Energy Economics Study on Biomass Energy Conversion Techniques

[1]J.Jenil Gavaskar, [2]Vibhu.B.Pillai, [3]N.K. Sanker, [4]M.Ayyappan, [5]M.R.Saravanan, [6]Dr.A.Pasupathy
[1,2,3,4,5]Dept. of EEE, KNSK College of Engineering, Tamilnadu, India
[6]Dept. of Mechanical, KNSK College of Engineering, Tamilnadu, India

Abstract
Energy is one of the critical inputs for economic development of any Country. In order to overcome the present energy scenario problems, Energy should be conserved since we are consuming disproportionate amount of energy and that day is not far when all our Non-Renewable resources will expire forcing us to rely just on Renewable Sources. This Paper deals with the various types of modern energy generation techniques and cost analysis as well as economics from Biomass. Biomass is biological material derived from living, or recently living organisms, such as wood, waste, hydrogen gas, and alcohol fuels. Correctly managed, biomass is a sustainable fuel that can deliver a significant reduction in net carbon emissions when compared with fossil fuels.

Keywords
Biomass, Energy Conservation, Renewable Energy, Energy Economics

I. Introduction

Commercial sources of Energy are only 50% of total energy consumption in India. Means non-commercial sources like fuel wood, agricultural waste & animal dung constitute ½ of the total energy consumption in India. At current rate of consumption & production, coal reserves in India would last for about 130 years. At current rate of consumption & production, oil in India would last only for about 20 to 25 years [1].

The modern lifestyle depends tremendously on the use and existence of fossil fuels. With levels of these fuels constantly decreasing, we should act now to become less dependent on fossil fuels and more dependent on renewable energy sources. The decreasing levels of fossil fuels aren't the only reason why we should begin to use renewable energy. Pollution is becoming a huge problem in many countries in the world, especially the developing world. With carbon emissions at an all time high, air quality can be very low in some areas; this can lead to respiratory diseases and cancer. The more carbon dioxide we pump into the atmosphere, the greater the Global warming effect becomes. We can slow down and dilute the effects of global warming through the wide spread use of renewable energy resources.

Biomass is available in unlimited quantities for unlimited period of time [2]. This review paper presents the various methods of Energy Conversion Techniques from Biomass and Comparative Economic study of Biomass Power Generation with Centralized Grid systems. This study proves that about 22% of Power reduction & 30% of Cost reduction can be achieved in a remote village when the energy generation is done by a Decentralized Biogas Plant.

II. Present Energy Scenario

65% of total rural energy consumption is met from fuel woods. At this rate, in near future, fuel wood could be a greater constraint than availability of food grains. From 1951 to 2004, the coal production has increased 12 times, crude oil 110 times & electricity 65 times [3]. Only 0.3% of world's known oil reserves are in India. Transport sector accounts for 56% of total oil consumption in India. Millions of poor people in India spent 100 man-days every year in gathering fuel wood for cooking purposes. India is the second largest exploiter of Wind Energy – 1000 MW, out of this 70% is contributed by private sector. There are 33 lakhs bio-gas plants, 2 lakhs solar cookers & 10000 street lighting systems using solar photo-voltaic technology. Out of the total electricity consumption in India, 34% goes to Industry, 24% to agriculture, 21 % to domestic use, 12% to public lighting & 2% to railway traction. Currently 5,87,560 villages in India have electricity. Still 1,12,400 villages haven't seen what electricity is [3].

III. Why Conserve Energy?

A. Problems in Conventional Systems

Energy should be conserved since we are consuming disproportionate amount of energy and that day is not far when all our Non-Renewable resources will expire, forcing us to rely just on Renewable Sources. The electricity that we use comes from nuclear power, coal power plants. Oil that we use to run our vehicles are fossil fuels that were created million of years ago from decaying plants. When burned they emit carbon-dioxide which is harmful to human and the environment. Apart from these it also helps us to save money, mitigates the numerous adverse environmental and social impacts associated with energy production and consumption. These include air pollution, acid rain and global warming, oil spills and water pollution, loss of wilderness areas, construction of new power plants, foreign energy dependence and the risk of international conflict over energy supplies. Energy conservation extends the lifetime of equipments and reduces the maintenance cost by operating fewer hours and at less than maximum capacity.

