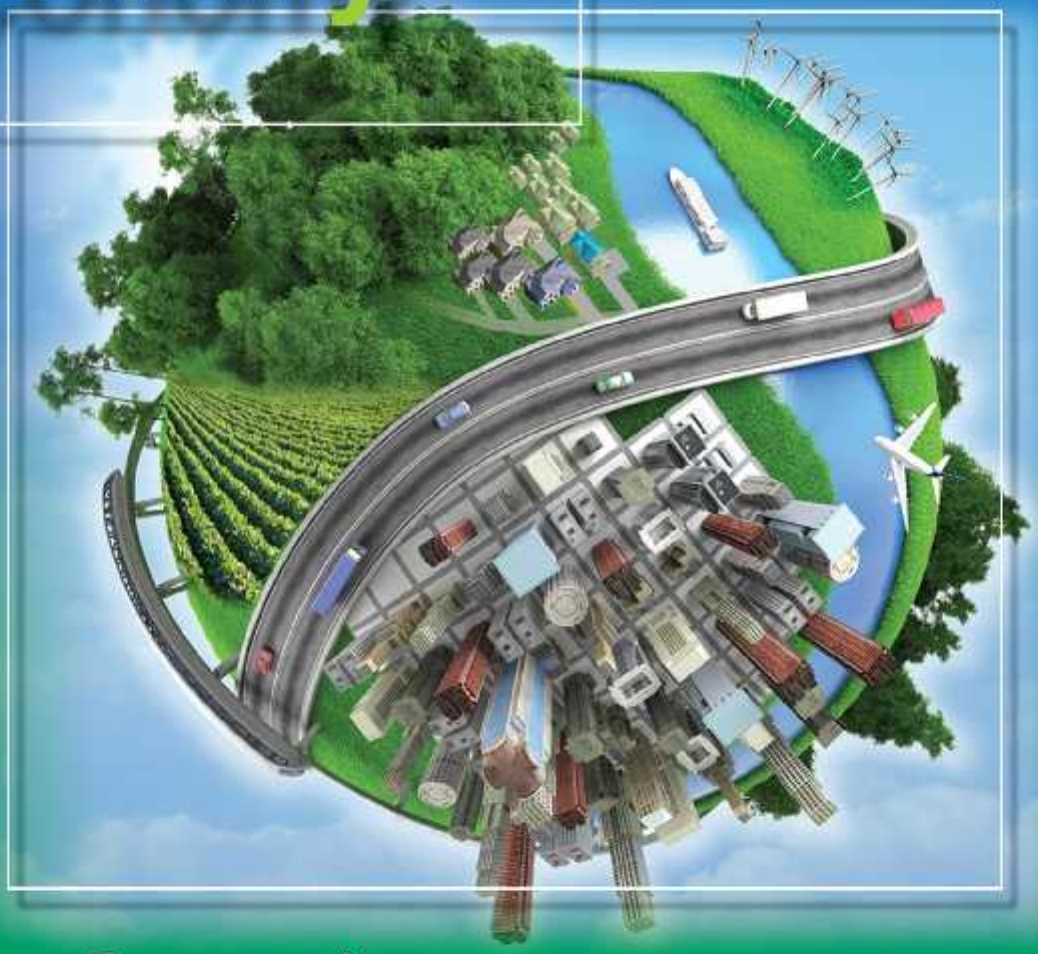
Proceedings Volume 01

# Energy Challenges in the Knowledge Economy



## Energy Symposium Sri Lanka 2015

ENERGY EMPOWERED NATION

26th and 27th June

Hilton Colombo and
Academy of Financial Studies

Ministry of Power and Energy

**Ministry of Power and Energy**

# Energy Symposium Sri Lanka 2015

***Towards an Energy Empowered Nation***

## Energy Challenges in the Knowledge Economy

**26th & 27th June 2015**

**Proceedings Part I**

Abstracts

**Technical Sessions**

27th June 2015

Academy of Financial Studies (Miloda), Sir Baron Jayathilaka Mawatha,
Colombo, Sri Lanka.

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## PREFACE

The International Symposium on Energy Challenges in the Knowledge Economy is the first of its kind held in Sri Lanka. It is organized to provide a forum for local and invited foreign experts in the field to discuss debate and share futuristic knowledge relevant to the energy challenges that the nation is facing in the evolving economy.

In an effort to implement the energy strategies and policies, the Ministry of Power and Energy has taken a clear decision to move towards evidence-based policy. This is a clear shift from ad-hoc, top-down ways of policy making. Democratic systems of governance, as they reach maturity, increasingly rely on systematically analyzed data. Such data come from organized research, expert teamwork, and institutional collaboration.

Evidence-based policy will reduce the risks of reaching the national goal of energy self-sufficiency by the year 2030. The new paradigm of energy economics underscores two fundamentally new energy transformations: replacing oil with electricity in transportation, and replacing high carbon, finite-supply coal and natural gas with renewable wind, solar, marine and biomass energies for electricity production. At the same time, this transformation in the productive sector is reflected in the corporate effort to adopt sustainable energy and environmental practices through newer systems of production, organizational processes and approaches to community.

We received nearly one hundred papers for the technical sessions. The quick response from the research community indicates richness in both on-going research and commitment to participate in action. On behalf of the organizers of the Ministry and the technical committee I thank all those who came forward with their work. I regret, however, that all the papers could not be accommodated due to limited scope of the sessions.

June 25, 2015

Prof. Gunapala Nanayakkara
Chair – Technical Committee

# Content

**1**

# Transport sector and its energy and environmental challenges: Policy perspectives

T.L. Gunaruwan

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Abstract

Transportation forms an essential ingredient of development, particularly by way of providing the necessary mobility to factors of production (including labour and material) and outputs of economic activities (CERIPA Report, 2012). It is also recognised as having a significant bearing on development Sustenance in all three angles, namely Social, Economic and Environmental. Transport activities, as a productive sector in the economy, also contributes to the national value added, to the tune of around 12% by the end of 2012. Over 2.3 million motorised vehicles and 3 million bicycles are operated to move 10 million passenger trips daily (over 95% of which is on land), and nearly 1.5 million are employed, either directly or indirectly, in the sector, of which 85% is informal. However, transportation, at the same time, is recognised as associated with significant negative externalities.

Emission of fumes (due to combustion of fossil fuels) causing morbidity and mortality, road congestion leading to increased travel times and thus, increasing generalised costs, and accidents are the commonly found negative externalities associated with transportation.

Increased traffic has resulted in severe congestion, reducing travel speeds to little over 10 kmph in the peak hours. This has caused inefficient burning of fuel, excessive and toxic vehicular emissions, and loss of valuable time of commuters in long hours of travel. According to Yatagama et al (2010), Colombo's atmosphere looks "unhealthier" than that of Hong Kong, Singapore, Bangkok, Taipei or Tokyo.

The consequences are costly. Sirithunga et al, found high prevalence of cough, throat irritations, nasal discharges and respiratory disorders among school children attending Colombo and Kandy schools compared to those of rural areas. Also, only 8% of children attending "city schools" could be categorized as having "perfect health" whereas the corresponding share of children attending schools outside cities was 32%. This is mirrored by Sri Lanka's "Disability-Adjusted Life Years" (DALYs) related to transportation being nearly one-third of total DALYs in 2010, as per the WHO estimates. The total life years lost owing to transportation works out to be over 280000, which amounts to a value loss of approximately USD 930 Mn, if estimated based on the per-capita GDP of the economy in 2013.

Inefficient burning of fuel owing to high and increasing share of private transport modes, and also owing to severe traffic congestion caused, once again, by road transportation and private transport modes which have lower carrying capacities in relation to their road space usage, are the main causes behind this unfavorable trend. It is estimated that over 80% of total fuel consumed in passenger transportation is attributable to highly "fuel intensive" private transport modes, which caters to a mere 45% of the estimated passenger transport modal

share. The rapid growth of private vehicle ownership is fueled by the per-capita income driven increase of affordability of general public. Simultaneous expectations for greater comfort, increased flexibility and reduced travel times, will increasingly induce public to own their private modes of transport. This trend has been observed in almost all countries through their process of development. This, together with the relative stagnation of the supply and qualitative standards of public transport, have pushed the public transport modal share down to less than 60% by 2012, from as high as over 80% by the turn of the millennium. Unabated continuation of this trend would mean Sri Lanka facing greater ill-effects in the years to come, on her way towards achieving middle income country status.

In the light of the above analysis, a three-pronged policy framework could be proposed to make the progress of Sri Lanka's transport sector more sustainable in the years to come. First, the currently implemented strategic drive to make the transport provision more environmentally friendly (within the current demand patterns and modal structures) has to be vigorously pursued. Second, the overall national transport policy has to be re-oriented to prioritise "public transportation" (which is more fuel efficient, less emission intensive and less congestive). Third, the overall economic management has to be geared in such a manner that the course of development becomes less "transport intensive" through vigorous promotion of motorable mobility demand management.

3.1 Policy Direction-1: Less Polluting Motive Power

- Improving combustion efficiency to reduce vehicular emissions
- Switching over to usage of less-polluting fuel types
- Improvement of infrastructure enabling smoother vehicular flows

3.2 Policy Direction - 2: Sustainable Modal Structure

- Promotion of public transport modes, and encouraging modal shift from private modes to public modes
- Promotion of vehicular types with greater economies of scale, reducing per passenger fuel intensity in transportation
- Promotion of railway mode, and encouraging modal shift from road to rail. Policy re-orientation in a number of directions is necessary in this regard;
    (i) Policy biases against the railway sector should be removed. Level-playing competition should be permitted if any pro-railway bias cannot be granted. Road pricing, or Government assuming railway infrastructure cost through a separate heading, is necessary in this regard.
    (ii) Increase in travel speeds of trains (to reduce travel time), and expansion of sub-urban corridors, will be needed to exploit comparative advantages of railways. Sub-urban commuter service and long-distance express service are two niches where railway can secure comparative advantage over road transport.
    (iii) Electrification of the Sub-urban sector is a priority.[Cabinet approval was recently granted to pursue this as a priority project]
    (iv) Freight transportation is another promising niche area where railway could shoulder a greater responsibility. The above mentioned elimination of anti-railway biases also will help achieve this objective.
    (v) All ports and airports should be provided with railway links. A network of rail-based Internal Container Depots in Colombo suburbs will help provide necessary logistics.

(vi) Railway priority policy also should be adopted in transporting freight by the Government and public enterprises (such as petroleum, fertilizer, wheat flour, and other essential services).

(vii) Prioritised attention should be paid to establish "park-and-ride" facilities at railway stations, and rail-bus coordinated services. Such will encourage increased use of railway for both passenger and freight transportation.

(viii) Management reforms of the railway sector are an urgent priority, if the railway is to stand up to face the challenges in the future, and to shoulder a greater transportation share, so that sustainability objective would be supported.

- Promotion of non-motorised transport modes

3.3 Policy Dimension – 3: Transport Demand Management

As per studies conducted by the University of Moratuwa, Sri Lanka's transport demand is 2 to 3 times higher than the average of similar income countries, which could indicate the existence of unproductive mobility demands which could possibly be substituted. What is important is accessing places and goods or services of appropriate quality, and not the mobility per se. Therefore, achieving the same welfare and growth impetus with less mobility need would save resources, and would be less costly to the economy, would also be growth supporting, and sustainable in terms of reduced emissions and foreign exchange savings otherwise would be spent on fuel imports.

Mobility needs may also be substituted by expanded and improved communication services, and by amalgamating public and commercial economic systems into integrated communication networks. Strategic land-use has to underline all State-driven programmes of settlement planning. Permitting further concentration of already urbanised centres or settlement clusters (concentration model) could be congruent with this vision. Government may also consider establishing decentralised "centres" of service provision with the availability of state-of-the-art quality of supply. This could include decentralisation of all Government bureaucratic services, hospitals, schools, etc. Strategic intervention is needed to enable the settlements around "centres" be as concentrated as possible, so that the distance to and from the services and settlements be minimised. That would help manage transport demand growth, and also would promote non-motorised travel owing to manageable distances. Such will also ensure required high load factors in public transport modes, thus bringing economics for their operations. The travel beyond the self-containing "centre" would then be minimised.

*Key words: Transport sector, policy implications, the transport demand*

**2**

# Economics of carbon emission reduction in electricity generation in Sri Lanka

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Abstract

This paper discusses economics behind the reduction of carbon emission in electricity generation in Sri Lanka. This study shows that the present annual Green House Gas (GHG) emission with respect to the electricity generation is about 2.8 million metric Tons. This is about 25% of the total national GHG emission in recent years. By year 2029, this level will increase to 26 million metric tons per year. The identified total GHG emission reduction potential in electricity generation in Sri Lanka is about 37GW. However, potentials for implementation within next 20 years are 3 GW and it will cost 8.5 billion US $. The total reduction in GHG will be 16 million metric tons per year. If one ton of $CO_2$ is valued at 20 US$, then total earning potential only on reduction of GHG will be 320 million US$ per annum. Considering the savings on avoided fossil fuel combustion, total investment can be recovered within 6.5 years and this further confirmed with sensitivity analysis. In order to achieve these benefits broad policies and guide lines are needed for this sector as explained in this paper. In addition to the evaluation of present carbon emission situation in electricity generation in Sri Lanka, this paper explores possible GHG reduction methods, their economic feasibility. The methodology employed and the policies derived can be used as guides to similar types of research in other countries as well.

*Key words: Economic cost benefits, technology policy, electricity generation, Greenhouse Gases (GHG), Kyoto Protocol (KP), Clean Development Mechanism (CDM)*

**3**

# Some aspects of nuclear power

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Abstract

The need of energy, especially electrical energy to achieve economic development is well known and all countries that have achieved economic growth have done so with a corresponding increase in their per capita consumption of electrical energy. The current per capita consumption of electrical energy of Sri Lanka is approximately 535 kWh per person per year, which is well below that of the countries that have achieved even a moderate economic growth. Economic growth would not be possible without a corresponding increase in the capacity generate electrical energy. If the future demand for electrical energy cannot be met with fossil fuels and renewable sources alone, the only other viable option available is nuclear power. This paper discusses the current global status of nuclear power, recent advances in nuclear power technology, economical factors and the actions that may have to be taken at present to make it possible to use nuclear power in the future if the need arises.

Whether Sri Lanka would need to use nuclear power to meet the future demand for electrical energy will depend on the growth in the future demand for electrical power and energy, and the energy options available to meet this demand. Since the use of nuclear power requires long lead times, if there is a possibility of having to use it to meet the future demand, action should be taken early to keep this option open. These actions would include creation of human resources required to make knowledgeable decisions regarding the use of nuclear power, identification of legal and regulatory requirements, investigations to identify sites suitable for nuclear power projects, investigation of the availability of indigenous uranium resources, entering into relevant international treaties and conventions, and the establishment of a public awareness programs.

*Key words: Nuclear power, energy demand, Sri Lanka*

**4**

# Energy policy implementation analysis for electricity sector expansion planning in Sri Lanka

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Abstract

The purpose of this paper is to analyze the Implementation of National Energy Policy Elements focusing on Electricity Sector Expansion Plan. National Energy Policy consists of nine Energy Policy Elements. Energy Policy Elements defined under Gazette No. 1553/10 on 10th June 2008 are:

1) Providing Basic Energy Needs
2) Ensuring Energy Security
3) Promoting Energy Efficiency and Conservation
4) Promoting Indigenous Resources
5) Adopting an Appropriate Pricing Policy
6) Enhancing Energy Sector Management Capacity
7) Consumer Protection and Ensuring a Level Playing Field
8) Enhancing the Quality of Energy Services
9) Protection from Adverse Environment Impacts of Energy Facilities

Out of these nine, five elements (1), (2), (3), (4) & (9): which have a significant impact on energy planning were chosen to analyze from the scenarios developed. The five selected scenarios were analyzed, considering Net Present Value, Emissions & Emission Reduction Costs, Primary Energy Sources, Levelised Unit Cost, and Primary Energy Share.

*Key words: Energy policy implementation, net percent value, national energy policy*

**5**

# An electronic trading possibility for carbon emission credits in Sri Lanka

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Abstract

This research paper explores the existing trading mechanisms for Certified Emission Reductions (CERs), a tradable commodity generated under Clean Development Mechanisms (CDM) of the Kyoto Protocol and proposes possible electronic trading system to improve the trading efficiency and the liquidity of the commodity in Sri Lanka. Most of these CDM projects are power generation plants based on renewable energy sources, as hydro, biomass and organic waste. These projects are financially viable, however involve large initial investments, long gestation cycle and long pay back periods. These become attractive propositions in the presence of additional financial benefits generated by selling CERs.

