Science Books Series 4

Alternative Energy for Sri Lanka

K.P.S.P. Perera

National Science Foundation

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Foreword

It is a privilege to write a foreword for Mr. K.P.S.P. Perera's book Alternative Energy for Sri Lanka. Given the nature of energy crisis, it is highly advisable to embark upon our own energy programme rather than relying on coal or oil. As stated by Mr. Perera, there are proven technologies that can convert the energy contained in the fuels mentioned in this book to electricity. Creation of a ready market for alternative fuels will solve many problems such as unemployment and poverty. A combined effort is required to get our alternative energy programme underway. Therefore all the intellectuals should unite and come up with novel ideas to use the alternative fuels mentioned in this book for a productive purpose such as power generation. Finally steps should be taken to tap this vast resource before things get worsen due to soaring oil prices.

K.R.D. Caldera
65 Thudella East
Ja-Ela.

Preface

Alternative energy resources if properly used can make a world of difference to countries like Sri Lanka. After all alternative fuels appear to be the most abundantly available resource which could be used for economic development.

Sadly without using abundantly available alternative fuels with appropriate conversion technologies, there are efforts made to generate electricity using coal and gliricidia wood to satisfy energy requirements.

Alternative fuels available for a National Energy Programme are identified in this work and the use of steam engines for conversion purposes is emphasized in this work.

Since generating power using alternative fuels with imported equipment is costly, the idea of using locally built steam engines is emphasized in this work. Since power plant cost for 1 MW of installed capacity is US$ 1 million, it is very unlikely that these plants will ever be brought to Sri Lanka.

Alternative fuels available for conversion include the following ; paddy husk, paddy straw, crushed sugar cane, saw dust, wood, un-recyclable waste paper, un-recyclable discarded plastics, spent lubricants, organic municipal solid wastes, agricultural crop residues, coconut leaves, coconut shells, coconut husks, dead grass, etc.

On the other hand there is also the possibility of increasing the vegetable oil (preferably palm oil) production in order to replace at least a part of petroleum fuels used by vehicles.

I have always made references to substantiate the facts stated in this work, for I didn't want to take any chances, given the fact that this work places more emphasis on lesser known alternative fuels in the Sri Lankan context rather than the widely accepted fuels such as coal and wood gas (gliricidia).

K.P.S.P. Perera

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Units & Measurements

Energy	- Joule	J	m^2 kg / S^2
Power	- Watt	W	J / S^2
Pressure	- Pascal	Pa	N / m^2, J / m^3

1 kWh = 3.6 MJ (Mega Joules = 3.6 X 10^6 Joules)

1 BTU = 1055.79 J

1 Calorie = 4.18 J

1 Joule = 1 Nm

1 Newton = 1 kgm / S^2

1 Tonne Coal Equivalent = 29.3 GJ (29.3 X 10^9 Joules)

1 Tonne Oil Equivalent = 42.6 GJ (42.6 X 10^9 Joules)

1 Horse Power = 746 Watts

1. Introduction

As far as alternative energy is concerned, there are power plants that use alternative fuels such as biomass and generate electricity which costs about US$ 1 million per Mega watt (MW) of installed capacity.

Alternative fuels which could be used for power generation include paddy straw, paddy husk, coconut leaves, coconut shells, coconut husks, mana grass, discarded plastics and polythene, spent lubricants, waste paper, saw dust, municipal organic wastes, wood, etc.

According to the Central Bank Annual Report for the year 2004, installed thermal power capacity of Sri Lanka is 1073 MW. Therefore the shift to alternative fuels would cost US$ 1073 million. Since Sri Lanka can hardly afford to import power plants that run on alternative fuels, the possibility of making components locally at low cost should be explored.

The use of steam engines to convert energy contained in alternative fuels into electrical power will be a low cost alternative. The Chapter on Steam Engines will deal with this topic extensively.

On the other hand steps should be taken to replace petroleum fuels as far as possible with vegetable oils. The Chapter on vegetable oils will deal with this subject.

An alternative fuels based energy programme will create many jobs, a ready market for combustible materials and save valuable foreign exchange and solve environmental problems as well.

Since Sri Lanka has a long way to go to attain self-sufficiency in cereal crops, there is immense potential to develop the alternative energy programme. If power plants which generate electricity at 20% efficiency are available, these can easily compete with oil based electricity generation while providing additional income to many.

According to the latest revision of the electricity tariff in Sri Lanka effective from 01-02-2006, 1 unit (1 kWh) is priced at Rs 10.90 for commercial purposes and Rs 7.50 for industrial purposes. A unit of electricity is sold at Rs 15.80 at the highest rate for households which consume electricity in excess of 180 units per month.

Given the calorific values of most agricultural crop residues at 20% efficiency, 1 kWh of electricity could be generated by burning 1 kg of combustible substance. Therefore a price of Rs. 5/= (5 US Cents) per 1 kg of alternative fuel is affordable. After all, the only obstacle for the alternative energy programme appears to be the non availability of appropriate technology.

As far as the power plant cost is concerned the figure of US$ 1073 million at US$ 1 million per installed capacity of 1 MW, is not a big amount compared to the money spent on vehicle imports and oil imports.

Sooner or later Sri Lanka will have to shift to alternative energy resources since the oil bill for the year 2004 stood at US$ 1209 million according to the Central Bank Annual Report for the year 2004, is bound to rise further.

The steam engine was the driving force of the industrial revolution in Europe. Therefore the efficiency of a steam engine should be increased by super heating of the inlet steam, and using the exhaust steam to pre heat feed water.

Finally adoption of appropriate technology can bring about big changes for the good to our society and after all, the available resource which can be put in to economic use is alternative fuels.

Without exploiting this plentiful resource no real economic development is likely to take place.

The Power Plant

To clear any doubts, the power plants that use sugar cane bagasse could be used to generate electricity using the alternative fuels mentioned in this book, although low cost alternatives are advocated. If I am not mistaken these plants are in existence at sugar factories in Sri Lanka.

In any event generating electricity using fuels mentioned in this book is not a major problem as the publication "Power Guide" published by the Intermediate Technology Publications, contains details of biomass energy technologies from pages 176 to 201. Therefore it could be safely assumed that proven technologies are available to generate electricity and the only problem with us is our failure to identify the appropriate fuels. The book "Power Guide" is available at the Open University Library, Nawala, Nugegoda.

Bio gas plant at Dehiwala Zoo

2. Alternative Fuels

General

According to the Central Bank of Sri Lanka Annual Report for the year 2004, 520661 ha of land was under paddy cultivation for the major crop season. At that time 439000 ha of land were under coconut cultivation, 9039 ha were under sugar cane, while 27060 ha were under corn. Agricultural crop residues from these plantations had a potential of generating electricity when 4570 GWh (4570 million units or 4570 million kWh) of electricity was generated using imported oil.

