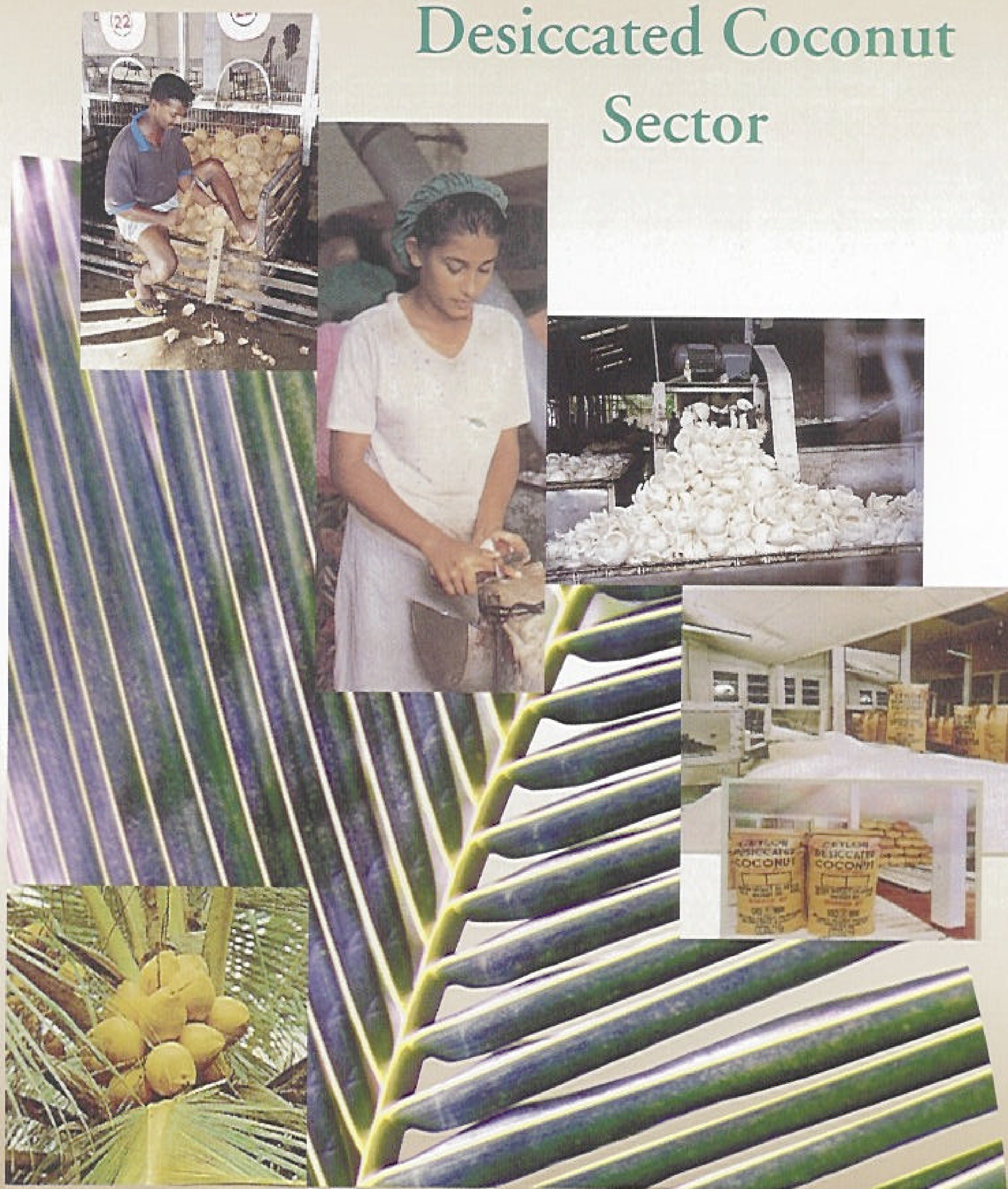
Small and Medium scale Industries in Asia:
Energy and Environment

Desiccated Coconut Sector



Asian Institute of Technology

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The *Asian Institute of Technology* (AIT) is an autonomous international academic institution in Bangkok, Thailand. Its main mission is the promotion of technological changes and their management for sustainable development in the Asia-Pacific Regions through high-level education, research and outreach activities which integrate technology, planning and management.

AIT carried out this *Asian Regional Research Programme in Energy, Environment and Climate* (ARRPEEC) Phase-II, with the support of the *Swedish International Development Cooperation Agency* (Sida). One of the projects under this program is **Small and Medium scale Industries in Asia: Energy, Environment and Climate Interrelations**.

The project was aimed at promoting activities to mitigate green house gas (GHG) emission and other pollutants in *brick and ceramic, desiccated coconut, foundry, tea and textile* sectors in **China, India, Philippines, Sri Lanka and Viet Nam**. The specific project objectives were to:

i) Review the operational practices and technological status of the selected sector;
ii) Identify and study factors for effective promotion of energy efficient and environmentally sound technologies (E3ST);
iii) Enhance capacity mobilization to promote E3ST; and
iv) Review existing policies and develop a scenario for sustainable promotion of E3ST.

Other publications based on this research include:

- Policy interventions to promote Energy Efficient and Environmentally Sound Technologies in Small and Medium scale Industries.
- SMI in Asia: Energy and Environment – *Tea Processing* Sector
- SMI in Asia: Energy and Environment - *Brick* Sector
- SMI in Asia: Energy and Environment - *Foundry* Sector
- Twelve issues of the quarterly SMI Newsletter
- A Road Map in CD version is also available which contains details and videos of production processes, all publications (newsletter, reports, articles) and other materials from the project.

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Foreword

After the industrial revolution, anthropogenic greenhouse gas (GHG) emissions have been increasing and a broad consensus has emerged that human life will be affected by earth's climate change. The GHG emissions result from many of the industrial, transportation, agricultural, and other activities through population growth, fossil fuel burning, and deforestation. The economic and social consequences of GHG emission imply that they should be addressed on a global scale. In a joint action under the United Nations Framework Convention on Climate Change (UNFCCC), developed countries committed themselves to reduce their anthropogenic emissions of GHG. They are implementing many partnership programs with industry to reduce emissions of carbon dioxide (CO_2) and other greenhouse gases. To address these issues in developing countries, UNFCCC established funds for their benefits in terms of capacity building and transfer of energy efficient and environmentally sound technological measures.

To enhance this global effort on protection of the environment, the Swedish International Development Cooperation Agency (Sida) initiated the Asian Regional Research Programme on Energy, Environment and Climate (ARRPEEC), a research programme aimed at producing policy-oriented research for mitigation of greenhouse gases and other hazardous emissions resulting from fossil fuel use. In Phase-I of ARRPEEC, studies were carried out in the industrial sector for the promotion of energy efficient and environmentally sound technologies. This knowledge led to the study of Small and Medium scale Industries (SMI) in Asia.

In Asian manufacturing establishments, SMIs play a vital role by contributing substantially to its economic and industrial development. Many SMIs do not perceive their own environmental impacts as significant when set against those of large numbers. But collectively they could make a great impact. Therefore it is important that they are encouraged to improve their efforts towards environmental protection for sustainable development. With this motivation, Sida supported the SMI project to mobilize and strengthen competence and capacity in national research institutions participating in the programme.

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Preface

The *Asian Regional Research Programme on Energy, Environment and Climate* (ARRPEEC) funded by the Swedish International Development Cooperation Agency (Sida) was broadly aimed at studies to promote activities to mitigate greenhouse gas (GHG) emission and other pollutants in various sectors. One of the projects undertaken for study in Phase-II of ARRPEEC was the Small and Medium scale Industries (SMI) sector considering its possible impacts to the environment. Five SMI sectors were identified for this study: brick and ceramic, desiccated coconut, foundry, tea and textile. The study was conducted in China, India, Philippines, Sri Lanka and Vietnam.

This report is based on research conducted on the desiccated coconut sector in the Philippines and Sri Lanka and details the production processes, specific energy consumption, technology status, including the important energy and environmental issues related to the sector. It highlights the production and operational practices of the desiccated coconut manufacturing industry, their energy consumption pattern and pollution generation. This report also provides energy efficient and environmentally sound technological (E3ST) options specific to this sector and presents the barriers in promoting E3ST.

It is believed that this report will be useful to policy personnel and government agencies involved in SMI, energy or environment; industrial organizations; researchers as well as other industries. A comparison volume discusses the policy options to promote E3ST in the study countries.

On behalf of the national research institutes (NRIs) and on our behalf, we take this opportunity to thank Sida for sponsoring this timely and important study and to AIT for providing an excellent atmosphere for carrying out this research.

Finally we would like to thank the following experts for critically reviewing this document: Mr. S. B. Rathnayake, Acting Director General, Coconut Development Authority, Sri Lanka; Mr. Felix Fernandopulle, Managing Director, Kudaweva DC Mills, Sri Lanka; Engr. Helen Arias, Section Head, Technology Promotion Section, Energy Efficiency Division, Energy Utilization Management Bureau, Department of Energy, Philippines; and Manuel I. Gloria, Jr., Principal Consultant, Eximport Aquatreat Systems, Inc., Philippines.

S. Kumar
C. Visvanathan

Executive Summary

The desiccated coconut (DC) sector is considered one of the Small and Medium scale Industries (SMI) that makes an important contribution to the economy of the Philippines and Sri Lanka in terms of export earnings and employment. However, they were found to have several issues regarding inefficient energy consumption and mismanagement of waste. In light of moving towards sustainable development of this sector, these issues need to be properly addressed. This report is an outcome of extensive research done for the sector to identify and evaluate viable Energy Efficient and Environmentally Sound Technological (E3ST) options to meet these issues in order that energy consumption is reduced and emission of greenhouse gases and other pollutants are mitigated.

The DC industry supplies the world with a dried white product of various textures and sizes, manufactured from coconut meat for use in a wide variety of foodstuffs. The annual global production of DC averages around 190 to 220 thousand tons, 65.7% of which is supplied by the Philippines and Sri Lanka. The global annual demand has been steady at around 195 to 215 thousand tons, 40% of which are consumed by the USA and the European Community. For the Philippines and Sri Lanka, export earnings from DC averages around US$ 65 M per year.

The production process for DC begins with the fresh green coconut that goes through a series of operations namely, seasoning, de-husking, de-shelling/hatcheting, paring and splitting, washing and inspection, blanching or pasteurizing, stabilizing, size reduction, drying, screening and grading before the final packaging. Between the two study countries, process variations were recognized along with the differences in type of equipment used, extent of modernization, product quality requirements, byproduct manufacturing facilities and some trends in production techniques improvement. Surveys showed that DC mills in the Philippines ran mostly in a continuous, mechanized process unlike those in Sri Lanka that were largely operated manually, especially in the traditional mills. The major variation was found in the stabilizing process, practiced only in the Philippines, where the washed coconut is treated in cold sodium metabisulfite solution to extend the shelf life of the final product. There are also ancillary production facilities in some DC mills that use DC byproducts for shell charcoal and coconut oil manufacturing.

The primary energy sources used by the DC sector in the study countries include firewood, fuel oil and electricity. In the DC mills, both thermal and electrical energy are used, with a specific energy consumption of 10 to 23 MJ/kg DC and 0.10 to 1.0 kWh/kg DC respectively. Energy audits showed that the drying process shares 66% of the thermal energy consumption. Key areas where loss can be reduced have been identified. Other issues of the DC sector include the continued use of outmoded inefficient technologies and the lack of finance to replace such. The need for more research and development and human resource training were also recognized as major concerns.

Based on the production process, the most significant source of pollution from DC mills is the highly organic wastewater (BOD_5 is 6 to 10g/L) they generate. This comes mostly from the discarded coconut water and spent water during washing. Specific pollution load varies with 4 to 14 L/kg DC in the Philippines and 6 to 7 L/kg DC in Sri Lanka, depending on the washing process used. Only very few mills have their own wastewater treatment facilities. Some treatment options that are recommended include the pretreatment of coconut water, and the aerobic or anaerobic treatment of DC wastewater. Air pollutants and in particular greenhouse gases (GHG) like carbon dioxide (CO_2), originating from combustion of fuel required for steam generation is emitted at a specific rate of 400 to 4,000 g CO_2/kg DC. Emissions from mills using firewood as fuel are also many times higher than those using fuel oil. There are many types of equipment available for controlling air pollution but for the DC sector, the associated high cost of the device is the main hindrance in acquiring them. Solid waste generation in the form of coconut husk, shells, parings etc. however, are not of serious concern as these are practically sold or utilized for byproduct manufacturing. Other major issues of the sector include the difficulty in following stringent government environmental standards and laws, and undesirable housekeeping practices that threatens occupational safety to its workers.

One of the best approaches in addressing energy and environmental issues is to apply preventive measures like shifting to E3ST options that basically use energy resources more efficiently and generate lesser waste. Specific E3ST options for improving thermal and electrical energy efficiency, wastewater management, air pollution management, and solid waste management were described along with the benefits derived from adopting them. Some illustrative cases of successful implementation of E3ST in existing DC mills were given. It was found that with the adoption of some E3ST options the DC sector in Sri Lanka could possibly reduce GHG emission by 36% (27,000 tons CO_2) per year.

There are barriers encountered by the DC sector in adopting E3ST options which include the lack of information on the benefits of improved energy and environmental performance, inadequate technological training of its human resources, absence of research and development at the factory level, uncertainties in energy prices and trading practice, financial constraints, poor working conditions and weak implementation of relevant policies and regulations if any. In aid of formulating policies for adopting E3ST in the DC sector, some general policy guidelines were recommended such as formation of industrial clusters, encouraging the use of renewable energy sources, enforcing energy pricing, taxes and subsidies strategically, strengthening research and development, providing financial instruments, establishing standards and norms and implementing energy and environmental rules and regulations firmly.

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Units and Abbreviations

BOD_5	Biochemical Oxygen demand
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DC	Desiccated Coconut
DO	Dissolved Oxygen
EC	European Community
E3ST	Energy Efficient and Environmentally Sound Technologies
g	grams
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GWh	GigaWatt Hour
ISB	Industrial Service Bureau
kg	kilograms
kWh	kilowatt hour
MJ	Mega Joule
MWh	MegaWatt hour
NO_x	Nitrogen Oxides
ºC	degree Centigrade
PM	Particulate Matter
SMI	Small and Medium scale Industries
TJ	Terra Joules
TSP	Total Suspended Particles
SO_2	Sulfur Dioxide
UASB	Upflow Anaerobic Sludge Blanket
UK	United Kingdom

CHAPTER 1: OVERVIEW OF THE DC SECTOR

This chapter describes the Desiccated Coconut (DC) industry on a global perspective. The overview focuses on the DC industry with its related energy and environmental issues in the top two DC-producing countries in the world, Sri Lanka and the Philippines.

Desiccated Coconut Industry

Desiccated coconut is a dried white, particulated or shredded product manufactured from freshly peeled coconut kernel, produced in many sizes and textures from extra fine to course grades. It is available in various specialties or fancy-cuts like chips, threads, flakes and slices. About 60 to 80% of the global DC production is used in the bakery and confectionery industries to enhance the texture, flavor, aroma, degree of chewiness and eye-appeal of a wide variety of foodstuffs like nut bars, cookies, biscuits, cakes, pies, and ice cream.

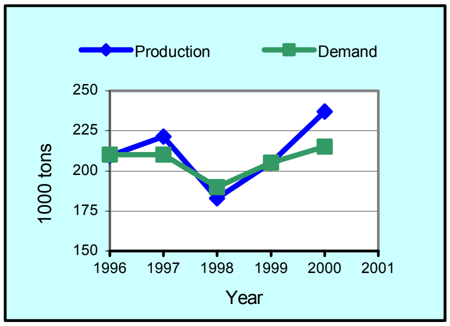
Fresh coconut is processed to produce desiccated coconut that is used in a wide variety of foodstuffs.

In countries where coconuts (*Cocos nucifera*) grow in abundance, like the Philippines and Sri Lanka, the DC industry is one of the export-oriented, Small and Medium scale Industries (SMI) that shares a significant portion of the whole food processing industry. The DC sector is an important source of local employment and export earning in these two countries.

Global Supply and Demand

The annual average global production of DC is estimated to range around 190–220 thousand tons. Being an agricultural commodity, DC output fluctuations are essentially driven by supply side factors rather than demand. These factors include prevailing climatic conditions in the area, price level of raw materials, and prices of DC in competitive countries. In certain years, the supply is about 10-15% higher than the demand and in other years, this situation could be reversed. In 2000, a substantial increase in supply was witnessed in the world market that resulted in over bought situations in many buying countries. As a consequence a lull in the market was observed during the first half of 2001.

Most of the DC production is limited to the Asia and Pacific region where Philippines, Sri Lanka, Indonesia and Malaysia account for more than 80% of the total global production. Other producers include India, Fiji, Ivory Coast



Annual global production and demand of DC have fluctuated over the period 1996-2000

and the Dominican Republic. The Philippines is the world's largest DC producer, with an annual output of 70–80 thousand tons, followed by Sri Lanka with an annual production of 50–70 thousand tons. In 2000 however, Sri Lanka exceeded the Philippines in DC production registering a record production of 89,029 tons against the Philippines' 75,000 tons. These two countries together, account for more than 60% of the global DC production (SLCS, 2000).

