



Article A Case Study on Renewable Energy Sources, Power Demand, and Policies in the States of South India—Development of a Thermoelectric Model

Vijayaraja Loganathan ^{1,*}, Dhanasekar Ravikumar ¹[®], Rupa Kesavan ², Kanakasri Venkatesan ¹, Raadha Saminathan ¹, Raju Kannadasan ³[®], Mahalingam Sudhakaran ⁴, Mohammed H. Alsharif ⁵[®], Zong Woo Geem ⁶[®] and Junhee Hong ^{6,*}

- ¹ Department of Electrical and Electronics Engineering, Sri Sairam Institute of Technology, Chennai 600044, Tamil Nadu, India; dhanasekar.eee@sairamit.edu.in (D.R.); sit19ee004@sairamtap.edu.in (K.V.); sit19ee001@sairamtap.edu.in (R.S.)
- ² Department of Computer Science and Engineering, Sri Venkateswara College of Engineering, Sriperumbudur 602117, Tamilnadu, India; rupakesavan@svce.ac.in
- ³ Department of Electrical and Electronics Engineering, Sri Venkateswara College of Engineering, Sriperumbudur 602117, Tamilnadu, India; kannadasanr@svce.ac.in
- Department of Electrical and Electronics Engineering, Pondicherry Engineering College, Pillaichavadi 605014, Pondicherry, India; sudhakaran@pec.edu
- ⁵ Department of Electrical Engineering, College of Electronics and Information Engineering, Sejong University, Seoul 05006, Korea; malsharif@sejong.ac.kr
- ⁶ Department of Smart City & Energy, Gachon University, Seongnam 13120, Korea; geem@gachon.ac.kr
- Correspondence: vijayaraja.eee@sairamit.edu.in (V.L.); hongpa@gachon.ac.kr (J.H.)

Abstract: This work aims to perform a holistic review regarding renewable energy mix, power production approaches, demand scenarios, power policies, and investments with respect to clean energy production in the southern states of India. Further, a thermoelectric-generator model is proposed to meet rural demands using a proposed solar dish collector technology. The proposed model is based on the idea of employing a parabolic concentrator and a thermoelectric (TE) module to generate electricity directly from the sun's energy. A parabolic dish collector with an aperture of 1.11 m is used to collect sunlight and concentrate it onto a receiver plate with an area of 1.56 m in the proposed TE solar concentrator. The concentrated solar thermal energy is converted directly into electrical energy by using a bismuth telluride (BiTe)-based TE module mounted on the receiver plate. A rectangular fin heatsink, coupled with a fan, is employed to remove heat from the TE module's cool side, and a tracking device is used to track the sun continuously. The experimental results show considerable agreement with the mathematical model as well as its potential applications. Solar thermal power generation plays a crucial part in bridging the demand-supply gap for electricity, and it can be achieved through rural electrification using the proposed solar dish collector technology, which typically has a 10 to 25 kW capacity per dish and uses a Stirling engine to generate power. Here the experimentation work generates a voltage of 11.6 V, a current of 0.7 A, and a power of 10.5 W that can be used for rural electrification, especially for domestic loads.

Keywords: renewable energy resources (RESs); power policy; thermoelectric power generation

1. Introduction

1.1. Background

The need for electric energy is snowballing worldwide owing to the rapid progression of global populace and industrial expansions that affect ecological system [1,2]. Various renewable energy resources are employed around the globe, particularly wind, solar, hydro, biomass, and waves, leading to rises and falls in oil rates, especially during confrontational events [3,4]. Furthermore, renewable energy is a cost-efficient exercise for the electric



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Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). energy sector, specifically hybridization [5,6]. Moreover, renewable energy harvesting (REH), along with smart grid (SG) systems, plays a vital role in providing a flexible, intelligent, and interactive grid system, as well as efficient load management. To manage the demand–response gap between actual and expected energy generation, an AI-powered recommender system for REH (AI-RSREH) in residential houses has been established, as well as a recommender system for the installation of solar photovoltaic panels (SPV). The data obtained through this analysis can be shared with stakeholders, such as utility companies and end customers, to take developmental measures further [7]. Wind power is primarily characterized by spatial and temporal variability with geographically widespread sites. The highly variable levels of wind power and the instability of power grids make for unbalanced conditions. This work propose an assessment framework using wind power data to quantify the variations of wind power and wind power ramping rates in order to exhibit the characteristics and benefits yielded by wind power aggregation at six different levels, from a low state/province/country level to a high global level. In addition, a wind power duration curve is used to exemplify the availability of wind power aggregated at different levels. The reductions in variability, as illustrated in the analysis, directly reflect the economic advantages of active power reserve, reduction in backup capacity, and balancing costs for energy markets. This data analysis can be used to deploy wind power plants accordingly in the future [8].

1.2. Literature Report

Hot dry rock (HDR) geothermal energy, which is unaffected by climate change, is used to address the capacity allocation of photovoltaic (PV) storage hybrid power systems (HPSs) in frigid plateau regions, and it may be able to replace conventional electrochemical-based power storage systems. HPS can satisfy the sudden power fluctuation rate requirements of grids and it can increase the equivalent firm capacity (EFC) of PV plants. HDR geothermal energy has the advantages of being stable, continuous, and unaffected by meteorological factors, which are highly preferable in providing energy storage services to grid-connected PV plants in alpine and high-altitude areas, thus increasing the reliability of grid operations. However, conventional HDR plants are not flexible enough to operate under such conditions in order to cooperate with thermal storage (TS) plants to form hybrid PV storage power systems [9]. In Indonesia, the OTEC system uses ammonia (NH₃) as a working fluid, which has a lower boiling point compared to water. To simulate an OTEC turbine, the computational fluid dynamics (CFD) method has been used. According to the simulated results, a two-stage, 40-degree turbine with 57.45 percent efficiency and 287.25 kW of generated power has maximum efficiency and net power [10].

A new application of ocean thermal energy conversion (OTEC), combined with the use of a thermal power plant as a co-generator, has also been considered. The tail-end warm water temperature in thermal power plants promotes heat transfer between the warm water and a working fluid, which raises the temperature of the working fluid as it is fed into the turbine as an input. When this high-temperature working fluid is fed with cold seawater, the difference in temperature helps increase efficiency and power output. The advantage is that it does not require solar energy for heating the surface seawater. The disadvantage is that it requires submarine cables to transfer power from the shore to the load centre. It is an integrated solution for small island communities, solving energy, water, and food issues [11]. A hybrid renewable energy source (HRES) is one that combines two or more renewable energy sources to improve system efficiency and energy supply reliability. HRES has been examined from various angles, including power architecture, mathematical modeling, power electronic converter topologies, and design optimization tools, with suggestions for improvements in the control systems [12].

