Ministry of Environment and
Renewable Energy
Sri Lanka

Technology Needs Assessment And Technology Action Plans For Climate Change Mitigation

Technology Needs Assessment

2011

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Sri Lanka being an island nation subjected to tropical climatic influences is highly vulnerable to climate change impacts. We are already experiencing significant climatic imbalances manifested through increasing average temperatures, drastic variations in rainfall patterns and extreme climatic events such as heavy rainstorms, flash floods, and extended droughts and weather related natural disasters in various forms and severity. These extreme and sometimes unseasonal events affect not only the human lives and properties but also have long term impacts on the ecosystems as well.

"*Mahinda Chinthana* – Vision for the Future", the Government of Sri Lanka's Ten Year Development Policy Framework assigns a very high priority to the management of the environment and the natural resources sector including addressing climate change impacts. In keeping with the Government's overall vision on tackling climate change impacts, the "National Climate Change Policy (NCCP) for Sri Lanka" identifies the need of active involvement in the global efforts to minimize the greenhouse gas emission within the framework of sustainable development and principles enshrined in the United Nations Framework Convention on Climate Change. The NCCP emphasizes the importance of exploring greenhouse gas mitigation technologies and best practices already available in the country and globally, and select nationally appropriate innovative technologies, disseminating, and implementation to the extent possible with sound monitoring mechanisms.

The Government and my Ministry in particular recognizes that the Technology Needs Assessment (TNA) Project implemented in collaboration with Global Environment Facility (GEF), United Nations Environment Programme (UNEP), UNEP-Risoe Center (URC) and the Asian Institute for Technology (AIT),as the first comprehensive national exercise undertaken towards addressing our climate change concerns. Thus, the TNA Report provides an assessment of the priority technology requirements and action plans for climate change mitigation activities in energy, industry and transport sectors. I am convinced that this exercise has been a nationally driven process involving local expertise and knowledge supplemented by international experiences.

In fulfillment of the Government's firm commitment towards taking appropriate national actions for tackling climate change related issues and also collaborative obligations to the international community in this context, I have great pleasure in presenting the **Sri Lanka's National Report on Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation** to the policy makers, potential investors, technology developers, scientists and all other stakeholders who are actively participating in sustainable development efforts of the country. I also recommend this report for consideration and emulation of the world community and invite them to be partners in achieving our economic, environmental and social development goals.

Susil Premajayantha, MP

Minster of Environment and Renewable Energy

Government of Sri Lanka

PREFACE

Sri Lanka ratified the United Nations Framework Convention on Climate Change (UNFCCC) in November 1993 and acceded its Kyoto Protocol in September 2002. In keeping with the obligations of the UNFCCC, the Government of Sri Lanka submitted its Initial National Communication in 2000 and submitted the Second National Communication in 2012. Over the last two decades, Sri Lanka has made a significant progress towards improving the national policy framework and strengthening the legal and institutional capabilities to facilitate implementation of obligations under the UNFCCC and Kyoto Protocol. These timely actions demonstrate the Government's firm commitment in addressing country's environmental and climate change related issues.

Although Sri Lanka is a low greenhouse gases emitter, it is highly vulnerable to adverse impact of climate change. Analysis of past records suggests that air temperature throughout the island has been on a rising trend during the last century. The future scenarios predict higher levels of emissions and possibility of adverse climate change impacts, if no mitigatory and adaptation actions are undertaken now.

The TNA explores country needs for the reduction of greenhouse gas emissions and adaptation technologies. It also re-affirms the will of the Government along with the international community to contribute to the joint efforts in addressing the climate change threat. It is envisaged that this process will open up access to funds, create an enabling environment for the transfer of priority technologies which will improve the climate resilience of the most vulnerable sectors in the country.

I would like to take this opportunity to extent my gratitude to the Global Environment Facility (GEF) for funding and the United Nations Environment Programme (UNEP) and the UNEP Risoe Center (URC) for implementing this project in collaboration with the Asian Institute of Technology (AIT). A record of appreciation is also extended to the members of the TNA committee, Sectoral working Groups and all other experts who have contributed to this national exercise.

B.M.U.D Basnayake
Secretary
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ACKNOWLEDGMENTS

This report on Technology Needs Assessment and Technology Action Plans for Climate Change Mitigation was the outcome of the project on Technology Needs Assessment (TNA)on Climate Change Adaptation and Mitigation for Sri Lanka conducted by the Climate Change Division of the Ministry of Environment and Renewable Energy from June 2011 to April 2013.

The TNA project in Sri Lanka was funded by the Global Environment Facility (GEF) and technically supported by United Nations Environment Programme (UNEP) and the UNEP Risoe Center (URC) in collaboration with the Asian Institute of Technology (AIT). First and foremost, my appreciation goes to the GEF, UNEP, URC and AIT for their financial and technical supports.

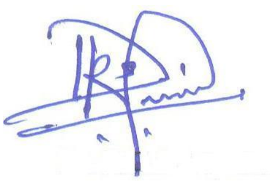
I wish to take this opportunity to express my sincere gratitude to Hon. Susil Premajayantha, Minister of Environment and Renewable Energy, Hon. Anura Priyadarshana Yapa, Former Minister of Environment, Mr. B.M.U.D. Basnayake, Secretary, Ministry of Environment and Renewable Energy and Mr. Gamini Gamage, Additional Secretary (Environment and Policy) of the Ministry of Environment and Renewable Energy for their leadership, directions and guidance provided to conduct this project successfully.

My appreciation is extended to the members of the TNA committee, sectoral working groups and all other experts who contributed to this project. I am grateful to the various governmental, non-governmental and private sector personnel who took time out of their busy schedules to meet with our consultants and to provide data and information.

I am thankful to all the consultants of the TNA project, namely Mr. H.M.Bandaratillake, Team Leader and sector experts Mr. P.G. Joseph (Energy Sector), Dr. (Mrs.) Erandathie Lokupitiya (Transport Sector), Mr. V.R. Sena Peris and Mr. Jagathdeva Vidanagama of National Cleaner Production Centre (Industry Sector).

My special thanks is also extended to the staff of the Climate Change Division of the Ministry of Environment and Renewable Energy, particularly to Ms. Anoja Herath, Coordinator of the TNA project, Ms. Nirosha Kumari and Ms. Surani Pathirana, Environment Management Officers of the Ministry of Environment and Renewable Energy.

Finally, on behalf of the Ministry of Environment and Renewable Energy I would like to thank all those who contributed to make this project realistic. Without their supports this project would never be success.



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TNA Committee – Annex A1
Workshop Participants – Annex A2

This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP- Risoe Centre (URC) in collaboration with the Asian Institute for Technology (AIT), for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein are a product of the National TNA team, led by the Secretary, Ministry of Environment and Renewable Energy, Government of Sri Lanka.

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ABREVIATIONS

ADB	Asian Development Bank
Air MAC	Air Resource Management Center
AIT	Asian Institute of Technology
BEASL	Bio Energy Association of Sri Lanka
CDM	Clean Development Mechanism
CEB	Ceylon Electricity Board
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CPC	Ceylon Petroleum Corporation
CRI	Coconut Research Institute
ESMP	Energy Sector Master Plan
FD	Forest Department
GHG	Greenhouse Gas
IDB	Industrial Development Board
IDEA	Integrated Development Association
IFS	Institute of Fundamental Studies
IPCC	Intergovernmental Panel on Climate Change
ITDG	Industrial Technology Development Group
LNG	liquid Natural Gas
LPG	Liquid Petroleum Gas
MCDA	Multi Criteria Decision Analysis
MOST	Ministry of Science and Technology
MSW	Municipal Solid Waste
N_2O	Nitrous Oxide
NCRE	Non-Conventional Renewable Energy
NEP&S	National Energy Policy and Strategies
NERDC	National Engineering Research & Development Centre
NGO	Non-Government Organization
NTP	National Transport Policy
R&D	Research & Development
RDA	Road Development Authority
RERED	Renewable Energy for Rural Economic Development
SLSEA	Sri Lanka Sustainable Energy Authority
SO_2	Sulfur Dioxide
TNA	Technology Needs Assessment
UNFCCC	United Nations Framework Convention on Climate Change (UNFCCC)
UOM	University of Moratuwa

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EXECUTIVE SUMMARY

This report describes the Technology Needs Assessment (TNA) for climate change mitigation in Sri Lanka that was undertaken between June 2011 and December 2011. In line with its obligations as a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), the Democratic Socialist Republic of Sri Lanka has undertaken a number of actions since ratifying the Convention in 1993. Sri Lanka submitted the Initial National Communication on Climate Change (INC) to the 6th Session of the Conference of Parties (COP6) in 2000, and acceded to the Kyoto Protocol in September 2002. The GHG Inventory for 2000 and Second National Communication (SNC) on Climate Change were completed in 2011. Over the last two decades the country has made a significant contribution towards strengthening of national policy, legal and institutional capabilities thus creating an enabling environment for implementation of the obligations under UNFCCC and Kyoto Protocol. Some of these policy interventions include development of National Environmental Policy (2003), National Climate Change Adaptation Strategy (NCCAS) (2011), National Climate Change Policy (2012) and Sri Lanka Strategy for Sustainable Development (2007). The National Advisory Committee on Climate Change (NACCC) was also established in 2008 and subsequently in 2012 restructured as the National Expert Committee on Climate Change Adaptation and National Expert Committee on Climate Change.

Under the UNFCCC, developing countries are encouraged to assess and report their technology needs for climate change adaptation and mitigation and developed countries have committed to assisting with the technology transfer. The TNA process in Sri Lanka has followed the guide lines and procedures recommended by UNDP/UNFCCC Handbook for Conducting Technology Needs Assessments for Climate Change (November 2010), Organizing the National TNA Process: An Explanatory Note (2010), and guidelines provided by the Asian Institute of Technology (AIT). The focus of the assessment has been on technologies that support Sri Lanka's economic development in a sustainable manner, in line with the National Development Policy Framework of Sri Lanka ("*Mahinda Chintana: Idiri Dakma*" – Vision for a New Sri Lanka, 2010). The methodology adopted in the TNA was a stakeholder-driven process to identify and assess environmentally sound technologies that will, within national development objectives, reduce the rate of greenhouse gas emissions and contribute from low carbon technology investments in Sri Lanka. The process of conducting the TNA was initiated by the Ministry of Environment with establishment of the National TNA Committee which mandated the Project Coordinator, National Consultants and Sectoral Stakeholder Working Groups to manage the process.

As the initial step of the TNA process, the priority sectors for mitigation were identified in consultation with the National TNA Committee. The priority sectors identified for mitigation were **Energy, Transport and Industry**, being the sectors with significant GHG emission reduction potentials. This prioritization was followed by preparation of a list of potential technologies for each sector in consultation with sectoral stakeholder working groups and other sector experts. Thereafter, this list was prioritized by using the Multi Criteria Decision Analysis (MCDA) process at stakeholder consultation workshops for each sector.

The process was involved in a) selecting basic criteria for evaluation, b) deciding on sub-criteria associated with each basic criterion and c) weighting the criteria and sub-criteria. Then the Performance Matrix was constructed based on the criteria and weighted scores followed by Benefit/Cost analysis for determining the most preferred, prioritized technologies.

Energy Sector:

The per capita and the total national GHG emissions in Sri Lanka is significantly very low and its contribution to the global problem of Climate Change is considered to be minimal. Nevertheless, the energy sector has taken steps to participate in climate change mitigation efforts by developing renewable energy sources and energy conservation measures aiming at reducing potential GHG emissions. According to the National Energy Policy and Strategies (NEPS) of Sri Lanka, *"the government will endeavor to reach by 2015, a minimum level of 10% of electrical energy supplied to the grid to be from Non-Conventional Renewable Energy (NCRE)*".

The TNA was a stakeholder consultation driven process which analyzed various technology options in the energy sector to identify the potential greenhouse gas emission reduction technologies. Through sectoral stakeholder consultations ten (10) potential technologies were identified as suitable mitigation options for the energy sector. The technologies were prioritized using Multi criteria Decision Analysis (MCDA). A sensitivity analysis was also carried out to examine any variations in the results by changing the weightings given for the evaluation criteria used in the MCDA process. The results showed that one group of technology options gives significantly higher benefits than the other two groups. Accordingly, three (03) most promising technology options viz; **(1) Conversion of Biomass and Waste to Energy, (2) Smart Grid Technology for Wind & Solar Integration with Hydro, (3) Building Management Systems** were identified for next stage analysis and development.

Transport Sector:

Public transport systems operated by both the government and private owners are widely used by the general public and are available in all parts of the country. The implementation of transport related policies and actions are carried out by multiple agencies falling under the purview of the Ministry of Transport and few other related Ministries. Transport sector is the major greenhouse gas (GHG) emitting sector in Sri Lanka in which about 60% of air pollution (especially in Colombo City) and 48% of the total CO_2 emissions originate from the transport sector. In total, CO_2 accounts for more than 95% of the transport-related emissions. The overall goals for selection of the technologies were to reduce city congestion due to heavy traffic including the large number of single- and low- occupancy vehicles, reduce air pollution, enhance fuel efficiency, and promote mass transportation and non-motorized transportation, all of which should lead to overall reduction in CO_2 emissions.

Initially ten (10) technologies were identified for the TNA. Prioritizing the identified technologies was carried out using the Multi Criteria Decision Analysis (MCDA). In prioritizing technologies, those options that had the highest benefit/cost ratios were selected as the best suited technologies. The analysis revealed that low cost and more environmental friendly options are more suited for the country. Based on the analysis the selected options in the order of priority are **; (1) Integration of Non- motorized transport methods along with regularized public transport system, (2) Promote car pooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles, and (3) Electrification of the existing railway system.**

Industry Sector:

Sri Lanka is not an industrialized country. The industrial production of the country has been rather low and this is reflected by the relatively low emission of 493 $GgCO_2$ for the entire industrial processing sector. Most of the local industries are not large scale and fall within categories of medium or small scale industries. Local industry sector has not expanded significantly in the recent past due to high energy costs and several other external factors. Although GHG emissions in Sri Lanka is at very low level, local industries have started improving their processes in order to reduce energy and resource consumption because of high cost of energy and other resource.

Green house gases are emitted due to burning of fossil fuels and usage of electricity generated by burning fossil fuels during industrial processes. Most of local industries in Sri Lanka are conscious of high cost of energy, hence they prefer low cost technologies which enable reducing energy bill and improve energy efficiency which are considered to be environment friendly technologies with the potential for GHG emission reduction.

Cross cutting technologies which are applicable to different type of industries are considered to be the most suitable climate change mitigation technologies for Sri Lanka. Hence, most of the selected options in the industry sector are cross cutting technologies. Ten (10) technologies mostly developed in Asian region were initially identified in consultation with the sectoral stakeholders were prioritized using Multi Criteria Decision Analysis process. Based on the results of MCDA, the technologies selected in the order of priority are ; **(1) Energy Efficient Motors, (2) Variable Speed Drivers for motors and (3) Biomass residue based cogeneration combined heat and power (CHP).** The ethanol kitchen stove and cook stove with Biomass Gasification are also recognized as favorable technologies in industrial and domestic level applications.

CHAPTER 1

Background and Introduction

1.1 Background

Sri Lanka ratified the United Nations Framework Convention on Climate Change (UNFCCC) in November 1993. The primary objective of this multilateral agreement is to achieve the stabilization of Greenhouse Gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic activities from interfering with the climate system. In September 2002, the Government of Sri Lanka acceded to the Kyoto Protocol. In terms of Articles 4.1(c), (j) and 12 of the Convention, countries are periodically required to submit reports to the Conference of Parties (COP) on strategies, plans and programmes regarding their attempts to address climate change. In order to fulfill these requirements, Sri Lanka submitted its Initial National Communication to the 6th Session of the Conference Of Parties (COP6) held in 2000. The GHG Inventory for 2000 and Second National Communication (SNC) on Climate Change were completed in 2011. Over the last two decades the country has made a significant contribution towards strengthening of national policy, legal and institutional capabilities thus creating an enabling environment for implementation of the obligations under UNFCCC and Kyoto Protocol.

Some of these institutional initiatives include, establishment of Climate Change Secretariat (CCS) within the Ministry of Environment (ME) to serve as a node for the implementation of UNFCCC decisions including the preparation of the GHG Inventory and the country's National Communications, and establishment of the Designated National Authority (DNA) for the CDM under the Kyoto Protocol (KP). In addition, the ME has been instrumental in establishing two CDM Centres at University of Moratuwa and University of Peradeniya in order to involve the University system in promoting CDM activities in the country, particularly in the areas of energy and agriculture respectively. Besides these, the Centre for Climate Change Studies (CCCS) has been established within the Meteorological Department (MD) for undertaking research on climate change including analysis of data collected by the MD and make projections of climate change based on IPCC findings and assist scientists in other institutes in carrying out impact studies in their relevant sectors. Furthermore, National Capacity Needs Self Assessment (NCSA) on Climate Change and other related areas have been carried out by the ME in 2007[1].

The recent policy and legal initiatives undertaken towards meeting the obligations of the UNFCCC include formulation of new environment related policies such as National Environmental Policy (2003), Climate Change Policy (2012) National Land Use Policy (2007) National Forest Policy (1995), National Policy on Wildlife Conservation (2000) National Watershed Management Policy (2004), National Air

[1] ME, 2007, Thematic Assessment Report on Climate Change

Quality Management Policy (2000), National Policy on Wetlands (2006) etc and the new amendments to the Forest and Wildlife laws (Forest Ordinance & Fauna and Flora Protection Ordinance)[2]. In addition, recently developed national strategies such as *Haritha* (Green)[3] Lanka Action Plan, National Climate Change Adaptation Strategy and Sri Lanka Strategy for Sustainable Development, demonstrate the emphasis that the Government places on addressing environmental and climate change related issues. Besides, the National Council for Sustainable Development was formed in 2009[2] under the chairmanship of the President of the Democratic Socialist Republic of Sri Lanka to provide leadership and guidance for sustainable development in the country. The Council is charged with the responsibility of producing an integrated policy, and overseeing and guiding the implementation of the *Haritha* Lanka Action Plan to ensure the sustainability of country's social and economic development programmes while safe guarding the environmental integrity of the country.

1.2 Objectives of the Technology Need Assessment (TNA)

The Technology Needs Assessment is carried out to identify measures and practices that might be implemented in different sectors of a country to reduce GHG emissions and vulnerability to climate change and to contribute to overall development goals. It provides multiple benefits at the country level, including the identification of barriers for deployment and diffusion of technologies and facilitate in removing of policy and legal gaps leading to improvement of enabling environments, increasing the capacity of local institutions and experts, and raising public awareness of climate change issues.

The main objective of the Climate Change Technology Needs Assessment is *"to identify and assess environmentally sound technologies that have synergy between reducing the impact of climate change and the rate of GHG emissions in Sri Lanka within national development objectives".* The TNA represents a set of country driven activities that identify and determine the most appropriate mitigation priority technologies for Sri Lanka. By adopting a consultative process, it identifies the barriers to technology transfer and measures to address these barriers through a sectoral analysis.

The Specific Objectives of the TNA are to;

a. Define priority sectors for which technologies are needed to sustain national development projects and programmes in light of the UNFCCC and potential impacts of climate change.

b. Identify suitable technologies that contribute to climate change mitigation in the relevant sectors.

c. Prioritize the identified technologies, their cost-effectiveness, and barriers to implementation.

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[2] Ministry of Environment, 2011, Sri Lanka

[3] National Action Plan for *Haritha* (Green) Lanka Programme, 2009, National Council for Sustainable Development, Presidential Secretariat, Sri Lanka

d. Develop an enabling framework for the development and diffusion of prioritized technologies for relevant sectors.
e. Develop project proposals for priority technologies for relevant sectors to mobilize resources for implementation of the programme.

1.3 National Circumstances

Sri Lanka is an island nation in the Indian Ocean, located about 80 km to the southeast of the Indian sub-continent, lying between 5°55' and 9°50' North latitudes and between 79°42'and 81°53' East longitudes. It comprises a mainland of area 65,610 km^2, including 2,900 km^2 of inland water bodies and several small islands with only six islands having area more than 1,000 ha located off the northwest coast. The mainland has a maximum length of 435 km in N-S direction and maximum width of 240 km in E-W direction. The south-central part of the country is mountainous, while the rest of the country is mostly flat undulating land. The country has a coast line of about 1,585 km, comprising sandy beaches and sand dunes, dotted with many lagoons, estuaries, marshes, mangroves and deltas. There are altogether 103 rivers spread around the country[4].

The climate of the country depends largely on the monsoon wind pattern. The annual mean surface air temperature of the island has an average value of about 27 °C, with the values varying between 35 °C in the lowlands and about 15°C in the highlands. The country receives rainfall over 2,500 mm annually in the south-west quadrant during the south-western monsoon period, while receiving below about 1,750 mm annually during the north-eastern monsoon period. Based on the rainfall, the country is divided into three climatic zones – wet, dry and the intermediate zones, with the dry and intermediate zones covering the major portion of the country. During the two inter-monsoon periods, there is rainfall spread over the entire country. The annual average rainfall received over the country is about 1,860 mm.

Sri Lanka gets affected by many extreme events annually including floods, landslides, droughts and occasional cyclones, causing much damage to property and to human lives. Efforts are being made to minimize the damage through improved monitoring systems providing real time rainfall information from landslide prone areas and also improving mechanisms for information dissemination to people in threatened areas. The government has recently established a separate Ministry on Disaster Management to coordinate work on disaster relief and related work.

Wide variation in population density exists across the districts in Sri Lanka. Colombo is overwhelmingly the most densely populated district with 3,729 persons per square kilometer, which is nearly 11 times higher than the national average. According to the 2001 Census of Sri Lanka population density stands at 300 persons per square kilometer whilst 72% of the population lived in rural areas, 22% in urban areas

[4] ME, 2012, Second National Communication on Climate Change, Ministry of Environment, Sri Lanka

and 6% in plantation estates. The mid-year population estimates in Sri Lanka for year 2010 was 20.65 million people with a population density of 329 persons per square kilometer and it is one of the most densely populated countries of the world[5]. The population growth rate is around 1.1 per cent at present and it is projected that the population will reach the 25 million mark by the middle of the century.

Sri Lanka's economy is based mainly on the service sector which has contributed 59% to the GDP in 2010, with the industrial and agricultural sectors contributing 29% and 12% respectively. The GDP (at current price) in 2010 has been Rs 5,602 billion (US$ 49.5 billion) with an average annual real growth rate of 8.0% in 2010. The per capita GDP (current price) has grown from about US$ 800 in 2001 to US$ 2,399 by 2010[6]. Sectors that have brought revenue to the country were industrial production, agriculture, fisheries, and tourism, mineral exports including gem stones, among others.

The human development indicators show values that are exceptionally high for a developing country. The life expectancy at birth is 74 years and the adult literacy rate, 91.4 per cent. Infant mortality is low (18.57 deaths/1,000 live births), and 93 per cent of the population have access to advanced health care. The Human Development Index (2010) is 0.658, approaching the level of developed countries, demonstrating a high quality of life. Sri Lanka is a multi-ethnic secular state. The major ethnic groups in the country are Sinhalese (73.9 per cent), Tamils (18.2 per cent) and Muslims (7.1 per cent). The majority of the population is Buddhists (69.3 per cent), and the other major religions are Hinduism (15.5 per cent), Islam (7.6 per cent), and Christianity (7.6 per cent).

Sri Lanka has carried out its Second National Greenhouse Gas (GHG) Inventory for 2000 in accordance with the revised 1996 IPCC Guidelines (RIG, 1996) and reported in the Second National Communication in Climate Change (2011)[7]. Based on this inventory, the total aggregate emission was 18,842.95 $GgCO_{2Eq}$ which comprised 61% from the energy sector (including energy industry, industry, transport, household and commercial and refinery sub-sectors), 25% from the agriculture sector, 10.8% from the waste sector, 2.6% from the industrial process sector and 0.2% from the land use change and forestry sector as shown in Table 1.1. With the uptake of 6,253.9 $GgCO_{2eq}$ from the land use change and forestry sector, the total net emission had been 12,588.9 $GgCO_{2eq}$. The figure 1.1 shows the CO2 Emissions from the Sub Sector within the Energy Sector

[5] Department of Census and Statistics, 2011

[6] Economic and Social Statistics of Sri Lanka, 2011, Central Bank of Sri Lanka

Table 1.1 Summary of GHG Emissions/Removals during 2000[7]

Sector	CO_2 Gg	CO_2 Removals Gg	CH_4 $GgCO_{2eq}$	N_2O $GgCO_{2eq}$	Total $GgCO_{2eq}$ (Net)
Energy	10,430.01		881.37	251.10	**11,562.48**
Ind. Processes	492.40				**492.40**
Agriculture			3,887.94	821.50	**4,709.44**
LUCF-Emissions	10.34		35.07		**45.41**
Waste			2,033.22		**2,033.22**
Total-Emissions	10,932.75		6,837.60	1,072.60	**18,842.95**
LUCF-Removals		-6,253.99			**-6,253.99**
Total-Net	**10,932.75**	**-6,253.99**	**6,837.60**	**1,072.60**	**12,588.96**

Source: ME, 2012, Second National Communication on Climate Change

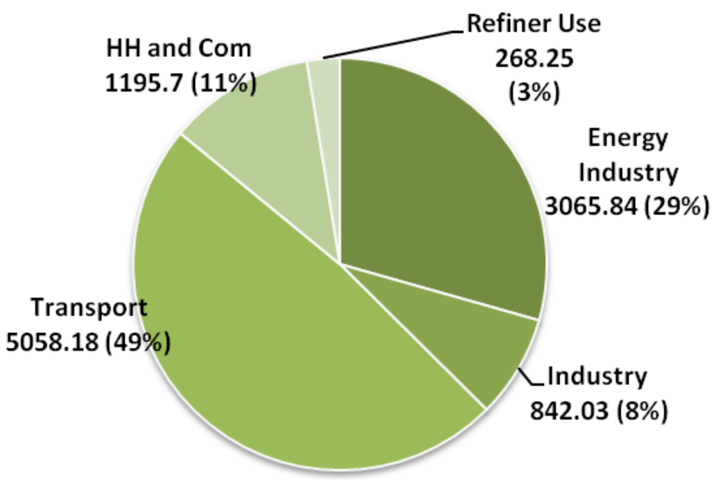

Figure 1.1: CO2 Emissions from the Sub Sector within the Energy Sector

Source: ME, 2012, Second National Communication on Climate Change

Figure 1.2 shows the projected energy sector related (including transport, power, industry and house hold & commercial sectors) annual CO2 emissions. In respect of the electricity sector, information was extracted from the Long Term Generation Expansion Plan prepared by the CEB.

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[7] ME, 2011, Second National Communication in Climate Change, Ministry of Environment, Sri Lanka

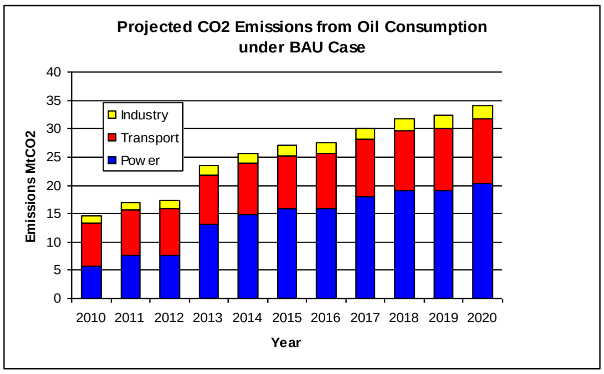


Figure 1.2: Projected Energy Sector annual CO_2 emissions

1.4 National Sustainable Development Strategies

The concept of sustainable development is not new to Sri Lanka, though the term itself has come into prominence only recently. The natural resource conservation had been an integral part of the ancient civilization of Sri Lanka and much evidence to this effect is available in ancient chronicles of Sri Lanka such as Mahawamsa[8]. Our ancestors have had a long tradition of living in harmony with nature in the course of harnessing natural resources for more than 2500 years.

After the Rio summit in 1992, the Government of Sri Lanka began to follow a more focused and comprehensive policy towards sustainable development. The nation is committed to ensuring environmental sustainability by 2015 as part of its commitment to achieving the Millennium Development Goals. Realizing the need to strike a balance between environmental conservation and economic development, the Government of Sri Lanka in 2003, enunciated the National Environmental Policy with the vision *"to achieve a healthy and pleasant environment sustaining nature for the well being of people and the economy".* The policy ensures a sound environmental management within a framework of sustainable development in the country and provides the direction for the necessary measures to conserve and manage Sri Lanka's environment and natural resources. Successive National Environmental Action Plans (NEAP), recently developed Climate Change Policy and national strategies such as *Haritha* Lanka Action Plan, National Climate Change Adaptation Strategy and National Sustainable Development Strategy of Sri Lanka provide a broad environmental policy framework for sustainable development in the country.

Although Sri Lanka has made substantial progress in economic development over the past few decades, significant challenges to sustainable development still prevails. These challenges have been identified as poverty, land degradation, realization of social well being, sustainability of water supply, sound

[8] The great historical chronicle of Ceylon (Sri Lanka) composed in the late 5th or early 6th century.

ecosystem management & clean environment, energy security, heritage and culture and good governance.

Although the overall population below the national poverty line *(Per capita monthly total consumption expenditure is below Rs.3,423 in the April, 2012 are considered poor[9])* has decreased over the last decade from 26% (1993) to 8.9% (2009/10) along with the growth in per capita incomes, there are wide regional disparities with in the country[10]. Further, poverty in the 7 poorest Districts has increased during the last decade though national per capita income rose during this period; while urban poverty halved, poverty in the plantation estate sector increased 50%. Over half the population is below the minimum level of dietary energy consumption, and there is a higher prevalence of under nutrition in rural and estate sectors than in urban areas. Food security in terms of availability, accessibility and affordability is uncertain notably in the estates.

The major environmental issues faced by Sri Lanka at present include land degradation, pollution and poor management of water resources, impacts of large scale deforestation in the past, loss of biological diversity due to non-sustained extraction of resources that exceed the recuperative capacities of ecosystems and species, air pollution, declining availability of fresh water, coastal erosion, degradation of marine and coastal habitats, inadequate facilities for solid waste disposal in urban areas, traffic congestion in the main cities, and increasing loss of agricultural productivity[11].
At the same time, Sri Lanka needs to accelerate economic growth in order to meet the rising expectations of a growing population, about a quarter of which is still below the poverty line, and on the other hand, there is a need to be judicious in resource use in view of the alarming rate at which the resource base is being depleted.

The Sri Lanka Strategy for Sustainable Development (SLSSD) which was developed by the Ministry of Environment and Natural Resources in 2007[12] aims to meet the country's various development needs as well as its development challenges, and to mainstream environmental considerations in policy-making and policy implementation. According to SLSSD, Sri Lanka's vision for sustainable development is *"Achieving sustained economic growth that is socially equitable and ecologically sound, with peace and stability"*.

The SLSSD seeks to achieve this vision through eradication of poverty, ensuring competitiveness of the economy, improving social development, ensuring good governance, and a clean and healthy

[9] Department of Census and Statistics, 2012

[10] Department of Census and Statistics, 2011

[11] Sri Lanka Environmental Outlook Report, 2010

[12] ME, 2007, Sri Lanka Strategy for Sustainable Development, Ministry of Environment and Natural Resources, Sri Lanka

environment. These five goals prioritize the challenges that have to be addressed in the path to achieving sustainable development.

Following are the general strategies adopted in the path to sustainable development:

i. Creating an economy for sustainable development
ii. Strengthening institutional structure for sustainable development
iii. Creating a policy framework for sustainable development
iv. Creating a regulatory framework for sustainable development
v. Creating a knowledge base for sustainable development

The SLSSD recommended establishing an implementation mechanism known as the “National Council for Sustainable Development (NCSD)” through a Parliamentary Bill as a policy making, approving and monitoring body under the leadership of His Excellency the President of Sri Lanka. Based on this recommendation, The Cabinet of Ministers of the Government approved the decision to establish the National Council for Sustainable Development (NCSD) chaired by His Excellency the Present of Sri Lanka in 2008 and to formulate the *Haritha* (Green) Lanka Programme. The *Haritha* (Green) Lanka Program was thus developed in 2009 and it aims to mainstream the subject of 'Environment into the national development planning process in the country. The NCSD is responsible for overall management and coordination of the programme. Ministry of Environment acts as the secretariat and the Ministry of Plan Implementation monitors progress of the programme.

1.5 National Climate Change Policies and Actions

The UNFCCC defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over a comparable time period”[13]. Climate change has been heralded as a threat to the global society. As a small island nation, Sri Lanka falls into the UNFCCC and IPCC’s category of ‘vulnerable’ small island nations under serious threat from various climate change impacts, such as sea level rise and severe floods and droughts (UNFCCC 1992; IPCC 2001)[14]. These threats are considered to have significant negative consequences on various sectors within Sri Lanka (ME, 2011). Climate change puts extra burdens on the social and economic challenges that the poorest already face, emphasizing and increasing their vulnerabilities due to the dependence of their livelihoods on climate sensitive natural resources and their weak social protection structures. By directly eroding the resources

[13] UNFCCC, 1992, United Nations Framework Convention on Climate Change, *(Sri Lanka became a party to the UNFCCC in 1993)*

[14] IPCC, 2001, (Intergovernmental Panel on Climate Change), Climate Change 2001: Impacts, Adaptation, and Vulnerability: Summary for Policymakers, a Report of Working Group II of the Intergovernmental Panel on Climate Change.

that poor people depend on for their livelihoods, climate change makes it easier for people to fall into poverty and harder for the poorest to escape from it.

Although Sri Lanka's GHG emissions are negligible compared to those of developed or larger developing countries, analysis of past records in Sri Lanka have highlighted that air temperature in the island has been rising throughout the country during the last century with a temperature increase of 0.016ºC per year between 1961 and 1990. Analysis of rainfall data reveals that the variability has been increasing in the past in most parts of the island resulting in water scarcities in the dry zone of Sri Lanka. Extreme weather events such as high intensity rainfall followed by flash floods and landslides, and extended dry periods resulting in water scarcity are now becoming common occurrences in the country.

As climate change is a complex issue requiring action by a varied group of stakeholders, lately the necessity of a national agenda to face this challenge has been conceived. In this context, the Government of Sri Lanka has developed a policy framework on the basis of UNFCCC guidelines that addressed the need for the nation to engage in climate change mitigation and adaptation measures. This national policy framework namely, "National Climate Change Policy for Sri Lanka" was approved by the Government in January 2012 with a view to provide guidance and directions for all the stakeholders to address the adverse impacts of climate change efficiently and effectively.

1.5.1 National Climate Change Policy for Sri Lanka

The national climate change policy is aimed at mainstreaming climate change issues within the overall national effort towards sustainable development and it creates the conditions necessary to overcome the major gaps existing at present. See the box for highlights of the National Policy.

SRI LANKA NATIONAL CLIMATE CHANGE POLICY

Vision: A future where climate change will have no adverse consequences on Sri Lanka.

Mission: Addressing climate change issues locally while engaging in the global context.

Goal: Adaptation to and mitigation of climate change impacts within the framework of sustainable development

Objectives:

- Sensitize and make aware the communities periodically on the country's vulnerability to climate change.
- Take adaptive measures to avoid/minimize adverse impacts of climate change to the people, their livelihoods and ecosystems.
- Mitigate greenhouse gas emissions in the path of sustainable development.
- Promote sustainable consumption and production.
- Enhance knowledge on the multifaceted issues related to climate change in the society and build their capacity to make prudent choices in decision making.
- Develop the country's capacity to address the impacts of climate change effectively and efficiently.
- Mainstream and integrate climate change issues in the national development process.

Collaborative action at all levels is necessary to transform this policy into meaningful set of actions to meet the challenges of climate change. It is an essential pre-requisite to proceed from the present position the country is in now, as far as climate change is concerned. Success of such a national agenda would largely be determined by the effectiveness of measures taken to overcome the main gaps existing at present.

1.5.2 Actions taken by Sri Lanka to counter Climate Change Impacts

Since ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1993, a number of actions have been taken by the Government of Sri Lanka towards complying with its obligations under the Convention[15].

These actions include *inter alia*, Ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994; Acceding the Kyoto Protocol (2002); Preparation of the Green House Gas (GHG) Inventory (1994); Preparation of the Initial National Communication on Climate Change (2000); Undertaking Research Studies on Climate Change; Establishment of the Centre for Climate Change Studies- CCCS (2001); National Capacity Self Assessment for the Implementation of the three Rio Conventions –NCSA (2004-2006); Establishment of Clean Development Mechanism (CDM) under the Kyoto Protocol; Establishment of the Sri Lanka Carbon Fund (2008); Preparation of the Second National Communication on Climate Change- SNC (2011); Establishment of the National Advisory Committee on Climate Change (2008); Establishment of the Climate Change Secretariat (2008), formulation of National Climate Change Policy for Sri Lanka (2011) and preparation of the National Climate Change Adaptation Strategy (2010).

In addition, large number of activities is being carried out by other agencies such as Government Ministries & Departments, research institutions, Universities and non-governmental organizations etc.

1.6 TNA Relevance to National Development Priorities

Despite successful control of population growth rate to be around 1.1% during the recent years, Sri Lanka is one of the most heavily populated countries in the world at present. The population pressure has brought in wide range of environmental problems such as land degradation, pollution and poor management of water resources, deforestation, loss of biological diversity, coastal erosion, increasing scarcity of water for agriculture and inadequate facilities for waste disposal in urban areas. In addition, wide range of issues in the transport sector and increasing loss of agricultural productivity are few other related major issues faced with. Besides these environmental issues, inequalities in income distribution

[15] Herath. A, 2008, Climate Change and Energy in Sri Lanka, Ministry of Environment and Natural Resources, Sri Lanka

and access to essential services in different Districts, in increasing income disparities and malnutrition[16] are the significant economic and social challenges prevailed at present.

In spite of these challenges, Sri Lanka has already made an impressive progress towards meeting the Millennium Development Goals in key areas of human development such as education and health. Being a developing country graduating to the middle income country status is remarkable achievement despite the severe social and economic setbacks of the 2004 Asian tsunami and long years of civil conflict.
The Government's new National Development Framework ("*Mahinda Chintana: Idiri Dakma*" - Vision for a New Sri Lanka, (2010) aims at accelerating growth, with particular emphasis on equitable development, recognizing that there has been a perpetuation of income disparities both among income earners and across geographic regions. It focuses on three main areas: (i) achieving more equitable development through accelerated rural development; (ii) accelerating growth through increased investment in infrastructure; and (iii) strengthening public service delivery.

In view of this, Sri Lanka needs to accelerate economic growth in order to meet the rising expectations of a growing population, about a quarter of which is still below the poverty line. Therefore, a sustainable high level of economic growth must be ensured without causing irreversible damage to the environment. The country's national development framework and SLSSD seeks to achieve this vision through eradication of poverty, ensuring competitiveness of the economy, improving social development, ensuring good governance, and a clean and healthy environment.

Concurrently, the TNA aims to reduce GHG emissions and vulnerability to climate change in priority sectors of Sri Lanka and to contribute to overall national development goals. It provides multiple benefits at the country level, including the identification of barriers for deployment and diffusion of technologies and facilitating removal of policy and legal gaps so as to improve enabling environments, increase the capacity of local institutions and experts, and raise public awareness of climate change issues.

The TNA process starts with an identification of a country's development and sustainability priorities with particular attention to GHG emission reduction potentials and adaptation needs in the context of the appropriate country scenarios on climate change. The priority sectors and technologies for mitigation of climate change are identified on the basis of the GHG emission reduction potential, and contribution from low carbon technology investments. Three (03) priority sectors were identified for mitigation based on the above criteria. These sectors are; **Transport, Energy and Industry**. The process aims at providing opportunities for achieving both, the country's development goals and sustainable development through protection against climate change impacts and mitigation of climate change.

[16] ME, 2007, Sri Lanka Strategy for Sustainable Development, Ministry of Environment and Natural Resources, Sri Lanka

Two main objectives expected from the TNA process are:

- To meet Sri Lanka's national development priorities, and
- To maximize the sustainability outcomes of the country, particularly through GHG emission reduction and protection against projected climate change damage.

CHAPTER 2

Institutional arrangement for the TNA and the stakeholders' involvement

2.1 TNA team, national project coordinator, consultants, etc

The Sri Lankan TNA has followed the guidelines from the UNDP/UNFCCC Handbook for Conducting Technology Needs Assessments for Climate Change (November 2010), Handbook for Conducting Technology Needs Assessments for Climate Change (2009) and Organizing the National TNA Process: An Explanatory Note, 2010[17]. Overview of the institutional arrangements involved in the TNA process, proposed by UNDP/UNFCCC Handbook for Conducting Technology Needs Assessments for Climate Change is shown in Figure 2.1.

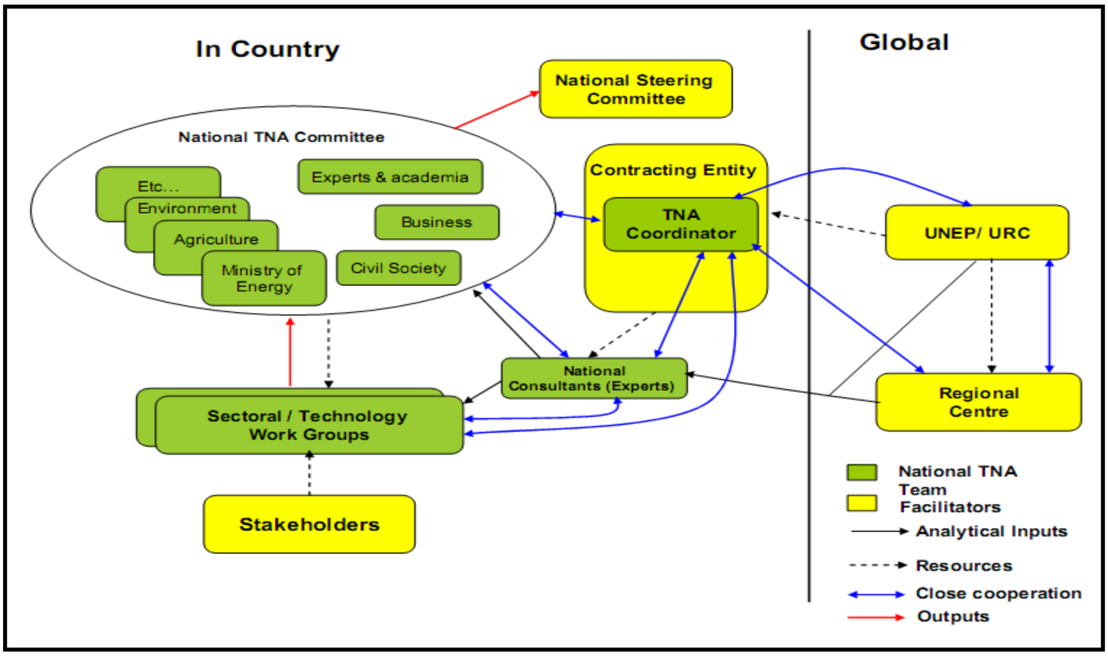


Figure 2.1 Institutional Arrangements for the TNA Project

[17] S. Dhar, j. Painuly, I. Nygaard, 2010, Organizing the National TNA Process: An Explanatory Note, UNEP Risoe Centre, Denmark.