The global annual demand for DC has not changed much during the last decade ranging from 195–215 thousand tons (SLCS, 1999). A total demand growth rate of 0.5% to 2% has been seen in the Middle Eastern and African countries though the demand for DC in a few European countries has been stagnant. The main consumers of DC are the USA and the European Community (EC), accounting for more than 40% of the global consumption. In 1999, the USA imported 32,000 tons of DC that comprises 17% of the total global demand making it the largest consumer of DC in the world. The rest of the global demand is from countries like Germany, Egypt, Netherlands, U.A.E, Belgium, Taiwan, Canada, Australia, other Middle Eastern and Latin American countries. Singapore also plays a crucial role in exports of DC manufactured in Indonesia and Malaysia because it imports around 50% of the DC produced in the above two countries and re-exports it to other destinations all over the world. East European countries have begun importing DC recently.

The DC market has remained relatively stable over the past years and has not grown much primarily due to lack of new market and product development. In the future however, stiffer competition in the confectionery industry and fluctuations in DC production are expected to affect global demand and intensify market competition in the DC sector.

Both in the Philippines and Sri Lanka, the DC industry forms an important food-processing sector in terms of its share in the gross domestic product (GDP) and export earnings. Since this industry is labor intensive it also generates sizeable employment opportunities. The structure of the DC industry in these two countries however differs in their production capacities as well as type and extent of machineries used in their DC mills.

DC Industry in the Philippines

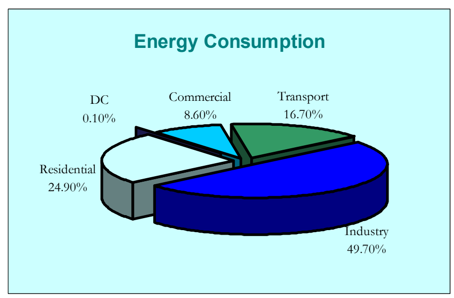
About 3.1 million hectares, i.e. 25% of the total agricultural land is used for coconut cultivation and about twelve billion nuts are produced annually. Coconut is the major crop in 62 out of the 72 provinces in the Philippines. In some coastal areas, small islands and marginal lands, coconut is the only cultivated crop. The highest yield of coconut is found in the provinces of Southern Mindanao, Southern Tagalog, and Western Mindanao. One-third of the Philippine population i.e. about 20 million Filipinos, depend directly or indirectly on this industry for their livelihood, of which about 10,000 people are directly employed in the DC mills.

There are 12 privately-owned DC processing mills in the Philippines that can be categorized as medium scale mills employing an average of about 50 to 100 people and having an average fixed asset of less than US$ 1.45 million. Franklin Baker Company, with two of its mills is the largest single DC producer in the Philippines as well as in the world. Six of the twelve DC mills are located in Luzon in the southern Tagalog region, because of the availability of the nuts and proximity to the Batangas and Manila ports. The other DC factories are situated in Mindanao.

The Philippines exports half of their total DC production annually to the USA, holding 90% of its DC market share. A significant amount is also supplied to the Europe. In 2000, export earnings from DC constituted about 0.88% of the total US$ 7.38 billion GDP of the country.

Overview of Energy and Environmental Issues

The major sources of energy used in the DC industry in the Philippines are electricity, fuel oil and coconut shell. For an annual DC production of 90,000 tons, the average energy consumption is about 90 GWh of electricity, 12,000 tons of fuel oil and 18,000 tons of coconut shell. This constitutes about 0.10% of the total energy consumption of the Philippines in 1998 and the electricity consumption is about 0.26% of the annual national electricity production.



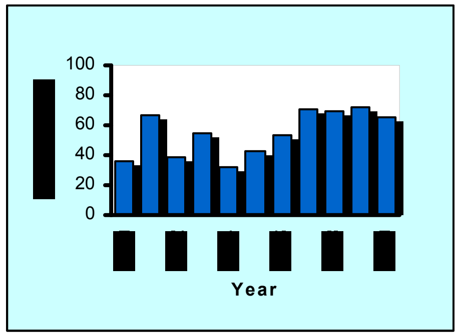
The Philippine DC sector shares 0.10% of the national total energy consumption..

Based on a yearly production of 90,000 tons of DC, the Philippine DC industry is estimated to contribute about 105,000 tons of carbon dioxide (CO_2) per year, corresponding to 0.53% of the national total emission. The DC sector has also been found to emit a total of 5 tons of particulate matter (PM). The wastewater discharged into natural bodies of water without any treatment was found to contribute a BOD_5 loading of 5,871 tons and is estimated to have a total volume of 1.35 million cubic meters per year. In proportion to national total, these figures represent 0.01% of PM and 0.07% of BOD_5. Although this may seem insignificant, DC mills could still exhibit considerable negative impacts on the local level.

DC Industry in Sri Lanka

In the early 1880s, a British trading company established the first DC mill of the world in Sri Lanka. Since then, the DC industry in Sri Lanka has become an important food processing industry in the country. Today, Sri Lanka is one of the world's top coconut producer, with an average annual production of 2.7 billion nuts. Coconut is grown in most parts of the country, and about 0.44 million hectares of land is used for coconut plantation. The main coconut growing area of Sri Lanka locally known as the 'Coconut Triangle' stretches from north of the capital, Colombo to the southwest coast between Puttalam and Kurunegala, forming the apices of the triangle.

By the year 2000, about 65 small and medium scale DC mills have been registered with the Coconut Development Authority (CDA) of Sri Lanka and most of these mills are located in Kurunegala, Puttlam and Gampaha districts. Out of the 65 mills, 59 are owned privately and the rest belong to cooperative unions. The DC sector employs about 10,000 personnel, representing 29% of the people involved in the coconut processing industry. Earnings from the DC sector have remained stable since 1997 at around US$65 million per year.



Annual DC Export Earnings of Sri Lanka registered a relatively steady rate since 1997.

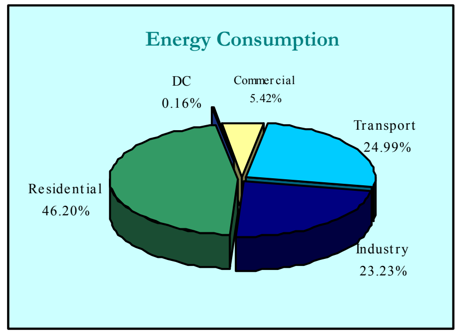
The DC mills in Sri Lanka can be broadly categorized into traditional and modern DC mills mainly based on production capacity, type of fuel used in the boiler and the type of dryer used. Mills that use fuel oil and advanced dryer mechanism, can be categorized as modern mills while the rest, predominantly using firewood and tray type desiccators, are classified as traditional mills. There are five medium-scale modern mills processing over 100,000 nuts per day. The others belong to the small-scale sector, processing less than 50,000 nuts per day. Some of these DC mills have switched from fuel wood to fuel oil and are now categorized as modernized mills. There are at least 20% factories that use fuel wood as a source of thermal energy (Galgamuwa, 1999).

One of the major consumers of DC from Sri Lanka is the UK, to which they supply the total market of about 16,000 tons per year. However exports have diminished to about a third due to heavy competition from Indonesia and the Philippines. Among the coconut products, DC accounts for the largest share of export earnings at 40% (US$ 65.22 million in 2000), while the other major export earners are coconut shell activated carbon, coir fiber pith, coir mats and rugs, coconut milk powder, copra, fresh coconut and seed nuts.

Overview of Energy and Environmental Issues

The major sources of energy used in the DC industry in Sri Lanka are firewood (traditional), fuel oil (modern) and electricity. Their annual energy consumption amounts to 21,660 tons of fuel wood, about 11,500 tons of furnace oil and 10 GWh of electricity. This constitutes about 0.16% of the total energy consumption of Sri Lanka. In the recent past, traditional mills began facing problems regarding supply of good quality firewood and uninterrupted supply of electricity. They addressed these by using second hand rubber wood for thermal energy production and installing diesel generators for electricity supply.

For an annual DC production of 60,000 tons, CO_2 emission is estimated at 74,000 tons, constituting about 2.44% of the annual national total. This CO_2 emission from the DC sector is mostly generated from combustion of firewood in the



The DC sector shares 0.16% of the total energy consumption in Sri Lanka.

traditional mills. The wastewater generated at an estimate of 0.5 million cubic meters annually is discharged to natural bodies of water without any treatment except oil separation. About 10 tons of PM and 3,850 tons of BOD_5 are generated from the DC sector in Sri Lanka.

Both the energy consumption and contribution of CO_2 from the DC sector are not much compared to the national total of the two study countries. However, addressing these two issues confronting this sector in the Philippines and Sri Lanka is important because they are crucial in reducing greenhouse gas (GHG) emissions and other local impacts.

CHAPTER 2: DC PRODUCTION PROCESS

This chapter presents the production process of desiccated coconut. Though the manufacturing process of DC is influenced by product quality requirements, quality of available raw materials and equipment, the fundamental process remains similar between the two study countries. A summary of the quality requirements and the variations in the manufacturing process are also given.

Production Process

Desiccated coconut is basically produced by drying the white meat of coconuts. In general, about 100 to 140 kg of DC is produced per 1,000 pieces of nuts. The following describes each step in the production process of desiccated coconut, emphasizing some differences in the operations followed in Sri Lanka and the Philippines.

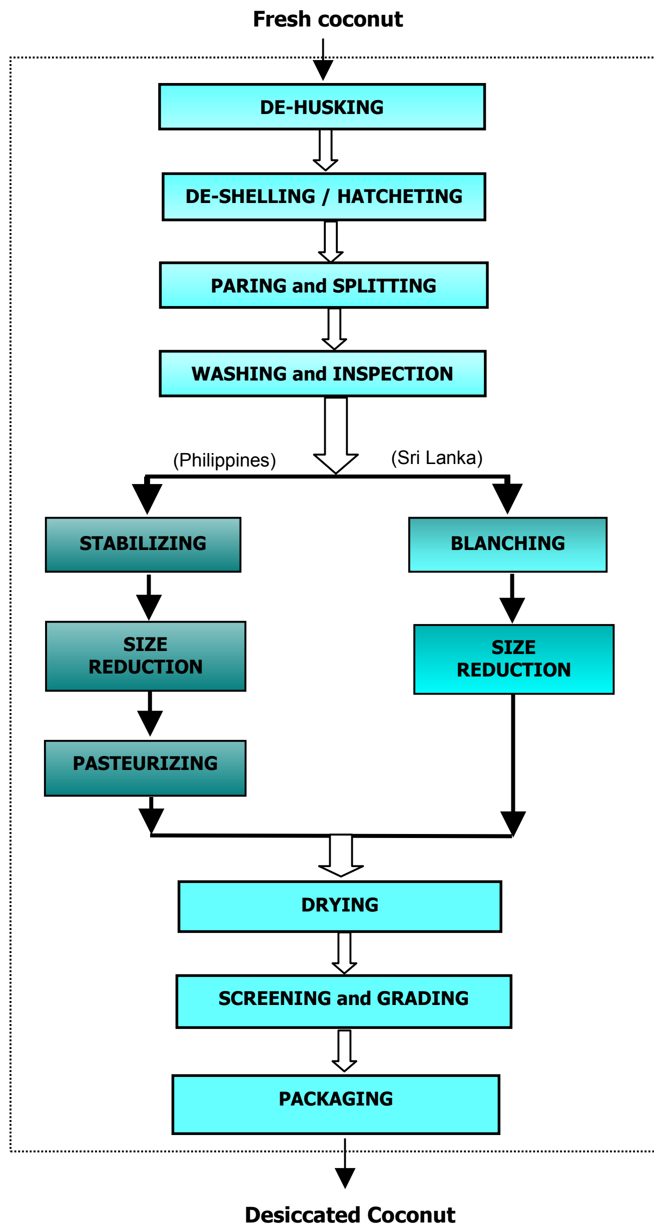
Seasoning of Fresh Coconut

A coconut tree starts yielding fruits at about 6 to 10 years after seed germination and reaches full production at 15 to 20 years of age. The gestation period of a coconut is about 50 to 60 days. Although it continues to fruit until about 80 years the economical yield is achieved only up to 60 years. The average production of one coconut tree is about 28 to 65 coconuts per year. However, in the Philippines, it was noted that well-managed coconut farms could yield 100 to 150 nuts per tree.

The average weight of a whole matured fresh coconut is about 1.2 kg. In Sri Lanka, the freshly harvested coconuts are mostly stored before processing for about 4 to 8 weeks, which is known as seasoning of the coconut. Seasoning is carried out to allow the fresh green colored outermost shell, called the husk, to dry until brown. This facilitates easy removal of the husk. During seasoning, the coconut meat inside is fully developed and the quantity of coconut water (sap water) and the sugar content in the coconut meat are reduced. This improves the quality of the final product and facilitates hatcheting. In the Philippines and a few mills in Sri Lanka, seasoning is not done and coconuts are immediately sent for processing upon harvest.

De-husking of Coconuts

The brown husk of the seasoned coconut is then removed to expose the inner hard-shelled nut in a process known as de-husking. The husk is usually sold as raw material for fiber processing. About 225 to 250 nuts/hour can be de-husked manually. In some of the traditional mills de-husking is carried out inside the factory whereas in modern mills, de-husked nuts are usually bought from local suppliers. The de-husked nuts are inspected and selected (according to locally developed maturity indices) for further processing. Spoiled or damaged nuts are used for copra manufacturing.



Flowchart of the DC production process, showing some process variations between Sri Lanka and the Philippines

In the Philippines, selected nuts are stored in nut storage bins. The number of nut storage bins depends on the number of dryers used. Usually each dryer has enough associated storage bins to allow sufficient supply for three days continuous production. On the other hand in Sri Lanka, selected nuts are either sent to the hatcheting pens for immediate use or stored in sheds or on the floor under palm leaf cover before processing. Nuts are generally used within three days of delivery or de-husking as mature nuts start degrading after 3 to 5 days.

Manual de-husking of coconut could be done at the rate of 225 to 250 nuts/h.

De-Shelling/Hatcheting

De-shelling or hatcheting as commonly known in Sri Lanka, is the removal of the hard coconut shell without breaking the soft coconut kernel inside. This is a labor intensive and delicate operation done either mechanically or manually. The production rates of either method are comparable at 200 to 300 nuts/h for mechanical de-shelling and 225 to 250 nuts/h for manual de-shelling. In Sri Lanka, hatcheting is usually carried out manually with a hatchet. On the other hand in almost all the DC mills in the Philippines, mechanical de-shellers are used. The de-shelled kernels are sent for paring through transfer chutes or carried manually in wire baskets. During de-shelling, the hard shells are collected and transported to the shell storage area by conveyors or manually by slotted bamboo containers from time to time. These shells are either used as fuel for boilers or for charcoal manufacturing.

Manual hatcheting of coconut is a labor ntensive operation producing 200-300 nuts/h.

Some DC mills have integrated carbonizing plants for coconut shell charcoal production.

Paring and Splitting

Paring is the removal of the top soft brown skin or testa from the de-shelled coconut to expose the white kernel by using a special paring knife. On the average, an experienced worker can pare about 225 to 250 nuts/hour. During paring, any discolored area of the white endosperm is cut out and discarded. The scraped brown testa, which often contains a small part of the white meat, has a high oil content of about 68% by weight of parings. These parings are either used for oil extraction in the integrated oil mill (many of the DC mills in the Philippines and Sri Lanka have in-house oil-mills) or sold to other coconut oil-producing mills.

The pared coconut kernel, which is a supple white ball of coconut meat, is then pierced to release the coconut water and cut into larger pieces (usually two or three). The process is known as splitting. The coconut water accounts for about 10% to 18% by weight of the whole nut. An average nut would contain about 200 mL of coconut water, which drains to the wastewater collection pits after splitting. The coconut water is highly organic and contains a high percentage of oil as well. The cut white meat is then put into hoppers for subsequent transportation to the washing area either manually or by conveyors. In the Philippines, the white meats are continuously sprayed with water over the conveyor and fed to a vibrating conveyor for inspection.

Washing and Inspection

In Sri Lanka, the white pared coconut meat is subjected to two-stage washing to remove unwanted particles like colored meat, leftover parings, sprouts, etc. Rigorous washing also reduces the sugar content of the meat thus preventing its discoloration by chemical reaction on prolonged storage or exposure to high temperature.

The two-stage washing process begins with manual washing of the coconut meats with chlorinated water for preliminary disinfection and bleaching. Then, in a series of wash tanks, the washed kernels are scooped up in wire baskets and vigorously shaken before these are rinsed by plain

Manual paring of de-shelled coconut , a delicate operation to remove the testa.

Manual washing of white pared coconut meat with chlorinated water for disinfection.

water to remove all traces of chlorine. After washing, the meats are inspected and any trace of remaining testa is removed and collected in bins or bamboo baskets.

Washing with chlorinated water is done mechanically in Philippine DC mills, using a screw conveyor fitted with nozzles. On the average, about 800 L/1000 nuts of wash water is required for a batch operation while a much higher amount of 2500 L/1000 nuts is needed for spray washing. The washed meats then undergo inspection before stabilization.

Stabilizing

The washed and inspected meat in Philippine DC mills is then treated with a cold solution of sodium metabisulfite solution (50mg/L) in stabilizing tanks in a process known as stabilization. This is done to facilitate drying at a later stage (even at elevated temperatures) without meat discoloration and to extend the shelf life of the product. The meat is somewhat cooled in the metabisulfite solution to harden the kernel thereby producing a sharper edge after disintegration. The coconut meat is then sent for disintegration or size reduction before steam pasteurization.

Pasteurizing

In Sri Lanka, pasteurization also called blanching, is usually done after washing and inspection to kill the microorganisms on the meat surface. In the traditional mills pasteurizing is accomplished by immersing the coconut meat in boiling water (above 95°C), for a minimum period of 1½ to 2 minutes in a pasteurizer (blancher). In some cases the meats are boiled for about 10 minutes to ensure proper sterilization. Typically the hot water pasteurizer contains ducts inside the vessel through which the hot flue gases are passed to heat the water (indirect heat exchange). Commonly, the pasteurizer is fabricated from stainless steel plate and has a capacity in the range of 1,800–4,000 liters. The pasteurized coconut is then transported for size reduction.