A multidimensional air quality system (MAQ) is an integrated assessment tool that is used to make decisions regarding the type of energy generation in order to consider the air quality, cost, greenhouse gas emissions (GHGs), and geographical location using databases, optimization, and enumeration algorithms. A case study of on-road transportation in the Lombardy region of Northern Italy found that a combination of renewable energy sources for power production can improve the air quality index. However, the cost and revamping feasibility with respect to solar and hydroelectric power plants remain major concerns [13]. This work also create an outline for the presentation of combined heat and power (CHP) frameworks, notably it evades from 100 to 500 kW over a period of 20 years. This review looks at different strategies for limited scope electricity generation to decide the primary monetary and ecological examples of various bio-squander and energy advancements, for example, (i) the direct burning of refined vegetable oil taken from squander cooking oils (warm pathway), (ii) the anaerobic processing of bio-squander (biochemical pathway), and (iii) the gasification of wood buildup (thermochemical pathway). The examination was conducted to advance energy decentralization. When bio-waste and wood deposits are utilized as unrefined components (UC) for burning, the ecological effects are decreased, as emanations from carbon dioxide (CO_2) , methane (CH_4) , and nitrogen oxide (NO_x) during power generation are utilized to transform the beginning RMs into fills adjusted to the limited scope of CHP systems [14]. A numerical streamlining structure can be used to plan energy choices between conveyance organizations (who manage utility-scale inexhaustible or regular generators) and arranged microgrid frameworks (who manage nearby sustainable energy creation and capacity). Cooperation between the appropriate network administrators (who utilize request-side administrative procedures for further network proficiency development) and microgrid frameworks (who work to diminish energy use by booking power usage under unique circumstances and provide energy to the grid) could dispense with the requirement for load shedding that lift the power provided by microgrids (22.3 MW) and offers environmentally friendly power shares by up to 5.03%. Without direct control or complete data on the miniature matrices inside these frameworks, ideal energy output is not conceivable by utilizing this engineering system [15]. In Taiwan, offshore wind energy and solar photovoltaics (PVs) are combined to produce 59.3 TWh each year and could replace the power generated from nuclear energy by 2025. An analysis found the proper offshore wind farm optimization that could replace coal-fired power generation by 2032 and 2040 with liquefied natural gas-fired power generation which accounting for only 5.6 percent of total Taiwanese power generation. The 31 offshore wind farms evaluated in this study have a total installed capacity of 26.5 GW, which can generate 103.6 TWh of electricity per year. If properly optimized, offshore wind power has the potential to become Taiwan's primary source of electricity [16].

A novel photovoltaic smart window prototype with luminous solar concentrators was investigated in some research study. The shade system's movement is independently controlled by the light shelf. The optical, thermal, and electrical performance of this integrated photovoltaic technology were compared with that of a traditional window. When it was practically tested in the physical environment, the energy generation was roughly 10 Wh/month, with up to a 50% reduction in energy demand for heating and cooling. The technology is efficient in terms of energy consumption and also delivers adequate power to run the control systems. The efficiency highly depends upon the presence of illumination and the season of the locality [17]. A hybrid system of the Nautilus platform, combining wave energy converters (WECs) and floating offshore wind turbines (FOWTs), has been developed. The power take-off (PTO) dampening of the wave energy converters (WECs) was improved to optimize their performance. Pitch angle and nacelle acceleration were the key performance indicators (KPIs). When the energy was produced, the levelized cost of energy (LCOE) and hydrodynamic stability were considered, and the hybrid design outperformed the simple FOWTs. This provides economic competitiveness and stability [18].

A small hydropower plant (SHP) has been proposed in which the initial cost is far less than the big hydropower plant, thus providing greater efficiency. It is carried out by simplifying the integration of turbine and permanent magnet (PM)-excited generator by installing special prefabricated concrete modules. In this way, the mechanical transmission of power is eliminated. For this system, a simple and inexpensive semi-Kaplan turbine with a non-classical spiral input is proposed. As the generation units are directly connected with the power system, it requires complex control systems [19]. The integration of wind and tidal renewable sources of energy at Cook Strait in New Zealand can help to avoid the detrimental effects of fossil fuels and to reduce the cost of electricity. For energy generation in that area, simulations have been undertaken to develop a DC-liked wind-tidal battery-based micro grid. At an offshore site near CPK0331, there are enough tidal currents to generate power for 69.3 percent of the year (referred to as the Central Park). At the Foveaux site, there is enough wind speed to generate power for 78.2 percent of the year. This type of power generation is cost-effective and a higher fraction of renewable energy has been utilized [20].

With bio-coal substituting lignite, the best mitigation potential was shown at lower high-temperature Conditions (HTC) temperatures and shorter residence times. China had the highest total mitigation potential (194 MT CO₂ equivalent), whereas India had the highest mitigation per kilogram of FW (1.2 kg CO_2/kg FW). However, the calorific values for lignite and hard coal vary, which can lead to some confusion about the proportions of hard coal and lignite that could be substituted in practice. High-moisture food wastes (FW) can be converted into bio-coal by hydrothermal carbonization, which can be used to replace coal. It represents a promising solution for reducing greenhouse gas emissions by avoiding landfills and generating electricity [21]. In the Rožná I Mine in Czech Republic, a technical and an economical model of the heating system using the geothermal potential of mine water was tested. The theoretical maximum output of this source of heat supply was calculated to be 837.4 kW which exceeds the demand for heat supply in that area. This strategy helps in finding an alternate way of using renewable energy in heat supply depending upon the geographical location and the type of renewable energy source available rather than using fossil fuels. The major drawback of the system is that it requires high investment subsidies when compared to a non-renewable source of heating [22]

The Raspberry Pi regulator is utilized to test the dual axis parabolic solar dish tracker for institutional and showing applications at gentle temperatures. The closed loop global positioning framework for the illustrative dish sun-based gatherer comprises of electromechanical parts, for example, a control box, a 12 V DC engine, a 12 V power window engine, a photograph sensor module, a stuff box, and two thermocouples. This model is little and light. The unit has been used in seminars on environmentally friendly power and applied warm science [23]. The impacts of Different cooling systems for electricity generation utilizing thermoelectric generators (TEG) in a parabolic (PDC) were tried. A lab size model was utilized to assess the TEG's presentation to mirror the on location explore conditions. The generator was cooled utilizing air-cooled (regular and constrained convection) and water-cooled cooling techniques. The water-cooled cooling technique further developed TEG execution and conveyed higher power yield than the other cooling strategies utilized, as indicated by the testing information [24]. In the GT-Suite programming climate, the exhibition of a parallel solar hybrid micro gas turbine (SHGT) in view of a parabolic dish is examined through a framework examination involving solar heat and biogas as fuel. The exhibition information of a turbocharger was increased to the current presentation information of the business mGT Turbec to approve a thermodynamic model of the SHGT. The reproduction results uncover that utilizing an equal design framework is more encouraging than utilizing a customary one since the equal setup framework has a variety to further develop electrical proficiency [25].

This examination will zero in on a trial that will utilize a solar concentrator to change sun powered energy into thermal power by concentrating sun-oriented radiation utilizing a parabolic dish reflector. A sun powered global positioning framework is utilized to situate the concentrator in two different rotational bearings, each in light of an alternate geological boundary (the review region). At last, a mathematical reproduction of a hypothetical model is utilized to work out the level of radiation at the reflector level. This study [26] shows the viability of the proposed commitment. A PC model of an exploratory parabolic dish collector (PDC) that involves solar thermal energy as a procedure of steam generation in a pasteurization process in propsed. To give a few fundamental examinations on the framework's vigor within the sight of huge shocks, a straightforward control strategy is applied. Regardless of the unreliability of solar energy, it is found that sufficient execution can be accomplished [27]. To plan and make a CSP Greenhouse framework that creates power, produces rural products, and dries them utilizing the leftover energy from the power yield, the new CSP dish reflect configuration utilizes level mirrors to concentrate the sun's beams, as with an explanatory mirror framework. However, it is undeniably more affordable and follows the sun in two tomahawks. With the extra pay created by horticultural results and agrarian item drying, the framework's expense viability improves, the venture's devaluation time frame is shorted, and the nursery produces power for a considerable length of time [28]. A parabolic dish solar concentrator (PDSC) is utilized to produce power from nuclear power utilizing Stirling motor, steam, photovoltaic and thermoelectric generators. The heat concentrator of a parabolic dish (PD) is utilized for centering radiation of the sun into the beneficiary. Another plan of the explanatory dish sun-based concentrator utilizing a double reflector Gregorian strategy applies an extra reflector to put the motor generator in the lower part of the essential reflector parabolic dish and checked utilizing "SolTrace", a product bundle for following the sun powered beam. It found that the intensity transition gathered was 0.73 MW/m^2 for the planned explanatory with 300 cm essential width. This explain is based on a calculation fixation proportion and 84.27% optical productivity [29].