According to Table 17 of the Central Bank of Sri Lanka Annual Report for 2005, paddy lands sown in Sri Lanka was 937000 ha and the paddy production was 3.2 million tons. At the rate of one kg of paddy husk per 2 kg of rice yield, there would have been over 1 million tons of paddy husk available. Given the calorific value of about 15 MJ per kg of paddy husk, and if 1 kg of paddy husk could generate 1 kWh (3.6 MJ) of electricity after making all the allowances for energy losses in conversion, use of this paddy husk alone could have generated 1000 GWh of electricity.

Prof. H.P.M. Gunasena, in his book 'Field Crop Production' (M.D. Gunasena & Co 1994), (page 26) states that the ratio of paddy straw to rice grains is 1 : 1, which gives an estimated paddy straw harvest of 3.2 milliol tons. Energy contained in rice straw is also approximately 15 MJ/kg. If 1 kg of rice straw could generate 1 kWh of electricity after all the energy losses, using this quantity of paddy straw alone, 3200 GWh of electricity could be easily generated.

The total number of units of electricity generated in 2005, according to the Central Bank of Sri Lanka Annual Report for

2005, (Table No. 36) was 8766 GWh. Thermal power generation was 5314 GWh.

Land under coconut cultivation is 395000 ha, as given in page 27 of the Central Bank of Sri Lanka Annual Report for year 2005. At 200 trees per ha of coconut land, there would be 395,000 X 200 = 79 million coconut trees. The total coconut production was 2,515 million nuts. At 12 coconut leaves shed per tree per year, annual yield of coconut leaves per year would be 79,000,000 X 12. If one fully dried coconut leaf weighs 1 kg, the coconut leaf harvest would be 79,000 X 12 tons (0.948 million tons).

Bio Gas

Nearly 3000 tons of municipal solid waste is being collected island wide daily. About 57% of this matter contains organic digestible material. Since the disposal of this much of solid waste is an environmental problem, steps can be taken to make bio gas and use it as a fuel in power generation. There is the possibility of using bio gas as a fuel in the future coal power plants in order to reduce the imported coal requirement.

In page 5 of the handbook titled, Running a Biogas Programme, David Fulford, Intermediate Technology Publications, 1988, it was stated that 667 litres of bio gas produced by 60 kg of cattle dung mixed with water to form 120 litres of slurry is sufficient to generate 1 kWh of electricity. Therefore from about 1800 tons of digestible municipal solid waste collected daily a significant volume of bio gas could be produced if large scale bio gas digesters are built. The ideal location for such a digester would be near a coal power plant so that the requirement of coal can be reduced. The colossal investment needed could be recovered by the sale of organic fertilizer.

Plastics and Paper

According to Municipal Solid Waste Statistics 1998 published by the Department of Census and Statistics, municipal solid waste contains 13% paper, and 8% plastics. These two items could also be used for power generation with proper conversion of energy. Whatever plastics and paper which could be recycled should be recycled. Plastics and paper which cannot be recycled due to contamination and found in garbage dumps, can be burned as a fuel. Environmental concerns are ill founded as currently municipal solid waste dumps are constantly set on fire.

Saw Dust

There are many registered and un-registered timber businesses in Sri Lanka. Saw dust from these industries could be used as an alternative fuel with appropriate conversion methods to generate power. Disposal of residues from timber related industries is a serious problem and saw dust presently dumped into waterways or burnt can be productively used in power generation.

Grasses

Every year certain grass lands are set on fire at the peak of the dry season in Sri Lanka. The dominant grass variety set on fire is locally known as 'Mana'. Steps can be taken to harvest this dead grass and burnt in a productive manner. Even in developed countries, the possibility of using grass as a fuel is explored. A grass variety called elephant grass *(Miscanthus giganteus)* is chosen for this purpose, and it is, said that this grass grows up to a total height of 14 feet or more and 1 ha of such grass contains enough energy to replace 36 barrels of oil worth US$ 2169. Environmental concerns are ill founded as most of the grasslands are set on fire during the driest period of the year.

Substitutes for Imported Cereals

Sri Lanka imported 993,000 tons of wheat for the year 2004 spending Rs 18,536 million. There is the potential to grow rice as a substitute crop to imported wheat. As long as there is a potential to increase rice production a reliable supply of alternative biomass fuels can be assured.

Water Weeds

There are large water bodies such as lakes in Sri Lanka. Steps can be taken to grow water weeds in these reservoirs so that dead plant material could be used as a fuel. According to Table 2.3 given below annual yield of dry matter from water hyacinth is 36 tons per ha and its energy value in terms of oil equivalents is 14 tons at least the water weeds removed from the water bodies could be used as a fuel. Sri Lanka Land Reclamation Company removes water weeds from the canals in the Colombo area and this material come at no extra cost.

The following table gives details about typical crop residues.

Table 2.1

Crop	Typical Yield Tonne/ha	Residue Tonne/ha	Calorific Value of Residue GJ/ha	Calorific Value of Residue kWh/ha
Rice	2.5	5.0	90	25000
Wheat	1.5	2.7	49	14000
Maize	1.7	4.25	76	21000
Sorghum	1.0	2.5	45	12000
Barley	2.0	3.6	65	18000
Millet	0.6	2.0	36	10000

Source :- Water Lifting Devices, Peter Fraenkel, Intermediate Technology Publications, 1990

Table 2.2

Relative heat values of various fuels (Approximate values)

	Calorific Value MJ/kg	Calorific Value MJ/m3
Fossil Fuels		
Petrol / Gasoline	44	32000
Fuel Oil	44	39000
Paraffin/ Kerosene	45	36000
Diesel/ Gas Oil	46	38000
Coal Tar/ Asphalt	40	40800
Anthracite Coal	35	56000
Bituminous Coal	33	42900
Lignite (Brown) Coal	30	37500
Peat	20	18200
Coke	28	22400
Natural Gas (Methane)	56	40
Coal Gas	09	20
Propane (Cylinder Gas)	48	90
Butane (Cylinder Gas)	47	120
Biomass Fuels		
Wood (Oak)	18	14400
Wood (Pine)	20	10000
Wood (Acacia)	16	11000
Charcoal	28	11000

Sunflower Stalks	20	10000
Wheat Straw	18	——
Beef Cattle Manure	14	——
Methanol (Methyl Alcohol)	20	19000
Ethanol (Ethyl Alcohol)	28	28000
Bio Gas (65% Methane)	20	23
Vegetable Oil	39	32000

Source :- Water Lifting Devices, Peter Fraenkel, Intermediate Technology Publications, 1990

