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A Feasibility Study on Power Generation and Transport Sector Transition

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Abstract: Sri Lanka is almost fully electrified now, but we still lean hard on imported fossil fuels to keep the lights on. That's risky, it leaves us open to price swings, blackouts, and environmental fallouts. And with energy demand climbing by nearly 5% every year, switching to renewables isn't just smart, it's urgent. This study focuses on a robust, affordable plan to replace approximately 35% of our daily fossil fuel electricity (i.e., 18.78 GWh per day) with renewables. The new energy mix relies primarily on hydropower (14.27%), solar PV (42.86%), and wind (22.84%), with about 20% from biomass or waste-to-energy. The plan examines in detail the amount of land required, the resources available, grid stability, and how these factors operate across Sri Lanka's different regions and weather patterns. But it's not just about electricity. The study also examines transport, which consumes a large share of our fossil fuels and emits substantial emissions. Here, it examines bioethanol and biodiesel as viable alternatives to petrol and diesel, using locally sourced feedstocks such as sugarcane molasses and high-FFA coconut oil.

Index Terms: Renewable Energy, Energy Security, Fossil Fuel Displacement, Hybrid Systems, Solar Power, Wind Energy, Biomass, Waste-to-Energy, Bioethanol, Biodiesel, Sustainable Transport.

1 Introduction

The Sri Lankan electricity sector, which is mainly under the Ceylon Electricity Board (CEB), has broadly been able to provide electricity to almost the whole country. Still, the mix of electricity is mostly based on the import of fossil fuels, which makes the national energy system economically vulnerable and at the mercy of the fluctuating fuel prices while also being a cause of environmental pollution. The annual electricity demand keeps on increasing and is projected to be around 4.9%, which is putting more pressure on the available generation capacity and energy security in the long run.

To overcome these challenges, Sri Lanka has made a decision to position renewable energy at the center of its energy policy. Increasing the share of the local energy resources such as hydro, solar, wind, and biomass is a way to cut down on the fuel imports, lower carbon emissions, and enhance the system resilience. Meanwhile, the transport sector is still the largest consumer of fossil fuels and therefore, it is crucial to implement an integrated energy plan that will solve the problems of both electricity generation and fuel consumption.

In this case, biofuels and renewable electricity are two possible alternatives to traditional energy systems that use fossil, based energy. Nevertheless, their widespread use should be confirmed through a detailed technical, economic, and environmental impact assessment as well as land, use constraints evaluation.

This investigation aims to explore the first renewable energy resources integration potential with the local energy mix in Sri Lanka. It is primarily aimed at recognizing their contribution to energy independence, emission reduction, and SDGs support. Besides analyzing existing literature, the article also comprises methods, feasibility study, results, discussion, and suggestions for the government.

2 LITERATURE REVIEW

2.1 Fundamentals of Renewable Energy and Comparison with Fossil Fuels

Electricity Generation in Sri Lanka is a mix of renewable energy sources and fossil fuel based electricity generation methods [21]. Most of the installed capacity in Sri Lanka is owned by the Ceylon Electricity Board (CEB) [1][3]. The distribution of electricity generated by the CEB as of 2019 was nearly 48% is hydropower and the main areas that contribute to the CEB's hydropower capacity are Mahaweli and Laxapana [1][3]. The main problems faced by CEB's hydropower generation plants are seasonal fluctuations in capacity because of the need for irrigation, variances in rainfall or inflow to the reservoirs during monsoon seasons [1][3].

Thermal generation will continue to be the predominant source of dispatchable capacity because it provides a stable baseload service to both CEB and private sector customers [1],[3]. However, thermal generation systems are a significant contributor of greenhouse gas emissions, present major environmental concerns and financial risks due the necessity of fossil fuel imports [1],[3]. On the other hand, renewable energy systems find their appeal in that they are low-emission and sustainable forms of energy; however they are limited by their intermittency and the location factor [1],[3]. Therefore, there is a pressing need for improving long-term sustainability and energy security through increased reliance on renewable sources supported by proper planning and appropriate storage options [1],[3].

2.2 Current energy scenario in Sri Lanka

2.2.1 Hydropower

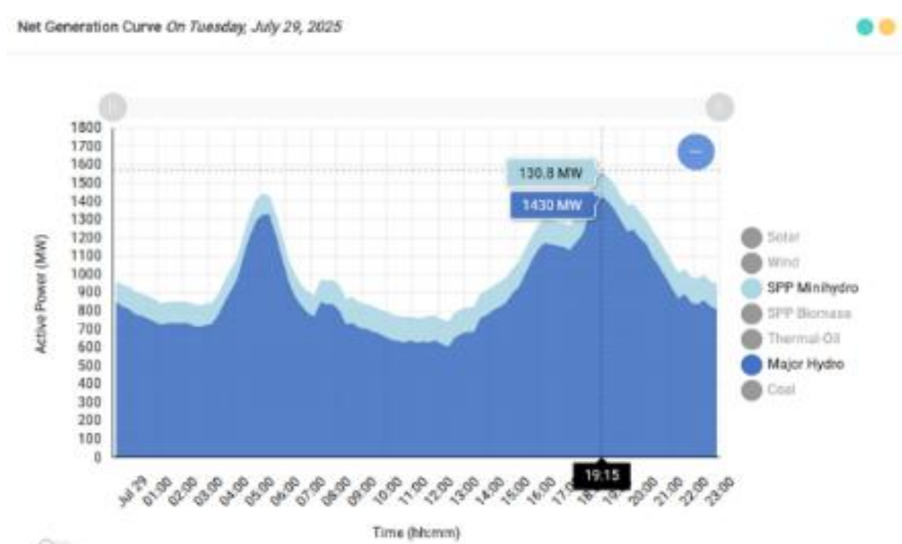

Fig. 1. Hydropower generation on July 29, 2025, with Major Hydro peaking at 1430 MW and SPP Mini hydro at 130.8 MW around 19:15. (Source: Ceylon Electricity Board website [4], accessed July 2025)

