Zero landfill, zero waste: the greening of industry in Singapore

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Abstract: This paper reviews how a land-scarce city-state is trying to achieve its goals of zero landfill and zero waste through the greening of industry. The main challenges Singapore confronts in its solid waste management are an increasing volume of industrial waste generated, a shortage of land for landfills, and escalating costs of incineration plants. To green its industries, there has been a coordinated effort to develop a recycling industry and to initiate public-private partnerships that will advance environmental technologies. Case studies on the steel, construction, waste incineration, and the food retail industry illustrate the environmental progress that has been made. These cases show also the crucial role played by the government in accelerating the greening of industry by facilitating the formation of strategic collaborations among organisations, and by reconciling the twin objectives of sustainability and profitability.

Keywords: waste minimisation; waste disposal; environmental sustainability; zero landfill; zero waste; recycling; solid waste management' pollution control; pollution prevention; environmental technology.

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1 Introduction

Singapore is a Southeast Asian island city-state of only 682 km^2 and a population of about four million. In the 1970s and 1980s, its environmental management was focused largely on pollution control with stringent legislation on water, air, and waste disposal.

In this sense, Singapore as one of the first-generation Newly Industrialising Countries (NICs), has shown successes where other NICs, such as Taiwan, Hong Kong, and South Korea faced much greater environmental challenges. That its pollution control measures have been effective may be reflected in Singapore's reputation for being clean and green. The hygienic environment is credited with enabling Singapore to quickly check the outbreak of the severe atypical respiratory syndrome (SARS) epidemic in 2003 and keep at bay the bird flu epidemic that impacted ten Asian countries in 2004.

Robust economic growth in the 1980s and 1990s saw Singapore's income rising rapidly to that of developed nations. Rising in tandem with its increasing consumption was waste generation. For example, the volume of solid waste increased approximately six-fold from 1,260 tonnes/day in 1970 to about 7,190 tonnes/day in 2002. Such a trend, if left unchecked, meant the need for a new incineration plant every five to seven years and a new landfill every 25–30 years (ENV, 2001). Thus, pollution prevention and environmental sustainability became the main foci in the 1990's. To meet these challenges, closing the solid waste loop through waste minimisation, the adoption of green technologies, and recycling became a priority. An ambitious goal calling for 'zero landfill and zero waste' was mooted to reduce as much as possible, the incineration of waste by promoting the recycling of waste and the innovative use of recycled materials. The Singapore Green Plan 2012 (SGP 2012) proposed to increase the recycling rate to 60% by 2012; strive towards zero-landfill; and, reduce the need to build new incineration plants from the current five to seven years to every 10–15 years or longer (ENV, 2002d). Public-private collaboration to develop new environmental technologies was also stressed.

This paper consists of three Sections. The first section provides an overview of solid waste management in Singapore, especially its key challenges arising from a shortage of land and escalating costs of incineration. The second section outlines how it has implemented a two-pronged greening strategy, i.e., development of a recycling industry, and the initiation of strategic partnerships. Four case studies follow to illustrate the multi-player collaborations and the facilitative roles played by various government authorities. Of particular interest is the role of the government in reconciling environmental sustainability and business profitability. The third section summarises the progress made to date and discusses critical issues relating to environmental reporting in Singapore.

2 Solid waste management

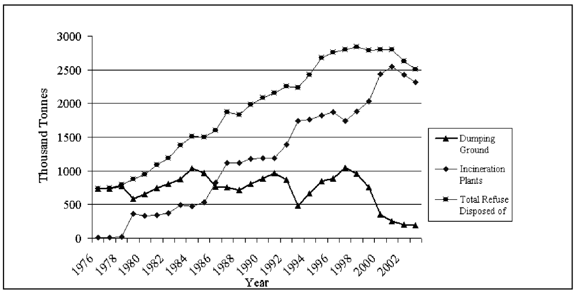
The Ministry of the Environment (ENV) formed in 1972, through its statutory boards, namely, the National Environment Agency (NEA) and the Public Utilities Board (PUB), manages sewerage, drainage, and solid waste disposal; monitors air and water pollution, controls hazardous and toxic wastes; and provides environmental public health services as well as public education on waste minimisation and recycling. In order to promote waste minimisation aggressively, the Waste Minimisation Unit (currently known as the Waste Minimisation Section under National Environment Agency) was established in February 1992. A specific waste management hierarchy was emphasised: waste prevention and reduction was prioritised as the highest, followed by reuse, recycle, and recover in that order.

Environmental public policy in Singapore had largely been driven by various media-based environmental legislation and regulations such as the Clean Air Act and Regulations 1971/1973, and the Water Pollution Control and Drainage Act 1975. These were consolidated in April 1999 as the Environmental Pollution Control Act. But there has been a significant shift in the government's management approach, moving from 'top-down, command and control' approach towards greater industrial self-regulation and collaborative initiatives. The injection of competitive market forces into environmental management in Singapore has resulted in greater participation of industry players in promoting environmental sustainability. There are about 400 companies in the waste management and recycling industry in Singapore. Waste collection and removal are the responsibility of four private companies. NEA awarded each company a five-year contract to collect refuse and to take part in island-wide recycling (NEA, 2002–2003).

While domestic waste collection went private in 1999, ENV continues to control and operate the four incineration plants situated at Senoko, Ulu Pandan, Tuas, and Tuas South. During incineration, energy is captured and converted into electricity, and ferrous metals are recovered to be recycled. Still, the role of the government in waste disposal will diminish significantly with the privatisation of these incineration plants. In 2005, the Tuas and Tuas South incineration plants will be privatised. A fifth plant, owned and run by a private company, is expected to be completed in 2006. Once this fifth plant is fully operational, the Ulu Pandan Incineration Plant will be shut down. The only landfill, however, will not be privatised, as there is no market competition in this area (Lau, 2000).