As per Sri Lanka's Line Ministry, Carbon savings have been sold at low price. Therefore companies are finding it difficult to attract funding for CERs at a reasonable price compared to market value of substitute products. The existing negotiation process is lengthy and complex and therefore the liquidity of CERs is very low and there is very high price volatility. The average price obtained by local CDM projects for CERs is considerably less than the current market price of substitute carbon products. As a result, only a very small fraction of the potential CDM capacity in Sri Lanka has been considered for actual implementation till now. In order to resolve these problems and to obtain maximum possible financial benefits from Kyoto Protocol, an elementary electronic trading system (ETS) is proposed to facilitate trading of CERs. The proposed ETS is a new technology concept and will entail problems associated in technology development, transfer, and assimilation in the systems, the paper examines some of these associated issues.

*Key words: Certified Emission Reduction (CER), Clean Development Mechanism (CDM), Electronic Trading System (ETS), Kyoto Protocol (KP), market conditions*

**6**

# Technical capacity building in the Sri Lanka's upstream oil and gas sector through progressive LC policy reforms

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Abstact

The recent natural gas discoveries in waters off the coast in Mannar Basin and the potential emergence of a key upstream petroleum sector in Sri Lanka's economy necessitate measures for the country's preparedness, including Technical Capacity Building (TCB) in the education sector and local supply chain. In this context the Government of Sri Lanka's wish is to ensure that the petroleum industry can be sustained primarily with Sri Lankan resources within the shortest possible time through an effective Local Content (LC) development strategy backed by progressive policy reforms.

LC in oil and gas industry refers to the added value brought to a host nation through capacity building of national human resources and technological & industrial advancement of the country through the participation of international contractors in oil and gas activities in the country.

The petroleum exploration efforts in offshore Sri Lanka thus far has resulted the slow emergence of a new industry with progressive benefits to Sri Lankan economy in terms of direct fiscal gains and added value through participation and development of nation labour, knowledge, technology, goods, services and research capabilities. Cairn Lanka has spent nearly USD 218 million during the period 2008-2014 of which 11% (USD 23 million) has spent in fulfillment of their LC commitments to Sri Lanka. Accordingly Government of Sri Lanka has already taken initiatives to build local technical capacities as an early starter and taken a strategic step forward make Sri Lanka Upstream Local Content Guidelines effective from March 2103. Still for all, Sri Lanka will require progressive LC policy reforms at successive stages of petroleum developments to play a balanced role in providing a winning proposition for both Government and Contractor; addressing regulatory requirements, business benefits and stakeholder expectations.

Therefore the aim of this paper is to probe through an investigation from the oil and gas producing countries' technical capacities and ensure adoption of a progressive and sustainable TCB framework with a view to guarantee maximum local participation in Sri Lanka's upstream oil and gas (O&G) industry without compromising standard. The specific objectives of this study leads to a broad analysis of the global and local context, LC policies and strategies, identify determinants and gaps of technical capacity building, identify policy reforms need to bridge the TCB gaps and finally to formulate a strategic TCB framework.

*Key words: Technical capacity building, Local Content (LC), oil and gas sector*

**7**

# Energy management in hotel sector in Sri Lanka: Adoption of good practices

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Abstract

Energy accounts for a major share of the operational costs in the hotel sector in Sri Lanka. For cost saving and environmental conservation aspects, proper energy management has become an important area that needs policy attention. The present paper aims to assess the level of adoption of energy management practices and to identify the determinants of such adoption. The analysis is based on primary data collected from registered hotels in the Western Province of Sri Lanka. The sample includes 78 hotels. The results indicate that, on average, hotels adopt 3.7 good energy management practices. The adoption of good energy management practices is determined by the hotel characteristics such as number of employees per room, age, chain affiliation, size and customer characteristics such as the origin and the purpose of visit. Policy attention should be particularly on motivating small hotels, independent hotels and newer hotels to adopt good energy management practices.

*Key words: Energy, hotels, determinants, good practices*

**8**

# Energy demand and dilemma of forecasting: A study on Ceylon Electricity Board

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Abstract

Electrical energy has become a major form of energy for end use consumption in today's complex society. The influence of electricity is tremendous in all facets of human life. It has been recognized as a basic human need, without which almost all human activities will be paralyzed. It is a critical component of infrastructure on which the socio-economic development of a country depends. At present, the power sector of Sri Lanka faces two serious problems, viz. power crisis in terms of high electricity prices and the financial and liquidity crisis of Ceylon Electricity Board (CEB) due to non-implementation of least cost generation plan in a timely manner. This situation needs a more accurate demand forecasting methodology. However, the demand forecasting model of the CEB National Forecast 2003 – 2023 for Planning Studies includes only a very few determinants. Therefore, this research was motivated by the requirement of a comprehensive and accurate long-run electricity demand forecasting model for Sri Lanka. This study has focused on the use of a comprehensive econometric model having six explanatory variables, viz. GDP, average electricity price, population, level of household electrification, energy intensity and implementation of rural electrification projects to estimate the long-run aggregate electricity demand for Sri Lanka. This is an in-depth empirical analysis because of the inclusion of non-traditionally defined variables such as the level of electrification, energy intensity and implementation of rural electrification projects. The results of the study show that all the explanatory variables are statistically significant in explaining the long-run electricity demand. Hence the study concludes that the electricity demand model developed in this study has a better forecasting accuracy compared to the accuracy of the forecasting model of the CEB National Forecast 2003 – 2023 for Planning Studies.

*Key words: Electricity demand, power forecast, demand determinants*

**9**

# Profitability of replacing conventional lighting devices with LEDs in Sri Lanka

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Abstract

This study focuses on energy consumption pattern of Light Emitting Diodes (LEDs), Compact Fluorescence Light (CFLs) and other conventional bulbs at manufacturing phase, at end consumer's usage phase and capacity usage in utility power network for lighting. During the study it is tested the validity of the statement made by the manufacturers and the dealers involved in marketing and the most commonly used phrase is that "LED bulbs are more energy efficient where it gives the Lumen output as that of an ordinal)) bulbs at a lower energy consumption".

Most modern electrical/ electronic devices consume both active power and reactive power; the power factor for the device denotes how those to power components are behaved with the device. The PF does have a significant effect on the amount of energy that is used to provide the effective power at the point of use and the PF is an indicator of how much more power is really consumed than the claimed amount. LED and CFL bulbs are known to be electronic devices which has comparatively low power factor. Due to this low Power Factor (PF) it draws a rather high current as it needs higher reactive power. However nowadays these low PF devices are well designed and equipped with other electronic devices in order to optimize the PF so the effect on the power utility will be minimized.

Due to increase of peak power demand- due to the lighting of houses, the power utility has introduced CFL and LED bulbs as a way of reducing power consumption to enhance security of energy supply. However there is no imposed methodology to make sure that the LED and CFL bulbs are with the correct power factor or within the acceptable power factor levels as it might create burden for the utility supplier. And it is made as one of the main objectives to this study where we analyzed the utility power consumption and thereby to determine the issues imposed on the utility supplier. We used LED, CFL, Incandescent and fluorescent tubes for the study as they are the most common devices that are being used by the majority for the lighting purposes.

This study analyzes several existing life-cycle assessment studies, academic publications, as well as manufacturer and other independent research reports of bulb types to determine the energy consumption in manufacturing phase. A sample of LED, CFL and Conventional bulbs were used to analyze the active power requirement to light up same buildingsseparately, while maintaining same lighting level of 38 foot candles [410LUX] with aid of Dialux software. Further it has compared the apparent power value against different power factors to find out which type draws more power to emit the same light level for each bulb types.

*Key words: Light Emitting Diodes (LEDs)*

**10**

# Energy demand management by reduction of Unaccounted for Water (UFW)

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Abstract

This study is focused on the analysis of the quantity of Specific Energy wasting over the water loss and for selecting the most number of leaks recorded areas in Regional Support Centre (RSC) Western region and to give recommendations to minimize the Energy and water losses in the transmission and distribution pipelines.

Basic information such as the production data on the average value of the Specific Energy Consumption (SEC), Production data, the type, diameter, flow rates of pipe lines for transmission mains etc. at Biyagama Treatment Plant (BWTP) and in the RSC Western region, key performance indicator records, details of the connections and number of leaks, the type, diameter, design velocities of distribution pipelines etc., were collected for the selected area of service.

The following are the main general conclusions from this study. Amount of loss of specific energy due to UFW is in a decreasing trend in the RSC Western region. But the level of UFW belongs to the intermediate level in the area as it is in between 10% -25%. Then, the action needed is to reduce the UFW level. In addition, production cost breakdown on the BWTP on May 2015 reveals that the 75% of its production cost of Rs.26, 420,319.60 is on electricity. Therefore, long term and short term plans should be prepared by reducing the percentage of UFW for managing the energy demand.

Analysis of Expected Energy loss over water leaks on a complete burst of transmission and distribution pipes emphasized the importance of having the buffer stock of pipes and fittings required to meet any emergency at BWTP and RSC Western region respectively.

According to the analysis of leaks reported during the last one and half years, Kelaniya, Biyagama and Wattala areas were found as the most sensitive areas for water leaks. Hence, water audit should be conducted to quantify the amount of water that is being loss for selected areas. Further, the following measures can recommend for controlling the situation; Improve response time to leak repair, system maintenance, replacement and rehabilitation and pressure management and level control.

*Key words: Unaccounted for water, energy demand*

**11**

# Nuclear technology for socio-economic development and electricity generation in Sri Lanka context

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Abstract

Sri Lanka Atomic Energy Board (SLAEB) is involved in promoting on development of Nuclear Science and Technology (NST) in the fields of Human Health, Industry, Environment, Food & Agriculture and Isotopes hydrology. Many scientific and technical institutions of Sri Lanka collaborated with SLAEB and gradually developed required infrastructures and human resources to meet the future needs with regard to better utilization, expansion and implementation of these technologies for the benefit of people in the country. In addition, the SLAEB conducts public awareness programs in order to make the public aware of the benefit of NST & Nuclear Power for electricity generation. Therefore, relevant authorities should be concerned to make their maximum contribution towards the enhancement of these activities in the future development of the country. Countries with high socio economic development have achieved this status by using nuclear power. Nuclear technology is used in various sectors such as Medicine, Agriculture, Animal husbandry, Generation of Electricity, Naval and Aeronautics. In January 2015 the Atomic Energy Regulatory Council was established to allow for the introduction of nuclear power generation technology in the country, and also to address concerns over the security of radioactive sources and to deal with radiation emergencies. In February 2015 the government signed a nuclear cooperation agreement with India. It is concerned with capacity building and training in peaceful application of nuclear energy, especially the use of radioisotopes, nuclear safety, radioactive waste management, radiation safety and nuclear security. In April 2015 it signed a nuclear cooperation agreement with Pakistan.

*Keywords: Uranium mixed oxide (MOX), gravity driven cooling system (GDCS), passive core cooling system (PCCS ), emergency core cooling system (ECCS)*

**12**

# Promoting building energy efficiency through performance-based standards: Is it a challenge?

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Abstract

Buildings account for nearly 40% of the global energy consumption, 16% of the world's fresh water, 25% of the forest timber while emitting almost 70% of oxides of Sulphur and 50% of carbon dioxide gas annually. Buildings could last for decades and hence the decisions made on them today have a long lasting impact on the future global energy consumption and emissions. Also, it is found that people spend almost 90% of their time inside buildings and as a result the indoor pollutant levels may reach 2 to 5 times higher than outdoor levels. In the present context, great emphasis is made on optimizing the energy efficiency and minimizing the carbon footprint related to buildings. Thus, in an overall perspective, building performance encompasses energy performance, indoor environment and air quality for human comfort and health, environmental degradation and economic aspects.

This paper intends to highlight the potential of performance-based building standards over the widely used prescriptive standards for building energy performance and the challenges posed in establishing the same for promoting energy efficiency. It discusses the distinct characteristics differentiating the two and the potential advantages of performance-based standards. Furthermore, the main aspects of such standards and the key benefits that they have brought about into the sector of building performance are highlighted. In case of performance-based standards, the compliance is based on stipulated performance metrics that have to be established by predetermined methods. This approach mainly utilizes design tools and building performance modelling techniques. Prescriptive standards establish minimum energy performance levels for the building sector where as performance-based standards proceed further and optimize the performance of buildings through which substantial savings can be achieved while meeting the design intent. However, performance-based methods demand additional effort in order to make use of their full potential. Hence, the building designer is expected to possess competencies on building performance modelling tools together with optimization methodologies. The lessons learnt through the application of performance-based methods can be extended to the Sri Lankan building energy sector, which still remains mostly as an unexplored area.

*Key words: Performance based standards, building energy performance modelling*

**13**

# Benchmarking of electricity distribution licensees operating in Sri Lanka

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Abstract

Electricity sector regulators are practicing benchmarking of electricity distribution companies to regulate allowed revenue to each company. Mainly this is done by using the relative efficiency scores produced by frontier benchmarking techniques. Some of these techniques, for example Corrected Ordinary Least Squares method has econometric approach to estimate efficiency scores, while method like Data Envelopment Analysis uses Linear Programming to compute efficiency scores. Using the relative efficiency scores, the efficiency factor (X-factor) which is a component of the revenue control formula is calculated. The approach used by the regulators to derive X-factor by the relative efficiency scores is varying among regulators.

In electricity distribution industry in Sri Lanka the allowed revenue for a particular distribution licensee is calculated according to the allowed revenue control formula as specified in the tariff methodology of Public Utilities Commission of Sri Lanka. This control formula contains the X-factor as well, but it has been kept zero, since there were no relative benchmarking studies carried out by the utility regulator to decide on X-factor.

This paper focuses on producing a suitable benchmarking methodology by studying prominent benchmarking techniques used in international regulatory regime and by analyzing the applicability of them to Sri Lankan context, where only five Distribution Licensees are operating at present. The main challenge was to produce robust efficiency scores using frontier techniques for lower sample size (i.e. five) where in contrast many countries have large number of distribution companies or licensees (i.e. large sample size).

Importantly this discussion gives directing signals to the utility regulator on possibility to control allowed revenue of Distribution Licensees according to their efficiencies.

*Key words: Data envelopment analysis, corrected ordinary least squares, distribution licensees*

**14**

# Managing lighting for roads and public spaces (LRPS) in Sri Lanka

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Abstract

Lighting for Roads and Public Spaces (LRPS) consume 1.5% of total energy sold in distribution areas of Ceylon Electricity Board. However, irrational use of lighting in roads and public places gives negative incentive on energy conservation activities. The methodology implemented in this paper is reviewing the status-quo of the Sri Lankan practices in line with the international best practices for LRPS and recommendation is dealt with replication of the best practices in Sri Lanka. LRPS has features of Public Goods like non-excludable consumption and non-rival consumption of lightings. There is no incentive for users of such services to pay for the service.

The best practice is the Government intervenes to directly provide the service itself, or implement an incentive mechanism for private suppliers to provide such services on consistent basis. In case of public goods, the general practice is recovering its costs by taxing the community that benefits of services. Local government legislations in Sri Lanka recognize this aspect in its provision which enable costs to be imposed on those who benefit rather than all ratepayers. The paper goes step further and recommend creating a setup where ratepayers could bargain for better service delivery with local authorities. This will eventually improve the governance structure of local authority with accountability to the ratepayers.

*Key words: Road lighting, public goods, ratepayers*

**15**

# Potential for energy conservation of water and waste water industry in Sri Lanka

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Abstract

Energy consumption of pumps constitutes a major portion of energy usage in Sri Lanka. National water supply and drainage board (NWSDB), Sri Lanka provides water to almost all consumers and is acknowledged as the largest power consumer in the country with 237 million kWh of electrical power being used for its water & waste water pumping stations. Pumps employed, vary in size up to 850 kW. A few years back, NWSDB embarked on a program of study to gauge the efficiency of the pumps used, partly due to new energy regulations coming into effect. Also the feeling that there is always a chance of hidden unknown wastage of power drove NWSDB towards study of its pumping systems. Investment grade instrument energy audits were employed in the study. So far, 284 energy audits covering 600 pumps have been conducted.