1.3. Objectives

This work focuses on the comprehensive review of renewable energy resources and suggests thermo-electric-generator (TEG) techniques and construction approaches for an alternative power production using solar energy as its case study. Based on the abovementioned means, the objectives of this article are as follows: to assess the conventional and renewable energy resources in India and its southern states; to demonstrate the energy of Southern states namely Andhra Pradesh, Tamilnadu, Kerala, Karnataka, and Odisha; to compare the different energy policies from various utilities; to illustrate the budget frame-work for energy production; and to develop an alternative energy production approach for the southern states of India, namely a the 'thermo-electric framework'.

1.4. Organization of the Article

The work is organized as follows: different sustainable power sources accessible in India, power creation and situations of different south Indian states, power strategies by the states, and speculation made on the perfect energy power creation area by the southern territories of India are discussed. Finally, this work proposes a thermo-electric-generator model as an alternative energy production that might be suitable for Indian power demands in the future. The complete framework of the article is illustrated in Figure 1.



Figure 1. Organization of the article.

2. Conventional and Renewable Energy Resources—A Review

2.1. Conventional Energy Resources

Energy sources can be partitioned into two sorts dependent on how rapidly they could be recharged: conventional and non-conventional energy. Energy which cannot reuse a wellspring of energy after utilizing it once is referred to as a "customary wellspring of energy" or a "non-sustainable power asset". These are the main regular wellsprings of energy and incorporate coal, petrol, petroleum gas, and thermal power. Oil is the most broadly utilized wellspring of energy. Coal, petrol, and petroleum gas represent around 90% of the world's development of business energy and hydroelectric and atomic power represent around 10%.

Limitations of Conventional Energy:

- Eliminating coal, oil, and gas is unsafe and can cause pollution. As a result, these petrol subordinates are non-feasible.
- As we go through viably accessible wellsprings of coal, oil, and gas, removing them turns out to be all of the more genuinely, more expensive, and more unsafe.
- Burning-through oil subordinates (both for warming and as fuel for vehicles) is the guideline wellspring of 'ozone hurting substances', carbon dioxide, and others that impact the air and are changing the climate.
- Contamination: the significant hindrance of these regular sources is that they cause high contamination. The consumption of kindling and petroleum products brings about air contamination. This can stay away from utilizing these non-regular sources.
- Modesty: The serious issue while utilizing regular sources, particularly petroleum
 products is that they are expendable sources. It requires a long period of time for
 them to be restored and recharged. In any case, non-regular sources are inexhaustible
 sources that do not get depleted.
- Dangerous: non-regular energy extraction is more secure. Numerous mishaps happen while removing energy from mines.
- Significant expense: the extraction of these energy sources is exorbitant both monetarily and on earth. The expense of energy creation and extraction is a lot less for nonordinary sources (assuming that the underlying expense of foundation is borne).

2.2. Clean Energy

Clean energy cannot try to be energy acquired from sources that cause air pollution, while useful power energy cannot try to be energy obtained from common sources. There is an unpretentious contrast between these two energy types, notwithstanding how they are a large part of the time concerned with something which is practically indistinguishable. The innocuous environmental power assets will not run out, instead of oil-based products and gas, and can join wind and sun-organized energy. In any case, while the best power energy sources are sensible, not all efficient power sources are viewed as being green. For instance, hydropower is a limitless asset, yet some would argue that it is not green since the deforestation and industrialization identified with the plan of hydro dams can hurt the climate. The ideal clean energy blend happens where successful power energy meets sensible power, for example, with sun-based energy and wind energy. A clear technique for surveying the contrasts between these varying energy types is:

Clean energy = clean air

Successful power energy = standard sources Efficient power = recyclable sources

Favorable of Clean Energy

 Clean energy provides an assortment of ecological and monetary advantages, such as providing a decrease in air contamination. A different clean energy supply likewise decreases the reliance on imported energies (and the related monetary and natural costs this brings about).

- Sustainable clean energy likewise has inborn expense investment funds, as there is no compelling reason to concentrate and move powers (for example, with oil or coal, as the assets recharge themselves normally).
- Another modern advantage of a spotless energy blend is the formation of tasks to create, fabricate and introduce the perfect energy assets of things to come.

2.3. Renewable Energy in India—A Glance

India is the world's third-largest power consumer and third-largest sustainable power producer, with inexhaustible energy accounting for 38 percent (136 GW out of 373 GW) of total installed capacity in 2020. India was ranked third in Ernst and Young's (EY) 2021 Renewable Energy Country Attractiveness Index (RECAI), behind the United States and China. India was declared responsible for delivering half of its absolute power from nonpetroleum derivative sources by 2030 under the Paris Agreement's Intended Nationally Determined Contributions targets in 2016. India's Central Electricity Authority established a goal in 2018 to generate half of the country's total electricity from non-petroleum products by 2030. India has also set a goal of producing 175 GW of renewable energy by 2022 and 500 GW by 2030. As of September 2020, 89.22 GW sun-oriented energy is now functional, tasks of 48.21 GW are at different phases of execution, and undertakings of 25.64 GW limit are under different phases of bidding. In 2020, three of the world's main five biggest sun-based parks were in India including the world's biggest 2255 MW Bhadla Solar Park in Rajasthan and the world's second-biggest sunlight-based park of 2000 MW, Pavagadasun based Park Tumkur in Karnataka and 1000 MW Kurnool in Andhra Pradesh. Wind power in India has a strong manufacturing base, with 20 manufacturers producing 53 distinct breeze turbine types ranging in size from 1 MW to 3 MW, with exports to Europe, the United States, and other nations. Solar, wind, and run-of-the-river hydroelectricity are less expensive climate-friendly power sources that are used as "must-run" sources in India to meet baseload, while contaminating and imported product subordinate coal-terminated power is gradually being moved from the "must-run base burden" power age to the heap following power age (mid-evaluated and mid-merit on-demand need-based irregularly delivered power) to meet the cresting need only. Some of the everyday top interest in India is now met with the inexhaustible topping hydropower limit. Sunlight-based wind power with 4-h battery stockpiling frameworks, as a wellspring of dispatchable age, contrasted and new coal and new gas plants are now cost-cutthroat in India without subsidy.

The International Solar Alliance (ISA) is led by India and currently includes 121 countries. In the mid-1980s, India became the first government in the world to establish a service for non-regular energy assets (Ministry of New and Renewable Energy (MNRE)). The development of India's sunlight-based energy industry is the responsibility of the Sun-oriented Energy Corporation of India (SECI), a public sector venture. Hydro electricity is directed independently by the Ministry of Power and excluded from MNRE targets. The Renewable Energy Production by sources such as hydropower, wind, solar, and bio-mass is illustrated in Figure 2. India positions the second situation as far as a populace that records 17% of the world's general populace. India is worldwide positioned third in the utilization of energy. Table 1 shows the EY's Renewable Energy Country Attractiveness Index (RECAI) standing in July 2021 in terms of introduced limits and interest in environmentally friendly power:

 Table 1. Renewable Energy Country Attractiveness Index (RECAI) positioning in July 2021 [30].

Country	Score	Recai Rank
USA	70.7	1
INDIA	66.2	2
CHINA	68.7	3



Figure 2. India renewable energy production as determined by source [31].

