Renewable and Sustainable Energy Reviews 73 (2017) 115–124

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The drive of renewable energy in Tamilnadu: Status, barriers and future prospect

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ARTICLE INFO

Keywords:
Renewable energy
Tamilnadu
Wind
Solar
Small-hydro
Cogeneration
Bio-derived energy

ABSTRACT

This article provides a comprehensive review on Tamilnadu's achievement in extracting renewable energy. It discusses the initiatives and policies framed to exploit the renewable natural resources. It also analyzes the various barriers in exploiting renewable energy and the future prospects of Tamilnadu. The core findings are: Tamilnadu, the southernmost state of India is immensely blessed with renewable energy sources mainly wind, solar, hydro and bio-mass. As a result of proper planning and immense investment, Tamilnadu has the highest installed capacity of grid connected renewable power in India and has a share of 35% of India's installed capacity of wind energy. Presently, the capacity addition is not up to the mark. Meanwhile, Tamilnadu leads the country in polluting the environment by emitting greener house gas. Also, there is an alarm in the depletion of conventional energy resources of Tamilnadu. It should not be satisfied with new promotional policies or projects but also, the progress of renewable energy utilization and installation must be monitored. To ensure continuous growth in renewable sector, more public awareness and Research and Development sector should be encouraged in Tamilnadu.

1. Introduction

India was the pioneer country in the globe to set up a separate ministry called Ministry of Non-Conventional Energy Sources in 1992 which has been renamed as Ministry of New and Renewable Energy (MNRE) in 2006. India's cumulative Grid Tied Renewable Energy Capacity has reached 36.642 GW (as on 31st July 2015), of which 65.13% comes from Wind, 11.27% from Small hydro, 12.05% from Biomass and nearly 11.27% is being contributed by Solar Photo Voltaic (SPV) [1]. India ranked tenth in the world based on its economy, steered by a real GDP growth of 7.3% in the year 2014-15 [2]. The per capita electricity consumption in India is 1010 units. National institute of solar energy has estimated India's solar potential of about 748.98 GW [3]. In India, wind power has been exploited to 21.136 GW, small hydro to 3.804 GW, biomass power/Cogeneration till 4.014 GW, waste-to-power till 107 MW and solar power till 2.632 GW [4].

The gap between energy demand and supply is prevalent across all states of India, thereby pushing the Government of India to take serious action to increase energy supply. India has a serious challenge to provide uninterruptible, affordable and hygienic source of energy. Energy crisis has to be rectified by considering environmental sustainability and social development by eradicating unemployment and poverty and also without polluting the environment [3]. Tamilnadu has adopted various standalone and hybrid renewable energy integration techniques in order to promote renewable energy harnessing. For a clear understanding of the innovations, barriers and frameworks developed across various countries, literature survey is performed and given at the subsequent sections.

1.1. Hybrid renewable energy integration in literatures

Hybrid renewable energy systems are being encouraged and in progress to avoid the demerit of renewable dependency on climate and season. Shafiullah developed hybrid renewable energy integration for sub tropical climate in Australia [5] in which prediction model, techno-economic model and load management system has been studied. The grid supply, solar PV, wind and energy storage are integrated and various analysis such as economic, environmental, regression are done. Reda et al., assessed energy usage of solar cooling in a Nordic country [6]. The cogeneration heating plants are investigated with the combination of solar plants driven by thermal system. In India, the modeling of off-grid electricity generation is performed and there is a vast emission reduction on par of cost incurred [7–10]. In India, many rural areas are yet to be electrified and there are various options to use hybrid integrated renewable generation in an economic way [11–13].

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http://dx.doi.org/10.1016/j.rser.2017.01.123
Received 24 September 2015; Received in revised form 23 November 2016; Accepted 18 January 2017

1.2. Policy frameworks in literatures

Efforts are being made in China in efficiently harnessing renewable energy. The financial investment, incentives, tariff, business models and various policies are studied and there are certain factors conducive for successful renewable deployment like attractive incentives [14,15]. The importance of policies and supports are stressed in [16–18] as without them, it is very difficult to attain the goals and visions of renewable energy deployment.

Though the distribution of renewable energy sources is important, the promotional policies and governmental actions are more important in bringing up a new technology to the people. In Europian countries [19–24], the "Footprint" approach is executed to assess the potentials and the governmental policy schemes, promotion systems, economic analysis and benefits are reviewed.

Renewable obligation policies for different technologies under UK banding policy leads to higher consumer price or more CO_2 emissions. As renewable technology involves a highly complex strategy, multi criteria analysis is performed in order to assess the benefits in a future prospect [25,26]. The possibility of storing excess renewable energy as carbon storage cycle is an insight in the storage techniques as it has good storage density and storage efficiency. The portfolio standards and the flexibility mechanisms are studied to provide pathway to a successful renewable implementation [27,28].

The various cost effective policies are discussed from Indian context. The CO_2 emission from thermal plants has already lead to disastrous effects which if uncontrolled, the present generation leave the planet unsafe for the future generation. The importance and the need to take risk in reducing green house emissions in order to alleviate the invisible killers can lead to healthy and sustainable development of India [29–33].

