Proceedings

Energy and Environment

KERALA ENVIRONMENT CONGRESS 2011

25th, 26th and 27th August 2011, Thiruvananthapuram

Organised by

Centre for Environment and Development
Thiruvananthapuram

In Association with

Rajiv Gandhi Centre for Biotechnology
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PROCEEDINGS OF

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FOCAL THEME

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FOREWORD

Energy resources have always been considered indicators of the might of the nations and therefore global relations have always been influenced by the state of energy resources at disposal- be it fossil fuels, nuclear, forests or others.

However, the recent realizations on global environment have unwound a close linkage between the energy resources, their use and the environmental consequences. While the availability is still by and large a local opportunity, environmental consequences due to their use pattern have proven to have global consequences and therefore, global relations are being subject of a large influence of the state of availability and use of energy resources of the nations. Climate change related international relations are the indicators of the global concerns on the behavior of individual nations.

Climate change is one of the examples of the consequences of energy management by mankind. Green House Gases can only be termed as the bye products of the use of energy which has surpassed the ameliorative capacity of the earth, resulting into accumulation beyond normal. Environmental consequences of that resulting into faster changes in climatic patterns, are now calling for strong mitigatory measures for GHGs and adaptive measures for the irreversible changes that are imminent. Mitigatory measures can only come from judicious use of energy, may it be for conversion of one form into another usable one, for extraction from the nature for generation of usable form or for its use in the pursuit of human development. However, for adaptations to the changing environment, as we humans are capable of creating microenvironment with the use of energy, the need of energy can only enhance. Thus the demand supply gap related to energy can only widen in future irrespective of trend of the population. In such situation, unfolding the complexities of the energy - environment interface has specific importance. It is in this context that in the National Action Plan on Climate Change, three out of the eight national missions relate to various aspects of energy conservation and efficient use.

Technologies on harnessing energy from newer non conventional resources constitute an area of utmost attention in view of the ever rising concerns about the finite nature of fossil fuels and the environmental consequences related to it. Other known systems have varied scope in view of the impending environmental, competing resource needs and safety concerns. In such situation, technological aspects on energy efficiency and optimizing productivity may have a long term utility which could not only promote judicious use but also check the environmental consequences often arising out of the escaping waste energy accumulating in material or energy form in the atmosphere.

Public utilities are working overtime for achieving the required levels of energy in all essential forms to the citizens. However, as the efficient use of energy at individual and industrial level are equally consequential, the awareness about energy efficiency needs to spread fast. However, the state of socio-economic development, issues of access and affordability and social compulsions at times direct the policies towards unsustainable management of the energy resources at the disposal of public institutions. Such losses need to be controlled by judicious policy interventions. Technologies can provide effective ways and means for achieving such objectives.

The 7th Kerala Environment Congress aims at highlighting the recent advances in the energy related aspects in science and technology. The Centre for Environment and Development has once again achieved the distinction of focusing on the linkage of science and the most important aspect of the human environment. The inputs from the participants on technologies, processes and societal role in energy efficiency, green processes and optimizing carbon footprints offer a deeper insight into the issues and thus options for consideration in the state. The information will be helpful in appreciation of relevant facts for formulation of energy related policies in a more objective manner.

S K Khanduri

KERALA ENVIRONMENT CONGRESS 2011

The Centre for Environment and Development(CED)initiated the Kerala Environment Congress in 2005 with the objective of creating a platform for bringing together scientists and technologists, policy-decision makers, development managers and students for sharing of knowledge, expertise and experience in subjects of relevance to support the development of the country and the State of Kerala in particular.

CED established in 1993 with its headquarters at Thiruvananthapuram is an independent research, training and consultancy organization specialising on environment and sustainable development related sectors. CED tries to work with various state,national and international agencies and provide scientific and technical support in the form of research inputs, capacity building and training and consultancy services and also providing implementation support to the Local Self Government Institutions particularly in states such as Kerala, Orissa, Pondicherry, Gujarat, West Bengal and Andhra Pradesh. The major Program Areas of the Centre are (i) Environmental Resources Management (ii) Environmental Engineering,Health &Hygiene (iii) Climate Change and Green Initiatives and (iv) Institutional Development and Knowledge Management. CED established its Eastern Regional Centre at Bhubaneswar, Orissa to give major thrust to our activities in the eastern and north-eastern regions and has nine Project Offices spread over the state of Kerala and outside. CED along with Human Development Foundation in Bhubaneswar has promoted the HDF-CED School of Management at Bhubaneswar, approved by AICTE and Government of Orissa where we have a campus with necessary infrastructure facilities including hostels and guest houses offering Management courses, MSW, BBA,MDPs and short term courses on Geoinformatics, Solid Waste Management, etc.. Our plan is to establish a National Institute of Innovation, Technology and Management(NIITM) under which there will be School of Management, School of Technology, School of Social Sciences and so on, with focus on research, not only in Bhubaneswar but in different parts of the country. CED is also managing two major Solid Waste Processing Plants of Thiruvananthapuram and Kochi Corporations. The Centre has at present nearly 350 staff from multidisciplinary areas.CED is the “Centre of Excellence of Ministry of Urban Development,Government of India on Solid Waste and Wastewater Management”, the Regional Resource Agency of Ministry of Environment and Forests, Government of India and also the Accredited Agency of Government of Kerala for Solid Waste Management.

During the last 18 years, CED has completed nearly 70 research, consultancy and training projects supported by various international and national agencies like the World Bank, UNDP-GEF, JICA, RNE, IDRC, ADB, Commonwealth Local Government Forum, Ministry of Environment & Forests.GoI; Ministry of Urban Development, GoI; Department of Science & Technology.GoI; Ministry of New and Renewable Energy (formerly DNES),GoI; Rural Development Department, Kerala; Kerala State Council for Science, Technology & Environment, Local Self Government Department, Kerala, State Disaster Management Agency, Kerala, Planning & Coordination Department, Orissa, Orissa Water Resources Department, Municipal

Administration, Orissa, Andhra Pradesh Municipal Development Department, Fisheries Department,Pondicherry, etc. The Centre is also coordinating the National Environment Awareness Campaign(NEAC) of MoEF in Kerala and Lakshadweep Islands.

The first Kerala Environment Congress was held at Kochi on 6^{th} & 7^{th} May, 2005 with the focal theme "Coastal and Marine Environment-Issues, Problems and Potentials". The second Congress was held at Kozhikode on 15^{th} &16^{th} December,2006 with the focal theme" Forest Resources of Kerala". The third Kerala Environment Congress was organized from 8th to 10^{th}, May 2007 at Thiruvananthapuram with "Wetlands of Kerala" as the focal theme.The fourth Congress was organized in association with Kerala Institute of Local Administration at KILA,Trissur from 22^{nd} to 24^{th} April,2008 with the focal theme"Environmental Sanitation,Health and Hygiene". The fifth KEC was held from 19^{th} to 21^{st} August,2009 at Thiruvananthapuram, with the focal theme "Water Resources of Kerala". The sixth KEC was held from 24^{th} to 26^{th} of July,2010 at Thiruvananthapuram,with the focal theme "Solid and Liquid Waste Management"

The seventh Kerala Environment Congress is being organized from 25^{th} to 27^{th} August,2011 in association with Rajiv Gandhi Centre for Biotechnology,Thiruvanant hapuram at its Conference Hall with the focal theme "Energy and Environment" This topic has relevance in the context of Global Warming and Climate Change related issues and the emergence of the concept of Green Initiatives to reduce the Carbon Footprint at the local, regional, national and global level. "Energy and Environment" is one the key sector which has considerable implications in the climate change adaptation and mitigation. The researchers,planners, policy-decision makers and development thinkers world over are working on this major subject of how to reduce carbon footprint through appropriate energy conservation and management programs.

The Congress includes invited paper presentations, as well as paper and poster presentations for Young Scientist Award. Since one of the major objectives of the KEC is to promote young researchers (age 35 and below), we have instituted Young Scientist Award for the best paper and poster presentation .An Open Forum on the topic "Energy Policy for Kerala" will also be organized on the third day .CED expect nearly 300 researchers, policy-decision makers, planners, students and development thinkers to actively participate and contribute in the Congress. This Proceedings Volume contains full papers of invited and other presentations of the Congress prepared by eminent experts in the concerned field .

CED gratefully acknowledge the support and association of Rajiv Gandhi Centre for Biotechnolgy to organize this Congress.

We hope that the deliberations in the Congress and the papers published in the Proceedings will help to evolve a strategy to formulate a microlevel plan for energy related activities with focus on green initiatives and also to support the formulation of a viable Energy Policy for the State of Kerala.On behalf of CED, we take this opportunity to place our sincere gratitude to all the distinguished participants and other invitees who have supported us to make this Congress a success.

Dr Babu Ambat
Executive Director, CED

Contents

Key Note Address

Review of Energy and Environment at Global, National and State level

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INTRODUCTION

Energy production and use in all its forms are of great importance to society, but it has made the greatest impact on the environment compared to any other human activity. Even the changes in agriculture and forestry had not inflicted such a large impact on the global living environment. The technological and scientific aspects of energy- environment interface like the interaction of energy forms and systems with the physical environment, energy conservation, food security etc have developed into major regional and global issues of techno-economic and socio-political dimensions. Till recently, such problems were local in nature like issues related to extraction, transportation and noxious emissions affecting the quality of life of the people in the immediate vicinity. But acid rains, accumulation of green house gases, radiation leaks from nuclear power plants, loss of biodiversity, earthquakes and other calamities arising out of energy production and use are having very major implications even beyond the boundaries of our living planet.

Energy is the prime mover of economic growth, and it is vital to sustaining a modern economy and society. It is central to sustainable development and poverty reduction efforts. It affects all aspects of development -- social, economic, and environmental -- including livelihoods, access to water, agricultural productivity, health, population levels, education, and gender-related issues. None of the UN Millennium Development Goals (MDGs) can be met without major improvement in the quality and quantity of energy services in developing countries. According to Ban Ki-moon, Secretary-General of the United Nations, “Expanding access to affordable, clean energy is critical for realizing the MDGs and enabling sustainable development across much of the globe.” Future economic growth significantly depends on the long term availability of energy from sources that are affordable, accessible and secure.

A study by the World Energy Council found that without any change in our current practice, the world energy demand in 2020 would be 50%–80% higher than the 1990 levels. The world's energy consumption today is estimated to be 2*109 kWh per year. Such ever-increasing demand could place significant strain on the current energy infrastructure and potentially damage world environmental health by effluent gas emissions such as CO, CO2, SO2, and NOx and resulting global warming. The energy consumption is mainly for the industries, transport and residential sectors, which accumulates to 90% of the worlds energy consumption. The world energy use sector wise is represented in Table 1.

Table 1
World Energy Use – Sector wise

Sector	Total Consumption (TWh)		Percentage of consumption	
	2000	2008	2000	2008
Industry	21,733	27,273	26.5%	27.8%
Transport	22,563	26,742	27.5%	27.3%
Residential & service	30,555	35,319	37.3%	36.0%
Non-energy use	7,119	8,688	8.7%	8.9%

Although 80% of the world's population lies in the developing countries (a fourfold population increase in the past 25 years), their energy consumption amounts to only 40% of the world total energy consumption. The high standards of living in the developed countries are attributable to high-energy consumption levels. Also, the rapid population growth in the developing countries has kept the per capita energy consumption low compared with that of highly industrialized developed countries. The world average energy consumption per person is equivalent to 2.2 tonnes of coal. In industrialized countries, people use four to five times more than the world average and nine times more than the average for the developing countries. An American uses 32 times more commercial energy than an Indian.

International Energy Agency (IEA) predicts that the global energy demand will increase by more than 50% by 2030, with 60% of that supplied by oil and gas. It also forecasts a severe gap between demand and supply, as has become evident by 2010. The impact of the growing demand from countries like India and China will be responsible for the future changes in the global oil demand against the finite and depleting oil reserves. With the global oil production expected to peak around the year 2015, it would result in a major crisis for the global economy. From a long term perspective and the need to maximally develop options as well as diversify energy sources, renewable energy sources remain important to India's energy sector. Global energy scene is undergoing unprecedented changes and therefore, supply and demand projections to 2030 for oil, gas, coal, renewable energy, nuclear, and electricity, plus projections of energy related CO2 emissions are still fluid. If current policies do not change, energy related emissions of carbon dioxide will grow faster than energy use. The pace of technology development and developments in other areas (alternative energy) are the keys to making the global energy system more economically, socially and environmentally sustainable in the longer term. Planners have been looking at these projections with suspicion and indicate that the GDP energy correlation has been delinked and the projections based on growth rate is the consumption obsessed growth scenario and it is possible to work out sensible alternatives.

The quantum of use of major energy sources at global level are given in Table 2

Table 2

Primary Energy Consumption by Fuel (In Million Tonne Oil Equivalent)

Country	Oil	Natural Gas	Coal	Nuclear	Hydropower	Total
USA	914.3	566.8	573.9	181.9	60.9	2297.8
Canada	96.4	78.7	31.0	16.8	68.6	291
France	94.2	39.4	12.4	9.8	14.8	260.6
Russian Federation	124.7	365.2	111.3	34.0	35.6	670.8
United Kingdom	76.8	85.7	39.1	20.1	1.3	223.2
China	275.2	29.5	799.7	9.8	64	1178.3
India	113.3	27.1	185.3	4.1	15.6	345.3
Japan	248.7	68.9	112.2	52.2	22.8	504.8
Malaysia	23.9	25.6	3.2	-	1.7	54.4
Pakistan	17.0	19.0	2.7	0.4	5.6	44.8
Singapore	34.1	4.8	-	-	-	38.9
Total World	3636.6	2331.9	2578.4	598.8	595.4	9741.1

INDIAN ENERGY SCENARIO

Major Sources of Energy

The major energy supply resources in India are (i) Petroleum and Natural Gas, (ii) Firewood as energy source and (iii) Electricity as energy source.

Petroleum and Natural Gas

The sector in recent years has been characterized by rising consumption of oil products and declining crude oil production. Oil sector is broadly divided into two segments - upstream and downstream. The upstream segment consists of two activities i.e. exploration and production of crude oil. Downstream activities include refining and selling crude oil products such as gasoline, aviation fuel, petrol, diesel and lubricants.

The latest estimates indicate that India has around 0.4 per cent of the world's proven reserves of crude oil. As against this, the domestic crude oil consumption is estimated at 2.8 per cent of the world's consumption. The balance of recoverable reserves are estimated as 733.70 million tonnes (mt) of crude and 749.65 billion cubic meters (BCM) of natural gas. The share of hydrocarbons in the primary commercial energy consumption of the country has been increasing over the years and is presently estimated at 44.9 per cent (36.0% of oil and 8.9% of natural gas). The demand for oil is likely to increase further during the next two decades. The transportation sector will be the main driver for the projected increase in oil demand. Consequently, import dependence for oil, which is presently about 70% is likely to increase. The chart showing the oil consumption in India is 23% of the total energy consumed which is represented in Fig. 1.

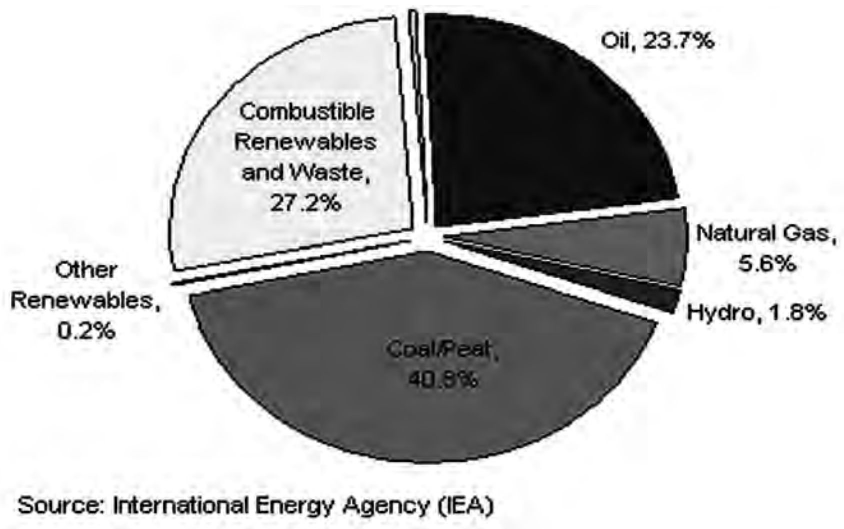

Fig. 1
Total Energy Consumption in India

The gas reserves had been developed largely for use as petrochemical feedstock and in the production of fertilizers, but gas is increasingly being used for power generation, industrial applications and more recently in the transport sector. Presently, the share of power generation capacity based on gas is about 10 percent of the total installed capacity. The India Hydrocarbon Vision 2025 of the Government identifies natural gas as the preferred fuel for the future and several options are being explored to increase its supply capacity including building facilities to handle imports of liquefied natural gas (LNG) and setting up of pipelines from major gas producing countries. India is also reported to have significant deposits of gas hydrates. According to research report “Indian Natural Gas Sector Analysis”, the natural gas market in India is expected to be one of the fastest growing in the world during the next two decades. Among its segments, LPG has made a substantial progress to become the most convenient, cost effective, and pollution free means of fuel, especially among the Indian middle class segment. It is expected that, LPG consumption in the country will grow at a CAGR of around 9% during FY 2011– 2013. The main reason for the growth of this segment is fast urbanization and rising income levels in the country that has fueled up the LPG demand. Moreover, in the villages LPG is fast becoming the most favorable source of cooking and vehicle fuels.

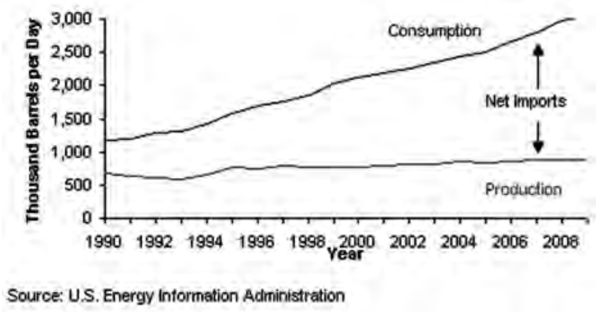

Fig. 2
Oil Production and Consumption (1990-2009)

Apart from LPG, the LNG and CNG are also showing promising future prospects. LNG and CNG segments have shown a tremendous growth in the past. India is currently facing severe shortfalls in natural gas demand and supply, which is anticipated to expand rapidly. Owing to the considerable gap between natural gas consumption and production, liquefied natural gas imports are set to register high growth during the coming years. However, the true extent of this resource and its potential for commercial exploitation is still being evaluated. India's natural gas production and consumption from 1995 to 2009 is represented below which shows substantial growth in the consumption from 2003 and production is well below the consumption.

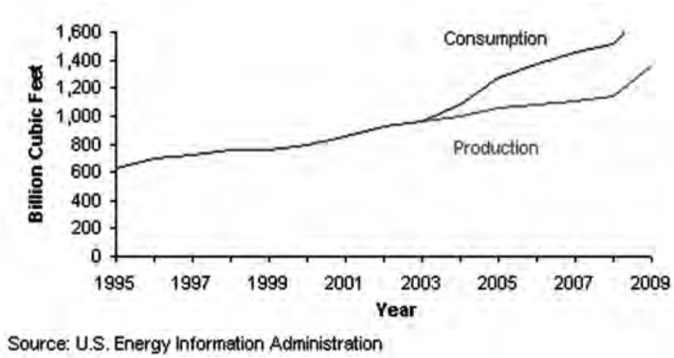

Fig. 3
Natural Gas Production and Consumption

The domestic production of petroleum products in India was 33.37 million tonnes and this constituted 29 per cent of the total consumption. Indigenous production was at 30 per cent during previous three years and the trend in the current year is also below 30 per cent. The potential sedimentary basin for hydrocarbon production in India is around 1.784 million km2 .Oil and Natural Gas Commission (ONGC) and

Oil India Limited (OIL) explored twenty-six locations, of which three accounts for 64 per cent of hydrocarbon resources of India and sixteen sedimentary basins are under various stages of exploration in the country. There are 26 locations yet to explore for the country of which Kerala-Konkan sedimentary basin is one.

In an effort to meet the demands of a developing nation, the Indian energy resource exploration and exploitation, capacity additions, and energy sector reforms have been revolutionized. However, resource augmentation and growth in energy supply have not kept pace with the ever increasing demands exerted by the multiplying population, rapid urbanization and progressing economy. Hence, serious energy shortages continue to plague India, forcing it to rely heavily on imports. The dependence on energy is expected to increase further to achieve the targeted Gross Domestic Product (GDP) growth rate of 8% during the next Five-year Plan.

The present level of energy consumption in India when compared to world standards is very low. The estimate of annual energy consumption in India is about 330 Million Tones Oil Equivalent (MTOE). Accordingly, the per capita consumption of energy is about 305 Kilogram Oil Equivalent (KGOE). As compared to this, the energy consumption in some of the other countries is of the order of over 4050 for Japan, over 4275 for South Korea, about 1200 for China, about 7850 for USA, about 4670 for OECD countries and the world average is about 1690 for the year 2004.

Coal

India has the fourth-largest reserves of coal in the world. Coal deposits in India occur mostly in thick seams and at shallow depths. Coal reserves have been assessed at about 286 billion tonnes, and Geological Survey of India estimates proven reserves to be at around 114 billion tonnes, or 40 percent of the total reserves. Indian coal has high ash content (15-45%) and low calorific value. Estimates put proven reserves worldwide at more than 847 billion tonnes.

Coal accounts for about 67% percent of the total energy consumption in India. The use of beneficiated coal has gained acceptance in steel plants and power plants.

The country's domestic consumption is large and as a result, India imports coal to meet the needs of power companies, steel mills and cement producers. India's coal demand is expected to increase multifold within the next five to 10 years, due to the completion of ongoing power projects, and demand from metallurgical and other industries. Government-controlled Coal India Limited (CIL) is the major domestic coal supplier with an 80% market share, although some industrial consumers in the power and steel sectors have access to captive mines. CIL's non-coking coal production target for 2012 is 452 million metric tonnes (431 MT in the previous year. Despite all this, the Indian coal ministry projects a coal supply shortfall of up to 142 million tonnes in 2012. For over half a century, India has been putting to use its lignite resources also for power production.

NTPC has central sector power projects based on coal, in addition to several states. Pollution from coal power plants have several dimensions and reducing this pollution has gained the attention of the concerned for over years. Globally, attempts at raising the efficiency of coal thermal power conversion to above 45% through raising the temperature of operation of the turbines have met with success, which would reduce pollution as well as help in conservation of coal.

Firewood as energy source

Households in rural India are highly dependent on firewood as their main source of energy, partly because non-biofuels tend to be expensive. The prevailing view therefore is that, when faced with shortages of firewood in the village commons, such households, and especially the women in them, have to spend more and more time searching for firewood and eventually settle for poorer-quality biomass such as twigs, branches and dry leaves.

Starting in the early 1970s, it was widely held that India would soon face severe firewood shortage. Demand for firewood, which together with animal dung and agricultural residue is one of the main cooking fuels used by rural households, was thought to be leading to widespread forest degradation. The degradation, it was believed, would soon be so severe that households would face a firewood famine. Meanwhile, the rural livestock population remained stagnant, offering little prospect of dung as a cheap fuel alternative. The efforts in expanding the more energy-efficient cooking stoves also did not meet with the desired end results. The percentage of households utilizing energy for cooking is represented in Table 3.

Table 3

Percentage of households and primary source of energy in India

Source of energy	Rural	Urban
Firewood	77.6	20.1
LPG	9.1	61.8
Dung cake	7.4	1.4
Kerosene	0.6	7.6

Source: Status report of fuel used in India, MSSRF, Chennai, India

The rural India is the major consumer for the firewood as energy. The firewood in rural India is sourced from forests and waste lands. The percentage of consumers utilizing the firewood from different sources is presented in Table 4.

Table 4

Percentages of consumers utilizing the firewood from different source

Source	Percentage of rural population using firewood
Own back yard	26
Forest	26
Roadside	17
Market	27
Others	4

Source: Status report of fuel used in India, MSSRF, Chennai, India

Electricity as energy source

Power development in India commenced at the end of the 19th century with the commissioning of electricity supply in Darjeeling during 1897, followed by the commissioning of a hydropower station at Sivasamudram in Karnataka during 1902. In the pre-independence era, the power supply was mainly in the private sector and that too was limited to the urban areas. With the formation of State Electricity Boards during Five Year Plans, significant steps were taken in bringing about a systematic growth of power supply industry all over the country. A number of multipurpose projects came into being and with the setting up of thermal, hydro and nuclear power stations, power generation stations increased significantly.

The Ministry of Power is primarily responsible for the development of electrical energy in the country. The Ministry is concerned with perspective planning, policy formulation, processing of projects for investment decisions, monitoring of the implementation of power projects, training and manpower development and the administration and enactment of legislation with regard to thermal and hydro power generation, transmission and distribution. In all technical matters, the Ministry of Power is assisted by the Central Electricity Authority (CEA).The Installed Capacity in India (as on 2010) is represented in Table 5.

Table 5
Total Installed Capacity in India (by source)

Fuel	MW	(Percentage)
Thermal	108362.98	64.6
Hydro	37367.40	23.o
Nuclear	4560.00	2.7
Renewable Sources	16786.98	10.0

Source: Economic Review, Kerala State Planning Board

The installed power generation in the country has increased from 156,092.23 MW as on 31.12.2009 to 167,077.36 MW as on 30.11.2010. Out of the total installed capacity of 167,077.36 MW, a major chunk of the energy generation comes from thermal energy (64.6%) which is 108362.98 M.W, followed by hydropower of 37,367.40 MW (24.7%), clear energy of 4560 MW (2.9%) and 16,786.98 MW (7.85%) of renewable sources. Contribution of ownership share to the national grid as on 30.11.2010 is shown in the Table 6.

Table 6
Ownership Share of Power Production in India

Ownership	MW	Percentage
State Sector	82,026.05	52.5
Central Sector	51,867.63	34.0
Private Sector	33,183.68	13.5

Source: Ministry of Power, Government of India

Potential for power generation

As the electricity consumption is concerned, India has reached a level of about 600-kilowatt hour (kWh) per head per year. The comparable figures for Japan are about 7800, for South Korea about 7000, for China about 1380, for USA about 13000, for OECD countries about 8050 and world average is about 2430. Thus, both in terms of per capita energy consumption and in terms of per capita electricity consumption, India is far behind many countries, and as a matter of fact, behind even the world average. It is imperative that both energy consumption and electricity consumption level should be enhanced. India is targeting a growth rate of 9–10%, having already reached a level of almost 8%. To sustain the double-digit growth rate for next 10-15 years, it would be essential that the level of energy availability and consumption, and electricity consumption in particular, has to be enhanced substantially.

Despite the resource potential and the significant rate of growth in energy supply over the last few decades, India faces serious energy shortages. This has led to reliance on increasing imports for meeting the demand of oil and coal. India is largely dependent on fossil fuel imports to meet its energy demands projected for 2030. India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. In 2009-10, the country imported 159.26 million tonnes of crude oil which amount to 80% of its domestic crude oil consumption and 31% of the country's total imports are oil imports. The demand of natural gas also outpaces supply and efforts are being made to import natural gas in the form of liquefied natural gas (LNG) and piped gas. The growth of electricity generation in India has been hindered by domestic coal shortages and as a consequence, India's coal imports for electricity generation increased by 18% in 2010. The power sector has also been experiencing severe shortages. The demand in primary fuel is represented in the Table 7.

Table 7
Primary fuel demand

Primary Fuel	Unit	Demand		Demand (MTOE)	
		2006-07	**2011-12**	**2006-07**	**2011-12**
Coal	Mt	460.50	620.00	190.00	254.93
Lignite	Mt	57.79	81.54	15.51	22.05
Oil	Mt	134.50	172.47	144.58	185.40
Natural gas	BCM	47.45	64.00	42.70	57.60
Hydro Power	BkWh	148.08	215.66	12.73	18.54
Nuclear Power	BkWh	23.15	54.74	6.04	14.16
Wind Power	BkWh	4.00	11.62	0.35	1.00
Total Commercial			411.91		553.68
Non-Commercial			151.30		170.25
Total E. Demand			563.21		723.93

mt: Million Tonnes; BCM : Billion Cubic Metre; BkWh: Billion kilo watt hour

Crisis in meeting demands and projections

In the process of emerging as an economic giant, India is facing the critical challenge of meeting a fast increasing demand for energy. As the economy is on the growth path, the demand for energy over next two decades will increase considerably. Energy is truly the most indispensable growth factor to the economy and human well being. Indian energy growth projections have also been caught in the supply sided, consumption obsessed, frames and needs rationalization. Serious equity issues also exist with wide gaps between per capita consumption levels of urban and rural areas across the states. Fossil energy sources such as coal and oil are currently the primary sources of energy that powers our not so fast industrializing civilization. They provide over 60% of the world's electrical power and 95% of the world's total energy demands. The inconsistency between a rapidly growing demand and a limited supply has made the oil market vulnerable to jitters, and global oil companies today feel that they have reached the end of growth period. Against rising oil price and declining production of oil, India continues to face the problem of energy crisis. Some of the major barriers include distribution challenges, lower scalability, international trade barriers and powerful oil lobbies along with relatively higher production costs etc.

Climate change related issues

Despite being the fourth largest economy, India's per capita emission levels are 70% below world average and 93% lower than those in the United States. It is highlighted that carbon emissions in India increased by 65% between 1990 and now, and are projected to grow by close to 70% in the next decade or so. But it remained low as compared to other major economies, accounting for only 2% of cumulative energy related emissions since many decades.

Need for energy conservation

Access to reliable and affordable energy services is essential for economic and social development and also for eliminating poverty, especially in the face of growing demand for energy and falling availability of resources. Energy conservation has therefore, become very crucial in today's world. Scarcity of energy services can negatively affect prospects for realizing sustainable development and achieving the millennium development goals. In view of fossil fuels getting depleted at a fast rate owing to the huge consumption rate all over the world, it is vital to concentrate on the renewable energy sources to satisfy the demand, both to conserve our finite natural resources for the coming generations and to ensure the long-term economic and social development.

ENERGY SCENARIO IN KERALA

Kerala's population as per 2001 census was 3.2 crores, while that of India 107.3 crores. As per the 2001 census, Kerala is placed third among the Indian states in respect of population density. It is to be noted that the density increased six times compared to the 1981 census. General economic activities, social and cultural setup, education and exposure to other cultures and economies coupled with consumerism, play a major role in shaping the energy consumption pattern of Kerala. Kerala's economy is largely operated under welfare-based democratic socialist principles. It is an economy, which is supported by large number of workforce engaged in different activities abroad. In the last one and a half decades, the state's economy has grown at an average rate of around 5.8%, which is very close to the growth of the national economy. However, the agriculture sector whose contribution to the economy was 18.17% in 2002-03 has come down to 16.74%. As reported, Kerala's farmers faced serious difficulties in pursuing their occupation.

High living standards, high density of population and the potential for future economic growth demand a high level of energy supply for Kerala. At the same time, it has no known reserves of fossil fuels or environmentally feasible large hydroelectric resources to be developed for energy use. The possible alternatives are in the area of renewable sources of energy. The living standard in Kerala is high compared to that of the national level. It holds a high Physical Quality of Life Index (PQLI) and a high Human Development Index (HDI).

Petroleum and natural gas are the most convenient commercial energy sources next to electricity in Kerala. The share of oil in primary energy consumption is almost 30%. The transport sector almost completely depends on petroleum products, which are growing at the rate of 10% per year, The length of roads in Kerala which was 145,704 km in 2003-04 is continually increasing, and the road density is nearly four times the national average. Petroleum products consumption in Kerala is increasing by 5-6 % a year, the total consumption during FY 2009-10 was 3.8 million metric tonnes while the total consumption of petroleum products in the country was 107.51 million tonnes. In Kerala, diesel consumption is the highest at 13,47,000 tonnes, followed by petrol at 4,30,000 tonnes. The LPG consumption in Kerala has risen 15% and has reached now 4,12,000 tonnes. Furnace oil consumption has increased to 4,20,000 tonnes while that of Naphtha has fallen considerably. This is mainly due to the increase in price of Naphtha and substitution by other fuels.

The availability of fuel for cooking is a major energy security concern in Kerala. The 2001 Census of India shows that 47% of Kerala households use a combination of fuel wood and gas for cooking and 33% use only fuel wood for cooking. The aspect of energy security is the issue of demand and supply balance, where there is short fall in supply.

As the electricity consumption is concerned, nearly half of electrical energy sold in Kerala is consumed by households, which represent about 79% of all energy users and 46% of the total electricity use. However, large industrial users, representing only 0.02% of consumers, utilize 30.8% of electricity. Table 8 provides the data on electricity use by sector.

Table 8
Electricity Consumption in Kerala

Category	No. of Consumers (as of 31/3/2008)	Of total consumers (%)	Consumption (MU or MkWh)	Of total consumption (%)
Domestic	7,137,739	79.01	5,802.85	46.50
LT Commercial	1,327,978	14.70	1,378.33	11.44
LT Industrial	122,449	1.36	984.18	8.17
LT Others	443,283	4.91	479.11	3.98
HT & EHT	2,307	0.03	3,605.38	29.92
Total	**9,033,756**	**100.00**	**12,049.85**	**100.00**

The sale of electrical energy has increased corresponding to the increase of total consumers. During 2008-09, 12877.65 MU of energy was sold, showing a decrease of 518.96 MU as compared to the previous year, mainly due to efforts in energy conservation. Overall power demand is rising and the existing power system is experiencing difficulties to meet the increased demands. The table 9 provides the data on Kerala power system

Table 9
Growth of Kerala Power System

Year	Inst. Cap. MW with in the State				Annual Sales MU	No of Consumers (Lakhs)	Per Capita Conspn. kWh	EHT lines Ckt Kms	EHT S/s (Nos)	HT lines Ckt Kms	LT lines Ckt Kms	Dist Trfrs (Nos)
	Hydel	Thermal (Incl. IPPs)	Wind	Total								
57-58	109.0	0	0	109.0	363	1.06	19	1600	15	3851	4980	1862
60-61	133.0	0	0	133.0	518	1.75	30	1900	22	5449	8899	2898
73-74	622.0	0	0	622.0	2121	7.77	79	3378	59	9645	25968	8285
80-81	1012.0	0	0	1012.0	4499	15.72	109	4638	92	14189	55963	11656
85-86	1272.0	0	0	1272.0	4172	23.96	136	5317	109	16917	76141	13314
90-91	1477.0	0	0	1477.0	5331	34.50	185	5885	140	20221	101834	17838
97-98	1676.5	85.3	2	1763.8	7716	52.11	239	7074	168	27083	138732	26826
98-99	1692.5	336.2	2	2030.7	9182	56.39	285	7381	177	28090	174196	28058
99-00	1742.5	594.2	2	2338.7	9812	60.30	300	7599	179	28672	180499	29551
00-01	1792.5	614.6	2	2409.1	10319	64.46	311	9085	194	30035	187169	31329
01-02	1795.0	771.6	2	2568.6	8667	66.62	395	9274	204	30971	191931	32585
03-04	1807.0	591.6	2	2400.6	8910	73.00	391	9718	225	33323	201638	34758
04-05	1843.6	591.6	2	2437.2	9384	77.99	400	9924	251	33998	207711	36442
05-06	1849.6	591.6	2	2443.2	10906	82.98	427	10178	269	35060	215152	38193
06-07	1849.6	591.6	2	2443.2	11331	87.14	465	10593	276	37891	223370	39872
07-08	1878.0	591.6	2	2445.2	12050	90.33	470	10650	281	38227	234252	43401

With the enormous increase in world energy prices, the economy of Kerala is struggling to cope with increases in production costs. Simultaneously, due to lack of addition of new generation capacity, Kerala is suffering from power shortages. Energy conservation (EC) has been widely acclaimed as the most cost-effective way to mitigate power shortages.

Power System in Kerala is comprised of hydro, thermal and wind sources. Hydro energy is the most reliable and dependable source in Kerala. Of the total installed capacity of 2746.19 MW, the major share of 1933 MW comes from 24 hydro stations; 783.11 MW is contributed by the thermal projects including NTPC at Kayamkulam which is Kerala's dedicated thermal station. Kanjikode Wind Farm in Palakkad has an installed capacity of 2.03 MW. Wind Energy from IPP is 28.05 MW. Capacity addition during 2009-10 was only 51.44 MW (1.9 %) to 2746.19 MW as on 31-3-2010 from 2694.75 MW on 31-3-2009. Table 10 depicts details of energy source and its installed capacity in Kerala as on 31-3-2010.

Table 10
Energy Source and its Installed Capacity in Kerala

Source of Energy	MW
Hydro – KSEB	1893.00
Thermal – KSEB	234.60
Wind – KSEB	2.03
NTPC	359.58
Thermal –IPP	188.93
Hydro Captive	33.00
Hydro – IPP	7.00
Wind – IPP	28.05

Hydro Power

Power generation in Kerala is largely from hydro resources. One of the peculiar attributes of the state is the network of river systems originating from the Western Ghats, although majority of them are short rapid ones with low discharges. Among the 44 rivers, 41 flows west to join the Arabian Sea, while 3 flows eastward and joins the River Cauvery finally discharging into the Bay of Bengal. According to an estimate, Kerala with a total catchment area of 32,820 sq.km have 78,000 M^3 surface water potential and total runoff of about 59,160 M^3. The undulating terrain and heavy precipitation in monsoon are some of the best factors utilizable for power generation in the state. As early as 1910, a small hydroelectric station was established in the state by the erstwhile princely State of Travancore. The Government of India augmented it as Pallivasal hydroelectric project in 1940 with an installed capacity of 13,500 KW (Public Works Department, 1974). In the year 1957, Government of Kerala established Kerala State Electricity Board (KSEB), as the main electric power generation agency in Kerala, which timely improved the power generating capacity of the state. At present, Kerala power system includes twenty-four hydro stations, two captive power plants, two thermal stations, three IPPs, five major interstate transmission lines, one 400 KV substation and two 220 KV substations with interconnecting grid. The total power generation capacity of the hydroelectric projects are 1875.6 MW, which produces 7174.28 MU of energy that amounts to 71 per cent of total power, and 60.07 per cent of the total energy generated by KSEB.

Thermal power

Kerala's thermal power stations have an internal generation potential of 4764 MU/771.62 MW, which in turn constitutes 30% of the total power, and 39.89 per cent of the total energy generation by KSEB. Brahmapuram Diesel Power Project was commissioned during the year 1998, followed by the commissioning of Kozhikode Diesel Power Project at Nallalam. The third thermal power project of NTPC at Kayamkulam was also synchronized to the grid in 1999. The power output from the Kayamkulam Power Plant is available exclusively to Kerala.

Wind Power

Wind farms are considered as potential 'green energy' generators. Several locations in Kerala are identified as ideal for setting up wind energy farms. The main wind areas in the state are the eastern mountainous regions of Idukki district along the border of Tamil Nadu and elevated areas in Palakkad. An installed capacity of 890 MW and 1026 MW are estimated in 30m and 50m levels respectively. The technically feasible wind potential of the state is estimated as around 605 MW, assuming 20% grid penetration and limited to 16 potential locations in Palakkad, Idukki and Thiruvananthapuram districts, where the wind power density is above 150 Watts/m2. Agency for Non-conventional Energy and Rural Technology (ANERT), Kerala has identified Ramakkalmedu as another potential area for wind energy extraction. The program is to be implemented jointly by ANERT and Centre for Wind Energy Technology (C-WET), Chennai. These projects are currently being implemented, but land related problems plague faster implementation.

ENERGY-ENVIRONMENT LINKAGES

In India, environmental pollution is a major problem due to increase in industrial activities and energy production and consumption, laxity in enforcement of pollution control regulations. Anthropogenic air pollution has rapidly increased since industrialization began. Many volatile organic compounds (VOCs) and trace metals are emitted into the atmosphere by human activities. The pollutants emitted into the atmosphere do not remain confined to the area near the source of emission or to the local environment and have got transported over long distances and created environmental problems. The industrial sector worldwide is responsible for about one-third of anthropogenic emissions of carbon dioxide, the most important among the GHGs. Opportunities exist for substantially reducing industrial emissions through more efficient production and use of energy, fuel substitutions, use of alternative energy technologies, process modification, and revising material strategies to make use of less energy. Natural resource degradation, pollution, and loss of biodiversity are detrimental because they increase vulnerability, undermine system health, and reduce resilience. The environmental issues when non-renewable energy is used could be global and transnational such as climate change, ozone layer depletion, etc, in addition to loss of natural habitats, lands lost on agriculture, and depletion of water resources in river basins, aquifers, and in water sheds.

As far as Kerala is concerned, even though hydroelectric power has been the major contributor of electricity for use in the state, and it has been the cheapest, less polluting and easily available source. But, large hydro power development has its own flaws. Hydropower generating stations in Kerala are located in different parts of the Western Ghats, one of the biodiversity hotspots of the world. Most of the projects were completed prior to the Environmental Impact Assessment (EIA) notification came into effect and therefore such issues were not under serious consideration then. In the case of hydroelectric projects, submergence of vast area of forests and collateral damages due to the activities of labor force involved in the construction of projects, and movement of men and machinery are the immediate effects noticed as undesirable. Increased human settlements in Idukki after the construction of the dam have altered the ecology of the entire area. A study conducted by Pandurangan and Nair (1996) revealed the deterioration of 33% of forest cover in the area. Displacement and rehabilitation of population in the catchments is another major impact of the hydroelectric projects. In certain cases, triggering of tremors are the most feared consequences of hydro projects. Reservoir Triggered Seismicity (RTS) are reported from various dam sites all over the world. In India, similar cases were observed from Koyna dam, Maharashtra (Gupta 2005). Tremors have been reported from 1988 to 2000 from Idukki hydroelectric project area, though not of any serious nature.

Impact of thermal power plants on environment is reported globally. Air emissions (toxic gases and fly ash), thermal pollution of water, noise pollution, solid waste and the resultant biological problems are the immediate effects of thermal power plants. The exhaust gases from burning coal and oil contain primarily particulates, sulphur and nitrogen oxides (SOx and NOx) and volatile organic compounds (VOCs). An estimate shows that a 500 MW plant using coal with 2.5% sulphur, 16% ash and 30,000 kJ/kg heat content will emit each day 200 metric tonnes of sulphur dioxide (SO2), 70 tonnes of nitrogen dioxide (NO2) and 500 tonnes of fly ash if no controls are present. In addition, the plant will generate about 500 tonnes of solid waste and about 17 GWh of thermal discharge (Pollution Prevention and Abatement Handbook 1998). The hot water released from the thermal plants into the rivers result in reduced dissolved oxygen (DO) content in the water and causes death of aquatic flora and fauna. Among the developing countries, Republic of China and India use large amounts of coal for power generation. Indian coal used in power stations contains high ash content with an average value of about 35-40% resulting in the generation of large amounts (100 million tonnes/year) of fly ash.

The most important environmental advantages of the wind energy are reduced impacts on human health locally, declining risk of acid deposition and land degradation regionally, and decreased risk of climate change globally. However, in spite of the benefits some limitations are also noticed in the case of wind farms. Several bird kills, especially migratory birds, are reported in the windy mountain passes, where most of the wind farms are located (Australian Wind Energy Association 2005). Noise pollution is another demerit of wind farms.

Harvesting solar power through Solar Photo Voltaic cells is not currently very cost effective, except in isolated hamlets and remote areas. The maintenance of PV cells and accessories such as storage batteries is also expensive. The cost of electricity generation from SPV on a life cycle basis is higher compared to coal-fired thermal power. The negative impacts of SPVs on environment are insidious; the mass production of PV cells can release highly toxic substances and other compounds. Biomass based power generation offers better environmental benefits such as reclamation of degraded land, improvement in land productivity, and lower level net emissions of green house gases and other pollutants such as particulates and SOx. Organized production of wood fuels (through commercial /cooperative sector) and modernized conversion has potential to make it a competitive commercial fuel. Energy plantation for biomass generation has become a means to restore deforested and degraded lands in tropical and subtropical regions.

The alternative for the clean energy utilization can be achieved through Green energy tapping and energy conservation mechanisms. The green energy tapping can be an alternative and substitute for the development with less environmental implications and energy conservation helps in minimizing the wastage of the energy. Hence tapping green energy to the extent possible has to be done along with energy conservation activities.

USE OF GREEN ENERGY

Over the last three decades, the Renewable Energy Programme in India had three distinct phases. In the first phase, from the late '70s to the early '80s, the thrust was directed towards capacity building and R&D, largely in national laboratories and educational institutions. The second phase, from early '80s to the end of 80s, witnessed a major expansion with accent on large-scale demonstration and subsidy driven extension activities mainly in the field of biogas, improved cook stoves and solar energy. These programmes created awareness and also generated field experience. The Extension Programme, particularly in the areas of biogas and improved woodstoves (chulhas), generated a vast network of institutions and non-government organizations, right down to the level of self-employed workers and organizations at the grassroots level. In the third (current phase), extending from the beginning of the 90s, the emphasis has been more on application of matured technologies for power generation, based on wind, small hydro, biogas cogeneration and other biomass systems, as well as for industrial applications of solar and other forms of energy. There is also a gradual shift from the subsidy driven mode to commercially driven activity in the area. Renewable energy applications have brought about significant changes in the Indian energy scenario. Apart from electricity generation, the application of these technologies has benefited millions of rural households by meeting their cooking and other energy requirements in an environmentally benign way. The social and economic benefits include reduction in drudgery among rural women engaged in the collection of fuel wood and cooking in smoky kitchens, minimization of the risks of contracting lung and eye ailments, reduction in deforestation, employment generation at village level and ultimately the improvement in the standard of living and creation of opportunity for economic activities at village level. There is a large potential for renewable energy in India, an estimated aggregate of over 100,000 MW. As against the estimated 85,000 MWe renewable energy based grid connected power generation potential in the country, so far only about 9372.5 MW installed capacity has been achieved. The renewable energy based power generation capacity presently constitutes 7% of the total installed capacity in the country for power generation from all sources. The country is aiming to achieve up to 10% of additional installed capacity to be set up till 2012 to come from renewable energy sources.

Energy from Waste

Energy recovery from urban waste has enormously increased. The technologies for recovery of energy from wastes not only reduce the quantity but also improve the quality of waste to meet the required pollution control standards, besides generating a substantial quantity of energy. According to estimates, about 42 million tonnes of solid waste (1.15 lakh tonnes per day) and 6000 million cubic metres of liquid waste are generated every year in urban areas. This translates into a potential for generation of over 1700 MW of power. The estimated potential of energy recovery from Municipal Solid Waste (MSW) over the next 5 years is given in Table 11.

Table 11
Estimates and projection of Solid Wastes and Potential for Power

Period	Projected MSW generation (TPD)	Potential for power generation (MW)
2012	215000	3650
2017	304000	5200

The major benefits of recovery of energy from MSW are to bring about reduction in the quantity of waste by 60 to 90%; reduction in the demand for land for landfill sites; and, net reduction in environmental pollution, besides generation of substantial quantity of energy.

New Technologies

The recently emerged environmentally friendly technologies are

- Hydrogen Energy and Fuel Cells
- Geothermal Energy
- Tidal Energy
- Wave energy
- Alternative Fuels for Surface Transportation and Biofuel
- Hydrokinetic power
- Improved gas generation from biowastes with power generation potential

ENERGY CONSERVATION AND ENERGY EFFICIENCY

Energy Conservation and Energy Efficiency are different things, but akin to one another. Energy conservation is achieved when quantum of energy consumption is reduced in physical terms. Energy conservation, therefore, is the result of several processes or developments, such as productivity increase or technological progress. On the other hand energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.

Energy efficiency provides additional economic value by preserving the resource base and reducing pollution. For example, replacing traditional light bulbs with Compact Fluorescent Lamps (CFLs) means you will use only 1/4th of the energy to light a room. Pollution levels also reduce by the same amount. In order to implement the energy conservation and inducting green energy, a strategy has to be formulated. In certain scenarios, Light Emitting Diode (LED) lamps are also an acceptable solution.

Strategy for Energy Saving

In the energy generation process, there are impacts on the environment on local, national, and international levels, from opencast mining and oil exploration to emissions of the potent GHGs - carbon dioxide in ever-increasing concentration. The Intergovernmental Panel on Climate Change has concluded that “the balance of evidence suggests a discernible human influence on global climate.” It pinpoints a rate of warming greater than any seen in the past 10,000 years. The exact impact of climate change is difficult to predict and will vary regionally. It could, however, include sea level rise, disrupted agriculture and food supplies, and possibility of more freak weather events such as hurricanes and droughts. Indeed, people already are waking up to the financial, social, as well as the environmental risks of unsustainable energy generation methods that represent the costs of the impacts of climate change, acid rain, and oil spills.

The key priorities of an energy policy must be to reduce fossil fuel use, move away from nuclear power, improve the efficiency with which energy is used, and increase the amount of energy obtainable from sustainable, renewable sources. Efficient energy use has never been more crucial than it is today, particularly with the prospect of the imminent introduction of the climate change levy. Establishing an energy use action plan is the essential foundation to the elimination of energy waste. A logical starting point is to carry out an energy audit that enables the assessment of the energy use and determine what actions to be taken.

Establishing an energy saving strategy is the essential foundation to the elimination of energy waste. In the process of developing a strategy, there are two options to manage energy resources.

- End-use matching/demand side management, which focuses on the utilities. The mode of obtaining this is decided based on economic terms. It is, therefore, a quantitative approach.

- Supply side management, which focuses on the renewable energy resource and methods of utilizing it. This is decided based on thermodynamic consideration having the resource-user temperature or energy destruction as the objective criteria. It is, therefore, a qualitative approach.

In order to attain the maximum energy conservation various types of activities are essential, some of which are as follows:

- Public awareness, capacity building and training programmes.
- Innovative energy strategies.
- Renewable energy sources and cleaner technologies.
- Adequate Financing.
- Monitoring and evaluation tools.

INSTITUTIONAL AND REGULATORY FRAMEWORK FOR ENERGY CONSERVATION IN INDIA

Institutional Framework

The importance of energy efficiency in the development of India was recognized as early as 1972 in the Fuel Policy Committee Report, and continued in the years that followed. The 1970s saw the growth of the national petroleum conservation programmes developed by the Petroleum Conservation Research Association (PCRA), an organization supported by the oil companies. The Indian Oil Corporation Ltd. was the leader, and the National Productivity Council (NPC) provided early technical support. In the 1980s bilateral co-operation such as with the Department for International Development, UK (DFID), German Federal Ministry for Economic Cooperation and Development, and the United States Agency for International Development (USAID) provided technical assistance to India's efforts at promoting and developing energy efficiency training and extension services. The objective was to spread awareness, create institutional capacity and provide energy audit diagnostics services.

The Energy and Resources Institute (TERI), the National Productivity Council (NPC), and the Association of Indian Engineering Industries (AIEI), later renamed to the Confederation of Indian Industries (CII), and the Industrial Credit and Investment Corporation of India (ICICI) were some of the earliest domestic agencies that pursued the design and delivery of energy efficiency services way back in 1964, well before the energy crisis, and was responsible for some of the earliest institutional initiatives. The landmark 1982 Inter-Ministerial Working Group Reports on Energy Conservation–Policies and Programmes, recognized the need for bilateral and multilateral support for bringing energy efficiency in various sectors. Later, in 1984, the Energy Management Centre in the Ministry of Power was created, followed by the Bureau of Energy Efficiency (BEE). Mid-1990s saw a renewed interest promoting energy efficiency through technical assistance and training activities aimed at exposing Indian enterprises to management and technological advance in the West.

India, the sixth largest and second fastest growing producer of GHG, showed renewed interest in promoting energy efficiency to mitigate the impact of climate change. Energy efficiency programmes in India received a further impetus through the line of credit from the World Bank / Global Environment Facility (GEF) to Indian Renewable Energy Development Agency (IREDA) to finance energy efficiency projects and develop the system of delivery through energy service companies (ESCOs). This complemented the other lines of credit provided by ADB (Asian Development Bank) through Indian development financial institutions such as the Industrial Development Bank of India (IDBI) and ICICI Bank to finance energy efficiency as part of the industrial modernization investment. More importantly, the early part of this millennium coincided with the successful passage of the Energy Conservation Act in 2001 with the responsibility for its implementation vested with the BEE.

Regulatory framework

The Energy Conservation Act, 2001. With the background of high energy saving potential and its benefits, bridging the gap between demand and supply, reducing environmental emissions through energy saving, and to effectively overcome the barrier, the Government of India has enacted the Energy Conservation Act 2001. The Act provides the much-needed legal framework and institutional arrangement for embarking on an energy efficiency drive. Under the provisions of the Act, Bureau of Energy Efficiency has been established with effect from 1st March 2002 by merging erstwhile Energy Management Centre of Ministry of Power. The Bureau is responsible for implementation of policy, programmes and coordination of implementation of energy conservation activities. Important features of the Energy Conservation Act are:

Standards and Labeling

Standards and Labeling have been identified as a key activity for energy efficiency improvement. The programme, which is in place is to ensure that only energy efficient equipment and appliance would be made available to the consumers.

Certification of Energy Managers and Accreditation of Energy Auditing Firms

A cadre of professionally qualified energy managers and auditors with expertise in policy analysis, project management, financing and implementation of energy efficiency projects would be developed through Certification and Accreditation programme. BEE designs training modules, and conduct a National level examination for certification of energy managers and energy auditors.

Energy Conservation Building Codes

The main provisions of the EC Act on Energy Conservation Building Codes are:

- Prepare guidelines for Energy Conservation Building Codes (ECBC).These would be notified to suit local climate conditions or other compelling factors by the respective states for commercial buildings erected after the rules relating to energy conservation building codes have been notified. In addition, these buildings should have a connected load of 500 kW or contract demand of 600 kVA and above and are intended to be used for commercial purposes.

- Energy audit of specific designated commercial building consumers (>500 kW)

Central Energy Conservation Fund

The fund would be set up at the Centre to develop the delivery mechanism for large-scale adoption of energy efficiency services such as performance contracting and promotion of energy service companies. The fund is expected to give a thrust to R & D and demonstration in order to boost market penetration of efficient equipment and appliances. It would support the creation of facilities for testing and development and to promote consumer awareness.

Role of Central and State Governments

The role of Central and State Government envisaged in the Act are: Central government is to notify rules and regulations under various provisions of the Act, provide initial financial assistance to BEE and EC fund, coordinate with various state Governments for notification, enforcement, penalties and adjudication. State governments are to amend energy conservation building codes to suit the regional and local climatic condition, to designate state level agency to coordinate, regulate and enforce provisions of the Act and constitute a State Energy Conservation Fund for promotion of energy efficiency.

Electricity Act 2003

The Indian Parliament also passed the Electricity Act in 2003. It consolidated laws related to generation, transmission, distribution, trade and use of electricity. Among other things, it called for rationalization of electricity tariffs, creation of a competitive environment, and open access in transmission and distribution of electricity. The Act also mandated the creation of Regulatory Commissions at the central, regional and state levels. As a consequence, the electric utility system is being unbundled, tariffs are being rationalized, and regulatory commissions are playing an active role in enforcement of bill collection and the promotion of demand supply management programmes in some of the states.

Recommendations of "Integrated Energy Policy-2006"

The policy prepared by Planning Commission, Government of India has following specific recommendations

- The BEE should be made an autonomous statutory body under the Energy Conservation Act and be independent of all the energy ministries. It should be funded by the Central Government.
- Existing national energy efficiency organizations like the Petroleum Conservation Research Association (PCRA) should be merged with the BEE. This will ensure that the BEE is responsible for energy efficiency for all sectors and all end-uses.
- Based on the recommendations of the merged autonomous body the government could directly provide funding support to financial institutions for promoting energy efficiency programmes.

- Energy efficiency and conservation programmes and standards should be established and enforced. The BEE should develop such standards for all energy intensive industries and appliances as well as develop modalities for a system of incentives/penalties for compliance/non-compliance. These standards should be at levels equal to or near current international norms.
- Mechanisms for independent monitoring and verification of achieved energy savings and the cost effectiveness of programmes must be established. Evaluation reports should be quantitative and made publicly available. An annual report of the investments and savings made through specific energy efficiency and DSM programmes should be prepared by the BEE and reported to the Parliament.The feedback from the monitoring exercises should help in modifying programme designs.
- Truthful labeling must be enforced with major financial repercussions if equipment fails to deliver stated efficiencies. In extreme cases, one can resort to black listing errant suppliers at consumer information websites and on government procurement rosters.
- Verification and labeling requires testing laboratories. A programme for setting up such laboratories in public, private and the NGO sectors is needed.
- National Building Codes should be revised to facilitate and encourage energy efficient buildings.
- Large scope exists to make buildings energy efficient. Construction materials are energy intensive and the use of appropriate materials and design can save a significant amount of energy not only in construction but also during use by building occupants. Innovative and energy efficient building technologies should be widely publicized through an annual prize. Reducing energy need for heating and cooling by orientation, insulation and using temperature differences in earth or water at some depth could also be significant.
- Improvement in energy efficiency and DSM require actions by a large number of persons and institutions. To mobilize them, the first task is to create awareness of the scope of possibilities and the extent of gains one can make through such measures.
- Promote and facilitate energy service companies (ESCOs) that can identify energy saving options and provide technical support needed or execution to industries and commercial establishments.

A study recently on the potential of carbon emission reduction in 37 public sector industries in Kerala, has revealed in 10 of them alone, in addition to saving large chunks of energy, 1,83,373 tonnes of GHG emissions/year could be saved. This works out to 61% of the estimated GHG mitigation potential in the State [Study carried out by Ottotractions, Kochi for the Department of Environment and Climate Change, Govt. of Kerala].

RECOMMENDATIONS

1. Considering the several factors under review above, it is clear that further development of energy in Kerala has to be done only with due consideration of all the factors that would affect the environment adversely, and following a sustainable course. Emphasis will have to be on alternatives in view of the special circumstances prevailing in the State.
2. The dependence on biomass for cooking energy entirely or partially by three fourth of households in Kerala have to be brought down through technology up-gradation for biomass use, increased use of gas for cooking including piped supply of cooking gas in urban areas, and re-cycling of wastes, including the introduction of domestic level high efficiency bio-digesters, high efficiency gasifier stoves, etc.
3. For small industrial and commercial uses biomass may have to adopt more efficient technologies of energy conversion, such as gasification of coconut shell, weeds and agro-wastes etc. Hydropower contribution to the grid through large projects for tapping the remaining potential is beset with problems and hence dependence on small hydropower, hydrokinetic generation etc may have to be resorted. Such projects can be successfully implemented in several tributaries of Kerala’s rivers, with least environmental impacts because of low land requirements and low cost. It is also possible to raise funds locally to a great extent for their accomplishment. Negligible T&D loss, local operation and maintenance are added advantages.
4. The potential for wind energy development have to be fully developed.
5. Other renewable energy technologies like solar thermal and solar photovoltaic, energy from the sea, fuel cell, hydrogen, recovery of energy from municipal and industrial wastes will have to be selectively deployed with the twin objectives of protection of environment and distributed generation of electric power.
6. Coal as a source of power is out of question for meeting energy demands of the State, even with current high temperature, high efficiency route.
7. Increased dependence on natural gas, even through importation and interstate pipeline, for industrial as well as for power production may be required and efforts in this line will have to be pursued vigorously.
8. On the demand side management, more efficient use of power and petroleum products will have to be compulsorily resorted to. Labelling and standards for energy related products will have to be relied.
9. Changes in the building design and architecture can also help in saving electric energy resources. Green building approach will have to be encouraged.
10. Benefits through Smart Grid technology may help in ensuring higher efficiency in energy production, transmission and use.
11. The most important step to be adopted in conserving power is to promote usage of energy efficient gadgets. Of these, the easiest is the Compact Fluorescent

Lamps (CFL). If majority of the lighting requirements are met using CFL that will lead to considerable energy saving. Later years may see lighting using LED, which will further help in saving electricity.

12. Though much needs to be done, Kerala remains the first state to establish a State Energy Management Centre (EMC), and coordinate activities related to targeted energy conservation. Kerala has established an Energy Conservation Fund.
13. EMC has been designated as the Nodal Institution of the BEE in the State. The CFL programme under BYL has been implemented with the utmost expediency (replacing 2 numbers of 60 W bulbs per house), saving around 300 MW of peak power, involving the participation of 83% of households under this scheme.
14. Success of developing a healthy interface of Energy and Environment requires extensive awareness programmes. In Kerala, students and housewives as well as the general public have been involved in such programmes on energy and environment for a number of years through the activities of several NGOs like KSSP, ECS, CED etc and through the regular activities of government promoted agencies like KSEB, ANERT, Pollution Control Board and EMC. However, there is still the need for such activities to be continued and strengthened.

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Special Address

Energy Scenario in India

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INTRODUCTION

India's per capita energy and electricity consumptions are less than one tenth of developed countries' per capita consumption. The disparities in urban vs rural; southern, western and northern region vs eastern and north-eastern region; and higher income vs lower income households are very high. Unfortunately, the regions where large fossil and renewable energy sources are available have lower per capita energy consumption. For sustainable and equitable socio-economic development such a situation needs to change.

Given the country's over dependence on coal, large scale import of oil and gas, difficulty in meeting the financial burden of import, environmental consequences of large scale energy production, transformation, transportation and use, it is not wise to strive to achieve the developed country level of energy consumption. To improve the quality of life of Indian citizens, there is no doubt that per capita energy consumption has to increase. Through judicious approach, higher quality of life can be achieved with moderate increase in energy consumption.

The country needs to make timely change of our emphasis on non-renewable energy. Such a change in strategy calls for a paradigm shift in our development approach, i.e. from an unsustainable growth oriented economic development to an environmental friendly equitable development. Since three most serious environment related problems (global warming, acid rain and ozone layer depletion) owe their origin to energy, it is in our national and global interest that we minimise 'energy want' without sacrificing the 'energy need' for a decent quality of life. A time-bound plan is essential to move to 'renewable energy dominant decentralised system' from the existing 'non-renewable energy focused, fossil fuel-centric centralised system'.

Energy is essential for every activity of life. There is a strong positive correlation between energy use and the quality of life. At global level, per capita income of a country is directly proportional to the per capita energy consumption (Table 1). Similar trend is also observed in the states of India as well (Table 2 and Fig. 1).