Fig. 1 shows us what Sri Lanka's hydropower generation looked like on July 29, 2025. On that day, Major Hydro was producing a lot of power, it peaked at 1430 megawatts. Sri Lanka's SPP Mini Hydro also producing power, it peaked at 130.8 megawatts around 7:15 in the evening. The amount of power being produced rose steadily from the morning. It kept going up until it peaked in the evening. This is when Sri Lanka needs the power, so it was good that hydropower generation was high. This really shows how important hydro power is, for making sure Sri Lanka has power every day. Hydropower remains the country's leading renewable source, supplying about 32% of national electricity and 48% of CEB's installed capacity (~1399 MW), with major plants along the Mahaweli and Kelani rivers [1]. Mini hydro plants (<10 MW), mainly private run-of-river systems, further support rural access. Despite its importance, hydro is seasonally dependent and vulnerable to rainfall variation and dry periods [4].

2.2.2 Solar Power

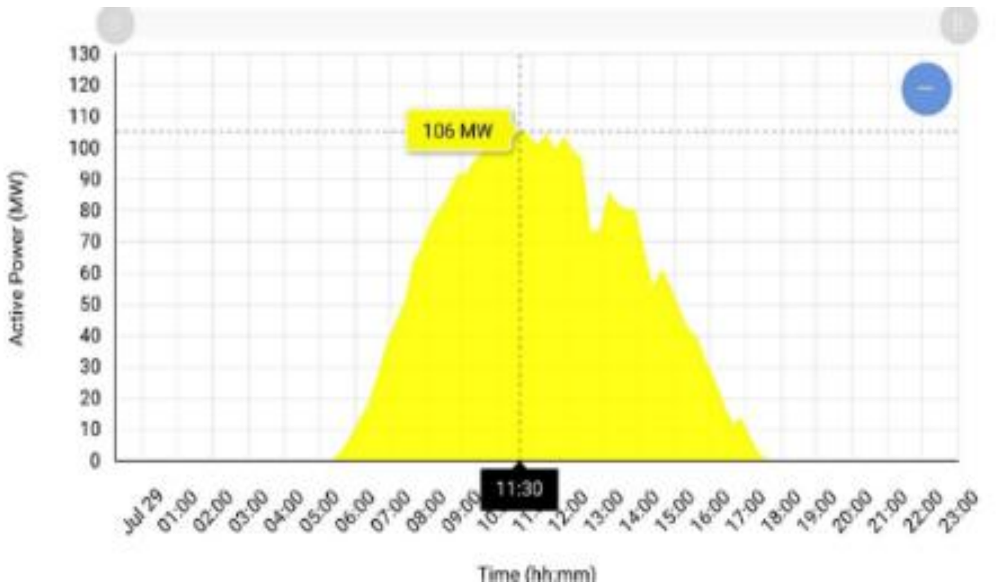

Fig. 2. Solar power generation curve on July 29, 2025, showing a peak output of 106 MW at 11:30 AM. (Source: Ceylon Electricity Board website [4], accessed July 2025)

Figure 2 shows what happens with power generation in Sri Lanka on July 29, 2025. Solar power generation starts to rise after the sun comes up. It gets stronger and stronger until it reaches its peak at 106 megawatts at 11:30 in the morning. Then it starts to go down as the sun sets. This shows that solar power is really good during the day. At night it is not there at all. This is because solar power is not always available. We can see this when we look at the numbers, from the Ceylon Electricity Board, from July 2025. These numbers are used to talk about power. They show us what solar energy can do and what it cannot do. Solar power is expanding through initiatives like Soorya Bala Sangramaya, adding about 287 MW mainly via rooftop net metering, alongside large projects such as the 100 MW Pooneryn and 30 MW Kilinochchi plants [1]. While promising, solar generation's variability demands better grid integration and storage solutions for reliable use.

2.2.3 Wind Power

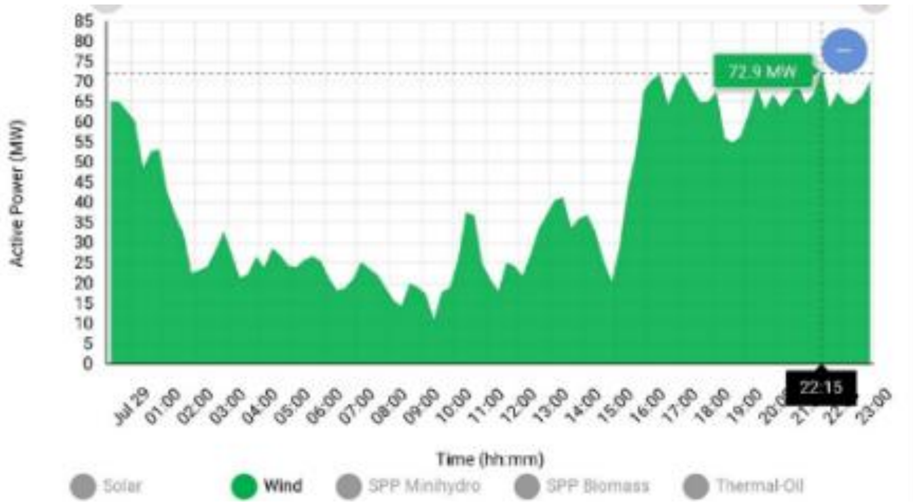

Fig. 3. Wind power generation on July 29, 2025, showing fluctuating output throughout the day with a peak of 72.9 MW recorded at 22:15. (Source: Ceylon Electricity Board website[4], accessed July 2025)

Fig. 3 shows Sri Lanka's wind power generation on July 29, 2025, demonstrating the high variability of this resource. Output fell below 20 MW between 02:00 and 08:00, increased from midday, and rose sharply after 14:00, peaking at 72.9 MW at 22:15. This pattern underscores wind energy's intermittency and the need for storage or backup systems in grid integration.