Based on the guidelines proposed by the UNDP/UNFCCC Handbook, following initial steps were taken in forming institutional arrangements for the implementation of the Project:

- Identification of the lead agency for TNA project implementation.
- Exploring objectives and scope of the Project through a consultatation meeting.
- Identification of relevant stakeholder agencies and personnel for the TNA Committee.
- Identification of the lead agency, lead technical institutions, other participants and establishment of a Core Technical Team.
- Define a process for stakeholder consultation by establishing the TNA Committee and sectoral Stakeholder Working Groups for the priority sectors.

Accordingly, setting up of the National TNA team was the first operational task undertaken in the TNA process. The **Ministry of Environment** being the focal point for UNFCCC and Kyoto Protocol was designated as the lead agency responsible for the TNA process. The Climate Change Secretariat is located in the ME and it also serves as the chair to the National Advisory Committee on Climate Change. The **National TNA Team** comprised of the inter-ministerial **National TNA Committee**, **Project Coordinator**, **National Consultants** and **Sectoral Working Groups**. The "National Advisory Committee on Climate Change", the highest level multi-stakeholder decision making body of the Ministry of Environment, functioned as the **National Steering Committee** for the Project. This Committee comprised of senior officers from all relevant line Ministries, members from Non-Governmental Organizations and the private sector.

TNA Committee: The TNA Committee that included senior representatives from relevant Ministries led the TNA process. The Committee chaired by the Secretary of the Ministry of Environment comprised of 21 members. Membership of the National TNA committee is provided in Annex A1. The composition of the National TNA team remained flexible to enable including any other members as required during the TNA process. Members of the National TNA Committee were those who are familiar with national development objectives and sector policies, overall insights of climate change, and potential climate change impacts and adaptation needs for Sri Lanka. This National TNA committee functioned as a Task Force overseeing supervising the TNA process and it provided the leadership for the project implementation. As agreed at the initial meeting, the specific responsibilities of the TNA committee included the following;

1. Identify national development priorities and priority sectors for the Technology Need Assessment.
2. Decide on composition and constitution of sectoral workgroups
3. Review and approve technologies and strategies for mitigation and adaptation as recommended by sectoral workgroups.
4. Review and approve the National Technology Action Plan for mitigation and adaptation including a roadmap of policies that will be required for removing barriers and creating the enabling environment.

The Project Coordinator: A senior officer attached to the Climate Change Secretariat with adequate scientific background, facilitation skills and familiar with the climate change negotiations and activities functioned as the Project Coordinator for the TNA project who was vested with the responsibility of managing the Project while providing vision and leadership for the exercise as the focal point. This included facilitation of communication with the National TNA Committee and Consultants, coordination and communication with sectoral stakeholders, recruitment of Consultants, formation of networks, information acquisition, preparation of Work Plans and monitoring of the progress of the TNA Project etc. Facilitation of TNA activities including administrative support, organization of TNA Committee meetings, organization of stakeholder workshops and meetings as well as implementation of the Work Plan of the Project was through the Project Secretariat under the direction of the TNA Coordinator.

National Consultants: A Team of three (03) national sector experts and a Team Leader provided the required technical expertise for the mitigation component of the Project. The responsibility of each sector expert included identification and prioritization of technologies, barrier analysis & market assessment and preparation of draft project proposals for priority technologies for their respective area of expertise. The Team Leader functioned under the overall guidance of the TNA committee and Project Coordinator. The responsibility of the Team Leader included providing over all guidance to sector experts, preparation of the consolidated Technology Needs Assessment (TNA) report.

Sectoral Working Groups:
Functioning of Sectoral Working Groups is discussed under the section on "Stakeholder Engagement Process".

2.2 Stakeholder Engagement Process

The TNA process was aimed at evolving a set of activities that is closely linked to other relevant national development processes and to reflect national response to climate change technology needs that is informed by the government & private sectors, the general public, and other stakeholders. Hence, the stakeholder involvement was considered very crucial to the success of TNA process and the implementation of recommended activities.

UNDP/UNFCCC Handbook (2009) recommends the following five steps for an active, inclusive stakeholder dialogue that will sustain over the course of the technology need assessment. These steps are;

- Identification of stakeholders
- Define the goals and objectives
- Clarification of stakeholder roles
- Establishment of an ongoing process for stakeholder engagement
- Involvement of stakeholders in each stage of the process

The stakeholders have been identified from the relevant organizations and institutions in terms of stakeholder engagement and institutional arrangements stipulated by the UNDP/UNFCCC Handbook (2010). Accordingly, the members of the Working Groups included representatives of the Government institutions having the responsibility for policy formulation and regulation, potentially vulnerable sectors, private sector industries, organizations , manufacture, import & sale of technologies, technology users, financial institutions, relevant NGOs, institutions that provide technical support, donor organizations and other relevant institutions such as Universities & research organizations.

In order to get the stakeholder participation in the TNA process, three (03) Technical Working Groups were established on sectoral basis representing **Transport, Energy and Industry sectors** as prioritized under prioritization process. The Technical Working Groups were mandated to decide on the technologies appropriate for respective sectors, undertake market/barrier analysis and recommend an enabling framework for sectors.

The goals, objectives and the working arrangements of the participatory process was discussed and agreed with all sectoral stakeholder working groups at the **National Inception Workshop.** The objectives of the Project and purpose of stakeholder participation was discussed and ratified at this meeting. The main purpose of the stakeholder engagement is to ensure their participation throughout the TNA process of selecting priority sectors, technology identification & prioritization, barrier analysis and development of enabling framework etc, as their participation in the process is crucial for successful implementation of the recommended technologies. Therefore, an ongoing arrangement has been established to ensure continuous and effective involvement of stakeholders at each stage of the TNA process.

The roles and responsibilities of stakeholder groups have been defined during the initial meeting. Each stakeholder Sectoral Working Group included around 15-20 persons representing related organizations in the respective sector. The compositions of the sectoral working groups were flexible with the provision of co-opting additional members depending on the requirement. The Project Coordinator together with Consultants facilitated the Working Group discussions ensuring maximum output from the deliberations.
The compositions of the Sectoral Stakeholder Working Groups are provided in Annex A2

CHAPTER 3

Sector Prioritization

3.1 An overview of sectors, and projected climate change and the GHG emission status and trends of the different sectors

The GHGs are produced mainly during the combustion of fossil fuels for generation of energy, both thermal and motive. Fuels such as coal, petroleum oil and natural gas are burnt to drive turbines to generate electricity, or operate boilers or run vehicles. The main GHG emitted from these combustion processes is CO_2. Various industrial processes could cause the emission of CO_2, CH_4, N_2O and NMVOC. Agricultural activities such as rice cultivation, application of nitrogen fertilizer, ruminant animal rearing and animal waste management contribute to emission of CH_4 and N_2O. In addition, Land Use, Land Use Change and Forestry (LULUCF) emissions include burning of crop residues, forest fires, land use changes, changes in woody biomass stocks and soil disturbances result in the emission of CO_2, CO, CH_4 and NO_x. Disposal of solid waste both in sanitary land-fills and open dumps as well as waste water treatment facilities results in the emission of CH_4. The GHG emission status of different sectors of Sri Lanka in year 2000 is briefly described below[18].

Energy Sector: This sector includes energy industry, refinery operations and household and commercial sectors. Emissions from fossil fuel combustion in electricity generation (energy industries), refinery operations, and household and commercial sectors are included as emissions from this section. The total CO_2 equivalent emissions from Energy sector were 5,523.5 $GgCO_{2Eq}$. The details of emissions from energy sector are provided in Table 4.1. (Transport and Industry sectors were taken up as separate sectors for sector prioritization).

Transport Sector: This sector includes Road transport, Railway transport, Air transport and Sea transport. Transport sector is a major greenhouse gas (GHG) emitting sector in Sri Lanka. The transport sector utilizes petroleum fossil fuels leading to significant amounts of carbon dioxide (CO_2) and other GHG emissions (N_2O, CH_4, CO, NO_X, NMVOC and SO_2). The total CO_2 equivalent emissions from transport sector were 5,084 $GgCO_{2Eq}$. The details of emissions from transport sector are provided in Table 5.1.

Industry Sector: The industrial sector includes all industries excluding industries identified under energy sector (energy industry and refinery operations). This includes energy consuming industries and industries included under industrial processes. This sector includes traditional industries, technology

[18] ME, 2011, Data from Second National Communication on Climate Change, Sri Lanka

intensive industries, small and medium enterprises and micro industries. Cement manufacture, lime production for construction industry and industries using $CaCO_3$ containing material and soda ash are some of the key industries contributing to GHG emissions within the industry sector. The total CO_2 equivalent emissions from the industry sector were 1,447.4 $GgCO_{2Eq}$. The details of emissions from this sub-sector are provided in Table 6.1.

Agriculture Sector: Methane emissions from livestock, rice cultivation, all GHG emissions and precursors from agriculture residue burning, direct and indirect emissions from soils have been included under agriculture sector. The total CO_2 equivalent emissions from this sub-sector were 4,709.44 $GgCO_{2Eq}$.

Land Use, Land Use Change and Forestry (LULUCF) Sector: The undisturbed natural forests free of anthropogenic activities which are in equilibrium have been excluded from these inventory calculations. Changes in forest and other woody biomass stocks including timber and fuel wood removal, carbon stock changes in plantation crops such as tea, rubber, coconut and home gardens, and carbon stock changes in soils have been considered in emission calculations for this sector. The CO_2 equivalent net GHG removals from this sector were -6,208.58 $GgCO_{2eq}$.

Waste Sector: In the Western Province where the population is the highest, daily collection of solid waste is estimated to be about 6,400 t/day. These are disposed mostly in open dump yards. Some efforts are being taken to sort recyclable materials and convert the organic component into compost. The emissions from this sector included CH_4 emissions from solid waste and waste water from industries. The total emissions from this sector were 96.82 $GgCH_4$ or 2,033.22 $GgCO_{2Eq}$ (.CO_2 equivalent).

The contributions for GHG emissions from different sectors in the country in year 2000 are shown below in Fig. 3.1. This amounted to contribution from energy sector (29%), transport sector (27%) agriculture sector (25%), waste sector (11%) and industry sector (8%).

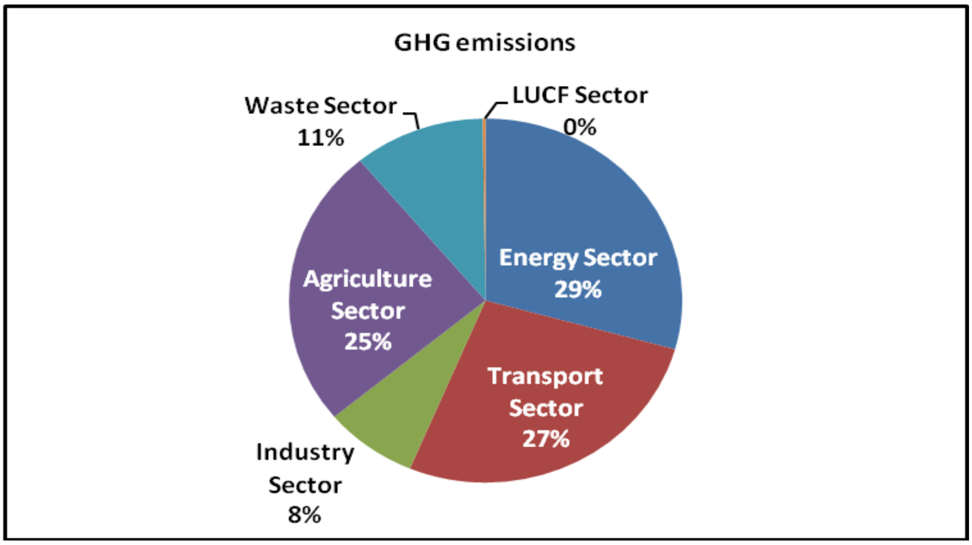


Figure 3.1: Contributions for GHG emissions from different sectors in Sri Lanka

3.2 Process and criteria of sector prioritization

Following are the main factors considered when defining criteria for selecting and prioritization of sectors for the Mitigation activities;

- Contribution to the development priorities of the country
- Contribution to climate change mitigation - GHG emission reduction potential
- The market potential
- Access to/availability of technologies in the sector.

Therefore, the sector prioritization process was started with the identification of development and sustainability priorities of Sri Lanka. The Development Policy Framework of the Government of Sri Lanka – "Sri Lanka Emerging Wonder of Asia: *Mahinda Chintana* – Vision for the Future" – presents Sri Lanka's economic policy strategies, actions and the roadmap for the next six years[19].

The economic development philosophy of *Mahinda Chintana* is that economic growth alone would not bring prosperity to the society but social, cultural, religious and environmental development are equally important. The development goals of the Government will be achieved by transforming the country to a modern, knowledge-based, environmentally friendly and well connected rural-urban network that benefits all citizens of the country through equitable access to development[20].
The main strategies of this policy framework are;

- A Prosperous Country: A Land of Plenty
- Enterprises with Strength to Conquer the World
- Developed Road Network and Transport System
- Focus on Modern Education and Knowledge Systems
- A Healthy Society
- Comforts, Convenience and Satisfactory Lifestyle
- Shared Values and Rapid Development

The development priorities identified in line with these strategies as stated in the policy framework are as follows. Please see Annex B for summary objectives of development priorities.

- Agriculture: feeding the nation
- Fisheries and Aquatic resources
- Self reliance in Livestock industry

[19] Sri Lanka Emerging Wonder of Asia: *Mahinda Chintana* – Vision for the Future, 2010, Department of National Planning, Ministry of Finance and Planning, Sri Lanka.
[20] Annual Report, 2010, Ministry of Finance and Planning, Sri Lanka.

- Irrigation: Water is our heritage and Life and
- Water services Perspective
- Healthy Society
- Housing for All – Prosperous and healthy Lifestyle
- Environment
- Modern Education and Knowledge Systems
- A Modern Economy Through Science and Technological Innovations
- Electricity for everybody, everyday
- Industry sector: Towards Global Competitiveness
- Developed Road Network and Transport System

Accordingly, these development priorities *vis-a-vis* potential sectors for the TNA & their contribution to development priorities, GHG reduction potential, and availability of technologies in the relevant sectors were considered by the stakeholders for prioritization of the sectors. The list of the stakeholder group participated in the deliberations is provided in Annex A2. The sectors thus prioritized and subsequently endorsed by the National TNA committee are **Energy, Transport and Industry** (see the explanation below for selecting the industry sector). The steps undertaken by the stakeholder group for prioritization of sectors for the mitigation component are summarized in Table 3.1.

Table 3.1: Strategic Choice of Priority Sectors

Steps	Description	Output
Step 1	Identifying Development Priorities	Agriculture, Fisheries & Aquatic resources, Livestock development, Water, Healthy Nation, Housing for all, Environment, Education and Knowledge Systems, Modern Economy Through Science and Technological Innovations, Electricity for everybody, Industry sector, Develop Road Network and Transport System
Step 2	Identification of Sectors that have high GHG relevance	Transport , Agriculture, Energy Industry, Waste and Industry Sectors
Step 3	Prioritizing sectors in terms development and sustainable mitigation priorities	Transport, Energy and Industries Sectors (Agriculture sector was included under Adaptation)

Note: The summary objectives of development priorities are provided in Annex B.

Based on the emission data provided in the Second National Communication on Climate Change[7], 29% of the total aggregate emissions in Sri Lanka were from the energy sector (excluding transport and industry), 27% from transport sector, 25% from agriculture sector, 11% from waste sector and 8% from industry sector (Figure 3.1). According to these data, the priority sectors for GHG mitigation in Sri Lanka are Energy, Transport, Agriculture, Waste and Industry sectors (Table 3.2). Although, the GHG contribution of agriculture sector is third highest in the rank, it was decided to take up agriculture sector under the adaptation component in the TNA process, due to its high vulnerability to climate change and importance in food security in the country. Agriculture sector is among the five most vulnerable sectors to climate change in Sri Lanka[21]. Therefore, it was not considered as a priority sector under the mitigation component of the TNA project. Nevertheless, when selecting adaptation technologies for the agriculture sector, the contribution to mitigation (emission reduction potential) has also been included as criteria for prioritizing the technologies.

In spite of the fact that the Industry Sector has received priority ranking of 5, it has been decided to include the industry sector as the third priority sector due to following reasons;

- Both energy and industry sectors depend primarily on fossil fuels and the technologies in these two sectors are closely related. Hence, it is mutually beneficial to consider industry sector over the waste sector.
- Some barriers and measures of energy and industry sectors are very similar or common. This would be an advantage for diffusion of technologies within both the sectors.

Table 3.2: Identification of sectors with high GHG relevance

Sector	Percentage share of the sector in GHG emissions in Sri Lanka (in year 2000)	Priority Ranking
Energy	29%	1
Transport	27%	2
Agriculture	25%	3*
Waste	11%	4
Industry	8%	5

Source: ME, 2011, Second National Communication on Climate Change

** Decided to include under adaptation component*

Accordingly, in consideration of the short and long term national development priorities as identified in the policy framework "*Mahinda Chintana*–Vision for the Future" *vis-a-vis* sustainable development goals

[21] ME, 2010, National Climate Change Adaptation Strategy for Sri Lanka, 2011 to 2016, Ministry of Environment

of Sri Lanka, and potential contribution to GHG emission reduction, following three (03) priority sectors were selected for the mitigation component of the Project;

- Energy
- Transport
- Industry

CHAPTER 4

Technology Prioritization for the Energy Sector

4.1 GHG emissions and existing technologies of the Energy Sector

4.1.1 GHG emissions from the Energy Sector

The main GHG emitted from the energy sector is CO_2. In addition to CO_2, various industrial processes contribute to the emission of CH_4, N_2O, CO, NO_x, SO_2 and NMVOC. The total CO_2 emissions from Energy sector (excluding transport sector) was 4,529.79 Gg. The Energy sector for the present TNA includes sub-sectors of (electricity generation) energy industries, household and commercial and refinery operations. The CO_2 emissions from these sub-sectors are 3,065.84, 1,195.70 and 268.25 Gg respectively. The GHG emissions from the energy sector are provided in the Table 4.1 below.

Table 4.1: GHG emissions from the energy sector

Sector	Emissions (Gg)						
	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Total Energy	4529.79	39.1	0.55	648.29	23.37	77.96	70.11
A. Fuel Combustion	4529.79	39.1	0.55	648.29	23.37	77.96	70.11
1. Energy Industry	3065.84	0.12	0.02	0.61	8.18	0.20	32.82
2. HH and Com	1,195.70	38.97	0.53	647.65	14.41	77.74	35.35
3. Refiner Use	268.25	0.01	0.00	0.03	0.78	0.02	1.94
B. Fugitive Emissions		0.10		0.22	0.14	1.46	2.20

The contribution of different sub-sectors within the energy sector for CO_2 emissions are shown in Figure 4.1.

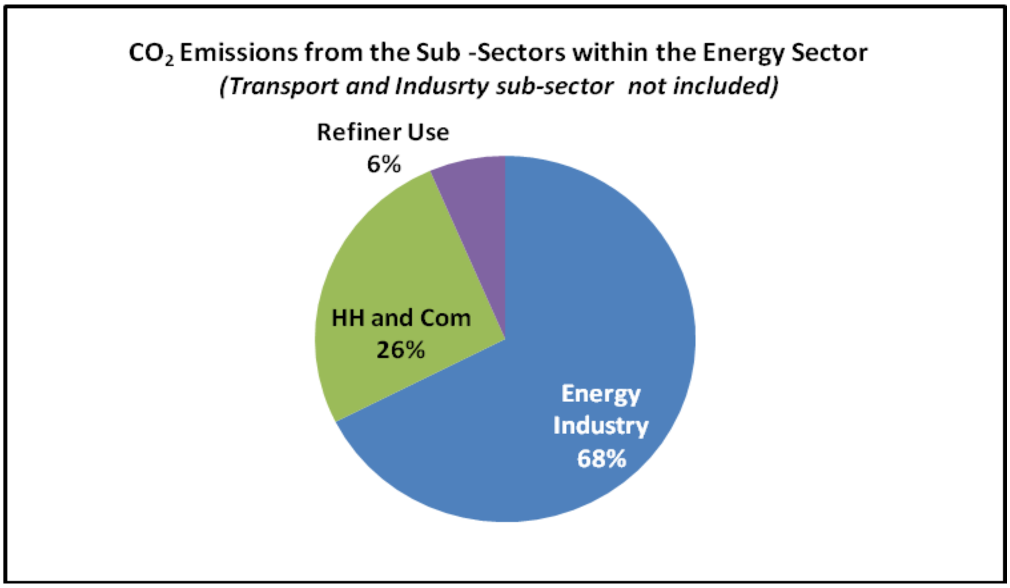


Figure 4.1: CO_2 Emissions from the Sub -Sectors within the Energy Sector

4.1.2 Current status of technologies in the Energy Sector

The current status of technologies in the energy sector is provided under three main sub sectors ie, electricity generation, industrial process heat generation and technologies used in the household sector.

4.1.2.1 Electricity Generation Sector

A. Grid-connected electricity Systems:

The grid-connected electricity generation in Sri Lanka deploys the following resources:

a)Large Hydro Power Plants
b)Small Hydro Power Plants
c)Petroleum Based Thermal Power Plants
d)Coal Based Thermal Power Plant
e)Biomass Based Thermal Power Plants
f) Wind Power Plants
g)Solar PV Power Plants

B. Off-Grid Electricity Systems:

a) Solar Home Systems
b) Village Hydro Systems
a)Use of Biogas for Industrial Heat Applications

4.1.2.2 Technologies Used in the Household Sector

a) Wood Gas Stove

b) Dual Burner Clay Stove

c) Use of Biogas for Household Cooking

4.2 Overview of possible mitigation technology options in the Energy Sector and their mitigation benefits

Sri Lanka's present primary energy supply is mainly based on biomass (48%), petroleum oil (43%) and hydroelectricity (9%), with the total amounting to about 415 PJ. The Non-Conventional Renewable Energy sources contribute only about 0.1%, while its contribution to the national electricity grid is about 4%[22]. The government plans to increase this ratio to 10% by 2015[23]. As per the National GHG inventory prepared by the Ministry of Environment, CO_2 emissions from fossil fuel combustion has been the major source of emissions and it has shown a growth from 5,447 Gg in the 1994 to 10,430 Gg for the year 2000 (The corresponding per capita CO_2 emissions were 304 and 545 kg, respectively). The fuel consumption data for the Power, Transport, Industries and Household & Commercial sectors for the period 2000 – 2007 are shown in Fig. 4.2.

As per the provisions of the National Energy Policy and Strategies (NEPS) of Sri Lanka, the government will endeavor to reach a minimum level of 10% of electrical energy supplied to the grid to be from Non-Conventional Renewable Energy (NCRE) by 2015. According to the power sector mitigation scenario as described in the LTGE Plan (2009 – 2022) of the CEB, 150 MW would be from Upper Kotmale hydro power plant and 612.5 MW would be from renewable energy plants that will be added by 2020, along with 2,260 MW of thermal power plants. These mitigated emissions along with the Business as Usual (BAU) emissions in the power sector are shown in Fig. 4.2. Between the two, there is a 28% reduction in CO_2 emissions in 2020.

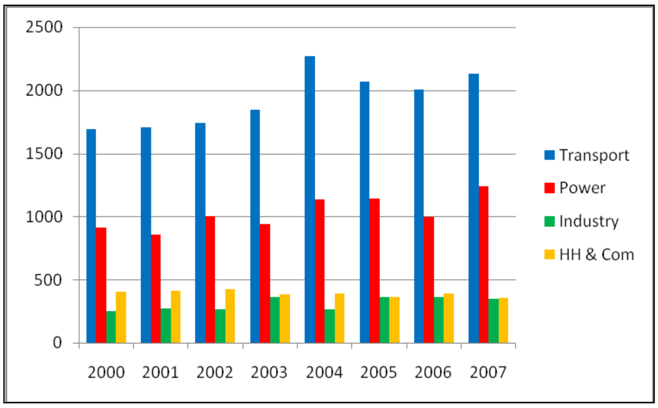


Figure 4.2: Oil consumption in ktoe during 2000 - 2007

[22] ME, 2011, Second National Communication on Climate Change, Ministry of Environment, Sri Lanka

[23] MoPE, 2006, National Energy Policy and Strategies, Ministry of Power and Energy, Sri Lanka

Source: ME, 2011, SNC

Sri Lanka has no petroleum, gas or coal deposits. Nevertheless, due to the geo-climatic conditions of Sri Lanka, the country is blessed with several forms of renewable energy resources. Some of them are widely used and developed to supply the energy requirements of the country. Others have the potential for development when the technologies become mature and economically feasible for use. Currently about 56.9% of the primary energy supply comes from renewable resources. Following are the main renewable resources available in Sri Lanka and their percentage share for the primary energy supply in the country:

- Biomass - 47.4%
- Hydro Power – 9.5%
- Solar & Wind – 0.04%

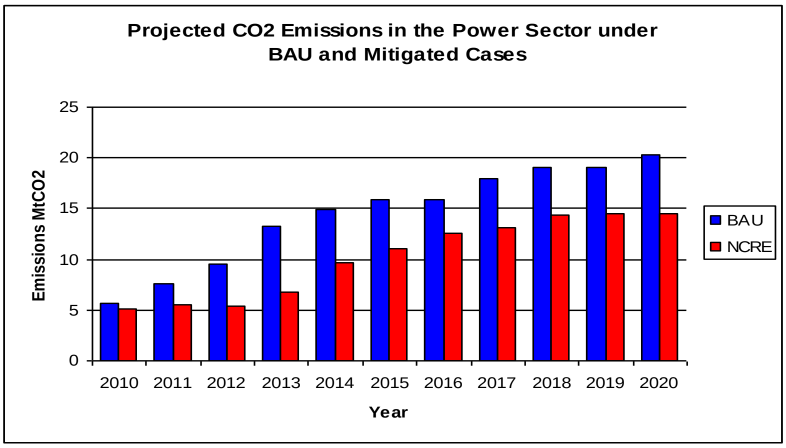


Figure 4.3: Projected CO2 emissions under BAU and Mitigated cases up to 2020

Source: CEB (2008)

In addition to the above, indigenous renewable resources and the availability of petroleum within the country territory is being investigated.

Mitigation of GHG emissions: Following three major paths are available to mitigate GHG emissions in the energy sector:

(a) Utilization of larger share of renewable energy resources to generate the energy needs.

(b) Use less carbon intensive fuels (such as Natural Gas) instead of using a high carbon intensive fuel (such as coal).

(c) Maximize energy efficiency with the view to achieve the same energy services with lesser use of energy sources thus reducing GHG emissions.

4.2.1 Technologies Identified:

At the initial deliberations of the energy sector technical stakeholder working group, the following mitigation technologies were identified for consideration;

1. Building Management Systems
2. Conversion of Biomass and Waste to Energy
3. Smart Grid Technology for Wind & Solar Integration with Hydro
4. DC Motor Driven Alternator for Grid-Connected Solar PV Systems
5. Water Pumping to Hydro Reservoir
6. Solar Tracker Cum Reflector
7. Biomass Gasifier for High Temperature Applications
8. Bio-methane for Transport Applications
9. Roof-Mounted Solar PV for Net Metering
10. Concentrated Solar Thermal Electricity Generation

4.2.2 Overview of the Technologies Identified:

An overview of technologies shortlisted for prioritization is provided here. A detailed description of these technologies is found in the Technology Fact Sheets provided in Annex C.

I. Building Management Systems:
This is a flexible and adaptable tool for the end-user to enable personalize or modify the current behavior of energy consumption by taking appropriate corrective actions. The solution enables integration into a single system for all elements in a modular and flexible way. Monitored parameters could be the following ones: Air conditioning control, Management of facilities and machines, lighting control, Fire and access control.

The following two sub-technologies are considered in this technology option:

(a) LED Lighting:

LED technology is advancing into new categories of white light applications, including surgical task lighting, where early indications suggest significant potential for energy savings and reduced maintenance.

(b) Solar Assisted Air Conditioning

Solar Assisted air conditioners help saving up to 30 -50 % of electricity. It has a wide target market such as, hotels, restaurants, hospitals, factories, schools, convention centers and high end residential complexes. It requires minimal direct sunlight exposure, heat from ambient and heat blown by the condenser is also utilized. There is a minimum of 30% energy saving if a conventional Air Conditioning unit is replaced by solar assisted AC.

II. Conversion of Biomass and Waste to Energy:

Following three sub technologies are considered under this technology option:

(a) Co-firing of Biomass with Coal
(b) Compact Biogas Digester for Urban Household Use
(c) Waste to Energy

(a) Co-Firing of Biomass with Coal

In the proposed technology, it is intended to use biomass and coal as fuels. Although several options are available for co-firing biomass with coal, the following option is recommended taking into account the need to minimize the extent of tampering with the existing equipment at a coal fired power plant,.
Use a separate biomass boiler to generate steam at the same temperature and pressure as that of the steam produced at the coal boiler. Steam produced in the biomass boiler is connected to a common steam header. Steam from this header is used to drive the existing steam turbines. Although this method is the most expensive option, it has the following advantages:

- The existing equipment such as coal conveyor, coal crusher, coal boiler etc. is tampered with.
- The percentage share of biomass could be varied from 0% to 100%.

(b) Compact Biogas Digester for urban household use

Appropriate Rural Technology Institute of Pune, Maharashtra, India (www.arti-india.org) has developed a "Compact Bio Gas Digester" to resolve issues related to conventional biogas digester. " The volume of this digester is 1.5 m3. It essentially consists of two plastic tanks. The research study carried out by the University of Moratuwa revealed that leaves of Gliricidia is the most effective material to be used as the feed material for biogas production using this technology.

(c) Waste To Energy

To address the problems related to Municipal Solid Waste (MSW) management, the government has taken many measures to facilitate reduction, reuse and recycling of solid waste. From the national point of view, reuse and recycling of waste material helps significantly reducing the use of original materials. Another approach is to use MSW as a source of fuel to generate electricity through combustion. The major problem encountered when MSW is combusted is generation of highly toxic substances such as dioxins. This toxic substance is formed when combusting halogenated plastic materials such as PVC. To

resolve this issue, an attempt has been made to use Plasma Gasification Technology. This process is highly capital intensive incurring high operational costs. As such, up to date no such facility has been established in Sri Lanka.
In this technology MSW is converted onto RDF pellets of consistent quality. Such pellets could be used in cement manufacture as the high temperature maintained during the cement production process enables degeneration of dioxins. Moreover, calcium carbonate used in cement production also absorbs all such pollutants and embed them into cement. Use of MSW as a fuel in cement manufacturing industry would contribute to saving of considerable quantum of foreign exchange while export of RDF would be a source of foreign exchange earnings.

III. Smart Grid Technology for Wind & Solar Integration with Hydro

The potential for wind based electricity generation and solar PV based electricity generation in Sri Lanka is highly significant. However both these technologies are intermittent making it difficult to integrate within the grid. The capital costs of these two technologies are gradually getting reduced there by, these two technologies are likely to reach grid parity status in the near future. Under such circumstances these technologies could play a very significant role in contributing to the electrical energy needs of Sri Lanka through smart grid technologies which enables integration with the national electricity grid.

IV. DC Motor Driven Alternator for Grid Connected Solar PV System

The traditional inverter / grid-interconnector deploy the solid state electronic technology. A serious obstacle encountered by the developers of grid-connected solar PV system is the high capital costs involved with this system. An alternative to this traditional technology is to make use of a D C (brushless) motor and a conventional rotating A C Alternator. The cost of this alternative technology is much lower than the solid state based inverter – grid interconnector. This technology deploys to integrate some of the well developed and commercialized components to replace the high cost of conventional solid state inverter to link solar PV modules to national electricity grids.
A less costly alternative system would enable many renewable energy developers to deploy solar PV systems to generate electricity and feed it to the national grid on a commercial basis under the standardized power purchase agreement.

V. Pumping Water into Hydro Reservoir

In this technology, water flowing along streams between the levels of two reservoirs is pumped into the upper reservoir. As the pumping head is significantly less than the generating head, there will be net energy gain.
Additional benefits could be harnessed through this technology by conducting the pumping activity during the off-peak hours in the CEB net work. If the necessity arises, the capacities of the hydropower plants

could be enhanced by constructing additional penstocks, turbines and generators. This additional capacity created could be used to meet the demand during peak load time.
Electricity generated from solar PV and wind energy could be made use for pumping water. Water thus pumped could be used to generate electricity in the normal manner utilizing the already installed hydro turbines and generators.

VI. Tracker cum Reflector for Solar PV

The output from a solar panel depends on the intensity of light falling on the panel. This intensity could be increased by rotating the panel to face the sun in the perpendicular direction and by providing simple reflectors (concentrators). The electrical output from a PV system could be enhanced by around 40% by incorporating a tracker arrangement for the solar panels to face the sun in the perpendicular direction and by incorporating suitable reflectors. In a Solar PV system the solar panel and the inverter-interconnector assembly are the costly items. The costs of solar tracker and reflectors are relatively smaller. The output of Solar PV systems could be increased by about 40 to 60% with relatively low additional cost by installing Solar PV systems with solar tracker and reflectors,.

VII. Biomass Gasifier for High Temperature Applications (High Temperature Gasifier)

Presently, high temperature and a clean environment required in the ceramic industry is achieved by the combustion of LPG which is a very expensive source of energy. The biomass gasifiers presently in operation in Sri Lanka do not have the capability of reaching such high temperatures. Moreover, producer gas generated in these gasifiers is contaminated with soot particles and traces of tar. Presence of such contaminants is not acceptable in the manufacture of high quality ceramic ware. Therefore, it is necessary to develop a technology which could overcome the above drawbacks when undertaking gasification of biomass. A number of technological approaches are now available to address these issues.
Introduction of this technology will enable reducing use of high cost LPG through a cheap source of energy such as biomass. However, since such technologies are currently not in use in commercial scale in Sri Lanka, these technologies will have to be sought from overseas.

VIII. Bio Methane for Transport Applications

Usually, biogas consists of approximately 60% of methane and the balance is Carbon dioxide. Traces of Hydrogen sulphide gas also could be found in biogas produced from certain types of organic materials.
In order to use biogas as a transport fuel, it is necessary to compress it into cylinders at a pressure of around 200 atmospheres. Prior to compression of biogas to such high pressures, it is imperative to remove the carbon dioxide from the gas for technical reasons. To protect the vehicle engine from damage, and to minimize engine maintenance costs, it is useful to remove hydrogen sulphide gas in

biogas prior to compression. It is proposed to make use of the biogas in existing biogas digesters in the country for this purpose.

IX. Roof-Mounted Solar PV for Net Metering

With the view to promote renewable energy technologies amongst the affluent urban community, the Government of Sri Lanka has introduced "Net Metering" scheme. Under this scheme, a renewable source based electricity generated at consumer premises through sources such as solar PV, wind or biogas etc. could be exported to the national electricity grid. The amount of electricity exported is recorded on a monthly basis. The amount of electricity exported through such schemes is deducted from the amount of electricity consumed from the national grid by the consumer concern. Thereby the consumer is required to pay only for the net energy consumed.
The above scheme is particularly attractive for the urban affluent household consumers. Currently a handful of consumers have made use of this Net Metering scheme introduced by the government. A more efficient and more cost effective technology would make this scheme more attractive.

x. Concentrated Solar Thermal Electricity Generation

The efficiency of Solar PV system in Sri Lanka is adversely affected by the presence of cloud cover thereby impacting on the output of such solar PV systems. Although electricity storage using secondary (lead acid) cells could resolve this issue, this a very costly option. A better alternative is to use solar thermal system. To improve thermodynamic efficiency, high temperature based systems are essential. Such systems could be developed using concentrated solar thermal devices. By incorporating heat storage devices such as molten salt and by combining such systems with biomass based heat generation, more cost effective systems could be developed.

4.2.3 Mitigation Benefits of the Technologies Identified:

Summary of the mitigation benefits of the technologies identified is given in Table 4.2 below.

Table 4.2: Mitigation Benefits of Technologies Considered

	Technology	Mitigation Benefit of per Unit of Technology/y (tCO_2e/y)	Annual National Mitigation Benefits (tCO_2/y)	Capital Cost of Generating 1 toe of energy (US $./toe/y)
1	Building Management Systems	8,667 (1000 kW LED) + 1331 (1000 kW Solar AC)=	199,920 tCO2/y	2,843.9

		9,998 tCO2/y/		
2	Conversion of Biomass and Waste to Energy	258,826 (30 MWe cofired boiler) + 166 (1t/h cogeneration boiler) + 0.53 (0.5 kg/d LPG eq Biogas unit)+ 27,740 (50t/d RDF) Total: 286,773tCO2/y	Total:9,057,593tCo2/y	132.6
3	Smart Grid Technology for Wind & Solar Integration with Hydro	1,497tCO2/y/1MW	1,497,000tCO2/y/ 1000 MW	2,152.6
4	DC Motor Driven Alternator for Grid-Solar PV Systems	133 tCO2/y/100 kW module	133,000 tCO2/y (100 MW)	3,631.8
5	Water Pumping to Hydro Reservoir	6.66 tCO2/y/10 kW module	456,000 tCO2/y/ 10% of hydropower	30,995.7
6	Solar Tracker Cum Reflector	66 tCO2/y/ 100 kW unit	66,000tCO2/y (100 MW)	3,631.9
7	High Temperature Gasifier	1114 tCO2/y/700 kWth unit	13,023 tCO2/y/4480 t LPG replacement)	4,518.5
8	Biomethane for Transport	115 tCO2/140l/d eq	13,734 tCO2/y(4434toe)	3657.6
9	Roof-Mounted Solar PV for Net Metering	13tCO2/y/10kWp	1,300 tCO2/y(1 MW)	9991.0
10	Concentrated Solar Thermal Electricity Generation	136,481 tCO2/y/50 MW	1,364,810 tCO2/y/500 MW	9378.0

Note: (i) The mitigation unit used is tCO2e/y per unit of project. Projects will be implemented in modules. As the sizes of modules are different for different technologies, the size of the module is included in the unit

(ii) The assumptions behind the calculation of benefits are provided in the Technology Fact Sheets of the Energy sector.

4.3 Criteria and Process of Technology Prioritization

The Multi Criteria Decision Analysis (MCDA) approach was used for prioritizing mitigation technologies in the energy sector. The criteria for selecting priority technologies were established through stakeholder consultations and the ten (10) potential technologies identified as listed in para 4.1.1 were considered for evaluation.

Multi Criteria Decision Analysis (MCDA):

a) Determination of Criteria and Weightings

The evaluation criteria agreed included the following;

- Contribution to development priorities
- Potential for GHG emission reduction
- Costs and benefits

The contribution of each technology to development priorities of the country was assessed in terms of (a) environmental, (b) social, and (c) economic development priorities. The cost of technologies was considered on the basis of cost in US$ for generating 1 toe of Energy. Thus, the criteria used are as follows;

Cost Criteria

- Cost for generating 1 toe (ie. Tonne Oil Equivalent = 10GCal) of energy (C)
- For electrical energy 1 GWh = 240 toe (As recommended by the Sri Lanka Sustainable Energy Authority).

  (Cost refers to capital cost of implementing a project to deliver 1toe of energy per year.)

Environmental Criteria

- Greenhouse Gas Reduction (GHGR)
- Positive Local Environmental Impacts (PLEI)

Social Criteria

- Direct Employment (DE)
- Skill and Capacity Development (SCD)
- Energy Security (ES)

Economic Criteria

- Local Economic Benefit (LEB)
- Local Share of Technology (LST)

Table 4.1 provides the cost of generating 1 toe of energy through the respective technology options.
As described in the MCDA manual[24] following steps were undertaken in the evaluation process.

[24] Multi-Criteria Analysis: A Manual, 2009, Department of Communities and Local Government: London

(b) Construction of Performance Matrix and Scoring Matrix: The Performance Matrix and Scoring Matrix were constructed based on the above criteria. Each option was then given a score against each criterion, considering the preference on a scale of 0-100 (i.e. the least preferred option getting 0 and most preferred option getting 100). Then the weightings to be assigned for each criterion was based on the relative importance of each criterion to the respective options. These values are provided in Table 4.2. The Scoring Matrix is provided in the Annex B.