Table 1
Socio-economic Indicator for Selected Countries (2008)

Country	Population (Million)	GDP (at 2000 USD ppp)/Capita	Total Primary Energy Supply (kgoe)/Capita	Electricity Consumption (kWh)/Capita
India	1139.97	724.4	540	566
China	1325.64	1963.3	1600	2453
Japan	127.69	40459.5	3880	8072
Germany	82.12	25513.6	4080	7148
US	304.53	38558.7	7500	13647
Sri Lanka	20.16	1198.9	440	409

Source: IEA, 2010, Key World Energy Statistics, pp. 48-57

Table 2
Per Capita GSDP and Electricity Consumption in the States and Country (2006/07)

State	Electricity (kWh)/Capita	GDP (Rs)/ Capita	State	Electricity (kWh)/ Capita	GDP (Rs)/ Capita
Andhra Pradesh	**802**	30485	Manipur	195	18746
Arunachal Pradesh	299	20601	Meghalaya	547	30660
Assam	175	21607	Mizoram	250	24680
Bihar	91	9600	Nagaland	173	26863
Jharkhand	659	23361	Orissa	665	19407
Goa	2098	92010	Punjab	1506	42984
Gujarat	1331	50282	Rajasthan	591	21979
Haryana	1208	47613	Sikkim	533	28307
Himachal Pradesh	872	42391	Tamilnadu	1080	48468
J & K	759	24625	Tripura	179	20628
Karnataka	806	35818	Uttar Pradesh	341	16756
Kerala	441	37372	Uttaranchal	707	30362
Madhya Pradesh	582	19650	West Bengal	397	29440
Chhatisgarh	935	24921	Delhi	1417	76087
Maharashtra	975	44634	India	672	31605

Source: TEDDY 2010 and Wikipedia

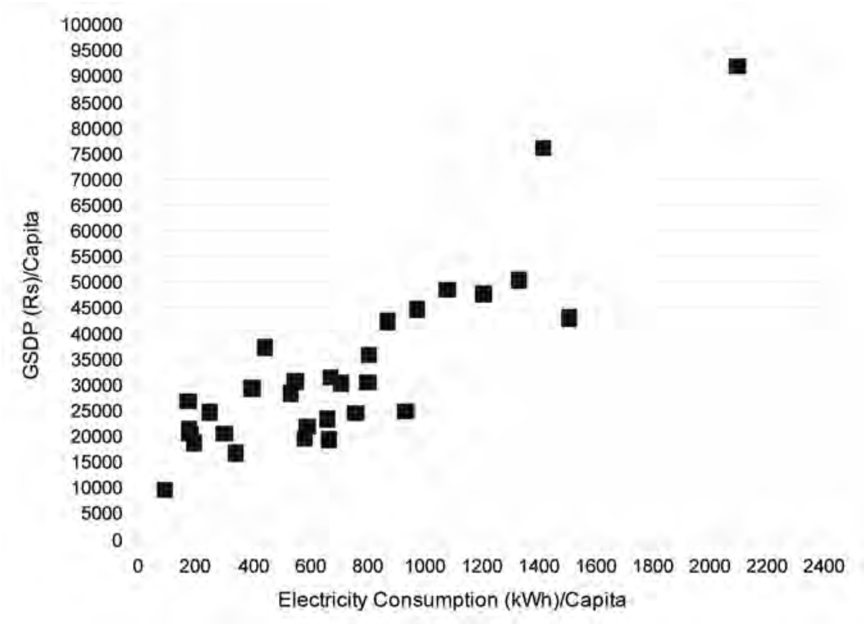


Fig. 1
Per Capita Electricity Consumption and GSDP
in the States and Country (2006/07)

All of the energy sources that we use, except geothermal and nuclear energies, are derived initially from solar energy.

The fossil fuels (coal, oil, and natural gas) are derived from organisms primarily (ocean plankton) that grew over several hundreds of millions of years, storing the solar energy which reached the earth's surface. Renewable energies (hydro, biomass, and wind) are also directly or indirectly derived from the energy of our sun. Solar energy, though technically not renewable, is normally classified as such because it is effectively inexhaustible on any practical timescale. Nuclear energy is derived from uranium nuclei contained in the earth. This element was formed in heavy stars and was scattered in space when those stars died. Uranium nuclei were present in the dust from which the solar system was formed about 4.5 billion years ago. The earth formed by accretion of such dust and some thermal energy due to this process still remains. However, most of the thermal energy contained in the earth comes from the decay of radio-active nuclei present in the earth and initially produced in stars (Ngo and Natowitz, 2009).

Energy used can be broadly divided into commercial and non-commercial form. Commercial energy, i.e. traded in the market, includes coal, oil, gas, electricity and in some cases biomass. Non-commercial energy includes mostly biomass that is used for cooking, predominantly by the rural communities. Accurate and more recent data on non-commercial energy use in the country is not available. In 2000, India's energy mix was 65% commercial and 35% non-commercial (TEDDY 2010, pp 2). Considering the stage of transformation, energy can also be classified as primary (coal, crude oil, natural gas, water, geothermal, wind, solar heat, biomass, etc.), secondary (steam, chilled water, petrol, diesel, biogas, hydro-electricity, solar electricity, etc.) and tertiary type (electricity). Primary energy sources are those that present prior to any human-induced modification. Higher energy sources are obtained from the transformation of lower sources.

Higher form of energy has advantages of cleanliness, ease of operation and control, and obviously expensive. A number of political, economic, social, technological, legal and ecological factors play a critical role in ensuring access to and use of right quantity and quality of energy by the people.

According to the Dy Chairman, Planning Commission (2006), the present energy scenario in India is not satisfactory.

The power supply position prevailing in the country is characterised by persistent shortages and unreliability and also high prices for industrial consumer. There is also concern about the position regarding petrolium products. We depend to the extent of 70 percent on imported oil, and this naturally raises issues about energy security. These concerns have been exacerbated by recent movements in international oil prices. Electricity is domestically produced but its supply depends upon availability of coal, exploitation of hydro power sources and the scope for expanding nuclear power, and there are constraints affecting each source.

In this paper an attempt has been made to study the energy scene of the country in the context of ensuring energy security and sustainable development of the people. In the next section, available energy resources of the country is presented. In Section 3, energy used by different sectors is discussed. In Section 4, the supply and demand side problems of energy are covered and possible strategies for energy security are suggested.

ENERGY RESOURCES OF INDIA

India has all the possible sources of energy. These include all forms of non-renewable and renewable energy sources. However, the energy sources are not uniformly distributed. Table 3 indicates the energy sources in major locations of the country.

According to BP Statistical Review of World Energy, India has the third largest proven coal reserves totaling 58600 million tonnes, and the country's reserve-to-production ratio (R/P) is 105. In 2008/09, the coal and lignite production in the country was 525 million tonnes (TEDDY 2010, pp 4-5).

The total oil reserve in the country was estimated to be 786 million tonnes in 2004-05. The proven reserve-to-production ratio was 23 in 2004-05 (Planning Commission 2006). In 2009-10 the crude oil production was 33.67 million tonnes (TEDDY 2010, pp 86). In 2009-10, 79% of the country's consumption was imported. The crude oil import bill amounting to Rs 3753 billion in 2009/10 put a huge burden on the economy.

Table 3
Key Location of Energy Sources

Energy Source	Key location	Remark
Coal	Jharkhand, Odisha, Chhatisgarh, West Bengal, Andhra Pradesh, Madhya Pradesh, Maharastra	Jharkhand, Odisha and Chhatisgarh constitute 69% of total reserve as on 1 April 2010
Oil	Onshore: Assam, Nagaland, Gujarat, Rajasthan Offshore: Andhra Pradesh, Tamil Nadu, Bombay High	94% of onshore production from the four states in 2009-10.
Gas	Assam, Nagaland, Gujarat, Andhra Pradesh, Tamil Nadu, Rajasthan, Tripura	89% of gas production from Assam, Nagaland, Gujarat, Andhra Pradesh, Tamil Nadu
Hydro-electricity	All the regions of India	76% identified capacity in North-eastern and Northern region
Electricity (hydro and thermal)	All the regions of India	Thermal power plants are concentrated in coal rich states
Uranium and Thorium	Uranium in Jharkhand and Rajasthan Thorium in coastal Odisha, Kerala, Andhra Pradesh and Tamil Nadu	
Wind Energy	Karnataka, Gujarat, Tamil Nadu, Rajasthan, Maharastra, Kerala, Madhya Pradesh, Andhra Pradesh, Odisha, West Bengal	77% of gross potential in Karnataka, Gujarat, Tamil Nadu, Rajasthan and Maharastra
Biomass Energy	All the regions of India	
Solar Energy	All the regions of India	More prominent in Rajasthan desert because of cheap land availability
Geothermal Energy	Chhatisgarh, Jammu and Kashmir, Madhya Pradesh	
Biogas Energy	All the regions of India	

Source: TEDDY 2010

According to the 2008 BP Statistical Energy Survey, in 2007, India had proven natural gas reserves of 1.05 trillion cubic meters, 0.59% of the world total (mbendi, 2010). In 2009-10 the natural gas production was 47.57 BCM (TEDDY 2010, pp 89). The proven reserve-to-production ratio is 22. Based on the discoveries made in recent years, the possibility of having large gas reserve in the sedimentary basins of the country appears to be high.

The estimated deposits of uranium and thorium in the country are respectively 70,000 tonnes and 360,000 tonnes. Since available uranium is of poor quality (0.06 to 0.07% of the ore) the reactors are designed to take advantage of large thorium deposits. The country has a plan to develop 20000 MW of nuclear capacity by 2020 and 63000 MW by 2032. It is expected that by 2050, 25% of electricity will be coming from nuclear power plants (TEDDY 2010, pp 122).

India has large potential for renewable energy exploitation. However, there is a wide gap between the potential and actual utilisation (Table 4). Technological constraints, high cost of production, weak institution and policy measures are coming in the way of large scale use of renewable energy.

Table 4
Renewable Energy Potential and Actual Achievement

Renewable Energy	Potential	Actual Installed Capacity (as on 31 March 2010)
Wind Power	45,195 MW	11, 807 MW
Bio-power and Bagasse Based Co-generation Power Project	21,881 MW	2,199 MW
Large Hydro Power (>25 MW)	1,48,701 MW	32,128 MW (Developed) 14,225 MW (Under Construction)
Small Hydro Power	15,000 MW	2,735 MW
Solid and Liquid Waste from Urban Areas	2,700 MW	12 MW
Biogas	12 million	4.2 million
Solar Water Heating	140 million m^2	3.53 million m^2
Solar PV System	50 MW/km^2	120 MW
Ocean Thermal Energy Conversion (OTEC)	300,000 MW	-
Wave Energy	40,000 MW	-
Tidal Energy	8,000 MW	-

Source: TEDDY 2010, pp 177, 188-190, 308

As on 30th June 2011, the country has a total installed electricity generating capacity of 176,990 MW, besides a grid connected captive capacity of 19,509 MW. Out of it, 115,650 MW is thermal (96,743 of coal fired, 17,706 MW of gas fired and 1200 MW of oil fired) power plants. Balance is contributed by nuclear (4780 MW), hydro-electric (38,106 MW) and renewable energy sources (18,455 MW) including small hydro, biomass gasifiers, urban and industrial waste power and solar. Based on the sources of primary energy for electricity production, the installed capacity mix of coal, hydro, gas, diesel, nuclear and renewable energy are 55%, 21.5%, 10%, 0.7%, 2.7% and 10% respectively (CEA, 2011).

Out of total generation of 766 Billion Units (BU) in 2009-10, the generation mix of thermal, hydro and nuclear sources were respectively 640.5 BU (84%), 106.6 BU (14%) and 18.6 BU (2%). The supply constrained demand of electricity had an energy deficit of 9.9% and peak power deficit of 12.6% in 2009/10 in the country. The state-wise electric energy and electric power deficit during 2008/09 are shown in Fig. 2 and Table 5 (TEDDY 2010, pp 167-170).

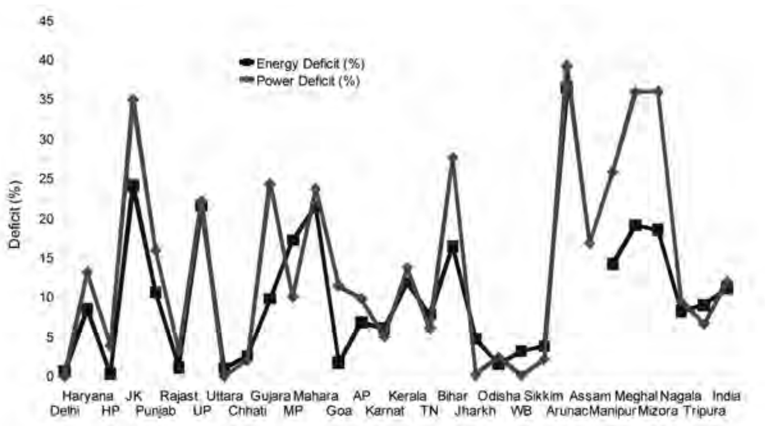


Fig. 2
Percentage Electric Power and Energy Deficit in 2008/09

Table 5
Electricity Supply Position in Different States (2008/09)

State	Peak Demand (MW)	Power Deficit (%)	Energy Available (MU)	Energy Deficit (%)
Delhi	4036	0	22273	0.6
Haryana	5511	13.1	26625	8.5
Himachal Pradesh	1055	3.9	6241	0.3
JK	2120	34.9	8698	24.1
Punjab	8690	15.9	37238	10.6
Rajasthan	6303	3.2	37388	1.1
Utar Pradesh	10587	22.1	54309	21.5
Uttarakhand	1267	0	7765	1
Chhatisgarh	2887	2	14475	2.6
Gujarat	11841	24.3	60851	9.8

Madhya Pradesh	7564	10	34841	17.2
Maharastra	18049	23.7	95761	21.4
Goa	466	11.4	2754	1.7
Andhra Pradesh	11083	9.8	66673	6.8
Karnataka	6892	5	40578	6
Kerala	3188	13.7	15562	11.8
Tamil Nadu	9799	6	64208	7.8
Bihar	1842	27.6	8801	16.4
Jharkhand	889	0.2	5110	4.7
Odisha	3062	2.4	20214	1.5
West Bengal	5387	0.1	30290	3.2
Sikkim	97	2.1	330	3.8
Arunachal Pradesh	130	39.2	271	36.4
Assam	958	16.8		
Manipur	128	25.8	477	14.2
Meghalaya	457	35.9	1386	19.1
Mizoram	100	36	269	18.5
Nagaland	95	9.5	436	8.2
Tripura	167	6.6	728	9
India	109809	11.9	691042	11.1

Source: TEDDY 2010, pp 167-170

ENERGY USE

The total commercial energy use in India in 2007/08 was 272.4 MTOE. Energy use in industry, transport, residential and commercial, agriculture, other energy use and non-energy use (fertiliser, petrochemical, etc.) were respectively 47%, 15%, 14%, 7%, 8% and 9% (TEDDY 2010, pp 3). In 2008, India's energy intensity of 0.14 kgoe/USD PPP is lower than that of China (0.2 kgoe/USD PPP) and US (0.19/USD PPP) (IEA, 2010).

The commercial energy consumption in India is highly dependent on coal. It contributes to about 53% in 2008-09. In the same year, the contribution of oil and gas were respectively 33% and 8%. Balance is from nuclear, hydro and other renewable energy sources.

492.8 MT of coal and 32.4 MT of lignite were produced in India in 2008-09. In the same year, 37.9 million tonnes of non-cooking coal and 21.08 MT of cooking coal were imported from Australia, Indonesia and South Africa. Simultaneously, India exported 1.7MT of coal to Bangladesh, Bhutan and Nepal. About 78% of coal is consumed by power sector. Balance is used mostly by cement (4%) and steel plants (18%).

156 MT of oil was consumed in the country in 2007-08. 75% of oil consumption was imported which accounted for 23.4% of total import bill and 6.3% of GDP of the country. Bulk of it is used in the transport sector.

32 billion cubic meter (BCM) of gas was consumed in the country in 2008-09. Out of it 65% was used for power generation. 24.3% of total gas consumed in the country is imported.

501,977.09 GWh of electricity was sold in the country with a connected load of 3,50,056 MW among 17,27,03,600 consumers in 2007-08 (Table 6, Fig. 3). In December 2010, the per capita electricity consumption in the country stood at 612 kWh (Wikipedia).

Table 6
Characteristics of Electricity Use in India (2007-08)

Consumer Segment	Electricity Consumed (%)	Connected Load (%)	Number of Consumers (%)
Domestic	24.1	38.3	77.2
Commercial	9.3	10.9	10.4
Industrial	37.7	27.7	2.2
Public Lighting	1.2	0.8	0.8
Traction	2.2	1.1	1.1
Agriculture	20.8	18.9	9.2
Public Works	2.3	1.2	1.2
Miscellaneous	2.3	1.1	1.1

Source: TEDDY 2010, pp 163-164

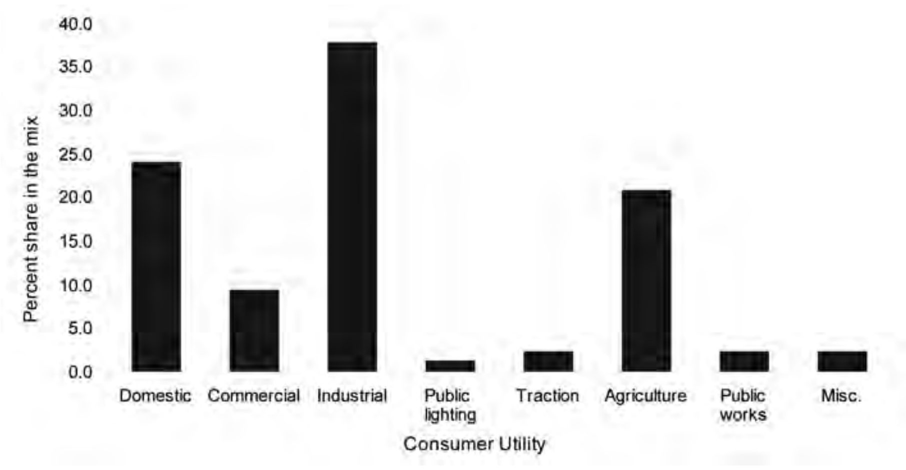


Fig. 3
Electricity Sales to Ultimate Consumer Utilities (2007-08)

As on 31 March 2008, out of 593732 villages in the country, 82.3% villages have been electrified. Similarly as on 31 November 2008, out of 138,271,559 rural households in the country, 44% of them are electrified (Table 7 and Fig. 4) (TEDDY 2010, pp 174-176).

Table 7
Extent of Village and Rural Household Electrified (March 2008)

State	% Electrified Village	% Electrified Rural Households	State	% Electrified Village	% Electrified Rural Households
Haryana	100	79	Kerala	100	66
Himachal Pradesh	98.2	94	Tamil Nadu	100	71
J&K	98.2	75	Bihar	52.9	5
Punjab	100	89	Jharkhand	31.1	10
Rajasthan	68.3	44	Odisha	55.8	19
Utar Pradesh	88.1	20	West Bengal	95.9	20
Uttarakhand	96.5	50	Sikkim	94.4	75
Chhatisgarh	95.6	46	Arunachal Pradesh	56.8	45
Gujarat	99.6	72	Assam	78.6	17
MP	96.3	62	Manipur	84.9	53
Mahararastra	88.3	65	Meghalaya		30
Goa	100	92	Mizoram	80.6	44
Andhra Pradesh	100	60	Nagaland	64.4	57
Karnataka	98.7	72	Tripura	57.2	32
			India	82.3	44

Source: TEDDY 2010, pp 174-176

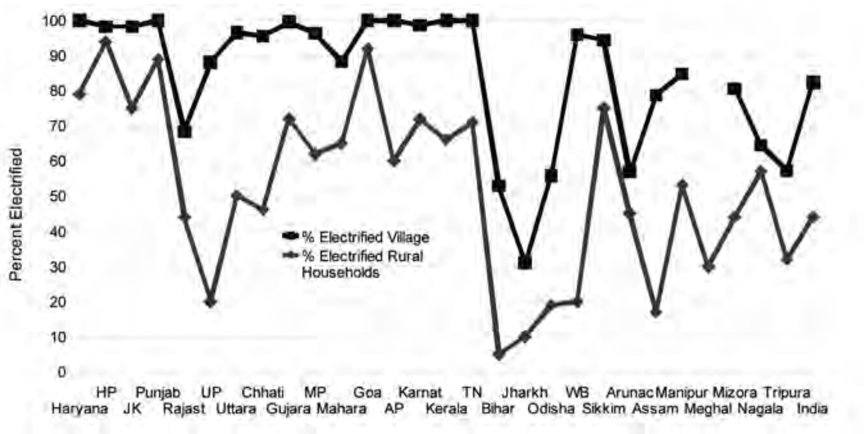


Fig. 4
Extent of Village and Rural Household Electrified

SUPPLY AND DEMAND SIDE FACTORS OF ENERGY MANAGEMENT IN INDIA

The per capita energy consumption in India in 2006 was 510 kgoe against 5416 kgoe for high income countries (World Bank, 2009). Energy consumption in India has been continuously increasing over the years. There is a large gap between actual demand and supply-constrained demand for energy in the country. A host of supply side and demand side factors influence the energy sector.

A. Supply-side Factors

Reliable and adequate supply of both commercial and non-commercial energy at an affordable price is a complex issue. It is difficult to develop appropriate supply-side strategies in the absence of reliable data, which often is the case for non-commercial energy. An analysis of factors affecting non-commercial energy cannot be neglected, since it constitutes a significant part of our energy mix. Although, no reliable recent data is available, against a commercial energy consumption of 191.6 MTOE in 2000-01 in the country; the non-commercial energy consumption was 80 MTOE in domestic sector and 23.5 MTOE in unorganised, small and cottage industries.

The commercial energy sector in India is highly dependent on fossil fuels. In 2007-08, about 89% of total primary energy supply is contributed by coal, oil and gas.

Although India has large coal reserve, it is faced with poor quality (high ash content and low calorific value), inefficient and expensive mining, environmental restrictions and poor labour relation. The environmental restriction include “application of the comprehensive environmental pollution index (CEPI), non-availability of forestry clearance against some of the projects, poor law and order situation in the states of Jharkhand and Odisha and excessive rainfall in the western part of the country” (Economic Survey 2010-11, pp 269). Since 90% of coal production in India is non-cooking coal type, for cooking coal in steel industry and steam coal for some thermal power plants, the country imports coal from Australia, South Africa and Indonesia. The imported coal was about 12% of country’s requirement in 2008-09. To ensure steady availability of right quality and quantity of coal in the country, the Government of India has initiated steps to acquire coal assets outside.

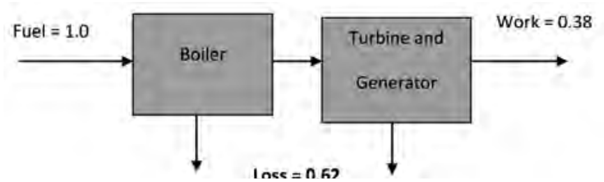
79% of India’s oil consumption is met through import. Crude oil import of Rs 3753 billion, accounted for 23.4% of import bill in 2007-08. In 2009-10, the crude oil production in the country was 33.7 MT and that of natural gas, including coal based methane was 47.51 BCM. According to the Economic Survey 2010-11 (pp 266), the production is expected to grow at about 12.5% for both oil and natural gas. To reduce demand supply gap, government has initiated steps to intensify exploration in different sedimentary basins of the country; import of liquefied natural gas (LNG); and acquire equity oil and gas assets overseas such as Sudan, Vietnam, Venezuela, Russia, Syria, Colombia and Brazil.

In India, both installed capacity and generation of electricity, are below the supply-constrained demand. The main reasons for shortfall in thermal power plant capacity addition include “delayed and non-sequential supply of materials by vendors, shortage of skilled manpower for construction and commissioning of projects, contractual disputes between project authorities, contractors and their sub-vendors, delay in readiness of balance of plants by the executing agencies, design problems and fuel shortage” (Economic Survey 2010-11, pp 263).

Large portion of India’s hydro-electric potential remains unutilised. About 54,364 MW comprising 93.16% of North-eastern region’s potential is yet to be developed. Similarly about 31043 MW comprising 59.4% of Northern region’s potential is yet to be developed (TEDDY 2010, pp 177). The key reasons for the slow development of hydro-power include difficult and inaccessible potential sites, difficulties in land acquisition, rehabilitation, environmental and forest-related issues, inter-state issues, geological surprises and contractual issues. However, the government has taken initiative related to life extension, upgrading and restoration of large hydro-electric projects.

India’s uranium is of poor quality and limited reserve. Till 2010, the country has entered agreements with Argentina, Canada, France, Japan, Mongolia, Namibia, Kazakhstan, Russia, UK and USA for the import of uranium fuel, reactors, nuclear equipment and technology. Considering the risks involved in nuclear power plants and strong opposition from civil society and different communities, it will be an uphill task to achieve government’s plan of developing 20,000 MW nuclear capacity by 2020.

There are various ways of energy conversion but some process waste more energy than other. One particular wasteful process is that of electricity generation in thermal power stations. A thermal power station normally transforms around 35% of the input primary energy into electricity. By using combined cycle, the efficiency can be improved up to 45-46% (Schwarz, 1983). In hot countries, like India, by reducing the inlet air temperature through absorption chiller, the combined cycle power plant efficiency can be improved. Further improvement in thermal efficiency of conventional power plants is restricted because of the constraint of material and physical property of working fluid. In warm climates about 45% of primary energy is dumped into atmosphere at condenser and cooling tower of a utility at a temperature of around 30^0C. This waste heat is practically useless (and sometimes harmful) for any industrial and domestic use, with the sole exception of horticulture and fish farming in cold climates. In terms of a national energy economy, this waste heat amount can be dramatic. By using the cogeneration technology in urban areas the wasted heat can be utilized for district cooling (through vapour absorption technology) and process energy in industries. The principles of conventional energy conversion and cogeneration system are shown in Fig. 5. Rather than maximizing the efficiency of electricity generation one can explore the possibilities of total energy use (electricity and hot/cold utility).



(Conventional Coal Fired Thermal Power Plants)

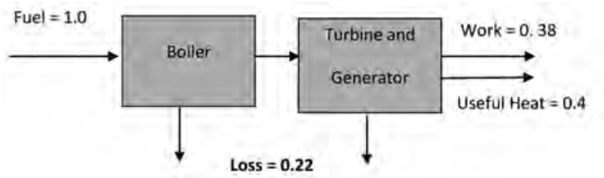


Fig. 5
Energy Savings from Cogeneration
(Cogeneration)

In India, inter-regional exchange of power is presently possible in synchronous mode among all regions, excepting south. Synchronous integration of southern region will help in optimal utilisation of generation capacity throughout the country. Open access in transmission, trading and power exchange brings competitiveness to the electricity market. Green power is being promoted through a number of policy instruments.

The aggregate technical and commercial (ATC) losses have remained very high in the country. Accelerated Power Development Reforms Program (APDRP) has helped in reducing technical and commercial losses. In 2007-08, ATC remained at 27.2%. There is an urgent need to bring down the losses.

The total power generation capacity from the renewable energy sources (RES) in the country was about 17221.86 MW, as on 31 March 2010. It constitutes approximately 10% of total installed electricity generating capacity. A significant segment of the RES are subsidy driven. In the absence of honest economic pricing of alternative non-renewable sources of energy, RES cannot stand on its own feet.

B. Demand Side Factors

There are six major factors, which influence the aggregate demand for commercial energy. These include:

- Process efficiency
- Economic growth
- Position in the technology trajectory of energy using systems
- Population growth
- Energy price
- Substitution for biomass

The process efficiency and prices often have negative impact on the growth of energy demand. Biomass still accounts for about one-third of energy demand in India. Substitution alone is likely to raise overall commercial energy demand in the country by perhaps one-third or more in the long term.

STRATEGY TO REDUCE PRIMARY COMMERCIAL ENERGY CONSUMPTION

There are three strategies to reduce primary commercial energy consumption, specially the fossil fuels (Fig. 6). They are:

- Reduce the end-use energy demand to satisfy the human needs.
- Improve energy utilization efficiency.
- Switch to renewable and other environmentally benign source of energy.

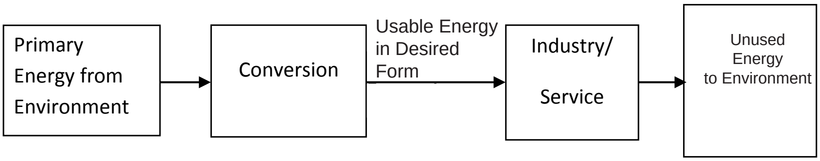


Fig. 6
Energy Flows in an Industrial/Service Operation

The end use energy requirement depends on the operating practice and standards of living. Unsound practices such as overheating and overcooling in living environment increases energy consumption that does not lead to higher quality of living. Affluent people and the developed countries cannot forego the luxurious lifestyle. The growth in standard of living coupled with population rise will demand far more primary energy consumption in future than at present in developing countries.

Switching to renewable seems to be the best option but their high unit cost does not make them economically viable. Considering the slow pace of renewable energy technology development, distorted price of commercial energy and overall complacency, it is not expected to be a viable alternative in the near future.

So ultimately improvement of process and adoption of various energy management techniques for energy conservation can be the immediate option. In major energy consuming sectors of economy, i.e. industry, transport, commerce, agriculture and mining, a number of steps have been taken which lead to lower energy consumption. Similarly, during energy conversion and transmission, a number of energy efficient technologies can be used for better efficiency. Some of the possible improvements in each sector are presented below.

Industry Sector

The industrial sector in India consumes about 56% of total commercial energy produced in 2007-08 and contains a number of highly energy intensive industries such as aluminum, iron and steel, textile, chemicals, and pulp and paper. The energy intensity of India's industrial output is 6416 kcal/USD is appreciably less than China

(8360 kcal/USD). The higher energy intensity of Indian industries compared to that of developed countries (3 times that of US and 4 times that of UK) is due to presence of large energy intensive industries, plant size, technology and vintage (TEDDY 2010, pp 229).

Energy consumption in industrial sector can be reduced by cascading, improvement in process and process control, recycling and material substitution. Various energy up-gradation and waste heat recovery processes are also used to improve the energy utilization efficiency. In industrialized countries, unit consumption of energy intensive products has decreased quite significantly, mainly through process changes.

Through application of adjustable speed drive in motors, improvement of boilers and combustion practices, substitution of lighter fractions by the heavier grades of refined oil and increased efficiency of heat exchangers used in the drying of agricultural products, and more efficient use of wood fuel (especially in domestic cooking) could result in a saving of 10-25%. 2000 m^2 of collector area can save a peak load of 1 MW.

The National Mission on Enhanced Energy Efficiency (NMEEE) has strategies to enable creation of energy efficiency market in the country. Its operating and enabling provisions include (TEDDY 2010, pp 241).

I) Perform, Achieve and Trade (PAT) mechanism for having provision to set energy efficiency targets, certify achievement and trade the saved energy with the laggards.

II) Market Transformation for Energy Efficiency mechanism to help shift to energy efficient appliances.

III) Energy Efficiency Finance Platform to help create mechanisms for Demand Side Management (DSM) financing

IV) Framework for Energy Efficient Economic Development to help develop fiscal instruments to promote energy efficiency.

Transport Sector

Transportation is one of the main energy consuming sectors. It consumed 51% of the petroleum products (comprising petrol, diesel, CNG and ATF) in 2006-07 and 2% of electricity in 2007-08 in India. Out of the total consumption of 47.7 MT HSD in India in 2007-08, the transport sector's consumption was 50.4% (24 MT) (TEDDY 2010, pp. 259).

The transport sector energy consumption depends upon fuel price, vehicle efficiency, economic growth, population growth, urbanization, conservation measures and infrastructure quality.

Domestic

Domestic consumers use energy for cooking, lighting, refrigeration, air-conditioning, ventilation, entertainment, water supply, etc. The sources of energy are electricity, LPG, kerosene and biomass. Based on 64th round NSSO, in 2007-08, 93.8% of urban households and 60.2% of rural households use electricity as the primary source of lighting. Balance use mostly kerosene for lighting. 61.8% of urban households and 9.1% of rural households use LPG as the primary cooking energy. Firewood is the primary cooking fuel in 77.6% rural households. Although actual consumption is not known, the projected firewood consumption in 2006 was 88.4 MTOE (TEDDY 2010, pp. 289). To provide clean lighting and cooking energy at the household level, Government of India has initiated schemes such as Rajiv Gandhi Gramin Vidyutikaran Yojana (RGGVY) and Rajiv Gandhi Gramin Yuva LPG Vitrak Yojana (RGYLVY).

Electricity in rural area is characterised by low quality (high voltage fluctuation), low availability (frequent and long interruption) and high transaction cost. Electricity sector reform since last one and half decade has not brought relief to the rural consumers. In fact the situation has become worse in a number of areas. To ensure better quality of service to rural customers, following strategies may be adopted (Modi, 2005).

- A climate of confidence must be fostered in the electricity sector that reflects a sustained commitment to a long term plan and stressing the importance of adherence to policies.
- A move toward greater cost recovery must be accompanied by reliable service that meets the specific needs of agriculture, while concurrently curtailing waste of energy.
- Information technology should be adopted to lower costs of bill collection and for accuracy.
- Focus on capacity building within and modernization of electricity infrastructure.

Commercial Sector

Air conditioning and lighting are the major electricity consumers in the commercial sector. Air conditioning alone contributes 50-70% of electricity used in the building. Some statistics show that the percentage of total operating budget for commercial office building, which goes to energy costs, has been steadily increasing and is now generally between 30-40%. A number of techniques are available which can be used to reduce energy consumption within the economic limit. They are

- Energy efficient building design
- Installation of energy management systems
- High efficiency lighting systems
- Chiller optimization

Water heating consumes a significant amount of energy in residential sector and some commercial sector buildings. Heat pump water heaters (HPWH) and heat recovery water heaters (HRWH) are two energy efficient types available. The energy savings from these heaters are in the ranges of 40-60% and 10-60% respectively. New compact fluorescent light bulbs are available in the market, which give the same light as the screw type incandescent bulb but use 75% less energy. Similarly high efficiency freezers and refrigerators are available which consume 50% less energy than the conventional one.

A good building design from the energy point of view and the matching of air conditioning and lighting system design do not automatically produce the anticipated energy saving. Intelligent controls, which can respond to variations in occupancy pattern and weather changes, should be applied to all aspects of energy usage.

Agricultural Sector

In India, major commercial energy consumption in agriculture is due to irrigation pump sets (15.35 million in March 2007). Their inefficient design and operation are a norm rather than exception. Farmers don't bother because of low or nonexistent electricity charges. Provision of variables speed drive mechanism and realistic tariff structure can help in improving the energy utilization efficiency in this sector. In 2007-08, the agriculture sector accounted for 18% of the total electricity consumption, amounting to 104,182 GWh. At 10% efficiency gain there will be an electricity savings of 4 billion kWh and at the farmers' end and 900 MW of equivalent generating capacity (TEDDY 2010, 217). Out of total diesel consumption in 2008-09, agriculture sector uses 12% (other users are: trucks 37%, buses 12%, cars 15%, industry 10%, generator 8% and railways 6%). Agriculture sector also uses energy indirectly in the form of fertiliser and pesticide. Better package of practices such as System of Rice Intensification (SR) can help reduce direct and indirect energy use and increase productivity.

POSSIBLE POLICY MEASURES

Organisationally energy sector is divided into a number of ministries and departments. These include Ministry of Coal, Ministry of Power, Ministry of Petroleum and Natural Gas, Ministry of New and Renewable Energy and the Department of Atomic Energy. At the state level respective departments and ministries undertake the job. Regulatory role is undertaken by Central Electricity Regulatory Commission (CERC), Petroleum and Natural Gas Regulatory Board (PNGRB), and Atomic Energy Regulatory Board (AERB); and State Electricity Regulatory Commissions (ERC). Integration of energy related initiatives in the country are undertaken by National Development Council and Planning Commission. Figure 7 indicates the organisation of the energy sector in the country.

Six key drivers of change affect energy sector in India. These include fast economic growth, privatisation, increasing household income, fast depleting biomass resources, limited domestic reserve of oil and gas; and adverse impact on the environment of the rapidly developing urban and rural areas. There is a need to undertake energy conservation and energy productivity enhancement. Unfortunately, strategies have not been successful to achieve desired result due to:

i. Poor pricing policy, weak institution and ineffective incentives to stimulate energy efficiency

ii. Lack of information

iii. Vicious cycle of poverty: energy saving devices require higher initial cost, and since poor people do not have savings for investment capital, they are forced to use inefficient equipment and pay many times more for a unit of delivered service.

iv. Lack of access to the best available fuel efficient design and production process

v. Lack of encouragement for public transport in place of private transport.

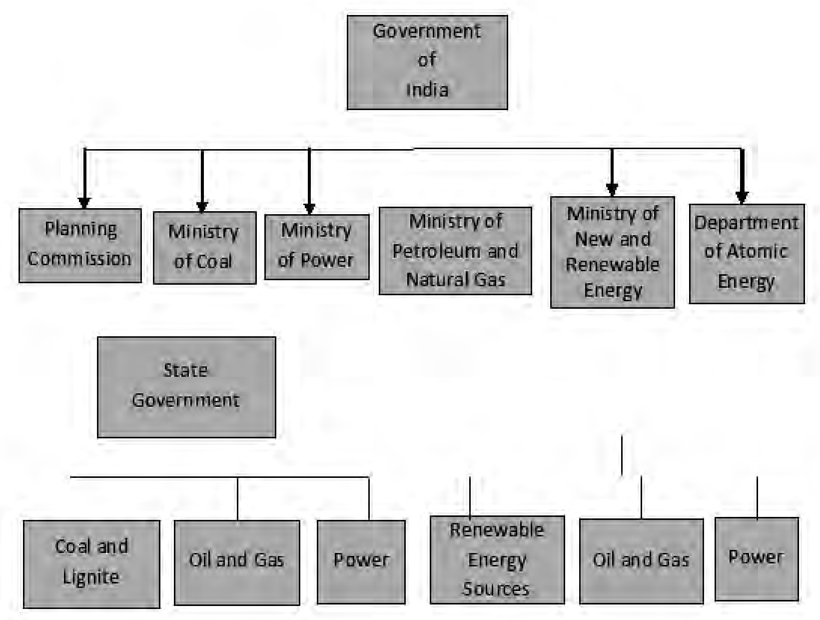


Figure 7
Organisation of Energy Sector in India

Planning Commission has Power and Energy, Energy Policy and Rural Energy Divisions. Ministry of Coal a number of Mining Companies (Coal India Ltd, Neyveli Lignite Corporation), Coal Controller's Organisation and other Organisations. Ministry of Power has Central Electricity Authority, Generating Companies (National Thermal Power Corporation and National Hydro Power Corporation), Transmission Companies (Power Grid Corporation of India Ltd), Power Finance Companies (Power Finance Corporation and Rural Electrification Corporation), Power Trading Corporation, Regulatory Organisations (Central Electricity Regulatory Commission and Appellate Tribunal for Electricity), Bureau of Energy Efficiency and Research and Training Organisations (Central Power research Institute and National Power Training

Institute). Ministry of Petroleum and Natural Gas has Exploration and Production Companies (Oil and Natural Gas Commission, Oil India Ltd and ONGC Videsh Ltd), Refineries (CPCL, BRPL, NRL, MRPL), Marketing Companies (GAIL, IGL and MGL), Integrated Oil Companies (IOCL, HPCL, BPCL), Engineers India Ltd, Advisory Organisations (CHT, DGH, OISD, PCRA and PPAC), Oil Industry Development Board and Petroleum and Natural Gas Regulatory Board. Ministry of New and Renewable Energy include Indian Renewable Energy Development Authority, Solar Energy Center, Centre for Wind Energy Technology, Sardar Swaran Singh National Institute of Renewable Energy, Alternate Hydro-energy Center and nine regional offices. Department of Atomic Energy consists of Atomic Energy Commission, Research Institutions (BARC, IGCAR, RRCAT, VECC, AMD), Generating Companies (NPCIL and BHAVINI), Input providers (HWB, NFC, IREL and UCIL), BRIT, ECIL, BRNS and Atomic Energy Regulatory Board.

Major private power sector companies include RPL, Tata Power, Torrent, CESC and Jinadal Power. Major private sector oil and gas companies include Cairn, RIL, SOL, Shell, PLL, RGPPL and Hazira Group. Major private sector renewable energy companies include Suzlon, Enercon, Tata BP Solar, NEG-Micon and Vestas-RRB.

Considering the importance of energy conservation and rational use of energy, Government of India established Bureau of Energy efficiency (BEE), a statutory Body under the Ministry of Power through Energy Conservation Act 2001. Over the years BEE has focused on Industrial and Building Energy Efficiency, Demand Side Management, Standards and Labeling for appliances and equipment, Professional Certification and Accreditation, Manual and Codes on Energy Conservation, Policy Research, delivery mechanism for energy efficiency services and energy conservation awareness in schools (TEDDY 2010, pp28).

Reform in the electric sector leading to privatisation has not resulted in desired outcome of reduction in transmission and distribution loss, investment in infrastructure to enhance reliability and availability of distribution infrastructure and meeting the expectation of agriculture and rural consumers. The regulatory system has not been effective to address the above issues. Similarly, privatisation in coal and petroleum sub-sector have benefitted the private and big players more than the state.

Instead of subsidising the energy price, incentives may be given for the use of and development of efficient process and product. There is a need to identify energy efficient products, processes and technologies and disseminate these informations among the consumers and producers, possibly along with financial incentives and penalties.

CONCLUDING REMARKS

Energy scenario in India is not satisfactory. The country has very low per capita energy consumption in comparison to developed countries, primarily dependent on low quality indigenous coal and imported oil and gas. There is a large gap between renewable energy potential and actual achievement. To bridge the gap the country has to overcome the constraints of technology, financial resource crunch, policies and institutions. Continued over-dependence on fossil fuels will further deteriorate the negative environmental consequences of global warming, acid rain and ozone layer depletion. The country is energy unsecured at present.

For sustainable economic development with longterm energy security, India has to move from the presently dominated centralised fossil fuel centric energy system to decentralised renewable energy centric equitable energy system. The energy related environmental problems should be resolved through source reduction rather than emission control. In the long run this can be effectively achieved by changing the products, (with technologies, policies and pressures) which generate waste and give rise to pollution. To implement this requirement Speth's suggestion, way back in 1988, covering several large-scale social and technological transitions are even relevant today.

1. Transition 1: Shift away from era of fossil fuels towards an era of energy efficiency and renewable energy.
2. Transition 2: Move from an era of capital and material intensive technologies to an era of new technologies that rely on inputs with low environmental costs.
3. Transition 3: Shift towards ecologically oriented production technologies ("design with nature").
4. Transition 4: Move toward "honest" economics in which policies do not subsidize the use of raw materials or the generation of waste.
5. Transition 5: Move to more national approaches to solving environmental problem.
6. Transition 6: Evolution to a stable population.

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Tinkering Won't Suffice

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INTRODUCTION

We are racing towards a catastrophe. Exponentially increasing demand on sources and sinks are not compatible with their finite nature. Two real dangers are right in front of us: the exhaustion of petroleum and natural gas in a few decades to come and the accretion of GHG in the atmosphere leading to global warming and consequent climate changes and other problems. The danger is so near and so real that tinkering a bit here, a bit there won't suffice. We require whole body changes – a multifaceted strategy and a crash action plan.

On the theoretical plane, one has to accept:

that infinite expansion is not possible on a finite earth,

that expansion of consumption is not the aim of existence, that we don't live to consume, but consume to live,

that every item we consume does not contribute to improving the quality of our life, many of them are contrary and most of them satisfy only our vanity,

that with increasing development of science and technology, if properly designed, we can make small scale more efficient, we can use more and more things including wastes as resources, we can overcome the necessity of metropolitan conglomerations with all their attributes - problems like slums, transport, electricity, water etc.,

that we can have a higher quality of life under rurban conditions, requiring less labour, requiring less travel, providing more leisure,

that the aim should be, thus, to develop fully *the human potential*.

This is a battle of ideas, an ideological battle

That has to go on. But there are immediate things to do.

We have to reduce the GHG emission, especially of CO_2 drastically.

We have to promote alternative, non carbon, sources of energy.

We have to clean up our environment, which release too much methane to the environment.

Sources and technologies are sufficiently known. True, they require substantial improvement before large scale application. What I present here is the summary of a plan of attack we had made for the state of Kerala.

The only truly renewable source of energy is the sun. Wind energy, hydro energy and biomass energy are all its manifestations. Solar energy can also be used directly for heating or for electricity production. All these are well known. Nuclear energy can be rejected for obvious reasons, known to even laymen. Besides sun's radiant energy there is the gravitational energy manifested in tidal power and also the geothermal energy. Their role is marginal globally and zero in Kerala.

Thus the major future sources of energy for Kerala are

i. Hydro electric

ii. Biomass

iii. Direct solar

iv. Wind

It is to be noted that burning of biomass is a carbon neutral process, unlike burning of coal or oil. It does not alter the concentration of CO_2 in the atmosphere. We suggest the following strategy for each of them.

HYDRO ENERGY

The yet untapped hydro resources amount to 1500-2000 MW according to different estimates. Many of them are fraught with environmental problems and inter-state disputes. Every proposal is contested. Here is a strategy, once earlier suggested to the state government.

The Electricity Board prepares a DPR of each of the remaining potential projects, together with its EIA by a competent agency, makes copies of these available to interested environmental groups and other concerned individuals. Help them with concrete data when they ask for it. They can make their own socio-economic and techno-ecological assessment of each of the project. Make both, public documents. Let public discuss the proposals and objections in detail for one year. After wards, conduct a referendum asking these questions about each of the project. Approve? Disapprove? Approve with modification?

Start work on approved projects simultaneously, with large scale people's participation. The entire programme should be finished in record time say five-six years. The total investment required for, say, 1000 MW (more will not be forthcoming) will be Rs.6000-8000 crores, including transmission. We can think of a 1 to 2 rupee 'capital surcharge' on every unit sold to supplement Board's resources. This can come to 30-40% of total investment. This will yield per year about 3000 MU of electricity additionally.

The estimated mini-micro hydro capacity too varies from 100 MWe-1000MWe. Let the respective district panchayaths prepare project proposals. There should be a single window arrangement at the state level to give all clearances including financial tie up within six months of putting in the application. Within 3-4 years all the mini-micro potential can be exploited. The expected additional annual yield is about 300-500 MU.

BIOMASS

Kerala generates, 120-150 lakh MTe of non timber biomass annually. 60-70 lakh Te are burned in houses for cooking. Of the nearly 90 lakh houses and institutions, about 30 lakh still use firewood for cooking, using inefficient conventional stoves. Another part is used in industrial units and the rest is allowed to rote, releasing both CO_2 and CH_4.

A crash programme to install high efficiency stoves in 3 million households can save at least 3 MTe of firewood per year, reducing annual CO_2 release by 6 MTe. The entire conversion cost is recovered in 6-8 months because of savings in firewood. We can, also collect an additional 3 MTe of biomass, currently unutilized. Thus Kerala has an annual biomass surplus of about 5-6 MTe. This does not include the leafy material and biodegradable home wastes. We have about 1-1.5 MTe of biodegradable waste.

The non-biodegradable biomass – say 5 MTe - can be gasified to produce electricity. Assuming 500 units of energy per tonne of dry biomass, this will yield 2500 MU of electricity. 1 MTe of biodegradable material too can provide at least 500 MU of energy. Thus the entire waste could be converted into wealth. Clean environment can also be a profitable environment.

Energy plantation is a thoroughly uneconomic one. One ha. can yield say 8 Te of dry fuel or 2-3 Te of oil. This is equivalent to 25-30 million Kcal. From the same area 40-50 M Kcal. can be extracted directly with a collection efficiency of 15-20%. In the form of electricity 1 ha. of fuel plantation can give only 4000-5000 units of electrical energy. Though SPV conversion we can get thirty times more.

SOLAR

Direct conversion of solar energy into heat or electricity is, by far, more efficient than the photo synthetic route. However Kerala, unlike Rajasthan, can offer no land area for solar collection. The only open area available to us is our reservoirs and backwaters. SPV stations on floating platforms can generate 30-40 MWe per Sq.Km. There is enough 'such open area' for about 10000-15000 MW. But, by far the more substantial one is the roof top. On an average a 3 KW SPV installation can supply all the needs of an upper middle class home. This needs be only 10-12 Sq.M of roof area, which even the poorest household will have. At least 3-4 million households and institutions can have 3-5 KW units installed on their roof tops. Currently the total cost per KW, including panel, inverter, storage and controls will come to Rs. 2.8-3.00 lakhs. On mass demand and improved production techniques this can come down to Rs. 2.0 lakhs and even lower. So an "Own Your Own Power House" programme can be initiated. Such a Power Plant will cost only Rs. 5-6 lakhs per household. At least 2 million middle class /rich households will be ready to invest if there is a reliable supply, installation and maintenance system – An Energy Services Company (ESCOM). Each such unit can generate about 5000 units per year and 2 million units can generate 10000 MU of electricity. California already has a One Million Roof-top Units Plan. Government of India has a plan to install 20000 MWe in coming two decades. The capital investments will come to Rs. 20 crores/MW or Rs.2.0 lakh per KW. The Solar Mission has a subsidy scheme at Rs. 81,000 per KW. The Government of Kerala can offer a state subsidy of Rs. 40,000 per KW. The current capital cost of reaching 1 KW to a home is about Rs. 80,000 per KW, generation, transmission and distribution included. The citizens will be ready to invest the rest.

At all India level at least 10% - in fact more – of the citizens can afford it. This means about 20-30 million households or 60000-90000 megawatts. The industrial and service activity required to back up such a vast solar programme will generate hundreds of thousands of new, skilled employment.

Unfortunately, the much proclaimed Solar Mission too, is satisfied with tinkering. They should promote large scale manufacture of SPV panels and accessories. The BHEL and BEL together can have a programme to manufacture and assemble one million units of 1 KW/3 KW capacity and develop service providers for the same. If necessary, panels could be imported. To begin with they can extend the present subsidy scheme to roof top SPV and to Systems Providers who should provide roof top systems in flat and villa owners. Kerala demand will be, easily 20000-50000 units per year. Kerala can be totally “solarized” in 15-20 years.

A 100/200 lpd solar water heater, a 3KW SPV unit, a microwave oven, an induction cooker, a hot box, a sensible cooking plan, a sensible illumination system using white LED, efficient gadgets – this is the scenario for an all electric – all solar home.

In case of floating platform type larger units – the energy storage can be effected, also through pumped storage systems. Suitable locations for such systems can be identified, while investigating the hydro sites, for both large and small. River bed storage might be sufficient.

Roof-top Solar Power Plants have the advantage of saving long distribution lines, especially in scattered North Indian Villages. One roof-top system to serve a cluster of households (single phase distribution system) can also be planned. It will be, in several cases, cheaper than drawing long distribution lines. Quick service facility becomes important. With today’s level of communication this will be easy to organize.

Mathematically even sun is not an unlimited source. The maximum that Kerala can contemplate is 30000 MW, providing about 10000-12000 units per capita (against the present consumption of 500-600 units per month). But one can easily conjure up a situation, were the demand surpasses this, in 4 decades, with a doubling time of 7 years!

But such endless doubling is never sustainable. Sooner or later one has to ask the question: how much energy? And what for? In the end wisdom has to take over from greed. Better from today itself.

Tomorrow could be too late.

Climate Change and Energy Initiatives

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INTRODUCTION

Energy is an essential input for economic development and one of the main factors of climate change since it results in emission of major green house gases (GHGs). Based on the sources of energy it has been grouped into either conventional (represents by fossil fuels) or non-conventional or renewable such as wind, solar, waves, etc. However the economic development and quality of life in a nation is almost directly proportional to the quantum of energy, especially from conventional sources, produced. Energy (power) development in India commenced at the end of the 19th century with the commissioning of electricity supply in Darjeeling during 1897, followed by the commissioning of a hydropower station at Sivasamudram in Karnataka during 1902 (Economic Review 2010). In the pre-independence era, the power supply was mainly in the private sector and that too was limited to the urban areas. With Five Year Plans, a number of multipurpose projects came in to being and with the setting up of thermal, hydro and nuclear power stations, power generation stations increased significantly. Due to the fast- paced growth of India's economy, the country's energy demand has grown an average of 3.6 % per annum over the past 30 years. In November 2010, the installed power generation capacity of India stood at 1, 67,077.36 MW and percapita power consumption at 612kwh.

Climate change is the significant change or shift in the long term weather patterns (temperature, precipitation, wind, etc) due to natural or anthropogenic factors. The warming trend over large areas of earth surface since the beginning of 20th century (along with large scale industrialization) has brought curiosity and attention of researchers, planners and policy makers around the world. This increase in temperature (approximately 0.60C over the past century) and its continuing trend along with the associated impacts on natural resources have become a serious concern of the global community irrespective of developed, developing and underdeveloped countries. Hence much focus has been given in formulating strategies and action plans to combat or rather limit the emission of green house gases through different policies and programs including Kyoto Protocol.

Nevertheless the dependency of the world on fossil fuels as the key element for development and growth had serious implications on climate change and energy scenario. Unless the issue of energy with all its ramifications is tackled, the climate change issues will not be solved. The attempts to impose climate change control measures on developing countries have sparked an outcry as it is linked directly to the growth rate and development. The problem of climate change can only be tackled by sorting the issue of energy which in turn is linked to development. The challenge of sustainable development while limiting climate change thus is occupying the central theme of policymakers and planners. The major energy sources in the country are fossil fuel (mainly used for power generation, transportation and industries), hydro power, nuclear, wind and solar. It may be ironical to note that the answer to the impacts of one type of energy source on climate i.e., fossil fuel, is none other than the alternate sources or otherwise denote as renewable sources. Nonetheless, both fields have their unique peculiarities and issues which need to be examined before much reliance is placed on either.

Sources of Electric Energy in the Country and State

The country is relying on conventional energy sources for its electricity, industries and transport ever since the inception of planning. The installed capacity of the power in the country has grown from 1713 MW in 1950 to 167077.36 as on 2010 (Ministry of Power, 2010). It consists of 108362.84 MW thermal (64.76%), 37367.76 MW hydro (24.9%), 4560 MW nuclear (2.85%) and 16786.85 renewable (8%). The total demand for electricity in India is expected to cross 950000 MW by 2030.The major fuel used in thermal are coal, gas and diesel and the renewable includes mainly wind and solar. Coal alone produces around 54% of power in the country. Among the renewables nearly 82% are with private sectors where the state contribution is only 18%.

In the Stateof Kerala, the sectoral contributions are slightly different from national scenario, where the majority of the power is provided by hydro electric projects. Out of the total installed capacity of 2746.19 MW, the major share, 1933 (10.38%), is through hydro-electric projects; 783.11 MW from thermal stations and the remaining 30 MW is contributed by wind power (Economic review, 2010). Efforts are being taken to tap more of renewable energy but the inherent problem of cost and other logistics still acts as an impediment.

DIFFERENT SECTORS AND THEIR CONTRIBUTION IN GHG EMISSION

On a global level, in order of importance, the green house gases are contributed by electricity generation, transport, industries, land use change, agriculture, forestry, fishing, commercial/public services, etc. The fastest growing sources are that of transport and electricity. Studies have shown that more than 60% (two third) green house gases emission are attributed to energy of which fossil fuel based electricity sector is main contributor (Figure 1). Worldwide this sector relies largely on coal, the most carbon-intensive of fossil fuels, amplifying its share in global emissions. Countries such as Australia, China, India, Poland and South Africa produce between 69% and 94% of the electricity and heat through the combustion of coal. Studies have revealed that between 2007and 2008, total CO2 emission from the generation of electricity and heat were almost stable. The future development of the emissions intensity of this sector depends strongly on the fuels used to generate electricity and on the share of non-emitting sources such as renewable and nuclear resources. The second largest sector, transport also shown almost stable emission of GHGs between 2007 and 2008. However the contribution of GHGs is increased from road traffic than any other mode of transportation in the world over.

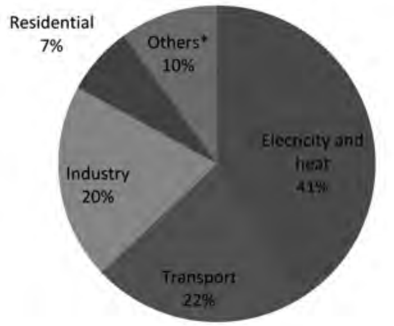

Fig. 1
Sector wise production of Green House Gases

*Others-includes commercial/public services, agriculture, forestry, fishing, energy industries other than electricity and heat generation, and any other non specified sectors.
Source: http://www.iea.org/co2highlights/CO2highlights.pdf

The two important turning points occurred in 2008 are for the first time CO2 emission from non-Annex countries surpassed that of Annex I countries and the CO2 emission level of the Annex I countries fell below 1990 levels (http://www.iea.org/co2highlights/CO2highlights.pdf). Emission of Annex I countries decreased by more than 2% where as those of non-Annex countries increased by almost 6%. The increase in emission from developing countries was primarily due to an increase in coal demand. Emission in the developed countries will continue to decrease in 2009, as a result of the ongoing financial crisis and the resultant slow down of the economic activity.

For India also, the sector-wise contribution of green house gases is acutely in favor of energy sector which accounts for 61% of the green house emissions, followed by agriculture (28%), industrial processes (8%), waste disposal (2%), and remaining from landuse and land cover changes, and forestry sector (Table 1). However, the dominance of the energy sector in its contribution to green house gases is very clear. At the same time, it has to be noted that on a sectoral basis, the maximum growth in emissions is from the industrial process sector (21.3 per cent per annum), followed by the emissions from the waste sector (7.3 per cent per annum). The energy sector emissions have only grown by 4.4 per cent per annum because of the strong actions taken in the energy sector. Significant increase in emissions from the industrial process sector can be attributed to the growth in cement and steel production in India over the decade. Though the composition of green house gases emission for India mimics that of the world, nonetheless India is not a major consumer of energy or emitter of greenhouse gases. The total primary energy supply in India has increased from 350 Mtoe in 1990 to 572 Mtoe in 2004. The increasing demand is due to rising demand of accelerated industrialization. The share of coal and oil as source of primary energy supply out of total has been increasing with time. The increase is more pronounced since 1990, when India stepped up the rate of economic development. The trend also shows the increasing energy dependency of India on fossil fuels.

Table.1
India's Initial National GHGs inventories

Fuel Type	**Green House Gases (Ggt)**			
	CO_2	**CH_4**	**N_2O**	**Total (CO_2 equivalent)**
Energy and transformation industries	353518		4.9	355037
Industry	149806		2.8	150674
Transport	79880	9	0.7	80286
Commercial/institutional	20509		0.2	20571
Residential	43794		0.4	43918
All other sectors	31963		0.4	32087
Biomass burnt for energy		1636	2	34976
Oil and natural gas system		601		12621
Coal mining		650		13650
Industrial processes	99878	2	9	102710
Emission from Aviation	2880			2880
Emission from Navigation	493			493

At present, India contributes 2% of the global green house gases emissions. According to the world energy outlook, the share of China in cumulative emission between 1900 to 2003 would rise to 16% and would approach that of the US (25%) and EU (18%), at that time India's cumulative emissions are projected to reach just 4%, which would be comparable to those of Japan at that time.

The carbon dioxide emissions in India are increasing at about 2.7% per year which reflects decreasing share of biomass in the total fuel mix (Figure 2). However the per capita emission of CO2 of India is much lower than many other countries. The per capita CO2 emission of US, the highest, stands at 20.01 metric ton (MT) during 2004, where that of European Union is at 9.40 MT and countries such Japan, China, Russia and India ranked as 9.87, 3.60, 11.71 and 1.02 respectively (NAPCC, GOI). The Human Development Index (HDI) versus energy (electricity) consumption indicated that the energy consumption is much lower in India than (<1000 kw/year) compared to many other developed countries where it reached more than 10000 kw/year to attain the maximum HDI of one.

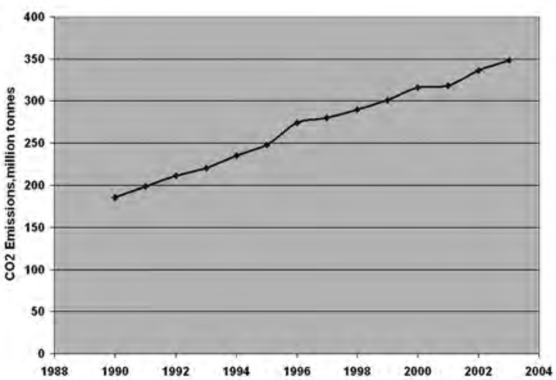

Fig. 2
Carbon dioxide emission in India during 1988-2004

ENERGY INTENSITY AND DEVELOPMENT

The intensities are measured in terms of energy, electricity utilized or carbon dioxide emitted for production of per unit of gross domestic product measured in PPP basis. This indicates the reduction in use of energy or emission of carbon dioxide with increasing economic growth. It is also expected that the intensities would decline further in future with increase in GDP. India has faired better than most of the countries in the world in this regard as of today. On other key indicators, India can be compared favourably with other countries of the world. The energy intensity in India is half of the world and it is much lower than European Union and US (figure 3).

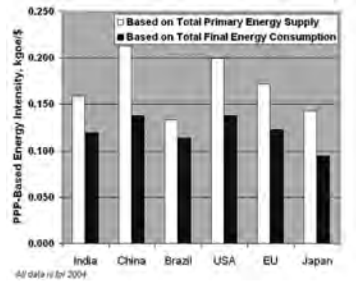

Fig. 3
Energy Intensity and CO2 Emission in India

The carbon intensity of Indian economy is declining at a rate of 1.5 % per annum. As per some projections made on the basis of current analysis, by 2035 GDP increases 3 fold, energy use increases 4 fold but CO2 emissions increase only 3 fold. Thus, the growth of India need not be viewed with alarm in developed world as its cumulative emissions in 2050 will not exceed 4% of global cumulative emissions (Figure 4). Thus the solution to the problem of the climate change lays elsewhere, the countries where the energy intake is high with respect to unit amount of production. This is particularly important in the context of Millennium Development Goals (MDG) stated by UN, where out of the 8 goals, except the last, i.e. develop a global partnership for development, all others have direct link with energy services including electricity. The positive correlation of commercial energy use and the human development indicators has been stated by numerous multilateral agencies including United Nations. In case the MDGs have to be attained the household access to energy and also the per capita consumption of energy is bound to increase. Or in other words, the emission of green house gases may also likely to increase unless otherwise renewable energy has major stake in the development process.

