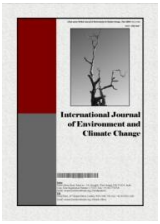

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Solar Trees: Shift from Grey to Green Sky for Future Fuel Pumps under Clean/Green Energy: India

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Authors' contributions

This work was carried out in collaboration among all the authors. Author SPM performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Author NCG designed the study, made estimation and simulation works. Author DDB managed the literature review of the study. Author SRN managed the laboratory works and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Clean/green energy embraces renewable resources like bio, geo, hydro, oceanic, solar, and aeolian power. They are utilized in energy generation, heating and cooling processes, transport, domestic and urban niches. India has aimed to rise in its per capita energy use to rise by 40%, and emission cut/GDP pledge by 33-35% till 2030 compared to 2005 level by building extra carbon sink 2.5-3.0 billion MT CO_2e by targeting renewable source to 175GW (100GW of Solar) by 2022. The killer SARSCoV-2 virus has the target and the clean/green energy growth. The reduction of CO_2

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has been depleted due to industrial, urban and transportation shut downs and the 2019 grey sky has converted old blue environment, Solar power plants considered to be best remedy for apocalyptic. The Solar tree or Solar Parks concept is novel and the most easy, economic and commercial method that can have utilities in all development sector. The work envisages the design by MATLAB (Simulink simulated). The fabrication of solar trees of 180 watt capacity in workshop including has been tested under different solar insulations. The result inferred that the solar tree can be a part to solar park, installed at fallow/hilly terrains in less area, low cost by 18.51%, with higher power generation by sustaining the environment serve as real trees. The solar trees near National Highways shall sell/hire batteries on commercial basis like fuel pumps and gas cylinders for supply to e-vehicles.

Keywords: Carbon emission; electricity generation; thermal power plant; solar PV system; solar power plant; solar tree.

ABBREVIATIONS

PV : Photovoltaic;
MNERE : The Ministry of New and Renewable Energy;
GHG : Green House Gas;
SPM : Suspended Particulate Matter;
HPP : Hydro-power Plant;
TPP : Thermal Power Plant;
SPP : Solar Power Plant;
MW : Mega Watt;
GW : Gigawatt;
SARS : Severe Acute Respiratory syndrome;
COVID : Corona virus diseases;
DPIIT : The Dept. for Promotion of Industry and Internal Trade;
RVEP : Remote Village Electrification Programme;
SECI : Solar Energy Corporation, India;
UNFCCC : United Nations Framework Convention on Climate Change;
CSP : concentrating solar power,
GHI : Global Horizontal Irradiance;
DNI : Direct Normal Irradiance;
DIE : Diffuse Horizontal Irradiance;
OTEC : Ocean Thermal Energy Conversion;
RES : Renewable energy Sector;
GDP : Gross Domestic Product;
CEA : Central electricity authority,
COVID-19 : Novice Corona Virus diseases-2019;
SARSCoV2 : RES: Renewable energy sources;
TERI : Tata Energy and Research Institute;
CMERI : The Central Mechanical Engineering Research Institute

1. INTRODUCTION

India, for its geographic position and anthropogenic stresses is vulnerable to climatic changes (CC) urging emergency under escalated concerns of burning of coal and fossil fuel for energy (Forested et al., [1], The blue sky of pre-Anthropocene days is continuously turning grey in India due to Urbanization, Industrialization, Mining, deforestation and energy generation for last five decades. Paradigm of shift has been observed globally from carbon based to clean energy systems and as clean energy has been a fringe player to the main energy sector. Thermal Power plant/ Hydro Power Plants (TPP/HPP) are incapable to accomplish the demand so multiple sources are explored such as wind, atomic, solar, solar (floating), hydroelectric, biomass and geothermal *etc.* to create a blue sky with ample of oxygen. The clean energy is renewable, abundant, inexhaustible, ecofriendly, minimizing climate changes and above all economic in long run.

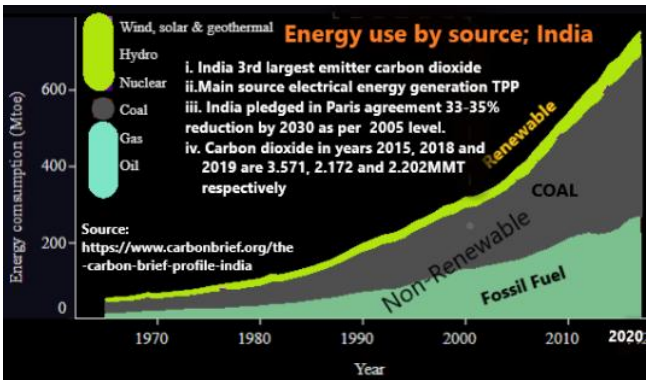

Fig. 1. Source wise energy generation India (Source: Carbon Brief; India)

2. REVIEW OF LITERATURE

The project Solar tree was first designed at the of Sarajevo University, Bosania Germany which is metal structure like a tree on which solar panels mounted that can generate energy like solar panels Avdić V et al., [2], Kavaz et al., [3]. The Si SPV solar generation generates ≈30-40gCO_2KWh/ life cycle in comparison to average generation ≈860gCO2 KWh/per life cycle of a non-renewable power plant, Alsema et al, [4], Base line database CEA-2008-09, Ramchandra et al [5], and (L-3). Continuous economic advancement in India have commanded rise in per capita energy. Projected rise by 40% and cutting Green House Gas (GHG) intensity by 33-35% by year 2030 is targeted though renewable energy generation which may diminish energy ingestion and rise in emission growth Jonas et al., [6]. Clean energy resources is the domain where India should thrust to promote ecofriendly power generation and save the regularly diminishing coal reserves, Khan et al [7], Athanas et al., [8], and L-1.Seeing the popularity of solar tree application worldwide it felt necessary to design and erect small scaled solar tree in India.

2.1 Scope of the Study

Present study envisages the growth of solar tree power related to sustainability, appropriate retrofits in industries, transport and domestic arena with some innovative ideas for production/ storing/ distribution and commercialization of green and clean energy development in India. Prototype modelling considering solar radiation the search is made to plan solar tree power generation for community use and commercialization Charles et al [9], Kumar et al [10].

The Solar tree or Solar Parks concept is novel and the most easy, economic and commercial method that can have utilities in all development sector. The work envisages the design by MATLAB (Simulink simulated) and fabrication of solar trees of 180 watt capacity in workshop including testing under different solar insulations. The tentative cost for erection of a tree is also to be calculated.

2.2 The Energy Security India

The urbanization, Industrialization and modernization of India demanded ample electrical energy for fast developed modern, mechanized, and urban comforts making a huge gorge between the demand and supply during peak hours from 1980 onwards since commencement of golden spike of Anthropocene in India, Mishra S P [11].

