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Renewable energy transition in Tamil Nadu: Strategies and solutions for complete transition

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Abstract:Energy is a valuable resource, a necessity, a commodity and a basic right, to all citizens. In spite of its value, it is always on short supply, as there is a rise in demand alongside a shortage or depletion of certain energy sources, such as fossil fuels. This has now led to the movement of many energy makers and citizens to start using renewable sources, such as solar, wind and geothermal energy. The ultimate end goal is one of complete transition to renewable energy sources. Tamil Nadu has already achieved an impressive 50% transition to renewable energy sources, but still heavily relies on coal and other fossil fuels for the remaining 50%. The present average demand of power in the state, as stated by the Environmental Information, Awareness, Capacity Building and Livelihood Programme (EIACP) PC Hub, is around 14,500 MW to 15,500 MW. The state operates the most diversified electricity generation portfolio in India, with an installed capacity of 31,894 MW which includes 50% of renewable energy, 28% from coal-based power plants including shares from central generating stations, 5% from nuclear power plants, 3% from gas power plants and 14% through Open Access and Captive Power Plants (CPP). This paper will study costs and trend analysis for different fuel usage, the ideal application of phase-by-phase transition of different regions to renewable energy sources that are most ideally suited based on climate and region, improvements and barriers in policies that may hinder or boost development, smooth transition of petrol bunks to electric, and strategies for environmental impact mitigation during transition, so as to ensure that the risk-reward ratio is more desirable and beneficial for the state.

Keywords: Mitigation, Transition, Analysis, Benefit.

1.Introduction

In our day-to-day lives, energy plays an important role. It fuels our careers, our homes, our workspaces and even plays a vital role in nearly every field in the world today. Hence, there is a demand for more energy, one that grows with each passing day, as a growing population of people require energy. Alongside this demand, there is also the threat of climate change and global warming, which adversely affects temperatures, climates and has ramifications against the environment. The use of fossil fuels, and non-renewable sources of energy cause land, water, soil and air pollution. To reduce the carbon footprint and to combat energy scarcity, a method or strategy to transition to renewable sources of energy needs to be adopted and duly implemented, also called renewable energy transition (RET). There are many factors to consider, such as costs of different fuel sources, current energy demand and production output and energy department policies which may provide concessions and benefits to energy producers. We must also analyze the current sources of energy production, to see if any modifications or additions can be made to better implement strategies and solutions for transition to renewable sources of energy. Mitigation of environmental impact, during transition, is the most important, as there is no truly clean way of transitioning to newer forms of renewable energies. Future goals of energy output will determine which strategies are most ideal for a favorable risk-to-reward ratio. We are studying the state of Tamil Nadu in India, which has already achieved impressive milestones in their journey to complete RET.

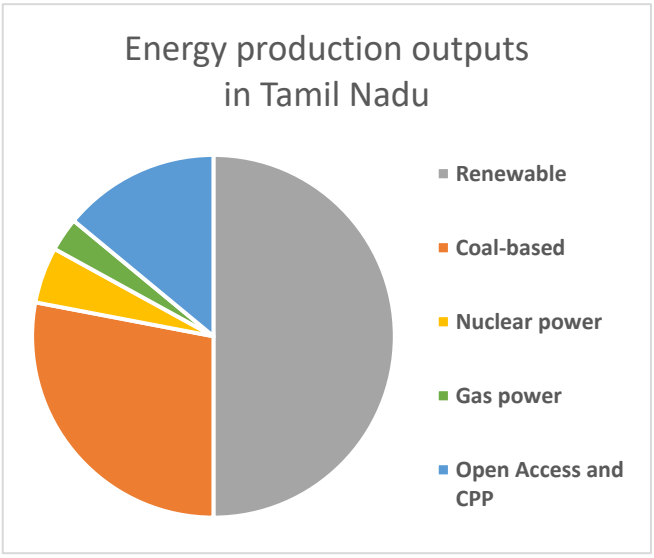

Fig. 1. Energy production outputs in Tamil Nadu, as per EIACP PC-Hub. Source: [1] (tnenvis.nic.in, 2023)

II.COST ANALYSIS

A very important part of our study involves analyzing different fuel prices and seeing how the cost trends change. It also helps us study which would be economically better to pursue, and which source of fuel would benefit the environment in the long run.