Mostly from private projects in Hambantota and Puttalam, Sri Lanka presently has close to 128 MW of wind capacity. The CEBs Mannar Wind Power Project is thus, the first public utility, scale wind farm, with a 100 MW initial phase and expansion potential up to 375 MW. As depicted in Fig. 3, evening generation supports solar generation by satisfying demand at night, however, the fluctuations emphasize that there is a need for a more robust grid and support systems.

2.2.4 Waste-to-Energy

Waste-to-Energy (WTE) came as a viable solution in Sri Lanka to address both electricity generation and municipal solid waste management. Two grid-connected incineration-based WTE plants, Keravalapitiya (10 MW) in Fig. 4 and Karadiyana (10 MW), have been commissioned, with particular emphasis on high-waste areas such as Colombo and Gampaha [1].

Professor Ajith de Alwis says that the waste in Sri Lanka is mostly organic and has a lot of moisture. This kind of waste is better for things like anaerobic digestion. Getting gas from landfills. The Pilisaru programme, which was started by the Central Environmental Authority, uses this waste to energy technologies along with ways to reduce, reuse and recycle waste. Waste to energy also helps make power in areas, which means we lose less energy when we send it to people. It also gives us useful things, like heat and soil conditioners. While regulatory, financial, and public acceptance barriers remain, WTE stands as a promising dual benefit solution for energy and environmental sustainability in urban Sri Lanka [1] [5].

Fig. 4. WTE plant at Keravalapitiya (10 MW) (Source: Captured image of WTE plant Keravalapitiya by M. D. R. Weerasuriya at Keravalapitiya)

2.2.5 Biofuels in Transportation

Sri Lanka's transport sector consumed about 137,991 TJ of petroleum energy in 2021, with road transport responsible for 96% of related CO_2 emissions [6]. Heavy reliance on imports creates energy security and foreign exchange risks, especially during global fuel price fluctuations [6].

Bioethanol and biodiesel are really alternatives to what we have now. Some studies, from the University of Moratuwa show that making bioethanol and biodiesel in our country can help us use less petrol and diesel save money on imports and help people in rural areas. Bioethanol and biodiesel can make a difference. However the bioethanol and biodiesel sector is still very new. We do make bioethanol from molasses at two sugar factories. It is only good enough for drinking not for use as fuel because we do not have the right equipment to remove the water from it. At the time we do not have any big companies making biodiesel just some small tests using oils that we cannot eat and waste oils. Bioethanol and biodiesel are important, for our future. Scaling up requires reliable feedstock supply chains, investment in processing facilities, and regulatory standards for blending and fuel quality, currently under policy discussion [7].

3 INTERNATIONAL BENCHMARKS

To assess Sri Lanka's renewable energy progress, it's helpful to compare it regionally and globally. In 2020, renewables made up 39% of Sri Lanka's Total Energy Supply (TES), It was more than the majority of the SAARC countries but less than Nepal (75%) and Bhutan (87%), which are entirely hydro, dependent. It is worth noting that Sri Lanka was the only SAARC country which experienced a decrease (1.8%) in the renewable energy share from 2015 to 2020 [8].

Worldwide, hybrid renewable systems combining complementary sources like solar, wind, or solar hydro improve their reliability and reduce the periods when supply is not available [9]. The solar energy mostly available throughout the year in Sri Lanka, the seasonal wind (Northwest and Central Highlands), and the well, established hydropower make the country an ideal place for such hybrids [8]. Countries like Brazil, India, and European nations have successfully implemented solar hydro, solar wind, and smart grid systems. To advance, Sri Lanka should establish hybrid zones, invest in grid upgrades and storage, enforce consistent policies, and apply complementarity analysis for planning [8][9].

4 METHODOLOGY

This study collects time Ceylon Electricity Board (CEB) data on daily peaks and total generation and source breakdown to figure out Sri Lankas current energy situation. The study looks at renewables like hydro and mini hydro and solar and wind and biomass. It also looks at fuels like coal and oil. The study shows that fossil fuels make up 35 percent of the energy used in Sri Lanka. This is 18.8 GWh, per day. The study says that this 35 percent of fossil fuels can be replaced with something. The idea is to figure out how to use hydro, wind, biomass or waste-to-energy. We have to see what is available and what we can really use. For example we need to think about if we can use the land and if we have the infrastructure. When it comes to transport we want to know if we can use biodiesel and bioethanol of diesel and petrol. We look at things like how feedstock we have how much we can process and how it will affect the environment. Each option for energy is looked at closely. We think about the technology and the economy and how it will affect the environment. We also think about how much it will cost, the cost of each unit how land we will need and how it will affect people. We do this for hydro, wind, biomass and waste-, to-energy. At the same time, hybrid configurations, storage, and smart grid needs are noted to ensure reliability and grid stability [1].

4.1 Baseline Energy Demand Estimation

The current daily energy demand in Sri Lanka was estimated using actual recorded values:

- Day Peak Demand: 2,315.8 MW [4].
- Night Peak Demand: 2,780.1 MW [4].
- Total Daily Energy Generation: Approximately 53.69 GWh [4].

Out of this, approximately 34.97% (18.78 GWh) is currently supplied by fossil fuel sources (thermal coal and oil) [4]. This study focuses on replacing that 18.78 GWh/day with a well-balanced, renewable energy mix.