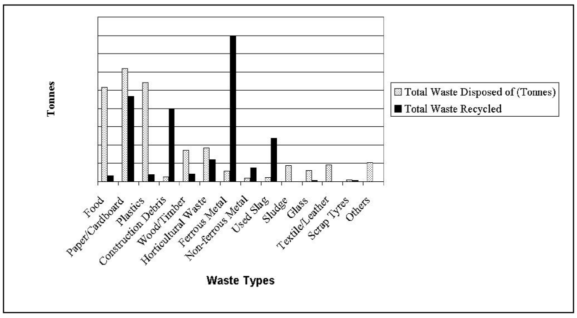
There are two main categories of waste in Singapore: first, domestic and trade waste collected from residential premises, food centers and markets, schools and trade premises; and second, commercial and industrial waste collected from commercial and industrial premises, construction sites and shipyards (NEA, 2002a). The volume of waste increased steadily from 739.9 thousand tonnes in 1976–2625.6000 tonnes in 2002, an increase of three and a half times. Figure 1 shows the amount of waste disposed at landfills or burnt in incinerators for the last three decades. The total refuse disposed of increased steadily from 1976 to a peak of 2.8 million tonnes in 1998 and stayed at that level for three subsequent years. However, a decline began in 2002, which continued into 2003. Decreasing volume of waste was sent to incineration plants and the solitary landfill. There were two possible reasons for the decline: effectiveness of recycling programs launched in 2002 and the lagged effect of the 2001 recession, the worst one encountered in Singapore since independence in 1965. Recycling did take on a new level of significance when the National Recycling Program was introduced in April 2001. The troughs found in the volumes of refuse sent to dumping grounds between 1976 and 2003 coincided closely with the peaks in volumes sent to incineration plants. Each matching trough and peak occurred in the year when an incineration plant became operational. Of the total waste sent to incineration plants or the landfill in 2003, approximately 42.7% was industrial and commercial waste (NEA, 2002e). Figure 2 shows the composition of total solid waste (i.e., waste disposed in landfill, burnt in incinerators, and recycled) in Singapore in 2003.

Figure 1 Refuse disposed of at authorised disposal sites (1976–2002)



Source: ENV (1998), ENV (1999), ENV (2000), Http://app.nea.gov.sg/cms/htdocs/article/asp?pid=401, and Http://app.nea.gov.sg/cms/htdocs/article.asp?pid=1469

Figure 2 Waste disposed of and waste recycled, 2003



Source: NEA (2004a)

Today, incineration is the main solid waste disposal method used in Singapore. In 2003, a total of 2.31 million tonnes of waste or about 92% of the total refuse generated in Singapore were incinerated. During the incineration process, energy is captured and scrap metal recovered. In 2001, for example, 1,159 million kWh of electricity were generated and 23,903 tonnes of scrap metal were recovered for recycling (NEA, 2004b; NEA, 2002a; ENV, 2002c).

While incineration has been very effective in processing large volumes of combustible waste, it is wasteful of non-renewable resources (NEA, 2002a). First, although it helps to reduce the volume of combustible waste, there is still a need to landfill the non-combustible waste and incineration ash left over from the incineration process. Secondly, building waste disposal facilities can be very expensive. An incineration plant costs about S $500 million to S $1 billion to build (US $1 = S $1.7); the Tuas South Incineration Plant, for example, costs about US $900 million.

Landfilling is not a better option either. Up to 1979, nearly all waste was disposed of by dumping in five landfills situated on the main island. Upon reaching capacity, the five landfills were closed, the last one in 1999. A new landfill was constructed at Pulau Semakau where non-combustible waste such as concrete slabs, bulky waste materials, and incineration ashes is sent. This landfill, which costs about S $610 million to construct, is expected to reach its full capacity by 2030. Setting up another landfill would mean utilising valuable land and financial resources that could be used for other purposes. Thus, reducing, re-using and recycling remain important solutions to waste management.

3 Towards the greening of industry

Singapore has a highly industrialised economy with strong focus on the manufacturing and service sectors. Foreign multinationals together with a few large domestic firms dominated the industrial scene in Singapore. Small and medium-sized enterprises continue to play only a minor role in the country's economy. Agriculture and mining are not significant at all. Manufacturing, which accounted for 24.3% of GDP in 2002, remains the main engine of growth, with electronics taking the lead. The chemicals industry takes second place, followed by petroleum refining, which is the third largest in the world.

In terms of its environmental performance, Singapore was ranked eighth among 36 countries in the 2001 GIN-DEX survey using World Bank and International Energy Agency data on carbon emission, water pollution, commercial energy use, and industrial output. The index, the product of a cooperation among the Greening Industry Network, Chulalongkorn University, and the US-Asia Environmental Partnership, captured the synergy between economic and environmental improvement in each country surveyed (Mccoy, 2001).

Singapore's approach to the greening of its industry is two-pronged in orientation: first, resource conservation through a more intensive and coordinated effort at developing the recycling industry; and second, waste reduction and elimination at source through product and process innovations as well as developing green technologies for industry through private-public collaborations. The next section will discuss efforts taken to accelerate and streamline the development of a recycling industry in Singapore.

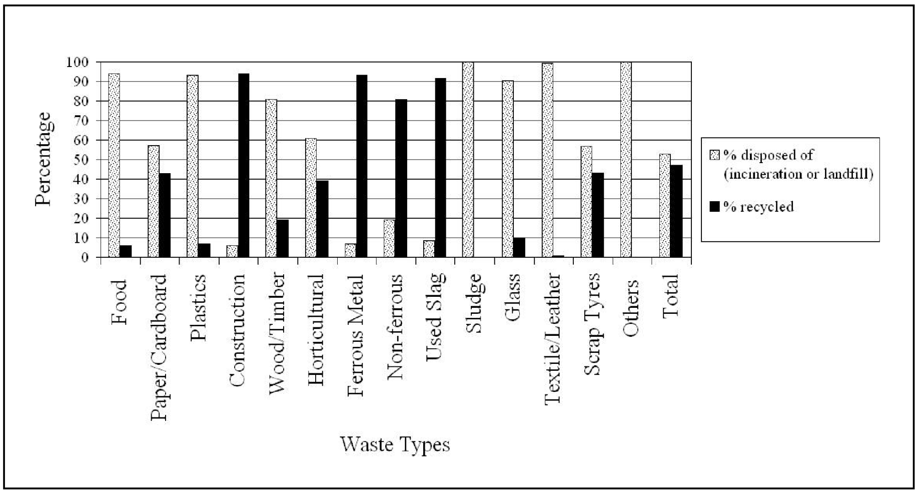
3.1 Developing the recycling industry

Aggressive recycling efforts in 2002 resulted in a 6.3% decline in waste output from 2,802,200 tonnes in 2001 to 2,625,600 tonnes in 2002. Overall recycling rate increased from 44.4% in 2001 to 47% in 2003. Figure 3 presents the percentage of waste disposed of and waste recycled in 2003. While construction debris, ferrous metal, and used slag had the highest recycling rates of more than 90%, food, plastics, glass, and textile/leather had the lowest recycling rates of below 10%. Table 1 presents the types of waste recycled and kinds of the recycled products produced in Singapore.