Table 4.3: Criteria and Weighting Factors Identified for the Energy Sector

Category		Criteria	Weight Factor
Costs		Cost of Energy Conversion Facility (C)	20
Benefits	Economic (28%)	Local Economic Benefits (LEB)	20
		Local Share of Technology (LST)	8
	Social (32%)	Direct Employment (DE)	12
		Skill and Capacity Development (SCD)	8
		Energy Security (ES)	12
	Environmental (20%)	GHG Emission Reduction (GHGR)	8
		Positive Local Environmental Impacts (PLEI)	12

(c) Calculation of Benefits: Benefits were calculated for each option as described in the manual *(Benefits = Total Score- Weighted Scores of Costs).* The costs and benefits for each option are given in table 4.4 below;

Table 4.4: Benefit/Cost Analysis

No	Technology Option	Cost (US $/toe)	Benefits	Rank
1	Building Management Systems (BMS)	2,843.9	54.1	3
2	Conversion of Biomass and Waste to Energy (BWE)	132.6	43.5	1
3	Smart Grid Technology for Wind & Solar Integration with Hydro (SGT).	2,152.6	54.9	2
4	DC Motor Driven Alternator for Grid Connected Solar PV Systems (DCM).	3,631.9	35.2	5
5	Water Pumping to Hydro Reservoir (WPH).	30,995.7	36.7	10
6	Solar Tracker Cum Reflector (STR).	2,813.7	38.8	4
7	High Temperature Gasifier (HTG).	4,518.5	42.6	7

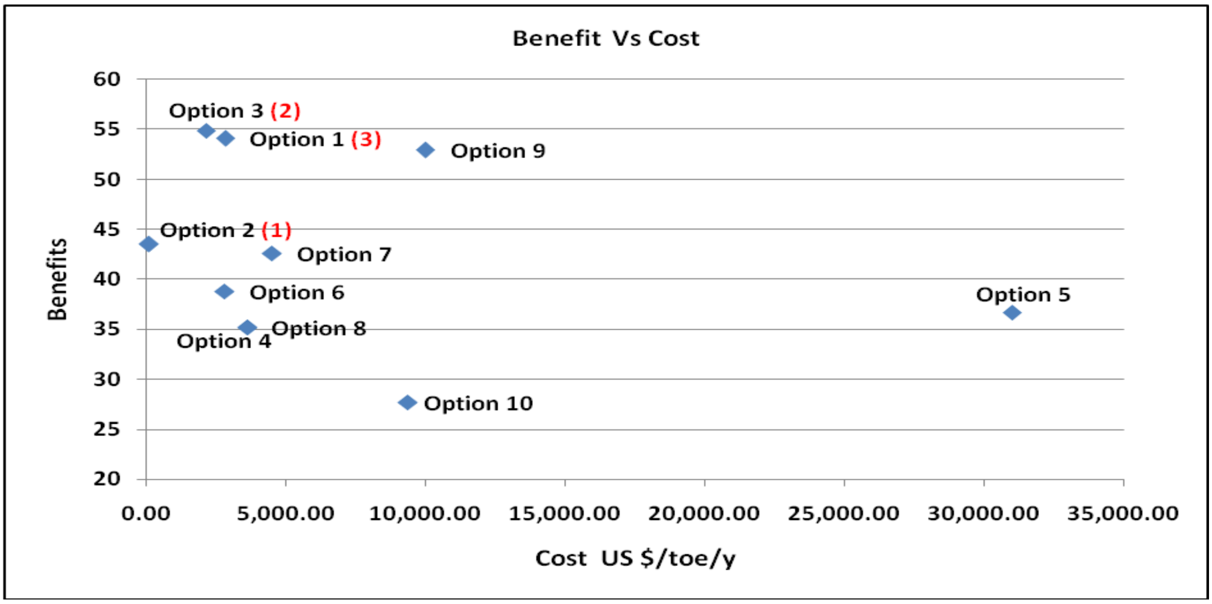
8	Biomethane for Transport. (BMT)	3,657.6	35.2	6
9	Roof-Mounted Solar PV for Net Metering (RMS).	9,991.0	52.9	8
10	Concentrated Solar Thermal Electricity Generation (CST).	9,378.0	27.7	9

The results of benefits and costs were analyzed as described in the MCDA manual by carrying out benefit cost analysis. In addition, Benefit/Cost ratio was also used in arriving at the ranks. The sensitivity analysis was also carried out to confirm the results.

4.4 Results of Technology Prioritization

Figure 4.3 which illustrate the benefits plotted against the costs clearly show that the values of benefits of the technology options 3 (Smart Grid Technology for Wind & Solar Integration with Hydro) and 1 (Building Management Systems) are clustered towards the benefit axis (relatively low cost options) with highest level of benefits. The technology option 2 (Conversion of Biomass and Waste to Energy) is very close to the benefit axis (lowest cost option) with relatively high level of benefits. Other options show relatively high cost or low benefits. These facts clearly show that the technologies 2, 3, and 1 are the preferred options and these are far superior to rest of the technologies. Based on results of the analysis, the most preferred three technology options in order of priority are; (*Technology 2*) **Conversion of Biomass and Waste to Energy**, (*Technology 3*) **Smart Grid Technology for Wind & Solar Integration with Hydro,** and (*Technology 1*) **Building Management Systems**. The sensitivity analysis carried out subsequently did not show any significant changes to the results of Fig. 4.4

Figure 4.4: Benefit Vs Costs for Identified Technologies



Accordingly the following technology options are recommended for further analysis;

1. **(*Technology 2*) Conversion of Biomass and Waste to Energy**
2. **(*Technology 3*) Smart Grid Technology for Wind & Solar Integration with Hydro**
3. **(*Technology 1*) Building Management Systems.**

Table 4.5: Summary Table for Prioritized Mitigation Technologies for the Energy Sector

No	Technology	Scale of Application *(Small, Medium or Large Scale)*	Time Scale	Potential Mitigation (GHG emission reduction) in the Time Scale	Benefits *(Output from the MCDA)*	Estimated total lifetime Cost (US $ = Rs. 110)
1.	**Conversion of Biomass and Waste to Energy**	Short Term: •30 MW cofiring+ •1t/h(50kW) cogen + •0.5kg LPGeq/d+ •50t/d RDF Long Term: •1000MWCofiring+ •180toe(17MW) Cogen+ •25tLPGeq/d + •500t/dRDF	Short Term: 2 Years Long Term: 10 years	Short term: 2250 tCO2/y. Long Term: 15 million tCO2/y in 10 years	43.5	Short term: Rs. 1,024,000,000 for Cofiring + Rs. 11,400,000,000,000 million. Long Term: Rs. 34,099,000,000 for cofiring + Rs. 3,876,000,000 for for cogen +Rs. 23,000 for Biogass + Rs. 100cogen +Rs. 1,150,000,000 +Rs. 1,000,000,000.
2	**Smart Grid Technology for Wind & Solar Integration with Hydro**	Short Term: 200MW of Solar and Wind Penetration. Long Term: 1000 MW of Solar and Wind Penetration,	Short Term: 2 Years, Long Term: 6 Years	Short Term: 1,497 tCO2/y Long Term: 1,497,000 tCO2/y	54.8	Short Term: Rs. 24,000,000,000 Long Term: Rs. 120,000,000,000
3	**Building Management**	Short Term: 1000 kW LED +	Short Term: 2 Years,	Short Term: 9,998 tCO2/y	54.1	Short Term: Rs. 4,177,000 for LED + Rs. 200,000,000 for Solar Assisted

	Systems	1000 kW Solar Assisted Air Conditioning. Long Term: 20 MW LED + 20 MW Solar Assisted Air Conditioning	Long Term: 10 Years	Long Term: 199, 920 tCO_2/y		Air Conditioning. Long Term: Rs. 83,540,000 for LED + Rs. 4,000,000,000 for Solar Assisted Air Conditioning.
Note: US $ = SL Rs. 110.00						

CHAPTER 5

Technology Prioritization for the Transport Sector

5.1 GHG emissions and existing technologies of the Transport Sector

5.1.1 GHG emissions from the Transport Sector

Transport sector is a major greenhouse gas (GHG) emitter in Sri Lanka. About 60 percent of air pollution (especially in Colombo City) comes from the transport sector[25]. In average, the transport sector contributes to 46.3% of the total GHG emissions in the country. The major system of transportation is the existing road network, which is supplemented by rail, air, and water transport modes. Road transport accounts for about 96% of passenger transportation and 99 percent of freight transportation. Railways accounts for about 4% percent of passenger transport and 1% of freight transport. Currently, the transport sector in Sri Lanka utilizes petroleum fossil fuels *(LPG, Gasoline and Diesel, Coal, Aviation Gasoline, Aviation Turbine and Fuel Oil)* leading to significant amounts of carbon dioxide (CO_2) and other GHG emissions (N_2O, CH_4, CO, NO_X, NMVOC and SO_2).

According to the national greenhouse gas inventory, CO_2 accounts for more than 95% of the transport related emissions[26]. Although the overall CO_2 emissions from transport sector is relatively low, given the size and population of the country, per capita CO_2 emission in Sri Lanka is more than three times that the per capita CO_2 emission in any other country in the region. Therefore, the transport sector has been identified as a priority sector for technology needs assessment to mitigate GHG emissions and explore for cleaner technologies relevant to transport.

The summary of the emissions from the Transport sector is provided in Table 5.1.

Table 5.1: Emissions of GHG and other gases from the Transport Sector

Sub-sector	Emissions (Gg)						
	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Road Transport	4,444.03	0.47	0.04	131.47	46.96	25.26	7.50
Railway Transport	80.46	0.01	0.00	1.09	1.31	0.22	0.15
Air Transport	496.99	0.00	0.01	0.70	2.10	0.35	0.16
Sea Transport	36.70	0.00	0.00	0.50	0.75	0.10	0.17
Total	**5,058.19**	**0.48**	**0.05**	**133.76**	**51.13**	**25.93**	**7.98**

[25] Air MAC, 2009. Clean Air 2015, Air Resource Management Centre, Ministry of Environment & Natural Resources

[26] ME, 2011, Second National Communication on Climate Change, Ministry of Environment, Sri Lanka

Source: ME, 2011, Second National Communication on Climate Change, Sri Lanka

The total CO_2 equivalent emissions from Transport sector is 5,084 $GgCO_{2Eq}$, comprising 5,058 Gg of CO_2 emissions, 10.$GgCO_{2Eq}$ of CH_4 and 16 $GgCO_{2Eq}$ of N_2O.

5.1.2 Current status of technologies in the Transport Sector

The number of vehicles imported and used in the country has seen a significant increase during the last few years. The government recently reduced the age of used vehicle importation from 3.5 years to 2 years. In order to maintain the air quality standards, in 2009 the government also banned the importation of three wheelers with 2-stroke engines. Currently only 3-wheelers with 4-stroke engines are permitted to import. The Vehicle Emission Testing program introduced in November 2008 as a Pilot Project in the Western Province is now in operation island wide. Out of the total land passenger transport, buses carry about around 48% and railways carry around 4% of the passengers, while the rest of the passengers are carried by the other modes[27]. Cars, vans and three- wheelers carry 13%, 12% and 12% respectively. (Table 5.2)

Table 5.2: Passenger and Freight transport in Sri Lanka

Vehicle	Fuel type	Contribution to Passenger/Freight Transport
Passenger Transport		
1. Buses	Diesel	48.3%
2. Cars	Petrol, Diesel, LPG, Hybrids	13.2%
3. Vans	Diesel, Petrol	12.6%
4. Three- Wheelers	Petrol/LPG, Diesel	11.8%
5. Motor bicycles	Petrol	6.5%
6. Railways	Diesel	4.3%
7. Lorries and other vehicles	Diesel, Petrol, LPG	3.3%
Freight Transport		
1. Trucks	Diesel	99%
2. Railways	Diesel	1%

[27] Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air.

5.2 An overview of possible mitigation technology options in Transport Sector and their mitigation benefits

5.2.1 Technologies Identified: The following technologies /actions were initially identified through stakeholder consultations for priority consideration. Composition of Sector prioritization Working Group appears in Annex A2.

1. Shift of 5% of transportation of freight from roads to rail
2. Improved public transportation, especially in Colombo area: Introduction of a Bus Rapid Transit (BRT) system
3. Integration of Non-motorized transport methods in Colombo along with regularized public transport system
4. Improving the traffic signal system for synchronization
5. Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles
6. Improvement of the condition of byroads
7. Electrification of the existing railway system
8. Promote and facilitate the import of low GHG emitting hybrid vehicles
9. Increase the use of cleaner fuel (i.e. Compressed Natural Gas (CNG) and biofuels)
10. Roadside tree planting and improving the overall roadside vegetation

5.2.2 Mitigation benefits of the Technologies Identified: All these technologies were identified based on their GHG mitigation potential, novelty, and benefits to the society at large. The overall goals of selecting these technologies are aimed at reducing traffic congestion caused by heavy traffic including the large number of single- and low- occupancy vehicles, reduce air pollution, enhance fuel efficiency, and promote mass transportation and non-motorized transportation, all of which ultimately contributing to reduced fossil fuel consumption leading lowering overall emissions of CO_2. The benefits of each identified technology option are given in the Technology Fact Sheets provided in the Annex C-1.

Currently, certain technology-related decisions already taken by the government are yet to be implemented primarily due to the fact that the transport sector is handled by several stakeholder agencies in Sri Lanka. For instance, the decision of the Ministry of Transport for increasing the share of freight transportation by the train is yet to materialize due to the reluctance of the Sri Lanka Railways because of the high costs associated with it. However, in this exercise on Technology Needs Assessment, appropriate technologies were selected disregarding such institutional issues for the overall environmental and socioeconomic benefit to the country at large.

5.3 Criteria and Process of Technology Prioritization

Prioritization of technologies was carried out by following the Multi-Criteria Decision Analysis (MCDA) approach. This approach provided opportunity to assess technologies across a range of development and sustainability criteria. The last three technologies in the above list of identified technologies were not considered in the MCDA, due to the following reasons:

- Use of hybrid vehicles is being a fairly recent initiative in the country, the sustainability and commercial viability of this technology is yet to be established.
- The last two technologies (use of cleaner fuel & roadside tree planting and improving the overall roadside vegetation) have already been considered in the energy sector TNA. Therefore, these options were not included in the MCDA for the transport sector.

The evaluation criteria for selecting priority technologies were established through sectoral stakeholder consultations. Out of ten technologies initially identified, only seven (07) technologies were considered for evaluation.

Multi Criteria Decision Analysis (MCDA):

a) Determination of Criteria and Weightings

Through stakeholder consultations, Performance and Scoring matrixes were constructed for the technologies based on pre-determined criteria (Fig. 5.1) to assess the performance of each technology option. The process followed is as follows;

The evaluation criteria included the following;

- Contribution to development priorities
- Potential for GHG emission reduction
- Costs and benefits

Through discussion with stakeholders, the contribution of each technology to development priorities of the country was assessed in relation to (a) environmental, (b) social, and (c) economic development priorities. The potential of reducing GHG emissions from each technology was also assessed. The criteria also included cost of technologies per km in US $. Each option was given a total score on a scale of 0-100 (i.e. the least preferred option getting 0 and most preferred option getting 100) based on order of preference. Each criterion was assigned a weight based on the importance, and scores of different technology option was converted to a weighted score based on the weights given to each criterion. The weighted score of cost was reduced from weighted total score, to get the benefit, *(Benefits = Total Score-Weighted Scores of Costs)* which was then plotted against the costs to determine the best technology options.

Table 5.3: Criteria and Weighting Factors Identified for the Transport Sector

Category		Criteria	Weight Factor
Costs		Cost US $ million per km	13.2
Benefits	Economic	Employment generation (EG)	07.9
		Per Capita fuel saving (FS)	13.2
	Social	Health benefits (H)	10.5
		Sustainability (S)	10.5
		Time efficiency (TE)	10.5
	Environmental	Reduction of CO_2 emissions (CO_2)	13.2
		Improvement of Air quality (AQ)	10.5
		Noise reduction (NR)	10.5

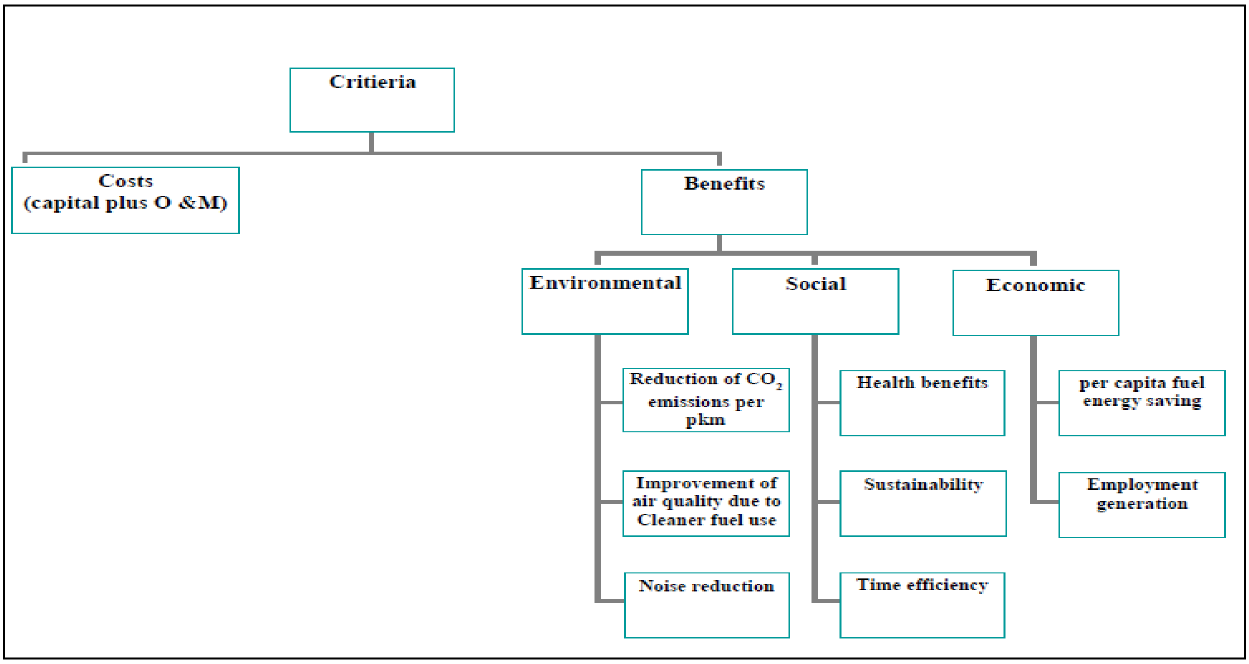


Figure 5.1: Criteria used in MCDA for the Transport Sector

b) **Construction of Performance Matrix and Scoring Matrix**:

The Performance Matrix and Scoring Matrix were constructed based on the above criteria and weighted scores. The Summary Scoring Matrix is provided in the Annex B.

c) **Calculation of Benefits:**

Benefits were calculated for each option as described in the MCDA Manual (Benefit = Total Score – Weighted Score of Costs).

The costs and benefits for each option are given in Table 5.3 below:

Table 5.4: Benefit/Cost Analysis for the Transport Sector

No	Technology Option	Cost/km US $ million	Benefits	Rank
1.	Shift of 5% of transportation of freight from roads to rail	5.00	6.56	7
2.	Introduction of a Bus Rapid Transit (BRT) system	3.00	50.21	6
3.	Integration of Non-motorized transport methods in Colombo along with regularized public transport system	0.17	64.07	**(1)**
4.	Improving the traffic signal system for synchronization	0.60	16.31	5
5.	Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles	0.35	57.09	**(2)**
6.	Improvement of the condition of byroads	0.16	5.26	4
7.	Electrification of the existing railway system	0.75	77.34	**(3)**

Note: *The Cost/km was included based on the consensus of all the stakeholders and national experts on Transport sector, given the range of technology options. Also, 'US $ million per km' unit was considered as the comparable unit, after going through several published reports and documents, mostly because most of the technologies came up could not be separated as cost per passenger km.*

The results of benefits and costs were analyzed as described in the MCDA Manual by carrying out benefit cost analysis and sensitivity analysis procedures. In addition, Benefit/Cost ratio was also calculated to verify the decisions on ranking. Based on results of the analysis, the most preferred three technology options in order of priority are; (*Technology 3*) **Integration of Non-motorized transport methods in Colombo along with regularized public transport system,** (*Technology 5*) **Promote carpooling** and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles and (*Technology 7*) Electrification of the existing railway system.

5.4 Results of Technology Prioritization

In prioritizing technologies, those options considered of having the highest benefits compared to costs based on the MCDA were given highest priority. Thus the following three technologies were chosen as the final, prioritized technologies, based on the benefit vs. cost plot. (Fig. 5.2)

1. Integration of Non-motorized transport methods in Colombo along with regularized public transport system
2. Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles
3. Electrification of the existing railway system

Fig. 5.2 illustrates the benefits, estimated as (total score - weighted score of costs), plotted against the costs which facilitated determination of the most suitable and prioritized technologies. Modal shift of 5 percent of freight transport and BRT system were 'outliers' mostly because of the high costs involved, in addition to the lower benefits compared to the prioritized technology options.

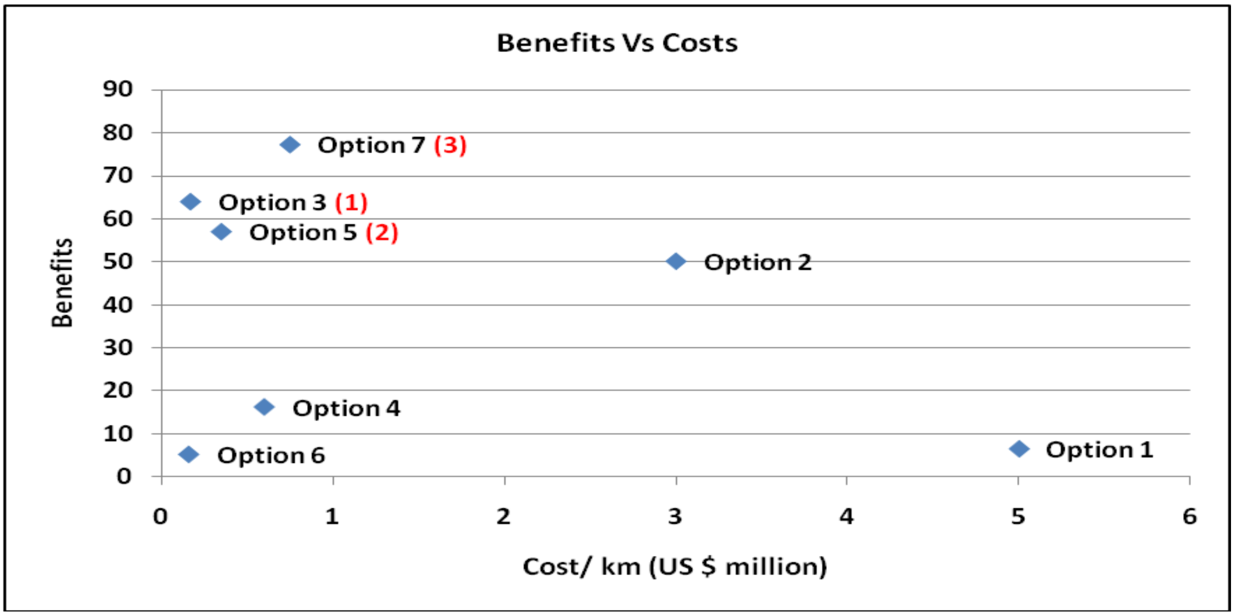


Figure 5.2: Benefit Vs Cost Plot for Identified technologies

(Option 1= Shift of 5 percent of transportation of freight from roads to rail; Option 2= Improved public transportation, especially in Colombo area: Introduction of a bus rapid transit (BRT) system; Option 3= Technology fact sheet for transport sector- Integration of Non-motorized transport methods in Colombo along with regularized public transport system; Option 4= Improving the traffic signal system for

Synchronization; Option 5= Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles; Option 6= Improvement of the condition of byroads; Option 7= Electrification of the existing railway system)

Table 5.5: Summary Table for Prioritized Technologies

No	Technology	Scale of Application	Time Scale	Potential Mitigation in Time Scale (g CO_2 per passenger km)	Benefits (output from MCDA)	Estimated Cost (US $ million/km)
1.	Non-motorized transport along with regularized public transport	medium	2-3 years	103	50.0	0.17
2.	Park-and-ride systems	medium	3 years	219.2	45.1	0.35
3.	Electrified railway system	medium	3 years	96.5	64.6	0.75

The following assumptions were made in calculating the mitigation potential under each technology option; *Option 1: 1 km daily walking by the passengers using regularized public transport (of which 40 percent originally using single occupancy petrol cars) was assumed, Option 2: Shifting of passengers from single occupancy petrol cars to Park-and-ride shuttles run on diesel with an occupancy of 30 persons was assumed; Option 3: It was assumed that the passengers shifted from single occupancy cars (40 percent) and conventional diesel trains (60 percent). The following CO_2emission rates were assumed for fuel/energy types: Petrol- 2.322 kg CO_2per litre; Diesel- - 2.672 kg CO_2per litre; Grid electricity: - 0.545 kg CO_2per kwh*

CHAPTER 6

Technology Prioritization for the Industry Sector

6.1 GHG emissions and existing technologies of the Industry Sector

6.1.1 GHG emissions from the Industry Sector

Industry sector of Sri Lanka is not a high energy and resource consuming sector. According to the Ministry of Finance[28], the island's industry sector share in the GDP in 2009 was 28.7% while growing at 8.4 percent from Rs. 701.1 billion in 2009 to Rs. 760.2 billion in 2010. The key industries contributing to GHG emissions are cement manufacture, lime production for construction industry, and industries using lime stone ($CaCO_3$ containing material) and soda ash. The energy required for industrial purposes is generated from several sources such as biomass, petroleum oils and electricity. Biomass is used in tea and rubber factories, bakeries, tile and brick industries and other small scale industries. Petroleum oil is used for operating boilers, ovens and furnaces in other industries.

The GHGs emitted from the industry sector includes CO_2, CH_4, N_2O, CO, NOx, NMVOC, and SO_2. The main fraction of GHGs in the industrial sector is CO_2 and it contributes about 86% of the total GHG emitted by the sector. Of this amount, about 63% is emitted from the industrial energy consumption and about 37% emitted from industrial processes. The emissions of CO_2 from industrial energy consumption and industrial processes sub-sectors are 842.03 Gg $CO_2$and 492.4 Gg CO_2 respectively. The total GHG emissions from industry sector are given in table 6.1.

Table 6.1: Summary of emissions from the industry sector for 2000

Sub-Sector	Emissions (Gg)						
	CO_2	CH_4	N_2O	CO	NOx	NMVOC	SO_2
Industry	**842.03**	**2.29**	**0.21**	**114.46**	**7.28**	**4.09**	**25.31**
Industrial Processes	**492.40**			**0.04**	**0.02**	**53.49**	**0.26**
A. Cement Manufacture	347.95						0.209
B. Lime Prod & Use	28.96						
C. Soda Ash Use	37.83						
D. Asphalt Use				0.002	0.004	14.083	0.005
E. Glass Manufacture						0.001	

[28] MF, 2010, Annual Report, 2010, Ministry of Finance

F. Steel Rolling	77.66				0.002	0.001	0.002
G. Paper Rolling				0.038	0.010	0.025	0.048
H. Food and Beverage						39.38	
Total Industry Sector	**1334.43**	**2.29**	**0.21**	**114.5**	**7.3**	**57.58**	**25.57**

Source: ME, 2012, Data from Second National Communication on Climate Change

Apart from the emissions generated due to industrial energy consumption, Cement manufacturing, Lime production, Calcite & Dolomite use, Soda ash use, Asphalt production & use, Glass manufacturing, Metal & Paper industry and Food & Beverage are the main industrial processes which produce higher GHG emissions. However, compared to emissions from industrial energy consumption, these industrial processes generate relatively low level of GHG emissions (Table 6.1).

Information on thermal energy consumption in the above mentioned industry sub sectors are not available. Nevertheless, based on the industry sector experience of sector experts (NCPC) these industry sub sectors are categorized as high, medium and low thermal energy consumers. Electrical energy consumption and level of thermal energy consumption are given in table 6.2.

Table 6.2: Electrical and Thermal Energy Consumption of Sub Industry Sectors

Sub Sector	Electricity (%)	Thermal (Rank)	Sub Sector	Electricity (%)	Thermal (Rank)
Textile	2	High	**Ice Making**	1	Low
Garments	10	Low	**Buildings**	7	Low
Rice	0.2	Low	**Tea**	4	Medium
Rubber	7	High	**Ceramic**	2	High
Steel	4	High	**Food & Bev**	3	High
Hotels	4	Medium	**Packaging**	2	High
Hospitals	3	Low	**Cement**	3	High

Local industry sector has not expanded significantly in the recent past due to high energy cost and several other external factors. Most of existing industries that use thermal energy have been converting their basic energy source from fuel oil to biomass since fuel prices continue to increase. Even though Sri Lankan GHG emission is at very low level compared to the other countries, local industries have embarked on improving their production processes in order to reduce energy and resource consumption because of high cost of energy and other resources.

6.1.2 Current status of technologies of the Industry Sector

Industry sector technologies can be basically divided in to two segments as;

- Industry or process specific technologies
- Cross cutting technologies that can be generally applied to almost all the industries.

Technologies can also be categorized into hard technologies which have real science and engineering inventions and soft technologies which are more likely to be innovations, strategies, techniques or management practices.

In the Sri Lankan industry sector, most appropriate technologies appear to be cross cutting technologies. Compared to the industrialized countries local industries fall within the categories of medium and small scale. If Sri Lanka introduces industry or process specific technologies, application of such technologies will be restricted to a few industrial organizations.

6.2 An overview of possible mitigation technology options in the Industry Sector and their mitigation benefits

6.2.1 Technologies Identified:

The initial sectoral stakeholder consultations have identified (List of stakeholders provided in Annex A2) the following as priority technologies for consideration.

1. Energy Efficient Motors
2. Variable Speed Drives
3. Ethanol Kitchen Stove
4. Cook Stove with Biomass Gasification
5. Biomass Residue Based Cogeneration Combined Heat and Power (CHP)
6. Rotary burners for thermal applications
7. Super Boilers
8. Gas absorption heat pumps
9. Composite cans with paper bottoms
10. Heating Technology for Recycling of used types

Most of these technologies are cross cutting having high potential for GHG emission reduction and other benefits rather than industry or process specific technologies which have limited applications in the Sri Lankan context. Please see the Technology Fact Sheets provided in Annex D3 for more information.

6.2.2 Mitigation benefits of the Technologies Identified:

CO_2 Mitigation potential was considered the highest priority when selecting technologies. In addition to CO_2 reduction potential other benefits are given in below table 6.4.

Table 6.3: Benefits of Technologies

Technology	Cost (US $/tCO2 reduction)	Economic Benefits	Environment Benefits	Social Benefits
Energy Efficient Motors	71.000	Electricity saving: 38,068 MWh/year	CO_2 reduction: 13,019 tCO_2e	Minimum maintenance and less resource wastage
Variable Speed Drives	104,563	Electricity saving:151,109 MWh	CO_2 reduction: 51,679 tCO_2e	Smart technology with minimum maintenance and defects
Ethanol Cook Stove	15,491	Energy Efficiency	Minimum environment impact due to renewable resource	Increased employment opportunities in bio ethanol manufacturing industry
Cook Stoves with biomass Gasification	18,073	Saving from fossil fuel imports	Environment impacts are minimum	Increased employment opportunities biomass producers and suppliers, reduced health impacts
Biomass residue based cogeneration combined heat and power (CHP)	161,364	Saving of 0.004 USD/kWh for electricity; 0.002 USD/kWh for thermal	CO_2 reduction: 11,300 tCO_2e/year	Increased employment opportunities for biomass producers and suppliers, reduced health impacts
Rotary burners for thermal applications	15,491	Saving from fossil fuel imports	Less Environment impacts	
Super Boiler	322,727	Saving from fossil fuel imports	Less Environment impacts	
Gas Absorption Heat Pumps	225,909	Saving from fossil fuel imports	Less Environment impacts	

Composite cans with paper bottoms	258,182	Energy and other resource saving	Less Environment impacts	
Heating Technology for recycling of used tyres	322,727	Energy and other resource saving	Environment damage is minimized	Reduces adverse social impacts due to health hazards

6.3 Criteria and Process of Technology Prioritization

Prioritization of technologies was carried out using the Multi-Criteria Decision Analysis (MCDA) process. The criteria and weighting factors for selecting priority technologies were established in consultation with the sector stakeholders.

Multi Criteria Decision Analysis (MCDA):

a) Determination of Criteria and Weightings

Each step of the MCDA process was involved with stakeholder consultations and the Performance matrix and scoring matrix for the technologies listed above were constructed by deciding on a criterion (Table 6.5) to determine the performance of each identified technology option. The criterion encompassed the following;

- Contribution to development priorities
- GHG emission reduction potential
- Costs and benefits

The contribution of each technology to development priorities of the country was assessed based on (a) environmental, (b) social, and (c) economic development priority considerations. The GHG emissions reduction potential of each technology was also assessed through the stakeholder consultations. Each option was given a score against each criterion on a scale of 0-100 based on the order of preference (i.e. the least preferred option getting 0 and most preferred option getting 100). Each criterion was assigned a weight based on the importance of the criterion, followed by calculating the weighted score. The weighted score of cost was deducted from the weighted total score, to get the benefit for each technology. Benefits were then plotted against the costs to determine the best technology options.

Table 6.4: Criteria and Weighting Factors Identified for the Industry Sector

Category		Criteria	Weight Factor
Costs (25%)		Initial Investment/tCO2 reduction	20
		Operation and Maintenance cost/year	5
Benefits (75%)	Economic (15%)	Lifecycle cost for unit of CO2 saving	5
		Reliability & Durability	5
		Policy Support / Taxes	5
	Social (30%)	Business / Job Opportunities	12
		Safety & Health Hazards	6
		Social Adaptability	12
	Environmental (30%)	Lifecycle Impact	10
		GHG Reduction Potential	8
		Pollution Load in wastewater	3
		Solid waste	3
		Noise, dust & Air quality	3
		Hazardous waste	3

Ranking of the technologies was carried out based on the technological details, the investment cost and other criteria such as annual operational and maintenance costs, lifecycle cost for unit of CO2 saving, reliability & durability and policy support & taxes etc. provided by the technology providers as appearing in the Technology Fact Sheets (TFS).

b) Calculation of Benefits:

Benefits were calculated for each option as described in the Multi-Criteria Decision Analysis Manual of the UN (Benefit = Total Score – Weighted Score of Cost). The costs and benefits for each option are given in table 6.6 below:

Table 6.5: Benefit/Cost Analysis for industry sector

Technology No.	Technology	Investment Cost (US $ /tCO2 reduction)	Benefits	Rank
1.	Energy Efficient Motors	71.000	58.04	**(1)**
2.	Variable Speed Drivers for motors	104,563	57.35	**(2)**

3.	Ethanol cook stove	15,491	45.78	5
4.	Cook stoves with Biomass Gasification	18,073	52.25	4
5.	Biomass residue based cogeneration combined heat and power (CHP)	161,364	47.28	(3)
6.	Rotary burners for thermal applications	15,491	25.78	6
7.	Super Boiler	322,727	26.90	10
8.	Gas Absorption Heat Pumps	225,909	31.33	7
9.	Composite cans with paper bottoms	258,182	20.95	9
10.	Heating Technology for recycling of used tyres	322,727	40.80	8

The results of benefits and costs were analyzed as described in the MCDA Manual by carrying out benefit cost analysis and sensitivity analysis procedures. Accordingly, the three most preferred technology options in order of priority are; **(*Option 1*) Energy Efficient Motors, (*Option 2*) Variable Speed Drivers for Motors and (*Option 5*) Biomass Residue Based Cogeneration Combined Heat and Power CHP** *(Please see the explanation provided under the Section 6.4 for selection of technology Nos.2 and 5 over technologies 3 and 4)*

6.4 Results of technology Prioritization

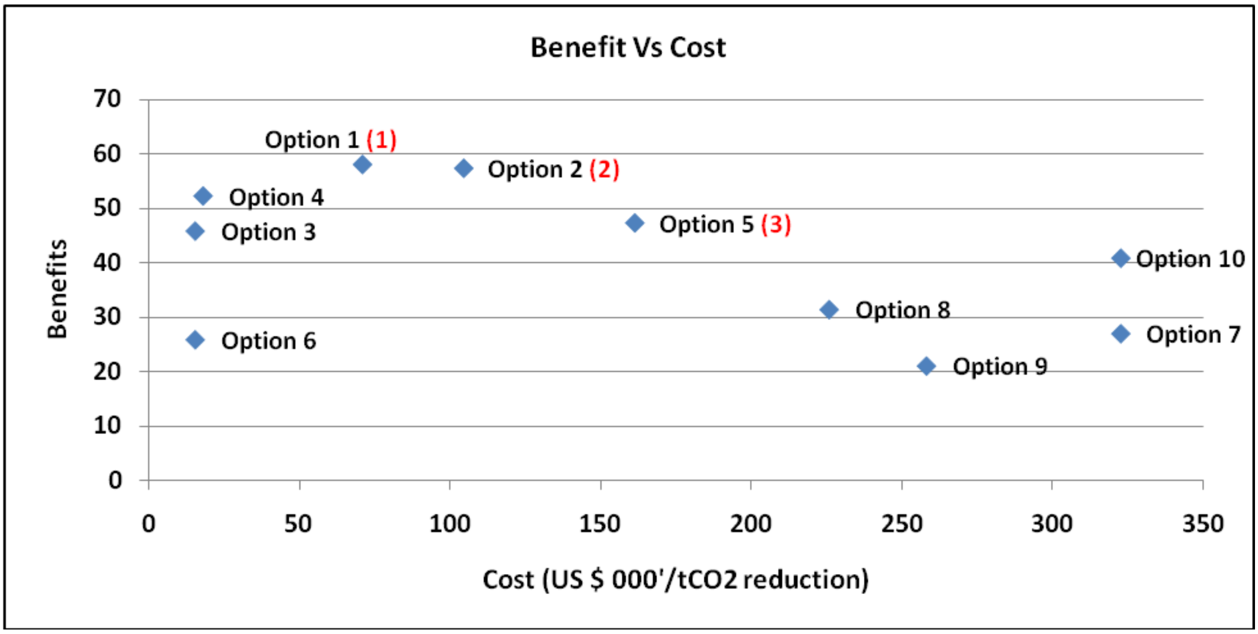


Figure 6.1: Benefit Vs Cost for Identified Technologies

According to the outcome of the Multi Criteria Decision Analysis, the technological options in order of priority are given below;

1. **Energy Efficient Motors**
2. **Variable Speed Drivers for Motors**
3. **Biomass Residue Based Cogeneration Combined Heat and Power (CHP)**
4. Cook Stoves with Biomass Gasification
5. Ethanol Cook stove
6. Rotary Burners for Thermal Applications
7. Gas Absorption Heat Pumps
8. Heating Technology for Recycling used Tyres
9. Composite Cans with paper bottoms
10. Super Boiler

Thus the following three technologies were chosen as the final, prioritized technologies, based on the benefit/cost analysis.

1. (Option 1) Energy Efficient Motors
2. (Option 2) Variable Speed Drivers for Motors
3. (Option 5) Biomass Residue Based Cogeneration Combined Heat and Power CHP

Technology No.1 (Energy Efficient Motors) provides high level of benefits (58.04) for relatively low cost. Although the technology Nos. 2 and.5 (Variable Speed Drivers for motors and Biomass Residue Based Cogeneration Combined Heat and Power CH) have relatively high investment costs compared to technology Nos. 3 (Ethanol Cook stove) and 4 (Cook Stoves with Biomass Gasification), technology No. 2 yield high level of benefits (57.35). But the benefits of technology No. 5 is relatively low (47.28). However, the two technologies, Nos. 2 and 5 were selected as the second and third priority technology options through stakeholder consensus.

Reasons for selecting technology Nos. 2 and 5 (Variable Speed Drivers for motors and Biomass Residue Based Cogeneration Combined Heat and Power CH) over technology Options 3 (Ethanol Cook Stoves) and 4 (Cook Stoves with Biomass Gasification) are given below.

Option 3

- Commercial level ethanol production facilities and dedicated supply chain mechanism are not available as yet.
- Most of ethanol producing raw material are edible materials. Application of these technologies may create food shortage or short supply of raw material for ethanol production.
- Can be basically used for heating applications in industries and at domestic level but impact to climate change is insignificant because this replaces existing biomass energy source at domestic level.

Option 4

- This technology option is more applicable at small scale industrial heating applications and household level.

Option 2

- Variable speed drive technology has wide range of applications in almost all the industries and service sector in Sri Lanka compare to technology option 3 and 4.
- Application of this option has direct impact to reduce electricity consumption and national cost of electricity generation. At present 85% electricity is generated in Sri Lanka by using imported non renewable energy sources such as diesel, fuel oil and coal.

Option 5

- Cook Stoves with Biomass Gasification is more applicable at small scale food industries but due to the food security and hygiene issues, industrialists are reluctant to go for these technologies.
- Biomass residue supply chain mechanism is at commercial level in Sri Lanka thus raw materials are available.

Although the Sri Lankan industry sector does not significantly contribute for GHG emission of the country, as a spin off, these selected technologies would contribute for improving energy efficiency.

Table 6.6: Summary Table for Prioritized Technologies

Option	**Technology**	**Investment Cost (US $ /tCO2 reduction)**	**Benefits**	**Scale of Application**	**Time Scale**	**Potential Mitigation in time scale (tCO2/Annum)**
Option 1	Energy Efficient Motors	71,000	58.04	Large, medium and small	10 years +	13,019
Option 2	Variable Speed Drivers for motors	104, 563	57.35	Large, medium and small	10 years +	51,679
Option 5	Biomass Residue Based Cogeneration Combined Heat and Power (CHP)	161,364	47.28	Large and medium	10 years +	11,300

CHAPTER 7

Summary/Conclusions

Although Sri Lanka is a low net emitter of greenhouse gases, analysis of past records has revealed that during the 40 year period 1961-2000, both the maximum and minimum temperatures at most weather stations have shown upward trends with rates ranging up to a maximum of 0.46 ^{o}C per decade in the case of maximum temperature and 0.27 ^{o}C per decade in the case of minimum temperature. On the other hand, the rainfall in all stations has shown decreasing trends with rates ranging from 1.5 mm/year to 19 mm/year, the high rates being shown in areas already receiving high rainfall. According to the National GHG Inventory completed in 2010, for the year 2000, Carbon Dioxide from fuel combustion has been the major emission source and it has shown a growth from 5447 Gg in 1994 to 10,430 Gg in 2000.

