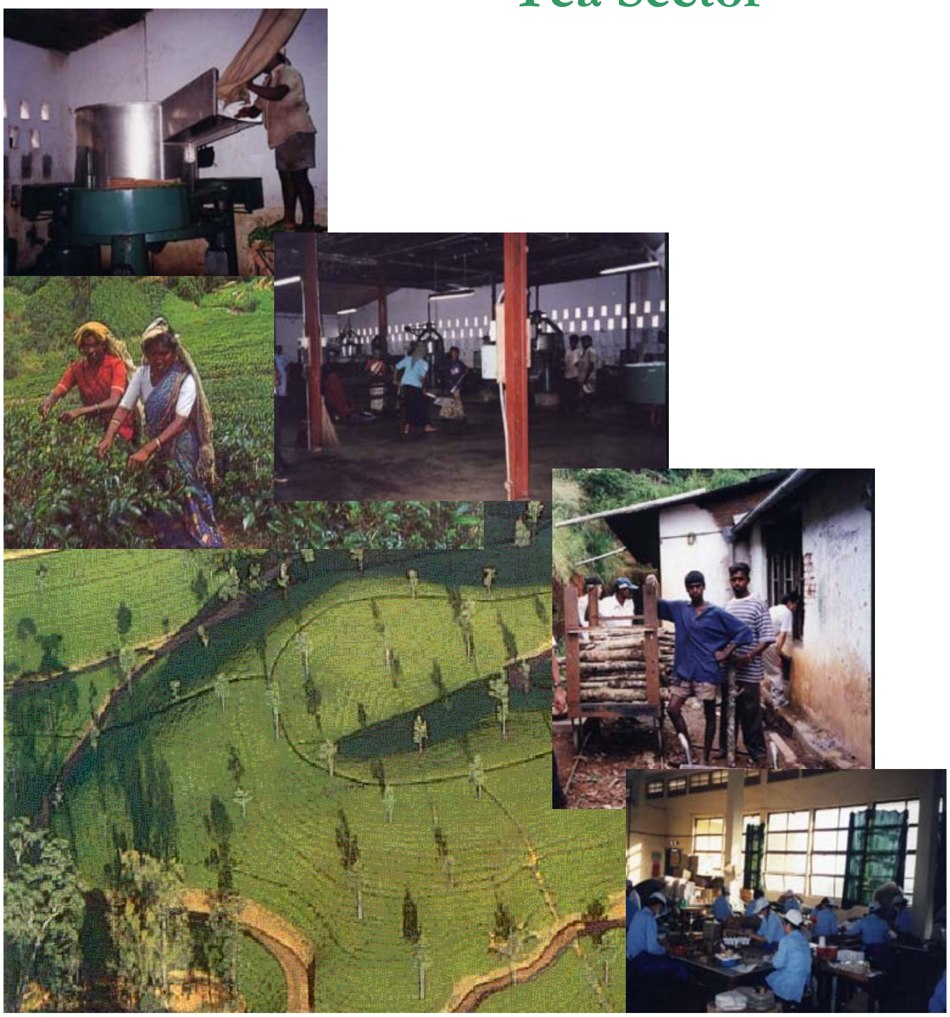
Small and Medium scale Industries in Asia:
Energy and Environment

Tea 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 concerns the **Small and Medium scale Industries in Asia: Energy, Environment and Climate Interrelations**.

The project was aimed at promoting activities to mitigate greenhouse gas (GHG) emissions 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 – *Desiccated Coconut* Sector
- SMI in Asia: Energy and Environment - *Brick* Sector
- SMI in Asia: Energy and Environment - *Foundry* Sector

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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, 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, SMI play a vital role by contributing substantially to its economic and industrial development. Many SMI 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 encourage improving 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 in 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 the 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 global 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 tea sector in the India, Sri Lanka and Vietnam, and details the production processes, specific energy consumption, technology status, including significant energy and environmental issues related to the sector. It highlights the production and operational practices of the tea manufacturing industry, their energy consumption pattern and pollution generation. This report also provides options for energy efficient and environmentally sound technologies (E3ST) 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 discussing the policies to promote E3ST and the Technology Fact Sheet book featuring available E3ST options will also be useful.

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

S.Kumar
C. Visvanathan

Executive Summary

This report on Small and Medium scale Industries (SMI) in Asia: Energy, Environment and Climate Interrelations is basically an attempt to study and analyze the energy utilization practices and the consequent environmental impacts of the tea sector in three study countries namely, India, Sri Lanka, and Vietnam. In light of moving towards sustainable development of the tea sector, some issues regarding inefficient energy consumption and pollution generation need to be properly addressed.

The tea industry is one of the major agro-industrial sectors contributing significantly to the national economy of these developing countries through potential employment creation and export earnings. India is the largest tea producing country in the world producing about 870,000 tons of black tea in 1998. Sri Lanka follows as the second largest black tea producer in the world, and the tea sector is also the country's largest employer providing a total employment for over one million people. The tea sector of Vietnam takes eighth place among the main tea producing countries with a share of about 1.4% and a minimal GDP value addition of 0.27% in 1996.

Tea production is basically a drying process of freshly harvested green tea leaves, reducing its moisture content from about 75–83% down to 3%. The major tea products are black tea and green tea. The difference lies in the choice of variety of tea plant and the conditions of processing. Black tea production involves the following processes: withering, rolling/ CTC (Cut, Tear and Curl), fermenting, drying/firing, grading and packaging. There are two kinds of processing methods used for black tea production – the Orthodox and CTC (Cut, Tear, Curl). In the Orthodox method, the withered leaves are twisted gradually in slow rollers, whereas in the CTC method, the leaves are shredded by mechanical cutters. The Orthodox tea is like twisted flakes, rich in aroma whereas CTC tea appears as powder, which is rich in color. The quality of the final product depends solely on the tea taster who evaluates the overall aroma, color and taste of the made tea. Among the study countries, it was found that the basic production process would be the same but the factory layouts and degree of modernization in production technologies varied.

The energy consumption by the tea sector was found to be less than 3% of the total energy consumption of these study countries. Tea production consumes both thermal and electrical energy at the ratio of 85:15. Thermal energy used in the withering and drying processes, is produced by burning coal, firewood or fuel oil in heaters. Out of these fuels, firewood is extensively used in India and Sri Lanka. The total specific thermal energy consumption in Sri Lanka and India varies between 4.45–6.84 kWh/kg made tea while it is about 10 kWh/kg made tea in Vietnam. Electrical energy on the other hand, is used mainly for running machineries. In the case of Orthodox tea production, the withering and rolling processes consume more energy while in CTC tea production, the CTC process consume much electrical energy. The specific electrical energy consumption for the three study countries ranges around 0.4–0.7 kWh/kg made tea.

Energy and environmental audits conducted in selected tea factories showed that energy efficiency is generally low mostly because of the use of outdated equipment and age-old technology. Data revealed that there is a wide variation in the specific energy consumption from 4–18 kWh/kg made tea, indicating a large potential that exists for energy conservation. Energy cost happens to be a small fraction of the total production cost. Therefore, tea industries in this region have not paid much attention to the energy problems in their units. Nevertheless, energy savings achieved through improvement of operation and maintenance practices could lead to mitigation of greenhouse gas (GHG) emissions.

This study also focused on the environmental impacts from the tea sector, which primarily is in the form of GHG emissions from fuel combustion. As a GHG, carbon dioxide (CO_2) is the single largest contributor to climate change. The total fuel consumption by the tea sectors in India, Sri Lanka and Vietnam contribute to CO_2 emission annually by 1.352 million tons, 0.708 million tons and 0.085 million tons respectively. Sulfur dioxide is another pollutant emitted from fuel combustion which is of concern because of its contribution to acid rain. Among the study countries, the total SO_2 emission per year was highest in Sri Lanka at 26.24 thousand mainly due to the extensive use of rubber wood as fuel for thermal energy generation. The other GHG emissions were found to be marginal. The extensive damage of deforestation created by the use of firewood is also to be reckoned with. Thus a need has arisen to promote and adopt Energy Efficient and Environmentally Sound Technologies (E3ST) in the tea sector.

Some of the E3ST options that can be adopted in the tea sector include using more energy efficient dryers, implementing waste heat recovery, observing better housekeeping measures, and using renewable sources of energy (hydro, biomass or solar energy). However, the adoption of E3ST is not so simple because the tea sector is basically traditional in nature. Barriers such as lack of awareness and access to technical information, lack of coordination and standards, lack of finances and infrastructure, and lack of R&D, have prevented the tea industries from adopting E3ST effectively. Therefore, necessary policy and regulatory measures have to be identified to overcome these barriers.

In the long run, tea industries have to adopt E3ST in their units so that they become competitive in the business of manufacturing and trading of tea in the international market. Only then will the tea sector be able to face the challenge of sustainable development in the future.

Contents

Units and Abbreviation:

CFM	Cubic Feet per Minute
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CTC	Cut, Tear, Curl
ECP	Endless Chain Pressure
E3ST	Energy Efficient and Environmentally Sound Technologies
FBD	Fluidized Bed Dryer
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GWh	GigaWatt Hour
kg	kilograms
kWh	kilowatt hour
MJ	Mega Joule
MWh	MegaWatt hour
NO_x	Nitrogen Oxides
RC	Re-conditioner
SMI	Small and Medium scale Industries
TOE	Tons of Oil Equivalent
TJ	Terra Joules
SO_2	Sulfur Dioxide

CHAPTER 1: OVERVIEW OF THE TEA SECTOR

This chapter briefly describes the beginnings of the tea industry, and trends in tea supply and demand from a global perspective. The overview focuses on the tea sector of the three study countries namely, India, Sri Lanka and Vietnam, describing its characteristics and contribution to the economy. It also outlines the energy and environmental issues of the tea industry.

Tea Industry

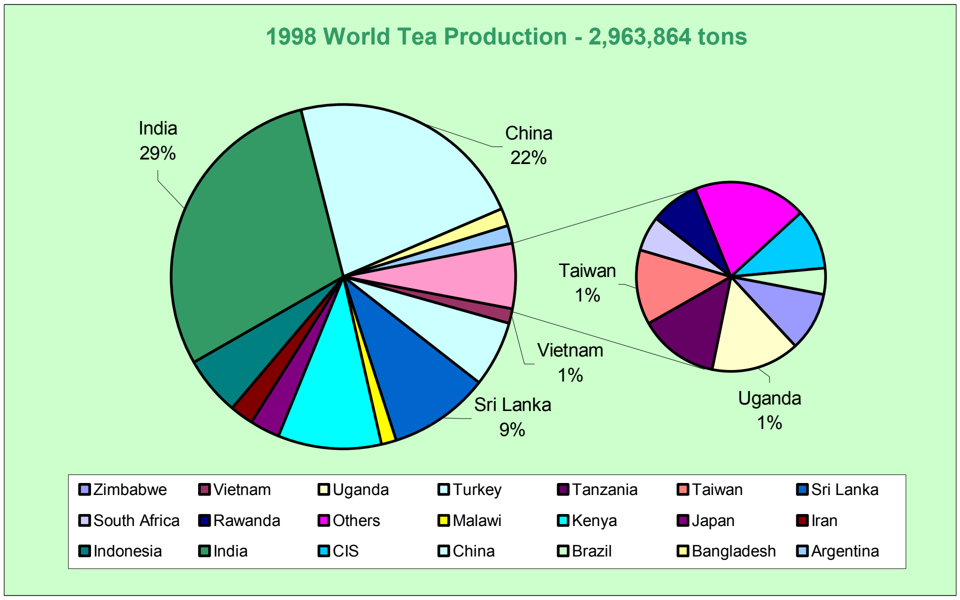
Tea is nearly 5,000 years old and was discovered, as legend has it, in 2737 B.C. by a Chinese emperor when some tea leaves accidentally blew into a pot of boiling water. In the 1600s, tea became popular throughout Europe and the American colonies. Now, tea is consumed as a beverage throughout the world and grown widely in countries of Asia, Africa and the Near East. Earliest mention of tea is from China in 350 B.C. It found its way to Europe in 1559, to England in 1615, and to Indonesia in 1684. Commercial cultivation began in India in 1823, and in 1867 in Sri Lanka (Wickramasinghe, 1978). Tea grows ideally at about 2,400 m (8,000 feet) height above sea level. It prefers a warm, humid climate, with plenty of well-distributed rainfall and long sunlit days. Therefore, it flourishes nearer the equator.

Freshly harvested tea leaves contain about 75–83% of moisture (wet basis) while the processed tea has a moisture content of less than 3%. Tea production is simply a drying process. However some chemical changes take place by natural fermentation, which give different varieties of tea. Though tea is produced throughout the world in similar processing conditions, they differ from each other, depending on the plant variety, climate, soil conditions, method of cultivation and nature of shade. Mainly, the production process and the plant variety dictate the flavor, aroma, color and stimulant characteristics of each kind of tea. Though there are many varieties of tea produced in the world (Appendix A), black tea is considered as the major product worldwide.

Global Supply and Demand

Tea is mainly produced in most tropical countries in Asia, South America and Southern Africa. In Asia, India, Sri Lanka, China, Vietnam, Japan and Indonesia are some of the leading countries that produce tea. India and Sri Lanka produce most of the black tea while the other countries produce green tea and their varieties. In Asian countries, tea is one of a major commodities exported to the United States of America (USA) and Europe.

In South America, Argentina and Brazil grow tea but it is not a major industry and most of the tea processed is exported to the USA. The extreme topographic conditions make mechanized tea plucking necessary, making it not suitable for higher end flavored tea.



In 1998, world tea production data showed that among the study countries, India was the top producer at 29%, followed by Sri Lanka at 9% and Vietnam at 1% (Source: Tea Director, 2001).

In Southern Africa, tea is grown mainly in Kenya, Tanzania, Malawi and South Africa. Kenya is the most important tea producer in Africa, (3rd ranked in tea industry) and it has captured a ready market in Northern Africa and Middle East for its products.

Records show that the world's tea industry is more or less concentrated in India, China, Kenya and Sri Lanka. However, India and Sri Lanka play a dominant role in black tea production in South Asia. In 1998, world tea production was about three million tons and in the last decade it grew at an average yearly rate of about 1.8%. Some estimates suggest that world tea production declined from a record 1998 output of nearly three million tons to 2.7 million tons in 1999 (Teaweb, 2001).

The tea industry is one of the major agro-industrial sectors contributing significantly to the national economy of many developing countries such as India, Sri Lanka and Vietnam through potential employment creation and export earnings ranging from 50–780 million US$. The industry in Vietnam is growing rapidly at about 10% estimated annual growth, and in India, the production is growing to cater to the high local demand and increasing export market. In Sri Lanka, it is expected that the production will level off at 300 million kilogram level, mainly due to land restriction. Both, India and Sri Lanka are trying to increase the yield of cultivation to a much higher level to increase tea production even more.

Study County	Share in GDP (%)	xport Earning (Million US$)	Work force (Millions)	Number of Tea Factories
India	1	480	1.3	1300
Sri Lanka	4.8	780	1.2	800
Vietnam	0.2	50	1	75

The tea sector of the three study countries contribute significantly to the national economy in terms of GDP, export earnings and employment generation.

The tea industry's contribution to GDP is substantial and is one of the study countries' major means of earning foreign exchange. The world demand on tea is on the increase, and most of the European and western countries prefer Asian black teas of strong character. During a ten year period, the world prices on tea rose by about 13%. (Thilakaratne, 1999). Other than bulk tea, value additions of tea by way of packaging, blending to get unique characteristics, impregnation, and flavoring of tea is very common in tea exporting countries, which has considerably increased the earning potential for tea growing countries. Appendix B reveals more data on economic trends in terms of tea exports (global share, amount and earnings) and GDP value addition by the tea sector in India, Sri Lanka and Vietnam.

Tea Industry in India

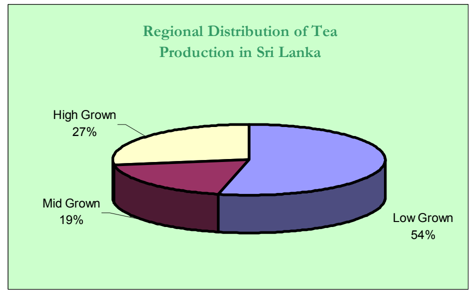
India is the largest tea producing country in the world producing about 870,000 tons of black tea in 1998. About 432,000 hectares of land is under tea cultivation. Northeast India produces a wider variety of tea than any other growing area in the world. India has over 300 major tea companies and has over 12,000 large tea estates. Overall, India accounts for 1,300 tea factories and 37,000 of large and small estates. They employ about 30,000 workers directly and about 1,000,000 people indirectly.