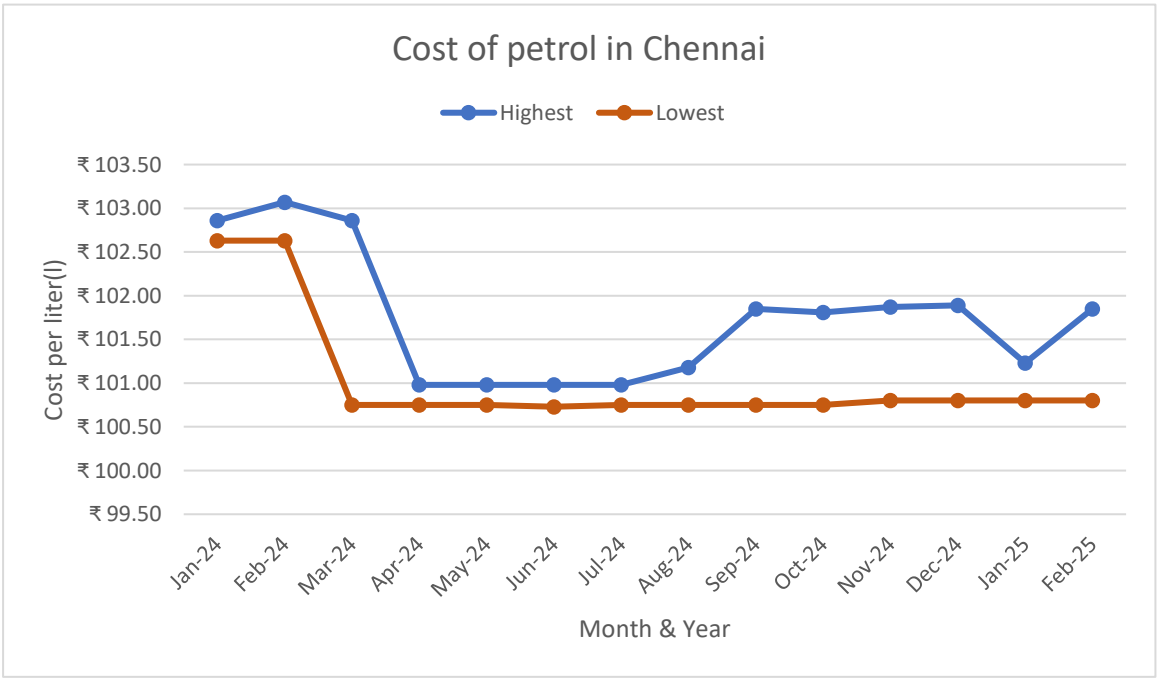

Fig. 2. Cost of petrol in Chennai. Source: [2]-[3] (BusinessToday, Goodreturns, 2025)