In most modern DC mills, blanching is done by exposing the meats to a steam flow at a temperature of about 120ºC for 1½ minutes in a steam pasteurizer. This process leads to better product quality and savings in process water. While in traditional mills the meat is loaded manually by baskets into the hopper leading to the pasteurizer, most modern mills use stainless steel conveyors to convey the meat to the unit operation.

Size Reduction and Steam Sterilization

After the pasteurization or stabilization process (as the case may be), the coconut meat undergoes size reduction i.e. cut, shredded or ground depending upon the final product requirement. The shredders or disintegrators are equipped with precision ground concentric cutting teeth and a series of adjustable parts and blades fixed on a revolving drum to produce different types of cut. The coconut meat is fed at the

Size reduction of coconut meat by a mechanical shredder processes it into different types of cuts.

center of the rotating unit by screw type conveyors and is cut or shredded and thrown towards the periphery by centrifugal action. The sized meat is collected through a discharge chute and transported to the next processing unit by another set of conveyors.

Size reduction in the Philippines is followed by pasteurization of meat. By reducing the size of the meat, a higher surface area of the meat is exposed to sterilization and a better degree of disinfection can be achieved. Sterilization is normally carried out by steam in a stainless steel belt conveyor fitted with an enclosed rectangular steaming section over about 75% of its length. Both ends of the rectangular steam chamber are fitted with hinged sealing curtains to avoid leakage of steam. Live steam at a pressure of 2 bars is introduced into the chamber through a series of fogging nozzles. The meat is exposed for about 6 minutes before being discharged onto the feed apron of the continuous band drying system. The condensate and steam are recycled back to the boiler for heat recovery. In Sri Lanka at least three modernized medium size mills are carrying out the sterilization process similar to Philippines at the final stage after disintegration.

Drying

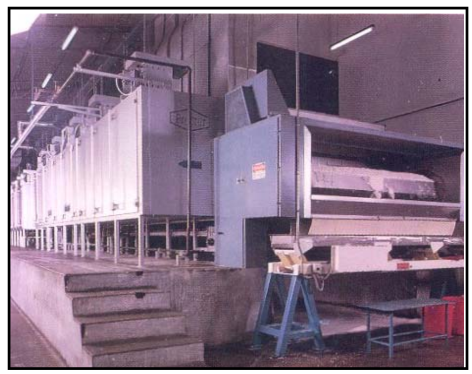
Subsequently, the sized meat is subjected to drying to reduce its moisture content from 55% to about 2.5% to 3%. This process is the main energy consumer in the DC mills due to the requirement of hot air. Several types of dryers are used for this process.

The most commonly used dryer in Philippine DC mills is the continuous multistage band Proctor-Schwartz dryer. The capacity varies from 500 to 1,000 kg DC/hr depending upon the need of the mill. These dryers normally incorporate advanced features like two-stage drying and a final cooling stage. A stainless steel perforated conveyor carries the meat through different zones of drying and cooling. The first stage is drying at 120°C to 135°C followed by a second stage at 90°C to 110°C. The final stage uses air at 35°C to 45°C to cool the product prior to grading. The overall drying time for this system varies between 15 to 20 minutes. For good quality DC, these dryers have automatic temperature and humidity controls.

In Sri Lanka, most continuous production modernized mills use Proctor-Schwartz dryers, Killburn dryers and Bedi & Bedi dryers while small to medium scale traditional mills use tray-type desiccators and semi-automatic dryers or a combination of the two. Desiccators are the oldest type of drying equipment used for DC in Sri Lanka. It has one or two drying chambers in which are placed four or five movable trays. Wet meat are loaded manually into a tray and pushed into the desiccator to come in contact with heated air inside. By the time the tray reaches the end of the drying chamber, the DC in it is fully dried so that dry DC are emptied into a bin and the emptied tray is sent back to the feeding end for refill. The feeding, pushing, emptying, and controlling of residence time are all done manually. The drying temperature is maintained at about 80°C to 105ºC and the residence time is around 45 to 65 minutes. The average drying output varies from 50 to 80 kg DC/hr (Timmins, 1994).

In a semi-automatic dryer, loading of wet meat is done manually and drying is achieved through countercurrent flow of hot air. These dryers are usually equipped with 7 trays placed one above the other at a distance of 20 cm. The meats are loaded uniformly on the top tray and allowed to dry for about 3 minutes. These are then discharged to the next tray automatically and this goes on in sequence until the dried product exits from the bottom. In most cases the drying is carried out in batches at about 75°C to 105ºC, for about 20 to 45 minutes, depending upon the type of dryer used and the size of the cut (De Silva et al., 1995). Their capacities could vary between 100 to 160 kg DC/hr. The hot DC product is then cooled on cooling tables before they are sent for screening and grading. Occasionally during cooling the DC is raked for inspection.

Normally, hot air is produced in an air-to-air heat exchanger or in a steam-to-air heat exchanger. Heat is supplied to the heat exchanger either in the form of heated air from heaters or by steam from boilers. Coconut shell, firewood or fuel oil is used as a fuel. In the Philippines, most DC mills have two boilers and they commonly use coconut shell and fuel oil. In Sri Lanka, the boilers use either fuel wood (in traditional mills) or fuel oil (in modernized mills).



The Proctor-Schwartz type dryer is commonly used in the continuous production of DC.

Screening, Grading and Packaging

The dried product is conveyed on an inclined vibratory mesh and screened manually to remove over burnt and charred particles in a process called screening. The final step of the process is grading, where the product is sorted into different particle sizes by grading machines also called sifters. The sifters consist of a series of mechanically oscillatory sieves. Typical assembly may comprise of a coarser mesh screen at the top, a medium mesh screen at the middle and a fine mesh screen at the bottom. Each of the tiers is fitted with discharge chutes to obtain the graded product. The production capacity of sifters varies widely from 350 to 1,500 kg DC/hr.

Typical size and weight distribution of DC Grades (Source: Timmins, 1994)

Grade	Mesh Size (mm)	Weight % (per batch)
Coarse	>1.680	03.0
Medium	>0.841	35.0
Macaroon or Fine	>0.595	52.0
Extra Fine	<0.595	10.0

After grading, the DC is packed in airtight paper bags to prevent absorption of moisture. Packaging is mostly done mechanically in the Philippines. The graded DC is transported by vibratory conveyors to rectangular collection bins fitted with truncated bottom hoppers and actuator controlled discharge ports. The DC is directly loaded in bags through these discharge ports. The actuators regulate the closing of the ports for precise weight. The temperature of the DC is checked (should be less than 40ºC) before packing in order to avoid condensation of moisture and discoloration of the product. For export quality packaging five ply kraft bags lined with heavy polyethylene material is used. Packaging comes in 50, 45 or 25 kg packs or as specified by the customer.

In traditional mills the packaging is usually done manually. The weight is checked to ensure compliance with the weight requirement. The liners are then heat-sealed and the bags stitched and further sealed with masking tape.

Screening and grading of DC is done using sifters to separate them into different sizes.

Final Product Quality Criteria

As a manufactured food product, DC has to conform to strict organoleptic, physico-chemical and hygienic standards. These standards vary according to the requirements of the end-user, and are frequently guided by international standards for export quality food products. Guidelines set by the Coconut Development Authority (CDA) of Sri Lanka and the Philippine Coconut Authority (PCA) form the basis

Quality Criteria of Desiccated Coconut (Source: Timmins, 1994)

Property	Parameters	Criteria
Organoleptic	Taste	Clean fresh taste; no soapy, rancid or other flavors
	Smell	Clean and fresh; no stale, musty or other odors
	Visual	White color; free from other material
	Feel	Smooth, dry and free flowing; no greasy or damp feeling
Physico-chemical	Parings Color	Not exceeding 10 particles for 100gm(Medium & Coarse grades) Natural white colored; no yellowish or other colors
	Grading	Uniform grading
	Adulterants	No infestation or presence of any other extraneous material
	Chemical	Moisture < 3% Oil Content >68% (Sri Lanka); > 60% (Philippines) pH 6.1 – 6.7 Acidity <0.3% (Sri Lanka); < 0.15% (Philippines)
Bacteriological	Total Plate Count	5,000 colonies/ g max
	Coliform Count	10 colonies/ g max
	Yeast Count	50 colonies/ g max
	Mould Count	50 colonies/ g max
	E. Coli	Nil
	Salmonella	Nil

for strict quality control and related hygienic procedures carried out at every step of the production process in the respective DC sectors. The quality of the final product is monitored according to different specific parameters like color, taste, smell, grading, physical appearance, moisture and oil content, coliform, yeast and E. coli count. The annual registration of DC mills is dependent on their conformity to the stringent requirements laid down by these government agencies.

Factory Design and Layout

A typical plant layout of a modular type DC mill in Sri Lanka has distinctly separated wet and dry sections that promote the reduction if not prevention of possible bacteriological contamination of the product. The wet section includes the deshelling or hatcheting, paring, washing, and sterilizing operations while the dry section includes the drying, screening, packaging and storage operations.

Trends in Production Techniques Improvement

Generally, DC mills in the Philippines have continuous operations with a processing rate of about 250,000 to 800,000 nuts daily thus requiring mechanization through deployment of machineries like dryers, conveyors and loaders. On the other hand, traditional mills in Sri Lanka mostly operate in a smaller scale with a processing rate of about 25,000 to 60,000 nuts daily. These mills are operated for 10 to 12 hours a day and many of the activities have to be carried out manually as mechanization is not always affordable. On the average about 12 to 39 man-hours are required per 1000 nuts (Gunadasa, 1999) in these mills. The labor productivity of the Philippine DC mills is about 1.33 times higher than that in Sri Lanka mainly because of the higher level of mechanization.

The scenario is now changing in Sri Lanka and recent trend shows that deployment of machineries is increasing in the DC mills, especially for medium scale ones. There is a gradual shift towards modernization in the traditional mills as well. The key areas of modernization include the use of conveyors to speedily transport and handle nuts, shells, kernels, parings and DC products, the shift to steam sterilization instead of the traditional pasteurization process that reduces spent water, the use of mechanical de-shellers and size reduction units, and the use of more efficient continuous type dryers over the semi automatic ones.

Moreover the CDA of Sri Lanka is promoting modernization activities by providing partial financing for improvements in electrification, water supply, hygienic and product quality considerations; establishment of quality control laboratories; installation of metal detectors; replacements of processing facilities with more efficient boilers, desiccators, semi automatic dryers, and sterilization facilities.

Ancillary Production Facility

Some of the more enterprising DC mills have also set up their own ancillary production facilities wherein the by-products in the desiccated coconut production are used as raw materials to produce a different product that adds to their income. This practice of producing either shell charcoal or coconut oil is not only considered economically beneficial to the DC mills but is also environmentally sound because it is a form of waste recycling.

Shell Charcoal Production

In many of the traditional DC mills in Sri Lanka, coconut shells are carbonized in brick lined open pits to produce shell charcoal that serves as fuel or as basic raw material for activated carbon production. Shell charcoal appears to have a good market demand. Carbonization is a process by which the compound structure of the shell is broken down and moisture and other volatile gases are driven out through pyrolysis to produce a dense matrix of carbon particles that can be used as a secondary fuel. Pyrolysis is done by burning the shells at 250ºC in limited supply of air thereby not allowing oxidation of the carbon.

A fire is initially started at the bottom of the pit before shells are added until they catch fire. The process is continued until the pit is completely charged. Initially a lot of moisture is emitted. Then, the exclusion of air is done by covering the charge with corrugated iron sheets. Sufficient space under the cover allows for a large volume of smoke and vapors to escape as the slow carbonization proceeds. The pit is covered for about three days after which the material is recovered, graded and packed. Typical yield of charcoal in this pit method is about 25% to 30% by weight of the coconut shells.

Since in the open pit method a lot of smoke and deleterious gases are formed, it is getting increasingly unacceptable. About 50% of the heat contained in the shells is lost in the emitted gases. Therefore in more modern mills integrated shell carbonization units are used in which the shells are carbonized in closed carbonizing units made of structural steel. Waste heat from the boiler is utilized for shell carbonization, which has reduced emission to a large extent. The yield has also increased up to 35 % of the weight of the shells. The capacity of these carbonization units varies from 475 kg to 950 kg per batch.

Coconut Oil Production

Oil extraction from parings and rejected coconuts is also practiced in many DC mills in the Philippines and Sri Lanka. About 35 to 50 kg parings are produced per 1000 nuts. The parings and rejected coconuts are sun dried in open areas and the dried rejected coconuts are called copra. Once dried these are pressed in oil extraction mills to derive coconut oil.

In many of the traditional DC mills in Sri Lanka coconut oil is recovered from coconut water. The coconut water is sent to the coconut oil sedimentation tanks after splitting. The wastewater is held for some time in the pits so that oil (being lighter than water) float up to the top of the wastewater. These are then skimmed away before being distilled in open rectangular vessels (kettles) to evaporate the water contained in the skimmed oil. About 16 liters of oil is skimmed off per ton of DC produced (Malcolm Pirnie Inc., 1993). This oil is then sold to oil mills for further refining and processing.

CHAPTER 3: ENERGY ISSUES OF THE DC SECTOR

This chapter discusses several energy issues encountered by desiccated coconut mills in the Philippines and Sri Lanka. Although the DC industry is not as energy intensive as most other types of food processing industries, there is still a great need to address energy consumption patterns in the different unit operations of the production process along with the energy losses associated with the use of various machineries.

Energy Source Availability in Sri Lanka and Philippines

The availability of fuel sources for DC mills in Sri Lanka and the Philippines is limited to a certain extent. Firewood, fuel oil and electricity are the major fuel used in Sri Lankan DC mills. The Philippines DC industry on the other hand utilizes fuel oil, coconut shell and electricity as energy sources with an average annual consumption of 90 GWh electricity, 12,000 tons of bunker fuel and 18,000 tons of coconut shell.

Both countries are predominantly importing fossil fuel and a major share of foreign exchange is used for this purpose. Energy prices have increased at a rapid pace (the fuel oil price almost doubled in the last two years in Sri Lanka from SLRs 8 in 2000 to SLRs 16 in 2001). This increasing fuel cost directly reflects on production cost and therefore could affect the overall competitiveness of the DC industry in the global market. The difficulties arising from foreign exchange shortage may also prohibit the use of petroleum products for heating purposes and this would be critical for the DC industry development.

The traditional DC mills in Sri Lanka may face shortage of firewood due to these high energy consumption and their associated inefficient technologies creating more demand for firewood. The rate of depletion of firewood is also a matter of concern. The increasing diesel price (from SLRs 13.60 in 2000 to SLRs 27 in 2001) may also indirectly influence the cost of firewood due to the increased transportation cost and high fluctuation on short-term firewood demand.

The hydropower potential in Sri Lanka is nearly completely harnessed and the country is gradually moving into thermal generation. Increasing demand (7% to 10% per year) and high cost of thermal power generation is expected to increase the electricity price. Due to power shortage, the industries face frequent power-cuts and so these industries heavily depend on diesel-based captive power generation. This not only increases the environmental concerns, but also increases the demand for imported fossil fuel thereby increasing the foreign exchange burden. It will also increase the production cost and related consequences.

In the Philippines, coconut shell is largely utilized as boiler fuel in both the desiccated coconut industry and in the oil mills. Aside from being used as a fuel, it is also being used as a raw material for the production of activated carbon, a high value product.

This underscores the fact that one of the best options available to the sector is to exploit the possibility of using its byproducts to meet their thermal energy requirement. However, other potential means of efficiently utilization of firewood, dedicated fuel wood plant-ation, solar thermal energy for drying could also be considered.

Energy Use Pattern in DC Mills

Both thermal and electrical energy are used in the DC production process. The share of each of these depends upon the process technology and the extent of mechanization implemented. Thermal energy is generated in-house by combustion of fuel in boilers while electricity is obtained from the grids. Thermal energy is used to produce hot water, air or steam required for pasteurization, drying and sterilization. Electrical energy is required for prime movers (motors) of different types of machineries like conveyors, blowers, mechanical de-shellers, size reducers, screening and grading machines, packaging machine, etc. A minor part of the electricity is also consumed for plant lighting.

Conventionally, energy use is expressed in terms of specific energy consumption, that is the energy consumed to produce a unit quantity of the product. The total specific energy consumption can be further categorized into thermal and electrical specific energy consumption for a DC production process.

Losses in the Thermal Energy Circuit

Boiler Losses – Normally about 15% of the total energy supplied to the boiler is lost from the stack. Boiler stack loss forms the major part (85-90%) of the total boiler losses. Other losses from the boilers include body loss and blowdown loss.

Condensate Loss – Some heat losses takes place from the recycling of hot condensate in boilers during transmission and heat exchange. Generally the condensate loss for a properly maintained boiler and transmission system is around 5% (Harry, 1998).

Dryer Stack Loss –A part of the supplied hot air in the dryer escapes through the stack before it can be fully utilized. This is mainly due to improper distribution of air, caused by short-circuiting, eddies, vortexes and turbulence.

Other Losses –Significant losses of about 10-15% may take place in the steam and air transmission systems due to improper insulation of pipe lines, long transmission lines, manifold having many bends, connections and valves, leaks in the transmission lines, radiation losses from the body of the desiccator, and losses in other equipment especially heat exchangers.