It is observed that the gap between the energy utility during average and peak demand has been reduced from 2012 in India due to surge in the renewable energy yield like solar, wind and small hydro power plants has bridged the gap.

2.3 Paris Pledge and CO_2 Status India

At COP21 on 12th Dec. 2015, the members of United Nations Framework Convention on Climate Change (UNFCCC) (replacing Kyoto Protocol), made a pledge at Paris to have low carbon on earth's atmosphere to combat global climate degradation for human sustenance. The India commited in the COP21 to moderate the intensity of GHG emission by 33-35% and GDP by 2030 as the year 2005 and started dessimianting the nation's data from 2014 to UNFCCc (CEA 2020[12]).

The coal or fossil fuel based power pants generate about 2/3rd of SO2, 25% of oxides of nitrogen (NOX), CO2, suspended particulate matter (SPM), Radio activity along with traces of mercury and other GHG gasses, whereas the renewable energy generation add to energy security, economic stability, healthy environment and more job opportunities with clean energy without above gasses (L-5).

The main player of COP21 (Paris pledge-2015), India planned to augment its clean/ green energy

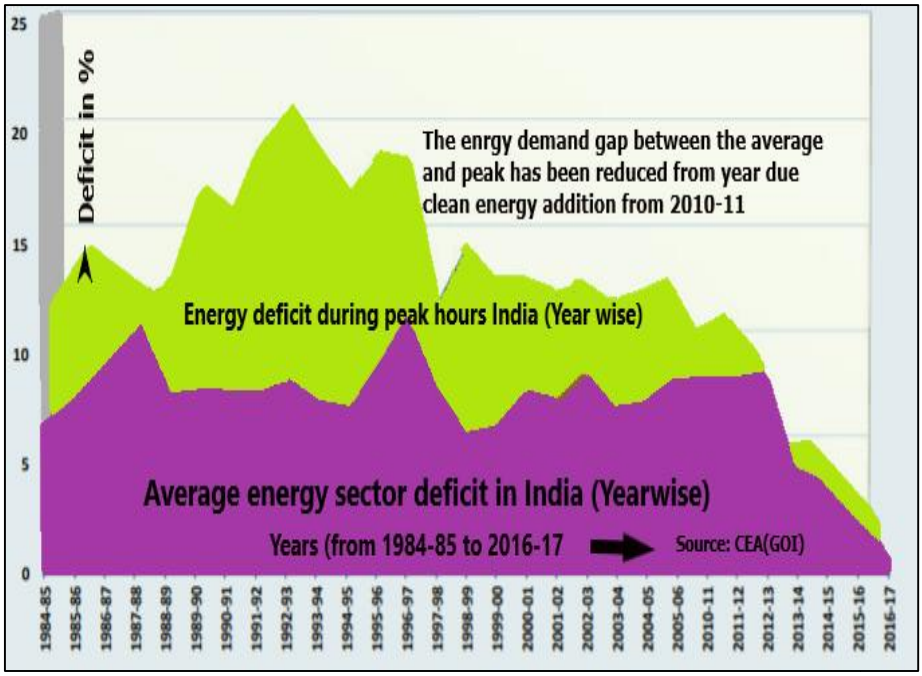

Fig. 2. The deficit of electrical energy in utilities from 1984-85 to 2016-17 (CEA 2020)[12]), L-2

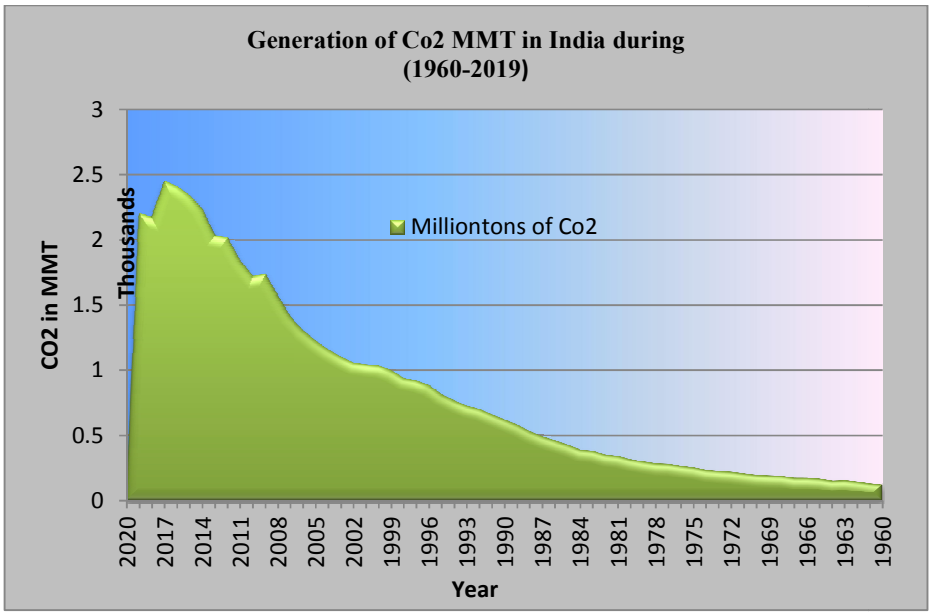

Fig. 3. The generation of amount of CO_2, in India during 1960-2020; (source: L-4)

installation to 175 GW including 100 GW (solar), 60 GW (Aeolian), 10 GW (bio-power & Geo), and 5 GW (Small-hydro). World Bank study reveals that the annual gross domestic product (GDP) growth of India was @7.0% (2017/18), @ 6.1% (2018/19e) 4.2% (2019/20f), and projected −10.2% (2020/21) (L-6). The emission growth rate vis-à-vis rise in India between 2018 and 2019 was @≈ 4.8% Keohane, R. O., et al., [13].

The year 2020 is a unique for energy generation, transmission, and consumption around the globe including. The mega-threat from killer Corona Virus Diseases (COVID-19) made life stagnant. Absence of the vaccine for the Severe Acute Respiratory Syndrome COVID virus-2 (SARS-CoV-2) virus, the govt. was forced to implement closures, shutdowns, and lock downs, as mass health care measure. The cities and industrial belts has been turned to melancholies for deaths, pandemics and migration. There was only option for workers from all sectors to save their lives leaving their livelihood. The industries, transport, utility and agriculture sectors ceased sprouting noxious gasses to make air from grey to blue. There was declined demand of electrical energy affecting the solar power sector, Mishra S P., et al, [14].