Tea is cultivated mainly in the northern region of India, Bengal's Darjeeling, and Dooars, Assam and Cachar. In the south, tea is grown in Tamil Nadu and Kerala's hilly western Ghat region. Of the total 1998 production, 77% came from northern India. Assam valley produced the highest share of 46% and Dooars produced 17%. Of the south, Nilgris of Tamilnadu produced 14%. Over 80% of tea manufactured in India is of CTC tea and average Orthodox tea production is 13% (Tea Board of India, 2000).

Type of Manufacture	No (Factories		
	North	South	Total
CTC	291	94	385
Orthodox	254	179	433
Dual	414	35	449
Total	**959**	**308**	**1267**

India's Tea Production by Processing Method and Location (Source: Ramakrishna, et.al., 1993)

In 1998, India exported 200 million kg of tea with an export value of US$ 480 million. In 1997, the income from tea exports represented 1.4% of a consolidated export income of US$ 33.9 billion (10% of GDP). Even though gross domestic value addition is about 1%, considering the employment both direct and indirect, land usage and foreign exchange earning potential, the tea industry is one of the major economic sectors in India.



The tea industry in Sri Lanka is classified according to the elevation of the tea plantation.

Tea Industry in Sri Lanka

Tea plant in Sri Lanka was first grown in 1839 at the Botanical Garden in Peradeniya, and the first tea estate was established in 1840. Tea is grown at high altitude as well as mid and low altitude areas. The tea area is found mostly around 7º N latitude in the mountainous country on the southwestern part of the island. According to the elevation, a plantation area is classified as low country (0–600 meters), mid country (600–1200 meters) and up country (above 1200 meters). Tea planted above an altitude of 1,200 meters is known as "high grown" which constitutes about 27% of the total planted area, while a little more than 50% is found in the low country.

In the central part of the island's hill area, about 187,000 hectares of land is under tea cultivation and it has the capacity for 192,000 hectare. Total tea coverage is 188,867 hectares, of which 56% is under public management, and the remaining 44% is under the management of small holders. In the small holders' sector, 82,916 hectares are cultivated by 206,652 tea growers as against 106,047 hectares in the public sector.

In Sri Lanka, the agricultural sector performed reasonably well in 1999 due to favorable weather. Tea production increased, albeit marginally, for the sixth straight year in 1999 to a new record high. Total production was 284 million kilograms. The tea sector in Sri Lanka has always been a vital component of her economy. Sri Lanka is the second largest black tea producer in the world. It is also the country's largest employer providing direct estate employment of 215,338 (Thilakaratne, 1999, quoted Central Bank Reports), and indirect employment of over one million people. It also contributes a significant amount to government revenue and to the gross domestic product. In 1999, Sri Lanka's economy slowed, the real GDP growth rate was 4.3%, compared to 4.7% in 1998 and 6.4% in 1997.

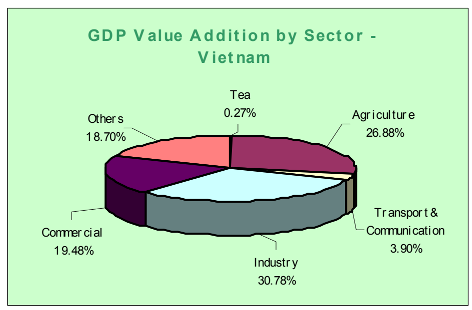
Although the agricultural sector remained strong, the industrial and services sectors weakened, and export earnings slowed substantially. The economy was particularly hard hit by depressed world prices for tea, rubber and garments. However, recent weakness in world prices for tea could depress export earnings (US embassy, Colombo, 2001). Prices at the Colombo tea auctions, which dropped sharply following the August 1998 Russian financial crisis, improved in the second half of 1999 due to increased buying by Russia and a drop in world supply. However, the annual average price in 1999 remained 14% below 1998.

The small holders' share in the national output was 58%. Despite productivity improvements, the yield levels in the recently privatized estate sector are about half the yield level in the small holders' sector. Sri Lanka exported 268 million kilograms of tea in 1999. Despite incentives provided to promote value added tea, such exports declined in 1999. In 1997, the total export earnings from tea was US$ 719 million (4.7% of GDP of 890 billion SLR) and in 1998 it was US$ 780 million (4.9 % GDP of 1,015 billion SLR) an increase of 40% over 1996 on GDP.

There were about 800 tea factories in 1994 and about 630 in 1996 were in operation (Sri Lanka Tea Board, 1995). About 350 factories are located in the low country region while 150 are in the up country region. In 1998, opening up of 14 (refurbished) factories in low country showed an upward trend in Sri Lanka's tea industry. The tea produced in Sri Lanka is mainly of Orthodox type; around 600 factories produce Orthodox while the rest produce CTC tea. Only 7% of the production come from the CTC process, and also the green tea production is negligible.

Tea Industry in Vietnam

Vietnam is an agricultural country whose agrarian production accounts for 90% of GNP. The tea industry started in 1918 and in the recent years a stable development is seen in the sector. The Vietnamese tea sector however has a minimal GDP value addition of 0.27% in 1996. About 71,000 hectare of land is under tea cultivation. The tea growing areas are: the high land area, over 600 meter above sea level, the midland area, 300–500 meter above sea level and the strip of land adjoining central and north Vietnam. The main tea grown areas are in the northern provinces and in Lamdong province in the south.



In 1996, the GDP Value addition of the tea sector in Vietnam was 0.27% (Source: Statistical Yearbook for Asia and Pacific 1998, Annual Report, 1999)

Tea was industrialized in 1918, when Union of Vietnam Tea Farming- Industry Enterprises (UTE) came into being. There has been a great importance to the research and application of new technologies in order to bring fundamental changes to the farming and manufacturing systems of tea for quality products. Vietnam Tea Research Institute is mainly responsible for these activities.

In the north, there are 75 state-owned tea processing bases, 30 of them belong to the Vietnam National Tea Corporation and the other 45 factories belong to the provinces. Their total production capacity is about 1,191 metric ton of green leaves per day, which is about 60% of the total green leaves harvested in the country. Only 15 factories of the state-owned factories are in larger-scale with installed capacity of over 20 metric tons per day. Besides, there are more than 1,200 non-state small-scale enterprises and tens of thousands of households involved in processing tea. Overall, the tea sector annually creates jobs for one million people.

The annual average growth rate of tea cultivated areas and production of tea are 4.03% and 4.2% respectively. In 1997, the whole industry produced about 47,000 tons of tea (Green tea 31,000 ton) and it was 50,000 tons in 1998. Vietnam takes eighth place among the main tea producing countries with a share of about 1.4%. The exports of tea also has an increasing trend and in 1998 it exported 33,500 tons with a value of US$ 50 million, twice the exports in 1995.

Overview of Energy and Environmental Issues

The tea industry is one of the energy intensive food-processing sectors consuming both electrical and thermal energy. About 12–15% of the total energy requirement is electrical energy and the rest is thermal energy. The electrical energy is used to run the machineries and the thermal energy is used to reduce the moisture content of the leaves from 70–80% down to 3%. Most of the thermal energy requirement is derived from firewood, lignite, coal and fuel oil and ultimately they contribute to direct emission of carbon dioxide (CO_2). The consumption of electricity also results in emission of CO_2. For example on average, about 7.1 kWh of energy is required to produce one kilogram of black tea in Sri Lanka (Sri Lanka Sector Report, quoting Haskoning, 1989) which more or less is equivalent to the energy requirement of steel production, 6.3 kWh/kg product (Mohanty, 1997). However, the energy requirement could vary depending on the country, region, process and other factors.

The operational practices and level of energy consumption of the tea sector using the traditional production technologies, have not changed much over the last 20 years. The reluctance to change its traditional methodology could be due to various reasons including the nature of the plantation sector, i.e. physically intensive, cost factors, economies of scale, psychological factors, etc. The remote, hilly location of the industry is also one of the reasons for their lack of technology improvement. Inadequate supply of power likewise hinders the industry from using high technology that requires a reliable source of power. Most of the tea-producing countries are located in the developing part of the world, where technology upgrading is less prioritized. The research and development (R&D) efforts for more efficient use of energy is also lacking. However, R&D plays a major role in the plantation sector to improve productivity. One of the adverse results of such non-adaptation of technologies is the impact on the environment as a whole, created by environmental pollution and high energy consumption.

The major pollutant from the tea industry is their emissions from the combustion of fuels used in heaters cum dryers. Fly-off fibers produced as waste are being used as the fertilizer for the tea plantation. In some regions of India, use of firewood has caused extensive deforestation while in Sri Lanka, the use of high sulfur rubber wood in the tea industry has caused high acid pollution. This has resulted in a host of energy and environmental issues, concerning overall energy efficiency of the industry, GHG emissions and environmental impacts, occupational health hazards and de-forestation due to the cultivation and usage of firewood as an energy source.

CHAPTER 2: TEA PRODUCTION PROCESS

Freshly harvested green tea leaves contain about 75–83% moisture (wet basis) and the rest is composed of catechol, flavonoals, tannins, catechin, enzymes, etc. During the production process, some additional compounds are produced and the moisture content is reduced to 3%, which facilitates the storage of the tea product. The finished tea has a complex flavor and about 140 compounds out of 400 compounds contributing to the characteristic of the tea flavors have been identified.

The major tea products are black tea and green tea. The difference lies in the choice of variety of tea plant and the conditions of processing. Green tea is from the small leaf variety of *Camellia sinensis var. sinensis* while black tea is produced from the larger leaf variety of *Camellia sinensis var. assamica.* This chapter describes in detail the production process of black tea by both the Orthodox and CTC method.

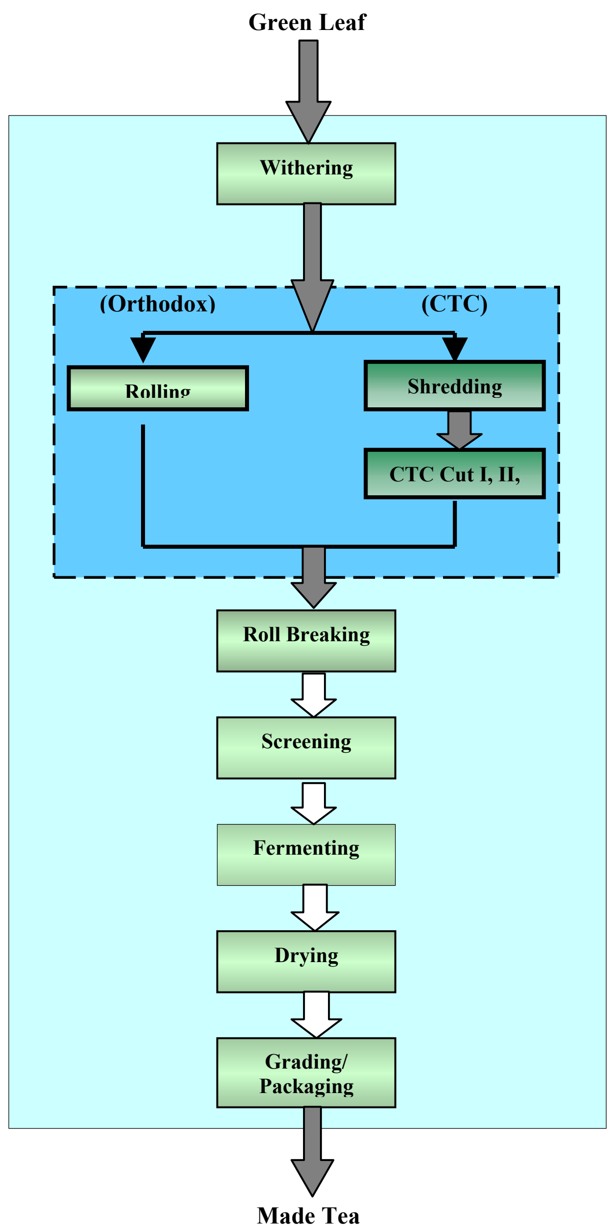
Black Tea Production Process

Tea leaves are harvested from a tea plant every 5–12 days depending on the tea grade. Only the most tender young leaves - the top two leaves and a bud are plucked manually and transported to the factory. Tea pickers use large lightweight bamboo baskets to transport the freshly plucked tea leaves. Great emphasis and close attention is paid to removing any coarse leaves that may have been picked out unintentionally to prevent them from getting into the final product. Damages (breakages) to the leaves may affect the quality of tea. The tea leaves are processed on the same day.

Black tea production involves the following processes: withering, rolling/ CTC (Cut, Tear and Curl), fermenting, drying/firing and grading. Two kinds of processing methods are used for black tea – the Orthodox and CTC (Cut, Tear, Curl) wherein the basic difference lies only in the cutting operation.

Specific Paramete		Orthodox	CTC
Finished product	Appearance	Flakes / Leafy	Graduals / powder
	Quality characteristic	Rich in aroma, less color	Rich in color, less aroma
Withering	Moisture content of withered leaf	55%	70 %
	Period of withering	20 hours	12 hours
Rolling/CTC	Additives	None	R.C powder
	Change in moisture content during process	Nil	Reduced to 55% from 70%
	Mechanical operation	High	Very high
Energy requirement		7 kWh/kg of MT	5 kWh/kg of MT
General	Application	Manpower intensive	For large scale production

Comparison of the Orthodox and CTC (Cut, Tear, Curl) Methods used for Black Tea Production



Black Tea Production process showing the variations between the Orthodox and CTC methods

In the Orthodox method, the withered leaves are twisted gradually in slow rollers, whereas in the CTC method, the leaves are shredded by mechanical cutters. The Orthodox tea is like twisted flakes, rich in aroma whereas CTC tea appears as powder, which is rich in color. Though many countries prefer orthodox tea lately, the trend is towards CTC processing.

Withering troughs with a wet-dry bulb thermometer to monitor tea leaf moisture content

Withering

Withering is principally a drying process to remove the surface moisture and partially the internal moisture of the freshly harvested green leaves. In addition, withering is done to get the correct physical condition, which will allow the leaves to be rolled without breaking. Also, the withering promotes dissipation of heat generated during continuous respiration (chemical changes). There are two major types of withering, open or natural withering, and artificial or trough withering. In the open method, withering is controlled by the thickness of spread, and the length of time of the withering phase.

Trough withering is a widely used withering process. Usually, the green leaves from the tea estates are brought to the factory in the afternoons and are spread thinly on banks of troughs (tats). The troughs are made of metal wire meshes with wooden support on which tea leaves are spread and the air is blown from the bottom so that the air passes through the green leaves. The air is supplied either directly from an air heater or the exhaust from the dryer, which is usually located at ground level whereas troughs are located in an upper floor. Withering is done at 20–25°C depending on the climatic conditions. For best withering, a wet and dry bulb temperature difference of 4°C is maintained. During withering, the moisture content of the green leaves is reduced to 55% (wb) (hard withering) for Orthodox tea production and 70% (wb) (light withering) for CTC tea production. Depending on the weather and the condition of the leaf, withering takes about 6 hours for light withering and about 12-18 hours for hard withering.

In withering, more air is blown at the initial stage and on an average the air flowrate is about 5,000 cubic feet per minute (CFM). After four to five hours, the flow rate is reduced to two-thirds of its initial value. To reduce the air flowrate, throttle valves are provided at the fan inlets. Once proper withering is achieved, the air flow is continued to prevent the spoiling of withered leaves.

Rolling

Rolling is a process in Orthodox tea production. The chemical compounds of the tea leaves are released to initiate oxidation in the fermentation process. Rolling twists the leaf, and at the same time, breaks the leaf structure (cells) to release the juices (catechins and enzymes) for oxidation. A compressed drum/roller twists the withered leaves on a continuous circular motion. A rolling machine size varies from 150–325 kg of leaf per hour. The roller has minimum cutting action and more compressed rolling action. The compression of the roller depends on the type of withering. Low pressure rollers are suitable for under-withered leaves and high pressure rollers for over-withered leaves. Normally, light rolling at the initial stage and heavier rolling at the later stage of the rolling operation are done. The duration of rolling varies from 15 to 45 minutes. This stage is a mechanically intensive operation that consumes considerable electrical energy and rolling machines have a rated capacity of about 11-15 kW.

The Orthodox rolling machine twists the tea leaves to release its chemical compounds.