The total specific energy consumption varies depending on the process and machineries used in a mill. The major determining factors are the fuel type used in the boiler, type of drying machine, extent of mechanical conveyance and other electrical machineries used in the mill. Traditional DC mills in Sri Lanka that use batch type desiccators and firewood for boilers have a specific energy consumption ranging from 3.5 to 6.5 kWh/kg DC. Modern mills exhibit a lower specific energy consumption range from 3.5 to 4.5 kWh/kg DC primarily due to energy efficient oil-fired boilers and advanced dryers.

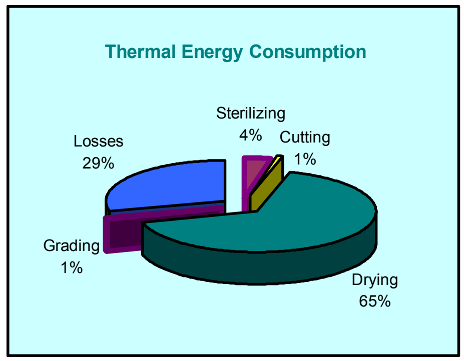
Thermal Energy Consumption

Based on several energy audits carried out in traditional and modern mills, the specific thermal energy consumption was found to vary from 10 to 23 MJ/kg DC. The total thermal energy consumption in modern mills usually ranges from 10–12.5 MJ/kg DC whereas in traditional mills, it can range from 12 to 23 MJ. In most modern mills, thermal energy constitutes about 65% of the total energy consumption but in traditional mills, it is about 90% to 95% of the total energy consumption.

Hot air required for drying is usually generated by air-to-air or steam-to-air heat exchangers and the energy demand is primarily influenced by the efficiency of the heat exchangers. Moreover efficiency of the dryer is also another important criterion that determines the quantity of hot air required.

The very high thermal energy consumption in traditional mills actually originates from the heavy losses in the drying process and the low efficiency of firewood boilers. The energy consumption of the old tray type desiccators is about 1.5–2 times that of advanced continuous dryers. The losses are mainly from the heat exchangers for which the thermal efficiency can be as low as 20%, the long drying time (nearly 45 min compared to 15 min for Proctor-Schwartz type) and the higher dryer stack losses (16% to 20%).

Hot water pasteurization requires about 2 to 2.5 times more energy compared to steam sterilization. This is primarily due to losses in the blancher and higher boiling time of about 10 min compared to 1 to 2 min exposure to steam. Higher losses in the blancher results from losses in the heat exchange mechanism (i.e. tubes inside the pasteurizer), radiation loss from the body (due to larger contact surface areas between the boiling water and the blancher) and loss of hot water at the time of recollection of the meats from the blancher. Minor losses are from conduction and convection and cascading of meat pieces to the boiling water for higher loading.

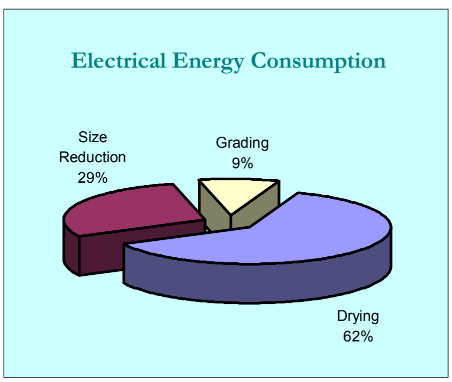


Thermal energy consumption pattern of different production processes in DC mills

Electrical Energy Consumption

The average specific electricity consumption of a DC mill varies between 0.10 to 1.0 kWh/kg DC. It was found that the electrical energy consumption is higher at 1.0 kWh/kg DC in the Philippines as compared to Sri Lanka primarily due to higher use of electrically-operated machineries.

Generally for both modernized and traditional mills of Sri Lanka electrical energy consumption is typically low, between 0.10 to 0.25 kWh/kg DC, due to manual de-shelling and manual handling and conveyance of material. Mechanical de-shelling consumes a major part of the total electrical energy, in the DC mills of the Philippines. Other than the mechanical de-shellers, abundant use of conveyors contributes to the higher electrical energy requirement in the Philippines.



Drying takes up 62% of the total electrical energy consumption of DC mills in Sri Lanka. (Source: Energy audit reports, IEMP, 1996)

The drying machineries use up 60% of the total electrical energy consumption of DC mills in Sri Lanka. In the drying process, electricity is consumed by blowers that circulate the hot air inside the dryer (at a constant airflow rate). In the case of traditional DC mills where drying is done in batches using tray dryers, the airflow rate can be reduced close to the end of the drying process in order to save some energy. But for continuous process drying, this option is not available. The size reduction and grading processes account for about 25% to 30% and 8% to 10% respectively of the total energy consumption. A minor part is also consumed in packaging in modernized DC mills.

Energy Use in Various Processes

Energy audits conducted in various DC mills in Sri Lanka showed that the major share of energy consumption is for the drying process. About 30% of the total energy consumed is lost mainly in the thermal energy circuit.

It was observed that for both cases of traditional and modern mills, the boiler loss is within the acceptable range of 15% to 25% (The Unites Illuminating Company, 1999). Normally due to incomplete combustion, stack losses are more in case of firewood combustion. This is primarily guided by the high hydrogen-to-carbon ratio of firewood leading to higher moisture formation during combustion that takes away more heat through the stack.

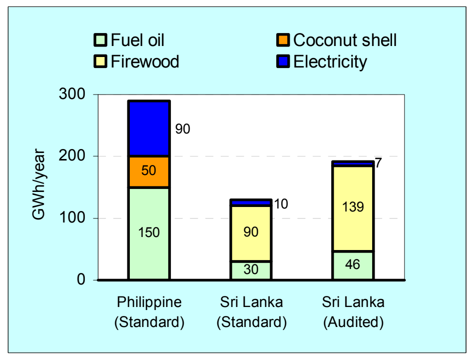
The major difference in the overall thermal performance is primarily contributed by losses from other sources. Even if the condensate loss (that is not separately determined for the traditional mill) is assumed to be about 10% to 12%, the observed losses from other sources is about 20% for traditional mills and 5% for modern mills.

Other significant sources of heat loss could be from the heat used for initial heating up of the desiccators, heat during idle desiccator time, and radiation loss from the desiccator body. General losses from pipelines add up further to the loss inventory. The exact proportions of these losses vary widely from mill to mill. But the discussions made so far indicate the key areas of possible energy savings.

Development Trends in Energy Use of the DC Sector

A primary issue challenging the traditional DC mill owners is replacement of outdated machineries by newer ones that have higher performance efficiencies. The two most important aspects are shifting from firewood to oil-fired boilers and from conventional tray type desiccators to either semi-automatic or continuous dryers.

Firewood has a lower heating value than fuel oil, and is more difficult to burn. Typically about 0.7 kg and 0.3 kg of firewood is required per kg of DC, for drying and hot water pasteurization respectively. On the other hand about 0.10 to 0.25 liters of furnace oil is required to produce the same amount of energy. Because of this, many of the DC mills in Sri Lanka have already shifted from using wood-fired to oil-fired boilers. However, because replacement of boilers requires a high capital expenditure and furnace oil is costlier, firewood is still widely used in the traditional mills. Many of the DC mills have also installed standby generators to ensure continuous production when power outages are common during the dry season.



Different fuel types used in DC mill boilers vary in the two study countries.

Many DC mills have also replaced the conventional tray type desiccators with advanced dryers to increase production capacity and reduce huge energy losses. In the traditional mills outdated desiccators are now discarded and modern dryers are installed. Since dryers form the major cost component in DC mill production equipment the only major constraint faced by the small-scale DC millers is shortage of capital. Many modern mills have likewise installed a number of conveyors and adopted better sifting machines as part of the modernization process. This improves the speed of transfer and reduces chances of contamination thereby increasing production capacity and labor productivity.

Associated Major Concerns on Energy

The energy and pollution related issues faced by the DC sector in the Philippines and Sri Lanka could be influenced by several factors. It is important to note that in order to ensure the sustainability of the DC sector, the following concerns should also be addressed.

Choice of Fuel

In the Philippines, the quality of the fuel (bunker C) greatly affects emissions. The choice of fuel, oil or coconut shell, is mostly dependent on price (cost to produce steam). An emerging issue is compliance with the Clean Air Act. Coconut shell is often wet when fed to the boilers. This often results in high total suspended particulates (TSP) in the emissions. TSP is one of the most important parameters regulated by the government agencies. On the other hand, these agencies are lenient on the issue of sulfur oxides due to the still high levels of sulfur on locally (Philippine) available fuel oil. Hence, the use of (non-renewable) fuel oil is gaining preference by reason of both cost and compliance.

Outmoded Technology and Lack of Finance

The DC sector uses inefficient equipment and outdated control systems particularly inefficient desiccators that cause high energy consumption and associated negative environmental im-pacts. Though only 30% of the indus-tries are traditional, they account for more than 60% of the total pollution. Use of old technology in traditional mills still increases the demand for firewood and consequent environmental pro-blems. Hence, adoption of efficient technology is a pre-condition to address other issues pertaining to both energy and environmental concerns.

Though a few mills are willing to adopt modernization in production process equipment or effluent treatment facilities, this industry faces problems in financing any installation and operation of energy-efficient technologies.

Need for R & D and Human Resource Training

Research and development (R&D) should be part of any manufacturing industry for further economic development. However, R&D activities are very limited in the DC sector. Research indicates that the main source of wastewater (coconut sap) could be converted into high value products (like vitamin rich drinks in the Philippines); also waste lubricants can either be reused after cleaning or can be used as an energy source. These examples show how R&D could be valuable for this sector. Due to small-scale operation of DC mills however, they usually could not afford to invest on R&D thus hindering the development of the sector. It is important for the DC sector to exploit the possibility of reusing and recycling their industrial waste in view of possible energy and financial savings.

Inefficient housekeeping and operational practices due to untrained manpower also contributes to the low performance of the industry. On the other hand, imposing stringent standards that require close monitoring of energy use and effluent discharge for compliance purposes also implies the need for competent human expertise.

CHAPTER 4: ENVIRONMENTAL ISSUES OF THE DC SECTOR

This chapter discusses water, air and solid waste generated from the DC industry with focus on the sources and generation rates, characteristics and current management practices of the pollutants. Their impacts on the ecosystem are described along with the available pollution control methods. A short description on the occupational hazards is also given for a comprehensive overview.

Overview of Waste Generation

Based on the production process, the most significant source of pollution from DC mills is the highly organic wastewater they generate. Air pollutants and in particular GHG, originating from combustion of fuel required for steam generation, distillation of oil and carbonization of coconut shells (where it is practiced) are also of interest. Solid waste generation in the form of coconut husk, shells, parings etc. however, are not of serious concern as these are practically sold or utilized for byproduct manufacturing.

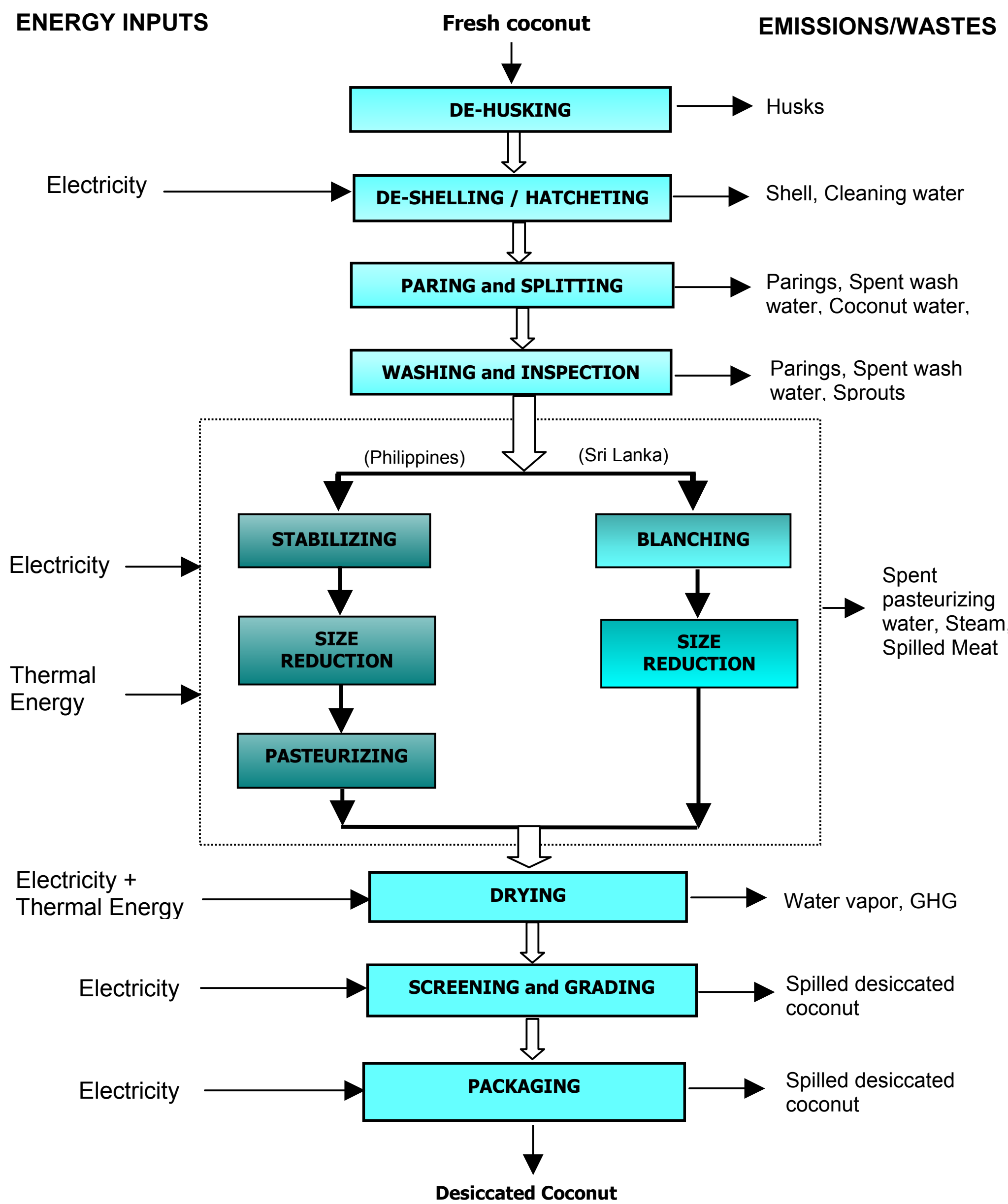
The overall quantity of various pollutants generated from different processes is commonly expressed in terms of specific pollution load that is, the amount of the pollutant generated per unit quantity of DC produced. Specific pollution load largely depends on the operational efficiency and production capacity of DC mills. Whenever such values exist, specific pollution loads can be conveniently used to calculate the actual amount of pollution generated by a particular mill. It can also be useful for comparative studies in aid of pollution control efforts within the sector.

Wastewater Pollution

Wastewater Characterization

Wastewater with high organic load is generated from several processes in a DC mill. The volume of wastewater generated depends on the production capacity and on the mechanization of the production process. In the Philippines, the volume of wastewater generated is approximately 4 to 14 L/kg DC, compared to 6 to 7 L/kg DC in Sri Lanka. The higher volume of wastewater in the Philippines is mostly due to differences in the washing process. While coconut is continuously sprayed with water during conveyance from paring to the washing unit in the Philippines, a less water consuming method of batch washing is done in most of the mills in Sri Lanka.

Spillage of coconut water from puncturing of coconut kernel in the deshelling operation is the first source of wastewater generation. Roughly about 3% to 5% loss of coconut meat in relation to coconut water is estimated at this stage. Then, about 1.0 to 2.4 L/kg DC of high strength wastewater is generated in the splitting operation when the coconut is pierced to remove the coconut water.



Energy inputs and Waste Generation from different Production Processes in a DC mill

This accounts for about 12% to 15% of the total wastewater generated from a DC mill in Sri Lanka and 7% to 10% of that in the Philippines. Fresh coconut water is acidic in nature and contains a very high amount of organics in terms of BOD_5 due to the presence of sugars and other oxidizable organic substances. It has a high fat content contributing to the high concentration of oil and grease at about 2,000 mg/L. The total solids concentration is also high at a range of 6,000 to 10,000 mg/L. Characterization data implies that fresh coconut water could significantly influence the quality of wastewater generated from the DC mills.

Water quality characterization of fresh Coconut Water and DC mill wastewater

Water Quality Parameters	Approximate Values	
	Fresh Coconut Water	Typical DC Mill Wastewater
pH	About 4.8	5.0 – 6.3
COD, mg/L	About 40,000	17,000 – 20,000
BOD_5, mg/L	13,000 – 15,000	6,000 – 10,000
Oil & Grease, mg/L	About 2,000	400 – 600
Suspended Solids, mg/L	2,000 – 3,000	2,000 – 4,000
Total Solids, mg/L	6,000 – 10,000	10,000 – 12,000
Chloride, mg/L	About 700	No Available Data
Total Nitrogen (as N), mg/L	200 – 250	No Available Data
Total Phosphorus (as P), mg/L	No Available Data	About 50

The major volume of wastewater is produced from the washing/rinsing, pasteurization and sterilization processes as spent water. About 4.5 to 19 L of water is required for washing per kg of DC, which constitutes about 75% to 90% of the total wastewater generated from the DC mills. Fine solids lost in the spent water also exert a higher solids loading to the wastewater. Wastewater is also generated from other sources like blowdown, condensate and steam leakage in boilers, cleaning of plant and machinery, floor washing, etc. Normally all these together with the coconut water are discharged into a common wastewater collection pit.