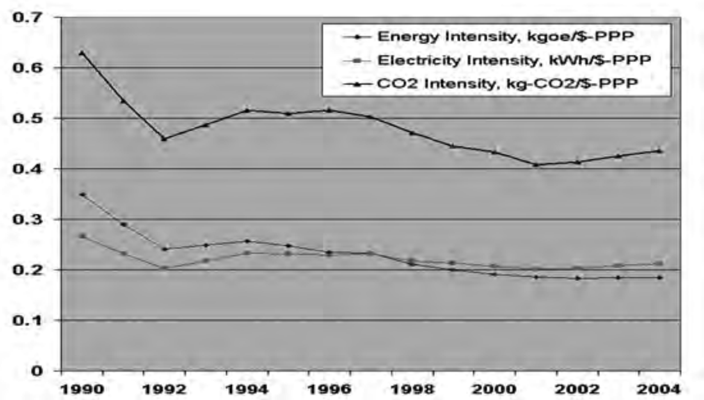

Fig. 4
Carbon Intensity in India during 1990-2004

The energy needs of India are growing and by 2012 demand for electricity will require an installed capacity of more than 2 lakhs MW, which is about 60% more than what India has at present and by 2032, the demand is expected to be in the region of 8 lakhs MW. To meet this projected energy demand vis-à-vis the developmental needs of India, the fossil fuels, particularly coal are going to remain mainstay for the country. The choice of fuel for India remains coal because the reserve to production ratio for coal in India is 300 years and 22 years and 30 years for crude oil and natural gas respectively. It is particularly important when the Indian Government is already spending upto 2% of its GDP on climate change adaption measures. This means that to target the carbon dioxide focused power sector, such technologies be identified which are less carbon intensive or zero carbon. The role of promotion of renewable comes in here. In addition, the old thinking of saving one unit of energy equals one unit of energy produced also holds true. The promotion of energy efficiency and energy conservation measures are necessary.

GREEN HOUSE GAS EMISSION BY FUEL

The emission of GHGs by fuels varies considerably. It was calculated that about 43% of the GHGs are emitted through the combustion of coal and followed by oil (37%) and nearly 20% by gas. Between 2007 and 2008, CO2 emission from the combustion of coal increased 3% and represented 12.6 Gt CO2. Currently coal is filling much of the growing energy demand of developing countries especially China and India, where energy intensive industrial production is growing rapidly and large coal reserves exists with limited reserves of other energy sources. The GHG emission potential of different fuels which is used for energy production from aviation to domestic (wood logs and wooden chips) are given in the table below (Table 2).

Table 2
GHG Emission Potential of Different Fuels

Fuel Type (per ton)	**Green House Gases (Kg)**			**Total Direct**	**Total Indirect**	**Grand Total**
	CO_2	**CH_4**(CO_2e)	**N_2O**(CO_2e)	kg CO_2e		
Aviation Spirit	3127.7	33.2	31.0	3191.9	563.2	3755.1
Aviation Turbine Fuel	3149.7	1.6	31.0	3182.2	585.4	3767.6
Biofuels (per litre)				0.04	3.5	3.5
Burning Oil	3149.7	6.7	8.6	3164.9	585.2	3750.1
CNG	2712.2	4.0	1.6	2717.8	397.7	3115.5
Coal (industrial)	2295.3	1.8	39.4	2336.5	381.7	2718.2
Coal (electricity generation)	2251.2	0.4	19.5	2271.2	371.5	2642.7
Coal (domestic)	2506.3	329.7	45.5	2881.4	446.1	3327.5
Coking Coal	2986.5	29.1	70.6	3086.2	476.8	3563.0
Diesel	3164.3	1.8	35.0	3201.1	607.1	3808.2
Fuel Oil	3205.5	2.6	11.6	3219.7	546.8	3766.5
Gas Oil	3190.0	3.2	290.3	3483.5	607.1	4090.6
LNG	2712.2	4.0	1.6	2717.8	951.9	3669.7
Lubricants	3171.1	1.9	8.5	3181.5	386.2	3567.7
Naphtha	3131.3	2.7	8.0	3142.1	442.9	3585.0
Other Petroleum Gas	2894.0	3.3	65.7	2963.1	352.5	3315.6
Petrol	3135.0	6.3	21.3	3162.6	559.7	3722.3
Petroleum Coke	3193.8	2.3	74.5	3270.5	389.0	3659.5
Wood (logs, chips, pellets, grasses, straw, etc)						363.80

Fossil Fuel Consumption and Green House Gas Emission in Kerala

The direct proportional relationship between population growth and infrastructural development and associated increase in facilities has reflected in the energy demand and fuel consumption also. The nearly 250 percentage increase of population since independence increased consumption of fossil fuels in many fold. Besides the population rise, people from all walks of life look for improved standards of living. This also leads to higher consumption of energy resources and resultant release of greenhouse gases. Apart from fossil fuels the use of wood and other energy supplement for domestic and captive purpose also release green house gases. Regarding the use of firewood, nearly 7.5 million households in Kerala are using, on an average, 5 kg/ per day firewood for their cooking purpose. This works out to be 37.5 million kg of firewood. The total consumption of petroleum products during 2003-04 in Kerala put together was 3,087,589 tons. The figures of each of the individual products are given in Table 3.

Table 3
Consumption of Petroleum Products in Kerala(2003-04)*

Product	Quantity (ton)	Effective conversion	Carbon Content	CO_2 Emission
LPG	409568	409568	334208	1225429
Naphta	703843	645425	548611	2011572
Petroleum	427669	392173	333347	1222271
Diesel	1314887	1205751	1024889	3757925
Kerosene	225048	206369	175414	643183
Low density oil	3745	3434	2919	10704
Furnace Oil LSHS	400595	367345	312244	1144893
Bitumen	81788			
Lubes	28538			
Aviation Fuel	72800			164000

*http://www.kerenvis.nic.in/files/pubs/SOE_05/tables.pdf

It was seen that among the different fuel type, petroleum products such as diesel, gas oil and aviation fuel stands a top in the GHG emission and biofuels and wood showed very low emission potential which justifies the necessity for formulating and implementing policies towards biodiesel and other less Carbon intensive fuels (renewable sources) for combating global warming (Table 4). In addition Decentralized Distributed Generation (DDG) projects are also being promoted which refer to variety of small power generating units along with local distribution system near the end users. DDG implies disbursed generation of electricity cum distribution. Mandates for blending biofuels into vehicle fuels have been enacted at the national level. Most mandates require blending 10–15 percent ethanol with gasoline or blending 2–5 percent biodiesel with diesel fuel. Such hybrids will help in reducing the emission of green house gases.

Table 4
The Breakup of Renewable Energy Potential and Installation in India

Type	Potential (MW)	Achievement (MW)
Wind	45195	7845
Small Hydropower (<25MW)	15000	2045
Biomass	21881	1326
Urban and Industrial Waste	2700	55
Solar		2.1
Captive		205
Total	84776	11749

One of the major bottlenecks in renewables is that the cost of production is exceptionally high compared to conventional generation. Hence, it may be stated that the generation capacity in India on renewables has shown lot of potential but the achievements have been very poor.

LIMITATIONS IN ESTIMATING GREEN HOUSE GASES

The twenty third session of the UNFCC reported many limitations in estimating the GHG inventory based on the original and revised guidelines of IPCC, which is applicable to energy sector also. The major concerns were the availability, quality, and lack of disaggregated data required to apply IPCC methodologies. Some of the specific problems encountered with energy sector are related to inconsistency in approaches, either sectoral or reference or both. Most Parties applied both reference and sectoral approaches to estimate fuel combustion emissions from the energy sector. Few Parties used only the reference approach for estimating their fuel combustion emissions, and some applied only the sectoral approach. Most Parties performed the comparison between the two approaches, as recommended by the IPCC Guidelines, and some of them reported on observed differences. This comparison is a useful self-verification procedure, which greatly improves the transparency and indicates the level of confidence in the inventories by giving an indication of the level of uncertainty of the results. The usefulness of applying both approaches would be enhanced if the differences found when comparing results were also explained by all Parties. The IPCC Guidelines request Parties to make efforts to report the estimated range of uncertainty in their emission estimates, where appropriate. Almost half of the Parties (55) reported uncertainties, 11 of them providing the information quantitatively, 33 qualitatively, and 11 both qualitatively and quantitatively. The sectors covered in estimating the range of uncertainty were more often energy, agriculture and land-use change and forestry (LUCF), and in some cases the waste and industrial sectors.

CONCLUSION

The energy use and CO2 emissions in India are increasing due to change in quality of life, and economic growth. The emission of green house gas has been also increased in the recent years compared to many other developed countries though per capita emission is much lower than the developed nations. This has seriously implicated us on curbing energy utilization and adopting energy efficient strategies and tapping more of renewable. In order to combat the impacts on climate change, the country has been initiated efforts in the direction of reducing energy use vis-à-vis GHG emission by promoting energy efficient technologies and energy conservation. The energy conservation efforts in India are implemented by Bureau of Energy Efficiency (BEE). The major activities of the BEE includes (i) regulating power plant energy efficiency, (ii) carbon capture and sequestration, (iii) clean coal technologies, (iv) appliance standards and labeling, (v) energy conservation building code and (vi) demand-side management.

India is pursuing energy conservation, promotion of cleaner fuels and renewable energy technologies. The Energy Conservation Act is a noteworthy initiative in this regard. The Government of India has been consistently promoting power generation from renewable sources. Today, India has one of the largest renewable energy programmes in the world, and is the world's fifth-largest producer of wind energy, with an installed capacity of 1507 MW. The government offers several fiscal and financial incentives to encourage the adoption of such technologies, biomass consumption, grid connected solar photovoltaic (PV) application, wind battery chargers, wind pumps etc. The Technology Information, Forecasting and Assessment Council(TIFAC) established under the Department of Science and Technology facilitates the transfer of environmentally sound technology. It has conducted a study on clean coal technologies, which are critically important given the large share (nearly 70%) of coal-based power generation in India, and the high ash content of the Indian coal.

Ministry of New and Renewable Energy (MNRE) has initiated several programs focusing on the utilisation of renewable energy sources in buildings. The MNRE has a solar buildings program and provides financial support for the design and construction of energy efficient and solar passive buildings. The goal was to construct 10 solar buildings in 8 states in 2006-2007 alone. The Ministry has taken the following supportive measures to promote the installation and use of solar water heating systems. The MNRE also provides financial support for workshops, seminars, and orientation courses related to solar buildings for engineers, planners, builders, architects, housing financing organizations, and potential house owners up to two lakh rupees. MNRE funds publications of documents on solar building including popular literature, technical books and manuals, promotional material in different languages, and award competitions, for up to two lakh rupees per activity. The Ministry has partnered with the Center for Innovation, Incubation and Entrepreneurship to implement the Solar Innovation Program, which incorporates research and development of technologies related to solar thermal, photovoltaics, and passive solar building design. The Solar Innovation Program is essentially a competition open to teams of entrepreneurs, researchers, and students to design new applications for solar for rural or urban areas within India. The MNRE has also launched and incentivized GRIHA (Green Rating for Integrated Habitat Assessment) as a national rating system.

There is currently a major drive in the country to popularise the use of CFLs, whose total sales have increased from about 20 million in 2002 to over 200 million in 2008. The Government is implementing an Economy Lamp Project and if the project target of replacing a minimum of 250 million incandescent bulbs with CFLs is achieved, then it is estimated that approximately 15 million tonnes of CO_2 emissions per annum would be avoided. In Kerala about 13 million CFLs have been distributed under this scheme (Economic review 2010). While popularising CFLs, India is already moving towards the next generation of energy saving lighting devices, the LED Bulb. The LED which is 90% more efficient than the incandescent and does not contain toxic mercury, several innovations has been introduced in the original Dutch design, to make it suitable for space lighting at lower cost in India. Similar interventions have made in the transport and industrial sector also to minimize the energy consumption and emission of green house gases. To conclude, some of the factors which contributed to the achievement of 9% GDP at declining trend in energy intensity and reduced per capita CO_2 emission are,

i. patterns of consumption significantly illustrated by food habitats and more efficient recycling in the country compared to many other developing and developed countries,

ii. increased industrial energy efficiency especially in the major industries such as cement, steel, aluminum, fertilizer, etc with state of the art technology,

iii. policies to promote energy efficiency and renewable energy, and

iv. accelerated introduction of clean energy technologies through CDM (over 700 CDM projects have been approved by the CDM authority and 300 of these have been registered by CDM executive board).

The above described initiatives and associated policy and porgram formulations at national level and in par with at state level have taken a leading role for the developing countries towards sustainable development. It focused on the perceived context of climate change and global warming and the overall drive in this direction would definitely give a ray of hope for the sustenance of our environment for the mankind.

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Invited Presentations

Bioenergy- The Green Energy Alternative

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INTRODUCTION

The early man used energy mostly in the form of food to power himself. He also used solar energy to keep his body warm or to dry essential materials for his sustenance. As civilization advanced, man utilized more and more energy and this continued pursuit for harnessing the environment made him dig deep into the earth for coal and petroleum. In his hasty endeavors he dug out more and more fossil fuels and burned them not bothering on how long they will last or on how the environment will react to this. Most estimates reveal that, at this level of consumption, petroleum may not last for another half century.

Our planet is now put on the verge of catastrophes like global warming, ozone layer depletion and acid rain as a result of mans' reckless extravaganza with energy. The increased level of green house gases in the atmosphere is mostly anthropogenic, resulting from the burning of fossil fuels. This of course is not only endangering the humans and his habitat in the coastal areas of the main land but also foster a multitude of environmental issues resulting in global climate change.

Energy is the most vital resource for any country. It is inevitable to search for alternate fuels and the world wide hunt for renewable energy is often directed towards biomass resources. Certain forms of energy are called 'renewable' because these energy sources are constantly replenished and will not get exhausted. Renewable energy technologies utilize these sources and convert them into usable forms of energy like electricity, heat, or mechanical power. These technologies are often described as 'clean' or 'green' because they produce little or no pollutants.

Sun is an inexhaustible energy source showering about 1kW energy per square metre of the earth's surface. All the renewable energy comes directly or indirectly from the sun. Solar energy in the form of heat and light is used for drying materials, heat water, cook food, generate electricity and power industrial processes. Heat from the sun causes air temperature differences that, along with the Earth's rotation, cause the wind to blow. The wind powers aero-generators that produce electricity or provide mechanical energy for different applications such as water pumping. Plants absorb CO_2 from the atmosphere and convert it into carbohydrates by utilizing light energy of sun which is stored as chemical energy in the biomass. Ultimately, most energy forms, even fossil fuels are derived from the sun as they are believed to be of biological origin.

BIO ENERGY - THE GREEN ENERGY ALTERNATIVE

Photosynthesis is the natural process in which sun's energy is captured by green plants to produce biomass which is utilized by the animal world. Biomass includes all contemporary biological matter, of both plant and animal origin. Solar energy captured by plants and stored as chemical energy in biomass can be converted to different forms and is called *bioenergy.*

Energy conversion of wastes and biomass is inevitable to provide clean energy for the society. Bioenergy is considered to be clean energy as they do not cause pollution as in the case of fossil fuels. Whatever CO_2 they produce, when burned, has been trapped from the atmosphere during their life time and if you allow plants to grow, the emitted CO_2 can be reabsorbed. Hence, systems which utilize energy produced from biomass are typical examples of energy recycling systems.

Bioenergy is likely to play a major role in the future energy development strategies. All biomass, plant, animal and microbial, originates through CO_2 fixation by photosynthesis. Photosynthesis may be defined as the photochemical reduction of CO_2. Biomass energy in developing countries, originates from fuel wood, animal wastes and agricultural residues and is primarily utilized for activities which are essential to survival such as cooking. Development of technologies that efficiently produce biomass and convert it to more convenient forms of energy is therefore very important.

In addition, bioenergy has the potential for decentralized energy generation which is highly relevant in a developing country like India. The technological developments in this area have a direct positive impact on the quality of life in rural areas. India and China are the pioneers in the development of biogas technology in the world and the favourable impact of this technology is well known. A survey conducted by MNRE (previously MNES) shows that a typical taluk in South India can sustain 2-10 MW power project based on surplus biomass. On a national level the possibility is around 19, 500 MW.

PHOTOSYNTHESIS AND BIOMASS

Photosynthesis can be simply represented by the equation:

$$6\ CO_2 + 6\ H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

Approximately 114 kilocalories of free energy are stored in plant biomass for every mole of CO_2 fixed during photosynthesis. Solar radiation striking the earth on an annual basis is equivalent to 178,000 terawatts, i.e. about 15,000 times that of current global energy consumption. Although photosynthetic energy capture is estimated to be ten times that of global annual energy consumption, only a small part of this solar radiation is used for photosynthesis. Approximately, two thirds of the net global photosynthetic productivity worldwide is of terrestrial origin, while the remainder is produced mainly by phytoplankton (microalgae) in the oceans which cover approximately 70% of the total surface area of the earth. Although photosynthesis is fundamental to the conversion of solar radiation into stored biomass energy, its theoretically achievable efficiency is limited both by the limited wavelength range applicable to photosynthesis and the quantum requirements of the photosynthetic process. The maximum theoretical efficiency is only 6.6 %.

BIOMASS ENERGY CONVERSION PROCESSES

Wastes and residues currently constitute a large source of biomass. These include forest and agricultural residues, municipal wastes, animal manure, solid and liquid agro industrial wastes (including pulp/paper/sugar/rice mills and fruit processing industries), fish and pharmaceutical (eg. antibiotics) industry wastes. All these biomass have different characteristics and different processes are to be employed for their efficient utilization. The processes are generally classified as *'Thermo chemical' and 'Biochemical'* processes. Thermo chemical processes are suitable for low moisture content materials while biochemical processes are employed for high moisture wastes. In thermo chemical processes, the application of temperature and sometimes pressure results in the production of energy or a readily usable fuel. In biochemical processes, living organisms (microbes) are involved. They convert the waste materials (organic) into a readily usable liquid or gaseous fuel through biochemical transformations. Some times the biomass materials are subjected to physical or chemical refinement. Briquetting of low bulk density biomass to increase its energy density is a physical refinement. There are also chemical processes to refine the biomass fuels like trans-esterification of vegetable oils to produce biodiesel.

Major biochemical processes for the conversion of biomass to fuels are methane production by microbial consortia under anaerobic conditions and ethanol fermentation by yeast. A wide variety of organic materials from animal and human excreta to waste paper can be converted in these processes. Depending on the feed stock, operating conditions and other process parameters, the equipment and processes widely differ.

Thermo chemical processes

The thermo chemical processes include direct combustion, different types of gasification processes and different pyrolysis techniques. Hydrogen gasification, Steam gasification, Liquifaction, etc are all thermo chemical processes which can be grouped under the above processes.

Combustion of biomass

Combustion is the most simple biomass energy conversion process where the reverse of photosynthesis occurs:

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{energy}$

Here the solar energy stored in biomass (as chemical energy) is released as heat energy. This heat energy can be directly used as process heat or used for production of steam which can drive a turbine or heat engine to produce mechanical shaft power. The conversion of mechanical energy to the readily usable electrical energy by way of a generator is well known. Sufficient supply as well as proper mixing of air with fuel particles is the essential prerequisite for efficient combustion. Restriction in air supply results in incomplete combustion and production of CO. In addition to loss of energy, highly poisonous carbon monoxide is emitted from inefficient combustion systems. About 200 million tonnes of firewood and an equivalent amount of agricultural residues are burnt annually in India with an approximate thermal efficiency of about 10 %. The smoky wood stoves in our rural households are examples for these inefficient combustion systems. Doubling the thermal efficiency of a wood stove reduces the fuel requirement to 50% and its favourable impact on environment is obvious. In India, many organizations and MNRE are promoting improved wood stoves (popularly referred as 'smokeless stoves') which are expected to have efficiencies in the range 20-25 %.

The total solid content (TS) of biomass has a thermally degradable, combustible volatile solid (VS) component and an incombustible 'ash' component. Sufficient air supply, both primary air and secondary air are required to ensure complete combustion of the VS. Ash is the incombustible mineral matter which is left over in the combustion process. Good combustion systems have a 'grate' on which the fuel is placed. Grate allows primary air to enter into the fuel bed freely. Ash falls down from the grate without obstructing free air flow in to the fuel bed. Glowing combustion of fixed carbon occurs at the grate where as the combustion of volatiles evolved from the biomass produce the flame. Both these processes are governed by different process kinetics. A thermo-gravimetric analysis can provide information on the mass conversion with respect to temperature profile or time. The primary step in the design of efficient combustion equipment is the calculation of the stoichiometric air requirement based on the chemical equations governing the oxidation of different elements like carbon, hydrogen, sulphur, etc., in biomass. Artificial or natural air draft is provided to supply sufficient air to the combustion chamber, often in excess of the stoichiometric requirement. Too much air carries the heat of combustion along with the flue gases (products of combustion, generally called exhaust) resulting in the lowering of overall efficiency.

Gasification of biomass

Direct combustion of solid biomass is generally inefficient and cannot be easily controlled. If we convert solid biomass fuels to a gaseous fuel, higher energy conversion efficiencies can be achieved due to the better mixing of air. Biomass materials such as firewood and agro residues contain carbon, hydrogen and oxygen along with some moisture and ash. Thermo-chemical gasification is the partial combustion of biomass material in a restricted air supply to produce a readily usable fuel gas known as 'producer gas'. This gas has a lower calorific value (1000–1200 kcal/Nm^3) compared to natural gas or liquefied petroleum gas, but can be utilized in combustion systems with high thermal efficiency under good degree of control. Usage of gasifiers instead of conventional direct burning devices can save a considerable quantity of fuel resulting in less pollution. For thermal applications, the technology has been well proven and gasifier systems having a capacity upto 500 $kW_{(t)}$ are already working in the field.

Theoretically, any biomass material with moisture content of 5-30% can be gasified. Examples are agricultural residues such as straws, stalks, coconutshell, coconut husk, rice husk, coir pith, arecanut husk, sugarcane bagasse, saw dust and forestry residues. Each kg of air-dry biomass (10% moisture content) yields about 2.5 nm^3 of producer gas. In energy terms, the conversion efficiency of the gasification process is in the range of 60 –70%. The producer gas generally obtained from wood gasification has about 18-22 % CO, 13-19 % Hydrogen, 1-5 % CH_4, 45-55% Nitrogen, 9-12% CO_2, 3-4% H_2O along with some hydrocarbons.

The gasification of solid fuel is generally accomplished in an air sealed closed reactor called gasifier. Depending on the movement of gases relative to the fuel bed, the gasifier designs are generally classified as updraft, down-draft and cross-draft gasifiers. Traditional down-draft gasifiers had throats in order to reduce the tar content of the gases, but throat-less designs are also available. Advanced designs such as fluidized bed systems, are also being developed by research organizations. Gasifier designs are usually designed for specific applications, with the fuel type, moisture content, ash content, size, etc. which affect the performance. Certain biomass fuels such as rice husk and coir pith may require very special designs.

The basic principle of gasification process is conversion of carbon in the solid biomass fuel into carbon monoxide by chemical reactions controlled by temperature. It is a complex phenomenon in which several thermo-chemical processes such as pyrolysis, combustion and reduction take place. Even though splitting of the gasifier into strictly separate zones is not realistic, it is assumed that these processes occur in different zones of the reactor at least for the purpose of understating the concept. Actually, different processes occur at the same time in different parts of the gasifier. The initial stage of gasification is drying, as biomass fuels generally have a moisture content ranging from 8 to 35%. In drying, they are not subjected to thermal decomposition but the water content is removed and converted into steam at temperatures above $100^{o}C$. The subsequent process in the gasifier is pyrolysis in which thermal decomposition of biomass fuels occur in the absence of oxygen resulting in the production of solid, liquid and gaseous products. The ratio of products is influenced by the chemical composition of biomass and the operating conditions. The oxidation of solid carbonized fuel to produce carbon dioxide takes place at a temperature of $700\text{-}2000^{o}$ C. Oxidation reactions supply the energy for drying and pyrolysis as well as for subsequent endothermic gasification reactions. Heat is required for the main reactions in reduction zone and hence, the temperature of gas goes down. If complete gasification takes place, all the carbon is burned and whatever CO_2 produced in oxidation reactions are reduced to carbon monoxide. But this seldom occurs and the product gas usually has some CO_2. Other combustible components are hydrogen and methane along with the inert nitrogen in the air supplied. The solid remains are ash and some char (unburned carbon). Apart from thermal applications, producer gas can be used in internal combustion engines usually in dual fuel mode. In almost all gasifier designs varying amounts of impurities like water vapour, tar, char and dust particles are present in the gas produced. A conditioning or cleaning of the gas is required for its use in engines.

Pyrolysis

Pyrolysis is theoretically the thermal degradation of biomass in the absence of air. Depending on the process parameters, there can be much variation in the quality and quantity of products. The products can be mixtures of combustible gases, liquids or solids. Pyrolysis is also called destructive distillation. Traditional charcoal making is also a pyrolysis process where the product gases or the vapours are not collected and condensed. The secondary fuels produced from pyrolysis have less total energy than the original biomass but are more convenient to handle and use as they have higher energy densities. It is well known that charcoal is a better fuel than wood. From 1000 kg of dry wood with a heating value of 20 MJ/kg we get about 300 kg of charcoal having a calorific value 30MJ/kg. Pyrolysis is not always done for fuel purpose and the objective can also be production of chemicals like methyl alcohol or acetic acid.

Energy Production by Anaerobic Digestion

Anaerobic digestion is the process of conversion of biodegradable organic matter into a combustible fuel gas called biogas. Methane (the combustible component of biogas) is produced by anaerobic decomposition (fermentation) or biomethanation – a process which takes place under oxygen deficient or chemically reducing environment by the action of micro organisms. The bacteria involved in the production of biogas are found naturally in decaying organic matter at oxygen deficient conditions like stagnant water bodies and marshlands as well as in the digestive tract of herbivorous animals. Biogas production technology has the advantage that it provides a better and cheaper fuel for cooking, lighting and power generation simultaneously producing a good quality, enriched manure to improve soil fertility. It also provides an effective and convenient way for disposal of organic wastes improving the hygienic conditions.

Biogas is the combustible gas mixture generated through biomethanation of organic materials with an approximate gas composition of 55–70% methane and 30-45% carbon dioxide as well as small quantities of gases like hydrogen, hydrogen sulphide etc. It is lighter than air and has an ignition temperature of approximately 700^{o}C with a calorific value of approximately 20 mega joules per cubic meter (or 4700 k cal/m^{3}). Biogas can be effectively used for thermal applications such as household cooking as well as for process heat in food processing industries. It is possible to produce mechanical power by using it as a fuel for IC engines. Spark ignition engines can run completely on biogas while compression ignition engines require pilot injection of diesel fuel. The existing diesel engines can be easily converted to work in dual fuel mode saving about 80 % of diesel.

Many species of microbes work cooperatively in an anaerobic digester, in which these polymeric materials (i.e. carbohydrates, proteins and lipids) are first decomposed to organic acids, and then to biogas which has methane, carbon dioxide and some minor products as constituents. The principal reactions taking place in the anaerobic digester are consecutive. Three distinct but simultaneous phases viz., solubilization, acidification (non methanogenic phase) and methanogenesis (methanogenic phase) exists in the anaerobic digestion process. The microbes involved are distinct groups with different growth characteristics. The first step involves the solubilization of complex organic materials (polymers) in the digester feed stock (cow dung or other organic material). Solubilizing bacteria secrete cellulose hydrolyzing enzymes and the polymers are degraded into soluble simple sugars. Hence, this phase is called solubilization phase. In the second stage, the bacteria reduce the soluble organic materials produced from the first phase to soluble simple organic acids. The acid formers are a heterogeneous group of bacteria, faster growing and less sensitive to their environment. In the third step, the methane bacteria reduce the organic acids, primarily acetic acid and some other oxidized compounds to methane and carbon dioxide.

A variety of raw materials which include agricultural wastes, municipal solid wastes, market garbage and waste water from food and fermentation industries, are applicable as substrates for this process. While cow dung can be successfully converted into biogas in a domestic biogas plant, industrial effluents (organic) is converted in high rate bioreactors like UASB reactors. Although small-scale digesters are popularly used at both the domestic and village levels, large-scale operations are still in need of considerable technical improvement and cost reduction and thus require both microbial and engineering studies.

Types of biogas plants

Any container which ferments the organic matter in an anoxic condition and has facilities to feed the input material, take out the spent matter and collect the biogas can be a biogas plant. Several designs have been in use for more than fifty years. The common domestic biogas plant types are generally classified into fixed dome and floating drum types. The former is basically Chinese design and the latter Indian. Janatha and Denabandhu models are fixed dome designs where the biogas is stored in a permanent masonry dome. The popular KVIC model and many similar designs like IARI are examples of floating drum type plant where the biogas is stored in a drum type container which floats above the digester slurry. Apart from domestic biogas plants there are also plants for community or institutional application where scaled up designs of Deenbandhu or KVIC models are commonly used.

Necessary Conditions for Optimum Biogas Production

Anaerobic digestion is a complex phenomenon involving innumerable biochemical reactions carried out by several species of bacteria. A satisfactory operation of an anaerobic digestion system can be achieved only by maintaining the favourable conditions for the growth of these bacteria. As biogas fermentation is carried out by three different groups of bacteria, a proper balance between these bacterial populations is necessary for satisfactory operation. Regular feeding schedule is the most important aspect for satisfactorily working of semi continuous biogas plants. Inside the digester, strict anaerobic condition has to be maintained since the methane producing bacteria is sensitive to the presence of O_2. A near neutral environment (pH 6.8-7.2) has a very favourable effect on biogas production. The optimum temperature for normal anaerobic bacteria, which survive and grow in a temperature range of 20^oC to 40^oC (*mesophilic*) is between 35^o to 37^o C. It is recommended that the total solid content (TS) of the feed material be maintained around 9-10% for continuous and semi continuous digesters. As cow dung has a TS content about 20%, a 1:1 (by volume) slurry of cow dung and water, corresponds to 10-12% TS, and is optimum for ordinary biogas plants. The maintenance of optimum carbon to nitrogen ratio in the range 25:1 to 30:1 is another important aspect in anaerobic digestion.

A number of materials may be toxic to the anaerobic bacteria such as ammonia, ammonium ion, soluble sulfides and soluble salts of heavy metals such as copper, zinc and nickel. Higher concentrations of metallic salts of Na, K, Ca and Mg are also inhibitory. Detergents are generally inhibitory to bacteria.

Hydraulic Retention Time (HRT)

It is the average length of time the feed material remains in the digester. The optimum retention time varies according to the type of digesters as well as type of feed material. For ordinary biogas plants operated on cow dung the HRT is between 30 to 60 days. Hydraulic Retention Time is the most important factor in determining the volume of the digester which in turn determines the cost of the plant; the larger the retention period, higher the construction cost. In India, the different HRTs are recommended for different temperature zones.

High Rate Anaerobic Bioreactors

Introduction of the *high rate anaerobic bioreactors* like, Up-flow anaerobic sludge blanket reactor and Anaerobic fluidized bed reactor have brought down the HRT of anaerobic digesters from 35-40 days of conventional biogas digesters to a few hours. Such drastic reduction in HRT has a dramatically favourable impact in terms of smaller digester sizes and consequently lesser digester costs. Further, it has opened the possibility of treating high-volume low-strength wastes such as industrial organic effluents by anaerobic process. Retention of bacteria within the bioreactor independent of waste flow was achieved by different techniques in the first generation high rate anaerobic bioreactors which employ a solids recycle system called anaerobic contact process. The concept of retention and maintenance of biological growth on an inert support material forms the theoretical basis for second generation *immobilized cell bio-reactor* designs. By maintaining a high concentration of active biomass within the reactor for long periods, these new designs allow efficient digestion of soluble wastes at hydraulic retention times of few days to several hours. They also ensure the treatment of both high and low strength soluble organic waste waters to more satisfactory levels at more economically viable conditions compared to aerobic systems.

In fixed film anaerobic systems like Up-flow Anaerobic Filter (UAF), the biomass is retained by attachment to an inert support medium and hence remains in the reactors for times longer than the hydraulic residence time. It consists essentially of a column packed with an inert support material such as gravel, plastic, ceramic, fired clay, mussel shell etc. In Up-flow Anaerobic Sludge Blanket (UASB) reactors the biomass is retained within the unit by development of highly settleable bacterial flocs, in the form of granules of 1-5 mm diameter. Well settleable sludge aggregates, dispersed under the influence of the biogas production, can be satisfactorily retained in the reactor by separating the biogas in a gas collector system commonly referred as GSS (gas-solid separator) device. It is important to separate biogas from the biomass to prevent carry-over of granules into the treated effluent. In Anaerobic fluidized bed reactors, the bacteria grow as a bio-layer around heavy small particles. These bio-layer covered particles are maintained in a fluidized stage by an upwards directed flow of water. The media is expanded, or fluidized, by the velocity of the influent plus a recycle loop. Owing to the heavy particles (e.g. sand) the settling velocity is very high, around 50 mh^{-1} enabling the application of high liquid velocities in the reactor (10-30 mh^{-1}). The up-flow anaerobic hybrid reactor hybridizes the UASB concept and random packing of a matrix in the top third of the reactor column. Many researchers evaluated the performance of this hybrid design and reported that this configuration combined the advantages of both UASB and UAF while minimising their limitations. The reactor was found efficient in the treatment of dilute to high strength wastewaters at high Organic Loading Rates and short HRTs.

LIQUID BIO-FUEL ALTERNATIVES

Even though bio-fuel includes all solid, liquid and gaseous fuels, the terminology 'Biofuel' is often used synonymously for liquid fuels for IC engines. The two most important candidates are Ethanol and Vegetable oil (modified as biodiesel). Both the fuels present a very promising alternative to petroleum since they are produced easily in rural areas where there is an acute need for modern forms of energy.

Alcohol as fuel

Ethanol is produced naturally by certain microorganisms from sugars. This alcohol fermentation process is used world wide to produce alcoholic beverages. The common microorganism is the yeast, *Saccharomyces cerevisiae*. Ethanol is a high octane fuel suitable for gasoline engines or spark ignition engines. The Brazilian alcohol programme was the first and most successful large scale biofuel programme in the world, which was implemented in 1975. They sell only alcohol-gasohol blend in petrol pumps. The United States also has a gasohol programme. Usage of pure alcohol in existing engines poses some technical problems. Alcohol is an octane booster for petrol and in India also we have started the use of alcohol blended petrol in several states.

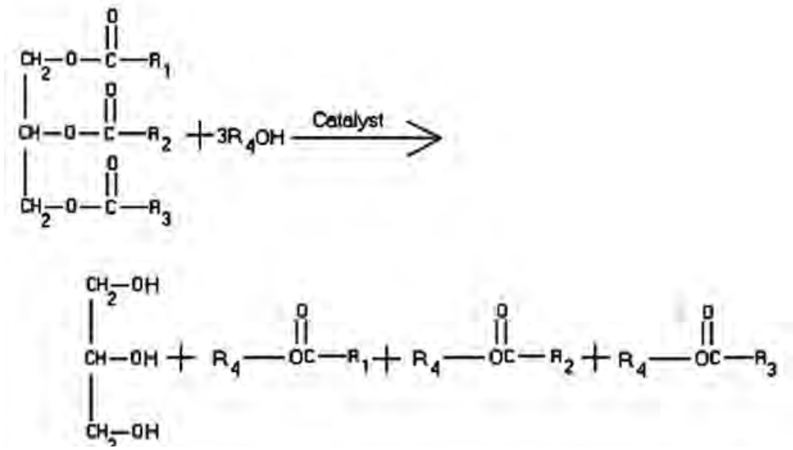
Ethanol can be produced from sugar substrates as well as from starchy and ligno-cellulosic biomass. The production of fuel alcohol from sugars is most simple as they can be directly fermented to alcohol. In the case of starchy biomass, the starch needs to be converted into sugar by hydrolysis. For ligno-cellulosic materials the preprocessing requirements are more. The cellulose needs to be broken down utilizing the enzymes cellulose. Even though technically feasible, the economic feasibility of alcohol production from ligno-cellulosic biomass is doubtful.

Ethanol production costs are only in the range of 18 - 25 % of gasoline production costs in Brazil. It is also noteworthy that for every 300 MT of sugar cane produced; approximately 700,000 jobs were created in Brazil. Volkswagen, General motors, Fiat, Ford, Peugeot are some of the manufacturers producing alcohol compatible vehicles in Brazil. We shall not further hesitate to use ethanol - gasoline blends in existing vehicles, simultaneously promoting the replacement with FFVs (Flexible Fuel Vehicles).

Vegetable oil as fuel - Biodiesel

The inventor of diesel engine, Rudolf Diesel, confidently predicted that plant based oils would be widely used to operate his engine. In fact, he used peanut oil for its demonstration. With the advent of petroleum fuel - a better and cheaper liquid fuel, the use of vegetable oils for fuel purpose became unpopular. However, in recent years, it has become necessary for us to put on systematic efforts again to utilize vegetable oils as fuel in IC engines. Some vegetable oils can be directly used in diesel engines as they have a high cetane number and calorific values very close to diesel. But, the use of straight vegetable oils in the present day diesel engines (Compression Ignition engines), is problematic. This is because, high viscosity and low volatility of vegetable oils lead to difficulty in atomizing the fuel and mixing it with air. Esters produced by the action of alcohol with vegetable oils, commonly called 'biodiesels' are fuels which can easily substitute diesel in a modern CI engine. A number of oils are considered world wide for conversion into biodiesel for use in engines. These include jatropha oil, soya bean oil, karanji oil, cottonseed oil, rice bran oil, rapeseed oil, sunflower oil, coconut oil, rubber seed oil, tobacco seed oil, mahuva seed oil etc.

Trans-esterification of vegetable oils is currently regarded as the most important means to process vegetable oils for fuel purpose. The product from trans-esterification, biodiesel, showed improved performance and reduced emissions. Biodiesel is a mixture of mono-alkyl esters of fatty acids derived from vegetable oils or animal fats. In simple terms, biodiesel is the product obtained when a vegetable oil or animal fat chemically reacts with an alcohol to produce fatty acid alkyl esters. A catalyst such as sodium or potassium hydroxide is required. Glycerol is produced as a by product.



Glycerol-Biodiesel molecules

Biodiesel has low viscosity compared to the parent vegetable oil and has physical properties better suited for diesel engines. The power output was found to be superior and they offer low smoke levels and high thermal efficiencies than pure vegetable oils. The cetane number is also improved.

Biodiesel as an alternative fuel for diesel engines is receiving great attention world wide. It is a renewable fuel and can be used either in pure form or in blends with diesel fuel in unmodified engines. Biodiesel has excellent lubricating properties. Even when added to regular diesel fuel in an amount equal to 1-2% (volume), it can convert fuel with poor lubricating properties, such as ultra-low-sulfur diesel fuel, into an acceptable fuel. As the primary feedstock for biodiesel is biologically produced from oil or fat that can be grown season after season, biodiesel is renewable and does not contribute to global warming due to its closed carbon cycle. They are also found to reduce exhaust pollutants to some extent. In addition to the reduction in pollution, popularization of biodiesel gives many other benefits to the country. It provides a market for excess production of vegetable oils. Production and use of biodiesel decreases the country's dependence on imported petroleum.

Even though much research work has been done within and outside the country, biodiesel production and use are not popular in Kerala. The most important oil crop of Kerala is coconut. Even though, there is only limited scope for its use as fuel at the current price levels, there are chances for wide fluctuations in coconut oil prices as experienced few years back. Studies conducted at the Kelappaji College of Agricultural Engineering and Technology of the Kerala Agricultural University has revealed that coconut oil biodiesel and its blends can reduce the pollution caused by diesel engines in Kerala. Countries like Philippines are already moving ahead to use coconut oil biodiesel in the transport sector.

CONCLUDING REMARKS

Bioenergy is an area attracting global attention for clean energy options. Biological processes for the production of gaseous and liquid fuels have been well demonstrated in developed as well as developing countries. Among different biomass conversion processes, methane production from organic wastes is economically feasible in Kerala within the restraints of scale and location. Although India is the pioneer in anaerobic digestion technology, research has to be intensified in several areas to make the technology adaptable in different situations. The most important area is energy conversion of municipal solid wastes. An integrated approach is still lacking where different processes are integrated into a system capable of meeting basic overall requirements for converting MSW into biofuels.

The economic compatibility of bioenergy systems depend on the comparative costs of fossil fuels. Presently, bioenergy sources are not always economically competitive due to the low prices of fossil fuels, often subsidized by governments of developing countries. In many cases, fossil fuel prices do not reflect their true costs. The costs accountable to the environment and the society need to be considered when their economics is compared with biofuels. These 'externality' costs of fossil fuel resources are paid by us, including the future generations, in environmental degradation, climate change and threats to economic sustainability. Hence, the development and expansion of bioenergy resources will require not only advances in technology but also an economic accounting for their lower environmental costs. Even though Kerala is a state where the issue related to energy and environmental degradation has great relevance, there are no research centres at present in any of our universities exclusively set up for energy research. Let us hope that such facilities will be developed here in the near future.

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Development through Energy Efficiency

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INTRODUTION

The economic development of any country is often linked to its consumption of energy. However the ever increasing demand for energy has led to considerable burning of fossil fuel which in turn has an adverse impact on environment. In this background, efficient use of energy and its conservation is of paramount importance. One unit of energy saved at the consumer end avoids 2.5 to 3 times fresh capacity addition. Further such savings through efficient use of energy can be achieved at less than one-fifth of the cost of fresh capacity creation.

The per capita energy consumption is too low for India as compared to developed countries. It is just 4% of USA and 20% of the world average. The per capita consumption is likely to grow in India with growth in economy thus increasing the energy demand. In theory, per capita energy consumption indicates the well being of human life. The more per capita usage is a human development index. Norway leads the world with 26700 kWh, US 14200, Japan 8500, France 8200, Brazil 2300, China 1700 and India just 680 kWh. For Kerala, it is much below the Indian average and is just 480 kWh/year. Suppose China and India are coming as the economic giants in 2030 and if our per-capita consumption reaches at the EU level, then in order to cater our needs we need one more earth.

Economic growth is desirable for developing countries, and energy is essential for economic growth. However, the relationship between economic growth and increased energy demand is not always a straightforward linear one. For example, under present conditions, 9% increase in India's Gross Domestic Product (GDP) would impose an increased demand of 12 % on its energy sector. In this context, the ratio of energy demand to GDP is a useful indicator. A high ratio reflects energy dependence and a strong influence of energy on GDP growth. The developed countries, by focusing on energy efficiency and lower energy-intensive routes, maintain their energy to GDP ratios at values of less than 1. The ratios for developing countries are much higher.

Energy intensity is energy consumption per unit of GDP. Energy intensity indicates the development stage of the country. India's energy intensity is 3.7 times of Japan, 1.55 times of USA, 1.47 times of Asia and 1.5 times of World average. In this case, how can our industries be competitive?

The energy inefficiency has damaged the atmosphere and climate. 60% of the Carbon-dioxide reaching in the atmosphere is produced either from a thermal unit or from an Industrial unit. The resulting increase in global temperature is altering the complex web of systems that allow life to thrive on earth such as rainfall, wind patterns, ocean currents and distribution of plant and animal species. That is why, energy conservation programme gets carbon credit from UNFCCC.

Energy efficiency is very important to all enterprises, especially for energy intensive industries. Any successful energy conservation programme needs the commitment of top management. Top management should give energy efficiency equal importance in their corporate objective as manpower, raw material, production and sales. The other important requirements are a well charted strategy plan, an effective monitoring system and adequate technical ability for analysing and implementing energy saving options.

A study conducted by National Productivity council, New Delhi for Energy Management Centre –Kerala and Bureau of Energy Efficiency gives an eye opening facts in various sectors.

ENERGY SAVING POTENTIAL IN AGRICULTURAL SECTOR

The annual electricity sale to agriculture sector in Kerala is 0.24 BU. The major energy consumption is in the area of energizing agricultural pumps. The population of agricultural pump sets is around 4.3 Lakhs, accounting for a connected load of 2155 MW and annual consumption of 0.24 BU. It is estimated that, by replacement of existing pumps with the BEE star labeled pumps, the achievable saving potential is 30-40% and sectoral saving potential works out to be 0.07 BU per year.

ENERGY SAVING POTENTIAL IN COMMERCIAL SECTOR

The annual electricity sale to commercial sector is 1.9 BU and accounts for 15.7 % of the total electricity sold. The commercial sector constitutes government and private establishments, hospitals, hotels, restaurants, educational institutions, malls etc. For assessment of saving potential, only those buildings with over 500 kW connected load have been considered.

There are 45 commercial buildings in the state accounting for annual energy consumption of 506 MU which works out to about 26.4% of the sectoral consumption. The annual energy savings potential for 45 commercial buildings is assessed to be 0.102 BU.

ENERGY SAVING POTENTIAL IN MUNICIPALITIES

The annual electricity sale to public lighting and public water works and sewage works out to 0.569 BU. For the major 53 Municipalities and 5 Municipal Corporations in Kerala considered, annual electricity consumption for street lighting is 23.1 MU and annual consumption for water and sewage pumping is 14.4 MU.

The total consumption works out to 37.5 MU. Based on sample studies, the energy savings potential for street lighting in municipalities and corporations is assessed to be 25% and works out to 5.8 MU per annum, While, the energy savings potential for water works & sewage in municipalities and corporations is assessed to be 20% and works out to 2.9 MU per annum. The aggregate sectoral saving potential among the above works out to 8.7 MU.

ENERGY SAVING POTENTIAL IN SME CLUSTERS

Study conducted in four energy intensive SME clusters, such as Rice Mills, Re-rolling, Seafood Processing, and Crumb rubber gives an annual energy saving potential of 138.255 MU and fuel oil saving of 12030.9 ToE.

ENERGY SAVING POTENTIAL IN INDUSTRIES

The annual electricity sales to the industry sector including low and medium voltage consumers (SME) and high voltage consumers (large industries) is 3.534 BU and works out to 29.1 % of the total electricity sold. The larger industries segment is covered for energy efficiency under the mandates of EC Act as designated consumers, while SME segment is being addressed for energy efficiency through cluster based initiatives by Bureau of Energy Efficiency. The energy savings potential for the sector is assessed to be 0.247 BU.

ENERGY SAVING POTENTIAL IN DOMESTIC SECTOR

In Kerala, the annual electricity sale to domestic sector is 5.62418 BU which accounts for 46.3% of the total electricity sold. The savings potential in rural segment by adopting CFLs and BEE star rated products is 40-50%. The savings potential in urban segment by adopting BEE star rated products is 15-20%. On the whole, the energy savings potential in domestic sector is estimated 20-25% which accordingly works out to 1.13 BU per year.

Now let us discuss on the Energy Conservation efforts in domestic sector.

Domestic energy consumption is the amount of energy consumed by different appliances used within the house. The amount of energy used per household varies widely depending on the standards of living, climate and type of house. The Household energy consumption mainly comprised of lighting, cooling/refrigeration, washing and cooking.

As said earlier, considering all the energy conservation potential, the total energy saving in domestic sector is estimated 20-25% which accordingly works out to 1.13 BU per year. In order to tap these potential, effective DSM (Demand Side Managment) programmes have to be implemented. Some of such successfully implemented DSM programmes in Kerala are:

Bachat Lamp Yojana (BLY)

The Bachat Lamp Yojana is a scheme developed by the Bureau of Energy Efficiency (BEE), Ministry of Power, Government of India to promote energy efficient lighting for households in India. Under the BLY scheme quality long-life CFLs would be distributed by the implementer(s) to grid-connected residential households in exchange of an incandescent lamp (ICL) at INR 15. Once the CFLs have reached their end of life or any CFLs which have failed prematurely during the project period, the implementer would arrange for the collection and disposal of CFLs as per applicable environmental norms. To bridge the cost differential between the market price of the CFLs and the price at which they are distributed to households, the Clean Development Mechanism (CDM) is harnessed. The implementer would cover the project cost through the sale of GHG emission reductions achieved in their respective areas.

Kerala is the first State in India to implement this project in the entire State. Under this project, 1,27,93,540 CFLs were distributed to domestic consumers and witnessed a reduction of 300 MW electricity during peak hours.

United Nations Framework Convention on Climate Change (UNFCCC) has approved all the CDM Programme Activity Design Document (CPA DD) of CFL distribution programme of Kerala. 20 CPA DDs were prepared for the projects in Kerala. The Carbon emission reduction calculated for this approved CPA DDs is about 20 lakh tonne during the project period.

Serve as a Volunteer for Energy (SAVE) programme

EMC in association with Malayala Manorama organized a programme for students and general public on the need of Energy Conservation. Quiz, Essay Competition and other programmes were organized and also the participants were requested to record their energy consumption for two months. After implementing best practices on energy conservation, the meter reading was taken and it was noticed that 217 MU were saved by the participants in the programme. The programme is continuing every year with different other programmes invlolving celebrities in cinema, art, etc.

Energy Clinic

This programme of awareness creation among housewives, who are the true energy managers of the household, is being implemented through women volunteers. The Energy Clinic volunteer plays a consultative role in helping/advising ignorant folks in choosing energy efficient home appliances to be procured. They also provide information on the correct method of using these appliances , whereby, these people are weaned off the conventional use of energy and drawn into the modern, more energy efficient appliances and equipments. This not only saves energy but also finds them some saved time for leisure and relaxation, provides good health for their mind and body by reducing pollution, takes away drudgery which in turn creates a strong platform for a healthy, happy family – the foundation for overall socio-cultural development; the end objective of a welfare State.

The Energy Clinic volunteer focuses on ;

- Methods of providing low-cost and efficient energy services to the urban and rural poor,
- Efficient energy management at the household and community levels,
- Best practices in energy efficiency and conservation, with a focus on using household appliances to reduce energy waste,
- Renewable energy applications (solar cookers, solar lighting, solar dryers etc.),
- Income generating activities

EMC started the Oorja Clinic programme in the year 1997 and at present has 283 trained volunteers spread over all districts of Kerala. The peculiar electricity consumption pattern of Kerala i.e. the increasing rate of domestic electricity consumption and the resultant high demand at peak load hours is one of the reasons for shaping such a programme. Each volunteer conducts two awareness programmes in a month. These programmes help in reducing the peak load demand.

Women Institute for Sustainable Energy Research (WISER)

With the objective of providing a plat form for women community in better research and development and training for optimum utilisation of energy resources, EMC in association with USAID/SARI/E, established a Women Institute for Sustainable Energy Research (WISER) in EMC for SAARC Countries.

WISER's objectives included

- Reduce poverty among rural women through increased access to and use of clean energy services, especially renewable energy sources such as solar and other feasible technologies in the region
- Create awareness among rural women on the negative impacts of using conventional sources of energy such as kerosene, firewood etc. on the natural environment, global warming and climate change etc.
- Promote micro-finance activities and help women become socially and economically empowered and contribute to the GDP in the region
- Collaborate with private sector entities to promote, manufacture and use appropriate and efficient domestic energy products and design services
- Serve as a regional resource centre, library, space for lectures and exhibitions, and training institute to educate women on energy efficiency and moulding them as 'catalysts for change' in the energy sector

Energy Conservation Clubs in Schools and Colleges

Energy Conservation Clubs are functioning at school and college levels. In order to strengthen the activities, EMC prepared two hand books on Energy conservation for school students with practical tips. These two books along with brochures, stickers and postures were sent to all High Schools in Kerala. Also, during energy conservation month celebration several competitions were organised for energy conservation club members at school, district and State level.

In order to educate the young generations on energy conservation, EMC has introduced 14 touch screen energy efficiency information, one in each district in the initial phase of the project. The schools will be provided with a touch screen computer with information of the energy scenario in general and the energy efficiency measures that can be implemented individually in school and in home. The database will also contain data on the local dealer of Energy Efficient equipments. There will be online query system, which can be answered by energy professionals in the Energy Management Centre. The system will be accessible to the students during the recess period or as decided by the school management like during their environment or science classes. The data provided will also include environment aspects as well.

The project will have provision for the students to monitor their household or school energy consumption as a whole or system/appliance wise and virtually simulate cases for adopting energy efficiency. This project will create awareness regarding energy efficiency in the surrounding households of the school and the public. The Supplier has made available the prototype system and EMC has given approval.

First LED Village in Kerala : The village' Ayakkurissi' in Palakkad district in Kerala is the first 'LED village' in south India; for which EMC joined hands with BEE to showcase this as energy efficient model village. 250 household bulbs and 50 streetlights were replaced with LED lights. Studies are envisaged for assessing the savings due to the above change

For realizing the significant energy saving potential envisaged among various sectors, there should be efforts from entrepreneurs, State Agencies and the Government. Energy conservation is always a win-win situation for all stakeholders.

Forest-Water-Energy Linkages in the context of Kerala

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INTRODUTION

Energy involved in the hydrologic cycle is considerable. The global average annual rainfall is 100 cm. About 30% is the precipitation on land, which is 7.7 times as great as the moisture contained in the atmosphere at any one time. The average evaporation for the whole earth is 2.37 mm/day: 70% precipitation over land is evaporated; 92% evaporation from ocean returns as rainfall and over 30% over land becomes runoff. One-fourth of runoff is diverted, two-third of which returns to streams and oceans and remaining one-third is consumed and returned to the atmosphere. These hydrologic processes are mainly responsible for erosion and accretion, formation of land forms, development of streams and watersheds and the water balance in different hydrologic units in the agro-climatic zones of the earth. The water in different phases of hydrologic cycle caters to different water uses of mankind and nature.

The energy-water-forest link plays a vital role in the management of environment and development of the State. Kerala State depends considerably on its hydro-electric projects, perhaps the main source to meet the power requirements from natural sources within the State. Therefore, there is a great need to scientifically manage the hydrology of upstream catchments so that these projects are sustainable. There is a close link between the forest ecosystem and the hydrology of upstream catchments, especially in an area where river flows are dependent on seasonal rainfall. The sedimentation from the catchments and their subsequent deposition in the reservoirs can be brought down by appropriate management of forest catchments in the western ghats. The sediment deposition in reservoirs is identified as a major reason for the reduction in the capacity to store water in the reservoirs. Apart from this, water is an important component for cooling in different types of power plants whether thermal or nuclear. In fact, while locating these plants two of the criteria to be fulfilled are the availability of water for cooling and disposal of water generally above normal temperature.

There has been a tendency to promote biofuels mainly to reduce the dependence on petroleum products which are comparatively costly and is a cause for high GHG emissions. All the more, biofuels are useful for local economy and creation of more jobs. Biofuels consume large quantity of water for their feedback production. It is feared that 'water for energy" may become a threat for 'water for food'. It is estimated that sugarcane ethanol calls for 11 litre of water/ litre of fuel in comparison to 3, 1 and 5 litre of water/ litre of fuel in the case of corn ethanol, conventional crude oil gasoline and tar sands gasoline respectively. It is worthwhile to note that sugarcane ethanol produces minimum of GHS compared to others. If total ethanol demand is met from sugarcane, 57.7 Mha of production land would be required in addition to 1.3 Mha of tropical forests or 174 Mha of dry land forest as carbon uptake land. Through an appropriate policy, it may be possible to apportion the use of blue, green, grey and CO_2 –water (calculated based on the evapotranspiration rates of these forests, reported by amount of CO_2 sequestrated). All the more, the people in the rural areas still depend on wood for meeting their major fuel requirement for cooking and other household purposes. Community management of the forest wealth gains importance in this context.

ECOSYSTEMS IN THE CONTEXT OF WATER MANAGEMENT

The ecosystems within a river basin can be broadly classified into terrestrial and aquatic. For convenience of treatment in the context of a river basin, these can be classified into upstream and downstream ecosystems.

The terrestrial ecosystems both natural like forests and grasslands and manmade like agricultural and urban systems contribute considerably to the hydrologic regime and the water management of the river basin. In fact, the ecosystems have their role in soil, water and biomass management of a watershed/ river basin. When compared to the aquatic ecosystems, terrestrial systems are comparatively dry from the point of view of hydrologic regime, rich as a biochemical source and low to medium in net primary productivity. Aquatic ecosystems are often flooded with water serving as a sink for bio-chemicals, with low primary productivity. On the other hand, wetlands are usually found at the interface between truly terrestrial ecosystems (such as upland forests and grasslands) and aquatic ecosystems (such as deep lakes and oceans) making them different from each , but highly dependent on both (Mitsch and Gosselink,1986) . Wetlands are often termed as ecotones to which materials are exported. The wetlands are intermittently or permanently flooded; these ecosystems serve as source, sink and transformer and their net primary productivity is generally high (Fig 1). The coastal ecosystems, especially coastal wetlands, are very much dependent on the water, sediments and biochemical transport from upstream reaches. These to a very great extent depend on the characteristics and the state of management of the upstream ecosystems and their communication with the sea, depending on the particular case.

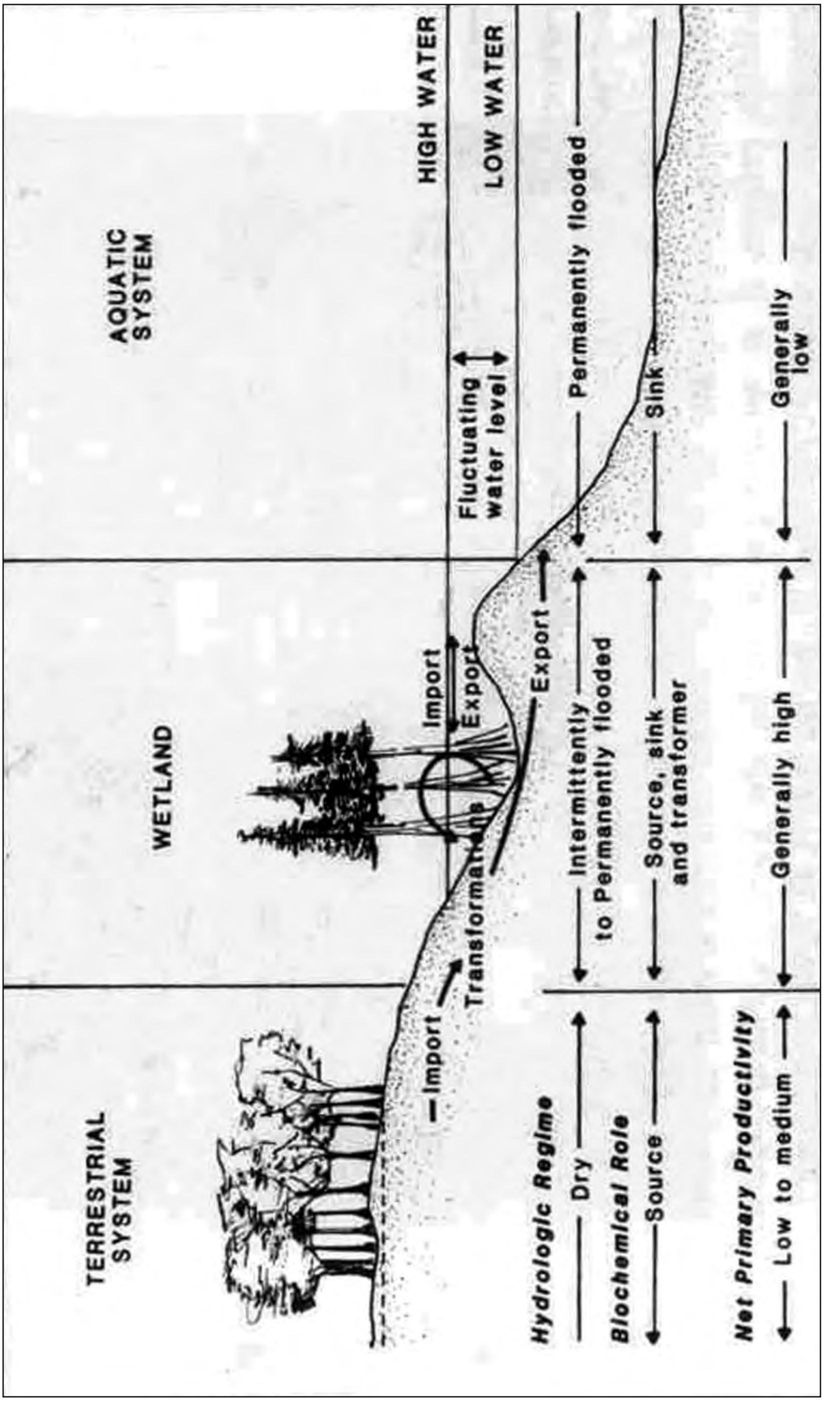

Fig. 1
Hydrologic regime, biochemical role and primary productivity of terrestrial, aquatic and wetland ecosystems

The water balance based on blue-green water, upstream-downstream requirements and human –ecosystem needs will depend on the conservation and management of different ecosystems.

The terrestrial ecosystems on the upstream of a river basin are important in the context of rainwater harvesting, groundwater recharge and for maintaining the stream flows during the lean season. Some of these contribute to food production, urban needs and biodiversity. Aquatic ecosystems are important from the point of view of food, fuel, medicinal plants, timber and biodiversity. Above all, these are important because of their recharging abilities, conservation of water and flood containing capacity. Therefore, this inter-connected web of terrestrial and aquatic ecosystems has to be conserved properly to serve as an 'environmental reserve' and to achieve this, scientific water management is necessary. Integrated water resources management, aiming at holistic approach or ecosystem approach, is important in the context of ecosystem conservation and management.

FOREST-WATER-ENERGY LINKAGES

Among the hydrologic functions of vegetal cover are: breaking the impact of rainfall; direct interception of a part of precipitation by the aerial portions of the plants; dissipation of soil moisture by transpiration; reduction in the loss of soil moisture by evaporation; binding the soil against erosion; and holding some moisture by the 'blotter' effect of litter (FAO, 1962).

The influence of vegetation upon infiltration and soil water storage is due to the effect of organic matter on and in the soil and to plant roots. Repeated measurements have shown a positive correlation between the quantity of organic matter present in soil and its water holding capacity. The studies in different parts of the world have shown that the water absorption capacity reduces due to forest fires and heavy use and trampling of soil. Such disturbed soils showed one-third of the rate of absorption of undisturbed forests.

Channels left by decayed roots also perform an important function in percolation and storage of water. Also, the growing tips force a way into minute cracks in the soil granules and through small passages between soil grains. When the roots die, they soon decay, leaving channels through which water may pass through the soil. The soil under relatively undisturbed forest and range cover is home of much animal life. Many animals, including most of the rodents and insects, dwell or borrow in soil. Fungus mycelia grow downwards and increase the lines of cleavage. These activities are conducive to the development and maintenance of a relatively high water-absorptive capacity. Any modification to the plant cover and surface soil by cultivation, burning, or over-grazing induces conditions favourable to the optimum development of these soil flora and fauna and results in a reduction in the capacity of the soil to take up water.

Water occupies the soil in three forms: hydroscopic (held in small pore spaces), capillary (tightly held on to soil particles) and gravitational (drained from larger pore spaces). Precipitation reaching the soil surface, which does not infiltrate or pond in small depressions, moves downhill over the soil surface as overland flow (Hewlett and Nutter,1969). Vegetation increases surface roughness, and litter particles on the soil surface form small dams and obstructions which slow down the velocity of overland flow and discourage concentration in rills and gullies.

Soil erosion may be broadly classified into: sheet erosion and channel erosion – the latter includes rill and gully erosion. Vegetation acts to reduce erosion by slowing down the velocity of water flowing over the soil surface. Some erosion is caused by overland flow; the effects of vegetation in reducing and retarding overland flow also operate to reduce erosion. Moreover, interception by canopy reduces the energy of rain drops.

