

Biomass for Boilers Installed in Large Scale Industries in Sri Lanka

Ediriweera Anusha¹ and Banadara W.A.R.T.W.²

¹Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, SRI LANKA.

²Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, SRI LANKA.

Corresponding Author: rangika@kln.ac.lk

ABSTRACT

Biomass plays a dominant role in primary energy supply in Sri Lanka. Huge amount of energy usage of the rural population is fulfilled by forest firewood, to increase the usage of biomass for energy in Sri Lanka, mainly in the industrial sector.

This study was conducted with the objectives of reviewing the status of bioenergy usage in Sri Lanka and evaluating the status of medium to large scale industries' biomass usage in biomass boilers in Sri Lanka illustrating some appropriate cases.

In Sri Lanka's energy mix, electricity power supplied through the Electricity board main grid or by diesel generator systems and thermal energy is supplied through kerosene, LPG, biomass, furnace oil, etc. Major source of biomass is fuel wood; mainly *Hevea brasiliensis*, *Eucalyptus grandis*, *Clusia rosea*, *Gliricidia sepium*, and *Acacia auriculiformis*. There are around 36 MW boilers in operational capacity; 20 MW from dendro, 12 MW from agriculture waste and the balance is from other biomasses. Biomass boilers operations consume 288,000 MT to produce the daily steam demand and majority from *Hevea brasiliensis* (rubber wood).

Hundred industries with biomass boilers were surveyed; Rubber, Tea, Edible oil, Beverages, Food, Packaging, Dairy, Furniture, Rice, Coconut, Construction, Others (bakery, tile factory, brick factory, briquettes

manufacturing center, hospital). Survey respondents use fuel wood, saw dust, coconut shells, paddy husk, and own waste, in 70,000 kcal/hr hot water generator boilers, 1500 kg/hr wood fired steam boilers, and 6000 kg/hr - 2000 kg/hr water-wall boilers.

Keywords- Energy mix, Biomass, large scale industries, wood chips, biomass boilers

I. INTRODUCTION

Biofuel are developed from timber materials or bio mass. Bio mass is renewable source of energy used for create heat for different applications, and it is used for power generation as well. Modern Bioenergy and traditional bio energy as two sectors. Traditional bio energy usage is combustion of biomass as traditional charcoal and wood. Modern technologies as liquid biofuels from bagasse and other plants, wood pellets so on. According (*World Energy Resources 2016*) to three-quarters of the world's renewable energy use with traditional bioenergy. Biomass can boost energy supplies with rising demand of all over the world.

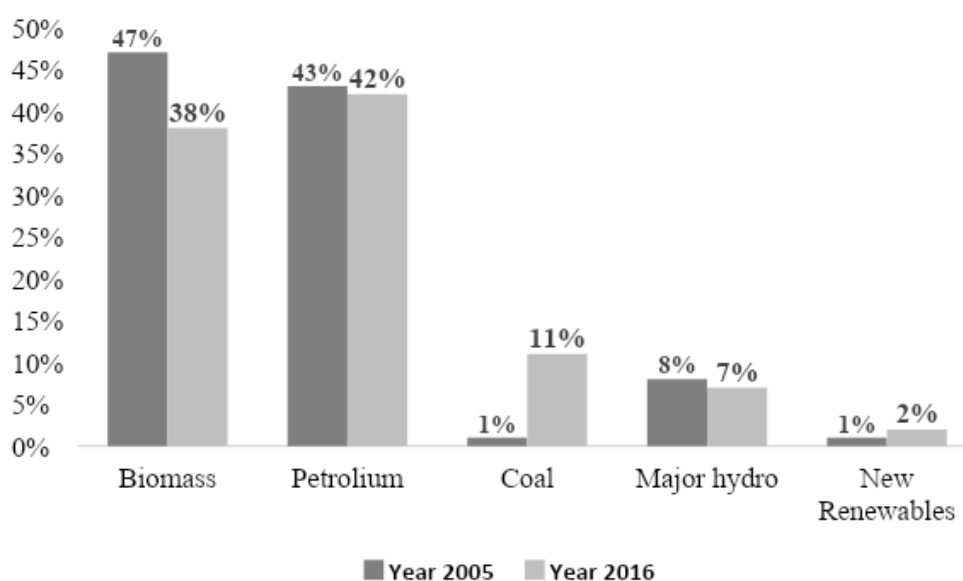


Figure 1: Primary energy supply sources in Sri Lanka in 2016 compared to 2005
Source: SLSEA, 2018

Sri Lanka, in the present context meets her energy demand mainly through the National grid. The total electricity generation in 2016 has been shared by bio mass 38%, Petroleum 42%, Coal 11%, Major hydro 7%, new renewables 2% in year 2016. This covers the sources such as mini and micro hydro, solar, wind and biomass. Furthermore, major hydroelectricity has been exploited to its maximum capacity by now and generation sources have been changed with the induction of coal power plant from 2016 (SLSEA, 2018).