There is irrefutable evidence that Sri Lanka is affected by the global climate change impacts. At the same time, the future scenarios predict higher levels of emissions and negative impacts of expected climate changes, if no mitigation and adaptation actions are undertaken now.

Sri Lanka being a developing country Party to the UNFCCC, is required to undertake a Technology Needs Assessment (TNA) with respect to climate change to explore country needs for the reduction of greenhouse gas emissions from the potential sectors. The TNA was carried out from June 2011 to February 2012 for priority sectors having significant emission reduction potentials. These sectors are Energy, Transport and Industry. Following technologies were identified as the most preferred technology options for GHG emission reduction for the respective sectors;

Energy Sector:

1. Conversion of Biomass and Waste to Energy
2. Smart Grid Technology for Wind & Solar Integration with Hydro
3. Building Management Systems

Transport Sector:

1. Integration of Non-motorized transport methods in Colombo along with regularized public transport system.
2. Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles.
3. Electrification of the existing railway system.

Industry Sector:

1. Energy Efficient Motors
2. Variable Speed Drivers for motors
3. Biomass residue based cogeneration combined heat and power (CHP)

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ANNEXES

ANNEX - A

Annex A1

NATIONAL TNA COMMITTEE

1. Secretary, Ministry of Environment – Chairman
2. Secretary, Ministry of Agriculture
3. Secretary, Ministry of Water Supply and Drainage
4. Secretary, Ministry of Fisheries and Aquatic Resources Development
5. Secretary, Ministry of Health
6. Secretary, Ministry of Economic Development
7. Secretary, Ministry of Transport
8. Secretary, Ministry of Power and Energy
9. Secretary, Ministry of Industry and Commerce
10. Secretary, Ministry of Disaster Management
11. Secretary, Ministry of Local Government and Provincial Council
12. Secretary, Ministry of Technology and Research
13. Addl. Secretary (Environment & Policy), Ministry of Environment
14. Director General, External Resources Department, General Treasury, Ministry of Finance & Planning
15. Director General, Department of National Planning, Ministry of Finance & Planning
16. Director (Policy Planning), Ministry of Environment
17. Director (Air Resources Management & International Resources), Ministry of Environment
18. Director (Biodiversity), Ministry of Environment
19. Director (Sustainable Environment), Ministry of Environment
20. Director (Climate Change), Ministry of Environment
21. Director, Industrial Technology Institute of Sri Lanka

Annex A 2

WORKSHOP PARTICIPANTS

STAKEHOLDER WORKING GROUP – SECTOR PRIORITISATION

List of Stakeholders

1. Mr. Samitha Midigaspe - Chief Engineer, Ceylon Electricity Board, Colombo.
2. Mr. Rohitha Gunawardane – Head Env Division, Ceylon Electricity Board, Colombo.
3. Mr. H.M.U.K.P.B. Herath – Director, National Aquaculture Development Authority of Sri Lanka
4. Dr. Nirmalie Pallewatte - Head - Department of Zoology, University of Colombo
5. Dr. Siril Wijersundara - Director General, Department of Botanical Gardens, Peradeniya
6. Mr. R.A.S. Ranawaka - Senior Engineer (R &D), Department of Coast Conservation
7. Dr. Terney Predeep Kumara - Head, Dept of Oceanography & Marine Geology, University of Ruhuna
8. Dr.(Mrs.) A.P Bentota - Additional Director, Oil Crops Research & Development Institute, Department of Agriculture
9. Dr. S.P. Nissanka - Head, Department of Crop Science, University of Peradeniya
10. Ms. Sujeewa Fernando - Environment Management Officer, Ministry of Health
11. Ms. Sarojini Jayasekara - Deputy Director, Central Environmental Authority, Battaramulla
12. Ms. R.D.S. Gunarathna - Asst. Director, Ministry of State Resources & Enterprise Development
13. Mr. Roshan Salinda - Project Manager, Green Movement of Sri Lanka, Nugegoda
14. Mr. Wijaya Samarasinghe - Director/Planning, Sri Lanka Railway Department
15. Mr. R.S.C. George, Deputy General Manager , National Water Supply and Drainage Board
16. Dr. Tanuja Ariyananda - Executive Director, Lanka Rain Water Harvesting Forum
17. Mr. K.M. Viraj J Priyanjith - Asst. Director, Ministry of Private Transport Services

COMPOSITION OF STAKEHOLDER WORKING GROUP
ENERGY SECTOR

1. Secretary, Ministry of Power and Energy
2. Secretary, Ministry of Petroleum and Petroleum Resources
3. Secretary, Ministry of Technology and Research
4. Chairman, Ceylon Petroleum Corporation
5. Chairman, Author C. Clark Centre for Modern Technologies
6. Chairman, Electricity Consumer Society
7. Chairman, Public Utilities Commission
8. Director General, Sri Lanka Sustainable Energy Authority
9. Secretary General, Ceylon Chamber of Commerce
10. General Manager, Ceylon Electricity Board
11. General Manager, Lanka Electricity Company Ltd
12. Managing Director, Lanka Indian Oil Company
13. Executive Director, Energy Forum

14\. Director, Climate Change Division, Ministry of Environment

15\. Director, National Engineering Research and Development Centre

7\. Director, Industrial Technology Institute

8\. Director, Practical Action

9\. Mr. Riyaz Sangani –of Vidulanka , Grid Connected Small Hydropower Association

10\. Mr. Parakrama Jayasinghe , Bio Energy Association of Sri Lanka

11\. Mr. Angelo De Silva , Sri Lanka Solar Industry Association

12\. Mr. Manjula Perera , Representative of Wind Power Developers

13\. Representatives of Universities of Moratuwa, Peradenita, Ruhuna, Sri Jayawardenepura and the Open University.

COMPOSITION OF STAKEHOLDER WORKING GROUP
TRANSPORT SECTOR

1. Ministry of Transport (Represented by Mr. Yalegama)
2. Secretary, Ministry of Private Transport Services
3. Secretary, Ministry of Ports and Highways
4. Chairman, Civil Aviation Authority
5. Director General, Sri Lanka Transport Board
6. Director General, Transport Commission
7. Commissioner, Department of Motor Traffic
8. Director, AirMac, Ministry of Environment
9. Chairman, Western Province Provincial Road Transport Authority
10. Director General, Sri Lanka Railway Department
11. Head, Airport and Aviation Services Sri Lanka
12. Managing Director, Sri Lanka Ports Authority
13. Director General, Road Development Authority
14. Dr. D.S. Jayaweera, Director General, Dept of Development Finance, Ministry of Finance.
15. Dr. T.L. Gunaruwan, Senior Lecturer, Dept of Economics, University of Colombo.
16. Prof. Sunil Chandrasiri, Dept of Economics, University of Colombo.

COMPOSITION OF STAKEHOLDER WORKING GROUP
INDUSTRY SECTOR

1. Secretary, Ministry of Industry and Commerce (Represented by Addl. Secretary)
2. Secretary, Ministry of Constriction Engineering Services Housing and common amenities
3. Secretary, Ministry of State Resources and Enterprise Development
4. Secretary General, Federation Chamber of Commerce and Industry of Sri Lanka
5. Chairman, Planter's Association
6. Chairman, Sri Lanka Tourism Development Authority
7. Chairman, Sri Lanka Tea Board
8. Chairman, Green Movement
9. Chairman, Ce1entre for Environment Justice
10. Chairman, Environment foundation Limited
11. General Manager, Industrial Development Board
12. Director General, NERD Centre
13. Director General, Board of Investment
14. Director General, Sustainable Energy Authority of Sri Lanka
15. General President, Sri Lanka Association for Advancement of Science
16. Executive secretary, Institute of Engineers SL
17. Chief Executive Officer, Plastic and Rubber Institute
18. Director, National Cleaner Production Center

17\. Project Director, Ceylon Chamber of Commerce – Switch Asia Project (Hotel Sector)

ANNEX – B

Summary Objectives of Development Priorities – *Mahinda Chinthana*

No.	Development Priorities/ Sectors	Objectives to be achieved
1.	Agriculture	(a) achieving food security of people (b) ensuring higher and sustainable income for farmers (c) ensuring remunerative prices for agricultural produce (d) uninterrupted access to competitive markets both in Sri Lanka and abroad (e) farm mechanization (f) expanding the extent under cultivation (g) reducing wastage in transit (h) ensuring environmental conservation (i) introducing efficient farm management techniques and (j) using high yielding seeds and improved water management.
2.	Fisheries & Aquatic resources	Exploiting the country's fisheries and aquatic resources in a sustainable manner, while conserving the coastal Environment. The government is targeting self-sufficiency in the national fish supply and a significant increase in fish exports.
3.	Livestock development	The dairy sector will be considered as the priority sector for public investment recognizing its contribution to the national economic development process. The Government also recognizes that there should be no restrictions on the rearing of animals for meat (goats, swine, rabbits etc) and meat processing by the private sector. The private sector needs to assume greater responsibility in developing the poultry sector. The role of the public sector in poultry development will be a regulatory function focusing on animal disease prevention and quality assurance.
4.	Water	The mainly aim at providing water in adequate quantities to lands which are going to be newly cultivated and ensuring water availability to existing lands to enable them to cultivate throughout the year. This will be achieved through five main drives; (1) Water resources development and management (2) Improvement and the modernization of irrigation infrastructures (3) Watershed management (4) Institutional reforms (5) Research & Development.
5.	Healthy Nation	Excellence in healthcare is planned to be achieved through the provision of patient-focused, comprehensive and high quality service. State, working in partnership with the private sector, will ensure equitable access to the health services. Private sector involvement in the healthcare network will be encouraged under a well-regulated system in order to provide high quality and safe healthcare services.
6.	Environment	Concerted efforts to be made in order to achieve: Prevent depletion of green cover; Minimize the trend of the human-elephant conflicts; Improve solid waste

		management practices; Minimize air pollution caused by inefficient fuel consumption; Prevent diminution of upper water shed water sources; Ensure effective coastal conservation and management
7.	**Electricity for everybody**	Diversification of energy resources used in the country will be encouraged and the future energy mix will be rationalized to minimize fuel fired power generation. Management and operation of energy supply systems of the country will be made ensuring efficient utilization and conservation of energy.
8.	**Industry sector**	The strategy of the government ensures that by 2020, Sri Lanka's industrial sector will be a highly value added, knowledge-based, internationally competitive and diversified sector which employs a highly paid, skilled workforce. The sector is expected to mobilize more local raw material and have a large value creation particularly for a growing economy. The government is also promoting environmental sustainability and green technology in industrial activities.
9.	**Transport System**	The national policy of the government in the first place is to ensure that transport infrastructure facilities and services are adequately developed to meet the demand of the community. The second aspect of the policy is to provide a reliable, safe and speedy transport system which is comfortable and affordable to the community and thereby contribute to the growth of the economy.

ANNEX - C

SUMMARY SCORING MATRIX

Summary Scoring Matrix of the Energy Sector

Technology	Cost (US $/ toe)	Weighted Scores									Benefits
		Weighted Cost	Economic		Social			Environmental		Total Score	
			LEB	LST	DE	SCD	ES	GHGR	PLEI		
1. Building Management Systems	2,843.9	18.2	12.3	6.9	7.4	8.0	5.6	1.9	12.0	72.3	54.1
2. Biomass and Waste to Energy	132.6	20.00	20.0	2.3	12.0	3.2	2.8	1.9	1.3	63.5	43.5
3. Smart Grid Technology	2,152.6	18.7	18.5	6.9	11.1	3.2	12.0	1.9	1.3	73.6	54.9
4. DC Motor Driven Alternator	3,631.9	17.7	6.2	4.6	0.0	6.4	11.3	0.0	6.7	52.9	35.2
5. Water Pumping to Hydro Reservoir	30,995.7	0	6.2	2.3	3.7	6.4	8.5	5.6	4.0	36.7	36.7
6. Solar Tracker Cum Reflector	2,813.7	18.3	6.2	4.6	7.4	6.4	0.0	7.5	6.7	57.1	38.8
7. Biomass Gasifier for High Temp	4,518.5	17.2	18.5	0.0	7.4	6.4	2.8	7.5	0.0	59.8	42.6
8. Biomethane for Transport	3,657.6	17.7	6.2	6.9	3.7	3.2	5.6	5.6	4.0	52.9	35.2
9. Roof-Mounted Solar PV	9,991.0	13.6	20.0	8.0	3.7	6.4	2.8	8.0	4.0	66.5	52.9
10. Concentrated Solar Thermal Electricity	9,378.0	14.0	0.0	6.9	11.1	0.0	2.8	5.6	1.3	41.7	27.7
Weight Factor		*20%*	*20%*	*8%*	*12%*	*8%*	*12%*	*8%*	*12%*		

Summary Scoring Matrix of the Transport Sector

Tech No	Cost/km US $ million	Weighted Scores										Benefits
		Weighted Cost	Environmental			Social			Economic		Total Score	
			CO_2 Reduction/km	Air quality from cleaner fuel	Noise reduction	Health benefits	Sustainability	Time efficiency	Per capita fuel Energy saving	Employment generation		
1.	5.00	0.00	0.00	0.00	2.63	3.51	0.00	0.42	0.00	0.00	6.56	6.56
2.	3.00	5.44	7.69	5.00	7.89	7.02	10.53	4.21	7.87	0.00	55.65	50.21
3.	0.17	13.13	13.16	11.00	7.89	10.53	0.00	0.00	13.6	7.89	77.2	64.07
4.	0.60	11.96	0.00	0.00	0.00	0.00	5.26	3.16	0.00	7.89	28.27	16.31
5.	0.35	12.64	12.17	5.00	7.89	3.51	5.26	3.16	12.21	7.89	69.73	57.09
6.	0.16	13.16	0.00	0.00	0.00	0.00	5.26	0,00	0.00	0.00	18.42	5.26
7.	0.75	11.55	12.85	5.00	10.53	7.02	10.53	10.50	13.02	7.89	88.89	77.34
Weight Factor		*13.2%*	*13.2%*	*10.5%*	*10.5%*	*10.5%*	*10.5%*	*10.5%*	*13.2%*	*7.9%*		

Summary Scoring Matrix of the Industry Sector

Tech #	Investment Cost (US $ /tCO2 reduction)	Weighted Cost	Weighted Scores												Total Score	Benefits
			Economic			Environmental						Social				
			Life cycle cost for unit of CO2 saving	Reliability and Durability	Policy support / taxes	Lifecycle impact	GHG reduction potential	Pollution load in waste water	Solid waste	Noise, dust, air quality	Hazardous waste	Business/ job opportunities	Safety & Health hazards	Social Adaptability		
1	71.000	20.48	0.94	5.00	0.00	8.50	6.40	3.00	3.00	2.40	2.40	8.40	6.00	12.00	78.52	58.04
2	104,563	17.75	1.25	4.50	0.00	8.00	6.40	3.00	3.00	2.40	2.40	8.40	6.00	12.00	75.1	57.35
3	15,491	25.00	1.88	3.00	0.00	5.00	5.60	1.80	2.10	2.10	2.70	9.60	4.80	7.20	70.78	45.78
4	18,073	24.79	1.25	4.50	0.00	6.00	7.20	1.80	2.40	1.80	2.70	10.80	5.40	8.40	77.04	52.25
5	161,364	13.13	1.88	4.00	5.00	0.00	6.40	2.40	3.00	1.50	1.50	12.00	0.00	9.60	60.41	47.28
6	15,491	25.00	1.88	3.00	0.00	7.00	1.60	3.00	0.00	0.60	1.50	0.00	1.20	6.00	50.78	25.78
7	322,727	0.00	5.00	2.50	0.00	3.00	2.00	3.00	0.00	0.90	0.90	2.40	1.20	6.00	26.9	26.90
8	225,909	7.88	3.13	3.00	0.00	7.00	2.00	2.10	0.00	0.60	0.90	2.40	4.20	6.00	39.21	31.33
9.	258,182	5.25	3.75	3.00	0.00	1.00	0.00	2.10	0.00	0.00	1.50	8.40	1.20	0.00	26.2	20.95
10	322,727	0.00	5.00	3.00	0.00	2.00	3.20	2.40	3.00	0.60	0.00	10.80	2.40	8.40	40.8	40.80
Weight Factor		*25%*	*5%*	*5%*	*5%*	*10%*	*8%*	*3%*	*3%*	*3%*	*3%*	*12%*	*6%*	*12%*		

1.Energy Efficient Motors; 2.Variable Speed Drivers for motors; 3.Ethanol cook stove; 4.Cook stoves in Biomass Gasification; 5.Biomass residue based cogeneration combined heat and power (CHP); 6.Rotary burners for thermal applications; 7.Super Boiler; 8.Gas Absorption Heat Pumps; 9.Composite cans with paper bottoms; 10.Heating Technology for recycling tyres

ANNEX - C

TECHNOLOGY FACT SHEETS (TFS)

Annex C- 1

Technology Fact Sheets (TFS)

Energy Sector

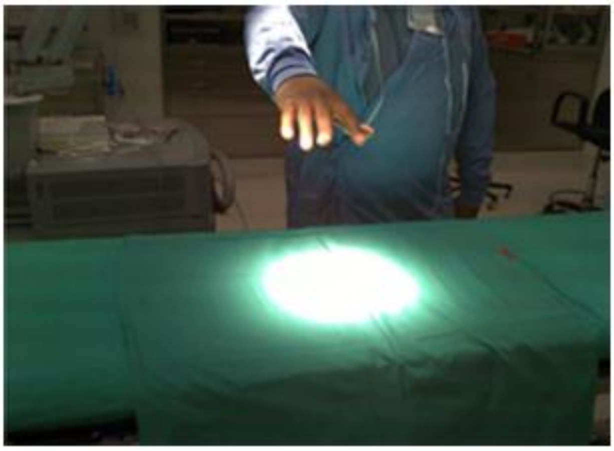
Energy Sector

Technology Fact Sheet - 1

LED Task Lighting

1. **Sector/ Sub Sector:** Energy
2. **Introduction:** LED technology is advancing into new categories of white light applications, including surgical task lighting, where early indications suggest significant potential for energy savings and reduced maintenance.
3. **Technology Name:** LED Task Lighting
4. **Technology Characteristics:** The halogen lamps typically used in surgical task lights suffer from relatively low luminous efficacy (lumens of light output per watt of input power), which is only worsened by filters that must be used to reduce the amount of non-visible radiation they emit. LED surgical task lights typically do not require such filtering media, and their higher efficacy can allow for reductions in connected load of 50 percent or more, with potential for additional energy savings through constant-color dimming and reduced cooling load in the operating room. Furthermore, while halogen lamps are typically rated for just 1,000 to 3,000 hours and fail catastrophically (sudden and without warning), LED surgical task lights are generally rated for 25,000 to 40,000 hours and are expected to “fail” by gradually fading in brightness. The U.S. Food and Drug Administration (FDA), which grants marketing clearance for medical devices, issued product testing guidance in 1998 for surgical task lights.
5. **Country Specific Applicability:**
6. **Status of the technology in the country and its future market potential:**
7. **Barriers:**
8. **Benefits:** Less maintenance, energy efficient, less weight, long lasting and reduce heat load of air conditioner
9. **Operations:**
10. **Costs:** Initial cost is high
11. **Reference:** US Department of Energy. Energy Efficiency & Renewable Energy

Parameter	Benefit
Efficacy	LEDs require less wattage to produce equivalent light levels.
Heat in Beam	Substantial thermal energy must be conducted away from LEDs, but they radiate relatively little ultraviolet (UV) or infrared (IR) energy.
Dimmability	Although system compatibility must be verified on a case-by-case basis, LEDs may offer dimming without color shift or flicker, thereby yielding additional energy savings.
Maintenance	LEDs promise significantly greater life and a non-catastrophic failure mechanism.



Energy Sector

Technology Fact Sheet - 2

Solar Assisted Air Conditioning Systems

1. **Sector/ Sub Sector:** Energy
2. **Introduction:** Solar Assisted air conditioning system is a newly developed technology in Philippines. It is a hybrid system of electricity and solar energy.
3. **Technology Name:** Solar assisted air conditioning system
4. **Technology Characteristics:** Solar Assisted air conditioner saves 30 -50 % of Electricity. It has wide target market – hotels, restaurants, hospitals, factory, school, convention centre and high end residential. It requires minimal direct sunlight exposure, heat from ambient and heat blown by the condenser is also utilized. There is minimum 30% saving if conventional AC unit is replaced by solar assisted AC. The saving energy is about 6,785,100,000 kWh/year.
5. **Country Specific Applicability:** Applicable in Sri Lanka
6. **Status of the technology in the country and its future market potential:**
7. **Barriers:**
8. **Benefits:**
9. **Operations:**
10. **Costs:**
11. **Reference:** Mr. Felix Richard A. Cordova

    President & CEO, Edward Marcs Philippines Inc. www.edwardmarcsphil.com ; E-mail: info@edwardmarcsphil.com Tel Nos: +632 9221371; +632 9221658; Mobile: +63917 6288839

Energy Sector

Technology Fact Sheet - 3

Co-Firing of Biomass with Coal for Electricity Generation

1. **Sector:** Energy Supply
2. **Introduction**

In this technology biomass is used as the fuel along with coal for the generation of electricity. Presently, only coal is used as the fuel in the 300 MW coal power plant at Norachcholai, in Sri Lanka. It is proposed to install 2 more units each of 300 MW capacity in the same location. Furthermore another power plant operating only on coal is planned at different location in Sri Lanka. In the proposed technology, it is intended to use biomass and coal as fuels.

3. **Technology Name**: Co-Firing of Biomass with Coal in Steam Boilers for the Generation of Electricity.
4. **Technology Characteristics: (Feasibility of technology and operational necessities)**

Feasibility of Technology:

As both coal and biomass are both solid fuels and their calorific values on weight basis do not differ much, it may appear easy to use biomass in a boiler designed for coal. However, combusting coal and biomass together encounters the following problems:

(a) **Fuel preparation, processing and handling issues**: In pulverized fuel boilers, the solid fuel need to be made into a powder before burning. Coal is a very brittle material. It is easy to grind it into powder form. On the other hand, biomass is very fibrous and flexible. It is not easy to grind. Biomass could be cut or sheared. Hence the type of equipment used to powder these two fuels are different. In other words if we the the same equipment to powder coal and biomass, then there will some restrictions. For this reason, if biomass and coal are mixed prior to powdering, then the maximum share of biomass in energy terms cannot exceed 10% of the energy content in the mixture.

(b) **Combustion related issues**: As the proximate analysis of coal and biomass are different, the bahaviour of the flame with and without biomass would be different. With higher percentage of biomass in the fuel mix, the stability of flame is very much affected. The likelihood of slagging in the combustion chamber is also high with higher share of biomass.

(c) **Ash related issues:** The physical and chemical properties of coal ash and biomass ash are different. Hence the ash handling equipment has limitations in simultaneous handling of coal ash wood ash. Ash from biomass combustion has a tendency of getting deposited in the heat exchanger region.

(d) **High Temperature Corrosion issues:** The presence of certain elements such as potassium in biomass leads to high temperature corrosion the superheater region. This aspect should be monitored.

(e) **Emission control issues:** The pollution control equipment such as de- NOx, de-Sox and electrostatic precipitator etc. has limitations when biomass and coal are simultaneously combusted.

(f) **Residue Utilization issues:** The operation of a coal power plant produces residues such as ash, desulphurization residue etc. A high share of biomass in the fuel mix significantly changes the characteristics of these residues. If not controlled, it might create problems in the utilization of these residues.

(g) **Capacity Reduction:** Biomass burns at a temperature lower than the temperature of combustion of coal. This results in some degree of capacity reduction.

Bearing in mind the above issues, the following technology options have been developed:

(a) **Use of Common Comminution Facility:** In this option, biomass is introduced upstream of the comminution facility. Hence biomass and coal are jointly pulverized in the same facility and the mixed fuel is handled jointly in the combustion process.

(b) **Use of Separate Metering and Comminution:** In this option, the fuels are handled separately until they are pulverized. Thereafter the two fuels are mixed and injected into the pulverized fuel pipework upstream of the burners.

(c) **Use of Separate Burners:** In this method pulverized fuels are prepared as per method (b) above and the two fuels are burnt using dedicated burners taking into account the characteristics of the two fuels.

(d) **Use of Biomass Gasifiers:** In this method biomass is separately pretreated, and converted into a low calorific value fuel gas (Producer gas) in a gasifier. The fuel gas is cleaned and combusted using suitably designed gas burners in the coal boiler. The share of biomass based fuel in the total fuel usage could be significantly higher in this process. However, higher share of biomass based fuel would result in some de-rating the boiler steam output.

(e) **Parallel Co-firing:** In this method, a separate boiler designed to use only biomass as the fuel is used to generate steam at the same temperature and pressure as that of the steam generated by the coal fired boiler. Steam generated from the coal boiler and biomass boiler are connected to a common steam header. Steam requirement of turbines are supplied from this common header. This last method, though the most expensive option, it has the following advantageous:

- This process does not encounter any of the problems enumerated earlier in co-firing.
- The share of biomass could be varied in the range almost zero to 100%.
- This method does not interfere with the operation of the coal fired facility. All guarantees applicable for the equipment initially provided for the coal firing facility could be continued as the use of biomass does not interfere with such equipment.

A number of co-firing facilities have been successfully installed and operated in many parts of the world. Following are some of such facilities:

1. Gelderland Power Station, Nijmegen, The Netherlands:
   - Total capacity: 635 MWe.

- Share of biomass: 20 MWe.
- Technology Option: Option (b) - Use of Separate Metering and Comminution.

2. Wallerawang Power Station, NSW, Australia:
    - Total capacity: 500 MWe.
    - Share of biomass: 7% by weight.
    - Technology Option: Option (a) - Use of Common Comminution Facility.
3. Studstrp Power Plant, Jutland, Denmark:
    - Total capacity: 350 MWe.
    - Share of biomass: 10% by weight.
    - Technology Option: Option (c) - Use of Separate Burners.
4. St. Andra Power Plant, Carinthia, Austria:
    - Total capacity: 124 MWe.
    - Share of biomass: 3% by weight.
    - Technology Option: Option (c) - Use of Separate Burners.
5. Zeltweg Power Plant, Styria, Austria:
    - Total capacity: 137 MWe.
    - Share of biomass: 3% by weight.
    - Technology Option: Option (d) - Use of Biomass Gasifiers.
6. Amer Power Plant, Geertruidenberg, The Netherlands
    - Total capacity: 600 MWe.
    - Share of biomass: 5% by weight.
    - Technology Option: Option (d) - Use of Biomass Gasifiers.
7. Avedore Power Plant, Copenhagen, Denmark
    - Total capacity: 430 MWe.
    - Share of biomass: 40MWe.
    - Technology Option: Option (e) – Parallel Co-firing.

Operational Necessity

The necessity to substitute at least a part of the coal fuel used for electricity generation is as follows:

- All the countries in the world, including developing countries are likely to be expected to reduce GHG emissions from 2015-2020.
- The carbon footprints of goods manufactured in Sri Lanka would play an important role in the international market.
- In the recent past countries such as China and India have started importing large quantities of coal. This has resulted in an increase in the price of coal. Moreover, with such increase in demand, the amount of coal available for purchase in this region has become an issue.

5. Country Specific Applicability:

Electrical Energy Supply Sector

The data provided by the Sri Lanka Sustainable Energy Authority (SEA) in their web: www.energy.gov.lk show that at present the national peak electricity demand is 2033 MW (28th September 2011) and the corresponding daily electrical energy consumption is 33.35 GWh/ day. The same data published during this year (2011) also show that the annual electricity peak demand growth is growing at about 400 MW per year and the daily electrical energy demand is growing at around 8 GWh/day/year.

In order to meet the above mentioned growth, the Ceylon Electricity Board (CEB), the sole utility responsible for the generation and distributing most of the electricity generated to the final consumers have been annually preparing and releasing their Long Term Generation Plan (LTGP). According to the last published LTGP, most of the future generation of electricity would be generated from coal based power plants as shown in figure 2.

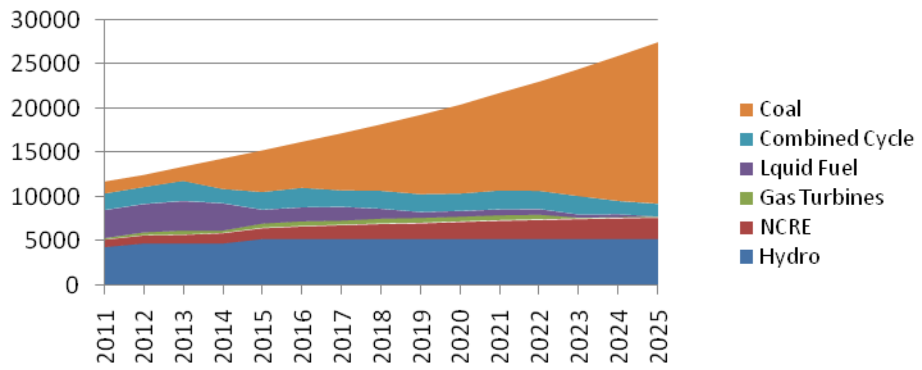


Figure 2: Annual Energy Generation (GWh/y)

In fact as per the above plan, EB has already commissioned and operating a 300 MW coal based power plant. The second phase of coal based power plant with a capacity of 2x300MW is under construction. Action has been initiated to construct another 2 x 500 MW coal based power plant in the country.

While the state owned utility CEB is planning to commission as many coal based power plants as necessary to meet the growing demand for electricity, the Ministry of Power and Energy, through the SEA is encouraging the private investors to develop renewable energy based power plants. In an attempt to generate at least 10% of the electrical energy requirements by the 2015, the SEA has offered an incentive scheme for the private sector to harness renewable energy resources and generate electrical energy and feed the national grid. A concessionary tariff based on the estimated cost of generation has been offered for each of the following technologies:

- Small Hydro: Rs. 13.04 / kWh
- Wind: Rs. 19.43 / kWh
- Biomass: Rs. 20.77 / kWh
- Agro/Industrial Waste: Rs. 14.60 / kWh
- Municipal Waste: Rs. 19.73 / kWh

In spite of the attractive tariff offered for biomass based electricity generation, only one power plant with a capacity of 0.5 MW has been commissioned a month ago. On the other hand by the end of 2010, a total of 86 small hydro power plants with a total capacity o 175.8 MW and 4 wind power plants with a total capacity of 30.15 MW and 2 agro residue based power plants with a total capacity of 11 MW have been commissioned.

A number of reasons have been attributed to the reluctance of investors to engage in biomass based energy generation. One important reason is that the difficulty in getting the desired energy output levels due to the high moisture levels prevailing in the biomass fuels. The development of this technology to dry the biomass fuels using waste energy available in the flue gas would resolve this issue.

Location of Coal Power Plant

The 3 x 300 MW coal power plants are located in a place called Nurachcholai, in Puttalum District. This is located in the Western coast of the island. With the intention of reducing cost, a breakwater has not been constructed. Instead, ships carrying coal are anchored in the deep sea at a distance of about 12 kilometers and coal from the ships is unloaded and transferred into barges. These barges shuttle between the ship and a jetty constructed at the coast thus moving the coal from the ships to the coast. A serious difficulty is encountered in this operation due to the stormy weather prevailing in this location most of the time of the year. Hence, the availability of adequate quantities of coal at this power plant is not assured.

On the other hand, plenty of suitable lands are available in the vicinity of the coal power plant for the production of sustainable biomass as fuel for use in electricity generation. Hence the proposal to substitute at least a part of the coal used for electricity generation with biomass would be very beneficial.

6. **Status of the technology in the country and its future market potential:**

Status of Technology in Sri Lanka

The cultivation and use of biomass fuel for energy generation have been extensively practiced in Sri Lanka for a very long period. In fact at present nearly 50% of the national primary energy is derived from biomass. Moreover, in the industrial sector, nearly 75% of the energy is derived from biomass fuel. However, there is plenty of room for technological improvements in these areas. The proposed technologies would be very much appreciated by this sector.

7. **Future Market Potential**

Electricity Generation Sector

At present a 300 MW coal plant is in operation. According to the Long Term Generation Expansion Plan of the CEB, the capacity of coal based electricity generation would be gradually increased to reach a value of 3600 MW by the year 2022. According to the study done by the Ministry of Science and technology, the potential for biomass based electricity generation in Sri Lanka is over 4000 MW. Hence the proposed technology of co-firing biomass with coal has clear potential at least till the year 2022.

8. **Barriers:** This section will be covered later.
9. **Benefits:** (How the technology could contribute to socio-economic development and environmental protection)

Social Benefits

The implementation of this technology would result in the cultivation, harvesting and transporting of biomass fuel. This would provide ample opportunities for the rural communities residing around the coal power plants.

In addition to the wood, these farmers will be in possession of Gliricidia leaves. This could be used to enhance the rural dairy industry and increase the production of organic fertilizer. All these mean that the introduction of this technology will provide productive employment to the under-employed poverty driven rural farming communities.

In addition the implementation of this technology also would provide opportunities for skilled and semi skilled workforce in the areas of installation high pressure steam boilers and ancillary equipment.

Economic Benefits

Electricity Generation Sector

As Sri Lanka does not possess any proven fossil fuel reserves and as the LTGP of the CEB is heavily depending on imported fossil fuels to meet the growing demand for electricity (see figure 2), the Ministry of Power Energy has formulated a policy to ensure that at least 10% of our electrical energy is generated from indigenous renewable energy resources by the year 2015. This share is to be increased to 20% by 2020. It is very unfortunate that those responsible for implementing this policy are promoting wind and solar PV. Wind and Solar PV do not contribute directly to any national economic benefits. Wind and Solar PV technologies depend entirely on foreign inputs for the import of necessary equipment and installation and commissioning staff.

On the other hand Sustainable Biomass based electricity generation results in significant local national input in the generation of electricity. All the fuel required for biomass based electricity generation is generated locally within the national boundary.

Moreover, on a level playing field, and if all costs including environmental, agricultural, health aspects are internalized, it can be proved that biomass based electricity generation is in fact the cheapest way of generating electricity.

Based on a net calorific value of 26,000 kJ/kg for coal and a landed cost of US$150/tone of coal and 15,000 kJ/kg for wood and a local price of Rs. 3.50 per kg, on an energy equivalent basis energy from coal is 2.77 times as expensive as the energy from locally available wood.

For the proposed 30 MW of biomass power plants, the savings in fuel cost would amount Rs. 0.68 billion per year and for the 3600 MW plant it would be 82 billion/ year..

Environmental Benefits

The increase in the use of biomass as an alternative to fossil fuels for industrial heat and electricity generation would result in the following environmental benefits:

- Less SOX and NOX emissions.
- Less GHG emissions: The 30 MWe project would result in 258,826 tCO_2/y.
- Additional Gliricidia plantations increasing the green cover in the country.

10. Operations: This will be written later.

11. Costs

Discussions held with local engineering companies who handle this type of equipment have indicated that to construct and commission a 30 MWe steam boiler with the capacity of 100 tonne of steam per hour would be Rs. 1026 million.

12. References

1. Calorific Values for Wood and Bark and Bibiliography for Fuelwood. A.P.Harker, A. Sandels and J.Burley. August 1982. Tropical Products Institute.
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11. Introduction of Natural Gas to Meet Energy Needs of Sri Lanka, Department of National Planning, May 2011.
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Energy Sector

Technology Fact Sheet – 4

Mechanization of Biomass Production

1. **Sector**: Energy
2. **Introduction:**

Based on a study carried out by the Ministry of Science and Technology, the Government of Sri Lanka has declared *Gliricidia sepium* tree as the fourth plantation crop in Sri Lanka. Many thousands of rural communities are engaged in cultivating this crop for a variety of reasons. Woody portions of the mature branches which are periodically harvested are used as fuelwood for industrial heat generation and electricity production. Due to high cost of labour the following activities in the cultivation, harvesting and processing of fuelwood have been encountered:

- Digging holes for planting seedlings.
- Harvesting of mature branches of trees without damaging the main stem.
- Crushing stems to facilitate drying prior to the use as fuel.

At a Stakeholder meeting arranged by the UNDP/ Sustainable Energy Authority (on xxx) the stakeholders emphasized the need to make these technologies available in Sri Lanka. Apart from identifying the source and the types of equipment, no progress has been made to make this technology available in this country. Meanwhile, the increase in the cost of manual labour in Sri Lanka and the subsidy granted for furnace oil are serious barriers for the development of sustainable biomass as a source of energy for industrial heat and electricity generation.

3. **Technology Name:** Mechanization of Biomass Production
4. **Technology Characteristics:**

Characteristics of the three machines (auger, harvester and crusher) are given below:

Earth Auger

Specifications

Model		AUG-500	
Engine	Brand & model	MITSUBISHI	KAWASAKI
		TB50	TH48
		2 STROKE	2 STROKE
	Displacement	51.7 cc	48.6 cc
	Max output (kw)	2.2	2.2
	Fuel tank capacity	1	1
	Carbure Type	Diaphragm	
	Start System	Recoil Starter	
	Clutch System	Automatic centrifugal	
Drive system	Reduction ratio	35:01:00	
	Drill rotational speed	170 RPM	
Attachment	Extension Shaft	Depth extension = 12" , 18"	
	Drills	Sign-spiral blade	
	Dills diameter	Available choice from 6", 8" , 10"	
	Length	880 mm	
Packing	Weight	8.6 Kg (Without drill)	
	L x H x W	59 x 38 x 27 cm	

http://www.peekayfarmequipments.in/earth-auger.htm

Approximate Cost: Rs. 15,000.00

Harvester

Suitable ready-made machines to meet the needs of Gliricidia cultivation in Sri Lanka are not available. As per details given below, we need to purchase some of the components and fabricate a system suitable for our needs,.

Pole Saw (M2600)

Product Description

Engine Model:1E34F

Engine Type:Air-cooled , 2 stroke

Displacement :25.4cc

2-cycle oil/Gasoline Mixing ratio:1:25

Ignition :CDI

Power:0.7KW

Carburettor:Diaphragm type

Guide Bar size :10"/12"

Chain Pitch:0.325"

http://great-power.en.made-in-china.com/product/HoImTUQKqPWD/China-Pole-Saw-M2600-.html

Wood Crusher

The bark in Gliricidia wood acts as a barrier for the escape of moisture. The easiest way to remove the bark from the stem is to crush the stems. Crushers used for crushing sugar cane for sugar extraction are suitable for this purpose. Moreover, crushing of Gliricidia sticks and subsequent shredding would convert

Gliricidia wood into small particle suitable for combustion in wood chip boilers. For better efficiency, the pulverized chips could be dried prior to combustion.

Details of some machines suitable for this purpose are given below.

Heavy duty Sugarcane Crusher

Item Code: TYPE-1

Marina Sugar Cane Crushers are ideal machines to extract Sugar Cane juice with uniform extraction rate

They are sturdy machines in tough working conditions and have proven their quality with low maintenance and reliability.

Technical Specifications

Cane Crushing capacity/hour*	750 - 1000 Kgs
Extraction	60 - 65 %
Power requirement	10 H.P
Speed of Driving Pulley	250 R.P.M
Size of Pulley	30" X 4. ½"
King Roller	8. 5/8" dia X 8. ½"
Crushing Roller	6" dia X 8. ½"
Extracting Roller	6. 1/8" dia X 8. ½"
Net weight	615 Kgs
Gross weight	750 Kgs

* Output Capacity indicated in Kilograms/hr.
* Output Capacity is a technical indication subject to factory testing conditions

Send Enquiry

Heavy duty Sugarcane Crusher- TYPE II

Item Code: TYPE2-Sugarcanecrusher

Heavy duty Sugar Cane Crusher

Type 2 Sugar Cane Crusher is 3 rollers, Double Roller, horizontal sugar cane crusher.

This machine is specifically designed to give uniformity, higher extraction and considerably greater output for commercial applications.

Technical Specifications

Cane Crushing capacity/hour*	500 - 600 Kgs
Extraction	60 - 65 %
Power requirement	8 H.P
Speed of Driving Pulley	250 R.P.M
Size of Pulley	30" X 4. ½"
King Roller	8. 5/8" dia X 6. ½"
Crushing Roller	6" dia X 6. ½"
Extracting Roller	6. 1/8" dia X 6. ½"
Net weight	590 Kgs
Gross weight	720 Kgs

*Output Capacity indicated in Kilograms/hr.
* Output Capacity is a technical indication subject to factory testing conditions

Send Enquiry

Feasibility of technology and operational necessitie

Holes for Planting Gliricidia Stems

The establishment of Gliricidia trees as a multipurpose plantation is done by planting Gliricidia stems in the ground, usually at a spacing of 1 meter apart. For this purpose it is essential to dig a hole of about 150 mm in diameter and 300 mm deep. Presently, this task is done by manual labour using steel crowbar. This is a tedious job. A healthy strong man will be able to dig about 32 such holes per day. Hence at the rate of Rs. 1,000 per day, to establish 8,000 trees in a hectare the cost of digging holes would cost Rs. 250,000. At such high cost, Gliricidia based plantations are not viable. With this machine, the above cost would be reduced to Rs. 25,000 per ha. The video in *http://www.sendspace.com/file/6h1enu* demonstrates this

Harvesting of Gliricidia Branches

Presently the cost of harvesting Gliricidia branches is aroundRs.1,000 per tone of wet wood. On a dry wood basis this is Rs. 2,000 per tonne. At such high cost, use of wood as a source of energy would not be viable. Hence there is a need to mechanize this activity. It is propose to mount a chain saw type of cutter in a suitable cart at a suitable height so that by pushing the cart along the path of Gliricidia trees all the branches of the trees would be cut at that height. The operation could be repeated at the next harvesting cycle.

The estimated cost of harvesting by the proposed method would be reduced to about Rs. 50 per tonne of dry wood

Crushing of Wood Prior to Drying and Feeding

At present Gliricidia wood is chipped using conventional wood chippers. Wood chips produced by these chippers do not separate the bark from the wood. As a result the moisture in the wood chips remain high. This results in high fuel consumption and difficulty in obtaining desired energy output levels.