Table 2.3 Potential bio-mass values of selected crops

Species	Annual Dry Matter Yield Tonne/ha	Ton Oil Equivalent per year
Sunflower	30	12
Hybrid Corn	13	06
Water Hyacinth	36	14
Sugar Cane (Average)	39	16
Sudan Grass	36	15
Bamboo	11	05

Source: - Water Lifting Devices, Peter Fraenkel, Intermediate Technology Publications, 1990

Table 2.4 Energy values of waste matter

Pollutant	Energy Values in BTU per lb
1. Newspaper	7500
2. Municipal Solid Waste	4500 - 5000
3. Polythene Terephthalate (PET)	10933
4. Aseptic Boxes / Milk Cartons	19000 for polyethylene 7000 for Paper
5. High Density Polyethylene HDPE	7047
6. Office Paper	7200
7. Yard Waste	4500 - 5000
8. Plastic Film Bags	18700
9. Scrap Tyres	12000 - 16000

Source: - Pages 1 - 54 Recycling Handbook, edited by John T. Aquino, Lewis Publishers 1995.

Table 2.5 Ash content and HCV in MJ per kg of some agricultural crop residues

	Ash Content %	HCV MJ/kg (Oven Dry)
Alfalfa Straw	6	18.4
Almond Shell	4.8	19.4
Cassava Stem	—	18.3
Coconut Shell	0.8	20.1
Coconut Husk	6	18.1
Cotton Stalks	17.2	15.8
Groundnut Shells	4.4	20.0
Maize Stalks	6.4	18.2
Maize Cobs	1.5	18.9
Rice Straw	19.2	15.0
Rice Husks	16.5	15.8
Sunflower Straw	—	21.0
Wheat Straw	8.5	17.2

Source: - Page 29, The Briquetting of Agricultural Wastes for Fuel, S Eriksson and M Prior, FAO Publication 1990.

Table 2.6

Paddy husk consumption for generation of 1 kWh of electricity & calorific values of saw dust and coir dust.

Country	Paddy Husk Consumption Per 1 kWh
China	2.3 kg / kWh
Philippines	2.5 kg / kWh
Thailand	3.5 kg / kWh
France	2.3 kg / kWh
Bio Mass	**Calorific Value**
Saw Dust	12.14 - 20.97 MJ / kg
Coir Dust	12 MJ / kg

Source: - Development of a Paddy Husk Gasifier and Effects of Design Parameters on the Performance of the Gasifier, Ms H. A. De Silva (A Research Thesis)

Gliricidia

There are attempts to give recognition to gliricidia as the 4th plantation crop in Sri Lanka. It is also said that there are 500,000 ha of marginal lands in Sri Lanka, which could be used to grow gliricidia. Therefore it appears that more confidence has been placed in gliricidia overlooking readily available alternative fuels. After all gliricidia is the preferred fuel wood since it gives wood gas easily compared to other wood varieties. In any event gliricidia has to be grown specially for this purpose whereas other agricultural crop residues are obtained without any extra effort with the harvest. The yield of gliricidia is estimated at 25 tons per ha per year, and the purchase price has been fixed at Rs 2.50 per kg. The technology is used to generate power by running an internal combustion engine as the prime mover. The calorific value of gliricidia is 4900 k cal/ kg.

An article written by Vimukthi Fernando on Fuel Wood Alternative, which appeared in a recent publication is reproduced here for further information.

"A plant known and used throughout the years by Sri Lankan villagers, hitherto grown as fences encircling their household compounds, paddy-fields or chenas, enriching the soil with its nitrogen fixing capacities, Gliricidia has come up as one of the best species suitable for dendro power generation. Identified as a SRC (short rotation coppicing) species, gliricidia has been found suitable for various agro-climatic zones of the country. Other fuel wood crops experimented include *Leucaena, Cassia* and *Acaia* varieties. When farming, a mix of species is encouraged for better growth of trees and for environment reasons".

"When it comes to fuel wood farming, the trees are planted at high density, at 1 to 2 meters distance between two plants. The plants are allowed to grow, and lopped at about 4 to 5 feet. It is the profusion of branches, or coppice, which stem out from just below the level when 'lopped' that is used as fuel-wood. These branches are harvested at about 1 to 2 inches in diameter. While the main stem is used as fuel wood the rest of the green vegetation is used as fodder or mulch.

"The lopped branches handled as sugar cane are left on the ground for about a week to dry, then cut into pieces in a customary *'dara mitiya'* size and transported to the electricity generating site."

"The first harvest of branches could begin after about 1 year to 15 months of planting. Harvesting could be done every 6 months. But in Sri Lanka, a tropical country these fast growing trees could even be harvested 3 - 4 times a year. The annual production of 1 ha is well over 25 tons of dry matter."

"However, conservative estimates at 20 tons per year assures an income of Rs 50,000 at the present rates of Rs 2500 per ton of fuel wood, a supplementary income for farmers since the maintenance costs are negligible."

Sugar Cane

In 2004 the area under sugar cane in Sri Lanka with the rattoon crop was 9039 ha, according to the Central Bank Annual Report. According to Table 2.3 given above, annual dry matter yield per ha of sugar cane is 39 tons equivalent to energy contained in 16 tons of oil. However it is stated in page 548, of H.P.M. Gunasena's Book, Field Crop Production, Published by M.D. Gunasena & Co, 1994, that sugar cane variety C O 547 gives a harvest of 25 -30 tons per acre (62.5 - 75.3 tons per ha) and the variety C O 775 in experimental trials has given a harvest of 65 tons per acre (163 tons per ha). In rattoon crops the sugar cane harvest is about 20 - 25 tons per acre (50.3 - 62.7 tons per ha)

Therefore if there is a shortfall of alternative fuels, extensive sugar cane cultivation could provide enough biomass for power generation. Given the fact that dry matter from 1 ha of sugar cane has energy equivalent to 16 tons of oil, Sri Lanka's energy requirement could be satisfied if more sugar cane is grown. Recently sugar prices have gone up and the reason attributed is the increase of ethanol production in Brazil using sugar cane. In countries like Brazil ethanol (ethyl alcohol) is used as a motor fuel. By extensive sugar cane cultivation, Sri Lanka will also be able to produce enough ethanol to be used as auto fuel. At present there is the need to grow about 70,000 ha of sugar cane to become self-sufficient in sugar.

Since sugar cane cultivation is less lucrative, sugar cane cultivation can be encouraged if sugar making is developed as a cottage industry. According to "Sugar Cane Cultivation with Illustrations" by Henry Abeywickrema, published by M.D. Gunasena and Co. in 1974, sugar could be obtained by boiling the crushed sugar cane juice and allowing the sugar to settle. Considering the retail price of sugar to be around Rs 80/= per kg, growing sugar cane to produce sugar is highly profitable. Abandoned paddy fields could be used for this purpose and bagasse could be used as an alternative fuel.