3. Energy Mix of Southern States

The approach of addressing individual load power demands can help to close the supply-demand gap, maintain energy security, minimize carbon dioxide [CO₂] emissions and reduce transmission losses. The power demand, power production, power policies, and the availability of renewable energy resources in different states of the Southern part of India such as Andhra Pradesh, Telangana, Odisha, Kerala, Karnataka, and Tamil Nadu are analyzed as follows:

3.1. Power—Energy Scenario in the State of Andhra Pradesh

The key objective of analyzing power generation and supply is to cater to the power demands of the state. The state has an estimated population of about 91,702,478 in 2021 comprising 13 districts with an estimated area of 160,205 sq km. The state's power utilization became 20.5% in August of 2021, which is higher than the public normal energy utilization of 18.6%. Regarding the energy consumed by various classes of users, the industrial category utilized the most energy, accounting for 33.42% of total energy sold by utilities in 2018–2019, compared to 32.71% in 2017–2018. Energy sales to industrial customers increased by 8.93% over the previous year. Domestic consumers, the second-largest segment of the population, consumed 27.78% of total energy sales, down from 28.11% the year before. This sector's energy usage climbed by 5.37% over the previous year. Due to the increase in pollution levels, the Andhra Pradesh Pollution Control Board is enabled to complete its capacities under the arrangements of the accompanying Pollution Control Acts, Rules, and Amendments to obtain all-around progress in for climate control in the State by viable execution of ecological laws. Control of contamination at the source to the greatest degree conceivable with due respect to mechanical accomplishment and monetary practicality. The total installed capacity of various power plants in this state by the Andhra Pradesh Power Generation Corporation Limited APGENCO) mentioned in Table 2 is stated as follows:

- The total capacity of the thermal power plant installed is 3410.0 MW.
- The total capacity of the Hydel power plant is 1773.6 MW.
- The total capacity of power plants using non-conventional energy resources is 405.426 MW. Thus, the overall total capacity of plants under APGENCO is 5589.0 MW.

- The total installed capacity of the Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL) is 1600 MW.
- The total installed capacity under the Government of Andhra Pradesh (A.P) is 7189.0 MW.

Total Installed Capacity of APGENCO				
S. No.	Type of Power Plant	Total Installed Capacity (In MW)		
1	Thermal Power Plant	3410.0		
2	Hydel Power Plant	1773.6		
3	Non-conventional Power Plant	405.426		
4	Total	5589.0		

Table 2. Total installed capacity of various power plants by APGENCO [32].

The non-conventional power stations under APGENCO include the solar plant at Talaricheruvu with a total capacity of 400 MW and the solar plant at Polavaram, and the Right Canal Bund Solar PV Plant with a capacity of 5 MW. Andhra Pradesh is India's second-largest producer of clean energy. Figure 3 depicts the load duration curve-system demand vs. percent time in Andhra Pradesh for the 2021–2022 period. With a total capacity of 8220 MW, the state presently provides 10% of India's renewable energy generation. Solar power facilities totaling more than 3500 MW have been installed in the state so far. Table 3 shows the state's peak demand as well as its installed capacity. Despite the fact that the state was in the midst of the COVID-2019 pandemic, 229 MW of solar power plants were installed.

Table 3. Peak demand and the installed capacity of Andhra Pradesh [33].

Year	APERC Approved Peak Demand	Alternate Scenario (In Worst Case)
2019-2020	11,450 MW	18,23 MW
2020-2021	12,219 MW	19,547 MW
2021-2022	13,209 MW	19,357 MW
2022-2023	14,315 MW	19,786 MW
2023-2024	15,539 MW	19,867 MW
	Current Installed Capacity of the Current Peak Demand: 10	state: 20,081 MW ,207 MW



Figure 3. Load duration curve-system demand vs. %Time of Andhra Pradesh for the 2021–2022 period [34].

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The contribution of various renewable energy resources toward power production in Andhra Pradesh is represented in Figure 4. It shows that thermal energy is the major source of power generation in the state followed by Hydropower.



Figure 4. Power from renewable energy resources for Andhra Pradesh [35].

3.2. Power—Energy Scenario in the State of Tamilnadu

The state's ongoing power request is in the scope of 14,500 MW to 15,500 MW. Tamil Nadu has the most different power generation portfolio in India, with a constraint of 31,894 MW that incorporates half of the sustainable power, 28% from coal-terminated power plants, including shares from central delivering stations, 5% from nuclear power plants, 3% from inner ignition plants, and 14% from long-term and medium-term open access and captive power plants (CPP). Tamil Nadu is a forerunner in harmless to the ecosystem power, with a presented restriction of 15,779 MW of maintainable power [36], representing about portion of the state's all out presented limit. During 2019–2020, the state produces 11,717 million units of wind energy and 3842 million units of daylight based energy. Though Tamil Nadu's pinnacle power request has vacillated fundamentally lately, it would in general ascent from November 2020, topping at 14,387 MW in October 2021, with environmentally friendly power satisfying the need. Figure 5 shows the Tamil Nadu Energy Development Agency's (TEDA) combined environmentally friendly power accomplishment (MW) from 1 January 2019 to 1 April 2019. Wind Energy (counting seaward wind), solar energy, biomass, and different types of bio-energy, small hydro, tidal energy, and ocean thermal energy are among the supportable power sources perceived by the state. Environment agreeable, sustainable power sources are plentiful in nature, effectively open locally, and financially savvy for decentralized applications.

Among the previously listed sources, the first three sustainable power sources, namely wind, solar, and bio-energy, are being installed extensively Tamil Nadu. The Tamil Nadu government recognized the importance of renewable energy to develop and disseminate non-traditional energy sources and hence established a separate agency, the Tamil Nadu Energy Development Agency (TEDA), as a registered society, as early as 1985, as per G.O.Ms. No. 163, P. & D. (EC) Department, dated 29 November 1984 with the specific objectives listed below:



- To promote the use of new and renewable sources of energy (NRSE), and therefore to implement projects.
- To encourage people to participate in energy-saving initiatives,

Figure 5. Cumulative achievement of renewable energy up to 01.04.2019 (MW) by TEDA [37].

The significant power production scenarios of the state from clean energy are stated below:

Wind Energy—Tamil Nadu is a pioneer in the country when it comes to advancing breeze energy. The state has India's highest breeze power limit, accounting for roughly 23% of the country's clean wind introduced limit, with an introduced limit of 8506.72 MW accounting for roughly 27% of the state's total introduced power limit. Limits introduced by Cl are 8507 MW. Tamil Nadu, with 23% of India's clean wind introduced limit, is far ahead of the rest of the country. From January 2019 to January 2020, the state has tackled approximately 11,717 million units of wind energy. On 27 July 2017, the maximum breeze age saddled on the matrix was 5095.6 MW, and on 19 July 2018, it was 107.317 MU.

Solar Energy—The total introduced limits based on sunlight are 3974 MW. During the 2019-2020 financial year, the state captured roughly 3842 million units of sunlight-based energy, a 35 percent increase over the previous year. On 17 February 2020, the highest sunlight-based age tackled to the matrix was 3018 MW, 20.12 MU. (1 MU = 1,000,000 units)

Green Energy—A sustainable power-based future is critical for addressing the environmental issues, as well as for local networks to transition away from the existing petroleum derivative economy, reduce contamination, improve energy security, reduce the risk of fuel spills, and reduce the need for imported energizes. It also aids in the stabilization of the country's normal assets. The "Tamil Nadu Electric Vehicle Policy 2019" was announced on 16 September 2019, and the Tamil Nadu administration has also designated the industries, energy, and transportation departments as nodal agencies for the implementation of this strategy in the state. TANGEDCO has set a maximum limit of 31,894 MW, of which 7175 MW is its own age (from all of its power plants). The reception of the U.N.'s Sustainable Development Goals will be commemorated for the fifth time in 2020.

Biomass Energy—The crucial objective of the biomass power and cogeneration program is to make propels for ideal use of the country's biomass hotspots for system power age and prisoner power age. Juliflora, bagasse, rice husk, straw, cotton tail, coconut shells, soya husk, de-oiled cakes, coffee waste, jute wastes, and groundnut shells, among other biomass assets, are utilized to create power. It is the thermo-substance that changes areas of strength for or into an ignitable gas mix (creator gas) through a mostly consuming course with air supply restricted to not exactly that expected for full burning. Gasification is the latest methodology for producing energy, and it catches 65–70 percent of the energy present areas of strength by changing it first over completely to ignitable gasses. The gasses are hence catapulted. The advancements for this produced fuel are still new and subsequently not precisely ready for business creation. The game plan of producer gasses with an all-out calorific worth of 1000–1200 kcal/m³ is displayed in Figure 6.



Figure 6. Arrangement of producer gas.