The proposed sugar cane crushers are capable of crushing Gliricidia wood into a fibrous materials, thus separating the bark from the stem. This wouldcenable moisture from wood to escape thus facilitating drying. As the bark has ling fiubres, it is essential to send the fibrous materials produced by the crusher through another disintegrater of the type used to make compost out of garden waste. These two types of machines are presently used in Sri Lanka for different applications. With a combination of these two machines, the problem encountered in the fuelwood sector could be solved.

5. Country specific / applicability:

The relevant issues pertaining to this operation in Sri Lanka are as follows:

Furnace oil used by industrialists for the generation of heat energy is heavily subsidized by the government. Therefore, unless fuelwood is marketed at low cost, industries would be reluctant to use fuelwood. Hence to promote biomass energy it is essential that biomass fuel is produced and marketed at low cost.

The cost of labour is increasing day by day. During the last one year it has doubled from Rs. 500 per day to Rs. 1,000 per day. Hence manual labour should used only in extreme situation. Mechanization is an essential way to keep the economy growing.

Modern youth is very reluctant to undertake any manual work. The social stigma attached to manual work is preventing the youth to enter this market. Operating a machine is not considered as a manual job. It is considered as a “Machine Operator” type of job. Hence there is a need to creat such jobs to keep our economy growing.

6. Status of the technology in the country and its future market potential:

This aspect has been already covered in section 4, 5 and 6.

7. Barriers:

This will be written after the completion of Barrier Analysis by the Project Team.

8. Benefits: (How the technology could contribute to socio-economic development and environmental protection)

The following benefits are expected from this mechanization technology:

Social Benefits

- More employment to rural communities in the cultivation, harvesting and delivering of Gliricidia wood to energy conversion facilities.
- More employment for skilled and semi-skilled workforce in the engineering field.

Economic Benefits

- Accelerated establishment of Gliricidia Plantations.
- Availability of adequate quantities of sustainable fuelwood.
- Lower plantation establishment cost.
- Lower fuelwood cost.

- More switching from fossil fuel burning to biomass burning facilities.
- Establishment of more biomass based electricity generating facilities.
- Lesser consumption imported fossil fuels.
- Increase in the production local organic fertilizer.
- Increase in the dairy sector activities

Environmental Benefits

- Lesser local pollution (SOX & NOX) from fossil burning.
- More green cover in the country
- Less pollution from the use of chemical fertilizers

9. **Operations:** *After completion of barrier analysis and only for selected technologies.*

10. **Costs:**

Inquiries made from local merchants who import and supply these items the following cost estimates are reached:

Hole Digger: Rs. 15,000.

Harvester: The cost including all necessary fabrication of attachments: Rs. 25,000.

Crusher and Pulverizer: These estimated cost is Rs. 100,000.

11. **References:**

1. Calorific Values for Wood and Bark and Bibiliography for Fuelwood. A.P.Harker, A. Sandels and J.Burley. August 1982. Tropical Products Institute.
2. Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
3. Long Term Generation Expansion Plan, 2009-2022. Ceylon Electricity Board. December 2008.
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10. *http://www.sendspace.com/file/6h1enu*
11. http://great-power.en.made-in-china.com/product/HoImTUQKqPWD/China-Pole-Saw-M2600-.html
12. http://www.peekayfarmequipments.in/earth-auger.htm
13. *http://www.depagro.com/sugarcane-crushers.html*

Energy Sector

Technology Fact Sheet – 5

Flue Gas Based Fuel Dryer for Biomass Combustors

1. **Sector:** Energy Supply
2. **Introduction**:

Most of the industrial and electricity generation facilities at present use biomass fuels with moisture content in the range of 30% to 50% (wet basis). Such high moisture in the fuel reduces the overall efficiency of energy generation thus increases the fuel consumption rate and auxiliary energy inputs such as more fan power. This in turn adversely affects the economic merit of using biomass fuel based energy generation. The high moisture level in the fuel also limits the maximum desired energy output rate from the facilities. All these result in discourage the use of biomass fuel based energy generation and encourage the use of fossil fuel based energy generation.

A technology of reducing the moisture content of biomass fuels with minimal incremental cost would resolve the above mentioned issues.

3. **Technology Name**: Flue Gas Based Fuel Dryer For Biomass Combustors
4. **Technology Characteristics: (Feasibility of technology and operational necessities)**

Feasibility of Technology:

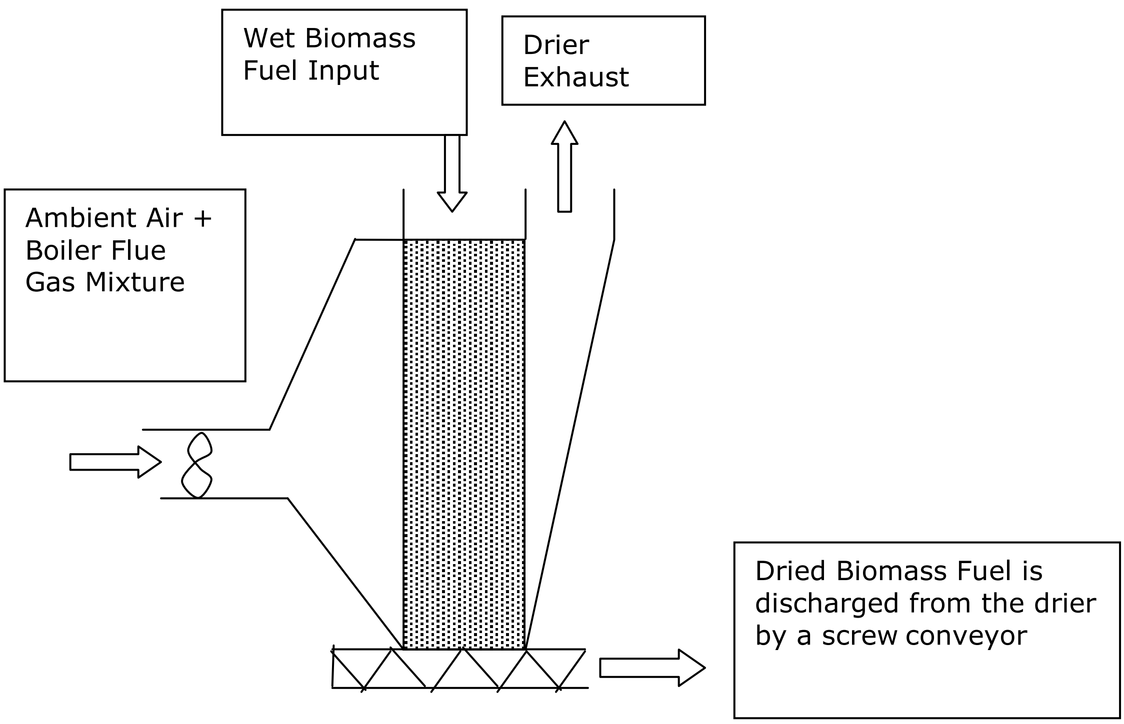
In a typical biomass combustion system, around 25% to 30% of the energy content in the fuel is carried away in the flue gas. Due to the very low sulphur content in biomass fuels, it is technically feasible to extract a part of energy available in the flue gas. To extract such energy from the flue gas and pass it to the intended medium steam, hot water or thermic fluid, the surface area of the heat exchanger required would be very large. Hence for economic reasons, such energy recovery process is not implemented.

Biomass fuel could be dried without the need of a heat exchanger, by simply blowing the flue gas directly into the wet biomass. The question of contaminating the fuel with undesirable constituents in the flue gas does not arise, as the fuel is meant to be completely combusted. However, it is necessary to mix the flue gas with ambient air before using it as the drying medium for the following two reasons: (a) To lower the temperature from around 200 oC to around 100 oC. (b) To lower the moisture level in the drying medium. Lowering the temperature is essential to prevent the biomass fuel from igniting itself. The reason for lowering the moisture level in the drying medium is to prevent condensation of water as the temperature is lowered from around 200 oC to around 50 oC when exiting from the drier.

The equipment required for this process is shown in figure 1. It consists of a vertical rectangular column. Into this column wet biomass in the form of chips is introduced at the top until the entire column is filled with biomass. At the bottom of the column, a screw conveyor discharges the dried biomass into a hopper. A bucket elevator is used for this purpose. Flue gas at around 200 oC is mixed with ambient air at 30 oC to obtain a mixed gas at a temperature of around 100 oC. This mixed gas is blown across the biomass column. As biomass is discharged from the bottom of the column by a screw conveyor, the biomass within the column moves downwards under gravity. The rate of discharge of biomass and the rate of flow of flue gas – air mixture across the column of biomass are regulated to ensure that the moisture content of biomass discharged from the drier is around 20% (wet basis). The exhaust gas from the dryer is vented into the atmosphere through a separate chimney.

The heat energy input to the dryer is provided entirely by the flue gas. Electrical energy is used to drive the fans for flue gas and ambient air and for driving the bucket elevator to feed the biomass into the vertical column and the screw discharge conveyor at the bottom of the column.

Figure 1: Sketch of Biomass Fuel Dryer



Operational Necessity

Most of the biomass fuels available locally have a moisture content of 30% to 60%. The Net Calorific Value (NCV) of 1 kg of a typical wood fuel at a moisture content of 60% (wet basis) is 14,757 kJ. If this 1 kg of wood is dried to 20% moisture, the NCV increases to 17,970 kJ. Hence by reducing the moisture of wood from 60% to 20% by drying it would reduce the fuel requirement to generate a specified amount of energy by 22 %. Hence the fuel cost of generating energy is also reduced by 22 %. Such a reduction in fuel cost would encourage industrialists and power plant operators to switch from fossil fuels to biomass fuels thus helping the world to reduce GHG emissions.

In addition to reducing the cost of fuel, reducing the moisture content also enables the combustion system to deliver the desired energy output level. With high moisture in the fuel, many combustion systems are unable to generate the desired level of energy output simply because the combustion grate area, the combustion volume, the amount of adequate combustion air, the temperature desirable for good combustion and the turbulence required to achieve good combustion are simply could not be met. (Time-Temperature-Turbulence principle). In an attempt to reach the desired level of heat output, operating staff of biomass combustions systems increase the volume of combustion air supply well beyond the optimum level. This in turn results in an increase in the heat losses due to heat carried away by the flue gas. This higher loss further increases the amount of fuel requirement. Thus further increases the cost of fuel.

Apart from increasing the cost of fuel requirement, higher moisture in fuel results in lower production output due to failure to generate the desired energy output level.

5. Country Specific Applicability:

Electrical Energy Supply Sector

The data provided by the Sri Lanka Sustainable Energy Authority (SEA) in their web: www.energy.gov.lk show that the present the national peak electricity demand is 2033 MW (28th September 2011) and the corresponding daily electrical energy consumption is 33.35 GWh/ day. The same data published during this year (2011) also show that the annual electricity peak demand growth is growing at about 400 MW per year and the daily electrical energy demand is growing at around 8 GWh/day/year.

In order to meet the above mentioned growth, the Ceylon Electricity Board (CEB), the sole utility responsible for the generation and distributing most of the electricity generated to the final consumers have been annually preparing and releasing their Long Term Generation Plan (LTGP). According to the last published LTGP, most of the future generation of electricity would be generated from coal based power plants as shown in figure 2.

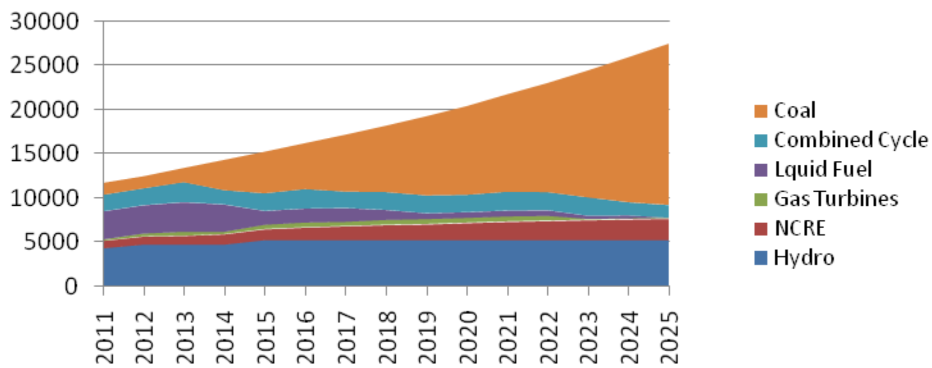


Figure 2: Annual Energy Generation (GWh/y)

In fact as per the above plan, EB has already commissioned and operating a 300 MW coal based power plant. The second phase of coal based power plant with a capacity of 2x300MW is under construction. Action has been initiated to construct another 2 x 500 MW coal based power plant in the country.

While the state owned utility CEB is planning to commission as many coal based power plants as necessary to meet the growing demand for electricity, the Ministry of Power and Energy, through the SEA is encouraging the private investors to develop renewable energy based power plants. In an attempt to generate at least 10% of the electrical energy requirements by the 2015, the SEA has offered an incentive scheme for the private sector to harness renewable energy resources and generate electrical energy and feed the national grid. A concessionary tariff based on the estimated cost of generation has been offered for each of the following technologies:

- Small Hydro: Rs. 13.04 / kWh
- Wind: Rs. 19.43 / kWh
- Biomass: Rs. 20.77 / kWh
- Agro/Industrial Waste: Rs. 14.60 / kWh
- Municipal Waste: Rs. 19.73 / kWh

In spite of the attractive tariff offered for biomass based electricity generation, only one power plant with a capacity of 0.5 MW has been commissioned a month ago. On the other hand by the end of 2010, a total of 86 small hydro power plants with a total capacity o 175.8 MW and 4 wind power plants with a total capacity of 30.15 MW and 2 agro residue based power plants with a total capacity of 11 MW have been commissioned.

A number of reasons have been attributed to the reluctance of investors to engage in biomass based energy generation. One important reason is that the difficulty in getting the desired energy output levels due to the high moisture levels prevailing in the biomass fuels. The development of this technology to dry the biomass fuels using waste energy available in the flue gas would resolve this issue.

Industrial Heat Sector

The latest Energy Balance 2007 published by the SEA reveals that the industrial sector in Sri Lanka uses biomass fuels to generate 82% of the heat energy required by this sector. The balance 18% is generated using petroleum fuels. On the prevailing market values and on a useful energy output equivalent basis, the cost of petroleum fuels is at least four times the cost of biomass fuels. Due to this significantly higher fuel costs, in the recent past there had been an attempt by the industrialists using petroleum fuels to switch to biomass fuels. In fact, despite a heavy subsidy given to furnace oil used by the industries, a handful of industrialists have switched from petroleum fuels to biomass fuels.

A number of reasons have been attributed to the reluctance of investors to engage in biomass based energy generation. One important reason is that the difficulty in getting the desired energy output levels due to the high moisture levels prevailing in the biomass fuels. The development of this technology to dry the biomass fuels using waste energy available in the flue gas would resolve this issue.

6. Status of the technology in the country and its future market potential:

Status of Technology in Sri Lanka

The technology of using flue gas from a combustion system to dry the biomass fuel has been implemented in Sri Lanka in one facility constructed by a private sector institution (Recogen Pvt. Ltd.). At this facility, Coconut shells are pyrolysed to charcoal. During pyrolysis of coconut shells, a part of the matter in the shells is volatized and liberated as gases and vapours. These gases and vapours are extracted from the reactor and combusted (by admitting combustion air) in a boiler to generate high pressure steam. The high pressure steam generated is used to drive a turbo-generator, charcoal produced in the process are used to manufacture activated carbon.

In this process of pyrolysis, the initial level of moisture in the biomass stock (coconut shell) plays an important role in the composition of the volatiles liberated. High moisture would result in a higher proportion of liquid tars and lesser amount of gaseous components. Moreover, a higher moisture level in the feed stock also lowers the quality of the charcoal produced. Hence the need to reduce the moisture in the feed stock is an important step in this process. The developers of this project were more or less compelled to develop a technology to dry the feed stock prior to admitting it into the reactor. Accordingly, a drying technology to dry the feed stock using the flue gas from the boiler has been developed and successfully deployed at this facility.

Future Market Potential

Electricity Generation Sector

At present a 10 MW biomass (agro-residue) based electricity generation facility has been commissioned a few years ago. Another 0.5 MW facility based on Gliricidia wood based power plant was commissioned about a month ago. Around 70 MW of power plants are in the pipeline. These 70 MW of biomass based power plants are expected to be commissioned within the next four years to meet the 5% of total generation target by the year 2015. An additional 70 MW of biomass power plants are expected to be commissioned before 2020 to reach the 20% target. All these plants will benefit from the proposed technology.

According to the study done by the Ministry of Science and Technology and European Union, the potential for biomass based power generation in Sri Lanka is over 4000 MW. Hence the long term potential of this technology is very large indeed.

Industrial Heat Generation Sector

At present over 82% of the industrial heat energy is generated from biomass. Most of this biomass is in the form of chunks. In these old furnaces biomass chunks are fed manually. The proposed technology does not match these old furnaces. Only around 12% of the existing biomass combustion systems could adopt the proposed technology. The amount of biomass coming under this category would be around 800,000 tonnes of biomass.

However, almost all the fossil fuel consuming combustion facilities are likely to switch to biomass once the present government subsidy granted to industrialists is removed. The total amount of biomass fuel required for such switch over would be 800,000 tonnes of biomass.

Hence the potential for this technology in this sector would be 1,600,000 tonnes of biomass per year.

7. **Barriers: This section will be covered later.**

8. **Benefits:** (How the technology could contribute to socio-economic development and environmental protection)

Social Benefits

The implementation of this technology will remove a serious barrier encountered in the sustainable production and use of biomass (Gliricidia Coppice Wood) as the fuel for the generation of electricity and industrial heat energy. This will result in many thousands of people from the rural farming communities engaging in the growing, harvesting (coppice cutting), transporting and deliver the harvested wood to the energy conversion facilities. In addition to the wood, these farmers will be in possession of Gliricidia leaves. This could be used to enhance the rural dairy industry and increase the production of organic fertilizer. All these mean that the introduction of this technology will provide productive employment to the under-employed poverty driven rural farming communities.

The introduction of this technology will also provide employment opportunities to the skilled workforce in the engineering sector. The fabrication, installation, commissioning and operation of the dryers would require many skilled, semi-skilled and unskilled staff. Hence the social problem of urban poverty will also be resolved.

Economic Benefits

Electricity Generation Sector

As Sri Lanka does not possess any proven fossil fuel reserves and as the LTGP of the CEB is heavily depending on imported fossil fuels to meet the growing demand for electricity (see figure 2), the Ministry of Power Energy have formulated a policy to ensure that at least 10% of our electrical energy is generated from indigenous renewable energy resources by the year 2015. This share is to be increased to 20% by 2020. It is very unfortunate that those responsible for implementing this policy are promoting wind and solar PV. Wind and Solar PV do not contribute directly to any national economic benefits. Wind and Solar PV technologies depend entirely on foreign inputs for the import of necessary equipment and installation and commissioning staff.

On the other hand Sustainable Biomass based electricity generation results in significant local national input in the generation of electricity. All the fuel required for biomass based electricity generation is generated locally within the national boundary.

Moreover, on a level playing field, and if all costs including environmental, agricultural, health aspects are internalized, it can be proved that biomass based electricity generation is in fact the cheapest way of generating electricity.

Based on a net calorific value of 26,000 kJ/kg for coal and a landed cost of US$150/tone of coal and 15,000 kJ/kg for wood and a local price of Rs. 3.50 per kg, on an energy equivalent basis energy from coal is 2.77 times as expensive as the energy from locally available wood.

For the proposed 140 MW of biomass power plants, the savings in fuel cost would amount Rs. 3.2 billion per year.

Industrial Heat Generation Sector

As mentioned earlier, the introduction of the drying of biomass fuel technology would have two impacts: (a) It will reduce the fuel consumption in the existing wood chip using furnaces and (b) It will encourage all the industrial sector petroleum fuel consumers to switch to biomass fuels. At present furnace oil is marketed at a subsidized price of Rs. 50 per litre. It is very likely that the subsidy will be removed soon and it will be marketed at Rs. 90/litre.

An estimated 800,000 tonnes of wood is presently used annually by the wood-chip consuming sector. Once the drying technology is introduced, the fuel consumption would be reduced by 22%. The impact to this subsector, presently using wood chips as fuel would be 33% of Rs. 3,500 x 800,000 tonnes amounting to Rs. 933 million per year.

When all the industries presently using petroleum fuels amounting to 200,000 tonnes per year switch to biomass fuel, the impact would be Rs. 200,000 x 90,000 – 800,000 x 3,500 = Rs.15.2 billion per year.

Environmental Benefits

The increase in the use of biomass as an alternative to fossil fuels for industrial heat and electricity generation would result in the following environmental benefits:

- Less SOX and NOX emissions.
- Less GHG emissions
- Additional Gliricidia plantations increasing the green cover in the country.

9. Operations

10. Costs

Discussions held with local engineering companies who handle this type of equipment have indicated that to construct and commission a dryer to match a 6MWth heater/ boiler that requiring 2 t of wood per hour would be Rs. 2 .0 million.

11. References

1. Calorific Values for Wood and Bark and Bibiliography for Fuelwood. A.P.Harker, A. Sandels and J.Burley. August 1982. Tropical Products Institute.
2. Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
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Energy Sector

Technology Fact Sheet - 6

Compact Biogas Digester for Urban Households

1. **Sector:** Energy
2. **Introduction:**

The conventional biogas digesters occupy too large to be accommodated in an urban household. More over the amount of conventional feed materials such as cow dung or perished vegetable materials are difficult to find in an urban area. An urban housewife would not like to handle such materials in such large volumes to generate biogas for cooking. On the other hand use of a solid fuel such as fuelwood is very cumbersome for an urban household. Even the best solid fuel stove developed by the NERD Centre is not elegant enough to satisfy a modern urban housewife. The lighting up and controlling the heat outputs of such stoves are very tedious. For these reasons LPG is the most preferred fuel for household cooking, despite the very high cost of LPG.

To resolve these issues, Appropriate Rural Technology Institute of Pune, Maharashtra, India (www.arti-india.org) has developed a "Compact Bio Gas Digestor".

3. **Technology Name:** Compact biogas Digester for Urban Household

4 **Technology Characteristics:** (Feasibility of technology and operational necessities)

The volume of this digester is 1.5 m3. It essentially consists of two plastic tanks. The larger tank acts as the digester vessel, while the smaller tank acts as the gas holder. The smaller tank is inserted into the larger tank with the mouth downwards. See Figure 1. Capital cost including all materials and labour and a gas burner is US$ 500 (LKR 57,000). 2 kg of starchy material is needed as the feed stock to produce 500 g of methane required to cook a day's meals for a family. If proper feed materials are used, the retention time in the digester is expected to be 72 hours.

Figure 1– ARTI Biogas Reactor

As starchy materials are difficult to or too expensive to obtain, the University of Moratuwa conducted trials on various materials to determine the output of biogas generation. This research study revealed that leaves of Gliricidia is the most effective material to be used as the feed material for biogas production. (Ref: 3). In this project it is proposed to demonstrate the feasibility of using Gliricidia leaves as the primary feed material along with food wastes generated in households in the ARTI type of digesters to generate adequate biogas for cooking purposes. It is also proposed to develop a suitable technology to process Gliricidia leaves and establish a supply chain to facilitate urban housewives to acces such materials at competitive prices. Figure 2 shows the use of biogas for cooking purposes in Sri Lanka.

Figure 2 - Use of Biogas for Cooking Sri Lanka

5. Country specific applicability:

Sri Lankan economy is growing at around 8% per annum. The annual percapita income is over 2000US$. This value is expected to reach double this value in the next 6 to 10 years. With such growth rate, the demand for LPG as a fuel for household cooking is increasing.LPG is an elegant fuel. It can be lit instantaneously. The heat output of an LPG stove could be varied from zero to full rated value with in a fraction of a second. Combustion of LPG does not produce any smoke. As LPG is free of sulphur, SOX emissions are nil. Hence every housewife who could afford the initial cost of switching from fuelwood to LPG and the operating cost of LPG has no hesitation in indulging in such changeover. The growth of LPG in the household and commercial sectors is remarkable. In fact not only the urban sector, households in the semi-urban sector too are gradually switching from fuelwood to LPG.

Even the most elegant solid fuel based cooking stoves would not satisfy the requirements of a contemporary housewife in Sri Lanka. On the other hand, LPG is either imported in its final form or is produced from imported petroleum fuels. The drain on foreign exchange resulting from this purchase is very severe. Hence there is an urgent need to develop an acceptable alternative to LPG.

Hence the challenge is many fold. Firstly, we need to develop a hardware which could be constructed in an urban household. Secondly, the device/ technology should be simple to operate by a non-technical housewife. Thirdly, there should an established supply chain to deliver or make it easily purchasable for any consumable item required to operate the proposed system. And lastly, it should be cheaper than LPG.

The proposed system meets all these requirements. ARTI of Pune, India has developed a simple reasonably priced hardware to produce biogas od adequate quantity for a household. University of Moratuwa (UOM) has identified a suitable material which could be used as the feed stock to generate the required amount of gas. UOM has found that Gliricidia leaves are an acceptable feed material for biogas production.

However, there is a need to organize the supply chain to provide regular supply of Gliricidia leaves to in a readily usable form to the households. This has not been done yet. R&D is needed to accomplish this task. Indications are that this could be achieved in the near future.

6. **Status of the technology in the country and its future market potential**:

Status of the technology has been already discussed in the previous section.

Market Potential:

The total number of households in the country is 4.5 millions. Of this amount 1.5 millionsare located within the urban and semi-urban areas. Unless an alternative is found, sooner or later, all these households will be using LPG for cooking meals in households. The expected consumption is over 200,000 tonnes of LPG per year. Hence the potential for the proposed technology is 1.5 million Compact Biogas Units and 10 million tones of Gliricidia leaves per annum. Although these are theoretically possible, it would be very difficult to meet this target, In the initial phase only 50,000 (out of 1.5 million) households are targeted.

7. **Barriers:** *After completion of barrier analysis and only for selected technologies.*
8. **Benefits:** (How the technology could contribute to socio-economic development and environmental protection)

The benefits of this technology are as follows.

Social Benefits

- Employment opportunities in the development of supply chain for feed materials.
- Employment opportunities in the construction of biogas digesters and production of biogas stoves.
- Employment opportunities in the collection and marketing of liquid fertilizers.

Economic Benefits

- Urban housewives will be able to reduce the cost of fuel used for cooking by switching from expensive LPG to cheap biomass feed materials.
- Savings in foreign exchange for the country from the reduction in consumption of LPG.
- Rural farming communities will be able to increase their income by processing and marketing Gliricidia leaves.

- Some of the middle income households would switch from fuelwood to biogas thus enjoying a smoke free and healthy home environment.
- Income from the production and use of liquid organic fertilizer.

Environmental Benefits

- A biogas unit introduced through this technology is capable of generating biogas which is equivalent to 0.5 kg of LPG per day. On a yearly basis this would replace182.5 kg of LPG with a calorific value of 46.1 MJ/kg. The emission factor for LPG is 63.1 tCO2/TJ. Hence each biogas unit introduced with this technology would reduce emission by 0.530 tCO2/y
- On a national basis, in the short term of the 5 million households in the country, if 1% of the households resort to this technology, the emission reduction would be 0.530 x 50,000 = 26,500tCO2/y.
- The switch to biogas from fuelwood in the middle income households would result in a smoke free and healthy environment in these homes.

9. **Operations:** *After completion of barrier analysis and only for selected technologies.*

10. **Costs:**

The capital cost of a 1 m3 compact biogas plant is US$ 500 = Rs. 57,000 (Ref. 5). This unit will generate equivalent of 182.5 kg of LPG. = 8413.25 MJ = 8413.25 x 4.18 Mcal = 35167.385 Mcal = 3.5167 toe. Hence the capital cost required to generate 1 toe = 57,000/3.5167 = Rs. 16,208/toe/y.

To develop the supply chain of the feed material an estimated Rs. 1.0 million is required.

11. **References:**

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2. Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
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Energy Sector

Technology Fact Sheet - 7

Waste to Energy

(Production of Residue Derived Fuel –RDF from Municipal Solid Waste – MSW)

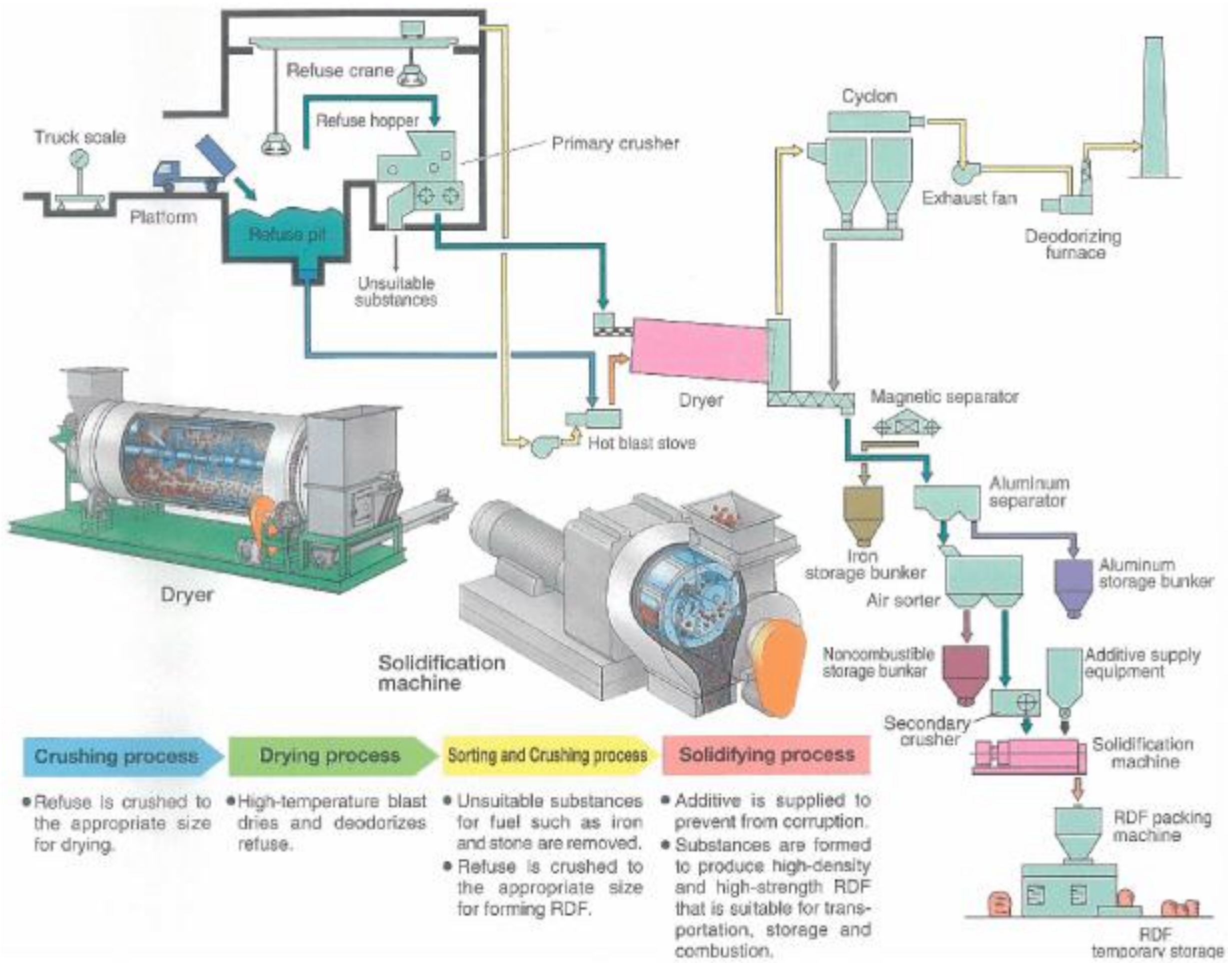
1. **Sector:** Energy Supply/ Waste/ Industry
2. **Introduction**

The city of Colombo daily generates 1250 tonnes of Municipal Solid waste (MSW) with a moisture content of around 60% and an organic content of 60%. The MSW also contains small quantities of halogenated PVC. Many attempts made to convert MSW into energy have not materialized. In the proposed technology, it is anticipated to convert MSW into a Residue Derived Fuel (RDF). This RDF could be used to replace a part of the coal used as the fuel in cement manufacture.

The manufacture of RDF from MSW consists of the following activities:

- Preliminary, manual recovery of recyclable and reusable items such as glass bottles, paper, hardboard, wooden items, large plastic pieces etc.
- Mechanized shredding and drying of MSW.
- Mechanized separation of shredded MSW into components such as organic materials, plastics, glass, metal etc.
- Storing segregated materials separately.
- Blending segregated materials in predetermined proportions.
- Pelletizing the blended materials.
- Packaging and transporting to the point of use.

A flow diagram is shown below:



3. **Technology Name:** Waste To Energy (Production of Residue Derived Fuel –RDF from Municipal Solid Waste – MSW)
4. **Technology Characteristics: (Feasibility of technology and operational necessities)**

Feasibility of Technology:

The processes associated in the manufacture of RDF from MSW utilize readily available machinery and equipment in many parts of the world. This process is practiced in many countries. Details of these installations in some of these countries are given below:

Country	No. of RDF Plants	Waste Input Tones/y	Fuel Output Tones/y
Austria	12	340,000	70,000
Finland	20	300,000	90,000
Italy	25	1,000,000	300,000
Netherlands	25	2,000,000	700,000
United Kingdom	3	250,000	90,000

Operational Necessity

The national daily production of MSW is 2,800 tonnes. Despite many attempts made to manage this material in an acceptable manner, only a tiny fraction of this material is properly utilized incurring enormous cost. The rest of the materials are taken to open dumps.

The reasons for the failure to implement acceptable proposals are as follows:

- The moisture in MSW is too high to be used for direct combustion.
- The cost of anaerobic digestion of organic materials is too high.
- The presence of halogenated plastics prevents conventional direct incineration.

The conversion of MSW into RDF and the use of RDF as a fuel substitute for the manufacture of cement would be acceptable as the estimated cost of production of RDF is comparable to that of imported coal on an equivalent energy content basis.

The need to reduce the consumption of coal and the reduction methane emission from open dumping of MSW would be mandatory for Sri Lanka in the years to come.

For these reasons it had become necessary to convert MSW into RDF and use the RDF as a substitute for coal.

5. **Country Specific Applicability:**

This aspect has been already covered under the previous section.

6. **Status of the technology in the country and its future market potential:**

Status of Technology in Sri Lanka

The following components of this technology are being practiced in Sri Lanka at present:

- Preliminary, manual recovery of recyclable and reusable items such as glass bottles, paper, hardboard, wooden items, large plastic pieces etc.
- Drying.
- Storing segregated materials separately.
- Blending segregated materials in predetermined proportions.
- Pelletizing the blended materials.
- Packaging and transporting to the point of use.

The following components of this technology are new to Sri Lanka and needs assistance to transfer these components of technology:

- Mechanized shredding of MSW.
- Mechanized separation of shredded MSW into components such as organic materials, plastics, glass, metal etc.

7. **Future Market Potential**

The total production of MSW in Sri Lanka at present is 2800 tonnes per day. With the rapid economic growth and urbanization, this value would increase rapidly. All these materials could be converted into over 8000 tonnes of RDF annually and used either in Sri Lanka or sold overseas. Hence

8. **Barriers: This section will be covered later.**

9. **Benefits:** (How the technology could contribute to socio-economic development and environmental protection)

Social Benefits

The total production of MSW in Sri Lanka at present is 2800 tonnes per day. With the rapid economic growth and urbanization, this value would increase rapidly. All these materials could be converted into over 8000 tonnes of RDF annually and used either in Sri Lanka or sold overseas. These would eliminate the present practice of open dumping of MSW and the associated health problems.

This process will also provide numerous job opportunities at all levels.

Economic Benefits

The 8000 tonnes of RDF to be produced annually would amount to 5000 tonnes coal valued at US$750,000. This is the direct economic benefit. But the indirect benefits arising from the proper managemewnt MSW would be enormous.

Environmental Benefits

The use of RDF as an alternative to fossil fuels for cement manufacture would result in the following environmental benefits:

- Less GHG emissions: The 50 tonne/ day RDF project would reduce GHG emissions by 27,740tCO2/y.
- Elimination of health problems associated with open dumping of MSW.

10. Operations: This will be written later.

11. Costs

The cost of producing 1oe of RDF in Sri Lanka is estimated as Rs. 9,594.

12. References

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2. Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
3. Long Term Generation Expansion Plan, 2009-2022. Ceylon Electricity Board. December 2008.
4. Long Term Transmission Development Plan 2005-2014. Ceylon Electricity Board. 2005.
5. Energy Sector Master Plan, Sri Lanka. Interim Report. Asian Development Bank, April 2004.
6. National Energy Policies and Strategies of Sri Lanka. Ministry of Power and Energy. October 2006.
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8. Mahinda Chinthanaya: Vision for a New Sri Lanka. A 10 Year Horizon Development Framework, 2006 -2016, Department of National Planning, Ministry of finance and Planning.
9. http://www.energyservices.lk/statistics/esd_rered.htm
10. Mr. Justine Seneviratne, General Manager, Lalan Engineering Co. (Pvt) Ltd.
11. Introduction of Natural Gas to Meet Energy Needs of Sri Lanka, Department of National Planning, May 2011.
12. The Hanbook of Biomass Combustion and Co-firing , edited by S jaakl van Loo and Jaap Koppeajn, Earthscan, 2008

Energy Sector

Technology Fact Sheet - 8

Smart Grid Technology for Wind & Solar Integration with Hydro

1. **Sector:** Energy Supply
2. **Introduction**

The potentials for wind based electricity generation and solar PV based electricity generation in Sri Lanka are very large. Each of the above technologies could generate many times the total electrical energy presently generated in the country. However, the development of these two technologies to meet grid-based electricity generation are not proceeding due to the reluctance on the part of the national electric utility due to the frequent and rapid variations in the level of outputs of power plants based on these two technologies. The cost of storing electricity generated by these sources to mitigate the fluctuations in outputs is prohibitively expensive.

Many developed countries have resolved this problem by adjusting the demand of energy in the system and output levels of hydropower plants to match the variations in the outputs of wind and solar PV power plants.

Such adjustments are feasible only by incorporating Smart Grid/ Smart Meter technologies.

3. **Technology Name:** Smart Grid Technology for Wind & Solar Integration with Hydro
4 **Technology Characteristics: (Feasibility of technology and operational necessities)**

Feasibility of Technology:

These technologies have been already implemented in many developing countrues in the Europe, Japan and North America. Details are avail in the references given.

5. **Operational Necessity**

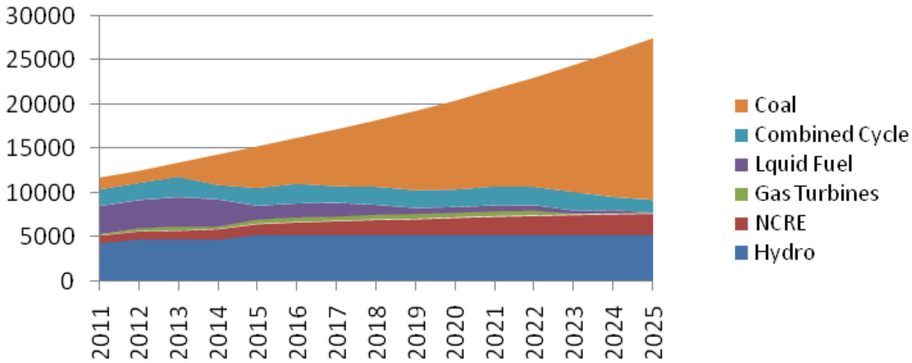
Without deploying this technology, it would not be technically feasible to appreciably increase the share of wind and solar PV based electricity generation in the national grid.

6. **Country Specific Applicability:**

Electrical Energy Supply Sector

The data provided by the Sri Lanka Sustainable Energy Authority (SEA) in their web: www.energy.gov.lk show that the present the national peak electricity demand is 2033 MW (28^{th} September 2011) and the corresponding daily electrical energy consumption is 33.35 GWh/ day. The same data published during this year (2011) also show that the annual electricity peak demand growth is growing at about 400 MW per year and the daily electrical energy demand is growing at around 8 GWh/day/year.

In order to meet the above mentioned growth, the Ceylon Electricity Board (CEB), the sole utility responsible for the generation and distributing most of the electricity generated to the final consumers have been annually preparing and releasing their Long Term Generation Plan (LTGP). According to the last published LTGP, most of the future generation of electricity would be generated from coal based power plants as shown in figure 2.



Annual Energy Generation (GWh/y)

In fact as per the above plan, EB has already commissioned and operating a 300 MW coal based power plant. The second phase of coal based power plant with a capacity of 2x300MW is under construction. Action has been initiated to construct another 2 x 500 MW coal based power plant in the country.

While the state owned utility CEB is planning to commission as many coal based power plants as necessary to meet the growing demand for electricity, the Ministry of Power and Energy, through the SEA is encouraging the private investors to develop renewable energy based power plants. In an attempt to generate at least 10% of the electrical energy requirements by the 2015, the SEA has offered an incentive scheme for the private sector to harness renewable energy resources and generate electrical energy and feed the national grid. A concessionary tariff based on the estimated cost of generation has been offered for each of the following technologies:

- Small Hydro: Rs. 13.04 / kWh
- Wind: Rs. 19.43 / kWh
- Biomass: Rs. 20.77 / kWh
- Agro/Industrial Waste: Rs. 14.60 / kWh
- Municipal Waste: Rs. 19.73 / kWh
- Other (Solar PV, Solar Thermal, Wave etc.): Rs. 20.77 / kWh

The solar PV module price and wind based systems, excluding storage batteries and inverters, are reaching US$ 2/ kWp. However, unless the system stability caused by the fluctuations in outputs of these power sources are resolved, it would not be feasible to harness such vast extent of resources.