Conclusion

As stated above, there are enough alternative fuels available locally and the need for imported coal and oil for power generation can hardly be justified. It has been stated that the world's stock of biomass contain more energy than proven reserves of coal and oil put together.

Saw dust burner

3. Steam Engines & Power Plants

Literature on Steam Engines

Since interest in steam engines has got lost, it is appropriate to refer to certain items of literature on steam engines.

The following has been stated about steam engines in page 104, Rail 2000, Commemorative Volume, published by the Department of Railways.

"The steam locomotives grew immensely in size and power. The 'Pennsylvania Giant' reached 101 miles per hour with a load of over 1000 Tons. Its weight was 500 Tons. This was considered the world's largest passengers steam locomotive in 1939. Freight steam locomotives also reached similar proportions and were able to haul 125 loaded freight cars at speeds over 50 m.p.h. The world speed record for a steam locomotive was set by the "Mallard" in 1938 and touched a top speed of 127 m.p.h."

The following section, which appears in page 193, Power Guide, Intermediate Technology Publications, 1994 speaks about the use of steam engines for electricity generation.

"The steam engine was the literal driving force of the 19th century industrial revolution in Europe. It has a number of advantages which lead it to still find favour in many developing country applications; high reliability, low maintenance requirements, simple controls, ability to match changes in power demand and a long lifetime. Some steam engines have been in operation for more than 100 years. Many are still used in developing countries. Steam engines however tend to be large constructions and therefore expensive. They have been displaced by small steam turbines which are available in the range of 100 to 1000 kW. However it should be remembered that for these small power applications, there is little difference in overall efficiency between small steam engines and turbines. For electricity generation, both types need a gearing system for coupling to the generator.

"The efficiency of a steam system depends upon the difference in pressure and temperature of the steam entering and leaving the engine or turbine. Increasing the steam pressure and temperature increases the power output and efficiency for a given engine. For simple systems efficiencies of 5% can be expected, whereas modern large plants can reach 40% efficiency. This increase in efficiency is bought at a price and increased sophistication".

"Only a few manufacturers of small steam engines remain. This is mainly due to their initial capital cost making it difficult to compete economically. At the lower end of the power range, against the diesel or petrol engine, a simple design system of 200 kW has been quoted at US$ 135 kW (installed capacity) for the engine plus US$ 500 for the boiler and auxiliaries, whereas a 200 kW diesel engine is approximately US$ 50/ kW. It is therefore important to compare equipment lifetimes. A small well-maintained diesel engine can be expected to last 10 years at most, whereas small steam engines can have lifetimes in excess of 30 years.

"Care should be taken with the discharge of cooling water from steam plants. Releasing large quantities of warm water in to lakes and rivers may lead to discernible increases in temperature which, even if they are only 1 or 2^0C can harm the aquatic life. Although this is only likely to be a problem for very large steam generation plants, it would be wise to monitor any discharges. Water cooling plants are available but can increase capital investment by up to 10%".

A description about the working of a steam engine could be found in page 27, Introduction to Energy Technology and Society, Edward S. Cassedy & Peter Z Grossman, "Steam engines operate on the Rankine Cycle and follow thermodynamic paths that follow changes in pressure and volume of the steam as the machine goes through its cycle of operation. In part, the paths of the Rankine Cycle are determined by the particular characteristics of the working substance as it changes from water to steam or from steam to water."

"A classic example of the Rankine Cycle is the reciprocating steam engine, which powered factory machinery in the 19th century and is similar to those used on railroad locomotives earlier in this century. There is a piston inside a cylinder that is connected to a flywheel by a drive shaft. There are also inlet and exhaust valves on the cylinder. The basic action of the engine is probably familiar. First the steam enters from the right into the cylinder. As the steam expands, the piston is driven horizontally to the left. But after the steam is thrust, the motion imparted to the flywheel forces the piston back to the right. In the process, the spent steam is expelled. The motion of the piston and the flywheel also controls the valves that regulate steam input and exhaust. As long as steam is fed to the piston chamber, the reciprocating motion will continue. The reciprocating steam engine is an example of an open thermodynamic cycle in that the working substance - steam - is exhausted from the system after its use."

The following is an article written by L.W. Mediwake on Drendo Power or Fuel Wood Powered Benguela Railway, in a recent publication.

"Today there is much discussion on the importance of fuel wood to meet the country's energy need. While it is the right option few people know that it has been already done many decades ago by British businessmen in Africa. The most classic example being the fuel wood powered privately operated Benguela Railway."

"The Benguela Railway located in Angola; Central Africa was built in 1904 by the famous Scottish mining engineer the late Sir Robert Williams an associate of Cecil Rhodes. The railway was built to transport the vast mineral resources of Central Africa and travel to the interior of the continent. It was built along the Benguela slave route a distance of 838 miles from the Atlantic coast to the Congolese Republic. The railway was a Anglo Portuguese Enterprise with its head office in Lisbon and the operational headquarters in Lobito Angola. A port built by the Railway Company was in the Atlantic Ocean. Construction, was completed in 1928 at princely cost of pounds 52 millions.

"Along with the Railway the Company grew its own fuel wood in 100 millions of pine trees producing 400 000 metric tons of wood a year to feed its British built locomotives, namely 105 Bayer Garrat engines carrying 1.5 million tons of goods in each direction a year."

In its hey day the mid sixties, it was possibly the only railway in the world with such a carrying capacity using its home grown fuel wood. The Benguela Railway began to pay back its investment 20 years after its foundation was laid. Some say it is old fashioned and that it should be modernized with diesel locos as the Zambian Railway has done. But for the present there is a kind of logic in persisting with steam. Few railways in the world can pass mile after mile to the shadow of its own fuel. The west forest of the company grows Eucalyptus trees which line the track and provide 400000 metric tons of wood each year to fire the railway boilers.

Three thousand men are employed to cut them and saw them into logs at the refueling points and to replant. Wood fuel was a economic necessity when the railway was planned due to lack of coal in Angola. In any case modern diesel locos apart from the high cost, damage the existing railway track. As recent experience in Brazil has shown, the Benguela railway is not just a railway but more like a government or a social institution. It has its own deepwater port in the Atlantic coast at Lobito with about 50,000 inhabitants 90% of whom work for the railway or the port. The company has its own huge workshop not only repairing but manufacturing spare parts at Nova Lisbon. Employing over 1000 people in the workshop, the company also has their own hospital and schools for the workers children. The company farm in Chenga produces 15000 eggs per week; rear their own pigs and fruit and vegetables for the railway and others. ...."