In order to encourage industrial waste recovery and recycling, waste disposal fees have been raised slowly to reduce the need to subsidise. For example in 2002, incinerating one tonne of refuse would cost S $87, while the diposal fee charged was S $67 per tonne. In May 2002, this fee was raised to S $77 per tonne to encourage waste reduction, minimisation, and recycling (Feedback Unit, 2002).

To speed up learning and adoption of environmentally friendly practices. NEA, JTC, Singapore Manufacturers' Federation, the Waste Management & Recycling Association of Singapore, and various representatives of private companies came together to jointly produce a 'Guidebook on Waste Minimisation for Industries'. The objective of the Guidebook is the dissemination of recycling information to promote greater efficiency and effectiveness in using, reusing and recycling resources by providing practical advice on waste minimisation. The Guidebook showcases model companies that have achieved significant cost savings by reducing waste generation.

Figure 3 Percentage of waste disposed of and waste recycled in 2003



Source: NEA (2004a)

Table 1 Recycling of waste in Singapore

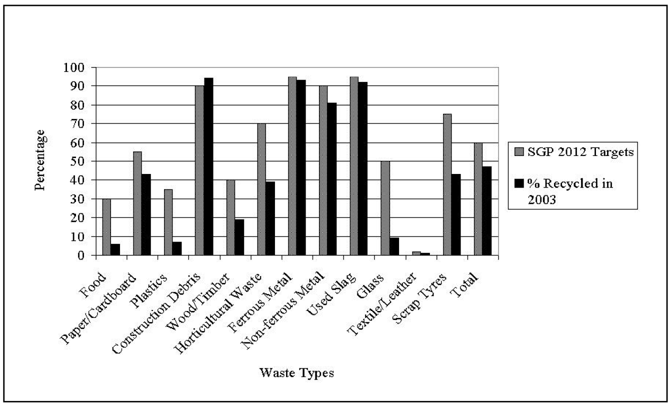
Types of waste	*Recycled products*
Horticultural waste and wood wastes	Charcoal, compost, fertiliser
Soya bean wastes, spent grain and spent yeast	Animal feed
Used copper slag	Paving blocks and processed copper slag for ship blasting
Wood-pallets, wooden-crates, cases	Technical wood, flooring and building materials, new wood pallets and crates
Construction and demolition waste	Recovery of materials and manufacturing of pre-cast concrete blocks from recycled concrete waste
Scrap metals	Iron rods
Scrap tyres	Remanufactured solid industrial, trucks, and car tyres, retreaded tyres
Pre-consumer plastics	Pellets
Waste concrete aggregates	Graded aggregates
Industrial waste	Recovery of materials
Electronics scrap	Recovery of precious metals

Two strategies are particularly significant in accelerating the development of a viable recycling industry in Singapore: the establishment of two recycling parks and the introduction of aggressive recycling programs in various high-rise industrial estates.

3.1.1 Recycling parks

NEA hopes to recycle 60% of all the waste generated in Singapore. Figure 4 presents the target rates of recycling for different waste categories. The recycling industry took off in a big way only after the government took the initiative to create recycling parks offering low rentals. Two recycling parks have been created. First, the Sarimbum Recycling Park was created to attract the setting up of recycling facilities at low cost rental. Sited at a landfill closed in 1992, this is a 30-hectare site. About 2.5-hectare was leased to the first recycling plant to reuse wooden pallets and crates. A second recycling plant was established soon afterwards to convert wood chips, leaves, branches, and other trimmings into fertilisers or soil conditioners. Over the four subsequent years, seven other recycling plants were set up to produce rubber floorings from scrap tyres and building materials from construction debris. Currently, twenty recycling plants are found on site (NEA, 2004b). Unlike existing construction and demolition recyclers that focus on low value-added utilisation of waste, the most recent addition, a Singapore-Australia 75:25 joint venture, will recover and process higher value-added secondary construction materials (ENV, 2003b).

Figure 4 Percentage of waste recycled in 2003 and the Singapore Green Plan 2012 targets



Source: Singapore Green Plan 2012

The second recycling park, the Ecopark is a 19-hectare site situated beside the Tuas incinerator and other industrial estates. A site for high value-added recycling, the area clusters recycling companies together to leverage on economies of scale. This is where Asia's first automated Material Recovery Facility, a S $7 million Singapore-Australia 60:40 joint venture, started its trial operations in September 2002, sorting recyclable household refuse such as used plastics, glass and metals for export overseas to be recycled. Recycling facilities for plastic and glass will be added as they become economically feasible with sufficient build-up in volume.

3.1.2 Recycling at industrial estates

Besides the setting up of recycling parks, the NEA is also actively promoting recycling among small and medium-sized factories (SMFs) by collaborating with the Jurong Town Council (JTC). The involvement of JTC is critical as it is Singapore's leading developer and manager of industrial facilities and business parks. It manages 70% of industrial land area. With 38 industrial estates under its wings, it has direct access to more than 7,000 companies, 2,000 of which are SMFs situated in high-rise factory buildings.

SMFs in Singapore generate 3,200 tonnes of solid waste every month that will take five Olympic-size swimming pools to hold. Yet, most SMFs do not have the critical volume to make recycling an economically viable alternative to incineration. In order to manage the whole waste chain more effectively and efficiently, common recycling programs are needed to coordinate waste separation and promote recycling.