- We use energy faster than it can be produced.
- Energy resources are limited.
- Most of the energy sources we use cannot be reused and renewed.
- Energy saved is energy generated.
- It is our duty to conserve today for tomorrow's use.
- Reduces reliance on fossil fuels

B. Importance of Renewable Energy

Consumption of Non-Renewable Sources must be reduced as much as possible. For the following reasons,

- Resource Depletion
- Save Money
- Reduce Carbon-dioxide Emissions
- Climate Change
- Ozone Layer Depletion
- Adverse affect on humans and the environment
- Acid Rain
- Global Warming
- Inexhaustable

IV. Biomass Energy

Biomass is a renewable energy because it contains the energy which comes from the sun. Biomass is basically an organic material made from plants and animals. Biomass in itself contains chemical energy. So, when burning the biomass fuel, the chemical energy inside releases the heat. It can also be used to produce steam which can further be used to generate electricity. Using biomass for energy can cut down waste and can also help in reducing the landfill.

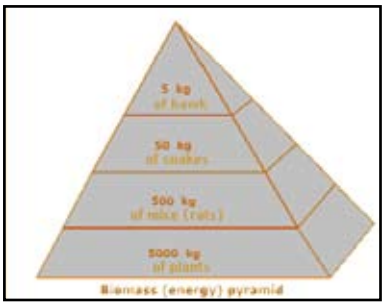

Fig. 1: Pyramid of Biomass

The biomass is defined as the total weight of dry matter present in the ecosystem at any one time. The biomass can be measured graphically. This graph represents the shape of a pyramid which is known as pyramid of biomass.

A. Advantages of Biomass Energy Sources

- Biomass energy source is renewable
- Biomass can reduce greenhouse effect
- Indigenous fuels
- Clean surroundings
- Reduction of Air pollution and Acid Rain
- Energy Production Techniques

Biomass may be used in a number of ways to produce energy. The most common methods are

- Combustion
- Gasification
- Fermentation
- Anaerobic digestion
- Pyrolysis

1. Combustion

Direct burning of biomass is the most straightforward method of energy production. The energy released by direct combustion takes the form of heat, and can be used to influence the temperature of a small environment or to power steam-driven turbines to produce electricity directly.

Fuel + Air → Heat + Ash + Inert Gases

2. Biomass Gasification

Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This mixture is called producer gas. Producer gas can be used to run internal combustion engines and can be used as substitute for furnace oil in direct heat applications and can be used to produce, in an economically viable way, methanol – an extremely attractive chemical which is useful both as fuel for heat engines as well as chemical feedstock for industries. Since any biomass material can undergo gasification, this process is much more attractive than ethanol production or biogas where only selected biomass materials can produce the fuel.

3. Fermentation

Fermentation is one of the most widely used biological technique to obtain various fermentation products for human consumption. Yeast and few kinds of bacteria carry out alcoholic fermentation. Decomposition of sugars by certain yeasts under anaerobic conditions forming alcohol and carbon dioxide is known as alcohol fermentation. The anaerobic respiration in the microorganisms is often called fermentation. Fermentation is named after its product, for example alcoholic fermentation, lactic acid fermentation.

4. Anaerobic Digestion

The generation and disposal of organic waste without adequate treatment result in significant environmental pollution. Besides health concerns for the people in the vicinity of disposal sites, degradation of waste leads to uncontrolled release of greenhouse gases (GHGs) into the atmosphere. Conventional means, like aeration, is energy intensive and expensive and also generates a significant quantity of biological sludge. In this context, anaerobic digestion offers potential energy savings and is a more stable process for medium and high strength organic effluents. Waste-to-Energy (WTE) plants, based on anaerobic digestion of biomass, are highly efficient in harnessing the untapped renewable energy potential of organic waste by converting the biodegradable fraction of the waste into high calorific gases. Apart from treating the wastewater, the methane produced from the biogas facilities can be recovered, with relative ease, for electricity generation and industrial/domestic heating.