Analysis of wastewater generated from audited DC mills shows that without undergoing any treatment, wastewater quality far exceeds the effluent standards of both Philippines and Sri Lanka in all the parameters taken into account. Considering that the receiving body of water would be inland surface waters, its pH range at 5.0 to 6.3 is more acidic than the allowed pH range of 6 to 9. Likewise, its COD and BOD values at 17,000 to 20,000 mg/L and 6,000 to 10,000 mg/L respectively, are much higher than the national limits set by the two study countries. The oil and grease concentration at 400 to 600 mg/L and total suspended solids content at 2,000 to 4,000 mg/L of the raw DC wastewater are also above the maximum allowable levels in both countries.

In Sri Lanka, a typical DC mill would have a wastewater generation rate of about 6 to 7 L/kg DC produced. This leads to specific pollutant loads of (in g/kg DC): 110 to 130 for COD, 40 to 65 for BOD_5, 2.5 to 4.0 for oil & grease and 65 to 80 for total solids.

Impacts of Untreated Wastewater

Wastewater from a DC mill if discharged untreated into the streams or rivers often induce severe shortage of dissolved oxygen (DO) in the water body near the discharge point and the downstream side. DO is consumed by the microorganisms present in the water to oxidize the organic matter into carbon dioxide and water. The depletion of DO is proportional to the organic load. This process occurs naturally and creates uninhabitable environment for the aquatic flora and fauna that depend on DO for respiration. Generation of obnoxious odors, staling of water and algal blooms are some of the serious consequences of such unwarranted discharges. This could also pose a serious threat to animals and human beings using these water resources for drinking and other domestic purposes. On the other hand if discharged on land e.g. unlined ponds, the wastewater can possibly contaminate the groundwater by percolation. Since groundwater is the major source of potable water for most of the developing countries, contamination thus produced is more dangerous. Moreover the wastewater being liable to fermenting can increase the acidity of the soil, which can damage the soil structure and fertility.

Wastewater Management Scenario

Surveys in Sri Lanka and the Philippines reveal that wastewater treatment is practically neglected in DC mills. Some mills only have oil separation while others have facilities for primary sedimentation to remove the settleable solids. Only a very few mills (about 2%) are engaged in complete wastewater treatment. The lack of attention to this problem is due to several reasons that include the unwillingness of DC millers to invest on technologies that will lead to increases in overhead and production costs, the financial constraints DC millers face so that they are reluctant to make investments that bring no additional returns, and the absence of working models of wastewater treatment in the DC sector that could convince the DC industry about its worth.

Wastewater Treatment Options

The following wastewater treatment methods are part of the guidelines on pollution mitigation for the Desiccated Coconut industry as prepared by the Central Environmental Authority (CEA) of Sri Lanka.

❖ **Pretreatment of coconut water**

It is highly recommended to separate the coconut water stream from the other wastewater streams because of its relatively higher oil content. This separation facilitates the pretreatment process for coconut water involving the removal of oil that could be sold to soap manufacturing industries.

In some mills in the Philippines, screening before oil separation is done to remove large particles. Both oil separation and primary sedimentation are usually done in the same rectangular earthen (or in some cases concrete) tank. Separation of solids in such tanks without solid removal facility is practically of little use and can even give rise to septic conditions.

Oil & Grease Separation Tanks, a basic unit needed in DC mill wastewater treatment.

During the rainy seasons, many of the DC mills that have no separate rain water drainage systems experience overflow of oil and solids in their discharge channels due to surge loads from surface water runoff. Therefore, during these times severe clogging problems are encountered frequently due to large volumes of water and washed solids in the open channels.

❖ Aerobic Treatment of DC Mill Wastewater

Aerobic treatment is carried out as a secondary treatment following the anaerobic treatment. Anaerobically-treated or oil-separated coconut water is mixed with the other wastewater streams from washing and sterilization and treated aerobically. No accurate data on the composition of this kind of pretreated wastewater is available, but its pollutant concentration should be lower than the composition of wastewater combined with coconut water.

Aerobic treatment processes involves the stabilization of waste by naturally occurring oxygen-requiring micro-organisms. The most common form of aerobic treatment is the highly efficient activated sludge process. Other modes such as trickling filters, aerobic ponds, facultative ponds, extended activated sludge processes, or rotating biological contactors can also be considered depending upon the situation and land availability. The major technical disadvantage with aerobic systems is high-energy demand and reduction in treatment efficiency under high organic loading that makes them costly.

The selection of a wastewater treatment system for a DC mill depends on a number of factors including size and location of the mill, availability of space, the characteristics of the receiving water, cost of wastewater treatment, and the availability of skilled personnel. If suitable lands are available near the mill and the receiving water is in diluted form, only anaerobic treatment may be necessary, whereas the combined wastewater may be applied to the surrounding lands or be used for irrigation.

❖ **Anaerobic Treatment of DC Mill Wastewater**

Anaerobic wastewater treatment involves the stabilization of waste by naturally occurring microorganisms that survive in the absence of oxygen. This process is highly applicable to the tropics where ambient temperature is high, favoring system functioning. Anaerobic treatment is capable of handling highly organic wastewater at a moderate efficiency and is usually considered as low cost technology from both capital expenditure and operation and maintenance point of view.

UASB Treatment facility for DC Wastewater in Sri Lanka

For mills that have space, simple anaerobic ponds may serve the purpose. For mills where much space is not available tailor-made anaerobic filters (e.g. attached growth anaerobic filters or suspended growth upflow sludge blanket clarifiers) may be used. An upflow anaerobic sludge blanket (UASB) system is now being tried out in one of the DC mills in Sri Lanka. However there are also disadvantages to consider with anaerobic systems such as requirement of larger space for ponds and filters, slow speed of waste stabilization, lower efficiency sensitiveness to presence of harmful chemicals (such as chlorine and metabisulphite), requirement of experienced operators and chances of generation of obnoxious gases for poorly operating systems.

Air Pollution

Air Pollution Characterization

Emission of harmful gases due to combustion of fuel oil, firewood, coconut shells or coconut husks, in the boiler is the primary source of air pollution in a DC mill. Though some dusts containing desiccated coconut fines are also emitted from the drying, screening and packaging processes, these are generally settleable dusts and do not pose any major environmental problem. Main pollutants like CO_2, CO, NO_x, hydrocarbons, dust, fly ash and particulate matters are produced in the combustion process and are of major concern.

The range of specific air pollutant loads from DC mills varies widely due to the different types of fuel used for combustion. Carbon dioxide, with a specific load ranging from 400 to 4,000 g/kg DC constitutes about 98% of the total emissions of DC mills. Carbon monoxide produced during incomplete combustion has a specific load widely ranging from 0.6 to 580 g/kg DC. Other air pollutants like SO_2 and NO_x are also detectable in the exhausts.

Specific Air Pollution Load

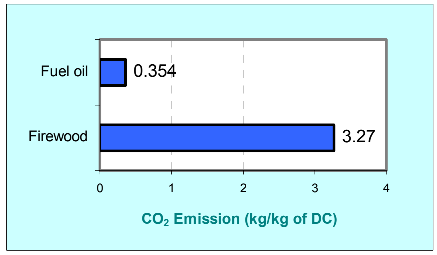
arameters	Specific Load (g/kg of DC)
Carbon Dioxide (CO_2)	400 – 4000
Carbon Monoxide (CO)	0.6 – 580
Nitrogen Oxides (NO_x)	Trace to 4.0

It was found that emissions from firewood combustion are much higher than fuel oil especially when second grade rubber wood is used due to incomplete combustion. The hydrogen-to-carbon ratio of firewood is higher than in fuel oil, which generates more moisture from combustion.

A comparison of emissions between firewood and fuel oil showed that the ratio (fuel oil : firewood) is roughly 1:9 for the specific CO_2 load. The pollution potential of traditional mills is thus several times higher than the modern mills because of the differences in their source of energy.

In DC mills where shell charcoal is produced from coconut shells, many air pollutants are generated from the carbonizing process. Carbonizing is usually carried out in brick lined open pits covered with galvanized iron sheets. In the initial phase of the process smoke containing mainly water vapor is generated. However, during pyrolysis a complex mixture of gases are given out and smoke loaded with soot and fly ash is generated. The smoke is typically characterized by a darker color with heavy creosotic odor.

Moreover in many of the DC mills in Sri Lanka the skimmed oil from wastewater



Firewood emissions of CO_2 is much higher than fuel oil.

is concentrated by evaporation, before being sold. Fuel wood and coconut shells are burnt for this purpose. This open burning of firewood and shells adds up further to the air pollution inventory.

GHG Emission and Impacts of Other Air Pollutants

The annual CO_2 emissions from the DC sector of the Philippines and Sri Lanka are estimated to be about 107,000 tons and 78,000 tons, respectively. This constitutes about 0.53% of a total CO_2 emission of 65.55 million tons (for the year, 1996) in the Philippines and about 2.44% of a total of 7.78 million tons in Sri Lanka (IEA, 1998). Overall specific CO_2 emission is found to be about

1.2 kg/kg DC and 1.24 kg/kg DC for the Philippines and Sri Lanka respectively. The average specific CO_2 emission from traditional plants in Sri Lanka is found to be about 2.2 kg/kg DC, which is much higher compared to the overall country average. Relatively high emission rates in the Philippines is noted in spite of fuel oil use in the boiler, mainly due to the use of coconut shells that constitutes about one third of the total share.

Unlike water pollution it is not easy to quantify and measure the impacts of air pollution from DC mills. This is mainly because the pollutants are carried away from the source and severe impacts may not be felt in the vicinity. The climate, geography, altitude, location and many other factors play a major role in shaping the effect of such pollutants.

Carbon dioxide, which forms the major portion of the flue gas from boilers and shell carbonization, is the most significant GHG. It is the single largest contributor to climate change, constituting about two thirds of the total GHG in the atmosphere.

Carbon monoxide on the other hand is hazardous than CO_2 at the local level as it creates severe impacts on humans and animals due to its strong affinity for hemoglobin in the blood, often paralyzing the circulation system. It readily reacts with many other gases synergistically, which can have significant atmospheric consequences.

Sulfur dioxide causes acid rain by reacting with the atmospheric moisture to form sulfuric acid, which is then brought down to the soil by rain. This increases the acidity of the soil and affects agriculture. It is also considered dangerous to plants, as plants are capable of converting SO_2 to sulphite ions that are highly toxic reducing agents. Common problems with humans are skin, eye and respiratory track irritation from SO_2.

The effect of dust, fly ash and particulate matter is generally limited to nearby areas where they would settle. Dust and particulate matter can damage the eye, skin and the respiratory mechanism of the workers and nearby inhabitants. These can also break the leaf structure by penetrating through the stomata, cause deposition of heavy metals and soiling of manufactured DC and machineries.

Air Pollution Management Scenario

Studies show that in the DC industry no significant measures have been taken to control emission of air pollutants. In most of the traditional mills in Sri Lanka the exhaust is directly discharged into the atmosphere through small stacks or chimneys. However, in the modernized mills dry cyclones are used to control dust from the boiler and dryers. Small stacks are only meant for discharging the pollutants at a height so that some dilution can be achieved but this is by no means a treatment process. Generally boilers in the traditional mills are smaller in capacity and are locally fabricated or obtained as second hand equipment from tea factories, therefore these are not accompanied by any proper air pollution control mechanism. The main hindrance of controlling air pollution is the cost associated with the mitigating equipment.

Options for Air Pollution Control

There are many types of equipment available for controlling air pollution. Some of the devices e.g. gas and chemical scrubbers, adsorption towers, electrostatic precipitators and baghouses can be very useful in controlling gaseous pollutants. However these require trained operators, high capital expenditures and operating costs.

Relatively cheaper mechanisms like dry cyclones or simply settling chambers may be more suitable for traditional DC mills, as the cost associated with such technologies are much lower. These devices are mainly used to capture dust, soot and fly ash from the exhaust stream. Cyclones and settling chambers are low efficient technologies (40% to 60%) but are much simpler in construction, operation and maintenance.

For modern mills where cyclones are already installed, better controlling methods like bag filters and wet-scrubbing systems can be adopted as advanced treatment, to control dust as well as gases in the emission. Installation of flue gas burners in the stack can reduce the concentration of unburned hydrocarbons and CO thereby potentially decreasing hazardous pollutants. In any case the importance of taller stacks need not be overlooked. Taller stacks or chimneys (depending upon pollution control code recommendations) can be constructed to discharge the emissions at a higher altitude, which will produce better dilution of pollutants.

Solid Waste Management

In traditional DC mills, the husk and coconut shells are produced as by-products from de-husking and de-shelling processes. Some meat loss takes place when manual de-shellers are used. Rejected coconuts and parings or scrapped testa are generated in the paring operation. These constitute the major source of solid wastes. Other than these, some spilled meat produced from size reduction, screening and packaging operation, forms a minor quantity. Residual sediments are produced in mills where skimmed oil distillation is carried out. Ash is generated from shell and wood combustion especially in mills where oil distillation and shell charcoal production is done along with steam generation. Specific solid waste load obtained from environmental audits carried out in the DC mills of Sri Lanka showed that the husk would exhibit the highest figures at 2.20 to 2.80 kg/kg DC, and least with the bottom ash at 0.05 to 0.20 kg/kg DC.

Coconut husk forms the bulk of solid wastes from DC mills.

Parameters	›pecific Load ‹g/kg of DC)
Husk	2.20 - 2.80
Shell	1.30 - 1.50
Paring	0.25 - 0.50
Bottom Ash or Slag	0.05 - 0.20
Sediments	about 0.18 kg/L of oil produced

However in the modern DC mills, de-husking operation is not carried out. Usually this operation is done elsewhere either in the coconut estates or the yard of the coconut dealer.

Impacts of Solid Waste

Most solid wastes from different processes in the DC mill do not have any major impact as they form valuable raw materials for other products. Coconut shells and husks find many applications in the market as a raw material for a variety of products like coir, coir pith, coconut shell charcoal, coconut shell powder, etc. Those mills that do not use the shells for heat generation or for producing shell charcoal, sell these as raw materials to either coir, coir pith, plyboard, and activated carbon manufacturing industries. Parings and rejected coconuts are usually sun-dried to form copra before these are sold for oil extraction and other purposes.

Bottom ash is disposed of in the factory premises and sediments are sold outside. Minor problems with ash handling and disposal are noted in some mills especially where firewood is used for combustion. Landfilling of ash without stabilization can cause leaching which is harmful to the groundwater. Other wastes e.g. municipal garbage, plastic bags, used paring knives are also sent outside for disposal.

Associated Major Concerns on Environment

It is also important to highlight two other environment-related issues affecting the whole DC sector. A thorough understanding of these concerns coupled with appropriate actions to meet the challenges they present are crucial to the sustainable development of the DC industry.

Enforcement of Environmental Laws and Standards

The Central Environmental Authority (CEA) of Sri Lanka has opted for the most stringent standards practiced by the developed world presumably due to pressure from environmental interest groups and donor agencies. Imposing of environmental laws and standards may be difficult as the technology is not available. This may lead to a situation of closure of the industry against inadequate possibilities for compliance, and could cause a heavy toll on the economy due to loss of production and unemployment.

Therefore, to ensure an effective environmental protection program, the enforcement of environmental laws should be followed by economically feasible solutions. It is vital to identify technology gaps and prescribe relaxed standards (for a limited period) pertaining to those industries where the abatement technologies are not affordable. A more rational approach would be a step-by-step adoption of standards, while continuously helping and guiding the industries to acquire technologies (from less complicated and affordable ones to more sophisticated and capital-intensive processes), allowing them sufficient time to prepare for stringent standards.

Occupational Safety

Noise, dust, vibration, airborne pollutants, mechanical hazards, radiation and heat stresses are of concern to the workers in the factory. Noise is generated by the machinery. In the drying section, boiler room and the pasteurization or sterilization sections, hot and humid conditions create an unpleasant atmosphere for the workers. Particulate matter is also generated in the drying section that is potentially harmful for the workers. Apart from this, several eye injuries are noted from tiny shell pieces flying off during the hatcheting process and finger injuries during paring. Simple measures such as reduction of noise by using mufflers, installation of exhaust fan for better ventilation, installation of particulate collection hoods in the drying section, and wearing of eye protection devices during hatcheting, can suitably reduce these occupational hazards.

CHAPTER 5: ENERGY EFFICIENT AND ENVIRONMENTALLY SOUND TECHNOLOGICAL OPTIONS FOR THE DC SECTOR

This chapter is devoted to the discussion of energy efficient and environmentally sound technologies (E3ST) that are available for the DC sector. An analysis of the barriers to the adoption of E3ST is also presented along with some general policy guidelines that would encourage its effective implementation.

Need for E3ST Options

Surveys conducted at the two study countries have shown that in the DC industry, pollution abatement receives the lowest priority in terms of financial investment allocation. This is because practically no market opportunity exists that would compensate for these environmental costs. At the same time, increasing the level of awareness about better energy and environmental management is hindered by the lack of appropriate guidelines for better waste management practices, cost effective technologies and dissemination of such information at the policy level.

For example in Sri Lanka, despite the lack of any pollution mitigation measures in the DC mills there is no concrete government regulation or policy to fully address this problem so no legal action could be taken against them. However, due to the rise of public awareness and vigilance the situation may not continue for long and officials may soon be forced to impose sanctions to such polluters. A more sustainable solution to the problem has to be applied to protect both the DC mills and the environment.

Traditionally it is assumed that implementation of a waste treatment device is the only major solution to environmental pollution control for an industry. A good waste abatement policy and practice is far worthy than setting up a treatment device. In fact, waste treatment technologies should only be installed if there is no viable option left to manage the waste other than treatment.

One of the best approaches in addressing energy and environmental issues is to apply preventive measures like shifting to energy-efficient and environment-friendly production processes. These E3ST options use energy resources more efficiently and generate lesser waste to obtain the desired output, thus inevitably its positive impacts will also reflect in terms of profit generation. Not always does adoption of these options require high capital expenditures. In fact some of these options require no additional expenditures but still the industries could achieve their goals.