The rolled leaf mass from the roller is more or less compressed into lumps. In Orthodox tea production, the roll breaker performs three essential functions. Firstly, it cools the leaf by breaking the lumps, then it aerates the mass, and thirdly by sieving out particles of small sizes, it separates the leaves into portions, called "dhool", that will facilitate a reasonably uniform rate of fermentation. Oversized leaf particles are fed back to the rolling process to get the second "dhool". The roll breaker consumes a marginal quantity of electrical energy.

CTC

In CTC tea production, a rotorvane is used to shred (pre-condition) the withered leaves. During shredding, the juices come out from the tea leaves. To avoid the loss of juices, a reconditioner (RC powder) is added, which is made up of the pulverized fly-off (leafy grade) from the dryer or fiber removed from the grading operation. CTC machines cut, tear, and curl the preconditioned tea leaves, and hence light withering is necessary. The RC powder and shredded leaves are well mixed and crushed by double action rollers. The CTC machines can burst leaf cells so severely that in some cases the withering stage is not so much important. A large amount of heat is generated due to the friction, and a large quantity of water is evaporated during this process. The moisture content is reduced to 55% from 70%. Depending on the tea grade, 3–5 banks of CTC machines are arranged in a row and the flow of material from one CTC machine to another is by belt conveyor. The CTC process is a mechanically intensive operation consuming appreciable electrical energy. A CTC bank processes about 600–1,300 kg of leaves per hour with a rated capacity of 11–18 kW.

Fermentation

The rolling/CTC process is followed by fermentation, which is a biochemical oxidation process where tea flavors are produced. The fermentation is an important process in black tea production. Oxidation takes place in a room/area or drum, where high humidity air at a temperature of 23-29°C is maintained. In the Orthodox process, natural fermentation is practiced whereas in the CTC process, drum fermentation or continuous fermentation is used.

In natural fermentation, the 'dhool' from the roll breaker are spread in thin layers on tables or perforated aluminum racked trays. The thickness of spread controls the rate of fermentation and the fermentation process takes about 3–4 hours. Mist chambers or blower/ atomizer type humidifiers are used to moisten the fermentation environment. In the case of CTC tea production, the tea leaves are fed into a rotating fermenting drum, in which oxidation air is supplied by blowers. Drum fermentation takes about 45 minutes.

As an indicator, the fermented tea leaves become reddish brown. Once the required fermentation is achieved, the fermented leaves should be dried (fired) to arrest further fermentation. Fermentation process gives the different characteristics of the tea brew, normally, shorter/light fermentation gives more flavored and aroma rich tea while longer/deeper fermentation gives color and liquor. Some manufacturers fire the 'dhool' immediately after rolling without fermentation. However, some oxidation takes place during the rolling operation.

Natural fermenting of 'dhool' in Orthodox tea production takes about 3-4 hours.

The natural (Orthodox) fermentation process does not require any energy unless humidifiers are used. In drum fermentation or continuous fermentation, electrical energy is consumed to rotate the drum and to run the blowers. During the fermentation process, CO_2 is produced.

Drying or Firing

The fermented tea particles are dried or fired to arrest the fermentation and also to reduce the moisture to about 3%. Clean and odorless hot air is passed through the fermented tea particles in dryers. The temperature of the hot air varies between

90–160°C depending on the type of dryer. Drying or firing is a thermal energy intensive operation that also consumes electrical energy to drive blowers and dryers.

Coal, firewood and fuel oil are used as fuel to produce hot air and some factories in India use biomass briquettes. Since flue gas of firewood or coal or furnace oil may contain fly ash and unburned carbon particles, which may cause undesirable smell and contaminate the tea products, clean hot air is produced by an air-to-air heat exchanger.

In India, low sulfur diesel is used in heaters. In diesel-fired heaters, flue gas is free from ash and particulate matter, and it is directly used for drying. The flue gas is at about 500°C and is mixed with the ambient air to get the required hot air. The direct-fired heaters are simple in design and require less maintenance (no cleaning of heat exchangers pipes). Many factories are therefore shifting towards the direct-fired heaters. Also, the regulation of temperature is much easier than other heaters. Its energy efficiency is very high at about 80% compared with conventional heaters with 45–55%.

Drying is a critical process that decides the final product quality of black tea. Two types of dryers are used in the tea industry: Endless Chain Pressure (ECP) dryer or Fluidized Bed Drier (FBD). In the ECP dryer, tea particles are spread over continuously moving chain-type trays through which hot air flows. The trays move from top to bottom while the hot air is blown from the bottom. The temperature of hot air is about 90°C. The ECP dyer has an advantage to dry both leafy grades and powdered grades.

A conventional Endless Chain Pressure (ECP) dryer with continuously moving trays.

In the FBD, tea particles are pneumatically fluidized by hot air at 140–160°C. Since the tea particles should have a minimum moisture content to get fluidized, it is more suitable for CTC (powdered grades) tea drying. Uniform drying is ensured in FBD and a better quality tea could be produced. This is also a more energy efficient method compared to ECP dryers with less mechanical controls. Moreover, FBD is available at a higher rated capacity of up to 500 kg made tea/hour while ECP dryers are only available in 160–220 kg made tea/hour capacity.

A recent development is the use of equipment with combined ECP and FBD dryers that is capable of both tray drying and fluidized drying. Fermented tea is first partially dried by moving trays and subsequently dried by fluidization. Steam is used as the medium for hot air production (steam-air heat exchanger) using fuel oil or natural gas in boilers.

From the dryers, lightweight tea particles (fly off) are blown out by hot air. The quantity of the fly-off depends on the type of dryer and the production process and it varies between 2–4% by weight of dried tea. The exhaust air from the drier is about 70°C, which contains fiber (fly-off) and high moisture. In some factories, the exhaust air is used for the withering operation.

Grading and Packaging

Dried tea consists of particles of different sizes, stalks, fibers, leaf portions, etc. The dried tea is sorted into different grades by passing it over mechanically oscillated sieves for grading. The stalks and fibers are removed by electrostatically-charged fiberglass rollers. The fine fibers are powdered by a pulverizer and used as the RC powder in the CTC process.

Color separating machine that electronically sorts the tea leaves into different grades

In grading, tea particles are sifted into different sizes then classified according to appearance and type. The color separator recently being used in the grading process could remove stalk particles by tracing the color electronically. Nomenclature for tea grading is found in Appendix C.

After grading, tea is packed in airtight containers in order to prevent absorption of moisture. Packaging could be either in tea chests (wood based) or specialized packaging as per requirement. In India, only bulk packing (in wooden chest or bags) is done at the factory level and trading companies pack tea for local or export markets, whereas in Sri Lanka and Vietnam, the packing (for example, tea bags) is done at the factory level.

The grading machinery consumes electrical energy. In addition, in electro-static rollers, incandescent bulbs are used to induce the electrostatic effect and these incandescent bulbs consume considerable amounts of electricity. The fibers and stakes are the major wastes generated in the grading process.

Quality Criteria of Tea

Each lot of tea must be sampled before it is allowed to leave the factory on its way to the customer. The freshly made tea is carefully measured out and brewed up in special cups made especially for sampling. The quality of the tea mainly depends on the fermentation and the drying process. There are no quantitative standards available for final product quality of tea. An official 'tea taster' ensures tea quality by tasting the tea infusion. For this purpose, tea samples are taken from the dryer outlet. The visual appearance of the leaves is checked before the actual tasting

Final Product Quality of Tea Rests on the Tea Taster

The task of the 'Tea Taster" begins when the tea samples are brought to the cupping table. A 'tea taster lidded cup' and bowl are positioned at each numbered setting. The dry leaf is then placed into the cup. Boiling water is added and the cup is covered to retain the heat. The infusion is timed for 6 minutes. Tea liquor is then drained completely from the lidded cup back into the bowl. The lidded cup is turned upside down thus allowing all of the infused or wet leaf to drop onto the lid. The wet leaves are examined carefully again. Finally, the 'tea taster' using a special spoon, spoons the tea with a sound, which to the outsider represents slurping. This slurping sound is caused by the tea being sucked into the mouth at the speed of 125 miles/hour. At this speed the tea explodes to the back of the palate into minute mist particles. These particles tell a story about the tea in volumes to the 'tea taster'.

begins. The brewed leaves are set on top of the brewing cups so that their color and aroma can be observed. The fresh tea is then poured into white cups to make the judgment of color easier. Aroma plays a major role in the sense of taste. The tester inhales the bouquet of freshly brewed tea before he tastes it. Typically, he swirls the tea in his mouth without swallowing and then spits it out to avoid becoming waterlogged (Stashtea, 2001).

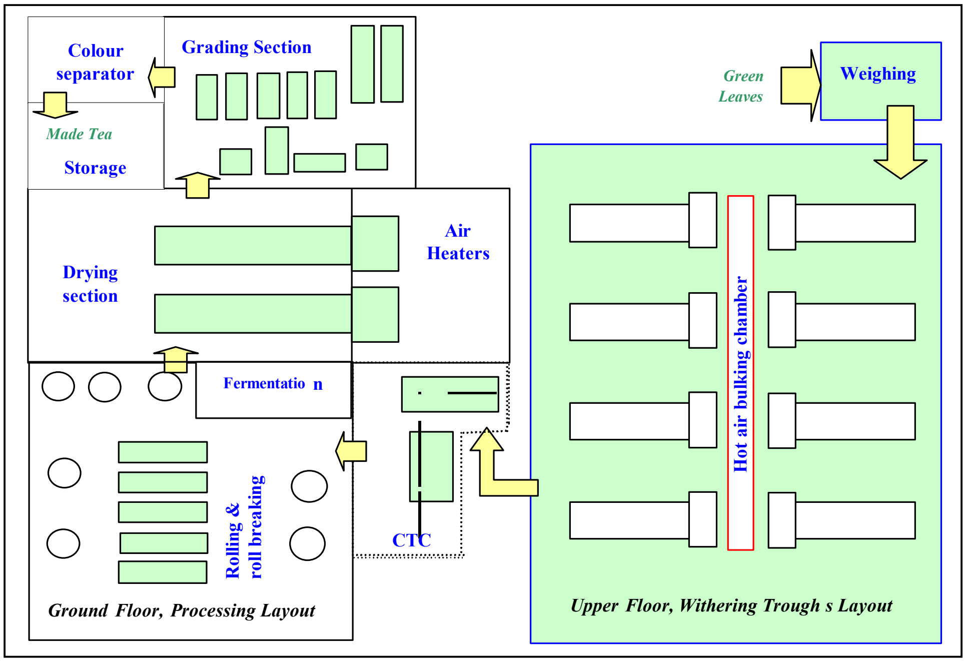
Factory Design and Layout

Tea factories have a functional design and most of the factories in Africa, Indonesia, South India and Sri Lanka are built in a similar layout. The factories are constructed with three or four lofts/ floors and usually the ground floor is used for production operation and the withering troughs are mounted in the upper floors.

Normally the factories have 8–24 withering troughs depending on the production capacity of the tea factory. The location of troughs depends on the source of hot air supply. If hot air is delivered by a central bulking chamber or a separate air heater, the troughs are usually placed facing each other. Otherwise, if the hot air is supplied from the drying area, the troughs are usually long and are placed in the same direction.

The superstructure of withering lofts is carried on a steel framework and is clad with corrugated iron sheets. A center or sideway air bulking chamber runs through the entire height of the building and is flanked on either side by paired wings. In some factories the heat from the drying area is allowed upward so that it can be used for withering. This is repeated at each level. Directly driven axial fans facing air inlets provide for air distribution and is usually controlled by an adjustable louver system. There is direct access to withering lofts from the factory compound. The floor of the loft above the rolling equipment is usually provided with chutes for the delivery of the withered leaves directly to the rollers.

The production area, mostly at the ground floor, is divided into separate sections for individual processing, like rolling and roll-breaking or CTC, fermentation, firing, sorting, packaging and storing. The air heater units for dryers are usually placed in a completely separate chamber adjacent to the drying area. Rollers are placed along



Typical Layout of a Tea Factory - the processing area is at the ground floor and the withering troughs constructed on the upper floors; the production flow starting with the green leaves is shown by the arrow.

the outside walls of the rolling room leaving the central position to the roll-breakers and sometimes for fermentation. However, some layout variations may occur from one factory to other in the arrangement of withering troughs, source of hot air supply, location of rolling or CTC machinery.

In Vietnam tea factories, the withering trough and other machineries are placed on the same floor. Moreover, the withering and drying processes use separate heaters. These factories are not designed to use the exhaust hot air from dryers. Appendix D shows some other variations of a tea factory layout.

Nowadays, the factory layouts are being changed to incorporate new technology and mechanization. In some cases, slight modifications are focused on automation and elaborate process control. However, the basic production process remains the same. In some tea factories, automation systems are installed for materials handling and other operations.

Trends in Production Technology Improvement

The tea industry continues to use the same old production process and the basic designs in technology have not been changed. However, modernization is occurring towards more mechanized materials handling and energy saving aspects of the production system. These improvements include using controlled process conditions, gradual shifting from fuel wood to cheaper or more convenient energy sources, and using better and higher capacity dryers. The Orthodox process is labor intensive and due to the increasing labor problems, the trend is towards automation. Moreover, the CTC process is more suitable for large-scale production that could be mechanized.

In India, technology development is much faster than Sri Lanka and Vietnam. The technologies employed in tea industries in Vietnam are not so advanced. Some of the state-owned large-scale enterprises adopted modern technologies imported from India whereas in small-scale tea industries, the equipment are still inadequate resulting to inferior tea quality thus decreasing their competitiveness in the market. Also many tubular heat exchangers are being replaced by tubeless heat exchangers (direct fired heater) with higher efficiencies. Even though India uses direct-fired heaters, Sri Lanka and Vietnam are yet to adopt the same, which is considered to be more energy efficient provided clean fuels are used with it.

Many tea factories in India use dual type processing using both Orthodox and CTC machineries. In many instances, they have installed both ECP dryers and FBD. Pulverizing machineries are now also used to make powder out of Orthodox oversized particles. On the other hand, Sri Lankan tea industries have made a general shift from a firewood-fired to a fuel oil-fired drying system. The increasing firewood cost and easier operation of oil-fired dryers could be the major reason for such a trend.

Technology Development in the Tea Production Process

1. Fully insulated dual fuel fired air heaters with draft controls, moving grate, 3 pass with economizers.

2. Automated withering with auto weighing, mechanized spreading, charging and discharging, controlled feed.

3. Fully automated material handling systems for Green leaves and Made Tea.

CHAPTER 3: ENERGY ISSUES OF THE TEA SECTOR

Tea processing is one of the energy-intensive food processing industries that consumes thermal energy to dry the leaves and electrical energy to cut the tea leaves. The thermal energy is derived from firewood, coal and fuel oil. Most tea industries use old traditional and inefficient technologies. This chapter discusses the issues on energy encountered by the tea sector in general. It also reviews the energy consumption and its degree of utilization in the tea factories of the three study countries.

Overview of Sectoral Concerns on Energy

Most tea industries use outdated systems in their production process. This is partly due to lack of finances for modernization. Old inefficient technologies and untrained manpower are responsible for the low performance of the tea sector. Of late, tea industries are facing acute financial, marketing, and labor problems. The quality of obtainable raw material varies widely from one plantation to the next. The area available for tea plantation is also becoming restricted and its expansion is already limited.

As for energy-related issues, one of the major problems that tea industries are likely to face in the immediate future is the availability of firewood for fuel. The rate of depletion of firewood has been alarming and heavy deforestation has already taken place. In the absence of equivalent afforestation, it is certainly a matter of concern.

The tea industry also has to face the increasing cost of imported petroleum fuels. In India for example, foreign exchange shortage would prohibit the use of petroleum products for heating purposes. Thus, tea industries would be forced to seriously look into alternative fuel sources. Moreover, some industries are facing frequent powercuts to overcome power shortages. This has resulted in industries using diesel generator sets to meet their power requirements. Because of this, the cost of tea production goes up considerably making it more difficult for the industry to compete in the market.

Thus, a number of factors could account for the poor performance and high energy consumption in tea factories. This has resulted in increased air pollution and consequent environmental degradation.