7. Status of the technology in the country and its future market potential:

Status of Technology in Sri Lanka

A total of 33 MW of wind based power plants and 2 MW of solar PV based power plants have been connected to the national grid. The demand for power in the system during off-peak time is around 800 MW. Hence during off-peak time, the total outputs of solar and wind are approaching 5%. Due to the variations in the outputs of these sources of power, the utility has not stopped accommodating any additional wind or solar power plants. The introduction of Smart Grid based system control technology would be able to address this issue.

Future Market Potential

The on-shore based wind power potential in Sri Lanka is estimated as over 24,000 MW. The solar PV potential is much higher. The present peak demand is only 2000 MW. Hence wind and solar power has great future market potential, if these are properly developed.

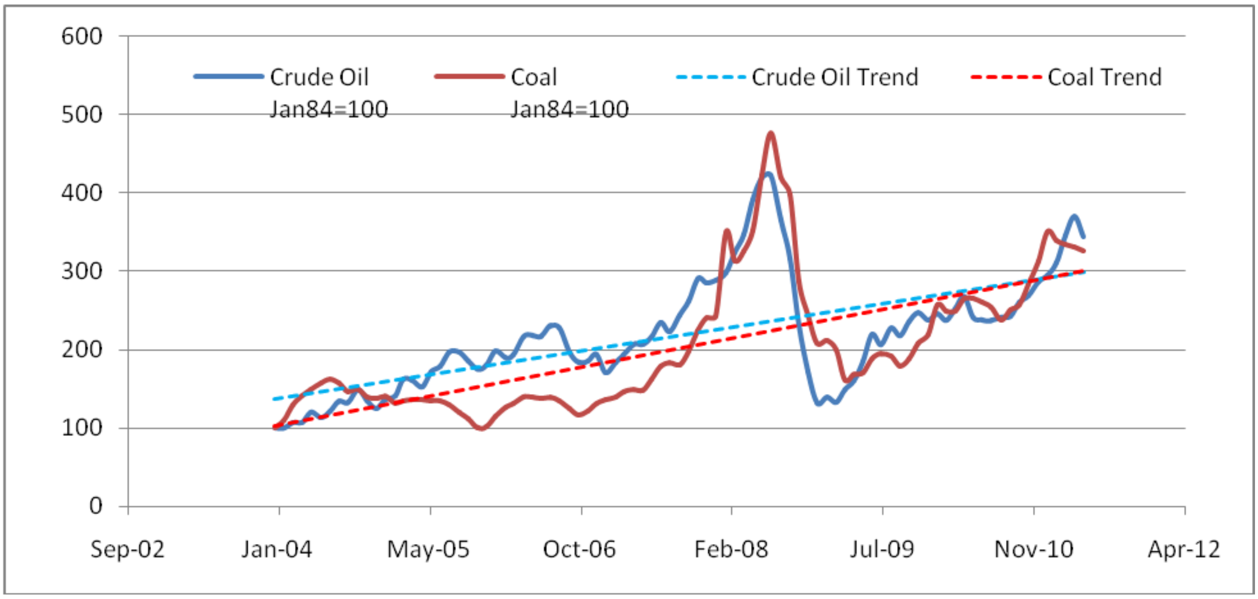
8. **Barriers:** This section will be covered later.
9. **Benefits:** (How the technology could contribute to socio-economic development and environmental protection)

Social Benefits

The large scale development of wind and solar PV based power development would result in generating significant extent of employment opportunities for all categories of work force in the country.

Economic Benefits

The escalating trends of petroleum and coal prices are bound to have serious negative economic impacts on the power sector in the country in the future. One option available to mitigate these impacts is to generate a significant share of the electricity from non-fossil fuels. Hence the introduction of large scale expansion of wind and solar PV based power projects would give economic benefits to the country.



Coal and Oil Prices2004-2011

Environmental Benefits

The large scale development of wind and solar PV based electricity generation projects would result in the reduction of fossil fuel based electricity generation. This would result in the following environmental benefits:

- Reduction on GHG emissions arising from fossil fuel based electricity generating projects.

- Reduction in NOX, SOX, particulate matter, heavy metal and radioactive chemical deposits.

10. Operations:

11. Costs

Smart Grid/ Smart Meter technologies are nascent technologies. Reliable estimates are not available at present. In any event the cost of establishing smart grid etc. need to be absorbed by the respective power generation technologies.

11. References

1. Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
2. Long Term Generation Expansion Plan, 2009-2022. Ceylon Electricity Board. December 2008.
3. Long Term Transmission Development Plan 2005-2014. Ceylon Electricity Board. 2005.
4. Energy Sector Master Plan, Sri Lanka. Interim Report. Asian Development Bank, April 2004.
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7. Mahinda Chinthanaya: Vision for a New Sri Lanka. A 10 Year Horizon Development Framework, 2006 -2016, Department of National Planning, Ministry of finance and Planning.
8. http://www.energyservices.lk/statistics/esd_rered.htm
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Energy Sector

Technology Fact Sheet – 9

DC Motor/ Alternator Based Inverter for Grid Connected Solar PV Systems

1. **Sector:** Energy Supply
2. **Introduction**:

A serious obstacle encountered by the developers of grid-connected solar PV system is the high capital cost of such system. A grid connected solar PV system has the following two major components: (a) Solar PV Module; (b) Inverter and grid interconnector. This cost of the first component varies from about US$ 2 to US$ 4 per peak Watt output of the panel. The price of this first component has been gradually declining over the past many years. The cost of the second component also varies from about US$ 2 to US$ 4 per Watt. The price of this second component is remaining at around the above mentioned values in the recent past.

The traditional inverter / grid-interconnector deploy the solid state electronic technology. An alternative to this traditional technology is to make use of a D C (brushless) motor and a conventional rotating A C Alternator. The cost of this alternative technology is much lower than the solid state based inverter – grid interconnector.

3. **Technology Name**: DC Motor/ Alternator Based Inverter For Grid Connected Solar PV Systems
4. **Technology Characteristics: (Feasibility of technology and operational necessities)**

Feasibility of Technology

This technology deploys to integrate some of the well developed and commercialized components to resolve the high cost of conventional solid state inverter to link solar PV modules to national electricity grids.

The first component used in this technology is a Brushless D C Motor. This component is deployed in electric vehicles. This component operates at reasonable efficiency and little maintenance. This component is widely used in the electric vehicles and in industrial drives. This component could be easily procured in the open market.

The second component is a conventional AC Induction Generator and Grid Interconnector. This component is widely used in the renewable energy sector to interconnect renewable energy based electricity generation systems to national AC electricity grid. This is common in small hydropower, wind power and biomass based systems. This component too could be easily procured from reputed manufactures in the open market.

Operational Necessity

The high cost of solid state based inverter technology has impeded the application of Solar PV technology to generate electricity in a distributed manner and feeding the national electricity grid. An alternative system which is significantly lower in cost would enable many renewable energy developers.

Country Specific Applicability:

4.1 Electrical Energy Supply Sector

The data provided by the Sri Lanka Sustainable Energy Authority (SEA) in their web: www.energy.gov.lk show that the present the national peak electricity demand is 2033 MW (28th September 2011) and the corresponding daily electrical energy consumption is 33.35 GWh/ day. The same data published during this year (2011) also show that the annual electricity peak demand growth is growing at about 400 MW per year and the daily electrical energy demand is growing at around 8 GWh/day/year.

In order to meet the above mentioned growth, the Ceylon Electricity Board (CEB), the sole utility responsible for the generation and distributing most of the electricity generated to the final consumers have been annually preparing and releasing their Long Term Generation Plan (LTGP). According to the last published LTGP, most of the future generation of electricity would be generated from coal based power plants as shown in figure 2.

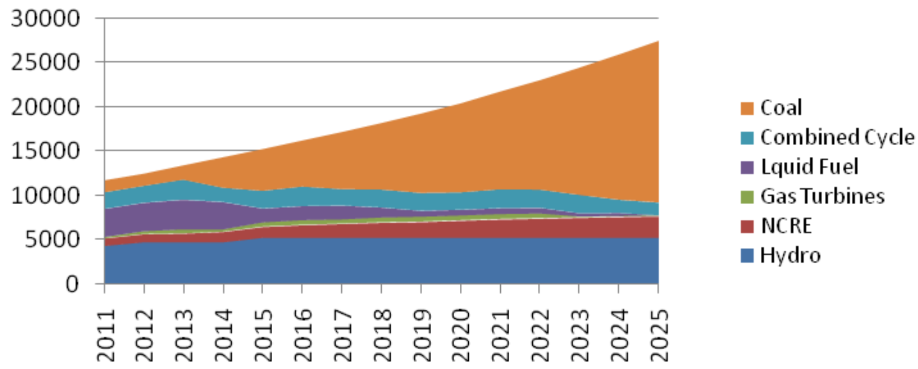


Figure 2: Annual Energy Generation (GWh/y)

In fact as per the above plan, EB has already commissioned and operating a 300 MW coal based power plant. The second phase of coal based power plant with a capacity of 2x300MW is under construction. Action has been initiated to construct another 2 x 500 MW coal based power plant in the country.

While the state owned utility CEB is planning to commission as many coal based power plants as necessary to meet the growing demand for electricity, the Ministry of Power and Energy, through the SEA is encouraging the private investors to develop renewable energy based power plants. In an attempt to generate at least 10% of the electrical energy requirements by the 2015, the SEA has offered an incentive scheme for the private sector to harness renewable energy resources and generate electrical energy and feed the national grid. A concessionary tariff based on the estimated cost of generation has been offered for each of the following technologies:

- Small Hydro: Rs. 13.04 / kWh
- Wind: Rs. 19.43 / kWh
- Biomass: Rs. 20.77 / kWh
- Agro/Industrial Waste: Rs. 14.60 / kWh
- Municipal Waste: Rs. 19.73 / kWh
- Other (Solar PV, Solar Thermal, Wave etc.): Rs. 20.77 / kWh

For a solar PV system with an annual load factor of 20% to generate and feed electricity to the grid within a tariff of Rs. 20.77 / kWh, the total capital cost of the system including the inverter/ grid interconnection equipment should not exceed Rs. 224 / kW (peak). The solar PV module price, excluding storage batteries and inverters, is reaching US$ 1 to 2/ kWp. There is very likely that this barrier of solar PV module price crossing the US$ 2 per peak Watt would be reached in the near future.

In order for solar PV systems to be commercially used for grid connected electricity generation, the total cost of such a system including the inverter and grid connection should not exceed US $ 2 per peak watt. Hence it is essential that the cost of inverter/ interconnection component should be as low as possible.

If the above target is reached, solar PV based systems would be able to enter the grid-connected renewable energy market in Sri Lanka.

6. Status of the technology in the country and its future market potential:

6.1 Status of Technology in Sri Lanka

The technologies to be used in this proposal are not available at present in Sri Lanka. Through the TNA Project it is proposed to obtain these technologies from appropriate countries.

6.2 Future Market Potential

The Long Term Generation Plan of the Ceylon Electricity Board depends heavily on fossil fuels to meet the future demand for electricity. According to this plan, by the year 2025, as much as 20,000 GWh of the 27,000 GWh per annum is expected to be produced from fossil fuels, mostly from coal. Solar PV is planned to make any significant contribution. However, if solar PV technology is made available so as to make the cost of generation of such energy competitive, then it is likely that solar PV could make a significant impact. If the proposed technology is introduced at least 5% of the 2000 GWh per annum could be met through this technology.

7. Barriers: This section will be covered later.

8. Benefits: (How the technology could contribute to socio-economic development and environmental protection)

8.1 Social Benefits

- Employment opportunities to skilled and semiskilled workforce in the country.

8.2 Economic Benefits

- Increase in the amount of electricity generated from renewable and indigenous energy resources based power plants.
- Decrease in the amount of electricity generated imported fossil fuel based power plants.

8.3 Environmental Benefits

To estimate the mitigation impact of this technology, it is assumed that without the introduction of this technology, the capital cost of conventional solid state driven inverter based grid connected solar PV systems would not be financially viable. It is assumed that with the introduction of this technology, the grid connected solar PV technology would be able to cross the threshold and the grid connected solar PV technology would become viable. The unit size of the technology is assumed to be a 100 kW system. The annual plant factor for a solar PV system in Sri Lanka has been found to be 20%. Hence the annual energy output of this unit would be: 100 x 8760 x .2 = 175.2 MWh/y. With the national Grid Emission Factor of 0.76 tCO_2/ MWh, the emission reduction would be: 175.2 x .76 = 133 tCO_2/y/100 kW module. Assuming 100 MW of Solar PV based system would be commissioned in the short term, the annual national mitigation benefit would be: 133,000 tCO_2/y

The capital cost of implementing this project is taken as 0.5 $ per peak watt. A 1-watt system would deliver: 1 x 8760 x 0.2 /1000 kWh per year = 1.752 kWh = 1.752 /10^6 GWh = (1.752/10^6) x 240 toe. = 0.00042048 toe. Hence to generate 1toe the capacity required = 1/.00042048 = 2378 watts. Hence the cost of implementing the project = 2378 x 0.5 x 112 = Rs. 133168 .

- Less local pollution (NOX and SOX) resulting from the reduction of fossil fuel based electricity generation.

9. Operations: This will be written later.

10. Costs

The estimated total cost of the proposed inverter/ grid-connection equipment is expected to cost 0.2 $ per peak Watt. To achieve a 5% target (of 20,000 GWh/y) by the year 2025, a total 600 MW of solar PV is needed. This would cost US $120 million for this component of the technology.

11. References

(1) Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
(2) Long Term Generation Expansion Plan, 2009-2022. Ceylon Electricity Board. December 2008.
(3) Long Term Transmission Development Plan 2005-2014. Ceylon Electricity Board. 2005.
(4) Energy Sector Master Plan, Sri Lanka. Interim Report. Asian Development Bank, April 2004.
(5) National Energy Policies and Strategies of Sri Lanka. Ministry of Power and Energy. October 2006.
(6) Statistical Digest 2010. Ceylon Electricity Board, 2011.
(7) Mahinda hinthanaya: Vision for a New Sri Lanka. A 10 Year Horizon Development Framework, 2006 -2016, Department of National Planning, Ministry of finance and Planning.
(8) http://www.energyservices.lk/statistics/esd_rered.htm
(9) Mr. N.K.Gunewardene, ElectroServ (Pvt) Ltd., Sri Lanka.

Energy Sector

Technology Fact Sheet – 10

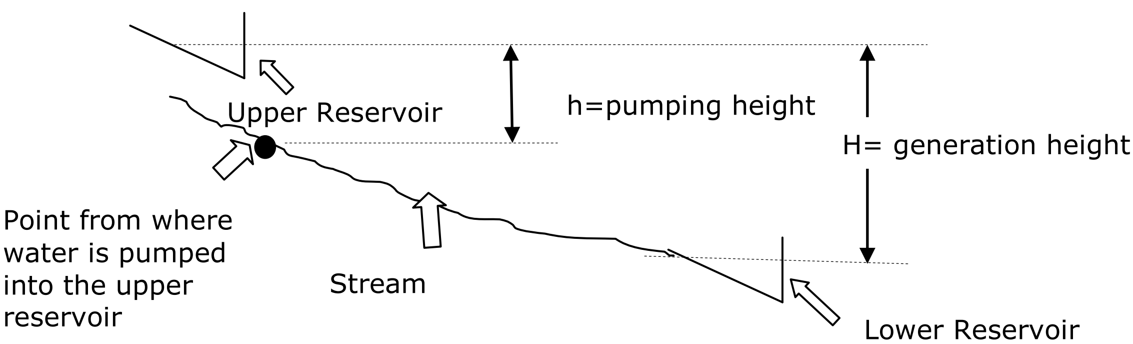
Pumping Water from Lower Streams In to Existing Hydro Reservoirs

1. **Sector:** Energy Supply
2. **Introduction**:

In Sri Lanka there are around 12 large and small water reservoirs are used in hydropower generation. These reservoirs store water to cater to seasonal or daily load variations. These reservoirs are located at different elevation to the mean sea level. Also these reservoirs are clustered into groups and are connected in a cascade manner within the group. Water from the top most reservoir is sent through tunnel/ open channel and penstock to power plant located at a lower elevation relative to the top most reservoir. Water discharged from the power plant is stored in a reservoir located very close to the power plant and at an elevation slightly lower than the discharge level of the power plant. Water in this reservoir is sent through another set of tunnel/ channel and penstock and used to drive another power plant. This process is repeated until the water discharged from the power plant located at the lowest elevation is discharged into a reservoir to be used for non-power generation application such as irrigation, industrial or household water needs.

Water flowing along streams between the levels of spill level of a reservoir and inlet level of reservoir immediately below it is usually ends up entirely in the lower reservoir. However, in respect of some parts of such water streams the difference in elevation between the point of the stream and the spill level of the upper reservoir is significantly less than the difference in levels between the inlet and outlet of the power plant utilizing the head of water in the higher reservoir. What this means is that if we pump water from such a stream at from such a point into the upper reservoir, then, the amount of water pumped into the upper reservoir will be able to generate more energy than the energy expended in pumping the water. This is possible because the difference in head against pumping is significantly less than the difference head used to generate power. Please see figure 1.

Figure 2.1- Levels of Reservoirs and Pumping Point



3. Technology Characteristics: (Feasibility of technology and operational necessities)

Feasibility of Technology:

The amount of energy required to pump a unit mass of water, neglecting frictional losses, is directly connected to the difference in height between the point of water intake and the point of discharge. Likewise, energy that could be generated from a unit mass of water from a reservoir is directly depends on the difference in height between the water intake in the reservoir and the point of discharge of the water from the hydro turbine.

In this technology, it is proposed to pump water from streams which conform to the above mentioned criterion. Such opportunities are available in plenty in Sri Lanka.

Operational Necessity

The total annual amount of electrical energy generated from the hydropower plants in Sri Lanka clearly depends on the amount of water collected by the reservoirs. Hence if more water could be collected into these reservoirs, then more electricity could be generated. However, care should be taken to ensure that the additional energy generated is significantly larger than the energy expended in pumping such water into the reservoirs.

As the amount of water collected by the natural process in the reservoirs is inadequate to meet the electrical energy demand of the people in Sri Lanka. Hence oil based and coal based power plants are operated to meet the shortfall.

4. Country Specific Applicability

Electrical Energy Generation Sector

The data provided by the Sri Lanka Sustainable Energy Authority (SEA) in their web: www.energy.gov.lk show that the present the national peak electricity demand is 2033 MW (28th September 2011) and the corresponding daily electrical energy consumption is 33.35 GWh/ day. The same data published during this year (2011) also show that the annual electricity peak demand growth is growing at about 400 MW per year and the daily electrical energy demand is growing at around 8 GWh/day/year.

In order to meet the above mentioned growth, the Ceylon Electricity Board (CEB), the sole utility responsible for the generation and distributing most of the electricity generated to the final consumers have been annually preparing and releasing their Long Term Generation Plan (LTGP). According to the last published LTGP, most of the future generation of electricity would be generated from coal based power plants as shown in figure 2.

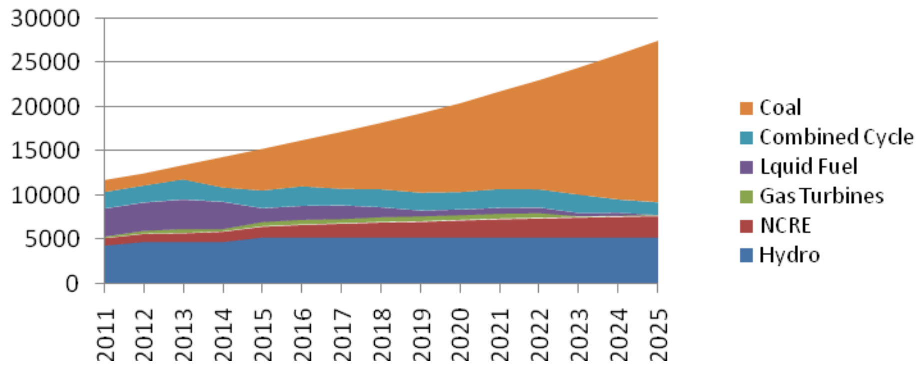


Figure 2: Annual Energy Generation (GWh/y)

In fact as per the above plan, EB has already commissioned and operating a 300 MW coal based power plant. The second phase of coal based power plant with a capacity of 2x300MW is under construction. Action has been initiated to construct another 2 x 500 MW coal based power plant in the country.

While the state owned utility CEB is planning to commission as many coal based power plants as necessary to meet the growing demand for electricity, the Ministry of Power and Energy, through the SEA is encouraging the private investors to develop renewable energy based power plants. In an attempt to generate at least 10% of the electrical energy requirements by the 2015, the SEA has offered an incentive scheme for the private sector to harness renewable energy resources and generate electrical energy and feed the national grid. A concessionary tariff based on the estimated cost of generation has been offered for each of the following technologies:

- Small Hydro: Rs. 13.04 / kWh
- Wind: Rs. 19.43 / kWh
- Biomass: Rs. 20.77 / kWh
- Agro/Industrial Waste: Rs. 14.60 / kWh
- Municipal Waste: Rs. 19.73 / kWh

As at December 2010, a total of 86 small hydropower plants with a total capacity of 175.763 MW have been commissioned. In addition 4 wind power plants with a total capacity of 30.15 MW have been commissioned. 2 agro-residue/ biomass based power plants with a total capacity of 11 MW have also been commissioned. It should be noted that the very high price paid for wind power generation is essentially payments made for the capital equipment, which is entirely foreign in nature with very little local value addition. Electricity generation using technology such as wind and solar do not contribute to the local economic growth.

Hence there is a need to develop renewable energy projects which contribute towards local value addition. The proposed technology will utilize equipment such as pumps, PVC pipes and cement are locally manufactured. All the materials, labour and skill required to implement this technology are local in nature. Moreover, the implementation of this technology will be able to help the country to increase its hydropower based electricity generation at the lowest cost. In this technology we are making use of an existing hydropower plants to increase their outputs with minimal capital and minimal operating costs.

This implementation of this technology will enable the country achieving the proposed targets.

Peak & Trough Problem of the Electricity Sector

A closer look at the daily load curve of the electricity system in Sri Lanka reveals the twin problems encountered by this sector. Please see figure 3.

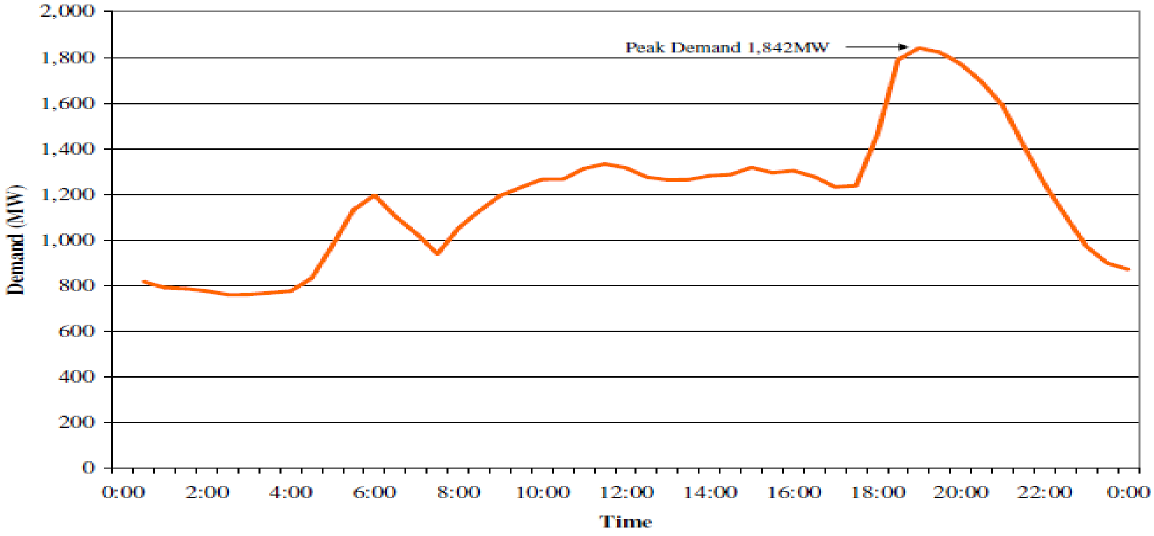


Figure 3: Electricity System Demand Profile on 28th November 2007

The first problem encountered is the very high demand of the system from around 6 p.m. to around 9 p.m. While the demand during this time interval is nearly twice that of the daily average demand, this high demand lasts only for a short period of 3 hours. The capacity of the system to meet this high demand is utilized only for a short time. This makes it difficult to recover the cost of the system in a reasonable period.

The additional water made available in the hydro reservoirs by the proposed technology, would enable to enhance the power output of hydropower plants to meet the demand for electricity during peak hours. Thus eliminating the use of fossil fuel based electricity generation.

The second problem encountered in the system is between 11 p.m. to 5 a.m. During this period the demand for electricity is very low. In fact the demand during period could be easily met from small renewable energy embedded generators and the “must run” hydro power plants. To balance the demand with the supply, power outputs of thermal power plants are reduced. For economic reason, output of the power plant with the highest marginal operating cost at that point of output is reduced. If necessary, the power output of the coal based power plant is also reduced and sometimes completely shut down.

Lowering energy output of coal based and petroleum fuel based combined cycle based power plants cause two problems: Firstly, capital cost of these base-load power plants being very high, these plants are expected to operate at high plant factors on a daily basis in order keep the total cost of electricity generated from these power plants are competitive. Secondly, base-load power plants have large thermal inertia. Varying the load, particularly shutting them down completely or starting them from no-load are not desirable for base-load power plants. Such operations affect the useful life of these plants.

The implementation of the proposed technology would enable the utilization of the power generation capacity available during the off-peak period to pump water from lower streams to upper reservoirs.

5. Status of the technology in the country and its future market potential:

Status of Technology in Sri Lanka

This technology is in its infancy. A prototype plant need to be constructed to convince the authorities concerned the merits of this concept.

Future Market Potential

The proposed technology could be applied to all the hydropower projects, both small and large, implemented in Sri Lanka. For the year 2010, a total of 5,634 GWh of electrical energy were generated through hydro power projects. The proposed technology is expected to increase this amount by 10%. In the future, the total hydropower generation is expected to increase up to around 6,000 GWh per year. Hence the future potential of the proposed technology is 600 GWh per year.

6. Barriers: This section will be covered later.

7. Benefits: (How the technology could contribute to socio-economic development and environmental protection)

Social Benefits

The implementation of this technology would result in the engagement of skilled and unskilled labour forces for the following tasks:

- Construction of weirs across streams to facilitate water intake structure for water pumps.
- Increase in the production water pumps.
- Manufacture of PVC pipes and fittings.
- Laying and connecting of pipes linking the pumping stations and reservoirs.
- Linking the pumping stations to the nearest electricity network to provide electricity for the pumping stations.
- Operation and maintenance of pumping stations.
- Enhancing the generating capacities of existing hydro power plants.

Economic Benefits

The direct economic impact of this technology is the value of 600 GWh of electricity annually generated. Market value of this energy at the rate of Rs. 15 per kWh is Rs. 9 billion per year.

The following indirect economic benefits could also be achieved:

- Increase in the amount of electricity generated from renewable and indigenous resources.
- Reduction in the amount of electricity generated from expensive, polluting and imported fossil fuels, particularly during peak demand period.
- Reduction in the cost of electricity resulting from the reduction of oil based, high cost electricity generation.
- Savings in foreign exchange due to reduction in the import of oil for electricity generation.

Environmental Benefits

- Less NOX and SOX pollution from fossil fuel based electricity generation.
- Lower GHG emissions.

8. Operations: This will be written later.

9. Costs

The cost of implementing this technology to a 1 MW small hydropower plant is estimated to Rs. 179 million. This technology could be extended to over 130 MW of hydropower plants, large and small, already installed. The cost of extending this technology to all the 130 MW hydropower plants would be Rs. 23,270 million.

11. References

1. Optimization and Estimation of Hydrolysis Parameters of an Anaerobic Co-digestion of Energy Crops with Organic Fraction of Canteen Food Waste. 4th International Conference on Sustainable Energy and Environment, 23-25 Nov. 2010, Bangkok. K.W.N. Dilnayana, P.G.Rathnasiri and A.A.P. De Alwis
2. Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
3. Long Term Generation Expansion Plan, 2009-2022. Ceylon Electricity Board. December 2008.
4. Long Term Transmission Development Plan 2005-2014. Ceylon Electricity Board. 2005.
5. Energy Sector Master Plan, Sri Lanka. Interim Report. Asian Development Bank, April 2004.
6. National Energy Policies and Strategies of Sri Lanka. Ministry of Power and Energy. October 2006.
7. Statistical Digest 2010. Ceylon Electricity Board, 2011.
8. Mahinda hinthanaya: Vision for a New Sri Lanka. A 10 Year Horizon Development Framework, 2006 -2016, Department of National Planning, Ministry of finance and Planning.
9. http://www.energyservices.lk/statistics/esd_rered.htm
10. Introduction of Natural Gas to Meet Energy Needs of Sri Lanka, Department of National Planning, May 2011.

Energy Sector

Technology Fact Sheet - 11

Solar Reflector cum Tracker to Enhance Energy Output from Solar PV Systems

1. **Sector:** Energy Supply
2. **Introduction**:

The Sri Lanka Sustainable Energy Authority (SEA) has commissioned a 500 kW (peak) and another 737 kW (peak) Solar PV power plants connected to the national electricity grid. These projects have been implemented as a total grant from the Governments of South Korea and Japan respectively. The above systems use a set of static solar PV modules.

SEA has established a solar park. Private developers will be invited to install Solar PV systems in this park and feed the energy generated to the national grid under the Standardized Power Purchase Agreement (SPPA).

The output from a solar panel depends on the intensity of light falling on the panel. This intensity could be increased by rotating the panel to face the Sun in the perpendicular direction and by providing simple reflectors (concentrators). By incorporating a tracker arrangement for the solar panels to face the Sun in the perpendicular direction and by incorporating suitable reflectors, the electrical output from a PV system could be enhanced by around 40%. In a Solar PV system the solar panel and the inverter-interconnector assembly are the costly items. The costs of solar tracker and reflectors are relatively much smaller. Hence it is proposed to install a demonstration Solar PV system incorporating solar tracker and reflectors to this demonstration model. The purpose is to illustrate the benefits of solar tracker and reflector so that future developers of solar PV based electricity generating projects in Sri Lanka would incorporate this technology in their projects.

3. **Technology Name**: Solar Reflector cum Tracker to Enhance Energy Output from Solar PV Systems.
4. **Technology Characteristics: (Feasibility of technology and operational necessities)**

Feasibility of Technology:

The Solar Tracker system consists of a clock-work mechanism linked to all the solar panel modules installed in a system. The clock-work mechanism and mechanical linkages constantly rotate all the solar panels in such a way the panels face the Sun in a perpendicular direction. The reflector/ concentrator is a simple assembly made of suitable light reflecting material permanently attached to each solar panel to capture additional sunlight and reflect such light on to the Solar Cell.

A disadvantage of the solar reflector / concentrator is that the a Solar PV project would require a larger land area. In the context of Sri Lanka, cost of land is much smaller than the cost of Solar panels. Hence implementation of this technology is justified.

These two technologies are readily available in the international arena. If necessary, it could be developed locally.

Operational Necessity

Under the Standardized Power Purchase Agreement (SPPA) formulated by the SEA, the price payable for Solar PV based electricity is Rs. 20 and cents 77. However, as the cost of solar PV systems including the inverter/ grid interconnector is around US$ 8 per peak Watt and the expected plant factor is around 20%, a proposal to generate and sell electricity to EB with the existing technology is not viable. By incorporating this technology, we could increase the output of energy by 50 to 100%. With such improvements, it would be feasible to implement such a project.

5. Country Specific Applicability:

Electrical Energy Generation Sector

The data provided by the Sri Lanka Sustainable Energy Authority (SEA) in their web: www.energy.gov.lk show that the present the national peak electricity demand is 2033 MW (28th September 2011) and the corresponding daily electrical energy consumption is 33.35 GWh/ day. The same data published during this year (2011) also show that the annual electricity peak demand growth is growing at about 400 MW per year and the daily electrical energy demand is growing at around 8 GWh/day/year.

In order to meet the above mentioned growth, the Ceylon Electricity Board (CEB), the sole utility responsible for the generation and distributing most of the electricity generated to the final consumers have been annually preparing and releasing their Long Term Generation Plan (LTGP). According to the last published LTGP, most of the future generation of electricity would be generated from coal based power plants as shown in figure 2.

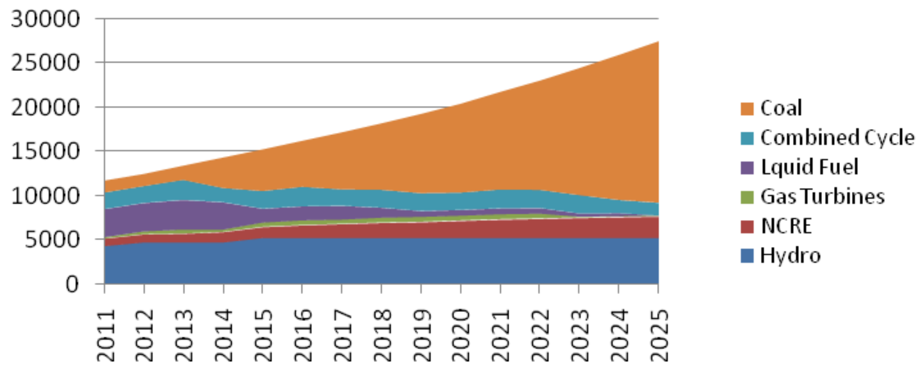


Figure 2: Annual Energy Generation (GWh/y)

In fact as per the above plan, EB has already commissioned and operating a 300 MW coal based power plant. The second phase of coal based power plant with a capacity of 2x300MW is under construction. Action has been initiated to construct another 2 x 500 MW coal based power plant in the country.

While the state owned utility CEB is planning to commission as many coal based power plants as necessary to meet the growing demand for electricity, the Ministry of Power and Energy, through the SEA is encouraging the private investors to develop renewable energy based power plants. In an attempt to generate at least 10% of the electrical energy requirements by the 2015, the SEA has offered an incentive scheme for the private sector to harness renewable energy resources and generate electrical energy and feed the national grid. A concessionary tariff based on the estimated cost of generation has been offered for each of the following technologies:

- Small Hydro: Rs. 13.04 / kWh
- Wind: Rs. 19.43 / kWh
- Biomass: Rs. 20.77 / kWh
- Agro/Industrial Waste: Rs. 14.60 / kWh
- Municipal Waste: Rs. 19.73 / kWh
- Other (Solar PV, Wave etc.) Rs, 20.77 / kWh

Apart from the 500 kW Solar PV project commissioned with a grant by the Government of Korea and a few SR projects, there aren't any commercial Grid-Connected Solar PV project commissioned in Sri Lanka. The implementation of this technology should resolve this issue.

6. Status of the technology in the country and its future market potential:

Status of Technology in Sri Lanka

This technology is in its infancy. A prototype plant need to be constructed to convince the authorities concerned the merits of this concept.

Future Market Potential

The price of Solar PV is declining all the time. In the future, with the incorporation of this technology and with the decline in the price of Solar PV technology, electricity generation with Solar PV should reach "Grid Parity". When this status is reached, we should expect a significant part of our electrical energy is generated through this technology.

7. Barriers: This section will be covered later.

8. Benefits: (How the technology could contribute to socio-economic development and environmental protection)

Social Benefits

The implementation of this technology would result in the engagement of skilled and unskilled labour forces for the following tasks:

- Construction of tracking devises.
- Construction of reflecting devises.
- Installation, operation and maintenance of tracking and reflecting devices.

Economic Benefits

- Increase in the amount of electricity generated from renewable and indigenous energy resources based power plants.
- Decrease in the amount of electricity generated imported fossil fuel based power plants.

Environmental Benefits

- Lesser SOX and NOX and particulate emissions due to reduction in fossil fuel based electricity generation.
- Less GHG emissions

9. Operations: This will be written later.

10. Costs

The estimated cost of the tracker and reflector assembly per peak Watt of installed capacity would be around US% 0.5 per peak Watt. For a MW system the cost would be US$ 500,000.

11. References

1. Renewable Energy World , July-August 2011.
2. Standardized Power Purchase Tariff, 2011. Sri Lanka sustainable Energy Authority.
3. Long Term Generation Expansion Plan, 2009-2022. Ceylon Electricity Board. December 2008.
4. Long Term Transmission Development Plan 2005-2014. Ceylon Electricity Board. 2005.
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8. Mahinda hinthanaya: Vision for a New Sri Lanka. A 10 Year Horizon Development Framework, 2006 -2016, Department of National Planning, Ministry of finance and Planning.
9. http://www.energyservices.lk/statistics/esd_rered.htm

Energy Sector

Technology Fact Sheet - 12

Biomass Gasifier for High Temperature/ Clean Environment

1. **Sector:** Energy Supply/ Industry
2. **Introduction**:

For applications such as manufacture of ceramic products, an energy source which could provide very high temperature and a clean environment is required. Presently, this is achieved by the combustion of LPG. This is a very expensive source of energy. With such high cost this sector is struggling to remain competitive in the international market.

All the biomass gasifiers operating in Sri Lanka at present do not have the capability of reach such high temperatures. Moreover, producer gas generated in these gasifiers is contaminated with soot particles and traces of tar. Such contaminants are not acceptable in the manufacture of high quality ceramic ware.

We need to develop a technology to gasify biomass without the above drawbacks. The following one or more approaches would address these issues:

- Preprocess the biomass fuel by proper size reduction and remove the fines and coarse fractions, and dry the biomass fuel to a consistent and desirable moisture level.
- Preheat the air used for gasification.
- Remove CO2 from producer gas prior to use.
- Preheat the air used for final combustion.
- Preheat the producer gas prior to final combustion.
- Dry the biomass fuel prior to gasification.
- Filter and wash the producer gas prior to combustion.
- Indirect method of pyrolysis – use of sand as intermediatory medium or indirectly heated ceramic or cast iron retort.
- Use oxygen, instead of air, as the gasifier medium.

As none of the technologies practiced in a commercial basis in Sri Lanka, these technologies need to be obtained from overseas countries.

3. **Technology Name**: Biomass Gasifier for High Temture/ Clean Environment
4. **Technology Characteristics: (Feasibility of technology and operational necessities)**

Feasibility of Technology:

In order to use biomass to replace LPG used in some of the industries such as the Ceramic industry, where high temperatures and a very clean environment are to be maintained, we need to gasifiy the biomass and purify the gas by filtering and scrubbing. Moreover, one or more of the following methods need to be deployed to obtain and maintain the desired high temperature in the production zone:

- Preprocess the biomass fuel by proper size reduction and remove the fines and coarse fractions, and dry the biomass fuel to a consistent and desirable moisture level.
- Preheat the air used for gasification.

- Remove CO_2 from producer gas prior to use.
- Preheat the air used for final combustion.
- Preheat the producer gas prior to final combustion.
- Dry the biomass fuel prior to gasification.
- Filter and wash the producer gas prior to combustion.
- Indirect method of pyrolysis – use of sand as intermediatory medium or indirectly heated ceramic or cast iron retort.
- Use oxygen, instead of air, as the gasifier medium.

Although most of the above measures are not practiced in Sri Lanka at present, these technologies could be developed with the resources and skills available in this country. If necessary, some of these technologies could be obtained from overseas.

Operational Necessity

The industrial sector in Sri Lanka presently consumes xx tonnes of LPG annually. It is likely that in the near future the following industries would try to switch to LPG to improve the quality of their products:

5. Country Specific Applicability:

Electrical Energy Supply Sector

The data provided by the Sri Lanka Sustainable Energy Authority (SEA) in their web: www.energy.gov.lk show that the present the national peak electricity demand is 2033 MW (28th September 2011) and the corresponding daily electrical energy consumption is 33.35 GWh/ day. The same data published during this year (2011) also show that the annual electricity peak demand growth is growing at about 400 MW per year and the daily electrical energy demand is growing at around 8 GWh/day/year.

In order to meet the above mentioned growth, the Ceylon Electricity Board (CEB), the sole utility responsible for the generation and distributing most of the electricity generated to the final consumers have been annually preparing and releasing their Long Term Generation Plan (LTGP). According to the last published LTGP, most of the future generation of electricity would be generated from coal based power plants as shown in figure 2.

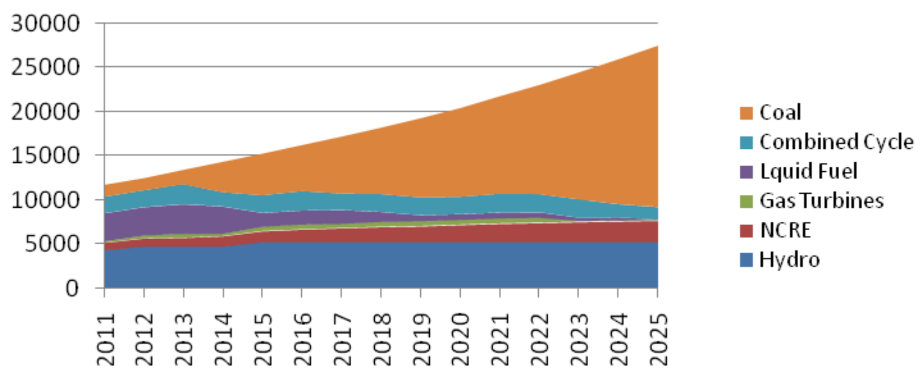

Figure 2: Annual Energy Generation (GWh/y)

In fact as per the above plan, EB has already commissioned and operating a 300 MW coal based power plant. The second phase of coal based power plant with a capacity of 2x300MW is under construction. Action has been initiated to construct another 2 x 500 MW coal based power plant in the country.