Biomass plays a vital role in the primary energy supply. As of the end of 2017, there were 10 biomass-based small power producers which is not active due to lack of bio fuel with a total installed capacity of 26.1 MW. As per the master plan of Sri Lanka renewable energy, estimation the country has a potential for 2,400 MW of biomass-based generation capacity (Sri Lanka Energy sector assessment, strategy and road map, 2019). Large quantities of firewood and other biomass resources are used for cooking in rural areas and less in urban areas. There are large amount of energy needs for the rural community is fulfilled by firewood, and the predictions on further increase of usage in biomass for energy in the country (Ediriweera A.L et. al 2020). It proves mainly for the industrial sector.

This study was conducted with the objectives of reviewing the status of bioenergy usage in Sri Lanka and evaluating the status of bioenergy usage in biomass boilers in medium to large scale industries in Sri Lanka illustrating some appropriate cases.

II. METHODOLOGY

The methodology commenced from the literature review on biomass energy usage in Sri Lanka

using annual reports developed by relevant authorities, peer reviewed publications, news bulletins, magazines, conference proceedings, etc. it partially depends on statistical data to estimate the availability of biomass for energy production and other uses ,Identifying main bio mass usage industries in Sri Lanka and assessment in each sector with a case study. To analyse this data surveyed within 100 stake holders with main industries using currently tea industry Bio mass boilers were surveyed.

III. FINDINGS OF THE STUDY

Energy and bioenergy use in Sri Lanka

Considering biomass energy resources, solar, hydro power, wind, are in to renewable energy. From the history of Sri Lanka fuel wood play an important role to support in the energy balance. Sri Lanka is an island of about 20 million population with urban, rural, and estate population of 14.6%, 80.0%, and 5.4%, respectively. Forest timber is the main cooking fuel used by 78.3% by households and 96.3% of estate sector households, 84.2% rural households, and 34.6% of urban households. (Nandasena sumal et. al.; Wickramasinghe Rajitha et.al.; Satiyakumar Nalini et.,el., 2012)

Sri lanka bio mass fuel usage from forest timber, tea branches, saw dust, dry wood stems, municipal solid waste, rubber plantations, coconut plantations, Gliriceedia plantations and other invasive plantations will be around 48%. Biomass energy is the most common source of energy in the household sector. Small commercial and manufacturing applications consume around 20.3% and agro industries consume about 7.3% of the total biomass consumption in year 2017 (Source: Sri Lanka Energy balance, 2017)

Table 1: Different types of energy sources used for cooking purpose in Sri Lanka, 2017
(Source: Sri Lanka Energy balance, 2017)

Type of energy source	Percentage usage
Fuel wood and other biomass	87.5 %
Electricity	6.6 %
Kerosene	4.8 %
LAG (LPG)	1.1 %

Biomass plays an important role in the industrial sector in Sri Lanka (38%), Petroleum (42%), and electricity from the main grid (12%) (SLSEA, 2018).

However, distribution of biomass usage in industries gives a huge support due to biomass is used by industries by tradition where biomass is readily available. But the government has stopped forest timber usage and it's an issue in the industry where as the plantation sector

has commenced plantations for their bio mass as well. Tea industry is the largest industrial consumer of fuel wood, consuming about 455,000 tons a year, followed up with the apparel sector representing 43% of industrial fuel wood consumption (SLSEA, 2018). Biomass is also used

for in certain small and medium scale industries such as bakery, brick, tile and rubber-processing.

Increase of fossil fuel prices, fuel wood demand in industries has been fluctuating around 72% in the period of 2000 – 2007 which means a change from 1,052 thousand toe to 1,506 thousand toe in absolute terms) Due to the cost and the environment benefits, the larger scale industries formally on furnace oil, diesel or LPG are planning to convert their processes in to use wood/biomass for the industrial boilers. Fuel switching from fossil fuels to fuel wood or other biomass as it offers a better economic and environmental justification. However the recent technological developments related to the conversion technology such as gasification and improved energy crop production have made possible to produce bio energy at lower cost and with higher conversion efficiencies, which could make it competitive with other commercialized fuels (SEA, 2017).

Sri Lanka has a full potential of biomass usage in to the economy since 94% of households in the rural sector use biomass for cooking purposes. Forest timber and other various biomass are the dominant fuels most of the energy used by households. In tea plantation sector,

fuel-wood is also used for space heating. However, in urban areas LPG, Kerosene and electricity are used for cooking and only 79% of households in rural areas rely primarily on fuel wood.

Fuel wood plantations in Sri Lanka

Sri Lanka Government identified the impotency of biomass for large scale power development and it will help to shift power generation away from the cost of expensive fossil fuels. However, end of year 2017, 10 biomass-based small power producers with a total installed capacity of 26.1 MW were identified. According to the Sri Lanka Renewable Energy Master Plan estimation, country has a potential for 2,400 MW of biomass-based generation capacity. Therefore gliricidia plantations for the supply of fuel wood for power generation from all the non-agricultural lands and the barren lands being used for the estate crops of tea and coconut as well (Palihakkara I.R et.al 2015). Development of this activity is now available for rural farmers and also for large-scale plantation enterprises to engage in Dendro cultivation (SEA, 2017). Year 2018, there are 1066.88 ha of lands were cultivated for fuel wood under different state own agencies and authorities.