2.4 Electric Power Development in India

To power sector in India was under the privileges of welfare but transferred as commodity since 1990's nation's growth solely depend upon it. The pre-independence electrical frame work (India Electricity Act 1910) was based upon technical function, safe generation and legal frame work of distribution between the legal producer and the consumer (Giri and Mishra S. P., [15], Durusu A et al., [16]). But after independence; i.e. 1970 onwards, there was rapid growth of urban, industrial, technology sector in India and a large number of conventional (Coal and Fossil fuel) and renewable power plants generated electricity to meet the gap of demand and supply and reduce the surge in evolving CO_2 in air due to the urban, agriculture and Industrial complexes which has turned the blue sky, energy security as priority, and racing for sustainable environment Carbon Brief May 12 [17], and (.L-7).

2.5 Status of Power Generation, India

From mid of 20th century, generation was from either HPP or TPP, the source for CO_2 and polluting gases in India. To inspire clean energy generation, India had invested 283, 532 and 1020miUS$ during 2016-17, and 2017-18 respectively. By installing 7.3 Giga Watt (GW) SPP and allowing wind power generation of 15.1GW in the year 2019 be ranked 3rd position in the globe (L-8). The hydro (HPP), fossil and coal based (TPP) electrical power generation were 1.362GW was total 371.6GW mainly comprising HPP's, TPP's, solar and wind generating plants(L-9) The green/ clean energy and conventional power project installations in India till June 2020,Table 1.

By 31.8.2020, the central, state and private sector share of electricity is 25.2%, 27.8%, and 47% respectively with total generation 372.693GW whereas renewable energy sources; (RES) contributes 23.8%. However the galloping jump from conventional to clean energy power plants has faced a snuggle to progress by apocalyptic pandemic COVID-19 by virus SARS CoV-2 from mid-March-2020.

2.6 Paradigm Shift from Coal/Fossil Fuel to Clean Energy

After 1980; the golden spike of the Anthropocene sub-epoch; India has expanded either urban based industries (utilities and services) or industry based urbans. About 31% of Indians prefer to stay in towns, cities or cosmopolis among concrete or asphalt jungle, though it is basically an agrarian country. For alleviation of economic status, Indians need well reinforced value chain, foster entrepreneurship of the poor class, sustainable indigenous fiscal support, and a genderless community. The robust growth in demography (1.7billion), expansion; electric power is the golden chain that plays a pivotal role which connect the social equity, sustainable environment, stable sun earth geometry (climate) and finally socio-economic growth.

Clean renewable energy generation is the commitment Indian government with a vow to install renewable power generation with a compound annual growth rate (CAGR) of 17.33% during years 2016 to2020 and targeted to reach 15820TWh by end of 2040. According to Paris pledge on climate change 2015, India has aimed to have installed capacity of 175GW of renewable energy dimensions by 2022 (MNERE): The Ministry of New and Renewable Energy) to illuminate the remote rural sector through Remote Village Electrification Programme (RVEP) Carbon Brief analysis, [17], Chandra Bhusan, [18], Siddique A et al, [19].

Table 1. India's total installed capacity of energy generation till June 2020

Source of electricity	Installed capacity	% of total generation	Source of electricity	Installed capacity	% of total generation
	Non-renewable			Renewable	
	Giga watt	%		Giga Watt	%
Coal	198.79	53.50	Wind	37.83	10.18
Hydro	45.69	12.3	Solar	35.12	9.45
Gas	24.99	6.73	Bio power	10.03	2.7
Nuclear	6.7	1.8	Small (<25MW) hydro	5.34	1.43
Peat/lignite	6.61	1.78	Mini (<1MW)hydro		
Fossile fuel	0.5	0.13	Micro (<100KW)hydro		
Total	283.28	76.24%		88.32	23.76%

Source: Central Electricity Authority (CEA).; June; 2020[12] and (L-10)

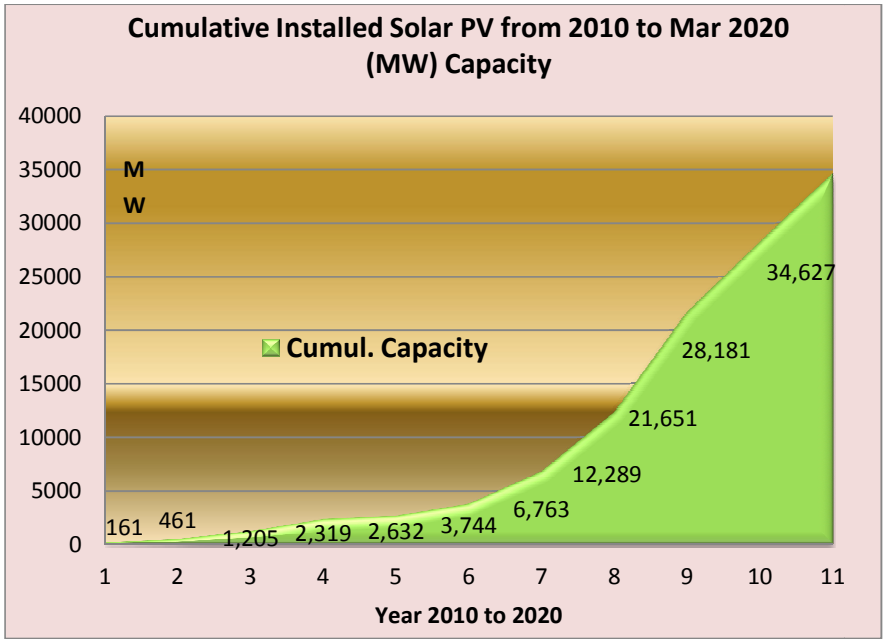

Fig. 4. The cumulative installed solar power in India (2010 to Mar, 2020 (Source: Wiki)

2.7 Federal Strategies/Initiatives India

The Department for Promotion of Industry and Internal Trade (DPIIT), Foreign direct investment (FDI) has reported that influx from the clean and green energy sector for the period Apr- 2014 and Mar- 2020, investment exceeding > 42bUS$ has been done in India's renewable energy sector since 2014 and cheaper that TPP based energy. The investments in solar energy sector are given in table below Table 2.Siddique A., [19, IRENA-[20], MNRE [21].

2.8 States Favourable for Solar Power

The CSP system has segregated 13 varied settings in 5 dissimilar climatic zones in India, Sharma et al [23], Kumar et al, [24]. The average global radiation is ≈ 5 Kwh/m2/day in NE and hilly areas whereas ≈7 KWh/m2/day in West Indian states and desert areas.

