ISSN No:-2456-2165

"Solar Energy: - Safe, Reliable, Eco-Friendly and Sustainable Growing Clean Energy Option for Future India: - A Review"

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Abstract:- This paper provides an overview on various aspects of solar energy including basic energy resources, global primary energy sources, world future trends in energy sector, history of power sector and energy production, global energy issues, world energy consumption, shrinking status of sources of fossil fuels, core drivers for development and deployment of new and renewable energy in India, Indian total power capacity mix, Indian renewable energy scenario, current electrical energy production status of India, Indian government initiatives for development of sustainable power growth using renewable energy, targets for growth of renewable energy in India, solar installed capacity, current electrical energy production by solar energy, off grid and captive power capacities, grid interactive renewable power status, energy conservation measures, types of solar radiations, renewable energy policies, energy planning and restructuring, solar energy scenario in India, solar map of India, advantages and disadvantages for application of solar energy, technical and economical barriers and challenges for development and utilization of solar energy technology ,components of solar radiation, solar energy description and types of solar energy extracting equipments, solar energy future contribution for sustainable development of India, seed and growth phase of solar energy, advantages of India for extraction of solar energy over other countries, solar energy devices, description of solar panel modules, various factors of solar energy i.e. capacity factor, load factor ,thermal efficiency, operational and economic efficiency etc., resources and opportunities for solar electricity generation, global horizontal irradiation, direct normal irradiance and diffuse horizontal irradiance in India, solar insolation, solar photovoltaic growth forecasts, solar thermal power, issues in solar-panel manufacturing, solar heating, grid stabilisation, hybrid solar plants, Indian government initiatives for development of solar energy, government support for rural electrification, research and development activities for renewable and solar energy development, major Government organisations supporting solar energy research and development activities, national solar mission, solar energy advantages over fossil fuels and other renewable energy sources for commercial and domestic usage, information and public awareness, expectations of Indian solar industries from Indian government, various organisations to support solar energy generation in India, domestic and off grid application of solar energy, major challenges and remedial measures taken for commercial application of solar energy, solar innovative ideas and projects, economic benefits of using solar energy, various articles and references predicting solar energy as a future of India etc.

Keywords:- *Solar Energy Scenario, Energy Scenario, Energy Issues, Conventional and Non-Conventional Sources, Solar Power, Renewable Energy, Indian Government Policies, Energy Security, Advantages and Disadvantages of Solar Energy, Energy Access, Solar Radiation, Solar Power Projects, Future Scope, Solar Energy Production and Demand etc.*

I. CORE DRIVERS FOR DEVELOPMENT OF RENEWABLE ENERGY INCLUDING SOLAR ENERGY IN INDIA

Core drivers for development and deployment of new and renewable energy including solar energy in India are found as mentioned ahead i.e. conventional energy sources are depleting i.e. oil by 2025, coal for maximum 200 years, imports of oil bills increasing due to increasing energy sector, scarcity of fresh water supply causing health problems and reduction in agricultural production per capita etc. therefore needed reduction in dependency on oil, coal, nuclear fuels and imports, there is requirement of 'energy security' to avoid dependency on other countries for oil imports and high grade coal requirements, electricity shortages between supply and requirement (despite increase in installed capacity by more than 113 times), shortage of 'peak electricity demand' as well as energy requirement (causing planned and un-planned measures taken by Indian government to bridge this demand-supply gap), 'energy access' to ensure availability of reliable and modern forms of energy for all citizens (including rural households), voluntary commitment by Indian government of reducing emission intensity of its GDP by 33-35 per cent from 2005 levels up to 2030 as per 'intended Nationally determined contribution'(INDC) for 'United Nations framework convention on climate change'(UNFCCC) and to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources with the help of transfer of technology and low cost international finance from Green Climate Fund (GCF), India's population growth (more than 1028 million) , scarcity of availability of fossil fuel energy, energy shortages due to increase in energy prices, electrification

ISSN No:-2456-2165

with renewable energy is much more efficient leads to a significant reduction in primary energy requirements (as most renewable fuel do not have a steam cycle with high losses while fossil power plants usually have losses of 40 to 65%), relatively low end of technology, abundant fallow land, few skilled engineers and persons required to run a solar power plant and, short period required to install them provide a huge levelling of playing field etc.