Energy Sources Consumed by the Tea Sector

India

The thermal energy supply to Indian Tea industry is mainly from coal, fuel oil and firewood. Most northern tea estates use coal and natural gas as the thermal energy source, and in southern India, it is coal (20%), firewood (20%) and furnace oil (20 %) (Bansal, 1993). Based on the total

Study Country	**Coal.** (tons)	**Fuel oil** (million liters)	**Electricity** GWh (share from thermal power plant)	**Firewood** (tons)	**Total Energy Consumption** TWh (share in country's total energy consumption)
India	130,000	642	660 (80%)	780,000	4.4 (0.2%)
Sri Lanka	-	18.3	230 (0.6%)	420,000	2.3 (2.8%)
Vietnam	29,000	-	24.6 (54%)	-	0.164 (0.16%)

Energy Consumption in 1997 of the Tea Industry in India, Sri Lanka and Vietnam

production in 1997 and specific energy consumption, the total energy consumption of the Indian tea sector is about 4.4 TWh, which is less than 0.20% of the country's total energy consumption. Considering the fuel utilization pattern in tea factories, the annual consumption is about 130,000 tons of coal, 642 million liters of fuel oil, 780,000 tons of firewood and 660 GWh of electricity.

Sri Lanka

Based on the annual production and specific energy consumption, it is estimated that about 2.3 TWh of energy is consumed by the Sri Lankan tea sector. It is just about 2.8% of the country's total energy consumption of 83 TWh. The thermal energy for tea industries is mainly supplied from firewood (80–85%) and fuel oil (15%) while electricity is from the grid (15-20%). More than 550 factories uses firewood as the major fuel and about 75 factories use oil. The estimated annual fuel wood requirement is about 70% of the thermal energy requirement, equivalent to 420,000 tons of firewood. It is about 40% of the country's total yearly firewood consumption (Sri Lanka Forestry Master Plan, 1995). This amount of firewood could only be supplied by about 210,000 hectares of forest area (ITDG, 1998). Also, about 18.3 million liters of imported oil (both diesel and furnace oil) is used in the tea sector.

Electrical energy consumption by the tea sector is pegged at about 230 million kWh, with a peak load demand power requirement of 100 MW. More thermal power generating capacity is slowly being added, but the country is still heavily dependent on hydropower, making the electrical power supply vulnerable to changes in weather. Sri Lanka faced a power shortage in the summer of 2000 due to low rainfall (US Embassy, Colombo, 2001).

A high grown factory has a higher energy consumption compared to a low or mid grown factory because the former uses separate heat sources for withering while the latter utilizes heat from the dryer. For low and mid country factories, second grade rubber wood is the main source for thermal energy. With increasing capacities of made tea annually, the trend is for some factories to change over from firewood to fuel oil as the next best alternative energy source.

Vietnam

For an annual production of 16 million kilograms of tea, the energy requirement is around 164.4 GWh, which is about 0.15% of Vietnam's total energy consumption. It is estimated that 80% of the thermal energy requirement is met from coal (29,000 tons), while the rest is supplied from electricity.

Of the overall electrical energy supply in Vietnam, 52% is produced from thermal power plants and 48% is from hydropower (AEN, Aug 1998). Of the required 24.7 GWh of electricity for Vietnam's tea sector, 13 GWh is supplied from coal-based power plants.

Energy Use Pattern in Tea Factories

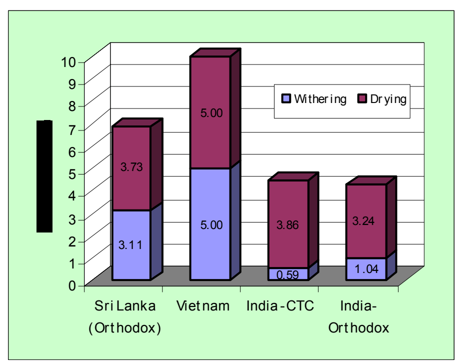
Thermal energy is used in withering and drying operations while electrical energy is used for running motors, fans, and lighting. The ratio of thermal to electrical energy consumption is about 85:15. The theoretical energy requirement to remove the moisture from one kilogram of made tea is about 1.9 kWh, whereas the actual energy consumption varies from 4–7 kWh. This depends on various process parameters and regional climate factors. The specific energy consumption varies from 4–10.4 kWh/kg made tea.

Thermal Energy Consumption

Thermal energy is produced by burning coal, firewood or fuel oil in heaters. In India and Sri Lanka, firewood is widely used, while in Vietnam, coal is used. Coal, fuel oil and diesel are also used in India.

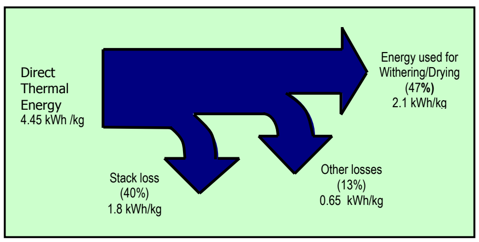
The total specific thermal energy consumption in Sri Lanka and India, varies between 4.45–6.84 kWh/kg made tea whereas it is about 10 kWh/kg made tea in Vietnam. The high thermal energy con-sumption in Vietnam is due to the use of separate heaters for the withering and drying processes.

Withering is an energy efficient process but it depends on the production schedule. For factories where large quantities of green leaves are handled, indirect thermal energy supply alone for withering will not be sufficient. In Vietnam, all factories have separate heaters for the withering process. Also in Sri Lanka, many up-country producers and some low grown factories use separate heat sources for withering and drying. The advantage is that withering and drying need not necessarily be done at the same



Comparison of specific thermal energy consumption for the withering and drying processes in all study countries

time. Since withering requires less thermal energy, a relatively small heat source would be sufficient. The specific thermal energy consumption for the withering operation in India is about 1.04 kWh/kg made tea for Orthodox tea while it is about 0.59 kWh/kg made tea for CTC tea. Based on Indian tea industries, the typical heat flow would show that of the direct thermal energy supply, 47% is used for the withering/drying operations and the rest constitutes the stack and other losses.



Typical energy flow for the withering and drying processes in tea production

The drying process has a specific thermal energy consumption of about 3.24–5.00 kWh/kg of made tea. It is about 75–85% of the thermal energy requirement and about 50–75% of total energy consumed, depending of the type of tea produced. Energy consumption for the drying process depends on the efficiency of the heater cum dryer, which is influenced by the type of fuel and its moisture content, heater insulation, and combustion air supply. The dryer efficiency also varies with the type of dryers.

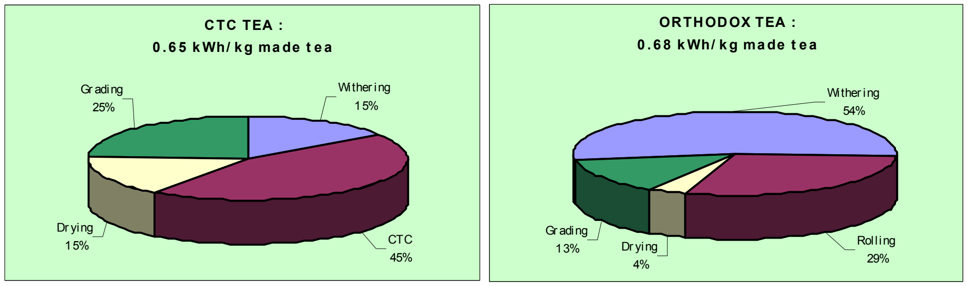
In the drying process, hot air generated from heaters is used to reduce the moisture content of fermented tea from about 55% to 3%. Most of the heaters cum dryers operating in India and Sri Lanka have an overall efficiency of about 20–40%. Most of the heat is lost in the heaters and in the flue gas.

Some factories produce both Orthodox and CTC tea using dual type processing. The dryer exhaust is used for the withering operation. The thermal efficiency of the dual process is higher than the CTC process probably due to the use of FBD and also its comparably higher capacity to process greater amounts of made tea.

In India, diesel-fired heaters are also used in the drying process where the flue gas is used directly for drying. Directly-fired drying gives the highest thermal efficiencies so far with a better output as well. The energy flow for diesel-fired direct heaters shows that of the total input diesel, the total losses is only 20%. Although there are reservations with regard to quality of the tea and contamination of the tea product, this practice gives the best cost benefit to the industry.

Electrical Energy Consumption

Electricity is used mainly for running the machineries and a small fraction for it is used for lighting. In the case of Orthodox tea production, the withering and rolling processes consume more energy while in CTC tea production, the CTC process consume much electrical energy.



Share of electrical energy for various processes varies between CTC tea and Orthodox tea production.

Data shows that the distribution of electrical energy varies between the Orthodox and CTC processing in India. In the CTC process, the CTC machine consumes the most electrical energy followed by the grading operation. While in the Orthodox process, withering takes most of the electrical energy followed by rolling. Among the study countries, total electrical energy consumption is highest in India and lowest in Vietnam. The reason for high electrical energy consumption in India is that most factories use dual processing or CTC only. Both these arrangements require energy consuming CTC machinery and pre-rolling /post-rolling machinery like rotorvanes, pulverizers, drum fermenters, etc.

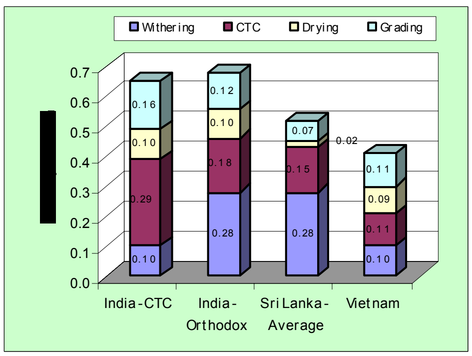
The energy requirement for the withering process is mainly electrical energy to run the trough fans. Withering consumes about 15–55% of the total electrical energy consumption. Sri Lankan tea factories consume comparably higher energy for withering, the highest for all unit operations because its production is mostly Orthodox, which requires hard withering in comparison to light withering in CTC tea production. Also, 100% withering is done by air blowing, as against some factories in India, where air blowing is only done intermittently to remove moisture.

Withering airflow can be reduced after initial withering is done. When the airflow rate is reduced however, the motors are not designed to reduce the energy consumption proportionally to the airflow rate. In effect, only 10% of energy reduction is achieved, even if the flow is reduced by 50%. In most cases, factors such as oversized equipment, minimal or no controls over speed of the motors or airflow, and the absence of monitoring process conditions have led to higher energy consumption.

The rolling/CTC process is also an electrically intensive operation. However, they are working with standard motors and influenced by the rolling pressure or cutting pressure. In the Orthodox process, rolling is equally energy consuming as in withering, while CTC is the highest energy consumer in CTC tea production. In the drying process, electrical energy is used for blowers and fans. In packaging, Sri

Lanka and Vietnam consume more electrical energy compared to India, where bulk packaging is practiced at the factory level and generally done manually.

The specific electrical energy consumption for the three study countries ranges around 0.4–0.7 kWh/kg made tea. A comparison of the specific electrical energy consumption for the different processes in the study



Comparison of specific electrical energy consumption for the different processes in tea manufacturing in all study countries

countries shows that for Indian tea industries, the CTC process takes up most of the electrical energy at 0.29 kWh/kg made tea in CTC tea production, while withering consumes the most at 0.28 kWh/kg made tea in the Orthodox tea production. The same was found true for Sri Lankan tea factories where withering uses up 0.28 kWh/kg made tea. In Vietnam on the other hand, withering and drying consume about the same levels of electricity at 0.11 kWh/kg made tea.

Trends in Technology Improvement

Comparing the specific energy consumption with literature value, Indian tea industries consume 25% less energy, which could be attributed to their technology modernization efforts. Indian tea producers are geared towards improving the technology aspects of the industry therefore tea factories are becoming more efficient and advanced. As the largest tea machinery exporter, tea factories in India do a lot of research and development in technology improvement thus leading them to greater benefits from increased energy efficiency. Recent developments in the area of drying, waste heat recovery and use of renewable sources could make energy consumption even lesser.

For Sri Lanka, the actual and literature values are more or less equal. Over the past few years, there were only few modernization projects in the tea industry. Technical support to industry was virtually non-existent. Recently though, support for the industry has been revived with the upward trend of the tea market. With obvious limitation in expansion of production (estimated maximum 300 million kilograms of made tea per annum), any infusion of new technology or investment in efficient technologies will become vital for sustainability.

In the case of Vietnam, the specific energy consumption is 50% higher than literature value, mainly due to lack of modern processing technologies. With possible expansion of cultivation by about 50% i.e 105,000 hectares in 2005, the importance of adopting better technologies will be more pressing to make them more competitive in the international tea market. The use of coal as the only source of energy has created its own drawbacks. With natural gas available for industry use, Vietnam could use such alternative cleaner fuels for better efficiencies.

In general, if the observed minimum thermal energy consumption of 4.38 kWh/kg made tea is achieved (for Orthodox) in the high energy consuming countries like Sri Lanka and Vietnam, the resultant savings will be extremely attractive. Based on 1998 production, there would be an annual savings of about 35% (805 GWh equivalent of thermal energy, namely fire wood) in Sri Lanka and about 56% (92 GWh equivalent of thermal energy from coal) in Vietnam.

Benchmarking for Specific Indicators

The benchmarking of indicators on energy and pollution, have so far not been done in the tea sector. One probable reason is that, the tea industry has all along concentrated its efforts in marketing and trading of tea, but not in manufacturing or process improvements. Another reason is that production methodology, type of process, and technology level, all have many country-specific parameters. Hence, comparison becomes often difficult and irrelevant between countries. However, it would be valuable to begin benchmarking with some available key indicators so that tea industries could have some figures against which they could determine their relative position in terms of performance, hence derive their improvement potential. Appendix E contains a summary of available energy consumption figures from various tea factories.

Total Specific Energy Consumption

The range of total specific energy consumption varies from 4.03–18.40 kWh/kg made tea. These measured figures reveal that south Indian factories consume less than north Indian, Sri Lankan and Vietnamese factories. For factories in north India and Vietnam, the reason for higher energy consumption could be the use of coal as fuel, while for Sri Lanka's tea industry it is due to the fact that these factories consume high amounts of energy in withering.

Specific Energy Consumption for Withering

The energy consumption in withering ranges between 0.01–3.63 kWh/kg made tea with an average of 1.8 kWh/kg made tea. Data show that Indian factories consume lesser amount for withering while Sri Lankan factories consume the highest energy in withering. The reason could be the high quantity of Orthodox tea produced in Sri Lanka against the high CTC tea produced in India.

Specific Energy Consumption for Drying

The specific energy consumption for drying varies between 0.51–6.95 kWh/kg made tea, with an average of 4.38 kWh/kg made tea, while the theoretical estimate is 2.9 kWh/kg made tea. For all the study countries, the specific energy consumption for drying ranges between 3.5–4.5 kWh/kg made tea. Therefore, 3.67 kWh/kg made tea can be regarded as a realistic target for most other factories.

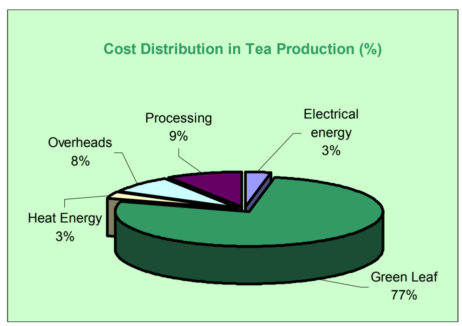
Rolling, Roll breaking, Fermentation and Grading

The energy consumed in rolling, roll breaking, fermentation and grading operations depend largely on the arrangement of the process, whether CTC or Orthodox, degree of mechanization, etc. But the energy consumed is basically electrical energy. Considering the total energy consumption, the energy consumed by these processes is marginal. The specific energy consumption for rolling/CTC, and grading operations vary between 0.1–0.3 kWh/kg of made tea. In rolling operation, Sri Lanka's tea industry is more or less in line with the expected figures, while the Indian tea industry consumes more energy. India's major production is the CTC varieties which usually consume higher energy because of the many equipment needed for CTC production over the normal Orthodox rolling operation. Also Indian factories use mechanized fermentation while Sri Lanka tea factories do not. All study countries have similar energy consumption for grading. Variation only occurs on the basis of mechanization and complexity of the grading system.

Share of Energy Cost in the Total Production Cost

With an overall average of 4.5–6.0 kWh/kg of thermal energy and 0.58–0.8 kWh/kg of electrical energy required for processing tea (Palaniappan, 1993), any reduction in either electrical or thermal energy consumption would result in both reduction of total cost of production and also the quantity of pollutants emitted.

But since the share of energy cost in total production cost is in the range of 5–14 % (ITDG, 1998) economic analysis will not yield attractive results in the short term. Under these circumstances, if the total energy consumption is reduced by 25%, the effective reduction in total cost of production would be less than 1.5% overall. Hence, initial attempts should focus on upgrading or refurbishing existing technologies to make them economically attractive in the short term.