In 2002, NEA began to collaborate with JTC and SembVisy Recycling to start a pilot-recycling program at one of the industrial estates called the Ayer Rajah Industrial Estate, which has more than 150 SMFs. During the experimental period, about 75,000 kg of wood waste, and 3,000 kg of paper, plastics, metal and glass were recovered for reuse or recycling each month in the one-year pilot program.

The success of this project led to the formation of a Joint Committee on Waste Minimisation between NEA and JTC. The objective of the Joint Committee was to introduce formal recycling programs to 40% of JTC industrial estates over a three-year period. This began with a recycling program in November 2003 at one of JTC's 21 high-rise industrial estates called the Kallang Basin Industrial Estate, where more than 200 factories are situated. With this program, segregation of waste and recycling have now been made a standard feature in waste collection contracts with all JTC multi-story or flatted factories (ENV, 2003a).

Successful recycling programs require the support of new environmental technologies to transform waste into usable secondary materials that can compete successfully with conventional materials in the marketplace. Such recycled secondary materials must therefore possess qualities that are at least equivalent to, if not better than, conventional materials and yet be priced competitively. This is where the second prong of the environmental strategy, building of strategic partnerships, becomes relevant.

3.2 Strategic partnerships for waste reduction

Strategic partnerships have been found to be useful in accelerating the development and adoption of green technologies. University research centers are important sources of technology for industry. Fostering strong linkages between university and industry helps in the exchange of technological knowledge. In fact, a domestic study comparing the various means of technology transfer found that the higher the industry commitment to participate in technology transfer through joint R&D projects, the more successful technology transfer practices are. The study also highlighted the crucial role played by the government in ensuring successful linkups by providing the funding and resources needed (Lee and Win, 2004).

A S$ 20-million Innovation for Environmental Sustainability Fund (IES Fund) was set up by the government to help finance the development of innovative environmental technologies through public-private collaborations. To enhance participation, NEA collaborates with town councils, community development councils, public waste collectors, recycling companies and research institutions. In February 2003, NEA launched the Singapore Environment Institute (SEI) to provide environmental management training and skills development and to facilitate knowledge sharing in sustainable development.

Besides providing financial assistance, the government also makes it easy for companies with environmental projects to gain access to other resources with the launch of the Environmental Test-bedding Initiative (ETI) in August 2003. This initiative, a collaborative effort among NEA, Economic Development Board (EDB), and Public Utilities Board (PUB), provides a one-stop platform for companies to obtain financial advice, infrastructure support, technical expertise, manpower, and regulatory supports. The ETI manages two programs, the Singapore Initiative in New Energy Technology (SINERGY) for advancing innovative alternative energy technologies and the Innovation in Environmental Technology (EnnovaTe) for promoting innovations and commercialisation of new environmental products and technologies for water treatment, waste management, and pollution control.

Two environment technology projects took off under the wings of these two programs. Under SINERGY is an alternative energy project carried out by a consortium, comprising the Development Resources Pte Ltd., IdaTech LLC, Housing Development Board, Nanyang Technological University (NTU) and NEA, to test a fuel cell system that supplies electrical power for lighting in a multi-story car park. Under EnnovaTe is a water treatment project, a partnership between Matrix Mambrane and PUB, to test membranes for the treatment of seawater and wastewater the success of which would mean the availability of an alternative source of water, greater adherence to the required environmental standards for industrial wastewater discharge, and cost savings (EDB, 2004).

To demonstrate strategic environmental tie-ups among industry players, government agencies, and research institutions in Singapore, the case studies below deal with environmental reforms in the following industrial sectors: steel, construction, waste incineration, and food retail.

3.2.1 Case 1: the steel industry

Incorporated in the1960's as the National Iron and Steel Mills, NatSteel has played an important role in the infrastructural and residential development in Singapore. In the 1980's, it broadened its operations by expanding into steel fabrication and construction-related products. Today, NatSteel has operations in some 12 countries and boasts of a turnover of S $1,544 million in 2002.

One common problem confronting steel mills is the disposal of waste slag, a non-metallic material produced as a result of the steel making process that poses great economic and environmental costs. The greening of NatSteel is related to its ongoing efforts at transforming waste slag and ladle furnace slag into usable steel slag aggregate and asphalt mix respectively.

At NatSteel, after two years of R&D collaboration with the public sector, a way was found to convert waste slag into steel slag aggregate that can be used in road construction. With proper pre-treatment, this by-product now not only meets stringent US EPA leaching tests but even outperforms natural rock, the conventional material used as road surfacing aggregate. Its superior quality includes better physical properties, binding properties, stronger interlocking structures, better skid resistance quality, stronger mechanical strength to withstand wear and tear, and better color retention. This translates into cost savings, as roads built with steel slag aggregate would require less maintenance and repair.

There is zero waste in the production of steel slag aggregate. During the processing stage, metals are recovered for reprocessing while slag dust is put into good use in the asphalt mix for road construction and resurfacing works. In Singapore, steel slag aggregate is now used widely in heavy traffic intersections, slip roads, major expressways, bus lanes and airport taxiways (Natsteel, 2003).

The secondary refining of molten steel results in another by-product called ladle furnace slag that heretofore has been disposed of by dumping at the Pulau Semakau Landfill. On average, about 24,000 tons of ladle furnace slag are produced in Singapore every year, enough to fill up three 1.7 m high soccer fields at the cost of S$1.1 million. A four-year joint research effort by NatSteel and NTU has now successfully recycled ladle furnace slag into modified asphalt mix. The modified asphalt, when used in road construction, has been observed to have stable and high anti-stripping properties that make roads very durable. A site test, set up in collaboration with NTU, the Land Transport Authority (LTA) and the NEA, and partially funded by the IES Fund, is now underway to study the environmental impact of using modified asphalt mix (NTU, 2003). If successful, it will mean substantial savings from having to import granite, as Singapore has no local source of granite.

The green culture has seen NatSteel go into the environmental business itself through one of its subsidiaries called NatSteel EnviroTech (previously known as NatSteel Abrasives). NatSteel EnviroTech produces blasting abrasives from copper and steel slag for sale to shipyards, construction industries, and fabrication engineering industries within the country or around the region. It also recycles waste slag into premium roadstone materials, provides air quality testing services, treats and recycles both domestic and industrial wastewater into useful environmentally friendly products.