Revelation of the losses was bordering on 30% of the energy used. Subsequently, necessary remedial actions to improve the efficiency of these pumps have been taken in 58 pumping stations. Results from these implementations clearly show the energy saved is close to the 30% level. This has resulted in huge financial savings to NWSDB and has translated into substantial reduction in GHG emissions.

Indirectly, this exercise is helping the water consumers; power utility CEB of Sri Lanka and the macro economy of the country itself. In most of these implementations, service level was enhanced by higher levels of supply of water, longer hours of supply etc. thus benefitting the water consumers. CEB is heavily dependent on imported fossil fuel for the generation and hence any reduction of demand is a great relief for them in many ways. Also saved power can be utilized for alternative beneficial uses elsewhere. Due to the reduction of demand on imported fossil fuel macro-economic burdens of the country will also be eased. The paper presents the findings on the potential of the energy savings in the water and waste water industry in Sri Lanka as well as the actual savings achieved.

*Key words: Waste water, energy saving*

**16**

# Possibility of biomass usage in the Sri Lankan tea and rubber industry

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Abstract

The rising and unquenchable demands for energy in the developing world together with the need to minimize the use of fossil fuels to protect our ecosystem from further deterioration in climate change, emphasizes the need to explore and exploit alternative energy sources, especially those that are indigenous to each country. Following extensive analysis, this paper identifies the problems facing the use of biomass as an alternative source of energy in Sri Lanka's tea and rubber industry. A number of key issues have been identified; these include biomass quality, lack of funds, high cost of investment on mechanization and insufficient incentives/subsidies to promote the use of biomass as an alternative energy source. This study proposes and recommends that the most effective approach to enhancing the utilization of biomass in tea and rubber industry in Sri Lanka to provide sufficient incentives for companies that achieve self-sufficiency in energy requirement, without burdening the already congested and costly national grid.

*Key words: Biomass, energy, national grid, technology management, tea industry, rubber industry*

**17**

# Biomethane as fuel for the transport sector in Sri Lanka

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Abstract

This concept paper investigates the feasibility of introducing biomethane as a transport fuel in Sri Lanka. There is an urgent need for introducing renewable fuel sources to ensure energy security, to conserve foreign exchange, to reduce carbon emissions, to mitigate climate change and to improve air quality as well. Anaerobic digestion (AD) has been widely accepted as a sustainable technology due to benefits such as waste management, low GHG emissions and renewable energy production. Current utilization pattern of petroleum fuel in the transport sector is first analysed. Due to availability of varieties of biodegradable organic materials, AD is identified as the best option for bioenergy production for this sector. Results from pilot scale AD plant and its application to a motor vehicle developed at University of Moratuwa are presented. Several test runs were conducted using purified compressed biomethane and confirmed the applicability to three-wheelers as an alternative fuel. Emission test further confirmed the quality of combustion products. It is proposed to establish large scale AD plants to generate biomethane with required quantity and quality and also develop infrastructure facilities needed with the view of introducing this technology to buses used the public transport sector.

*Key words: Transport fuel, pilot plant, biomethane, GHG emission*

**18**

# Energy potential of municipal solid waste (MSW) and sewer generated within Colombo municipality

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Abstract

The objective of this study is to quantify the energy potential of Municipal Solid Waste (MSW) and sewer generated within Colombo municipality and by applying sustainable waste management techniques.

Anaerobic digestion process is considered due to its ability to handle high organic loading rates and low sludge production, and its potential for production of energy by generating methane. Engineered Landfill Bioreactor is found to be the best option for treatment of MSW. The "First Order Decay Model" is identified as the model for prediction of methane from MSW in landfills. Chemical composition of MSW is determined by applying an ultimate analysis and using a stoichiometric based approach. Anaerobic co-digestion of sewer and organic fraction of MSW (OFMSW) is conducted using CSTR. The "Anaerobic Digestion Model No.1" is applied for prediction of methane from sewer and OFMSW. Input parameters are determined based on information collected and standard kinetic parameters are used in the model.

The study determines the energy potential of MSW collected in the Colombo City is nearly $7.03 \times 10^4$ GJ per annum and that from anaerobic co-digestion of sewer and food substrates around $3.04 \times 10^5$ GJ per annum. If parameters could be determined for the wastes generated locally the accuracy of the methane generation potential could be further enhanced.

*Key words: Anaerobic co-digestion, landfilling, ADM1, energy potential*

**19**

# Atomic energy for national development of Sri Lanka: Comparative legal analysis with Indian context

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Abstract

Sri Lanka being an island state is recognized as a core spot of the world strategic location synchronized by the countless environmental resources. One such is the Atomic energy which has not yet been addressed in depth in the Sri Lankan context. Therefore, it is a need of the hour to expand the legal dissemination regarding the uprising usage of atomic energy for national development. In order to accomplish this task, the paper focuses to perform a comparative legal analysis with the Indian context considering the resemblance of both states. Therefore, the objective of this study is to uplift the level of legal protection for atomic energy as an environment resource and to mark preservations for future generation. Accordingly, this will be based on qualitative research methodology which basically entails to compare Sri Lankan Atomic Energy Authority Act No 19 of 1969 with Indian Atomic Energy Act No 32 of 1962. In conclusion, these reforms are to be proposed to surmount energy challenges in the knowledge economy and to sustain towards an energy-empowered nation.

*Key words: Atomic energy, national development, preservation for future generation*

**20**

# Optimization of energy usage by developing of web based energy monitoring system for Ambatale water treatment plant

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Abstract

Ambatale water treatment plant is the largest water treatment complex in Sri Lanka. The maximum production capacity of the treatment plant is 550,000 m3/day. The treated water of this plant is transmitted to six service reservoirs which are located in different places in Colombo district from main transmission lines. Cost analysis of Water Treatment and transmission process shows that the major cost component is the electrical energy. Average monthly energy consumption is 5.4 GWhrs and the maximum demand is 9000 kVA.

The electrical system of Ambatale water treatment plant has 19 power transformers which are in continuous operation. The individual energy measurements of these 19 sections are very important to study the characteristics of energy usage of each section. The Ambathale water treatment plant has no SCADA system for controlling and monitoring of the process. In addition to that there is no any method to monitor energy usage continuously of the treatment and transmission. The ever increasing energy demand in Sri Lanka cannot be matched with the increase in generation. Therefore optimizing and minimizing of energy is the solution for this issue. In this context, we hope to study overall energy consumption as well as individual incoming feeder consumption by using modern technology at Ambatale water treatment plant. This paper describes low cost web based energy monitoring system implemented at Ambatale water Treatment Plant to achieve these goals.

*Key words: SCADA System, Energy Monitoring System (EMS), Water Treatment Plant (WTP)*

**21**

# Transformation of lighting towards solid state lighting in Sri Lanka

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Abstract

The lighting load of the country contributes considerably to the night peak demand of the electricity system. In 2010, the contribution of the lighting load to the night peak demand was 35%. Major contributors to this lighting load were incandescent lamps and CFLs. Incandescent lamp is the most energy inefficient lamp. Energy efficient CFLs were introduced in 1995 and CFL penetration to the system is currently around 45%. Still incandescent lamps dominate the lamp population and contribution to the night peak. During last 2-3 years LEDs have flown in to the market and its share by now is approximately 10%. LEDs are having a higher efficacy around 90–100 lm/W. Mealtime, linear fluorescent technology also has developed to an energy efficient light with smaller tube and electronic ballasts. Under this study several scenarios were worked out, including replacement of incandescent lamps with CFLs, replacement them with LEDs and replacement of all with LEDs. The results show that there is capacity savings in the night peak ranging from 239.7 MW to 413 MW based on the current lighting load.

LED technology proves higher efficacies and the technology is still developing and is expected to reach 180 lm/W levels by 2020. This is three times the efficacy of CFLs. It is a clean technology and has many other advantages as well. Flexibility in switching and dimming further enhance the energy conservation. Different colors and color changing flexibility promotes dynamic lighting and could be used for beautification and exterior lighting of buildings and monuments. Its applicability is vast in both indoor and outdoor lighting. Different light distributions can be easily achieved with different optics.

LED lamp is an assembly of few components like the LED chip, heat sink, optics and the driver. Proper co-ordination and good quality of these components is vital for the best performance of the LED lamps. Hence, manufacturing of LED lamps within the country could be promoted and it will add more value with in the country enhancing the economy. One major concern with LED is the quality of all components in the assembly. Failure of any component will results in the failure of the lamp. Lumen depreciation and color shift are another concern with LED lamps. Therefore, quality assurance and product testing is a key aspect in using LEDs. Testing on lumen maintenance or life and the color shift takes long time. Therefore, RCL along with SEA, SLSI and University of Moratuwa is in the process of developing a short term test method to assess the life and the color shift with the assistance from LRC, NY, USA.

With proper quality assurance and product testing mechanisms in place, LEDs have far more advantages and energy savings than other lighting technologies. The technology still continues to develop and local manufacturing and mass production or procurement can bring down the price of LED lamp to an affordable level. Therefore, transformation towards LED lighting is a prudent move that can benefit all stakeholders including the environment.

**22**

# A new energy saving concept - An overview of the practices worldwide

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Abstract

New technologies are developed and used to provide considerable fuel savings and reduce greenhouse emission worldwide. X-Plate (Xenogenic Plate) is the innovative fuel saving proven technology. It is a device which is flexible and easy to install at various process applications such as boilers, thermal power stations, cement, ceramic kilns, steel plants, gasification units, or any other industry that uses any fuel for combustion with oxygen. This paper gives an overview of the innovative fuel saving proven technology.

*Key words: X-plate, fuel saving, energy saving, emissions*

**23**

# Energy optimization with the demand variation and pressure management of Gothatuwa distribution system

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Abstract

Water treatment is a high energy intense process. The major portion of energy is used to drive the pumps to deliver water to the end user. The electrical energy is used to pump from treated reservoir to service reservoir. In common the distribution system consists of elevated water towers and sometimes collected reservoirs available. In the municipal areas in common practices used to pump secondary or tertiary to these elevated towers. The common practice in designing municipal water supply systems is with elevated water towers.

Alter pumping to the elevated towers, water is distributed to the consumers through the common distribution line which is directly connected to the tower. Municipal water supply system demand is varying drastically with the time of the day. Normally both low and high elevated areas are fed by these elevated towers. According to this scenario low pressure and high pressure areas are not separated and consumer complaints in the low pressure areas are naturally high. As well as water leakages will be generated due to high pressure in low elevated areas. Therefore these leakages are leading for high energy wastages.

This paper describes how to apply modern technological aspects to optimize energy usage and maintain constant pressure in the water supply system by using Variable Speed Drives and directly feeding to the distribution system (by passing the elevated tower) of Gothatuwa Water Supply Scheme.

*Key words: Energy optimization, water supply system, variable speed drives, pressure management*

**24**

# Case study: Conservation of energy by provision of ownership for water in underserved settlement in Colombo city

S.G.G. Rajkumar

Abstract

Colombo City water supply was initiated in 1876, by storing raw water in impounded reservoirs away from the city. The city population continued to increase resulting in tapping other sources for raw water. Obtaining raw water from river require quite a lot of energy, subsequent pumping to storage tanks and delivery to point of usage require additional energy. Obtaining raw water has its own limitations; the source availability, irregular rain pattern etc. Having an old system over 100 years is naturally prone for higher level of losses from deteriorated reticulation. The water was provided free of charge during the municipal council management. After formation of National Water Supply and Drainage Board, consumption metering commenced in 1980. Payment had to be made in proportion to the consumption. There was a segment that could not be metered as their residence were temporary, they depended on common water outlets, this represented 40% of the city population. They were categorized as underserved population.

Value of commodity is not known unless payment is made for them, to serve the people, different approach of management could be adopted to solve a long standing social problem. The stakeholders could be from the organization or from outside. This case study looks into one of the management approach taken to reduce Non-Revenue Water in Colombo City from 54% to 46% using available resources that enabled conservation of energy. The tools used include creation of awareness, empowerment, and ownership to dignify the underserved water users.

*Key words: Create ownership, energy conservation, water loss, empowerment*

**25**

# Effects of distributed solar power on distribution utilities

S.C. Diddeniya*, M.D.P.R. Gunatillaka, and D.M.D. Ranawaka

Abstract

The rapidly dropping Solar PV cells and associated equipment prices resulted in heavy penetration of solar power generation at low voltage network level all over the world. Starting in developed countries new technologies are emerging to integrate solar power into the grid electricity supply and almost without a delay same systems are leaking in to the markets of developing countries. As per an article in report, USA lost 700,000 electricity customer quickly, as they opted solar and other means of sources for their energy. Australian utilities experience negative load growths and even in Sri Lanka, domestic load growth of 100% electrified provinces became stagnated. Most evidently the non-conventional renewable energy sources such as solar contribute to this phenomena. Should this be allowed in a liberal market or controlled through laws, financial instruments such as tariff need to be discussed, having found the impact of the solar power generators on the network.

Addition of distributed solar power to a LV feeder is limited by the voltages appearing closer to the end of the feeder, while reducing the revenue of the utility. Therefore the distribution utility is compelled increase tariff and this acts in vicious circle. Solutions to this newly encountered issues, has solutions, but different for different viewpoint.

*Key words: RE distributed generation, solar, net metering, tariff*

**26**

# PPP model for waste to energy conversion in Colombo municipal area

P.S. Karunarathne

Abstract

Sri Lanka has created a green momentum by launching an ambitious program to develop renewable energies and promote energy efficiency. Solid waste is one of most important sources of biomass potential in many parts of the world, which can be used as renewable energy sources. With economic development and the evolution of population, the quantity of solid waste is increasing rapidly in Colombo and other major towns in Sri Lanka; according to the recent researches, the overall generation of municipal solid waste was more than 800 tons per day in Colombo municipal area, and the amount of industrial solid waste, including non-hazardous and inert industrial waste was 500 tons per day, with a stock quantity of 300 tons. The hazardous waste generated amounts to 250 tons per day. The management of solid waste and its valorisation is based on the understanding of solid waste composition by its categories and physicochemical characteristics. Elimination is the solution applied to 80% of waste produced in Sri Lanka. Wastes are disposed in the following ways: open dumps (50%), burned in the open air in public dumps or municipal uncontrolled ones (20%), and controlled dumps and landfill (10%). On the other side, the quantities destined for recovery are too low: only 15% for recycling and 5% for composting.

Waste to energy is very attractive option for elimination solid waste with energy recovery. In this paper, we provide an overview for this technology, including its conversion options and a business model which can be run by Colombo Municipal Council with a domain of "Municipal Solid Waste to Energy"

*Key words: Sri Lanka, Colombo renewable energies, solid waste, physicochemical properties, waste management, valorization, waste to energy*

**27**

# A energy storage model for improving national electricity load profile of Sri Lanka

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Abstract

National load profile is indicating two peaks in its electricity demand profile. It is revealed that those peaks have been caused due to the usage of domestic sector and the significant high peak is observed in evening from 6.30 p.m. to 10.30 p.m. The proposed concept is to clip the peak in the electricity load profile and saving the energy. The concept of storing of energy gathered from the main grid during the off-peak hours and reusing it during the on-peak hours is introduced. As a storage device a novel household battery technology will be introduced with 160Ah (~2kWh) and 250Ah (~3kWh) capacity. A roadmap to develop low cost indigenous/local battery is presented. While the proposed battery system is developed, using of presently available conventional battery is proposed as an immediate action for the implementation of the concept.

*Key words: A energy storage model, national electricity load profile*

**28**

# Conversion of batch - type anaerobic digesters into continuous type at Dikowita biogas site

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Abstract

The National Engineering Research & Development Centre of Sri Lanka introduced "Semi-Dry Batch Type Anaerobic Digester" in early 1990s. Initially for these batch type digesters paddy straw was used as the main feedstock with addition of cow dung as seed material. The batch of feedstock degrades approximately in six months period. Three weeks after feeding the batch, combustible biogas starts to produce and drops the yield towards the end of the six months period. Subsequently the same technology was adapted in medium scale for degradation of organic solid waste. In this process the need to lift the floating gas holders to feed the digester from time to time and removing the digestate after the digestion period have been cumbersome and some solid waste disposal projects based on that technology were discontinued.