Share of energy cost is only about 6% of the total production cost of tea.

CHAPTER 4: ENVIRONMENTAL ISSUES OF THE TEA SECTOR

The tea industry's contribution to environmental pollution in comparison with other core industries is very small. It generates neither liquid effluent nor hazardous waste material. However, the thermal energy use generates pollutants that are airborne which have substantial impact on the environment in terms of greenhouse gas emissions. Some solid wastes are also produced in the process. This chapter discusses the environmental impacts of major pollutants from the tea sector.

Overview of Waste Generation

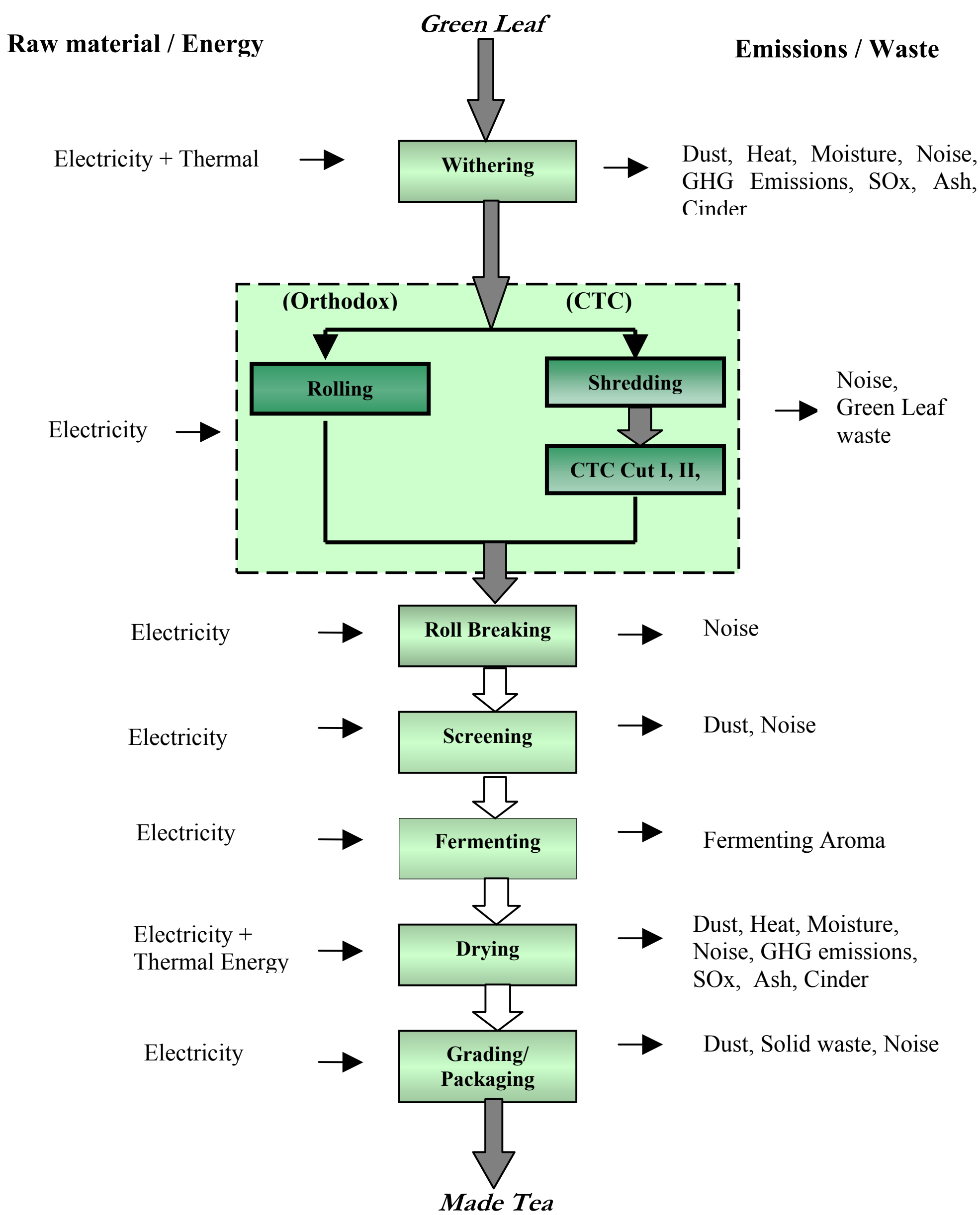
The major wastes generated from the tea factory are air pollutants and solid waste. Air pollution is particularly emitted from the combustion of fuel to generate hot air. The total quantity of different pollutants generated from different processes depends primarily on production capacity and overall operational efficiency of the tea factory. This is expressed in terms of specific pollution load, that is, the total quantity of a typical pollutant generated per total quantity of tea produced. The specific pollution load values can be used to calculate the actual amount of pollution based on the production capacity of a particular factory. It can also be used to compare and control generation of different pollutants if such figures are known for other factories or if standard indicators are available.

Solid Waste Generation

In the withering process, rejected green leaves are the major wastes when the leaves are spread/loaded on the troughs. Small quantities of leftovers and litter are also generated in the rolling and CTC processes. On the average, the tea industry generates about 100 kg of waste green leaves or litter per ton of made tea produced.

During drying, tea leaves and fibers could be blown from the dryer. The average blownout is about 2–4% of made tea. In heaters, the use of firewood, coal and briquettes generate ashes and clinkers. Coal or firewood-fired heaters produce about 100 kg of ash per ton of made tea on the average.

A significant amount of ash and clinker are generated in wood-fired heaters.



Energy Inputs and Waste Generation from the different processes involved in Tea Production

During sifting, fibers (stake) are produced. In some factories, these fibers are pulverized and recycled in process as the re-conditioner (RC powder). Otherwise, these fibers and blownouts are denatured, in which every 25 kg of fibrous waste is mixed with 1 kg of lime and buried in pits. Some portions of the denatured wastes are used as fertilizer for tea plantations.

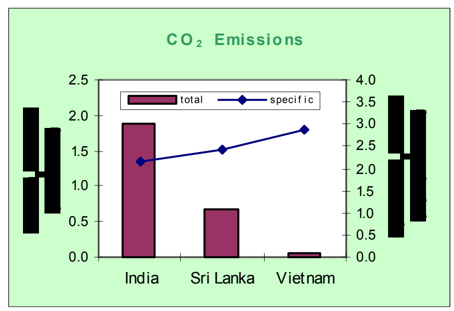
Air Pollution

Air pollution in the tea industry mainly comes from emissions of harmful gases during combustion of fuel (firewood, coal and fuel oil) in air heaters for the withering and drying processes. Though some fine tea dusts are also emitted from the drying, screening and packaging processes, these are generally settleable dusts and do not pose any major environmental problem. The main pollutants of concern are carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons, dust, fly ash and particulate matters, which are produced during fuel combustion.

Emissions from firewood combustion (common fuel in south India and Sri Lanka) are much higher than fuel oil. This is especially so when second grade rubber-wood is used and undergoes incomplete combustion. Therefore, pollution potential in firewood-fired factories is higher than the coal or oil fired factories, particularly with respect to CO_2 emission. The emission factors for this study used in the succeeding emission figures were based on the IPCC guidelines.

Carbon Dioxide Emissions

As a greenhouse gas (GHG), CO_2 is the single largest contributor to climate change, constituting about two thirds of the total GHGs in the atmosphere. The total fuel consumption by the Indian tea industry contributes to CO_2 emission by 1.352 million tons per year. Moreover, energy consumption by this sector causes additional indirect CO_2 emissions of about 0.6 million tons per year. In total, the tea sector generates about 1.94 million tons of CO_2 per year or 2.23 kg of CO_2 per ton of made tea. The Indian tea industry records the lowest specific CO_2 emission at 2.15 kg CO_2/kg made tea, compared with the other study countries, principally due to its low specific energy consumption.



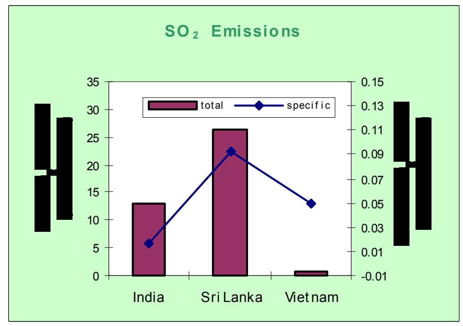
Total and specific carbon dioxide emissions of the tea sectors in India, Sri Lanka and Vietnam

For the tea industry in Sri Lanka, given its yearly consumption of firewood and fuel oil and the contribution of electrical energy usage at about 5,000 TOE, the annual CO_2 emission is about 0.708 million tons and the specific CO_2 emission is about 2.49 kg CO_2/kg made tea. On the other hand, the Vietnamese tea industry contributes to CO_2 emissions by using an equivalent of 23.2 kTOE of thermal energy annually. This results in a CO_2 emission of 0.085 million tons per year and the specific CO_2 emission is about 2.86 kg CO_2/kg made tea.

The withering and drying processes, which consume thermal energy, are the major sources of CO_2 emissions. Even though coal is the main fuel used for thermal energy generation, audited results from tea factories show that firewood (biomass) emits more CO_2 than other fuels. The only advantage is that unlike fossil fuels, firewood is a potentially renewable resource. However, both of these sources emit higher specific CO_2 emissions compared to fuel oil and natural gas. Emissions from burning firewood are substantial considering the volume of firewood burned and also due to its high specific CO_2 emissions. In addition, for every 1 TJ of firewood used, 40 hectares of deforestation occurs, without considering any reforestation efforts (ITDG, 1998).

Sulfur Dioxide Emissions

Sulfur dioxide is another pollutant emitted from fuel combustion which is of concern because of its contribution to acid rain. For India, the total SO_2 emission is about 13.16 thousand tons per year with a specific SO_2 emission of about 0.016 kg SO_2/kg made tea. Compared with India and Vietnam (0.81 thousand tons SO_2 per year), the annual total SO_2 emission from Sri Lankan tea factories is very high (at 26.24 thousand tons SO_2 per year) mainly due to the extensive use of rubber wood as fuel for thermal energy generation. Even though the annual tea production in India (860 million tons) is much higher than that of Sri Lanka (280 million tons), it is interesting to note that India's SO_2 emission is much lower than that of Sri Lanka.



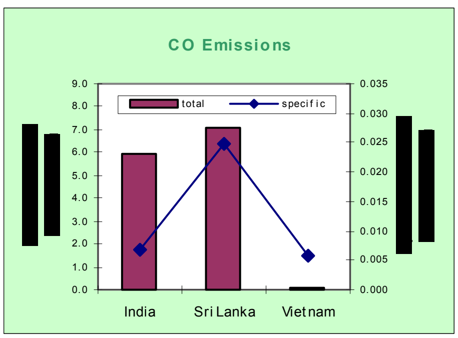
Total and specific sulfur dioxide emissions of the tea sector in India, Sri Lanka and Vietnam

Additionally, Indian tea factories use coal in generating hot air for drying. The use of rubber wood has caused undesirable effects on the tea plantation in Sri Lanka as well as corrosion problemss in the chimney and other material structures owing to the emission of SO_2. Although emissions of sulfur oxides are not as significant as CO_2 emissions, further study is needed to know how such emissions can affect the greener plantations, where normally the tea industry is located.

Among the study countries, very few factories use fuel oil as source of thermal energy. Fuel oil is to be imported and cost of fuel oil is constantly increasing. Furthermore, use of fuel oil leads to increased SO_x emissions due to the natural sulfur content of the fuel.

Other GHG Emissions

Other greenhouse gas emissions such as carbon monoxide, methane, nitrogen dioxide and nitrous oxide, attributed to energy use by the tea sector, have also been quantified for the three study countries. The total and specific emissions for each of these pollutants vary widely, depending on the type and amount of fuel consumption. In the tea production process, manual control of fuel feed and blowers (for combustion air) is practiced, which could lead to incomplete combustion of fuels. This could cause a major environmental effect at the factory level when excessive CO is produced because it could lead to fatal suffocation of the workers.



Total and specific carbon monoxide emissions of the tea sector in India, Sri Lanka and Vietnam

The annual total CO emission of the tea sector is highest in Sri Lanka at 7 thousand tons followed by India at 5.94 thousand tons. Specific CO emission is also highest in Sri Lanka at about 25 g/kg made tea and lowest in Vietnam at 5.6 g/kg made tea. Emissions of CH_4, N_2O and NO_x are much less compared to these values and their contribution to atmospheric pollution may be considered insignificant at this point.

Other Environmental Impacts

Occupational Hazards

Noise and dust are two other main pollutants generated in tea manufacturing. In the withering process, the noise produced by the trough fan/blower and the resultant dust and/or particulate matter from the withered leaves are matters of concern. Recently, many factories are opting to mechanize this process by installing moving perforated belts for laying out green leaves, motorized breakers for leaf separation and automated discharging. This automation minimizes the presence of workers exposed in this hazardous area.

The high amounts of dust and hot ambient conditions at the dryer section, aside from additional dust, ash and heat in the air heater section are also concerns for health. The dust generation in the dryer room is greater if ECP is used because of its open outlets. Comparing the two production methods, the CTC would generate more particulates than the Orthodox due to the powdery end product of the former. In most factories, the dried tea is still manually handled in the grading and transferring operations, which also adds to dust generation.

In firewood or coal-fired air heaters, dust originates from the combustion material (soot and ash). The temperature of the surroundings depends on the heat exchanger type. Tubular heat exchangers generate higher heat while tubeless heat exchangers are more efficient. The fermentation process, where strong aroma of the stimulant contaminates the air, has not been tested for human impacts yet. But for a factory outsider, the smell of fermenting tea is rather strong.

Land Use Conversion

Tea industries worldwide are more or less located in hillside areas where there is above average rainfall, low ambient temperature, and substantial vapor saturation taking place (salubrious climate). The local atmospheric impacts caused by the tea sector may come in different forms.

Tea is cultivated by clearing forest cover. Even though tea cultivation is also vegetation, it could not be equated to forest cover. Another problem is the effect of fertilizers and consequential soil erosion that takes place after pruning and uprooting which could negatively affect nearby aquatic resources. Nevertheless, since tea cultivation is a cash crop, the economic gains of cultivating it are considered more important than the estimated adverse effects on the environment.

For an industry that needs 1.23 million cubic yard of firewood per year, the supply could not be found only from the captive forest that plantation companies have. The demand for fuel wood is far greater than the supply and this phenomenon is dramatically reducing forest lands. It also causes indirect problems such as increased erosion and metabolic losses due to increased soil temperature and aeration. The environmental consequences of deforestation and land degradation are severe. They include ecological instability, loss of agricultural production, desertification, climate change, and loss of biodiversity. It is estimated that over 90% of fuel is supplied by the low grown areas in Sri Lanka. Deforestation is one of the serious environmental impacts from the tea industry, which creates a domino effect in terms of aquatic resources degradation, biodiversity loss, and other related human issues.

Recommended Mitigation Measures

Even though the tea sector does not contribute significantly to GHG emissions compared to other core industries like cement, fertilizers, etc., it is certainly worthwhile to examine a few options available to mitigate its environmental effects due to GHG emissions. Some of the suggested mitigating measures include: switching to cleaner fuels (i.e. shift to biogas or fuels with a lower C/H ratio), efficiency improvements, adoption of cleaner production techniques, use of renewable sources of energy for both thermal and electricity generation, afforestation, and cogeneration.

Each one of these measures has its own advantages and can surely contribute significantly to the overall mitigation of environmental impacts of the tea sector. However, the best method to reduce CO_2 emission immediately is by efficient use of fuel. But in reality, the CO_2 emission may be lesser than predicted because of inefficient combustion. It is possible to save a minimum of 15% of the present energy consumption in tea industries in India and a higher percentage in Sri Lanka and Vietnam. The investment required will vary depending on the situation existing in the individual unit. For projects needing large investments, it may be worthwhile to do life cycle costing analysis. It is also possible to take the help offered by energy service companies like Intesco-Asia, and IREDA, in funding some of the long-term projects. For environmental protection, international funding is also available. It is also possible for the tea sector to create its own development fund out of their income to finance these mitigation projects.