Solar energy in India has average 300 sunny days for solar energy extraction due to tropical country with potential for 30 MW /Sq Mt. (almost 5000 trillion KWh due to 3000 hours of sunshine) with ranking 6th in global solar energy production and massive potential of at least 20 GW to be installed by 2022 causing creation of new employment opportunities i.e. almost 10 million man days employment per annum approx. therefore there is vast scope for solar energy to extract as a future energy option for India.

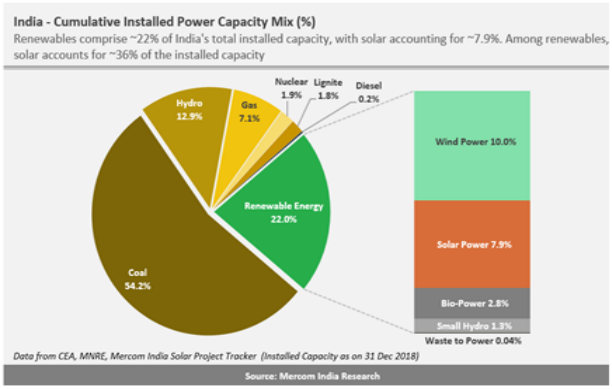
II. GLOBAL ENERGY SOURCES, ENERGY ISSUES AND FUTURE TRENDS

Use of energy sources for growth of power sector and energy production had started with industrial revolution in 1700 A.D. with use of coal, then in 1870 A.D. with use of IC engine and then use of oil and natural gases. Second World War initiated use of nuclear energy for fuel. basic energy resources can be categorised as primary energy resources that can be stored i.e. oil, fuel, natural gas, biomass, wood, geothermal, nuclear etc. while secondary energy resources that can be converted from primary sources i.e. electricity, steam etc. which can be commercially marketable while some can be categorized as non commercial energy sources i.e. cattle dung, agricultural waste, firewood etc. There are renewable energy sources that are inexhaustible like wind, solar, geothermal, tidal, hydro etc. as compared to exhaustible non renewable sources i.e. fossil-coal, gas, nuclear etc.

Global primary energy sources availability has been considered as follows i.e. coal which approx. 9, 84,453 million tonnes (leaded by US-25%, Russia-16%, China-12%, India - 9% etc.), Petroleum oil approx. 1147 billion barrels (leaded by Saudi Arabia -23% with one barrel equal to 160 litres), natural gas approx.176 billion cubic metre (leaded by Russia -27%) will last for 65 years, Shale i.e. sedimentary rock, kerogen-petroleum liquid (leaded by Canada, Kazakisthan, Russia etc.), Tar sand (i.e. clay, sand, water, bitumen etc.), heavy hydrocarbon etc. which can be used for power generation and energy use.

World future trends in energy sector due to fossil fuel is found that developing countries energy use will grow (almost more than 2.7 million/year) while coal will remain predominant energy source with carbon dioxide emission (almost more than 2%/year) will grow continuously due to fossil fuels, natural gas will be fastest growing primary energy source(almost more than 2.2%/year) and oil will dominate the sector (almost more than 39% of total energy use) therefore there will be continued reliance on fossil fuels through year 2025. Global energy issues are counted as acid rain due to acid preparation, global warming due to heat trap by green house effect, soiling and corrosion of metal parts due to suspended particles matter, health issues, diseases, pollution in industries, faster energy consumption than source etc. mainly caused due to hazardous CO, CO_2, HC, NOx, SOx gases etc. Therefore world need to think about renewable energy as Renewable energy is the fastest growing source of new electricity generation, increasing by 3.0 percent and outpacing the average annual increases for natural gas (almost more than 2.6 percent), nuclear power (almost more than 2.4 percent), and coal (almost more than 1.9 percent) etc. World energy consumption will grow by 53 percent to year 2035 and half of that growth will come from Asian countries like China and India. These countries's renewable energy capacity may be doubled by 2022. By 2040, renewable energy capacity of these countries is projected to equal coal and natural gas electricity generation with increase in heat rate, thermal efficiency, capacity factor, load factor, economic efficiency and operational efficiency of renewable energy including solar energy usage etc. therefore China and India will lead energy growth by 31 percent (50 percent of the world's energy will come from solar and wind by 2050 as projected).