Studies were conducted in three clusters of watersheds in the forest areas of the western ghats of south-west India to understand the role played by the forests in water management of this humid tropical region with an average rainfall of 3000 mm. Three watersheds, one each with 60% and more canopy, between 30 and 60% of canopy and less than 30% canopy constituted each of the three clusters ; the clusters were selected at Muzhy in Kozhikode and Vazhani and Chimoni in Trichur district of Kerala. Based on the data collected from the field, following general observations were made:

(i) The annual and monsoon runoff from a unit area of exploited watershed (less than 30% canopy) is more than that of other two in all the individual clusters; discharge from dense forest watershed (more than 60% canopy) lasts longer than the other watersheds after the monsoon season; the runoff coefficient with respect to rainfall is very high for exploited watersheds; the unit hydrographs of one-year duration show that lag time subsequent to a storm in a dense watershed is 35% more than that of the exploited watershed.

(ii) Based on the observations of throughfall and stemflow, it is seen that the average interception from a typical mixed forest watershed of western ghats is 10% of the rainfall.

(iii) The quantification of bed load accumulated at the weir sites on the downstream of the watersheds shows that the bed load accumulation at the exploited watersheds is more than six times of that of dense forest watersheds.

(iv) In all the seasons at all the depths considered, maximum soil moisture was observed in the dense forest watershed followed by other exploited watersheds in each of the clusters.

(v) The water balance study indicates that the deficit during the summer months of January-May is more in the exploited watersheds of each cluster than the forest watersheds (James et al, 1987).

The mountain forests are important as sources of water for irrigation and power generation. They intercept and store water from rainfall, mist and snow and release it slowly, thereby reducing soil erosion, avalanches and flooding impacts.

Most of these functions of forests are very important for Kerala, which depends largely on its hydropower from the reservoirs in the Western ghats. Moreover, forests, meadows and wetlands together play a vital role in physical, chemical and micro-biological filtering of water which penetrates soil, and also in locally limiting floods and drought affects by regulating flows. The riparian vegetation has an important role in filtering sediments and pollutants. In that sense, some of the experts are of the view that it is in maintaining high water quality that forests make their most significant contribution to the hydrological characteristics of watershed ecosystem.

In the energy sector, the present stress is on renewable energy, reduction in carbon emission and improving energy supply security. It is worthwhile to note that one of the largest producers of fuel wood is India (306 Mm^3) followed by China (191 Mm^3) and Brazil (138 M m^3). Household surveys of fuel wood use have shown considerable consumption even in industrial countries. Wood energy is an environment friendly alternative to fossil fuel energy and its efficiency has increased at least for industrial applications. Wood energy based systems are initiated in several industrialized countries. Fuel wood is the important form of wood energy in rural areas of developing countries, while charcoal remains a significant energy source in many African, Asian and Latin American urban households. Developing countries consume 90% of the world's wood fuel and wood is the primary source of energy for cooking and heating in developing countries. This trend is bound to continue. It is in this context that we have to see the importance of afforestation, reforestation and social forestry initiatives.

Forests have an important ecological role in fixing and storing carbon from the atmosphere during photosynthesis. This function is considered to be very important in the context of global warming and climate change. The carbon intake of different types of forest varies: tropical evergreen forests generally uptake three times more carbon than mixed deciduous forests. When the trees degrade, the stored carbon is released back to the atmosphere. Forest soils and vegetation together store about 40% of all carbon in the terrestrial biosphere. There has been a view that apart from blue, green, grey waters, a CO_2 water component also may be added, which is defined as the water consumed in the process to neutralize the equivalent CO_2 emissions over the life cycle of a product. This is calculated based on the evapotranspiration rates of these forests, reported by amount of CO_2 sequestrated. Therefore, great care has to be taken in formulating the management policies of forests, in which water and energy aspects have to be integrated with forest management.

Global Water Partnership 2000 emphasized on 'water for food, nature, and industry and other uses.' 'Nature for water' dimension is to be incorporated in it. Development of integrated water resources management plans at the watershed/ river basin level was an issue discussed at the World Summit on Sustainable Development in 2002. In the International Year of Freshwater 2003, the experts and policy-makers focused on three core issues: incorporation of forest hydrology knowledge in water policies; inclusion of forest sector contributions in integrated water resource management policies; and payment for forest and water related environmental services.

FOREST-WATER LINKED ENVIRONMENTAL PROBLEMS OF KERALA

The important forest-water related environmental problems of Kerala are:

- Frequent floods and droughts
- High rate of sedimentation and debris flows
- Salinity intrusion into rivers
- Degradation of wetlands
- Pollution of water sources

Frequent Floods and Droughts

Though it may not be possible to change certain factors contributing to frequent floods and droughts, like spatial and temporal distribution of rainfall, geology, geomorphology etc, it is definitely possible to have a planned land use as well as development and conservation strategies. If proper planning is done with regard to land use, soil conservation and developmental activities in a river basin, it may be possible to a great extent to control floods, droughts and high rate of sedimentation.

It is reported that during the 1924 floods, most of the areas in the erstwhile Travancore and Cochin States came under water, either under flood water or sea water. The rain continued for 9 days, leading to deaths of hundreds of people and thousands of cattle and other animals. Most of the deaths were reported from the high ranges. The year 1961 witnessed not only a long duration flood but also an intensive one, caused by heavy rainfall for 7-10 days in the last week of June. The annual rainfall in 1961 was 56 per cent above the annual mean. The maximum daily rainfall values recorded in 1961 at Calicut, Cochin and Trivandrum are: 234 mm, 186 mm and 136 mm respectively. The highest daily rainfall values recorded in the history of rainfall data collection at Calicut, Cochin and Trivandrum are: 470 mm (19 May 1992), 240 mm (3 April 1991) and 400 mm (18 October 1964) respectively. In the 1961 floods, the worst affected basin was that of the Periyar. Most of the roads were submerged. More than 100 deaths were reported from different parts of the State. Over 50000 houses were damaged and more than 50000 ha land seriously affected. During the 1992 floods, maximum rainfall was recorded on 10 October 1992 at Punalur, ie, 270 mm. The floods took away about 100 lives and 7500 houses were washed away. The total loss to the State due to this flood is estimated to be above Rs 1000 crores. On 10 July 1997, 279 mm of rainfall was recorded in 24 hours in Calicut city, which caused severe floods. The conditions favourable to floods have been since enhanced due to various activities related to urbanization and development.

Though the existing reservoirs are not originally intended to contain floods, they can be operated in such a manner that they contain at least a small portion of flood waters during critical times. Certain multi-purpose projects with capabilities to contain floods also may be planned in future, upstream of highly flood-prone areas.

The Western ghats region, especially in ldukki and Wynad districts, are more prone to the debris flow or the so called ‘landslides’ .On an average, 5 people die every year due to debris flows. Some of the recent debris flows were in Moolamattom

(September 1988), Ilappilli (October 1991) and Adimali (July 1997) in central Kerala and Padinjarathara (June 1992), Pazhukadavu (June 1992) and Adakkakundu (June 1993) in northern Kerala.

The water scarcity in summer months, locally called as droughts, is mainly reflected in dry rivers and lowering of water table. This adversely affects the drinking water sector. During the drought years, 15-20 per cent of the homestead open wells dry up, affecting about 3 million people. Most of the larger water supply schemes depend on surface water sources. When these sources either dry up or do not yield water to the requirements, most of the drinking water supply schemes fail to cater to the requirements of the people. In addition, flow reduction in rivers has impact on irrigated agriculture and to some extent on hydro-electric power generation. Not only rice crop but also plantation and spice crops of Kerala get affected during dry years; in some cases, perennial crops totally perish. The drought conditions in the Bharathapuzha basin during 1983 and 1987 are used by the author as a case study to come to these conclusions.

Sedimentation

The high rate of sedimentation from the Western ghats is mainly due to the changes in vegetation pattern and various developmental activities, such as construction of buildings, roads etc. From the studies conducted at CWRDM, it is indicated that the average sediment yield from the Western ghats is 15-20 tonnes/ha/year (CWRDM, 1992). An integrated watershed management practice may be one of the solutions to conserve soil and water. The capacity of Peruvannamuzhi reservoir has reduced by 15% due to large-scale soil erosion from deforested catchments.

Salinity Intrusion

The State of Kerala with an average width of 70 km has 44 rivers, of which 41 originate from the Western ghats and flow to the Lakshadweep sea. These short, fast-flowing, monsoon-fed rivers often encounter salinity intrusion into their lower stretches during the summer months. When the fresh water flow reduces, two major problems are encountered in these water bodies: (i) salinity propagates more into the interior of the river, and (ii) the flushing of the system becomes less effective. Both these aspects have an impact on drinking, irrigation and industrial water supply schemes situated in the downstream reaches (James, 1996). Detailed investigations have been carried out to understand the mixing and circulation at the river mouths in south-west India (James, 1989). The coastal belt is the most thickly populated area on this coast with the density in certain pockets reaching up to 5000/km^2. Important cities like Greater Cochin, Calicut, etc are situated in the coastal belt, on the banks of the estuaries. All the more, these wetland bodies are important from the points of view of biodiversity and mangrove forests.

Based on the studies conducted with the help of mathematical models, it is found that the salinity in the Beypore estuary propagates to a distance of 24 km upstream, thereby creating problems to the existing water supply scheme to the Kozhikode Corporation area (James and Sreedharan, 1983); the flushing time in summer from a distance of 20 km from the mouth is 20 days and more, creating pollution concentration in the lower stretches. These problems are acute in some of the estuaries nearby important cities and industrial complexes. Problems of salinity intrusion are also observed in the Periyar, Meenachil and Kuttiyadi rivers, which have been studied in detail (James, 1985).

The present measures for preventing salinity intrusion into the intake points of drinking water supply schemes is by the construction of temporary barrages, which prevent the flow and create ecological problems, especially concentration of pollutants upstream of the obstruction and also adverse impact on flora and fauna. Areas upstream of Thanneerrnukkom barrage in the Vembanad and Pathalam barrage in the Periyar are typical examples (James, 1996 a).

Degradation of Wetlands

Wetlands help in controlling floods, recharging groundwater and maintaining water quality. Considering the role of wetlands as source, sink and transformer, these are called the 'kidneys of nature'. One of the most important values of wetlands is biodiversity conservation. Ditching and draining are hydrologic modifications of wetlands, specifically carried out to dry them out. Reclamations destroy or change the character of most of the wetlands of Kerala. Moreover, the climate change is expected to have several adverse impacts on wetlands, especially coastal wetlands.

Canals and ditches are dredged for three primary purposes: (i) flood control, (ii) navigation and transportation, and (iii) industrial activity. Large-scale reclamation works are mainly for human settlements, cultivating plantation crops and construction of roads and industrial complexes. Other human activities also have caused significant changes to wetlands. These changes are: land clearing and hydrological modifications such as stream channelization and dam construction. Increase in erosion in the uplands leads to increased deposition of sediments in the wetlands, such as forested swamps and coastal marshes. This increased accumulation of sediments can cause increased bio-chemical oxygen demand and can alter the hydrologic regime of the wetlands over a relatively short time. Stream channelization and dams can lead to a change in the flooding frequency of many wetlands and thus alter the input of nutrients. Dams generally serve as nutrient traps, retaining materials that would otherwise nourish downstream wetlands. Impoundments upstream reduce the downstream flows considerably during the summer months and enhance the salinity intrusion problem. In some areas, stream channelization has caused stream down-cutting that ultimately drains wetlands.

Most of the rice fields in Kerala are reclaimed for settlements, industrial purposes and cultivation of plantation crops. Around 30 per cent decrease in the area of rice fields are observed during the past one decade and a half. The present trends indicate that there will be a total disappearance of rice fields by the end of this decade.

The case study of the Vembanad backwater may serve to illustrate the reclamation tendencies of wetlands in Kerala. Shrinkage of Vembanad wetland to 37 per cent of its original area due to land reclamation has been the most important environmental consequence of human intervention in this water body. About 23105 ha land has been reclaimed from the backwater during 1834-1984. Incentive given by the government after the Second World War by way of interest-free loans for intensive rice cultivation encouraged reclamation activities. During the period from 1941 to 1950, almost all shallow regions of the wetland were reclaimed by constructing 'bunds' or embankments. It is estimated that 21 per cent reclamation took place during the span of last 15 years. The depth reduced by 40-50 per cent in all zones, except between Aroor and Wellingdon Island and the Cochin port zone. The water carrying capacity of the system reduced to 0.6 km^3 from 2.4 km^3; this has an adverse impact on the flood absorption capacity of the wetland.

Pollution of Water Sources

The Periyar, one of the larger river systems of Kerala, is highly polluted with effluents discharged from major industries located on the banks. These industries discharge hazardous pollutants like phosphates, sulphides, ammonia N, fluorides, heavy metals, and insecticides into the downstream reaches of the river. Apart from major industries, coir retting by conventional methods also adds to the pollution in the Periyar estuary. Barrages have been constructed to prevent salinity intrusion into the upstream reaches. The enormous quantities of wastewater discharged daily into this branch of the river (around 10Mm^3) are not flushed out, leading to stagnation and pollution build-up to high toxic levels. This water is found to be highly acidic (pH 1.9), loaded with ammonia , flourides and phosphates, resulting in massive fish-kills.

The Vembanad backwater system is a receptacle of a large variety of industrial effluents, domestic sewage from Cochin and a string of small towns nearby. Cochin city alone generates 2550 million litres/day of waste water that directly enters into the backwater untreated. Total dissolved solid content of water in this zone is as high as 53750 mg/litre during summer and comes down to 160 mg/litre during the rainy season when the flushing is much better. The existing sewage treatment plant in Cochin covers only a small fraction of the population. The pollution load from Cochin Corporation and Alappuzha town are 195547 kg/day of BOD and 64237 kg/ day of BOD respectively. Annual fertilizer consumption in Kuttanad is: 8409 tonnes of N, 5044 tonnes of P and 6786 tonnes of K. Pesticides/fungicides/weedicides are applied to the tune of about 500 tonnes/annum. The observations in the Vembanad backwater system indicate that faecal coliform bacteria is very high. The quality of water is very poor near Alappuzha - nitrate values went up to 30 mg/litre.

The other water bodies in the State have also started showing symptoms of pollution. The Sasthamcotta lake and Pookot lake also need close watch and monitoring. The pollution of groundwater sources are reported from certain urban areas in Kerala. Once polluted, it will be very difficult to improve the quality of groundwater sources.

ROLE OF FORESTS IN SUSTAINING HYDRO-ELECTRIC PROJECTS IN KERALA

Due to non-availability of other sources and several socio-economic factors, the State mainly depends on its water resources for power generation. In spite of the fact that the State Water Policy (2007) recognizes that hydroelectric energy is comparatively cheap, clean, affordable and highly suitable for meeting the peak demands of the State, there are several oppositions from the public in implementing these projects, some of them rational and others emotional. According to the Water Policy, it is stated that hydroelectric projects with optimum storage shall be given utmost importance. The live storage capacity of the reservoirs owned by the Government is around 3500 Mm^3; annually, these reservoirs help in utilizing 10000 Mm^3 of water for power generation. This also includes the re-utilization of the tail-race. A study being carried out in CWRDM shows that the water released from these reservoirs in summer months is of great use for lift irrigation, water for drinking and industrial purposes downstream and to maintain minimum environmental flows in rivers like Periyar, Muvattupuzha and Chalakudy. The total hydroelectric power potential of the State is presently estimated at 5000 MW. Most of the basins are yet to be investigated to ascertain their potential. There is a need to accurately assess the hydroelectric potential of the State and take up those projects which are technically feasible, economically viable and environmentally safe. This has to be done on a priority basis since people of the State are suffering for want of power for domestic, agricultural and industrial purposes. Even pumping at the drinking water supply schemes does not take place on time due to non-availability of power. There have been also sporadic attempts to introduce small hydroelectric projects wherever field conditions permit. However, the progress has been very slow in this direction.

Almost all the reservoirs of hydroelectric projects are in the highland belt of Kerala, which permit good head and gravity flow to the power house. The catchments of all these reservoirs are in the midst of tropical forests in the western ghats. These forests play a vital role in conserving and regulating the flows and sustaining the flows almost all through the year. The studies on transport of sediments and their deposition in the reservoirs of hydroelectric projects have shown that the sediment load is more from disturbed forests than dense ones. In fact, sediment deposit in Kakkayam reservoir of Kuttiyadi hydroelectric project was much less than several of the reservoirs in the Periyar basin. The main reason which prevented exploitation of the catchment of Kuttiyadi is inaccessibility to the forest catchment. The reduction in capacity of these reservoirs would adversely affect the power generation in a State which is already starved of power. Therefore, those agencies involved in power generation have to focus on the conservation of forest catchments together with the forest department. Detailed management action plans have to be prepared by all those involved and implemented in a phased manner. These services are to be duly recognized by the consumers and those in the downstream stretches of the river basin. R&D and policy support also should be made available to implement the management action plans. Afforestation and reforestation programmes are also important in the context of global warming and climate change. In fact, the State which depends considerably on its hydropower has to be prepared to face the consequences of climate change and its impact on hydrology and especially on spatial and temporal storage fluctuations in reservoirs.

CONCLUSIONS

The paper brings to light the close link among forest, water and energy sectors through case studies and past literature on the subject. Forests play a vital role in conserving water, regulating flows, improving the water quality and reducing the sediment yield from the catchments.

Kerala State depends on its hydropower to a great extent. In fact, water is the only natural resource available in the State for power generation. There is a felt need to conserve and reforest the catchments of the reservoirs of these projects to ensure timely flows to suit the design requirements and control of sediment load to the reservoirs, which bring down the storage capacity. A concerted effort is called for in this direction by Kerala State Electricity Board, Water Resources Department and Forest Department.

An estimate of actual fuel wood utilized may be made and future requirements ascertained so that necessary planning for meeting this resource may be possible. Wood energy being more environment friendly than fossil fuels, attempts should be made to make use of it efficiently as done in several developed and developing countries.

There is a tendency to go for biofuels considering the cost of petroleum products and the level of emission of GHG. However, this option has to take into account a water component. There is going to be a conflict between the advocates of 'water for food' and those of 'water for energy'. There has been a view that apart from blue, green and grey waters, a CO_2 water component also may be added to the list, which is defined as the water consumed in the process to neutralize the equivalent CO_2 emissions over the life cycle of a product. Now-a-days, people are talking about 'nature for water' and not 'water for nature or environment'.

The paper also presents the forest-water linked problems of Kerala and strategies to overcome some of these problems.

There is a close link among forest, water and energy. Recognizing this link, future policies have to integrate all these sectors. Knowledge on forest hydrology has to find a place in water policies. Such an integrated and multi-sectoral approach is bound to invite some resistance. But, this resistance can be overcome by the R&D support based on inter-disciplinary research, awareness programmes and attempts to convince policy-makers.

The need for integrated water resources management with due stress on forest hydrology and energy considerations is emphasized. A series of approaches and actions can be adopted in order to most appropriately integrate these into river basin management. These include:

- Integrated land and water management
- Resource identification and evaluation
- Multi-disciplinary and multi-sectoral approaches

- Comprehensive EIA and CBA (including SEA, EIA of projects and policies, EIA of early stage of project or policy development cycle, economic cost and benefits of EIA recommendations, risk and sensitivity analysis)
- Identification of current and future water resources scenario
- Identification of water related problems
- Economic incentives for sustainable management
- Involvement of stake-holders, encouragement of public participation and public awareness creation
- Greater institutional capacity and appropriate institutional structure for river basin management

Those who are involved in the forest and water-related environmental services are to be given payment or incentives. Most of the forest management services are done by those in the upstream catchment and benefits are often reaped by those in the downstream reaches. Therefore, incentives are to be introduced for better efficiency in managing the ecosystems.

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Waste Disposal and Energy Recovery for Remote Locations

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INTRODUCTION

Tourist and pilgrimage locations in India attract thousands of tourists every year. Rapid growth in this sector attracts so many issues with utilities like power, water, food, etc for the tourists/pilgrims. It also attracts waste management issues. Large number of these tourist/pilgrimage locations is in remote areas of the country. These places have limited access to electricity or other clean forms of energy. On the other hand, huge volume of energy rich wastes generated in these places is another major concern for the local bodies. If we utilize the untapped energy from these wastes, that itself can supplement the energy requirements for these areas.

Different types of negative impacts are generated by tourism/pilgrimage as beneficiaries exploit the nature for their personal benefits without giving much importance to the nature. The scale of tourism development in relation to the carrying capacity of the environment greatly influences the extent of environmental impacts. The most common problem in tourism areas is the littering of debris on the landscape. This is due to large number of people using the area for picnicking. Improper disposal of solid waste from hotel, restaurants, and resorts generate both litter and environmental health problems from vermin, disease and pollution. It can also lead to the degradation of tourist sites.

The waste generated in these areas consists of plastics, clothing, food waste, paper, sewage sludge etc. Majority of these wastes have high energy content and currently dumped in open dump yards. These dump yards are polluting the environment and produces greenhouse gases like methane and carbon dioxides. This contaminates the natural resources like water. In some cases they are disposed off in incinerators, again causing enormous harm to the environment and the natural area.

All these places being in mountains or high altitude locations, the ambient temperature are below the normal values. This necessitates requirement of hot water for utility supply. In addition to that, the heat energy can also be used for air conditioning requirement during the summer season. The high energy content in the wastes generated at these areas can be utilized to meet a portion of the energy requirements in these tourist/pilgrimage places.

This paper describes a promising rotary kiln based gasification technology suitable for disposal of the waste generated at these places and for energy recovery. The recovered energy can be used for supplying hot water for cooking, bathing and cleaning. In some case the energy can be used for power generation as well as air conditioning.

ROTARY KILN GASIFICATION TECHNOLOGY

TURNW2E™ Gasification Technology is small-scale distributed waste gasification system especially designed for converting all types of wastes into fuel gas, which is subsequently used for energy recovery. It can operate using a wide variety of wastes including sorted MSW, industrial wastes, forestry wastes, biomass, demolition wastes and agricultural wastes. The gasifier is designed to accept a variety of wastes with differing compositions and origins. The wastes can be processed individually or in combination with other wastes. The conversion of solid wastes to gaseous fuel is achieved by using standard gasification processing steps which include reacting waste with air or oxygen and steam. The fuel gas contains primarily carbon monoxide, hydrogen, methane, carbon dioxide, and water. After cleaning, this fuel gas burns cleaner than natural gas because of its low combustion temperature. The fuel gas can be used for multiple uses like power generation, for the production of combined heat and power, for the production of hydrogen and for the production of liquid fuel.

The heart of this technology is the patent pending rotary kiln gasifier with unique internal arrangement for introducing oxygen at various locations inside the Gasifier. This feature permits to adjust the temperature to crack the heavy oils into smaller hydrocarbon chains. Since tar is a major problem in the gas produced from conventional gasifiers, this unique feature allows considerable reduction in tar present in the gas. In addition to this, system has no restrictions on the bulk density, size distribution etc. The use of rotary kiln ensures favourable reaction conditions for gasification like turbulence, mixing, retention time etc.

The Rotary Kiln Technology has skilfully surmounted this issue of moisture and low heating value of the waste by incorporating the ability to mix the wet waste with dry wastes reducing the overall moisture levels to levels needed for gasification and then co-processing these wastes. The Rotary Kiln is also designed to enable the introduction of hot gases independent of air and or oxygen which may be needed for drying these wastes prior to gasification. Most of the time the mixing of the wastes is sufficient to overcome the difficulties associated with the moisture and the feature of internal drying is rarely utilized. The Rotary Kiln Gasification system is designed to operate at atmospheric pressure and at temperatures ranging from 700^0C to 1000^0C. The operating temperature depends largely on the properties of the waste feedstock. A typical process flow diagram is shown in Fig.1.

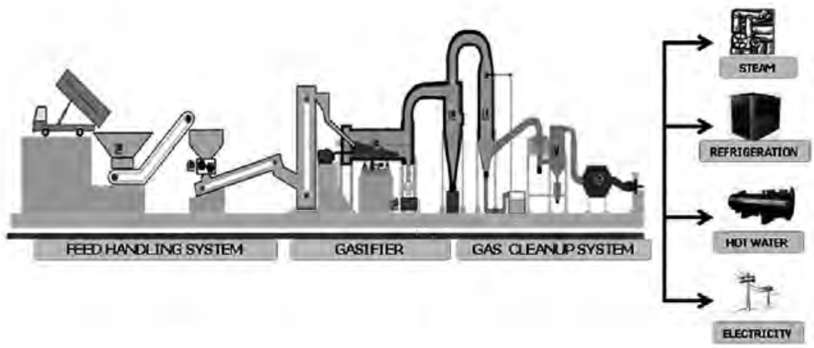

Fig.1.

Process Flow Diagram For A Typical Turnw2e[tm] Gasification System

TURNW2ETM GASIFICATION SYSTEM - ADVANTAGES

TURNW2E[TM] Gasification Technology incorporates a unique and highly flexible rotary kiln gasification system for the conversion of all types of wastes into energy as electricity and/or steam. The technology is particularly suited for mixed wastes like clothing, food waste, plastics, sewage sludge etc. The rotary kiln has a lengthy track record for reliability when used in similar processing applications and has a record of availability of greater than 99 percent and minimum maintenance requirements.

Presently mass burn systems like incineration are acknowledged as having issues related to the emissions of carcinogenic compounds such as dioxins and furans. The gasification of waste; to convert it first into fuel gas and then utilize this fuel gas to produce steam or electricity is the optimum way to eliminate the emissions associated with incineration processes. The intermediate gasification step between waste and the combustion of fuel gas makes it possible to remove all of the “bad actors” that contribute to the formation of carcinogenic compounds. This step also simplifies the permitting process since the gasification process is merely an intermediate step to produce clean fuel with combustion properties similar to those of natural gas. The permitting efforts can then shift to the power generation or steam generation processes, which are routine applications.

When compared with other gasification technologies, rotary kiln gasification system distinguishes itself from others in six unique process and operational areas. These are a) the reliable gasification of non-homogenous waste; b) sufficient turndown capacity to process varied quantities of waste; c) the production of consistent gas quality to meet the client’s requirements; d) the ability to process difficult wastes (such as plastics); e) Producing syngas with tar content less than 10 ppm; f) a simple and reliable system most suited for operation by relatively unskilled operators.

TURNW2ETM gasification system utilizes simple and mostly off-the-shelf components to reduce time for fabrication and installation. The two main components are 1) the rotary kiln gasifier to convert waste through partial oxidation with air into a syngas containing a mixture of combustible gases, including carbon monoxide, hydrogen, carbon dioxide, water vapour, nitrogen and some hydrocarbons; and 2) the device to utilize syngas and to convert it into useable energy like electricity, steam, hot water, air conditioning/chilling or a combination of these.

Some of the features like large turndown ratio and the transportable nature makes it suitable for small scale applications in remote areas like tourist/pilgrimage places. A system designed for 10 TPD waste capacity can be operated as low as 1 TPD when situation demands. There is large amount of heat energy in the system that can be recovered during the process. Very small foot print area is required for incorporating the system makes it more attractive for remote installations. In addition to that, the system being fully automated requires only 2 man power for operation of the plant. One is used for handling feed and the other one for operating the system from the control desk.

ENERGY RECOVERY POTENTIAL FROM TYPICAL WASTE

Energy recovery potential from typical 10 TPD system is depicted in Table 1.

Table 1
Energy Recovery Potential from a 10 TPD TURNW2E™ SYSTEM

PARAMETER	VALUE	UNIT
Plant Capacity	10	TPD
Waste Feed Capacity	400	kg/hr
Avg Waste Feedstock HHV	3000	kCal/kg
Moisture Content of Waste Feedstock	20	%
Gasification Temperature	980	deg C
Syngas Production per Unit of Feedstock	1140	Nm3
Syngas HHV	780-1000	kCal/Nm3
Power Generation Potential	**260**	**kW**
Steam Generation Potential @ 10 bar Pressure hour	**1150**	**kg**
Hot Water Generation @ 50 deg C Delta T per hour	**14**	**m3**
Refrigeration Potential @0.7 COP	**200**	**TR**

HOW IT BENEFITS THE TOURIST/PILGRIMAGE LOCATIONS

The tourist/pilgrimage locations demand for a suitable technology for the waste issues they have been facing for the past few years. The waste generated in this sector is high in energy content and are not handled in a safe and environment friendly manner. The TURNW2E™ system can be a good option for converting these wastes into usable energy. The best example in Kerala is Sabarimala, a well known pilgrimage place where thousands of pilgrims visit every year during the season. It is the largest annual pilgrimage in India with an estimated 45–50 million devotees visiting every year. TURNW2E™ waste to energy system can provide a solution for the waste issues and the thermal energy can be used for energy requirements for utility systems. As the system is transportable in nature, it can be relocated to another place. The system can be easily disassembled, transported to another location and assembled again in the new location. Most of these equipments are skid mounted on container and hence transportation is easy.

CONCLUSION

The smaller size and low foot print requirements makes TURNW2E™ system suitable for waste disposal and energy recovery in remote locations. This low emission environment friendly technology is a technically and financially feasible solution for the waste management issues in the remote tourist/pilgrimage locations.

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Biomethanation of Wastes to Energy – Emerging Trends and Overcoming Environmental Challenges

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INTRODUCTION

Biomethanation of rural and urban wastes had remained unpopular for being not able to support local enterprises. Modern biomass and USW biomethanation plants have overcome these lacunae and are poised to become a street-side option. While these were originally designed for rural residues, decentralized conversion of urban residues safely, without odour and aesthetically may become the driving forces for them to become popular where these seem to be the most sensible, logical and enterprise(able) option. Tweaking biomethanation and allied technologies in India can ensure urban habitats become near zero-waste entities.

Rapid urbanization and increase in wastes and residues

India is urbanizing rapidly and at rates that greatly threaten the local environment and is largely created by the extent of energy use and the resultant generation of incompletely utilized wastes. The expansion of cities and urban bodies have been occurring in many ways as indicated below.

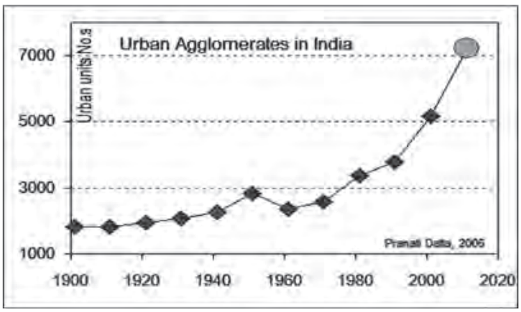

Fig 1
Rapid increase in the number of towns post 1980 (adapted from Pranati Datta, 2005)

It is thus important to note that the increase in the number of urban areas (cities and towns) is firstly caused by an increase in the number of these towns and cities as seen in Figure 1. The post 1980 increase is significant. Secondly, even among older and established cities it is seen that the cities are growing firstly by agglomerating the neighbouring villages and small towns to create an urban agglomerate – while the core or the central areas are also growing (Table 1). As a result it is seen that the density of inhabitation is growing rapidly (Figure 2) wherein the densities have rapidly raised from about 8000/km2 in the 80's to levels as high as 25000/km2 in some areas. This kind of increase in density leads to high production and accumulation of wastes. As the level of waste generation is reaching 1kg/cap/d, the total wastes generated per square km will be about 3600t/annum or simply 36/ha/yr. At such a high level of waste production there are not only serious environmental issues but, hardly any simple solutions, especially those that are environmentally friendly and we in India need to devise novel solutions as we are the first in the world to face such crises.

Table 1
Rate of expansion for central and peripheral areas

U .A./City	Urban Agglomerates Growth Rate		City Proper (Growth Rate)	
	1981-91	91-2001	1981-91	91-2001
Gr. Mumbai	33.7	29.9	20.4	20.0
Delhi	46.9	51.9	43.2	36.2
Bangalore	41.3	37.8	7.4	61.3
Pune	44.8	50.6	30.2	38.3
Surat	64.4	85.1	62.2	62.3
Kanpur	23.8	32.5	25.8	35.0
Jaipur	49.6	53.1	49.2	59.4
Indore	33.7	47.8	31.6	46.3
Kochi	38.3	18.8	13.5	2.4
Madurai	19.7	10.0	14.6	-1.9
Kolkata	19.9	19.9	6.6	4.1
Chennai	26.4	18.5	28.9	9.7
Ludhiana	71.8	33.7	71.7	33.7
Nasik	63.7	58.8	80.6	63.9
Rajkot	47.1	53.1	25.7	72.8
Adapted from Bhagat (2006)				

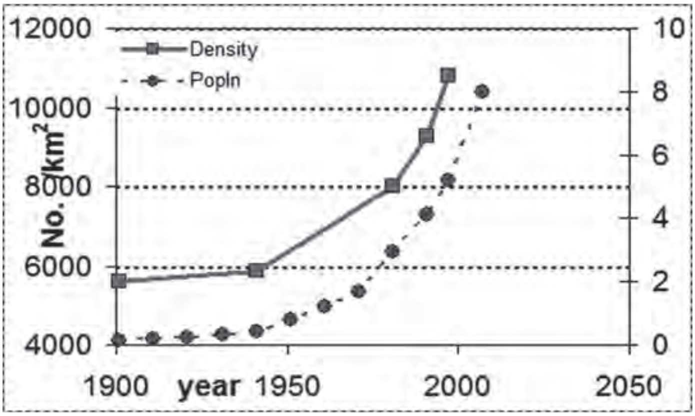

Fig. 2
The density of population has increased significantly and is rapidly climbing to reach levels above 25000/sqkm (Adapted from Chanakya (2010)

Cultural History of Wastes and Residues

Exacerbating the issue further is the fact that for a long time in our civilization, till about 25years back, we have lived by generating no or very little wastes. As seen later on in the discussion most urban areas did not produce USW in significant quantities that it warranted serious public participation and debate. As we had learned to live with animals even in urban areas, much of our wastes being food based, all the decomposables were handled in a manner that it could become food for cattle or similar animals. Therefore even today, we do not understand seriously why unused food or vegetable /meat wastes cause such serious concerns to our fellowmen. As a result of this, there is very little sense of responsibility among us for having caused / generated wastes that would remain long in nature. Further, with the rapid absorption of the carry-bag, plastic packaging and obsolescence culture, all components of wastes are rendered unusable by being wrapped in non-degradable plastics. This approach seriously affects technologies that can be used for waste management and maintaining environmental harmony especially in a rapidly urbanizing country like India. Similarly, in rural and peri-urban areas, a large extent of rural crop and other organic residues are becoming a problem to deal with. The rapid reduction of the use of farm animals in agricultural operations and the greater use of farm machinery in most agricultural operations have resulted in various agro-residues such as straws, grain chaff, shells and husk, crop biomass after harvest, etc. being not harvested or stacked for cattle and other on-farm use. In many cases, the straws are not even harvested and instead set afire on the cropland when sufficiently dry. It is estimated that, these add up to between 40-60 and 500 million tonnes of USW and rural residues. All these can form a sustainable source of energy if their primary function of returning locked up nutrients and organic matter to soil is retained in the energy recovery process – suggesting predominantly biomethanation.

Inadequacy of Land /spaces for Landfills

With the enactment of SWM&H Rules (2000) and the need for treating decomposables into aerobic compost or biomethanation, it has become necessary for urban local bodies (ULB) to find suitably large tracts of land to create waste processing, treatment and disposal centres viable for a 25yr time horizon. Very soon it has been found that most ULBs do not have adequate land parcels around them to purchase and build these statutory waste processing and disposal centres. Closer to cities the land occupancy rates are so high that is almost impossible for most cities to create these landfills and compost yards /biomethanation plants for sizes recommended. The sites being far off from the cities it is also difficult to find users for the power generated, compost and biogas produced.

Characteristics of wastes and residues being generated

Some of the early reports on the composition of urban solid wastes have shown that these wastes are predominantly non-usable by virtue of containing over 45% dust and inorganic dust. However, more recent studies indicate that in fact a large part of the household wastes are in reality fermentable wastes – comprising of material of fruit, vegetable, meat and unused /uneaten food types. Table 2 and Figure 3 show that contrary to most early reports, the primary wastes contain a very large fraction of fermentable and decomposable fractions. This being the case, the moisture content in them will also be very high – especially there would be varying proportions of cooked /unused food, fruit and vegetable peels, etc. This situation is conducive to the material being fermented to biogas rather than being composted. Consider that with a predominant food, fruit and vegetable fraction, the compostable component or compost recovery would be very low.

Table 2
Composition of household wastes measured in small towns (Chanakya and Swamy, 2011)

Waste type	Composition (% by weight; source – unpublished CST report)								
	Tumkur	Puttur	Mandya	Hassan	Davan-gere	Chikka-ballapur	Belgaum	Nanjan-gud	Average
Fermentable	84.37	78.95	77.94	91.37	81.43	92	83.83	69	82.36
Paper and cardboard	35.35	5.62	13.02	4.99	6.24	4	7.33	8.50	10.63
Leather and Textiles	0	0.90	0	0	1	0	1.31	0	0.40
Glass	3.77	4.11	0	0	2	0.38	2.34	1	1.70
Polythene /plastics	18.64	7.37	9.04	3.64	9	2	5.50	7.13	7.79
Metals	0	2.78	0	0	2	0.64	0.41	0.02	0.73
Inert and dust	0	0	0	0	3.14	0	0.71	14.97	2.35
Recyclables	0	0.27	0	0	0	0	0.17	0	0.05

Fig. 3
Composition of Urban Wastes generated from different sectors in a city

SUITABLE LOGICAL, SOCIETAL AND TECHNOLOGY OPTIONS

This above situation being the case, the best technology option to ensure:

a. energy recovery maximization (60-98% conversion to biogas),

b. plant nutrient and organic matter return to crop land (c.85%N recycle),

c. highest recycle potential and least environmental footprint (of other components of USW),

d.lowest level of secondary wastes (practically none)

e.largest number of potential beneficiaries involved

would therefore be decentralized biomethanation plants dispersed both urban areas (for USW) and rural areas (for agro-residues). This situation is also conducive to total recycle or even attempting a zero waste system based on biomethanation and the creation of a series of value added products from the three by-products namely biogas, digester liquid and digested residue. This potential is discussed later on in this paper.

Need for separation /segregation

In order to achieve the best from these biogas plants utilizing solid wastes as the main feedstock, it is important that non-biodegradable materials in the feed is reduced to low levels. This calls for segregation of wastes at source – i.e. the point of generation the household. However, a large number of efforts have shown that due to various reasons, source segregation although done with great effort and enthusiasm, has not usually met with an equally strong commitment by the municipalities for segregated waste treatment and management. This is mainly because the transportation system is not geared to collect fermentables and dry wastes separately and with adequate frequency. On the other hand, it is very easy to try out moderate source segregation by users and a second line of segregation by the collection system that knows which components fetch better price and which of the components need to be routed differently. In this context, where the users are still apprehensive about use of segregation practices and use of segregated wastes for the next generation level processing to adopt an intermediate position of hopefulness. A position that informs that some segregation will also be carried out by the collectors so that the wastes are segregated and semi-processed very close to origin which could be called near source segregation. The advantages of these have been reported in the previous congress and are elaborated in a separate paper in this congress. This source segregation augmented with collector level segregation brings the level of segregation to a near acceptable level to operate decentralized biomethanation plants (such that the bulk of the USW, the fermentables, need not be transported to far-off places for processing). The augmented near source segregation could be short term measure for complete source segregation to come in the future. However, the most important component is that the fermentables collected separately needs to be fermented locally, within a kilometer of the source thus avoiding over 80% of the cost of transport, C-footprint and building stake among the generators to greatly increase sustainability. Second, now that the recyclables become easy to segregate, secondary segregation according to the recycling industries' needs, the level of materials taken out of the waste stream could reach as high as 95-98%. Placing decentralized biomethanation as the need, greatly reduces environmental pressures in the urban waste streams.

KEYSTONE TECHNOLOGY APPROACH

Biogas plants have been in vogue for over a century now. Our only success story is the cattle dung biogas plants (Gobar-gas) whereas there are so many substrates that can be fermented to biogas. India generates about 500 million tonnes (dry) of usable rural residues (USR), over 50 million tonnes mixed urban solid wastes (USW) and 200 million tonnes (dry) cattle dung annually, all of which have a tremendous potential for biogas energy generation. Developing anaerobic digesters and valorization technologies for rural residues and USW that are appropriate and acceptable to the Indian context has been difficult because these biomass feedstocks cannot be fermented in cattle dung digesters designed for animal dung slurries. There is a rapid increase in clean energy demand in rural India and biogas from these residues can contribute a significant part. The USW generation rates have reached between 0.3-1.0 kg/cap/d and needs new waste processing technologies. The conventional biogas /biomethanation plants are reported to be economically speaking less attractive. It is therefore important to make a basket of technologies that function within our current understanding (or lack of it). Incorporating sustainability principles into the USW collection, processing and recycling technologies becomes challenging. Moreover, we will continue to produce a predominantly organic USW long into the future which is best handled and processed closer to the point of generation rather than transporting it over distances as large as 40-50km and rendering the USW thus transported quite unfit for further use. In other words decentralized systems would greatly avoid the Rs1500/tonne transportation costs that we pay today. Much of the organic content of USW has very high degradation potential and therefore could be converted to methane, manure and other socially relevant and economically viable basket of byproducts that cater to the factor of increasing the connect and attraction to stakeholders. Much of these apply to rural residues as well. Therefore it is now necessary that we find ways to convert a revenue 'consuming' exercise and make it into a sustainable revenue generating enterprise. The three outputs of a biogas plant, the gas, digested residue and the digester liquid then become the basis for creating several processed products for value addition (Figure 4).

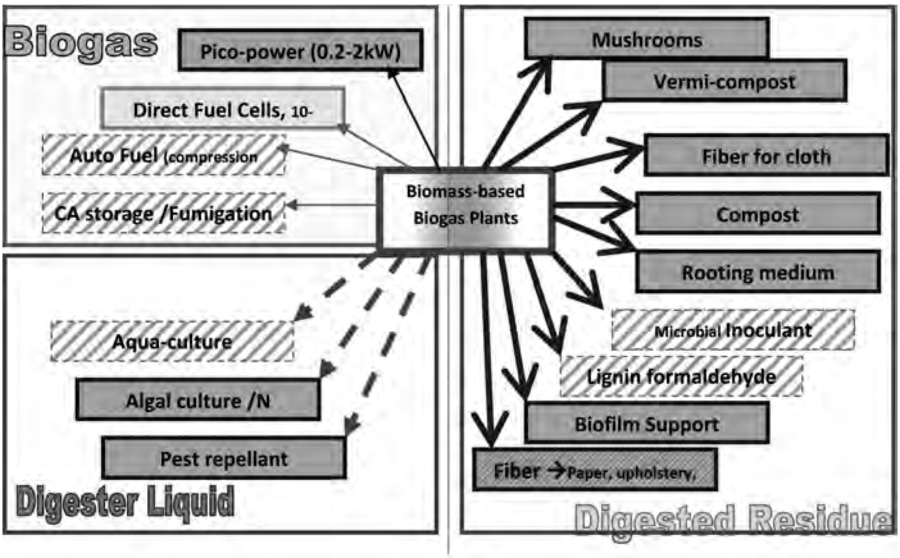

Fig. 4
Multiple uses of biogas outputs are possible now with newer technologies for converting them into a variety of value added products.

EMERGING TRENDS IN BIOMETHANATION

Biogas plants have been in the early stages compared and tested based on several concepts of efficiencies. Early stages led by dissemination programs, low cost, easy to build and local material use, etc. were seen as virtues. Later on, in the 1980's to 2000 biomethanation plants were shown as efficient producers of clean energy, therefore efficiency concepts measured as feedstock conversion efficiency, volumetric gas conversion efficiency, etc. A better technology or design was the one that could produce more in a small volume. As sustainability objectives were also added, the biogas plant emerged as a multi-feedstock conversion device with multiple products. As seen in Figure 5, much of the earlier efforts were towards dissemination of biogas plants for many reasons but generally driven by development goals. In other words biogas plants were popularized or their designs altered to suit many of the objectives or problems that plagued the decade. From finding an efficient recycler of crop-N by anaerobic composting (IISc, Fowler and Joshie, 1921; Pusa Institute, Acharya, 1935) to the current decentralized, environment friendly, green energy source, biomethanation technologies have come a long way (Chanakya and Sharatchandra, 2005; Chanakya et al, 2009). To the less initiated, it appears that biomethanation rarely made it to the top or became popular in any of the above mentioned decades. However, it is important to note that, biogas plants and biomethanation have multiple benefits. As a result for various other crises too, biomethanation has been propped as the panacea. In today's environmental technology parlance, small biogas plants could be tweaked to produce a variety of other products or could be used to reduce toxicity of several toxic materials. They could also be altered to produce a variety of intermediate products, bio-hydrogen, bioelectricity, etc. thereby making a multiproduct option and gradually promoting the concept of decentralized bio-refineries. In this way, the humble biogas plants have come a long way and are expected to provide multiple solutions to many environmental problems as well.

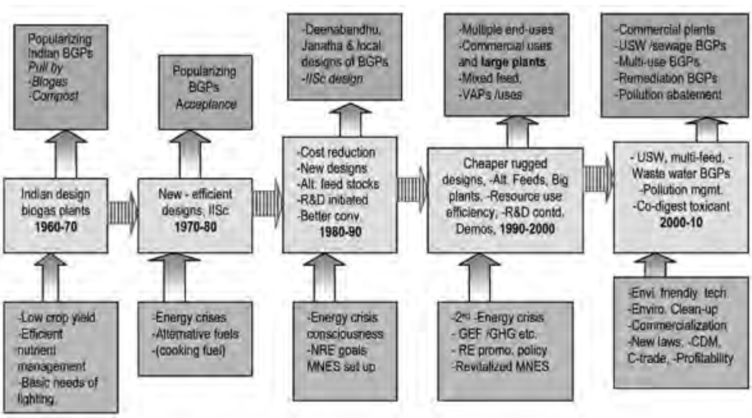

Fig. 5
Gradually changing components of the biomethanation scenario in India over last few decades.

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Energy Use in Information Technology Sector

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INTRODUCTION

Information Technology (IT) has made inroads into almost every facet of human activity. Computers, which form the backbone of IT, interestingly, are viewed from two angles in this context. Firstly, the computers changed a host of areas beyond recognition, like communication, governance, commerce, process control etc., making them more efficient, fast and free of human errors - a most welcome development. On the other side, the ever increasing number of computers and the related hardware in use, add to the electrical load, which, of late, is in the radar of environmentalists concerned about the rise in pollution consequent to more use of electricity. This leads to technology challenges to computer and communication professionals, forcing them to look inwards and device ways to reduce consumption and remain eco-friendly in their operations, as much as possible.

We are living now in a society which draws heavily on the benefits offered by Information Technology (IT). Computers have come a long way from its early days of large mainframes which were energy guzzlers to the latest gizmos called tablets, led by iPads and its competitors, designed to be frugal in energy use. In the formative years, on account of the high cost and complexity warranting handling by computer experts, only large business houses or industries could afford computers. And, these computer departments enjoyed privileges of the highest order compared to all other departments - airconditioned prime space, lavish lighting, unlimited power etc. There was not much compulsion to reduce these requirements in those days, as the managements were not techno-savvy enough to make judgements on these demands in those days.

PERSONAL COMPUTER ERA

The introduction of Personal Computers (PCs) spearheaded by IBM in early 80s, changed the scenario. As some experts observed, PCs ushered in an era of democratisation in computing. Designed in a layman-friendly way, PCs were simple enough to be operated even by those with minimal training. Airconditioning, hitherto a must for computers, was not essential for PCs which could operate in many harsh environments against all odds. Low power consumption was another feather in their cap, compared to many earlier computers. Operating Systems starting with MS DOS and later Windows, Linux, applications like Word Processors and a host of others were readily made available by different developers for lay-users to put PCs in various applications - day-to-day affairs to advanced level.

INTERNET, THE GAME CHANGER

The computing scene entered the next landmark era with the advent of Internet, the network of computer networks. Internet was designed as a unique communications network that would work even if some of its sites become faulty. If the most direct route is not available, routers would direct traffic through alternate routes, thereby ensuring continued service. As is the case with any new technology, in early days Internet was used only by high profile people, say, computer experts, scientists and such others. Today, Internet has become ubiquitous, faster, and easily manageable by non-technical communities. Social Networking, an offshoot of the Web, now enables people of all ages and strata to interact with others anywhere in the world through sites like Facebook, Twitter, Linked-In, YouTube, Flickr, Second Life, Delicious, Blogs, Wikis... This, in short, gives a glimpse of the transformation of the computers from its early high tech avatars to the present, down to Earth versions. With more and more people depending heavily on computers for their day to day activities, leveraging on the web, an unprecedented proliferation of computer systems has resulted. They perform in different forms, say,

- millions as servers in data centres
- more as end-user devices like desktops, laptops, tablets or smartphones

Now the pinch is felt by the power sector as the demand for energy increases from these computing devices in millions. To address this, on one side, the hardware designers spend all efforts to come out with energy efficient designs of their computer chips and related hardware. On software side, operating systems and applications are now oriented towards energy efficient usage of hardware they are required to work with.

DATA CENTRES ALIAS SERVER FARMS

A data centre is a computer facility designed for continuous use by several users, and well equipped with hardware, software, peripherals, power conditioning and backup, communication equipment, security systems, etc. Also known as server farms, they store, manage, process, and exchange digital data and information, providing application services such as web hosting, internet, intranet, etc. The number of servers - heavy duty computers working 24 Hrs/ 365 days in data centres, sharing resources among its clients - in data centres established globally, is increasing day by day, as more people take to IT services. To give a feel of the numbers, Intel has over 100,000 servers, while Facebook has more than 60,000 Nos in their data centres, as per some earlier estimates. Similarly, Google has 4,50,000 servers (3 years back) and Microsoft has 2,18,000(2008)... These put huge demands on airconditioned space, electric power etc. Such server farms have to be fed with power without any break for two purposes: to run the airconditioners to cool the servers and also for running the servers and related hardware. Some studies show that in 2010, servers were responsible for 2.5 % of total energy usage in U.S. while the related airconditioning consumed another 2.5%. It is estimated that if this trend continues, by 2020, servers would use more of the world`s energy than air travel.

In this connection, some efficiency benchmarks like Power Usage Effectiveness (PUE) and Data Centre Infrastructure Efficiency (DCIE) are continuously monitored by data centre managers. Power Usage Effectiveness is a metric, created by members of the Green Grid, an industry group focused on data center energy efficiency. PUE is calculated by dividing the total amount of power entering a data center by the power used to run the computer infrastructure within it. PUE is therefore expressed as a ratio, with overall efficiency improving as the quotient decreases toward 1. Data Center Infrastructure Efficiency (DCIE) is the reciprocal of PUE and is expressed as a percentage that improves as it approaches 100%.

Table 1
Efficiency Benchmarks

PUE	DCiE	Level of Efficiency
3.0	33%	Very Inefficient
2.5	40%	Inefficient
2.0	50%	Average
1.5	67%	Efficient
1.2	83%	Very Efficient

PUE = Total Facility Power / IT Equipment Power
DCIE = IT Equipment Power / Total Facility Power

[Source: Green Grid]

Now that data centre activities are increasingly assuming larger proportions with time, efforts are on to make them as energy efficient as possible by using innovative technologies like server virtualization, data de-duplication etc. Through virtualization more mileage is taken from the grossly underutilized servers in use today, thereby avoiding the addition of new servers as demand increases. Every server virtualized saves 7000 kWh of electricity annually, some vendors providing virtualization services, claim. Data de-duplication is another process in which specialized data compression techniques are used to improve storage utilization, which may also help in energy saving, though indirectly.

SEARCHING THE WEB – GOOGLE EXPERIENCE

The innocent looking ‘search’ for some information through Google or other search engines is also not without its impact on energy usage. According to a study by a

Harvard Ph.D. student, an average search querry on the Google emits 7 grams of CO2. Google refutes this figure and says it is closer to 0.2 grams only. Whatsoever, the fact remains that a search action by us leads to some energy usage at our end as well as in the far away server farm catering to us.

Data centers account for most of Google's energy needs. Taking the energy use seriously, Google has designed their systems to make world's most efficient data centers - using about half the energy of a typical data center, Google claims. Also, these web searches often take the place of more carbon- and time-intensive activities, like driving a car or watching TV.

Table 2
CO2 Emissions of Daily Activities vs. Google Searches

Activity	Equivalent Google Searches
CO2 emissions of an average daily newspaper	850
A glass of orange juice	1,050
One load of dishes in an EnergyStar dishwasher	5,100
A five mile trip in the average U.S. automobile	10,000
A cheese burger	15,000
Electricity consumed by the average US household in one month	3,100,000

Energy usage by IT sector is under the scanner of computer professionals, power utilities, users and planners. The philosophy of 'Doing More with Less' has already been applied in many IT subsystems. For example, CRT monitors (0.53W/Sq.in) are giving way to energy efficient LCD monitors (0.23W/ Sq.in); desktop computers moving to less power hungry laptops and now on to tablet computers is another case in point. Some details of energy consumption are given in Table 3.

But the real challenge is posed by silicon chips, the workhorse behind all computer hardware today. The present, silicon-based electronic circuits dissipate much heat as a result of the electrons in the current colliding with the device material, a phenomenon called resistive heating. In fact, this heating outweighs other smaller thermoelectric effects that can locally cool a device. Computers with silicon chips use fans or water to cool them, a process that consumes a major chunk of the energy required to power a device. There is an all out search for an alternative to silicon chips ridden with this self heating problem. And some solutions are in the vicinity, one of them being the computer chips made out of graphene - carbon sheets 1 atom thick - which could be faster than silicon chips and operate at lower power. Graphene Electronics, still in its infancy, may bring about a sea change in the coming years to enable IT systems to work with better energy efficiency.

Table 3
Energy Consumption

Computers

Desktop Computer	60-250 Watts
On screen saver	60-250 W (No saving)
Sleep / standby	1 -6 W
Laptop	15-45 W

Monitors

Typical 17" CRT	~80 Watts
19" LCD	17-31 W
20-24" LCD	18-72 W

CLOUD COMPUTING - AN ENERGY SAVING OPTION AS WELL

Before discussing the energy saving potential realizable through the new paradigm that has dawned on the IT arena in the last few years, viz., cloud computing, a quick look at its basics is appropriate. Cloud computing is not a totally new technology as such, but is a different way to make available computer resources to provide information and various related services. Beginning with the main frame computing, the IT sector eventually gave way to the client-server model, combining functions of wireless technology, ubiquitous computing, and now, cloud computing.

World is moving away from the earlier practice of businesses, industries and governments establishing all the IT resources in-house and running it, to a model where hardware, software and their routine operational management are handed over to a third party, enjoying huge savings – Cloud Computing model. Just as electricity moved to become a public utility through the power grid, bits and bytes will also move to a similar information grid model, with many service providers competing to offer software and hardware as a service, chargeable on usage basis.

In simple terms, cloud computing is an Internet-based computing solution that delivers IT as a service. Computers in the cloud are configured to work together and the various applications use the collective computing power as if they are running on a single system.

Before cloud computing, websites and server-based applications were executed on a specific system. With the advent of cloud computing, resources are used as an aggregated virtual computer from which computing power, data storage etc. are drawn as per the needs at that time. In other words, if a particular application needs super-computer level power for a short period, it can be drawn from the cloud's large resource, making proportional payment .

Even an ordinary Gmail user has access to a rudimentary cloud system in the form of Google Documents available as part of Gmail. One can create a text document or power point or Excel equivalent and store it in the Google Docs to be accessed at any other time from anywhere, including sharing with others. Dropbox (www.dropbox.com) is another free service that lets one store photos, docs, and videos in cloud way. There are many others in this category.

The cloud computing paradigm has definite advantages which makes it attractive, say,

- It can reduce both capital and operating expenses because resources are only acquired when needed and are only paid for when used
- Cloud computing frees computer experts allowing them to focus on delivering value rather than spending time on maintaining hardware and software.
- Immediate scaling, either up or down, as per current needs, at any time without long-term commitment is possible.

Going back to the energy side, a major breakthrough in energy saving in IT sector may come from cloud computing. An organisation that adopts cloud computing can reduce its energy consumption, lower its carbon emissions and decrease its capital expenditure on IT resources while improving operational efficiency. As per a study, by 2020, large U.S. companies that use cloud computing can achieve annual energy savings of $12.3 billion.

Based on economic considerations, U.S. businesses plan to accelerate their adoption of cloud computing from the present 10 percent to 69 percent of their information technology spend by 2020 to reap the benefits. In its 2007 *Report to U.S. Congress on Server and Data Center Energy Efficiency Opportunities*, Environmental Protection Agency (EPA) estimated that the nation's servers and data centers consumed about 61 billion kWh in 2006 (1.5 percent of total U.S. electricity consumption) for a total electricity cost of about $4.5 billion. As one of the fastest growing sectors, national energy consumption by servers and data centers could nearly double by 2011 to more than 100 billion kWh, representing a $7.4 billion annual electricity cost, the report says.

CONCLUSION

Demand for enhanced functionalities in IT sector from time to time, uncertainties in energy supply, and environmental concerns are forcing data centers to consider energy use as a techno-managerial challenge. It is a welcome development that the designers, users, planners and other stakeholders associated with IT activities are giving equal importance to the energy side of IT systems, accepting this challenge. World over, developments are taking place in laboratories to bring about major breakthroughs on hardware, software, data centre infrastructure etc. to tap the potential for energy efficiency improvement. Let us put faith on the R&D prowess of the researchers and await ground breaking results. They have done it in the past and are capable of repeating the feat.

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Energy Management in Industry: Key to Environment Protection

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INTRODUCTION

Energy is an important driver of economic growth. Energy consumption in India has increased consistently over the years. India is the fourth largest consumer of energy in the world in terms of primary energy. Since energy is a critical commodity in terms of demand and supply, production and consumption, sustainable management and conservation of energy are vital in the context of energy crisis. According to Cape Hart et al, energy management means *"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions"*. Energy management is the discipline and measures executed to achieve the minimum possible energy use and cost while meeting the true needs of the activities occurring within a facility. Actions intended to achieve this energy efficiency focus on reducing necessary end-use, increasing efficiency, reducing wasted energy, and finding superior energy alternatives. The major objective of energy management is to achieve and maintain optimum energy procurement and utilization, throughout the organization and to minimise energy costs / waste without affecting production and quality and minimise environmental effects.

ENERGY AUDIT: A TOOL FOR ENERGY MANAGEMENT

Energy Audit attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management program. As per the Energy Conservation Act, 2001, Energy Audit is defined as the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption. In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists. The energy audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programs which are vital for production and utility activities. Such an audit program will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame. The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a "bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

APPROACHES TO ENERGY MANAGEMENT

Technical Measure: It implies a change in type of machinery, tools or implements with which energy is being used.

Basic kind of approach: Leak plugging eliminates waste in existing system

Machine switching: It involves replacing existing machineries/equipments with energy efficient one.

Structural measures: Those measures which require a change in structure of economy so that a lesser amount of energy is required to produce a given level of national income

Social and behavioural measures: Life style behaviour pattern of people should be altered to consume lesser amount of direct and indirect energy imbibed in goods and services consumed by people. These don't require investment but only to educate and create awareness among people.

Measures for industrial energy management

Energy Management is not an easy task. Several measures have been suggested by energy economists.

- Operation of plant in full capacity;
- Heat recovery and re usage;
- Combustion and steam system improvement;
- Process modification;
- Co-generation;
- Systematic use of unused energy;

- Publicity & Education and presentation of Awards to Energy efficient Industries; and
- Introduction of energy efficient process and computer controls system.

ENERGY MANAGEMENT PROGRAM

Based on the understanding of the current status of energy use and position of the company, with the strength/weakness analysis and other relevant information and compare with the best practice data or benchmark in the industry, the following steps are taken to get a good Energy Management program. It is desired that the top (senior) management announces the "Energy Policy Statement". This is very effective to let people inside and outside the company clearly knows the management's commitment to Energy Management. A corporate level energy policy would give the major objective, purpose and motivation to all the efforts made throughout the organization in improving energy efficiency and managing best end use of energy. It usually includes concrete targets in the field of Energy Management so that everyone can understand it. The energy policy statement shall match the company's mission statement or overall management strategy plan. The Energy management program shall be realistic, practical and attainable with due consideration of many related elements and management resources of the company or factory. It also shall be expressed in terms of the measurable or quantifiable parameters. It usually include a lot of managerial measures of Energy Management promotion activities such as motivation techniques, means to improve awareness, training, and so on.

For successful implementation of energy management system, top management shall make a commitment to allocate the required man power and funds. Top management has to appoint Energy Manager and constitute a dedicated team to help the energy manager and closely monitor the progress. Energy Manager helps an organization to achieve its goal by implementing the energy policy and establish energy performance as its core value. Duties and responsibilities of energy manager are assigned under the Energy Conservation Act, 2001.

Barriers for Energy Management Program

- Lack of understanding and support by top management;
- Lack of understanding and cooperation of managers within factories;
- Poor awareness of people to get successful results;
- Insufficient capability of people due to lack of training;
- Lack of adequate technology due to lack of information;
- Non-availability of manpower for EC activities within factories;
- Little budgeted allocation of funds for EC activities due to the company's financial status;
- Management always tries to increase production than a decrease in energy consumption;
- Time required to switchover from present energy consuming equipment to energy efficient one;

- High cost of energy saving devices and equipments; and
- Inadequate energy saving equipments.

ENERGY MANAGEMENT AND CONSERVATION INITIATIVES IN INDIA

The total installed generating capacity of the utilities in India increased from 147 965 MW (as on 31 March 2009) to 159 398 MW, representing an increase of 11.4% (CEA 2010). At present, the installed capacity comprises 102 454 MW of thermal power (coal, gas, and diesel), 36 863 MW of hydropower, 4560 MW of nuclear power, and 15 521 MW of renewable energy. Out of the total installed capacity, the highest share is contributed by the State sector (52.5%), followed by the Central sector (34%), while the private sector contributes the rest. The country experienced an overall energy shortage of 9.9% and peaking power shortage of 12.6% in 2009/10.

The industry sector in India is a major consumer of energy, accounting for about 56% of the total commercial energy consumption (as fuel and feedstock) during 2007/08 (153 million tonnes of oil equivalent [MTOE]), with coal and lignite meeting 64% of the total commercial energy consumption. There is enormous scope for improvement in energy efficiency in energy-intensive sectors, such as cement, steel, fertilizers etc and it varies depending upon the type of industries.

Micro, small, and medium enterprises

The micro, small, and medium enterprises (MSMEs) sector is the backbone of the Indian economy, accounting for about 8% of the GDP. There are about 26 million units operating across the country, which account for about 40% of the manufacturing output and about 34% of the total exports. Cost factors weigh more for an MSME unit than issues such as energy efficiency and pollution. Hence, an MSME unit uses the cheapest fuels that are available in its locality. The share of energy in the overall production costs varies between 30% and 40% in an energy-intensive MSME. Almost all rural MSMEs burn biomass such as fuel wood, husks, and assorted agricultural wastes for energy, as these are easily available.