.... The writer is an Economic Geographer holding a Doctor of Natural Science Degree from the University of Bonn, Germany. He has been involved in rural technology and rural economic matters for over two decades. The Center for Rural Technology, which he built in Kundasale and used as a demonstration centre by many Peradeniya University Professors, was totally destroyed by acquisition and inundation by the Victoria Project.

From the above description it is clear that steam engines or locomotives could also be run using fuels such as wood. Therefore it could be assumed that steam engines could be run by firing other alternative fuels as well.

From the above description, the capabilities of steam engines are very clear. In 1986 railway people restored the discarded steam locomotive 'Viceroy', which is still operational. The efficiency of a steam engine can be increased if steps are taken to use boiler flue gas to super-heat the inlet steam. Exhaust steam can be also used to pre-heat feed water and boiler flue gas too could be used for this purpose. By these measures efficiency of the steam engine is likely to increase enough to generate 1 kWh of electricity by burning 1 kg of biomass fuels.

Loco Works, Perambur, Chennai, India has restored a 150 year old steam locomotive named 'Fairy Queen' built by M/S

Kitson, Thompson & Hewitson of UK. This feat is similar to what has been achieved by our Railway men in 1986, by restoring the steam locomotive Viceroy Special.

Manufacturers of Steam Engines and Turbines

Since very little is known about manufacturers of steam engines, a List of manufacturers of steam engines as found in the publication 'Power Guide', Intermediate Technology Publications, 1994 is given below with a brief product description. The existence of these enterprises needs verification. This information is useful when making decisions.

- **Spillingwerk GmbH -** Werftrasse 5, W-2000
  Hamburg 11, Germany
  Tel +4940781335

Status: manufacturing high speed steam engines for 40 years, although involvement in steam systems dates back to 1890.

Products: High speed one-cylinder and two cylinder double expansion steam engines, built on a modular basis to allow for expansion of capacity as power demand increases; primarily for combined heat and power applications.

There are three engine types available in the power range included in this directory. Equipment is designed to ensure that maintenance can be carried out by local staff.

- **Skinner Engine Company** 337 West 12th Street
  PO Box 1149, Erie PA 16512, USA
  Tel +1 814 454 7103

Products: Multi - cylinder steam engines in Delta range 45 - 600 kW, engine generator sets up to 500 kW and single stage turbines which cover a range from 0.3 kW to 2.3 MW

- **Mernak SA** Rua Otto Mernak 276, Caixa Postal 23
  96 500 500 Cachoria, Brazil
  Tel +55517222144

Products : Single cylinder reciprocating steam engines in the power range 30-225 kW, overall efficiency 10 - 14 % also complete systems of boiler plus engine. Can be used for mechanical or electrical power generation.

A list of manufacturers of steam turbines is also included here. If affordable this technology could be used for power generation. As long as locally available fuels are used the conversion technology is not important.

Manufacturers of Steam Turbines

- **Nadrowski Turbinenfabrik GmbH -** PO Box 6104, 4800 Bielefeld
  Germany
  Tel +49 521 10 850

Products: Steam Turbines up to 5 MW

- **AKZ Turbinas SA -** Via Anhanguera km 229,
  14 140 000 Cravinhos SP Brazil
  Tel +55 16 651 1416

Products: Turbines with single or multiple stages either back pressure or condensing systems. Overall efficiencies range from 35 - 90%. Costs: From US$ 30000.

- **Dresser Rand Company -** 37 Coats Street, Wellsville,
  NY 14895, USA
  Tel +1 716 593 1234

Products: Range of single stage steam turbines up to 2.5 MW as well as mini multi stage turbines and standard turbine generator sets.

A long list of various manufacturers of boilers, furnaces and other equipment which could be used in conversion of alternative fuels could be found in the publication the Power Guide mentioned above. Details about power plants which use biomass as fuel could also be found in the Wartsila website. (www.wartsila.com)

Since the cost of imported equipment is high, it is cheaper to make components locally. The gliricidia fired power plant of 1 MW capacity at Walapane cost US$ 1 million. It could be safely assumed that appropriate technology could be bought at US$ 1 million per 1 MW installed capacity, whereas if steps are taken components such as steam engines, boilers, furnaces and generator sets can be made locally at a fraction of the imported cost. It will be cheaper to import equipment from countries like Brazil rather than developed countries in Europe. As far as generator sets are concerned, Soar Technologies of Negombo Road, Welisara, build generator sets locally according to a news item.

Coal Power

Coal power is the preferred alternative to oil fired thermal electricity in Sri Lanka. Since little is known about the coal requirement, following information about a planned coal power plant will be useful. The following data appeared in page 75 of the publication Coal Power for Industrialization and National Progress in Sri Lanka, Ceylon Electricity Board Publication 1992.

- Coal Usage for a 150 MW plant @ 70% Plant Factor - 370,000 tons per year
- Coal Burn Rate - 60 tons per hour

- Electricity Generated by two150 MW plants - 1850 GWh @ 70% Plant Factor
- Electricity Generated by two 300 MW plants - 3700GWh @ 70% Plant Factor

Price of coal will not be cheaper when the price of a barrel of oil is at US$ 60. There is no need to rely on imported coal specially when there is the potential to develop our own alternative energy programme.

Finally it should be stated here that every effort should be made to build components like steam engines locally. Attaining efficiencies of about 20% will be more than enough as a unit of electricity (1 kWh) could be generated by burning 1 kg of biomass fuels.

To learn more about coal power plants, the following description given in pages 102 & 103, of Energy Resources & Policy by Richard C Dorf is useful and worth reproducing here.

"Black Mesa is a barren plateau on the Navajo and Hopi Indian Reservations in North Eastern Arizona. The largest strip mine in the US is located where the Peabody Coal Company has leased 65,000 acres of land from the tribes. The Black Mesa mine feeds coal into two electric generating stations called The Mohave and Navajo generating stations. The Mohave station consists of two 755000 kW units and utilizes a slurry pipeline to receive coal from the Black Mesa mine. The Navajo station consists of three 750,000 units. The coal at Black Mesa is soft, bituminous, low sulphur coal and is available relatively close to the surface.

"The station at Four Corners produces 2085 MW alone. The Navajo and Four Corners plants supply power to the metropolitan areas of Los Angeles, Las Vegas, Phoenix and Tuscon via transmission lines. These plants use 30,000 tons of stripped coal daily. Regrettably the Navajo and Four Corners Plants also produce significant emissions of sulfur and nitrogen oxides and limited quantities of particulate matter."