III. INDIAN ENERGY SCENARIO



Primary energy consumption (Units in Million tonne of oil equivalent)

Primary Energy	Consumption 2016 (Mtoe)	Consumption 2040 (Mtoe)	Energy Share 2016	Energy Share 2040	Overall Growth
Oil	212	485	29%	25%	129%
Gas	45	128	6%	7%	185%
Coal	412	955	57%	50%	132%
Nuclear	9	44	1%	2%	389%
Hydro	29	52	4%	3%	80%
Renewable	17	256	2%	13%	1406%
Total	724	1921			165%

Source: BP Energy Outlook 2018

Fig 1:-Indian cumulative power capacity mix, CEA, MNRE, Mercom India Solar Project Tracker Table:-Primary energy consumption (units in million tonnes of oil equivalent), BP Energy Outlook 2018

ISSN No:-2456-2165

India has 17% of world energy production with 1.5% population growth rate. India is 4 th largest economy in the world by GDP growth (of 7 to 8 %) and 11 th largest energy producer in world (almost more than 2.4% of world energy production), it ranks 6 th in energy consumption (almost more than 3.5% of world consumption) out of which agricultural sector accounts 10% of electrical energy consumption (with 5% of revenue generation) and industrial sector utilised 50% of energy (with 80% of revenue generation). India is facing problems of highest transmission and distribution losses (almost 40 to 50% of total electrical power generation). Thermal power (which includes coal, lignite, gas and diesel) accounted as a predominant source of power in the country with its cumulative installations up to 63.2 percent (i.e. more than 223 GW) and there is requirement of additional power for coping up with peak demand of energy.

IV. INDIAN GOVERNMENT MEASURES FOR ENERGY SUPPLY AND DEMAND MANAGEMENT

Measures and strategies has been taken by Indian government for energy planning and restructuring energy sector for coping up with growing energy demand by restructuring and intensification of various sectors like increase in thermal power generation capacity, increase in hydropower development, increase in energy production, augmentation of national grid for inter regional energy transfer capacity, energy conservation coupled with energy production to optimise energy consumption, accelerated exploitation of domestic energy resources, optimisation of tariff structure of various energy sources, reduction in transmission and distribution losses and effective energy conservation methods, reduction in demand by increasing efficiency, introduction of fuel efficient vehicles like CNG vehicles, change in mode of transport from private to public transport, optimum fuel mix, privatisation of oil and energy sector, easy registration process to attract foreign investment(FDI), amendment in Indian electricity act to increase renewable energy percentage , direct benefit transfer of subsidy to manufacturer , power supply obligation(PSO), smart meters provision for net metering, Ujwal DISCOMS assurance Yojana (UDAY) for state-owned power distribution companies (DISCOMS) to reduce aggregate technical & commercial (AT&C) losses , preparation of national policy on biofuels mix for promotion of use of biofuels in vehicles with traditional fossil fuels , 100 billion units of renewable electricity generation, restriction on use of large battery energy storage system , cultivation of energy crops on marginal and degraded land etc.

V. INDIAN RENEWABLE ENERGY SCENARIO

Indian renewable energy scenario is currently new ray of energy hope for India as wind power is found as 4 th globally in total wind power installation, solar energy is 6 th globally in solar power installation while India is 5 th globally in renewable energy installation. India has about 900 GW from commercially exploitable source (viz. wind energy more than 102 GW, small hydro power more than 20 GW, bio-energy more than 25 GW and solar power more than 750 GW etc.). Future renewable energy scenario is expected that upto year 2022 Indian electrical power will achieve milestone targets including achieving 227 GW (earlier 175 GW) of energy from renewable sources (nearly 113 GW through solar power, 66 GW from wind power, 10 GW from biomass power, 5GW from small hydro and 31GW from floating solar , offshore wind power etc.) .