CHAPTER 5: ENERGY EFFICIENT AND ENVIRONMENTALLY SOUND TECHNOLOGIES FOR THE TEA SECTOR

One of the approaches for tackling the energy and environmental issues is to implement energy efficient and environmentally sound production processes or adopt new technical and management measures. This chapter describes the various energy efficient and environmentally sound technologies (E3ST) suitable for the tea sector. An analysis of what factors hinder the effective adoption of E3ST will also be discussed along with some recommended strategies on how to overcome these barriers.

Need for E3ST

The adoption of E3ST is an integrated preventive approach aimed at improving both resource efficiency and eco-efficiency thereby reducing the risks to humans and the global environment as a whole. These goals are achieved by using energy resources more efficiently while maintaining the same desired output, and in the long run reduce production costs and minimize wastes.

Implementing these options does not always require high capital expenditures. Some of the options require only marginal costs but can achieve a high energy savings with reduced emissions. The emission reduction is possible by reducing energy/material consumption using efficient processes or adopting appropriate alternative energy sources or technologies. Any improvement in energy utilization and adoption of E3ST in the tea industry has a crucial role at the factory level (cost reduction), local level (deforestation, fuel import) and global level (GHG mitigation).

E3ST Options for Energy Efficiency Improvement

Process improvements either by modifications or management practices could reduce electrical energy consumption. However, it would have a relatively low impact in terms of cost reduction and GHG mitigation because electrical energy shares only 15% of the total energy consumption. The thermal energy consumption on the other hand, can be reduced by good operating practices and by adopting new technologies through which substantial savings could be made.

Improvements in Electrical Energy Utilization

Electrical energy usage may be significantly reduced by making some improvements in the withering process. The withering process consumes about 20% of the total electricity consumption

Tests on Electrical Energy Saving in Withering
Tea Research Institute, Sri Lanka

Bulk of the electricity consumption is consumed at withering by the electric three phase motor driven axial fans, which operates continuously for about 12 hours in high grown and 18 hours for low grown regions.

The corresponding electrical energy requirement for 1000 kg Green Leaf trough is 4 kW. This is equivalent to 0.22 kWh/kg made tea for 12 hr withers, and 0.32 kWh/kg for 18 hour withers. This clearly shows there is a great potential in electrical energy reduction.

Trough Length m (ft)	Capacity (kg)	Air Flow Required (m^3/min)	Equivalent Power @20mm Hg (kW)	Installed Motor Size kW (hp)	Calculated Motor Rating (kW)	*Oversize %*
18.3 (60)	988	593	1.45	3.7 (5)	3.7	***0***
21.9 (72)	1183	710	1.74	5.5 (7.5)	4.4	***25***
25.6 (84)	1382	829	2.03	7.4 (10)	5.2	***42***
30.5 (100)	1647	988	2.42	11.0 (15)	6.2	***77***
36.6 (120)	1976	1186	2.91	11.0 (15)	7.4	***49***

*(75% efficiency, 25% Safety Factor allowed) (Samaraweera ,1986)

By improving the trough design, mainly withering in two stages, high air pressure at initial stages, low pressure at later stages and replacing oversized motors with better efficient motors, it is estimated that the electricity consumption can be reduced by 30–50%, equivalent to a savings of 28 GWh per annum at the national level.

(Mohamed et. al., 1997)

in a tea factory. The specific electrical energy consumption for tea processing varies from 0.48–0.60 kWh/kg made tea. Studies and observations have shown that the trough fans are mostly oversized and there is no control over the speed of motors or air flow. There is inadequate monitoring of process conditions and these have often led to higher electrical energy consumption.

In most of the tea factories, it has been noted that the trough fans generate about 5,000 CFM of air per kW of motor, whereas a modern motor-fan generates about 13,000 CFM of air per kW of motor. The high energy consumption is due to the improper design of the fan and inefficient motors and so there is a considerable potential to conserve electrical energy.

Variable speed motors are a more suitable option. This will consume less energy and regulate the air flowrate according to the withering condition and demand. It is believed that at least 25% of the energy costs for withering can be reduced by installing two speed axial flow fans, which will facilitate higher airflow at the beginning and lower airflow at the later stage. This represents a reduction of 35 GWh from withering and about 25% decrease in total electrical energy consumption in Sri Lankan tea factories.

Some factories have reduced their electricity consumption in the withering operation by installing individual power factor correction capacitors and through well-planned production schedules. Through these improvements, the specific energy consumption is reduced to 0.23

kWh/kg made tea (De Silva, 1993). If this could be considered at the national level, there is a large potential for reduction of electricity consumption, which works out to about 70 GWh in Sri Lanka based on the production of 280 million kg of tea production in 1998. For India (870 million kg made tea in 1998), it would save about 313 GWh of electricity and for Vietnam, it would be 4.5 GWh equivalent.

This kind of reduction in energy consumption consequently leads to a substantial reduction in GHG emissions. For India where the major fuel is coal for power generation, the reduction in CO_2 could be about 25,000 tons per annum. For Sri Lanka, which is based on fuel oil, and for Vietnam, which is coal based, the reductions could be about 590 tons and 420 tons per annum respectively.

Improvements in Thermal Energy Utilization

Thermal energy contributes about 88-92% of the total energy consumption in tea factories. The specific energy consumption varies between 4.5–6.8 kWh/kg made tea. There is a large potential for improvement in thermal energy utilization by waste heat recovery from the dryers cum heaters

❖ Using More Energy Efficient Dryers

The efficiency achieved in an ECP dryer is 36% whereas it is 54% in FBD (De Silva, 1993). However, many Orthodox tea producers still use ECP dryers, because it can be used to dry both CTC and Orthodox tea.

Performance Parameters	**Type of Dryer**		
	ECP- 6ft	**FBD – 24 x 4**	**Combined FBD (Tempest 244)**
Electrical Power (kW)	18	61	24
Output at 70 % Wither (kg/hr)	180	300	300
Water Evaporation rate (kg/hr)	380	700	700
Coal Consumption (kg/kg tea)	0.9	0.7	0.65
Equivalent Thermal Energy (kWh/kg)	5.76	4.48	4.16
Electricity Consumption (kWh/kg)	0.061	0.123	0.156
Specific Energy Consumption (kWh/kg)	5.82	4.60	4.32
Wither factor %	Any	70 -73	Any
Heater Unit	Any type	Gas/ Oil	Any type
Drying time	Controlled	Variable	Controlled
Fly off (% of made tea)	3 %	16%	< 2%

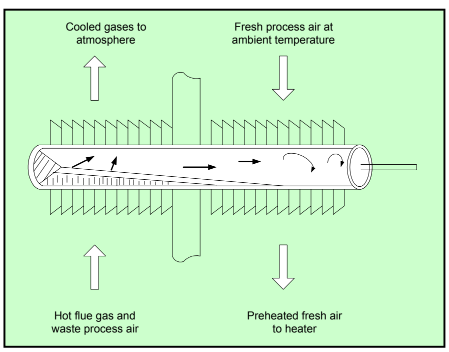
Performance comparison of the Endless Chain Pressure (ECP) dryer, the Fluidized Bed Dryer (FBD) and the more recent innovation with improved efficiency, the combined FBD dryer.

Lately, by incorporating the features of both ECP & FBD dryers, the combined FBD dryer (Tempest) has been introduced in India. This dryer with a higher output and better energy efficiency is becoming popular in India and Sri Lanka.

❖ Waste Heat Recovery

A considerable amount of heat energy could be recovered from the flue gas and dryer exhaust. The thermal energy losses through the flue gas is in the range of 23–30%, and about 40–50% through the dryer exhaust (hot moist air).

The flue gas heat can be recovered by economizers, which can preheat the air intake to air heaters. A 40ºC increase in intake air will reduce the fuel requirement by about 35% (De Silva, 1993). Commercial units are available for both preheating fresh air and also to preheat water in the case of boiler systems. The air preheater/economizer, which recovers about 50% of the flue gas losses, results in a 20% reduction in fuel consumption.



Schematic diagram of an air-to-air heat exchanger for waste heat recovery

❖ Direct Fired Heaters

Most tea industries use indirect heaters, which are essentially tubular heat exchangers using coal or firewood. Recently, the tea industry started using direct-fired heaters where flue gas is directly sent to the dryer. This system is ideal for FBD as well as conventional dryers. Fuel economy and uniform temperature are assured. However, this is possible only if a clean fuel such as low sulfur LPG or oil is available.

❖ Recirculation of Exhaust Air from the Dryer

It was observed that exhaust air from the dryer is not fully saturated and it could still absorb moisture from the tea leaves. Therefore, a portion of the exhaust can be recirculated. Normally, the recirculation fraction is kept around 0.3–0.4. By this process, it is possible to save around 15% of electrical energy. This method is adopted in dryers used in other industries. However there are problems in adopting this in tea dryers due to the fact that exhaust air contains tea particles which may block the air lines. But this can be overcome by provision of efficient filters. The economics is also favorable on a case-to-case basis and the investment required is very marginal.

❖ Fuel (Firewood) Efficient Air Heaters

Inefficient heat transfer in heat exchangers/dryers results in high consumption of fuel, which in turn leads to more GHG emission. In the tea industry, the major use of thermal energy is in the drying process and in some factories, the withering process also uses a separate heater.

Efficiency of good firewood-fired air heaters could be about 65% (De Silva, 1993) while energy audits in Sri Lanka revealed that heaters are operating only at an efficiency level of 35%. This is because of outdated heaters, inadequate thermal insulation, air leakages, clogged air tubes, etc. It is also due to incomplete combustion caused by wet and un-chopped firewood, and manual feeding of firewood.

Blocked tubes of a wood-fired heater contributes to reduction in heat transfer efficiency

In the case of firewood-fired heaters, a reduction in moisture content from 50% to 25% increases the calorific value from 8 MJ/kg to 13 MJ/kg (Joseph, 1995). For an industry which derives thermal energy from 420 kT of fuelwood per year in Sri Lanka, feeding of air dried chopped firewood means a reduction of firewood consumption in the range of 200 kT. In terms of deforestation it is equivalent to 100,000 hectares of biomass plantations recovered (ITDG, 1998).

Regenerators recover waste heat from the moist hot air from the dryers. A prototype regenerator had been tested in Sri Lanka with an aluminum rotating mass, which has the surfaces cyclically exposed to hot air and ambient air. The recovery was about 20% (De Silva, 1993).

Better Housekeeping Measures

Undertaking an energy audit in the tea industry could lead to a reduction in energy consumption and environmental impacts, and this could be simply achieved through better housekeeping measures such as (Gupta, 1983):

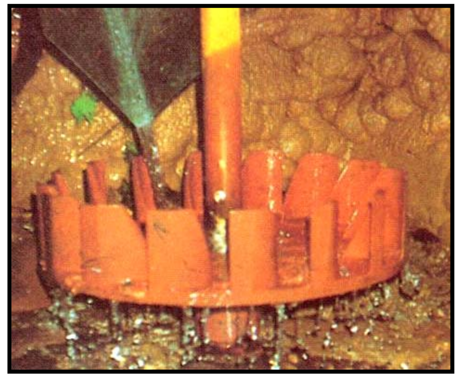
- Reduce heat losses by insulation, avoiding leaks and using proper sized equipment (e.g. motors)
- Adopt a clear preventive maintenance system
- Improve heat transfer efficiency by cleaning tubes and ducts
- Usage of dried firewood instead of moist firewood
- Improve operation like excess air control
- Improve capacity utilization and load factor
- Observe proper production planning and control

Use of Renewable Energy Sources

Mini-Hydro Generation

Before national grid supplies were supplying electricity to tea plantations, mini-hydro power was the source for electrical energy in many countries. Mini-hydro does not need water storage and they are basically small power systems. Upstream and downstream disturbances are minimal and ecological damages are marginal. In a study done by ITDG-Sri Lanka, out of the 206 existing potential sites investigated, only 20% sites are in operation, 35% have been abandoned and 36% has high potential for mini-hydro generation. Additional 42 MW of installed power could be added to the power system, resulting in 332 GWh generation per annum, which is more than sufficient to supply the whole tea industry. The average power cost of mini-hydro generation is estimated to be Rs. 2.38 per kWh (0.032 US$/kWh), in comparison with normal tariff rate of Rs. 4.50 per kWh (0.063 US$ / kWh). This is 50% less than the present cost of electricity and will also reduce the dependency on the national grid supply. The disadvantage of seasonal availability of water could surpass the advantage of having cheaper supply of energy with lesser environmental impacts. However this option for renewable energy generation needs detailed investigation.

The total potential of mini-hydro in India is estimated at 10,000 MW against an achievement of only 210 MW (2%). A further 140 MW is under installation (Annual Report MNES, 1999/2000).



A mini-hydro (vertical shaft) power plant in is one way of harnessing renewable energy sources by the Indian tea sector.

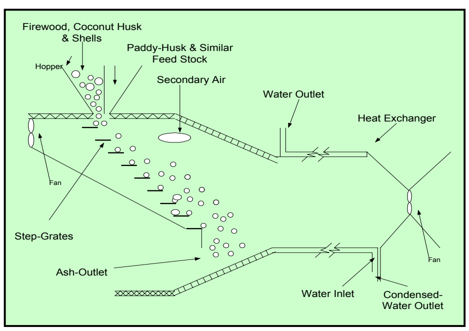
Indian power planning includes 2000 MW from mini-hydro plants. The tea estates are most suited for this purpose, and the results of explorations have indicated that south Indian plantations are more suited for hydel power as they are usually at an elevation higher than 1000 meters amsl and are exposed to northwest and southwest monsoons. Again however, the cost factor is prohibitive and only a few big units have made attempts to put-up such mini-hydro plants.

Biomass Residue Utilization

The tea industry in Sri Lanka consumes about 43% of the total biomass consumed in the industrial and commercial sectors. Though firewood is the major biomass used, the use of other residue biomass has also been studied (Mantrithilake, 1998). Sawdust would be a potential source of energy, especially for low and mid-grown regions, where biomass is freely available.

The applicability of this rests upon the development of suitable burners, which could have the capacity to burn lump fuel as well as fines. However, use of such entails a large space requirement for storage.

A step grate furnace has been tested mainly to reduce CO emissions, which are higher at the initial stages of wood firing, and reduce overall CO_2 emissions by improving combustion efficiency. (Basnayake, 1998). The test results proved that the step grate furnace could achieve peak heat generation within 15 minutes. The heat exchanger efficiency was 90% and the total CO_2 emissions would be about 0.85 kg/kg made tea. This is a reduction of approximately 40% of CO_2 emissions over the conventional combustion of firewood.



The step grate furnace utilizes biomass residues as fuel and reduces CO_2 emissions by 40% over conventional firewood combustion

Cogeneration

Wood gasification has been tested as a system for cogeneration of process heat and electricity. The system includes a wood gasifier, a gas burner, and a gas engine coupled to a generator. The prototype apparatus (De Silva. 1993), designed for a feed rate of 190 kg/hour, had a rated cogeneration capacity of 500 kW thermal and 60 kW electricity.

The composition of the gas achieved is in comparison with the other producer gases, but the CO_2 percentage was higher than CO. The reduction in fuel consumption would be 0.58 kg/kg made tea as against a normal combustion rate of 1.38 kg/kg made tea. The use of the gasifier has resulted in over 50% reduction in energy requirement. But in Sri Lanka, the system is not very popular because the gasifier requires firewood to be in smaller particle sizes, and there are still design parameters to be sorted out like in the case of overheating of throats.

Cogeneration is much more attractive for factories with a higher number of CTC batteries and if the fuel is firewood, it gives the best of benefits. If the air heater's thermal energy efficiency is higher than 80%, cogeneration would not be viable. Generally though, wood-fired air heaters achieve less than 50% reduction in fuel consumption. With an average dryer efficiency of 50%, the overall efficiency becomes less than 25%, and a cogeneration efficiency of 40% can be achieved, with additional benefit of electricity or motive power. However, co-generation is favorable only for large-scale factories.

Solar Energy for Withering and Drying

The use of solar thermal energy is on an upward trend, and is now commercially used. Applications of solar energy in the tea industry has been extensively tested and proven in India. The Indian experience (Palaniappan, 1993) shows that in a study carried out in a south Indian tea factory, a 212 m^2 area solar air preheater resulted in a 34% reduction in fuel consumption. With a specific thermal energy ranging between 4.5–6.0 kWh, this represented 168 million coal equivalent savings for the whole Indian tea sector. Also, the temperature obtained was 40ºC above ambient. At the same time, this can reduce the withering time by about 3 hours, resulting in electrical energy savings.