**Table 2: Total cultivated land extent in year 2018
(Model fuel wood plantation for sustainable energy supply and livelihood development, 2018)**

Organization	Number of hectares (ha)
Cultivated Forest Department Land Extent	101.60
Coconut Cultivation Board	242.80
Rubber Research Institute of Sri Lanka	100.00
Regional plantation companies	123.67
Non-governmental organizations & community -based organisations	498.1
Total cultivated Land extent	1066.88

Improvements of timber based bio mass energy will support to poverty reduction, support to reduce foreign savings and will support for environmental friendly technology. This will be based on plantations on *Gliricidia sepium*, *Acacia auriculiformis*, *Leucaena leucocephala*, *Cassia simaea*, *bamboo* and to a lesser extent *Eucalyptus camaldulensis* and *Calliandra calothyrsus*. The land availability, for these plantations will be identified as scrub land suitable for the growing of forest plantations particularly for short rotation fuel wood and to increase the present forest cover of 1.7 million ha to a more acceptable level (Gunathilake H A J et. al.; 2009; Joseph P Get, et. al.; 200, Wickramasinghe. H et. al., 2009.) During the dry seasons farmers could be occupied to find alternative work to meet their requirements which would be flexible to fit into the

demands of the current farming calendar.

Increase of fuel wood usage is an issue to the forest cover; hence it is necessary to expand in the cultivation of trees with a bio mass ability. Due to increase of fossil fuel and there environmental hazards, the development of alternative energy sources which are cost effective and environmentally friendly has become very serious issue. Among all tested species, *Gliricidia sepium* received the high priority. It has been shown to have the capacity to produce wood in excess of 20 mt /ha/year (SEA 2017) The Sri Lankan Government has given recognition to upgrade fuel wood farming to a similar level to that of other major plantation crops such as Tea, Rubber and Coconut by declaring *Gliricidia* as the 4th Plantation Crop (Palihakkara I.R and Makoto Inoue 2018).

Table 3: fuel wood types and usage as a source of energy their calorific values, land extents, climatic regions, and uses (Forestry Sector Master Plan (1995-2000))

Species	Avg. wood Production (cum/ha)	Calorific Value (kcal / kg)	Land extents exist in the country by 2019 (ha)	Climatic region in Sri Lanka	Uses
<i>Gliricidia sepium</i>	25-40	4,900	40	Low and mid elevations	Plantations, live fences and other hedge rows
<i>Calliandra calothyrsus</i>	15-50	4,500-4,750	50	Mid and high elevations	Tea lands
<i>Acacia decurrens</i>	15-25	3,530-3,940	25		Tea lands: high altitudes
<i>Acacia auriculiformis</i>	05-60	4,800-4,900	60	Low and mid altitudes	Wide spread
<i>Pariserianthus falcata</i>	30-50	2,865-3,357	50	Low and mid altitudes	Mainly on tea lands
<i>Casurina equisetifolia</i>	30-50	4,950	50		Coastal areas
<i>Leucaena leucocephala</i>	24-60	4,200-4,600	60	Low altitudes	Wide spread
<i>Clusia rosea</i>	125-150	4,154	150	Mid and high elevations	Tea lands
<i>Eucalyptus grandis</i>	40-200	4,700-4,800	200	Mid and high elevations	Tea lands

The Forestry Sector Master Plan (1995-2000) was formulated with the intention of implementing National Forest Policy. Several sections were dedicated to bioenergy development. The Plan mentioned development a national bioenergy strategy, and the establishment of a single agency responsible for coordinating the implementation of this strategy has not happened yet. Some strategies are highlighted for the promotion of fuel wood plantation as the main biomass source for energy purposes. Planting and maintaining a sufficient fuel wood plantations, encourage planting different bio fuel species in home gardens by providing an additional income to the planter, Planting bio fuel species along the state roads, riverine areas and stream banks and other available lands, allocate government lands on a long-term lease to plant trees, arrangements to provide credit facilities and other necessary incentives, advise barren tea lands into fuel wood plantations with fast-growing and high calorific value fuel wood species, training for government, NGO and plantation organizations working in forestry and tree production systems to plan and implement integrated tree based farming systems. Promote biomass for power generation and thermal applications in the industry and commercial sectors, Sri Lanka government policy decision to promote the commercial cultivation and utilization of fuel wood-

Sustainable fuel wood supply is a necessity in facilitating fuel wood use and its primary aim for catalysing commercial investment on fuel wood supply chains and establishment of a physical locations for storage and value addition. Building a bigger local market

for sustainable fuel wood and raise investor confidence among private sector and promote shift energy source from fossil fuel to sustainable biomass energy.