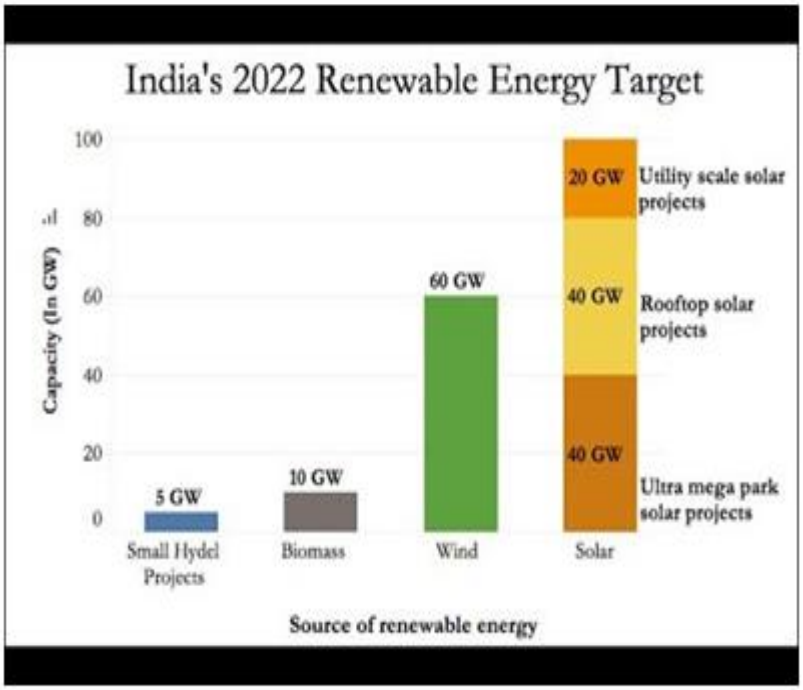


Fig 2:- India's 2022 Renewable energy target, MNRE

India's total power capacity mix was at around 353 GW at the end of December 2018 of which renewable energy accounts for 22 percent (i.e. more than 77.5 GW), out of which solar energy accounted for 7.91 percent (i.e. more than 27.9 GW), wind energy for 1 accounted for 10 percent (i.e. more than 35.1 GW), hydro power's cumulative installations accounted for 12.9 percent (i.e. more than 45.4 GW), small hydro power cumulative installed capacity accounted .28 percent (i.e. more than 4.5 GW), nuclear power accounted for declination to 1.92 percent.

Sector	Target	Achievement(April-Dec 2018)	(as on 31.12.2018)
I. GRID-INTERACTIVE POWER (CAPACITIES IN MWp)			
Wind Power	4000.00	993.15	35138.15
Solar Power - Ground Mounted	10000.00	3270.09	23858.13
Solar Power - Roof Top	1000.00	290.49	1354.12
Small Hydro Power	250.00	31.65	4517.45
Biomass (Bagasse) Cogeneration)	250.00	374.70	9075.50
Captive Power/ Biomass Cogeneration non bagasse	100.00	49.93	704.74
Waste to Power	2.00	0.00	138.30
Total	15602.00	5002.21	74786.3
II. OFF-GRID/CAPTIVE POWER (CAPACITIES IN MW_E)			
Waste to Energy	18.00	4.79	176.94
Biomass Gasifiers	1.00	0.00	163.37
SPV Systems	200.00	132.66	804.06

Table 1:- Installed capacity of grid Interactive Renewable power as on 31.12.2018 (MNRE)

VI. SOLAR ENERGY OVERVIEW

Solar energy created by fusion of hydrogen nuclei into helium nuclei. Solar energy reaches from the Sun to Earth (distance of about one fifty million kilometres) in the form of radiant energy in about eight-and-a-half minutes at a speed of about three lakh km per second. There are 2 types of solar energy i.e. direct source i.e. thermal and photovoltalic while indirect source i.e. tidal, biomass, wave, ocean, tidal etc. The Earth receives over 1, 73,000 terawatts of energy every year, which is more than 10,000 times of human needs i.e. Sunlight of one hour on earth could account for the power of the entire world for an year.