3.2.2 Case 2: the construction industry

The construction industry has played a significant role in transforming Singapore into a modern city. The challenge faced by the industry today is not only to achieve optimal use of land through intensive development, but also to strive for better environmental performance. This industry is both materials and energy-intensive and its greening focuses primarily on reducing its consumption of materials and energy.

Inefficient construction methods and resource utilisation may account partially for the generation of construction waste. This can be prevented with conscious incorporation of environmental concerns during the building design stage and a more stringent resource management during the constructions stage. Unfortunately, many studies have found that the environmental performance of the construction industry in Singapore leaves much to be desired (Ofori, 2000; Ofori et al., 2000; Tan et al., 1999). The industry has a low level of awareness of environmental auditing and a general reluctance to take action other than those needed to meet regulatory requirements. It is not ready for systematic environmental management. Instead of using metal forms, permanent, or system formwork, and prefabricated elements, building contractors continue to use timber formwork, which contributes to deforestation. In addition, inefficient use of materials that resulted in high levels of wastage was noted even for companies that have implemented ISO 9002. Clients were found to be even less interested in environmental protection and energy conservation than contractors.

In 2002, about 406,600 tonnes of construction debris were generated. Ninety percent of the waste was recycled while the remaining 10% was disposed of at the offshore landfill. The high percentage of recycling, however, does not imply the end of the waste disposal problem for the construction industry. There remains a sizable volume of C&D waste sent for landfilling everyday, that is, about 170 tonnes in weight and 340 m^3 in volume. In volume, C&D waste represents the second largest source of solid waste dumped at Pulau Semakau Landfil (BCA, 2002).

Yet, on a more positive note, the lack of environmental awareness in the construction industry has begun to change with more fervent involvement of NEA and Building and Construction Authority (BCA), emphasising three key strategies for enhancing sustainability; first, recycling of construction and demolition (C&D) waste, second, minimising waste through adoption of best practices in the industry, and, third, meeting ISO 14000 series of standards.

To support recycling of C&D waste, the NEA oversaw the setting up of several recycling facilities for concrete waste, general construction waste, and demolition waste. Currently, three recycling plants are in operation, converting C&D waste into low value added secondary aggregates for further processing into non-structural concrete products for use in new building or as hardcore materials for temporary road access in construction sites. For example, the SembEnviro Alex Fraser Construction and Demolition Materials Recovery Facility plant that opened in September 2003 can transform C&D waste into higher value-added products and materials.

To ensure the long-term success of C&D waste recycling, the NEA also promotes the use of recycled materials in the construction industry. It encourages collaborations among recycling and construction companies and research institutions to explore the innovative use of recycled materials as substitutes for conventional construction materials and to examine the performance of these recycled building materials and products.

Pilot projects, involving NEA, PUB, LTA, NTU, and Hock Chuan Hong Waste Management Pte Ltd (HCH), have been created to test the suitability of pre-cast concrete products such as precast concrete drains and recycled road kerb at some experimental sites. HCH had previously succeeded in manufacturing pre-cast concrete drain slabs from recycled aggregates. Meanwhile, another joint project among BCA, the National University of Singapore (NUS), RDC Concrete, WR Grace, and Eng Seng Construction, is conducting research into the use of waste to produce self-compacting concrete, a new construction material.

Under BCA, an experimental project is also underway to test the performance of concrete cubes with different mixes, compressive strength, and water absorption. For example, concrete mixes produced with normal and recycled aggregates have been compared with regard to their workability and characteristic strength. Suitable concrete mix has been identified and used to produce precast products such as road kerb and channel drain. In its effort to encourage broader recycling efforts, BCA has also permitted the use of copper slag, waste generated by the ship repair industry, as partial replacement of fine aggregates (BCA, 2004).

Besides C&D waste, the construction industry also generates large volumes of soft marine clay from excavation works carried out at construction sites such as road and underground subway construction sites. Using IES Fund, the NEA is supporting a pilot project to explore the possibility of converting clay into a usable form to substitute for sand and earth in foundation engineering works. If this is proven to be technologically and commercially viable, land hungry Singapore will enjoy large cost savings as the need to import sand and earth for reclamation works will be reduced (BCA, 2002).

The construction industry is also trying to minimise waste by preventing pollution at source. One strategy is wider adoption of pre-fabricated concrete components, the production of which generate less solid waste, reduce noise and air pollution, and consume less energy compared to the traditional cast in-situ method. Another strategy is to minimise waste generation at construction sites through dissemination of best practices. NEA, collaborating with BCA, the Singapore Contractors Association Limited (SCAL) and NUS, has launched several waste minimisation projects. One of these benchmarks various waste levels and then identifies ways to eliminate the generation of waste. Knowledge and experience acquired from these joint projects are then disseminated widely across the construction industry through the Code of Practice for Demolition. The code provides guidelines related to the dismantling of reusable components of a building such as doors, windows, and cables, and the separation of waste for recycling.

In another project, seven local companies collaborated in developing an integrated concrete manufacturing and distribution system. This joint effort, named Project Dolphin, integrates the whole supply chain of raw materials for concrete manufacturing by containerising inputs such as sand and aggregates at source, essentially ensuring pollution free environment by placing the entire production and delivery of ready mix concrete within an enclosed space. This integrated system enhances the overall environmental performance of the industry by reducing wastage from spillage due to multiple handling or dropping of aggregates onto public roads, and minimising dust pollution by eliminating the use of tipper trucks and wheel loaders. This new system is expected to cut down by 70% the amount of land required for concrete production, and eliminate 50% of the trips made in transporting raw materials. In total, it confers a saving of $2.1 million (NEA, 2002d).