"The Hopi and Navajo tribes will receive about 25 US cents per ton for the coal. Some US $ 75 million over the lifetime of the project. The plants currently generate about 6000 MW and transmit this power to the user regions. In some sense this is a case of metropolitan areas simply moving the waste products and environmental damage attendant upon a generating plant to another area the Four Corners while consuming power themselves. The first plant of the Four Corners project began operation in 1963 and the full project may be operational by the early '80's. However opposition to one of the proposed plants, the Kaiparowits Plant in Utah may result in that plant never being completed. In addition limited success has been achieved in the attempt to reclaim more than 1500 acres of land strip mined on the reservations."

"A 78 - mile railroad has been constructed solely to carry coal from Black Mesa to the Navajo generating station near Page in Northern Arizona (near the Glen Canyon Dam). The Navajo plant has a total capacity of 2250 MW and uses water from lake Powell for the plant's cooling water. The Navajo Plant was completed in 1976 and incorporates an extensive environmental quality control system. About US $ 200 million was expended on environmental protection equipment, one fourth of the total cost of the project."

"Coal from Black Mesa is also supplied to the Mohave plant in Southern Nevada by means of a 430 - km pipeline. The coal is mixed with water to form slurry and transported via the pipeline. A slurry pipeline is a relatively efficient means of transporting coal when sufficient water is available at a low price. The Navajo and Four Corners projects are two of the largest of their kind in the world and if coal is to remain a primary fuel over the next 25 years we can expect to find several similar developments in the western United States."

Dendro Power Plants

An article written by Vimukthi Fernando on the Fuel Wood Alternative, is reproduced here for further information.

"The fuel wood, about 1 - 2 inches in diameter purchased from the farmers is tipped into the loading hopper. There the sticks are chopped into small pieces of about 3 - 6 inches each and fed into the furnace or gassifier."

"There are two methods of electricity - generation using fuel wood. While one uses steam the other method more suitable for small plants, uses a combustible gas."

"In the first method, fuel wood is combusted in a boiler to raise steam at high temperature and pressure."

"High - Pressure steam is used to drive turbo alternators to produce electricity. This is very similar to traditional oil or coal fired systems and used all over the world for many years. In Sri Lanka, sugar industries use this technology to meet their power needs."

"In the second method, wood is partially combusted to produce a combustible gas. This gas is cleaned and used as fuel to drive IC engines to produce electricity. It is a method similar to that of driving motor vehicles on liquid petroleum gas."

From this piece of information it could be understood if an internal combustion engine could be used to generate electricity, similarly a steam engine could be used for similar purpose.

Oil Fired Power Generation

As far as oil fired power generation is concerned 10 GWh of electricity from the National Grid consumes around 1.2 million litres of oil. No further explanation is needed due to low plant cost oil fired power generation has taken root firmly in Sri Lanka. At the above rate, to generate 4570 GWh of thermal power in 2004, 548.4 million litres of oil (about 548,400 tons) would have been used. The value of such a volume of oil has to be understood in the context of the potential to substitute it with locally available alternative fuels.

Paddy Husk Gasifier

Details of a paddy husk gasifier of Indian origin is given in page 217, of the publication "Power Guide" (Intermediate Technology Publications, 1994). Products include a gasifier for electrical / mechanical power generation of 45 - 250 kW, using rice husk a diesel engine with fuel replaced at 80 - 85%, and a 160 kW generator set using a gas engine. Fuels used include rice husk, bagasse, saw dust, wood chips, and coconut shells. 1 kg of rice husk could generate 0.7 - 0.86 kW of electricity.

Address: - Grain Processing Industries (India) Ltd, 29 Strand Road, Calcutta, 700 001 (WB) India. Tel: - +91 33 231 639

Dendro power plant

4. Coconut Palm & Vegetable Oils

Due to certain properties of the coconut palm, it can be considered as a premier biomass crop. Scientifically coconuts are grown at a maximum of 200 palms per ha. Therefore trees per unit area of land is low. Due to this fact coconuts can be grown in the driest parts of Sri Lanka assisted by harvested rain water. Coconuts can also tolerate salinity of sea water.

Biomass from Coconut Cultivation

When biomass is harvested from the coconut tree no harm is caused to the tree. A fully dried fallen coconut leaf weighs about 1 kg. Annually a coconut palm sheds about 12 leaves. At 200 trees per ha, the annual coconut leaf yield is anything between 2 to 4 tons per ha of coconut plantation. At a harvest of 100 nuts per tree per annum, the coconut husk harvest will be 6 tons per ha. Coconut shell harvest will be 3.39 tons per ha. It could be clearly understood that a large quantity of biomass can be produced from 439,000 ha of coconuts grown in Sri Lanka.

Coconut Cultivation & Rainwater Harvesting

The water requirement of an adult coconut plant is estimated at 45 litres a day. During a rainy season of 3 months and a dry period of 9 months in the driest parts of Sri Lanka, and annual rainfall of about 60 cm, if enough rainwater is harvested coconut trees can be provided with the recommended daily water requirement for 9 months. The water requirement for 270 days per plant would be 270 X 45 = 12,150 litres (12.15 m3). There are plastic water tanks with a capacity of 10,000 litres. However these water tanks are expensive. A low cost alternative will be rain water harvesting containers made of recycled plastics, PET material.

There is also the possibility of harvesting rain water on a polythene film placed in a trench (2ft wide x 2ft deep x any length) to form a water tank made of polythene. An experimental trench of 60 cm wide x 60 cm deep x 120 cm long was dug to find out the suitability of this method by me sometime back. A 3 ft wide 2 ply polythene film of 8 ft length was torn along one of its seams to obtain a polythene film of 6 ft wide. This polythene film was placed in the trench dug in such a manner to form a water tank made of polythene. When filled with rainwater this tank was covered fully with another film of polythene to prevent evaporation losses of water and mosquito breeding. The water lasted well over a year.

Watering of coconut trees is necessary for yield maximization. Therefore coconuts can be grown in the driest parts of Sri Lanka in this manner.

Fuel from Coconut Oil

The chemical formula of coconut oil is C-56 H-72 O-6. By cracking the coconut oil molecules various motor fuels can be obtained. Dr. P.K. Thampan, in his "Handbook on Coconut Palm," Oxford and IBH Publishing Co, 1981 states in page 257 as follows on making fuels from coconut oil.

"Researches have also shown the possibility of preparing products like petrol, kerosene oil substitutes, heavy oils etc. from coconut oil. The commercial utility of such findings is still to be established. By cracking coconut oil at 356° to 388° C under pressure (3.2 kg/cm2) motor fuel (46.2%) and diesel oil are obtained. The yield of motor fuel increases when higher pressures are applied. Products similar to gasoline are also obtained by distilling calcium soaps of coconut oil fatty acids with high boiling hydrocarbon oil and excess of lime.".