5. Pyrolysis

Pyrolysis involves the heating of biomass in the absence of oxygen. Biomass such as wood or agricultural waste is heated to 1000 degrees Fahrenheit and allowed to decompose into gas and charcoal (carbon). A major advantage of pyrolysis is that carbon dioxide, one of the main drawbacks to most biomass energy conversion processes, is not produced. A disadvantage, however, is that the biomass must be heated to relatively high temperature, a process that itself requires significant amount of energy.

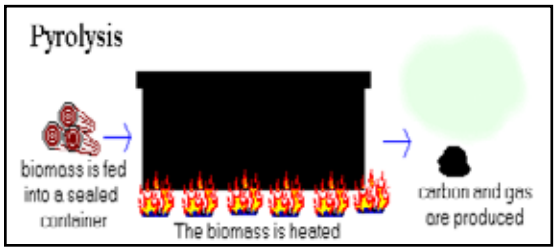

Fig. 2: Process of Pyrolysis

C. Biomass Resources in India

India is very rich in biomass. It has a potential of 19,500 MW (3,500 MW from bagasse based Cogeneration and 16,000 MW from surplus biomass). Currently, India has 537 MW Commissioned and 536 MW under construction. The fact reinforces the idea of a commitment by India to develop these resources of power production.

Following is a list of States for biomass production and potentiality.

- Andhra Pradesh (200 MW)
- Bihar (200 MW)
- Gujarat (200 MW)
- Karnataka (300 MW)
- Maharashtra (1,000 MW)
- Punjab (150 MW)

- Tamil Nadu (350 MW)
- Uttar Pradesh (1,000 MW)

Table 1: Biomass Potential in India

Source	Potential	Installed
Bio mass	16000 MW	222 MW
Bagasse	3500 MW	332 MW

India is a tropical country blessed with abundant sunshine and rains, thus offering an ideal environment for Biomass production. Further, the vast agricultural produce also makes available large quantities of agro-residues which can be used to meet energy needs. With an estimated production of about 350 million tonnes of agricultural waste every year, residual biomass is capable of mitigation of GHG emissions to the extent of 300 million tonnes / annum.

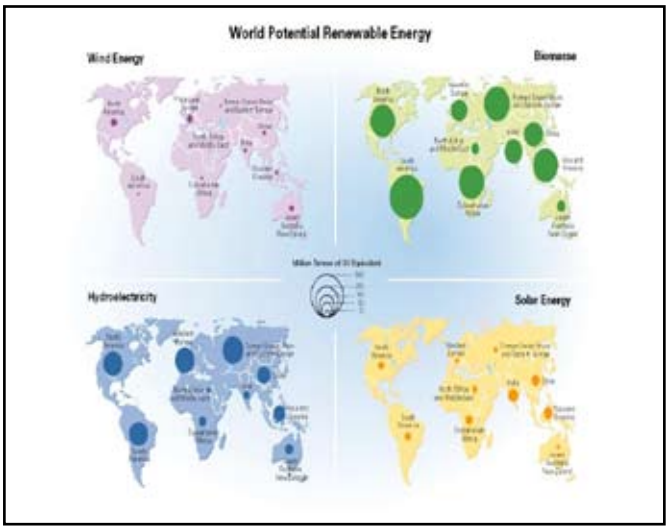

Fig. 3: World Potential Renewable Energy

V. Energy Economics

There is a general perception that the cost of electricity generated by renewable energy technologies is always higher than electricity generated by fossil fuel sources. While this is true in many places, it is no longer valid for the rural areas of rural India. In most of the Indian villages diesel generators are often the only source of power but power from biomass gasifier based plants are considerably cheaper where ever biomass is available. Even for dual fuel operation where 20 % diesel is used, the generation costs are lower, especially with high running hours and loads. The savings are dramatic when pure gas engines are used. Even when grid power is available, the actual cost of power at the point of consumption is very high largely due to line losses in transmission and distribution. High subsidies and financial losses keep the power price low for agricultural pumps but now that industrial and commercial consumers pay the actual cost of power, the biomass gasification based electricity can easily compete when pure gas engines are used.