The advantage of present solar tree as it is facing the east, west and south but north considering solar irradiation direction from north is not sufficient due to topography and global Positioning of India. Ramchandra et al, [5], Kumar G B A [24], Deepak kumar [25] reported that Global Insolation >5,25 KW/m2/day is most favourable for Gujarat, Rajasthan, Andhra Pradesh (Undivided), Maharashtra, Madhya Pradesh, Karnataka, Himachal Pradesh, and UP in India, are zenith hotspot solar energy exploration areas. The hot spot areas having

potential areas for solar power exploration are given in Table 3.

The solar energy was started from the year 2010 based on climate change issues and started supplementing power from 2012 in India. The Direct insolation is given by:

$DHI = \frac{(G-D)}{sin\varphi}\ where$ where G= Global insolation, D= diffuse component and φ= sun's elevation angle. So also GHI = DHI + DNI* cos(θ). Where θ= the solar zenith angle) (Ramachandra et al [5], Deepak Kumar et al., [25]).

Table 2. Proposed investment in solar energy sector in India through different agencies

#	Name of the SPP (PP: Power Project)	Period	Installed cap. prop. (MW)	Financial outlay INR/ US$	Agency
1	Vikram Solar (WB)	4/2020	300MW	175biINR/250mi $	NTPC(CPSU–II)
2	Kamuthi Solar PP (TN),	1/2020	648 MWp	45.5bINR/6 bUS$	SECI; Adani Green energy
3	Adani Green Energy	6/2020	(6GW+2GW)	452bINR/6bUS$	SECI
4	Green energy company	2011(fixed), 2019,(plan)	4300Mw/planned 8GW	370mi$ /800 mUS$	Brookfield/ ReNew Power
5	Kurnool Ultra Mega Solar Park	Mar/2017	1.0 (GW)/ 24 Km^2	□7,000 crore (US$980 million)	APS PCL/
6	ReNew Power; (Solar floating)	4/2020	150 MW floating	7500mINR/ 0.11 b US$	Shapoorji Pallonji,
7	Bhadla Solar Park(Rajasthan)	20 Mar. 2020	2255 MW/57Km^2	98.5bnINR/$1.4bn US$	Bhadla, Phalodi tehsil, Jodhpur
8	Ever source Capital	Feb/2020	1.5 GW	1 biUS$	Ever stone and Light source
9	Green Cell Mobility Private Limited	Sept/2020	Buses/ one bus to run 600 km/day	700 miUS$	Rajasthan State Road Transport Corp. (RSRTC)
10	Indraprasta, SPP, ND (SECI)	July/2019	5MW &385 electric buses	under design	Converting the present TPP

Source: (L-11), (L-12), and CEA 2020 [22]

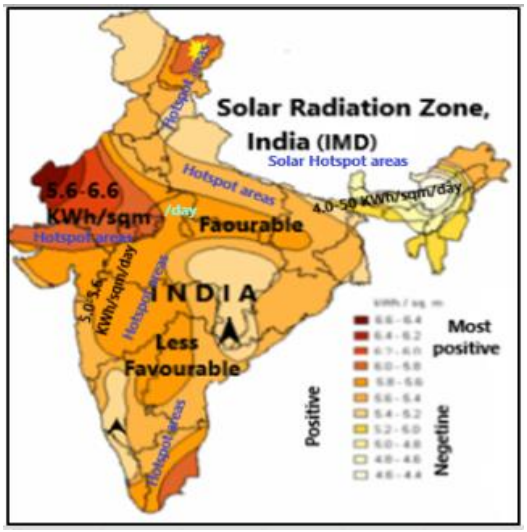

Fig. 5. Solar radiation zones in India
(source: TERI (IMD data),/ Ramachandra et al., 2011[5])

Table 3. The hotspot areas of different states in India are potential for solar Power exploration

Rank	State	Solar insolation range (GHI) KWh/m^2/day	Potential SPP Area (Th Ha)	Barren/Fallow Patches	Solar potential state(GW/MW) (est)	Harnessed by2018
1	Gujarat	>5.25	2595	14	31382 MW	5.12%
2	Rajasthan	>5.25	2295	07	21833MW	14.11%
3	AP/Telangana	5.14 to 6.03	2056	07	23726 MW	12 / 22%
4	Maharashtra	>5.25	1718	6	43779 MW	3%
5	Madhya Pradesh	4.5 to 5.25	1351	4	21873MW	7%
6	Karnataka	5.08 to 6.02	788	4	5328MW	19.58%
7	Himachal Pradesh	>5.25	656	14	53 GW(IREDA)	
8	Uttar Pradesh	>5.25	507	02	25061 MW	3.49%
9	Tamil Nadu	4.82 to 6.05	492	04	30447 MW	6.74%
10	Bihar	4.79 to 5.42	432	05	95.91 MW	

Sources: (L-13), (L-14), (L-15),and L-16),

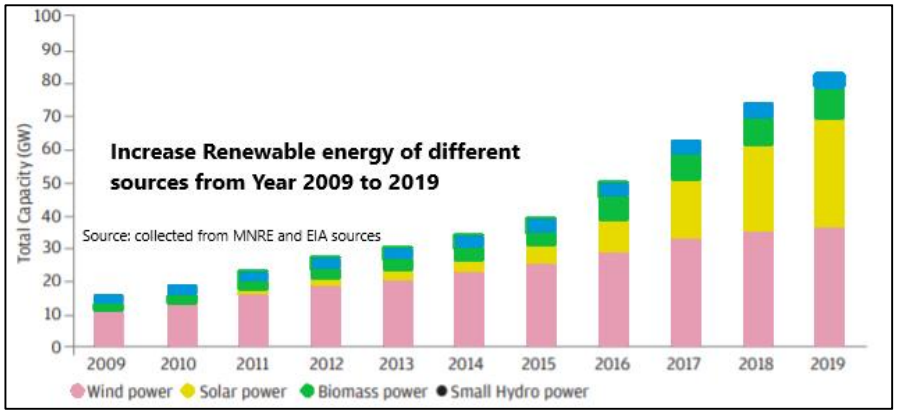

Fig. 6. Cumulative rise in Renewable energy from 2009-19
(Source: Compiled MNRE & EIA)

3. METHODS AND METHODOLOGIES

Harvest of solar energy is primarily capture and preserving solar insolation in form of light or heat energy and later converting to electrical energy for utilities. The solar dynamism for sustainability has in general six methods. The methodologies are by applying (I) PV solar panels (ii) Thermal Energy collectors (Electromagnetic radiation collection) (iii) Solar water heaters (Concentrating solar power) (iv) Molten salt solar power (v) Conventional solar cells (Vacuum tubes or semiconductors) (vi) Nano structured solar cells (using dye-sensitized TiO_2 films) and (VII) Biofuels (Natural Photosynthesis). The modern methodologies in arrangement of solar panels are mimicking butterfly, β – Ray (Spherical) sun-power generator (For use in dark designed by Andre Broessel), Psomopoulos C.S., [26].