Therefore, two batch type anaerobic digesters out of 16 nos of 50MT capacity digesters at Dikowita Biogas site were converted in to continuous type with baffle walls. An inlet tank, digester, outlet tank, sludge separation tanks and leachate collecting tank were constructed for each digester. Then daily feeding of organic waste, comprising vegetable/ food wastes continues for a period of 7 months. Feedstock rate and the states of digestate and leachate were monitored. The accumulated sludge on top the sand filter was tested for bio fertilizer parameters for both digesters.

The result showed that the normally batch system on the average yielded about 15-20$m^3$/day of biogas and it is 25-30 $m^3$/day with the continuous system. Analysis showed that the biogas produced contained on the average 50%-65% methane while carbon dioxide and other trace gases made up the balance 35%-50%. The gas produced burnt well in a biogas burner with a blue flame. 20kW natural gas engine generator was run with biogas for testing purposes. Biogas was purified by removing 70% of $H_2S$ and 55% of moisture before using for engine application.

Measurement of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Volatile Solids (TVS), ammonical nitrogen ($NH_3$-N), Total Suspend Solids (TSS), Total Solids (TS), and pH were taken for the influent and effluent samples on a weekly basis during this period. Bio-fertilizer (solid & liquid) analysis showed the inclusion of the nutrients. Harmful microbes like coliforms were not present.

*Key words: Biogas, anaerobic digestion, bio-fertilizer*

**29**

# Thermal regeneration and its applications towards energy sustainability in industrial pollution control

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Abstract

Same as "the journey is a foot" and "the ocean is a drop", "the energy is a Watt". Every unit of energy utilization as well as transformation should be done in the best effective manner, which would not be naturally happening. As a solution approach, "A national plan with effective multifaceted approach with sustainability in mind" is a critical need of the day for the uninterrupted growth and the sustainability of the nations, and even to face the global competitiveness.

The above context is very much significant for the nations' use of thermal energy. This paper identifies the need of sustainability in the thermal energy usage in pollution control, as a growing national importance. The paper discusses the importance of thermal regeneration technique, in heat recovery in "solid waste incineration" and "in thermal oxidation of VOC laden air emissions". Also, the paper introduces a sensitivity parameter $X$ to judge the sensitivity of heat interaction in incineration / oxidation of pollutants.

*Key words: Regeneration, pollution control, VOC, energy, sustainability*

**30**

# Sodium/reduced graphene oxide composite anodes of sodium-ion rechargeable batteries made using Kahatagaha graphite

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Abstract

In recent years, graphene has been attracting considerable attention due to its unique morphological and electronic properties. Despite its interesting features attention has diverted towards its partially oxidized form, graphene oxide (GnO), that has emerged as an alternative to graphene for selected applications, thanks to its low cost, production scalability, ease of processing and good compatibility both with aqueous and organic solvents. Graphene is different from the conventional semiconductors because it is identified as a zero band-gap semiconductor.

GnO consists in atomically-thin graphene sheets that are covalently decorated with oxygen-containing functional groups, either on the basal plane or at the edges, so that it contains a mixture of $sp^{2-}$ and $sp^{3-}$ hybridized carbon atoms. In particular, tailoring of the size, shape and relative fraction of the $sp^{2-}$ hybridized domains of Graphite Oxide (GO) by chemical or thermal reduction provides opportunities for tailoring its optoelectronic properties. For example, as-synthesized GO is insulating but just by varying the oxidation level, with a controlled de-oxidation, a partially reduced GO can act as a semiconductor material [14,4].
However graphene oxide (GO) was made using Natural Graphite. In Sri Lanka Kahatagaha is famous for its natural graphite and a value addition to this resource seen vital for the optimum benefit of natural resources.

This research work reveals the performance of Sodium / reduced Graphene Oxide Anode material for a Sodium ion rechargeable battery which was developed using Kahatagaha Graphite.

*Key words: Graphene, semi-conductor*

**31**

# Loss comparison between the conventional ac distribution system and hybrid ac-dc distribution system

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Abstract

Most of the modern commercial buildings use a large number of computers, their peripheral devices and LED lamps that are operated by dc electricity. In order to supply these devices, the ac electricity is converted into dc at the device level. This conversion incurs losses thus reducing the overall energy efficiency of the building. With the penetration of rooftop PV generation, which is primarily dc, another conversion becomes essential where the locally generated dc electricity is inverted into ac for distribution within the building and then converted back to dc at device level. The losses of a hybrid ac-dc distribution method are compared with the losses of the traditional ac distribution system to investigate the feasibility of the hybrid ac-dc distribution system.

*Key words: AC electricity, DC electricity, hybrid AC-DC system*

**32**

# Moisture analysis in power transformers

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Abstract

Moisture in power transformers operating at high voltages and elevated temperatures can cause inadvertent failures due to electrical breakdown of insulation materials. Moisture is harmful for both solid and liquid insulation. Operating and Maintenance (O and M) personnel are required to have a basic knowledge of moisture behavior and its effects in transformers at varying operating conditions. This paper discusses a modest way of understanding moisture dynamics and its effects in oil filled power transformers mainly useful for O and M staff. A set of curves has been introduced to represent all important parameters viz. Temperature, Relative Moisture Saturation (RS), Moisture in Paper (MiP) and Moisture in Oil (MiO) on the same coordinates. Relative Saturation of moisture in oil (RS) has significant effect on electrical Breakdown Voltage (BDV).When operating temperature of the transformer varies with loading, cooling and ambient conditions so does the RS value due to migration of moisture among different insulation materials. The graphical presentation of these set of curves will help estimating the final operating point of the paper oil system in terms of moisture contents and temperature of the system which can influence the BDV of oil significantly. Also they explain the possibility of measuring different BDV values of the same oil due to sampling and test conditions. The Other main usage of these curves is the easy understanding of moisture effect on BDV during transient conditions of a transformer in operation such as sudden cooling due to tripping and high temperatures due to overloading for short durations where there is possibility for BDV to exceed the safe limit. Operation and maintenance staff will be able to predict and avert the possible unsafe situations with the help of this approach.

*Key words: Mio, mip, rs, bdv, dfra*

**33**

# Site selection and basic design configuration for pumped storage power plants and pumped storage power plant complexes

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Abstract

Sri Lanka is currently looking forward for the coal based power plants for its power requirement. Currently one coal power plant is in operation along the west coast of the island with installed capacity of 3 X 300MW. As per the national energy plan there will be more than 10 new coal power plants to be introduced to the power system in future.

Sri Lanka's electricity demand is rapidly fluctuating with time. The daily load curve shows a minimum of 1000MW during off peak time whereas during peak hours, it rises to 2150 MW. This kind of rapid variations in load leads to coal power plants to be operated with low efficiency. Such situations are created opportunity for and emphasizes the importance of having storage power plants in the power system of Sri Lanka. Pumped storage power plant (PSPPs) is one of such storage power plant that could be deployed in Sri Lanka. Country's natural geography is ready to facilitate nearly 5000MW of PSPPs and some attractive sites are already been identified. Most importantly some of them can be designed as the Pumped Storage Power Plant Complexes. A common large upper pond or lower pond can be utilized by two or more lower ponds or upper ponds form a PSPP complex. The economic viability of having PSPPs in Sri Lanka can be improve with this kind of PSPP complexes and this paper is to discuss the basic design principles of proposed PSPP complexes in Sri Lanka.

*Key word: Pumped storage power plant complex, design configuration*

**34**

# Economical evaluation of pumped storage power plant complexes and comparison with other candidate pumped storage power plants proposed for Sri Lanka

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Abstract

The daily electricity demand in Sri Lanka varies significantly with the time. The daily maximum demand occurs between 0630pm to 0930pm and the lowest demand occurs between 0030am to 0430am. The maximum demand is more than twice the lowest demand. According to the Ceylon Electricity Board (CEB) Long Term Generation Plan 2013~2032, 16 number coal power plants with 4700MW will be added to the Sri Lanka power system in future. For economic operation of coal power plants in a power system which has significantly varying load throughout the day, significantly emphasis the requirement of energy storage mechanism such as Pumped Storage Power Plant (PSPP).

The studies revels that Sri Lanka has several attractive natural sites for Pumped Storage Power Plants, among them two sites can develop as Pumped Storage Power Plant Complexes (PSPPC). This paper present the economic evaluation of possible sites and the findings shows that developing 1000MW Maha Pumped Storage Power Plant Complex would be the most economical candidate site when considering the capacity requirement with the time.

*Key word: Pumped storage power plant complex, construction cost, B/C, EIRR*

**35**

# Performance of small scale reactor system in waste plastics to fuel conversion process

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Abstract

Disposal of solid waste has become a major environmental issue in Sri Lanka. That is further aggravated by non-bio degradable solid waste like plastic and polythene because the polymer compounds used in plastic and polythene are hardly degradable in a natural manner and causes numerous negative environmental impacts.

In this research work the possibility of using small scale reactor system to convert waste plastic into a hydrocarbon fuel and the optimum process parameters to obtain maximum liquid yield were investigated. The effect of different process parameters such as operating pressure, batch size and set temperature, on the liquid yield and reaction time was investigated and experimentally improved. Experimental results showed that the developed reactor system has the capability of converting waste plastics (PE and PP) into hydrocarbon fuel at a maximum of over 99% conversion rate at the improved process conditions of operating pressure, batch size and set temperature. The maximum liquid and gas yields were 66% and 31% respectively. Analysis of net energy return of the reactor system show that 16,521 kJ of net energy can be produced per 1 kg of waste plastic. The gross energy return of the reactor system is 42,021 kJ per kg of waste plastic.

End products of the process were analyzed to determine their composition and properties. Liquid fuel obtained from the process was found to consist of linear, branched and aromatics hydrocarbon in the range of $C_5$ to $C_{10}$ with high concentration of $C_7$ and $C_8$ hydrocarbons. The density, viscosity and calorific value of the liquid fuel were found to be 774.5 kg/m$^3$, 2.5 mPaS and 43.5 MJ/kg respectively. Distillation tests of liquid fuel were also performed according to the ASTM-D 86/IP 123 method. According to the analysis results the properties of liquid fuel are close to that of commercial fuel.

Gaseous fuel obtained from the process was found to consist of methane, propene (propylene), isobutane and 1-propene, 2-methyl (isobutylene). The calorific value of the gaseous fuel was found to be 42.7 MJ/kg.

Performance of the small scale reactor system is extremely good in view of conversion rate as it gives highest possible conversion rate of over 99%. A decent liquid and gas yield were also given by the reactor system with 16,500 kJ/kg net energy return. Further, properties of liquid and gaseous fuel obtained from the process are close to that of commercial fuels. Therefore, this small scale reactor system can be used in waste plastics to fuel conversion process.

*Key words: Small scale reactor system, waste plastics, hydrocarbon fuel, properties*

**36**

# An assessment of the public exposure level of electromagnetic fields caused by overhead power transmission lines in Sri Lanka

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Abstract

Many researches are being carried out in the world for identifying the harmful effects caused by electromagnetic fields generated by high voltage power lines on human activities. Therefore, it is timely requirement of evaluating the public exposure level of electromagnetic fields caused by power transmission lines in Sri Lanka at this stage because 400kV transmission voltage is planned to be introduced here by 2018. The paper presents the magnitude of electromagnetic fields caused by existing 132kV, 220kV and the proposed 400kV transmission lines. The calculation has been e carried out with first principles with the assistance of the computer software package, MATLAB.

The results indicate that the public exposure levels of 132kV and 220kV systems are not up to the harmful limits defined by International Commission on Non-Ionizing Radiation Protection (ICNIRP). However, the results show that the electric field intensity caused by 400kV system is very closer to the harmful limit. Since, the values of the generated electromagnetic fields depend on tower height and conductor phase configuration their effect on public can be further reduced by selecting an appropriate tower design for 400kV system. The necessity of the preparation of code of instructions for public to safe use of Right of Way of the 400kV transmission line is stressed here.

*Key words: Transmission lines, electromagnetic fields*

**37**

# Study on energy loss due to interconnection of embedded generation to the distribution network

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Abstract

This paper presents the impact on the distribution line losses due to embedded generation. Studies were performed using SynerGEE simulation model on the selected feeders, where significant Embedded Generations (EG) are connected. Initially, a study was conducted assuming a hypothetical feeder with constant load and different level of EG capacity. It is seen that depending on the location of the load along the feeder and the EG capacity, the losses on the feeder will vary. Hence an attempt was made to identify the optimum EG capacity that will result in minimum allowable loss on a feeder. Thereafter, studies were performed on actual feeders with load variation and EG capacity variation. It is concluded that excessive losses occur during low load condition and also during higher generation from EGs. Hence, appropriate measures to be in place in the longer term to absorb higher generation from EGs to minimize the losses in the distribution feeders.

*Key words: Simulation model, energy loss*

**38**

# Hydrocarbon exploration: Accomplishments, opportunities and challenges in the Mannar basin, Sri Lanka

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Abstract

Located in its territorial waters, Sri Lanka at present is in possession of three sedimentary basins namely; Cauvery, Mannar and Lanka. After a prolonged pause of 25 years, hydrocarbon exploration activity is now being carried out successfully in the deep water Mannar basin, since its commencement in 2001. The N-S trending Mannar Basin is a precratonic failed-rift basin and consists of three main tectonic phases defined as pre-rift, rift and post-rift. The basin potential for hydrocarbon generation has been proved already, owing to the discovery of gas and condensate brought to light from the two wells named Dorado and Barracuda. Dorado discovery was made in a forced-fold structure and the Barracuda discovery was made in intra-volcanic sand layers. These discoveries predominantly contain gas with a negligible volume of condensate, all of which need to be appraised in order to analyze the uncertainties associated with reservoir parameters.

Interpreted plays and leads at multiple stratigraphic levels have been enveloped in to the major play levels as Tertiary plays (Fans/ Channels/ Mounds/ roll over anticline), Upper Cretaceous (Forced folds/ intra-basalt turbidite sands/ sub volcanic clastics), Albian (Fans/ reefs/ mounds), Synrift (Fans) and Basement (weathered basement). Tectonic evolution, stratigraphy, play definition (both proven and unproven) and mature source rocks existing below Campanian- Maastrichtian horizon are in fact indicative of higher undiscovered hydrocarbon potential which require further exploration. However, a major portion of the basin still remains underexplored. Allocation of substantial funds towards carrying out high cost drilling, development and production operations in deep water settings, poor seismic imaging due to intrusive and extrusive igneous activities, inefficient government procedures serve as key challenges for further exploration of hydrocarbon in the Mannar basin.

*Key words: mannar basin, dorado, barracuda*

**39**

# Optimizing the cable designs for wind energy applications

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Abstract

Generating electricity from the wind is one of the most cost effective ways of using renewable energy. By 2014 there was more than 350 GW of wind turbine capacity installed worldwide. According to the Sri Lankan Government's energy sector targets published in 2015, the Government targets to "increase the share of electricity generation from renewable energy sources from 50% in 2014 to 60% by 2020 and finally to meet the total demand from renewable and other indigenous energy resources by 2030". It is anticipated that wind power will play a major role when achieving the Government's ambitious energy sector targets.

A typical onshore wind farm connection is used and a number of strings of wind turbines are connected to the collector bus bar at 33 kV. A central wind farm transformer steps up the voltage to 132 kV for connection to the public network. In many wind farms, the same cable is used from the end to the beginning of each string. However towards the end of the string power from a few turbines is flowing whereas at the beginning power from the entire string is flowing.

This paper discusses a concept which could further reduce the size of the cables beyond the tapered cable design. The new concept is based on the fact that the current carrying capacity of a cable depends on the heat balance on the cable and when the wind blows more heat is taken away from a cable quickly. Therefore when the wind speed is high, even under high currents flowing through the cable the heat produced by the copper (I2R) losses of the cable will not increase the temperature of the cable beyond the permissible level. This in turn increases the current carrying capacity of the cable. As current flowing through a collector cable within a wind farm is directly related to wind speed, the above phenomena was used to further reduce the cross sectional area of the collector cables.

Wind power will play a major role in the future power system. In order to promote more wind farm connections, the capital cost (CAPEX) should be minimised. Even though the cost of the collector cable network is about 5% of the total CAPEX of the wind farm, any reduction of Cu or Al use for cables is welcomed both by the environmental point of view and the cost point of view. In this paper, a method of reducing the size of the cables used for a wind farm is presented. A case study was used to validate the proposed method. The results show a great reduction of cable size used for the collector network.