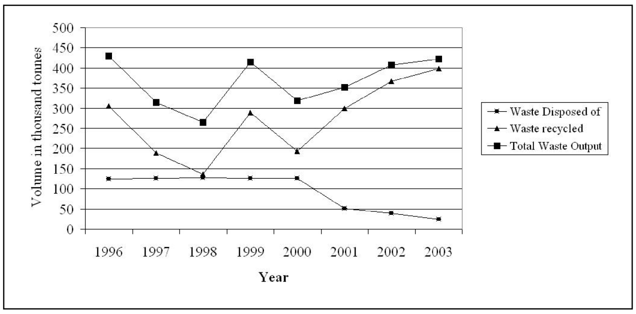
BCA plays another crucial role in promoting environmental sustainability in the construction industry by administering the ISO 14000 (Environmental Management System) Certification Scheme. Introduced in Singapore in 1996, the ISO 14000 series is a set of international standards on environmental management that address issues such as environmental management systems, environmental performance evaluation, environmental labeling, and life-cycle assessment. For example, ISO 14001 and 14004 are standards related to environmental management systems (EMS), while ISO 14010, 14011, and 14012 are related to environmental auditing standards. The ISO 14001 standard on EMS is especially popular in Singapore as it provides a framework for achieving productivity gain and global competitiveness (NEA, 2002c). A financial scheme, the Local Enterprise Technical Assistance Scheme, has been put in place to aid small and medium enterprises to gain ISO 14001 certification. By December 2003, about 473 companies in Singapore had been awarded the ISO 14001 certification, among them the Tuas Marine Transfer Station/Semakau Landfill (Spring Singapore, 2004).

BCA encourages construction firms, developers and consultants, and suppliers of building materials to strive for certification. It is compulsory for BCA-registered contractors in the top two grades (A1 and A2), who carry out public sector building and civil engineering works, to implement environmental management systems that meet ISO 14000 standards by July 2004. By November 2003, more than 60% of the 70 larger construction companies had already obtained certification. These forward-looking contractors will take a pro-active role in monitoring their material wastage levels for concrete and steel, and consumption of water and energy.

Certified contractors are expected to monitor their waste generation and energy consumption, review construction methods or work processes to reduce waste, and when it is economically feasible, to adopt environment friendly technologies. Neo Corporation was the first construction company in Singapore to receive the ISO 14001 certification in 1998. The first developer to be awarded ISO 14001 certification was City Developments Limited, one of the major developers in Singapore. Its environmental strategies include instilling a green culture in developing property projects, reviewing the environmental impacts at all stages of the development process, and soliciting the involvement of employees, consultants and contractors (BCA, 2003).

In sum, the construction industry is gradually greening through the joint efforts of various organisations to recycle C&D wastes, develop and use building materials made from recycled aggregates, and prevent pollution at source by advancing green technologies and achieving ISO 14000 standards. To date, significant progress has been made. Figure 5 shows that the sharp increase in construction debris in 2001 was closely matched by a rise in volume recycled and a concurrent decline in construction debris disposed of by incineration or dumping. In 2003, the 94% recycling rate of construction debris even exceeded the SGP2012 target of 90% (Figure 4).

Figure 5 Construction debris disposed of and recycled, 1996–2003



Source: NEA (2004a).

3.2.3 Case 3: the waste incineration industry

The third case-study reviews recent developments in the greening of the waste incineration industry in Singapore. Waste incineration generates waste too. Incineration ash is the waste left after incineration. On average, about 6,800 tonnes of waste are burnt everyday by the four incineration plants in Singapore, which produce about 1,600 tones of incineration bottom ash that have to be disposed of. There are two types of incineration ash; namely, bottom ash and fly ash. Bottom ash is the residue collected off the incineration grates, an inert material comprising of mostly glass, ceramic, rocks, and silica. Fly ash is the finer residue obtained downstream of the furnace. It is more hazardous than bottom ash as it contains easily leachable heavy metals and has higher lime content (Bai and Sutanto, 2002). To reduce the volume of incineration ash sent to the landfill, researchers in Singapore are exploring innovative methods to use incineration ash for road construction, lightweight concrete products, soft soil stabilisation, or for land reclamation (Show et al., 2003).

The suitability of using fly ash for road construction is still highly questionable, as environmental studies have shown that that it may lead to leaching, where heavy metals and acid seep into the ground and pollute the groundwater. Much more research is needed to find ways to stabilise the fly ash that waste incineration produces. Untreated bottom ash can cause the destruction of roads due to expansion and cracking. The swelling property of bottom ash must therefore be tested prior to its use in road construction. Bottom ash must be treated to enhance its mechanical features and to reduce its potential chemical problems.

In May 2002, a strategic partnership among NEA, PUB, LTA, and Hanson Pacific Private Limited, an international building materials company with expertise in processing ash for road-building in Europe, was formed to explore the feasibility of using bottom ash for road construction. By weight, the bottom ash represents 65% of the total waste disposed of at the Pulau Semakau Landfill; by volume, it represents 50%. At a disposal cost of S$ 77 for each tonne, this translates into a total sum of S$ 45 million a year for 1,600 tonnes of bottom ash daily.

The S$ 74,000 project was partially financed by the IES Fund and carried out in two stages. In stage one, bottom ash was processed and screened to remove ferrous metals such as lead, non-ferrous metals, and other impurities. It was then left to age for about eight to ten weeks. Laboratory tests were done to examine the suitability of its properties for road construction. Processed bottom ash was found to meet LTA's specifications for road-based materials. Leachate tests showed that the levels of heavy metals and other contaminants were kept within limits set by the United States Environmental Protection Agency, and its dioxins levels met the 'Guidelines Values of Dioxin Levels in Soil' in Germany, the Netherlands, and Sweden.

In stage two, an experimental road 150 m long was built in February 2002 using 1,200 tonnes of processed IBA. To facilitate the collection of groundwater for testing, six groundwater standpipes were installed near the road. This road was opened to traffic in May the same year. Heavy vehicles ply this road frequently. After six months of monitoring, no cracks or localised sinking were found. This experiment showed that bottom ash could potentially be used for road construction as no adverse effects on groundwater quality and storm water runoff was observed. This experimental road also afforded a more comfortable ride than conventional roads based on the International Roughness Index used to assess road quality worldwide.

Armed with these results, NEA is moving to increase the use of bottom ash in road construction, holding talks with several companies to build a plant to process it for this purpose. It has been estimated that if recycled ash is used for road construction in Singapore, it would reduce by 30% to 40% the amount of bottom ash sent to the Pulau Semakau Landfill (Kaur, 2003; ENV, 2002b; NEA, 2003). It would also reduce the need to use traditional road construction materials such as natural gravel and crushed rock, which are non-renewable resources extracted from nature. The NEA is also investigating the use of incineration ash for land reclamation.

