	7
Steam supply (tonne/year)	15.7×10^3	
Benefit (million US$)	0.65	net loss
Pay-back time (years)	8.6	N/A
Investment cost per tonne of black liquor (US$/tonne)	375	1,750

discussed below. Altogether four comparisons are made, consisting of one technology pertaining to each sub-sector and one horizontal technology, i.e. cogeneration.

Continuous casting machine in the iron and steel industry

The first example is the adoption of continuous casting in steel manufacturing in order to cut down on energy losses and improve productivity. Table 1 compares the benefits of adopting continuous casting in the iron and steel industry in India and Sri Lanka.

To meet its steel demand, raw steel has to be imported at a higher cost in Sri Lanka. Due to the limited supply of finished product in the market and the factory's ability to provide customized products, the effect of value addition is very important in this country. The finished products are sold at nearly four times the raw material price, whereas in India they are sold at only twice the raw material price. Therefore, the factory in Sri Lanka gets the maximum benefit from the project through increased productivity (88%) in comparison with energy saving (only 12%). Even the benefits from energy saving are more important than in India, as the energy price is relatively high due to the bulk of Sri Lanka's commercial fuel being imported. These differences explain the reason for such important differences in economic performance, affecting the attractiveness of E³STs to an enterprise.

Initial specific investment required for the project in Sri Lanka is significantly higher than in India for the following reasons: necessity to import most of the retrofitting equipment for the plants, different times of implementation, and higher cost of borrowing capital from the financial market.

It can be seen from the above that a specific measure considered for adoption could lead to either positive or negative results, depending on its suitability to local conditions. Factors such as import duties on raw materials or equipment, interest rates, etc., which are beyond the control of the factory, can influence the decision-making process. For the sake of national interests, e.g. less dependence on imported fuel and a cleaner environment, national authorities may formulate policies to render the adoption of some selected E³STs more attractive to industries without creating undesirable effects on other sectors of the economy.

Black liquor chemical recovery in the pulp and paper industry

The second example focuses on an environmentally benign project, combustion of black liquor in the pulp and paper industry, which helps recover chemicals used in the pulping process as well as generating some steam for the factory. Table 2 compares the performance of a black liquor chemical recovery system adopted in the pulp and paper industry in China and Sri Lanka.

Following project implementation in 1978, the cost of alkali recovery in the factory in Sri Lanka was found to be much higher than the market price of alkali due to some technical problems in the recovery plant, such as a lower recovery rate than that for which the system was designed, high initial investment since most of the equipment was imported, and the high cost of borrowing capital for the project. Note that the high silica content of black liquor (the raw material used is paddy straw) caused severe process problems, resulting in the shut-down of the recovery plant in the Sri Lankan paper mill.

In China, the alkali recovery plant has been operating continuously for the past ten years. There was a low initial investment, as most of the equipment was procured locally. The cost of chemical recovery is less than one fifth of its market price.

One issue arising from the above comparison deserves closer attention, i.e. the choice of technology. According to the factory management in Sri Lanka, the principal reason for the failure of their attempt was inappropriate technology choice. Several factors (technical, financial and administrative) contributed to making the wrong choice:

1. The technology selected was not yet proven.
2. Initial investment was extremely high (over US$ 20 million in 1978). The investment cost per tonne of black liquor was nearly five times that in China, ignoring the fact that the project in China was implemented a decade later.
3. The project's up-front cost was not of major concern to the factory, as the project was funded through a soft loan under bilateral agreement

Vertical roller mill in the cement industry

The third example involves the adoption of a vertical roller mill instead of a ball mill for grinding in a cement mill. Table 3 compares the performance of the E³ST in the cement industry in India and the Philippines.

It is interesting to note that this replacement, which involves approximately the same capital outlay in both countries, results in significantly different financial returns. This could be attributed to differences in energy pricing and in the operational efficiency of the existing equipment.

Equipment presently used, which has lower energy efficiency, can provide greater scope for improvement. This is the reason for the two-fold energy saving in the factory in the Philippines as compared with that in India.

The higher electricity tariffs imposed in the Philippines permit the local enterprise to enjoy almost three times higher financial returns from the energy saved. On the other hand, the factory located in India is not convinced about adopting the technology, as the existing electricity tariff structure leads to a very long pay-back period of 17 years.