4.2 Classification of Energy Sources

The sources are divided into the following categories,

- Renewables: waste-to-energy, biomass, wind, solar PV, and hydropower (large and small).
- Non-renewables: IPP thermal oil, CEB coal, and CEB.

Approximately 65% of the daily generation already comes from renewable sources [1]. The remaining approximately 35% fossil share is to be eliminated by the suggested mix.

4.3 Renewable Energy Substitution Strategy

The 18.78 GWh/day fossil fuel component was replaced with a comprehensive renewable energy mix. Based on potential energy output, resource availability, scalability, land use, and economic viability, the percentage of each renewable source was determined.

Table 1. Renewable Energy Substitution Strategy

Renewable Source	Contribution (GWh/day)	Share (%) of Replacement
Hydropower (expansion)	2.68	14.27%
Solar PV	8.05	42.86%
Wind Power	4.29	22.84%
Biomass/Waste-to-Energy	3.76	20.02%
Total	18.78	100%

Table 1 presents, a substitution strategy for renewable energy based on energy potential, resource availability, scalability, land use, and economic viability to replace the fossil fuel demand of 18.78 GWh daily with a renewable mix. Solar PV is the largest contributor at 8.05 GWh/day (42.86%), followed by wind power at 4.29 GWh/day (22.84%), biomass/waste, to, energy at 3.76 GWh/day (20.02%), and hydropower at 2.68 GWh/day (14.27%). When combined, these sources accomplish total substitution, providing a sensible, workable strategy that advances the country's objectives for energy security and sustainability.

5 TECHNOLOGY SPECIFIC CONSIDERATIONS

5.1 Hydropower (14.27%)

Building new mini/micro hydro plants in underutilized river basins and expanding current hydropower projects. given priority because of its low marginal cost, dispatchability, and dependability [10]. According to the Renewable Energy Resource Development Plan for 2021–2026, expansion will make use of small to medium river basin locations that are appropriate for mini and micro hydro development. Particularly in established markets like Mahaweli and Laxapana, hydropower provides excellent dispatchability and dependability at low marginal cost once infrastructure is constructed [10].

5.1.1 Capacity Required

Assuming that Sri Lanka's small and micro hydro systems have an average capacity factor of 25 to 30%, which is typical for run-of-river systems in monsoonal climates.

$$\text{Required capacity} = 2.68\ \text{GWh/day} \div (24\ \text{h} \times 0.27\ \text{capacity factor}) \approx 415\ \text{MW}$$

This aligns with the medium-term realizable potential (~400 MW), making it feasible with the full deployment of existing unused small hydro sites.

5.1.2 Available Regions & Catchments

Sri Lanka hosts approximately 600 potential mini-hydro sites spread across the central highland and mid-country basins, including,

- Districts: Ratnapura, Kandy, Matale, Badulla, Nuwara Eliya, especially across river systems like Kelani, Kalu, and Mahaweli tributaries.
- Example developments:
  - ✓ Erathna project (10 MW, Kuru Ganga tributary of Kalu Ganga) expected generation ~40 GWh/year from ~14.5 km² catchment.
  - ✓ Denawaka Ganga project (7.2 MW, Ratnapura basin) 25 GWh/year with ~172 km² catchment area.

Scaling linearly, targeting 2.68 GWh/day would require an aggregate catchment area on the order of ~65–70 km² distributed across multiple river basins.

5.1.3 Feasibility & Land Use

There is little need for major land clearing since most small/micro hydro plants follow the natural flow of rivers and use the nearby facilities thus, no need for separating farmland. The major impact on the catchment is still hydrological rather than agricultural. The 600 sites that have been identified are mostly in non, sensitive tea estate areas and moderately steep catchments. The truth is that there are environmentally sensitive places that should be taken care of like the Sinharaja buffer zones, streams such as Athwelthota that are very fragile and so on.

Among the reinstallation initiatives under the micro hydro program supported by the Asian Development Bank are 19 micro hydro plants that were previously operated and have been turned off (Together almost 1.3 MW) in Badulla, Kandy, Kegalle, Matale, Nuwara, Eliya, and Ratnapura districts. Thus, these plants are being restored and renovated, which will increase their total power generation capacity and supply area and ensure the continuity of electricity access in rural areas.

5.2 Solar PV (42.86%)

Sri Lanka receives 1,247–2,106 kWh/m²/year of global horizontal irradiance (GHI), translating to an average of ~4.5 kWh/kWp/day energy yield. Practical solar PV output in Sri Lanka averages ~4.485 kWh/kWp/day, or ~1,637 kWh/kWp/year.

A target share of 42.86% of the replaced fossil generation (~8.05 GWh/day) implies requiring approximately 1.8 GWp of installed solar capacity.

$$8.05 \text{ GWh/day} \div 4.485 \text{ kWh/kWp/day} \approx 1{,}795 \text{ MWp}$$

5.2.1 Land requirement for that capacity

Assuming 10 MW per 53.5 ha (~5.35 ha/MW), this is equivalent to about 960 ha (~9.6 km) which is less than 0.6% of the total land area of Sri Lanka. Areas like Hambantota, Monaragala, Ampara, Anuradhapura, Vavuniya, Mannar, Trincomalee, and Puttalam can be used.

5.3 Wind Power (22.84%)

Positions along the coast and in the northwest (such as Mannar, Puttalam) have average wind power densities of 300 to 400 W/m at 50 m, with a few locations where it's even more than 800 W/m. The capacity factors of these big size installations such as the Thambapavani Wind Farm (Mannar, 103.5 MW) and Mampuri farms (Puttalam) are approximately 26, 27%.