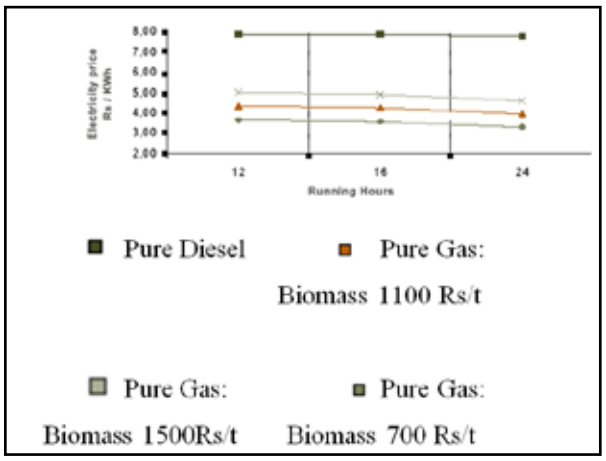

Fig. 4: Generation Costs for Typical 55 kW Power Plant

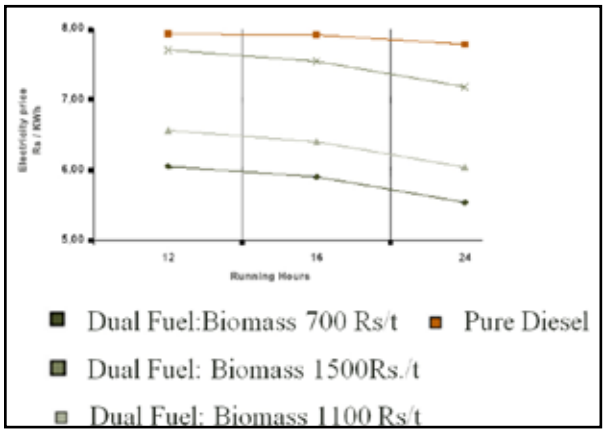

Fig. 5: Generation Costs for Typical 50 kW Power Plant

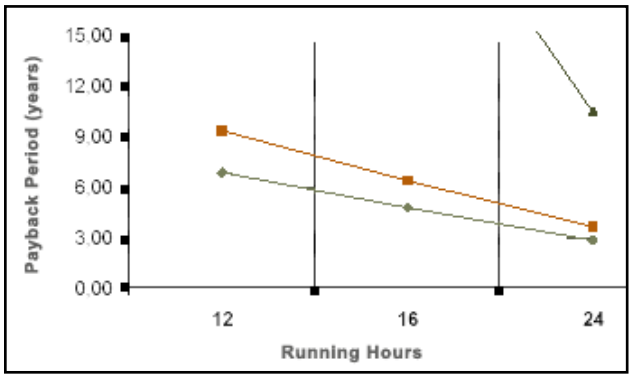

Fig. 6: Dual Fuel Operation Pay Back Period vs Running Hours

VI. Case Study- Biomass Gasifier:

A. Gosaba Island Rural Electrification

About three million people inhabit the Delta Region of Sunder bans, West Bengal State. Two millions of them do not have access to electricity. It is not economically feasible to extend grids to many islands wide spreaded in the Delta Region. The 500 kw (5 x 100 kw). Biomass gasifier duel fuel power generation system (70% biomass + 30% diesel) was installed at Gosaba Island, Sunder bans in June, 1997 (fig. 2). Gosaba Island located. About 80 km south west of Kolkata. It takes 1.5 hours by boat from the nearest port of Mainland. There were only 16 customers when the operation started because people did not believe the system really works. But customer increased very quickly and currently 1150 HH are connected. The plant is currently operating 15 hours a day (10:00 am to 1:00 am Next day). The island developed dramatically ever since the installation of the power Station. There are so many

commercial stores and more than 10 hotels, and people from nearby islands come to Gosaba for shopping.