Solar heat panels installed on the roof of a tea factory results in significant reductions in fuel consumption (Source: Palaniappan, 1993)

In Sri Lanka, solar technology is at the development stage. Even though the climatic conditions are different from India in general, there is a potential for using solar energy, especially in the mid and low country plantations, where intense sunlight is available for a substantial amount of time. This could be sufficient at least for the withering process. Experiments carried out in Sri Lanka have shown that well designed solar collectors could heat air to 80ºC. The study concluded that by coupling solar collectors to an efficient drying system, it is possible to supply around 70% of the annual thermal energy for a factory.

Potential for GHG Mitigation through E3ST

By adoption of E3ST in the tea industry, it is possible to save about 15–20% in total energy consumption. This in turn could result in GHG reduction of a similar extent. Therefore, based on the country study's total CO_2 emission of 1.872 million tons, 0.682 million tons and 0.046 million tons for India, Sri Lanka, and Vietnam respectively, the potential reduction in CO_2 emissions corresponds to 340 thousand tons, 124 thousand tons, and 9,000 tons respectively.

In spite of the benefits from E3ST in tea production, the adoption of such is not yet widespread and to some extent, the tea sector has been reluctant in implementing changes in their systems.

Barriers to Adoption of E3ST

In order to formulate the appropriate policy measures for the successful promotion of E3ST in the tea sector, it is essential to first identify the specific barriers to adoption of E3ST. A clear understanding of such hindrances could help in devising strategies to overcome them. The important barriers are considered in the following section.

Lack of Awareness

Small scale industries are normally owned by hereditary systems and work as proprietary concern. Often, owners are not aware of the changes taking place in the field of technology nor is much attention paid to improvement of the operating system. The general awareness regarding environmental regulations and legislation is very low. They are also unaware of the potential gains achievable from improved efficiency. They also lack information on available E3ST.

Lack of Access to Technical Information

Generally, small scale industries do not have any access to technical information. There is also no exchange of information between different units. There are not many training programs conducted exclusively for respective small sectors. The owners also do not nominate their operators for any programs or seminars due to paucity of trained staff. Technical publications are not easily available for reference. Educational opportunities for the workers are seldom tapped to improve their technical knowledge/skill.

Lack of Coordination

Though SMI form a large percentage of industrial establishments in many Asian countries, they are often scattered around the country, making information dissemination difficult. It takes time and effort to get to them. Only in some countries like India, SMI have formed industry associations that work towards a common objective.

Lack of Standards and Benchmarks

Standards are strategic approaches to the efficient use of resources and SMI do not apply these management techniques owing to their technical, manpower and financial limitations. There are no sector-specific standards/benchmarks/indicators to know actual performance against desired performance. Again, there are no national standards or international benchmarks for the tea sector. The performance varies from place to place, region to region, nation to nation. For example, in India the specific energy consumption in south Indian tea factories is much less than Assam tea factories. Again, Sri Lanka has higher specific energy consumption than Indian tea units. The lack of benchmarking hinders the tea industry from improving on their systems.

Lack of Finances

SMI require significant resources for the implementation of E3ST. Normally, pollution abatement receives little or no attention, as there is no market opportunity to avail of financial assistance from banks or other sources to implement E3ST. It is difficult to access special funds or soft loans from commercial banks where collaterals are required. Further the industries have no confidence on this type of investment especially because E3ST is something that they are not familiar with. Most industries only have full confidence in their own tested and proven production systems.

Lack of Research and Development

Small scale industries do not contribute much to the development of the sector by way of investing in research and development efforts. New methods and systems could not be tried because of this. For example, tea industries are still using cast iron heater tubes which cannot withstand temperatures of more than 400ºC . This has resulted in using significantly high excess air than what is required. This results in low combustion efficiency of the heater.

Lack of Infrastructure

Many small scale industries do not have basic facilities to undertake tests like testing the quality of tea, estimation of moisture, etc. There are not many facilities to measure process parameters like air flowrate, pressure, etc. Therefore, it is difficult to know and assess their current level of performance. In many cases, even the rated capacity of the standard equipment is not known. In fact, this is the biggest hurdle in evaluating the performance of small scale industries.

In summary, there appears to be a lack of awareness and information on E3ST and information of successful technologies. Most of the tea industry personnel do not understand the concept of E3ST as well as its integrated energy, environmental and economic benefits. It is generally believed that any technology upgrading related to environmental improvement is too costly to be afforded by SMI. This is further aggravated by the lack of dedicated technicians in tea factories to look into technological improvements. However, the lack of capacity to access the latest technological information is also another reason. There is a need for data/ information on successful implementation of E3ST in the tea sector to demonstrate the effectiveness and benefits of energy saving technologies. Many of these barriers could actually be addressed through some policy measures.

Elimination of Barriers to Promote E3ST

In such circumstances, effective strategies have to be developed to create awareness, impart training, and give the entrepreneurs sector-specific information, legislative compliance support, and on-the-job technical advice. At the same time, these strategies should be inexpensive, user-friendly and acceptable within the limitations of SMI. Creating awareness through policy measures is one way of promoting E3ST. Financial support through funding is also essential in this context.

Several international organizations and other institutions provide financial and technical support for promotion of E3ST through cleaner production practice, energy and environment audit. As a result, organizations such as small scale industry associations, technical institutions, environmental groups, and NGOs assist SMI in their energy and environmental activities thus developing some competence in specific areas. However, energy and environment related issues demand a holistic approach. Compartmentalized preventive measures are inappropriate, and interdisciplinary oriented approaches are needed to overcome these barriers. In developing such mechanisms for SMI, cooperation among various groups plays a vital role.

The promotion of E3ST therefore requires substantial institutional capabilities which are available but in a disorganized manner. There is a need to mobilize these forces namely technology providers, equipment suppliers, financial institutions, research and development organizations, policy makers, government departments, NGOs, and trade associations, in order to enhance the competence of SMI. This capacity mobilization will not only facilitate the technical and institutional arrangements, but also promote sound policy measures.

Therefore, networking of major forces at the national and regional levels can lead to easier mobilization of their capacities and is an important step towards the promotion of E3ST. Networking is the basic route of information dissemination. Networks represent free flow of information and are emerging as important tools for local development and fostering universal participation. Networks help overcome the various barriers to promote E3ST by creating awareness on environmental issues among the various users and providing reliable information. They also assure efficient use of resources, create a conducive atmosphere for exchange of information/expertise, facilitate training in specific areas, enhance cooperation with local agencies and develop sector based standards and benchmarks which are essential to promote E3ST. E3ST adoption not only prevents pollution but ensures higher productivity and profit to the industries.

Lack of access to technical information can be addressed by circulating information, through training programs, seminars, workshops, publications, journals, websites, etc. Lack of coordination can be solved through well-organized associations to a great extent. Benchmarks and standards can be evolved over a period of time. To start with, a minimum achievable target for energy use and environmental emissions can be fixed based on the prevailing systems and practices. Afterwards, this can be further enhanced to optimum level. This can be accomplished through industry associations.

Financial barriers can very well be taken care of by either allocating an exclusive fund catering to the use of small scale industries for energy and environment-oriented projects or by giving financial support to the Energy Service

Companies (ESCO) which can cater to the financing of small scale industries . Alternatively, a Special Purpose Vehicle (SPV) can be created with equity participation from government, multilateral agencies and certain financial institutions. The SPV, which should be professionally managed, can assume a wide variety of roles that could include the following:

- develop showcase projects
- develop measurement and verification protocols
- build capacity for energy performance contracting
- financial support to ESCOs
- provide guarantees to energy and environment projects

The government, respective industries, financial institutions, educational institutions and international agencies should also support the R&D efforts. Infrastructure facilities like testing equipment, flow measurement systems, and other measuring instruments have to be created at different locations so that the tea sector can use these facilities to improve energy efficiency. This can be handled either jointly by both government and industry owners concerned. Alternatively, the respective associations can also handle this. In fact, the Indian government has already created regional testing laboratories to cater to the SMI. Based on the points discussed above, it is possible to develop some guidelines for the implementation of E3ST in small scale industries. At present, there are no policies existing exclusively for small scale industries much less for specific sub-sectors.

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APPENDIX A: TYPES OF TEA FOUND AROUND THE WORLD

Black tea: Black Tea, a dark colored fine powder or flakes, is the most popular tea in the world that yields a hearty-flavored, amber brew. There are highly priced small jars/boxes with exclusive teas (100g-400g) and tea bricks (1-3 kg) mostly found in Central Asia and Russia.

Green tea: Green tea skips the oxidizing step. It has a more delicate taste and is light green/golden in color, widely produced in China, Vietnam and Japan.

Oolong Tea: Oolong tea is a cross between black and green tea in color and taste with a special flowery aroma, produced only in China and exported to Japan where it is very popular.

White Tea: While flavored teas is a light fermented tea made from fresh leaves selected with many white hairs.

Yellow Tea: The quality characteristic of the tea is that the dry tea and tea infusion are both in yellow color.

Herbal tea: Herbal teas contain no true tea leaves, but are created from the flowers, berries, peels, seeds, leaves and roots of many different plants that create exciting flavors and aromas in a rainbow of colors from pale yellow to deep red.

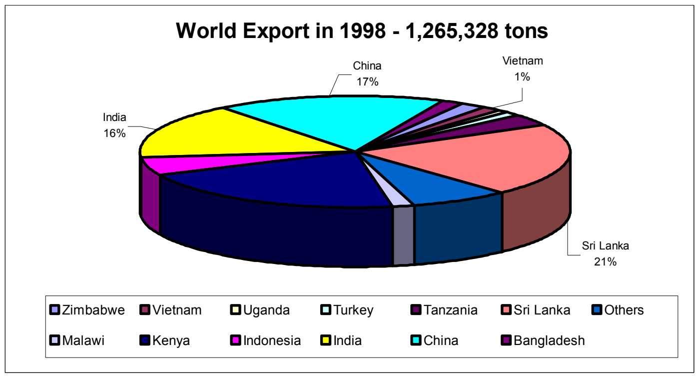
Iced Tea: In 1904, Richard Blechynden, a tea plantation owner put a load of ice into the brewed tea and served the first 'iced tea' in St. Louis World's Fair, the United States.

Bagged tea: In 1908, Thomas Sullivan, a tea merchant of New York, developed the concept of "bagged tea" as a natural marketing opportunity when he realized the restaurants were brewing the samples in the bags to avoid the mess of tea leaves in the kitchens.

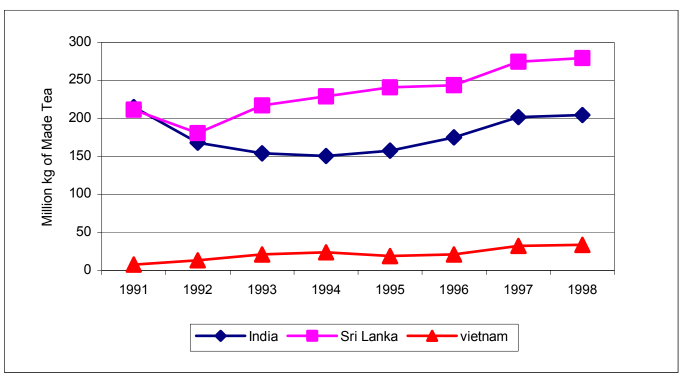
(Source: Stashtea, 2001)

APPENDIX B: CONTRIBUTION OF TEA SECTOR TO ECONOMY OF STUDY COUNTRIES

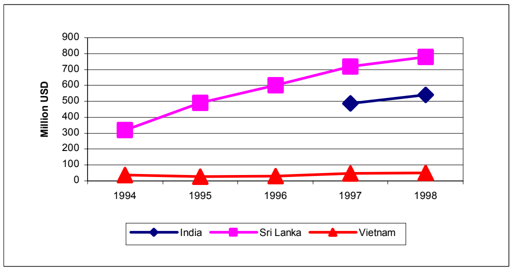
1. Share of World Tea Exports in 1998 (*Source: Tea Directory, 2001)*



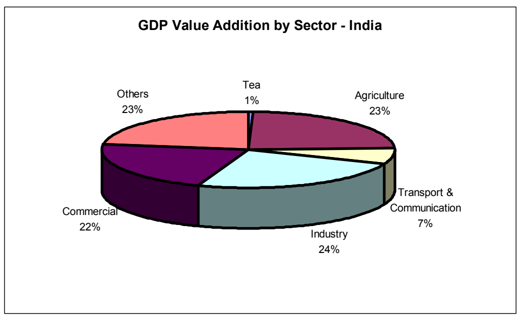
2. Trend of Tea Exports for the three Study Countries
(Source: Statistical Yearbook for Asia and Pacific, 1998)



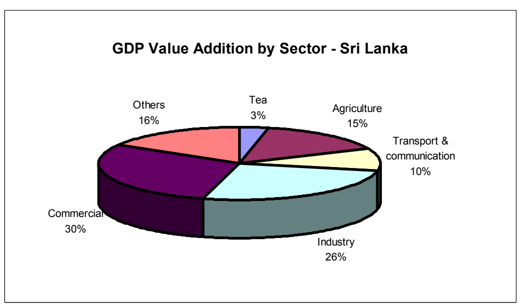
3. Trend in Tea Sector Export Earning
(Source: Statistical Year Book for Asia and Pacific, 1998)



4. Share of GDP Value Addition by tea sector in India in 1996
(Source: Statistical Year Book for Asia and Pacific, 1998)



5. Share of GDP Value Addition by tea sector in Sri Lanka in 1996
(Source: Statistical Year Book for Asia and Pacific, 1998)



APPENDIX C: NOMENCLATURE IN TEA GRADING

1. **Tea grades in Orthodox process** *(Source: Kannan, 1993)*

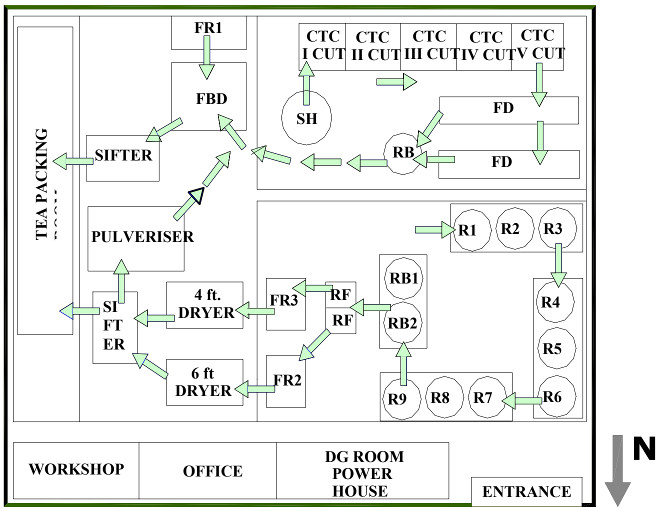
TGFBOP	Tips Golden Flavour Broken Orange Pekeo
GFOP	Golden Flavour Orange Pekeo
TGFOP	Tips Golden Flavour Orange Pekeo
FP	Flavour Pekeo
FBOP	Flavour Broken Orange Pekeo
FBOP - 1	Flavour Broken Orange Pekeo - 1
BOP	Broken Orange Pekeo
GBOP	Golden Broken Orange Pekeo
SBOP	Small Broken Orange Pekeo
BOPF	Broken Orange Pekeo Flavour
Fanning	
Dust	
PST	Partly Sifted Tea

2. **Tea grades in CTC process** *(Source: Kannan, 1993)*

BP	Broken Pekeo
PF	Pekeo Flavour
PD	Pekeo Dust
FP	Flavour Pekeo
SRD	Super Red Dust
SFD	Super Fine Dust
FD	Fine Dust
GD	Golden Dust

APPENDIX D: VARIATIONS IN TEA FACTORY LAYOUT

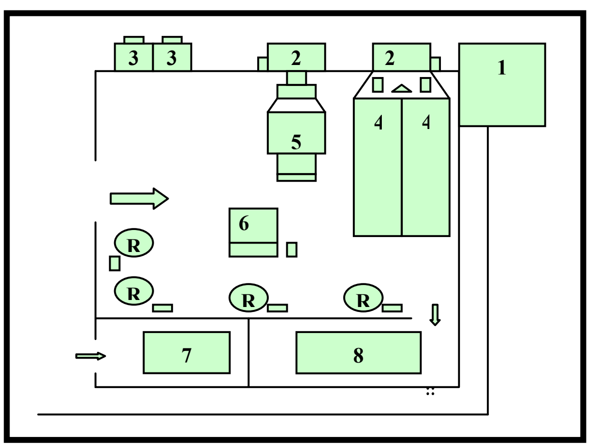
1. Layout of an Indian Tea Factory



FD	Fermentation drum
SH	Shredder
R1-R9	Roller machines
RF	Rack fermentation
DG	Generator
FR1- FR3	Furnace Room
RB , 1,2	Roll breaker

Note : Furnaces are placed inside the process building. These dryers could be direct firing type . India uses direct firing more commonly.