P.L. Fraenkel in his work, "Water Lifting Devices," mentions as follows on use of vegetable oils as motor fuel. "Some successes have been reported with running diesel engines on vegetable oils. Tests have been run on seed oils from peanut, rape, soybean, sunflower, coconut, safflower and linseed. Sunflower oil in particular shows promise as a fuel for diesel engines. The main problems relate to the much higher viscosity of vegetable oils compared with diesel gas oil: this makes, it difficult to start a diesel on vegetable oil, but once warm it will run well on it. Tests have shown that the performance is little affected, but fuel consumption on vegetable oil is slightly higher due to its low calorific value. A major problem with unmodified vegetable oils has been a tendency for engines to coke up rapidly, leading to reduced power and eventually engine seizure if no corrective action is taken"

In the same work the following has been stated about cracking of vegetable oils. "Large scale processing of vegetable oil can crack the oil much the same way as the crude oil, to produce veg-gasoline as well as veg-diesel. During the Second World War, China developed an industrial batch cracking process for producing motor fuels from vegetable oils, mostly tung oil. The China Vegetable Oil Corporation of Shanghai was able to produce 0.6 tonne of Veg-Diesel, 250 litres of Veg-Gasoline and 180 litres of Veg-Kerosene per tonne of crude vegetable oil."

Coconut Oil Substitute for Diesel

A motor mechanic named Deamer, in the Pacific Island Vanuatu has converted diesel vehicles to run on coconut oil. He has developed a small and inexpensive pre-heater that lowers the viscosity of the oil before it enters the engine and also worked with another local distributor to develop filtration techniques to remove water and impurities. Since vehicles are run on coconut oil, in Vanuatu the same technology could be used in Sri Lanka when oil prices reach sky high. Coconut oil prices will come down due to an increase in production.

Oil Palm vs Coconuts

Oil Palm has a distinct advantage over coconut oil in terms of oil yield. It is said that 1 ha of oil palm gives as much as 6 tons of oil yield whereas 1 ha of coconut could produce only 2.5 tons of oil. (p 75, Oil Seeds and Oil Milling in India, A Cultural and Historical Survey, K. T. Achaya, Oxford & IBH Publishing Co Pvt Ltd, 1990) Oil Palm is grown in the rainforest region in Sri Lanka and oil palm cake is of little use. Therefore coconut will be the preferred crop.

Coconut Oil Cake

Coconut oil cake or 'Poonac' is a valuable, cattle feed. Since Sri Lanka imported milk products to the value of US$ 122 million in 2004 according to Central Bank Annual Report, 2004, this commodity (coconut oil cake) from large scale oil milling will be a boon to the dairy industry.

Excess coconut oil cake if available can be used to feed wildlife, whose habitats are reduced at an alarming rate. At least steps can be taken to feed the wild elephant population which faces imminent extinction in the near future.

Economics of Coconut Oil Milling

According to the coconut prices in 2006 price of 1 metric ton of Philippines coconut oil is Rs 60,003/= (US$ 600). With a barrel of oil at US$ 60, coconut oil is fast becoming competitive with the imported oil. According to the Annual

Report of the Central Bank of Sri Lanka for the Year 2004, cost of production of a coconut is Rs 7/50. At 8 nuts per kg of oil, the cost of production is Rs 60, which is exactly the CIF Rotterdam price of Philippines coconut oil. Diesel is sold at Rs. 50 a litre. Therefore in the event of a sharp rice in oil prices coconut oil will be a cheap alternative to petroleum.

Table 4.1 Coconut Conversion Tables

1 Kernel Products

Item	Coconut Number	Copra (MT)	Desiccated Coconut MT	Coconut Oil(MT)	Coconut Poonac
1 MT Copra	4900	1.000	0.724	0.615	0.308
1 MT Desiccated C.	6800	1.381	1.000	0.850	0.425
1 MT Coconut Oil	8000	1625	1.176	1.000	0.501
1MT Coconut Poonac	16000	3250	2.352	2000	1000
1000 Coconuts	1000	0.203	—	0.125	0.063

2. Coconut Shell Products

Item	Whole Shell Number	Shell Flour MT	Shell Charcoal MT
1 MT Shell	5900	0.750	0.300
1MT Shell Flour	7900	1.000	0.400
1 MT Charcoal	19700	2.500	1.000
1000 Shells	1000	0.130	0.050
1 MT Activated Carbon	65000	—	3300

3. Coir Fibre

Item	Husk	Mattress Fibre	Bristle Fibre
1 MT Coir Fibre	7900	0.650	0.350
1 MT Mattress Fibre	11800	—	—
1 MT Bristle Fibre	23600	—	—

Source : Coconut Development Authority.

Summary

Considering the economic benefits, it is advisable to grow coconuts in the marginal lands identified as suitable to grow gliricidia. With favourable climatic conditions coconut production surpasses the 3000 million nuts mark. With irrigation and fertilizer application coconut production can reach 4000 million nuts per year. Since the value of coconut cultivation is significant in the alternative energy field, top priority should be given to increase coconut production. As coconuts are grown in Assam, India, research should be carried out to find out whether these varieties can be successfully grown in cooler higher elevations in Sri Lanka to increase the area of coconut lands. Steps should be taken to maximize the coconut yield per tree by supplementary irrigation and fertilizer application, so that coconut oil can be used as a substitute for imported oil. For instance with a coconut harvest of 100 nuts per tree, which is easily achievable by supplementary irrigation and fertilizer application, the coconut harvest can be increased to 7.9 billion nuts from the present average of 395,000 ha of land under coconuts. 8 coconuts could produce 1 kg of coconut oil. Therefore by putting about 1 million ha of new lands under coconut, the oil bill of Sri Lanka could be slashed considerably. Around 3.5 million tons of oil (crude and refined) is imported to Sri Lanka, while at higher yields 20 billion coconuts could be collected from 1 million ha of coconut lands. This is equivalent to 2.5 million tons of coconut oil. There is a real necessity to grow more coconuts, as Sri Lanka needs more grass lands in order to produce more milk. Therefore growing grass and coconuts can be done together at no extra cost as well. Further if necessity arises, sugar cane also can be grown as an under crop in coconut lands to increase ethanol production, which in turn could be used as an alternative fuel.

Hydraulic jack operated coconut oil extracting machine

5. Miscellaneous Topics

Sri Lanka Striking Oil

It has been speculated that petroleum reserves may be found in the off shores of Sri Lanka.

Given the refining capacity of the Petroleum Corporation refinery at 50,000 barrels per day, and the quantity of refined petroleum oil products imported to Sri Lanka, a 200 million barrel oil reserve would not last long.

After the Gulf war in the 1990's price of crude oil fell below US$ 10 a barrel. Even with cheaper imported oil, no big impact was felt on the economy. On the other hand energy from alternative fuels mean more jobs and additional incomes to people. Drilling of this oil will be done with foreign collaboration. The likely basis will be product sharing. Under a likely scheme Sri Lanka is to get 51%, while the foreign oil company gets the balance oil.