3.3. Energy Scenario in the State of Kerala

The total power consumption in the state was 72.12 million units in October 2021. Usually, the power generation within Kerala is only 30 percent of the state's total consumption. However, in October 2021 the total consumption became 52%. The Daily Load Curve of Residential Load in Kerala is demonstrated in Figure 7. It shows that the demand remains high during winter when compared to summer due to the geographical location of the state.

Installed Capacity of MW as of 2021: The types of power plants that help in providing electricity to the state located in various districts are hydro power plants, diesel/low Sulphur heavy stock (LSHS), wind-energy-based power plants, solar energy-based power plants, and thermal energy-based power plants.

- Kerala State Electricity Board (KSEBL): the KSEBL generates a total power of 2246.685 MW
 of which the hydro power plant contributes to about 2052.00 MW, the diesel/low
 Sulphur heavy stock (LSHS) based power plant contributes about 159.96 MW, the
 wind energy based power plant contributes about 2.025 MW, and solar energy-based
 power plant contributes up to 32.70 MW.
- 2. Captive Power Plant: the Captive power plant contributes a total power of about 85.7 MW of which the hydro power plant contributes about 33 MW, the solar energybased power plant contributes about 32.70 MW, and the wind and thermal energybased power plants contribute up to 10 MW each. Independent power producersbased power plants generate a total power of 502.83 MW of which thermal power plants contribute 359.58 MW, hydropower plants contribute about 33.00 MW, wind energy-based power plant contributes about 58.25 MW, and solar energy-based power plants contribute about 52.00 MW.

3. Co-generation Power Plant: the co-generation thermal-based power plant contributes up to 10 MW. Thus, the overall installed capacity of the state is 2823.0140 MW. The installed capacity of MW as of 2021 in Kerala by the Kerala State Electricity Board (KSEBL) by various types of power stations is described in the Table 4.

Controlled by	Type of Power Station	Total Installed Capacity (MW)	
	Hydro Power Plant	2052.00 MW	
KOEDI	Diesel/LSHS	159.96 MW	
KSEBL	Wind Energy	2.025 MW	
	Solar Energy	32.70 MW	
	Hydro Power Plant	33.00 MW	
	Solar Energy	32.70 MW	
CAPTIVE	Wind Energy	10.00 MW	
	Thermal Energy	10.00 MW	
	Thermal Energy	359.58 MW	
	Hydro Power Plant	33.00 MW	
IPP	Wind Energy	58.25 MW	
	Solar Energy	52.00 MW	
Co-generation	Thermal	10.00 MW	
0	Total	2823.0140 MW	

Table 4. Installed capacity of MW as of 2021 in by KSEBL [38].



Figure 7. Daily load curve of residential load in Kerala [39].

The installed power capacity in MW across Kerala in the financial years from 2011 to 2021 is represented in Figure 8.

The solar sector's installed capacity in the state is projected to increase to 2500 MW by 2030, a long-term contribution in energy security as well as ecological security by reducing carbon emissions. Entrepreneurs, startups, industries, and institutions in the state are encouraged to develop new solar-powered solutions and establish an R&D hub by making collaborations with educational institutions, research centers and industries to work on research projects and commercialization of emerging technology solutions and to expedite the establishment of integrated combinations of solar power technologies and solar-based hybrid cogeneration technologies. It helps to focus on improving existing system's efficiency and lowering the balance-of-system costs.



Figure 8. Installed power capacity across Kerala from financial year 2011 to 2021 (installed power capacity in MW) [40].

3.4. Power—Energy Scenario in the State of Karnataka

Karnataka's peak electricity demand was 9356 MW in November 2021. Although the peak electricity demand in Karnataka has changed significantly in recent months, it has tended to decline from December 2020 to November 2021, ending at 9356 MW in November 2021. The load duration curve of Karnataka is shown in Figure 9.





Installed capacity of MW as of 2021—The types of power plants such as hydro power, thermal power, combined generation station (CGS), wind energy, co-generation, mini-hydel, bio-mass, solar energy, captive power plants, and independent power producers (IPP) are helping to provide electricity to the state.

The installed capacity in MW as of 31 December 2021 in Karnataka is shown in the Table 5. The state produces a total power of 30,799.85 MW out of which the hydropower plant contributes about 3798 MW, the thermal power plant contributes up to 5020 MW, the

combined generating station (CGS) contributes up to 4415 MW, the wind energy based power plant contributes up to 5095.44 MW, the co-generation based power plant contributes up to 1731.16 MW, the mini-hydel based power plant contributes up to 903.46 MW, the bio-mass based power production contributes up to 139.03 MW, the solar based power plant contributes up to 7505.46 MW, the captive power plant contributes up to 992.3 MW, and independent power producers (IPP) contribute up to 1200 MW. From the available data, it is visible that the maximum of the power required for the state comes from solar energy. The state has encouraged the use of renewable sources of energy for power production.

S. No.	Power Plant Based Upon Source	Total Installed Capacity in MW
1.	Hydro	3798 MW
2.	Thermal	5020 MW
3.	CGS	4415 MW
4.	Wind	5095.44 MW
5.	Co-Generation	1731.16 MW
6.	Mini Hydel	903.46 MW
7.	Bio Mass	139.03 MW
8.	Solar	7505.46 MW
9.	Captive	992.3 MW
10.	ÎPP	1200 MW
	Total	30,799.85 MW

Table 5. Installed capacity in MW as of 31 December 2021 in Karnataka [42].

Solar Energy—As the overall share of renewables continues to rise, solar energy facilities provide roughly 20% of Karnataka's daily power needs. The state holds the country's greatest installed solar power capacity of 7346 MW, with Pavagada having the largest local plant (Tumakuru). Solar energy provides for more than half of the state's installed green energy capacity, according to data from Karnataka Power Corporation Limited (13,544 MW). Green energy provides 45% of the state's daily electricity consumption, with solar and wind power accounting for the majority of that.

Wind Energy—The overall district-wise potential of wind power projects in Karnataka with all of the 27 districts is 13,236 MW. The state government has passed government orders (GO's) for wind energy projects to increase the power production capacity to their various districts such as 3 plants in Bagalkote, 10 plants in Ballari, 2 plants in Bidar, 5 plants in Chitradurga, 5 plants in Dharwad, 15 plants in Gadag, 15 plants in Koppal and 20 plants in Vijaypura district, respectively.

Small Hydel Power Plants—Pico Mill (Pico Water Mill) (Up to 5 kW)—The phrase "pico hydro" refers to the hydroelectric power output of less than 5 kW. These generators have shown to be beneficial in small, rural villages with limited electrical needs. This system is highly useful for those who live in distant, hilly places where power distribution transmission lines cannot be laid. PICO watermills have been installed by the KREDL in Kodagu, Dakshina Kannada, Uttara Kannada, Hassan, and Mysore, among other places. The Ministry of Natural Resources and Environment (MNRE) is supporting the program financially.

Biomass-based power production—During the 12th Plan Period, the state government has introduced a scheme to encourage the promotion of grid-interactive biomass power and bagasse co-generation in sugar mills. The following are the objectives of the ministry's initiative: to establish biomass power plants for electricity generation interfaced with the grid for commercial purposes with a minimum steam pressure of 60 bar or higher; and to promote the cogeneration projects in private, collaborative, and public sugar mills for excess power generation from bagasse that is interfaced with the grid with a minimum steam pressure configuration of 40 bar and above or 60 bar and above undertaken by independent power providers (IPPs)/state government undertakings or state government joint venture companies using the BOOT/BOLT model.

3.5. The State of Odisha—Power Production and Supply a Glance

Odisha Power Generation Corporation Ltd. (OPGC) is an Odisha government corporation. It works best in nuclear power plants located at Banharpalli, Jharsuguda. It has a 1740 MW absolute age limit (2×210 MW in the first stage and 2×660 MW in the second stage). OPGC began as a fully owned government company on 14 November 1984, with the primary goal of setting out, operating, and maintaining massive thermal power generation stations. In order to achieve that goal, OPGC constructed the IB Thermal Power Station, which has two units of 210 MW each, in the Ib valley area of the Jharsuguda District, Odisha. In 1994, the first unit was put into service and the second in 1996.