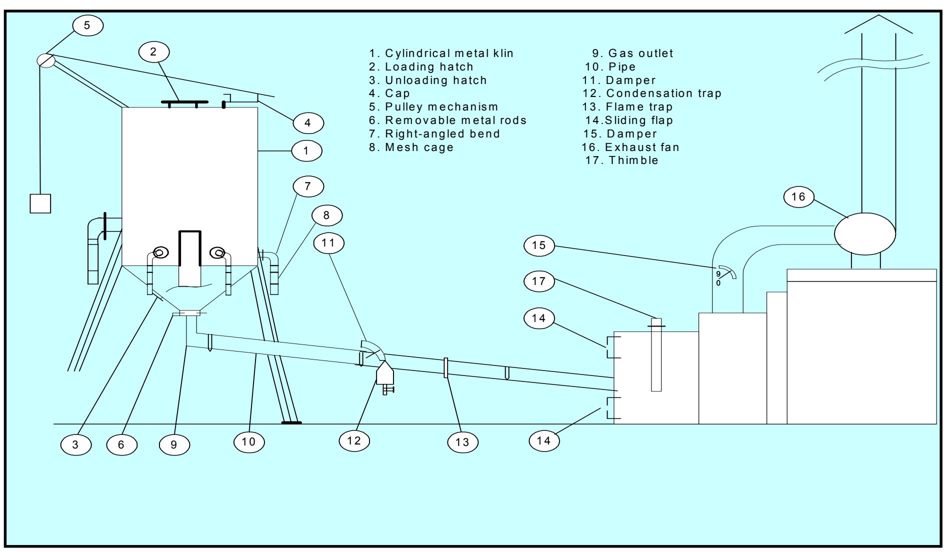
E3ST Options for Energy Efficiency Improvement

Improvement of Thermal Energy Usage

As discussed previously, the thermal energy loss mainly takes place in boilers, heat exchangers, dryers and during transmission. Therefore these are the key areas where improvements can be done to reduce wastage of heat energy. Waste heat recovery can also be a very suitable technique to reduce the energy demand. Any reduction in thermal energy demand will reduce emissions thereby effectively addressing air pollution management issues.

❖ **Waste Heat Recovery**

Waste heat recovery is one way of improving the energy efficiency of the mill. The flue gas (kiln gas) from the shell carbonizing process can be appropriately used in tandem with the fuel oil or firewood in the boiler. The technology is already in use in Sri Lanka since 1983. A typical load of 1,550 kg coconut shell could produce 550 kg of charcoal and at the same time provide about 6.9 GJ of energy (Breag and Baker, 1995). The benefit of such system is that the heat that would otherwise be wasted (with accompanying environmental impact) is recovered and reused and at the same time a byproduct is manufactured.



Schematic diagram of the waste heat recovery system from shell carbonization used in Sri Lanka

Waste heat from the boiler flue gas (if the temperature is above 250°C) can also be utilized in a similar fashion for:

- Heating of feed water
- Heating of firewood or fuel oil
- Heating of combustion air
- Heating of makeup water
- Indirect drying of coconut meat using a heat exchanger
- Oil distillation
- Carbonization of shells
- Drying of parings to form copra.

❖ Improving Boiler Efficiency

There are proven operating techniques to improve boiler efficiency some of which are:

- Operating at optimum air-to-fuel ratio. Too much excess air leads to higher heat losses while too little excess air leads to incomplete combustion which gives rise to more pollution.
- Use of cleaner fuels and moisture-free firewood which can save stack losses and reduce smoke during combustion
- Preheating fuel and air, installation of heat recovery systems (e.g. air preheaters) from flue gas to preheat the fuel can result to 5% fuel savings
- Proper maintenance of boilers, blowers, etc. to reduce deposits of soot, slag, scale and other contamination
- Installation of economizers and turbulators
- Controlling blowdown loss

E3ST Option: Using Less Moisture-Containing Firewood

Moisture content of firewood used in certain DC mills in Sri Lanka is sometimes higher than 50%. Experiments showed that energy efficiency could be raised by 20% through using dried firewood with moisture content around 25%, along with controlling the excess combustion air and sufficient training of operators. This leads to a potential fuel wood savings for the DC sector of 8,664 tons/year amounting to Rs 10.83 M and reduction of CO_2 emissions by 15.92 tons/yr.

Basis: Efficiency of 20% increase will save 40% usage of firewood
Fuel wood (1999) usage = 21,660 tons
IPCC factor (1996) = 29.9 tons C/TJ

Therefore, reduction in CO_2:
= 145.2 TJ/yr x 29.9 x 44/12
=15.919 tons/yr

Source: ISB, Sri Lanka

❖ Using More Efficient Dryers

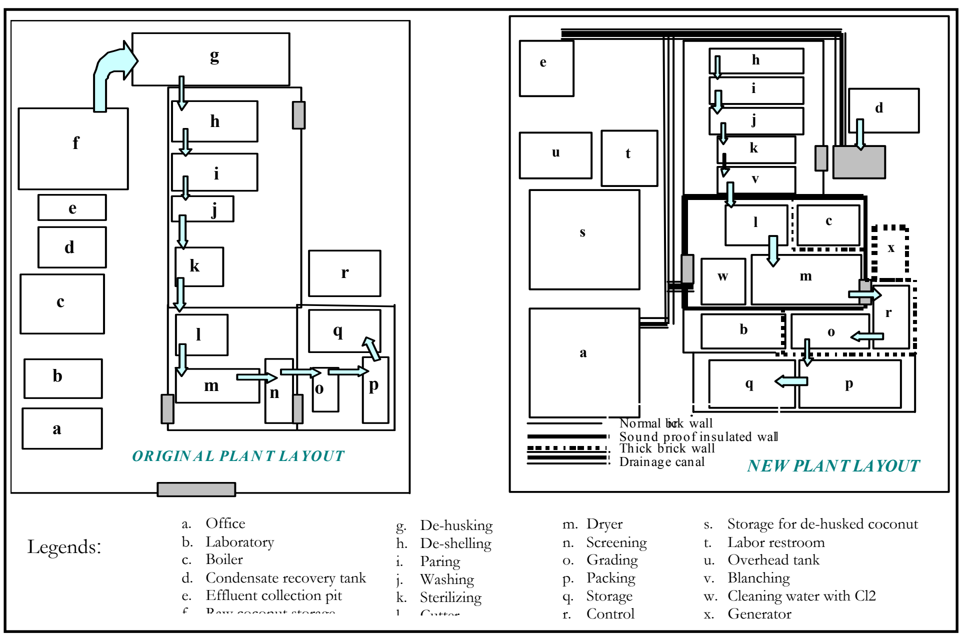
Traditional DC mills that still employ old tray type desiccators because of capital constraints, could insulate the desiccators and reduce the loading and unloading time of coconut meats.

It was found that in traditional mills significant losses take place in transmission, condensate recovery, and hot water pasteurization. Reduction of these losses needs good housekeeping and better maintenance. Operational efficiency of dryers could be greatly improved through periodic maintenance, repair and overhauling of heat exchangers. The use of modern efficient dryers can bring significant energy savings.

Preheating and idling time of desiccators can be optimized by carefully synchronizing the upstream production and desiccator usage time. Controlling these two factors can also bring about considerable energy savings. Proper loading and regulating quantity of supplied air, temperature and residence time can bring further savings. Insulation of pipes, repair of leaks, elimination of long steam transmission lines can be few of the simple measures to reduce such losses.

❖ Plant Layout Restructuring

In some cases it was observed that plant layout restructuring could lead to more efficient delivery of energy needs inside the mill. An example would be relocating the boiler room closer to the washing and sterilizing units which will shorten the steam pipelines thus reducing heat losses during conveyance. Similarly installation of lids in hot water pasteurizers can reduce the loss of heat from the top (which is generally open to air) improving energy use and workers' safety. In an audited DC mill in Sri Lanka, it was found that significant energy savings could be achieved with some restructuring of the plant layout and putting up walls of appropriate materials.



The plant layout of a DC mill may be restructured (from the left diagram to the right) to make the operations more energy efficient and minimize waste.

Improvement of Electrical Energy Efficiency

In the Philippine DC mills, a large number of machineries are used and consumption of electricity is also high. Installing capacitors in the main panel or in the individual line for motors can considerably improve the power factor. Installation of energy efficient motors in the mechanical de-shellers, sifters and dryer blowers can save electrical energy significantly.

GHG Reduction Estimation by Adopting E3ST Options

Reduction of GHG is primarily dependent on the reduction in energy consumption. It is estimated that by switching over to oil fired boilers from the traditional firewood boilers, CO_2 emission can be reduced by about 13,000 tons/year i.e. 18% of the total emission by the DC sector in Sri Lanka. With improvement in the boiler operation, installation of continuous dryers and waste heat recovery devices, a yearly reduction of about 27,000 tons i.e. 36% can be achieved. Taken together, the estimated total reduction is about 35,500 tons/year i.e. 48% of the yearly generation.

The reduction potential for CO_2 from electrical energy saving is only about 0.5% as electrical energy consumption in DC mills is very low in Sri Lanka. But for the Philippines the reduction can be about 5,000 tons/year i.e. 4.7% of the total yearly production.

Despite the possible benefits derived from adopting E3ST options, there are still hindrances in fully implementing them. These barriers go beyond the problem of capital requirement. It involves a complex mix of factors encompassing other sectors of society that if understood in a better light, such barriers could certainly be hurdled.

E3ST options for Wastewater Management

As discussed in the previous chapter, the main source of organic pollution in the DC mills is the coconut water. Yet coconut water serves as a good raw material for producing vinegar, coconut wine, nata de coco, commercial beverages, cattle feed and coagulant aid. It can be also employed in a number of medical uses.

In the Philippines, vinegar is produced from coconut water as it contains 3% sugar, making it a suitable substrate for fermentation. A processing plant with a daily capacity of 3,000 liters would require an initial investment of US$ 124,000. The payback period would be 6.5 years with an internal rate of return of 23.5% (IEMP, 1996). Another option is to use coconut water or coconut milk as raw material for nata de coco, a gel-like product popular in Japan and a few other Asian countries. It could be started with a low initial investment of about US$ 20,000 and the pay back period is around 6.8 years (Cocoinfo, 1994). Coconut water can also be packed and marketed as a ready-to-drink beverage.

Use of Coconut Water for Commercial Drink Manufacturing
An E3ST Option adopted by Peter Paul Philippines Corporation

Peter Paul Philippines Corporation, a DC manufacturer entered into a joint venture with Taiwan's Chia Meei Company to produce a commercial drink using coconut water. The process involves pasteurization and centrifugation to produce a clear, non-oily solution for packing in sterile containers. The product is then frozen and exported to Taiwan for final processing. The following are the benefits derived by Peter Paul Philippines from the venture:

- The BOD level of wastewater was reduced by 50 percent
- The annual cost saving is approximately US$3,700, (assuming the cost saving is about 10% of the total wastewater treatment cost of about US$ 37,000).
- Peter Paul and Chia Meei Company now profit from a raw material that is conventionally considered as waste.
- Since workers are now paid per whole pared coconut, they pare the coconut more carefully, resulting in a better controlled paring thickness, less coconut wastage and increased DC production. An increase of 13.6 kg DC per ton coconut processed resulted in an estimated annual savings of US$ 370,000, based on the 10,000 tons of DC production per year.

In any case, using coconut water for byproduct manufacturing would require separate handling of its stream in the DC production line. If the coconut water is not discharged into the common sewer line, then it will lead to recovery of a better quality coconut oil and the oil recovery tanks can also be downsized.

If coconut water is not utilized in any manner, it should at the least be treated separately. In this way, the wastewater generated from the other unit operations will have a lower organic load, making it more amenable to simple biological treatment processes that require lower capacity equipment. On the other hand, since the volume of coconut water is less compared to the total wastewater, this small volume can be well treated by anaerobic treatment processes.

The major volume of wastewater is generated from washing, sterilization, cleaning and pasteurization as spent water. The primary effort should be focused on the reduction of water consumption, which could be best achieved by recycling of water. Spent water from the hot water pasteurization can be used for washing the meat after preliminary filtration. It is estimated that this process can reduce about 50% of the volume of wastewater.

In the Philippines where washing of meat is done on conveyors every effort should be made to collect the spent water for reuse. The very high water requirement arising from this process can be reduced by water recycling and substantial savings can be made. It is worth to explore the possibility of shifting from a continuous to a batch washing process because the latter significantly uses up lesser volumes of water. It is also possible to look into the use of coconut water for the washing process if doing so would not increase the invert sugar content of the meat. In case coconut water cannot be used directly for washing, a possibility of blending it with fresh water can also be investigated.

Many of the modern DC mills in Sri Lanka have already opted to go for steam sterilization instead of hot water pasteurization predominantly practiced in traditional mills. This shift leads to significant reduction in the effluent volume.

Other obvious measures like good housekeeping, prevention of condensate loss by leakage, installation of separate drainage system for segregation of surface runoff, usage of pressurized water for floor cleaning, maintenance of water inventory can also contribute to a better wastewater management system.

E3ST options for Air Pollution Management

Air pollution particularly GHG emission is closely linked to the thermal energy consumption in DC mills. Therefore, any reduction in air pollutant generation can be effected only by reduction in energy consumption. Since CO_2 is the important ultimate product of any fossil fuel combustion and it is the most significant GHG, the only way to reduce CO_2 emission is to reduce the need for fossil fuel combustion. Treating the exhaust gas is of little significance in this respect.

Minimizing heat losses and recovering waste heat can lead to significant reduction in energy consumption. Reduction can also be obtained by switching over from firewood and coconut shell to furnace oil or by minimizing use of second grade rubber

Energy Recovery from Flash Steam
An E3ST option adopted by Kudaweva DC mills, Sri Lanka

At the main steam radiator to the dryer, steam pressure is maintained at 9 bars and the temperature of the condensate just after the radiator is around 175°C so it immediately flashes when coming out to the open condensate tank. Consequently, fuel loss is about 1,400 L/month. To avoid such fuel loss, an additional radiator was installed to the output condensate line of the main radiator. This installation requiring a capital investment of Rs. 200,000 with a payback period of 9 months led to a monthly savings of Rs. 24,000 and a *CO_2 mitigation of 53.4 tons/yr.*

Basis: Annual oil savings: 1,400 L/mo x 12 mo/yr = 16,800 L; Per 1000 L oil, 0.69 toe energy is saved; 1 toe = 0.0419 TJ; Total Energy Mitigation =0.69 TJ/year; IPCC factor (1996) = 21.1 tons C/TJ in oil. Therefore, Annual CO_2 savings = 0.985 TJ x 21.1 tons C/TJ x 44/12 = 53.4 tons

Source: ISB, Sri Lanka

wood. But if firewood and coconut shells remain as sources of energy, observing proper storage to avoid its contamination and drying with preheating prior to combustion can result in higher combustion efficiency. Switching to the use of cleaner fuel like natural gas can likewise be investigated.

Production of shell charcoal by open pit method should not be encouraged as it is found that open pit carbonization generates almost equal amount of pollutants as from the boiler. Instead installation of carbonization units as developed in Sri Lanka can be done to reduce air pollution to a large extent. Integration of shell charcoal carbonizers with boilers for waste heat recovery can effectively reduce air pollution. The carbonizers can be also modified for condensation and recovery of methanol and acetic acids given off during carbonization. These products are valuable chemicals that can be an extra source of income. Similarly, oil distillation by burning in open kettles can be stopped and carried out in closed chambers with exhaust collection ducts to capture and treat the pollutants along with that of the boiler.

E3ST options for Solid Waste Management

The system of utilizing the byproducts like the shells, husks, parings, etc. in DC mills for the manufacture of other commercial products is considered a sound waste management practice. In some traditional plants where handling and disposal of bottom ash is a problem, this byproduct can actually be sold as fertilizers or binders in a number of construction materials. As mentioned earlier, there are a host of other products that can be manufactured from various solid wastes generated in a DC mill.

Summary of Viable E3ST Options

It is considered useful to summarize the options that have been discussed so far and classify them in terms of their sequential adoption from a short term to a long term E3ST option. The employment of suitable treatment technologies described in Chapter 4 also forms part of these E3ST options.

List of potential E3ST Options for the DC Industry

Measures	**E3ST Options**	
	Ener y	**Enviro ment**
Short Term	▪ Energy auditing and installation of measuring devices ▪ Improvement of boiler operation by using optimum air-to-fuel ratio and controlling blow down ▪ Proper storage of fuel especially firewood ▪ Improvement of operation of desiccators by adjusting supply air, loading, reducing loading and unloading time and reducing preheating requirements and idle time ▪ Maintenance of all equipment like burners, desiccators, heat exchangers and blowers ▪ Reduction of losses in transmission lines and condensate recovery by proper insulation, repair of leaks and installation of condensate traps	▪ Raw material and waste auditing; training of workers, maintaining information database ▪ Providing shelter for oil sedimentation tanks ▪ Segregation of coconut water ▪ Recycling of hot water for washing ▪ Recycling of spent water from continuous washing ▪ Installation of rain water drainage system ▪ Installation of taller stacks as recommended by air pollution control codes ▪ Installation of afterburners ▪ Installation of preliminary devices (e.g. collection hoods, closed chambers) for restriction of emission from oil distillation and shell carbonization
Medium Term	▪ Effective utilization of energy by installation of preheaters, economizers and turbulators ▪ Power factor correction ▪ Installation of high efficiency motors ▪ Installation of proper carbonization units ▪ Installation of some waste heat recovering systems ▪ Boiler relocation for reduction in transmission line	▪ Processing of coconut water into commercial product i.e. vinegar, nata de coco, coconut wine, etc. ▪ Construction of anaerobic ponds or simple anaerobic filters ▪ Installation of dry cyclones or settling chambers ▪ Changeover to mechanical de-shelling
Long Term	▪ Switching over to oil-fired or gas fired boilers ▪ Installation of modern dryers ▪ Full scale waste heat recovery system	▪ Installation of full scale wastewater treatment plant ▪ Installation of wet cyclones, venturi scrubbers or baghouses

Barriers to Adoption of E3ST

The sector-specific standards/benchmarks/indicators are not tailored to meet the needs of SMI in any realistic way. Further, SMI may not have information on standards and benchmarks used in other countries. There is a general lack of awareness of the benefits of improved energy and environmental performance, as also of pollution prevention. For the entrepreneurs, it is important to provide information on the costs and benefits that can be derived from adopting environmentally sound production processes. This requires substantial institutional and human capabilities and the same could be enhanced if industry associations were established.