Highlights

- India is the largest producer of sponge iron in the world and ranks fifth in crude steel production. The specific energy consumption for steel production varies from 6.5 Gcal/tonne to 7.0 Gcal/tonne of crude steel as against the international level of 4.5 Gcal/tonne to 5.5 Gcal/tonne.
- The average capacity of Indian paper mills is less than 15 000 tonnes per year, which is less than one-seventh of the capacity available in Europe. The specific energy consumption by wood-based paper mills in India is 9 tonnes steam and 1300 kilowatt-hours (kWh) electricity per tonne of paper.
- The textile industry in India is the second largest, contributing about 14% to industrial production, 4% to gross domestic product (GDP), and 17% to the country's export earnings.

- The Indian Fertilizer Industry is the third largest in the world.The performance of the Indian fertilizer industry in terms of energy efficiency is comparable on a global level ie specific energy consumption for ammonia production is 8.71 Gcal/ton which is close to global average of 8.76 Gcal/ton
- Major technology improvements and the adoption of various energy conservation measures in the fertilizer sector over the last three decades has reduced the energy consumption per tonne of ammonia reduced substantially (30%–50%).
- India is the second largest market for cement in the world .The cement industry uses coal and electricity as the main sources of fuel. Energy cost accounts for about 40% of the total manufacturing cost in some of the cement plants and coal accounts for 15%–20% of the total production costs. The specific thermal energy consumption and electrical energy consumption for state-of-the-art cement plants are as low as 667 kcal/kg of clinker and 68 kWh/tonne of cement, respectively. These are comparable with the best cement plants in Japan, where the specific thermal energy consumption and electrical energy consumption are 650 kcal/kg of clinker and 65 kWh/tonne of cement, respectively. Various energy audit studies have estimated that at least 5%–10% energy saving is possible in both thermal energy consumption and electrical energy consumption in cement plants through the adoption of various energy conservation measures.

Energy management and conservation initiatives started during 1974.In 1978 Petroleum Conservation Research Association (PCRA) were founded. Energy Management Centre, New Delhi was formed by Govt. of India in 1989. In 1997 Energy Conservation Bill was passed by Parliament .Subsequently Energy Conservation Act was passed in 2001.The Bureau of Energy Efficiency (BEE) formed under the Ministry of Power (MoP) has been entrusted with the responsibility of implementing the Energy Conservation Act, 2001. The Act has identified 687 industries (including thermal power plants and railways) as designated consumers (DCs), which includes sub-sectors such as aluminium, cement, fertilizer, pulp and paper, and textile. The DCs have to report their energy consumption and energy conservation efforts in individual units on a yearly basis through an online e-filing system. Apart from DCs, the BEE has identified the small and medium enterprises (SMEs) sector as a chief energy consumer. In this regard, it has initiated the BEE–SME program, which aims at improving the energy efficiency of the SME sector. Energy Management Centre is the Designated Agency of BEE in Kerala.

Table 1 indicates that percentage share of energy cost in total cost and percentage energy conservation of some selected industries. Share of energy cost is high in Ferro Alloys, it is about 36.5%. Cement and Aluminium industries have share of 34.9% and 34.2% respectively. Sugar and refinery industries have the least share of 3.4% and 1.0% respectively. It is evident that percentage saving potential of Indian industries is ranging from minimum 8 - 10% and at maximum of 25 – 30%. The conservation potential is high in sugar industries ranges from 25 – 30%. Textile and

Pulp and Paper industries have saving potential of 20 – 25%. Industries like iron and steel, aluminium, refineries and ferroalloys are having energy saving potential of 8 – 10 %. It is evident that Indian Industries are having a fruitful scope of energy conservation potential. So at present the thrust need is to use appropriate technology and save the energy as much as possible. The above said statements are supported by different studies conducted by different government and private organizations. Inter-Ministerial Working Group on Energy Conservation set up by the Government of India estimated energy saving potential to be approximately of 25% in Indian Industries. Another study by FICCI revealed that annual energy saving potential could be 8-25 %.

Table 1
Energy Saving Potential of Some Selected Indian Industries

Name of Industry	% share of energy cost in total cost	Conservation Potential %
Iron & Steel	15.8	8 – 10
Pesticides	18.3	10 – 15
Textiles	10.9	20 – 25
Cements	34.9	10 – 15
Pulp & Paper	22.8	20 – 25
Aluminium	34.2	8 – 10
Ferrous Foundry	10.5	15 – 20
Petrochemical	12.7	10 – 15
Ceramics	33.7	15 – 20
Glass	32.5	15 – 20
Refineries	1.0	8 – 10
Ferro – Alloys	36.5	8 – 10
Sugar	3.4	25 – 30

Source: www.winrockindia.org

ENERGY MANAGEMENT IN THE INDUSTRIAL SECTOR: A CASE FROM JAPAN

Since the oil crisis, Japan's industrial sector has played a central role in the efficient use of energy. Due to the efforts, the sector has successfully maintained almost the same energy consumption level as in the oil crisis despite the growing output. The sector accounts for nearly 45 % of the total energy demand in Japan. Despite those proactive efforts, there was a growing awareness that more measures were necessary in order to take more effective actions on global environmental issues. In June 1997, Japan Business Federation (Keidanren) announced the "Keidanren Voluntary Action Plan on the Environment", aiming to promote the efficient use of energy.

As a national policy, the Law Concerning the Rational Use of Energy (Energy Conservation Law) was revised to reinforce the sector's voluntary energy management. The revision of 2002 expanded the range of the "Type 1 Designated

Energy Management Factory" which had been limited to five industries such as the manufacturing industries. Through the revision, business operators became obligated to submit periodic reports, who own factories classified as "Type 2 Designated Energy Management Factory". The revised law came into force on April 1, 2003. In unison with the revision of the Energy Conservation Law, new criteria to assess energy use of factories and business offices were enforced on April 1, 2003, which were to control inefficient electric power facilities, to promote the implementation of the cogeneration system, which is highly energy efficient and to make good use of ESCO companies.

Regulatory structure was changed from regulating each factory or workplace to regulating the company wide management in 2008. The amendment obliged a company who uses a certain amount of energy as the whole company to regulate all of its factories and workplaces it has this revised law came into force partly on April 1, 2009 and wholly on April 1, 2010. In addition, there are financial incentives such as low interest loan programs to boost investment in developing energy efficient products and technologies under the law concerning energy conservation and recycling assistance and tax breaks under the tax measures to promote the investment in restructuring the country's energy supply-demand. Government introduced commendation / Award to excellent energy control-designated factories, conduction of the ENEX Exhibition of energy conservation technologies and equipment etc. Also government initiated development of practical application of technologies to rationalize energy utilization.

Energy Audit Program is conducted free of charge by the Energy Conservation Centre, Japan. Several Audit Experts make an interview with persons in charge about the Management Standards for the factory or building which is going to have an energy audit. Then they make an on-site survey how the facilities in the factory are operated. After the survey, draw up a list of areas which need remedies and give advice for energy saving potential and needed actions. Japan has created an industrial culture that puts energy conservation at its heart.

A case study of Denso Corporation, Japan who has reduced 50% reduction in Energy by Energy Management is attached as Annexure 1.

Experience confirms there are three distinct levels of effort and effectiveness in energy management.

1. The first level involves repairs, improvements and adjustments. Importantly, it also provides quick wins. These motivate workers. They show that changes in behaviour and process can make a difference;
2. The next level of activity creates the foundations for long-term energy efficiency. It includes tasks that improve data transparency on energy usage and cost. At the second level we can improve our understanding of the factors that drive energy inefficiency. We can define roles, responsibilities and authority for energy management and can identify and implement process changes to improve energy efficiency; and

3. The final and most challenging level establishes a long-term, process excellence-led approach. It seeks to change behaviour and culture to create sustainability and establish an enduring platform for continued energy management improvement.

Six months to make a difference

- Measurable and positive difference to energy consumption can be experienced in just six months. The first four to eight weeks involve gathering and analysis data and implementing quick win activities to capture the "low hanging fruit" of energy saving.
- The next four to eight weeks are used for design and implementation of a management system to identify additional opportunity and support behavior change. The next period then uses the system to aid culture change and drive maximum results.
- Then, during the final period, any external support pulls back while the organization itself drives the process, with further coaching and auditing to encourage success.
- With a committed and structured approach, reduced scale and increased predictability of industrial energy consumption is possible.
- The next key migration is to controlled consumption, including a focus on start-up and shut-down procedures as part of maintaining a steady state.
- Once control is established and maintained, we can then implement maintenance programs to help move toward pro-active energy management. These include requirement forecasting and demand management. By working through these stages and their specific activities, world class energy conservation becomes realistic.

Expect measurable improvements in the key areas of operations and maintenance, production, work environment, the wider environment, and, of course, cost savings.

- **Operations and Maintenance**

  The operational measures taken as part of energy conservation will result in reduced maintenance costs and reduced purchases of ancillary materials.

- **Production**

  The 'steady state' approach to production, among many benefits, will yield reductions in product waste and increased production. Expect also to see improved product quality, together with increased production reliability and shorter process/ cycle time.

- **Work environment**

  For the people on the shop floor, a major personal incentive to adopt energy saving behaviours is the improvements those behaviours bring to the work environment.

- **Environment**

  The 'green credentials' of every industrial operation are rapidly becoming as important as productivity and profit. A reduced energy consumption approach typically reduces hazardous waste and dust emissions. It also cuts waste water output and reduces CO, CO2, NOX and SOX emissions.

- **Cost benefits**

  Of course, one of the greatest attractions of reduced energy consumption is the money saved. Expect to see costs benefits in three key areas :

  1. Achieved rebate / incentive
  2. Reduced / eliminated demand charges
  3. Reduced Electricity bill charge

Companies that consume less energy are typically more efficient, more productive and more profitable. Today's bill can even become tomorrow's revenue secure.

There are various industries in Kerala like The Kerala Ceramics Ltd, Kundara which is surviving only because of energy management initiatives as described as Case Study Annexure 2

CONCLUSION

Scientists predict that Oil to last for 40 years, natural gas to last for 60 years and coal to last for 100 years only .Consumption of fossil fuels continues to increase in geometrical progressions resulting in to abnormal level of Green House Gas emission Energy Security and Environment Management are the major problems faced by Nations globally .Never ending hike in price of fossil fuels stalled the developmental activities of majority of developing countries who are spending the major portion of their revenues for procurement of energy particularly oil, resulting in neglecting the basic needs of people . Countries like USA, polluting environment heavily are not able to make a consensus to reduce green house gas to the agreed level. Hence all efforts are to be taken to avoid wastage of energy resources, to strive for efficient utilization of resources and for development of Non conventional Energy Resources. Energy Management will help industries to reduce cost of production and to make the products globally competitive. Moreover, Environment Management is possible only through Energy Management.

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Case Study-1

50% reduction in Energy by Energy Management in Denso Corporation, Japan (Winner of 2009 Grand Prize of Ministry of Economy, Trade and Industry)

Company outline

Denso Corporation is founded on December 16, 1949 with a capital outlay of 187.4 billion yen. Revenue is 3142.7 billion yen with Current profit of 35.3 billion yen. Total Number of employees is 119,919. Company has 187 Number of subsidiaries (Japan: 68, North/Central/South America: 38, Europe: 33, Australia/Asia: 48). Major products are car parts - Air-conditioning related products, Car body related products, Power train related products, and Drive/Safety related products.

Energy management system

In December 1992, Denso established an Environment Committee as a supreme decision-making organization for the environment business. Business leaders, overseas regional managers, and environment business managers of group subsidiaries attend it twice a year to create policies, assess progress status of activities, and discuss issues and solutions. In 2008, positioning the global warming measures as the company's priority issue, the executive director established **CO_2 Special Project Room** as his own-controlled organization. As the comprehensive manager, the executive director is in charge of internal and group's CO_2 management, whole company comprehensive management of energy-saving budget, decision of investment cases, and development of energy-saving technology for manufacturing processes and facilities. In order to promote the activity, the CO_2 Special Project consists of three working groups from the viewpoint of strengthening and enhancing the company's energy-saving characteristics.

a. Energy Working Group (continued): Develops exhaustive improvements in manufacturing activities that consume most of energy.

b. Energy Technology Working Group (strengthened): Mainly Manufacturing Engineering Department designs and develops energy-saving manufacturing facilities on its own.

c. Negotiating Working group (new): Spreads and promotes internally and externally the company's energy-saving technology and mechanism and energy-saving property of co-generation.

Major activities

(a) Development of energy-saving technology

In 2000, when the company set the CO_2 reduction target for 2010 in [Denso Eco-vision 2005], the production increase of 12% per year was expected. Therefore, it is presumed that the CO_2 reduction target for 2010 could not be achieved simply by extending the conventional activities. Subsequently, the company assumed energy reduction of more than 30% was necessary for the newly introduced facilities. Denso is designing, developing, and manufacturing production facilities on its own. As the measure of the CO_2 reduction for 2010, company inaugurated the energy-saving fabrication study committee (Energy-saving Engineering Working group from 2008) with the responsibility to develop energy-saving technologies. The committee has been implementing the long-term CO_2 reduction as a planned theme.

(b) CS3 (CS Cubic = Compact, slim, simple, speed) activities

Production technology development to completely eliminate every kind of waste that may occur in production facilities

Current production system

- Mainly large versatile machines
- Taking many/batch processing→inventory

Ideal system

- Compact facility/system fit for parts size
- Simple facility structure to realize high quality
- Slim net fabrication to generate high added value
- Produce speedily only the necessary quantity

(c) Energy JIT (Just In Time) activity

Denso has adopted the principles of JIT, which are for energy management and operation at factories and is engaged in which aims to make the factories more flexible to production changes. While the conventional energy-saving activities were aimed at eliminating waste in production, company's Energy JIT is aimed at completely removing that part of energy which is not contributing to production. Energy JIT varies in conjunction with production volume and consists of Supply JIT that optimally provides energy and Production JIT that makes the fixed energy being variable. It aims at improvement and development throughout from supply to production.

(d) Exhaustive improvement: PEF (Perfect Energy Factory) activity

Though each of 20 manufacturing departments of the company is engaged in energy-saving activities on its own, there are many cases that can be shared by many departments. By establishing the mechanism by which a certain case can be shared by the entire company, company managed to promote the entire-company as the CO2 reduction enhancement measure.

(e) Exhaustive co-generation

Since there are many device departments and precision fabrication departments in the company, there are many processes that require air conditioning and many processes, and many cleansing processes that need hot water. Thus, each factory uses lots of steam throughout the year. Since the early 1990s, the company has been promoting the introduction of highly efficient co-generation as the important energy-saving measure.

- Introduction results: 13 units, 94,999 kW (Generated power in FY 2008, 512,000 MWh (37% of the total electricity consumption))
- CO_2 reduction effect (results in FY 2008): 153,000 t-CO_2 reduction

(f) Natural energy development utilizing own technology

As part of CO2 reduction measures raised in eco vision, company is promoting introduction of natural energies. In introducing natural energies, company uses its own technologies and own alternator to introduce micro waterpower, utilizing the waterfall difference when the water used in the factory is discharged and introducing micro wind power that utilizes cleansed exhaust from a factory.

(g) Energy-saving performance/evaluation and visualization of enthusiasm
(m) CO2 as business index

The company established the internal award system in 1993 to help energize energy-saving activities of each manufacturing department (20 in all) in the business group. The evaluation items widely include not only the CO2 target achievement status (emissions, intensity), but also internal and external contributory activities, such as participation in energy-saving results announcement and energy-saving support for the group and vendors. These results are linked with application for energy management excellent factory of the Ministry of Economy, Trade and Industry, raising energy-saving awareness of department directors.

The same thing goes for energy-saving cases. They are linked with raising energy-saving awareness of employees. Also, like sales, profit and quality, the CO_2 target achievement status is incorporated in the company business management index and positioned as the company's critical issue.

Effects

- **CO_2 intensity down 52% compared with 1990.** Since 2000, as a result of energy-saving enhancement, such as energy-saving technology development, exhaustive improvement, and introduction of highly efficient facilities like co-generation towards achievement of CO_2 reduction target for 2010. The results of 2008 are as follows
- CO_2 intensity: Down 52% (2010 target: Down 40% from 1990)
- CO_2 emissions volume: Down 4% (2010 target: Down 10% from 1990) In particular, since 2000, the CO_2 emissions volume has been flat and the intensity has greatly improved due to CO_2 reduction enhancement like PEF development and energy saving technology development though the production grew more than twice.
- **Active energy-saving activities by employees (Big increase in the number energy-saving improvements about 800 cases/y → 2,500 cases/y).** Since Eco-vision was launched in 2000, the number of energy-saving improvements has drastically increased compared with 2000 or earlier due to exhaustive implementation of themes common for the entire company in the PEF activity and each dept's own active proposals to new improvements.

External evaluation like energy-saving excellent case

Each department's improvements and energy-saving activities of employee and factory have been highly acclaimed from external organizations. For 9 years between FY2000 and FY2008, the company received 51 awards like, Award of Minister of Economy, Trade and Industry: 4 times, Award of Director General of Agency for Natural Resources and Energy: 12 times, Award of Chairman of Energy saving Center/Excellent Award: 12 times, Award of Director General of Bureau of Economy, Trade and Industry: 23 times

Conclusion

Company has achieved 2009 Grand Prize of Minister of Economy, Trade and Industry and the case is an excellent example of Energy Management which includes environmental management as well.

Annexure – 2: Energy Management in The Kerala Ceramics Ltd.

Company Outline

The Kerala Ceramics Ltd. was set up in 1963 as a fully owned Government of Kerala Undertaking (under Companies Act) with its registered Office at Kundara, The company has two divisions – Porcelain Division manufacturing Ceramic crockery items, and Clays and Minerals Division. Clays and Minerals Division was set up with technical collaboration of Japanese firms and major portion of processed China Clay, Spray dried Kaolin was exported to Japan. Porcelain Division was closed during 2004, as the operations were unviable. At present Clays and Minerals Division is only working and has 208 employees. It has two captive mines and one beneficiation plant at Kundara, Kollam District. Plant has a capacity to produce 18,000 MT of refined and spray dried Kaolin and the production achieved is 10,000 per MT. At present company markets two brands of Spray dried varieties and also various grades of natural dried kaolin.

The principal operation in wet dressing of Kaolin is the classification process which has two objectives: (1) to separate other minerals, and (2) to obtain required particle size. Screening, settling, hydro cyclones and centrifuges are mainly used for classification.

Additional processing stages generally to increase brightness and to adjust other physical characteristics are also included in the refining circuits. The coloured iron compounds are rendered colourless and soluble by bleaching and removed during the water washing and filtration stages. Dewatering is done through high pressure filter presses and product is finally dried in a spray drier. Spray drier is a modern equipment in which clay slurry is atomised into an exceedingly fine spray on entering top of a large conical chamber. The fine droplets slowly descend passing through a stream of hot air. A fine powder is formed that is both free flowing and virtually dust free.

Need for Energy Conservation

Kerosene (SKO) /Diesel has been used for heating air for generating hot air required for drying China Clay. The average consumption of SKO was in the range of 68.2 liters /MT and hence company was making loss. The increasing cost of SKO, reduction of market share due to high cost of production and the company's desire to reduce dependence on fossil fuels compelled it to explore the viability of alternative sustainable fuels.

Energy Conservation Initiatives

The company engaged Institute for Energy Studies, Anna University, Chennai, for conducting a feasibility study. The study revealed that the existing system can be replaced by Agro waste based Hot Air Generator. The proposal was to go for an indirectly heated Fluidized-bed Combustion System. Accordingly, the company installed a Hot Air Generator, which works on multiple agricultural wastes. The Hot Air Generator can work with empty palm fruit bunches, rice husk, saw dust, cashew shells etc.

The total investment for the Bio fuel based hot Air Generator was Rs.75 lakhs. The Company received a subsidy of Rs 28 lakhs from ANERT. The equipment was commissioned on 18-03-2008.

Energy Saving Rs 1.07 Cr/year

The company could save Rs. 323 lakhs up to 31-03-2011 by the switching over of HSD to agricultural waste as fuel, ie., an average saving of Rs 107 lakhs per year and the pay back period was 9 months.

Company was able to save Rs 1500/- per MT of production due to change of fuel. Hence, the product became globally competitive and company is continuing to make profit for the last 3 years. At present, company is making exports also. Further, GHG is also reduced substantially and company is registered for obtaining additional revenue towards Certified Emission Reductions (CERS) as per Kyoto Protocol. The savings could have been far more, if the company had achieved production at the rated capacity of 18,000 MT/year.

Conclusion

Due to high cost of production, product was not competitive globally and had lost export orders and domestic orders, and as a result company was on continuous loss and was on the verge of lock out. It is only because of the fossil fuel change to biomass, resulting in reduction of cost of production, the company is surviving. Company restarted export and is getting valuable orders and is making continuous profit.

A Sustainable Energy Scenario for Kerala

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INTRODUCTION

Kerala is totally devoid of any of the conventional sources of industrial energy, like coal, oil, or gas. However, it does have a reasonable potential for Hydroelectric power generation. Earlier estimates had put it at about 3000 MW. Hydel installed capacity, which stood at 102.35 MW in 1956, has grown to 1888 MW by 2010 (GOK, 1977) On an average, they contribute about 6000 MU of energy, every year, to the state grid. However, the state's electrical energy consumption, which amounted to just 441 MU in 1956, has grown to about 17000 MU by this time. 19 more hydel projects, worth about 280 MW (822 MU) is in the pipe line. The KSEB is pressing for some more projects, but most of them are beset with controversies. All of them entail the destruction of pristine forest land, and it is doubtful whether they will ever get clearance from the MoEF. However, there is some potential for Small and Micro hydel projects, which do not involve large scale inundation or displacements. But even making allowances for all these, hydel will not be able to meet even half the electrical energy requirement of Kerala, which is steadily rising. The current deficit is made up by purchase from the National Grid as well as from IPPs or private providers. The assumption that we will always be able to meet our requirements by buying from the National Grid or private providers, is not quite safe, as the whole world is fast running out of fossil fuel resources.

This points to the urgent need for exploring alternative and sustainable means of producing electricity, as the modern world is totally dependent on electricity

SUSTAINABLE ENERGY SOURCES

The only real sustainable energy source is the Sun. Everything else is ephemeral. (It might be argued that even the Sun will eventually blow out. But that is so far away, and, anyway, no life will be possible, in the absence of the Sun!) There was a time when it was thought that the stupendous energy locked up within the atomic nucleus, will provide us with practically inexhaustible electricity and heat. However, the persisting problems of safety and waste disposal, as well as the ever present threats of proliferation of nuclear weapons, not to speak of steadily escalating costs, have effectively debunked the claims of nuclear energy.

So, that leaves us with solar energy and its various derivatives like wind, wave and biomass.

Wind Energy

Among all the new renewable energy technologies, the WEG (Wind Electric Generator) is perhaps the most commercially developed, so much so that they can be ordered almost off the shelf, in standardized capacities. Kerala's wind map has been prepared through a joint project of ANERT and MNRE (former DNES) and its potential is variously estimated between 600 and 1026 MW.[1] However, our progress has been painfully slow, even though we had a head start with a 100 kW installation in Kozhalmannam (Palakkad Dist), as early as 1988. There are several reasons for this tardiness, but the major one is the difficulty in acquiring suitable land for installing the wind machines. The attempt to establish a major wind farm in Attappadi has run into serious problems, following allegations of grabbing Adivasi land, illegally.[2] This shows that there is need to evolve a new model of land utilization in Kerala, where land is so scarce. There are large wind farms abroad, where the machines are installed in the middle of huge farms, occupying only the space required for the machines and connecting roads, without causing any disturbance to the farming activities, which thrive in the rest of the land.[3] The title can rest with the farmers, who will be paid a rent for the land which is leased to the Wind Energy Company, on a long term basis. Can this model be tried in Kerala?

Wave Energy

Kerala had a head start in Wave Energy Conversion also, with a Pilot Experiment being commissioned in Vizhinjam in 1991.[4] Even though the experiment was termed a success, it has not yet been followed up with a pilot plant of commercial significance.

However, since that time, many new concepts in Offshore Wave Energy Conversion have been developed and the US agency EPRI gives an assessment of the most promising devices: "E2I EPRI believes that only one of the eight devices evaluated in this wave energy conversion device assessment study is acceptable for selection by the State Advisors for application in a pilot plant for testing without addressing further device specific issues; namely, the Ocean Power Delivery Pelamis. Three devices (Energetech, Wave Dragon and WaveSwing) could be used if a few remaining issues are addressed, which are mostly related to deployment and recovery. The remaining four devices (WaveBob, AquaBuOY, SeaDog and OreCon MRC 1000) are still in an R&D stage of development. They could be used if remaining R&D issues are addressed."[5]

Pelamis has become the world's first company to deliver electricity to a grid from an Offshore Wave Energy Converter, on a commercial basis, at the European Marine Energy Centre in Orkney, Scotland. The machine was rated at 750kW.[6]

The potential of the Kerala coast for wave power generation has not yet been comprehensively assessed. However, preliminary studies show that the potential in the southern region is about 4 kW per meter length, or 4 MW per km (Dr. R. Jayaraman, Unpublished report, College of Engineering, Trivandrum). This is not insignificant, and could make a useful contribution if it could be tapped without causing any disturbance to the ongoing fishing activities. The Vizhinjam Plant was of the Oscillating Water Column type. Because of the major civil works which form a necessary component of this design, this cannot be located far from the shore, and hence could pose problems for local fishing activity. However, the Pelamis design makes use of floats, which can be located offshore, without obstructing local fishing activity. This is only a tentative statement, and a detailed evaluation of the various options and their costs has to be undertaken without any further delay. An advantage of Wave Energy Conversion is that since it extracts the bulk of the energy from oncoming waves, it could help to ameliorate our perennial problem of coastal erosion. This could be a welcome bonus of energy generation!

Biomass Based Energy Conversion

Biomass is actually humanity's earliest energy source, but the technology for generating electricity from biomass in a commercially successful way, is comparatively recent, and hence qualifies to be termed a "Non-conventional" or "New" Energy Source. There are different routes for this, the most common being Biomass gasification. The Wood Gasifier, again, is a rather old technology, the first IC Engines during World War II having been fired with wood gas. But recent developments have made them almost unrecognizable in size and function. The Indian Institute of science (IISc) Bangalore is a leading institution in the world in gasifier research, and Indian made gasifier plants are now exported to even industrially advanced countries. Mega Watt sized gasifer electric plants are now commercially functioning and serving rural areas, which are unserviced by the grid. Their relevance for Kerala arises from the fact that we have an abundance of coconut tree wastes, which offer a perennial and renewable resource, which is now going to waste. There was a time when these wastes were avidly consumed as domestic cooking fuel. But with the fast spread of LPG as the preferred cooking fuel, even in lower middle class homes, this vast resource is now turning out to be an environmental hazard. Incidentally, it has been pointed out that biomass gasification is the only way Kerala can meet its domestic cooking fuel requirements in a sustainable and equitable way.

It has been proven that IISc Gasifiers can work with coconut wastes, but their techno-socio-economic viability is yet to be established. This is another research project that Kerala ought to take up on a priority basis.

Another thermal process for electricity generation using biomass is incineration in special boilers, which are designed to accept loose biomass. The old Lancashire boiler, which heralded the industrial revolution, is making a come back, in new 'avtars.' Thermax is pioneering this effort in India, and they are already marketing a range of boilers with travelling grate, which can accept all kinds of biomass, including bagasse and other agro-wastes.[7] Incineration has received a bad name because of the irresponsible operation of substandard equipment, for disposing off MSW. However, boilers are well designed engineering equipment which are operated under controlled conditions, and can be ensured to satisfy PCB regulations.

An alternative route for electricity generation using biomass is biomethanation. This is another technology which is well proven. The advantage of biomethanation is that it can accommodate household as well as municipal solid and liquid wastes.[8]

One lesson that has to be kept in mind when examining such projects, is that they call for an integrated approach. The cost of generating electricity through these technologies will definitely be higher than the cost of electricity from conventional power plants, at current fuel prices. However, this has to be viewed against the fact that the disposal of these wastes is also a social necessity, for which we might already be spending huge amounts. So, the extra cost of electricity has to be offset against this additional expenditure. Moreover, the energy economics is bound to change drastically, once the fossil fuels become really scarce, which they are bound to, soon enough.

More sophisticated technologies like Pyrolysis, Plasma Smelt Process, etc., are now becoming available for biomass energy conversion, but their cost effectiveness under Kerala conditions, remains to be proven.

Solar Energy Conversion

Solar Energy is *the* energy source on which all living things have depended on, from the very dawn of life. However, its use for electricity generation started only in the last century. Here again, we have two distinct routes: Solar Thermal and Solar Photo Voltaic. In the solar thermal route, the heat of solar radiation is concentrated to produce high temperatures, which is then used to generate steam, which in turn drive turbines and produce electricity in the conventional way. The advantage of this technology is that all the power generating equipment is conventional and readily available. Nothing remains to be developed. However, the concentrators are quite expensive. Since they are material intensive, the possibility of any dramatic cost reduction in this technology is unlikely. However, mass production has helped to reduce the cost significantly, and already it is reported that the new generation Solar Thermal Plants in the Mojave Desert in USA ,(Total capacity 354 MW) are delivering electricity to the grid at rates comparable to those delivered by gas power plants.[9] And the good news is, the price of gas can only go up!

The advantage of SPV, on the other hand, is that it has no moving parts, and it involves a lot of electronics and material science, which always hold out the promise of dramatic cost reductions. The cost of solar cells, of 1 watt peak capacity, which was in the range of $20 in the nineteen sixties, came down to about $3.5 per peak Watt in the nineties. But there it has been stuck for a long time. Major programs have been launched, especially in California, to encourage decentralized house top generation, and to supply power into the grid during daylight hours.[10] Since the demand peak occurs during sunny hours in California, due to the high component of air conditioning load, this makes a preferential tariff for peak hours favourable for solar PV electricity generation.[11] Yet it is obvious that a critical breakthrough can occur only if the cost of PV cells come down to $1 or at least $2 per Wp. Recent reports indicate that the break through has been achieved with the help of Nanotechnology based production systems.[12] If it is true, it can be safely said that the "Solar Era" has truly arrived.

It is gratifying that India has launched an ambitious solar program (Jawaharlal Nehru National Solar Mission) towards a "Solar India" with the immediate objective of generating 20,000 MW of solar electricity by 2022.[13] A 140 MW solar thermal plant is being commissioned in Mathania, Rajasthan.[14]

However, doubts have been voiced whether Kerala can ever depend on solar energy as its mainstay, given our two monsoons and also our acute shortage of land. As for the first, studies have shown that thanks to our favourable geographic location, close to the equator, we get strong insolation when the sun is available. The Sun is almost directly overhead for about six months in an year (March to September) . And for four of the other six months (December to March), there is fairly consistent sunshine with little cloudiness. Hence, the total annual insolation in Trivandrum is as high as 2069.55 kWh/sq m, which is comparable to that for Nagpur![15]

Thus availability and technical feasibility will not be a problem. However, as far as land is concerned, certainly Kerala will have to invent an alternate mode of land utilization. House top based energy generation, following the Californian model, is certainly a good possibility, provided our State Electricity Board takes a pro-active policy and agrees to introduce differential metering, which would allow solar generators to feed into the grid during daylight hours and to draw from the grid during evening and night hours, paying only for the difference.

But it cannot be denied that any predominantly solar based system has to have provisions for energy storage, and here lies the Achilles' heel of solar energy. Everyone knows that storage of electricity is extremely expensive, and storage at such quantities is well nigh impossible. In Solar Thermal Power Plants, thermal energy is stored in molten salt or pebble beds. In the case of Solar PV, suggestions have been made to store energy in the form of hydrogen, which can be generated using electrolysis when solar electricity is available in excess of demand. This hydrogen can be used as and when required, either for electricity generation, or even as IC Engine fuel for transport vehicles. But in the special case of Kerala, a system of Pumped Storage has been suggested (Parameswran and Menon, 2008) as a more appropriate, and perhaps cheaper option. The system will work as follows:

Let us take the case of Idukki Hydroelectric Power Plant as an example. The surface area of Idukki reservoir, at FRL, is 60 sq km or 60 million sq m. The solar energy falling on this area when the sun is shining bright and overhead is at the rate of 60 million kW or 60,000 MW. We can deploy floats on the reservoir surface, and mount solar PV panels on them to generate electricity. Even at 10% efficiency, this can yield 6000 MW of electricity during daylight hours. Of course it will not be possible, not desirable, to cover the full reservoir surface with such float mounted solar panels. However, even if we assume that a third of the area can be covered, the yield will be

2000 MW. Compare this to the present installed capacity of the Idukki Hydel plant, which is just 780 MW. Moreover, if the Idukki power house is run at full capacity, we will run of water in 4 months. So we use its machines only sparingly, preferably during peak hours. Now imagine that we are able to use the excess electricity generated during daytime to pump the water which has flowed down, back into the reservoir. Special pumps will have to be installed and extra pipes may have to be erected for this purpose. This is the additional capital investment required for the Pumped Storage Power Plant. However, the pay back is that we will be able to run the power plant at full capacity for more periods, or even continuously. It might even be feasible to raise the capacity of the Power Plant several fold, by adding new penstocks and new turbines.

Such a combination of Solar and Hydel with pumped storage, can very well be the backbone of a sustainable energy system for Kerala.

CONCLUSION

Any sustainable energy scenario has to be necessarily based on solar energy and its derivative like hydel, wind, wave and biomass.

In the case of Kerala, only limited potential exists for wind, wave and biomass. However, these have to be assessed and measures initiated for tapping them in the most appropriate manner. Research in these areas to fill up the information as well as knowledge gaps ought to get the highest priority.

We may have to wait until the long expected break through is achieved in bringing the cost of solar cells to $1 per Wp, before launching a full scale campaign for 'solar homes' and large scale centralized solar power plants. However, in anticipation of this breakthrougfh, we can and we should undertake techno-economic and environmental feasibility studies of 'reservoir based float-mounted solar farms' in conjunction with pumped storage. Kerala should lose no time in initiating such perspective studies.

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Energy Consumption in Transport Sector and its Effect on Climate

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INTRODUCTION

Energy has been universally recognized as one of the most important inputs for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, growth of an economy, with its global competitiveness, hinges on the availability of cost-effective and environmentally benign energy sources, and on the other hand, the level of economic development has been observed to be reliant on the energy demand. Transport is a vital sector of a nation's economy and it demands a good share of the energy from the nation. The main drivers for transport sector growth were road transport and, more recently, air transport. Among the transport sectors, road transport has a strongly dominating temperature effect, both on short and longer terms. Road traffic is one of the major anthropogenic emission sectors for NO_x, CO and NHMCs (non – methane hydrocarbons). Road traffic clearly provides the largest net contribution to warming through its large emissions of CO_2 and significant emissions of ozone and soot. A clean environment is the basic need for the existence of life. But, due to advent of scientific applications, miraculous changes have been introduced in the field of industrial development, agricultural techniques, transportation systems, medical sciences, communication appliances, computer technologies and satellite networks. But, in this process, we have caused an irreparable loss to the natural environment.

Fossil fuel combustion by aviation, shipping and road traffic contributes about one fifth of the total global anthropogenic emissions of CO_2. These emissions are growing more rapidly than those by other sectors such as power generation and industry. Petroleum products are one of the major sources of primary energy and in India about 35% of the total energy requirement is met by petroleum products. It is quite apparent that coal will continue to be the predominant form of energy in future. There is, therefore, an urgent need to conserve energy and reduce energy requirements by demand-side management and by adopting more efficient technologies in all sectors.

Transport is a vital sector of a nation's economy and it claims a good share of the energy consumed. In order to shield the environment from the perilous pollutants emitted from the transport systems; the control of emissions is very much significant. There are many ways of reducing emissions from traffic such as improving standards of maintenance of vehicles, reducing the volume of traffic flow etc.

PRESENT SCENARIO

Environmental pollution has been recognized in recent years as a serious threat to the quality of life enjoyed by the people in most of the countries. The major contribution to this catastrophe is the air pollution. Pollution in the atmosphere can bring about changes in atmospheric properties from the obvious observation of heavy smoke to subtle effects on urban temperature or regional precipitation. Air pollution is the presence of contaminants such as dust, fumes, gases, mist, smoke, etc., which are injurious to humans, plants and animals. These active air pollutants may be either gases or particles. Air pollutants can effect more than the visibility, although because it can be readily observed by the affected citizens, visible air pollution must be regarded as one of the more objectionable pollutant effects.

Transport sector is highly disturbing the climatic change and experts say it is only going to get worse. Almost 80 percent of the total active air pollutants were contributed from the transport sector. The recent data reveals that transport was responsible for around 10% of the total net man-made warming nearly a decade ago; topping the list was CO_2 followed by tropospheric ozone (O3). The increase in CO_2 levels is due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere) and cement manufacture.

Based on the impact of road traffic on climate change and to assess the severity of those air pollutants from road traffic emissions; several major studies were conducted. Some of the important studies are mentioned below:

'The Impact of road traffic on tropospheric ozone' by S.Matthes, V.Grewe, R.Sausen and G.J. Roelofs; Atmos. Chem. Phys., 7, pg.1707–1718, 2007 made a detailed study about the contribution of road traffic emissions to the atmosphere. According to S. Matthes et al, in their study concerning the global impact of road traffic on tropospheric ozone found that road traffic is one of the main emitters of the ozone precursors such as NO_x, CO and NMHCs (non-methane hydrocarbons) formed by the combustion of fossil fuels inside internal combustion engines (gasoline and diesel). In order to study the impact of road traffic emissions on the atmospheric composition, S. Matthes, et al., used the global circulation coupled model system ECHAM4/CBM, where ECHAM4 is spectral general circulation model coupled to a chemistry module (CBM-IV), which includes higher hydrocarbons, to investigate the global impact of 1990 road traffic emissions on the atmosphere. Emissions are implemented as flux boundary conditions into the model system. The year 1990 was chosen as reference year, since, the complete emission data and atmospheric observations were available. Improving over previous global modeling studies, which concentrated on road traffic NO_x and CO emissions only, they assessed the impact of NMHC emissions from road traffic. It was revealed that NMHC emissions from road traffic played a key role for the impact on ozone. These were responsible for (indirect) long range transport of

NO_x from road traffic via the formation of PAN, which was not found in a simulation without NMHC emissions from road traffic. Long-range transport of NMHC induced PAN impacts on the ozone distribution in Northern Hemisphere regions far away from the sources, especially in arctic and remote maritime regions.

The impact of emissions from various traffic modes on atmospheric composition and climate has been analyzed by Peter Van Velthoven on 'Impact of Emissions from Shipping, Aviation and Road traffic on atmospheric composition and climate'; in 2010. According to him, the fossil fuel combustion by aviation, shipping and road traffic contributes about one fifth of the total global anthropogenic emissions of CO_2. These emissions are growing more rapidly than those by other sectors such as power generation and industry. In addition to CO_2, the transport sectors also emit nitrogen oxides (NO_x=NO+NO_2), carbon monoxide (CO), and hydrocarbons (HCs) that lead to further perturbations of the atmospheric concentrations of the greenhouse gases ozone and methane. The emissions of particles and particle precursors by the transport sectors change the optical depth and properties of aerosols, which affects the radiation balance of the atmosphere regionally. The total climate impact of aviation emissions (excluding the uncertain impact on natural clouds) was estimated to be a factor 2-3 higher than that of CO_2 alone.

From the studies carried out, Peter Van Velthoven et al deduced that emissions from fossil fuel combustion by aviation (~2%), shipping (14%) and road traffic (22%) contribute together about 38% of the total global anthropogenic emissions of NO_x (excluding biomass burning). The road traffic has been estimated to contribute between 8 – 15% of the total emissions of CO. The contributions of shipping and aviation to global CO emissions are estimated to be much smaller, likely due to more efficient fuel combustion.

Emissions by the transport sector (aviation, road traffic and shipping) are of concern because they grow more rapidly than those from other sectors. The emissions of NO_x by transport lead to an increase in ozone in the northern extra tropical troposphere and a global decrease in methane. The effect of NO_x emissions by shipping on methane was larger than expected, likely because they occur in a relatively clean environment. In summer, road traffic emissions have an appreciable impact on ozone up to the tropopause due to upward transport by convective clouds over land.

ENERGY RESOURCES AND CONSUMPTION

Energy resources are renewable as well as non-renewable resources. Energy is considered to be an index of development for a nation as the developmental activities of the nation depends upon the consumption of energy in that particular country.

Energy Resources

Non-renewable Energy Sources

The sources are of two kinds such as renewable resources, which can be generated from the natural processes and Non-renewable resources which are resources that available in a fixed quantity in the Earth's crust. Renewable energy such as solar energy, tidal energy, hydropower, biomass, geothermal energy and hydrogen are also called nonconventional energy, which can be used again and again. Non-renewable energy sources such as coal, petroleum, natural gas, nuclear fuels like uranium are also called conventional energy source because they cannot be used again and again in an endless manner. (Coal, oil, and natural gas are the three primary commercial energy sources in India.)

Coal: India now ranks third amongst the coal producing countries in the world. Being the most abundant fossil fuel in India till date, it continues to be one of the most important sources for meeting the domestic energy needs. It accounts for 55% of the country's total energy supplies. Most of the coal production in India comes from open pit mines contributing to over 81% of the total production while underground mining accounts for rest of the national output (MoC 2005). Despite this increase in production, the existing demand exceeds the supply. India currently faces coal shortage of 23.96 MT.

Power: India has made significant progress towards the augmentation of its power infrastructure. The country experienced energy shortage of 7.3% and peak shortage of 11.7% during 2003/04. The growth in electricity consumption over the past decade has been slower than the GDP's growth, this increase could be due to high growth of the service sector and efficient use of electricity. Per capita electricity consumption rose from merely 15.6 kWh (kilowatt-hours) in 1950 to 592 kWh in 2003/04 (CEA 2005). However, it is a matter of concern that per capita consumption of electricity is among the lowest in the world. Moreover, poor quality of power supply and frequent power cuts and shortages impose a heavy burden on India's fast-growing trade and industry.

Oil and Natural gas : The latest estimates indicate that India has around 0.4% of the world's proven reserves of crude oil. The production of crude oil in the country has increased from 6.82 MT in 1970/71 to 33.38 MT in 2003/04 (MoPNG 2004b). The production of natural gas increased from 1.4 BCM (billion cubic meters) to 31.96 BCM during the same period. The quantity of crude oil imported increased from 11.66 MT during 1970/71 to 81 MT by 2003/04. Besides, imports of other petroleum products increased from 1 MT to 7.3 MT during the same period. The exports of petroleum products went up from around 0.5 MT during 1970/71 to 14 MT by 2003/04. The refining capacity, as on 1 April 2004, was 125.97 MTPA (million tonnes per annum). The production of petroleum products increased from 5.7 MT during 1970/71 to 110 MT in 2003/04. India's consumption of natural gas has risen faster than any other fuel in the recent years. Industries such as power generation, fertilizer, and petrochemical production are shifting towards natural gas. India's natural gas consumption has been met entirely through domestic production in the past. To bridge this gap, apart from encouraging domestic production, the import of LNG (liquefied natural gas) is being considered as one of the possible solutions for India's expected gas shortages. Several LNG terminals have been planned in the country. Two LNG terminals have already been commissioned: (1) Petronet LNG Terminal of 5 MTPA (million tonnes per annum) at Dahej, and (2) LNG import terminal at Hazira. In addition, an in-principle agreement has been reached with Iran for import of 5

MTPA of LNG. India produced roughly 880 thousand barrels per day (bbl/d) of total oil in 2009 from over 3,600 operating oil wells. Approximately 680 thousand bbl/d was crude oil; the remainder was other liquids and refinery gain.

Renewable Energy Sources

Renewable energy sources offer viable option to address the energy security concerns of a country. Today, India has one of the highest potentials for the effective use of renewable energy. India is the world's fifth largest producer of wind power after Denmark, Germany, Spain, and the USA. There is a significant potential in India for generation of power from renewable energy sources—, small hydro, biomass, and solar energy. The country has an estimated SHP (small-hydro power) potential of about 15 000 MW. Installed combined electricity generation capacity of hydro and wind has increased from 19 194 MW in 1991/92 to 31 995 MW in 2003/04, with a compound growth rate of 4.35% during this period (MoF 2005). Other renewable energy technologies, including solar photovoltaic, solar thermal, small hydro and biomass power are also spreading. Greater reliance on renewable energy sources offers enormous economic, social, and environmental benefits. The potential for power production from captive and field-based biomass resources, using technologies for distributed power generation, is currently assessed at 19 500 MW including 3500 MW of exportable surplus power from bagasse-based cogeneration in sugar mills (MNES 2005).

Energy Consumption

The principal sources of energy in India are coal, oil, hydro-power and nuclear power. Traditional sources such as animal power, animal dung, bio-gas and fire wood etc also occupy an important role. Being the most abundant fossil fuel in India till date, coal continues to be one of the most important sources for meeting the domestic energy needs. About 75% of the coal in the country is consumed in the power sector (MoC 2005).

However petroleum products are one of the major sources of primary energy and in India about 35% of the total energy requirement is met by petroleum products. But the availability of crude oil deposit in India as well as worldwide is less compared to the demand and it is becoming more and more difficult to find new deposits. High quality crude reserves are concentrated almost exclusively in the Middle East where the reliability of supply has been problematic in the past.

Because of historic investment in infrastructure and product development, diesel oil is likely to remain the most widely used fuel for heavy vehicles for at least few more years. Apart from its cheap availability so far, it is convenient to transport and handle. During 1996-97 about 35.176 million tons of diesel oil was consumed in India which is about 6.51 percent, the growth rate of diesel oil was about 9.07 percent. It is estimated that about 66 percent of the Country's diesel oil consumption is in transport sector. Road transport constitutes one of the major consumers of petroleum products. Trucks and buses consume about 86 percent of the total diesel oil consumed in the transport sector, indicating the importance of diesel oil economy in buses and trucks.

It is estimated that about 33 percent of the total diesel oil consumption is by buses and trucks of State transport undertakings and the balance 67 percent consumption is by unorganized fleet operators.

The energy intensity of India is over twice that of the matured economies, which are represented by the OECD (Organization of Economic Co-operation and Development) member countries. India's energy intensity is also much higher than the emerging economies—the Asian countries, which include the ASEAN member countries as well as China. However, since 1999, India's energy intensity has been decreasing and is expected to continue to decrease. The indicator of energy–GDP (gross domestic product) elasticity, that is, the ratio of growth rate of energy to the growth rate GDP, captures both the structure of the economy as well as the efficiency. The energy–GDP elasticity during 1953–2001 has been above unity. However, the elasticity for primary commercial energy consumption for 1991–2000 was less than unity (Planning Commission 2002). This could be attributed to several factors, some of them being demographic shifts from rural to urban areas, structural economic changes towards lesser energy industry, impressive growth of services, improvement in efficiency of energy use, and inter-fuel substitution.

According to the International Energy Agency (IEA), coal/peat account for nearly 40 percent of India's total energy consumption, followed by nearly 27 percent for combustible renewable and waste. Oil accounts for nearly 24 percent of total energy consumption, natural gas six percent, hydroelectric power almost 2 percent, nuclear nearly 1 percent, and other renewable less than 0.5 percent. Although nuclear power comprises a very small percentage of total energy consumption at this time, it is expected to increase in the light of international civil nuclear energy cooperation deals. According to the Indian government, nearly 30 percent of India's total energy needs are met through imports. The figure below represents the Total Energy consumption in India by IEA.

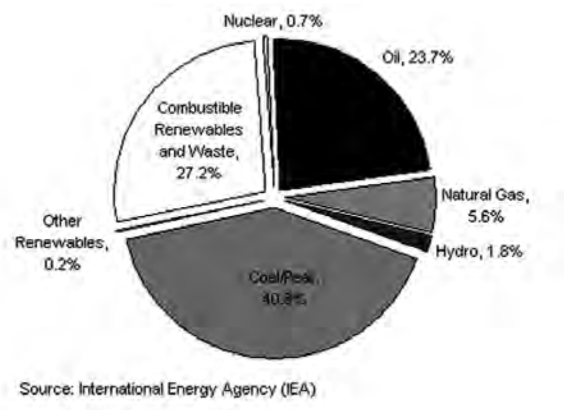

Fig. 1
Total energy consumption in 2007

India produced roughly 880 thousand barrels per day (bbl/d) of total oil in 2009 from over 3,600 operating oil wells. Approximately 680 thousand bbl/d was crude oil; the remainder was other liquids and refinery gain. In 2009, India consumed nearly 3 million bbl/d, making it the fourth largest consumer of oil in the world. EIA expects approximately 100 thousand bbl/d annual consumption growth through 2011.

In 2009, India consumed roughly 1.8 Tcf of natural gas, almost 300 billion cubic feet (Bcf) more than in 2008, according to EIA estimates. Natural gas demand is expected to grow considerably, largely driven by demand in the power sector. The power and fertilizer sectors account for nearly three-quarters of natural gas consumption in India. Natural gas is expected to be an increasingly important component of energy consumption as the country pursues energy resource diversification and overall energy security.

Despite the steady increase in India's natural gas production, demand has outstripped supply and the country has been a net importer of natural gas since 2004. India's net imports reached an estimated 445 Bcf in 2009 (Fig. 2).

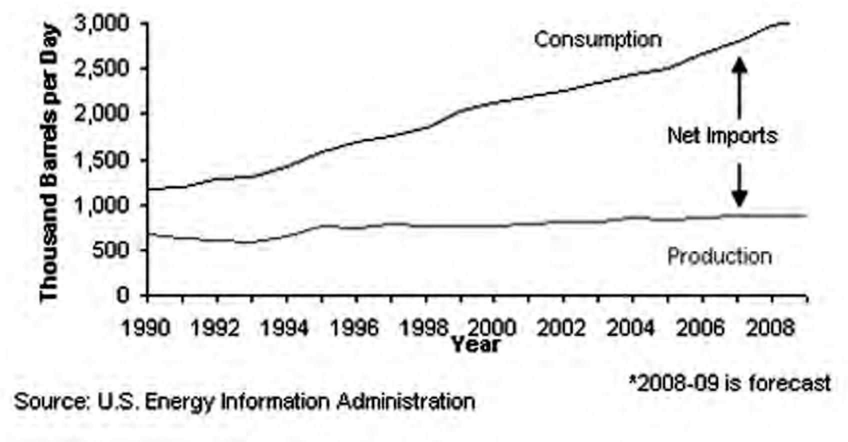

Fig. 2
India's Oil Production and Consumption

Energy Consumption in Transport Sector

Transport is a vital sector of a nation's economy and it claims a good share of the energy consumed. In India, its share in 1978-1979 was 32%, next only to industry whose share was 39%.

As far as mobility is concerned, road transport is the dominant mode. Representing 90% of all passenger journeys and 75% of all freight hauled, it has boomed in recent decades. In the last 25 years, the vehicle fleet has more than doubled in the OECD countries (80% of the world fleet). Today, there are nearly 600 million private automobiles and 209 million light trucks registered in the world. Passenger transport demand is closely related to household revenue, commuting distance and the distance between home and school. Road transport totally dominates the energy balance: in the three key OECD regions—the U.S., Japan and the Europe of Fifteen — it represented 96% of the 13760 billion passenger-km traveled in 2000 (cf. Fig. 3).

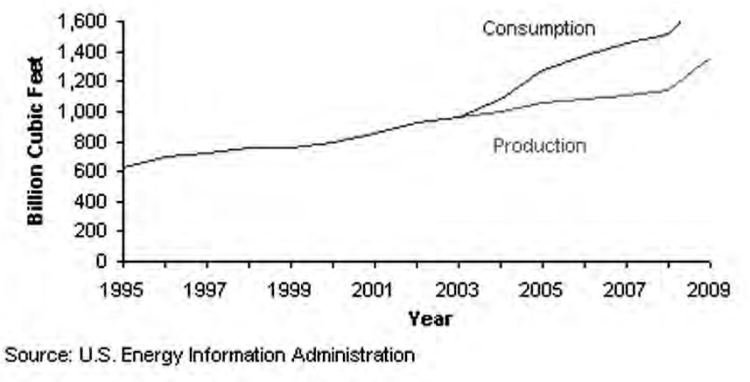

Fig. 3

India's Dry Natural Gas Production and Consumption (1995-2009)

Air, rail, tramway/metro and waterway transport account for the rest. Only Japan, which has the requisite infrastructure, reports a larger proportion of public transit. Over time, the household transport budget has remained fairly constant at about 13% of total household revenue. The figure shown below is the pie chart representing world petroleum consumption in 2002.

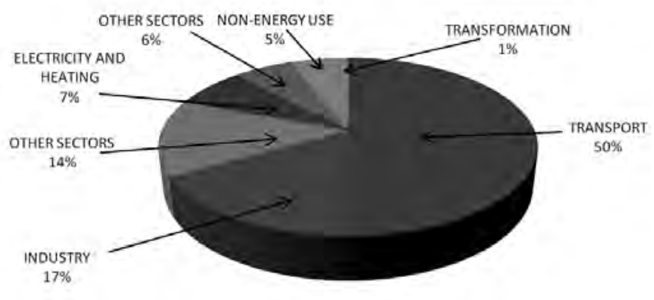

Fig. 4

World petroleum consumption in 2002

Oil has come to occupy an important place as an energy source in the transportation sector because of many inherent advantages. Apart from its cheap availability so far, it is convenient to transport and handle. In the road transport industry, it has so far no substitutes, though efforts are continuing to run battery-powered vehicles. Technology may see a great break-through in this direction in the future, but at least in the short term, the road transport sector has to manage with an ever increasing shortage of oil products. Under these grave circumstances, all possible avenues for economy in fuel consumption in the transport sector must be explored. One of the promising areas is by large-scale improvements in the roads of the country. The world still consumes more oil than any other primary energy. In 2002, oil represented 36% of the market, or about 3.8 Gtoe (Gigatons of Oil Equivalent). The transport sector is clearly dominant in petroleum product consumption: 50%, versus 42% in 1973. The OECD countries are the main drivers of petroleum product consumption in the transport sector. Collectively, they absorb 75% of the 1.75 Gtoe consumed by world transport, especially the United States, the Europe of Fifteen and Japan (55%).

Fuel consumption splurge in Kerala

Kerala had all along been a huge consumer durables and perishables market for the country as a whole. But the per capita income of an average Keralite did not warrant such a high level of expenditure. But, a recent study found that the per capita consumption in Kerala exceeded the national average by close to 50 per cent, which was not backed by any excess income generated within the State. A state wise list of Transport Density in India was presented as per the Ministry of Road Transport (Table 1); out of which Kerala holds the eleventh-position in traffic density.

Table 1
State wise Transport Density in India

Sl.	State	No. of Vehicles (in lakhs)	%age of total	Rank
1	Maharashtra	89.69	12.33	1
2	Tamilnadu	85.75	11.79	2
3	Gujarat	70.87	9.75	3
4	Uttar Pradesh	64.60	8.88	4
5	Andhra Pradesh	57.19	7.80	5
6	Delhi	25.48	5.83	6
7	Karnataka	39.77	5.47	7
8	Rajasthan	38.34	5.27	8
9	Madhya Pradesh	38.04	5.23	9
10	Punjab	35.29	4.85	10
11	Kerala	27.92	3.84	11
12	Haryana	25.48	3.50	12
13	West Bengal	25.48	3.50	13
14	Orissa	15.25	2.10	14
15	Jharkhand	12.17	1.67	15
16	Chattisgarh	12.16	1.67	16
17	Bihar	7.51	1.03	17
18	Assam	7.27	1.00	18
19	Chandigarh	5.86	0.81	19
20	Uttaranchal	5.16	0.71	20
21	Jammu & Kashmir	4.39	0.60	21
22	Goa	4.36	0.60	22
23	Pondichery	3.13	0.43	23
24	Himachal Pradesh	2.89	0.40	24
25	Nagaland	1.72	0.24	25
26	Manipur	1.06	0.15	26
27	Tripura	0.76	0.10	27
28	Meghalaya	0.73	0.10	28
29	Daman & Diu	0.48	0.06	29
30	Mizoram	0.42	0.06	30
31	Dadra & Nagar Haveli	0.35	0.05	31
32	Andaman & Nicobar	0.28	0.04	32
33	Arunachal Pradesh	0.21	0.03	33
34	Sikkim	0.17	0.02	34
35	Lakshadweep	0.05	0.01	35
Total		727.00		

From, the above table it is clear that the fuel consumption in Kerala is quite high which may progressively augment in the up-coming years.

Factors affecting Fuel consumption of Motor Vehicles

The factors affecting fuel consumption can be grouped as follows:

Vehicle characteristics

Some of the vehicle characteristics, which may affect fuel consumption, are briefly indicated below:

- Age of the vehicle: as the engines become old and the other moving parts of the vehicle get worn out, more energy is consumed in propulsion.
- Make: Vehicles of different makes show small variations in fuel consumption due to inherent features of engine design.
- Horse power and engine capacity
- Condition of the engine: the condition of the engine (tuned or untuned), especially the ignition system, the spark plugs, the transmission system, the condition of the valves etc. affect fuel consumption to a large extent.
- Tyres: the inflation pressure of the tyres, the composition of the number used in tyre, the design etc. are factors which affect fuel consumption. The tyre comes into close contact with the road surface and the friction developed between the tyres and the road surface has to be over come when the vehicle moves. The friction factor is governed by the tyre characteristics indicated above. It has been found by the Central Road Research Institute that radial tyres can bring about an economy of about 5-7% in fuel consumption of cars. Radial tyres have not yet been introduced for commercial vehicles in the country.

Driver Characteristics

The manner in which the driver drives the vehicle influences fuel consumption to a great extent. Sudden acceleration and deceleration will increase the consumption of fuel. A steady state speed, especially at optimum value, will result in minimum fuel consumption.

Road conditions

The important road features, which affect fuel consumption, are:

- Type of the surface and its roughness: It is well known that a smooth and well maintained surface provides the least frictional resistance. Hence, the fuel consumption on such surfaces will be the lowest.
- Vertical profile of the road: When a vehicle has to negotiate an upward gradient, it has to overcome the natural forces of gravity. Hence, the steeper the upward gradient is, the greater is the fuel consumption. On the other hand, the fuel consumption when the vehicle takes a downward gradient is lower than the vehicle on a level horizontal surface. This underlines the need for constructing roads with well designed vertical profile. Even though it may seem to construct roads with undulating vertical profile initially, in

the longer run it will be far more economical to operate the vehicles if great care was taken to select proper gradients initially.

- Width of the road: The majority of the roads in India are single lane with a width of 3.5 m which forces the vehicle to move on the ill-maintained undulating earthen shoulders whenever vehicles have to cross one another or overtake one another. The wear and tear of the vehicles and the fuel consumption mount steeply when the vehicles have to undertake such manoeuvres. This is because of the acceleration and deceleration involved and because of the rough surfaces in the shoulders. The intermediate lane(5.5m width) roads do provide a certain amount of relief during crossing and overtaking but severely restrict the speed of the vehicles and thus cause high fuel consumption. The ideal road is a two-lane road where the vehicles can move in their respective lanes having firm and smooth surfaces.
- Curvature of the road: The curvature of the road indirectly affects fuel consumption because of the vehicles have to slow down the speeds when entering curves and frequent acceleration and deceleration are caused. There, is however no direct effect of curvature on the fuel consumption.

Fuel Characteristics

The various properties of fuel which affect the consumption are:

i. The octane value
ii. The wax contents
iii. Sulphur content
iv. Temperature of the fuel

Environmental factors

Some of the environmental factors, which affect fuel consumption are:

i. Altitude of the place: at high altitudes, there is lack of oxygen and thus the vehicles consume more fuel
ii. Ambient temperature
iii. Rain or dry conditions which affect the speed of the vehicles and thus indirectly affect the fuel consumption
iv. Wind direction and velocity

EFFECT OF TRANSPORT ON CLIMATE CHANGE

Transport sector is highly disturbing the climatic change and experts say it is only going to get worse. Almost 80 percent of the total active air pollutants were contributed from the transport sector. The recent data reveals that transport was responsible for around 10% of the total net man-made warming nearly a decade ago; topping the list was CO_2 followed by tropospheric ozone (O3).

Almost 80 percent of the total active air pollutants were contributed from the transport sector. Transport is highly disturbing the climatic change and experts say it is only going to get worse. The recent data reveals that transport was responsible for around 10% of the total net man-made warming nearly a decade ago; topping the list was CO_2 followed by tropospheric ozone (O3). Transportation emits a broad mix of components with very different characteristics with respect to climate impacts. They operate on different time scales and cause both warming and cooling. And right before the 22^{nd} century kicks in, transport's contribution to man-made warming may reach 20%.The transport sector is responsible for a large share of gas and particle emissions that affect the climate. These emissions also threaten human health, crops, and the material infrastructure. Higher standards of living and increased travel are largely to blame. The only sector to see an increase in emissions of greenhouse gases is the transport sector.

Global Impact of Road Traffic on Climate

Among the transport sectors, road transport has a strongly dominating temperature effect, both on short and longer terms. Road traffic is one of the major anthropogenic emission sectors for NO_x, CO and NHMCs (non – methane hydrocarbons). Road traffic clearly provides the largest net contribution to warming through its large emissions of CO_2 and significant emissions of ozone and soot. It is revealed that NMHC emissions from road traffic play a key role for the impact on ozone. They are responsible for (indirect) long range transport of NO_x from road traffic. Total warming from road traffic is estimated to be about 0.19 Watts per square meter (W/m^2), or about seven percent of the total climate forcing, because of the increase in the concentrations of ozone, soot, and greenhouse gases. This surprisingly low percentage results from road traffic having a shorter history than other emissions sectors, and thus having less responsibility for the accumulated concentrations of long-lived greenhouse gases. However this share will increase in the future.

Understanding the total impact of road transportation requires not only taking into account the total quantity of emissions, but also on how various components interact with each other and the climate. Scientists say CO_2 is the leading climate gas from road traffic. They also predict a rise in these emissions and a drop in other gas emissions. The greater concentrations of CO_2 in the atmosphere create a green house effect on earth. The increasing level of CO_2 was estimated to an extent of about 20% by 1980 (Owen, 1985). This level is expected to be doubled by 2035 to what it was at the pre-industrial revolution level. In other words, the increase in atmospheric carbon dioxide build-up has been estimated to be 260 parts per million (ppm) to 28 ppm before the industrial revolution to nearly 345 ppm today. This means that the concentration of CO_2 in the atmosphere may work like glass of a motorcar. The simple analogy will reveal the mechanism. In summer, if we keep the car window closed in the open day, the sun's energy move inside the car easily. But in this process, the sun's energy is converted into an infrared-ray-heat-energy and hence cannot pass through the glass outside. The heat energy is trapped inside the car. Similar kind of function is performed by the carbon dioxide molecules in the atmosphere. Thus, greater the presence of carbon dioxide molecules, there is greater chances of trapping sun's energy into this level (i.e. CO_2 level). This, finally, leads to a greater conversion of sun's energy into the heat-energy as the level of CO_2

build-up increases. The increase in level of CO_2 may lead to an estimated increase of temperature of about 3^0C by year 2035.The increase level estimates of CO_2 are higher in case of the polar regions i.e. a rise of 7^0C to 10^0C. The effect of carbon dioxide build-up in the atmosphere and its resultant global increase in temperature are multiples, e.g., rainfall shifts, climatic change, melting of ice in the polar region and distressing plant growth.