Even if we strike oil, it is advisable to conserve it to use as feedstock in chemical industries rather than burning it as motor fuel. If Sri Lanka is endowed with a world class petroleum reserve, which could be readily tapped, there is no necessity to sign an agreement to build a coal power plant. Completion of a giant power plant will take years and by then there will be plenty of oil to run existing as well as new oil fired power plants.

In any event I wish all the success for oil drilling because with the new found prosperity, if any, Sri Lanka can get rid of her foreign debt and also the dependence on remittances from migrant workers to Sri Lanka.

Machinery for Alternative Energy Programme.

In the websites *www.approtec.org* or *www.kickstart.org* several machines which could be used in a biomass energy programme are mentioned. As fuel crops need *irrigation*, various foot pumps, listed in the above websites are of some interest. There is a foot pump called the Super Money Maker Pump which draws water up 23 feet and has a total pumping head of 46 feet. Two acres of land can be irrigated in a day. The Money Maker Plus Water Pump draws water up 23 feet and has a total pumping head of 69 feet. It is capable of irrigating 1.5 acres of land per day. Details of a manually operated Hay Bailing Machine is also given in the website. This piece of equipment can make 80 bales of straw a day. This type of machinery is useful as large quantities of fuels such as paddy straw and grasses could be handled with ease. There is also a manually operated press for oil seeds to extract oil. These technologies can be purchased at a price of US$ 1000 each.

Other equipment such as size reduction machinery, briquetting machinery, and combustion equipment could be found in the Publication "Power Guide", Intermediate Technology Publications, 1994, with a list of names and addresses of manufacturers.

Transport of Alternative Fuels.

Since large quantities of alternative fuels need transportation, buses idling in state owned bus depots for want of repairs could be converted to carry alternative fuels. Then there is the 15 cube (1500 cubic foot) trailer manufactured by Dutch Lanka Trailers, which has the carrying capacity of 15 cubes. Railway wagons which also has capacity about 45 tons per carriage could be used for this purpose. By strategically locating the power plants the need to transport alternative fuels can be minimized.

Making Steam Engines Locally

Since importing equipment from abroad is expensive, an effort should be made to build components locally. Given the facilities available in government institutions, and cheap labour, costs will be much lower. To improve the efficiencies of steam engines, boiler flue gas could be used to super heat inlet steam as well as to feed water to the boiler. Exhaust steam can be used to pre-heat the feed water to the boiler or it can be condensed and used as feed water to the boiler. Since the size of power generation is small (about 500 kW) measures can be easily taken to curb energy wastage. If 1 kWh of electricity is generated by burning 1 kg of biomass fuel such as paddy straw, the efficiency levels can be considered as satisfactory.

Therefore many steam engines big enough to generate ½ MW of electricity could be made and connected to the national grid in the same manner as mini hydro power plants are connected to the grid. The steam engine is of simple design and with local expertise steam engines similar to existing steam railway locomotives could be built. Similarly the boiler too could be made resembling those found in steam locomotives. Engines could be then coupled to a locally built generator. Power plant costs can be reduced in this manner greatly and measures can be taken to minimize the heat losses and improve the overall efficiency of the system.

Boilers

Boilers similar to ones found in existing steam locomotives of the Railway Department could be made locally and easily at a lower cost. Since repairs to these boilers are carried out regularly, technical know-how could be obtained easily. There are four steam locomotives in running condition belonging to Sri Lanka Railways.

Fertilizer

Ash from burning of alternative fuels is a rich source of potassium. Therefore the need to import potassium fertilizer can be reduced. In 2004 Sri Lanka imported US$ 107 million worth fertilizer. With enough power generated, a urea fertilizer plant too could be set up to manufacture urea fertilizer using the Haber Process.

Bio Diesel

The manufacturing process of bio-diesel is given as follows:-

- Oils pressed from plants like rape seed and soybean yield fats called triglycerides, which are then heated.
- After the heating has purified the oil, methanol and a catalyst such as potassium hydroxide is added.
- These chemicals break triglycerides into substances called glycerol and esters. Esters form the biodiesel fuel.

Since coconut oil is also a triglyceride molecule, bio-diesel can be made without any difficulty.

6. Conclusion

Energy Prices

According to the Annual Report of Central Bank of Sri Lanka for the Year 2004, the price of 1 kg of LP Gas was Rs 63.12. As at February 2006, 1 MT of LP Gas was US $ 625. Given the calorific value of LP Gas at 48 MJ/kg, that of vegetable oil at 39 MJ/kg and the price of coconut oil at US$ 600 per Mt, it is very clear that alternative fuels are becoming competitive. If we assume that biomass fuels contain one third of energy contained in LP gas, and LP Gas is four times more efficient than fuel wood 12 kg of biomass (i.e. fuel wood) has to be burnt to do the work of 1 kg of LP Gas. 1 Kg LP Gas costs Rs 76.80 (cylinder price). Therefore at this rate the value of 1 kg of fuel wood will be Rs 76.80/12 = 6.40. However the price paid for gliricidia wood is Rs 2/50 per kg. At current energy prices, the use of alternative fuels is cheaper.

Cheaper Electricity

In Sri Lanka 2960 GWH of hydro-electricity was generated in 2004. If enough thermal power using biomass is generated the cheaper hydro electricity can be reserved for industrial uses. Cheaper electricity can be allocated to industries such as steel, tires & tubes, cement, automobile manufacturing, fertilizer, chemicals, paper, milk powder, electrical appliances, power looms and pharmaceuticals. By developing these industries, Sri Lanka will be able to overcome balance of payments difficulties.

The Available Resource.

As alternative fuels are the abundantly available resource, which can be put to productive economic use, many new employment opportunities can be created in the alternative energy sector as well as elsewhere. If everything is made locally there will be more employment opportunities. When the unemployment problem is solved there will be no poverty as incomes of the people will rise.

Since measures taken to develop our country since independence have failed, a sustainable programme such as this, which utilizes an abundant resource for production has to be implemented. If anything Science and Technology can do to our society, it has to be this type of alternative energy programme, which is beneficial to the society at large.

The efficiency of a steam engine can be increased up to 40% as mentioned earlier, and as commissioning of other power plants consume money and time, making steam engines locally is a quicker way to get out of dependence on oil fired electricity generation. Therefore the possibility of using alternative energy with low cost locally made equipment should be given serious thought.

Finally, for power generation, if alternative fuels readily available run out, sugar cane can be grown to fill the shortfall. Sugar cane will also come to the rescue if sufficient quantities of vegetable oil are not available. Ethanol made from sugar cane can be used as a substitute.

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