1.3. Renewable status of other countries in literatures

World Bank has lauded renewable energy rich states viz. Tamilnadu, Gujarat, Andhra Pradesh, Karnataka for their efforts and achievements in tapping renewable sources [36]. One among the renewable rich states in India, Tamilnadu is continuing to tap its renewable sources. Various journals report the renewable energy development in the individual countries and states. The potential, current scenario and future prospect of Bangladesh was studied and it is concluded that biomass is more beneficial in accordance with the resource. The massive solar program of 500 MW is on the stage of completion in Bangladesh as part of renewable energy drive [37,38]. China has involved in renewable power generation in a massive scale so as to beat the energy crisis. Its policy implications as well as incentive approaches are applied practically and the targets and renewable obligations are monitored periodically. The analytic network process has disclosed various policies improvements and strategic measures in order to successfully promote renewable energy [39–42]. The renewable potential of Africa is largely untapped and the potential, current situation are studied in North Africa, South Africa and in certain African countries [43–46]. With more awareness and proper governmental policies and goals, Africa can become energy surplus in the days to come. The PEST analysis and SWOT analysis are conducted on various renewable energy resources in Poland [47–49]. The results are very clear and can be used as a guiding source for future prospects. The sustainable development and the reduction of carbon emissions are very clear if more renewable energy are added in the generation portfolio of Indonesia [50].

In Pakistan, the potential of rice husk and poultry wastes are analyzed and the economic perspective approach shows that Benefit cost ratio is to the tune of 128:1 and the net present worth and internal rate of return is promising [51]. A survey on Pakistan's geothermal energy is carried out by Younas et al. [52] where the effect of using geothermal energy for power generation is discussed. India has made success in the development of renewable energy and the government is taking sincere efforts through various financial supports, supportive policies and frameworks. India's renewable resources are identified by a separate agency and efforts are being put to uncap it as India leads the world in releasing particulate matters [53–58].

Fig. 1. Political map of Tamilnadu.

The main objective of this paper is to illustrate the renewable potential of Tamilnadu and the state's achievement in deploying renewable energy so far. The status and the favourable conditions for harnessing renewable energy are discussed. More importantly, it describes the limitation and bottlenecks in further exploitation of renewable sources. The investigation is executed for underutilization of RES in the generation profile of Tamilnadu during summer season and winter season.

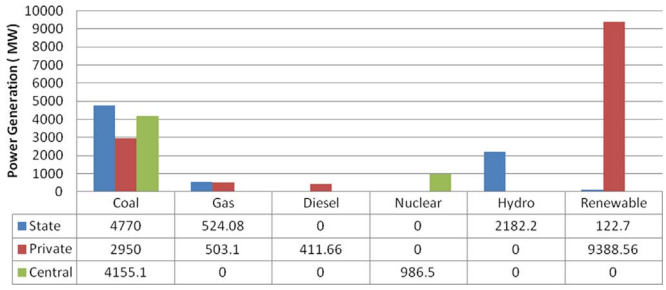
2. Tamilnadu's renewable status, potential and achievement

Tamilnadu, the eleventh largest state and the seventh most populous state in India, has the highest number of business enterprises and stands second in total employment in India. It is in the extreme south of the country (Fig. 1).

Tamilnadu is rewarded with nature's gift of renewable energy sources like solar, small-hydro and wind. In addition, the domestic and commercial wastes can be useful energy sources by ensuring safe disposal. Tamilnadu has 32% of India's renewable installed capacity [59]. To stress and promote renewable energy in Tamilnadu, Tamilnadu Energy Development Agency (TEDA) has been set up in 1985. The installed power capacity by various sectors in Tamilnadu is presented in Fig. 2 [4].

The renewable capacity addition by various policies of TEDA is 9548.87 MW [60]. Fig. 3 shows the installed renewable capacity in Tamilnadu where 88% is contributed by wind energy.

Tamilnadu has the highest installed capacity of grid connected renewable power (8075.38 MW) followed by Maharashtra (5630.19 MW) and Gujarat (4430.20 MW) [1]. Tamilnadu tops the



	Coal	Gas	Diesel	Nuclear	Hydro	Renewable
State	4770	524.08	0	0	2182.2	122.7
Private	2950	503.1	411.66	0	0	9388.56
Central	4155.1	0	0	986.5	0	0

Fig. 2. Status of Installed power capacity in Tamilnadu as on May 31, 2016.

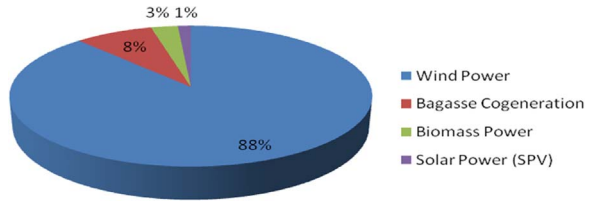


Fig. 3. Installed renewable capacity in Tamilnadu.