Two additional units (Units 3 and 4) having a limit of 660 MW each were included in the second stage in the year 2019 which added a limit of 1320 MW to the prior existing 420 MW to IB Thermal Power Station [43]. As a piece of the change in the energy area of the state, 49% of the value was stripped for a Private financial backer (American Company) for example AES Corporation, Arlington, Virginia, the USA in mid-1999. After the exit of AES in December 2020, the Government of Odisha (GoO) procured the 49% value held by AES through one more auxiliary Odisha Hydro Power Corporation Ltd. (OHPC), Odisha, India. In this way, OPGC turned into a completely claimed organization of the Government of Odisha w.e.f. tenth December 2020.

The government of India, to meet its decarbonization goals encourages industries to manufacture battery cells locally to establish a domestic supply chain for clean energy transport and better storage of renewable energy [44].

3.6. Power Policies Formulated in Various States across South India

The various power policy framed by the southern states are provided in Table 6 and the major domain focuses for various states are shown in Figure 10.



Figure 10. Power polices of South India a glance.

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	Andhra Pradesh	Karnataka	Kerala	Tamil Nadu
I	Andhra Pradesh Renewable Energy	I Karnataka Renewable Energy	I Kerala Solar Power Policy:	II Tamil Nadu Solar Energy
Π	Export Policy, 2020: The government issued a new ordina nce on 7 July 2020, to effectively utilize free suitable lands and to promote and build renewable energy projects for	Folicy 2016–2022: It was developed by Karnataka Renewable Energy Development Limited (KREDL). The Power Policy's goals are to reach a minimum capacity growth	The government shall grant a 20% subsidy for group housing society projects and residential welfare associations with a capacity of up to 500 kW. If a customer prefers to build	Foncy: The strategy desires to make a system that will assist with speeding up the advancement of sun-based establishments in the State, advancing both
	all-around energy export outside	of 6000 MW in stages by 2022, make	the plant in its entirety, they	utility classification and
	a Solar Power Policy in 2018.	Karnataka an investor-triendly state	can choose to receive up to 40%	shopper class sun-powered
	b. Sale of Power to AP	projects, including as wind,	subsidy to encourage	empowering instruments.
	DISCOMS (s):	wind-solar hybrids, small hydro,	industrialists to involve in	Around 40% of the objective
	c. The government would	biomass, cogeneration,	renewable energy production	(9000 MW) will be reserved for
	of solar power projects for	waste-to-energy, and tidal, incentivize intra-state open access	solar sector's installed capacity	sun-oriented energy
	the sale of electricity to AP	business models, and stimulate the	in the state to 2500 MW by	frameworks.
	DISCOMSs which will enter	initiation renewable energy	2030, a long-term contribution	Motivators are given chance to
	developers who are chosen	Alcheve Chelthi Nidhi	in energy security as well as ecological security by reducing	energy in the horticulture area.
	through a competitive	(Green Energy Fund):	carbon emissions, Encourage	The State government will
	procurement procedure in	A "Green Energy Cess" of	entrepreneurs, startups,	likewise advance the
	Accordance with the Ministry of Power's tariff-	INR 0.05 (five paise) per	the state to develop new	assembling of sun-based
	based competitive bidding	unit would be charged on	solar-powered solutions and to	inverters, and batteries, and
	standards.	commercial and industrial	accelerate the implementation	henceforth The Tamil Nadu
	use:	energy project funding and	solar power technologies and	(TEDA) would collaborate
	e. Solar power providers are	energy conservation and	solar-based hybrid	with the Union Ministry of
	solar power plants for	efficiency measures. A donation of 10% of this	cogeneration technologies that	New and Renewable Energy
	captive use within the state	amount will be sent to the	efficiency in existing systems.	various concessions and
	or for third-party sale both	Energy Conservation Fund,	an R&D hub shall be	incentives.
	within and outside of the state by the government.	support energy	established by developing	a. The major objective is
	Renewable Energy	conservation efforts,	with educational	public-private
	Certificates (RECs) will be available for these projects	from KPTCL for evacuation	establishments, research centres, industries, and	partnerships and joint
	provided that the criteria	approval. KPTCL/ESCOMs	utilities.	ventures to raise funds
	and standards of the	have agreed to reduce monitoring charges by 5%	a. Interventions on the	projects, production
	properly met.	(5 percent), any allotments	supply side:	facilities, research, and
	f. Solar Parks:	that have not made any	Appointment of	development [48]
	g. The government of A.P.	progress or demonstrated a desire to construct the	suppliers/system	b. Promotion of
	with 4000 MW capacity at	projects within seven (7)	accordance with the	prosumer—a producer
	first along with the state	years of the policy's release	policy's standards for the installation of solar	c. To develop an
	government's assistance in the construction of vital	cancelled and all projects	systems, In order to	investment-friendly
	infrastructures such as	that were allocated ten (10)	facilitate decentralized	political atmosphere
	power transmission, water	introduction of this policy	the State will be	persons, businesses,
	roadways.	and have not made	informed of grid	local governments,
	h. Solar Rooftop	adequate progress will have their allotments annulled	the LT level.	departments, and
	Projects–Gross/Net Metering	b. Promotion of Wind-Solar	b. Promotion of Solar	others to contribute to
	i. On a gross or net meter	Energy Hybrid projects and	Thermal Collectors:	and engage in solar energy generation
	basis, the solar rooftop	Distributed Generation Projects:	The state promotes	particularly for
	as well as residential,	The Covernment of	systems by	electricity consumers
	commercial, and industrial	Karnataka will stimulate the	implementing a	becoming "prosumers"
	supported by the	construction of Wind-Solar	primary strategy of	(a
	government. The tariffs are	to maximize the use of land	adjustments to make	d Configuration of new
	applicable for a period of 25 years for Fligible	resources and evacuation	solar water heating	service connection
	Developers who set up solar	plans to encourage	systems (SWHS)	meters
	rooftop projects within the	small-scale hybrids,	industrial structure	All new service connection meters in
	Operating Period of this policy	particularly in rural areas	that requires hot water	Tamil Nadu must be
	j. Solar Pump sets:	available. The Karnataka	for processing. It also	equipped for bidirectional energy
	k. For the next five years, it is	Renewable Energy	use of solar steam	recording and display,
	expected around 50 000 solar-powered pump	(KREDL) aspires to build	systems for a wider	so that all new service
	sets will be operating in the	10 GW of renewable energy	including agriculture.	existing service
	state, with no additional	plants, both with and	communal cooking in	connections whose
	Grid-connected solar pump	1 GW of the 10 GW of	residential institutions,	part of routine
	systems will be encouraged	renewable energy	barracks, midday meal	maintenance, are ready
	by the government to help	installations will be accounted to the rooftop	programs, hospitals	to implement solar
	electricity to DISCOM's [45].	solar energy	[47].	metering at any point
		installations [46].		in the future.

 Table 6. Power policies formulated in various states across South India.

Table 6. Cont.

Andhra Pradesh	Karnataka	Kerala	Tamil Nadu
Inference of power policy of Andhra Pradesh: The power policy of Andhra Pradesh is mainly focused on encouraging the development of solar power projects for the sale of electricity, solar roof-top projects, solar parks and solar powered pumpsets.	Inference of power policy of Karnataka: The power policy of Karnataka is mainly invested on encouraging the development renewable energy projects by making the state—investment friendly.	Inference of power policy of Kerala: The power policy of Kerala is mainly focused on encouraging the installation of Solar panels for energy production and solar water heating systems for heating in large scale.	Inference of power policy of Tamil Nadu: The power policy of Tamil Nadu is mainly focused on encouraging the consumers to become a prosumer and configuring new energy meters for better monitoring of energy production and energy usage.