Components of solar radiation are direct radiation, diffuse radiation and reflect radiation measured as Global horizontal Irradiance (GHI), Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI). Solar insolation (incident solar radiation) caters for ½ to $^1/_3$ rd of heating needs of household as average solar radiation by earth in energy is 722 W/m^2. Solar energy devices can be categorised as passive solar energy devices and active solar energy devices. Some examples are solar photovoltaic system (where the PV cell consists of thin layers of semiconductor materials that produce electricity when exposed to light (like crystalline silicon i.e. mono-crystalline silicon, poly-crystalline silicon etc., cadmium telluride and copper indium selenide/sulphide), solar cells i.e. thin film solar cells, off-grid (domestic and nondomestic), grid connected (distributed and centralized) and solar thermal power systems where the heat is collected by lenses or mirrors and transformed to mechanical energy through a steam turbine and then into electricity (like parabolic trough, power tower, concentrating linear fresnel reflector, parabolic dish system etc).

VII. INDIAN SOLAR ENERGY SCENARIO

The country's solar installed capacity had reached 27 GW as on 31st December 2018 out of 360 GW total installed capacities of power stations in India (with higher potential to tap solar energy in the states of Andhra Pradesh, Gujarat, Madhya Pradesh, Rajasthan, Punjab, Haryana and Maharashtra due to their strategic location).The 20 GW capacities were initially targeted for year 2022 but Indian government achieved the target four years ahead of schedule. The country added 3 GW of solar capacity in FY 2015-2016, 5 GW in FY 2016-2017 and over 10 GW in FY 2017-2018, with the average price of solar electricity getting reduced to 18% below from that of coal electricity.