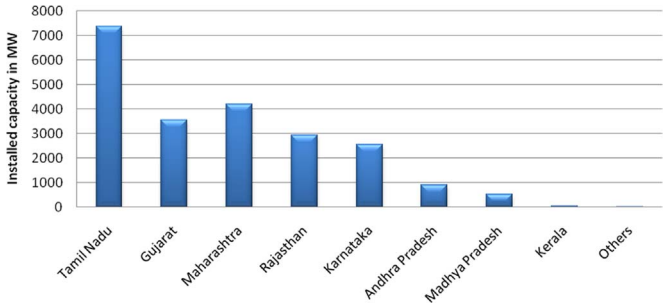


Fig. 4. State wise installed wind capacity of India [63].

other states in its wind power generation with an installed capacity of 7597.65 MW and has 35% of India's installed wind capacity. Fig. 4 shows the state wise installed wind capacity of India where Tamilnadu tops the other states [63].

2.1. *Wind energy*

The southern districts of Tamilnadu namely Coimbatore, Kanyakumari, Thoothukudi, Tirunelveli, Theni have strong winds at a speed of 18–24 kmp h due to the tunneling effect during the southwest monsoon which blow from Arabian Sea through four major breaks in the Western Ghats–Aralvaimozhi, Kambam, Palakkad and Shencottah passes. Nearly, 80% of the total wind energy is generated from the month of June to September. Fig. 5 shows the Muppandal area in the Aralvaimozhi Pass which is the largest wind turbine cluster in Asia with about 3,000 windmills and has 1500 MW of installed wind energy generation capacity [66].

2.2. *Bio-derived fuel*

Tamilnadu is one of the leading states of biomass power projects as well as bagasse cogeneration projects in India [68]. Tamilnadu can also make symbolic development in its biomass power extraction in the days to come [32]. It gives a promising solution to Tamilnadu's power crisis and has the ability to improve clean development mechanism [70]. The use of biogas is blossoming especially in villages of Tamilnadu but at a small scale. The total number of livestock of Tamilnadu is estimated to be 117.348 million and even if 70% of the dung are utilized for biogas, many remote villages can be self sufficient in its electricity requirement [71]. Energy plantation serves in providing cheap and reliable feedstock supply and improves the quality of life of rural population. MNRE assisted assessment study in 49 taluks in Tamilnadu indicate surplus raw material of 549.16 billion tone with a power generating potential of 228.80 MW [59]. The major biomass raw materials of Tamilnadu are bagasse, wood chips, sugarcane trash, coconut fronds, coconut shell, coconut husk, coir, pith, poultry waste, rice husk, Prosopis juliflora and saw dust. Based on an extensive study by Energy Alternatives India [73], 1160 MW based on agricultural residue and 429.9 MW from wasteland/forest cultivation summing up a total biomass based power potential of 1589.9 MW in Tamilnadu. Tamilnadu occupies third place in sugar production across India with a large number of sugar mills and the potential of bagasse based co-generation plant has been estimated at 800 MW in Tamilnadu. Table 1 shows the installed bio-derived power generation plants along with their installed capacity.

Fig. 6 show the bio-methanation plant in Namakkal district of Tamilnadu which produces 4 MW of electricity after processing 300 t of poultry waste everyday.

2.3. *Small-hydro*

Tamilnadu has many perennial and non-perennial rivers, flowing within its geographical boundary. The rivers mostly which are rain fed originates from the Western Ghats in India and get drained into Bay of Bengal as well as Indian Ocean. Tamilnadu consists of 17 river basins and 61 major reservoirs, where water can be stored and large and small hydro power projects can be constructed based on the catchment area, head availability, water capacity and flow duration curve [77]. Presently, there are 20 small-hydro projects in operation with the total installed capacity of 123.05 MW. The installed capacity of these small projects ranged from 0.7 to 25 MW.

2.4. *Solar energy*

Solar power projects are budding in Tamilnadu and have seen a substantial rise in the past 3 years. Out of the total area of 13 million hectare of Tamilnadu, 0.492 million hectare has been identified as solar hotspots among the arid or unculturable land [80]. Solar power is the new buzzword in the State with the Government announcing Tamilnadu Solar Energy Policy 2012. Solar powered Green House

Fig. 5. Muppandal wind farm in Tamilnadu with 1500 MW of installed capacity.

Table 1
Status of bio-derived fuel.

Type of bio-derived plants	Installed capacity [74]
biomass power plants	211 MW
Off-grid biomass	16.6 MW
grid connected biomass gasifier	1.5 MW
Off-grid biomass gasifier	16.262 MW
standalone biomass gasifiers	7.5–1.5MW
cogeneration power plants	659.4 MW
Grid connected waste to energy plant	6.65 MW
Off-grid waste to energy plant	11.42 MW

Fig. 6. Bio-methanation plant in Tamilnadu.

Fig. 7. Solar powered green house constructed in Tamilnadu.