The bio mass terminal is a need of developing sustainable fuel wood production. However, some studies showed that the annual rice straw energy potential can be used to fulfil 257 days of steam demand and annual energy potential of rice husk can be used to fulfil the 246 days of steam demand in Sri Lanka. However, dendro has been identified as the most suitable fuel type with several side benefits. To overcome annual steam demand from biomass boilers, it is required to maintain around 13000 hectares of dendro plantations annually (*Arachchige et al., 2019; Sandupama PW et al., 2019*). At present, this will apply only for fuel wood and not apply to other sources. Ex: agro waste and residues. The main idea of bio mass energy terminal is to reduce greenhouse gas emissions from fossil fuel used for thermal energy generation in the Sri Lanka industrial sector by removing barriers to the realization of sustainable biomass plantation and aim to improve biomass-based energy technologies. Terminal will operate as a collection and distribution centre of biomass energy, even out demand and supply fluctuations, and play an important role in the long-term sustainability of the biomass energy sector.

Usage of biomass in medium to large scale industries

There are around 36 MW boilers are in operational capacity; 20 MW from dendro, 12 MW from agriculture waste and the balance is not yet commissioned by the Sustainable Energy Authority of Sri Lanka. Bio mass boilers operating in Sri Lanka which consume

approximately 8000 MT bio mass for 1 MW (36 MW x 8000 MT – 288,000 MT) metric tons of biomass to produce the daily steam demand, and most of the

industries are currently using rubber wood as the main source of biomass (SEA, 2019).

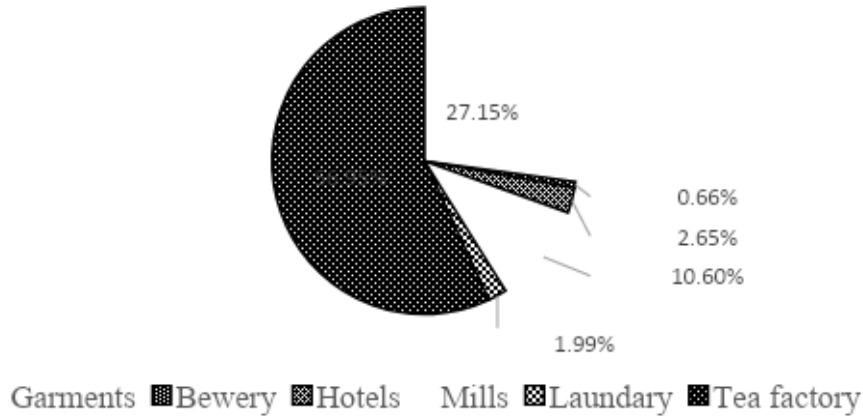


Figure 2: Percentage of industries with installed biomass boilers

Source: Sustainable Energy Authority, 2017

The main problems with biomass industrial boilers are deforestation to meet the biomass demand. CO2 emission to the atmosphere, Water sources depleted, atmospheric temperature increased, High amount of ash

generated, as it comes with bigger sizes, shredding and convert it to small pieces will take time and labour hours. Expensive and finally lead for the many environmental pollution problems.

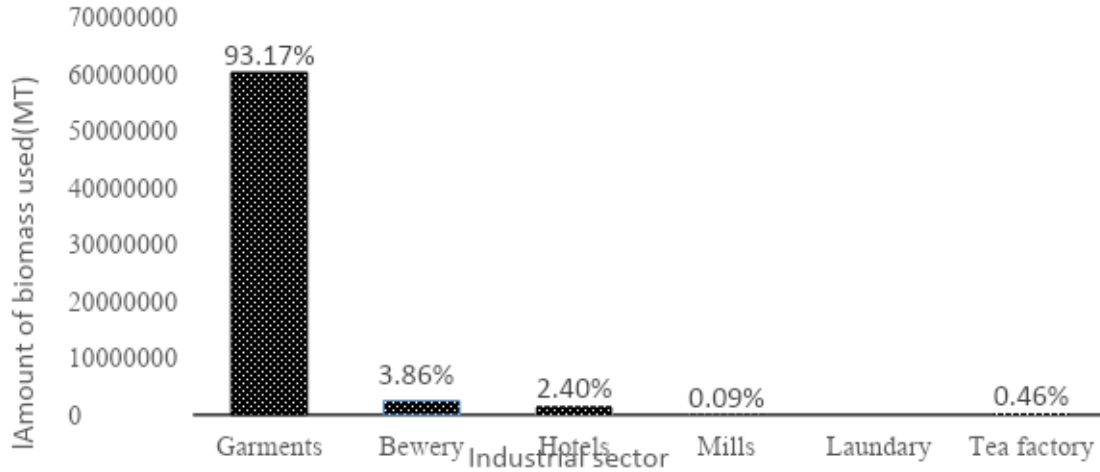


Figure 3: Annual fuel wood consumption by industrial boilers in MT

Source: Sustainable Energy Authority, 2017

Biomass based thermal energy has been popular among the Sri Lankan manufacturers due to contribution of fuel cost towards high manufacturing cost and contribution of biofuel on climate change mitigation. This trend were stable due to the supply chain of biomass, technical stability and maintenance, policy changes government. However, Sustainable Energy Authority, NERD and non-government organizations (Biomass

Energy Association) are involved in promoting biomass as a source of fuel for thermal energy generation. There may be many problems will hinder renewable mode of energy generation in future.