The desiccated coconut is not a major polluting industry. The energy cost is only about 7% of the total production cost. With respect to E3ST adoption, the industry is more focused on waste minimization and pollution mitigation. It is generally believed that waste treatment is a costly measure with few economic benefits for the adopter. In this light, the barriers to effective adoption of E3ST in the DC industry are discussed below.

Sectoral Structure

The DC industry at present is facing market uncertainties both in supply and demand. As an agricultural product supply of DC fluctuate erratically based on the coconut production. Coconut production is affected largely by extreme natural calamities such as cyclones, drought, El-Niño, etc. The industry has to compete with other coconut industries for its raw material.

Thousands of coconut trees have been cut in the Philippines for easy profit despite the effort of the PCA enforced by Republic Act (RA) 8067 to prevent cutting of productive trees. The result is that most of the companies are operating below capacity, and hence less profit. In the demand side, the market for DC products has been sluggish and forecasted to increase minimally as no new markets have been identified. Again this has resulted in below capacity operation for most of the mills.

With quite a number of DC factories competing for the supply of raw material and market for DC, the industry now is very competitive that interaction between companies is limited to business matters. Sharing of information is not practiced for fear of divulging valuable data.

Any new investment therefore will be weighted according to its economic benefits and on contribution to the reduction in production cost. Individual investors compute the return based only on financial cost and benefits, neglecting involvement of social cost by their activities which could be many times larger than their individual cost, in the form of environmental pollution, harmful effects on flora & fauna, disturbance to biodiversity, etc. Environmentally sound technologies that have no direct benefit for the company may not be considered important to them. Therefore management often exerts resistance against adopting end of the pipe waste treatment technologies, which for them are very technical and costly. To break this resistance some kind of financial incentives have to be introduced.

Lack of Information

There is a low awareness among employees on the environmental impact of the effluent discharge from DC mills. In the Philippines, several studies showed that DC mill workers use water liberally in the washing and cleaning processes. There is also lack of technological information on the performance of the company, and their contribution to pollution. Water used is not monitored and effluent characteristics are not regularly sampled for analysis. In most instances, the environmental management function is given as an add-on responsibility to technical staff.

Most companies do not have information of the technological advances and development in the DC industry. Some were informed but they do not have the technical capacity to assess its merits and demerits. They rely on seeing a working example before being convinced.

Inadequate Human Resources and R & D

Technical capabilities in most mills are lacking making maintenance and operation of advanced technologies difficult. There are no research and development (R & D) activities at factory level. There are a number of critical issues pertaining to the DC industry needing further attention but are not highlighted at the right forum e.g. appropriate technology in using firewood in Sri Lanka with high efficiency, manufacturing of products using coconut water as a raw material and minimizing the quantity of wastewater generated during processing of DC.

In Sri Lanka machine operators of most DC mills have a lower level of education and they are paid comparatively very low wages. Human resource development is not an important issue for factories which are only interested in short-term benefits.

Uncertainty in energy prices

Sudden surge in world market prices of oil and its impact in the DC sector have posed a hurdle towards shifting to E3ST in Sri Lanka. As a result of sudden escalation in oil prices the cost of production of modernised mills has increased by about 3–4%. However the cost of production of DC in traditional mills has increased only by about 1% in 2000. Also, the modernisation of more mills has pushed down the price of firewood thus encouraging traditional mills to postpone modernization procedures.

Trading practice

DC is internationally traded based mostly on future market prices. It is difficult to forecast the future price of DC on many occasions due to lack of cooperation among the DC trading countries and lack of transparency in sharing information. As a result, some DC millers incur heavy losses leading to liquidity problems and invariably lesser concern is given to environmental protection.

Financial Constraints

To encourage adaptation of E3ST technologies, financial assistance is available in the form of soft loan in both countries. However DC mills in both countries are so far not attracted by the loan facilities. This scenario proves that loan facilities alone cannot promote adaptation of E3ST options to the DC industry.

Poor working conditions

The working conditions prevailing in DC mills in Sri Lanka is extremely poor. Hacheters and parers especially are carrying out a monotonous task without any motivation. Furthermore operators of desiccators are working in an environment at high temperature, and with much smoke and gases from firewood.

Regulation and policy barriers

In Sri Lanka, no policy has been formulated so far to steer the energy sector. As a result, energy sector-related activities are not at par with most other countries in the world. There are lapses observed on the part of implementation of environment-related regulations in both participating countries Sri Lanka and Philippines.

Policy Guidelines for Adopting E3ST Technologies

Based on the discussion of specific barriers in adopting E3ST options by the DC sector, it is deemed necessary that its effective promotion be aided by some changes at the policy level. The following identifies some essential factors that could serve as guidelines in successfully implementing programmes on E3ST.

Industrial clusters

The concept of industrial clustering is considered as an age-old concept. However with the liberalization of many economies in the world the above concept has received a new dimension. Clusters could be in many forms such as free trade zones, industrial estates, export processing zones, etc. By locating a group of industries in close proximity to needed resources then the industrial sector can be mobilized with higher efficiency. Moreover government and private institutions that provide facilitation services can concentrate their efforts in providing efficient service. Environmental pollution factors could be minimized due to better monitoring and availability of information. However, concentration of industries in one locality will lead to accumulation of higher concentration of pollutants in that vicinity.

Cross-country Comparison – Structure of energy pricing

Country	Price of Energy	Source of Energy	Energy Pricing Structure
Philippines	Comparatively higher energy prices helps in conservation	Mostly imports fossil fuels but has some available local sources like geothermal, natural gas and hydropower	No cross subsidies conducive to energy conservation
Sri Lanka	Comparatively low to medium level price	Mostly imports except firewood and hydro power	Cross subsides available for diesel, not conducive to energy conservation

Renewable energy

A number of Asian countries are heavily dependent on imports to meet their energy demand. Recent escalation of energy prices in the world market however has forced everyone to rethink the possibility of exploring alternative sources of energy. Countries that are heavily importing energy and engaged in export trade like Philippines and Sri Lanka could loss their edge in the market if energy prices escalate continuously. As a result, several economies in the region are already considering to explore locally available renewable sources of energy in the form of wind, solar, geothermal, etc.

In the Philippines, the use of coconut shell, a renewable source of energy, is being practiced. However, DC plants are encountering regulatory problems in terms of high level of total suspended particles (TSP) being emitted when coconut shell is burned. Thus, to encourage the use of renewable energy, some of the existing stringent regulatory measures may have to be relaxed.

Energy pricing, Taxes and Subsidies

In most countries certain sources of energy is priced at consumer affordable level to meet basic energy needs of the disadvantaged communities and regions. The government as a social obligation subsidizes additional cost involved in this regard. Sometimes these subsidies may eat up a larger portion of the GDP of a country. In Sri Lanka, energy sources for the transport sector is subsidized to a certain extent. Therefore subsidized energy is sold in the market for a lower price than other forms of energy and as a result demand for such form of energy is much higher than other forms. For instance one liter of petrol is sold at a price nearly two times more than one liter of diesel. If the price is very low and unrealistic then there is a tendency towards wasteful and inefficient usage of energy.

Research and Development & Training facilities

In developing countries most of the research activities are carried out by educational and research institutes. The relevant research problems are identified by either those institutes or by funding agencies. They handle macro level problems and very rarely give attention towards applied research or practical problems prevailing in the industries. Industry level researches are very rare and even if they do they would only handle micro level problems due to financial and technical constraints. Therefore there is a need to identify realistic problems prevailing in industries to be able to tailor further research activities to meeting their specific needs.

This could be achieved by better coordination between industries and research institutes. Moreover the findings of research institutes very rarely cross their boundaries and do not reach the target audience. Hence, it is imperative that the funding agencies should extend their role a few steps further from the research stations to ensure appropriate trickling down of information to the targeted segments of society.

In addition to the lack of research and development activities, there appears to be a low level of utilization or commercialization of the current research and development findings. At the same time, the highly competitive market situation among the DC manufacturers limits the amount of cooperation necessary to conduct research and development on sector-wise issues.

In early 1980s in Sri Lanka, the research and development activities in DC sector was carried out by Coconut Development Authority. However, later when these activities were slowly transferred to the millers, there was no coordination and collaboration of the research activities.

Financial Instruments

Financial incentives are more powerful tools for change of practice and attitude. This kind of incentives is provided in many forms such as soft loans, grants, and duty rebate tax reduction. At present there are number of financial assistance schemes implemented by the participating countries. In Sri Lanka and Philippines private and public sector institutions have already introduced some financial assistance schemes to promote the adaptation of E3ST technologies. In Sri Lanka, the National Development Bank has introduced two financial assistance scheme called Pollution Control and Abatement fund and "e-friends" a soft loan to conduct environmental and energy auditing. The above schemes may be attractive for new comers and industries, which generate income from waste materials and so far the above facilities are not significantly utilized by the DC sector.

Standards & Norms

Standards and norms serve as guidelines to industries on how to adopt new technologies. Without setting proper standards it is difficult to monitor the activities of a sector. Generally environmental emission standards are applicable to all kinds of industries and not just for a specific industry or process. Sometimes for a specific industry guidelines could be set instead of standards, which are more flexible.

Law enforcement

Natural resources such as water, fauna and flora, air, biodiversity, etc. are classified under public properties. Therefore conservation of natural resources to ensure their availability for future generation is a prime obligation of a government. If the government finds certain elements wasting or misusing the resources it is a duty of the government to rectify the situation by enforcing the law.

APPENDIX A: EFFLUENT DISCHARGE LIMITS (PHILIPPINES & SRI LANKA)

PHILIPPINES

SUBJECT: REVISED EFFLUENT REGULATIONS OF 1990, REVISING AND AMENDING THE EFFLUENT REGULATIONS OF 1982

Section 5. **Conventional and Other Pollutants Affecting Aesthetics and Oxygen Demand.** Effluents from domestic sewage and industrial wastewater treatment plants not covered under Section 6 of these Regulations, when discharged into receiving waters classified as Class A, B, C, D, SA, SB, SC and CSD in accordance with Section 68, as amended, of the 1978 NPCC Rules and Regulations shall not contain in the following pollutants in concentrations greater than those indicated in Tables 2 A and 2B.

Table 2A – EFFLUENT STANDARDS: Conventional and Other Pollutants in Protected Waters Category I & II and in Inland Waters Class[A]

Parameter	Unit	Protected Waters				Inland Waters	
		Category I (Class AA & SA)		Category II (Class A, B & SB)		Waters Class C	
		OEI	NPI	OEI	NPI	OEI	NPI
Color	PCU	(b)	(b)	150	100	200[(c)]	150[(c)]
Temperature ^{0}C rise (max. rise in degree Celsius in RBW)		(b)	(b)	3	3	3	3
pH (range)		(b)	(b)	6.0-9.0	6.0-9.0	6.0-9.0	6.5-9.0
COD	mg/L	(b)	(b)	100	60	150	100
Settleable Solids (1 hour)	mg/L	(b)	(b)	0.3	0.3	0.5	0.5
5-Day $20^{0}C$ BOD	mg/L	(b)	(b)	50	30	80	50
Total Suspended Solids	mg/L	(b)	(b)	70	50	90	70
Total Dissolved Solids	mg/L	(b)	(b)	1,200	1,000	---	---
Surfactants (MBAS)	mg/L	(b)	(b)	5.0	2.0	7.0	5.0
Oil/Grease (Petroleum Ether Extract)	mg/L	(b)	(b)	5.0	5.0	10.0	5.0
Phenolic Substances as Phenols	mg/L	(b)	(b)	0.1	0.05	0.5	0.1
Total Coliforms	MPN/ 100 ml	(b)	(b)	5,000	3,000	15,000	10,000

Table 2B – EFFLUENT STANDARDS: Conventional and Other Pollutants in Inland Waters Class D, Coastal Waters Class SC and SD and Other Coastal Waters not yet Classified

Parameter	Unit	Inland Waters (Class D)		Coastal Waters (Class SC)		Class SD & Other Coastal Waters Not Classified	
		OEI	NPI	OEI	NPI	OEI	NPI
Color	PCU	---	---	(c)	(c)	(c)	(c)
Temperature ^{0}C rise (max. rise in degree Celsius in RBW)		3	3	3	3	3	3
pH (range)		5.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	5.0-9.0	5.0-9.0
COD	mg/L	250	200	250	200	300	200
5-Day 20^{0}C BOD	mg/L	150(d)	120	120(d)	100	150(d)	120
Total Suspended Solids	mg/L	200	150	200	150	(g)	(f)
Total Dissolved Solids	mg/L	2,000(h)	1,500(h)	---	---	---	---
Surfactants (MBAS)	mg/L	---	---	15	10	---	---
Oil/Grease (Petroleum Ether Extract)	mg/L	---	---	15	10	15	15
Phenolic Substances as Phenols	mg/L	---	---	1.0(i)	0.5(i)	5.0	1.0
Total Coliforms	MPN/ 100 ml	(j)	(j)	---	---	---	---

NOTES for Table 2A and Table 2B:

1. In cases where the background level of Total Dissolved Solids (TDS) in freshwater rivers, lakes, reservoirs and similar bodies of water is higher than the Water Quality Criteria, the discharge should not increase the level of TDS in the receiving body of water by more than ten percent of the background level.

2. The COD limits in Tables 2A and 2B generally apply to domestic wastewater treatment plant effluent. For industrial charges, the effluent standards for COD should be on a case to case basis considering the COD-BOD ratio after treatment. In the interim period that this ratio is not yet established by each discharger, the BOD requirement shall be enforced.

3. There are no effluent standards for chloride except for industries using brine and discharging into inland waters, in which case the chloride content should not exceed 500 mg/L.

4. The effluent standards apply to industrial manufacturing plants and municipal treatment plants discharging more than thirty (30) cubic meters per day.

<u>LEGEND</u> for Tables 2A & 2B

(a) Except as otherwise indicated, all limiting values in Tables 2A and 2B are 90th percentile values. This is applicable only when the discharger undertakes daily monitoring of its effluent quality, otherwise, the numerical values in the tables represent maximum values not to be exceeded once a year.

(b) Discharge of sewage and/or trade effluents is prohibited or not allowed.

(c) Discharge shall not cause abnormal discoloration in the receiving waters outside of the mixing zone.

(d) For wastewater with initial BOD concentration over 1,000 mg/L but less than 3,000 mg/L, the limit may be exceeded up to a maximum of 200 mg/L on a treatment reduction of ninety (90) percent, whichever is more strict. Applicable to both old and new industries.

(e) The parameters Total Suspended Solids (TSS) should not increase the TSS of the receiving water by more than thirty (30) percent during the dry season.

(f) Not more than 30 mg/L increase (dry season).

(g) Not more than 60 mg/L increase (dry season).

(h) If effluent is the sole source of supply for irrigation, the maximum limits are 1,500 mg/L and 1,000 mg/L, respectively, for old industries and new industries.

(i) Not present in concentration to affect fish flavor or taste or tainting.

(j) If effluent is used to irrigate vegetable and fruit crops which may be eaten raw, Fecal Colifoms should be less than 500 MPN/100 mL.

SRI LANKA

Table 1. General standards for discharge of effluent into inland surface waters.

	Determinants	Unit	Tolerance Limit
1	Total Suspended Solids (TSS)	mg/l, max	50
2	Particle Size of Total Suspended Solids	mg/l, max	To pass sieve of aperture size 850µ m
3	pH value at ambient temperature		6.0-8.5
4	Biochemical Oxygen Demand in 5 days @ 20^0C (BOD_5)	mg/l, max	30
5	Temperature of discharge		<40^0C in any section of the stream within 15 m downstream from the effluent outlet
6	Oil and Greases	mg/l, max	10.0
7	Phenolic compounds (as phenolic OH)	mg/l, max	1.0
8	Cyanides (as CN)	mg/l, max	0.2
9	Sulphides	mg/l, max	2.0
10	Flourides	mg/l, max	2.0
11	Total residual chlorine	mg/l, max	1.0
12	Arsenic	mg/l, max	0.2
13	Calcium, total	mg/l, max	0.1
14	Lead, total	mg/l, max	0.1
15	Chromium, total	mg/l, max	3.0
16	Copper, total	mg/l, max	0.1
17	Lead, total	mg/l, max	0.0005
18	Nickel, total	mg/l, max	3.0
19	Selenium, total	mg/l, max	0.05
20	Zinc, total	mg/l, max	5.0
21	Ammoniacal Nitrogen	mg/l, max	50.0
22	Chemical Oxygen Demand (COD)	mg/l, max	250

Notes:

1. All efforts should be made to remove color and unpleasant odor as far as practicable.
2. These values are based on dilution of effluents by at least 8 volumes of clean receiving water. If the dilution is below 8 times, the permissible limits are multiplied by 1/8 of the actual dilution.
3. The above-mentioned General Standards shall cease to apply with regard to a particular industry when industry specific standards are notified for that industry.