Scheme and solar street lighting Scheme are the highlights of Solar projects Fig. 7. Solar air conditioning systems, solar steam cooking systems, solar air heating plants, solar photovoltaic power plants are also encouraged in government buildings and industries. About 1061.82 MW of solar PV modules has been installed by state owned and private solar firms. TANGEDCO has supplied 12,000 solar lanterns, 6378 solar street lights and solar home lights, in addition to 4206 solar thermal systems and 285 solar pump systems.

Under REC scheme, 1 MW solar PV power plant has been commissioned in Coimbatore district of Tamilnadu in May 2012 as in Fig. 8.

Table 2 and Table 3 lists the grid and off-grid renewable energy potential in Tamilnadu re-assessed by World Institute of Sustainable Energy [61].

Tamilnadu has 35% of country's wind energy installation [60]. The major achievements being:

1. First to introduce wind mills in the country in the year 1986.
2. First to erect 2 MW wind mill.
3. First to commission biogas plants in distilleries and power plants in Sago sector.

Fig. 8. Grid connected 1 MW solar power plant in Tamilnadu under REC scheme.

Table 2
Grid connected renewable energy potential in Tamilnadu [61].

Technology	Independent potential (MW)
Wind 80 m (no farmland)	36,344
Wind 80 m (farmland)	160,510
Wind 80 m (offshore)	127,428
Wind–solar hybrid	7913
Repowering	1370
Solar PV	259,700
Solar CSP	78,505
Biomass	450
Bagasse based cogeneration	1073
Energy plantations	9500
Small hydro	7.15
Total	682,800

Table 3
Off grid renewable energy potential for Tamilnadu [61].

Types	Off-grid
Rooftop PV	29,850 MW
Solar water heating	24,225 Million Units
Solar pumping	7041 MW
Solar process heating	59,761 Gigajoules

4. Pioneer in erecting co-generation plants in sugar mills.
5. First to commission grid connected 1 MW biomass Gasifier plant.
6. First to construct sewage waste to power plant.
7. Pioneer in bio-methanation plant from poultry litter waste.
8. First to commission 1 MW SPV Plant under MNRE scheme.
9. First to commission 5 MW SPV Plant in May 2011 under Clean Development Mechanism (CDM).

3. Policy implications in Tamilnadu

The government of Tamilnadu has enacted many policies to expand renewable energy sector which includes capital subsidy, tax incentive, private investment, foreign direct investment and competitive bidding [34]. The renewable energy certificate mechanism is introduced in 2010 to crab attention of investors to invest in renewable energy sources. It has set a target of achieving 15% renewable energy mix in India by 2020 [35].

The National Action Plan on Climate Change (NAPCC) recommends India's per capita green house gas emission should not exceed those of developed countries [31].

The eight 'National Missions' under the NAPCC plan are:

- National Solar Mission.
- National Mission for Enhanced Energy Efficiency.

- National Mission on Sustainable Habitat.
- National Water Mission.
- National Mission for Sustaining the Himalayan Ecosystem.
- Green India Mission.
- National Mission for Sustainable Agriculture.
- National Mission on Strategic Knowledge for Climate Change.

Tamilnadu has applied various schemes proposed by NAPCC to improve the renewable power generation. The Tamil Nadu Power Finance and infrastructure Development Corporation Limited is authorized to provide the loan to set up wind farm in their industries or houses. Indian Renewable Energy Development Agency (IREDA) provides loan for establishing biomass and bagasse cogeneration projects [62]. TEDA is in support with Tamilnadu Biomass Power Producers Association for encouraging large scale energy plantations in waste land by growing high potential crops like Juliflora. In Tamilnadu, CCCL Infrastructure with 5 MW capacity has been selected under 'NTPC Vidyut Vyapar Nigam scheme' of MNRE and commissioned their project on March 2012 and 7 solar plant developers have been selected under 'Roof Top Photo Voltaic & Small Solar Generation Program scheme' of MNRE each with an installed capacity of 1 MW out of which 6 solar power plants have been already commissioned [56]. Table 4 gives the incentives and schemes offered in Tamilnadu to set up renewable power generation.

Tamilnadu established solar policy in 2012 as a pioneering step in installing solar energy [64]:

TANGEDCO had a vision of establishing 3000 MW by 2015. The main objectives are:

- To achieve energy security.
- To reduce carbon emissions.
- To project Tamilnadu as solar hub.
- To generate 3000 MW of solar energy by 2015.
- To achieve grid parity by 2015.
- To encourage indigenous solar manufacturing facilities in the state.
- To promote research and development in the solar energy sector and hybrid systems.
- To create skilled manpower and employment in a new industry.

4. Opportunities of renewable energy resources

Table 5 shows the opportunities in Tamilnadu to stand top in power generation.