3.1 Enhancing Carbon Tax and Reducing Solar Tariff

India has dropped its solar tariffs up to `2.36 INR ($0.0316)/KWh in Karnataka, and rising carbon tax from Rs200/MT to Rs 400/MT of CO_2 e indicate that the unit cost of solar has been scaled down by 20% to 30% less than thermal/Hydro power, reaching one among the lowermost tariff country in the globe during July 2020 Carbon Copy, Mericom India [27].

3.2 Utilities of Various Electrical Powers

The Industrial, urban and domestic use of the solar energy are Saini et al., [28]); The solar trees caters the need of the industrial, commercial, domestic and the agricultural community by providing electricity power for street lighting, water heaters, electric/electronic appliances used in domestic utilities and hotels, restaurants and enormous uses. The rise in cost of fossil fuel, the new extended application solar energies added are e-Rickshaw, e-buses, high-capacity water pumps, cooking ovens, e-tractors, power tillers in agricultural fields, fishing boats/ small ships and e-power tillers. The versatile uses tempted the group of workers to think of other application. The utilities are given in Fig 7.

3.3 Future Prospect of Solar Plants; India

Considering the pandemic; the sojourn of activities in India, the target of 275GW generation was capped by 69 MW forced to reconsider to 220GW renewable energy generation in India by 2022. It is proposed by constructing the Largest the gizmo solar PP Tree under clean technology, India acclaimed after Tata Power signs MOU with Tata Motors, Adani green at Pokhran (1500MW) and the Central Mechanical Engineering Research Institute (CMERI's) solar tree at Durgapur and 35000MW power surplus in Maharashtra, Sahara solar power plant Titlagarh, Odisha, (L-17). To rise solar power generation, Kotak Mahindra, NTPC, NISE (National Institute of Solar Energy, Gurgaon) and CSIR's CMERI (Central Mechanical Eng. Research Inst., Calcutta) pitches financial funding/ bolstering solar energy projects. To reduce fossil fuel consumption Uber has promised convert all its Taxies to be propelled by electric vehicles by2040 by investment of $800 million as players of solar energy. The Kamuthi solar power plant, Tamil Nadu can be one of the largest SPP India having capacity of 648 MW over an area 10Km^2, The Kurnool Ultra Mega Solar Park, AP, India is generating 1000MW installed over 23Km^2 and saving 700Th MT of CO2 emission. Similarly Shakti Sthala, Pavagada, Karnataka shall install 2000MW capacity, the largest solar park of India, https://www.originenergy.com.au/blog/5-largest-solar-farms-in-the-world/.

3.4 Solar Farming

These solar trees designed by CMERI can generated at 11.5KW peak and can generate clean and green power of 12-14Kunits for adoptable to grid connections of domestic and agriculture sectors. The modern electric vehicle charging stations (EVCS) or battery boosted EVCS can be installed (off grid/ on grid) with the solar tree power and space savers. India with solar PV technology at 118 GW transpires as the utmost prevalent power generating technology for land use at optimum potential (Millstein et al., NREL, [29]). The solar tree concept has the advantages like minimum coverage of ground area, least shade area, optimized material consumption with maximum energy generation, minimum upkeep, a best suit for off grid system at inaccessible areas.

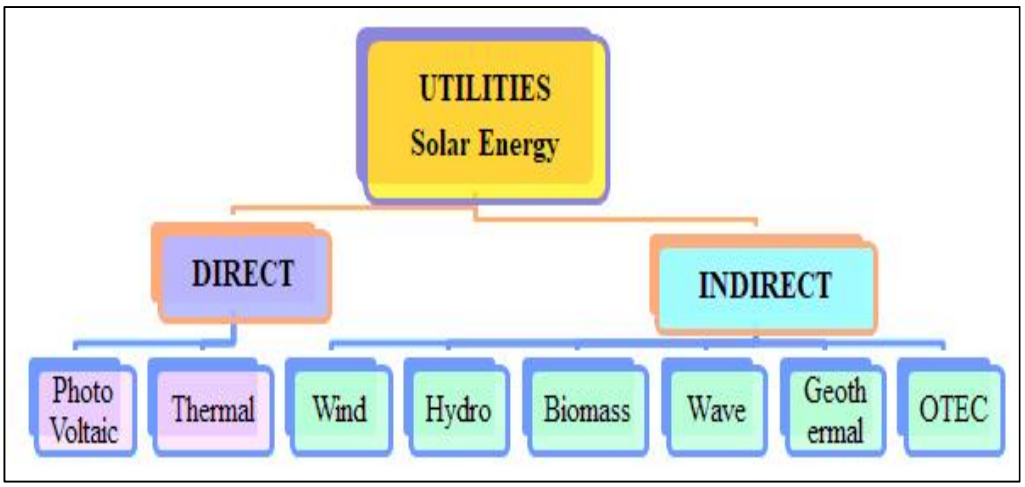

Fig. 7. The Clean green energy utilities in settlements, Industrial and domestic sectors

3.5 Solar Farming Nexus

Solar establishments shall change the land use and land cover of the areas because of depletion of solar irradiation below the PV panels, SAT under shaded areas. It is observed cool during day and warm during night. The solar arrays hold more moisture than the open-sky planting crops. Instead researches reveal that the production of chiltepin pepper, jalapeño and cherry tomato produce better harvest altered heat scenario and higher agro-voltaic condition. Simultaneous solar farming with selected agriculture can produce better yield under reduced water loss and PV array efficiency improvements (Nature sustainability).

3.6 Methods and Methodology

The first solar Tree project was initiated at CSIR-CMERI Durgapur for domestic use with cost of each unit □750,000 (~$9,595) with 35 solar photovoltaic (PV) modules in each tree with each unit of capacity 330 W (L-18) Present study is a prototype one which is individual unit generating 10 Watt.

3.7 Solar Tree Specification

Size of the Base Structure- 1524 mm x 600mm
Height of the GI Pole- 4572 mm (diameter=10cm)
Length (End to End panel connection) - 2134 mm
Size of the Leaf Structure- 350 mm x285 mm x24 mm

The designed tree shall generate 18 X10W /day = 180watt/ sun shine day

The circuit was formulated & simulated by modelling by using the Mat lab Simulink model for an open circuit (*ckt.)* at constant voltage, short circuit was done Fig. 9(a), & (b) & (C).

3.8 Solar Low Cost Automatic Street Light (Design)

Design of the Battery: It is proposed to design a single leaf street light, on road side lightening with proposed load 9 W for 10 hours/day.