Fig. 7: Biomass Gasifier at Gosaba Island, West Bengal

There is a bank (State Bank of India) opened and support economical activities. Telecommunication system is available. Internet is available and there is a PC training centre. The hospital can conduct basic operations. The electricity is also used for public purposes such as street lights, school lighting, drinking water supply and irrigation. The project is 100% funded by government since this is a pilot project but owned and operated by Gosaba Rural Energy Cooperative. Biomass fuel is supplied by both farmers and from the plantation.

B. Tamil Nadu Gasifier Installations

Ankur Scientific which is an Indian leading gasifier manufacturer (67% share of total gasifier installation) installed 60 gasifier systems in Tamil Nadu State in a year 2004. The 57 out of 60 systems were 9 kW capacities. Other three were one each of 4, 40 and 250 kW capacities. The 250 kW one is for school power supply installation while others are all water pumping purposes. Most area of Tamil Nadu State is connected by grid [5].

1. Odanthurai Panchayat

Panchayat is a general term of village cooperative in India. Odanthurai Panchayat installed a 9kW biomass gasifier power generation system to substitute the grid electricity usage for pumping of drinking water supply system. The biomass gasifier system saves about 70% of pumping cost compare to using grid electricity. This panchayat also has other renewable energy projects such as solar street lighting and biogas using human and domestic animal excrement. The biogas system is connected to each house for cooking purpose. People do not use firewood. Panchayat is purchasing waste wood from a sawmill in the village at very low price of Rs. 0.3/kg ($6.7/t) for the fuel of the gassier. No demand of waste wood for cooking purpose might contribute the very low price. Total energy planning rather than just electrification can improve the efficiency.

Fig. 8: Biomass Gasifier at Odanthurai Panchyat

Table 2: Operation Cost Per Unit Electricity

Description	With grid system	With gasifier system
Electricity	Rs. 4.5 / kWh	Rs. 0.45/ kWh
Labor cost	Rs. 0.45	Rs. 0.66
Maintenance cost	Rs. 0.07	Rs. 0.28
Total	Rs. 5.02	Rs. 1.39

The grid electricity tariff is Rs. 4.5/kWh ($0.10) and not expensive but gasifier installation saves large amount of cost of the water supply system.

Table 3: Summary of Odanthurai Panchayat Gasifier System

Plant capacity	9 kW
Cost of installation	Total - Rs. 310,000 ($6,700)
MNES subsidies	Rs. 135,000
Panchayat contribution	Rs. 175,000
No. of consumers	3497 people
Operation hours	12 hours
Tariff structure	Rs. 30 ($0.67) / HH / month
Fuel efficiency	1.5 kg of wood / kWh
Cost of fuel	Rs. 0.30 / kg ($6.7/t) dry wood

2. Nellithurai Panchayat

This is almost the same installation with Odanthurai Panchayat. The difference is that Nellithurai Panchayat operated the gasifier during the night to supply power for 90 street lights to maximize the plant capacity factor [4]. There were street lights connected to grid electricity but the panchayat stopped using them and installed new street lights connected to the gasifier system. Electricity Bureau (EB) does not allow small IPP (< 1 MW) to supply electricity in the area connected to grid therefore the idea of street lighting is adopted. The cost for water pumping and street lights used was about Rs. 20,000 ($450) per month but the cost reduced to Rs. 6,000 ($130) per month after installation of biomass gasifier system.