To generate ~4.29 GWh/day, at a ~26% capacity factor this requires approximately 693 MW of wind capacity,

$$4.29 \text{ GWh} \div 24 \text{ h} \div 0.26 \approx 693 \text{ MW}$$

This is within the projected feasible realizable onshore wind potential of Sri Lanka (~1 GW) and is consistent with the studies of stability constraints that permit up to ~540 MW of wind at night, peak load (2021) and ~660 MW by 2025.

5.3.1 Land requirement for that capacity

- Turbine footprint (small, ~1–2% of area)
- Spacing (5 to 10 rotor diameters apart)
- Access roads, substations, buffer zones

5-10 MW per km² of gross area (depending on turbine size and spacing). We'll use 7 MW/km² as a realistic average (moderate-density layout).

Land Area = 693MW / 7MW per km2 = 99km2

Net land use (actual physical disturbance) is typically only ~1-2% (~1.5-2 km²), and we can use the rest of the land (mostly agricultural/scrubland) as remains usable under turbines.

Table 2. Suitable Land Areas in Sri Lanka for Wind Farms

Region	Key Locations	Wind Power Density
Mannar	Silavathurai, Thalaimannar	>800 W/m²
Puttalam	Mampuri, Kalpitiya	400–600 W/m²
Jaffna	Point Pedro, Pachchilaipalli	300–400 W/m²
Kilinochchi	Iranamadu region	300–500 W/m²
Eastern Coastal Belt	Trincomalee, Batticaloa	300–400 W/m²

Table 2 illustrates the extent of the land in Sri Lanka that is appropriate for setting up wind farms. Mannar district along with Silavathurai and Thalaimannar has a power density of more than 800 W/m. Therefore, it is the first location where largescale wind farm installation is suggested. Puttalam district along with Mampuri and Kalpitiya has a power density ranging from 400 to 600 W/m, thus, it is an area where wind farms can operate efficiently. Jaffna, Kilinochchi, and the Eastern Coast have a wind power density of 300500 W/m, so these areas can be used for medium, sized projects. The mapping indicates the differences at the local level and is a great tool for the efficient utilization of wind energy in the different regions.

5.4 Biomass/Waste-to-Energy (20.02%)

Biomass power plants based on agro, residue such as rice husk and coconut shells and urban waste, to, energy by burning in the areas of Colombo and Gampaha have been selected due to their dual benefits of power generation and waste management [10]. Biomass sources are the clean energy segments that originated from agricultural residues (e.g., the rice husk, coconut shells, and rubber seed) and the municipal solid wastes of urban centers. Though in detail, quantified yield data are less standard, the Renewable Energy Resource Development Plan, and several studies locate biomass and waste as trustworthy contributors at a current share of 0.5% to 2% and with a potential of scaling up to meet ~3.76 GWh/day [10].

5.4.1 Energy Potential from Agricultural Residues

A Geographic Information System, based study figures the rice industry of Sri Lanka with the byproducts (rice husk and straw) of the mill could be the source of the power generation of about 977 MWe, producing about 5.65 TWh/year (15.5 GWh/day) if these residues were fully utilized, i.e., 100% of straw and 30% of husk[11][12]. As the demand is only for 3.76 GWh/day, this is still a potential that is far from being exhausted. The full potential only used up to ~25% already yields ~1.4 TWh/year (~3.8 GWh/day).

5.4.1.1 Calculation breakdown

Full potential: 5.65 TWh/year ÷ 365 ≈ 15.5 GWh/day.

Required share ~3.76 GWh/day ≈ 24% of full potential.

Thus, using a fraction of rice-husk/straw residues is realistic.

5.4.2 Feedstock Availability

Sri Lanka is generating about 4.7 million tons of rice straw, and 1.1 million tons of rice husk every year. The straw is almost totally (~100%) left without use, and a mere (~30%) portion of the husk is feasible for utilization. Coconut shell biomass, which is a by, product of the areas that are a source of coconuts, is having calorific values ranging from 26 to 31 MJ/kg, therefore, it is appropriate for briquette or direct combustion conversion [11].

5.4.3 Economic Feasibility

The rice, husk/straw systems with Grate, Fired Combustion followed by Steam Turbine (GFC/ST) in high, potential districts (Kurunegala, Polonnaruwa, Anuradhapura) were found to produce positive NPV and profit indices >1, at realistic costs per MW and O&M rates.

Waste, to, energy projects such as Aitken Spences 10 MW plant are estimated to cost around LKR 13 billion (~USD 50 million), with the funding models consisting of a mix of equity and term loans. The capital cost at the beginning of the project is quite high; however, the per unit cost can be lowered if the project is divided into several plants.

6 TRANSPORT SECTOR

The transport sector in Sri Lanka was the largest energy consumer among the sectors in Sri Lanka, accounting for around 35% of the total energy demand in 2021. Besides the residential sector, the transport sector has been the second largest energy consumer in the country for several years; however, its share has been increasing gradually and even at certain periods, it has gone beyond the level of the residential sector [1]. The transport sector is almost entirely dependent on fossil fuels. Its consumption has fluctuated between 154.8 and 183.2 PJ during 2016, 2021, thereby reaffirming the sector's leading role in transportation [1]. Then petroleum, which is used for airport and seaport facilities, the present situation clearly shows that petroleum consumption has remained the major source of the transport sector. It is a matter of great urgency to promote renewable energy sources in the transport sector with such a heavy dependence on petroleum so as to reduce emissions and to save the country from the adverse consequences of the continuing depletion of the foreign currency reserve [1].