2. Layout of a Vietnamese Tea Factory



1	Coal Storage
2	Furnace
3	Dryer (??)
4	Withering Trough
5	Dryer
6	Dryer
7	Office
8	Fermentation Room

Marked difference in the Vietnamese factory layout is the placement of withering trough and other equipment on the same floor and withering and drying processes use separate heat supplies. The layout does not allow for utilizing the hot air from dryers, probably because of the extreme cold conditions.

APPENDIX E: AVAILABLE ENERGY CONSUMPTION VALUES IN TEA FACTORIES

1. **Specific Energy Consumption (SEC) in kWh/kg made tea**

Factory Location	SEC	Data Source
India –Factory 1	**4.03**	India -audits
Lowest Energy Observed	**4.03**	Sooriyamoorthi CE,1993,PEN
Calculated lowest (thermal)	**4.50**	De Silva,1993,PEN
India Bench Mark	**4.53**	India -audits-PSG
South India-CTC	**4.85**	Ramakrishna P,1993, (PEN)
India-Orthodox	**4.96**	Bansal NK ,1993 (PEN)
India-CTC	**5.10**	Bansal NK ,1993 (PEN)
South India-Orthodox	**5.63**	Ramakrishna P,1993, (PEN)
India – Factory 2	**5.82**	India -audits
Sri Lanka -Mid Country	**5.84**	Sri Lanka -audits
Sri Lanka -LOW Country	**6.71**	Sri Lanka -audits
India -Factory 3	**6.90**	India -audits
Sri Lanka -LOW Country	**7.05**	De Silva,1993,PEN
Sri Lanka -UP/MID Country	**7.05**	De Silva,1993,PEN
Sri Lanka -Sector	**7.10**	Haskoning, 1988
Assam -CTC	**7.99**	Ramakrishna P,1993, (PEN)
Sri Lanka -UP Country	**8.01**	Sri Lanka -audits
Doors -CTC	**8.24**	Ramakrishna P,1993, (PEN)
Vietnam- Gia Thang	**11.70**	Vietnam -audits
Vietnam- Bench Mark	**12.70**	National Tea coop., Vietnam
Vietnam- Hanoi	**18.40**	Vietnam -audits

2. Specific Energy Consumption for Withering (SECW) in kWh/kg made tea

Factory Location	SECW	Data Source
India-Factory 1	**0.01**	India -audits
India-Factory 3	**0.06**	India -audits
South India-CTC	**0.10**	Ramakrishna ,1993, (PEN)
India –Factory 2	**0.12**	India -audits
Sri Lanka -Mid Country	**0.28**	Sri Lanka -audits
India-CTC	**0.81**	Bansal ,1993 (PEN)
Doors -CTC	**0.95**	Ramakrishna ,1993, (PEN)
South India-Orthodox	**1.03**	Ramakrishna ,1993, (PEN)
India-Orthodox	**1.22**	Bansal ,1993 (PEN)
Assam -CTC	**1.37**	Ramakrishna ,1993, (PEN)
Calculated lowest (thermal)	**1.50**	De Silva,1993,PEN
Sri Lanka -LOW Country	**2.96**	De Silva,1993,PEN
Sri Lanka -UP/MID Country	**2.96**	De Silva,1993,PEN
Sri Lanka -LOW Country	**3.11**	Sri Lanka -audits
Sri Lanka -UP Country	**3.63**	Sri Lanka -audits

3. Specific Energy Consumption for Drying (SECD) in kWh/kg made tea

Factory Location	SECD	Data Source
India –Factory 2	**0.51**	India -audits
Calculated lowest (thermal)	**2.90**	De Silva,1993,PEN
India-Orthodox	**3.34**	Bansal NK ,1993 (PEN)
Sri Lanka -LOW Country	**3.42**	Sri Lanka -audits
Sri Lanka -UP/MID Country	**3.67**	De Silva,1993,PEN
India-CTC	**3.84**	Bansal NK ,1993 (PEN)
Sri Lanka -LOW Country	**3.87**	De Silva,1993,PEN
India-Factory 1	**4.03**	India -audits
Sri Lanka -UP Country	**4.19**	Sri Lanka -audits
South India-Orthodox	**4.33**	Ramakrishna P,1993, (PEN)
South India-CTC	**4.42**	Ramakrishna P,1993, (PEN)
Sri Lanka -Mid Country	**5.33**	Sri Lanka -audits
Assam -CTC	**6.32**	Ramakrishna P,1993, (PEN)
India – Factory 3	**6.67**	India -audits
Doors -CTC	**6.95**	Ramakrishna P,1993, (PEN)

APPENDIX F: LIST OF ORGANIZATIONS RELATED TO THE TEA INDUSTRY

India

1. Tea Board India: 14,B.T.M.Sarani, Brabourne Road, P.O. Box 2172, Calcutta 700 001
   Phone +91 33 235-1411; Fax +91 33 221-5715; Email: teadevex@cal.vsnl.net.in
   http://tea.nic.in

2. Indian Tea Association: Royal Exchange, 6 Netaji Subhas Road, Calcutta-700 001
   Phone: (91-33) 210-2474; Fax: (91-33) 243-4301; e-mail:ita@cal2.vsnl.net.in
   http://www.indiantea.org/

3. Consultative Committee of Plantation Association: Royal Exchange, 6 N.S. Road, Calcutta 700001

4. United Planters Association of Southern India: Glenview, P.B. No. 11, P.O. Coonoory, Nilgiri 643 101, Tamil Nadu

5. Calcutta Tea Traders' Association: Royal Exchange, 6 N.S. Road, Calcutta 700001

6. Tea Association of India: Indian Exchange, 4 Indian Exchange Place, Calcutta 700001

7. Darjeeling Planters' Association: Royal Exchange, 6 N.S. Road, Calcutta 700001

8. Coonoor Tea Traders Association: P.B. 31, Coonoor , Nilgiri 643 101, Tamil, Nadu

9. Federation of Tea Traders' Association: 74 New Barden Lane, Mumbai 400 003

10. Guwahati Tea Auction Committee: G. S. Road, Disput, Guwahati 781006, Assam

11. Indian Tea Planters' Association: P.O. Box 74, Jalpaiguri 735 101, West Bengal

12. Tea Packeters Association of India: 9 Shakespeare Sarani, Calcutta 700071

13. The Tea Trade Association of Cochin: Sebrof House, Willingdon Island, Cochin 682003, Kerala

14. Federation of All India Tea Traders' Association: S P Mukherjee Road, Siliguri 734405

15. Federation of All India Tea Traders' Association: 1 Allenby Road, Bikaneri Building, 2nd Floor, Calcutta 700020

16. The Tea Trade Association of Coimbatore: Tea Trade Centre, 7/64B Mettupalayam Road, P.O. Thudiyalur, Coimbatore 641045, Tamil Nadu

17. Planters Energy Network – PEN: Contact person- Dr. C. Palaniappan, 171/2 MK University Road, Rajambadi, Madurai 625 021,Tamil Nadu, India
    Phone: 0452 - 858607, 856020 ; Fax : 0452 - 858607, 742886
    E-mail: pen@vsnl.com ; http://business.vsnl.com/solar_heater/

Sri Lanka

1. Sri Lanka Tea Board : Sri Lanka Tea Board, 574, Galle Road, Colombo 3, Sri Lanka.
   Telephone: 582236, 583687, 587386; Fax: 589132
   Email: tboard@sri.lanka.net ; http://www.lanka.net/teaboard/index2.html

2. Tea Research Board of Sri Lanka: St.Coombs, Talawakelle, Sri Lanka.
   Telephone: 05122601, 0528385, 0528386

3. Janatha Estates Development Board: 55/75, Vaxhall Lane, Colombo 2, Sri Lanka

4. Sri Lanka State Plantations Corporation: 55/75,Vaxhall Lane, Colombo 2, Sri Lanka

5. Tea Small Holdings Development Authority: 70, Parliament Road, Pelawatta, Battaramulla, Sri Lanka

6. National Institute of Plantation Management: M.D.H.Jayawardena Mawatha, Rathuwila Watte, Athurugiriya, Sri Lanka

7. The Planters' Association of Ceylon: 32,Vajira Road, Colombo 5, Sri Lanka

8. The Colombo Tea Traders' Association: P.O.Box 274, Nawam Mawatha, Colombo 2, Sri Lanka

9. The Colombo Brokers' Association: 210, De Sarem Place, Colombo 10, Sri Lanka

10. Plantation Re-structuring Unit: Ministry of Plantation Industries, 2nd Floor,-Unity Plaza, 2 Galle Road, Colombo 4
    Tel: 502002,502006; Fax: 941-502006

Vietnam

1. Viet Nam National Tea Corporation: 46 Tang Bat Ho Str, Hanoi, VietNam
   Tel: (844) 9715378 / 91209152; Fax: (844) 8212663

2. Viet Nam National Tea Corporation: 25 Nam Ky Khoi Nghia St., District 3, TP HCM
   Tel: 8441423 ; Fax: 8444326
   vinateahcmc@hcm.vnn.vn; http://www.hcmctrade.gov.vn/SaiGonTea

Equipment Suppliers

1) Consultant and Supplier of tea factory equipment/machinery,
Gem Forgings Private Ltd.
13 Brabourne Rd.
Subol Dutt Building, 6th Flr.
Calcutta-700001, West-Bengal
India
Tel: (91)(33) 242 8531
Fax: (91)(33) 242 7131
E-Mail: gemtea@giascl01.vsnl.net.
Contact: Ajay Garg, Managing Director

2) Supplier of Equipment, Machinery, Supplies & Service
Wellington Tea
45, B.P. Cross Road No. 2
Saibabacolony
Coibatore-641 011,
India
Tel: (91)(422) 431 705
Fax: (91)(422) 430 886

3) Supplier of Equipment, Machinery, Supplies & Service
Ceylon Tea Services Ltd.
P.O. Box 1938
Colombo,
Sri Lanka
Tel: (94)(1) 933-070
Fax: (94)(1) 933-080
E-Mail: Infor@Dilmahtea.Com
Contact: Merill J. Fernando, Chairman

APPENDIX G: LIST OF WEB SITES RELATED TO THE TEA INDUSTRY

General

1. Teatalk: Online Information about tea: http://www.teatalk.com/
2. General information on tea plant, tea processing, tea growing areas, etc… http://tea.hypermart.net/teapage.html
3. General information on tea business: http://www.tea.com/
4. Information about Indian tea sector, http://www.teaindia.org/
5. http://stashtea.com/ is the home page of the Stash Tea Company. It has interesting information on tea, its historical development, tea tour, medicinal properties of tea, tea auction market, etc.
6. Tour of Tea Processing Plant in Asia: http://www.teatalk.com/general/tour/tour1.htm
7. Tea Process tour: http://www.stashtea.com/teatour/40.htm
8. About tea processing http://tea.hypermart.net/manu/blackprod.html
9. Processing information on tea: http://www.longbottomcoffee.com/ctu15.htm
10. Tea processing in Japan: http://www.isei.or.jp/Tea_Museum/processing-1.html
11. Tea cultivation in Japan http://www.isei.or.jp/Tea_Museum/tea_cultivation.html
12. Tea-general information: http://www.teawebex.com/html/teatails.html
13. Tea processing info: http://www.mindburp.com/coffee/growtea.html
14. Information about Kenyan tea industry. http://tea-directory.com/World%20Tea/WTKenya.htm
15. Processing tour in Sri Lankan factory: http://www.galen-frysinger.org/tea_growing.htm
16. General information about various tea processing: http://utweb.utampa.edu/faculty/kbeach/Stimulants/sld018.htm
17. Slide show http://www.tamu-commerce.edu/coas/agscience/clasnote/fdsc210/ch19/sld024.htm

Equipment Suppliers

1. Aarkay Industries: manufacturer of tea machinery http://www.aarkay.net/
2. Tea Package machinery manufacturer: http://www.ima.it/
3. http://www.vtek.chalmers.se/~v92tilma/tea/class/chinaproduction.html
4. http://www.customizemachineries.com/teha_product_range.html
5. http://ajantasteel.com/steelsworth/fans.htm
6. Tea machine manufacturer, http://www.teatrend.com/timachines/index.htm

Standards and Benchmarks

1. Statistics: http://www.teawebex.com/html/global_overview.html & http://tea-directory.com/World%20Tea/WTKenya.htm
2. World tea industry over view http://tea-directory.com/World%20Tea/wtturkey.htm

Publications

1. Tea & Coffee – a bimonthly premier magazine for the tea and coffee industry http://www.teaandcoffee.net
2. B. Sivaram, 1996, *Productivity Improvement and Labour Relations in the Tea Industry in South Asia,* Working Paper - Sectoral Activities Programme (SAP 2.54/WP.101), International Labour Organization, Geneva, 1996. http://www.ilo.org/public/english/dialogue/sector/papers/proschem/
3. CDM-tea: Energy efficiency in the tea sector proves to be more attractive than in the food and beverage industry. 6. Specific CDM qualities ... http://www.esd.co.uk/downloads/icc_IndusEnEffic.pdf (tea CDM Kenya)
4. CDM-Tea: Fuel-switching in the tea sector: oil fired to biomass http://www.esd.co.uk/downloads/icc_KenyaCDMfinalreport.pdf (tea-KenyaCDMfinalreport)

5. Tea Leaves a Newsletter published by American Premium Tea Institute (APTI)
American Premium Tea Institute (APTI), 2160 Century Park East, #2002, Los Angeles, California 90067
Telephone: (310) 277-2636; Fax: (310) 277-2696
E-mail: apti@teainstitute.org; Website: www.teainstitute.org

6. Development of the Williames Hi-Tech International Tea Harvester, Australian New Crops Newsletter, Issue No 7, January 1997, http://www.newcrops.uq.edu.au/newslett/ncnl7-72.htm (Development of the Williames Hi-Tech International Tea Harvester-Australian New Crops Newsletter)

Industrial Associations/ Organizations

1. Indian Tea Association: http://www.indiantea.org/
2. Tea Board of India**:** http://tea.nic.in
3. Sri Lanka Tea Board: http://www.lanka.net/teaboard/index2.html
4. Viet Nam National Tea Corporation: http://www.vccisme.com.vn/sme_yellow_vntea.htm
5. Global Tea boards http://www.teawebex.com/html/global_teaboard.html
6. Kenya tea development agency: http://www.kenyaweb.com/agriculture/boards/ktda.html
7. The East African Tea Trade Association: http://www.africaonline.co.ke/eatta/info.html
8. A discussion board/ Forum for tea lovers http://tea.hypermart.net/cgi-bin/robboard/
9. Tea Forum http://www.tea.com/cgi-bin/ubb/Ultimate.cgi
10. Bangladesh tea board: http://www.bdteaboard.com/
11. American Premium Tea Institute serves to provide information for education, training and reference materials about tea http://www.teainstitute.org/index.html

Companies

1. Anuraj Agencies– Importers and Exporters: http://www.erosh.com/erosh/EXPORTS/TEA/tea.html
2. Barnes & Watson Fine Tea: http://barnesandwatson.com/

3. Longbottom Coffee and Tea, Inc: http://www.longbottomcoffee.com/company.htm
4. Ningbo is one of the main tea-production bases in China http://www.nbtea.com/encompy.htm
5. Unilever, Sri Lanka: Suppliers of tea bags, flavoured tea, instant tea, and bulk tea: http://www.lanka.net/lisl2/yellow/lipton/index.html
6. Maruichi Green Tea, Japan, http://www.maruichi-jp.com/e_index.htm
7. http://stashtea.com/ is the home page of the Stash Tea Company. It has interesting information on tea, its historical development, tea tour, medicinal properties of tea, tea auction market, etc.
8. Exporters of Ceylon tea: http://www.stassengroup.com/stassen/Home/home.html
9. Tea Manufacturers http://stashtea.com/

Academic/Training/Research

1. Slide Show About Tea: http://utweb.utampa.edu/faculty/kbeach/Stimulants/sld001.htm
2. Slide Show About Tea: http://www.tamu-commerce.edu/coas/agscience/clasnote/fdsc210/ch19/sld001.htm