The external power battery is to be used from a local available standard design of 12 V systems to store by charging. The current in ampere required for the battery for generation is 10 hr. /day will be 10hr X 9 W=90Wh load, and the ampere need for the battery = 90 Wh /12 V = 7.5A. So the consideration of 12 V, 7.5Ah/10 Ah Solar Lead Acid C10 battery is required for the system. To avoid shading the panel leafs are to fixed facing sun and directed east, west and southerly.

Design of the Solar Charge Controller -The charge controller should be capable of 2-5 A (I_{sc} = 1.29 A of the Solar Panel). The required solar charge control shall be- 12 V, 2Ah/4Ah

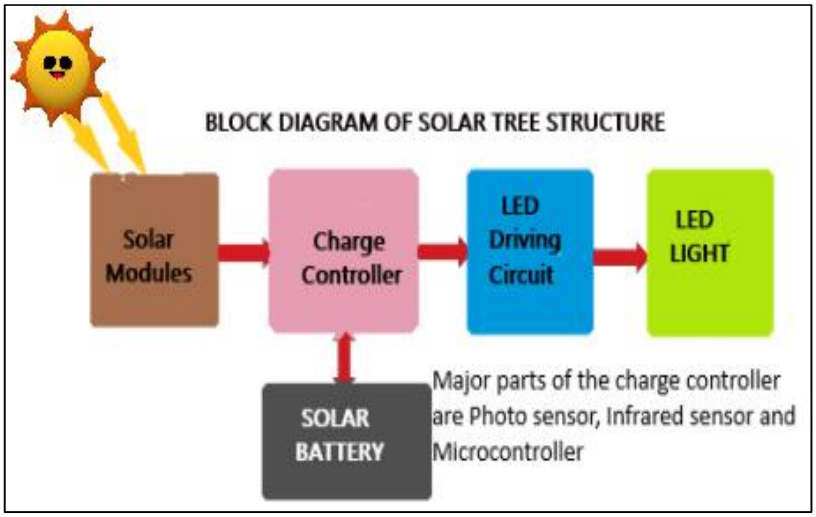

Fig. 8. The block diagram of solar tree power generation in the laboratory

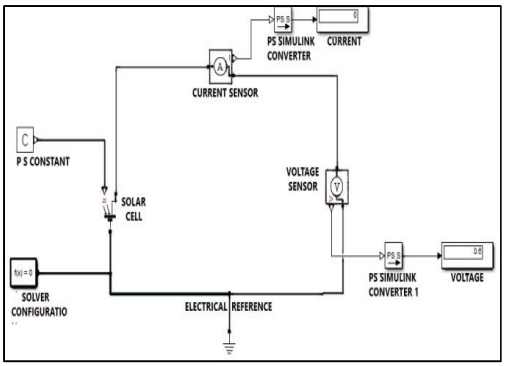

Fig. 9(a). Open Circuit Voltage (V_{oc}=0.6 V) of Solar cell using MATLAB Simulink model

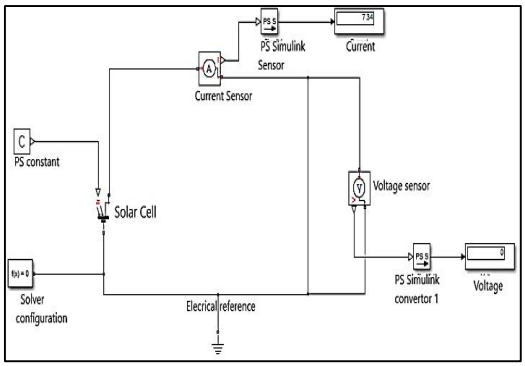

Fig. 9(b). Short Circuit Current (Isc=0.7A) of a Solar cell using MATLAB Simulink model

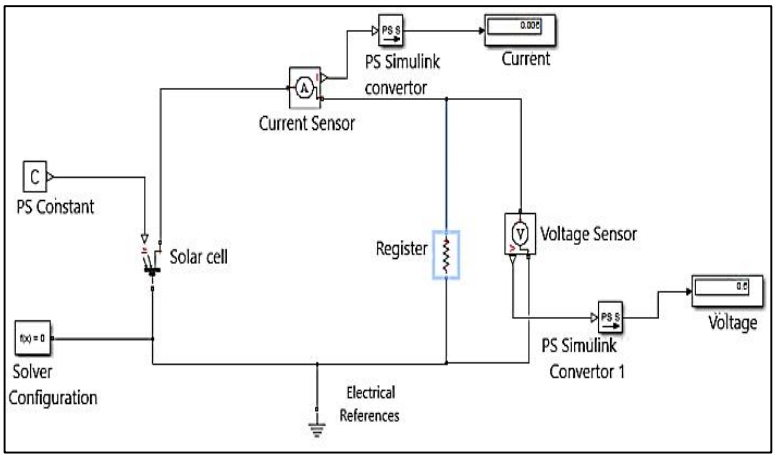

Fig. 9(c). Simulation of Solar PV Cell using MATLAB Simulink model

Panel Size: To charge a 12 V battery at least 15 V voltage is required where the panel voltage = 17V (Vmp), Voc = 21.50 V and Isc = 1.29 A Average Sun hour = 7-8 hour/day. The 20W panel output current will be 1.29 X 7 hours= 9.03 Ah/day. So the batteries can easily charge/day.

Panel watt=17x1.25 = 20 W required. The specifications are: Solar Poly-Crystalline Si Panel: 20 Wp, for 12 V System Auto-Charge controller (Light sensor): 12 V, 2-4 A. The street light will be of rating 9 W/12V and the battery 12 V 7.5 Ah/10 Ah as per requirement.

As per design the components will be provided.

Electrical components –Different electrical and structural components used are: Cable Size: 1.5 mm, MIS Pole: Length- 3.0m, Dia- 0.75 mm.

If the street light will be illuminated by 9W bulb than it will emit light up to 10 hours or if street light is 10 W than it will emit light up to 9hrs. Since the demand of the solar energy generated is to be stored, the produce shall solve our purpose.

4. RESULTS AND ANALYSIS

Before going for the design of the solar tree the solar panels were taken out door and tests results were taken for the output voltage and output current of the set up with or without connecting to the battery and the results are given in Table 4.

From the above results it can be inferred that the peak voltage and current generation in both the conditions are obtained when the sun is overhead and the direct solar irradiation is the highest. The V/I characteristic curve for the above data is given in Fig. 10.