TNEB took the initiative to set up a wind farm in Mullakadu in 1986 to prove the possibility of wind farms and promoted assurance among private wind farm developers who then set up wind farms in Muppandal, Kethanur and Kayathar starting from 1990 [65]. The amount of waste generated from India's population, the existing practices of waste management, the energy potential from waste, the current status as well as the failures met are classified in [69]. Besides providing electricity, a 10 MW biomass plant can provide employment for over 1500 marginalised families directly as well as indirectly like collecting bio waste, transportation of biomass raw materials, breaking down and chipping of biomass, skilled operation in biomass power plant and wasteland cultivation with energy plants like Juliflora [34]. In Tamilnadu, the hydro power resources have been fully acquired by TANGEDCO except one micro hydro project of 350 kW capacity that is a private sector investment. It has more than 35 stations with a generating capacity of around 2182 MW of large hydro which has been grid-connected. The major hydroelectric power plants in the state include Kundah hydro-electric power house (585 MW), Kadamparai hydro-electric Pumped Storage Power Plant (400 MW), Mettur Hydro Electrical power project (250 MW), Periyar hydro-electric power plant (140 MW), Pykara power station (210 MW) and Kodayar Hydro-electric Power Plant (100 MW). The Kadamparai Pumped Storage Hydro power station (4×100 MW) was commissioned in the year 1986 and is the first hydro electric station in India to operate both in generation and pumping mode since 1987 [78].

With the exception of two large hydro plants and five small-hydro plants, all the other hydropower projects in Tamilnadu were built

Table 4
List of policies and incentives to promote renewable energy.

Incentives	Comments
Wind	
Generation based incentive (GBI)	MNRE has given GBI to independent wind power producers who are not availing accelerated depreciation benefits in 2009 [59]
5 year tax holiday and 100% depreciation	Announced by TEDA
• Wheeling and transmission charges are only 5%	
• Energy wheeling and energy banking.	
Accelerated depreciation are given 80%	
Surplus energy from the wind mills at a rate of Rs. 2.90 per unit	–
Wind electric generator is permitted to import under Open General License	This is to get qualitative product
Biomass	
• 80% accelerated depreciation for cogeneration systems,	Announced by TEDA
• ten years tax holiday,	
• concessional customs	
• excise duty exemption for machinery and components.	
Debt financing	This is for several equity investors looking for good projects to invest
Clean Development Mechanism	Certified emission reduction and preferential tariff for power exported to grid
Solar	
Solar powered Green House Scheme	100Wp SPV panel and 5 no. of Compact Fluorescent Light of 9 W each with the facilities of grid back up and with 5 year replacement warranty [64].
Solar street lighting Scheme	100 thousand street lights with 20 W LED lights having the features of auto dimming to 6 W from 10 pm to 5 am, grid back up, remote monitoring and with 5 year replacement warranty [64]
Renewable Energy Certificate (REC) scheme	Issued by CERC for every MWHr solar power generation to the solar power developer
Jawaharlal Nehru National Solar Mission (JNNSM)	Under MNRE to install 20,000 MW of solar power by 2022 [55].
Net metering	solar power generated by domestic consumers from rooftops can be fed into the grid and the consumers will only have to pay for the net electricity consumed [3].
Wheeling and banking charges, exemption from payment of electricity tax, tax concessions [60].	Announced byTEDA

Table 5
Opportunities of renewable energy in Tamilnadu.

Wind	Availability of potential sites, shorter gestation period for installing and commissioning wind turbines and better performance of wind turbines. Potential sites are nearer to places where labor force and accommodation were available. It was well connected with highways which facilitated the transport of heavy machinery of wind turbine generator. Presence of major wind turbine manufacturers and suppliers near sites. Investors and Developers were confident about the supply and service of the machines are within the stipulated time.
Biomass	Tamilnadu, a leading producer of agricultural products in India, can acquire enormous biomass raw materials in its season. Cogeneration of bagasse is a successful energy project as sugar mills adopt latest techniques of cogeneration [33]. Biomass requires the least investment capital among the other renewable energy sources. For instance, when 1 MW of power generation from solar plant requires Rs. 16 crore investment (approximately US$2.6 million), biomass plant requires Rs. 5 crore (approximately US$0.81 million) [72]. For establishing a 1 MW bagasse based cogeneration project, the capital investment required is Rs. 3.5 crore (approximately US$0.57 million).
Small hydro	Tamilnadu has already harnessed large hydro projects to its maximum degree possible. Presently, focus has been set on small hydro plants, as it has been recognized that small hydropower projects can play a vital role in improving the overall energy scenario of Tamilnadu and in particular for inaccessible and remote areas. Small hydro projects do not face the problems of deforestation and resettlement.
Solar	Tamilnadu due to its location in the solar belt, receive an average high solar insolation of 5.4–6.0 kWh/sq m. with around 300 clear, warm days, summing to 3000 h of sunshine in a year.

Table 6
Latest small hydro projects in Tamilnadu.

Name of small-hydro project	Capacity	Expected annual GHG emission reduction	Commissioned
Periyar Vaigai-3	2×2 MW	12947 tCO_2 e/a	Sep/Oct 2013
Periyar Vaigai-4	2×1.25 MW	8782 tCO_2 e/a	June 2014
Bhavani Barrage 1	2×5 MW	14140 tCO2 e/a	December 2013
Bhavani Barrage 2	2×5 MW	14140 tCO2 e/a	October 2012

before 2001. The recent addition of small hydro projects has been given in Table 6 [79].