Promoting sustainability biomass energy production and modern bio-energy technologies in Sri Lanka, The primary goal is to reduce greenhouse gas emissions from the use of fossil fuel for thermal energy

generation in the Sri Lankan industrial sector. The goal will be reached by means of removing obstacles to the realization of sustainable biomass plantation, increase of market share of biomass energy generation and adoption of biomass- based energy technologies in Sri Lanka and to achieve the above discussed targets following areas has to be streamlined and consists of following components, like Policy Institutional support for effective fuel-switching using fuel wood, Barrier removal for sustainable fuel wood production, Enabling environment for fuel wood suppliers, Wood-based energy technology development etc.

Sri Lanka is blessed to have a minimum proportion of its energy needs from bioenergy all over the island. Fuel wood is the most significant bio resource, used for household cooking, although its share is in decline as the use of petroleum for transport and electricity generation is increasing. Nonetheless, the prohibitive cost of petroleum imports and increasing

global concerns about climate change are encouraging the Sri Lankan government to put in place measures for exploring alternative sources of energy, bioenergy being a favourable choice.

Furthermore, Sri Lankan usage of biogas energy potential from agricultural, human, municipal and livestock waste is identified as 4,000MWh per day as well as for biofuels. It is estimated that Sri Lanka could generate over 24,000GWh per year from dendro power alone (both naturally grown and from energy plantations) (Jayasinghe P., 2009). This is nearly 4 times the country's total hydro power potential and is adequate to meet the country's electrical energy demand for many decades (Jayasinghe P., 2009).

Survey findings

Survey results of 100 large scale industries on their biomass consumption of coconut, textile, edible oil, tea, rubber, food, furniture, rice, others using bio mass energy are illustrated in Table 3.

Table 4: Type of biomass consumed by the industrial sector per year % and total in Metric Tons (MT)

Industry Sector	Industries surveyed %	Fuel wood consumption per year %	Saw dust consumption per year %	Coconut shells consumption per year %	Own generated waste consumption per year %	Paddy husk consumption per year %
Rubber	2	34	10	-	-	-
Tea	45	33	10	3	-	12
Textile	20	18	15	7		6
Edible oil	1	3	12	32	88	11
Beverages	2	3	-	-	-	-
Food	10	2	10	-	-	-
Packaging	3	1	-	-	-	-
Dairy	3	1	-	-	-	-
Furniture	5	-	6	-	-	-
Rice	2	-	5	4	-	70
Coconut	1	-	27	30	-	-
Construction	1	-	-	1	-	-
Others	5	5	5	23	12	1
Total Biomass (MT)		697,370	208,216	55,280	16,000	178,000

There is a need for research to produce more up-to-date data on the energy potential from naturally grown bio resources to justify the need for energy crops. The same applies for quantifying the potential of fuel wood in meeting the country's energy demand. Data on biogas production potential is available, but since production would be quite decentralised (with the exception of production from landfills or buildings such as abattoirs or

prisons) it does not appear to be a feasible option for centralized energy production. However further research is still needed on: suitable species for biofuel production, climatic and soil conditions, diseases, nutrient requirements and yield data. Furthermore, due to the absence of sufficient commercial-scale bioenergy plantations in Sri Lanka, their social and environmental impacts are still unknown.

Case study 1- Tea Industry and biomass boiler usage

Sri Lanka Tea industry has a prominent brand name and having the main production for agriculture based foreign exchange earner. Sri Lanka produces about 300 million kg of tea annually and there are about 700 factories in operation in the country. Their energy usage is based on electrical energy and thermal energy. Electrical energy is supplied through grid or diesel generators and the thermal energy is used to generate hot air for the drying and withering processes and the fuel source widely used is bio mass firewood. (Asia pacific news, 2020) Sustainably grown fuel wood is readily available in these estates the saving of fire wood, user friendliness of the system and ability to produce better quality tea makes this system more viable.

The use of biomass resources differs, depending upon the climate. Fuel wood in the estates mainly comprises from tea pruning, up-routings from the tea fields, and cuttings from shade trees. Firewood use in the tea estates can be divided into; tea pruning 61.7%, roots 29.5% and cuttings of shade trees 8.8% (Danapala Kiran, et. al.; Wijayatunga priyantha et. al.;2002).

Increase of the cost of tea production will be a reason of the cost of fuels used by the industry. *Eucalyptus grandis*, *Eucalyptus robusta*, *Eucalyptus* species, *Eucalyptus camaldulensis*, *Acacia mangium*, *Acacia decurrens*, *Corymbia torelliana*, *Gliricidia sepium*, *Hevea brasiliensis*, *Cinnamomum zeylanicum*, *Anacardium occidentale*, *Leucaena leucocephala* MB, *Calliandra calothyrsus* are common fuel wood Species in

Sri Lanka and *Grevillea robusta*, *Khaya senegalensis*, *Tamarindus indica*, *Macaranga peltate*, *Thespesia populnea*, *Cassia spectabilis*, *Terminalia catappa*, *Pterocarpus indicus*, *Pongamia pinnata*, *Gmelina arborea*, *Trema orientalis*, *Myroxylon balsamum*, and Bamboo are other secondary fuel wood species use in Sri Lanka.