Table 4. Observations of Voltage (V) vs. Current (I) in the solar street lighting system

Time	Solar Panel is not Connected to the Battery)		Solar Panel Connected to the Battery		Remark
	V_{oc} (Volt in V)	I_{sc} (Ampere in A)	V_{oc}' (Volt in V)	I_{sc}' (Ampere in A)	
0600 AM	0	3.56	11.90	7.08	Sun rises
0800 AM	1.56	3.55	12.00	7.06	Sun on head
1100AM	4.2	3.58	12.10	7.10	Sun on head
0100 PM	14.02	3.44	12.20	7.22	Sun on head
0500 PM	20.01	0.069	11.80	7.17	Sun on head
0330PM	1.01	0.0	12.00	6.89	Full Shadow
0800PM	0.00	0.0	12.00	6.56	Night time
0500AM	0.00	0.0	11.00	6.42	Dawn

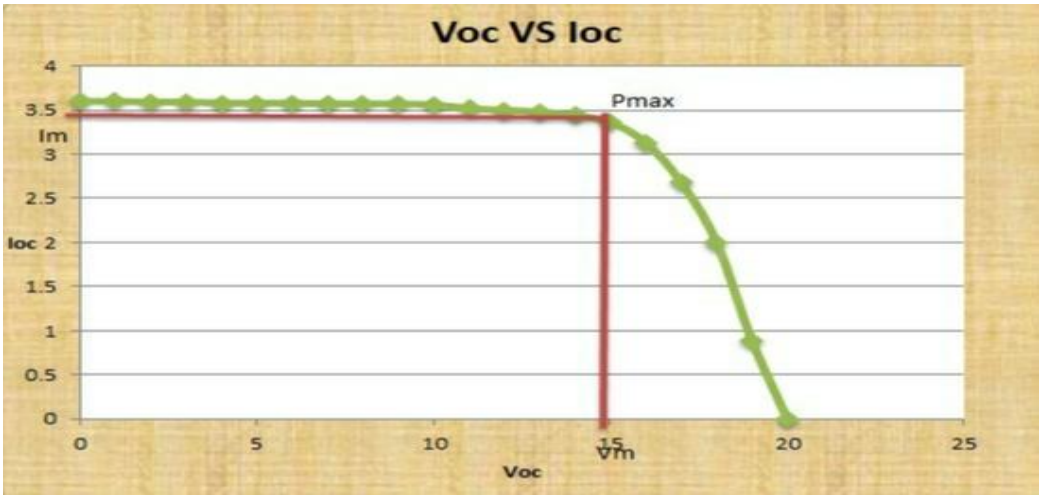

Fig. 10. Figure VI Characteristics of 20 Watts Luminous Solar Panel designed

4.1 The Solar Tree Project

The solar tree projects have the optimal economic use if the power plant design considers (I) the maximum use of natural, material and technical resources (ii) the strict project implementation and maintenance, (iii) future expansion on demand (iv) commercial and financial aspect (as Initial investment is too high) and finally (vi) disposal of wastes without having a noxious biome during disposal of PV modules. The above facts argues for a clean and green technology over an unused/fallow land with instant use of the product but most economically. The cost evaluation for these solar trees should be affordable for the domestic and commercial uses.

4.2 Commercial/ Financial Feature a Single Tree

Commercially a solar tree project shall undergo the following steps like Site identification, prefeasibility study like (solar insolation and record of rights), Feasibility and EIA studies and administrative approval, Financing sources, detailed design, Contract procedures, Land acquisition/ hiring, Construction, commissioning and maintenance. The project has the lions share till construction and can be used like landed property till the project in operation.

The Solar tree as per design were erected within the university lab and tested for its efficacy and verifying the results, Fig 11(a), Fig 11(b), Fig 11(c), and Fig 11(d). As the results got satisfied

the design criteria the branching is done by joining each unit PV module Fig 11(a).

4.3 Costing and Estimation

Since no standard rate is available for components of solar tree in India, the present estimate is prepared as per current available price. The prices of Luminous Solar panels in 2020; depend upon its capacity and variation in technology. According Loom Solar companies the price of luminous solar panels available are @ 20,40 , 75, 100, 160, 270, 335watts… up to 500W and with average cost ranging from Rs2650/- to Rs 14500/ and watt wise from INR 35/W - INR 65/W on commercial basis excluding civil and mechanical set-up without civil and mechanical setup (L-19). The present cost involved in the workshop it comes to around Rs11340/-/per tree for the 18 solar luminous panels.

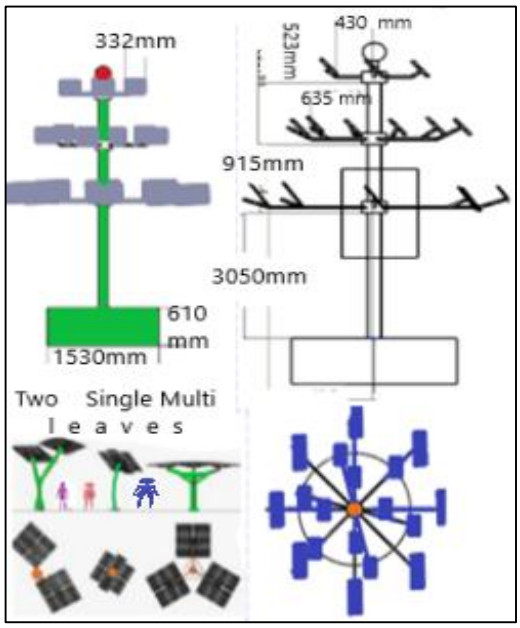

Fig. 11(a). The SPP to be designed

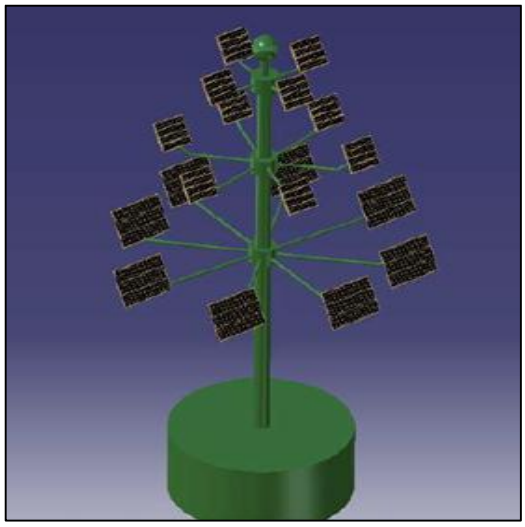

Fig. 11(b). The components of the solar tree

Fig.11(C). The testing of the solar tree

Fig. 11(d). The solar PV modules in operation in lab

The fabrication and construction of solar where solar modules are welded a pillar, and fetches the appearance of one tree trunk. The architecture of the trees in a cluster appears like a solar park and can be a part to town planning development. The mechanical fabrication and the civil construction for fitting and fixing a solar tree has been calculated in Table 5 and was found to be Rs 7000/-/ tree in present set up and when it will be manufactured in commercial scale the cost. India mart claims Rs150000/-/per KWh (2020 rate) and at that rate the cost of 180watt tree shall be Rs27000/-/tree. In the present workshop set up the cost of 360 W solar tree costs around Rs 22000/- per 180watt tree. So by introducing solar tree one can save about Rs 5000/- per tree and shall be less 18.51%, (L-20).