3.7. Gas Emission from Various Renewable Energy Sources

From the above analysis of renewable energy, the gas emission from the various sources of clean energy are accounted and represented in Figure 11.



Figure 11. Gas emission from various renewable energy sources.

4. Budget Allocation by Southern States—A Comparison

Tamil Nadu has a total installed power generation capacity of 32,149 MW, including 16,167 MW of renewable energy capacity. Tariff subsidy in the amount of Rs. 8, 413.98 crore has been allocated in the budget. To compensate the Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO) for its losses, as per the UDAY (Ujwal DISCOM Assurance Yojana), a provision of Rs. 7, 217.40 crore has been made in the obligations. Since 2011, TANGEDCO has added 15,296 MW of generating capacity through state and central sector projects and power purchases, bringing its total installed capacity to 31,780 MW, including 13,343 MW of renewable energy. To get electricity out of the new generation capacity that was built in the Southern areas of the state, as well as to improve transmission links along the route. The 765 kV and 400 kV lines proposed for the Chennai-Kanyakumari Industrial Corridor. By constructing a 400 kV substation at the site, the networks will be upgraded. Ottapidaram and a 765 kV sub-station in Virudhunagar, along with transmission lines. This project has a total cost of \$200,000 to complete. With a 451-million-dollar loan from the Asian Development Bank, Rs. 4, 650 crore was raised. A total of Rs. 450 crores have been set aside for execution [49]. Budget estimates of various states from 2021–2022 (in Rs. crores) is shown in the Table 7 and it is showcased that investment of various states in generating power from clean energy is increasing year to year. This shows that a

S. No.	State	2019–2020 Actuals	2020–2021 Budget Estimates (BE)	2020–2021 Revised Estimates (RE)	2021–2022 BE	Annualized Change (2019–2020 to 2021–2022 BE)	Budget Provisions 2021–2022
1.	Karnataka	13,123	12,918	12,918	12,576	-2%	Subsidies of Rs. 9167 crores have been allocated to Karnataka Power Transmission Corporation (KPTC) to promote renewable energy- based power
2.	Kerala	17.34	386.92	907.00	454.44	84%	production. Rs. 2 crore has been allotted for KSEBL.
3.	Andhra Pradesh	11,592.04	6176.14	6078.45	6438.80	-15%	2568.29 lakhs have been allotted to the PTRANSCO, DISCOMS, and
4.	Telangana	7222	10,111	10,111	10,633	22%	APGENCO. Rs. 7665 crore has been allocated along with allied subsidies towards assistance to the Transmission Corporation of Telangana Limited (TSTRANSCO) to promote solar based power production in agricultural sector.
5.	Tamil Nadu	9497	13,118	17,042	16,020	30%	Rs. 7108 crore been allocated for taking over the future loss of Tamil Nadu Generation and Distribution Corporation Limited (TANDGEDCO) under LIDAY scheme
6.	Orissa	22.0237	103.4661	103.4665	52.2729	46%	Rs. 49.56 crore has been allocated for new and renewable energy development.

Table 7. Budget estimates of various states from 2020 to 2022 (in Rs. crores) [50].

By observing the above power production scenario from the various stated of India and fund allocation by the states to meet their power demand, this work further suggesting an alternative energy production that was not implemented by the utilities extensively, namely thermo-electric power generation. This case study on thermo-electric power generation can be an initiation that can be implemented by the utilities extensively in the future.

5. Thermo-Electric-Generator (TEG)

5.1. Methodology and Materials

Thermoelectric-materials convert temperature differences into electric voltage, and thus help in generating power directly from the heat. A good thermoelectric material must have low thermal conductivity (κ) to form a temperature gradient to generate a large voltage difference and high electrical conductivity (σ) to allow direct current to flow

through it when a connection is established. The measure of the magnitude of electrons flowing in response to a temperature difference across that material is given by the See-beck coefficient (S). The efficiency of a given material to produce a thermoelectric power is governed by the equation $zT = S2\sigma T/\kappa$.

Large scale concentrating solar power (CSP) plants uses mirrors to concentrate the thermal energy from the sun to drive traditional steam turbines or engines that generate electricity whenever required. The four main utility scale CSP designs currently in use are parabolic troughs, tower systems, linear troughs and parabolic dishes. Figure 12 shows the arrangement of solar parabolic dish thermoelectric generator. It consists of a parabolic dish collector (PDC), a flat aluminum receiver plate attached with thermoelectric modules that are connected electrically in series and thermally in parallel in between the receiver plate and the bottom surface of the heat sink that acts as heat exchanger on its focal plane and encloses the receiver plate. The top surface of the receiver plate acts as the hotter side and the bottom surface of the heat sink acts as the colder side of the thermoelectric module, respectively. Ceramic fiber blankets are used to insulate the heat sink and the receiver plate to avoid heat loss due to radiation.



Figure 12. Model of parabolic dish.

The reflector surface that is fixed on the aluminum rib by a set of bolts and nuts is made by 20 triangular pieces of aluminum sheet polished on one side. By adjusting the bolt at the base plate, manual tilting of the parabolic dish to different angles can help ensure that the sunrays are always directed towards the collector at different times of the day. To absorb the concentrated solar radiation to retain the energy, the receiver plate surface exposed to the aperture area of the dish is coated with black paint which is used to drive the thermoelectric generator. The quantity of heat absorbed by the receiver plate relies mainly on the reflectivity and absorptive nature of the material.

The receiver plate is 2 mm thick and has an area of 0.1 m. The heat sink, whose bottom surface is made of aluminum, can help maintain the temperature of the cold face as low as possible by extracting the waste heat from the thermoelectric modules and by cooling with water. A thermocouple is fixed in the middle portion of the heat sink to measure the bulk temperature of water. The thermoelectric generator is comprised of n-type and p-type Bismuth Telluride (BiTe) semiconductors and four series-connected thermoelectric modules.

As long as a difference in temperature is present across the module, the thermoelectric module generates DC electricity. The design specifications are listed in Table 8.

 Table 8. Design specification of the thermo-electric-generator module.

Design Details	Specifications
Parabola—Diameter of the open mouth	0.66 m
Parabolic Concentrator—Surface area	0.342 m^2
Parabola—Height	0.0508 m
Concentrator—Reflectivity	0.78
Focal distance	0.48 m

Thermoelectric elements develop the See-beck effect by converting a part of thermal power into electrical power. A thermoelectric generator (TEG) device can be shaped by electrically connecting a number of thermoelectric elements in parallel and/or in series. The generator efficiency, η , is determined by comparing the amount of electricity produced (P TEG) to the total amount of heat induced (QH). The possibility of using this device to recover wasted heat can considerably help in saving energy and reducing the emission of greenhouse gases.

A measuring system and a modeling approach that allows for the characterization of TEG devices under various loads and temperature gradients and the evaluation of material properties by considering the thermal contact resistances have been developed. The model was applied for evaluating the expected gained power and efficiency at different places of the exhaust pipe of an intermediate size car with the use of conventional thermoelectric elements. Furthermore, the reliability of the TEG module was evaluated and the possible repercussion on fuel consumption was interpreted.

Figure 13 depicts the block description of the TEG module. The solar energy is taken as an input power source which is the light energy (i.e.,). 1000 Watts per square meter. The input source is directed towards the parabolic dish. The received source is taken to a particular focus point where the TEG module is fixed which directly converts heat flux into electrical energy. Energy meter displays the energy received in the display LED. A dual axis tracking system is fixed to trace the direction of the sun. After the energy measurement it is passed to the charge controller where the energy is boosted up and stored in the battery and used for the load.



Figure 13. Parabolic dish-TEG-block representation.