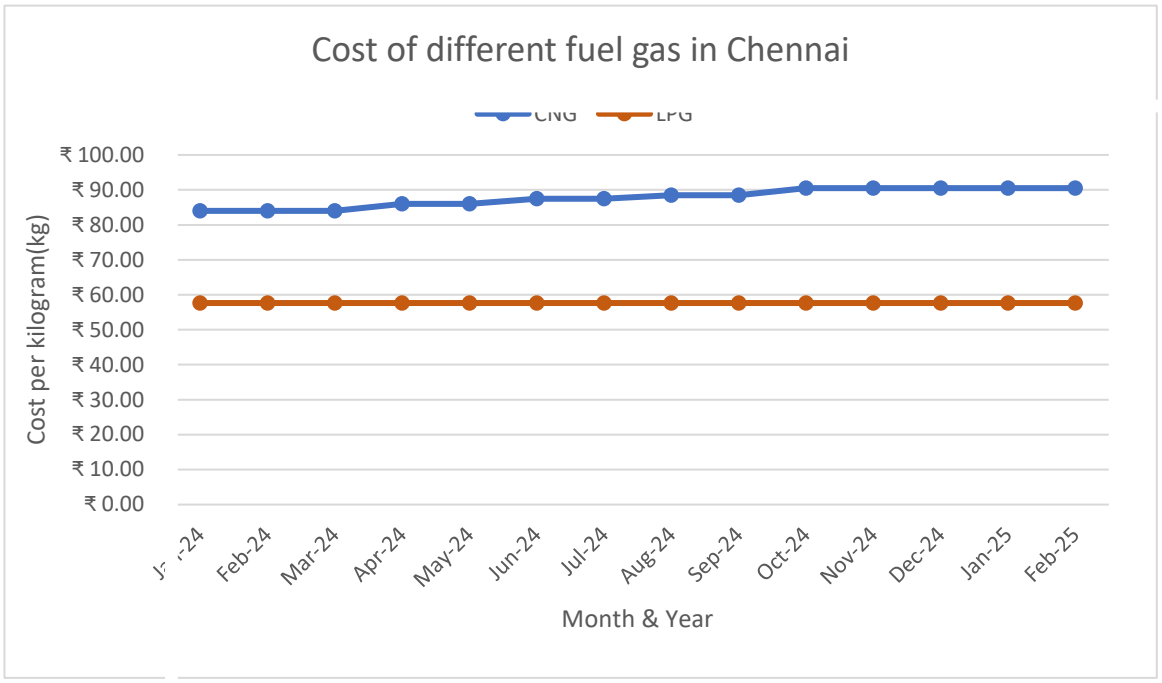

Fig. 3. Cost of diesel in Chennai. Source: [4]-[5] (BusinessToday, Goodreturns, 2025)

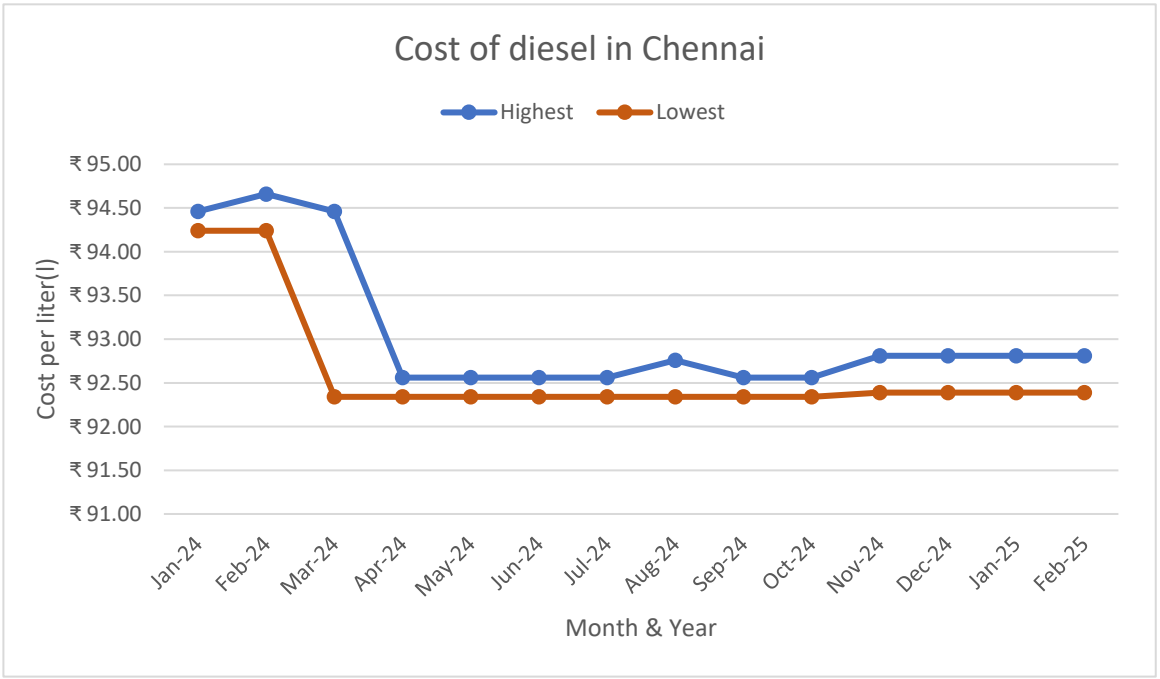

Fig. 4. Cost of different fuel gas in Chennai. Source: [6]-[7] (Goodreturns, 2025)

The above-seen figures (See figs. 1,2 and 3.) all show the trends in cost of various fuel available in Tamil Nadu, specifically in the city of Chennai. We have considered Chennai as our control group, mainly because it is the main metropolitan hub of most activities, being the capital city of the state. Studying these trends, due to all fossil fuels being priced dynamically, it is seen that the lowest prices remain consistent across most months, with there being fluctuations only in the highest prices. The prices change day-by-day and so, we can consider the average daily amount needed, to lie between the highest and the lowest, in a month. Fuels will never stay at the same set

price, as they are priced according to global costs which rely heavily on availability, logistics and politics. But we do not understand the economic effects of these prices, especially in the context of vehicular movement. So let us consider an example, using a car which has an electric and a petrol variant, such as a Tata Nexon. The Nexon has a petrol automatic variant which claims it can travel 17.2 km/l, and has a capacity of 44 liters. The Nexon EV variant has a battery capacity 30 kWh and can travel 9.17 km/kWh. Let us see what the costs of travelling 20 km would be for each respective variant. The costs for EV charging are given below (See Table I.), for Tamil Nadu. Charging stations and their costs can be referred to from [8].