While the state owned utility CEB is planning to commission as many coal based power plants as necessary to meet the growing demand for electricity, the Ministry of Power and Energy, through the SEA is encouraging the private investors to develop renewable energy based power plants. In an attempt to generate at least 10% of the electrical energy requirements by the 2015, the SEA has offered an incentive scheme for the private sector to harness renewable energy resources and generate electrical energy and feed the national grid. A concessionary tariff based on the estimated cost of generation has been offered for each of the following technologies:

- Small Hydro: Rs. 13.04 / kWh
- Wind: Rs. 19.43 / kWh
- Biomass: Rs. 20.77 / kWh
- Agro/Industrial Waste: Rs. 14.60 / kWh
- Municipal Waste: Rs. 19.73 / kWh

In spite of the attractive tariff offered for biomass based electricity generation, only one power plant with a capacity of 0.5 MW has been commissioned a month ago. On the other hand by the end of 2010, a total of 86 small hydro power plants with a total capacity o 175.8 MW and 4 wind power plants with a total capacity of 30.15 MW and 2 agro residue based power plants with a total capacity of 11 MW have been commissioned.

A number of reasons have been attributed to the reluctance of investors to engage in biomass based energy generation. One important reason is that the difficulty in getting the desired energy output levels due to the high moisture levels prevailing in the biomass fuels. The development of this technology to dry the biomass fuels using waste energy available in the flue gas would resolve this issue.

Industrial Heat Sector

The latest Energy Balance 2007 published by the SEA reveals that the industrial sector in Sri Lanka uses biomass fuels to generate 82% of the heat energy required by this sector. The balance 18% is generated using petroleum fuels. On the prevailing market values and on a useful energy output equivalent basis, the cost of petroleum fuels is at least four times the cost of biomass fuels. Due to this significantly higher fuel costs, in the recent past there had been an attempt by the industrialists using petroleum fuels to switch to biomass fuels. In fact, despite a heavy subsidy given to furnace oil used by the industries, a handful of industrialists have switched from petroleum fuels to biomass fuels.

A number of reasons have been attributed to the reluctance of investors to engage in biomass based energy generation. One important reason is that the difficulty in getting the desired energy output levels due to the high moisture levels prevailing in the biomass fuels. The development of this technology to dry the biomass fuels using waste energy available in the flue gas would resolve this issue.

6. Status of the technology in the country and its future market potential:

Status of Technology in Sri Lanka

The technology of using flue gas from a combustion system to dry the biomass fuel has been implemented in Sri Lanka in one facility constructed by a private sector institution (Recogen Pvt. Ltd.). At this facility, Coconut shells are pyrolysed to charcoal. During pyrolysis of coconut shells, a part of the matter in the shells is volatized and liberated as gases and vapours. These gases and vapours are extracted from the reactor and combusted (by admitting combustion air) in a boiler to generate high pressure steam. The high pressure steam generated is used to drive a turbo-generator, charcoal produced in the process are used to manufacture activated carbon.

In this process of pyrolysis, the initial level of moisture in the biomass stock (coconut shell) plays an important role in the composition of the volatiles liberated. High moisture would result in a higher proportion of liquid tars and lesser amount of gaseous components. Moreover, a higher moisture level in the feed stock also lowers the quality of the charcoal produced. Hence the need to reduce the moisture in the feed stock is an important step in this process. The developers of this project were more or less compelled to develop a technology to dry the feed stock prior to admitting it into the reactor. Accordingly, a drying technology to dry the feed stock using the flue gas from the boiler has been developed and successfully deployed at this facility.

Future Market Potential

Electricity Generation Sector

At present a 10 MW biomass (agro-residue) based electricity generation facility has been commissioned a few years ago. Another 0.5 MW facility based on Gliricidia wood based power plant was commissioned about a month ago. Around 70 MW of power plants are in the pipeline. These 70 MW of biomass based power plants are expected to be commissioned within the next four years to meet the 5% of total generation target by the year 2015. An additional 70 MW of biomass power plants are expected to be commissioned before 2020 to reach the 20% target. All these plants will benefit from the proposed technology.

According to the study done by the Ministry of Science and Technology and European Union, the potential for biomass based power generation in Sri Lanka is over 4000 MW. Hence the long term potential of this technology is very large indeed.

Industrial Heat Generation Sector

At present over 82% of the industrial heat energy is generated from biomass. Most of this biomass is in the form of chunks. In these old furnaces biomass chunks are fed manually. The proposed technology does not match these old furnaces. Only around 12% of the existing biomass combustion systems could adopt the proposed technology. The amount of biomass coming under this category would be around 800,000 tonnes of biomass.

However, almost all the fossil fuel consuming combustion facilities are likely to switch to biomass once the present government subsidy granted to industrialists is removed. The total amount of biomass fuel required for such switch over would be 800,000 tonnes of biomass.

Hence the potential for this technology in this sector would be 1,600,000 tonnes of biomass per year.

7. **Barriers:** This section will be covered later.

8. **Benefits:** (How the technology could contribute to socio-economic development and environmental protection)

Social Benefits

The implementation of this technology will remove a serious barrier encountered in the sustainable production and use of biomass (Gliricidia Coppice Wood) as the fuel for the generation of electricity and industrial heat energy. This will result in many thousands of people from the rural farming communities engaging in the growing, harvesting (coppice cutting), transporting and deliver the harvested wood to the energy conversion facilities. In addition to the wood, these farmers will be in possession of Gliricidia leaves. This could be used to enhance the rural dairy industry and increase the production of organic fertilizer. All these mean that the introduction of this technology will provide productive employment to the under-employed poverty driven rural farming communities.

The introduction of this technology will also provide employment opportunities to the skilled workforce in the engineering sector. The fabrication, installation, commissioning and operation of the dryers would require many skilled, semi-skilled and unskilled staff. Hence the social problem of urban poverty will also be resolved.

Economic Benefits

Electricity Generation Sector

As Sri Lanka does not possess any proven fossil fuel reserves and as the LTGP of the CEB is heavily depending on imported fossil fuels to meet the growing demand for electricity (see figure 2), the Ministry of Power Energy have formulated a policy to ensure that at least 10% of our electrical energy is generated from indigenous renewable energy resources by the year 2015. This share is to be increased to 20% by 2020. It is very unfortunate that those responsible for implementing this policy are promoting wind and solar PV. Wind and Solar PV do not contribute directly to any national economic benefits. Wind and Solar PV technologies depend entirely on foreign inputs for the import of necessary equipment and installation and commissioning staff.

On the other hand Sustainable Biomass based electricity generation results in significant local national input in the generation of electricity. All the fuel required for biomass based electricity generation is generated locally within the national boundary.

Moreover, on a level playing field, and if all costs including environmental, agricultural, health aspects are internalized, it can be proved that biomass based electricity generation is in fact the cheapest way of generating electricity.

Based on a net calorific value of 26,000 kJ/kg for coal and a landed cost of US$150/tone of coal and 15,000 kJ/kg for wood and a local price of Rs. 3.50 per kg, on an energy equivalent basis energy from coal is 2.77 times as expensive as the energy from locally available wood.

For the proposed 140 MW of biomass power plants, the savings in fuel cost would amount Rs. 3.2 billion per year.

Industrial Heat Generation Sector

As mentioned earlier, the introduction of the drying of biomass fuel technology would have two impacts: (a) It will reduce the fuel consumption in the existing wood chip using furnaces and (b) It will encourage all the industrial sector petroleum fuel consumers to switch to biomass fuels. At present furnace oil is marketed at a subsidized price of Rs. 50 per litre. It is very likely that the subsidy will be removed soon and it will be marketed at Rs. 90/litre.

An estimated 800,000 tonnes of wood is presently used annually by the wood-chip consuming sector. Once the drying technology is introduced, the fuel consumption would be reduced by 33%. The impact to this subsector, presently using wood chips as fuel would be 33% of Rs. 3,500 x 800,000 tonnes amounting to Rs. 933 million per year.

When all the industries presently using petroleum fuels amounting to 200,000 tonnes per year switch to biomass fuel, the impact would be Rs. 200,000 x 90,000 – 800,000 x 3,500 = Rs.15.2 billion per year.

Environmental benefits

The increase in the use of biomass for industrial heat generation would result in lesser amount of fossil fuel used for the same purpose. Hence lesser GHG emissions.

9. Operations

10. Costs

Based on the experience in the import and use of a conventional thermal gasifier and on inquiries made to indian gasifier manufacturers, the estimated cost of a 700 kWth gasifier for high temperature applications would be Rs. 7,000,000.

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Energy Sector

Technology Fact Sheet - 13

Biomethane for Transport

1. **Sector**: Energy/Transport
2. **Introduction**

Biogas is produced by a biological process by a group of micro organism by the digestion of easily biodegradable organic materials in an anaerobic (oxygen free) environment. Usually, biogas consists of methane (approximately 60%) and the balance Carbon dioxide. Traces of Hydrogen sulphide gas could be found in biogas produced from some type of organic materials.

In order to use biogas as a transport fuel it is necessary to compress it into cylinders. To cover a reasonable distance between re-fillings of cylinders, the compressed gas should have a pressure of around 200 atmospheres. Such gas cylinders are very similar to cylinders used for storing oxygen for hospital and industrial applications.

Prior to compression of biogas to such high pressures, for technical reasons, it is essential to remove the carbon dioxide from the gas. The removal of carbon dioxide also increases the energy content in the compressed gas cylinder, thus increasing the travel distance achievable between re-filling. There are many technologies practiced to absorb and separate carbon dioxide from a gas stream. One or more of these standard technologies could be deployed for this purpose.

To protect the vehicle engine from damage, and to minimize engine maintenance costs, it is useful to remove hydrogen sulphide gas in biogas prior to compression. Here again one of many technologies available could be deployed to remove hydrogen sulphide from biogas.

3. **Technology Name:** Biomethane for Transport
4. **Technology Characteristics:** (Feasibility of technology and operational necessities*)*

Relevance of Compressed Natural Gas (CNG) as Transport Fuel

Although the use of compressed bio methane as a transport fuel at present is limited to a few countries in the world, the use of compressed natural gas as fuel for transport vehicles is wide spread in the world. Natural gas and bio methane (after the removal of carbon dioxide and hydrogen sulphide from biogas) are chemically and physically almost identical – CH_4 – Methane. The differences are in the way it is produced or extracted.

Natural gas is a fossil fuel extracted from the ground in gas, oil or coal fields. It is available only in limited number of countries. At the present rates of extraction and discovery of new fields, this resource in the earth is expected to last for another 50 years.

Bio methane on the other hand is produced by biological processes by a host of naturally occurring micro organism utilizing easily biodegradable biomass wastes such as animal dung, decaying leaves, fruits and vegetables etc. As such biomass is produced by the process of photosynthesis utilizing solar energy and atmospheric carbon dioxide and soil moisture, this is a renewable process.

All vehicles, equipment, devices and appliances used in the compression, storage and use of CNG for transport purposes could also be used for compressed bio methane without ant alternations or modifications.

When methane (bio methane or natural gas) is used as the fuel in internal combustion engines instead of liquid fuels such as diesel or petrol, the undesirable emissions are much lower. For this reason, many countries have introduced legislations to use methane as the fuel for urban transport fleets. A noteworthy example is New Delhi. Here all "Public Vehicles" meaning vehicles used by the public, such as busses, taxies, three wheelers etc. are allowed to use ONLY CNG within the city limits. With the recent introduction of this legislation, the air pollution level in the city has improved drastically.

For the year 2007for which published data are available, nearly 50% of the total petroleum imports of 4,287,880 tonnes amounting to 2,134,200tonnes were used for transport applications. Hence the transport sector is heavily dependent on imported fuel. Apart from incurring heavy foreign expenditure, this sector is solely depends on imports. This is a threat to national security. Hence there is a need to find an indigenous resource of producing transport fuel. Hence the development of this technology would address this issue.

5. Country specific applicability

Apart from the heavy expenditure and dependence on foreign imports for transport fuel, the country has the potential to produce significant amount of biomethane from the liquid wastes generated within the country. These liquid wastes need to be treated prior to disposal. Table 1gives the quantities of liquid wastes produced annually.

Availability of Raw Materials in Sri Lanka for Bio Methane Production

Data collected by the University of Moratuwa on the availability of industrial waste water in Sri Lanka is given in Table 1.

Table 1 – Availability of Industrial Liquid Waste

Industry	COD Loading (ktonne/y)	COD Removal (ktonne/y)	Bio gas Potential (million cu. m. /y)	Energy (TJ/y)	Tonne oil equivalent
Food & Beverages	4.502	3.601	1.801	48.62	1167
Distilleries	0.830	0.706	0.353	9.53	229
Tanning	2.946	2.356	1.178	31.81	763
Desiccated coconut	2.628	2.102	1.051	38.38	91
Rubber Processing	10.600	8.480	4.240	114.48	2184
Total	21.506	17.245	8.623	242.82	4434

Source: University of Moratuwa.

Many of the above industries have taken action to treat these wastes through anaerobic digestion. Others are in the process of doing so, as a statutory requirement. This process of anaerobic treatment generates methane gas. At present most of these gases are utilized for low grade energy production such as process heat. A better option would be to use it for transport application. By the proposed technology intervention these objectives could be achieved.

6. Status of the technology in the country and its future market potential

In order to use biomethane as transport fuel the following steps need to be taken:

- Production of biogas by anaerobic process.
- Clean the gas by the removal of carbon dioxide and hydrogen sulphide by chemical or absorption process.
- Compress methane thus produced into high pressure (200 barg) cylinders.

University of Moratuwa, in collaboration with the Ministry of Science and Technology has developed most of the above steps. In respect of the last step, the University has been able to compress the gas only to about 50 barg. The University is in the process of achieving this step.

It is now necessary to demonstrate a commercial scale operation to invite the private sector to invest in this technology.

Future Market Potential

As a first step, the objective is to use biogas produced by the treatment of a part of industrial waste water. The objective of this phase is to demonstrate a commercial scale operation. For this purpose it is proposed to establish a facility to p[roduce 140 lites of diesoline per day.

In the second phase it is proposed to extend this to all the industrial waste water. This amounts to 4400 tonnes of oil equivalent. This is only 0.02% of the national transport fuel needs.

In the third step, it would be possible to use the short-term biodegradable materials present in the MSW collected in the country by the various local government bodies. According to data compiled by the Ministry of Environment, over 80% of the matter present in MSW is short-term biodegradable materials. The moisture content of MSW collected in Sri Lanka is over 60%. More than 1000 tonnes of MSW is collected daily in the city of Colombo. Of course to use this material it is essential to construct suitable digesters. We need to plan how this could be done.

The potential in this third phase is to generate about 20,000 tonnes of oil equivalent of biomethane. This is about 1% of the national fuel requirements for transport. The biodegradable materials in the Colombo MSW would be just suffient for this purpose.

In the fourth phase it would be possible to use surplus Gliricidia leaves and other biodegradable produced in the country. Perhaps, optimistically, the entire requirements of 2 million tonnes of oil equivalent could be produced in this manner.

7. Barriers: *After completion of barrier analysis and only for selected technologies.*

8. Benefits: (How the technology could contribute to socio-economic development and environmental protection)

The benefits of the scheme are as follows:

Social Benefits

- Energy security in respect of transport fuel as at present the entire transport sector in Sri Lanka is dependent on imported petroleum fuels.
- Introduction of a new technology to the country.
- Employment to skilled and semi-skilled workforce in the engineering and manual work force.

Economic Benefits

- Production and use of a cost effective indigenous transport fuel.
- Saving of foreign exchange
- Use of digester effluent as organic fertilizer.

Environmental Benefits

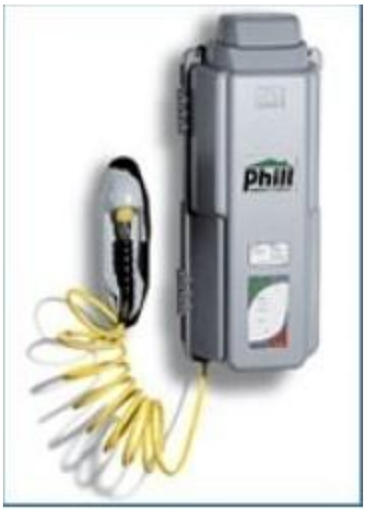
- Cleaner local environment as the combustion of methane does not produce any particulates, sulphur dioxide or carbon monoxide.
- Reduction in GHG emissions.

9. **Operations:** *After completion of barrier analysis and only for selected technologies.*

10. Costs:

Based on the data provided by the University of Moratuwa the cost of establishing a facility making use of an existing water treatment plant and a “Phil” type compressor to generate the equivalent of 140 liters of diesel per day sufficient to operate a bus is Rs. Rs. 3,000,000. See Figure 1 of a “Phil” compressor.

Figure 1– The Phil Compressor **Figure 2: Car GetiingFilled With NG**



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Mitigation benefits of technologies considered – Energy Sector

1. Building Management Systems

To estimate the mitigation impact of this technology option it is assumed that a 1000 kW output of LED lamps and another 1000 kW output of Solar Assisted Air Conditioning Systems are installed. The impacts for the above two technologies are calculated separately.

(a) LED Lamps

LED technology is advancing into new categories of white light applications, including surgical task lighting, where early indications suggest significant potential for energy savings and reduced maintenance.

The halogen lamps typically used in surgical task lights suffer from relatively low luminous efficacy (lumens of light output per watt of input power), which is only worsened by filters that must be used to reduce the amount of non-visible radiation they emit. LED surgical task lights typically do not require such filtering media, and their higher efficacy can allow for reductions in connected load of 50 percent or more, with potential for additional energy savings through constant-color dimming and reduced cooling load in the operating room. Furthermore, while halogen lamps are typically rated for just 1,000 to 3,000 hours and fail catastrophically (sudden and without warning), LED surgical task lights are generally rated for 25,000 to 40,000 hours and are expected to “fail” by gradually fading in brightness. The U.S. Food and Drug Administration (FDA), which grants marketing clearance for medical devices, issued product testing guidance in 1998 for surgical task lights.

The following values as provided by the Sri Lanka Sustainable Energy Authority are used:

- IL (Incandescent Lamp)/ LED (light Emitting Diode) equivalents: 60 W IL = 6 W LED
- Cost of 60 W IL: Rs. 25
- Cost of 6 W LED: Rs. 2500
- IL life: 200 hours
- LED life: 50,000 hours.

On the above basis, the cost of reducing 1toe/y is: Rs. 149,468 toe/y

The cost of reducing 1tCO2/y is: Rs. 47,596/tCO2/y

The mitigation benefit from a 1000 kW system is: 8,667 tCO2/y/1000kW.

The National Mitigation Benefit is estimated as 20 MW= 173,340tCO2/y/20 MW

(b) Solar Assisted Air Conditioning

Solar Assisted air conditioner saves 30 -50 % of Electricity. It has wide target market – hotels, restaurants, hospitals, factory, school, convention centre and high end residential. It requires minimal direct sunlight exposure, heat from ambient and heat blown by the condenser is also utilized. There is minimum 30% saving if conventional AC unit is replaced by solar assisted AC.

In this technology a Solar Water Heating system is installed to provided hot water for an absorption refrigeration system which would replace a 1000 kWe vapour compression based air conditioning system. It is assumed that the solar water heating system would operate with an annual plant factor of 20%. The capital cost of A 100 kW Solar heating system is Rs. 20,000,000.

The cost of providing 1 toe of energy is calculated to be: Rs. 476,190/toe/y

The cost of reducing 1 toe of CO2 is calculated to be: Rs. 3,580/tCO2/y

The mitigation benefit of a 1000 kW system is: 1,331 tCO2/y/1000kW

The National Benefit is estimated as 20 MW = 26,620tCO2/y/ 20 MW

2. Conversion of Biomass and Waste to Energy

Under this technology option the following sub technologies are considered:

(a) Co-Firing of Biomass with Coal

The estimated cost of a biomass fired boiler of 100 t steam per hour at 173 bar and 541o C capable of generating 30 MW of electricity is Rs. 1026 million (Lalan Engineering Ltd.). The heat content of steam at the above specification is 3420 kJ/kg. Hence heat generated per hour is 3420 x 100,000 = 342 GJ/ h = 342 x 8000 GJ/y = 2,736,000 GJ/y .

Cost of generating 1 toe/y (41.8 GJ) = 1,026,000,000 x 41.8/2,736,000 = Rs. 15,675.

CO2 reduction achievable per year= 2736 x 94.6 t = 258,826 t CO2/year.

The cost of reducing 1tCO2/y = Rs. 1026 million/258,825tCO2= Rs. 3,964/tCO2/y

The national mitigation potential is estimated as 1000 MW = 258,826 x 1000/30 = 8,627,533 tCO2/y/ 1000 MW

In order to implement this technology the following process need to be developed.

(a1) Mechanization of Biomass Production

The mechanization process would not have any direct emission reductions. However, the mechanization will have the following impacts:

- Modern youth are reluctant to work with manual tools. They prefer to work with machines. Hence it would be easier to find suitable people to work in the plantations.
- The labour requirements for the establishment and operation of plantations would be much less.
- For the above reasons, many hectares of fuelwood plantations will be established due to this technology.
- Hence there will be many cases of fuel switching in the industrial sector and many biomass based electricity generating power plants getting established in the country.
- This will reduce the emissions drastically.

With the mechanization of 11,200 ha of fuelwood plantations, 336,000 tonnes dry fuelwood will be produced annually. This will replace 30x .4 x 8000 tonnes of coal = 96,000 t of coal per annum. This will result in a reduction of 96,000 x 2.49 = 239,040 tCO2 per annum. In the short term, 500,000 ha of fuelwood plantations will be established. This will reduce the emissions by 239,040x 500,000/11,200= 10.67 million tCO2 reductions per annum.

The total cost of mechanization equipment for 11,200 ha plantation is Rs. 4,480,000. This will generate 336,000 tonnes of wood annually equivalent to 120,574 toe. Hence the cost per toe = 4,480,000/ 120,574 = Rs. 38/toe.

The cost of reducing 1tCO2/y = Rs. 4,480,000/239,040=Rs. 18.74/tO2/y

(a2) Biomass Fuel Dryer

It is proposed to construct the first dryer at a place where a 100 t/h steam boiler is installed for co-firing biomass with coal. The fuelwood consumption is about 42 tonne /h. The installation of this dryer would result in a savings of 22% of the fuelwood. The emission reduction benefit would arise from the fact that the quantity of wood saved could be used in a place where petroleum fuels are used. On this basis, the emission reduction as a result of this dryer would be 15.75 tCO2/h. If the facility operates with a plant factor of 80%, then the annual emission reduction would be: 15.75 x 8760 x .8 = 110,376 tCO2/y.

If 10% of the 15 million t of biomass fuel is dried through this, the CO 2 emission reduction would be 110,376 x 1,500,000/ 336,000 = 492,277 tCO2 per year.

The estimated cost of constructing a dryer for a 100 t /h boiler is estimated as Rs. 200 million. The energy benefit of this dryer is 336,000 x .22 x .38 = 28,090 toe. Hence the cost per toe is 200,000,000/28,090 = Rs. 7,120/toe.

(c) Compact biogas Digester for Urban Household

A biogas unit introduced through this technology is capable of generating biogas which is equivalent to 0.5 kg of LPG per day. On a yearly basis this would replace182.5 kg of LPG with a calorific value of 46.1 MJ/kg. The emission factor for LPG is 63.1 tCO2/TJ.

Hence each biogas unit (= 0.5 LPG/day) introduced with this technology would reduce emission by 0.530 tCO2/y

On a national basis, in the short term of the 5 million households in the country, if 1% of the households resort to this technology, the emission reduction would be 0.530 x 50,000 = 26,500tCO2/y.

The capital cost of a 1 m3 compact biogas plant is US$ 200 = Rs. 23,000 (Ref. 5). This unit will generate equivalent of 182.5 kg of LPG. = 8413.25 MJ = 8413.25 x 4.18 Mcal = 35167.385 Mcal = 3.5167 toe.

Hence the capital cost required to generate 1 toe = 23,000/3.5167

= Rs. 6540/toe/y.

The cost of reducing 1tCO2/y is Rs. 23,000/.53= Rs. 43,396/tCO2/y

(d) Waste To Energy

The conversion of MSW to RDF is not common in Sri Lanka or in the neighboring countries. As per a report published by the European Union (EUROPEAN COMMISSION – DIRECTORATE, GENERAL ENVIRONMENT, REFUSE DERIVED FUEL, CURRENT PRACTICE AND PERSPECTIVES (B4-

040/2000/306517/MAR/E3, FINAL REPORT, WRc Ref: CO5087-4, JULY 2003), the average cost of production of a tonne of RDF with a calorific value of 16 MJ/kg is 62.5 Euro (= US$81.25 = Rs. 9181.25). Under local conditions, the cost of generating 1toe (41.8GJ) of RDF is expected to be 40% of the European cost. = Rs.9,594.

Daily collection of MSW in the city of Colombo is 1250 tonnes per day with a moisture content of 60%. Hence the dry matter collection is 500 tonnes per day. Assuming 10% of this converted into 50 tonnes RDF, the heat content of RDF produced per day would be 50,000 x 16 MJ/d = 800 GJ/d. = 800 /41.8 =19toe/d. Assuming this is used to replace coal for cement production, and taking the IPCC value of 94.6 tCO2/TJ as the emission factor for coal, the amount of CO2 reduction achieved per day would be: 94.6 x 800/1000 = 76 tCO@/d or 27,740 tCO2/year.

The mitigation benefit of 50 tonne of RDF/d = 27,740 tCO2/y

The cost of reducing 1 tCO2/y is estimated as Rs.100,000,000/27,740=Rs. 3,600/tCO2/y.

The cost of reducing 1 toe/y: 100,000,000/ 19x 365 = Rs. 14,420/toe/y

The national mitigation potential is estimated as 500 t RDF/d =277,400 t CO2/y.

3. Smart Grid Technology for Wind & Solar Integration with Hydro

The cost associated with the EU project involving 49.1 MW of wind, solar, biogas etc. is estimated as 160 million Euro. However, for the purpose of introducing this technology in Sri Lanka it is assumed that the average cost of introducing Smart Grid/ Smart Meter in order to adjust the hydropower outputs as required by the variations in wind and solar power would be obtained at a cost of US$1/Watt including the cost of wind and solar power plant. It is assumed that 1000 MW of wind and solar power projects would be introduced in the next 6 years (100 MW per year in the first two years and 200 MW per year thereafter).

The average annual plant factor of wind power plants in Sri Lanka is 30% and for solar PV plants is 15%. Hence the overall average is 22.5%. On these basis, the annual energy generation from 1MW wind and Solar would be 1000 x 8760 x 0.225 kWh/y = 1.971 GWh/y = 1.971 x 240 toe/y = 473 toe/y.

Hence cost per toe/y = 1x 112 x 1,000,000/ 473 = Rs. 236,786/toe/y.

Annual tonnage of CO2 emission reduction from 1 MW unit would be: 1,971 x .76 tCO2/y = 1,497 tCO2/y/MW.

The cost of reducing 1tCO2/y would be: Rs. 112 X 1,000,000/1497 = Rs. 74,816/tO2/y.

The national mitigation potential for 1000 MW of wind and solar penetration would be = 1497 x 1000 = 1,497,000 tCO2/y/1000 MW.

4. DC Motor Driven Alternator for Grid Connected Solar PV Systems

To estimate the mitigation impact of this technology, it is assumed that without the introduction of this technology, the capital cost of conventional solid state driven inverter based grid connected solar PV systems would not be financially viable. It is assumed that with the introduction of this technology, the grid connected solar PV technology would be able to cross the threshold and the grid connected solar PV technology would become viable. The unit size of the technology is assumed to be a 100 kW system. The annual plant factor for a solar PV system in Sri Lanka has been found to be 20%. Hence the annual energy output of this unit would be: 100 x 8760 x .2 = 175.2 MWh/y. With the national Grid Emission Factor of 0.76 tCO2/ MWh, the emission reduction is calculated as follows:

Emission Reduction = 175.2 x .76 = 133 tCO2/y/100 kW module.

Assuming 100 MW of Solar PV based system would be commissioned in the short term, the annual national mitigation benefit would be: 133,000 tCO2/y

The capital cost of implementing this project is taken as 1.5 $ per peak watt. A 1-watt system would deliver: 1 x 8760 x 0.2 /1000 kWh per year = 1.752 kWh = 1.752 /10^6 GWh = (1.752/10^6) x 240 toe. = 0.00042048 toe. Hence to generate 1toe the capacity required = 1/.00042048 = 2378 watts.

Hence the cost of generating 1toe of energy = 2378 x 1.5 x 112 = Rs. 399,504/toe.

The cost of reducing 1tCO2/y = Rs. 100,000x 1.5 x 112/133 = Rs. 126,316/to2/y

5. Pumping Water into Hydro Reservoir

It is assumed that in the initial phase of introduction of this technology, a pumping unit would consist of a pump with a capacity of 10 kW motor pumping against a head of 100 m. The net head of a generator is taken as 300 meters. It is also assumed that each pump will operate with an annual plant factor of 50%. The efficiency of the pumping system is assumed as 50%. The Generating station has an efficiency of 80%.

Based on the above parameters, there is a gain of 3 x 0.5 x 0.8 = 1.2. That is a 20% of net energy gain. Corresponding to the above parameters, The annual net energy generated from a 10 KW system would be 10 x 0.5 x 8760 x 0.2 = 8760 kWh/y = 8760 x 240/ 1,000,000 = 2.10 toe.

The annual emission reduction = 8760 x 0.76 / 1000 = 6.66 tCO2/y/10 kW.

If this system is introduced to 10% of the hydro power generation there will be potential to generate an additional 600 GWh of electrical energy per year.

This will result in a national emission reduction of about 456,000 tCO2/y.

It is also proposed to deploy Solar PV based electricity or Wind Power based electricity for pumping this water. In this manner, the problem encountered by CEB in accommodating large share of Wind or Solar PV into the CEB Grid due to fluctuations in the output of these resources could be resolved.

If Wind or Solar PV based electricity is deployed for pumping water, then the emission reduction would be much larger as there will be no “Project Emissions”.

The capital cost is based on the value assigned by Sustainable Energy Authority for small hydro based power generation in the latest tariff published (Ref. 4). On this basis, the 10 kW system would cost at the rate of Rs. 716 per Watt. Total cost is: Rs.7,160,000. This system would generate 52560 kWh of electricity. = (52560/1000000) x 240 toe = 12.6144 toe. Hence to generate 1 toe 10/12.6144=0.79 kW system.

Hence the capital cost required to generate 1 toe of energy = 7,160,000/ 2.1 = Rs. 3,409,523/toe/y.

The cost of reducing 1 t of CO2/y = 7,160,000/ 6.66 = Rs.1,075,075 / tCO2/y

6. Tracker cum Reflector for Solar PV

For this purpose it is assumed that this technology is introduced to 100 kW Solar PV Module. Assuming that this unit has a annual plant factor of 20% (this is typical for Sri Lanka), and as per literature (Renewable Energy World, July-August 2011), the tracking of solar PV modules would increase the output by around 40%. To be conservative a value of 30% increased is considered for this calculation. In respect of solar reflectors, it is assumed that a 20% increase would be possible without exceeding the temperature restriction of solar cells. Hence an overall increase in the output would be 50%. Hence the annual increase in the energy output from the 100 kW module is calculated as follows:

100 kW x 8760 h x 0.2 (plant factor) x 50% = 87600 kWh/ unit/y.

Based on the Sri Lanka Grid Emission Factor (2010) of 0.76 kg CO2/ kWh, the incremental emission reduction achieved would be 87600 x 0.76/1000 tCO2 = 66 tonnes/y/ 100 kW unit.

Assuming that in the short term a total of 100 MW of such systems are commissioned in Sri Lanka, the net additional CO2 emission reduction achieved would be 66000 tCO2 per year.

The capital cost of implementing this project is taken as 1.5 $ per peak watt. A 1-watt system would deliver: 1 x 8760 x 0.2 /1000 kWh per year = 1.752 kWh = 1.752 /10^6 GWh = (1.752/10^6) x 240 toe. = 0.00042048 toe. Hence to generate 1toe the capacity required = 1/.00042048 = 2378 watts.

Hence the cost of implementing the project = 2378 x 1.5 x 112 = Rs. 399,504 /toe.

The cost of reducing 1 tCO2/y = 100,000 x 1.5 x 112/ 66 = Rs.254,545/tCO2/y.

7. Biomass Gasifier for High Temperature

For this technology, a high temperature gasifier of 700 kWth output is considered. (This corresponds to 1tonne of steam per hour output.). It is assumed that this unit is used to replace the equivalent LPG

burner. Assuming that that this unit is operated at a plant factor of 80%, the annual energy output of this is:

700 x 3600 x 8760 x .8 = 17,660 GJ/y

Assuming a calorific value of 44,300 kJ/kg (SEA, Energy Balance 2007) this unit would replace 17,660 x 10^6/ 44,300 kg = 398 tonnes of LPG/y.

Emission factor of 63.1 tCO2/TJ oft LPG and a calorific value of 46.1 MJ/kg.

Hence the annual emission reduction is calculated as: 17,660 x 63.1/ 1000 = 1,114 t CO2/ unit/y

The annual consumption of LPG by the ceramic sector is estimated as (Sri Lanka Sustainable Energy Authority) 4480 t/y.

Hence the estimated national reduction in the short term is: 1157 x 4480/ 398 = 13,023 t CO2/y

The capital cost of a 700 kWth biomass gasifier capable of delivering gas to generate high temperature and clean environment is expected to cost (Source: Ministry of Science and Technology) Rs.21,000,000. This would generate 700 kW. With a plant factor of 80%, the annual output would be 700 kW x 8760 x .8 = 4905600 kWh of heat. = 4905600 x 3600 / 1000000=17660 GJ= 4225 Gcal = 42.25 toe.
Hence capital cost required to generate 1toe = Rs. 21,000,000/ 42.25 = Rs. 497,040/toe.
The cost of reducing 1 t of CO2 = Rs. 21,000,000/1157=Rs. 18,150/tCO2/y.

8. Biomethane as Transport Fuel

Under this project it is proposed to utilize biogas generated at from a large existing reactor to produce Compressed Methane to be used as transport fuel for a bus consuming 140 litres of dieseline per day. The emission reduction from demonstration project would be 140 x 0.84 x 10,500x 4.18 x 74.1 = 0.382tCO2/day.

Yearly emission reduction from this unit (= 140 l of diesel/d) = 0.382x 300 = 115 tCO2/y

On a national basis, it is propose to utilize all the biogas generated through industrial waste water. This is estimated as 4434 toe (UOM).

The national amount of emission reduction from 4434 toe would be 4434 x 10x 10^9 x 4.18 x 74.1/10^12 = 13,734 tCO2/y.

The capital cost of establishing a plant to produce CNG equivalent to 140 litres of diesoline per day would be Rs. 310,000,000 (Ref.6). 140 litres /d of diesoline = 140 X .84 x 10500 x 4.18 = 6144600kJ/d x 300 = 1843380000 kJ/y = 1843.38 GJ/y = 1843.38x 4.18 Gcal/y = 7705G cal/y=770.5 toe/y.
Hence the capital cost to generate 1 toe/y is: 310,000,000/770.5 = Rs. 402,336/toe.
The cost of reducing 1 t CO2/y = 310,000,000/115 = Rs.2,695,652/tCO2/y

9. Roof-Mounted Solar PV for Net Metering

As per Access Engineering (Pvt) Ltd., a typical 10 kWp Solar PV system complete with inverter and interconnection switch gear would cost Rs. 4.6 million. The annual energy saved per year would be 17440 kWh/y = 17440* 240/1000000 = 4.1856 toe/y.
Cost of generating 1 toe = 4,600,000/4.1856 = Rs. 1,099,006/ toe/y.
Annual CO2 emission reduction would be: 17440 x 0.76/1000 tCO2/y = 13 tCO2/y/ 10kWp.
If 100 such systems are installed:
The national annual emission reduction would be 1,300 tCO2/y.
Cost of reducing 1 t CO2/y = 4,600,000/13=Rs.353,846/tCO2/y

10. Concentrated Solar Thermal Electricity Generation

The cost of a 50 MW Concentrated Solar Thermal Power commissioned recently in Europe is estimated as 300 million Euro (US$390 million = Rs. 44460 million). The annual average plant factor is expected to be 41%. Electrical energy output of the plant is estimated as: 50,000 x 8760 x 0.41 kWh/y = 179,580,000 kWh/y = 179.58 x 240 toe/y = 43099 toe/y.

Hence cost generating 1 toe/y = Rs. 44460 million/ 43099 = Rs. 1,031,578 /toe.

The estimated CO2 emission reduction from a 50 MW concentrated Solar Thermal power plant would be 179,580,000 kWh x 0.76/1000 tCO2/y = 136,481 tCO2/y/ 50 MW.

The national mitigation potential would be about 500 MW: = 1,364,810t CO2/y/500 MW.

The cost of reducing 1 t CO2/y = 44460 x 10^6/136481= Rs.325,760/t CO2/y.

Technology Fact Sheets (TFS)

Transport Sector

Technology fact sheet for transport sector- Modal shift in 5% of freight transport

Sector	Transport
Introduction	Transport sector is a major greenhouse gas (GHG) emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of land passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Shift of ~5% of transportation of freight from roads to rail
Technology characteristics	Currently ~ 1% of freight transport is done using railways. Due to congestion and higher energy consumption and GHG emission in road transportation of freight, it is quite beneficial to move at least 5 percent of freight transportation to the railway system. Using rail for freight transport emits only 23 grams of CO_2 per ton-km traveled, while road transportation of freight emits 61 grams of CO_2 per ton-km traveled (ADB, 2010).
Country specific/ applicability	This is an achievable goal, especially through public private partnerships with the government Railways and relevant stakeholders from the private sector. Building new infrastructure for loading unloading purposes and any new development in the tracks involves an initial high cost, and proper planning is needed prior to establishing increased freight transportation through rail within the country, to avoid it being a loss.
Status of the technology in the country and its	The railway network in Sri Lanka was initially built and used only for transporting goods (i.e. plantation products), when the country was under

future market potential	British rule. The first railroad was built between Colombo and Kandy. Transporting such goods continued for many years, and over time with increasing population and traffic needs, rail transport became more passenger oriented. Sri Lanka had 32 percent of freight transportation through the railway system in 1979, and it has declined drastically since then (Ministry of Transport, 2008). The civil war during the last three decades severely affected the rail transport to more northerly areas. The draft national transport policy promotes increased use of rail for freight transport. With proper infrastructure development, it could attract more private sector partners for the use of railways for transportation, mostly for the transportation of export goods and containers needing more than 200 km domestic freight transportation.
Barriers	In Sri Lanka, freight transportation has drawn less attention compared to passenger transportation, even at policy level. There is limited availability of space and facilities for loading and unloading goods and parking of the container trucks close to the relevant railway stations. One important financial barrier for modal shift is the high investment required for infrastructure and intermodal facilities (as rail transport of freight still requires pre- and post-haulage by truck).
Benefits	Socioeconomic- - Lower fuel consumption and higher energy efficiency. - Reduced congestion, especially in more populated areas and during peak hours. - Avoiding the traffic delay due to freight transporting trucks also causes a smoother flow of other vehicles and less idle time on the road Environmental- - Lower fuel consumption and higher energy efficiency lead to lower GHG emissions.
Operations	
Costs	Modal shift from roads to rail requires high initial investment on developing infrastructure and intermodal facilities. However, the long term benefits are higher.
References	ADB 2010. Reducing Carbon Emissions from Transport Projects AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean

	air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011 Ministry of Transport. 2008. Draft national policy on transport in Sri Lanka. National Transport Commission.

Technology fact sheet for transport sector- Improved public transportation, especially in Colombo area: Introduction of a bus rapid transit (BRT) system

Sector	Transport
Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Improved public transportation, especially in Colombo area: Introduction of a bus rapid transit (BRT) system
Technology characteristics	BRT is another mass transit system that provides a faster journey compared to regular buses, as BRT runs mostly on bus-only, exclusively right of way lanes. Modal integration at stations, rapid boarding and alighting, real-time information displays are also common features. The travel time is less in these sophisticated, low cost buses, and due to high fuel efficiency, the GHG emissions are reduced. Mass transit modes are in general 50-80% more efficient compared to personal cars. Some BRT systems have been approved by the United Nations to generate and sell carbon credits.
Country specific/ applicability	BRT systems are already operating in other developing countries in the region, and can be applied in Sri Lanka, as well, especially in city areas with heavy traffic and congestion due to too many low occupancy personal vehicles on the road. The possibility of using any existing road sectors, as well, needs to be considered in minimizing the costs associated with introducing this ‘new’ mass transport mode in the country.

Status of the technology in the country and its future market potential	Currently, state- and privately owned buses are the principal mode of public transport. So far there is no BRT operating in the country. The ministry of transport has plans to have 3 BRT routes around Colombo.
Barriers	Space requirement for developing infrastructure (bus lines, stations, and terminals), and at some places there might not be the possibility to expand the existing road space.
Benefits	Socioeconomic- - BRT in city center areas is one of the cheapest public transport options compared to metro or trains. - Low investment costs. Although the initial costs are relatively high, in the long term, benefits are much higher. - BRT systems help enhance the efficiency of public transportation and reduce air pollution. - These systems can transport a larger volume of passengers per day compared to the existing public bus service, in a cost-effective, high quality manner, enhancing the sustainability of the urban transport systems. - Reduced congestion and travel times. - Increased road safety Environmental- - Reduced air pollution. - BRT causes lower GHG emissions per passenger km, and are highly efficient with optimal performance. E.g. BRT TransMilenio of Colombia, as a CDM project, has a CO2 reduction of ~200,000 tonnes CO_2 yr^1 (Grütter, 2007).
Operations	
Costs	According to IPCC (2007), the cost of BRT systems could be US $ 1-15 million per km. For Sri Lanka a cost of US $3-6 million per km has been estimated
References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Grütter, J.M. 2007. The CDM in the Transport Sector. Module 5d. Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities. GTZ. Germany. India Journal. 2011. Metro Gets UN Certification, Earns Rs 470 Million Carbon Credits. India Journal on Septermber 30, 2011.