Medium size estates fired by biomass dryers are in suburb areas of southern province and the largest organic tea manufacturers 2-160 Ton/hour (manufactures on average 3000 kilogrammes of green tea leaf daily. Tea factories has installed a biomass fired dryer to facilitate the strong sustainable philosophy of “going green” and “zero carbon emission” concept. The dryer was commissioned in January 2017 and installed in the factory premises. Prior to the introduction of the new biomass dryer, the estate was manufacturing up to 110 kilogrammes of tea per hour using two old dryers. The extreme temperatures that prevailed in the work stations and the efficiency of the new dryer has increased production by more than 100 percent, offers a better temperature control mechanism and has increased the control of the biomass feeding and the estate has recorded a very low carbon footprint of 0.51kg per made tea kilo. The value addition has been increased per hour production and the improvement of the quality of tea, which in turn has increased the price of tea sold at the auctions to get overall, the tea has a better aroma, taste and feel, which has been vastly appreciated at the auctions (Daily mirror 7th September 2017).

Table 5: Tea Industry and biomass boiler usage

Technology application	Specification of Biomass fired dryer
Main application for	Drying tea leaves
Capacity	1000 kW
Baseline technology	Old biomass dryer
Annual GHG reduction	273 t CO2e

Case study 2– Hospitality industry and bio mass boiler usage

Hospitality industry is in Sri Lanka play a vital role in the economy. Tourism has grown with the attraction to the country and it consumes about 5% of the total energy consumed industrial sectors. The energy performance of hotels will be depending on the services provided to the clients. However it is essential to set benchmarks for each hotel catogaries according to the level of service provided (Sri Lanka Energy balance 2017).

Rising of energy price and eco consciousness with the travelers is forcing hoteliers to explore environment-friendly and sustainable methods of running their properties. Renewable energy is a profitable way of

reducing costs and subsidizing overheads, particularly renewable heat in the form of biomass.. The use of biomass energy at one of the international hotel chain in Sri Lanka Jet wing Hotels goes back to 2008. Since then the use of biomass has become a standard practice in there hotels wherever possible. The first biomass boiler was installed at Jet wing Blue with technical and financial success. This was replicated at Jet wing Sea, Jet wing Lighthouse, Jet wing Beach and Jet wing St. Andrew’s. The boilers were utilized to generate hot water for guest rooms and steam for the laundry. Taking a further step, steam-driven absorption chillers were installed instead of electricity driven conventional chillers powered entirely by steam produced from the biomass boiler. This made the reduction of electricity consumption of the hotel by

around 50-60 percent. This novel technology was first installed at Jet wing Lagoon, with the success of its operation and the financial saving achieved, similar systems were installed at Jet wing Yala, Jet wing and most recently a steam-driven absorption chiller was commissioned at Jet wing Blue.

Main target of Jet wing Hotels' sustainability strategy is to manage and reduce energy and carbon footprint. The transition to biomass energy aids in both avoiding emissions from equivalent non-renewable energy sources (diesel or grid electricity) and reducing associated operational costs. In terms of financial savings to obtain approximately 40-50 percent saving from the biomass boiler and 20 percent saving on boiler and absorption chiller installations. Cinnamon fuel wood, used at Jet wing Hotels, is considered a sustainable source of fuel wood due to its short cropping cycle when compared to other more widely available fuel wood such as rubber and off cuts. Cinnamon is a virtually carbon

neutral source of energy and the transition to biomass energy has resulted in avoiding over 2,000 MT CO₂ emissions (per annum) from across the Jet wing Group of hotels. (UNDP/FAO - GEF Terminal Evaluation for Promoting Sustainable Biomass Energy Production and Modern Bio-Energy Technologies- 2018) Cinnamon is not grown as a fuel wood the wood itself is considered a waste or by product of the industry. In creating and maintaining a stable supply chain for the purchase of this 'waste' product, the hotel managed to provide the cinnamon farmers with an additional income passing on part of benefits of our savings to the villagers.

The estimated mitigation of carbon emissions avoided is over 2,000 MT per annum. 30 cinnamon wood suppliers who collect the product from different villagers in the region and communities involved around this project are also benefitted, not just to the farmers but also the local supply chain comprising collectors and distributors.