APPENDIX B: ANNUAL CO_2 EMISSION ESTIMATION FROM DC SECTOR (PHILIPPINES AND SRI LANKA)

Philippines:

Basis:

1. CO_2 generated by electricity in 1996 is 13.21 million tons (Source: IEA, 1998);
2. Electricity consumption in 1996 is 34,775 million kWh (Source: UN Statistical Yearbook for Asia and the Pacific, 1999).

Therefore,

ton CO_2 per MWh = 13.21 ton CO_2/34.775 MWh = 0.38 ton CO_2 per MWh

For an annual production of 90,000 tons DC:

Type of Energy Source	Per ton DC	Annual Energy Consumption	CEF Ton C/TJ	Ton C	Ton CO_2 (ton C * 44/12)
Electricity	996kWh	89,640 MWh	----	---	33,037
Steam a. Fuel oil	5401 MJ	486.09 TJ	21.1	10257	37,609
b. Coconut shell	3600 MJ	324.00 TJ	29.9	9688	35,412
				Total	**106,058**

In electricity generation, the share of the DC sector is 0.26% (89,640 MWh/34.775 million MWh). The CO_2 emission from the Manufacturing industry in 1996 is 13.78 million tons CO_2. The share of DC industry is 37,609 tons CO_2 (CO_2 from Coconut shell is not included because it is a biomass) which is 0.27% of manufacturing industry. The total contribution therefore by the Philippine DC industry to CO_2 emission is 0.53% of the national total.

Sri Lanka:

Basis:

1. CO_2 generated by electricity in 1996 is 0.93 million tons (Source: IEA, 1998);
2. Electricity consumption in 1996 is 4,366 million kWh (Source: UN Statistical Yearbook for Asia and the Pacific, 1999).

Therefore,

ton CO_2 per MWh = is 0.93 ton CO_2/4.366 MWh = 0.213 ton CO_2 per MWh

For an annual production of 60,000 tons DC (30% produced by traditional and 70% by modernized mills):

Type of Energy Source	Per ton DC	Annual Energy Consumption	CEF Ton C/TJ	Ton C	Ton CO_2 (ton C * 44/12)
Traditional (18,000 tons DC per year)					
Electricity	161kWh	2898 MWh	----	---	617
Steam: Fuelwood	20,030 MJ	360.54 TJ	29.9	10,780	39,527
				Subtotal	**40,144**
Modernized (42,000 tons DC per year)					
Electricity	184 kWh	7,728 MWh	---	---	1,646
Steam: Fuel Oil	9,950 MJ	417.9 TJ	21.1	8,818	32,333
				Subtotal	**33,979**
				Grand Total	**74,123**

In electricity generation, the share of the DC industry is 0.31% (10,626 MWh/3.466 million MWh). The CO_2 emission from the whole manufacturing industry in 1996 is 1.52 million tons CO_2. The share of DC industry is 32,333 tons CO_2 (CO_2 from fuelwood is not included because it is considered a biomass) which is 2.13% of manufacturing industry. The total contribution therefore by Sri Lanka DC industry to CO_2 emission is 2.44% of the national total.

APPENDIX C: ESTIMATION OF REDUCTION OF CO_2 BY ADOPTING E3ST OPTIONS

1. **Primary reduction in CO_2 emission can be achieved by switching from firewood to fuel oil:**

- The reduction of CO_2 is about (110 – 74) = 36 tons/TJ i.e. 33%
- Assuming that total CO_2 emission from firewood in Sri Lanka is 39,527 tons / year from traditional mills
- *Total reduction in Emission is (39,527 * 0.33) = 13,000 tons*

2. **Reduction in Emission by Reducing Thermal Energy Losses and Replacing Desiccators:**

- Achievable Boiler efficiency = 85 %
- Achievable Dryer efficiency (assuming that in continuous dryers stack loss is minimum at 10%) = 90%
- Condensate Loss = 5%
- Other Losses = 5%
- Based on above, achievable Thermal Energy Efficiency = 70 %
- Net increase in Thermal Efficiency = 70 – 52 = 18%
- Assuming that by installing waste recovery devices fuel consumption can be further reduced by 20% (Taplin Jr., 1998)
- Total fuel saving vis-à-vis emission = 18% + 20% = 38%
- *Therefore net reduction in CO_2 emission = 0.38 * (39,527 + 32,333) = 27,000 tons / year*

3. **Reduction in Electrical Energy consumption by installing power factor correction and energy efficient motors:**

- Assuming that the normal power factor is 0.75 for DC mills, improvement that can be possible by installing power factor correction = (0.85 – 0.75) = 10%
- Assuming that energy efficient motors can reduce the consumption further by 5%
- Net reduction in Electrical Energy (vis-à-vis CO_2 emission) = 15%
- *Therefore net reduction in CO_2 emission = 0.15 * (617 + 1646) = 350 tons / year*

APPENDIX D: LIST OF NATIONAL INSTITUTES AND ORGANIZATION RELATED TO THE DC INDUSTRY

General

1. International Development Enterprises http://ideorg.org /
2. Sri Lanka Desiccated Coconut http://www.sources.de/infop/com/st_annes/history.htm

Publications

1. Asian and Pacific Coconut Community Books, Reports, Proceedings, And Other Publications http://www.apcc.org.sg/pmother.htm
2. About a desiccated coconut company in Viet Nam: http://ideorg.org (http://ideorg.org/archive/coconut.htm)
3. Measures Affecting Desiccated Coconut – Brazil: **http://www.sice.oas.org/dispute/wto/coconut3.asp**
4. Co-comunity newsletter : http://www.apcc.org.sg/cocomun/
5. Asian and Pacific Coconut Community's video documentaries http://www.apcc.org.sg/video.htm
6. Information Network on Post-*h*arvest Operations http://www.fao.org/inpho/pp-dr/pp-arch/full-doc/frame-e.htm
7. Publication from Coconut Development Board of India http://coconutboard.nic.in/publica.htm
8. Coconut Processing In The Mekong Delta, Vietnam: http://www.ideorg.org/techgallery-library/documents/coconut.htm
9. Post-harvest Operations-Coconut: http://www.fao.org/inpho/compend/text/ch15.htm

Industrial Associations/Organizations

1. Asian and Pacific Coconut Community (APCC) - http://www.apcc.org.sg/
2. Coconut Development Board of India: http://coconutboard.nic.in

Academic/Training/Research

1. Information Network on Post-harvest Operations: http://www.fao.org/inpho/
2. Central Food Technological Research Institute, India http://www.cftri.com

Machine manufacturers

1. Gardeners Corporation, 6 Doctors Lane, Near Gole Market, Post Box 299, New Delhi - 110 001
2. Vivega Engineers, 143-C, Nava India Road, Coimbatore - 641 007.
3. Padmanabh Corporation, No.69, Lake view Road, Kamakoti Lane, West Mambalam, Madras - 600 033.
4. Premier Engg. Products, 3rd floor, C.R.C. Building, M.G. Road,Cochin - 682 011. (Dryer)
5. Heat Flow Engineers, Plot 305, Netaji Nagar, Perungadi, Madras - 600 096. (Dryer)
6. Bedi & Bedi Pvt. Ltd., 11/13, 1st Main Road, Jawaharlal Extension, Bombay-560 046. (Dryer)
7. Kilburn Engineering Ltd., Subhash Nagar, Bandra, Bombay - 400 078 (Dryer)
8. Package India, W-115A, 111 Avenue, Anna Nagar, Madras - 600 040. (Packaging machine)
9. Technology available from CFTRI, Mysore. http://www.cftri.com

APPENDIX E: LIST OF WEB SITES RELATED TO THE DESICCATED COCONUT INDUSTRY

Case Studies

1. CleaNet Environmental Clearinghouse - http://www.cleanet.lk/Case/Default.htm
2. Wastewater treatment in DC industry http://www.cleanet.lk/Case/Default.htm
3. Reducing waste in the desiccated coconut industry in Philippines: http://www.emcentre.com/unepweb/tec_case/food_15/recovery/r2.htm
4. Establishment of a DC industry in India: http://coconutboard.nic.in/dc.htm
5. Coconut shell charcoal production in India: http://coconutboard.nic.in/charcoal.htm
6. Activated carbon production from coconut shell in India: http://coconutboard.nic.in/activatd.htm
7. Coconut shell powder production in India: http://coconutboard.nic.in/shelpwdr.htm
8. Environmental Management in LUDESCO, a desiccated coconut producing facility in Philippines http://es.epa.gov/new/contacts/newsltrs/unep/unep-8.html

Equipment Suppliers

1. Complete turn-key project on dessicated coconuts processing plants: http://www.datae.com.my/product.htm
2. Central Food Technological Research Institute, India http://www.cftri.com

Manufacturers and Exporters

1. Fiesta Brands Inc: http://www.fiesta-brands.com
2. International Coconut Corporation: http://www.internationalcoconut.com
3. John Keells Group, Sri Lanka: http://www.keells.com/jkhome/plantation/coconut.htm
4. Kapar Coconut Industries: http://www.kaparcoconut.com & http://www.kci-coconut.com

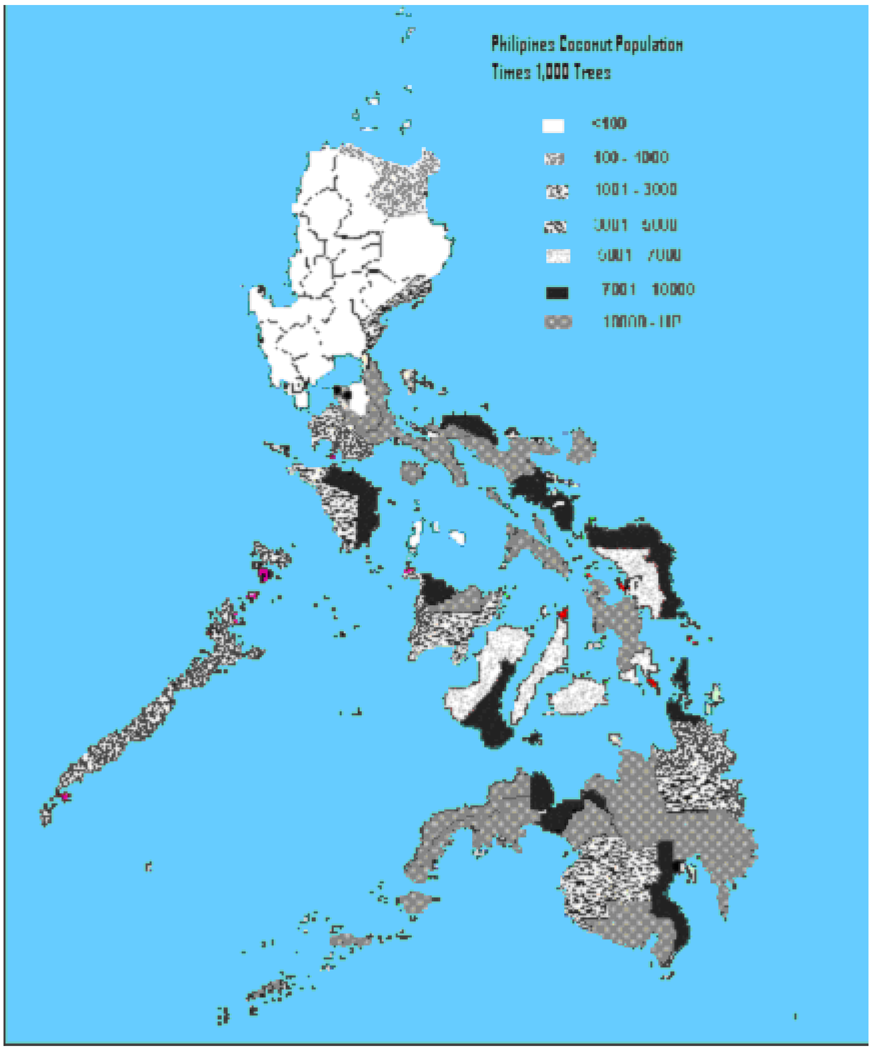
5. M & S Food Industries, Malaysia http://www.msfood.com.my/msfood/main.html
6. P.T. RAJA ALBATROS MAS: http://www.colibrinet.com/ram/
7. RV Industries: http://www.rvindustries.com/index.htm
8. S&P Coconut Industries, Malaysia: http://www.mtex.com.my/mtex/bom/BScompany_detail.asp?comp_id=spfood
9. Sri Lanka-Exports: http://www.erosh.com/erosh/EXPORTS/COCONUT/coconut.html
10. Coconut - yellow page : http://www.worldyellowpages.com/coconut.htm

Miscellaneous

1. http://www.soupsong.com/fcoconut.html
2. General information: http://www.orst.edu/food-resource/a/coco.html

APPENDIX F: COCONUT PLANTATION MAPS (PHILIPPINES AND SRI LANKA)

Philippines



Sri Lanka


JAFFNA
MANNAR
TRINCOMALAE
PUTTALAM
KURUNEGALA
BATTICALOA
CHILAW
KEGALLE
AMPARA
GAMPAHA
COLOMBO
RATNAPURA
KALUTARA
GALLE
HAMBANTOTA
MATARA
DC MILL

APPENDIX G: GLOSSARY

Acid Rain	-	Rain that brings down acid formed in the atmosphere by the reaction of gases with atmospheric moisture
Aerobic Wastewater Treatment	-	Biological wastewater treatment that is carried out in the presence of oxygen, generally producing carbon dioxide and water as major end products
Anaerobic Wastewater Treatment	-	Biological wastewater treatment that is carried out in the absence of oxygen, generally producing carbon dioxide and methane as major end products
Biochemical Oxygen Demand (BOD)	-	The amount of oxygen required to oxidize the biodegradable portion in the organic wastewater under standard controlled conditions (20 °C, pH = 7) for a specific number of days (usually five days for BOD_5). It gives a measure of organic pollution in a wastewater
Blanching	-	Same as pasteurizing
Blowdown	-	Water from the boiler wasted intermittently to avoid solids build up in the boiler feed water, which can increase scaling.
Carbonization	-	Process by which coconut shells are transformed into charcoals by driving out moisture and other volatile gases
Coconut Meat	-	The innermost soft white layer without the testa
Copra	-	Dried rejected nuts and parings usually with high oil content
De-Husking	-	Removal of the brown colored outer fibrous covering (husk) of the seasoned coconuts
De-shelling	-	Removal of the outer hard brown shell of the de-husked coconut
Desiccator	-	A closed hot chamber in which drying is carried out. It is usually composed of multiple trays on which meats are dried. Normally the temperature is maintained by external heat exchangers.

Dissolved Oxygen (DO)	-	The quantity of oxygen present in water at a particular temperature, generally expressed in mg/L and is widely used as an indicator to qualify the condition of the receiving water
Grading	-	Sorting the dried coconut meat according to their sizes
Greenhouse Gases (GHG)	-	Gases that absorb heat in the atmosphere, responsible for enhancing the earth's greenhouse effect e.g. CO_2, CH4, NOx etc.
Hatcheting	-	Same as De-shelling; as commonly known in Sri Lanka, using an instrument called a hatchet.
Husk	-	The outermost fibrous layer of the full coconut
Kernel	-	The innermost white meat of a coconut
Nut	-	Usually coconut without the husk but having the hard outer shell
Organoleptic Parameters	-	Characteristics of DC concerning taste, smell, color and touch
Paring	-	Removal of soft brown skin that sticks to the coconut meat
Pasteurizing	-	A process by which microorganisms and germs on the coconut meat are killed. It can be carried out by immersing the meat in boiling water or by exposing to steam
pH	-	log inverse of hydrogen ion concentration, it is a measure of acidity or alkalinity of the wastewater
Pyrolysis	-	Process carried out in the absence of oxygen to breakdown the shell structure and other volatile gases without oxidizing the carbon in the coconut shells
Sap Water	-	Coconut water
Seasoning	-	The green coconuts are kept in storage for 3 – 6 weeks for the outer husk to dry and the inner meat to attain full maturity

Shell Charcoal	-	The dried coconut shell can be heat treated to form charcoals that have a high heating value
Shell	-	The hard brown outer shell that overlies the husk
Sifter	-	Grading machines for sorting out according to sizes
Specific Electrical Energy Consumption	-	The amount of electrical energy used to produce a unit quantity of DC, expressed as kWh/kg.
Specific Energy Consumption	-	The amount of total energy used to produce a unit quantity of DC, expressed as kWh / kg.
Specific Pollution Load	-	The amount of pollutant generated per unit quantity of the product expressed as mg/kg, g/kg, kg/kg or L/kg.
Specific Thermal Energy Consumption	-	The amount of thermal energy used to produce a unit quantity of DC, expressed as MJ/kg.
Splitting	-	Piercing of the coconut meat or kernel to release the coconut water
Stabilizing	-	Treating the coconut meat with sodium metabisulfite in order to avoid discoloring and improves the storage life of the product
Stack Loss	-	The sensible and latent heat carried away through the stack by the flue gas, water vapour and air
Testa	-	The brown colored skin attached to the coconut kernel
Total Solids (TS)	-	The total amount of solids present in the wastewater. It can be divided into suspended and dissolved solids.
Turbulators	-	Thin strips of metal installed in the hot gas lines of a firetube boiler to break the laminar flow of gases in order to improve the heat exchange
Waste Heat Recovery	-	To recover heat from the flue gas from boilers, desiccators or carbonizers and using them to supply the heat energy to other processes