Table I. The costs of EV charging in Tami Nadu

EV charging cost (per kWh)		
Type	**Highest**	**Lowest**
AC	₹ 20.00	₹ 7.00
DC	₹ 24.00	₹ 15.00

The lowest cost of petrol in Chennai is consistently ₹ 100.75 for one liter, for most months (see Fig. I.), so let us consider this for our example. As for the EV variant, let us consider the cost of AC charging, as it is cheaper even though it takes longer to charge than DC, preferably the cheapest average rate being ₹ 15 per kWh. Doing the maths, we can see that making the 20 km trip on the petrol variant would cost ₹ 117.15, while the EV variant would only cost ₹ 32.71. Using home chargers allows EV users to charge their cars at night, and during long trips, DC chargers are preferable. Even considering a long trip of 100 km and DC chargers, the price for charging would be only ₹ 261.72 for EV, whereas petrol would be far more expensive, at ₹ 585.75. The carbon footprint would be significantly lesser, as there would be lesser emissions, and no gases from exhaust.

The study of costs for fuel and public use is most important, as it can be used to raise awareness and make the people understand the benefits of funding renewable sources of energy, both environmental and economic. But that alone is not enough, as policy and communities also play a role in RET. All energy plants must have public support and funding, and with a lack of support, would not be possible to construct, as stated by authors [9].

Region-based transition

Tamil Nadu is located at the southernmost part of India, making it closer to the equator than most other parts of India. This also means that it has a greater potential for solar photovoltaic production, and since it is coastal, it can also be used for wind energy and hydroelectric energy production. The current goal, for the government of Tamil Nadu, is to achieve near-complete RET by 2030. As per [1], they achieved an impressive 50% transition to renewable sources of energy, and have already undertaken plans to construct and expand more renewable energy power plants. According to the Policy Note of Energy Department 2024-2025 [10], the Tamil Nadu Green Energy Corporation Limited (TNGECL) was formed to take over the green energy activities such as Hydro, Wind, Solar etc.

The region of Kanyakumari, in the southernmost tip, receives the most sunlight and winds, and so has the biggest wind farm in the country, the Muppandal Wind Farm, and many solar farms. The Muppandal Wind Farm has a combined capacity of 1,500 kW, and offers employment to many engineers and other positions in the wind farms. As stated by [11], Prior to the construction of the wind farm, Muppandal was a major agricultural hub. The local and rural population were agriculturists and pastoralists, but now, agriculture is a dying profession in the region, as the installation of the turbines have significantly reduced the water levels in the water table. To avoid major displacement, younger people sold or leased their lands, took up jobs in the wind farms and metro cities. The older population were unable to adapt, as their land was no longer fit for cultivation. Similarly, there are many wind turbines along the region, all the way to Thoothukudi, making the region no longer fit for agriculture. To avoid this level of displacement in other regions, the wind farms must be brought off-shore, and placed along the coastline of the state. There are many solar farms in Tamil Nadu, and one of the biggest solar farms in the world, is found in the same region of Kanyakumari. The Adani Kamuthi Solar PV Park generates over 600 MW of electricity, and is spread over 2,500 acres of land. The farm uses roughly 200,000 liters of water to keep the solar panels clean, every day. Majority of the hydroelectric energy produced in the state comes from the its dams and hydroelectric power plants.

There is an untapped potential of off-shore wind and hydroelectric power plants, along the coast of Tamil Nadu, but so far, only wind power plants have been considered. According to [18], There are plans to construct an off-shore wind farm along the Gulf of Mannar, and there is also an enormous potential for off-shore wind energy generation of 35 GW along the Coast of Tamil Nadu from Kanyakumari to Nagapattinam [10], but they are yet to begin planning. Solar farms can be placed in almost any region of Tamil Nadu that is close to the southern side, as most of the state receives high amounts of sunlight, but as of yet, they have yet to be adopted and implemented

by the public. As per the author [12], there is also potential for a geothermal energy power plant in the Tamil Nadu – Pondicherry province, as there is the possibility of a geothermal reservoir being present in the province.