The targeted 3000 MW of solar power has been planned to achieve through utility scale projects, rooftops and REC mechanism [55].

5. Practical barriers and consequences

There are certain major issues faced by renewable power sectors are, as wind and solar systems are nature dependent, more balanced systems are required in order to make it 'firm power' evacuation facilities and strengthening of transmission lines is the need of the hour. The electricity price to consumer for using solar cooker, solar lanterns, solar geysers and biogas plants are comparatively higher and consumers are not interested to use these technologies even though they agree with its merits. So far, consumers has no mandate to use green power and is optional. Private firms/entrepreneurs are unwilling to invest in renewable projects as there is long term renewable energy policy accompanied by low cost funding. Only few providers are financing renewable energy projects when compared with conventional generation projects. Tamilnadu fails to attract energy sector investments as there is no guarantee of power purchases such as Feed-in Tariffs. There is slow market growth in developing countries because of a range of technical, regulatory and financial barriers. Table 7 shows the major barriers prevalent in Tamilnadu to successfully operate renewable based generation.

Due to poor evacuation facilities of wind energy, significant generation capacity were unutilized and caused revenue loss to the wind farm owners. The penalty levied for reactive power consumption were improved by installing capacitors. Consequently, it led to long delays, more breakdown periods and loss of generation when repair occurs. In the financial year 2012-13, only 191 MW of wind energy was added in Tamilnadu against an all-time high capacity addition of 1083.460 MW in 2011–12 [67]. In 2013–14, the state added merely 89 MW until January 2014. The GBI scheme has been reinstated in December 2013. The removal of accelerated depreciation for wind energy has made the sector unviable. Fig. 9 shows the capacity addition and cumulative capacity addition of wind energy in Tamilnadu. The year 2013–2016 shows a great dip in capacity addition.

6. Research outcomes and future prospects

Deregulation has enhanced the opportunity of renewable power generation. The major renewable energy sources like wind, biomass, cogeneration are already dominant in Tamilnadu whereas solar and hybrid systems are emerging [56].

The targeted projects should be well supervised and administered in order to achieve the goal of power generation in the stipulated period.

The awareness and options in taping small scale can be encouraged in every house and industries which will contribute more altogether. With large scale untapped potential yet and the conducive government policies, renewable is a flourishing power project as well as investment options in Tamilnadu in the days to come.

The Government of Tamilnadu is pledged to promote renewable energy generation in the state by introducing policies and incentives conducive to its varying climatic requirements. Just like rain water harvesting successfully implemented in Tamilnadu years back, the Government aims to make renewable energy a people's movement and some form of renewable energy is to be installed in every house and industries.

Mini and micro hydro projects are being set up in remote and isolated areas by the private sector as well as consumers. Tea garden owners in the remote hilly areas are setting up micro hydro projects to meet their own requirement of power. Organizations such as Water Mill Associations, registered non-governmental organizations are being encouraged and oriented to install watermills in the inaccessible areas to generate electricity for small scale power demand in villages. MNRE subsidy scheme is available for setting up new micro/small-hydro projects as well as for renovation and modernization of existing small-hydro plants in Tamilnadu.

90 investors to supply a total of 226 MW of solar power To reduce transmission and distribution losses, industrial estates being encouraged to set up solar plant in its own buildings. Tamilnadu which leads renewable energy with its wind production needs to continue in taping nature to completely overcome the power deficit. With government support and more incentives in the initial years, the capacity addition of renewable production in the recent years is not up to the mark. The Twelfth Five Year Plan should be well executed with support from all commercial, industrial and political policies.

6.1. Useful guidelines to motivate future research works

Besides biomass, solar, wind, and hydro energy, Tamilnadu has the potential of the oceanic wave, tidal power as it is situated across Bay of

Table 7
Barriers in promoting renewable energy.

Wind	Biomass	Small Hydro	Solar
Inadequate evacuation capacity at its nearest substations	biomass power plants with even 80% plant load factor have faced temporary shut down owing to unrealistic tariff and increased feedstock cost [32]	Small-hydro is the least option due to its geographical distribution and rain-dependence.	Customers are ignorant of the durability and the overall efficiency of installing of solar plants
TANGEDCO levied penalties for excess Reactive Kilo Volt Ampere Hour consumption, which hindered the setting up of wind farms	exists competition in obtaining land between biomass plant cultivation and food grain production	To recover from the shortage in shortest possible time, more concentration is being placed on sources of power generation with shorter gestation period, easy availability of equipments and more capacity utilization	There is lack of stability of incentives as Generation Based incentive was discontinued without prior notice.
Wind turbine suppliers and owners did not properly maintain the wind turbine generators.	alternative option of paper production from sugarcane bagasse is common instead of power generation	In spite of all good effort while planning and formulating hydro power projects, in reality, a number of hydro projects take longer gestation period of construction due to reasons, such as environmental issues, rainfall dependence as well as gap between investigations and field-realities.	There is poor customer service and lack of marketing campaigns; There is lack of collaboration between the owners and solar panel industries.
discontinuation of the GBI scheme from April 2012 to December 2013	Moreover, power tariff is insufficient to match the increasing costs of human labor, feedstock, transportation and storage, requiring an annual revision in government tariff policy [34].	For TANGEDCO, investment in small hydro power projects is not preferred much as the capacities of these projects are always small and with lower capacity utilization.	The high investment cost of the solar PV module is the major reason implementation.
	Feedstock availability depends greatly on seasons and when natural disasters happen, it leads to rain and crop failures which add to the poor supply chain management [75].		There is no dedicated governmental support and There is no influence in marketing.
	the attainment of the designed efficiency of the boiler is a great challenge due to the usage of fuels having different chemical composition and moisture content [76].		