Table 6: Hospitality industry and bio mass boiler usage specification

Technology application	Water heater
Main application	Hot water for guest rooms
Output	Power 150 litres/hour of water at 100 OC
Annual GHG reduction	8 tCO ₂ e
Investment	1500 US\$

Case study 3- Home based dried food production and bio mass boiler usage

Considering healthy, organic and vegan diet patterns among global consumers. Processed food manufacturers in Sri Lanka are combining innovative food processing methods with highly nutritious traditional local ingredients to prepare food and beverage. These processed food and beverages are mainly based on natural fruits, vegetables, and cereals like rice and millet that are natural. The processed food and beverage sector covers a wide range of products including coconut, vegetables, and fruit-based products, concentrates and juices, semi-cooked food, confectionery, and bakery products, ready-

to-serve food, beverages, animal feed, and preparations of cereals and flour in Sri Lankan market. Sri Lanka exports focused on agricultural products in primary form without a value addition. With the global trends moving towards health-conscious consumers, exports currently value added products. Hence the Sri Lanka agricultural practices, agro industries and manufacturing companies expanded product range to meet these demands and products to meet the global quality standards in processing, packaging and green manufacturing. Success is in numbers; there has been a significant growth in export values over the last 10 years.

Table 7: Home based dried food production and bio mass boiler usage specification

Technology application	Dryer
Application	Drying fruits and vegetables
Output capacity	Power 240 kg/day
Annual GHG reduction	29 tCO ₂ e
Investment cost	2000US\$

Case study 4- Small hotels and bio mass boiler usage

Small hotels have to be prudent about costs and productivity. Its 9-bed roomed hotel requires hot water for the guest rooms as well as for cooking and drinking purposes in the kitchen, and laundry opted for power-saving measures and invested in a 12-kW biomass fired boiler under a co-financing investment of 726 US\$. Since the installation of the biomass fired boiler, the hotel's monthly electricity bill has reduced by 50 percent. The hot water needed can be regulated as and when required,

ensuring there is no wastage. Firewood is sourced from the local timber store at no cost. Lesson learned one of the key requirements for hotels in the hill country is hot water. The biomass fired boiler is discreetly concealed in the beautiful garden of the hotel with easy accessibility. There is no smoke or smell when the boiler is in use, thus ensuring the healthy and salubrious atmosphere that guests enjoy in this region. There is also room for scalability if and when the hotel increases its capacity.

Table 8: Small hotels Boiler usage specification

Technology application	Water heater
Main application	Hot water for guest rooms
Output	Power 150 liters/hour of water at 100°C
Annual GHG reduction	8 tCO ₂ e
Investment cost	1500 US\$

Case 5- Healthcare industry and bio mass boiler usage

Monaragala general hospital is the largest government healthcare institution in the Uva province catering to over 500,000 patients an year. The hospital comprises 10 wards, an Intensive Care Unit, Preliminary Care Unit, Special Care Unit, medical laboratory, blood bank, Out Patients Department, and a Radiology Department. But what is unique about this hospital is the 'green' initiatives carried out by the hospital authority.

The hospital mandate is to move on with environmental management activities that adhere to zero waste and zero carbon emission through proper energy and waste management initiatives such as bio gas from composting, organic farming and biomass energy practices. To adhere this philosophy the hospital practiced every member of the hospitals' staff; from tending to the organic vegetable plots, to ensuring recyclable bins located all across the hospital premises are being properly used, to feeding the biomass boiler for the use of hot

water, etc. to conform to zero carbon emissions and the hospital collaborated with the Promoting Sustainable Biomass Energy project, and installed a biomass boiler that provides hot water (for drinking and personal use) in five of its wards, and hot water for cooking and drinking in the kitchens and for other uses. The new boiler is powered by discarded coconut shells from the kitchen, wood chips from the garden, and other biodegradable wastes.

The capacity of 12 KW boiler was commissioned in December 2016 and provided up to 600 litres of hot water per day. The annual Green House Gas (GHG) reduction is 2.57 TCO₂. The hospital cost saving of almost 1100 US\$ in the first six months since the boiler installation. Since its installation the CO₂ saved is 3493.5 kgs and there has been a saving of 4992 KWh of electricity units. This is such an achievement towards our goal of zero carbon emissions. The ultimate goal is to reduce 8,000 kgs of carbon emission an year.

Table 9: Healthcare industry and bio mass boiler usage Bo specification

Technology application	Hot water
Output Capacity power	12 kW
Previously	LPG
Investment Cost	2900 US\$
Commissioned	December 2016
Annual GHG reduction	2.57 tCO ₂

Case study 6- Yoghurt Industry and bio mass boiler usage

Yogurt has always been a popular dairy-based meal/snack. In Sri Lanka, yogurt is consumed as a snack and dessert amongst children and adults. One of the popular yogurt in the Uva province considering the sales per month and their biggest cost was electricity consumption and the price they doled out for almost there 90 KG gas cylinders per day for the heating process. That was our biggest cost and they hardly made a profit after paying off these bills. Also, there were times when

the production had to be halted or discarded because of contaminants or improper heating as one of the main requirements in yogurt production is the accurate heating processes to ensure the final product is of the best quality. In 2016 Sustainable Biomass Energy Project and co-financing availed of a 12-kW biomass fired water heater for 2400 US\$. This heater can boil 230 liters of milk per month saving the industry around 167 US\$ per month. Sustainable fuel wood is sourced from a neighborhood timber store.