4.4 Novel Thoughts of Commercial Use

Modern use of solar trees can be thought of selling commercially on national basis like e-battery fuel pumps on roadside so that e – rickshaws, e-tractors, e-juice makers, rice fryers, tea stalls, and e-busses like fuel pumps are seen in market. In the towns the solar tree clusters to be erected for street light supply signaling and along with other domestic uses. Modern conventional use of energy using fossil fuel, coal based TPP, HPP must be shifted by use of safe, economical solar power for CO_2 air contamination Shukla P R., et al, [30].

Table 5. The cost estimate for a 18pannelx10watt solar tree unit in the present laboratory

Mechanical Structure (A)					
Sl. No.	**Particulars**	**UoM**	**Qty.**	**Unit Price (Rs)**	**Total Price (Rs)**
1	GI Round Pipe Dia 4" (Pole)	kgs	40	45	1800
2	Round Pipe Dia 1" (branch)	kgs	30	45	1350
3	GI Round Pipe Dia 6" (bearing)	kgs	2	45	90
4	CR Sheet 22 SWG	kgs	24	35	840
5	Nut & Bolt (dia 6mm x 1 1/2")	kgs	10	45	450
6	Round rod 6mm	kgs	15	34	510
7	MS flat 25 x5	kgs	18	34	612
8	Nut & Bolt (dia 12mm x 6")	kgs	2	45	90
9	Fabrication and Coloring charges	LS			1000
	Grand Total				Rs. 6742
Sl.No.	Material	Qty	Rate/Unit	GST	Amount (Rs.)
Solar PV System (B)					
1	LUMINOUS 10 Wp Solar Panel	18	600/PC	5%	11340
2	EXIDE 12V 6LMS75 AH Solar Battery	1	5,724.00	28%	7326
3	LUMINUS 10 A CCR	1	500	5%	525
4	5 or 6 W LED Light	5	70/PC	10%	385
5	LED Flexible Streep	LS			800
6	1 mm Cable				500
Total (A)+ (B) TOTAL Rs. 20876.00					
Civil Structure (C)					
1	Base foundation in Concrete	LS			600
	Labor Charge	LS			500
		Grand Total (A B + C)			**= Rs. 21976.00**
			Say		**=Rs 22000.00/solar tree**

NB: The costs excludes tax credits (if any) other financial incentives

4.5 Maintenance of Solar Trees

Solar trees are of metal structure fixed on different branches exposing sun with solar panels like twigs of a tree. The solar panel may fail and the metal structures may rust by weathering. The battery cells and the LED used may also deteriorate and become unusable. These trees for a regular servicing and maintenance should be cleaned with fixed water sprayer at the top of the structure and self-cleaned, either by rain or by mechanical pumps, cleaned and painted annually or regularly (in case of saline weather) which increases the productivity of panels and longevity of the structure. Additional battery back-up must be provided that works for 2-4 hours on full load to function when the sky is cloudy and no sunlight.

5. DISCUSSION

The high target and less allocation of funds, the solar market in India has become wobbly. The pandemic COVID-19 has compelled India to downsize its goal of 175GW by 2022. The solar power was capped by 69GW by Mar-2020 against 100 GWs goal, L-21. Cumulative solar power installed by up to June-2020 was 37.83 GW (10.18%) and the growth is slow during 2020.The snag of lesser margins in growth was due to COVID-19 and higher solar tariffs which has affected the common man in installing Solar tree/ PV units. So the manufacturers and the suppliers are forced to work at times with wafer-thin margins for a lower cost, good margin to meet the Government target and for their livelihood.

Rooftop/ground solar has exhibited compound annual growth rate of 117% between 2013. But only 3% hit of its goal was achieved by 2017. Policy lacunas are the initiatives, loss in solar industry and tariffs imposed. The federal India is making cry for prioritizing the renewable sector for a blue sky and problems associated with large HPP and TPP's. It has additional advantages of the perineal source decorating the upper class people's gardens, orchids but depriving the public. The challenge behind are the financial strategies, adoptive choices, Govt.

taxes and Pandemic COVID-19 for the new arena.

Small vertically integrated solar trees are solution to the problem under land constraint in India. The decentralized and sporadic grid is reliable for its appropriateness in geographic, topo-graphic and hilly lands and extreme climates due to clustered but segregated generation units without abating the green and clean environment. The height of the tree can receive 10-15% extra sunlight and removes shade problem in agricultural fields, gardens, orchids *etc*. and one acre can accommodate 500 solar trees generating about 15KW/ day.

Agriculturists in India should adopt solar energy by substituting old gadgets by solar appliances to have economic and user friendly solar trees which provides optimal use of land and facilities using free sunlight and less maintained solar panels Benedek J. [31], and Barron Gafford, [32].

The electric vehicles(EV's) have been multifold due to 11times increased in subsidies over 2017 as support vehicle and Renewable energy subsidies are down by 35%, there shall be wide scope of commercial energy generating solar fuel shed are expected on roadside.

6. CONCLUSION

Solar trees provide the most efficient tool for generating energy but also optimally utilize the land and the facilities at low cost in India. The solar trees are constructed for saving energy, easy installation, positioning everywhere, clean and green power, reliable power production and above all ecofriendly. The present Solar system is used to generate power in situ and transmitted through grids. The paradigm shift from conventional to renewable source is done by computerized modelling and simulating and store. The stored solar power can later be used by electric vehicles in a commercial basis instead of fuel pumps sailing petrol, diesel and gasoline. The problem of electric grid system in India can be resolved by this solar tree sporadic grid system.

To hit its 2022 target of 175 GW, 106 GW will have to be added in four years could not be met as 2020 was an year of doldrums whereas more than twice the capacity added in the last four. The solar tree can be best utilized for charged battery distribution system for electric bikes, e-rickshaw and e-tractors.

The present mono 10 twig leaf system solar tree can produce 360W at a cost of Rs37200/- INR per unit. When compared to the present standard market rate the solar tree shall provide cost benefit at @25.6% so can be affordable to the common people of India. Establishment of solar trees near NH shall provide batteries as commercial basis like fuel pumps and gas cylinders.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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