ISSN No:-2456-2165

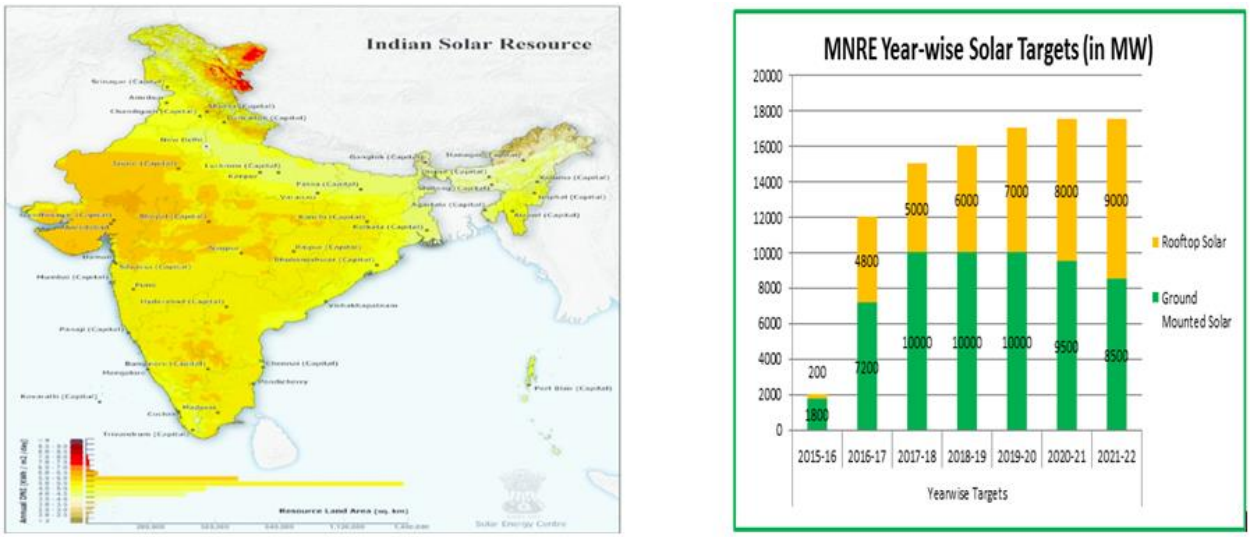


Fig 3:- Indian solar energy resources and MNRE Year wise solar targets, MNRE

Owing to increase in solar energy production and contribution as a source of energy in India ,there are lot of energy development activities has been done like 90 % rural areas electrification and more than 90% solar pumps set up was done, solar street lights more than doubled, solar home lighting system increased by 1.5 times, national lab policy on testing, standardisation and certification has been notified, 25,75,000 MW solar lamps distributed to students, solar PV contribution was increased more than 2.5% of renewable power generation,100 billion units of renewable electricity(RE) generation done in 2018, SPV with aggregate capacity of 47 MW deployed for various applications, solar energy generation capacity increased by 8 times , 25,000 MW was tendered,15,000 MW is under progress and 70,000 MW was installed up till now, out of ambitious target of 1,10,000 MW power generation up to year 2022.

Year	Installed capacity	Annual growth (MW)	Annual growth (%)	Year	Installed capacity	Annual growth (MW)	Annual growth (%)
2010	161 MW	N/A	N/A	2015	3,744 MW	1,112 MW	42.25 %
2011	461 MW	300 MW	186.34 %	2016	6,762.85 MW	3,018.85 MW	80.63%
2012	1,205 MW	744 MW	161.39 %	2017	12,288.83 MW	5,525.98 MW	81.71%
2013	2,319 MW	1,114 MW	92.45 %	2018	21,651.48 MW	9,362.65 MW	76.19%
2014	2,632 MW	313 MW	13.50 %	2019	NA	NA	NA

Table 2:- Year wise annual growth (MNRE)

VIII. MAJOR CHALLENGES FOR COMMERCIAL APPLICATION OF SOLAR ENERGY

There are some major challenges for commercial application of solar energy i.e. its expensiveness than natural gas, difficulty in commercial exploitation (as it is in dilute and spread out form), requirement of large collection area (i.e. average 1Kw/m^2 of power to area required in hottest regions), weather dependency with seasonal variation in intensity of solar radiation(i.e. change due to dust, fog, smoke etc.), nocturnal non availability of solar radiation, need of heavy energy storage device, generation cost is 4 times higher than that of other fuel power generation , requirement of higher capital cost, maximum efficiency below 30% , higher initial cost and poor efficiency of the PV modules, higher payback time of solar installations, availability of limited supply of system components such as batteries, inverters and other conditioning components, requirement of protection of solar companies from cheap imports from other countries, fall of prices due to cheap raw material polysilicon prices, dropping processing cost, heavy competition, protection from bankruptcies etc.

IX. REMEDIES FOR SOLAR ENERGY DEVELOPMENT: FOR COMMERCIAL APPLICATION

Some challenges for solar energy development are solved while some are on the verge of solution i.e. high initial capital investment for solar energy domestic application has been dropped with advances in aspects like solar photovoltaic glass windows to power the home, resiliency and reliability of the electricity supply, long-time warranty and low maintenance costs, fairly competitive technology for levelised cost, incentives, subsidies for residential solar power installation, local and state government's federal tax credits benefits etc.

Proper awareness of community about solar energy was resolved by industries investment in training of professionals to assess consumer needs, formation of a nation-wide standard of industry best practices with support from the Department of Renewable Energy, set up of better-established warranties from the manufacturers and service contracts, upgradation of the engineering involved and production of trust-worthy estimation, provision of license agreements and insurance certificates, development of new marketing mechanisms, introduction of review platforms like 'best company', 'consumer affairs', 'solar reviews' etc.

The another problem of suitable space requirement for solar energy was resolved by choice of regional solar power provider**,** individual affordable access through either the installation of home solar units or through a contract with a commercial solar power provider, technology up gradation with huge variety availability of competitive solar-powered consumer products with lesser space requirement to easily adopt solar energy and a greener life (i.e. portable solar panels, solar-powered chargers, solar lights etc.).