Various gases and particles emitted by the transport sector impact the climate. While some emissions cool the Earth, others warm it, and some effects last for many years, while others last for only a short time. In addition to emissions of CO_2, mobile sources also emit a number of gases that live only a relatively short time in atmosphere (up to a few months) but can have a significant radiative forcing. Combustion engines emit nitrogen oxides (NO_x), carbon monoxide (CO), and unburned hydrocarbons, which are chemically transformed in the atmosphere, creating other gases such as ozone. Ozone is a greenhouse gas and poses a regional air pollution problem damaging human health and agricultural crops. Diesel engines emit considerable amounts of small soot particles that absorb sunlight and thus lead to a warming of the climate. Since, two/three wheelers having two-stroke engine units which emits more of hydrocarbons relative to four-stroke engines (motor cars, trucks etc.) the level of air pollution (through hydrocarbons) in metropolitan cities which has already high will be puffed up.

Lead is an important pollutant emanating from automobiles. The suggested lead level criteria in air quality-guide of WHO (World Health Organization) provides a level of 2 $\mu g/m^3$. This level of lead content in air in most of the world countries has been exceeded. The concentration of lead is maximum near the areas with highest density of vehicular (combustion type) traffic. Only if the use of lead in gasoline is reduced or replaced by some other alternative sources the pollution so generated in the air may be controlled, if not at least eliminated.

Scientific investigations had shown that lead is mixed to gasoline to increase the high octane rating (a measure of antiknock or smooth and easy running of vehicles). If the octane rating is low, the fuel and air mixture can ignite prematurely and disturb the smooth and easy running of the engines and cause knocking. Therefore, until recently, the octane rating of gasoline was normally raised by the addition of lead in concentrations of between 0.3 and 0.6 grams per liter, despite the unfavourable effects it had on the environment. However, this toxic lead emission in the environment can be controlled with the use of methanol. The methanol engine can considerably lessen the amount of carbon monoxide emission that of the gasoline engine and reduce the air pollution. This is because of the fact that octane rating of methanol is considerably high, i.e. 130-140, than that of the standard or premium fuel (the normal lead free gas with an octane rating of 90-92 can be raised to standard octane rating of 98-100 by mixing 20% methanol to standard to obtain the standard or premium fuel). Another important characteristic of methanol is the higher vapourization time, which is about three times as high as that of gasoline, since methanol does not volatize as easy as gasoline.

The advantage of using methanol as motor fuel is its relatively favourable effects on the environment. The emission of toxic lead in exhaust fume is avoided; which can be done with the mixing of lead-free gasoline and methanol to attain the octane ratings of standard commercial gasoline. In India, the octane level is about 87, which need greater attention, if toxic lead level of the air is to be maintained at a quality level. The toxic level of lead has been found at near toxic levels at congested road crossing which is poisonous for man. This also effects the lowering of intelligence in young children whose lead levels are measured in the blood streams and hence, it may be noted as an important parameter of air pollution.

Also, the dust created in the air from the automobiles creates an umbrella, often known as the dust dome. An investigation conducted by the Air Hygiene and Silicosis Research in Germany in the Ruhr industrial district has suggested that coarse dust content of the air had declined sharply in early seventies, but the fine dust concentration mainly from the running of vehicular traffic in ventilating air has remained fairly constant. The same viewpoint can also be substantiated by the fact that in cities there is less of sunshine. This has been estimated to an extent of 10 percent in case of Los Angeles. Implicit to it is the fact that atmospheric pollution may reduce the amount of sunlight because particles matter (including 1.5 tonnes of carbon monoxide per gallons of gasoline, 300 pounds of hydrocarbons and 100 pound of nitrogen oxide, which in a year in America comes from consumption of about 75 billion gallons of gasoline), scatters radiation (Owen, 1985).

Comparison of Road Traffic with other Modes of Transport

Fossil fuel combustion by aviation, shipping and road traffic contributes about one fifth of the total global anthropogenic emissions of CO_2. These emissions are growing more rapidly than those by other sectors such as power generation and industry. In contrast to road transport, air transport has several strong but short lasting, effects on the global temperature. Aviation emits between 2 and 3 percent of the total human-produced CO_2 emissions, but that does not tell the full story. Effects down the cause – effect chain must be considered when we assess the climate impacts of this sector. Shipping emissions occur in a relatively clean environment but it is not clear to what extent this affects their impact on climate. Until recently, also the impact of road traffic emissions was quite uncertain because of uncertainty about vehicle emission factors, and lack of information about road traffic intensities in developing countries. The current shipping emissions differ from the road and aviation sectors by having a cooling effect on climate that lasts 30 – 70 years. Sulphuric fuels, particularly heavy oil used aboard ships, lead to the creation of sulphate particles that directly and indirectly increase the reflection of sunlight and thus have a cooling effect. This cooling effect results from the very high emissions of SO_2 and NO_x. However the warming effect will dominate in the long term because shipping also emits significant amounts of CO_2. But still when we quantify and compare climate impacts of the different transport sectors, the conclusions will vary strongly depending on which method and climate indicator is used and the adopted time perspectives. Even though both shipping, rail and air traffic create disturbances on the natural balance of climate, the emissions from road transport has become so big that the impact of emissions from today's road traffic on the global temperature in 2100 will be six times greater than that from today's air traffic. Today's global Road traffic emissions have a strong and long – lasting effect on climate. Road traffic emissions occur mostly over the land surfaces of the eastern US, Europe, the Far East and India. In these regions also other, non-traffic, sources are important. Ship emissions are largest over the North Atlantic and along the coastlines of the US, Europe, and East Asia. Aviation emissions peak over the east and west coasts of the US, and Western Europe. At upper levels the aircraft emissions in the North Atlantic Flight Corridor constitute an important perturbation. The supersonic flights normally take place at stratosphere level and release nitrous oxides (N_2O, laughing gas) and water vapour directly into the stratosphere. The nitrous oxide in the stratosphere leads to acceleration of natural destruction of ozone. Overall, the east coasts of the US and Asia and Western Europe, including the North Sea, are regions with a relatively high emission contribution by transport. Emissions by the transport sector (aviation, road traffic and shipping) are of concern because they grow more rapidly than those from other sectors. The emissions of NO_x by transport lead to an increase in ozone in the northern extra tropical troposphere and a global decrease in methane. The effect of NO_x emissions by shipping on methane was larger than expected, likely because they occur in a relatively clean environment. In summer, road traffic emissions have an appreciable impact on ozone up to the tropopause due to upward transport by convective clouds over land. The acidifying effects of emissions by transport are mostly concentrated in a few regions, including Western Europe and the east coast of the US and Asia.

CONCLUSION

The transport sector is one of the largest consumers of energy and the largest consumer of petroleum products. It is a primary source of air pollution and the second largest contributor to CO_2 emissions. Some possible measures can be taken to reduce energy consumption and emissions in the transport sector. In the freight transport sector, for example, there is considerable scope to consider model shifts away from road towards rail, as well as significant improvements in freight transport logistics.

In order to shield the environment from the perilous pollutants emitted from the transport systems the control of emissions is very much significant. There are many ways of reducing emissions from traffic such as improving standards of maintenance of vehicles, reducing the volume of traffic flow etc. These are also important elements in an emission control strategy. If complete combustion of fuels were possible vehicle exhaust would contain only carbon-dioxide and water vapour. But this is not possible as a result of number of factors, including the short time available for combustion in the engine, the poor mixing of the fuel and the air, and also due to the high temperature of combustion; vehicle exhaust also contain CO, HC, PM and NO_x.

Emissions from motor vehicles depend on a large number of factors. The main ones are the vehicle technology, including the fuel used and the mileage driven. Other factors such as fuel quality, vehicle maintenance, driver behavior and the rate of scrappage of older vehicles can also be important. For each vehicle, there is a compromise during its design between optimizing for fuel consumption, emissions and performance. In the early phases of emission control, the emphasis was on improving the precision and timing of the injection of fuel into the combustion chamber and the design of the combustion chamber itself to improve combustion and also to minimize the deposit of fuel on the walls of the chamber, which leads to exhaust HC emissions.

Increasingly, as emission limits have become more stringent, new techniques for emission had been emerged. Both petrol and diesel vehicles depend on the use of ‘after-treatment’, that is the removal of the pollutants in the exhaust rather than controlling its formation in the engine. Now, more than 270 million of the world’s 500 million car’s and over 85% of all new cars produced worldwide are equipped with ‘after-treatment’ system.

Further limits are to be introduced for new vehicles sold in these markets over the next few years. It is likely that the main focus of future legislation for cars, buses and commercial vehicles will be on particulate matter (PM). Vehicles are used for many years before they are scrapped. Therefore, it takes some years for the benefits of the cleaner/more fuel-efficient new vehicles to have maximum impact on the environment. The types of HC emitted from petrol and diesel engine vary considerably, reflecting the differences in the fuel. Typically petrol cars have greater emissions of lower molecular weight HC (e.g. benzene) while diesel have greater emissions of high molecular weight compounds (e.g. polycyclic aromatic compounds).The main alternatives of petrol and diesel available on the European market are natural gas (compressed or liquefied), Liquefied petroleum gas (LPG) and electric vehicles. Viewing the above noted major atmospheric pollutants, it can be concluded as the major source areas of these contaminants are city and ever increasing use of energy either for vehicles or running the industry or running the home-services etc.

A viable strategy and policy frame work have to be evolved to reduce the emissions and pollutions from trasport sector, increased use of renewable energy sources and appropriate changes in the process of transport sector to minimize energy use as well as emission leading to mitigation of climate change.

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Energy Management in Health Care Services

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INTRODUCTION

For health care facilities, energy has always been an essential element to the delivery of quality services. Inpatient facilities use more energy per square meter than any other commercial building type and spend crores of rupees annually on energy. In addition to traditional energy requirements, the explosion in the use of technology by health care facilities has increased the energy demand.

While the demand for energy is rising, so too are costs - the result of several factors, including increased demand in all sectors. Modern Hospital is the central hub of health care. It forms the focus of techniques and technology of ever increasing sophistication. As a result, energy accounts for a growing percentage of health care operating costs. At the same time, there is greater focus on controlling costs as the dynamics of the health care system have changed. Health care facilities must now treat energy supply costs, reliability and quality as risks to be managed.

To understand how to conserve energy, one must first understand how it is consumed, the interrelationships of the various systems and subsystems, etc…., in each building. Once this understanding is obtained, technical, administrative, health care and other personnel can collaborate to determine where, when and how modifications should be made to reduce consumption. Implementation of modification and the overall progress itself then becomes the responsibility of management personnel who utilize conventional management techniques to help ensure realization of energy conservation goals

Although, there are literally hundreds of different options available, the major thrust behind all of them is to improve the efficiency of all building systems, subsystems, and components. This focus has three primary effects.

First, it eliminates energy wastage.

Second, it significantly expands areas of opportunities for conservation while also providing a substantial amount of flexibility for management to select which options it wants to implement at any particular time.

Third, it promotes conservation without affecting the environments required for performance of health care and related services, and without loss of comfort, productivity, safety or security.

The impact already is being felt in long term care facilities and other buildings across the world. Energy savings of 15% to20% and more in the first year of application have been documented and, typically, most of the measures taken to achieve these savings require little capital investment. In cases where capital investment is required, payback generally is three years or less. As the cost of energy increases, these paybacks will become increasingly shorter. Perhaps most important, the substantial energy and energy cost savings possible can be achieved without disrupting effective delivery of health care services.

UNDERSTANDING ENERGY CONSUMPTION IN HOSPITALS

All health care facilities have three fundamental systems which affect energy use. These are energized systems, non-energized systems, and human systems.

Energized systems are those which consume energy directly. Typical energized systems include, among others, those used to provide heating, ventilation, air conditioning (cooling), humidification, dehumidification, lighting, hot water heating, interior conveyance, food cooking, dishwashing, sterilization, laundry processing, waste handling and physical therapy as well as various pieces of equipment such as computer, lamps, sewing machines and televisions.

Non-energized systems are those which do not consume energy directly, but which do affect the amount of energy which an energized system must expend to get its job do. Typical non-energized systems include walls, windows (glazing), floors, roof, ceiling, doors etc.

Human systems comprise those persons who somehow have an impact on when, and in what quantity energy is consumed. These persons include, to name just a few: residents; nursing staff; therapists; administrative personnel; laundry and food service employees, operating, maintenance and housekeeping personnel; volunteers, and visitors. Human systems also impact on the amount of plastics and disposables which are used, most of which are petroleum based and, accordingly, are energy-intensive.

Energy management in health care facilities can be different in relation to the purpose for which health care facilities generally exist, that is, to help residents attain a maximum degree of maintenance or rehabilitation. Accordingly, a change made to any of the three systems must be completely compatible with this goal. Also because many health care facility residents suffer from one or more chronic illnesses, or disabilities, comfort is of prime importance. Lowering indoor temperature in winter would have far more of an impact on a long-term care resident than it would on a typical office worker.

The second reason stems from the first. Provision of high quality care often requires purchase of new, more effective equipment. Addition of equipment especially in older facilities means that complex systems become even more complex. For example addition of a hair dryer for beauty care or an infrared treatment lamp may require new wiring and will change the heat gain characteristics in the room involved.

Table 1
Electrical Power consumption of various equipments

Equipment	Kilowatts/Hour
64-row-over 64-row MDCT	30
16-row-40-row-MDCT	20
6-row-8-row-MDCT	20
2-row-4-row-MDCT	5
1-row-SDCT	5
3T MRI operating time	40*
Non-operating time	16.5*
1.5T MRI operating time	27*
Non operating time	12.2*`
1.0T MRI operating time	27*
Non operating time	12.2*
0.4-0.9T MRI(permanentmagnet)	4*
0.2-0.3 T MRI (permanent magnet	3*
Angio unit operating time	18**
SPECT	2.7
SPECT-CT	5.1
PET	4
PET-CT	10
Ultrasonography	1

No matter how many concerns must be addressed, however, it is still possible to document exactly in which element of each group of systems consumes or affects consumption of energy. As a result, it is also possible to determine what modifications can be made to reduce the amount of energy consumed through an effective program for energy management.

Because each building is a unique entity, there is no way that a general documents such as this can indicate what specific conditions exist at a facility. However, it is possible to indicate general conditions which affect all buildings. To illustrate the concerns which the program must address, consider the subject of air conditioning which, together, usually comprise the largest single “book” of energy consumed in health care facilities .To start, one should not think of air conditioning simply in terms of adding or removing heat from the inside air to achieve a given temperature. The factors which influence heat loss and heat gain, and a few of the many steps which can be taken to reduce their impact are:

- Infiltration
- Solar heat
- Transmission
- Ventilation
- Lighting
- Equipment
- Occupants

These factors and their impact are described as follows.

Infiltration

Infiltration refers to the passage of outside air into a building through apertures such as cracks around windows and door jambs, doors and windows left open, outside air dampers which do not close tightly, etc. The cool, outside air which enters the building must be heated to maintain desired indoor conditions. During summer, infiltration causes heat gain. The warm outside air which enters the buildings must be cooled to meet desired conditions. In many cases additional energy must be expended to further treat the outside air by humidification, dehumidification, or filtering. Although non-energized systems (windows, doors etc..) are prime determinants of the amount of air infiltrated, human systems also are important. When door or windows are left open to offset interior temperature which is too hot or too cool, the waste involved is magnified even more.

Transmission

Transmission refers to the amount of heat transmitted into or from a building through the various components of the building envelope, primarily exterior walls, windows, doors, skylights, roof and floor. The amount of heat loss or heat gain caused by transmission depends on the difference between indoor and outdoor temperatures in accord with the basic principle of heat flow. The rate of transmission depends on the building position of the various materials utilized in construction of the building envelope.

Ventilation

As with infiltration and transmission, ventilation contributes to heat gain or heat loss (and humidification/dehumidification) depending upon the season involved. The ventilation system provides a building with fresh air by exchanging inside air for outside air.

Lighting

Lighting contributes to a building ‘a heat gain in direct proportion to the wattage of lamps involved. Heat gain is generally beneficial in winter months because it provides heat which otherwise would have to be provided by mechanical systems. In summer months the mechanical cooling system must compensate for the heat gain from light sources. There are many techniques available to modify lighting systems while keeping them consistent with the need for proper illumination.

Solar Heat

Solar heat, like the heat of light contributes to heat gain throughout the year. The specific effect of solar heat depends on the geographical area involved, the intensity and direction of the rays, the materials which comprise the building envelope, color and texture of walls, extent and type of solar controls, and other factors. Numerous non-energized systems-such as blinds and drapes-can be utilized to make maximum use of solar effect.

Equipment

Virtually all energized devices including business machines; printing presses; therapy’ sterilization; laundry and food service equipment, television sets, etc. contribute to heat gain. In some cases this heat, or portions of it, can be recovered from one part of a building where heat is not needed and be ducted to another part of a building which requires heat.

Occupants

People contribute to heat gain whenever the room temperature falls below their body temperature. People also affect the moisture content of air through perspiration and exhalation. The way in which different types of spaces are utilized will determine the extent of heat gain involved. Modification can reduce the load placed on heating and cooling equipment, and so the energy required for the equipment’s operation. Accordingly, while setting the thermostat to a lower temperature than otherwise would be maintained to achieve savings.

Energy Management in Hospitals

Adjustment and modifications of the heating and cooling equipment itself can achieve substantial economies. It has been shown, for example, that air conditioning systems of even the most modern buildings often have extensive inefficiencies usually due to faulty installation, maintenance or operation, Correction often result in substantial energy savings. Other modifications also can be made.

One must understand the particular needs of each department and the spaces it contains. For this reason, input from various departmental personnel is necessary to ensure that all of their unique concerns and requirements are given careful consideration. As a case in point, it would be unwise to reduce illumination levels in a space if such a reduction would impair the visibility required to perform a task, be it following a recipe or inventorying pharmaceuticals. Whenever human systems are involved, management (another human system) usually must be involved as well, generally to create incentives, monitor progress and provide additional incentives, training or other forms of premedical action if necessary.In essence, successful application of energy management and through its achievement of substantial energy conservation first require intimate knowledge of the makeup of each of the facilities.

Energy management in health care today is both a challenge and an opportunity. A health care facility must balance its power needs realistically against its operating budget. The best ways to meet this challenge are by combining traditional approaches of energy management with more innovative ones.

New approaches to handling energy requirements include demand-side management. This involves ways to reduce the need for energy. Facilities should create system-wide energy conservation programs. This can be done by identifying cost-effective measures to reduce energy consumption and by implementing a programme of system efficiency improvements.

Hospitals should examine how they use energy to determine where cuts can be made especially in older buildings. As hospitals construct new buildings, the most energy efficient systems should be considered. Older buildings are prime candidates for reduced energy use. For example, light fixtures can be modified or heating and cooling systems can be altered from constant-volume to variable-volume drive applications. Process instrumentation, equipment changeovers and new controls should also be considered.

One approach is to contract a conservation-performance specialist who can evaluate the systems and recommend cost-saving modifications. The expenses of retaining a contractor to ensure efficient performance should be amply offset by the savings that result. An independent expert will be engaged to verify the validity of the recommendations and the most cost-effective way for implementation.

The steps to supply-side management may include

1. load profiling
2. load aggregation
3. onsite generation alternatives
4. electrical system upgrades to remove old, inefficient equipment and
5. Peak-saving opportunities.

The bottom line is that secure sources of power must be available at all times. It is mandatory that emergency power supply is ensured so that critical facilities will remain safely in operation even if there is an interruption in power. Hospitals are taking varied approaches to meeting this requirement. Diesel-fueled emergency generators have been installed on site to start up quickly and maintain the power supply for a period of time after an outage. These have certain drawbacks in that the diesel fuel creates air quality issues, and, furthermore, generators will keep going only as long as their fuel source lasts.

Among the newest strategies is the outsourcing of energy management. Outsourcing various functions is not new to the health care industry; in recent years, more and more services, such as food preparation, laundry, waste disposal, bill collection and information technology have been entrusted to outside parties.This approach has several advantages, the most obvious of which is that energy issues are handled by those whose primary business is in that field rather than by organization whose area of competence is in a field entirely different - health care.

CONCLUSION

The infrastructure development in the health care sector is increasing day by day in the country.As explained above energy utilization is a major component in any health care facility and there is very little awareness on the use of energy and the implications it may cause in the energy-environment sector.It can be seen that the carbon footprint of health care facilities are very high and there is very little efforts initiated either by the hospitals themselves or the authorities to reduce the carbon footprint of health care facilities. It is high time to identify the implications of energy use in this sector and the strategy to be adopted to reduce energy use without affecting the quality of the services. Strategies have to be planned both at the institutional level as well as formulating policies by the government.

Electricity Needs of Kerala in the Coming Years

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INTRODUCTION

The State of Kerala is unique in many respects and often comparable with many developed nations across the world. High health standards, highest literacy rate in the country, highest Human Development Index, lowest birth and child death rate etc give Kerala the top position in India. It is three times as densely settled as the rest of India. Kerala is one of the most socially progressive states with the highest life expectancy of 73 years.

Energy, as we all know, is the most critical resource for the development of the mankind and as of today, Electricity remains as the king among all forms of energy. India is ranked eighth in the world in terms of total electricity generated. In spite of sustained growth, the per capita electricity consumption is around only 680 kWh(Kerala has 530kWh) only and that pulls India among the lowest in the world. No doubt, Energy is an essential input for economic development and improving the quality of life. But it is a fact that over 40 percent Indians have no access to electricity.

Unlike yester-years, electricity situation in the state of Kerala is not insulated from the rest of India. Due to the innovative changes in the sector with the radical shift with the enactment of Electricity Act 2003 and its subsidiaries orientated fundamental changes leading to a dynamic market for energy sector in the country. For a state like Kerala when the internal demand grows beyond its own capacity, accessibility to the national level market is inevitable and hence the global scenario would have a greater footing on the power scenario of the state in the decades to come.

The punch of electricity shortage was not known to the state till 1983. For two decades from 1962 ‘abundant hydro-power/export of energy/profit’ has been the guiding philosophy of the Kerala State Electricity Board. This deterred the board from thinking about thermal power. However, realistic hydro-energy estimates fall far short of the projected electricity demand.

NATIONAL STATUS - A QUICK LOOK

The Indian power sector has the 5th largest electricity generation capacity in the world today. We have more than one hundred and sixty four thousand MW today, not to mention the world's third largest transmission and distribution network. The Government of India has an ambitious mission of Power for all by 2012. This requires that at least 2, 00,000 MW generation capacity should be added by 2012. The power requirement will double by 2020 to 4, 00,000 MW.

Hon.Power Minister, Mr. Sushil Kumar Shinde while addressing the Economic Editor's Conference, New Delhi about the problems which were plaguing the Power Sector, made it explicit that achieving commercial viability and sustainability of the sector to ensure quality supply at affordable price is the primary task.

A major initiative was the enactment of the Electricity Act, 2003. Its core principles include de-licensed generation (except hydro), power development in rural areas, rural distribution through cooperatives and franchisees, open access in transmission and distribution systems in a phased manner. It also aims to achieve power to all and to increase the per capita availability of power to over 1000 units by 2012.

Coal occupies the major proportion followed by Hydro in the country. But for a state like Kerala without potential coal reserves, the suitability of constructing coal based thermal plants were much debated. Moreover, tapping unharnessed hydro potential has many reservations bridging the energy gap is a big challenge ahead of the state.

Table 1

Abstract of the actual generation capacity of all forms of power generation plants in India

SL.NO	REGION	Thermal				Nuclear	Hydro	R.E.S. (MNRE)	TOTAL
		COAL	GAS	DSL	TOTAL		(Renewable)		
1	Northern	24232.50	4134.76	12.99	28380.25	1620.00	14322.75	3165.55	47488.55
2	Western	31945.50	7903.81	17.48	39866.79	1840.00	7447.50	5357.96	54512.25
3	Southern	20982.50	4690.78	939.32	26612.60	1320.00	11338.03	9341.67	48612.30
4	Eastern	19522.88	190.00	17.20	19730.08	0.00	3882.12	359.64	23971.84
5	N.Eastern	60.00	787.00	142.74	989.74	0.00	1116.00	223.60	2329.34
6	Islands	0.00	0.00	70.02	70.02	0.00	0.00	6.10	76.12
7	All India	96743.38	17706.35	1199.75	115649.48	4780.00	38106.40	18454.52	176990.4

Captive Generating capacity connected to the Grid (MW) = 19509 (As on 30-06-11)

STAGES AND STATUS OF ELECTRICITY DEVELOPMENT IN KERALA

The Kerala State Electricity Board, was constituted by order dated 7.3.1957 under the Electricity (Supply) Act, 1948 towards Generation, Transmission and Distribution within the state of Kerala. As per section 172 (a) of the Electricity Act 2003 and as mutually decided by the Government of India and Government of Kerala, KSEB has continued as Transmission utility and Distribution licensee till 24-09-2008. In exercise of powers conferred under sub-sections (1), (2), (5), (6) and (7) of section 131 of the Electricity Act, 2003, State Government vide the notification G.O (Ms).37/2008/PD dated 25th September, 2008 has vested all functions, properties, interests, rights, obligations and liabilities of KSEB with the State Government till it is re-vested the same in a corporate entity. Accordingly, KSEB has been continuing all the functions as a Generator, State Transmission Utility and a Distribution Licensee in the State. Now there are 101 lakh consumers spread over the urban and rural areas of the State. Present Maximum Demand of Kerala System is 2998 MW and the daily consumption has reached 56.26 million Units.

Until the recent past, the hydroelectric plants owned by the Board supplied a major portion of the energy requirement of the state. However, after the promulgation of the Forest Conservation Act in 1980, the implementation of new hydroelectric projects had been seriously affected and costly thermal energy had to be generated / purchased to meet the increasing demand. Unlike many other states in the country, major portion of the energy distributed is being consumed by domestic users and now, it accounts for approximately 46% of the total energy consumed. So the peak demand in the state has increased to almost twice the off-peak demand leaving the investments made non operating unproductive.

Generation

The history of Hydropower development in Kerala begins with the commissioning of Pallivasal Hydro Electric Project in 1940. Next few decades saw the progressive developments of various schemes. 300 MW Sabarigiri Hydro Electric Project in 1965 and 780 MW Idukki Hydro Electric Project in 1976 are milestones in the endeavour of power development of Kerala State Electricity Board. At present, KSEB has a total installed capacity of 2229.6 MW(as on 23.5.2010) including the two Diesel power plants at Brahmapuram and Kozhikode. The other major power plants that are catering to the energy demands of the state are the Kayamkulam thermal power plant of NTPC with an installed capacity of 359.6 MW, BSES Kerala Power Ltd., Kochi with an installed capacity of 157 MW and the 21.436 MW plant of KPCL, Kasaragod. Kerala has approximately 1030 MW of power allocation from Central Government owned Power Projects.

Table 2
Installed capacity

Hydel	Capacity (MW)	Availability (MW)
KSEB	1886.75	1509.40
IPP -Ullumkal	7.00	2.80
Thermal		
KSEB	234.60	187.68
IPP	367.23	293.78
Wind	29.33	
CGS	843.56	674.80
Total (including costly IPPs)	**3368.47**	**2668.46**
Total (excluding costly IPPs)	3011.24	2382.68

Transmission

Transmission system is an essential link between Generating stations /Interstate links to sub centers for ultimate distribution of power to consumers. The Kerala power system grid is connected to the Southern Region Transmission system through two 400KV double circuit lines. They are (1) Udumalpet- Madakkathara line and (2) Thiruneveli- Pallippuram(Trivandrum) line. There are 6 major inter-state transmission lines. at 220KV level and 110KV level. The 220 KV lines are (1) Kaniyampetta- Kadakola (single circuit). (2) Idukki – Udumalpet (single circuit). (3) Sabarigiri - Theni (single circuit). (4) Edamon – Thirunelveli (double circuit). The 110 KV lines are (1).Parassala - Kuzhithura and (2) Manjeswaram - Konake. The major substations include one 400 KV sub-station, and seventeen 220 KV substations. The main grid comprises of the 220 KV systems.

Table 3
Overview of the transmission system as on 31.3.10

Sl. No.	Capacity	No. Substations	Line length in Circuit Kms
1.	400KV	2*	260**
2.	220KV	17	2701.38
3.	110KV	123	3969.61
4.	66KV	82	2386.60
5.	33KV	106	1347.39
Total		**329**	**10737.53**

Distribution

Electricity for the entire state is distributed, (except for the part of Munnar and erstwhile Trissur Muncipal area limits) by Kerala State Electricity Board. Similarly entire power requirement including that of six other licensees operating in the state is catered by the Board only.

Contribution of Power from different Sources

Average peak demand of the state is 3000MW with daily average energy consumption of 53MU. Above 60% of the total energy requirement is met through high cost thermal sources and more than 50% is brought from outside the state sources.

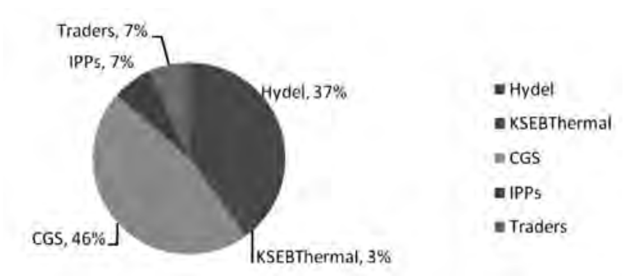

Fig. 1
Contribution of power from different power sources

POWER SCENARIO IN THE COMING YEARS

When consolidated, the 'expected capacity additions in the state and national levels' and the 'demand growth' (as per the 17th and the preliminary reports of the 18th power survey) state that there is considerable shortfall in power availability to the state beyond the period 2013-14. The period prior to that was also marked by several critical issues. The major one among them is the probability of completing the internal hydel stations anticipated for each year. The two major thermal capacity additions anticipated from within Kerala are the conversion of the Kayamkulam-RGCCPP station to 2000 MW capacity as well as commissioning of the Cheemeny and Brahmapuram gas based stations.

Table 4
Power Scenario in the forthcoming decade

Demand- Supply position	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Present availability	2668										
Anticiapted demand (as per Power Survey)	3159	3335	3528	3743	3957	4168	4374	4574	4803	5043	5295
Hydro additions	80	2	52	47	251	72	5	5	204		
Thermal stations in Kerala						808		528			
Power from outside state				64	98	60					
UMPP							240	152			
CGS	146	80									
Anticipated Availability	2895	2976	3028	3139	3488	4428	4673	5358	5562	5562	5562
Demand- Supply mismatch	264	359	500	604	469	260	299	[illegible]	[illegible]	[illegible]	[illegible]

Another essential milestone to be accomplished is the transmission system strengthening to bring in additional quantity of power from outside sources. As per prevailing allocation from the Central Grid Stations is about 1133 MW.

Table 5
MW Share allocation of SR Beneficiaries from SR ISGS

Beneficiaries	RSTPS St.I & II	RSTPS St.III	NLC TS-II Stg1	NLC TS-II Stg.2	MAPS	KGS 1 & 2	KGS Unit 3	Talcher STPP-Stg.II	NLC TPS-I Exp.	Total	Weighted average %
APTRANSCO	670	168	114	203	43	134	142	407	0	1883	24
KPTCL	411	103	131	177	33	122	133	373	111	1596	20
KSEB	282	70	70	99	25	46	43	440	59	1133	15
TNEB	526	132	187	279	330	117	103	497	232	2404	31
Others	211	27	128	82	8	21	18	283	18	795	10
TOTAL	2100	500	630	840	440	440	440	2000	420	7810	100

DEPENDENCE OVER NATIONAL GRID

The energy potential in the country is concentrated in certain pockets. Kerala has no potential Coal reserves and all of them are located in far of states and this poses a challenge to embark upon massive inter-regional transmission capacity. Only the untapped hydro-electric potential is the possible source for enhancing internal generation to meet the growing demand. Proclamation of the Forest Conservation Act 1980 has hampered the institution of new hydel power generation projects in the state. Only a fraction of the hydro power generation potential has been exploited thus far; of a power generation potential of about 4333 MW, only 1834 MW has been reined in and about 204 MW is expected through the small and mini ongoing projects in the state.

Even if the developmental plans and the statistics of the ongoing power plants in the state materialize on time, it is obvious that strengthening the regional transmission grid would turn to be the most critical aspect for assuring quality power at competitive rates for the state of Kerala. From the present interstate import capability of 1500 MW level, the immediate requirement is strengthening the interstate transmission potential enabling Kerala to transmit another 1500 MW through the Southern Regional Grid within a span of five years.

The Central Transmission Utility (CTU) is responsible for transmission between states and between regions. Power Grid Corporation of India Limited (PGCIL) is the designated central transmission utility. It owns and operates 80 per cent of India’s inter-state transmission networks and, more importantly, accounts for 95 per cent of the transformation capacity at that level. So two key tasks that PGCIL faces in the short and medium term are expanding transmission capacity to match the increase in generation capacity and completing the development of a national grid that will facilitate movement and trading of power. Demand for transmission capacity has increased dramatically, not only through increases in generation capacity but by the new developments in power market viz. open access, trading ,inter-regional transfers,etc. The transmission system has to not only expand in capacity but also be more flexible and have greater margin to enable integration of power sources like merchant plants, captive plants and wind farms

Transmission requirements are also becoming more complex in nature. Electricity market has developed high momentum in India through Bilateral trades, power exchanges and similar other dynamic markets. Open access regulations and a large number of merchant power plants are being developed, power from these plants will flow in multiple directions, and it can have wider variations depending upon the daily/seasonal patterns across the country. Moreover there are various market avenues for getting electricity from the power market now operating in the country. Such sources are:

- Unscheduled Inter Change under ABT Regime.
- Day ahead and Term Ahead from Energy Exchanges
- Power SWAP with Traders/Licensees
- Short Term and Medium Term purchase from Traders
- Case-I Bidding for five years
- Long Term PPA with Generators and Traders

Kerala being the tail end state of the regional grid it has numerous constraints, especially through the one that persists between the ‘S1’-Subregion (AndhraPradesh and Karnataka) and ‘S2’-Subregion (Tamilnadu, Pudussery and Kerala,) results as a major bottleneck for the state to avail power from other sources and regions whenever available at cheaper rates. A typical situation is depicted below in the energy exchange rate across the regions.

Table 6
Indian Energy Exchange

Exchange Rates (In KWh)	NR	S1	S2	WR ,ER & NER
Trade date: 02 August 2011		**Delivery date: 03 August 2011**		
Max (in an hour)	4.85	9.00	9.00	4.85
Min (in an hour)	2.20	2.98	2.98	2.20

The outline of the regional grid as of today clearly indicates the truth that there are numerous 'dotted lines' to link Kerala with the national grid to facilitate power drawal at economic rates for the state. Moreover the northern half of the state does not have 400 KV link to ensure adequate supply to this region.

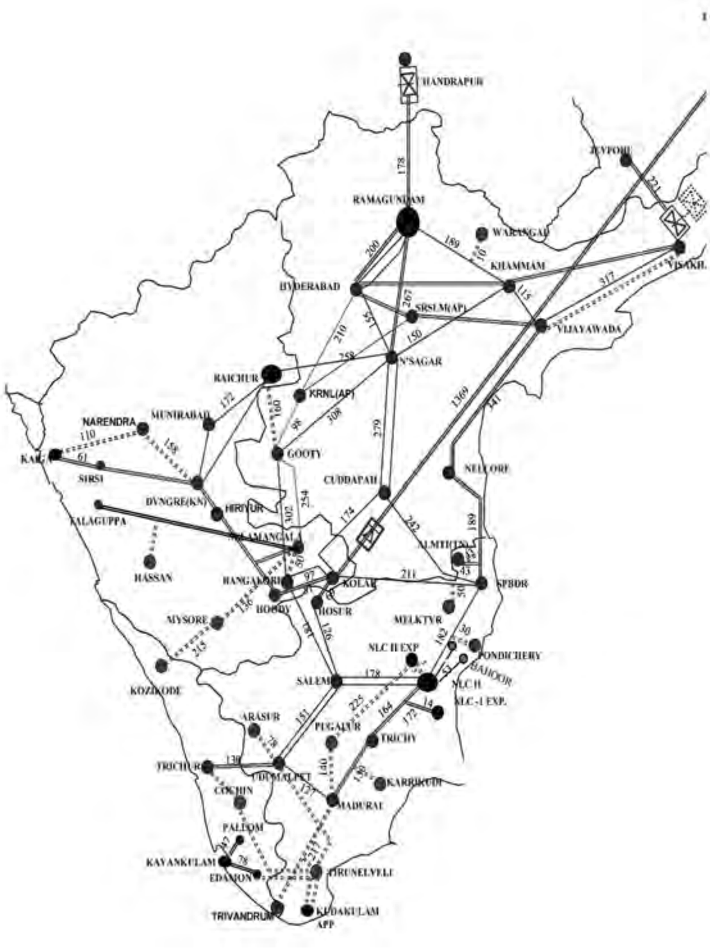

Fig. 2
Grid Map of the Southern Region

There are equal constraints now existing in the inter regional transmission capacity also, prohibiting southern regional constituents, including Kerala from availing power available at cheaper rates from other regions of the country.

Unscheduled Interchange (UI Charges) under the novel concept of Availability Bases Tariff (ABT) could benefit Kerala in a big way over the years. Frequency (for power distribution fixed as 50 Hz.) is one of the major quality factor like voltage, power factor etc. During yester years drastic drop in the regional grid frequency had prevented Kerala from availing the allocated quantity of central share due to the technical blockade developed due to the frequency fall. Enactment of the ABT regime had benefited Kerala much in drawing its share from the national grid.

It has got an equally important commercial dimension also. The rate structure varies from free power at 50.3 Hz to above seventeen rupees for every unit of energy drawn during under frequency conditions. Here once again the corridor constrains in the S1-S2 sub regions prohibits us from en-cashing such an opportunity.

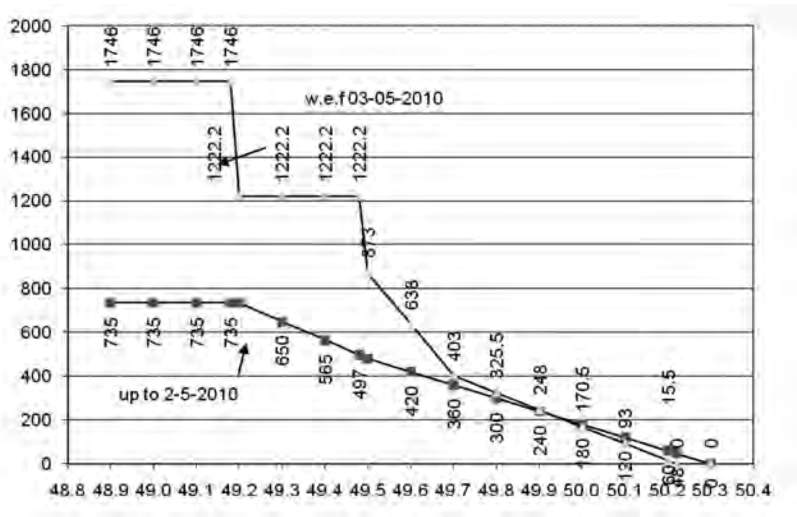

Fig. 3

UI Rate w.e.f. 03-05-2010 (in paise per kWh)

"State will need 6,300 MW power by 2020"

"The State's requirement of electricity would rise to 6,300 MW by 2020." .... Union Minister of State for Power K.C. Venugopal has rightly stated the size of the demand growth in the forthcoming years. Even if abundant hydel potential remains untapped not much progress can be expected to add up power generation. Coal availability in the existing stations as well the upcoming others are also not attractive. Role of imported coal and consequent cost increase is another expected havoc in the power sector during the forthcoming years.

Future of Gas market turns to be dull and dark. Trends indicate that it may not be better than the case of Naphtha plants commenced in the beginning of the previous decade. Renewable sources are yet to become cost effective because of the prohibitive initial capital cost they carry. Low load factor as well as unpredictable nature makes it only a supplementing means. However blend of different modes of nonconventional means of generation is not only the need of the day but it has been mandated by the Electricity Act 2003 also.

NTPC Ltd. is venturing outside its known territory of operation - generation of thermal energy - by exploring wind energy possibilities and signed a memorandum of understanding (MoU) with the Kerala government for setting up wind wheels at potential locations in the State to generate an estimated 200 MW. Places such as Ramakkalmedu and Udumbanchola in Idukki district and Kanjikode and Attappady in Palakkad district have been identified with a total potential to generate 650 MW.

CONCLUSION

Meeting the rising demand for Electricity in the state of Kerala is a big challenge ahead for the years to come. Enhancing domestic power generation has numerous hurdles ahead. But the recent developments in the power market in the national level have opened out numerous means to tackle the situation for facilitating quality power at competitive rates. In addition to the attempts for harnessing internal energy sources, another essential ingredient parameter is strengthening Southern Regional Grid.

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Overview of Renewable Energy Penetration

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INTRODUCTION

The renewable energy targets commit a progressive introduction of renewables in the total primary energy consumption. Renewables based power generation require careful planning for efficient integration into the existing grid. Distributed generation also calls for meticulous planning. Other areas for penetration of renewables are in the energy substitution and functional integration of energy efficiency and renewables. This paper overviews the various aspects of penetration of renewables in the energy scenario and also citing the various barriers to overcome.

The need for transformation of the global energy system with a lower environmental footprint is now widely recognized among decision makers in government, political leadership as well as leaders of non-governmental organizations (NGOs), the corporate business sectors and the national academies.

The United Nations (UN) report (AGECC, 2010) on “Energy for a Sustainable Future” (April 2010) is one of many that calls for a drastic realignment of the global energy system on a large scale as an urgent priority to enable a sustainable future for all. UN report explains:

> “Clean, efficient, affordable and reliable energy services are indispensable for global prosperity. Developing countries, in particular, need to expand access to reliable and modern energy services if they are to reduce poverty and improve the health of their citizens, while at the same time increasing productivity, enhancing competitiveness and promoting economic growth. Current energy systems are inadequate to meet the needs of the world’s poor”. “Making the transition to a sustainable energy future is one of the central challenges humankind faces in this century. The concept of energy sustainability encompasses not only the imperative of securing adequate energy to meet future needs, but doing so in a way that :
>
> (a) is compatible with preserving the underlying integrity of essential natural systems, including averting dangerous climate change;

(b) extends basic energy services to the more than 2 billion people worldwide who currently lack access to modern forms of energy; and

(c) reduces the security risks and potential for geopolitical conflict that could otherwise arise from an escalating competition for unevenly distributed energy resources."

SHARE OF RENEWABLE

Reliance on fossil fuel based sources of energy and their associated impact on energy security, development goals, detrimental impacts on the environment, impacts on sensitive ecosystems and land use and Green House Gas emissions have been well documented and articulated over the past three decades.

In 2008, about 19% of global final energy consumption came from renewable sources, with 13% coming from traditional biomass, which is mainly used for heating, and 3.2% from hydroelectricity (Anon., 2010). New renewable, i.e., small hydro, modern biomass, wind, solar, geothermal, and bio-fuels, accounted for another 2.7% and their share is showing a rapidly increasing trend. The share of renewable in electricity generation is around 18%, with 15% of global electricity coming from hydroelectricity and 3% from new renewable. Global Renewable Energy Growth Rate is depicted in Fig.1.

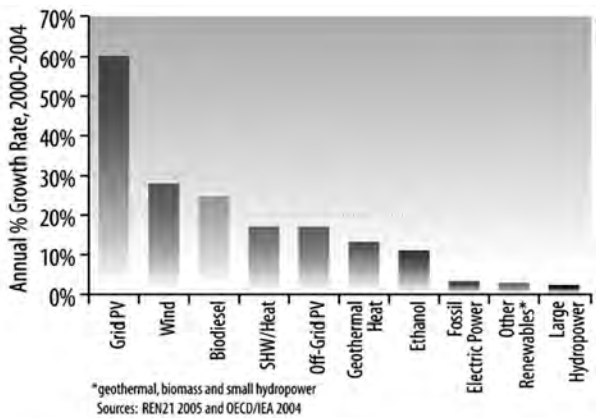

Fig. 1
Global Renewable Energy Growth Rates

Wind power is growing at the rate of 30% annually, with a worldwide installed capacity of 158 GW in 2009, and is widely used in Europe, Asia, and the United States (GWEC, 2009).

At the end of 2009, cumulative global photovoltaic (PV) installations surpassed 21 GW and PV power stations are popular in Germany and Spain (Anon., 2010).

Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel. Ethanol now provides 18% of the country's automotive fuel (Hofstrand, 2008). Ethanol fuel is also widely available in the USA.

Renewable energy costs have declined at rapid rates across the board over the past several decades and are projected to continue to decrease as shown in Fig.2.

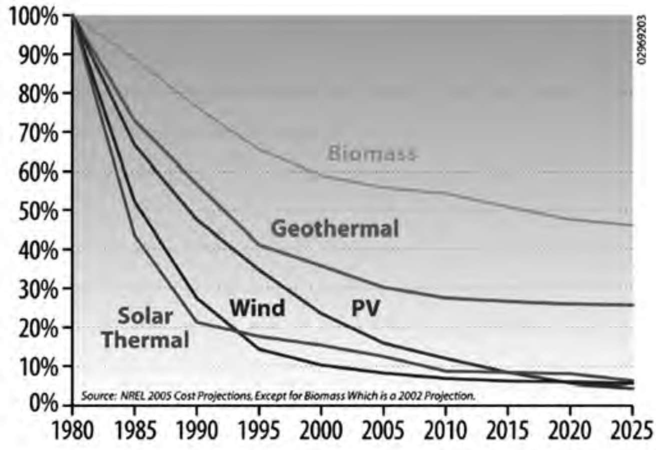

Fig. 2
Trend of Declining Renewable Energy Costs

The above cost reductions result from improvements in technology performance and increasing scales of production and use, coupled with increasing prices for conventional energy sources and other market and policy drivers. These cost reductions have allowed mature and stable renewable energy technologies, such as wind power, bio-energy, solar hot water and PV systems, geothermal energy, and hydropower to achieve significant market penetration around the world.

The primary markets for renewable energy technology are:

- Power generation (grid-scale)
- Rural energy (off-grid)
- Hot water and space heating
- Energy for Process
- Transportation fuels.

Renewable for Power Generation

In India Electricity Regulatory Commissions set targets to Power Distribution Companies (DISCOMs) to meet a fixed percentage of their electricity sale from renewable, which is termed as Renewable Energy Purchase Obligation (RPO). RPO follows the National Action Plan on Climate Change (NAPCC) published in 2008.

The Central Electricity Regulatory Commission (CERC), India, has advised the Union Power Ministry to achieve the level of renewable purchase obligation (RPO) by states to 10 per cent by 2015. Initially, NAPCC envisaged the RPO to be five per cent in 2010 and thereby increasing 1 per cent every year to reach 15 per cent in 2020. Indian states such as Tamil Nadu and Karnataka have already achieved an RPO level of more than 10 per cent, whereas many other states such as Punjab, Haryana, Madhya Pradesh, West Bengal, Uttarakhand, Jharkhand and Bihar have not even touched 2 per cent. According to CERC, in order to meet the 10 per cent RPO level by 2015, about 45,482 mega watt (MW) of renewable energy capacities would be required.

India has 150 GW of renewable energy potential; about half in the form of small hydropower, biomass, and wind and half in solar, cogeneration, and waste-to-energy (Sangsyan, et al., 2011). It has tripled its renewable energy generation capacity in the past five years, now ranking fifth in the world in total installed renewable energy capacity, and it has established a legal and regulatory framework for sector oversight.

The Integrated Energy Policy (IEP) of India states that Renewable forms a longer-term perspective and renewable remains important to India's energy sector. With a concerted push and a 40-fold increase in their contribution to primary energy, renewable may account for only 5 to 6% of India's energy mix by 2031-32. The IEP committee recommends that for promoting renewable, incentives should be linked to outcomes (energy generated) and not just outlays (capacity installed). IRP emphasises that:

- Power Regulators must create alternative incentive structures such as mandated feed-in-laws or differential tariffs to encourage utilities to integrate wind, small hydro, cogeneration etc. into their systems.
- An annual renewable energy report should be published providing details of actual performance of different renewable technologies at the state and national level
- Policies for promoting specific alternatives suggested in the main text of IEP include fuel wood plantations, bio-gas plants, wood gasifier based power plants, solar thermal, solar water heaters, solar photovoltaic, bio-diesel and ethanol.

IEP also recommends that the Indian Renewable Energy Development Agency Ltd (IREDA) be converted into a national refinancing institution.

The Electricity Act, 2003 of India also provides to promote generation of electricity from renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licensee.

Another land mark in India is the declaration of Biodiesel Purchase Policy by Ministry of Petroleum and Natural Gas in 2005, with effective from 1.1.2006. To achieve 20% Biodiesel Blending, India needs more than 10 MMT of Biodiesel. Indian Oil Corporation is having biodiesel R&D

World Electricity Generation from Non-Hydro Renewable Energy Sources is depicted in Fig. 3.

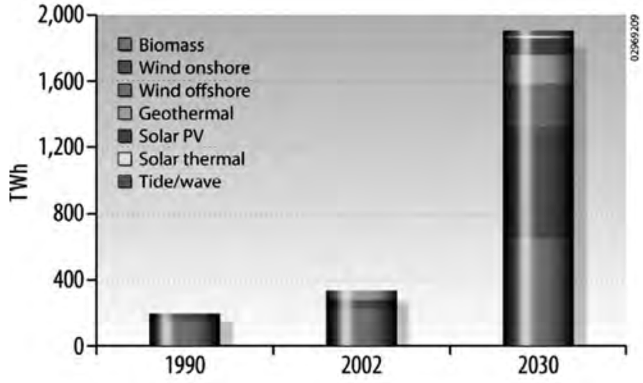

Fig. 3
World Electricity Generation from Non-Hydro Renewable Energy
(Ref: International Energy Agency. World Energy Outlook 2004)

Renewable for Non-Electric Energy Use

Renewable energy substitution and utilization in processes, space heating and cooling, transportation and for cooking are also much significant.

The number of people relying on traditional biomass for cooking and heating is projected to grow from 2.4 billion in 2002 to 2.6 billion in 2030, with especially large reliance on traditional biomass in developing countries in Africa and Asia

Demand for renewable bio-fuels is increasing rapidly around the world in response to high oil prices; desire to reduce reliance on imported petroleum, and concern about the environmental impacts of oil production and consumption. There is much room for growth in bio-fuels. Bio-fuels accounted only for around 3 percent (or 33 billion liters) of worldwide gasoline consumption in 2004. Demand for transportation fuels are expected to grow continuously. The total vehicle stock in developing and transition countries is expected to triple between 2002 and 2030, to 550 million vehicles, reaching 75 percent of the vehicle stock in developed countries, although per capita oil use in developing countries is expected to stay well below that of developed countries.

Bio-fuels, emerging into commercial market, has an added advantage of biodegradability and so relatively harmless to the environment in use as well as in case of any spillage.

For example, “algae”, a low-input, high-yield feedstock to produce bio-fuels, is claimed in laboratory experiments that up to 30 times more energy per acre than land crops such as soyabeans can be produced. But these yields have yet to be produced commercially. With the higher prices of fossil fuels, there is much interest in alga culture (farming algae). The Department of Energy, USA estimates that if algae fuel replaced all the petroleum fuel in the United States, it would require only 15,000 square miles (38,849 sq kilometers), which is roughly the size of Maryland, or less than one seventh the amount of land devoted to corn in 2000.

Encouraged by these targets, booming growth is envisaged in the renewable energy industry. However, renewable energy still faces challenges, including high costs, the need for resource assessment, limitations in the grid and other factors.

The International Energy Agency (IEA) estimates the current bio-energy supply to be about 11 percent of the total primary energy demand of 50 EJ/year of which 7–10 EJ/year is used in industrial countries and 40–45 EJ/year is used in developing countries. Until the middle of 19th century, biomass dominated the global energy supply with a seventy percent share.

An in-depth analysis of economic development targets, energy resource availability and environmental factors, are required as a sound reference for policymaking and formulating research and business plans.

Grids Powered by Renewable energy - Challenges for supervision and real time production control

In Spain, about 40% of the overall electricity demand is supplied by wind power at some moments of the day in the Spanish electricity system. This record constitutes a real challenge for transmission system operators (TSOs). In this type of situation, renewable energy penetration strongly depends on the ability of TSO to evolve towards a new way of operating the system, dedicated predictability for renewable generation, voltage dip management and managing the power balance.

European Union (EU) directive on the use of energy from renewable sources may also be noted here. This not only requires to redesign grid codes, but also commissioning a dedicated centre for renewable energy management, development of specific applications to maximize renewable generation and provide production limits to each renewable energy plant, voltage control and congestion management and deep revision of power reserve policy.

Comparison of PV systems in terms of sustainability parameters

As shown in the Table-1, PV systems have important advantages to compete with other energy generation systems for sustainability such as availability, CO2 emission, land use, fresh water consumption, social and environmental impacts.

BARRIERS AND CHALLENGES

Number of outstanding barriers which put renewable energy at an economic, regulatory, or institutional disadvantage relative to other forms of energy are listed below:

- The higher relative costs of the technologies (despite cost reductions) in a number of applications. Renewable energy systems have higher upfront capital costs than conventional alternatives, though lower operation and maintenance (O&M) costs.
- Lack of mature markets and favourable policy, regulatory, and legal frameworks to encourage the development and investment in renewable energy.
- Subsidies for fossil-based fuels, coupled with cost that does not reflect the environmental cost as well make it difficult for renewable energy to compete; compounded by lack of fuel-price risk assessment.

Table 1
Comparison of PV systems in terms of sustainability parameters

Production Technology	Unit Energy Cost [$/kWh]	CO_2 Emission [g/kWh]	Availability	Efficiency [%]	Fresh Water Consumption [kg/kWh]	Land Use [km2/GW]	Social and Environmental Effects
Nuclear	0.0172 - 0.0273	10 - 50	280 years (99% of all world reserves are within boundaries only 10 countries)	30 - 45	30 -100	1 - 4	- Danger of radioactive leaks - Public reaction - Nuclear waste issues
Coal	< 0.1	1000	185 - 260 years (50% of all world reserves are within boundaries of only 3 countries) (26% USA, 16% Russia and 11.5 %China)	30 - 45	15 - 30	10 - 20	- High toxic gas emissions - The public's negative perception - The effects of environmental pollution and greenhouse gas - Mining difficulties
Natural Gas	< 0.1	500 - 600	120 years 41% of total reserves are within Middle East and 27% are within Russia boundaries)	45 - 55	15 -30	1 - 4	- Be imported fuel for many countries - The public's negative perception because of dependence on foreign sources - High CO2 emissions
Wind	0.4 - 0.5	10 - 50	Infinite	24 - 54	< 1	50 -100	- Noise pollution - Visible pollution (minor) - Adverse effects on wildlife (bird deaths) - Positive public perception - Low CO2 emission
Hydroelectric	0.1 - 0.3	1 - 100	Infinite	> 90	65 - 70	75 - 750	- Climate change - Major land use and because of its negative effects on natural environment
Photovoltaic	0.8 - 1.2	15 - 100	Infinite	12 - 22	< 1	28 - 64	- The toxic waste created during the module production - Visible pollution (minor) - Positive public perception - Low CO2 emission - Quiet operation

- Inadequate institutional capacity for all aspects of renewable energy project/ program design, development, and implementation, including lack of skills and knowledge.
- Imperfect capital markets; insufficient access to affordable financing for project developers, entrepreneurs, and consumers; and financing risks and uncertainties.
- Lack of awareness and understanding of the benefits, costs, and applications of renewable energy among policymakers, the local private sector, finance institutions, and prospective customers.
- Inadequate information on the renewable energy resource potential.
- Restrictions on siting and construction, transmission access, and utility interconnection.
- The small scale nature of the technologies, often coupled with the geographic dispersion and low population densities of rural customers, contributes to high transaction costs for renewable energy projects and insufficient cost recovery.
- Inadequate demonstrated models for scale up.
- Insufficient mechanisms for international cooperation, including technology transfer, trade, and financial flows.

Rapid increase of renewable energy in developing countries calls for a detailed study on penetration of renewable energy. Such a study would require addressing the above barriers, including development of supportive policy and regulatory frameworks, securing public-private sector commitment, strengthening local capacities and entrepreneurship, transferring technologies, and increasing access to affordable financing and consumer credit.

It would require transitioning from traditional biomass utilisation to modern use of biomass, cleaner fuels, and improved cook stoves; maximizing use of hydro resources (large, small, and micro) in an environmentally sustainable manner; more efficient use of biomass residues for power generation and transport, including growth of dedicated crops; and increasing deployment and reducing costs of solar, wind, geothermal, wave, tidal, and other renewable energy sources. The good news is that these issues have been tackled successfully in several countries around the world and models exist for replication elsewhere or for customising to suit geo-political or socio-economic conditions. . The challenge then becomes how to provide renewable energy services in an affordable and accessible manner.

KEY MARKET DRIVERS FOR RENEWABLE ENERGY ACROSS VARIOUS COUNTRIES

Key Market Drivers for Renewable Energy across various countries are shown in the matrix below (Anon., 2005).

Factors Affecting Demand for Renewable Energy

	Climate Change[1]	Environ-mental Issues	Energy Security	Consumer Demand	Increased Reliability	Local Economic Development
Europe	●	●	●	◐	○	◐
Japan	◐	●	●	◐	○	○
United States	◐	◐	●	◐	◐[2]	◐
Developing Countries	○	○	◐	●	◐	●

1. Government vs. individuals
2. Region specific

● High ◐ Medium ○ Low

Price spikes and supply concerns over fossil based technologies are further increasing interest in and demand for the technologies. Market drivers will vary across countries. For example, in Europe, environment, climate change, and energy security are the key market drivers. In the US and Japan, energy security is the greatest driver for renewable energy followed by environmental, climate change, and consumer demand considerations. In developing countries, the prospects for energy access and economic development are the prime market movers Under ADB''s Clean Energy and Environment Program Renewable Energy such as Biomass energy, Small to mid-scale run-of-river hydropower, Wind power and Geothermal power are marked as Priority

Target Projects

In the last few years, renewable energy technologies have experienced substantial improvements in cost, performance, and reliability, tending to make them competitive in a range of applications.

Led by wind and photovoltaic (PV) technologies, and emerging bio-mass and bio-fuel applications and efforts of institutions and Governments such as India's Ministry of New and Renewable Energy (MNRE) spread with its State Nodal Agencies and experts individuals, academic institutions, Research and Development Centres and investments by Local and Multinational companies transform the market to respond seriously. With supportive policy and regulatory frameworks renewable penetration is expected to take large strides in national and international energy economic scenario of both developed and emerging economies.

CONCLUSION

The Benefits of renewable energy technologies include:

- Utilize locally available resources: the sun, wind, biomass, geothermal, and hydropower.
- Reduce the need for fuel imports which has substantial impact on balance of payment
- Enhance energy security by diversifying the energy portfolio, improving price stability and reducing risks associated with unpredictable future energy cost
- Advantage of placing energy source sited close to the load or demand requirement, offsetting transmission and distribution costs and losses
- Conserve a country's natural resource base.
- Provide health benefits, social upliftment, particularly to women and children through the transition to improved cook stoves and cleaner fuels, electric lighting, communication, education, entertainment and social networking
- Contribute to rural and semi-urban social and economic development through the provision of modern energy services, including lighting, heating, cooking, cooling, water pumping, transportation, and communications that enhance people's lives and livelihoods.
- Environmentally beneficial, lacking the nitrogen and sulphur oxides that are harmful to humans, animals, and plants, and carbon dioxide and methane emissions which contribute to climate change

RECOMMENDATION

To aid this process it is suggested that a detailed penetration study may be carried out with respect to Renewable Energy in each State as well as Country wise.

Penetration can be measured in terms of:

- percentage share of RE in the installed capacity
- actual RE based generation to the total generation as percentage
- actual RE commercially exploited to the RE potential available

- extend of replacement of fossil fuel based energy as percentage in terms of energy units
- peak demand reduction by RE based power
- Carbon foot print mitigation by the use of RE

Assessed proven potential, application of technology, end use compatibility, cost of energy, other socio-economic and policy matters shall be mapped in doing so. For example, in 2010, the capacity penetration of wind power in India (vis-à-vis the peak load) was 8.5%, while the penetration energy-wise was less than 1% (Madsen and Natarajan, 2011). Such studies shall infer upon the Technology, Strategy, Key Change Agents and Mechanism(s). The role of Global and Regional Environmental interventions may also be accounted for, if sustainability considerations would play a major role in economic policies, the nation could have a strong mitigation policy with Renewable Energy Technologies (RETs) playing a central role.

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Energy Conservation in Built Environment: The Concept of Green Buildings

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INTRODUCTION

The built environment, and in particular buildings, have a key role to play in addressing environmental concerns. Spurred by increasing per capita income and standard of living, the Indian construction industry has experienced an annual 10% growth in gross built-up area over the past decade. Demand for housing continues to increase; organized retail is expanding, as is retail, commercial and office space, especially by multi-nationals; and special economic zones are being set up. The energy consumption and emission of associated greenhouse gases will continue to rise, unless actions are taken urgently to direct the construction industry towards sustainable consumption and energy production.

Buildings are large consumers of energy, land, materials and water and generate vast quantities of solid waste both during construction and operation. Globally, buildings account for one-sixth of fresh water withdrawals, one-quarter of wood harvest and two-fifths of material and energy flows (Roodman and Lenssen, 1995). With rising population growth, and the subsequent growth in built-up space, it is important that future construction activities incorporate resource optimisation and efficiency measures.

A movement towards energy-efficient, environmentally-aware architecture and design, or green buildings, is taking place all over the world. Green building is not a new concept in India; there are many good examples of sustainable building design. Some even consider all traditional buildings in India green.

However, when the world moved from eco-sensitive architecture to energy efficient architecture and beyond, many threads were actually lying loose because we took wrong assumptions. Meaning the solutions projected as the answers were put forward, without really understanding the real problem. For example, in projecting aluminum as a solution for preserving wood or in the case of projecting nuclear energy as a solution for energy-crisis, the solutions, were not really sustainable because the basic assumptions were wrong. It is costing us dearly. By the time we realized that our solutions were not really saving the planet, it was already too late and marched so far, that we actually could do very little to correct it.