Table 3
Vertical roller mill in the cement industry (India vs. the Philippines)

Country	India	the Philippines
Project	120 tph cement mill	120 tph raw material mill
Status	Not adopted	Adopted in 1991
Adopter		Capacity: 2,500 tpd cement plant
Total investment (million US$)	5.71	6.0
Discount rate (%)	12	8.3
Interest rate (%)	15	15.1
Energy price (US$/MWh)	80	110
Energy saving (kWh/tonne)	5	10
Benefit* (million US$)	0.336	0.924
Pay-back time (years)	17	6.5

* This is over and above the benefit derived from the existing system

Cogeneration in the pulp and paper industry

This example concerns the application of cogeneration in a pulp and paper mill in China and India. Though initial investment in the cogeneration plant in India is about 40% higher than in China, the factory enjoys higher financial returns from energy savings due to higher electricity tariffs. In general, the cost of energy in China is around 50% less than in India. Energy saving projects in China are therefore not likely to be considered as a priority when they have to compete with other projects for funding, unless other mechanisms and external interventions (incentives and regulations) affect the situation. For example, an energy consumption quota was imposed on the enterprise as a part of government policy in the 1980s. The price of energy beyond the quota was substantially higher, which persuaded the companies to opt for energy savings.

Investment in the cogeneration plant is much lower in China as compared to India, mainly due to differences in raw material, labour and energy costs, etc. and in the time of implementation.

Conclusion

The economic viability of a given project is considered to be the key issue in the adoption of E³STs. The choice of the right technology is of paramount importance to the enterprise. The existing level of the technology, up-front cost, operating expenditure, efficiency of the equipment, and the level of in-house skill available need to be considered when selecting a new technology. Even here, the enterprise may not have adequate access to information on available technologies which are well-suited to meet its requirements. Actors outside the enterprise could play an important role in decision-making by providing relevant information and facilitating contacts between the supplier and adopter of the E³ST.

The following observations and conclusions could be made based on the cross-country comparison:

Projects with low investment and short pay-back periods were normally adopted by the industries. But there are cases of projects with much poorer financial performance being adopted, whereas some economically attractive projects were not implemented. This proves that not all projects are examined on the basis of rigorous economic analysis. Other factors, whether internal or external to the enterprise, do have an influence in the decision-making process.

Sometimes a project by itself may be financially attractive, but the company may lack funds to implement it or the project may be competing with another investment project which fetches even higher financial benefits. Or the factory management may not feel confident or may not have personnel competent to handle a more complex process.

Similarly, a project may not be that lucrative, but the factory may go ahead with it due to external pressure in the form of mandatory regulations. In some other cases, the authorities may facilitate the adoption of some technologies which are likely to bring long-term benefits to the adopter as well as to the country. The industry itself may have some other reasons to adopt a technology, such as the indirect gains to be expected in the form of improved product quality, savings in raw materials or the cost of waste treatment, etc.

In general terms, the higher the investment needed for a project, the greater are the benefits. The risks associated with it are also likely to be more important as the pay-back periods are longer, especially when the time value of money is taken into account.

In the cement sector, most technologies were adopted by the industries irrespective of whether the pay-back periods were short or long. This could be because the technologies are universally available and the adopters are generally well aware of their advantages.

Projects aiming at environmental benefits alone have little chance of being adopted by the industries without any external assistance, or without pressure being applied in the form of environmental regulations or strong opposition groups.

Some E³STs have longer pay-back periods because of high initial investments and non-inclusion of external benefits such as environmental and resources conservation, pollution abatement, etc. From the adopters' (enterprises') point of view, what matters is the direct cost and benefit. Therefore, to internalize the above external benefits, certain policy measures need to be implemented.

Even after taking care that a proper selection of technology is made, the economic outcome may not necessarily be positive due to internal problems at the factory or parameters which are external to the factory and beyond its control.

To make E³STs economically viable for the enterprise, various external factors should be in place with the right stimulating effect, such as rational energy pricing, environmental regulations and incentive regimes, financial environment, transparent economic system, etc.

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