*Key words: Wind power, renewable energy, cable design*

**40**

# Energy efficiency benchmarking of pumps in water and wastewater industry Sri Lanka

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Abstract

Pumping of public portable water in Sri Lanka constitutes the largest power consumption in the country, 237 million kWh being utilized annually at present levels, but growing at a rapid rate. Overall efficiency of the pumps bears a direct correlation to the efficient use of electric power. According to the energy audits carried out in the field, there is at least 20% economically redeemable energy wastage by conservative estimation, while the actual loss percentage found was close to 30%.

To gauge the operating efficiency of the pumps, there has to be benchmarks against which to compare the actual efficiency and find out any wastages of energy. Benchmarking of the pumps poses a challenge due to the wide ranging sizes, ranges of flow & head of the pumps. Size of pumps range up to 850 kW, head up to 180 m flow rate up to 4,300 m3/h.

Achievable efficiency of pumps is directly related to the pump type, specific speed and similar parameters. There is widely published data on the empirical relationship among pump types, specific speed and related pump parameters. Therefore an empirical system of determination of efficiency benchmarking was developed and implemented which is undergoing field verification at the moment. The system is based on empirical correlation data published by reputed institutions supplemented by the methodology devised by us.

Specific energy consumption (SEC) was calculated and used as the final extended parameter of comparison. Benchmark SEC was arrived at, using the empirical method of determination explained in this paper. From the above SEC figures, it can be determined whether any pump is performing below acceptable benchmark levels.

This exercise needs ongoing validation of the benchmarks against best efficiencies of pumps available in the market and the results of the actual SEC figures found in the studies. This paper summarizes the approach, formulation of the methodology and findings in the field on the topic of this paper.

*Key words: Specific energy consumption, operating efficiency, pumps*

**41**

# Framing a two-fold gas policy through GTL technology: An inter-play of natural gas and waste management

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Abstract

The need to introduce various innovative technology often become important mainly when observing the amount of proved natural gas reserves that remain stranded, such as gas discovered in fields located away from the existing infrastructure and also associated gas which is often produced with oil where it is disposed-off either by re-injecting it to the reservoir or by flaring in large quantities in an environmentally unfriendly and wasteful manner. While such practices are often subject to stringent regulations and taxation, the rise in the supplies of unconventional energy sources mainly experienced by countries such as North America, also tend to greatly influence the price of gas at present. Therefore many discoveries presently offer marginal economics, where the task of delivering the output becomes the key issue. In order to remedy this issue, GTL has been identified and introduced as the best alternative technology and process that could make available a better mode of delivery bridging the supply chain gap. The manifold benefits offered by GTL processes although remain unspoken of, the wide-spread applications of this technology have grabbed the attention of many sectors. As the output of the GTL processes can be further refined to generate an array of products, such as industrial feed stock, specialty products and high-quality clean fuel namely diesel and jet fuel, for which there prevails a greater demand, the GTL technology is able to add significant value to gas production. Therefore, with a decline in demand projected for the use of gasoline, the refining industry may have to settle down for GTL process-based output to sustain its activity chain in the near future. Furthermore, GTL technology is also able to curtail the on-shore as well as off-shore flaring of associated gas, while converting such particles into valuable resources. Such a technology may even be identified as a timely remedy, when observing the volume of gas flared up annually which in fact is equivalent to 16% of the gas consumption in North America, 13% of the gas consumption in Europe and Eurasia, and 90% of the combined gas consumption of Central and South America. (World Bank, 2012).

Nevertheless it is vital to understand why big is not always beautiful and the story of large-scale GTL plants in operation explain well its gravity. Although it is defined as a beneficial technological advancement, till date only four GTL plants have been in operation commercially. As such plants undertake large scale operations, the process requires large volumes of gas as feedstock to run its operations. Therefore, the need to replace large-scale GTL plants with small-scale GTL plants stem from such impediments that disrupt the regular GTL process-based activity chain. Small-scale GTL plants offer better market access as there is less entry cost and can be easily installed in more locations. The refinery capacity is often expanded by such processes, as small-scale GTL technology is also able to produce hydrocarbon-based feed stock from small quantities of gas. It has also been observed that the FT process which is associated with GTL plants is also the backbone of the biomass-to-liquids (BTL) processes from which high-quality, ultra-clean diesel and jet fuel from waste biomass, including municipal waste can be produced. This clearly implies that small-scale

GTL plant operations may play an even better role in various waste management strategies if rightly applied. Thus considering the benevolent nature of the newly introduced small-scale GTL technology therefore, it is noteworthy to state that such small-scale GTL processes may become advantageous during all stages of production pertaining to upstream, midstream and downstream sectors.

*Key words: Natural gas, small-scale GTL Technology, waste biomass*

**42**

# Transcending time and space: A prelude to the scenario 4878

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Abstract

Energy supply and energy demand occur mostly in different special and temporal contexts and require a carrier to connect the supply with demand. The energy carriers of yesteryear include steam in the industrial revolution, hydraulics and compressed air later and electricity. Today, the dominant carriers are processed fossil fuels and electricity and these carriers are now identified as energy vectors. On one side, global networks transport processed fossil fuels through various transport modes and is still a formidable energy vector in today's context. On the other side, electricity is fast becoming the dominant energy vector. Both these vectors possess distinct characteristics offering opportunities and challenges when used in different energy services. Electricity has transcended the space domain quite effectively, connecting demand centers to distant generators whilst failing to meet the challenge of the time domain, due to the want of a good energy storage solution. Fossil fuel vector, on the other hand has transcended the time domain with a vast global network of supply, interspersed with strategic storage assets with substantial capacities. However, the fossil fuel vector fails to meet the challenge of the space domain, as it is a costly affair to haul large quantities of fuel across the globe.

However, the recent advances in information technology, renewable energy and storage solutions provide an opportunity for the electricity vector to transcend both time and space domains effectively. A world which can be energised from renewable energy resources alone, visualised as the Scenario 4878, is no longer a distant dream, if all efforts are focused on distributed generation, storage and truly global transmission grids. This paper attempts to construct a scenario where global energy demand is met by renewable resources using a more advanced electricity vector.

*Keywords: Energy vector, energy carrier, energy storage, distributed generation, space and time domains*

**43**

# Development of "Biomass fuelled rotary type bakery oven"

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Abstract

Temperature controllable rotary type bakery ovens are normally run on diesel, kerosene or furnace oil. Bakery ovens running on fuelwood, with accurate temperature controlling are not seen in the society. For quality rice flour bread baking, temperature controllability is very important. This requirement has been achieved by developing a biomass fuelled temperature controllable rotary type bakery oven. The newly developed bakery oven unit consists of six major components as a) Biomass combustion chamber, b) vertical tube heat exchanger, c) Oven chamber, d) Rotating trolley unit, e) Hot air circulating unit and temperature controller unit. Fuel used for the oven is fire wood pieces or fire wood sticks with a diameter of less than 2 inches for efficient combustion. During the operation, fuel wood is fed manually at suitable intervals.

The hot air generated in the heat exchanger unit is directly sent to the oven chamber from the bottom and sent out from the top after passing through the rotating bread trays. Efficient utilization of heat is achieved by circulation of air in a closed cycle through the heat exchanger and the oven chamber. In this oven, total circulation of hot air reduces the fuel consumption and baking occurs efficiently without drying. Air circulation within the oven chamber has been arranged so that there is a reasonably uniform temperature distribution within the oven. Temperature within the oven chamber is controlled accurately ( set value ±2 $^0$C ) by a specially designed valve unit which releases part of hot air, to the surrounding as the set temperature is achieved. The valve has been fixed in the inlet hot air duct just outside the oven. Capacity of the oven is 80 loaves per batch and average baking time is 55 minutes. It takes nearly 45 minutes for initial heating up to set temperature of 240 $^0$C and consumes nearly 20 kg of fuel wood; while consuming 8–10 kg for baking of each consecutive batch
Main advantages of this novel technology are, accurate temperature controllability, ability to operate with sustainably grown wood pieces such as gliricedia instead of large fire wood logs which are used in traditional bakeries, low specific fuel consumption of 200g of fire wood/bread which saves 60% of firewood in comparison with traditional biomass bakery, portability, avoiding the use of skilled labor for operation etc. the other major advantage for this bakery oven is reduction of labor requirement by about 50% when compared to traditional bakery. The other special feature of this oven is introduction of a specially designed hot bread unloading trolley which avoids the need to take out the heated bread trolley which normally happens in any rotary type ovens. With this new device, all bread trays can be loaded or unloaded at once and quickly minimize the heat loss from the oven during the opened period while loading/ unloading.

*Key words: Fuel wood, oven*

**44**

# Effective use of DC energy storage schemes for mitigating long duration voltage sag/swell in the power system

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Abstract

Present Power quality problems in the distribution systems have increased due to the increased utilization of sensitive and critical equipment in the system. Power quality issues may contain transients, voltage sags, voltage swells, under voltage, overvoltage, harmonics distortion, flicker and voltage imbalance, etc. DC Energy storage technologies can be effectively used to overcome voltage sag/swell conditions in the power system. Dynamic Voltage Restorer (DVR) is one of the economical equipments which can utilize the DC energy storage schemes to rectify the said problems. The DVR injects an appropriate voltage in series with the grid voltage, in order to avoid loss of power as it can maintains the load voltage at its nominal magnitude and phase by compensating the particular voltage sag/swell. Therefore, energy storage is the key factor for deciding the capability of DVR. Battery storage is the most traditional storage used in DVR and number of studies has been carried out to use new energy storage technologies in DVR.

In this paper, responses of the DVR in compensating long duration voltage sag/swell conditions are discussed with Super Capacitor based storage, an emerging technology and the same is compared with battery storage as well. MATLAB simulations have been used to model the storage schemes as well as to analyze the responses of DVR. In addition, an economic analysis has been done to compare the two energy storage schemes in compensating the sag/swell conditions.

*Key words: Economic analysis, power quality, Dynamic Voltage Restorer (DVR)*

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# Waste stabilisation ponds as an energy efficient sustainable wastewater treatment technique

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Abstract

Waste Stabilization Ponds (WSP), often referred as oxidation ponds or lagoons are holding basins used for wastewater treatment where decomposition of organic matter is processed naturally, i.e. biologically. The activity in the WSP is a complex symbiosis of bacteria and algae, which stabilize the waste and reduces pathogens. The result of the biological process is to convert the organic content of the effluent to more stable and less offensive forms. Many characteristics make WSP substantially different from other wastewater treatment techniques which include design, construction and operation simplicity, cost effectiveness, low maintenance requirements, low energy requirements, less sludge production and sludge disposal will arise after long operation periods, easily adaptive for upgrading and high efficiency.

The activity in the WSP system is a complex symbiosis of bacteria and algae, which stabilize the waste and reduces pathogens. The result of the biological process is to convert the organic content of the effluent to more stable and less offensive forms by a natural treatment technique. Hence WSP systems do not require energy for its operation as it is a natural wastewater treatment technique compared to 15-19 kWh/person-year required for aeration alone for Activated Sludge Extended Aeration Systems which is typically used in Sri Lanka.

The presence of algae in facultative ponds is important for treatment of wastewater but escape of algae cells from facultative ponds retard the performance efficiency of maturation ponds. Instead algae in the facultative pond effluent can be captured and utilized as energy source either as biomass for power generation or as biodiesel can produce 5,000-15,000 gal/ha/yr of oil.

*Key words: Algae, biodiesel, biomass, energy, waste stabilization ponds*

**46**

# A green technology to generate bio-energy while producing biochar

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Abstract

According to WHO the fourth most important health issue in the world is indoor air pollution originated from firewood use. Around 80% of Sri Lankan households use firewood as their energy source. This has number of environmental problems as well. Any effort to reduce smoke and particulate matter generation during firewood cooking is advantageous. If unutilized agricultural wastes could be used to generate bio-energy while reducing indoor air pollution would have multiple benefits. In this study we have designed a biochar stove to produce bioenergy from agricultural wastes commonly available in the Dry Zone of Sri Lanka. The stove can be placed on a bench top, handled easily and could be used for domestic cooking purposes. The technology used was the Top-Lit Up Draft technology in the designed biochar stove. In this design both primary and secondary air flow can be controlled easily and the produced biochar can be taken out with ease. This stove generated heat from corn cob wastes to boil 1.5 L of water in 20 minutes. We were able to produce biochar with a conversion efficiency of 30% by weight. The produced biochar can be used as a soil amendment to improve fertility. Since the atmospheric $CO_2$ captured by the corn plant is protected in the form of stable biochar, this can be considered as a green technology.

*Key words: Biochar, stove, bio-energy, greenhouse gasses*

**47**

# Gas engine technology as a complement to renewable energy

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Abstract

As energy producers increase the amount of renewables in their production mixes, the need for efficient but flexible power plants becomes ever greater. Wind and solar power plants offer the possibility of producing power without burning fossil fuels, however as the sun and wind are not always available, conventional power plants are still required to ensure constant energy production. This creates a dilemma as more renewables in the mix requires conventional power plants to be stopped and started more often and run at part loads. Conventional power plants are often built on gas turbine technology, however gas turbines in part load lose much of their efficiency, requiring far more fossil fuels be burnt per kilowatt produced. Secondly, stopping and starting turbines reduces their operating life, requiring more frequent maintenance overhauls. A gas engine however, provides the perfect fit to complement renewable energy production.

MAN Diesel and Turbo has developed single and two-stage turbocharged advanced Otto cycle gas engine for stationary use in power plants, which can be utilized in highly flexible and efficient decentralized gas engine plants, offering combined heat and power (CHP) and providing a fast-operating reserve in a very short time.

Four stroke gas engines operate according to the Otto cycle principle unitizing a spark plug to ignite the fuel mixture. In a lean-burn gas engine, the gas to air ratio is lower, meaning the engine burns less fuel, the peak temperature is reduced and less $NO_x$ is produced. This result in an environmentally friendly engine that is highly efficient, flexible and avoids the potential of knocking. Gas engine technology provides a number of advantages over turbines when flexibility is critical, or a power plant is required in high altitude or temperate environments.

The higher efficiency of engines in single cycle, both in part load and full load, is one of the major advantages of gas engine technology. Their ability to start much quicker and having no limitations on starts and stops provide additional operational savings and makes this technology a very efficient solution for fluctuating load profiles. The optimum efficiency can be reached in a short time after the starting signal. Additionally being able to provide power within minutes, limits the amount of spinning reserve required.

Furthermore the gas engines are able to keep the 100% power output up to high site elevations and up to high ambient temperatures. Compared to gas turbines which have gradual de-rating due to altitude and ambient temperatures, the gas engines provide a wider operating window for100% load and the corresponding best possible efficiency.

In regard to the ageing of equipment the engine technology has significant advantages. While gas turbines suffer from up to 5% power reduction over the life time, there is no effect on power output for engine technology. Additionally the fuel consumption for gas engines increases marginally during the operation of the plant and comes back to the initial

consumption after a major overhaul. This is not the case with the turbine technology. The efficiency loss is higher compare to engines and will be always lower than at the time of the installation. As engines have no start and stop limitations for influencing the maintenance cycle, the maintenance costs both low and predictable. The maintenance schedule for engine is solely based on operating hours, whereas start and stops would accelerate the aging effect (higher consumption, lower output) for turbines and shorten the time between overhauls.

In summary, MAN Diesel and Turbo gas engine technology provides very flexible and efficient solutions for utilities and industrial clients for base and peak load applications. With these advantages, engines are the perfect complement to the expanding renewable energy sector by providing flexible, efficient yet dependable power generation.

*Key words: Gas engine technology*

**48**

# Energy efficient weft insertion for conventional weaving looms

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Abstract

In the weaving industry, speed of weft insertion is the key factor which determines the production rate, however, the energy consumption for weft insertion is significantly high. There are various techniques of weft insertion system implemented for increasing the production speed and the quality of fabric, such as air jet, water jet, rapier, and projectile weft insertion. Even though, the large amount of initial cost for high speed modern weaving looms retreats the people in developing countries to involve in competitive weaving industry. The present study describes the energy efficient weft insertion in conventional weaving looms by electromagnetic force system, which can be portable and simply integrated with conventional shuttle weaving looms to increase the picking speed with low cost. Off grid solar batteries can also be used to empower weft insertion in conventional shuttle weaving looms, which enhance the small scale industries.