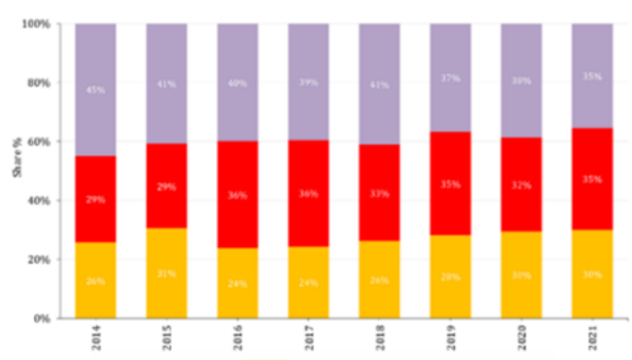

Fig. 5. Energy Demand by Sector. (Source: Sri Lanka Energy Balance, Sri Lanka Sustainable Energy Authority [13], accessed July 2025)

Fig 5. illustrates Sri Lankas energy consumption per sector from 2014 to 2021. Transport's participation has gone up from 29% to 35%, showing a rise of its share in the total energy used, while industry changed slightly, from 26% to 30%. Household, commercial, and other sectors together have reduced their share from 45% to 35%, which can be explained by either the improvement of the efficiency or the saturation of demand. The trend implies the necessity of focusing on transport and industry when planning energy transition measures.

Worldwide, the energy consumption of road transport was 2.1 Gtoe in 2021, representing a 7% increase compared to 2020, but still 4% lower than the pre, pandemic levels [14]. The share of alternative fuels was 8.8% of the total consumption (~185 Mtoe), with biofuels supplying 91 Mtoe (49.3%), out of which 51 Mtoe of bioethanol and 40 Mtoe of biodiesel, were the major contributors, as a result of the demand for Hydrotreated Vegetable Oil (HVO). The geographical distribution of biofuel usage was as follows: Latin America 15%, North America 6.5%, Europe 5.2%, and Asia 2.3%. The use of biofuels, in particular in Asia, was not much affected by the COVID, 19 situation and kept growing steadily in 2021 [14].

Refining petroleum in Sri Lanka, mainly at the Sapugaskanda refinery, is a major source of fuel for the country but also creates a lot of pollution. Even when it is run at its full capacity of 2.3 million tons per year (50, 000 bbl/day) [13], the refinery cannot meet the demand of the whole country, which means that it is necessary to import a huge quantity of refined petroleum products [13].

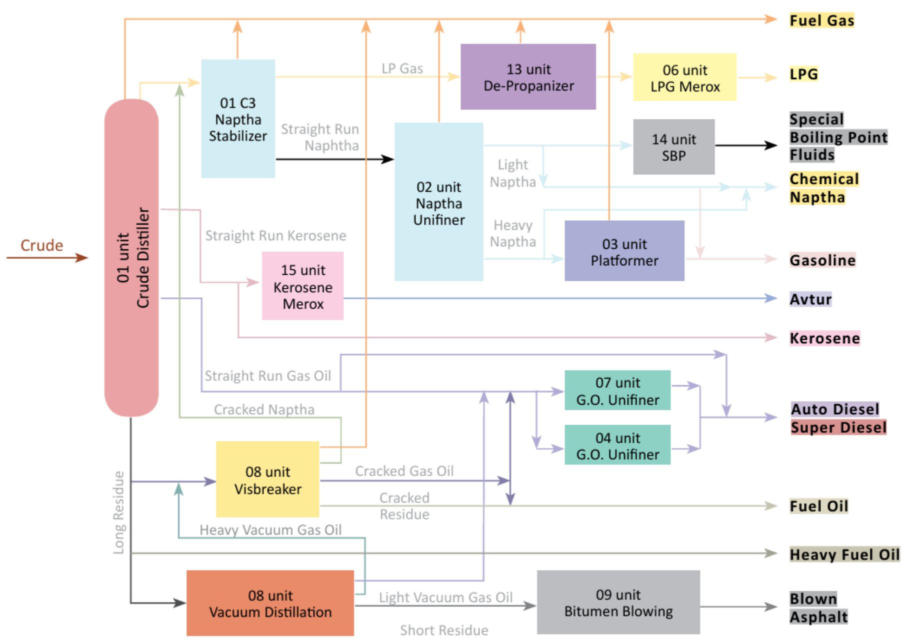

Fig. 6. Sapugaskanda Refinery Process Flow Diagram. (Source: Sri Lanka Energy Balance, Sri Lanka Sustainable Energy Authority[13], accessed July 2025)

Fig 6. displays a process flow diagram of Libyan Oil Refinery that shows the series of the unit and product outputs that are obtained from the refining of crude oil in Sri Lanka. The first stage of the process sees raw oil pumped into the 01 Crude Distiller Unit, which in turn separates it into the primary fractions such as straight, run naphtha, kerosene, gas oil, and residue. Next, these fractions are processed in different units.

Straight run naphtha is initially stabilized by the C3 Naphtha Stabilizer and later by the Naphtha Unifiner (02) and Platformer (03) to produce lighter components, i.e. gasoline, chemical naphtha, and

Special Boiling Point (SBP) fluids. Kerosene is processed through the Kerosene Merox (15) unit and then utilized to produce avtur (aviation turbine fuel) and kerosene. The gas oils are exposed to hydrotreatment at G.O. Unifiner Units (04 and 07) thus the products of auto diesel and super diesel are obtained. The heavy residues are sent to the Visbreaker (08) and Vacuum Distillation (08) units to get vacuum gas oils and short residues that can later be processed into fuel oil, heavy fuel oil or passed to the Bitumen Blowing (09) unit for blown asphalt production. Moreover, the system has De, Propanizer (13) and LPG Merox (06) units that are used to treat LPG and produce fuel gas.

The chart details the complicated refining stages that turn crude oil into the vital petroleum products needed for transport, industry, and domestic use in Sri Lanka. Nevertheless, mismatches between supply and demand lead to inefficiencies and increase the environmental impact of both local refining and international logistics.