3.2.4 Case 4: the food retail industry

The final case-study deals with Singapore's efforts in the environmental reform of the food retail industry. In 2002, Singapore generated about 494,700 tonnes of food waste, of which only 6% were recycled while 94% were incinerated. The food retail industry is fragmented with a multitude of players; 2,294 supermarkets, provision shops, mini-markets, and more than 11,000 market stalls operating in 150 locations spreading across the island (Canadian High Commission, 2004a). The food service industry is equally fragmented with 3,210 hotels, restaurants, fast food outlets and cafes, and more than 6,500 food stalls operating in hawker centers (Canadian High Commission, 2004b). Many food waste generating sources are widely dispersed, which may account for the dismal recycling rate of 6%.

But why even incinerate? Landfilling of biodegradable organic material would seem appropriate if one assumes that this waste material decomposes and returns to nature. Unfortunately, this is not the case. Organic wastes, mixed with other types of wastes, do not return to their original state in nature. Landfills do not have the necessary conditions to allow for the completion of biological decomposition reactions to take place. Instead, landfills are ‘prison cells’ for wastes. Thus, mixed wastes are deposited in landfills permanently separated from the environment by impermeable layers and marine clay to prevent contamination (Fehr et al., 2002). However, incineration of food waste is not the most desirable, as materials are destroyed. To close the food waste loop in an environmental way would require processes, technologies and management methods that eliminate the need to landfill or incinerate biodegradable organic waste.

SGP has set a goal of increasing the recycling rate of food to 30% by 2012 although so much food waste is generated everyday that it must be treated before it can be discharged as a constituent of wastewater into the sewage system. The food waste in domestic wastewater is treated in a conventional activated sludge system in which there are diverse microorganisms that give rise to a multitude of metabolic reactions leading to the degrading of organic matter.

Biological waste treatment plants used in restaurants, catering centers, food processing factories that process restaurant fats, oils and grease frequently stall due to the variability in the metabolic activities of microorganisms. Restarting these plants take time. The Productivity and Standards Board (predecessor of Spring Singapore) in collaboration with NUS and cooperation of the Singapore Inflight Catering Center have found ways to reduce breakdowns and start-up times. By reducing the biochemical oxygen demand (BOD) of the microorganisms, the efficiency of such treatment plants can be improved. By carefully choosing an optimum consortium of microorganisms, researchers have reduced the start-up times of these plants (Fong and Tan, 2000).

Another similar project involving JTC and NTU, and largely funded by The Enterprise Challenge (TEC), was undertaken to implement biological treatment of industrial food waste at a JTC high-rise factory complex with more than 200 food processing companies. (TEC is a S$ 29 m fund established to provide financial support and test beds for innovations that have potential in improving public service delivery). The main aim of this project was to reduce the BOD level of industrial food processing effluents to levels permitted under the Sewerage and Drainage (Trade Effluent) Regulations 1999. The success of this project would mean an improvement in the efficiency of food waste treatment, less demand on the municipal wastewater system, more efficient use of land with the elimination for individual waste treatment systems, more economical waste treatment with the sharing of treatment facilities for high-rise food factories, and lower business cost with lower tariffs paid for polluting trade effluents (ENV, 2002a).

NTU researchers have also been able to speedup conventional composting by using a mixture of sewage sludge and solid food waste to stabilise the organic waste, reduce smell and inactivate disease-causing microorganisms. It is not easy for microorganisms to utilise the contents of sewage sludge technically because there is too much nitrogen relative to carbon in the mixture. Also, the viscous nature of sludge means that it is not well aerated whereas oxygen is needed for effective composting. NTU researchers, funded by PUB, have found that mixing sewage sludge with solid food waste lowers the amount of nitrogen relative to carbon and renders the texture of the mixture less viscous, so more oxygen is transferred into the bulk of the compost compared to sewage sludge alone.

The final product is a gray powder with only 5% moisture content. Usually, to accelerate composting of organic matter, finished compost, not cultures of microorganisms, is used. However, a starter culture made up purely of microorganisms has been found to do better because there is more control of desired metabolic processes with lower risk of disease-causing bacteria being found in the final product of biodegradation. By identifying a selected strain of a germ (Bacillus thermoamylovorans) that does not form spores, the researchers have also been able to prevent the growth of spores during biodegradation, which can cause allergies in human beings (Wang et al., 2003).

A public-private collaboration in June 2003 saw a private firm, CPG Corp, install a 100-kg capacity composting machine costing S$ 350,000 at a site in the town of Tanjong Pagar where there are 160 food stalls which generate, on average, 1.5 tonnes of food waste daily. The machine now converts oily food scraps and innards into dry odourless compost in a process that takes about three to four hours. Compost produced is used to grow vegetables in a rooftop greenhouse nearby.

Initial reactions from the hawkers have been positive. Most cited a vast improvement in the hygiene of the place. For example, pests such as crows, cockroaches and rodents were fewer while bad odors were eliminated as well. Others cited the economic benefits of 20% cost savings as the on-site composting machine eliminated the need to transport food waste to incineration plants. Once the commercial viability of this composting machine is proven, it will mean an increase in the food waste recycling rate. If the food waste generated by all the wet markets and food centers in Singapore is converted into compost, the recycling rate of food waste will rise very quickly to 19% (Teh, 2004), a large step closer to achieving the national goal of 30%.

Meanwhile, NEA and NTU are collaborating to develop an integrated food waste bioconversion system that will produce biogas and fertiliser from food waste. The generated biogas will be used to generate energy for recycling or composting while the fertiliser can be used for agriculture or landscaping.

4 Discussion and conclusion

A shortage of land in Singapore for landfills and the escalating cost of incineration plants impelled the government to promote a recycling industry and form strategic partnerships among business firms, government agencies, and research institutions to develop innovative green technologies.

The case studies above illustrate the importance of strategic partnerships in the greening of industry in Singapore. Government agencies such as NEA, PUB, EDB, and BCA play an active role in building bridges between university research centers and industry players, initiating joint research projects, and providing the necessary funding and regulatory support. Such collaborations not only enable more effective transfer of technology, but also ensure the economic viability of environmental projects. The imprimatur of government agencies in Singapore helps promote greater industry acceptance of recycled products and green best practices. Government involvement and financial support encourage business firms to invest in the exploration and testing of recycled aggregates as substitutes for conventional raw materials.