*Key words: Electromagnetism, solenoid, projectile, weft insertion*

**49**

# Renewable energy: An attempt towards biodiesel production from cyanobacteria and micro-algae isolated from fresh water bodies of Sri Lanka

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Abstract

The present study was carried out to examine the optimum growth conditions for cyanobacteria isolated from fresh water bodies of Sri Lanka and fatty acid analysis of selected strains towards biodiesel production. Collected samples were cultured in different media (BG-11, GO and ASN-III) recommended for cyanobacteria with different growth parameters (pH, light intensity, shaking). Media for rapid growth were selected in terms of days taken for bluish-green growth to appear in the cultured samples. Growth concentration termed as total pigments was determined by measuring the sum of chlorophyll-*a* and pheophytin-*a* pigment. In the present study, BG11 supported best growth at the optimum pH of 7.5, under 2000 lux light intensity and 200 rpm rate of shaking. Addition of original water instead of distilled water during initial sample preparation and use of vortex mixture with glass beads during isolation found an effective technique to obtain uni-algal culture. A positive correlation was observed between biomass and total pigments of cyanobacteria. In terms of fatty acid composition, out of three selected strains, only *Spirulina* sp. was efficient towards biodiesel production.

*Key words: Cyanobacteria, micro algae, growth optimization, culture parameters, total pigments, morphology*

**50**

# Biogas for national energy mix - Bringing in Gandhian way of Ahimsa to energy systems

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Abstract

It has been identified by 2030 the world will be in need of 50% more energy than what it had in 2012. The population is set to grow and the consequent demands on water and food by the same time are predicted to have 30% and 50% more from the baseline at 2012. This is no easy task and the issue is actually compounded by everyone having work within the constraint of climate change. The world is seeking ways to limit the temperature growth to not more than $2^0$C from the pre-industrial position. These are challenging tasks by any nature.

Biogas technology is quite a benign technology system. It has had an interesting history and has always been identified as a solution provider to issues facing the society. When biogas became populrised in Asia soon after the first oil crisis, the expectation of it was to serve as a low cost energy source for cooking and lighting. As waste was to be the raw material the benefit from the public health point of view was equally understood. Thus there was the movement to connect toilets and the deployment of biogas systems in sanitation. The well known biogas example in Matuga, Mumbai in India was linked to a leper colony and dealt with sanitation with the product used for cooking and lighting. With the passage of time the link of organic waste in landfills and the consequent rogue emissions of methane (landfill gas) to the atmosphere with the understanding of climate change has resulted in diverting organic waste from landfills and making use of anaerobic digestion systems. The captured methane is used in power or as a transport fuel and this has brought in a close loop system for urban waste and urban energy needs. Today it is the possible climate response via the biogas systems that is getting the attention of decision makers. It is important to understand that biogas systems are better as decentralized energy systems and this again is the pathway some economies are planning for their future.

Biogas energy generation can be identified as Gandhian way of energy generation. The system depends on the use of benevolent stream of microorganisms in an air tight oxygen free environment. No harsh temperature and pressure conditions are needed as the process makes use of life in micro scale. The only requirement being the provision of necessary and sufficient conditions for the anaerobic organisms to grow and function. They in turn make use of the waste provisions and through the metabolic activity produces what we the society can use for power and energy. Thus this is an excellent pathway to develop a society based on waste recycling and renewable energy. The absence of harsh conditions and the gentle process conditions are the equivalents to ahimsa conditions. The gentle, ambient conditions (especially possible in environments such as in Sri Lanka) of biogas systems make it a clean technology of choice for sustainable development.

Sri Lanka has a unique history with biogas. The technology came in around 1960's and took

roots in 1970's following the fuel crisis. The Colombo Declaration identifying biogas technology for Asia was released in 1973. The world's first renewable energy village with biogas unit as the centre piece of technology providing electricity with a mini grid happened at Pattiyapola in the Southern Province. Sadly we failed to capitalize on these developments. Biogas had been by and large relegated to serving few households with the tag line 'a rural energy system' or 'pro poor energy mechanism'. This needs to be changed.

The paper will address the transformation necessary in making use of the biogas system for Sri Lanka. Also argued strongly would be to setup a biogas based power plant to serve the City of Colombo in line with proximity principle of environmental management as well as demonstrating a climate friendly business capital. Also emphasized will be the triple benefit opportunities of biogas technology - environmental, energy and agriculture - for Sri Lanka. This again highlights the ahimsa approach as multiple benefits with one effort etc.

*Key words: Biogas technology, renewable energy, sustainable development, climate friendly*

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# Suppression of recombination channels of Dye-sensitized solar cells made of $SnO_2$ using core shell structure of $SiO_2$ extracted from rice husk

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Abstract

Dye sensitized solar cells (DSC) are one of the most promising types of solar cells for next generation of solar cell technology that has power conversion efficiency as high as 12%. Compared with conventional silicon photovoltaics, DSSCs offer the cost savings in the materials and a range of solution deposition methods for device manufacture. However, there are still many challenges to be met before DSCs can truly compete with current silicon solar cell technology. Device efficiency, stability and lifetimes and scalable methods for device fabrication are the key issues in this field of research. A lot of work has been done to improve efficiency of DSSCs taking different avenues, which includes increasing the surface area of the metal oxide, developing new dyes with broad absorption spectra, suppressing the recombination channels and introducing light-scattering materials in the film.

Utilization of mesoporous films made of nano particles of titania for DSSC is the imperative innovation made by Gratzel and co-workers in 1991 to achieve high efficiencies. After that it was realized that it is also possible to achieve high efficiencies even with other high band gap semiconductors such as $SnO_2$ and ZnO made in nano range. However DSSCs of high efficiencies comparable to that made of $TiO_2$ films have been achieved with other high band gap semiconductor films made in the form of composites. The improvement is principally accepted as the suppression of recombination of germinated charge carriers due to passivation of trap states and charge carrier confinement.

Materials such as $Al_2O_3$, MgO, and $ZrO_2$ have been used previously as barrier layers in DSSCs, but we could not find any record of use of $SiO_2$ for the same purpose. But $SiO_2$ particles have been used to scatter light in $TiO_2$ films but not in other semiconductor films such as $SnO_2$ or ZnO.

In this research work we improved the efficiency of the DSSCs by introducing thin barrier layer of $SiO_2$ surrounding the $SnO_2$ crystallite to prevent recombination of charge carriers in the diffusion assisted transportation. Here the thin barrier of insulating material enhance the lifetime of germinated charge carriers of DSSC so as to improve the efficiency.

*Key words: Dye sensitized solar cells, photovoltaics*

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# Organic hole conductors harmonize with Dye-sensitized solid state solar cells

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Abstract

One of the most pressing challenges that the modern society faces today is satisfying the ever increasing demand for energy compromising with the environmental pollution. Out of the available sources of energy, solar energy is ideal as it is quite, clean and renewable. The sun is also a colossal nuclear reactor generating enormous amount of energy through fusion of Hydrogen atoms in to Helium. The energy generated in the sun reaches the earth as electromagnetic radiation. The enormous distance between the sun and the earth minimizes the harmful effects created by the nuclear reaction in the sun. As man-made nuclear reactors are dangerous and unsafe, it is better if we can utilize the energy freely available from the sun to generate power. As such, the best is to find ways to transfer energy from the sun to usable form without moving towards risky nuclear power plants.

Dye-sensitized solar cells (DSSC) have gained recognition as a potential alternative to the conventional silicon solar cells because of its low-cost and high conversion efficiency. A standard DSSC consists of a dye-sensitized $TiO_2$ photo anode, an iodide/triiodide redox electrolyte, and a counter electrode. The electrolyte plays an important role, which serves to reduce photo excited dye molecules after injection of electrons to the nanoporous $TiO_2$ film. However, since the electrolyte is very volatile, the efficiency and the lifetime of DSSCs decrease consequently due to leakage and vaporization. Therefore, many solid state hole conducting materials have been investigated to replace the electrolyte with various inorganic materials that include CuI and CuSCN. Organic photovoltaics are also an emerging solar cell technology that utilizes organic polymeric materials which is predicted to have a significant role in renewable energy sector around the world in future.

In our studies we have investigated the fabrication of dye sensitized solid state solar cells using organic solid hole conductors such as Poly(3-hexylthiophene) (P3HT), polyaniline (PANI) and Poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) to replace the volatile liquid electrolyte.

*Key words: Organic hole conductor, solar cells, DSSC*

**53**

# Feasibility of biodiesel production from waste cooking oils in Sri Lanka

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Abstract

Biodiesel is an environmental friendly and very attractive alternative fuel for Sri Lanka, a country that solely relies on imported petroleum fuel for transportation. However, biodiesel production from edible oils is not practicable due to limitation of agricultural land in Sri Lanka, even though it is considered as the main resources for world biodiesel production. Biodiesel production from non-edible oils is another way of solving this problem. There are three types of non-edible feedstocks that could be used for biodiesel production; oil extracted from non-edible vegetable crops, animal fat/waste cooking oil and microalgae oil. The main constrain associated with the non-edible oils is the high amount of Free Fatty Acids (FFA) in the oil and this cause problems during conventional transesterification reaction. Waste Cooking Oil (WCO) is one of the non-edible oils recognized as a potential non-edible feedstock in worldwide. The availability of WCO in Sri Lanka and the potential biodiesel production is estimated from this study.

*Key words: Biodiesel, high FFA, non-edible oils, trasesterfication, WCO*

**54**

# Challenges in integrating renewable energy and future smart grid

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Abstract

This research article portrays a design of a Coordinated Control Landscape (CCL) which has the control over the Renewable Energy Sources (RESs), Energy Storage Units (ESUs) and flexibly controllable loads in an electricity distribution system. It functions in three operating modes and they are Normal (NM), Power Balancing (PB) and Energy Management (EM) modes. PB mode is active when the electricity network suffers from network peak or adverse voltage conditions by maintaining the balance between generation and demand through scheduling RESs, ESUs and loads (through demand response). PB mode also handles serious power quality issues imposed by the intermittent nature of RESs. In addition, customers suffer from increased cost of energy consumption. The EM mode of CCL schedules the network components and reduces the energy consumption and cost of energy consumption, also maintaining customer satisfaction. Results obtained in a simulation carried out in a distribution network with 500kVA capacity illustrate the performance of the proposed CCL design.

*Key words: Integrated renewable energy, smart grid*

**55**

# Power quality analysis of grid connected wind power plants in Puttalam area: A case study

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Abstract

Power Quality is a major aspect of any power system. Therefore, identifying Power Quality issues is important for utilities. Continuous addition of wind power generation to the electrical network influence power quality, in a very specific manner.

At present a total installed capacity of 100MW of Wind Power in Puttalam area is connected to the Sri Lankan national grid. A grid connected wind power plant should adhere to the power quality requirements stipulated in the CEB Grid connection requirement for Wind Power Plants - Addendum to the CEB guide for Grid Interconnection of Embedded Generators, December 2000. However there exists a power quality issue such as voltage and current distortions created by harmonics, Voltage Flicker which violates the Grid Code. This case study investigates power quality issues related to integrated wind power plants at Puttalam Area.

*Key words: Power quality, wind power plants*

**56**

# Thickness optimization of P3HT:$PC_{60}$BM organic bulk heterojunction solar cells based on optical performance using numerical modeling

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Abstract

Optical modelling is used to investigate the thickness dependent performance of organic solar cells based on a widely used mid performance polymer blend P3HT:$PC_{60}$BM. The device optimization is carried out for most commonly used device architecture, with widely used material for end electrodes and charge extraction layers. The maximum possible short current density ($J_{sc,max}$) for the given device architecture at each active layer thickness is calculated taking into account the losses at each layer present in the device stack and also the reflections at each interface. Among the absorption peaks detected at various active layer thicknesses, the peak occurring at 75nm is identified as the optimal in terms of device performance with $J_{sc,max}$ of 11.82 mA/$cm^2$.

*Key words: Organic solar cells, thickness optimization*

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# Evaluation of Gliricidia recourses in Kandy district for dendro thermal power generation (DTPG)

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Abstract

Gliricidia (*Gliricidia sepium)* is used as a multipurpose leguminous tree crop in range of farming systems in Sri Lanka. The advantage of Gliricidia as a multipurpose species is its fast growth, wide adaptability, easy establishment and tolerance to frequent lopping. Dendro thermal power is the generation of electricity from sustainably grown biomass (fuel wood) (Wickramasinghe and Weaver, 2006). Although only 8 % of electricity is generated using oil all over the world, in Sri Lanka 70 percent of electricity is generated from oil and it is a huge problem for Sri Lanka. Petroleum fuels could be replaced with relatively cheap Gliricidia wood to generate the required heat energy. Every liter of fuel oil can be replaced by 5-10kg of fuel wood while minimizing the burden on national economy and foreign exchange. Every liter replaced will provide 5-10 man minutes of opportunity for rural labor to participate in a mainstream economic activity.

This study was conducted in the Kandy District. The main agro ecological regions traverse through the Kandy District was identified. They are upcountry wet zone (WU), mid country wet zone (WM) and mid country intermediate zone (IM). Also the crop models under which Gliricidia is produced was identified and they include pepper grown on Gliricidia, Gliricidia grown under coconut, Gliricidia in live fences and Gliricidia as a shade tree in tea. Four sites for each crop model were selected to evaluate the biomass production of Gliricidia. Destructive sampling (lopping of trees) was done to estimate the biomass. Pepper model was evaluated under 4, 6 and twelve months lopping frequencies. Coconut model was evaluated at 6 and 12 months lopping frequencies. Tea model was evaluated at 6 months lopping frequency. Gliricidia production by different models across the agro-ecological regions was compared. Both fresh weight and dry weight were taken. The data presented are for 20% moisture content as it is the moisture content of wood used in dendro thermal power generation.

Woody biomass production of Gliricidia under different crop models across three main agroecological regions traverse through Kandy district are given in the Table 1. The results show that wood production decreases with increasing lopping frequencies. Mean differences of biomass production under different agro ecological region were not significant ($p=0.05$) except in the case of 12 month lopping frequency in pepper - Gliricidia model.

Table 1: Wood biomass production of Gliricidia (kg per tree at 20% moisture content).

| Climatic Zone | Pepper (Per Year Weight) | | | Coconut (Per Year Weight) | |
|---|---|---|---|---|---|
| | 4 Months Lopping Frequency | 6 Months Lopping Frequency | 12 Months Lopping Frequency | 6 Months Lopping Frequency | 9 Months Lopping Frequency |
| Mid country Intermediate Zone | 13.09 | 13.72 | 10.44 | 8.46 | 8.22 |
| Mid Country Wet Zone | 13.97 | 9.75 | 8.57 | 10.35 | 7.26 |
| Upcountry Wet Zone | 12.83 | 9.84 | 9.65 | | |
| Duncan MRT (P=0.05) | $p$=0.05 | $p$=0.05 | $p$<0.05 | $p$=0.05 | $p$=0.05 |

The average weights of Gliricidia wood produced under three main models are given in the Table 2. When these average weights were multiplied with the extents of different crop models (that produce Gliricidia) grown in Kandy district will estimate the Gliricidia wood production in the district. Using the three models 281,520 t of Gliricidia wood under 20% moisture content can be produced. There are 6,661 ha of pepper lands, 46568 ha of coconut lands and 22599 ha of tea lands in Kandy district. All the pepper lands are planted with Gliricidia. It is assumed that 23,284 ha of coconut lands (5% of total coconut lands) are intercropped with Gliricidia and 11300 ha of tea lands (50% of total) are using Gliricidia as shade trees. Hence the amount of Gliricidia wood produced under pepper, coconut and tea models are 126,759 t, 43,122 t and 111,639 t, respectively.

Table 2: Production of Gliricidia per hectare per year under different models.

| System | IM | | | WM | | | WU | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. weight per tree (kg) | No. of trees per ha | Weight per ha (tons) | Avg. weight per tree (kg) | No. of trees per ha | Weight per ha (tons) | Avg. weight per tree (kg) | No. of trees per ha | Weight per ha (tons) | Avg. Weight per ha (tons) |
| Pepper | 12.41 | 1682 | 20.87 | 10.76 | 1682 | 18.10 | 10.77 | 1682 | 18.12 | 19.03 |
| Coconut | 8.34 | 2160 | 18.01 | 8.81 | 2160 | 19.03 | - | - | - | 18.52 |
| Tea | - | - | - | 9.54 | 1076 | 10.27 | 8.82 | 1076 | 9.49 | 9.88 |

Normally, 1KW electricity can be generated using 2kg of Gliricidia under dendro thermal power generation. Hence, 141 GW can be produced using the Gliricidia wood produced by the three models (281, 520 t).