CONCEPT OF GREEN BUILDINGS

Theoretically a Green building is the one which causes minimum damage to our planet, minimum impact on the environment, because of its construction, existence and finally its destruction after its life. Here the word ‘minimum’ damage is very important, it is not ‘no’ damage. There is a saying that an Environmentalist is the one who cannot build his house; because stone foundation means some hillock flattened somewhere, brick walls means some paddy field destroyed somewhere, reinforced cement concrete and steel and aluminum windows means some acres of land is mined for minerals and its inhabitants evacuated, etc. and most finishing building materials means energy use and emission of CO_2 to atmosphere. It is true, as one will realize once you go deep into it, that it is difficult to actually make a building Green. I should also put on record that it is possible to construct a 100 per cent Green building; but then one has to change his basic view points towards many things.

A green building is one that is environmentally and socially considerate and economical. In the early stages of a green building project, careful consideration is given to integration with the natural environment, i.e. by minimising land take, seeking opportunities to redevelop contaminated land and protect vulnerable habitats. Green buildings are normally designed with occupancy comfort as a priority. Indoor environmental quality is achieved by appropriate ventilation, day lighting and the provision of outdoor views. Green buildings are proven to use fewer materials and to consume at least 40 per cent less energy and freshwater than a conventional building and; therefore, generate less waste. This is achieved by design efficiencies, installation of energy and water-efficient appliances and fittings and the use of green technologies e.g. solar power, rainwater and grey water harvesting and high-performance building materials.

NEED FOR GREEN RATING

Suppose if one builds a building and claims that it is a Green building and another one also builds a building and claims it is even more Green, how can one decide on which is more Green? So there arises the need for a measuring scale, a rating system, to measure the Greenness of a building. Many such scales were developed by many countries and agencies. India has Green Rating for Integrated Habitat Assessment (GRIHA), UK has Building Research Establishment Environmental Assessment Method (BREEM), USA has Leadership in Energy and Environmental Design (LEED) and Australia has Gold Star of, to name a few. LEED is undoubtedly the best known of these ratings.

POLICY INITIATIVES FOR GREEN BUILDINGS IN INDIA

Bureau of Energy Efficiency (BEE)

The Bureau of Energy Efficiency in India was established in 2002 under the Energy Conservation Act (ECA) 2001, with objectives of i) reduce energy intensity, ii) creating awareness and energy conservation and iii) professional certification and accreditation. A key function of energy efficiency policy developed by BEE is to provide a measurement and monitoring framework so that corrective actions can be taken or more stringent implementation mechanisms put in place to support the achievement of objectives within.

Under the energy efficiency policy, Government of India has announced several energy efficiency and energy security initiatives: along with enhanced energy access of the wider environmental aspects of green buildings such as water and materials minimisation. The Energy Conservation Building Code (ECBC) 2007, originally designed as a voluntary code, has been integrated in some environmental management tools such as Environmental Impact Assessment (EIA) and Green Rating for Integrated Habitat Assessment (GRIHA). The National Mission on Sustainable Habitats (NMSH) also provides guidance on implementation of the ECBC.

Energy Conservation Building Code 2007

The ECBC aims to reduce baseline energy consumption by setting minimum energy performance standards for new commercial buildings, including for building envelopes, mechanical systems and equipment, including heating, ventilation and air conditioning (HVAC) systems, interior and exterior lighting system, service hot water, electrical power and motors. Section 14 (p) of the Energy Conservation Act empowers the Government of India to prescribe the ECBC for commercial buildings (at present having a connected load of 500 kW or contract demand of 600 kVA) or building complexes for efficient use of energy and its conservation. State governments have the flexibility to modify the ECBC to suit local or regional needs.

The ECBC is presently voluntary but is expected to be made mandatory in the future. The Government of Delhi has already approved mandatory implementation of ECBC in new government buildings/building complexes (new construction), including buildings/building complexes of municipalities/local bodies, boards, corporations, government-aided institutions and other autonomous bodies of the city government.

The Ministry of Health and Family Welfare is developing six institutions on the model of the All India Institute for Medical Sciences under the Pradhan Mantri Swasthya Yojana (PMSSY) at Bhopal, Jodhpur, Rishikesh, Patna, Bhubaneshwar and Raipur. These are being developed as ECBC-compliant buildings.

Industry leaders have also taken an independent role in developing and implementing Leadership in Energy and Environmental Design (LEED) across India. LEED, originally developed by the United States Green building Council, offers a platform for ECBC integration as well.

Green Rating for Integrated Habitat Assessment (GRIHA)

GRIHA, developed to rate new commercial, institutional and residential buildings in India, fully integrates and mandates compliance with the ECBC. It encourages optimization of building design to reduce conventional energy demand. It further recommends the optimization of the building's energy performance within specific comfort limits. A built-up area of over 9 million square metres has been registered under GRIHA. Endorsed by the Ministry of New and Renewable Energy, Green Rating for Integrated Habitat Assessment (GRIHA) is a five star rating system for green buildings. GRIHA focuses on passive solar techniques for optimizing indoor visual and thermal comfort. It encourages the use of refrigeration-based and energy demanding air conditioning systems only in cases of extreme thermal discomfort

To promote energy efficiency, GRIHA encourages optimisation of energy performance in building design to reduce conventional energy demand. It further optimises energy performance within specified comfort limits. It mandates that certain minimum operational energy requirements are met from renewable energy sources of electricity to reduce dependence on grid electricity. A building is assessed on performance predicted over its entire life cycle, from inception through operation. GRIHA has been developed to rate new commercial, institutional and residential buildings in India emphasizing national environmental concerns, regional climatic conditions and indigenous solutions. It integrates and facilitates the implementation of all relevant Indian codes and standards for buildings.

GRIHA is a voluntary tool, but has been adopted for all future buildings of the Central Public Works Department (CPWD), Ministry of Urban Development, Government of India. The CPWD is the largest agency responsible for constructing government buildings across the country. The Pimpri Chinchwad Municipal Corporation (PCMC) has announced financial incentives for developers to make buildings GRIHA-compliant. Further, a property tax rebate is also offered by the PCMC to people who occupy and own GRIHA-compliant buildings.

National Mission for Sustainable Habitat (NMSH)

The NMSH emphasises the extension of the ECBC, attempts to promote energy efficiency in the residential and commercial sectors through use of energy-efficient appliances and creation of mechanisms that would help finance demand-side management. It emphasizes the extension of the ECBC and energy efficiency into the mainstream by suitably incorporating it within municipal byelaws. Several states and municipal corporations have also launched initiatives on energy efficiency and renewable energy integration. These include compliance with ECBC and mandatory incorporation of solar hot water systems.

Environmental Impact Assessment

The Environmental Impact Assessment and environmental clearance process for large construction projects mandated by the Ministry of Environment and Forests requires compulsory compliance with the ECBC for projects and buildings that fall under its purview.

Scheme for Star Rating of Office Buildings

To accelerate energy efficiency activities in existing commercial buildings, the BEE has developed a star rating programme for buildings based on actual performance in terms of specific energy usage (in $kWh/m^2/year$). The programme rates office buildings on a scale of 1-5 stars; 5-stars indicate the highest energy-efficiency.Currently, the programme targets air-conditioned and non air-conditioned office buildings in the warm and humid, composite, and hot and dry climatic zones; it shall subsequently be extended to other climatic zones and building types.

The Star Rating Programme provides public recognition to energy-efficient buildings, and creates a 'demand side' pull for such buildings. Existing buildings with a connected load of 500 kW are considered for the BEE star rating scheme.

INSTITUTIONAL MECHANISM FOR POLICY IMPLEMENTATION

The Government of India has embarked on a number of programmes and initiatives to support stakeholders of the building sector to comply with and follow the strategies for achieving resource and energy efficiency in buildings. Various ministries of the Government of India (at the national level) and the associated initiatives (with reference to the building sector) that are coordinating the efforts have been mentioned below:

Ministry of Power/Bureau of Energy Efficiency

- Energy Conservation Act 2001 enacted
- Energy Conservation Building Code (ECBC) 2007 launched (voluntary)
- Appliance labelling (partly mandatory)
- Star rating programme for existing buildings (rates commercial buildings on energy performance)

Ministry of Environment and Forests

- Mandatory Environmental Clearance from the Ministry of Environment and Forests/State Environment Impact Assessment Authority mandatory for all large constructions (built up area>20,000 sq m and area development projects>50 ha), 2006
- Resource (energy, water) efficiency integral part of clearance
- ECBC mandatory

Ministry of New and Renewable Energy

- Promotes energy efficient buildings through its Solar Buildings Program
- National green building rating system "GRIHA" launched (partly mandatory),2007
- Mandatory for central government and PSUs to go for minimum 3 star rating (2010),100 million sq ft registered
- Incentives given by MNRE
- Solar Cities Program
- Coordinating the Jawaharlal Nehru National Solar Mission

Prime Minister's Office

- National Action Plan on Climate Change- Relates to sustainable development, co-benefits to society at large, focus on adaptation, mitigation, and scientific research

Ministry of Urban Development

- Coordinating the National Mission on Sustainable Habitat

Each national-level government ministry is supported in its implementation activities by the corresponding state agency. The current mechanism followed by the BEE for implementation of the ECBC and energy efficiency in the building sector is as follows:

- The ECBC sets minimum standards for new commercial buildings with a connected load of 500kW.
- The ECBC defines climate zone wise norms of energy requirement per square metre of area.
- The ECBC User Guide has been prepared to guide and assist the building designers, architects and other stakeholders to implement and comply with ECBC requirements.
- BEE has empanelled expert architects for designing ECBC compliant buildings.
- A star-rating programme for office buildings has been developed by the BEE.

STATE AND MUNICIPAL LEVEL POLICIES

In 2005, the Haryana government issued an order addressing several aspects of energy efficiency in buildings. In particular, the use of SWH systems was made mandatory for several building types. The order also made the use of compact fluorescent lamps (CFL) mandatory in all new government buildings, government aided institutions and government corporations.

The Pune Municipal Corporation (PMC) is one of the few examples in India of integrated approaches to sustainability. The PMC partners with NGOs and community groups to address sanitation and eco-housing. Pune has also created a model eco-housing programme, working with The Energy and Resources Institute (TERI), US Agency for International Development (USAID), US-Asia Environmental Partnership and the International Institute for Energy Conservation. The programme helped to develop eco-housing assessment tools (for certification as an eco-home), integration of eco-housing fiscal and policy initiatives, as well as demonstration projects by PMC and by private developers. In particular, the PMC has created policies to encourage solar water heating, use of vermin-composting onsite and rainwater harvesting (IIEC, 2010).

The 2003 building bylaws of Bangalore City incorporate a mandate for solar water heating (100 l/day/'unit' specified) in specific building types. Solar photovoltaics are also mandated for multi-unit residential buildings (with more than five units) for lighting set-back areas, driveways and internal corridors. Solar water heating related policies were implemented by cities like Thane, Nagpur and Rajkot.

ISSUES RELATED POLICY IMPLEMENTATION

A recent study conducted under EU-India Action Plan Support Facility (Environment Component), technical assistance to develop best practices in green building sector (APSF, 2011) has identified various issues related to the implementation of policies related to green building concept and suggested the following challenges to achieve energy efficiency in India's buildings sector.

(i) Lack of coordination amongst current implementation agencies: The ECBC and other strategies have been developed to manage electricity demand and enhance supply using renewable energy. However, a coordinated national strategy is required to implement and monitor the current government programmes to achieve national energy savings. For example, whereas the BEE and designated State Nodal Agencies enforce the ECBC, the local development authority or municipal corporations sanction power for building plans and check for ECBC-compliance. This gap between enforcement and implementation must be eliminated to reduce wastage and optimize energy use and efficiency.

(ii) Lack of an overall implementation protocol/enforcement mechanism: There is lack of institutional capacity to implement regulatory, policy and market requirements for end use products for energy efficiency. Although there are regulations, the specifications mentioned in the building and urban planning bylaws require urgent revision. For example, there are no mandatory requirements for minimum energy performance and the implementation and monitoring mechanisms are very weak. The ECBC is currently a voluntary code. However some states and agencies such as Haryana and the Central Public Works Department (CPWD) and the Ministry of Urban Development are working towards mandatory compliance with the ECBC (by committing that future buildings will be GRIHA-compliant). There is a lack of supporting regulatory documents/processes for the agencies to follow and technical capabilities for ready reference and correct implementation of the ECBC.

(iii) Lack of awareness and technical know-how: Consumers and retailers are unaware of the benefits of green buildings, and there is no regulatory framework for enforcement of energy efficiency in buildings. There is a general apprehension of high initial costs and lack of a life cycle cost approach to carry out cost benefit analyses. The Ministry of New and Renewable Energy has announced financial incentives for GRIHA-compliant projects. Similarly, the PCMC offers property tax rebate to occupants of green buildings. However, based on feedback received from various stakeholder groups, there is no awareness on these initiatives and benefits offered by the government.

(iv) Lack of demand: There is an increased demand for architectural styles that do not address the climatic requirements of a given region. As a developer/construction agency, it is important that there is demand for climate-sensitive and sustainable habitats to direct construction activity towards minimum detrimental impact on the environment. In parallel, there are split incentives for incorporating and supplying energy-efficient residential buildings. Developers do not benefit directly by incorporating energy-efficient features in new developments and thus, the penetration of EE techniques and technologies is limited.

ISSUES RELATED TO GREEN BUILDING CONCEPT

Wrong Basic Assumptions

The word "Green' has now become a fashion, there is a lot of glamour attached to it. We seem to use it every where and in every context. If we ask the public its meaning; we will be often astonished by what we hear. Recently I have asked my students to ask 10 lay persons each, about what they understand as Green Building. Though the word 'environment friendly' was among the top five answers, the words 'Glass covered building', 'Hi-tech completely air-conditioned buildings', etc. were also among the very top of the list. 'Energy efficiency, water conservation have all become jargons people use regularly without really understanding them. We all know how important it is to understand the problem correctly to come out with the appropriate solution.

To elaborate it a bit further, during the late 60's, one of the earliest environmental cry was to save wood. Soon aluminum windows were projected as the solution to the problem, assuming that it will save the planet. Later, when there were more studies on energy efficient materials and it was realized that aluminum was one of the most energy intensive material. Since by that time a lot of people and Governments have already invested a lot on this industry, the aluminum industry set-on to reduce the energy intake, etc. Then, new problems propped up in connection with mining, many villages have been mined away, thousands had to be rehabilitated into bad conditions and most of the mined land is lying dead now and probably forever. Now after almost half a century, the environmental lobby is in fight with mining lobby in many parts of India and the world. The problem cannot be easily solved now, as it goes into many dimensions and years.

Now we are at the threshold of a new movement, that of 'Green'ing everything. We commonly see advertisements of Green buildings, Green electrical appliances, Green building materials, etc. This time, let us make sure that we will not build it on wrong basic assumptions and make the same mistakes again.

Lately I have felt the need to substitute some word, other than 'Green Building' to describe the concept of 'truly environment friendly building construction practices' to my students because I realized that even Architecture students understand this word differently, the top of the list was of course "LEED rated building'.

Green Rating Related Issues

When one talk about Green building, it is often confusing that whether he talks about a 'truly environment friendly building as per the theoretical definition of Green building' or he talks about a 'Green rated building'. This is very important because, it may sound amusing, but the truth is not only that these two are drastically different but unfortunately even often conflicting. For example, a building in the warm humid climate of Kerala, which is completely covered with Glass, negating the basic rules of climatic design, completely air conditioned, covered with the most energy intensive products like aluminum etc. can also qualify to become ‘Green Building’ because of the definitional problem. In spite of that, mostly both these meanings are used in synonym, and this is the first and foremost of the problem.

Another problem is that, it is important to see who frames these rules of Green rating, the Green scale. If we entrust the ‘business people’ to frame rules for Green buildings, it is obvious, or rather I would say it is their duty, to see to it that the rules will not say anything about reducing the use of glass or air conditioning or any products they sell. If we still go ahead and entrust them this job, and we expect to see in their proposal, something about how to design a building with minimum of energy intensive products, or how to design spaces incorporating climatic design aspects, then our future generation, our children will surely blame us, and not them, as the culprits. This is the second of the problem in making.

We all know what a glass-house is, and its effect inside it, due the phenomenon called ‘Green house effect’. Sun rays pass through glass as short wave radiation and on hitting any surface, the reflected rays become long wave and it will not be able to pass through glass again, and ultimately ending as heat inside. In Kerala’s warm humid climate, we always had wooden windows to shield off the hot sun, a design wisdom based on climatic design. If we substitute our windows with glass, green house effect will make the interiors more like a glass-house. Therefore, it has been always taught in Climatology classes that, glass can be a villan, if not properly used, in Kerala architecture. We teach them from first year about climatic influences on buildings, and the importance of designing according to climate. In spite of this when they read some Green rating manual, they are made to believe that not only a completely glass covered building can be a ‘Green building’ but also that, more the glass more ‘Green’ the building will be.

Similar is the case with an air-conditioned building. One of the basic lessons in Climatic design was to design the building in a way to make sure that the building will not heat up in the first place than to cool it later, but they now are of the view that it doesn’t matter how you design the building, the thermal comfort part will be taken care of by ‘energy-efficient’ air conditioners. This distorted vision on what’s Green can become a real problem in the future.

Another problem is the use of aluminum, indiscriminately every where without understanding the environmental impact of mining. We are now encouraging to use aluminum for not just windows and doors, but we can see that the entire walling material is fast becoming Aluminum (ACP) sheets globally, and worse we are calling it more ‘Green’. Complete Aluminum buildings are becoming a new architectural trend in developed countries and are being projected as the construction material of future, by world architectural websites and magazines. When we read, ‘over three billion pounds of aluminum is used annually by the construction industry in US alone’, we don’t amuse any more because we commonly see ACP sheet covered building in most of our small towns. In fact we now also commonly see the new tread of covering old multi-storied buildings with ACP sheets to give it a ‘modern’ look. This is another problem in making because of wrong basic assumptions.

Development is not just the growth of GDP. If we cannot get fresh air to breath, good water to drink, good (un-poisoned with pesticide) food to eat, what is the point in having higher GDP. It doesn’t mean one have to be anti-development, we just have look at what we know as development from a higher perspective. May be our concept of development was in itself based on wrong assumptions. We just have to strike perfect balance between GDP and protection of our planet. The concept of “truly environment friendly building’ had an objective; to make sure that our buildings will reduce the impact it will create on environment. It should be designed as a solution to resource conservation. It will be energy efficient, etc. It is high time to introspect whether our ‘Green Buildings’ do that, if not what went wrong and where did it go wrong.

GREEN BUILDING CONCEPT IN KERALA

The rated ‘Green Building’ concept is in its beginning stages in Kerala. A few have been completed and some more are on the way. If we study these rating rules more closely, we can make out that they have fallen pray to misguided priorities, misinformation and self interest. It’s the right time to put things on the right track, correct basic concepts on what a real Green building should be by definition. If we don’t do it in a year or so, the concept will any way be built, but on wrong foundations, as it is happening else where in the country.

What should be done?

First and foremost thing to be done is to spread the idea of what actually a Green Building (used here forth as in Sustainable building) should be, in Kerala context. As stated earlier basically it is a building that causes minimum damage to the environment (1) because of its construction, (2) because of its existence and (3) and finally its destruction or decay after its life. Let’s analyse it a bit further.

We will go the reverse order, when one builds a RCC building, say a house, he is building it for how long? A civil engineer may say, it will last for maximum of 200 years, a sociologist may say it will be useful for two to three generations (in this modern era where the very concept of a home is changing very fast, it may not serve that long) . So what happens to ‘it’ after its life? It means all the bricks, cement, concrete, steel, flooring tiles, etc. Well, since all these things are non-biodegradable, most of it become non-biodegradable waste, mostly ending up as land-fill somewhere. Remember that the house our great grandparents built were having laterite foundations, laterite or wooden walls, lime plaster, wood and thatch roofs, etc, all biodegradable, at the end of its life, it just goes back to earth. So the first step in making a Green building should start at choosing the right building-materials for the building. One can choose biodegradable materials like compressed earth blocks, laterite, wooden windows, bamboo or wooden floors, etc. or recyclable materials. On choosing building materials, the aim is to reduce the use of non-biodegradable, non-recyclable materials, high embodied energy materials as far as possible.

Secondly, a Green building is one which causes minimum damage to the environment because of its existence. A building to perform its duty needs lots of things like electricity, cooking gas, water, etc. which all give its impact on the planet. It also produces lot of things like Solid waste, Liquid waste, etc. As one can see, what it consumes most for its existence is energy. In fact buildings are responsible for about 40% of global energy related emissions. Most of this energy is used as electricity for lighting and thermal comfort. As far as lighting is concerned, the LED light bulb revolution that has already started can really make a huge difference. In 10-15 years time it would be common to meet every house's complete lighting needs with a solar panel. That makes the energy used for thermal comfort the biggest concern, as far as energy use in buildings are concerned. The best way to solve this problem is to see to it that the building is designed according to the climatic needs of the area. In Kerala the main problems are high temperature and humidity. If these two problems can be solved, or at least reduced it's intensity, by means of proper passive architectural design, the major problem is solved. If studied closely, it can be seen that, energy efficient architecture in itself, will come down mainly to climatic building design plus use of low embodied building materials for construction.

Water is another main commodity needed for the existence of any building and therefore making the building water-efficient is another main part of Green building. Not only that one has to make sure that water is used efficiently but also see to it that water after use is recycled, and not wasted, and finally it is taken back to the aquifer below, in the site itself. Water efficiency can be brought in landscaping also by xeriscape, choosing the right, local plants and also in making sure that for watering the plants only recycled water is used. Using water efficient duel flush water closet flush tanks, etc. will also help towards this cause. The ultimate aim in this area should be to make a zero discharge building site; that is to make sure that no water used, goes out of the compound but down in the site itself.

Production of solid waste is another component and its management is the next part. It is high time one has to realize that 99% of the plastics we use today are not bio-degradable, even with the aid of the most modern technology. Therefore until at least a time our science and technology comes out with a solution to this, we should restrict our use of plastics, and other non-biodegradable waste to minimum. There is no other solution today. Sorting of the house hold waste to biodegradable and non-biodegradable is a very important step in this direction, so that at least plastics can be recycled.

The third component is the impact on environment due to the building construction itself. Here the main thing is the conservation of natural resources like sand, earth, minerals, air and water (in terms of pollution), Fossil fuel (mainly in terms of transportation of materials to site and used for the manufacture of building materials), etc. Conservation of depletable resources is an essential component here, and it is here that we are still groping in the dark. There is still no viable replacement to basic materials like sand, cement and steel (even considering, M-sand, mud, etc.). Bamboo is one material that is making its presence really felt in Green buildings. India is the second largest producer of bamboo after China and so we have lots of potential in this area. When a 60 feet tree takes 60 years to replace itself a 60 feet bamboo takes just 59 days to replace (there are bamboos which grow up to 120 cms a day).

CONCLUSION

Buildings rarely stand in complete isolation. The vast majority function as part of an interconnected system of buildings and infrastructure collectively termed the built environment. Supply-side and demand-side interventions are intrinsically linked. They need to be made conjointly to provide uninterrupted service, to help foster economic growth and social stability. During design and construction, each individual building should be thought of as a single piece. The pieces must ultimately form a bigger picture, i.e. a coherent built environment which generates, distributes and uses energy efficiently to reduce costs and carbon emissions.

Traditionally, large-scale generation projects and delivery of nationally-significant infrastructure have been dealt with separately from the buildings that they will ultimately serve. However, significant economic and environmental benefits can be realised by exploiting synergies. Policies should be developed to encourage greater cooperation between designers of different projects and incentives deployed to facilitate cooperative design solutions.

It is high time that we develop a set of guidelines for making sustainable buildings in Kerala context, because the climatic conditions of India are so vastly different that a single set of guidelines cannot usually work for the country. Perhaps even some of these guidelines can be made into rules and be made mandatory through Municipal/ Panchayat rules for building approval. And if we form any Green rules, for the purpose of building truly environment friendly building, anywhere in the world, let the first rule be; design according to the climate'.

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What shall be the Energy Policy for Kerala? Some thoughts.........!

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INTRODUTION

The energy front in India is alarming when the nation prepares for a high growth rate of 8 to 10%. However, this is not a unique phenomenon only to India but also to the developing countries of the world over. India faces formidable challenges in meeting its energy needs and providing adequate and varied energy of desired quality to users in a sustainable manner and at reasonable costs. India needs economic growth for human development, which in turn requires substantial increase in access to clean, convenient and reliable energy for all. Thus the energy challenge is of fundamental importance. Hence it is important for States like Kerala to have its own vision, priorities, technological input, institutional mechanism, legal and financial support, changes needed in the present policies and legal frameworks in the energy sector from a development perspective taking into consideration of its limited available biotic and abiotic natural resources for taking care of a very large population who demands for adequate support from the Governments of Kerala (Government of Kerala and a large number of Local Self Governments). It is proposed that the State of Kerala needs to have an "integrated energy policy" in line with the National Integrated Energy Policy.

VISION – AN INTEGRATED ENERGY POLICY FOR KERALA

"It is to reliably meet the genuine demand for energy services of all sectors including the lifeline energy needs of vulnerable households in all parts of the state with safe, clean and convenient energy at a break-even cost with a technically efficient, economically viable and environmentally sustainable manner using different fuels and forms of energy, both conventional and non-conventional, as well as new and emerging energy sources to ensure supply at all times with a prescribed confidence level considering that shocks and disruption can be reasonably expected" - to provide energy security to all. This vision ultimately proposes an integrated energy policy for the State of Kerala in line with the National Integrated Energy Policy.

ENERGY SCENE OF KERALA

The conventional sources of energy in Kerala are fuel wood, petroleum products and electricity. Till recently Kerala has been depending solely on hydro-power for electricity, availability of which is limited due to lack of technically favourable sites and unfavourable ecological impacts. Nuclear power and fossil fuel-fired thermal stations are the other conventional sources. Owing to widespread popular opposition, because of high population density, fragile ecology and environmental safety, nuclear and coal based power stations could not be installed in Kerala. The only other alternative was fossil-fuelled thermal stations like Kayamkulam and Brahmapuram. It is widely accepted that fossil fuels are limited, that its price will go on increasing, that they do not offer a long term solution, that they contribute to global warming and that alternative sources are need to be identified.

Power System in Kerala encompasses hydel, thermal and wind sources. Hydel energy is the most reliable and dependable source in Kerala. Of the total installed capacity as on 31-3-2010, 2746.19 MW, the lion's share of 1933 MW of installed capacity comes from 24 hydel stations; 783.11 MW is contributed by the thermal projects including NTPC at Kayamkulam which is Kerala's dedicated thermal station. Kanjikode wind farm, Palakkad has an installed capacity of 2.03 MW. Wind Energy from IPP is 28.05 MW. Capacity addition during 2009-10 was only 51.44 MW (1.9 %) to 2746.19 MW as on 31-3-2010 from 2694.75 MW on 31-3-2009. It is interesting to note the installed capacity of State Sector 2129.63 MW (77.55%), Central Sector 359.58 MW (13.09%) and the Private Sector 256.98MW (9.36%).

PROSPECTS

Cater to ever-increasing demand of power, Government of Kerala has decided to give encouragement to power generation from Non-conventional (renewable) Energy Sources in the Energy Policy of 2002. It was proposed to generate energy from municipal waste, agro waste, industrial waste, sewage and other biomass, small-hydro units, solar photo voltaic, wind, tide, wave, geothermal etc. These technologies are environment friendly, however their technological input, institutional mechanism, legal framework and cost-effectiveness are yet to be proved. The use of Municipal Solid Waste for power generation, besides generating power, will eliminate the problem of pollution and disposal of urban waste. PPP needs to be encouraged in all these sectors. If the ideas proposed in the vision to happen, Kerala needs to make its energy production around 4000MW by 12th Plan period which could be raised to 5000 to 6000 MW in the 13th Plan, so that atleast 75% of the State's requirement could be met.

Ministry of New and Renewable Energy (MNRE), Government of India has formulated legal, financial and administrative frame work for promotion of investments in this sector and has advised the State governments to formulate policies which are yet to emerge. State owned different R &D organisations like EMC, ANERT and selected Engineering Colleges may be encouraged to develop the required technologies on energy from municipal waste, agro waste, industrial waste, sewage and other biomass, small-hydro units, solar photo voltaic, wind, tide, wave, geothermal etc. KSEB may be given the responsibilities for developing the required institutional mechanism and legal frame work for each one of these energy source based projects. Expertise may be developed for the preparation of Environmental Impact Assessments for each one of these energy sources. A "Kerala Energy Fund" may be developed so as to meet the energy related R & D activities in the State. It is also suggested that this policy may be formulated so as to face the challenges for 2020, synchronising with that of the 12^{th} and 13^{th} Five Year Plans, with required course correction whenever and wherever necessary.

CONCLUSION

The need for an integrated energy policy of Kerala has been proposed which shall be formulated in the 7^{th} KEC deliberations and outcome from the Open-Forum.

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Policy documents of earlier plan periods of GOI and GOK and large number of other related documents have been referred and relevant portions have been extensively incorporated in the text is profusely acknowledged and thanked.

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Young Scientist's Award Presentations

Energy and Environment: A Microalgal Approach

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INTRODUCTION

Alarming environmental issues have been raised in the last century due to the extensive use of fossil fuels and the world is now facing depletion of natural oil resources. The negative consequences caused by non-renewable oil resources and the concern about petroleum supplies have triggered developments in environment friendly fuels or biofuels (Jason et al., 2006). A liquid or gaseous fuel predominantly produced from biomass is generally defined by the term biofuel. Biofuels are preferred over fossil fuels as they are more environment sustainable, have lower CO_2 emissions and can potentially reduce the atmospheric pollution (Reijnders, 2006). Production of bio energy and bio materials is derived from biomass, which represents an abundant carbon-neutral renewable source (Ragauskas et al., 2006).

Biomass is an attractive feedstock because it is renewable, has no net emission of CO2, and NOx, low sulphur content, and also it has significant economic potential (Cadenas and Cabezudo, 1998). Biomass can sequester carbon through the growth of the feedstock and hence show a great reduction in green house gas emissions (Searchinger et al., 2008).

Among different biomass sources used for biofuel production, for e.g. wheat, wood waste, agricultural wastes, Municipal waste (MSW), farm slurry, vegetable oils, oil seeds, sewage and fishery wastes; microalgae – the tiny photosynthetic organisms with simple requirements of growth is currently receiving attention. The fatty acids in the microalgae when extracted have the potential to be converted to a cleaner, less toxic, biodegradable and renewable fuel (Jorge and Michele, 2011). Algal biomass is used to produce bio ethanol, bio diesel and biogas (Demirbas, 2007). Microalgae can be subjected to various biological processes; fermentation for production of bio ethanol and extraction of oils for biodiesel (Skjanes et al., 2007). Anaerobic digestion is another biological conversion method adopted to make microalgal biodiesel sustainable (Sialve et al., 2009). Advances in biotechnology, chemistry,and engineering introduce a new manufacturing concept called biorefining for converting renewable biomass to valuable fuels (Ragauskas et al., 2006).

These ideas form the fundamental framework for this research of anaerobic digestion of microalgae to produce biogas. The theme of this project is a part of a broader exploration into an environmentally sustainable and economically viable biorefinery to produce bioenergy from microalgae. Microalgae is considered to be an upcoming, promising alternative energy source which helps to keep the development of human activities in the energy research area in harmony with nature. This study aims to present the optimum utilities of pre-processed microalgal biomass – utilisation of the microalgal biomass to produce biogas using anaerobic digestion technique.

MICROALGAE

Microalgae are the photosynthetic unicellular microorganisms that can produce lipids, proteins and carbohydrates consuming large amounts of CO2 over short periods of time. These products can then be processed into biofuels like biodiesel, bioethanol and biogas and to other useful chemicals via thermochemical and biochemical processes. Microalgae, due to their flexibility in growing conditions, can be grown either in open ponds or closed systems like photobioreactors and hence preserving arable croplands and potable water. Microalgae represent a green, economically viable and environmentally stable option that is capable of meeting the global demand for bioenergy (Demirbas, 2011). *Nannochloropsis and Chlorella vulgaris* are the two microalgae selected for this research.

Microalgae can be used to produce methane (biogas), ethanol, to produce hydrogen photosynthetically and from the accumulated lipids, fatty acids can be extracted to produce biodiesel (Scragg et al, 2003). It can synthesise various products by photosynthesis and also through catabolism of carbohydrates via respiration and fermentation under dark aerobic conditions. These compounds are then completely broken down into carbon dioxide by aerobic respiration (Ueno, 1998). Ethanol produced by microalgae can be purified and used as a fuel and the CO_2 can be recycled as a nutrient for the cultivation of the species or can be used in the process of anaerobic digestion (Harun et al., 2010). In today's scenario of global warming, biofuel is a promising alternative to fossil fuels. They can efficiently replace petroleum fuels due to their widespread availability, affordability, accessibility of technology, ease of transport, storage, versatility in use in engines and socio-economic, and environmental welfares. Using of microalgae shows the benefits of continuous production, use of waste water, no usage of crop lands, synthesis of organic compounds through photosynthesis, and easy adaptation to varying environmental conditions (Jorge and Michele, 2011). Thus it can be said that "oilgae – oil from microalgae", the promising research areas of today will contribute towards a more sustainable future.

Microalgal biomass

Biofuel demand is increasing day by day due to the pressures of climatic changes, ever increasing green house gas emissions and fuel prices, oil supply crises, the need for environmental stability and social security in the near future. Biomass is usually produced from oleaginous crops such as rapeseed, soybean, sunflower and palm. Microalgae is used as an alternative feedstock as a third generation biofuel source because they contain high amounts of oil that can be extracted, processed and refined into transportation fuels, with the aid of current technologies. They have fast growth rate, permit the use of non-arable land and non-potable water, use less water, do not displace food crops cultures and can be harvested every now and then almost daily (Gouveia and Oliveira, 2009).

Biomass is one of the better sources of energy. Among biomass, microalgal biomass has gained recent attraction for biofuel production because of its biodegradable nature, high growth rates, low costs, availability, and the high energy conversion efficiency it offers when compared to traditional terrestrial plant feedstocks. The idea of using microalgae for biofuel generation is not new but is now taken seriously because of the escalating price of petroleum products and more significantly the concern over global warming. Microalgal biomass is converted to biodiesel via transesterification, to bio-ethanol via fermentation and to biogas with the help of anaerobic digestion processes (Hossain et al., 2008).

Microalgal biomass mainly contains carbohydrates, lipids and proteins which can potentially be used for Biofuel production. Microalgal biomass solves the current environmental problems of demineralisation, salinisation, desertification, soil erosion and depletion of natural water and oil sources (Hossain et al., 2008; Gerpen, 2005). This research utilises the microalgal biomass after the extraction of lipids/oils, called Lipid extracted Microalgal Biomass Residue (LMBR), which is subjected to anaerobic digestion processes to produce biogas. Lipid-extracted Microalgal Biomass Residues or LMBRs are the residual biomass derived from biodiesel production sources. They contain considerable quantities of proteins and carbohydrates which can be subjected to anaerobic digestion to produce biogas (Chisti, 2008). The conversion of LMBRs into biogas by anaerobic digestion could function as the dual role of renewable energy production and sustainable development of the microalgal biodiesel industry (Yang et al., 2011).

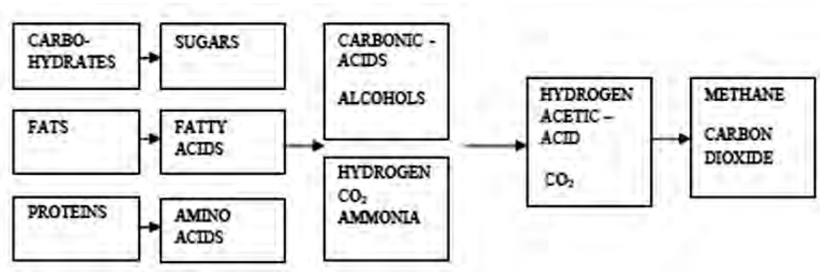
In this study, the main objective is to know the process of anaerobic digestion of microalgae and thereby assess the potential of the entire process to completely utilise the biomass and meet the energy deficit to control the adverse effects on the environment.

ANAEROBIC DIGESTION (AD)

Anaerobic digestion (AD) is a natural, biological process which involves the breakdown of organic compounds in the absence of air and transforms it into methane, carbon dioxide and water. The anaerobic digestion process is a sequential process of three different stages. They are hydrolysis, acidogenesis (fermentation) and methanogenesis, all being biological reactions. The hydrolysis stage views the breakdown of carbohydrates into soluble sugars. The different stages are governed by different groups of microorganisms; hydrolytic (cellulolytic and proteolytic), acid forming bacteria (Saprophytic) and methane forming bacteria (Methanogenic). At fermentation stage, otherwise called as acetogenesis or acidogenesis, the bacteria convert this biomass to alcohols, acetic acid, volatile fatty acids and gas containing H_2 and CO_2. This is then primarily metabolised by methanogenic bacteria into CH_4 (60-70%) and CO_2 (30-40%) (Rao et al., 2010). Organic fraction of MSW, sewage slurry, market wastes, farm slurry, energy crops like maize/grass silage, whole crop wheat, whole grain maize and mixtures of these can be good feedstocks for AD.

Substrate from different feed stocks is mixed in a biogas digester to ferment the biomass in oxygen-free (anaerobic) conditions. The digestion tank needs to be warmed and mixed thoroughly to create the ideal conditions for the microorganism to convert biomass into biogas.

To illustrate the process a flow chart is shown below.



HYDROLYSIS ⟶ ACIDOGENESIS ⟶ ACETOGENESIS ⟶ METHANOGENESIS

Fig. 1
Anaerobic Digestion

AD of microalgal biomass

The idea of employing anaerobic digestion to algae was first detailed by C.G. Golueke et al (Golueke et al., 1957). Biogas, the principal product of anaerobic digestion, contains 55-65% of methane (CH_2), 30-45% carbon dioxide (CO_2), traces of Hydrogen sulphide, (H_2S), and water vapour. It may also contain small amounts of hydrogen (H_2) and Carbon Monoxide (CO).

Equations showing the CH4 formation can be summarised as –

Organic Material ⟶ $CH_4 + CO_2 + H_2 + NH_3 + H_2S$-----------→ (1)

Complex Organics⟶ Simpler Organics⟶ Organic Acids⟶ Methane+CO_2 -- →(2)

(Source: (1), (2) http://www.wtert.eu)

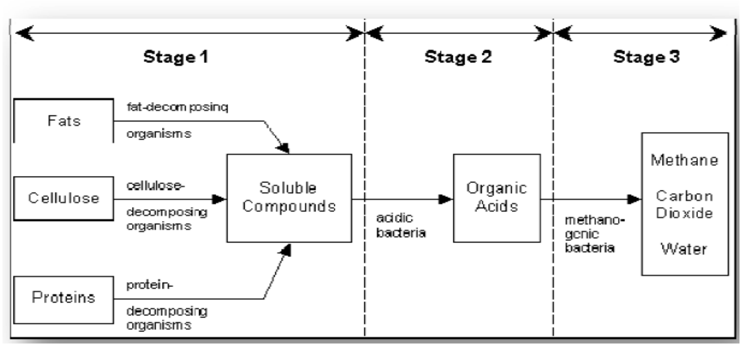


Fig. 2
AD of Microalgal Biomass (Source: http://www.daviddarling.info)

From the above equations it can be noted that AD is a process whereby organic matter/biomass is broken down into smaller chemical constituents. Generally for AD to be effective, on microalgal biomass, digester design will be a key consideration. It homogenises the digesting material and also improves the bacterial contact with the material. It also enhances the methane production by removing the gas from the immediate zone of generation as it forms. AD is basically a wet process. For microalgal biomass, the moisture content is between 80-90%, which also makes the anaerobic digestion process optimised. For maximum yield and a controlled process, a two staged or semi continuous anaerobic bioreactor is preferred which allows more control over the process.

To acquire the maximum yield of methane from algal biomass, two methods are adopted –pretreatment and co-digestion. Pretreatment prior to AD improves the biodegradability of the biomass. Physical processes like separation techniques, concentration or dehydration are applied to mobilize and maximize the biomass fraction to be digested. Chemical treatments (temperature, pH, VFA), thermal treatments and ultrasonic cavitation improves the kinetics of the production and methane yield. Since the limits and possibilities of AD are known better co-digestion has now become a well known methodology. Various feedstocks can be co-digested together, for example algal biomass, agricultural wastes, farmhouse wastes, wastes from paper industry, market waste, sewage sludge, etc. Some pretreatments like chopping, sieving, removal of metals, glass and mixing are undertaken prior to codigestion (http://www.ieabiogas.net).

Microalgal biomass has the advantage over plant biomass that they can be grown in a liquid medium and has a three dimensional mobility and flexibility in growth and cultivation. Furthermore microalgal biomass does not contain lignocelluloses and hence minimum pre-treatment is required. It also combines the recovery of CO_2 through the process of AD by utilising it again for the growth of microalgae. After digestion, the sludge is used as a biofertilizer, incinerated or even used as animal feed, which are all green and clean (Jorge and Michele, 2011).

BIOREFINERY APPROACH – THE VISION

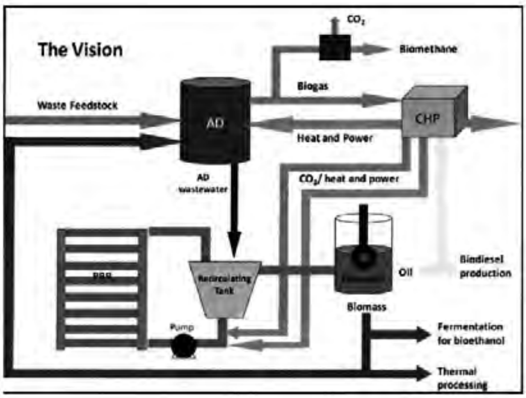


Fig. 3
The Vision

Algae will be cultivated in a closed photobioreactor fed with wastewater from an anaerobic digestor (AD). The wastewater from the AD is rich in nutrients vital for the growth of algae. The use of wastewater will reduce the requirement to purchase commercially available nutrients. Once harvested, the algae will undergo a novel extraction process in order to remove the oils from within the cells. The oil will then be separated and used for transport fuel or for Combined Heat Power (CHP) and the remaining cell biomass will be recirculated back into the AD recycling the nutrients and producing biogas. The biogas and oil can be diverted into a CHP which will provide energy for the process stream or exported to the grid and the any carbon dioxide emissions from the CHP can be recirculated back into the algae PBR for sequestration via photosynthesis. This system is novel in that it does not have the same demand on potable water resources, nutrient inputs, land or infrastructure requirements that other bioenergy processes tend to require (Melville and Chapman, 2010).

CONCLUSION

The ever growing need for new fuels is a key driver to carry out research in the bioenergy field. Algal biofuels cannot currently compete with fossil fuels on price using current technology and processes. This makes it essential to develop a cheaper and economical way of producing green fuels. Using microalgae for biogas production holds great potential due to the continuous nature of production, simple cell division cycle and usage of unwanted and discarded resources and also due to their capability to fix a large amount of carbon dioxide. Reducing CO_2, is an important factor in the consideration of alternative fuels.

Biogas production from algal biomass is an area which still needs much research. Even though research has been conducted worldwide in this field as shown by the literature search above, a biorefinery approach which looks at all aspects of microalgal biomass utilisation is not yet fully developed. Various factors associated with the microalgae –

- its cultivation and harvest in a cost effective way
- methods of oils extraction to produce biodiesel
- methods to enhance the production of biodiesel, and/or biogas
- correct utilisation of techniques like AD, etc

which are still in research stage need to be addressed as practical ideas. The concept of biorefinery paves the way for it.

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Multi-Use Microalgae for Biofuel Generation and Wastewater Treatment

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INTRODUCTION

There has been a continuous increase in the energy demand over the years which is expected to rise with time. Fossil fuels are not be a sustainable form of energy source due to the greenhouse gas (GHG) emissions and resulting impact on the environment like acid rain, global warming etc. (Hill et al., 2006). This has hence caused a significant rise in the interest of identifying renewable sources of energy which are carbon neutral. Currently commercially available biofuels are bioethanol and biodiesel derived from sugarcane and corn starch and soybean and rapeseed respectively, all of which depend on scarce land and compete with food crops. Such biofuels have a major demerit over the fossil fuels of not being economically competitive, though they are environmentally beneficial when compared to fossil fuels. There is concern of terrestrial biofuel production on impact of use, growth and cultivation of food crops and food availability. Keeping these factors in mind the biofuel derived from algae has therefore be put forth as an alternative approach that can be raised on wastewater, recovering polluting nutrients found in wastewater and finally getting rid of the water bodies of typical pollutants and rendering the water resource reusable. This provides a dual use approach.

BIOFUEL FROM ALGAE

Green unicellular microalgae have been identified as potent sources of renewable energy (Benemann et al., 1977; Oswald and Golueke, 1960). Microalgae can generate significant extent of biomass and oil suitable for conversion to biodiesel. Microalgae have higher biomass productivity than plant crops with regard to land area for cultivation, reduced GHG emissions and lower costs. Algal feedstocks can be used directly or converted to liquid fuels similar to plant-derived feedstocks by various biochemical or thermochemical conversion processes (Amin, 2009; Brennan and Owende, 2010). Dried algal biomass can be subjected to direct combustion for heat generation though it is least practiced (Kadam, 2002). Biochemical conversion processes include fermentation and anaerobic digestion of the algal biomass to yield biofuel and also production of hydrogen by bio-photolysis. Thermochemical conversion processes involve gasification, pyrolysis, hydrogenation and liquefaction of the algal biomass for the production of gas or oil-based biofuels. Lastly, lipids that are stored within the microalgae are converted to biodiesel by transesterification (Miao and Wu, 2006). A lot of research has been focused on identification of microalgae strains that show high lipid yields, identifying conditions for high accumulations of lipids (particularly triacylglycerol) under different stress conditions like nitrogen (N) limitation, phosphorous (P) limitation and increased biomass productivity (Griffiths and Harrison, 2009; Converti et al., 2009; Dean et al., 2010; Li et al., 2008; Rodolfi et al., 2009).

Potential for biofuel production

The primary advantage of algal biomass as a biofuel feedstock is the compact growing conditions with minimal freshwater conditions when compared to plant based biofuel crops thereby increasing the land productivity. Microalgae could be grown near the sea making use of saline or the brackish water. Another such added feature of microalgae is its growth in wastewater. This feature has been exploited for low cost and environment friendly wastewater treatment over the conventional methods (Green et al., 1995; Oswald et al., 1957). The critical problem with wastewaters is the presence of high concentration of N and P, toxic chemicals which demand high-cost chemical treatments for their removal (Gasperi et al., 2008). In these wastewaters total N and P concentrations are found in the range of 10–100 mg L^{-1} (low) and >1000 mg L^{-1} (high) in municipal waste waters and agricultural effluents respectively. Bio-accumulation and innate ability to grow on such a rich nutrient medium have made the microalgae an extremely attractive resource for sustainable and cost effective wastewater treatment (de-Bashan and Bashan, 2010; Hoffmann, 1998; Mallick, 2002). Combining this feature of ability to grow on wastewater with the well known knowledge of use of wastewater grown algae as a means of energy production is the current spotlight of algal biofuel research (Benemann et al., 1977; Oswald and Golueke, 1960). The next important assessment is the economic viability of algal biofuel. There have been contradicting assessments and arguments on the biofuel production. There are reports claiming economical and environmentally sustainable production of biofuel while another view is skeptical on the long term viability and economics of algal biofuels. Most frequent condemnation is the use of fossil fuel in the biofuel production process which is not considered in the appraisal of algal biofuel viability: which would in fact give rise to a net negative energy output.

ALGAE AND WASTEWATER

India produces a lot of domestic and industrial wastewater that often reaches water bodies rapidly and impairs the reuse of this water for domestic and agricultural purposes. Reuse necessitates removal of the high concentration of nutrients particularly N and P which if left to accumulate in rivers and lakes can lead to high risk of eutrophication. The conventional method of removal of P is by precipitating the P using chemicals or is converted to bacterial mass as activated sludge. However, P obtained after these processes is either buried in landfill or treated further to generate sludge fertilizer. Microalgae have abilities which play a very important role on remediation, especially in the final (tertiary) treatment phase of water (Ahluwalia and Goyal, 2007; Mallick, 2002). Algae based treatment for removing P is efficient as compared to conventional chemical treatment. This is a low cost option and is attractive to the developing countries. In addition, algal means of remediation is environmentally agreeable as they generate no additional pollutants or sludge byproducts and allows efficient recycling of nutrients. Recovered N and P in algal biomass can be used as fertilizer or as animal feed (Munoz and Guieysse, 2006; Wilkie and Mulbry, 2002). Majority of the research on algal wastewater treatment has been carried out at a scale of laboratory, pilot ponds and experimental high rate algal ponds. These studies have focused on estimating the algal potential to remove N and P and in certain studies heavy metals along with the maximal algal biomass production. They also focus on methods to harvest algal biomass to evaluate the sustainability of the microalgae for biofuel.

Algal growth in wastewater

Microalgal growth in wastewater depends on a vast range of variables. As with microorganisms, parameters controlling growth are the growth medium, pH, temperature, concentration of various essential nutrients which primarily includes N, P and organic carbon, light availability, oxygen and carbon dioxide availability for growth. It has been proved that the growth of microalge in primary settled sewage water increases with increased photoperiod and by addition of carbon dioxide (Ip et al., 1982). Also, with increased temperature there is decrease in the algal biomass. The presence of heavy metals and toxic organic chemicals is also another critical factor affecting the growth of algae which is particularly an issue with industrial effluents. Apart from abiotic factors there are also biotic factors that hamper algal growth. Pathogenic bacteria, predatory zooplankton and other organisms can threaten and may even compete with the microalgae for nutrients. The starting inoculum size is a significant controlling factor for growth of the whole population. The influence of each of these factors varies from one wastewater to another and with time (season as well as adaptation). The tolerance of algal species varies. Unicellular chlorophytic microalgae are tolerant to many wastewater conditions and are very efficient at accumulating nutrients from wastewater (Aslan and Kapdan, 2006; Gonzalez et al., 1997; Ruiz-Marin et al., 2010). *Chlorella* and *Scenedesmus* are generally predominant in oxidation ponds (Masseret et al., 2000) and in high-rate algal ponds (Canovas et al., 1996). Nevertheless among chlorophytes there are significant variations in the efficiency. For example, *Chlorella vulgaris* is more effective than *Chlorella kessleri* at accumulating N and P (Travieso et al., 1992), while another study indicates *Scenedesmus obliquus* grew better in municipal wastewater than *Chlorella vulgaris*.

Municipal sewage wastewater

During the final phase of the treatment of the water, just prior to the discharge into the environment, removal of dissolved inorganic compounds including N and P occur naturally and is brought about by the unicellular green microalgae. Mostly, often observed are *Chlorella* and *Scenedesmus*. Growth of *Chlorella* in variously pretreated wastewater was analyzed. Amongst the various parameters for which the system was tested, it was found that the N and P removal, metal ion removal and growth rates were comparable in wastewater prior to and after primary settling. However, in the final wastewater treatment phase the algal growth was the highest. These high growth rates are attributed to high levels of N and P (131.5 mg L^{-1} total N and 201.5 mg L^{-1} total P) although N:P ratio was non-optimal. *Chlorella minutissima* was identified as the key algal species in many wastewater treatment oxidation ponds in India. *Chlorella minutissima* could grow well in high concentrations of raw sewage and subsequently dominate the oxidation pond system. This species can utilize either ammonia or nitrates as N source. The algal growth was found to be highest under mixotrophic (photo-heterotrophic) conditions rather than photoautotrophic conditions. The biomass productivity under mixotrophic conditions was 379 mg $L^{-1}d^{-1}$and under photoautotrophic conditions was 73.03 mg L^{-1} d^{-1}. Hence, this species could be a potential resource for high biomass productivity in wastewater high-rate ponds.

Agricultural wastewater

India is an agricultural country and over 60% of its land is cultivated. A large extent of run off from agricultural land may therefore be expected to occur carrying with it significant levels of fertilizer derived nutrients added to the agricultural land. However, as in most parts of India runoff and stormwater are arrested and stored in a chain of village water tanks. The water is then threatened with eutrophication. On a similar note over 40% of our cultivated area is irrigated through a system of canals and drainages. Much of the excess water from irrigated fields return to these canals making them pick a very large level of plant nutrients and making the water prone to high algal growth. Currently this is considered a problem which in reality is a resource poorly tapped. These water tanks and canals can be seasonally inoculated with appropriate algal species to firstly harvest the plant nutrients, second to raise algal biofuel, third maintain water quality and environmental quality and finally, if possible capture and sequester carbon from various local carbon sources.

Agro processing activities are also non-point source generation of plant nutrients. Coir, jute, hemp and banana fiber retting, decentralized hide processing, animal washing, fish cleaning, coffee fruit processing, etc, generate nutrient rich wastewater that are also rich in organic loads. While organic loads are rapidly digested and converted to bacterial biomass – what is left or retained in these receiving waters is large load of plant nutrients that are eventually converted to algal biomass. It is common to see these water bodies turn green with algal loads. These too, like in the earlier case are an entrapped nutrient resource to awaiting recovery of multiple products such as algal biomass, biofuels, energy, animal feed and facilitate carbon dioxide capture.

Agricultural wastewater is also generated from the effluent in manure management systems and have high N and P content. Due to high concentrations of nutrients, algae have shown efficient growth and efficient removal of N and P from manure-based wastewater. Studies have shown efficient growth of green algae *Botryococcus braunii* in piggery wastewater containing 788 mg L^{-1} NO_3 which removed 80% of initial NO_3 content. Studies on the benthic algae indicated that certain species such as *Microspora willeana*, *Ulothrix* sp. and *Rhizoclonium hieroglyphicum* are more efficient than the planktonic algae because of higher nutrient uptake rates. These algal growth rates were found to be similar to growth rates found on municipal wastewater.

Industrial wastewater

Research on algal remediation of industrial wastewater has been concerned predominantly with heavy metals (chromium, zinc, etc) and organic toxins (hydrocarbons, biocides, surfactants, etc) removal compared to the N and P removal dominant in domestic wastewater studies. In such heavy metal laden waters the algal growth rates were found to be relatively low thereby reducing the chances of using such industrial wastewater for large scale generation of algal biomass as compared to municipal and agricultural wastewaters. Industrial wastewater is not a potential resource for algal biomass except in a few cases. However a recent study suggests that carpet mill effluent may be a resource for biofuel production (Chinnasamy et al., 2010). Carpet mill waste water accounts for 100–115 million litres of wastewater per day. This wastewater includes process chemicals, pigments, inorganic elements, low concentration of metals and low concentration of total P and N. Two freshwater microalgae *B. braunii* and *Chlorella saccharophila*, and a marine alga *Pleurochrysis carterae,* were found to grow in untreated carpet wastewater low in P and N (Chinnasamy et al., 2010). With large volumes of such wastewater being available, there is a large potential for algal biodiesel. Typically paper, pulp and power generation, primary agricultural processes such as coir retting, coffee processing, etc generate large volumes of wastewater and little is studied about the potential to use microalgae in mixotrophic mode.

Dairy industry wastewater has high BOD and COD concentrations as it contains ammonia, minerals and phosphates. They also contain high levels of lactose, fats and proteins (Hill and Bolte, 2000; Orhon et al., 1993; Perle et al., 1995; Sarkar et al., 2006; Vidal et al., 2000). Large volumes of wastewater are also created by the process water used for cleaning the production unit in dairies (Danalewich et al., 1998). Cheese-whey wastewater contains 30–50 g/L BOD and 60–100 g/L COD along with high levels of N and P (Gelegenis et al., 2007; Demirel et al., 2005). P. bohneri has been used to treat the tertiary effluent anaerobically and a growth rate of 0.62d-1 with a biomass yield of 329 mgL-1 (Blier et al, 1995). The ammonia and P removal rate was 5.9 mg N–NH3 L-1d-1 and 2.9 mg P—PO43- L-1 d-1, respectively. At various N levels in the range of 30-50 mg N–NH3 L-1 the maximum algal biomass concentration of 565 mg L-1 was obtained at the end of 16 days and the growth rate was 0.58 day-1 in diluted effluent (30 mg N–NH3 L-1). Ammonia removal was nearly the same for all the dilutions while P removal was the highest at 50mgL-1 (Blier et al., 1996).

Biosorption of heavy metals

There are many heavy metals biosorbed by various green microalgae from solution as shown in Table 1. Chlamydomonas reinhardtii, a green flagellated green microalgae commonly found in fresh water, has been put to use as a biosorbent for heavy metals (Tuzun et al, 2005). The Hg(II), Cd(II) and Pb(II) ions were found to be biosorbed in to amino, carboxylic acid, hydroxyl and carbonyl groups. The maximum biosorption capacities were 0.360, 0.379 and 0.465 mmol g-1 dry biomass for Hg(II), Cd(II) and Pb(II) ions, respectively. The biosorption was influenced by initial metal ion concentration, biomass concentration and pH.

Table 1
Freshwater microalgae having biosorption capabilities of heavy metals from solutions

Algae	Metal	pH range	Range of heavy metal uptake, (mmol g-1)	Reactor Type & operation mode	Reference
Chlamydomonas reinhardtii	Hg(II)	2.0-7.0	0.183	BSR	(Tuzun et al., 2005)
	Cd(II)	2.0-7.0	0.149	BSR	(Tuzun et al., 2005)
	Pb(II)	2.0–7.0	0.297	BSR	(Tuzun et al., 2005)
Chlorella miniata	Cr(VI)	1.0–4.0	0.087–0.664	BSR	(Han et al., 2007)
Chlorella vulgaris	Cr(VI)	2.0	0.356–0.492	PBR	(Aksu and Acikel, 2000)
	Fe(III)	2.0	0.150–0.325	PBR	(Aksu and Acikel, 2000)
	Cd(II)	2.0 - 5.0	0.0135	BSR	(Al-Rub et al., 2006)
	Ni(II)	2.0 - 5.0	0.988	BSR	(Al-Rub et al., 2006)
	Cu(II)	2.0 - 5.0	1.290	BSR	(Al-Rub et al., 2006)
	Cd(II)	4.0 - 4.5	0.609–0.770	BSR	(Aksu and Donmez, 2006)
	Ni(II)	4.0 - 4.5	0.482–0.995	BSR	(Aksu and Donmez, 2006)
Cladonia rangiformis	Cu(II)	2.0 - 5.0	0.024–0.108	BSR	(Ekmekyapar et al., 2006)
Fucus spiralis	Cd(II)	4.0	0.284–0.489	BSR	(Freitas et al., 2008)
	Zn(II)	4.5	0.156–0.243	BSR	(Freitas et al., 2008)
	Pb(II)	5.0	0.231–0.351	BSR	(Freitas et al., 2008)
Laminaria hyperborea	Cd(II)	4.0	0.284–0.489	BSR	(Freitas et al., 2008)
	Zn(II)	4.5	0.156–0.243	BSR	(Freitas et al., 2008)
	Pb(II)	5.0	0.231–0.351	BSR	(Freitas et al., 2008)

Sargassum	Cu(II)	5.0	N.A	PBR	(Figueira et al., 2000)
	Cd(II)	5.0	N.A	PBR	(Figueira et al., 2000)
	Zn(II)	5.0	N.A	PBR	(Figueira et al., 2000)
	Pb(II)	2.0-7.0	1.260	BSR	(Martins et al., 2006)
Sargassum filipendula	Cd(II)	5.0	1.26 mequiv. g-1	BSR	(Fagundes-klen et al., 2007)
	Zn(II)	5.0	1.28 mequiv. g-1	BSR	(Fagundes-klen et al., 2007)
	Ni(II)	3.0	1.174–1.468 mequiv. g-1	PBR	(Borba et al., 2006)
	Cu(II)	2.5-5.5	0.598	PBR	(Volesky et al., 2003)
Sargassum fluitans	Cu(II)	5.0	N.A	PBR	(Naja and Volesky, 2006)
Sargassum wightii	Ni(II)	3.0-4.5	N.A	BSR	(Vijayaraghavan et al., 2006)
	Cu(II)	3.0-4.5	1.105	BSR	(Vijayaraghavan et al., 2006)
	Ni(II)	4.0-5.0	0.818	BSR & PBR	(Vijayaraghavan and Prabhu., 2006)
	Cu(II)	4.0-5.0	1.448	BSR & PBR	(Vijayaraghavan and Prabhu., 2006)
Sphaeroplea	Ni(II)	2.0-8.0	3.400–4.150	BSR	(Rao et al., 2005)
	Cu(II)	2.0-8.0	2.210–3.410	BSR	(Rao et al., 2005)
Sphaeroplea (acidtreated)	Ni(II)	2.0-8.0	3.400–4.150	BSR	(Rao et al., 2005)
	Cu(II)	2.0-8.0	2.210–3.410	BSR	(Rao et al., 2005)
Spirogyra	Cu(II)	2.0-8.0	0.936–2.098	BSR	(Gupta et al., 2006)
Spirulina platensis	Cr(III)	n.a	1.638–2.211	BSR	(Shashirekha et al., 2008)
Turbinaria conoides	Pb(II)	4.0–5.0	1.100–2.121	BSR & PBR	(Senthil Kumar etal., 2007)

Abbreviation – N.A – Not Applicable, BSR – Batch Stirred Reactor; PBR – Packed Bed Reactors

Other studies confirmed the biosorption and bioreduction mechanism involved in the removal of Cr(VI) by Chlorella miniata (Han et al. (2007). The proposed mechanism for biosorption of Cr(VI) are as follows: (1) At low pH, Cr(VI) are adsorbed on the amino group of the algal biomass followed by adsorption onto the protonated sites; (2) by bioreduction of Cr(VI) to Cr(III) (as $Cr(OH)_4^-$) by the reductants such as polysaccharides in the algal biomass; (3) release of Cr(III) from the biomass. The study also reports that the equilibrium time for Cr(VI) removal was governed by initial pH, biomass and Cr(VI) concentrations. Chlorella vulgaris is widely exploited as a food supplement. The physical structure of the algae eases in the biosorption, its cell wall provides an array of ligands with various functional groups for binding different heavy metals (Aksu and Acikel, 2000; Al-Rub et al, 2006; Aksu and Donmez, 2006). Sphaeroplea is well known for its adsorption of Ni(II) and Cu(II) (Rao et al., 2005). This algae when treated with acid has enhanced adsorption capacities - its capacity increases from 3.40 to 4.15 mmol g-1 and 2.21 to 3.41 mmol g-1 for Ni(II) and Cu(II), respectively. Fast metal sorption is the most desired for the practical application in the real industrial wastewater treatment. Cu(II) have been biosorbed from aqueous solutions by Spirogyra species. The biosorption and desorption experiments were performed in batch mode under various pH and microbial loads. The results indicated Spirogyra species to be an effective biosorbent for Cu(II) removal. The combined separation of heavy metals and increased biomass content indicated an economically viable process of energy generation as well.