In conventional TEG's, the model consists of a parabolic dish collector made of aluminum receiver plate attached with thermoelectric modules on its focal plane, a linear one-axis tracking system, and an air-cooled aluminum fin heat sink as a heat transfer system. At a solar beam radiation of 600 W/m^2 in TEG, the instantaneous thermal efficiency of the parabolic dish collector is 67%. The overall efficiency of the system is 1.68%., wherein the proposed system consists of a concentrated parabolic dish made of reflective surface (reflective glasses of 96% reflectivity) with thermoelectric modules on its focal plane. The system uses a dual axis tracking system with a liquid cooler which leads to an increased temperature difference. The quantity of heat absorbed by the solar parabolic dish collector depends on the reflectivity of the concentrated surface and absorptivity of the receiving surface. The experimented results are analyzed and found to be efficient.

5.2. Simulation Study of the Proposed TEG Model

To verify the proposed system, a simulation model is designed using MATLAB/ Simulink by connecting various required blocks to make a TEG model as shown in Figures 14 and 15. The internal resistance of this model is fixed as $0.7 \times 30 = 21 \Omega$. In order to increase the generated power, TEGs were added to the series connected model in parallel. Thus, the TEG internal resistance of the system is lowered as $21/2 = 10.5 \Omega$ as shown in Figure 16. In addition, current, voltage, and power indicators were put to measure the power to be generated depending on load and temperature variations.





The design is capable of generating 11.2 V and 1.6 A at the load side with a power of 17.9 W that can be fed to a domestic load.



Figure 15. TEG modelling.



Figure 16. Modelling of resistance in TEG model.

5.3. Experimentation of the Proposed TEG Model

The TEG array consists of four modules with two thermoelectric generators that are connected electrically in series and thermally in parallel. The output from the TEG array is given to the voltage divider network where the output voltage is read at pin A1. The negative terminal is given to the current sensor at pin A5. NPN type transistor act as switch. From TEG array till C2 the circuit is considered to be a boost circuit. The primary and secondary filter capacitors are placed with a diode centered and are shown in Figure 17.



Figure 17. Circuit modeling of the proposed system.

The power is stored in the battery and given to the load. T1 and T2 as temperature sensors for the hot side and cold side of the module are given to A2 and A3 of analog. A variable temperature signal was applied to the hot side and cold side as input in order to determine the reaction of the boost converter Display is taken from A4 and A5 in i^2c communication.

Here, a solar tracking system with a dual-axis solar tracker has been designed to move the solar panels to trace the direction of sun throughout the day wherein the angle at which the solar panels receive solar radiation (known as the angle of incidence) can be minimized by orienting the panels in such a way that the light strikes the panel perpendicular to its surface and hence maximize the system's electricity production. Solar trackers are generally employed for large, free-standing solar installations mounted on the ground. They are predominantly used in the utility-scale and commercial/industrial solar markets and are generally not used in most residential solar projects. In the experimental model, a dual-axis tracker is designed and is shown in Figure 18, which allows the panels to move on two axes, aligned both north-south and east-west known as elevation axis and azimuth axis, respectively. A dual-axis tracker can improve the performance from 35 to 45%.

As shown in Figure 19, the DC motor will move according to the conditions provided by the LDR. In the dual axis solar tracking system, 2 DC motors are present to control the elevation axis and the azimuth axis of the solar tracker separately to ensure that all of the sensors receive the same intensity of light. In this simulation, the highest intensity of light is fixed to 15.1 Lux and the lowest intensity of light is fixed at 0.1 Lux for assumption purposes. The movement of DC motor in accordance with the direction of sunlight falling upon the four LDR sensors can be interpreted in the following ways:

When the intensity of light hit on LDR1 is greater than LDR2, LDR3, and LDR4, LDR1 produces a higher voltage output when compared to the other sensors. DC motor A rotates in clockwise direction to control the movement of the elevation axis and DC motor B rotates counter-clockwise direction to control the azimuth axis of the solar tracker.

When the intensity of light hit on LDR2 is greater than LDR1, LDR3, and LDR4, LDR2 produces a higher voltage output when compared to the other sensors. The DC motor A moves in counter-clockwise direction to control the elevation axis and the DC motor B moves in clockwise direction to control the azimuth axis.



Figure 18. Experimented dual-axis tracker.



Figure 19. Proposed dual-axis tracker circuit.

When the intensity of light hit on LDR3 is greater than LDR1, LDR2, and LDR4, LDR3 produces a higher voltage output when compared to the other sensors. The DC motor A moves in counter-clockwise direction to control the azimuth axis and the DC motor B moves in clockwise direction to control the elevation axis.

When the intensity of light hit on LDR4 is greater than LDR1, LDR2, and LDR3, LDR4 produces a higher voltage output when compared to the other sensors. DC motor A moves in counter-clockwise direction to control the azimuth axis and DC motor B moves in clockwise direction to control the elevation axis.

When all of the sensors receive the same intensity of light, both the DC motors stay in the same position instead of rotating. Thus, the elevation axis and azimuth axis remains unchanged.

In real applications, when the solar panel is directed perpendicular to the sunlight, the power production can be improved.

Based on the circuit model presented in Figure 19, an experimental setup is developed and displayed in Figure 20a,b, respectively, with energy meter circuit incorporated in proposed TEG module as shown Figure 21. The proposed TEG module comprises of current sensor, voltage sensor, boost converter, and step-down module that supply a 5-watt electric lamp and a low powered mini-fan.



Figure 20. (a) Experimental model of proposed TEG; (b) front view of parabolic dish.



Figure 21. Energy meter circuit in the proposed TEG model.

From the experimented thermoelectric generator model shown in Figure 19, an output voltage of 11.7 V is yielded with a load current of 0.9 A. Also, the power is measured from the TEG unit and is given as 10.5 W.

By connecting more proposed TEG module in parallel, one can yield more power that can be inverted (DC to AC) using various configurations of inverters designed in [51,52] and fed to households and other domestic targets to meet their power demands. Also, large scale implementation of this model can be effectively used for remote cellular base stations by reducing the involvement of diesel generators [53,54]. This increases the power productivity of the various states and decreases the states in investing more funds to produce power from clean energy and other sources. Also, the proposed power generator significantly reduces the pollution as compared to conventional energy power production and reduces the cost of energy generation and utilization. Thus, this model provides methods for sustainable development for all of the human beings in the way outlined by the U.N through their SDG's.

6. Conclusions

This paper provides a detailed discussion concerning energy availability, renewable energy available in India, power production and demand scenario of various south Indian states and the power policies and fund allocation strategies by these southern states of India for power production. According to the survey based on renewable policy of India, the power production from clean energy is increasing day by day. The policy is expected to attracts the attention of both local investors and foreign investor in the field of power generation from the RES with an expected investment of US\$85 billion to be carried out in another five years. Also, new thermo-electric-generator (TEG) techniques and experimental models are proposed to meet the domestic demand of the various states. In the proposed TEG model, a maximum receiver plate temperature of 383 K is observed at the solar beam radiation of 1050 W/m² while a minimum receiver plate temperature of 326 K is observed at a solar beam radiation of 600 W/m^2 in the modified TEG. For the same solar beam radiation hit on the solar tracker, the temperature of the receiver plate is higher than that of the TEG without cover. The results show that an increase in input of solar beam radiation increases the receiver plate temperature, and the variation of instantaneous thermal efficiency of the parabolic dish over the measured solar beam radiation is displayed. The maximum instantaneous thermal efficiency of the parabolic dish is 25% of the solar beam radiation. Thus, the proposed system produces a voltage of 11.6 V, a current of 0.7 A, and a power of 10.5 W. The simulation result approximately matches the hardware results, and is presented in the paper. Thus, the implementation solar-energy based thermal power generation in rural electrification will play a significantly important role in fulfilling the demand-supply gap for electricity. The proposed solar dish collector technology uses a Stirling engine for power generation wherein the dishes take care of 10 to 25 kW capacities, respectively. The further development of rural-level distributed power generation is possible by hybridizing the proposed solar dish collector technology with biomass gasifiers for the generation of hot air.

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