*Key words: Gliricidia, dendro power, fuel wood*

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# Potential of sugarcane as a source of green energy in Sri Lanka

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Abstract

This paper highlights the potential of sugarcane crop and the development of the sugarcane industry to contribute to supply of green energy in Sri Lanka. It elaborates sugarcane as an energy crop, i.e., a crop that is capable of providing energy for the people; dietary energy, and the energy needs for domestic and commercial purposes. In addition to sugar, sugarcane industry has a high potential for generating electricity and fuel alcohol by using its by-products, cane tops/trash, bagasse and molasses and fuel alcohol directly from cane juice. This contribution could be enhanced further by introducing energy cane.

Sri Lanka is endowed with favourable environment for sugarcane cultivation in dry and intermediate zones of Sri Lanka, and plans are underway to expand sugarcane cultivation in Uva, Eastern, North Central and Northern provinces to achieve 40% self-sufficiency in sugar by the year 2020 and 100% by the year 2030. The development of sugarcane industry in an integrated manner makes it possible to achieve this target, and it can make a significant contribution to food and energy security, foreign exchange saving, income and employment generation, development of rural entrepreneurship, clean development, etc.

To contribute more to energy sector, research on the development of energy cane, production of fuel alcohol from molasses and bagasse are required. In addition, pricing of sugarcane and alcohol and excise duties on fuel alcohol are some areas need policy measures.

*Key words: Energy security, food security, green energy, Sri Lanka, sugarcane*

**59**

# Comparison of resource assessment study results and actual performance of wind power plants located in Puttalam region

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Abstract

Wind power generation is the top player in renewable energy field. To select the best suitable sites for wind power generation, wind mapping is required to be carried out with reliable data. In view of the above, second wind resource assessment study (1999 - 2002) was conducted by Ceylon Electricity Board in the Puttalam and Central Regions of Sri Lanka. Under this project, 40m high wind measuring masts were erected to obtain the wind speed and directional data at different heights in four locations of Puttalam region, including Narkkalliya.

The seasonal wind pattern in Narakkalliya conforms to the general monsoon wind climate experienced in Sri Lanka with an annual average wind speed of 7.15 m/s at the measuring height of 40m. Winds are strongest from June to August giving a mean wind speed of 10.0 m/s. On the whole, monsoon winds remain steady during both seasons giving Weibull Shape Factor (k) values of 5 for SW winds and 3 for NE winds. Due to the existence of two persistent wind regimes, the annual wind regime shows a slightly bi-modal distribution. Winds in Narakkalliya display a remarkable directional persistence. Percentage duration that winds blow from the direction sector 180-270 degrees, which is the predominant direction of SW winds, accounts for 60%, while winds blowing from 0 to 90 degrees (NE monsoon winds) accounts for 25%. There is very little diurnal variation in the strength of winds during both monsoons. Contrasting diurnal variation (with strong daytime winds) was observed during the inter-monsoon month of March when sea-land breezes, which are driven by the local pressure gradients, dominate the wind system. Turbulence intensity of the wind regime shows marked difference along different directions.

Based on the wind speed measurements collected during the study period, a sample wind farm was modeled in Narkkalliya with single type of machines but with different sizes of rotor diameter (48m and 44m). It was estimated that total capacity factor of 35% could be obtained with the selected machine of 48m rotor diameter and at 50m hub height. Estimated capacity factor with 44m rotor is 32%. Estimated energy production during the Monsoon season (May - October) was around 76% (Capacity Factor 52%).

The capacity factors of seven wind farms exist in Puttalam region were calculated using actual electricity generation in years 2013 and 2014. These calculated results show a similarity in the actual results and the model power plant output. It is to be noted that percentage energy production during each seasons in all the power plants are almost equal.

The capacity factor of a wind farm plays a major role in determining the economic viability of a wind farm. When compare with capacity factor and the levelaized cost of electricity of on-shore wind plants of the world, it could be seen that the feed-in-tariff offered in Sri Lanka is the highest even though the capacity factor is comparable to the global figures. This may

be due to use of high capital cost component and low capacity factor embedded in the feed-in-tariff calculations.

Wind Resource Map of Sri Lanka shows that wind power potential in the Mannar region, North of Kalpitiya Peninsula, and some areas in Jaffna Peninsula is higher than the Puttalam region. Also the interest rate applicable for capital loans, which is a component to determine the discount rate, and the price of wind machines, are gradually decreasing due to increase competition and growth of wind power market in the world, giving favorable investment opportunities in wind power development. Since all these factors are favorable for wind power generation, it could be expected that the feed-in-tariff of Sri Lanka would be in comparable with the feed-in-tariff of other countries in the region with the development of wind farms in these areas.

*Key words: Wind power, wind resource assessment, feed-in-tariff*

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# Utilization of bioenergy for mechanization of small scale paddy farming sector in Sri Lanka

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Abstract

Rapid escalation of fuel prices, depleting hydrocarbon reserve of the world and environmental pollution due to fossil fuel burning have forced to look for alternative fuels to cater the ever increasing demands of energy specially focused on farm mechanization. The aim of the study were evaluating extractable oil amount from scraped coconut refuse (SCR) and testing its suitability for producing biodiesel, testing the performance of coconut methyl ester (CME) and conducting field experiment for two wheel tractor operation using biodiesel, CME and compare the results with using mineral diesel(MD). SCR was dried and oil was extracted. The number of coconut nuts required for oil extraction was recorded. CME was produced from the coconut oil which was extracted from the SCR. The properties of produced CME were tested for observing the suitability. CME and MD were used to plough the low land paddy cultivation by using two wheel tractors (R180) with three replicates and field efficiency and fuel consumption were recorded. The results revealed that 25m1 of oil was extracted from SCR of one nut. Fuel consumption and field efficiency were not significantly different ($p>0.05$) between CME and MD. CME can be used as alternative fuel for the two wheel tractor with compression ignition engine with environmentally friendly manner as CME were fulfilled ASTM standards. According to the results coconut oil extracted from the SCR can be utilized successfully for producing biodiesel to fulfill the energy requirement for farm mechanization.

*Key words: Bio energy, small scale paddy farming*

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# Cultivation of microalgae *Chaetoceros calcitrans* for biodiesel production as affected by different nitrate concentrations and salinity levels

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Abstract

Microalgae are considered as a promising biological material for the production of biodiesel. The key to economic algal biomass production for biodiesel is optimization of the growth conditions. The aim of the present work was to study the effect of nitrate concentration and salinity level on growth and lipid production of marine diatom, *Chaetoceros calcitrans* cultured in an outdoor culture system, in view of its possible utilization as novel raw materials for biodiesel production. Guillard and Ryther`s modified F/2 media was used as the culture media with different sodium nitrate concentrations such as, 0.0375 g/L, 0.075 g/L and 0.15 g/L. In the second experiment, *Chaetoceros calcitrans* was cultured in different salinity levels; 35 ppt, 30 ppt and 25 ppt. At the end of the 15 days growth period, cells were harvested by flocculation and dry weight and the percentage lipid content were estimated.

Average dry matter yield and the % lipid contents were observed as 0.5 g/L with 6.5 % lipid, 0.6 g/L with 6.2 % lipid and 0.7 g/L with 6.0 % lipid in 0.0375 g/L, 0.075 g/L and 0.15 g/L nitrate concentrations respectively. Significantly lower average dry matter yield and significantly higher % lipid content was observed in the treatment with lowest nitrate concentration ($p > 0.05$). Further, no significant effects on measured parameters were observed when *C. calcitrans* cultured in different salinity levels, which indicates its ability to grow in range of salinity levels (25 ppt to 35 ppt). Therefore, it is clear that *C. calcitrans* can be cultivated at low nitrate concentration (0.0375 g/L) and wide range of salinity levels (25 ppt to 35 ppt) to produce biodiesel.

*Key words: Chaetoceros calcitrans, nitrate, salinity level, dry weight, lipid yield*

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# Grid integration of large scale fixed speed wind farm considering static voltage stability

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Abstract

This paper addresses the influence of integrating a large-scale wind farm on static voltage stability of a power system based on the factors such as, wind speed, wind farm interconnection bus, interconnection cable length and wind farm size. Using the continuation power flow method, effects of each factor were analysed and an index, is proposed to locate a large scale fixed speed wind farm in a power system.

*Key words: Continuation power flow, static voltage stability, wind farms, wind farm placement index*

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# Feasibility of solar PV integration in to the grid connected telecom base stations

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Abstract

Integrate Solar PV in scalable on to the grid connected and standalone power generation system has increased attention in these days due to its sustainability and more greener generation. This has become a good option to reduce the telecom Radio Base Stations utility power consumption. The techno economic feasibility of Solar PV integration methodologies in to On-Grid telecom based stations, basically in to the DC bus by rectifier systems comprising of inbuilt DC to DC converting Solar PV charger controllers or in to the A/C bus through grid tie inverter system facilitate with "Net metering" are discussed in this paper. It was found that it is successful to integrate Solar PV in to on grid sites with different tariff structures.

*Key words: Renewable, solar photovoltaic, economic feasibility, net-metering, telecom, base station*

**64**

# Energy creation through sustainable waste solution - Geocycle Sri Lanka

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Abstract

Hunger and global requirement for energy is a growing interest for reasons of energy security, diversity, and sustainability as well as for greenhouse gas emission and mitigation. In recent years, the world has enacted regulations and adopted aggressive goals to encourage increased usage of biofuels and other alternative resources. In Sri Lanka, the energy consumption is increasing at alarming rate and demand for power has been running ahead of supply. It is also now widely recognized that the fossil fuels (i.e., coal, petroleum and natural gas) and other conventional resources, presently being used for generation of electrical energy, may not be either sufficient or suitable to keep pace with ever increasing demand of energy. Also, generation of power by coal based steam power plants or nuclear power plants causes pollution, which is likely to be more acute in future due to large generating capacities. The recent severe energy crisis has forced industries to develop new and alternative methods of energy generation. This paper discusses how Holcim (Lanka) has successfully adopted the use of alternative fuels and thereby reducing on fossil based virgin fuels.

*Key words: waste to energy, alternative fuels*

**65**

# Economic and financial sensitivity of power generation through municipal solid wastes for environmental sustainability

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Abstract

The main objective of this study was to explore and analyze the economic and financial risks of using Municipal Solid Waste (MSW) in Western Province of Sri Lanka, as environmentally sustainable source of energy. The results presented in this paper revealed that thermal technologies such as gasification or pyrolysis afford an effective way of transforming MSW to power, despite the high capital cost associated with the need to use sophisticated process technology. Another approach involving the use of a combination of Refuse Derived Fuel (RDF) based incineration/gasification and bio-gas based power plants, has also been identified and tested. The aforementioned two technologies have been financially analyzed, using baseline financial analysis, and found to be economically feasible. However, sensitivity analysis revealed that either approach is associated with an element of high risk, which has to be evaluated against the backdrop of the immense environmental benefits, which the public of Sri Lanka stand to enjoy. The methodologies adopted in this paper together with its findings and recommendations are also applicable to other countries within the region as environmentally sustainable source of energy.

*Key words**:** Municipal solid waste (MSW), sustainability, environment, waste management, power generation, renewable energy, economic and financial feasibility*

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# A green technology to generate bio-energy while producing biochar

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Abstract

According to WHO the fourth most important health issue in the world is indoor air pollution originated from firewood use. Around 80% of Sri Lankan households use firewood as their energy source. This has number of environmental problems as well. Any effort to reduce smoke and particulate matter generation during firewood cooking is advantageous. If unutilized agricultural wastes could be used to generate bio-energy while reducing indoor air pollution would have multiple benefits. This study designed a biochar stove to produce bioenergy from agricultural wastes commonly available in the Dry Zone of Sri Lanka. The stove can be placed on a bench top, handled easily and could be used for domestic cooking purposes. The technology used was the Top-Lit-Up Draft technology in the designed biochar stove. In this design both primary and secondary air flow can be controlled easily and the produced biochar can be taken out with ease. This stove generated heat from corn cob wastes to boil 1.5 L of water in 20 minutes. We were able to produce biochar with a conversion efficiency of 30% by weight. The produced biochar can be used as a soil amendment to improve fertility. Since the atmospheric $CO_2$ captured by the corn plant is protected in the form of stable biochar, this can be considered as a green technology.

*Key words: Biochar, stove, bio-energy, greenhouse gasses*

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# Study on large scale wind power integration to power system

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Abstract

Jiuquan is the first wind power farm with more than lOGW capacity that's ever planned in China. It is important to consider how to effectively and safely transfer the wind power to the load center. As the wind energy is inherently not continuous, peak regulation should be considered. In this paper, the design phase is thoroughly discussed, particularly in terms of peaking capacity, reactive power compensation, voltage control, stability etc. The paper also shows the overall wind power integration and transmission scheme.

*Key words: Wind power, transmission planning, peak regulation, reactive power compensation*

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# Development of global CSP: Optimization of thermal energy storage capacity in parabolic trough and solar tower plants

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Abstract

Concentrating solar power (CSP) is an attractive zero-carbon renewable energy for electricity, which has been rapidly developed in the world. The main types of CSP plants are described and compared in the review, and then the global CSP capacity and current solar energy activities in China were analyzed. Based on the 50 MW CSP plant in Delingha region in China, the optimization of thermal energy storage (TES) capacity and solar multiple in a parabolic trough and a solar tower CSP plants were studied. It revealed that the lowest levelized cost of energy (LCOE) could be acquired with optimal TES capacity and it decreases obviously with the increasing of solar multiple (SM). At the same SM, the parabolic trough system needs more TES capacity than the solar tower system to get the lowest LCOE. Moreover, for the 50 MW parabolic trough type CSP plant, solar tower plant has higher annual electricity energy output and higher annual solar to electricity efficiency than parabolic trough plant.

*Key words: Concentrating solar power, global capacity, parabolic trough, solar tower, thermal energy storage capacity*

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# Environmental sustainability criterion to assess biofuels: A meta-analysis on commonly used (environmental) life cycle impacts categories

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Abstract

Transport sector energy demand increased in par with increasing mobility, 133% higher petrol consumption comparing 2003 vs 2013 and 28% for diesel (Sustainable Energy Authority, 2014) which also a significant foreign exchange on fuel importation. In 2013 it was USD 10,394 million (Sustainable Energy Authority, 2014) which was doubled within ten years. However still there is no sustainable alternative or non-conventional fuel use for transport sector in Sri Lanka.

It is important to assess the environmental sustenance of such options and this research expects to find and assess through Meta-analysis the environmental sustainability criterion used in biofuels studies and select an appropriate life cycle impact (LCIA).

Meta-analysis refers to techniques used to combine the results of multiple studies. A global literature survey was performed with a special emphasis on transport fuel. 120 papers were studied and sorted. Then the collection was segregated into different sectors: Life cycle assessment (LCA), Life Cycle Sustainability Assessment (LCSA) and Cleaner Development Mechanism (CDM).

As the step two, a detail classification was used based on the impact category: for this step LCA and LCSA literature collections were reviewed along with findings. These were tabulated and statistically analyzed. ILCD Handbook on: Framework and requirements for Life Cycle Impact Assessment (LCIA) models and indictors, published by Joint research Council (JRC) – European Commission on 2010 was used to identify LCIA categories.

As per the methodology 112 papers were shortlisted and analysed on LCIA criterion. Also two journal papers Li Borrion (2012) et al ( LiBorrion n, , McManus, and Ha, 2012) and Wilso (2012) et al (Wiloso, Heijungs, and de Snoo, 2012) have given major contribution by summarizing the biofuel LCA and LCIA latest outcomes.

As nations USA, EU and Europe take the lead significantly on biofuel researches while few Asian countries China, India, Malaysia and Thailand shown some immerging trends. With the geographical distribution the field stock (biofuel sources) has strongly varied.

Analysing researches by focused LCIA categories; climate change, eutrophication and photochemical is essential and acidification and resource depletion also considered. Selecting atleast above five LCIA categories will enable both policy makers and implementing corporates to consider environmental sustainability aspects of biofuels.