The change from Iranian Light crude to alternatives like Murban, Siberian Light, URAL, and ESPO, due to sanctions, has resulted in lower process efficiencies and increased difficulties in controlling emissions. These different crude blends upset the refinery's optimal operations, thus increasing emissions, waste, and the potential for groundwater or air pollution. Furthermore, refining produces solid wastes and releases greenhouse gases that add to the environmental burden of the Sri Lankas transport sector [13].

6.1 Bioethanol

Sri Lanka produces only a small amount of bioethanol and is not equipped to blend fuels, whereas most vehicles are still powered by petrol or diesel. A commercially available E10 is not there, however, feedstocks such as sugarcane, molasses, and cassava present a great deal of good. The sugar industry, particularly in Pelwatte and Sevan Gala, has the capacity to raise ethanol production, but the output is very low at the moment. Ethanol blends could have helped to lower the country's petroleum imports, lessen the emissions, and boost the agriculture sector if there were a policy to support them, an infrastructure for blending, and vehicles compatible with the blends. Currently, bioethanol is just a hidden potential in the Sri Lankan energy sector that needs to be discovered before the transport transition can be called sustainable.

6.1.1 Bioethanol – Petrol Blends

Bioethanol is a renewable alcohol, based fuel made by fermenting sugar and starch, containing plants, and it can be mixed with petrol to drive spark ignition (SI) engines [4]. A bioethanol, gasoline mixture, particularly at low concentration levels such as E3, E5, and E10, has been found to increase the octane rating while being compatible with most petrol engines of the recent models. Almost all vehicles of the contemporary type can run on E10 without any engine modification, while Japanese used imports are generally safe up to E3 [1]. Nevertheless, for blends exceeding E10, it is necessary to check vehicle compatibility and use corrosion inhibitors to avoid damage to the fuel system [1].

6.1.1.1 Cost & Efficiency Comparison

To assess cost benefits, a comparison between Lanka Petrol 92 Octane and E20 (20% Ethanol) blend is made using July 2025 prices,

<u>Lanka Petrol 92</u>

Price: Rs. 305.00/L [15]

<u>Ethanol</u>

Price (100% Ethanol): 8,96 €/L [20] { Rs 3172.47}

E20 Blended Fuel Price per Liter,

E20 Price= (0.8×305.00) + (0.2×3172.47) = 244.00+634.494 = Rs. 878.494

Thus, the E20 blend provides a extra cost of Rs. 573/L compared to pure petrol, But it has enhancing combustion performance and best environmental benefits.

6.1.1.2 Efficiency and Environmental Benefits of the Blend

Bioethanol features a higher-octane number than regular gasoline. The incorporation of ethanol into petrol elevates the Research Octane Number (RON) and Motor Octane Number (MON), which makes knocking less severe and thus the thermal efficiency is higher. As an instance, blending 20% ethanol into petrol 88 raises the RON by 11% and MON by 12%, thus significantly improving the anti, knock properties of the fuel and allowing the use of engines to be at higher compression ratios, which are directly linked to better thermodynamic efficiency. Even though ethanol has a lower energy content, its higher oxygen content facilitates cleaner and more complete combustion. As a result, the emissions of carbon monoxide, unburned hydrocarbons, and particulate matter are very low, thus making ethanol, petrol blends a cost, effective tool in the abatement of urban air pollution [4]. The problem of cold start can be solved by using a small amount of petrol, and low, level blends (E3E10) offer a minimal risk of corrosion if the quality of the fuel is up to the standard and preventive maintenance is carried out [1].

Moreover, the user experience in a country like New Zealand reveals that there is no substantial power loss and a lot of people report that the throttle response of the mid, range is improved, the driving is smooth, and the emissions are reduced even after more than 100, 000 km of use [1]. Such practical knowledge confirms the viability of ethanol blends under different driving conditions.

6.2 Biodiesel

Biodiesel is a possible renewable source that can be used instead of diesel made from fossil fuels in the transport sector of Sri Lanka. This can be done especially with a low, value high free fatty acid (FFA) coconut oil that is obtained from such byproducts as poonac and sludge. In general, the high price of fixed oils is the main factor that limits biodiesel production. However, local experiments have shown a method that can use both acids, catalyzed and base, catalyzed transesterification to effectively produce biodiesel from a high FFA coconut oil (7.2% FFA) which conforms mostly to ASTM D6751 standards.

The reaction produces about 30% crude glycerin [16], which after inexpensive physical treatment can be converted to industrial consumables like biodegradable cleaners [16]. The important biodiesel characteristics, for example, viscosity (5.077 cSt), cloud point (+10 C) [16], flash point (123 C)[16], and water/sediment content (<0.01%) are all in the range of values accepted by the standards [16]. This confirms the technical compatibility of biodiesel with conventional diesel engines mainly by blending strategies. These results demonstrate that locally sustainable biodiesel production is possible by the use of waste materials in a way that is less harmful to the environment and also contributes to the reduction of fossil fuel consumption [16].

6.2.1 Biodiesel-Diesel Blends

One of the most viable and environmentally friendly methods of transport is definitely blending of biodiesel with petroleum diesel. To a large extent this can be a very effective way of reducing the dependency on fossil fuels and also diminishing the emission of gases that cause the greenhouse effect. It was found that a large number of diesel engines are capable of running on such mixtures as B5 (5% biodiesel) or B20 (20% biodiesel) without any mechanical changes [17]. Thus, vehicle owners can make a transition in a very simple and easy way. New Zealand for instance is a country where B5 is pretty much universally compatible, and even B20, B30 is being used in trucks and buses that carry out commercial activities with little if any changes in operations [17].