Table 10: Yoghurt Industry Boiler usage specification

Technology Application	Yogurt production
Output capacity Power	150 liters /hour of water at 100 ^o C
Annual GHG reduction	17 tCO ₂ e
Investment cost	4800 US\$
Commissioned	December 2016

IV. CONCLUSION AND DISCUSSION

Biomass is widely used in the industrial sector, for a variety of thermal energy applications to the employ a range of energy conversion devices utilizing direct combustion technology. The tea processing industry and the apparel sector are the largest industrial consumer of bio fuel wood. It uses furnaces, boilers, gasifiers for drying and weathering tea. The coconut industry has the fuel wood furnaces, coconut shell-fired copra kilns, fuel wood boilers and carbonization gas-fired furnaces to meet the energy requirement. Rubber processing industry has furnaces and boilers. Tobacco industry has fuel wood barns and paddy husk-fired barns. Sugar industry is using Bagasse-fired boilers. The brick, tile, lime, pottery and bakery industries use fuel wood kilns for their production processes. Distilleries use fuel wood furnaces and paddy husk-fired boilers in their manufacturing process. The rice milling industry utilizes paddy husk-fired boilers for parboiling operation. Energy efficiencies of most of the machinery are not satisfactory and there is considerable potential for energy conservation and utilization of improved biomass energy technologies in each application.

Bakeries, hotels and restaurants are using a significant amount of fuel for cooking and baking. Still the ovens and cook stoves still operate with low efficiencies. LPG, kerosene and diesel are also used as alternative fuels, mainly for convenience, but the increasing costs of these fuels have compelled users to seriously consider switching to improved biomass energy technology.

The main issues of the lack of bio mass fuel wood in Sri Lanka means that excessive bioenergy requirements will be a threat to bio resources in the country. However, if biofuel plantations and other production expanded to meet the demand of a growing bioenergy industry will impact on land and food availability in the future. The other problems with the use of firewood mainly with the generation of ash and smoke, difficulties of transport and storage.

Traditional Cook Stoves are the three-stone stove and the semi-enclosed mud stove called “Sinhala Lipa” (similar to the U-Chulah stove), and the Anagi stove is the most popular Improved Cook Stove using in Sri Lanka. Improving Cook Stoves could play a vital role in reducing overall expenditure on firewood, saving around 41% of the fuel wood currently used in Traditional Cook Stoves (Musafer N., 2008). Based on research 12% of fuel wood in the domestic sector is currently being used in improved Cook Stoves, hence there is still great potential for energy savings. Industrial scale, currently 5 major fuel-wood installations in Sri Lanka with a total capacity of 7.18MWth, consuming a total of 56 tonnes of fuel wood per day (Jayasinghe P., 2004). These are for wood gasifiers for generation of hot air for drying products, for firing rotary kilns and for thermal incineration. However, it is difficult to develop continuous supply chains. Mostly electrical energy is supplied through grid or diesel generators and thermal energy is supplied through various solid, liquid and gaseous fuels such as diesel, furnace oil, kerosene, LPG, biomass etc.

**Table 11: Employing bio mass Energy in a large scale Industry –A SWAT analysis
(Adopted from Nunes Leonel et. al.: Godina Radu et. al.: Matias Jogo 2019)**

Strengths	Weaknesses
<ul style="list-style-type: none"> • Increase of energy efficiency. • Increase competitiveness by reducing the energy costs. • Increase of apparel dependent industries, suppliers, creation of job market. • Decreasing the imports of natural gas, coal, etc. 	<ul style="list-style-type: none"> • Difficulty in logistics and supply priority for initial investment. • Spaces utilization for the updated equipment. • Recurrent price variation and certain physical traits of the biomass. • Absence of a clear successful example for validation on biomass as an alternative.
Opportunities	Threats
<ul style="list-style-type: none"> • Difficult to penetrate into the energy market. • Lack of a steady national policy that could promote sustainable exploitation of renewable energy in industry. • Doubt of decision makers regarding the potential of biomass 	<ul style="list-style-type: none"> • Difficult to penetrate into the energy market. • Lack of a steady national policy that could promote sustainable exploitation of renewable energy in industry. • Doubt of decision makers regarding the potential of biomass

According to the data collected from the industry, mainly they use fire wood from the forest, wood chips, saw dust and 2% of briquettes. The cost of a briquettes are 12 LKR – 18 LKR with the cost of transport. Price of wood logs 6/50 LKR – 4/50 LKR. The fuel-wood is obtained from plantations of *Gliricidia* and from farmers in the region who grow these trees as the company's out-grower's agricultural programs.

RECOMMENDATIONS

Continuous production and supply of biomass energy in a different way is important to prevent deforestation, preserve biodiversity, and reduce GHG emissions which contribute to climate change and mostly to promote the increased use of biomass energy in industrial boilers would be an ideal option against fossil fuel. It is important to make sure the availability of biomass and the biomass supply chain should be strengthened. Further, processing biomass with modern technologies will help to increase efficiency and the awareness on modern technology on bio mass fuel supported industry will be an optional.

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