Policies and barriers

As argued by the authors [13], there must be a synergy among technology, society and policy. Engagement of a community, with its policy makers, and with the awareness required of various different sources of renewable energy and their impacts, would be better equipped to grasp and help implement better solutions for RET. They should participate in schemes, that will help spread and use renewable sources of energy, be it for generation, transport, or installation of said energy. For their participation, the government must provide incentives and concessions.

A major step taken in this direction, happened in 2019, when the Tamil Nadu Solar Policy – 2019 [19] was approved. It was to bring awareness and encourage consumers, private companies and the public to begin using and investing in both solar photovoltaic and thermal panels. It gave the people the choice between using solar for their own purposes and feeding the surplus into the grid, or buying solar power at the tariff amount from solar energy producers. There were two methods of ownership: upfront, where the producer would purchase the panels and operate it, and deferred, where the producer would use the solar panels, but it belonged to a supplier, which the producer would lease it from. The policy also had incentives, and initiatives, along with mandates for government buildings, residential and commercial buildings, all being encouraged to install solar panels and invest in electric vehicles. There were plans for initiatives and events that would raise awareness of the benefits of solar energy and mandated workshops and training held by Tamil Nadu Energy Development Agency (TEDA).

There are new policies that were approved during the year 2024, to further expand and add to the already impressive renewable energy portfolio of the state, namely the Tamil Nadu Repowering, Refurbishing and Life Extension Policy for Wind Power Projects-2024 [20], and the Tamil Nadu Small Hydro Projects (SHP) policy. They target the wind and hydroelectric energy sectors respectively. The repowering, refurbishing and life extension policy [20], as the name implies, targets the old turbines, encouraging old turbines to be repowered and made to produce electricity till it reaches 20 years or life expectancy, whichever is earlier. It can then be refurbished and repaired to work well beyond its lifespan. The new policy provides incentives with micro-siting, tax exemptions, relaxation in building and development norms, the ability to convert to solar wind farms, financing, etc. The SHP policy aims to set up small hydroelectric power plants on rivers, canals, etc. It is to drum up interest and awareness in renewable energy, and provides concessions, on sharing of electricity produced to third-parties. These policies are merely the beginning, and the Policy Note [10] states the projects, such as dams and power plants that are under construction, operational, etc. It also states the various other projects such as solarization of structures be they residential, commercial, institutional, etc.

Solutions and strategies

When transitioning to renewable energy, the construction of new power plants and energy farms, and the conversion of old ones will certainly come with its fair share of problems, such as how to effectively use an old power plant, and how t o mitigate carbon footprint when constructing newer power plants. We must devise strategies and solutions that allow us to minimize the environmental impact of transitioning to renewable sources of energy, while allowing us to fully harness the potential for energy production. This means we must revise the way we approach energy production and consider more hybrid options than simply wind and solar hybrid farms, or simply EV charging stations.

5. 1. Gas station conversion:

Gas stations will eventually need to be converted fully to EV charging stations. When considering conversions, there are additions and modifications that we can look at that will help both the energy consumer and the energy producers. As per the author [14], the most obvious modification would be conversion of parking spaces to charging spaces. This will allow many people to park their cars and charge them simultaneously in a single station. The other modifications that can be made is that the underground fuel tanks can be made into Hydrogen fuel storage tanks, which will then allow hydrogen fuel cell technology to be integrated into the station, allowing hydrogen cars to be refueled at the normal fueling station alongside EV chargers, in lieu of petrol and diesel. This has been explored by author [15]. The rooftops can be fitted with solar panels, which are fed into batteries used to charge cars or power the building or fed back into the grid. The station can be embellished with green spaces, to reduce any possible environmental impact, and improve air quality. The station building can be made into a larger retail, entertainment and recreation space, as this will be used by the people who drive EVs and they need activities to do during the charging of their vehicles. Underground hydrogen fuel storage has been explored by authors [16]-[17].

5. 2. Limit and regulate power plant requirements:

To avoid loss of agricultural land, as seen in Muppandal [11], we must limit the number of turbines we place on or near agricultural land, and expand off-shore or onto land that is windy, but unsuitable for agriculture. To do this, we can start by constructing mini solar and wind farms, so that we can harness both forms of energy, without harshly impacting the water table of the surrounding land. Hybrid power plants of hydroelectric power, solar power and wind power can also be constructed off-shore.

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