Weather dependency of solar power generation was resolved by measures like increase in home-based energy storage capacity, improved conversion efficiency, accessibility to programmable control units (to hold electricity sell the excess back to local utility during peak demand hours) etc. Problem of toxicity in solar cell production such as lead, gallium arsenide and cadmium was reduced by strict environmental controls for the operation inside production plants and strict isolation of it from surrounding environment .

X. SOLAR ENERGY DEVELOPMENT INITIATIVES BY INDIAN GOVERNMENT

Indian Government has taken initiatives for development of solar energy for country by some of following measures like conversion of 'solar energy corporation of India (SECI)' to look after specific solar energy along with 'renewable energy corporation of India' (RECI) for development of appropriate benchmarks, support for facilitation of resource assessments, support for research, development and demonstration facilities, encouragement for innovative and affordable applications of solar technologies , formation of 'Jawaharlal Nehru national solar mission' (JNNSM) with target of 27 GW solar generation by year 2022 by three-phase approach (i.e. first four year (2009-13) as 'phase-1', next 4 years of the twelfth plan (2013–17) as 'phase-2' and the thirteenth plan (2017–22) as 'phase 3'), 'international solar alliance (ISA)' for universal solar energy access with the help of 'international steering committee (ISC)' and 'National institute of solar energy (NISE)' by constituting an 'interim administrative cell (IAC)' of ISA in 'ministry of new and non-renewable energy (MNRE)', bilateral and multilateral 'co-operation frameworks' for joint efforts through innovative policies, projects, programmes, capacity building measures and financial instruments, conduct of 'solar parks scheme' (47 solar parks with 28 MW capacity currently) and 'grid connected roof top program', development of mini/micro grid projects for rural electrification by 'Pradhan Mantri sahaj bijli har ghar yojana (SAUBHAGYA)' and 'Din dayal upadyay gram jyoti yojana (DDUGJY)' , provision of benefits like fiscal incentives ,tax holidays, depreciation allowance etc. to companies involved in solar energy etc.making solar energy available to both rural and urban areas.

Indian government also initiated conduct of 'energy efficient solar/green buildings' programme, conduct of 'GRIHA certification cum rating program', development of model 'Solar City' program, development of 'Green Campuses', amendment in National tariff policy to support solar energy generation, implementation of 'viability gap funding (VGF)' process , national 'clean energy fund (CEF)' distribution, increase in budget for 'national solar mission'(NSM), development of 'intrastate transmission waiver system', introduction of 'renewable energy obligation' (RGO) program, implementation of 'competitive transparent bidding process' for reduction in per unit cost, subsidised loan process, conduct of 'Surya Mitra' vocational training program, set up of 'Delhi Mumbai industrial corridor development corporation limited (DMICDC) by MNRE 'bunding process', introduction of 'round the clock renewable power with solar hybrid policy' with subsidy mandating cell and modular to be made in India (except thin film solar panel technology) , expression of interest (EOI) and quality control for setting up solar photovoltaic PV system, notification of solar components under bureau of Indian standards (BIS) act, initiation of 'Abhinav Soch-Nayi Sambhawanaye' project for new and renewable energy sector , initiation of 'start up and make in India' projects to motivate solar business, launching of 'Renewable energy certificate (REC)' mechanism helps in the creation of a pan-India renewable energy market, initiation of 'viability gap funding' process ,establishment of 'Akshay Urja' shops, formation of 'Association of renewable energy agencies of states (AREAS)' , formation of 'The energy and resources institute' (TERI) etc. making feasible and attractive solar business to international, private and individual concerned.