Table 4: Summary of Nellithurai Panchayat Gasifier System

Plant capacity	9 kW
Operation hours	9:00 am – 6:00 pm / Pump x 3 6:00 pm – 2:30 am / Pump x 1 and street lights (36 W) x 90
Tariff structure	Rs. 30 ($0.67) / HH / month
Fuel efficiency	1.5 kg of wood / kWh
Cost of fuel	Rs. 800 ($17.8) / t dry wood

3. Pallipalayam Panchayat

They installed 40 kW gasifier systems for water supply system. The system is almost the same as other two installations shown above except the plant capacity. They purchase fuel wood from village people. The species are mainly wild grown Juliflora. No planting activities have been conducted.

Fig. 9: Biomass Gasifier at Pallipalayam Panchyat, Tamilnadu

Table 5: Summary of Pallipalayam Panchayat Gasifier System

Plant capacity	40 kW
Operation hours	10 hours / day
Year of installation	2004
No. of consumers	1,000 HH
Tariff structure	Rs. 40 ($0.90) / HH / month
Fuel efficiency	1.5 kg of wood / kWh
Cost of fuel	Rs. 1000 ($22.2) / t dry wood

VII. Conclusion

The centralized power sector has failed to be the motive of development for the rural areas is clear from the national statistics. Out of the half million villages in India, about 3,10,000 villages have been declared to be electrified and 80,000 more villages remain completely un-electrified. In actual practice, most of the so-called electrified villages do not have reliable, regular, adequate, or good quality power. No commercial investments in micro enterprises can therefore be made by either individuals or companies without installing diesel generators which have a very high generating cost. In addition, with the advent of mature renewable energy technologies, the supply of power to the remote rural areas from the centralized grid is no longer competitive, for example, with a modern biomass gasification based decentralized power plant.

Table 6: Cost of Supplying Power to a Village

Energy Production	Generation MW		T&D Losses		End Use Energy	
	MW	Cost Rs in million	MW	Cost Rs in million	MW	Cost Rs in million
Centralized Grid Supply	1	35	0.3	5	0.7	57
Decentralized biomass power plant	1	35	0.1	5	0.9	44

Table 7: Savings from Decentralized Power Supply

Energy Production	Power Saving	Power Saving	Avoided Cost	Saving in Cost	Amount
Generation / End Use	0.2 MW / MW	22%	13 million Rs/MW	29.5 %	
CO2 emissions					5500 t/y per MW

The economic consequences are quite dramatic. For 80000 un-electrified villages, a modest 50 kW of installed capacity per village will lead to total saving of 52000 million Rs. (Rs. 5200 Crore / 1100 million US $) in power plant investments. In energy terms, the saving in T&D losses will release a generation capacity of 800 MW for profitable sale. Reduced pollution and reduction of CO2 emissions will be the other advantages of a decentralized renewable energy based system for the rural areas.

VIII. Recommendation

Keeping in view the reserves of the fossil fuels and the economic concerns, these fuels are likely to dominate the world's primary energy supply for another decade but environmental scientists have warned that if the present trend is not checked then by 2100, the average temperature around the globe will rise by 1.4 to 5.8 degrees Celsius, which will cause a upsurge in the sea water level drowning all lands at low elevation along the coastal lines. So the world has already made a beginning to bring about the infrastructural changes in the energy sector so as to be able to choose the renewable energy development trajectory. In developing countries where a lot of new energy production capacity is to be added, the rapid increase of renewable is, in principle, easier than in the industrial countries, where existing capacity would need to be converted if a rapid change takes place. Nevertheless India must give more thrust to research and development in the field of non conventional energy sources not only to mitigate green house effect but also to lessen dependence on oil/gas import, which consumes major chunk of foreign exchange reserve. It is also clear that an integrated energy system consisting of two or more renewable energy sources has the advantage of stability, reliability and economically viable. Last but not the least, it is for the citizens also to believe in the power of renewable energy sources, and understand its necessity and importance.

References

[1] Ministry of Non Conventional Energy Sources, Annual Report for the FY 2002 -2003.