	IPCC, 2007. Transport and its infrastructure. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Metz, B. and Davidson, O.R. and Bosch, P.R. and Dave, R. and Meyer, L.A. (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, USA. Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011

Technology fact sheet for transport sector- Integration of Non-motorized transport methods in Colombo along with regularized public transport system)

Sector	Transport
Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Integration of public transport system with Non-motorized transport methods (e.g. walking, bicycling) in Colombo
Technology characteristics	With the increased fleet of vehicles on the road, there is a need for reduction of congestion, especially during peak hours and at city centers. One way of resolving this is to promote more public transportation, walking, and bicycling in congested areas/ city centers. Developing more parking spaces for bicycles, having well defined bike lanes on the roads, and strict law enforcement with regard to road rules, having pedestrian walkways, sidewalks, and overhead pedestrian bridges, proper electronic signaling at pedestrian crossings, etc., could help promote and draw more attention towards non-motorized transport. Since these non-motorized modes also serve as access modes for public transport, promoting non-motorized transport also help increased use of public transportation. However, since non-motorized transport could reduce the time efficiency of travel sometimes, making the public transport more regularized is also important along with that, in order to have proper benefits out of non-motorized transportation.
Country specific/	With proper planning and law enforcement, this is something easily

applicability	implementable in the country.
Status of the technology in the country and its future market potential	Currently non-motorized transport is mostly used in more northerly (North, Northwest, and North central parts) and rural areas of the country, while Colombo and the neighboring cities with heavy traffic and passenger transport hardly use and take the minimum benefit out of non-motorized transport means. Although there are bike lanes on certain roads in Sri Lanka, due to poor enforcement of road rules, using bicycles in the middle of other traffic has become a burden to the riders, especially in the latter city areas of the country. Therefore proper demarcation of bike lanes on roads and more awareness creation of the road rules considering them, are needed. Also there is a need for the development of more bicycle parking areas with racks for secure bike storage. With the improved facilitation of pedestrian walking, as described above, more people can be drawn towards the use of public transport and/or walking, as well. Given the situation in the country, prior to promoting increased use of bicycles in the urban areas, proper implementation of road rules with regard to the current level of bicycling is needed. Therefore, in this exercise we have considered only the promotion of walking in urban areas, by developing proper traffic signals at pedestrian crossings, and improvement/development of pedestrian sidewalks
Barriers	Lack of space on certain roads for developing well demarcated bike lanes and sidewalks for non-motorized modes of transport, lack of appropriate parking spaces for storing bicycles
Benefits	Socioeconomic- - Non-motorized transport help reducing traffic congestion in city centers - Promotion of such practices help prevent unnecessary use of vehicles for traveling shorter distances, especially in city centers. - Health benefits - Avoided costs in using private motorized vehicles - More efficient use of walkable space in urban areas Environmental- - Zero or very low GHG emissions and low air pollution - Reduced noise
Operations	
Costs	Can be applicable within a low cost budget. Costs for traffic signals including those for pedestrians range from $30,000 to $140,000 (PEDSAFE, 2011a). Cost of sidewalks is ~$40 per linear meter (PEDSAFE, 2011b)

References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011 PEDSAFE, 2011a. Traffic signals. Available at http://www.walkinginfo.org/pedsafe/pedsafe_curb1.cfm?CM_NUM=37 PEDSAFE, 2011b. Recommended guidelines/priorities for sidewalks and walkways. Available at http://www.walkinginfo.org/pedsafe/moreinfo_sidewalks.cfm

Technology fact sheet for transport sector- Improving the traffic signal system for Synchronization

Sector	Transport
Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Synchronization of traffic signals
Technology characteristics	In traffic signal synchronization, a series of traffic lights along the road turns green allowing smooth flow of vehicles, reducing the congestion and need to stop in the middle of traffic; this helps avoid travel delays, especially in heavy traffic, and causes lower emissions and air pollution The synchronization system is usually activated during morning and evening peak hours, and the signals are coordinated based on the congestion level. The existing traffic signals in these areas can be updated for having better synchronization. Updated traffic signal control equipment along with signal timing optimization can reduce congestion; in Texas, USA, synchronization of traffic signals reduced traffic delays by 23 percent (US Department of Transportation, 2011), while on average it can reduce the travel time by up to 15 percent (US Department of Energy, 2011).
Country specific/ applicability	This is an important technology, especially in avoiding the heavy traffic entering and moving out of city areas with heavy traffic during peak hours.
Status of the technology in the country and its	Currently there are ~120 traffic signals in the country and majority of those are in Colombo district. Currently majority of the traffic signals are controlled

future market potential	by the Roads Development Authority and Colombo Municipal Council. There is a need for establishment of more traffic signals at certain other intersections which are currently being controlled using traffic police officers. Traffic light synchronization will definitely help improve the efficiency of the existing traffic lights, while leading to a smoother flow of vehicles, high fuel use efficiency, and lower pollution
Barriers	
Benefits	Socioeconomic- - Reduced congestion and enhanced time use efficiency - Better transportation system and improved quality of traffic light signaling - Avoidance of unnecessary traffic delays/stops - Improved safety, without having to make sudden stops - Higher fuel use efficiency. Environmental- - Lowered air pollution and GHG emissions due to higher fuel use efficiency (But this is only a short term benefit, as smoother flow of vehicles with no congestion can draw more vehicles to the road over time).
Operations	
Costs	US $ 2500-3100 per signal (US Department of Transportation, 2011)
References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011 U.S. Department of Transportation, 2011. Intelligent Transportation Systems for traffic signal control. Available at http://ntl.bts.gov/lib/jpodocs/brochure/14321_files/a1019-tsc_digital_n3.pdf U.S. Department of Energy (DOE). 2011. Traffic signal synchronization for energy savings. DOE Technical Assistance Program. DOE.

Technology fact sheet for transport sector- Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles

Sector	Transport
Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Promote carpooling and park-and-ride systems during rush hours and on roads with heavy volumes of vehicles
Technology characteristics	Park-and-ride lots are parking facilities where the commuters can leave their personal vehicles in such and transfer to a common coach or do carpooling (i.e. several commuters traveling in one car) for the rest of their journey. Cars or personal vehicles are parked in the facility throughout the day, and picked up when the commuters return at the end of the day. Typically, such facilities are found in the suburban areas. Carpooling and park-and-ride options can be considered for roads where congestion is extremely high, causing traffic delays. Availability of these facilities needs to be given enough publicity and awareness, with substantial details on who and where to contact regarding the same. This system is especially applicable in industrial zones and busy city areas, and passengers should have secure parking facilities for parking any personal vehicles before getting to a common vehicle in reaching the final destination.
Country specific/ applicability	Easy applicability in Sri Lanka
Status of the technology in	Currently, there is one proper park-and-ride system operating in the country (i.e. CityLiner), between Katubedda, Moratuwa and Colombo Fort. The massive vehicle

the country and its future market potential	park at Katubedda provides parking facilities for nearly 150 vehicles. Commuters are transported by the CityLiner Coach Service to the Fort via Nawam Mawatha. The coach service is operated by the E.C.D. Global (Pvt) Ltd., under the permission of the Western Provincial Road Passenger Authority. The development of more such facilities in other areas will help further environmental benefits, reducing overall traffic congestion in Colombo area.
Barriers	
Benefits	Socioeconomic- - It helps reduce the load of traffic moving towards Colombo from Moratuwa daily, and help prevent unnecessary traffic delays and more idle time on roads caused by congestion. - Smoother flow of vehicles and more efficient fuel use. - Reduced overall cost through less use of personal vehicles Environmental- - Low GHG emissions and low air pollution - Reduced noise through milder traffic
Operations	
Costs	Can be applicable within a cost of US $ 0.5 million (FTPN, 2011)
References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Florida Transit Planning Network (FTPN), 2011. Park & Ride Lots. Available at http://planfortransit.com/ozonereduction/Docs/Park%20&%20Ride%20Lots.pdf Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011

Technology fact sheet for transport sector- Improvement of the condition of byroads

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Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Improvement of the condition of byroads
Technology characteristics	Proper maintenance of byroads for efficient and smooth flow of traffic with lower CO_2 emissions; proper maintenance of the road edges/shoulders to prevent erodibility and damage. The material used in road construction is also important in relation to CO_2 emissions; although construction of asphalt/concrete roads are favored most of the time, a study by Prof. R. Shanthini at University of Peradeniya, Sri Lanka, has found that 'metalling and tarring' roads have lower emissions and high durability for roads in rural sector.
Country specific/ applicability	Applicable island wide
Status of the technology in the country and its future market potential	Currently, most of the main roads are occupied by heavy volumes of vehicles, and passengers tend to choose certain byroads, bypassing certain heavily congested main roads. However, most of the time byroads are poorly maintained, causing vehicle damage and slower driving speed. This is mostly obvious in situations when the byroads are used as detours. Proper and timely road maintenance practices should be enforced through the respective local authorities.

Barriers	
Benefits	Socioeconomic- - It will help avoid unnecessary traffic delays and more idle time on roads caused by slow driving under poor road conditions. - Smoother flow of vehicles on proper byroads causes efficient fuel consumption and less damage to vehicles Environmental- - Lowered emissions due to better fuel use efficiency (But this is only a short term benefit, as smoother flow of vehicles with no congestion can draw more vehicles to the road over time).
Operations	
Costs	Can be applicable within a low cost budget.
References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011

Technology fact sheet for transport sector- Electrification of the existing railway system

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Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Electrification of the existing railway system
Technology characteristics	Electrification of the existing railway system, at least part of it, will save both energy and the maintenance cost, while providing sustainable transport. The diesel powered electricity generator in the existing trains that drive the motors connected to the wheels, remain idle most of the time, except when running at steady speed. When the train is electrified through the grid, there is no such wastage of fuel and when the train brakes or decelerates, the motors will transform to generators, producing electricity, which will be returned to the grid for later use. In electrification of the railway system, the existing railway tracks could be used (with zero voltage) with electricity provided through overhead lines (25 kilovolt) drawn above the railway lines and loops (IESL, 2008).
Country specific/ applicability	The electric trains become more efficient and beneficial with the higher frequency of use; thus more busy sectors with a large number of passengers and frequent trips would get the highest benefit out of electrification.
Status of the technology in the country and its future market potential	The existing railway network in the country is ~1500 km long. The railway network in Sri Lanka was initially built and used only for transporting export plantation products, and with increasing population and traffic needs, rail

	transport became more passenger oriented. Currently the existing trains are diesel powered, and electrification of one sector of the railway network has been proposed by IESL (2008).
Barriers	
Benefits	Socioeconomic- - Better, smooth, and more sustainable transport - Reduced noise and pollution - Lowered energy requirement and cost - Lower maintenance cost - Higher acceleration and speed and reduced travel time per unit distance - More passengers moving towards rail transport, thus reducing the congestion on roads - Higher energy use efficiency - Electric traction gives higher power-to-weight ratio compared to diesel power Environmental- - No exhaust fumes. - Lower GHG emission and reduced environmental pollution
Operations	
Costs	Initial investment cost could be high. However, this cost could be reduced by using the existing railway tracks with electricity provided through overhead lines drawn above the railway lines and loops.
References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka IESL (The Institute of Engineers, Sri Lanka), 2008. A proposal for railway electrification. IESL. Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011

Technology fact sheet for transport sector- Promote and facilitate the import of low GHG emitting hybrid vehicles

Sector	Transport
Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Promote and facilitate the import of low GHG emitting hybrid vehicles
Technology characteristics	Hybrid electric vehicles have an internal combustion engine and one or more electric motors. These vehicles are most feasible for use in urban traffic, where there is a frequent need for braking. The hybrid vehicles have substantial tailpipe CO_2 emission reductions only at relatively low speeds (i.e. speeds below ~50 km/h). In full hybrid cars such as Toyota Prius, the vehicle can be propelled fully electric at low speeds and use the internal combustion engine at higher speeds or when the electric energy stored in the car battery is low.
Country specific/ applicability	Given the higher fuel efficiency, hybrid cars are especially attractive and suitable for crowded city areas in Sri Lanka.
Status of the technology in the country and its future market potential	Hybrid cars (e.g. Toyota Prius and Honda Insight) are already in use at a smaller scale in the country. However, the import of hybrid vehicles has remarkably increased lately. During the early half of the current year (from January to May), a total of 10,025 hybrid vehicles were imported in Sri Lanka; 70 percent of the new cars added to the vehicle fleet were hybrids, and motor cars using petrol were only 30 percent (Jayaweera, 2011). Reduced import

	taxes could induce further movement towards Hybrids, causing better market, cleaner air and lower emissions.
Barriers	
Benefits	Socioeconomic- - Higher fuel efficiency and more beneficial in city areas with higher traffic and lower speeds. Environmental- - Reduced CO_2 emissions without additional infrastructure requirements. A full hybrid vehicle driven mostly in urban areas could have CO_2 emission reductions up to 25% (Passier et al, 2007)
Operations	
Costs	The original cost of hybrid cars could range from US $23000 to $48000 depending on the type and brand of car and the features of the car
References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011 Passier, G., F.V. Conte, S. Smets, F. Badin, A. Brouwer, M. Alaküla, D. Santini (2007). Status Overview of Hybrid and Electrical Vehicle Technology 2007; Final report of Phase III, Annex VII, IEA. TNO, Delft, The Netherlands

Technology fact sheet for transport sector- Increase the use of cleaner fuel (i.e. Liquid natural gas (LNG)/ Compressed natural gas (CNG) and biofuels)

Sector	Transport
Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Increase the use of cleaner fuel (i.e. Liquid natural gas (LNG)/ Compressed natural gas (CNG))
Technology characteristics	Currently the vehicles used in Sri Lanka use petroleum fuel such as unleaded petrol (gasoline), diesel, or LPG. Natural gas has lower CO_2 emission level, compared to the above fuels, and currently used worldwide as a cleaner fuel. Natural Gas is about 80 percent methane (CH4), and can be temporarily converted into liquid form (LNG) at minus 160 degrees Celsius for ease of transport and storage. CNG and LNG are appropriate for spark ignition engines. The high octane rating (i.e. ~120) allows a higher compression ratio compared to what is possible for gasoline, and it also enhances the engine efficiency. CNG is suitable for cities with high pollution due to its reduced emission levels Biofuels are considered zero CO_2 emitting; ligno-cellulosic sources in biomass such as grasses and woody material are converted to biofuels. Crop residues such as wheat and rice straw, corn stalks and leaves, and energy crops can be utilized. Ethanol, methanol, and biodiesel can be produced from fermentation of these other crop material or wood-waste. Cellulotic crops

	have much higher yields per ha than sugar and starch crops (IEA, 2006). The production of crops however requires large harvesting areas.
Country specific/ applicability	Applicable island wide.
Status of the technology in the country and its future market potential	The Ministry of Petroleum Industries in Sri Lanka has plans for installing an LNG pipeline in Colombo and suburbs, and vehicles are planned to be converted to run on CNG. Although vehicles that run on biofuels are considered to have zero GHG emissions, currently Sri Lanka does not have any biofuel use. Although countries like Brazil have large areas of sugar cane that are being used for production of bioethanol, Sri Lanka does not have enough biomass production from sugarcane; feasibility of using rice stover has not been properly studied yet. A committee appointed by the Ministry of Science and Technology has identified policy measures to facilitate the use of biofuels as an alternative option for fossil fuel. This committee has examined the possibility of using compressed bio methane in transport; the committee has identified a private company to clean, compress, and use biogas produced from a municipal garbage digester facility. The Ministry of Science and Technology has also conducted trials on Jatropha, to determine yields, for possible future pilot studies on biodiesel.
Barriers	
Benefits	Socioeconomic- - Cheaper and cost effective with higher fuel use efficiency. - Cleaner air - Health benefits Environmental- - Low GHG emissions due to better fuel use efficiency
Operations	
Costs	Initial costs ~US $600 million. The total annual savings from fuel switch to LNG has been estimated at US $ 572 million, with more than 50 percent coming from electricity generation.
References	AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka IEA, 2006. Energy Technology Perspectives 2006: Scenarios & Strategies to 2050. International Energy Agency, Paris. Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011

Technology fact sheet for transport sector- Roadside tree planting and improving the overall roadside vegetation

Sector	Transport
Introduction	Transport sector is a major GHG emitting sector in Sri Lanka. About 60% of the air pollution (especially in Colombo City) comes from this sector (AirMAC, 2009). The main way of transportation is through the road network, which is supplemented by rail, air, and water transport means. Out of passenger transport, buses carry about 50% and railways carry about 4% of the passengers, while the rest of the passengers are carried by the other modes (Jayaweera, 2011). Road transport accounts for about 96% of passenger transportation and 99% of freight transportation (Jayaweera, 2011). Currently, the transport sector in Sri Lanka utilizes petroleum-based fossil fuels, leading to significant amounts of CO_2 and other GHG emissions (e.g. N2O, CH4) considered under the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Technology transfer, defined as the flow of experience, know-how and equipment between and within countries, is one of the priorities under the United nations Framework Convention on Climate Change (UNFCCC). Technology needs assessment (TNA) is a key element of the technology transfer, and is carried out with the intention of moving towards cleaner, less GHG emitting technologies.
Technology name	Roadside tree planting and improving the overall roadside vegetation
Technology characteristics	Planting trees and/or proper establishment of shrubs and grasses can improve the protection of roads from unnecessary eroding and runoff. However, a minimum clear zone of 10 feet from the road edge is suggested for avoiding any road accidents. Planting trees will also help sequester carbon, reducing the net emission due to fossil fuel burning in road transportation.
Country specific/ applicability	Applicable island wide.
Status of the technology in the country and its future market potential	Currently some parts of the country already have well established tree planting, and expanding it to the other potential parts of the country can increase the beauty and scenic view, while protecting the roads and the immediate neighboring areas.
Barriers	
Benefits	Socioeconomic- - Low cost of implementation. - Enhanced scenic view, while protecting the environment.

	Environmental- - Roadside vegetation minimizes the net CO_2 emission from roads and transportation, by sequestering part of the emissions due to fossil fuel burnt in transportation.
Operations	
Costs	Low cost option.
References	. AirMAC 2009. Clean Air 2015. Air Resource Management Center. Ministry of Environment & Natural Resources, Sri Lanka Jayaweera, D.S. 2011. Analysis on effectiveness of fiscal strategies introduced on hybrid vehicles and market response- policy reforms on clean air. Presentation at the Center for Science and Environment Conference, India, held on September 28-29,2011

Technology Fact Sheets (TFS)
Industry Sector

Industry Sector - Mitigation

Technology Fact Sheet No. 1

1. **Sector/ Sub Sector:** rubber processing
2. **Introduction:** Energy requirement of the rubber processing factory can be provided by using saw dust. It is a waste material from saw mills which creates several negative environment issues.
3. **Technology Name: Biomass residue based cogeneration combined heat and power (CHP)**
4. **Technology Characteristics:** The average thermal requirement of the rubber processing factory studied is 1720 kW, and its average electrical power requirement is 1138 kW, giving a heat to power ration of about 1.5:1. The proposed combined heat and power (CHP) plant will run at a constant load of 2250 kW electricity (net); excess electricity will be fed into the national grid. Process stream will be available at a constant rate of 3375 kW. Steam in excess of the demand will be either wasted or used for preheating of combustion air or boiler feed water. The design capacity factor of the plant is 0.8, while overall efficiency is 34.5% (13.8% electric, 20.8% thermal)
5. **Country Specific Applicability:** It is applicable in Sri Lanka
6. Status of the technology in the country and its future market potential:
7. **Barriers:** Lack of biomass feedstock supply assurance, lack of local expertise or know-how and skills, lack of awareness or information, lack of micro credit finance mechanisms
8. **Benefits:** Greenhouse gas (GHG) emissions could also be reduced by the equivalent of about 11,300 t CO_2 per year. The lower cost of energy from cogeneration systems could be key to the survival of local industrial plants in today's competitive environment.
9. **Operations**:
10. **Costs:** The estimated cost of electricity delivered by the CHP plant is US$ 0.04/kWh and the estimated cost of thermal energy is US$ 0.019/kWh, both of which are lower than the corresponding cost of grid electricity at US$ 0.044/kWh and the cost of furnace oil-based thermal energy at US$ 0.021/kWh

    Estimated investment cost is around US$ 161,363 per tCO_2e reduction. This cost includes purchase (import) cost, installation and commissioning cost. Installation cost covers civil construction cost, equipments and controllers expenses (import cost was calculated based on current exchange rates, 1 USD = 110 LKR: in December 2011).
11. **Reference:** "technologies for mitigation of greenhouse gas emissions: barriers and promotional approaches-Sri Lanka" Asian Regional Research Programme in Energy, Environment and Climate by Asia Institute of Technolog

Industry Sector - Mitigation

Technology Fact Sheet 2

1. **Sector/ Sub Sector:** Methods of electrical energy reduction that is applicable to all industries using electrical drives (motors).
2. **Introduction:** Electrical energy is a clean energy available for many applications, but can have a high environmental impact due to low overall efficiency from primary energy source (if non-renewable) to the user end. By reducing the usage or making the usage efficient, environmental impact can be greatly reduced.
3. According to global energy surveys, it is estimated that two thirds of electrical energy in the industry is consumed by motors and hence high efficiency requirement is inevitable in view of overall energy efficiency. If every installation could contribute even by a fractional improvement of efficiency, the gross saving would be enormous.
4. **Technology Name: Energy loss reduction by means of energy efficient motors**.
5. **Technology Characteristics:** Energy saving by means of reducing losses of motors and hence with increased efficiency.
6. A general description of the technologies are given in Appendix-1
7. **Country Specific Applicability:** Applicable universally, but can have more benefits in tropical countries like Sri Lanka.
8. **Status of the technology in the country and its future market potential**: The solutions are included in many standards high-efficient motors are available in the market. There are several ESCOs who can provide such solutions, but prefer established organizations with reputed products in view of support.
9. **Barriers:** Initial expenses and technology know how that has to be applied to different types industries.
10. **Benefits:** As a rule of thumb, reduction of one unit of electrical energy can save nearly twice the equivalent energy of primary energy. If non-renewable energy is used, such technologies can provide higher mitigation effects in energy usage applications compared to renewable energy generating and usage. Expected annual electricity saving is about 38,068 MWh and GHG saving is about 13,019 tCO_2e. Expected lifetime of the technology at high efficiency level is ten (10) years. (Calculations are given in appendix 1)
11. **Operations:** No special operation is required, as all methods are more or less similar to the presently used operations (efficient motors) and the other type (automation) is generally programmed to operate automatically. However, involvement of a trained technical personnel or supplier may require incase of a problem.

12. Costs: Estimated investment cost is around 71,000 USD per tCO_2e reduction. This cost includes purchase (import) cost, installation and commissioning cost. Installation cost covers civil construction cost, equipments and controllers expenses (import cost was calculated based on current exchange rates, 1 USD = 110 LKR: in December 2011).

Appendix -1

1. Efficient Motors

According to global energy surveys, it is estimated that two thirds of electrical energy in the industry is consumed by motors and hence high efficiency requirement is inevitable in view of overall energy efficiency. If every installation could contribute even by a fractional improvement of efficiency, the gross saving would be enormous. Already there are agreements between motor manufactures and various enactments in the USA and Europe. Energy Policy Act 1992 (Epact 92) has directives for minimum efficiency levels for general purpose motors up to 200HP in USA. Based on such directives NEMA (National Electric Manufacturer's Association) listed different efficiency bands for motors. The motors that have higher efficiency by 2% – 8% than the standard efficiency motors are categorized as "Premium Efficiency Motors'.

Manufacturers state the efficiency classes in three groups – EFF1, EFF2 and EFF3. The highest efficiency of a particular category varies with the power rating (kW or HP), number of poles (or the speed). EFF1 has the highest efficiency. To illustrate these relationships considering a 1.1kW motor, efficiency of EFF1 type is equal or more than 82.8% and that of EFF2 type is equal or more than 76.2% and any type with lower efficiency than the latter falls into EFF3 type. The similar efficiency values for 75kW motor are EFF1 $\geq$ 94.6% and, EFF2 $\geq$ 93.6%.

Energy efficient motors have other benefits in addition to energy savings. They have better life due to high quality insulation, magnetic circuits and bearings. These properties with high quality manufacturing processes also lead to very low vibration and more susceptible to voltage unbalances and overloading.

Calculation of potential GHG reduction and energy saving by using EEM

Industrial electricity consumption in Sri Lanka (A)[a]	3,148,100,000 kWh		
Electricity used for motors in local industries (60% of A)=(B)[b]	1,888,860,000 kWh		
Assume 40% motors are replaced by EEM (40% of B)=(C)	755,544,000 kWh		
Electricity for small motors (1.5-3.0 kW) (40% of C)	(75% E)[1]	82.3% E[2]	Saving
	302,217,600	275,410,936	26,806,664 kWh
Electricity for small motors (5-50 kW) (45% of C)	(92% E)[1]	94.6% E[2]	
	339,994,800	330,650,334	9,344,466 kWh

Electricity for small motors (above 50 kW) (15% of C)	(93% E)[1]	94.6% E[2]		
	113,331,600	111,414,786	1,916,814	kWh
Total Expected saving			**38,067,944**	**kWh**

Annual saving based on year 2010 data	38,067,944	kWh
Electricity saving for 10 years period	380,679,439	kWh
CO_2 reduction per year due to electricity saving (1kWh=0.342gCO_2)	13,019	tCO_2e
Saving for 10 years (based on year 2010)	130,192	tCO_2e

a - Energy Balance year 2010: Sri Lanka Sustainable Energy Authority

b - Sri Lanka Sustainable Energy Authority

1 - Existing efficiency level of motors

2 - Efficiency level of Energy Efficient Motors

Industry Sector - Mitigation

Technology Fact Sheet No. 3

1. **Sector/ Sub Sector:** Methods of electrical energy reduction that are applicable to all industries using electrical drives (motors).
2. **Introduction:** Electrical energy is a clean energy available for many applications, but can have a high environmental impact due to low overall efficiency from primary energy source (if non-renewable) to the user end. By reducing the usage or making the usage efficient, environmental impact can be greatly reduced. The following account provides details of two such techniques.
3. **Technology Name: Energy saving by means of speed control of motor drives.**
4. **Technology Characteristics:** The solutions rely on energy saving by controlling the motor speed, thereby replacing inefficient mechanical speed controlling devices. The net results are application dependant.
5. A general description of the technologies are given in Appendix-1
6. **Country Specific Applicability:** Applicable universally, but the benefits depend on the industry type and plant type.
7. **Status of the technology in the country and its future market potential**: There are several ESCOs who can provide such solutions, but prefer established organizations in view of support.
8. **Barriers:** Initial expenses and technology know how that has to be applied to different types of industries.
9. **Benefits:** As a rule of thumb, reduction of one unit of electrical energy can save nearly twice the equivalent energy of primary energy. If non-renewable energy is used, such technologies can provide higher mitigation effects in energy usage applications compared to renewable energy generating and usage.

   Expected annual electricity saving is about 151,109 MWh and GHG saving is about 51,679 tCO_2e. Expected lifetime of the technology at high efficiency level is ten (10) years. (Calculations are given in Appendix 1)

10. **Operations:** Variable speed drives are generally programmed to operate automatically. However, involvement of a trained technical personnel or supplier may require in case of a problem.
11. **Costs:** Estimated investment cost is around 104,563 USD per tCO_2e reduction. This cost includes purchase (import) cost, installation and commissioning cost. Installation cost covers civil construction cost, equipments and controllers expenses (import cost was calculated based on current exchange rates, 1 USD = 110 LKR: in December 2011).

Appendix -1

Variable Speed Drives

Constant speed motor drives are associated with various losses due to its inability to adjust the speed to suit the application. It is possible to save energy as much as 60% depending on the application using speed control. High savings can be achieved with fans and pumps that are very common in most of the industries. The traditional speed controls use mechanical speed reduction methods such as gearwheels and belt with pulleys. Both these methods have high energy losses due to friction. Moreover, motor running at a higher speed contributes additional losses such as frictional and iron losses. Further, such speed control systems are bulky or needs considerable space with the need of frequent maintenance depending on the usage and environment.

The variable speed control system or an electronic drive can adjust the speed to suit the application not only by adjusting the speed but also torque characteristics of the motor. Since the speed controller is electronic, the energy loss in the controller very much less than that of a mechanical speed controller and also very compact. However, electronic drives should have stable supply for its trouble-free operation. Various manufacturers provide other technologies to achieve fine improvements of motor operation to achieve more energy saving and optimizing the operation.

Motor driven pumps and fans controlled by variable speed drives, as described above, can achieve high energy savings according to the theory. The basic law of fluid flow shows that the power requirement is proportional to the cube of the flow speed. If the speed is reduced by 80% (this does not affect most of the process unless high precision of speed is required) the energy requirement can be reduced by 51%! This is a typical application in withering process in tea manufacturing. Most of the pumping applications can also achieve this type of saving if the speed is reduced, as it cannot be a problem as pumps generally operates only intermittently – runs at full speed and then idle. However, since average electronic drives generally produce non-sinusoidal current waveform, it is preferable to use motors recommended for such application for better life span.

Calculation of potential GHG reduction and energy saving by using VSD

Industrial electricity consumption in Sri Lanka (A)[a]	3,148,100,000 kWh
Electricity used for motors in local industries (60% of A)=(B)[b]	1,888,860,000 kWh
Assume 40% motors are fixed with VSD (40% of B)=(C)	755,544,000 kWh
Expected saving by using VSD (20% of C)=D	151,108,800 kWh

Annual saving based on year 2010 data	151,108,800 kWh

Electricity saving for 10 years period	1,511,088,000	kWh
CO_2 reduction due to electricity saving (1kWh=0.342gCO_2)	51,679	tCO_2e
Saving for 10 years (based on year 2010)	516,792	tCO_2e

a - Energy Balance year 2010: Sri Lanka Sustainable Energy Authority

b - Sri Lanka Sustainable Energy Authority

Industry Sector - Mitigation

Technology Fact Sheet No. 4

1. **Sector/ Sub Sector:** Industry and household
2. **Introduction:** Alcohol burning stoves based on ethanol can be used for cooking, water heating and heating of buildings. The technology can be applied in households, institutions and industries where it is used for boiler heating. Ethanol is produced from sugar plants or other sources of biomass
3. **Technology Name: Ethanol Cook stove**
4. **Technology Characteristics:** As ethanol provides a higher heat flux with no soot or smoke, cooking and hot water production can take place faster and pollution free. The greenhouse gas emission reduction contribution from ethanol cook stoves depends on the feedstock used for the ethanol, the distance from feedstock location to ethanol production, and what it replaces. Ethanol is an alcohol that is produced by fermentation of sugars from various crops, such as maize, sorghum, wheat, cassava and sugarcane. It can be used for different energy applications varying from boiler heating in industries to water heating and cooking. This description focuses on the latter service. Improved biomass cook stoves can aim for 30% efficiency and reduces the amount of wood fuel used and thus decreases pollutant emissions.
5. **Country Specific Applicability:** Technology is applicable in Sri Lanka
6. **Status of the technology in the country and its future market potential**: Technology is not available in Sri Lanka at commercial level. There is a high potential for this type of renewable energy applications in the future
7. **Barriers:** Initial investment for cook stove and ethanol production facility and constant supply
8. **Benefits:** Smart fuel source and lesser environmental impacts
9. **Operations:**
10. **Costs:** An ethanol gel stove could cost between USD 2 and USD 20 per unit and the fuel cost would be USD 0.30-0.70/litre of ethanol. The 'CookSafe' stove can boil a litre of water in eleven minutes, and a litre of ethanol can last between eleven and thirteen hours of burn time. The NARI stove was estimated to cost Rs 800 to 1000 (between €12 and €15) if mass produced. The Superblu stove from Malawi claims that it costs approximately 2.5 Malawi Kwacha (MK) an hour (around € 0.014) to cook on this stove while it costs around € 0.14 an hour with charcoal and MK15 (€ 0.12) an hour with paraffin.

Industry Sector - Mitigation

Technology Fact Sheet No. 5

1. **Sector/ Sub Sector:** Industry and household
2. **Introduction:** Biomass gasification household stoves work by a high temperature conversion of biomass in a restricted oxygen environment to a mixture of nitrogen, carbon monoxide, hydrogen, and methane. The hydrogen and methane are then burned without emitting pollutants. For larger applications pure oxygen may be used which gives a higher calorific value gas without the nitrogen. The technology can be used at household, community and industry level.
3. **Technology Name:** Cook stoves in biomass gasification
4. **Technology Characteristics:** Gasification is the process of converting a solid fuel to a combustible gas. To this process usually a restricted amount of oxygen is added, either pure or from air. A carbonaceous solid material can also be gasified to produce a hydrogen-rich gas by bringing it in contact with steam at a high temperature. Air gasification of biomass produces a low calorific value gas, the producer gas containing about 50% nitrogen, and can fuel engines and furnaces. Gasification of biomass with pure oxygen results in a medium calorific value gas free of nitrogen. Gasification is the process of converting a solid fuel to a combustible gas. To this process usually a restricted amount of oxygen is added, either pure or from air. A carbonaceous solid material can also be gasified to produce a hydrogen-rich gas by bringing it in contact with steam at a high temperature. Air gasification of biomass produces a low calorific value gas, the producer gas containing about 50% nitrogen, and can fuel engines and furnaces. Gasification of biomass with pure oxygen results in a medium calorific value gas free of nitrogen.
5. **Country Specific Applicability:** Technology is applicable in Sri Lanka
6. **Status of the technology in the country and its future market potential**: Biomass gasification is currently commercially available technology in Sri Lanka. Its future market potential is high due to fossil fuel prices.
7. **Barriers:** Continues supply and availability of biomass and quality of biomass.
8. **Benefits:** It is a renewable energy source
9. **Operations:**
10. **Costs:** The cost of biomass gasification systems for thermal applications excluding fuels and ash handling facilities has been reported to amount to about USD 55,000 for a unit that substitutes 100 litres/hour of furnace oil; the cost per liter of oil substituted per hour tends to be higher for lower capacities. The economic and financial aspects of using a gasifier to replace liquid fuels are

extremely favourable across different unit capacities; the payback period for a small and medium gasifier is around 6 months.

Industry Sector - Mitigation

Technology Fact Sheet No. 6

1. **Sector/ Sub Sector:** Industry thermal energy application
2. **Introduction:** This is a novel flue gas heat recovery system with specialized controls to maximize energy efficiency and maintain stable performance under industrial conditions.
3. **Technology Name:** Super Boilers
4. **Technology Characteristics:** The Super Boiler uses heat recovery from flue gas to increase energy efficiency and state-of-the-art combustion to reduce emissions. The boiler is capable of a 93-94% fuel to steam efficiency conversion, while releasing less than 9 ppmv (parts per million by volume) of NOx.

a. The Forced Internal Recirculation (FIR) Burner combines staged, premixed combustion with forced internal flue gas recirculation to minimize the formation of both thermal and prompt NOx. The burner's unique design provides excellent flame retention for stable combustion at low emission levels. The FIR Burner is applicable to a wide range of water tube boilers. This revolutionary burner design promises increased system efficiency, NOx emissions below 9 vppm, CO emissions below 50 vppm, and total hydrocarbon (THC) emissions below 50 vppm.

b. Ultra-Low NOx burners achieve ultra-low NOx emissions by combining a unique type of clean-burning combustion technology called ultraclean, low-swirl combustion (UCLSC), with premixed flames. High energy efficiency is achieved in this type of combustion because the appropriate ratios of air and fuel are mixed to burn completely. In addition, the characteristically lifted flame of the burner provides for highly efficient heat transfer because no heat is transferred from the flame to the burner.

c. Ultra-Low NOx Burners emit 10 to 100 times less nitrogen oxide than conventional burners. Also, the cost of these burners is comparable or lower than that of many conventional burners.

5. **Country Specific Applicability:** Applicable in Sri Lanka
6. **Status of the technology in the country and its future market potential:**
7. **Barriers:**
8. **Benefits:** 13% fuel saving
9. **Operations:**
10. **Costs:**
11. **Reference:** US Department of Energy. Energy Efficiency & Renewable Energy

Industry Sector - Mitigation

Technology Fact Sheet No. 7

1. **Sector/ Sub Sector:** Industry thermal energy application
2. **Introduction:** A new Calcpos rotary burner (CRB), using the available fuel gas pressure as a free source of drive energy, eliminates electric motors, providing a simple, cost effective means of retrofitting existing fired heaters for energy and environmental reasons.
3. **Technology Name:** Calcpos Rotary Burner (CRB)
4. **Technology Characteristics:** By virtue of its inherent, superb mixing capability, the CRB also provides a high performance, ultra-low emissions burner enhancing heat transfer effectiveness, thus reducing energy use. A laboratory tested prototype of 10.6 million Btu per hour capacity operating at 3.4% O2 produced a compact flame with NOx and CO emissions less than 1.0 and 2.0 ppmv respectively. This performance will typically result in energy savings of 5.0% compared to current fired heaters. Efficiency-degrading flame impingement and tube fouling are also eliminated with the CRB. Additional operational improvements in basic rotary burner technology include increased combustion stability, innovative fan and pilot ignition design, and compact geometry to facilitate on the fly heater conversion.

5. **Country Specific Applicability:** It is applicable in Sri Lanka
6. **Status of the technology in the country and its future market potential:**
7. **Barriers:**
8. **Benefits:** Reduced energy use, Elimination of CO and NOx emissions, Easy and cost-effective retrofitting of existing fired heaters
9. **Operations:**
10. **Costs:**
11. **Reference:** US Department of Energy. Energy Efficiency & Renewable Energy

Industry Sector - Mitigation

Technology Fact Sheet No. 8

1. **Sector/ Sub Sector:** Heating Ventilation and Air Condition
2. **Introduction:** Gas absorption heat pumps (GAHP) systems provide a green way of heating and cooling buildings with up to 150% efficiency. Gas absorption heat pumps (GAHP) can provide sustainable solutions for both industrial and commercial businesses as well as for homes.
3. **Technology Name:** Gas absorption heat pumps
4. **Technology Characteristics:** The systems take advantage of freely available energy from the air and turn it into higher or lower temperature for building heating or cooling. The technology is clean as GAHP systems compared to the best condensing models available on the market can considerably reduce CO_2 emissions compared to the best condensing models available on the market. An important feature is that GAHPs can produce heat in extreme temperatures - even at -20°C. While conventional heat pump water heater designs are limited to using toxic ammonia water systems, this system uses heat drawn from the ambient environment to achieve energy efficiency. This approach extends the application of the invention beyond industrial settings to residential and commercial use. The system features one assembly with a condenser and an evaporator, a second assembly with an absorber, a desorber, and a heat exchanger, and a thermal coupler. The system employs lithium bromide, which is now widely used in commercial air conditioning. In current systems, however, efficiency has been limited by crystallization at the solution heat exchanger outlet and at the absorber. ORNL researchers found a way to avoid crystallization by increasing evaporating pressure. Further crystallization is averted by directing the process water first through the absorber and then through the condenser. The water flow direction can be changed at run-time to optimize performance.
5. **Country Specific Applicability:**
6. **Status of the technology in the country and its future market potential:**
7. **Barriers:**
8. **Benefits:** Energy saving**,** Less impact on Environment
9. **Operations:**

12. **Costs:** Estimated investment cost per tCO_2e is about 225,909 USD. This cost was estimated by referring available information in the internet and using experts' knowledge and experience. Sufficient cost factors and local suppliers are not available in Sri Lanka.

10. **Reference:** http://www.energ.co.uk/

Industry Sector - Mitigation

Technology Fact Sheet No. 9

1. **Sector/ Sub Sector:** Waste Recycle / Heating
2. **Introduction:** This is an innovative **patented** technology for recycling of Worn-out Automobile Tyres (WAT). WAT heating method does not create any significant temperature gradient within the reactor.
3. **Technology Name:** Heating Technology for Recycling Tyres
4. **Technology Characteristics:** The induction heating of the metallic wire, which is surrounded by rubber from all sides, allows the heating of every tyre piece uniformly and without overheating. The width of the rubber layer between two adjacent wires does not exceed several millimetres, producing efficient and uniform heating. The heating process, which is automatically controlled, allows not only the production of byproducts of required quality, but also saves energy. Processing under the conditions of low temperatures removes the opportunity of forming such dangerous carcinogenic products as dioxins and pyrenes, as found in high-temperature pyrolysis. In this process all light hydrocarbons are present in the liquid fraction, which is confirmed by means of chromatographic tests. This allows the production of marketable end products by further technological processing.

   Worn Out Automobile Tyres (WAT) are commonly (i) treated as waste, and disposed of in dumps and landfills or (ii) treated with recycling methods that do not unlock anywhere near their full potential
5. **Country Specific Applicability:**
6. **Status of the technology in the country and its future market potential:**
7. **Barriers:**
8. **Benefits:** Reduce environment risk, solid waste generation, provide alternative raw material, energy efficiency
9. **Operations:**
10. **Costs:** Estimated investment cost per tCO_2e is about 322,727 USD. This cost was estimated by referring available information in the internet and using experts' knowledge and experience. Sufficient cost factors and local suppliers are not available in Sri Lanka.

11. **Reference:** Asia Pacific Centre for Technology Transfer, SkyQuest Technology Consulting (Pvt) Ltd.

Industry Sector - Mitigation

Technology Fact Sheet No. 10

1. **Sector/ Sub Sector:** Packaging
2. **Introduction:**
3. **Technology Name:** **Composite cans with paper bottoms**
4. **Technology Characteristics:** Significantly more environmentally friendly than steel cans, these composite cans require 34% fewer energy inputs and 27% less raw material by weight to produce and result in **20% fewer greenhouse gas (GHG) emissions**. The paperboard used to manufacture these round composite cans is 100% recycled content.
   a. The rigid paperboard packages, which contain an average of 55% recycled content and 50% post-consumer content and the low-barrier version of the can is completely recyclable in the mixed paper stream and the paperboard used is 100% recycled material.
5. **Country Specific Applicability:** Applicable in Sri Lanka
6. **Status of the technology in the country and its future market potential:**
7. **Barriers:**
8. **Benefits:** Reduce environment risk, solid waste generation, provide alternative raw material, energy efficiency
9. **Operations:**
10. **Costs:**
11. **Reference:** Asia Pacific Centre for Technology Transfer, SkyQuest Technology Consulting (Pvt) Ltd.