Energy inefficient and out-dated technology and equipment incur not only high operating costs because they require more energy to operate but also high environmental costs because of pollutants emitted into the environment. Yet, the cost of acquiring energy-efficient technology may deter companies from making the necessary investment. To overcome this dilemma, two special incentive schemes are provided for under the Income Tax Act such that qualifying energy efficient or energy-saving equipment and pollution control equipment can be written off in one year (NEA, 2002b). First, a one-year accelerated depreciation allowance for energy-efficient equipment and technology encourages companies to replace energy inefficient technologies with energy efficient and environmentally friendly ones. Second, a one-year accelerated depreciation allowance for highly efficient pollution control equipment is designed to encourage investment in pollution control technologies. Under both these schemes, companies are allowed to depreciate 100% of the capital expenditure incurred.

To raise environmental awareness among domestic companies and encourage a proactive environmental management approach, the Singapore Environmental Council launched the Singapore Environmental Award in 1997. This award recognises significant and innovative initiatives taken to reduce negative environmental impacts of production processes and products. Innovative initiatives may include attempts to conserve energy, enhance recyclability of products or packaging, reduce generation of toxic or hazardous wastes, and adopt clean production technologies. Selection criteria for the award include actions that go beyond compliance with environmental standards, rules and regulations; actions taken to address the cause rather than effects of pollution; the level of top management commitment and involvement; applicability of innovative initiatives to other companies; and finally, the environmental and commercial viability of innovations (Singapore Environment Council, 2004).

On World Environment Day in 2004, another environmental award, the inaugural Singapore Green Plan 2012 Awards, was given. Formerly the Green Leaf Award, it gives recognition to excellent contributions by individuals, organisations and companies to protect the environment, especially significant achievements in enhancing environmental sustainability and attaining specific targets set out in the SGP. This Award is designed to encourage companies to go beyond fulfilling regulatory requirements in their environmental efforts by contributing to sound environmental practices and sustaining positive environmental impacts. Two companies won it in 2004, namely, STMicroelectronics Pte Ltd and HSBC. STMicroelectornics, a semiconductor company that had devoted 2% of its capital investment since 1995 to reduce the environmental impact of its operations, was recognised for its best practices in energy efficiency, waste and water recycling, and company-wide pro-environment culture, while HSBC was recognised for its excellent efforts in nature conservation and environmental education as well as a pro-environment company culture (NEA, 2004c).

Another step in the greening of industry entails governmental regulatory pressure in the form of environmental self-reporting, or the regular public disclosure of environmental information such as waste volumes, pollution emissions, and pollution prevention efforts. Two surveys of the annual reports of public listed companies in Singapore found that voluntary disclosure was inadequate. At best, there was minimal disclosure on environmental policy, environmental benefits of products or processes, and announcements of ISO 14001 certification. At worst, information given was either uninformative or irrelevant. In general, quantitative data for tracking environmental progress were lacking; so were environmental targets or audits (ACCA, 2002a; Perry and Teng, 1999).

Possible reasons for such dismal environmental reporting include a lack of environmental awareness, perceived benefits and government pressure. Similarly dismal is the state of environmental reporting by the private sector in Hong Kong despite the fact that an environmental reporting initiative for all government departments, bureaux, and government-owned organisations had been launched way back in 1998 (ACCA, 2002b).

One major issue that needs to be resolved before the government can move on to promote environmental reporting and auditing in a big way is the fear that environmental audit reports may be used against the company involved (Quazi, 1999). That is, the content of an audit may be used as evidence of violations and proof of prior knowledge of violations. An environmental audit may contain self-incriminating evidence of wrongful handling and disposal of hazardous waste, as well as non-compliance with emissions standards. Moreover, there remains the possibility of uncovering environmental problems that are technically unsolvable or financially infeasible to ameliorate with current technology. The liability associated with such negative environmental information may tarnish the reputations of the corporations involved (Lang, 1999).

Overcoming this fear of prosecution calls for innovative regulatory enforcement strategies. This may mean giving companies assurances of leniency in situations where, upon self-discovery of violations, companies make good-faith efforts to reduce environmental damage and ensure speedy compliance. Good-faith effort should be recognised as a strategic defense against strict prosecution and heavy penalties (Lang, 1999).

Environmental disclosure is only a means to an end. It is a necessary first step to promote greater voluntary and proactive environmental management by industries. With systematic and objective tracking of environmental performance, industries may be encouraged to integrate environmental concerns explicitly into their strategic thinking (Quazi, 2001). They may be encouraged to design products and manufacturing processes that are both economically feasible and environmentally sustainable as well.

In conclusion, the general approach of the Singapore government towards achieving greater environmental sustainability is one that emphasises technological solutions. That progress has been made was evident when the government announced in July 2004 that another landfill was not going to be necessary. Previous pollution control approaches are now being complemented by innovative solutions to enhance resource conservative and pollution prevention at source. Given its well-attested organisational skills, industrial peace, and a corruption-free political and business culture, Singapore may well become a model of an innovator, adopter, and disseminator of environmentally sustainable policies and solutions.

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List of Acronyms

ACCA	The Association of Chartered Certified Accountants
BAC	Building and Construction Authority
C&D	Construction and Demolition
EDB	Singapore Economic Development Board
EnnovaTe	Innovation in Environmental Technology
ENV	Ministry of Environment
EPA	Environmental Protection Agency
ETI	Environmental Test-bedding Initiative
HCH	Hock Chuan Hong Waste Management Pte Ltd
IES	Innovation for Environmental Sustainability
JTC	Jurong Town Council
LTA	Land Transport Authority
NEA	National Environment Agency
NICs	Newly Industrialising Countries
NTU	Nanyang Technological University
NUS	National University of Singapore
PUB	Public Utilities Board
SCAL	Singapore Contractors Association Limited
SGP 2012	Singapore Green Plan 2012
SINERGY	Singapore Initiative in New Energy Technology
SMFs	Small and Medium-sized Factories