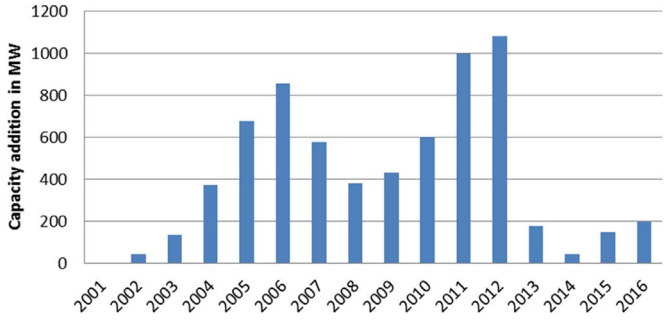


Fig. 9. capacity addition of wind energy in Tamilnadu.

Bengal and Indian Ocean. However, the potential of these resources is still under investigation and necessary efforts have been given to make them affordable and viable in Tamilnadu context.

Proper planning of Wind installation has to be executed in order to avoid loss of capacity utilization and loss to the wind farm owners. The promotional policies, tariffs and incentives can be made simple and propaganda to the industrialists and domestic consumers so as to attract interest from them.

Manufacturing of solar components can be encouraged in the state and solar manufacturing ecosystem can be formed which can include solar research centres, training centres, resource assessment facilities and facilities to test manufactured components [64].

6.2. Vision Tamil Nadu 2023 [81]

Tamilnadu has set up ambitious and constructive 'Vision Tamilnadu 2023' in which power sector has been given more importance. US $68.27 billion has been estimated to invest in energy sector. Generation projects of capacity 20 GW will be added to the grid in which at least 5 GW will be added before 2017 to meet the energy crisis. US $3.79 billion is to be invested for wind power and US $8.34 billion is to be invested for solar power. The physical target of

Table 8
Renewable energy target for the Twelfth five-year plan of Tamilnadu.

S.No.	Resources	Capacity addition (MW)
1	Wind	6000
2	Solar	3000
3	Bio-derived	1285
4	Waste to energy	250
5	Small-hydro	100
6	Others (Ocean, Wave, Tide, Geothermal, Hydrogen)	15
Total		10,650

renewable addition is shown in Table 8. Table 9 shows the renewable projects under construction.

Wind solar hybrid system has been encouraged at wind potential areas having an annual average wind speed of about 4.17 m/s at 20 m height and with a normal solar radiation of 5.4–6.0 kWh/sq m. The cost of the hybrid system is also cheaper by 40–50% than the pure solar system [83]. The system can be installed at the roof top and the area required for the installation of solar panel will be 8 sq.m/kw. The cost of 1 kW hybrid system would be approximately around Rs. 2 lakh (approximately $3203) [74]. Seminars are being conducted in Tamilnadu and applications for a total of 1.554 MW from 41 Institutions/Organizations/Individuals have been received and recommended for sanction from MNRE.

6.3. Research outcome on RES utilization

The load curve (Fig. 10) was fetched from the State Load Dispatch Centre [82]. The morning peak hour and evening lighting peak are noticed in a consistent basis. Based on the data available, the generation of various plants is noted and the availability percentage and the utilization percentage are calculated (Tables 10 and 11).

By analyzing these two tables, in winter season, the hydro plants availability percentage is 61.2% in winter season against 34.7% in

Table 9
Projects in pipeline.

Wind	TANTRANSCO to set up five 400-KV substations and three 230-KV substations with 765-KV transmission lines in Tirunelveli and Udumalpet areas to accommodate the additional capacity of 3000 MW which is in pipe line
	TANGEDCO has agreed to establish Regional Load Despatch Centre exclusively to monitor and control wind generation.
Small-hydro	Six small-hydro projects contributing 33 MW and is in the way of getting commissioned.
	Nearly, 197 potential sites for small-hydro plants have been identified from which 660 MW can be generated.
	To establish small hydro projects in the run of river scheme with a total capacity of 110 MW.
Bio-derived	189 numbers of human and poultry waste linked biogas plants have been under construction
	183 MW of cogeneration capacity is being set up in 12 co-operative and public sector sugar mills
Solar	Solar Parks in 24 districts with a capacity of 50 MW each.

summer season and the utilization percentage is 91.2% in summer season against 47.4% in winter season. Thus, the hydro plants are well utilized and efforts should be made in order to achieve maximum utilization.