[2] Indian Renewable Energy Development Agency Limited Annual Report for the FY 2002 – 2003.

[3] Ravindranath N.H., Hall. D. O.,"Biomass Energy & Environment: A developing country prospective from India", Oxford University press, 1995.

[4] Dassappa, S. Sridhar, H.V. Sridhar, G. Paul, P.J., Mukundha H.S.,"Biomass gasification – A substitute t fossil fuel for heat application", Biomass Energy 2003.

[5] Somasekar, H. I. Dassappa, Ranindranath N.H.,"Rural Bio Energy Centre based on Biomass Gasifier for Decentralized Power Generation: Case Study of Two Villages in South India".

[6] Somasekar, H. I. Dassappa, Ranindranath N.H.,"Rural Bio Energy Centre based on Biomass Gasifier for Decentralized Power Generation: Case Study of Two Villages in South India".

J.Jenil Gavaskar is pursuing his B.E. Degree in Electrical & Electronics Engineering from KNSK College of Engineering, Nagercoil under Anna University, Chennai. He has already published a paper in the Conference Proceedings and presented many papers in the Seminars organized by various Institutions & industries. His area of interest includes Renewable Energy Systems and Embedded Systems.

Vibhu B. Pillai is pursuing his B.E. Degree in Electrical & Electronics Engineering from KNSK College of Engineering, Nagercoil under Anna University, Chennai. He has already published a paper in the Conference Proceedings and presented many papers in the Seminars organized by various Institutions & industries. His area of interest includes Energy Management and Power Electronics.

N.K. Sanker is pursuing his B.E. Degree in Electrical & Electronics Engineering from KNSK College of Engineering, Nagercoil under Anna University, Chennai. His area of interest includes Energy Management and Power Electronics.

M. Ayyappan is pursuing his B.E. Degree in Electrical & Electronics Engineering from KNSK College of Engineering, Nagercoil under Anna University, Chennai. He has already published a paper in the Conference Proceedings and presented many papers in the Seminars organized by various Institutions & industries. His area of interest includes Renewable Energy Systems and Embedded Systems & Electrical Machines.

M.R. Saravanan received his B..E. degree in EEE from Arulmigu Kalasalingam College of Engineering Srivilliputhoor under Madurai Kamaraj University in 2001. He completed his M.E. degree at College of Engineering, Guindy, Anna University, Chennai with the specialization in Energy Engineering in the year 2006. He was a Senior Design engineer with M/s Stelmec Limited, Mumbai for 3 Years and completed one year training in the O & M of 230/110kV SS SWG Products. He joined as a Lecturer in SKR Engineering College, Chennai in the year 2004 and presently working as an Assistant Professor in the Department of EEE, KNSK College of Engineering, Nagercoil. He is also pursuing for his Ph.D. in the area of Thermal Energy Storage Systems. His area of interest includes Solar Energy Storage Systems & Energy Conservation.

Dr. A. Pasupathy received his B.E. Degree in Mechanical Engineering in the year 1988 from The Indian Engineering College. He obtained his Master's degree in the field of Energy Technology form Pondicherry Government Engineering College in the year 2001. He received his Doctor of Philosophy (Ph.D) through Anna University Chennai in the research topic of "Studies on Thermal Management in Buildings using Phase Change Material" in the year 2007. He worked as a Marine Engineer in Barber / Bergesen Ship Management Limited, Norway for 10 Years and having one year experience in the Erection Field. He served as Professor / Head, Director, and vice – Principal& Principal in various reputed Engineering Colleges in Tamilnadu for 12 Years. Presently he is working as Principal of KNSK College of Engineering, Nagercoil. He has published / presented several papers in various International & National Journals / Conferences. His area of Interest includes Heat Transfer, Thermodynamics, Thermal Engineering, Energy Conservation, Design of Heat Exchanger and Thermal Energy Storages Technologies. At present, four Research Scholars are doing research under his supervision in the field of Solar Thermal Storage Technologies using Phase Change Materials.