*Key words: Life cycle impact, biofuels, environmental sustainability criteria*

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# Driving cycle concept to evaluate fuel efficiency of existing roads

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Abstract

Fuel efficiency is one of the major parameters to be considered when evaluating existing roads for improvements because the fuel consumption has a direct impact on the GDP of a country and also contributes to environmental sustainability. Many methods have been used around the world to evaluate fuel efficiency on road sections but driving cycles have not been used directly anywhere in the world.

A driving cycle has been developed in Sri Lanka recently for emission estimation for setting up emission standards. Further analysis shows that it is possible to use the same dataset collected to develop driving cycle for emission purposes to evaluate fuel efficiency of existing roads. Two road categories based on traffic volumes have been identified as a pilot study and then a driving cycle is developed for each road group. The road groups are evaluated according to the guidelines given in the literature. Finally, a proposal has been made to extend this method to evaluate individual roads using representative driving cycles. Evaluation can be done comparing nine selected target parameters and depending on the criteria used for driving cycle development, fuel efficiency level including traffic flow and fuel efficiency level based on infrastructure condition only can be identified.

*Key words: Driving cycles, fuel efficiency, road evaluation*

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# Solution for grid stability when promoting renewable energy

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Abstract

This paper discusses the importance of engaging energy storage technology as an effective solution for grid stability. The use of renewable energy is on the rise as technological advancements are driving economic benefits and domestic participation. The most exemplary is the domestic Solar and Net Metering application. The essential issue when using renewable resources is the inconsistency and instability. Electricity generated from these resources is unstable. When such electricity is fed to the national grid through grid tied solutions, they cause major challenges to the utility providers. Ironically Sri Lanka's geo positioning creates very high potential for Solar Energy and rising up to this challenge is of prime importance. The solution discussed is inspired by the storage aspect of Hydro Power, the most stable renewable resource. The reservoir primarily being used for developing the required kinetic energy, further extends and acts as a storage device stabilizing the power output. Drawing this parallel, the solution then is to introduce Storage to dampen and iron out instability when using other Renewable resources. Since storage in the form of electricity is of ease, the solution proposed is to have short duration energy storage devices at every (domestic or industrial) renewable energy generation site. The storage capacity/duration can be very small (5-15mins depending on the renewable source), just enough to iron out the peaks and valleys which also makes good economic sense. Short duration Storage just prior to the invertors is the technical recommendation, hence the input to the inverters will be stable and the related stable outputs then can be fed to the national grid without any further issue. This can be easily achieved by employing the now very advanced battery systems or super capacitors or even be indigenously developed by our own scientists. The solution can be made scalable and even be converted to an off grid solution if the need arises. We would like to call this Flash-Site-Storage (FSS) system. This solution is poised to be a powerful factor in enabling the Ministry's vision of Energy self-sufficiency and sustainability.

*Key words: Renewable energy, grid stability, energy storage*

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# Energy security of future Sri Lanka: Analysis of roles and interactions of stakeholders

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Abstract

Energy policy, energy security and development are correlated in any economy. However, formulating an appropriate energy policy is a daunting task as it needs to consider all involved agents and their interactions in time and space on know-how, project planning, financing, implementation, social, economic and environmental impacts etc covering energy generation, distribution and consumption. Effective and efficient energy policy can lead to address the issue of energy security of a country and paves the way for development as energy infrastructure is one of the most vital ingredients in manufacturing and service production. Thus, country's energy policy plays an important role in developing a sustainable energy service, which in return helps to improve the energy security of the country and followed by development. However, this task requires a significant time, resources and consideration of the impact of unexpected disturbances (e.g. geopolitics and oil prices). Therefore, conceptual models are useful for simulating different scenarios and assess their impact on future decision making.

This work presents a conceptual energy service model, which facilitates the assessment of roles of stakeholders and their interactions, identifying barriers which inhibit the innovation that will ultimately lead us to propose a framework to promote innovation in energy sector via all-inclusive approach. First energy generation, distribution and consumption patterns of the country are analyzed to project the energy service trends. Data and information generated during the energy generation, distribution and consumption are used to acquire new knowledge. All agents involved at various stages of energy service sector and how their actions would impact on the provision of sustainable energy services are considered. Thus, the proposed model produces an "energy security barometer". This barometer can be used to assess the impact of change in the behavior of different stakeholders. Then, policy makers and planners can simulate different scenarios to promote innovation in energy sector via relevant interventions. Finally advantages, limitations and future development needs of the proposed model are presented.

*Keywords: Energy security, stakeholder analysis, knowledge-based economy*

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# Highway solarisation: The low carbon, energy efficient, environmentally benign system of energy supply

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Abstract

International Energy Agency (IEA) started its "Energy Outlook for 2009" document by identifying the following two central energy challenges facing us to-day: (i) securing the supply of reliable and affordable energy and (ii) effecting a rapid transformation to a low carbon, energy efficient and environmentally benign system of energy supply. The current generation modes of energy and application of energy was analysed in respect of (a) cost, (b) long-term availability, (c) efficiency of usage and (d) impact on the environment. This analysis led to the conclusion that energy generated and used for transportation makes the biggest negative impact in respect of all the four aspects (a) - (d) mentioned above. This implied that a unit of energy generated and used for transportation with a more reliable, low carbon, environmentally benign source of energy would make the biggest impact in respect of the energy challenges mentioned above.

The literature survey carried out in respect of new sources of energy and new modes of vehicles to match these sources indicated that battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (HFCVs) to be the most favoured in respect of Acceptability; though they fell behind in respect of Accessibility and Availability. Improving Accessibility of facilities for BEVs is far easier than for HFCVs due to the need for a separate new infrastructure for hydrogen generation, compression/liquefaction and distribution and BEV was selected as the most appropriate solution.

The perfect fulfillment of IEA's energy challenge needed the generation of electricity fulfilling (i) and (ii) mentioned above. The currently proposed electricity generation modes were analysed using a set of criteria based on (i) and (ii). This led to the selection of photo-voltaic (PV) Solar energy as the most appropriate source of energy and the focus of the research was directed to the limitations of PV Solar as indicated in Intergovernmental Panel for Climate Change document "Technical Assessment Report IV". The ensuring analysis indicated that laying PV Solar Panels above and along the highway and using the generated energy for vehicle electrification is the most appropriate solution.

A quick calculation also indicated that the solarisation of existing and planned highways in Sri Lanka would yield enough energy for 100% electrification of current vehicle fleet and a significant portion of the daytime electricity need above the base load as indicted in the published demand curve. This 100% vehicle electrification using Highway Solarisation will reduce 80PJ of waste energy, 7.5MT of $CO_2$ and 6.5 MT of Water Vapour entering the atmosphere per year as well as reduce 41PJ /year of solar radiation been absorbed by the Sri Lankan Highways and these reductions will actively contribute to reduce climate change.

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# Improving energy efficiency in ports for sustainable port operation and development: The way forward

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Abstract

Energy is a vital input in the production process. Transport sector energy use has been alarmingly high as a result of greater requirement of mobility of people and freight within countries and across countries and main economic regions. The enhancement of energy efficiency is shipping and port sector has been one of the main considerations in the current decade in response to mitigating environmental issues stems from international shipping and other maritime activities. The reason is that a well-coordinated energy management leads to energy costs savings, and in turn it can generate new businesses opportunities for a port. Thus, port authorities and terminal concessionaries need actively engage in the identification of energy flows and sources within their port terminals. The main objective of this paper is to examine the present development in port sector with regard to energy efficiency enhancement within ports.

First, the level of energy consumed by various port equipment and their respective costs were estimated. Results show that a larger share of electric energy is used at terminal level and mainly used for cargo handling and cargo storage in reefer containers. In Port of Colombo, the total energy consumption for the use of port equipment alone accounts for about 3.3 million US dollars. Results show that a considerable amount of energy is consumed in ports. Thus efficient energy management and energy efficiency enhancement is a must in sustainable port operation and development, given a larger share of energy is generated by burning fossil fuels, to preserve the net benefit of using sustainable energy solutions in port operation.

*Key words: Port operation and development, efficiency in energy use, sustainability*

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# Power sector development projects in Sri Lanka: Scarcity, equity and environmental issues

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Abstract

Concerns of equity, scarcity and environmental aspects are essential prerequisites for sustainable renewable energy. However, Sri Lankan energy projects have paid little attention to such aspects leading to widening intra and inter-generational inequities and degradation of the natural resource base. The study therefore aims at analysing three hydropower projects in terms of scarcity, equity and environmental aspects.

Moragolla hydropower project (27 MW), Samanalawewa hydropower project (120 MW) and Broadlands run of river project (40 MW) were selected for the study. Scarcity aspects related to natural resources involved were analysed based on the absolute scarcity or uncompensated damages induced by the projects. Intra generational equity aspects were analysed using both social cost benefit framework and a qualitative analysis which involved identification of different social groups affected by each project. Intergenerational aspects were analysed with changing discount rates and interspecies equity was analysed using a qualitative approach. Environmental impacts were valued in monetary terms to the extent possible.

All three projects had uncompensated impacts either on the environment or on the people thus indicating absolute resource scarcity. All three projects contributed to reduction in global warming indicating lesser impact on global sink scarcities. The social cost benefit analysis of Broadlands project suggests that in order to be viable, the project need diversion of at least 9% of electricity generated to the poorest households in the country. For the Moragolla and Samanalawewa projects, there were uncompensated impacts on the poorest groups especially on their essential livelihood activities. Impacts on future generations are also significant. Environmental damage cost per MW is Rs million 2.6, 1.4 and 0.4 for the Moragolla, Samanalawewa and Broadlands power projects respectively. Implications for energy policy in reducing externality and inequality impacts are also discussed.

*Key words: Hydropower project, scarcity, environmental issues*

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# Solution for peak load shifting and off-peak revenue generation

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Abstract

This paper discusses the importance and opportunity of engaging Energy Storage and Smart Grid Technology on a national scale and capitalizing on the significant underutilized off-peak capacity prior to any further increase of installed capacity. Having a stable demand curve is the projected ideal for any Energy provider for maximum efficiency. A larger portion of Sri Lanka's Energy consumption follows domestic living and lighting requirements giving rise to two peak curves usually between 5.30am to 9.30am and 6.30pm to 10.30pm. Whilst these peaks inefficiently drive the installed capacity up, the off peak durations are a significant loss of business opportunity, especially during the period of 10.30pm to 5.30am. The solution discussed in this paper is a combination of Smart Meters and Energy Storage devices. Whilst the former drives multiple time based tariff systems the latter enables the utilization of off peak Energy during peak hours. Methodology 1 discusses the option where domestic consumer charges a home based Storage device during off-peak, low tariff hours and consume the Energy during peak household needs. Methodology 2 discusses the option of using the same principle, however instead of a separate Storage Device, the consumer charges an Electric Vehicle. Methodology 3 discusses where national scale large Storage Devices are deployed on the grid and are programmed to charge during off-peak hours and discharge during peak hours there by reducing peak stress on the Grid. Both methodologies 1 and 2 promotes off-peak consumer behavior through the application of Smart Meters and multiple tariffs and thereby shifting load out of the peak curves and increasing off-peak revenue. Methodology 3 specifically is used for load shifting purposes and flattening the peak curves and is controlled at the national level by the utility provider. It is timely that the Sri Lankan Energy sector stake holders consider the application of Smart Grid Technology and Energy Storage Technologies and fully utilize the off-peak band with for realizing the Ministry's vision of Energy self-sufficiency and sustainability.

*Key words: Renewable energy, grid stability, energy storage, peak load shifting*

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# Energy challenges in the knowledge economy: Need for institutional policy on knowledge management

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Abstract

The organizations in knowledge based economy require to create new knowledge to overcome the major challenges in the particular sector. The paper address the major challenges in the energy sector of Sri Lanka, as discussed in the Sri Lanka Energy Sector Development Plan for a Knowledge-based Economy 2015-2025. To overcome such challenges the creation of new knowledge with reference to the Nonaka's model, 1995, is proposed. The model is widely used in many countries to create knowledge in the particular sector and it's applications will be highly benefited to overcome challenges in the energy sector in Sri Lanka. To acquire the global knowledge, the association with a global organization is emphasized and proposed to include in the energy policy of Sri Lanka. Further, the action plan for each challenge is proposed to include and implement in the policy framework of energy sector in Sri Lanka.

*Key words: Knowledge economy, policy implications, knowledge management*

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# Energy policy and the role of organizational leaders in adopting sustainability strategies

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Abstract

Currently the main demand of energy in Sri Lanka is fulfilled by biomass (56%), Petroleum (34%) and hydropower (9%). In 2010, as per the report, published by Sri Lanka Sustainable Energy Authority "Sri Lanka Energy Balance", transport and industrial sector consumed 27% and 24% from the total energy usage respectively, whereas 49% was consumed by household, commercial and other sectors in the national economy. According the national gazette notification published in June 2008, total primary energy demand is expected to increase by 3% out of which 7-8% increase is expected from electricity and petroleum sub sectors. As a result of limitations in expanding hydro power plants and slow popularity of use of biomass, it can be assumed that country's incremental primary energy requirement will be fulfilled by mainly through imported fossil fuels in the medium term. It goes without saying that competitive advantage that Sri Lankan manufacturing sector has been enjoying would be further at a massive risk due to unfavourable fluctuations of crude oil prices in the world market. Hence, the main focus of this paper is to examine the sustainability efforts among the business organizations in the Sri Lankan manufacturing sector with a view to proposing a different perspective for the national efforts in driving sustainability.

In this study, we could see both the barriers to energy efficiency and drivers for improved energy efficiency as well. Hasanbeigi, Menke, and C du Pont (2010) found in a study focusing Thi manufacturing industry that cost reduction as the main motive behind the energy saving drive. However, Cagno and Trianni (2013) found that most important driving forces in Italian firms were investments subsidies for technology. In a Swedish study, Rohdin et al. (2007) identified creation and implementation of long-term energy strategy with the involvement of the top management as the key driver of energy management initiative. Thollander et al (2013) in a cross country study identified commitment from the top management and people with real ambition to implement energy-efficient investments as key to drive successful energy management programmes in a company. This leads to examine further why make some leaders to be fashionable about effective energy management or sustainability drive whilst others are different.

*Key words: Energy policy, sustainability strategies*

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# Sri Lankan oil and gas exploration: A private sector case study on successful local initiatives

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Abstract

Today the World's Energy is highly depended on exploring and producing of Oil and Gas and we see many countries being blessed with its own resources, which has helped those economies to accelerate in growth and prosperity. However, there are many more countries who are yet to realize this dream! Sri Lanka, who foresee ownership of these hydrocarbon reserves are one of the latest countries to join the league of new exploring countries having the potential over the next decade to become an Oil and Gas producing nation, having made two considerable gas discoveries in Mannar Basin - Block# 2.

The Oil and Gas Exploration and Production (E and P) business life cycle which typically has a long life cycle spanning to decades shall immensely benefit by having Sri Lankan companies engaged from its inception. Developing the local content is key to Sri Lanka's economy to build a sustainable future for this emerging industry sector and more importantly to create a 'Knowledge Economy'. The case study presents a company that has embraced a deliberate business strategy to enrich and involve Sri Lankan/local content in its business activities in the Oil and Gas industry and has managed the challenges well amidst stiff competition and limitations that comes with local industry which is at its infancy and has to fit into a globally large mature industry segment.

This paper discusses a private sector case study on successful local initiatives taken in the Sri Lankan

Oil and Gas Exploration Sector. The noteworthy key initiatives of the local company examined are;

a) Local support services to Seismic Surveys carried out – engaging local fishing communities, local interpreters, equipping local boats with safety gear and radar systems, HSE Training
b) Conducting all Air Logistics (Passenger and Cargo) for the industry using Sri Lankan pilots and helicopters
c) Investing and setting up a local Supply Base facility at a 6 acre land and training Sri Lankans to work in an O and G environment, investing in much needed machinery and equipment to manage O and G Supply Chain activities locally.
d) Setting up Sri Lanka's first Oil Field equipment import, storage, serving and exporting facility as a 'regional hub' for an International services contractor.
e) Setting up Sri Lanka's first Oil and Gas BPO centre for Engineering Drafting Services targeting UK North Sea Oil Companies

No country is identical in setting its local content development policies and strategies and though operated in a similar industry and every country has its own way of getting the local companies involved in Oil and Gas activities. Engaging local companies from the very outset or inception of the industry, even at a small scale is critically important to build local capacities and capabilities in Sri Lanka.

*Key words: Oil exploration, gas exploration, local initiatives*

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