BIOFUEL GENERATION FROM WASTEWATER GROWN ALGAE

Microalgae generate and accumulate lipids. These lipids could be saturated fatty acids, polyunsaturated fatty acids, glycolipids or triacylglycerols. The quantity of lipids produced depends on the microalgae species and growth conditions (Chisti, 2007; Griffiths and Harrison, 2009; Hu et al., 2008). Most of the studies indicate highest concentration of lipid accumulation in either photobioreactor or batch culture and not in open pond (Griffiths and Harrison, 2009). These high concentration of lipids in the cell are observed in low biomass situations where these are made to accumulate lipids under nutrient stress conditions. Hence determining lipid output from high biomass culture conditions is an intriguing field of research (Dean et al., 2010; Rodolfi et al., 2009). On analyzing various studies on increased lipid productivities where microalgae have been grown in small batch cultures, small semi-continuous culture or bioreactors, accumulation of lipid may be at (a) low range (<10% of dry weight), (b) moderate range (25-35% of dry weight) and (c) high range (>35%) when coupled with high biomass productivity. When untreated carpet wastewater was used, the lipid content ranged from 12-18.1% of cell dry weight and varied among species. Cell biomass produced was 23-34 mg/L/day. Biomass production was in the range of 16.1-28 tonnes/ha/year and an estimated lipid production of 3260-3830 L/ha/year (Chinnasamy et al., 2010) suggesting it to be a promising source of energy as well.

Chlamydomonas reinhardtii was grown in batch culture on municipal wastewater collected from a variety of treatment phases wherein it showed total lipid yield of 11.6% of dry weight (Kong et al., 2010) and when grown in biocoil the lipid yield reached to 25.25% of dry weight with biomass productivity of 2000mg/L/day, lipid productivity of 505mg/L/day along with high N and P removal efficiency (Kong et al., 2010). Similarly B. braunii was grown in secondary treated municipal wastewater wherein the lipid content was 17.85% of dry weight and interestingly these values were higher than when compared with the culture grown in synthetic growth medium and the lipid yield was 10.96% of dry weight suggesting that nutrient stress could play a role in the increased yield of lipids (Orpez et al., 2009). On the other hand, mixed algal cultures isolated from local wastewater ponds grown in anaerobically digested dairy manure wastewater in batch cultures reached peak lipid accumulation on the 6th day of growth with lipid content being 14-29% of dry weight and lipid productivity being 17mg/L/day (Woertz et al, 2009). Another such study on dairy manure wastewater treatment by Chlorella species determined total fatty acid content range from 9-13.7% dry weight, biomass ranging from 1.47-1.71g/L with lipid productivity of 11mg/L/day (Wang et al, 2009). These studies indicate dairy manure wastewater to have a potential for algal biomass production but not necessarily biofuels production. Raw swine effluent and diary effluent with or without CO_2 has been compared. Algal productivity on dairy effluent was twice that recorded on swine effluent whereas the lipid content was found to be greater in swine effluent. The fatty acid productivity in dairy effluent was 156 mg fatty acid m-2d-1 and 210 mg fatty acid m2 d-1 without and with CO_2, respectively. In the case of swine effluent it was just 86 mg fatty acid m-2d-1 (Mulbry et al., 2008). These and many other studies suggest that along with biofuel production on waste water, waste carbon dioxide produced could be channelized into increasing both primary algal production as well as the level of lipid accumulation.

CONCLUSIONS

The current scenario on algal biofuel technologies available for an alternative source of energy is likely to be economically non viable. However, dual and multiple use of algae for wastewater purification, algal biofuel production and carbon dioxide sequestration by microalgae is an attractive option with respect to various environmental and energy benefits such as reduction of GHG emissions, cost effective energy and nutrients as fertilizer, carbon dioxide capture etc. The high biomass productivity indicates the potential of generation of biofuel by microalgae as one of the renewable and sustainable methods.

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Energy, Nutrients and Pollutant Recovery from Municipal Landfill Leachate by Sequential Anaerobic and Algal Pond Treatments

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INTRODUCTION

Metro cities in India produce about 3000-7000 tonnes of solid waste per day on an average which in turn contains a large fraction of nutrients like nitrogen and phosphorous. The presence of large extent of fermentable fraction (72-90%), contributes to the high extent of moisture present in the MSW (70-80%). During composting of such wastes by the windrow method or when stacked in the open during monsoon, a high level of dark and odoriferous leachate is produced. This process also leaches out many plant nutrients present in the decomposing waste. The leachate thus produced has potential to be treated anaerobically (Alkalay et al, 1998; Cameron and Koch, 1980) and aerobically (Robinson and Maris,1983; Agdag and Sponza, 2005). The aerobic treatment of leachate is often economically unviable (Ho et al., 1974; Cheung et al, 1993) as lot of energy would be required for aerating the organically rich leachate. There is the additional problem of ending up with a larger quantity of sludge. An anaerobic treatment process therefore significantly reduces the need to constantly remove the sludge from the bioreactor treating leachates (Chan et al., 2009).

While attempting biological treatment of leachate from USW, there are two issues to be addressed with respect to leachate: one is the toxicity of the compounds in the leachate to decomposing bacteria, especially acetogenic and methanogenic bacteria and the other is the presence of recalcitrant compounds that will persist even under best conditions for bacterial decomposition. The toxicity component could either be due to organic or inorganic sources (Pohland and Gould,1986). Inorganic toxicity of leachate is attributed to alkaline earth metals, heavy metals, anions like chlorides, sulphates, sulpendes, nitrates and ammonia (Cameron and Koch, 1980; Alkalay et al, 1998).

The presence of higher quantities of sulphur in the feed/wastewater help the growth of sulphate reducing bacteria that reduce S compounds along with hydrogen to produce H_2S. Under anaerobic conditions this H_2S emerges along with the biogas.

H_2S is corrosive and it reacts with metals to form metal sulphide. However, this property may also be used to precipitate heavy metals as their insoluble sulphides. On the other hand, a higher concentration of hydrogen sulphide suppresses the growth of hydrogenotrophic methanogens as they scavenge and compete for the limited hydrogen availability. Carbonates (CO_3^{2-}), sulphide (S^{2-}), phosphates (PO_4^{3-}) produced during anaerobic digestion may combine with various salts and metals to form their respective carbonates which precipitate along with the sludge (Callander et al, 1983). This phenomenon reduces the complexity and cost of post treatment of anaerobically digested waste water that remove unwanted and potentially hazardous salts and metals from the leachate and thereby renders the digested liquid more usable in agriculture and aquaculture. The leachate is a rich source of nutrients like nitrogen, phosphates, etc and this property could be utilized to recover value from the process of treatment. Organic toxicity (toxicity to methanogens in particular) could be due to several hydrolysable tannin derivatives like gallatonic acid polymers, gallic acid polymers and pyrogallol. Much work on pthalic acid esters, substituted phenol, and other aromatic compounds has been carried out earlier (Young.,1984, O'Connor and Young 1989).

The recalcitrant compounds generally encountered are humic, fulvic and hymatomelanic acids which contribute to know more than 50% of the soluble organics in what is generally referred to as the secondary leachate (Rebhun and Manka, 1971). It must be noted that the concentration of recalcitrant compounds is the same before and after aerobic or anaerobic treatments though the overall degradation is 50% more in aerobic treatment (Gourdon et al, 1989).

Under the current scenario it is considered important to remove the N from wastewaters, where N in water is considered a pollutant. All modern wastewater treatment systems are designed to 'strip' the wastewater of the N content. Current methods like ammonia stripping are known to have 93% removal of ammonia nitrogen (Cheung et al 1997). However, the focus now should be more towards sustainable nitrogen recovery. A biological approach towards sustainable N recovery is to grow and harvest algae on the wastewater in question simultaneously obtaining a value added product as well as pollutant removal. Research efforts on nutrient uptake and nitrogen removal by algae have been carried out in various places. Garcia et al (2000) studied the effect of retention time and concluded that the algal pond with retention time of 7 days had a nitrogen removal of 73% whereas the pond having retention time of 4 days had nitrogen removal efficiency of 57%. Nitrogen removal efficiencies by algal and duckweed-based systems have reported 55.85% removal by algal ponds and 44.6% removal by duckweed, respectively (Zimmo et al, 2004). The nitrogen and phosphorous scavenging potentials as well as the influence of various organic N forms in various micro algae have been reported earlier (Lau et al, 1994; Singh et al, 2007). Many studies have shown that ammonium is a preferred source of nitrogen in comparison to nitrate (Thompson et al, 1989; Przytocka-Jusiak et al, 1984) as is found in the case in most leachate sources. However, higher concentrations of ammonia are toxic to algae. Ammonia at a concentration >2mM (=34mg/l) and at pH values above 8 inhibits photosynthesis of *Scenedescmus obliquus* (Abeliovich et al, 1976). A 20.4mg/L free NH_3 led to a 50% reduction in algal assimilation of carbohydrates (Azov and Goldman, 1982). Also photosynthesis of *Chlorella pyrenoidosa*, *Anacystis nidulans* and *Plectonema boryanium* is susceptible to ammonia inhibition at a concentration of ammonia 5mM above pH 7 (Abeliovich et al, 1976). Other reports have assessed the toxic effects of leachate by culturing *Chlorella, Dunaliella and Scenedesmus* species (Cheung et al, 1993).

The objectives of the present study were to evolve and verify a set of treatment options keeping in view a lower maintenance need, easy operation, higher treatment level that are as follows: 1. Use anaerobic digestion of landfill leachate as a primary treatment method that can reduce the organic loading of the leachate to create a byproduct (e.g. biogas) that can be used as a fuel. 2. Quantify the metal precipitation that occurs during anaerobic digestion 3. Use a consortium of algae (e.g. Spirulina etc) as a secondary treatment option to recover the nitrogen, phosphate, salts remaining in the anaerobically digested leachate.

MATERIALS AND METHODS

Leachate collection

Leachate was collected from a waste processing site in north Bangalore. The composting site accepts around 300-600tpd of MSW per day for processing. A part of it is sent for composting and another part for landfill. The leachate samples were collected from the compost yard (called windrow leachate) and from landfills in the immediate neighbourhood on three occasions (07 Aug 2010 and 6th Nov 2010, 7th Feb 2011). Samples were collected from the leachate pond fresh and as they were filling into the pond and may be considered as fresh leachate. At the study site windrow leachate was being channelized to a leachate collection pond prior to sending it for treatment. All leachate samples collected and studied here were sampled fresh, frozen within a few hours for studies to be carried out later. Another type of leachate from the landfill site originated from freshly piled wastes and had significant decomposable organic matter. There were incidences of rainfall prior to the first two sampling dates and therefore the leachate samples could have been more dilute than found in dry weather.

Algae Isolation

An algal species adapted to this leachate was collected from a natural pond near the landfill site. This pond received appreciable quantities of leachate from a landfill closed and abandoned earlier and was carried into the pond both as seeping leachate as well as along with runoff. This alga, identified as *Spirulina,* grew in thick mats on this pond for nearly 2 years and is therefore believed to be adapted to the organics and inorganics of the leachate. This algal mat was collected (Fig. 1) and cultured in a conical flask containing media of the following composition (as g/L) $NaHCO_3$ -15, Na_2CO_3 - 8.89, NaCl - 0.92, Na_2SO_4 - 1.88, KNO_3 - 2.57, $CO(NH)_2$ – 0.0766, K_2HPO_4 - 0.5, $MgSO_4.7H_2O$ - 0.25, $CaCl_2.2H_2O$ - 0.05g/l. These cultures were placed in sunlight to enable growth.

Anaerobic treatment of leachate

The biological methanation potential (BMP) of the leachate was estimated similar to the methods followed for the BMP assay for agricultural or solid organic waste. This used anaerobic bacterial inoculum from the biomass based biogas plants located in CST (ASTRA), IISc. 10ml of bacterial inoculum and 50ml of the leachate were crimped in 125ml serum vials and the gas production volume was noted at appropriate intervals, more frequently at the early stages and less frequently after 25 days. The BMP assay was carried out for 80 days and the composition of biogas produced was constantly monitored. Also the leachate from windrow and landfill sites were set up for batch digestion in 4, 2 litres PET bottles. The treated leachate from the PET bottles was used to raise algae.

Chemical properties

Standard wastewater analysis like COD, BOD, pH, TKN of the treated leachate and untreated leachate was carriedout according to the methods given in APHA 1985. After anaerobic treatment, the residual leachate was decanted carefully to separate the settled matter (sludge) and the supernatant. In order to measure the alkaline earth metals and heavy metals, the treated and untreated samples were filtered using a 0.45 micron cellulose filter and their concentrations were measured in a Fischer Inductively Coupled Plasma –Atomic Emission Spectroscopy (ICP-AES) set at a temperature of 10000K with argon as the carrier gas. The composition of the biogas was measured using a gas chromatograph with a FID detector set at 350°C, oven temperature of 90°C with nitrogen as the carrier.

Algal cultivation on leachate

The anaerobically treated leachate obtained from the PET bottles was diluted 10 times and 0.5g wet weight of *Spirulina* from the stock was inoculated and maintained as batch cultures. A compact fluorescent lamp (CFL) with a power rating of 15W was used which corresponds to approximately 800 lumen. The growth rate was monitored at weekly intervals for the first 15 days and reported as mass of algae (wet) per m^2 of growth area . A control with leachate diluted 10 times was maintained without any algal inoculation where no growth of *spirulina* observed to occur /arise from natural sources. While the early studies on algal growth was carried out in batch mode coupled with total material harvest, latter studies employed a batch-fed mode harvesting between 20-30% of algae weekly (40% by volume). The fed batch mode was carried out with a working volume of 300ml while maintaining 60mg N/L (from leachate).

RESULTS AND DISCUSSION

The BMP assay was carried out for a period of 90 days (Fig.1). This showed considerable biogas production of 588.8 l/kg VS which corresponds to 0.588m^3gas/kgVS with a COD reduction of 77.6% and 97% BOD reduction. The BMP pattern showed the need for a short 10 days acclimation time even in the presence of a very large level of inoculum used. After a 10 days acclimation, the gas production rate was rapid. The leachate was used with its current concentration and no dilution was attempted in the BMP. The rapid decomposition following the acclimation period indicates that under continuous digestion using an acclimated sludge /inoculum, the HRT required would be low. Biogas produced had 60-75% of methane from the 15^{th} day of the BMP assay. This suggests that VFA induced inhibition of methanogens are unlikely with this feedstock. We infer that the dark colour of the remaining COD (22.4%) after anaerobic digestion maybe due to the presence of humic acids that do not undergo degradation under anaerobic conditions (Christensen et al, 1998). However, further research needs to be carried out to determine the optimum HRT and sludge recycling rate required for this leachate for effective anaerobic treatment at a large scale. The initial BOD/COD ratio is 0.284 which reduced to 0.052 after anaerobic digestion. The extent of BOD reduction and removal of suspended organic matter is very clear in the photo of the digesting leachate, especially in micro-digesters using biomass biogas plant sludge as inoculum (Fig. 2). This clearly indicates that a reasonably clear effluent could be recovered from an anaerobic stage and this clarity (absence of turbidity) would be quite useful for algal growth. Nevertheless the presence of humic acid in the leachate is not toxic to algae or soil. However anaerobic digestion has its own limitations in reducing the nitrogen concentration from the leachate that was evident from a mere 7.4% reduction in N concentration occurring during anaerobic digestion.

Fig. 1
Pond near leachate treatment plant with algal growth

Fig. 2
Leachate before and after anaerobic treatment

The presence of alkaline earth metals and heavy metals at the current concentration (Table 1) did not affect the anaerobic bacteria with respect to production of biogas. Nevertheless anaerobic digestion played an important role in reducing the concentration of heavy metals especially the alkaline earth metals by precipitation. As biogas produced has lower concentration of hydrogen sulphide and higher carbon dioxide concentration, these play an active role in precipitations of heavy metals due to the formation of their respective metal sulphides, metal carbonates and partly due to adsorption onto bacterial sludge. Some degree of heavy metal removal was detected and the exact mechanism needs to be investigated later (Table 1). For the proper functioning of methanogenic bacteria, a slightly alkaline environment (>7) is preferred, which also ensures that the precipitated heavy metals do not resolubilize into the digested leachate. Pickling of anaerobic digester due to accumulation of volatile fatty acids can also reverse the precipitation of heavy metals. Therefore failed anaerobic digester would also fail to reduce the metal concentrations.

Table 1
Parameter analysis before and after anaerobic digestion of leachate

Parameter	Fresh Leachate from windrows (07 aAg 10)	Windrow leachate after anaerobic digestion
Ca	357.2	48.83
K	2645	2097
Mg	195	150.9
Na	1546	1229
Pb	0.1996	0.678
Zn	0.4783	0.3706
Fe	1.429	1.991
Cr	0.125	0.7415
Sn	-0.0023	0.0978
Mn	0.1724	0.0472
Ni	0.2408	0.1052
Al	0.4497	ND
Si	25.7	62.46
Cu	0.1612	ND
Co	0.0367	ND
COD	7040	1580
BOD	2000	60
TKN	920	852

ND-not detected

The anaerobically digested leachate still has high nitrogen concentration with non dischargeable COD which needs to undergo a secondary treatment. Therefore an algal growth on the anaerobic digested leachate was carried out. The treated leachate had the brown colour, albeit at lower intensity, as comparable to untreated leachate. This limits their direct application in algal cultivation because light penetration is hampered to some degree and could be a rate limiting factor. In order to avoid this, the leachate was diluted to a level that can ensure maximum light penetration for the algal growth. The algae grown in the anaerobically treated leachate (diluted ten times) followed the growth curve pattern as shown in Fig. 3. It was accompanied by a nitrogen loss from the system as shown in Fig. 4 and Fig. 5. The algae had an initial 2 day lag phase (which is likely to reduce in further inoculations as it would have adapted to the concentrations maintained).

However, on 11 days algal species resembling C*halmydomonas* species was observed. After a prolonged period of cultivation it was noticed that several mosquito larvae

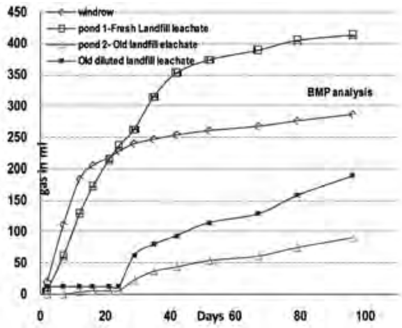

Fig. 3
BMP assay of different types of leachate

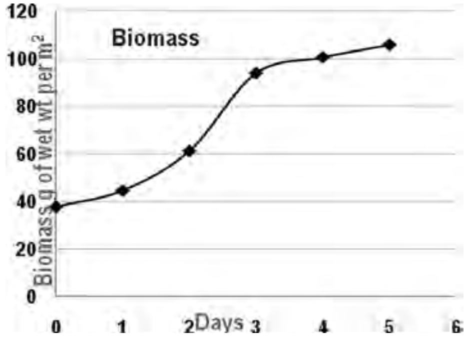

Fig. 4
The growth curve of algae growing in anaerobically treated leachate

began to grow in the medium. Within a couple of days of detecting larvae, most algal species were found to disappear, presumably fed upon by the larvae. Such occurrences were observed only in the control and were not found to occur in other cultivation ponds using leachate.

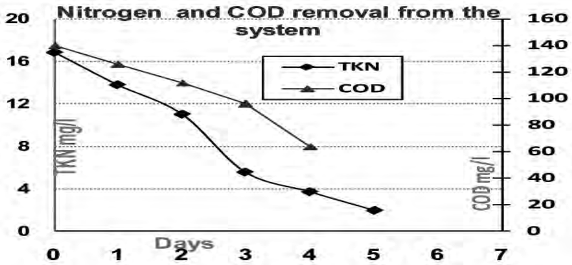

Fig. 5
Nitrogen removal in the diluted anaerobically treated leachate during algal growth stage

The harvesting of such algae is very simple as they form mats (Fig. 6) and can be easily filtered or harvested at night when they settle at the bottom. In order to achieve easy harvest with low moisture content, the supernatant water could simply be siphoned from the tanks leaving behind a settled algal mat that could easily be harvested. In this way it forms an energy efficient system of nutrient and algal biomass recovery.

These unsterilized cultures were prone to contamination (Fig. 7) and results and observations suggest that this can be minimized by optimizing the feed rate to maintain pH levels ≥ 9. Many other studies discuss direct treatment of leachate with algae, we suggest anaerobic treatment followed by algal treatment since valuable energy can be captured as well as the colour of the leachate is greatly reduced making it more suitable for light penetration hence for higher algal yields. Lin et al (2007) report that *Chlorella pyrenoidosa* and *Chlamydomonas snowiae* are inhibited by ammoniacal nitrogen ≥600mg/l. It then makes it possible to grow algae directly

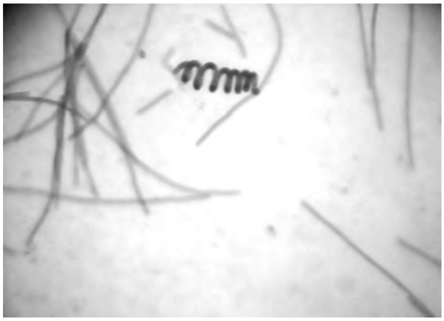

Fig. 6 & 7
The algal mat formation and the microscopic images of the culture

in leachate with concentrations of 400mg/l, which is average ammoniacal N found in leachate (Kulikowska and Klimiuk, 2008). In our study the leachate was diluted to allow algal growth at 60mg/L considering the reasonable dark colour of the leachate. However, it will be interesting to gradually acclimate the culture to grow at the current concentration reaching 400-600mg/L.

With leachate as the medium for algal growth, the issue of metal uptake and adsorption by algae is an important one. Biosorption, the process of passive cation binding by dead or living biomass, represents a potentially cost effective way of removing toxic metals from industrial wastewaters. It was found that the accumulation of heavy metals by algae is one of the most effective methods. Studies of Nourbakhsh et al. (1994) and Tsezos and Volesky (1981) showed that the non-living algae may have the same or even greater adsorption capacity than living algae. If the dead algae is being used then the pH maintained would be 6 so as to keep the metals in the soluble form whereas the living algae maintain the pH well above 7, hence the metals are usually not in soluble form resulting in lower adsorption. Previous work (Gamham et al, 1992; Aksu and Kutsal, 1991) showed that the adsorption processes were carried out in two steps, starting with the rapid one (physical adsorption between the metal ions and the algae surface) and then the slow one (chemical adsorption). Metal ion binding during biosorption processes has been found to involve complex mechanism, such as ion-exchange, complexation, electrostatic attraction and microprecipitation (Volesky and Holan, 1995). In our study we are unable to distinguish heavy metals that could be partitioned to be removed by the above individual processes although the total metal removal is reported here.

CONCLUSIONS

In this study we demonstrate the potential for a three stage sequential treatment of compost-yard and landfill leachates wherein it is possible to firstly use an anaerobic digestion process with acclimated inoculum to remove over 97% BOD, second remove a large extent of alkaline earth and heavy metals by precipitation in an anaerobic reactor with longer HRT, third treat the remaining humus rich effluent by algal culture to oxidize the organic content while simultaneously remove soluble nutrients such that the leachate could be reused in agriculture or aquaculture. The use of microalgae (*Spirulina* singly or unspecified mixed culture) in enabling uptake of nutrient from anaerobically treated leachate has been found to be viable.

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Decentralized Energy Potential of Bangalore Solid Waste

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INTRODUCTION

With an estimated population of 7.8 million, Bangalore is among the five large cities of India. It covers an area of 800 km^2 (BBMP, 2010). The city's waste is characterized by a high content of fermentable components (72%) where domestic and eatery sectors contribute over 75% of total wastes (Chanakya and Sharatchandra, 2005). Presently, Bangalore employs a quasi-centralized collection system leading to landfilling of collected wastes. Various forms of informal waste recycling processes function in the cities of Karnataka and their value addition has been described earlier (Van Beukering, 1994).

USW GENERATION

Bangalore city generates around 3000 to 4000 tpd of USW– the daily collection is estimated at 3600 tpd (Chanakya *et al*., 2009). It comprises of wastes generated from residences, markets, hotels and restaurants, commercial premises, slums, street sweepings and parks. Residence contributes 55% of total of wastes and is highest among all sources (TIDE, 2000). Waste generated from hotels and eateries form about 20%, fruit and vegetable markets contribute about another 15%, trade and commerce about 6% and from street sweeping and parks form about 3%. The slum areas contribute only 1% of total USW, since in Bangalore slum population and area is low in comparison to other towns and cities.

USW COMPOSITION OF SEVEN CITIES OF KARNATAKA

The waste composition of Bangalore comprising: 72% fermentables, 11.6% paper and cardboard, 1.01% cloth, rubber, PVC and leather, 1.43% glass, 6.23% polythene, 0.23% metals and 6.53% of dust and sweeping (TIDE, 2000) is given in Table 1. In one study we have conducted in year 2010 in seven important cities (Tumkur, Puttur, Mandya, Hassan, Davangere, Chikkaballapur, Belgaum and Nanjangud) of Karnataka. We have selected 15 houses randomly at the ward level and it has been monitored for three continuous days. Waste composition of seven cities show 82% fermentable, 11% paper and cardboard, 8% plastic and 1% of metal. City-wise waste composition is given in Table 2. Among all cities, Chikkaballapur and Hassan have high percentage of fermentables. Percentage of paper and cardboard and plastic are highest in Tumkur.

Table 1
Physical composition of USW in Bangalore

Waste type	**Composition (% by weight)**						
	Domestic	Markets	Hotels/ eatery	Trade and commercial	Slums	Park /street sweepings	Avg. All sources
Fermentable	71.50	90	76	15.6	29.9	90	72
Paper and cardboard	8.39	3	17	56.4	2.49	2	11.6
Cloth, rubber, PVC, leather	1.39		0.33	3.95	0.54	0	1.01
Glass	2.29		0.23	0.65	8.43	0	1.43
Polythene/ plastics	6.94	7	2	16.6	1.72	3	6.23
Metals	0.29		0.26	0.38	0.23	0	0.23
Dust and sweeping	8.06		4	8.17	56.7	5	6.53

Source: TIDE, 2000

Table 2
Physical composition of domestic USW in seven cities of Karnataka

Waste type	**Composition (% by weight; source – unpublished CST report)**								
	Tumkur	Puttur	Mandya	Hassan	Davan-gere	Chikka-ballapur	Belga um	Nanj angud	Aver age
Fermentable	84.37	78.95	77.94	91.37	81.43	92	83.83	69	82.36
Paper and cardboard	35.35	5.62	13.02	4.99	6.24	4	7.33	8.50	10.63
Leather and Cloth / textiles	0	0.90	0	0	1	0	1.31	0	0.40
Glass	3.77	4.11	0	0	2	0.38	2.34	1	1.70
Polythene /plastics	18.64	7.37	9.04	3.64	9	2	5.50	7.13	7.79
Metals	0	2.78	0	0	2	0.64	0.41	0.02	0.73
Inert and dust	0	0	0	0	3.14	0	0.71	14.97	2.35
Recyclables	0	0.27	0	0	0	0	0.17	0	0.05

When we compare physical waste composition of small cities with metropolitan cities, it is clear that both have high percentage of fermentables. Fermentables incorporate food waste, garden waste, vegetable waste and fruit waste. The elemental composition of these constituents of fermentable is derived based on elemental mass percentages on dry basis as listed in Table 3. The average elemental composition of the organic fraction of the USW is presented as $C_5H_{8.5}O_4N_{0.2}$ (Bizukojc and Ledakowicz, 2003). Degradation of fermentables in the open environment emits Green House Gases (GHG) like methane (CH_4) and nitrous oxide (N_2O) along with leachate containing Carbon and Nitrogen impacts the underlying lithological strata. High percentage of wet and fermentable waste, require daily removal and treatment. In a decentralized system, wastes gathered from primary collection by handcarts may be subject to immediate treatment by aerobic composting or biomethanation within the locality or ward. In wardwise waste treatment with biomethanation, as the wastes gradually becomes enriched with decomposable material; it also becomes an increasing source of energy. From 1988 to 2000 there is reasonable change in waste composition: fermentable, paper and plastic has increased by 7%, 3% and 0.2%, respectively.

Table 3
Elemental composition of these constituents of fermentable

Waste type	**Mass percentages on a dry basis**				**Elemental composition, based on molecular weight of elements**
	C	**H**	**O**	**N**	
Food waste	44.83	6.38	32.13	2.83	$C_{18}H_{32}O_{10}N$
Yard or garden waste	42.35	5.33	31.89	1.62	$C_{29}H_{44}O_{17}N$
Vegetable peals	49.06	6.62	37.55	1.68	$C_{34}H_{55}O_{20}N$
Fruit peals	47.96	5.68	41.67	1.11	$C_{51}H_{72}O_{33}N$

Source: Rhyner *et al.*, 1995; Tillman, 1991 as referenced in Meraz *et. al.*, 2003

ENERGY AND RESOURCE RECOVERY CLOSE TO SOURCE OF GENERATION

Case 1: Potential recovery with aerobic composting

Ideal USW processing requires near perfect source segregation of USW at the point of generation – namely households. This requires a great social/attitudinal change and is likely to be slow in happening. A medium term measure is possible: segregation immediately outside houses - during collection immediately thereafter. There are many dispersed attempts to do so - the RMV II experience in Bangalore is cited here. This field data collected for 21 days in a ward 'RMV extension stage II' near IISc campus. BBMP is managing the MSW at this locality. The ward councillor was interested in improving waste management system. A 60 days project was started by NGO 'Exnora Green Cross' in this locality. The system planned included primary collection with gradually increasing level of source segregation (into organic and inorganic waste), storage and disposal of different types of solid waste in an environmentally friendly manner. Trained waste collectors were appointed for door-to-door collection and for waste segregation. Every day on an average around 2.6 kg fermentable wastes were collected from each of the families. The fermentables (including food waste and garden wastes) were composted on raised platforms to ensure better aeration and lower smell. With the progress of time number of composting beds was increased. This increased number of compost beds increased the associated problems like smell and flies. After 21 days this project was stopped by ward councillor fearing election reversely. However, meticulous data was collected as to the types and quantities of recyclables that were brought to this site. Based on this project information, economic costs are calculated for decentralized waste management with compost plant as given in Table 4. Under the existing scenario, we show that with compost as the main product and in an enterprise mode and under conditions existing in Bangalore the cost recovery period would be in the range of 4 years (Table 4, assuming 100% recycling). This is however identified and may not be achieved easily. The potential capability to recycle may then be between 50-80% of recyclables in the wastes. Under this optimum scenario it is clear that capital recovery may not be possible at all.

Table 4
Decentralized Waste Management with compost plant

Decentralized Waste Management with compost		
Categories	**Rs/year**	**Optimum Scenario**
Capital Investment	206500.00	
Cap costs Rs/yr@10.00%	20650.00	
Depreciation	38225.00	
Maintenance	30975.00	
Operation cost (Rs/yr)	493946.00	
Total expenditure per year	**583796.00**	583796.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Compost sale	229950.00	183960.00
Total net income per year	**584469.11**	**467575.29**
Surplus of income over expenditure	673.11	-116220.71
Capital Recovery Period	306.8	

Case 2: Potential recovery with biomethanation process

The decentralized processing and recycling system based on compost and 100% recovery shows a small promise of profitability in an enterprise mode assuming this is carried out on a soft lease basis (no land costs). It is obvious that it is economic only at 100% recovery and this may be difficult to achieve. There is clearly a need for another source of revenue generation to make the enterprise profitable. Thus instead of aerobic composting the organic fraction (leading to only one saleable product – compost), it is proposed to convert it to biogas and compost (two saleable products) by installing a biomethanation plant of the CST design – similar to the one successfully operated for over 5 years in Siraguppa (Rahman *et al*, 2009). We examine the conversion of the fermentable to biogas and expect that sale of biogas locally would offset the financial deficit projected above.

In this scenario, the extent of recyclables recovered and earnings accrued does not change from the previous scenario, the income from collection fees also remains the same. The various costs and returns on investment are worked out for a decentralized waste management with a biomethanation plant as given in Table 5. In this scenario, it is clear that under ideal situation of 100% recovery of recyclables, collection costs and biogas and compost revenues, the payback period is only 2 years. Even under an 80% recovery situation, the viability is good.

Table 5
Decentralized Waste Management with biogas plant

Decentralized optimum Waste Management with biogas plant		
Categories	**Rs/year**	**Optimum Scenario**
Capital Investment	586500.00	
Cap costs Rs/yr@10.00%	58650.00	
Depreciation	35425.00	
Maintenance	39975.00	
Operation cost	493946.00	
Total expenditure per year	**627996.00**	627996.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Income from biogas	325215	260172.00
Compost sale	229950.00	183960.00
Total net income per year	**909684.11**	**727747.29**
Surplus of income over expenditure	**281688.11**	**99751.29**
Capital Recovery Period (years)	2.1	5.9

DECENTRALIZED ENERGY POTENTIAL OF BANGALORE USW-USING BIOMETHANATION

An estimated quantity of USW of 3600tpd of Bangalore can generate 0.1944 million m^3 of biogas/d, which can be used as source of energy LPG substitute. The city has 198 wards with variations in area and population spread. A decentralized wardwise biogas generation is planned using average per capita waste generation (BBMP, 2010) and population statistics of Bangalore. Since a major fraction of wastes come from residential area, so to capture this waste, we considered the per capita waste generation of the city. Assuming that all the city wastes collected from houses reaches to treatment sites, we have calculated the biogas from all the wards of Bangalore. Usually, one ton of fermentable generates 75 m^3 of biogas in plug flow model of biogas plant designed in CST. We also assumed that in each of ward has collection and segregation facility and treated in plug flow biogas plants. A wardwise biogas production is given in Fig 1. Total quantity of biogas varies from 364 to 691m^3/d. In central part of city where population is dense it shows high production of biogas in comparison to periphery of the city, where population is less dense. Waste generated from commercial places other than restaurants could then be sort for recycling – while that remaining as unfit for recycling would be small and sent to landfills. In this way compared to the nearly 100% landfilling practiced today, the net USW to be landfilled in this scenario will be <10% currently generated.

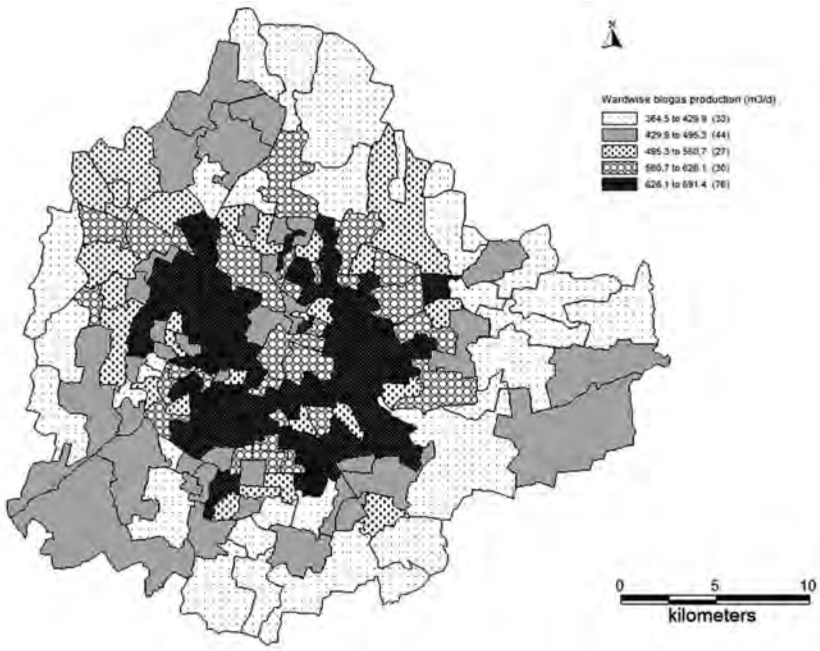

Fig. 1

Decentralized energy (biogas) production in Bangalore

CONCLUSION

The costs of USW collection, transport, processing and disposal have gradually become high. There is a need to treat the waste nearer to source to offset there high costs. Biomethanation process provides a clean energy source (biogas) along with compost for treatment of fermentables. This approach requires setting up decentralized anaerobic digestion (biomethanation) within residential. Decentralized systems run so far (other than biogas plants) have had aesthetic (smell and insect) and economic problems and have always been short lived. Biomethanation plants also provide many sources of revenue from sale of biogas, compost and by-products. In this paper we also present wardwise distribution of biogas potential in the city. It also gives an idea where waste generation is more. It is therefore important that this concept be tried with at various municipalities so that we could become zero-waste cities of the future and we will look at wastes as a source of energy.

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Growth Rates, Nutrient Removal, Energy Production and Wastewater Treatment Potential of some Green Algae

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INTRODUCTION

There is an urgent need to develop biofuels because of increasing global energy demand and depleting petroleum resources. Algae are seen as potential candidates, however there is a great shortage of natural and fresh water resources to grow these algae (Amarasinghe et al, 2007). Cultivating algae in industrial and domestic wastewater can simultaneously purify wastewater and generate algal biofuel feedstock. The need to produce biofuel crops, including algae, is likely to create heightened competition for fresh water, land and fertilizers, all of which will lead to the difficult issues of food versus fuel versus wastes.

Microalgae are considered potent feedstock candidates for biofuels as they can be raised on ponds made on non-arable lands. Algae have a large water footprint in terms of energy returned on water invested (0.5–1.1 for enclosed and 0.05–1.0 MJ L^{-1} for open ponds; Subhadra et al, 2011). They require as high as 11–13 million liters of water per hectare for cultivation in open ponds along with significant macro-nutrients like nitrogen and phosphorous, representing 10 to 20% of the total cost involved in algal production (Chinnasamy et al, 2010). The cost of nitrogen and phosphorus fertilizers have almost doubled between 2003 and 2010 translating into increased cost of algal biomass production. For economic viability, the cost of production needs to be lowered by 20–25 folds. Thus it is essential to find alternative sources of water and nutrients for large-scale cultivation of algae to produce biofuels and other valueadded products. It has been suggested that wastewaters (Chinnasamy et al, 2010) and wastes rich in organic and inorganic nutrients (Jiang et al, 2009) may be used in place of freshwater and fertilizers, respectively.

The alga, *Botryococcus braunii* has been shown to yield an extract containing 70% hydrocarbon that closely resembles crude oil. *B. braunii* is classified into A, B and L races depending on the type of hydrocarbons synthesized. Race A produces C_{23} to C_{33} odd numbered *n* alkadienes, mono-, tri-, tetra-, and pentaenes, that are derived from fatty acids (Metzger et al, 1990). Race B produces C_{30} to C_{37} unsaturated hydrocarbons known as botryococcenes and small amounts of methyl branched squalenes (Metzger et al, 2005). Whereas race L, produces a single tetraterpenoid hydrocarbon known as lycopadiene (Metzger et al, 1990). Hydrocarbons extracted from the alga can be converted into fuel such as gasoline and diesel by catalytic cracking (Hillen et al, 1982). *B. braunii* (Races A and B) strains are also known to produce exopolysaccharides up to 250 g/m^3, whereas L race produce up to 1 kg/m^3 (Banerjee et al, 2002).

Many algae are facultative in such a mixotrophic lifestyle, an alga can first consume the organic component of pollutants and later on, in autotrophic mode, consume a large fraction of plant nutrients such as nitrogen and phosphorus in these wastewaters. In such a case, many dark colored wastewaters become potentially amenable for algal mediated remediation with generation of algal biofuel (Wen et al, 2003). The mixotrophic growth of *Chlorella protothecoides* is reported to produce 69% higher lipid yield on glucose with 61.5% less release of CO_2 as compared with typical heterotrophic metabolism (Xiong et al, 2010).

The utilization of wastes and wastewaters to cultivate algae could simultaneously solve the problems of: (1) freshwater demand (2) high cost of nutrients and (3) need to remediate waste. However, most wastewater streams vary greatly in composition (e.g. carpet industry effluents, poultry litter, slaughter house wastes, dairy effluents, swine wastes, municipal waste and wastewater, compost plant/landfill leachate and effluents from anaerobic digesters). These are rich in plant nutrients but are often hindering light penetration and have reducing effect on algal photosynthesis.

MATERIAL AND METHODS

Monoculture of *B. braunii: B*. *braunii*, isolated originally from fresh water ponds in Mamallapuram, Tamil Nadu, India were subcultured on modified Chu13 media (Largeau et al, 1980). Sugar factory wastewater was sampled from Mysugar, Mandya which was then passed through activated charcoal to achieve a COD and pH 1496mgL^{-1} and 6.5 respectively. Dairy wastewater was collected from Mysore - Chamarajnagar Dist. Cooperation. Milk Producer's Societies Union Ltd., Mysore which had a COD and pH of 1134mgL^{-1} and 6.8 respectively. Both the wastewaters were inoculated with *B. braunii* at various concentrations as indicated below. Alga was grown in 250ml conical flasks, in triplicates.

- o Undiluted effluent with and without centrifugation
  - ➢ Dairy Waste: 40ml untreated dairy waste + 1ml alga (cdw, fdw).
  - ➢ Sugar Waste: 40ml sugar industry wastewater + 1ml alga (csw, fsw).
- o Diluted Cultures
  - ➢ Dairy Waste: 20ml untreated dairy waste + 20ml distilled water + 1ml alga (ddw).
  - ➢ Sugar Waste: 20ml sugar industry wastewater + 20ml distilled water + 1ml alga (dsw).

- o Partial Media Culture
    - ➢ Dairy Waste: 20ml media + 20ml untreated dairy waste + 1ml alga (mdw).
    - ➢ Sugar Waste: 20ml media + 20ml sugar industry wastewater + 1ml alga (msw).
- o Control medium: 40ml media + 1ml alga (control)

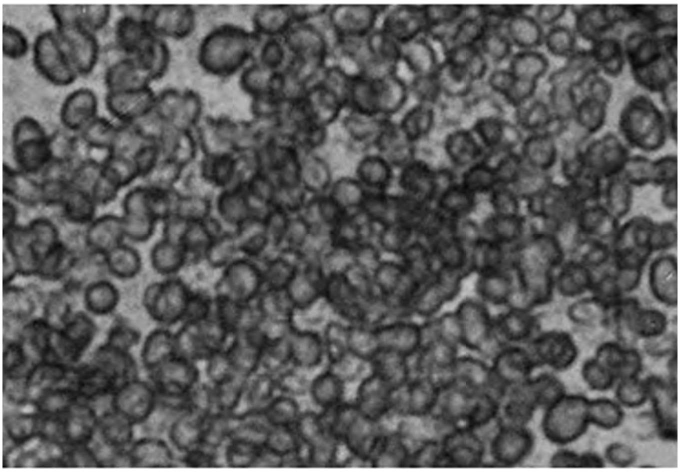

Fig. 1
Light microscopic (40X) picture of the alga Botryococcus braunii

The pH of each of the culture was adjusted to 7.5 with KOH before autoclaving (Lee et al, 1998). All the cultures of *B. Braunii* were incubated at 25±1°C temperature with 1.2±0.2 klux and 16:8 light dark cycles for 30d.

Mixed Culture of Green Algae: Mixed cultures were raised on biogas plant wastewater that had a nitrogen and phosphorus composition as presented in Table-1. The mixed algal communities were originally from various nitrogen rich wastewaters of Karnataka.

Table 1
Composition of Synthetic sewage and Wastewater from Anaerobic digestor

Parameters Measured	Synthetic Sewage	Wastewater from anaerobic digestor
COD (mg/l)	392	410
TKN (mg/l N)	20.16	18.54
TP (mg/l N)	10.2	8.3
Sulfates (mg/l)	30	30
Alkalinity (mg/l as $CaCO_3$)	117.6	1125

The four sets of mixed species were (Fig. 2):

1 *Gomphonema, Pinnularia* and members of *Euglenophyceae (MSp-1)*

2 *Anabeana, Chlorella* and *Nitzchia (MSp-2)*

3 *Ulothrix Nodularia,and Palmella* (suspected; *MSp-3)*

4 *Chlorococcum and Chlorella (MSp-4)*

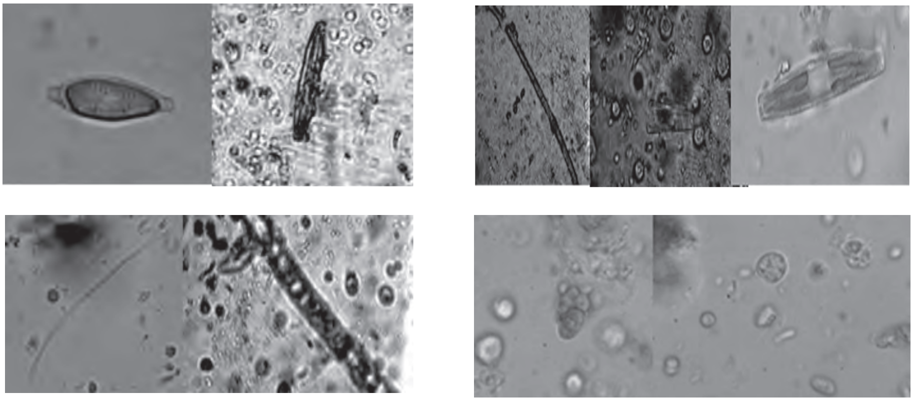

Fig. 2
Mixed species isolated from the existing water bodies.

The cultures also had a few other members of the classes of cyanophyceae, chlorophyceae and bacillariophyceae in a small percentage.

Four sets of mixed species were grown in duplicates in both the anaerobic and synthetic wastewater along with controls that involved growing the algae in tap water free from chlorine. The ponds used for this purpose had a surface area of 0.12 m^2. The algae were harvested using a 100μ nylon mesh placed in a funnel on the 7th day. Algal biomass was derived and chlorophyll estimations were made as per Lichtenthaler et al, (1987). Hydrocarbons were extracted in hexane and analyzed gravimetrically as well as by GC (Dayananda et al, 2005).

Wastewater quality parameters were measured as per Standard Methods, APHA(1975).

RESULTS

Effect of Spent wash and Dairy waste on the Monocultures: Our experiments showed that the wastewater from the sugar industry is rich in potassium, phosphorus and nitrogen and needs to be treated before discharging it into any of the natural water body. Similarly, dairy waste was found to be rich in nitrogen and hence require efficient nitrogen removal before its discharge into any natural water body.

B. braunii was able to grow in all the concentrations of wastewater from sugar industry and dairy waste. Fig. 3 and 4 depict that the biomass yield was maximum in centrifuged sugar waste (csw) with the yield of 0.956gL^{-1}. Media sugar waste (msw) supported the algal growth similar to that of the control media. Among the various

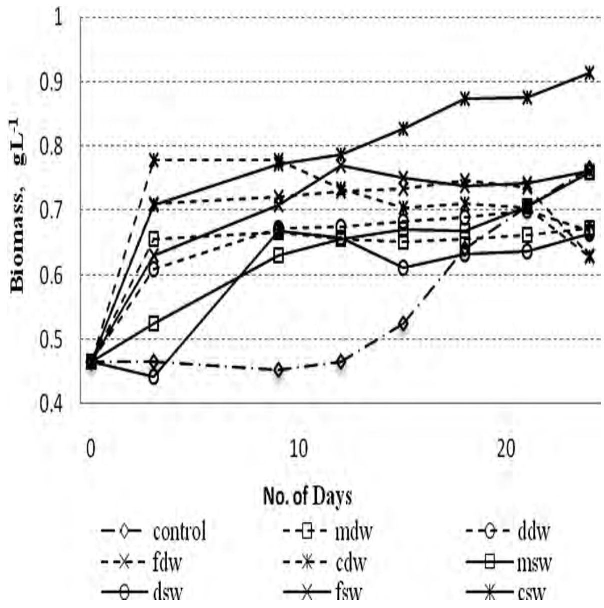

Fig. 3
Growth of the alga in sugar waste and dairy waste

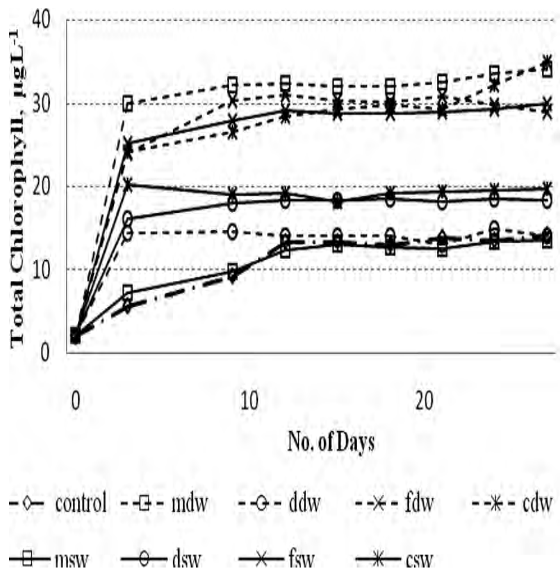

Fig. 4
Changes in the total chlorophyll content in different cultures of sugar waste and dairy waste

concentrations of dairy waste, media dairy waste has performed the best with a biomass yield of 0.69gL^{-1}. The total chlorophyll in centrifuged concentrated dairy waste (cdw) and media sugar waste (msw) is highest.

Fig. 5 shows that the percentage of lipid accumulated by the algal biomass in the control media was maximum. Among the various concentrations of dairy waste, dilute dairy waste accumulated maximum lipid (58.6%) and among the various concentrations of wastewater from sugar industry, media sugar waste accumulated a maximum of 47.1% of lipid. Further, from Fig. 6, it is evident that there exists a considerable reduction of COD in both the types of wastewaters towards the end of the inoculation period.

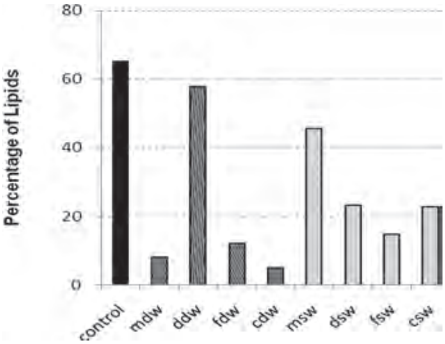

Fig. 5
Influence of the culture with different concentrations of wastewater on lipid production

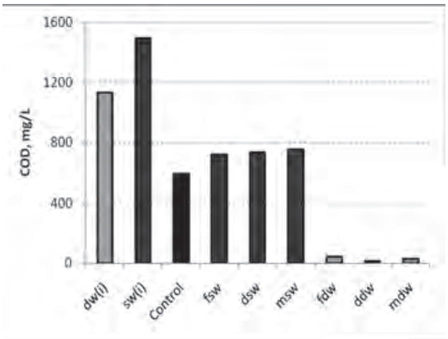

Fig. 6
Initial and final COD values of the wastewater before and after treatment

Effect of synthetic sewage and wastewater from the Anaerobic Digester on the mixed cultures: The algal dry weight of mixed species 4 (MSp-4) could not be quantified in anaerobic digester wastewater by the method adopted here, as the algae did not form clumps and remained in a suspension and was not easily harvestable. However, the same inoculum was able to form a high density culture in synthetic wastewater along with the formation of harvestable clumps of algae. It is necessary to mention that the dry weight reported here accounts only for the algae that can be harvested by filtering through a 100μ mesh. The total nitrogen uptake has been calculated based on the percentage of nitrogen in each mixed species of algae and their corresponding dry weights (Fig. 6, Fig. 7, Fig. 8, Fig. 9, Fig. 10).

The extent of N loss was variable and ranged from 43 to 80 %. The overall nitrogen being captured is on the higher scale as the depth of the pond is quite shallow for denitrification process arising from anaerobic conditions at the bottom. To further decrease nitrogen loss, volume of water being treated, depth and retention time needs to be optimized. Increasing the inorganic carbon content would further result in the higher yield of total biomass by almost 100% (Eliassen et al, 1969) and thus enabling in increase in the nitrogen captured.

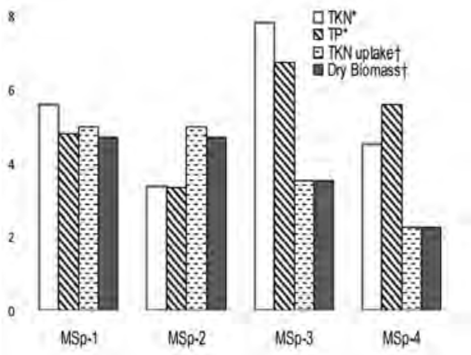

Fig. 7
Quality of synthetic sewage and biomass after harvesting
(Quality of synthetic sewage after treatment in mgL^{-1}*
† Biomass after harvesting from the synthetic sewage $gm^{-2}d^{-1}$)

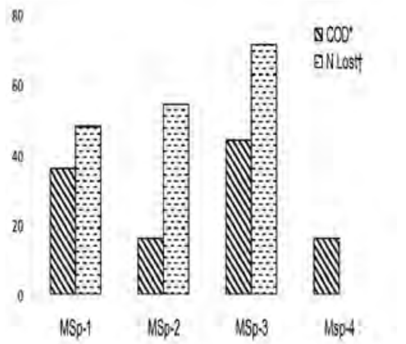

Fig. 8
Characteristics of synthetic sewage after harvesting
**COD in mgL^{-1} † N Lost in percentage*

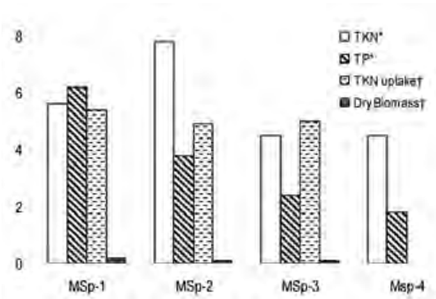

Fig. 9
Quality of digester wastewater and biomass after harvesting
(Quality of digester wastewater after treatment in mgL^{-1}*
† Biomass after harvesting from the digester wastewater $gm^{-2}d^{-1}$)

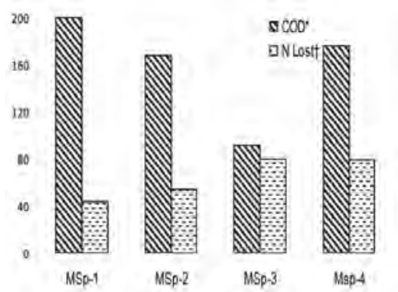

Fig. 10
Characteristics of digester wastewater after harvesting
**COD in mgL^{-1}*
† N Lost in percentage

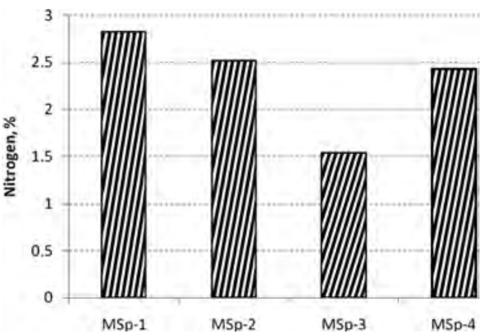

Fig. 11
Mixed species and their corresponding nitrogen content

CONCLUSION

The first part of the study shows that the algae *B. braunii* can perform better in wastewater like wastewater from sugar industry and dairy waste that are rich in organic and inorganic nutrients in comparison to the standard Chu13 media. This has enormous implications in reducing the cost involved in production of the biomass and wastewater treatment. The results of mixed culture indicate that water from the anaerobic digester works as a better algal culture media, in spite of its dark colour, probably because of its higher alkalinity. Further, in this work, we show the feasibility of capturing nitrogen and phosphorous from the wastewaters in the form of algal biomass. This allows the storage of nutrients till the next crop season along with quick release of nitrogen into the soil since algae degrades rapidly.

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Material and Energy Recovery from Elephant Dung

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INTRODUCTION

The evolution of any scientific idea has been either to create something innovative or to find a solution to an existing problem. With respect to this, the concept of "*Material and Energy Recovery from Elephant Dung*" can be placed under the second category. Thrissur, the cultural capital of Kerala is an abode to many elephants, sheltered as a sacred symbol to the local people associated with the temple activities and the pilgrims. Therefore, the Guruvayur Devaswom Board started Anakota (the word meaning "a shelter to elephants") which houses about 64 elephants owned by the Board. Eventually Anakota evolved into a popular tourist destination as well as being designated as the world's largest domesticated habitat for elephants. With passage of time the Guruvayur Devaswom Board had to face a new challenge. The disposal of elephant dung had now become a major environmental issue. A simple methodology which would answer this environmental issue as well as yield a suitable solution to other noteworthy issues is the material and energy recovery from elephant dung. The primary intention of our study was to recover material and energy from elephant dung.

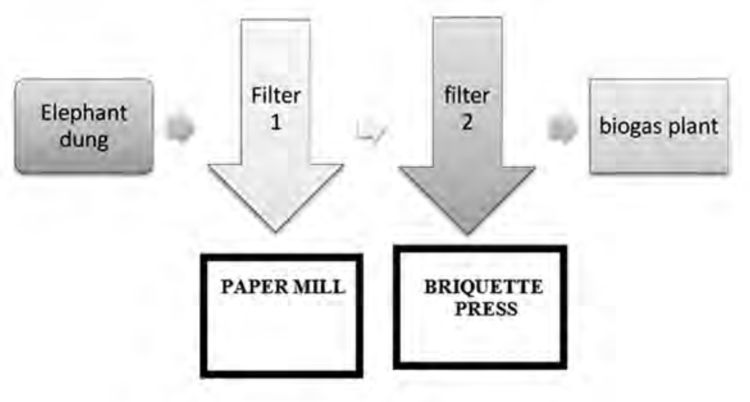
i. To produce reliable substitutes of energy, such as biomass briquette and biogas.

ii. To reduce the felling of trees for paper production as the cellulose content in dung can be directed towards the production of paper.

iii. To overcome the pollution caused due to dumping of elephant dung or its burning.

PROTOCOL

Fresh samples of elephant dung were collected from Anakota, Guruvayur. These samples are weighed and quantified. Quantified elephant dung is introduced into the washing unit. Elephant dung is then washed with water and this step is repeated several times. The products of this step include the long cellulose fibres, the shorter and finer fibre particles and the water used for washing. The long fibres will be sent to the paper producing unit. The shorter and finer fibres can be used for the formation of biomass briquettes. The water used for the washing process can then be sent to the biogas production unit. The longer dried fibres can be spun into ropes. The mosquito repellent is made by taking small amounts fresh dung; shaping it into a convenient shape, and finally drying it.



Condensed process flow

The fact that cellulose is used for paper production is known. The novelty of our project was that it exploited the high cellulose content in the elephant dung and utilised it for the production of paper and other related products. The major scientific idea involved in this project was to first segregate the fibres by proper washing and cleaning of the dung. These fibres are basically long strands of cellulose which can be processed using bioengineering skills for paper production. This could potentially prove to be a ground-breaking alternative for paper production as against the conventional method that involves the felling of thousands of trees every month. For the production of one tonne 100% virgin paper, cutting of 24 trees are required. This can be prevented by utilizing the pulp recovered from elephant dung to produce the same amount of paper.

Proceeding with the production of paper was when we stumbled on the brainwave of generating biomass briquettes, which could serve as blocks of energy. Here the shorter fibres obtained on washing of the elephant dung was suitably moulded into small briquettes. These could serve as fairly good substitutes for coal, lignite, firewood and offer numerous advantages as to being cheaper than coal having a higher practical thermal value, much lower ash content and a consistent quality.

After producing well dried and hardened biomass briquettes, the weight of each rectangular shaped briquette was measured to be about 25g. These briquettes were submitted to 'Enviro-designs Ecolab' at Kochi, Kerala to determine the calorific value. The calorific value of the briquette was estimated to be 4168Kcal/Kg. Now this was an astounding result when compared to other commercial fuels, petroleum products, agricultural residues and animal wastes. It was an excellent value lying between 500Kcal/Kg of hard coal and 2310 Kcal/Kg of lignite coal. Thus comparing results, it can be said that 1Kg of these briquettes can be effectively used in place of 1.804 Kg of lignite coal or 0.8336 Kg of hard coal.

In India about 46% of total energy consumption is estimated to be met from various bio-mass resources, i.e. agricultural residues, animal dung, forest waste, firewood, etc. India produces a huge quantity of agricultural residues and a major part of it is consumed in traditional uses (such as fodder for cattle, domestic fuel for cooking, construction material for rural housing, industrial fuel for boilers, etc). The direct burning of agricultural residues in domestic as well as industrial applications is very inefficient. Moreover, transportation, storage and handling problems are also associated with its use. One of the approaches that are being actively pursued worldwide towards improved and efficient utilization of agricultural and other biomass residues is their conversion into pellets or briquettes. The briquetting of biomass improves its handling characteristics, increases the volumetric calorific value, reduces transportation costs and makes it available for a variety of applications.

The water that was collected from the processing step can be used for biogas production. Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of bio fuel. One type of biogas is produced by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure or sewage, municipal waste, green waste and energy crops. This type of biogas comprises primarily methane and carbon dioxide.The water that is used for the washing of dung is directly poured into an anaerobic biogas plant. About 20%of cow dung slurry (or any agro refuse) could be added to accelerate the biogas production. The plant was left closed for 30 days during which biogas were produced.

Biogas is a renewable fuel, so it qualifies as a renewable energy substitute. Biogas can be used as a low-cost fuel in any country for any heating purpose, such as cooking. It can also be used in modern waste management facilities where it can be used to run any type of heat engine, to generate either mechanical or electrical power. Biogas can be compressed, much like natural gas, and used to power motor vehicles.

Another interesting application was the production of ropes from elephant dung. The long and strong cellulose fibres were spun into ropes. The rope thus obtained was found to be tensile and efficient for daily purposes.

The high demand for elephant dung as a mosquito repellent has made it much sought after at those cattle fair. Villagers have traditionally bought elephant dung to use as mosquito repellent. When it is burnt, the smoke is considered as an instant killer of mosquitoes. Elephant dung is the cheapest mosquito repellent. And like herbal medicines, it has no side effects. Elephant dung is more effective than any other mosquito repellent available in the market. Before this, value addition to the mosquito repellents could be done by adding other components such as citronella oil, neem extract and fragrance producing compounds.

RESULTS AND CONCLUSION

Coming to the statistics, from Anakota (Guruvayur) alone, in a month 350 tonnes of elephant dung can be collected. This can optimally be used to produce 8-9 tonnes of briquette and 85 tonnes of paper pulp in a month. The briquettes have a calorific value of 4168 cal/g. Thus one tonne of briquette can be a substitute for 800-850 kg of hard coal. Also, the paper pulp produced is equivalent to what is obtained on cutting of 2000 number of trees. Again the sludge from the biogas plant can be used as a fertilizer. At the end of this process, no part of the elephant dung is wasted or left behind, but is completely transformed into useful and economical products such as briquette, paper, biogas, rope and mosquito repellent.

Thus, we propose that employing this method would be a novel solution leading to valuable energy and material recovery from waste while effectively preventing pollution; profitably earning a stable source of income.

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Author Index

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