The thermal plants which emit greener house gases are utilized to a maximum in both seasons. Though thermal plants supply base load plants, it can be replaced by gas and other raw materials. The pollutants from thermal plants are very harmful.

The biomass plants have very low availability index in both the seasons. The plants which were constructed by investing a huge amount should be well maintained and the raw materials should be collected in a consistent way. It often discourages the investors to further invest in biomass sector.

The power generation capacity of gas plant owners, independent power producers and captive power producers too are very less than their installed capacity. The power purchase to mitigate the load shedding is always high which leads to higher purchase cost to the government. It can save the money by proper planning of utilizing the existing renewable plants.

7. Conclusion

In the present paper, the renewable energy status of Tamilnadu has been analyzed. Tamilnadu's energy need is increasing in an exponential rate due to rapid economic development and rise in population. As the economy is projected to grow at 7.9% per annum, the per capita consumption is also increasing, the demand is also expected to grow in an exponential way. Tamilnadu needs to realize the vast potential of renewable energy and need to take its utmost effort for attaining the ambitious goal of attaining 10.65 GW by 2023. The wind farm set up which was peak by the year 2012 has drastically reduced in the year 2014 owing to poor evacuation infrastructure. The under utilization of renewable energy has to be improved by finding the exact reasons. Tamilnadu should make sincere effort in setting up of sufficient transmission green corridor to evacuate green energy generated in its area. As Tamilnadu tops all the other states in emitting more CO_2 (268.3 kg for urban and 139.6 kg for rural), these targets provide a sustainable development, reduce CO2 emissions. However, the solar PV has to be made more awareness in every household and industries so as to increase its effective capture. Government subsidies, renewable energy certificate (REC), strict policies are highly required for promoting renewable source based generations. Investment based Renewable energy generations can be encouraged as Tamilnadu witness more potential industries and people. Research and development labs can be set up by government in order to test the new technologies as well as invent efficient panels and so on.

Table 10
Data collected as on July 12th, 2016.

Type of plant	Installed Capacity (MW)	Available MW during morning peak hours	Consumed MW during morning peak hours	Availability percentage	Utilization percentage
Hydro	2307.9	800	377	0.347	0.471
Thermal	4660.0	2400	2220	0.515	0.925
Gas	516.1	154	154	0.298	1.000
IPP	852.5	535	125	0.628	0.234
Captive	2142	790	764	0.369	0.967
Cogen	659.4	80	80	0.121	1
Biomass	230	5	0	0.022	0.000
Wind	7598.16	3714	3714	0.479	1
solar	1142.41	110	110	0.096	1.000
CGS[a]	5464.0	4183	3726	0.766	0.891
Purchase	3189.5	1913	1913	0.600	1.000

[a] Central generating stations.

Table 11
Data collected as on Dec 15th, 2015 (Winter season).

Type of plant	Installed Capacity	Available during morning peak hours	Consumed during morning peak hours	Availability percentage	Utilization percentage
Hydro	2288	1400	1277	0.612	0.912
Thermal	4660	3950	3840	0.848	0.972
Gas	516.08	146	146	0.283	1.000
IPP	958	340	340	0.355	1.000
Captive	1759	654	653	0.372	0.998
Cogen	659.4	167	167	0.253	1.000
Biomass	230	13	13	0.057	1.000
Wind	7499.32	75	43	0.010	0.573
solar	358.26	14	14	0.039	1.000
CGS	5429	2961	2961	0.545	1.000
Purchase	2750	2750	2254	1.000	0.820

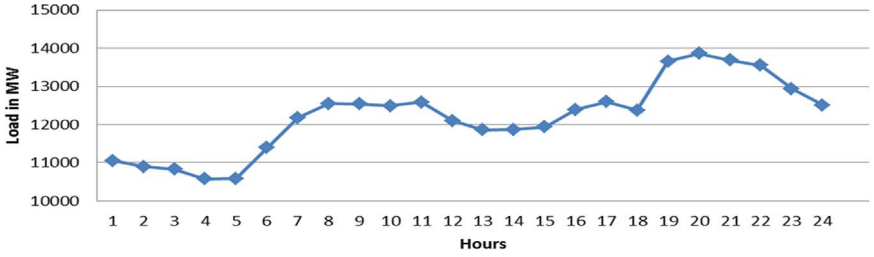


Fig. 10. Load curve of Tamilnadu on July 12th, 2016.

Acknowledgement

The authors thank the reviewers for their insightful comments and the authors extend their sincere thanks to the management of Thiagarajar College of Engineering, Madurai, Tamilnadu for their constant push in doing research on renewable energy and acknowledge the financial support from University Grants Commission (UGC), India under Maulana Azad National Fellowship (MANF) Scheme (F1-17.1/2013-14/MANF-2013-14-CHR-TAM-20866).

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