The experiment on the diesel engine of a compact agricultural tractor, among others, indicated that there is no significant difference in the power or torque between pure diesel (D2) and B20 [18]. The only change that they noticed was a very slight one of 2.8% in specific fuel consumption when B20 was used [18]. It thus confirms that the latter is an efficient and practical renewable blend. The reason is that for higher blends such as B50 or B100 there are considerable drops in power and efficiency thus making it the right choice only for a fleet that is ready to handle the negative side of performance [18].

6.2.1.1 Cost & Efficiency Comparison

Using current Sri Lankan fuel prices and global biodiesel spot prices, a basic cost-efficiency comparison reveals the following:

Lanka Auto Diesel,

Price: Rs. 289/L [15]

Biodiesel,

→ 3.78541 L = 1 Gallon

→ 1 Litre B100 Price = ₹ 68/Litre [Rs 233.23] [19]

Blending 20% biodiesel (B20) with Lanka Auto Diesel gives,

$$\text{B20 price per L} = (0.8 \times \text{Rs. } 289) + (0.2 \times \text{Rs. } 233.23) = \text{Rs. } 277.846$$

Hence, B20 is marginally less expensive (by around Rs. 11.154 per liter) than a pure Lanka Auto Diesel, providing a saving making along with the benefit of the environment if obtained under good rate of the world. This difference in price could be further widened with more domestic supply made from waste cooking oils or non-edible crops, thus contributing to the country's energy security and environmental sustainability.

6.2.1.2 Efficiency and Environmental Benefits of B20 Blends

Using B20 biodiesel blends (20% biodiesel + 80% diesel) is a physically efficient method that also brings environmental benefits. Tests of the engine of agricultural tractors showed no significant decrease of power and torque, only 2.8% more specific fuel consumption which is a very small efficiency tradeoff [17]. In terms of B20, the situation is just a bit better than that of pure Lanka Auto Diesel, B20 is a little bit less expensive. So, the price of B20 is Rs. 277.846/L whereas that of Lanka Auto Diesel is Rs. 289/L, which is calculated on the basis of international biodiesel rates and exchange values [15] [19].

On the other hand, biodiesel is a cleaner fuel that emits less CO and particulate matter; thus, it is in line with national goals of reducing emissions from the transport sector [17]. Since B20 can be utilized without any modification to the engine, it is an instant, low, barrier way to the diesel fleets that are already in operation to be decarbonized.

7 RECOMMENDATIONS

In order to move to a less harmful and safe energy future, Sri Lanka must first give up the use of fossil fuels step by step by using its plentiful renewable energy sources. The strategies below are suggested as per the feasibility study.

7.1 Accelerate Renewable Integration in Power Generation

- ✓ By focusing on areas with high solar irradiance (e.g., Hambantota, Monaragala), expand solar PV installation to add around 1.8 GWp for the replacement of 42.86% of fossil generation.
- ✓ By the development of wind power projects in coastal and northwestern areas (e.g., Mannar, Puttalam) achieve approximately 693 MW. Besides, take advantage of the seasonal complementarities with solar.
- ✓ Increase the use of small/micro hydropower, especially in the development of less, utilized river basins, up to 415 MW to cover 14.27% of the daily demand while ensuring minimal land use and environment protection.
- ✓ Use biomass and waste, to, energy, mainly by the utilization of rice residues and urban waste, to have a contribution of 3.76 GWh/day.
- ✓ Induce decentralized models and public, private partnerships through incentives.

7.2 Enhance Infrastructure and Policy Support

- ✓ Invest in major system changes to the grid, cutting, edge grid technologies, and energy storage to manage intermittency and increase renewable energy reliability.
- ✓ Implement well, defined, stable renewable energy policies and simplify permitting procedures to attract private investment.
- ✓ Create hybrid renewable zones (solar, wind, hydro) and use complementarity analysis tools to assist regional energy planning.

7.3 Promote Biofuels in the Transport Sector

- ✓ Upgrade the fuel distribution network to support the introduction of ethanol, blended fuels (such as E10, E20) and enable vehicle compatibility standards. Allow and encourage the production of ethanol from sugarcane, molasses, and cassava.
- ✓ Increase the production of biodiesel by the use of waste oils and high, FFA coconut oil. Facilitate the use of B5, B20 blends in the vehicles of public and commercial transport fleets, accompanied by the implementation of good quality control.
- ✓ Help pilot projects and research activities aimed at developing affordable biofuel production technologies at a local level, thus contributing to import substitution and the creation of additional income in the countryside.

7.4 Institutional and Cross-Sectoral Coordination

- ✓ Set up a combined energy planning system that connects electricity production and transport to maintain policy compatibility, use resources economically, and cut emissions.
- ✓ Facilitate the partnership of government agencies, research institutions, and private sector to carry out feasibility studies, transfer of technology, and implementation of capacity, building projects.

8 CONCLUSIONS

Sri Lanka's escalating energy needs and dependence on imported fossil fuels are major reasons why a safe and environmentally friendly energy system is a must. The current research implies that it is both feasible from a technical standpoint and a financial one to substitute approximately 35% of the fossil fuel, based electricity with renewable energy sources. Emission can be reduced and energy independence can be enhanced by using a well, balanced combination of hydropower, solar PV, wind, and biomass/waste, to, energy, with each source evaluated for availability, scalability, land use, and cost.

The transport sector, which depends almost entirely on petroleum, is a significant source of renewable energy integration through bioethanol and biodiesel. Emissions and fuel costs can be lessened and the efficiency can be enhanced without the need for major modifications to the vehicles through blends such as E10 and B20. Although there are obstacles in terms of infrastructure, policy, and market, the advantages are great.

In general, Sri Lanka possesses the natural resources, the potential, and the know, how for a successful shift. Supporting policies will be essential to enable strategic spending on hybrid systems, grid upgrading, and community biofuel production. Combining clean transport with power generation can deliver energy security, help to slow global warming, and bring about fair economic growth over time.

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