Indian government also increased the previous status of solar energy reach to Indian communities and regions by various measures like distribution of solar lamps (more than 25,75,000 units) , distribution of the solar street lights (more than 6,20,196 units), increase in solar home lighting system by 1.5 times (more than 16,69,956 units), set up of 90 % solar pumps (more than 1,77,011 units), set up of biogas plant for rural household (more than 2.5 lakhs units) , increase in renewable energy capacity (from 35,000 MW to more than 70,000 MW currently), commissioning of solar PV projects and solar thermal power projects under 'National solar mission (NSM)', set up of SPV project by Delhi Mumbai industrial corridor development corporation limited (DMICDC) under the MNRE bundling scheme, set up of grid connected solar PV power projects (GCSPV) by NTPC and other PSUs /NTPC 'Vidyut vyapar nigam

limited (NVVN)', installation and commissioning of grid-interactive rooftop SPV (GIRSPV) projects under National clean energy fund (NCEF), transfer of solar water heating system to IREDA as a loan scheme, installation of concentrated solar thermal area (ST) and solar steam cooking systems, promotion to 'Foreign direct investment (FDI)', introduction of'Pradhan Mantri Yojana for augmenting solar manufacturing (PRAYAS)' to promote the production of solar panels and equipment in India etc.; which had steered the solar energy field in India by its huge potential, opportunities and market availability.

XI. INFORMATION AND PUBLIC AWARENESS OF SOLAR ENERGY WAS DONE BY INDIAN GOVERNMENT

Information and public awareness of solar energy was done by Indian government through a 'Multi-agency approach' namely by state nodal agencies, Directorate of advertising & visual publicity, Door Darshan (DD), various news and television channels, All India Radio (AIR), department of 'Posts' etc. (using the electronic, print and outdoor media) for facilitating proper awareness and information to all sectors of communities and regions regarding solar energy feasibility for various domestic and commercial applications.

XII. RESEARCH AND DEVELOPMENT IN SOLAR ENERGY SECTOR IN INDIA

Indian government had set up various organisations and various research and development (R &D) activities to support solar energy generation in India i.e.'National institute of wind energy (NIWE)' collects data from 'solar radiation resource assessment stations(SRAS)' to assess and quantify solar radiation availability and develop 'Solar Atlas' of the country, 'National institute of solar energy (NISE)' has assessed the State wise solar potential by taking 3% of the waste land area to be covered by Solar PV modules, 'The Indian Institute of Science, Bengaluru (IISc)' has developed 'Biomass Atlas of India', and the 'Alternate Hydro Energy Centre', 'Indian Institute of Technology, Roorkee (IIT)' has assessed small hydro potential in the country.

The research and development activities carried by Indian government with the help of these organisations for renewable energy development (including solar energy) includes formation of 'National laboratory policy (NLP)' for efficiency increase, cost reduction and development of new indigenised technology for commercialisation of renewable energy (which includes higher efficiency solar cells), efficient solar thermal power generation, growth in clean energy sector, solar radiation research and assessment , up-gradation of SPV module test facility, up-gradation of solar cell test facility, expansion of battery test facility, enlargement of SPV water pumping test facility and other labs, up-gradation of solar thermal labs, establishment of IT cell, renovation of work shop facility, establishment of R&D monitoring cell, setting up of 500 kW SPV power plant, establishment of the secretariat of 'International solar alliance (ISA)',establishment process start up for 28 number of R&D projects in area of solar photovoltaic (SPV) and solar thermal (ST) power generation, establishment of 'Renewable energy management centres (REMC)' run by 'National load dispatch centres (NLDC)' equipped with advanced forecasting tools, smart dispatching solutions and real time monitoring of renewable energy(RE) generation, constitution of 'Research, design & development project appraisal committee (RDPAC)', constitution of 'National centre for photovoltaic research and education (NCPRE)', development of CZTS solar cells and modules - non vacuum process, grid tied solar PV power generation on a water body, prototype preparation of cost-effective and highly efficient 'Solar-powered electric vehicle (SEV)', establishment of solar thermal power plant with 16 hours thermal storage for continuous operation, development of 2-Axis tracking parabolic dish based concentrated solar power system(CSP), development of thermal power plant with biomass based thermic fluid heating system in a process industry etc.; which will give new horizon to growth of solar energy by accessing extractable potential for domestic, commercial and technological development in India.

XIII. APPLICATION OF SOLAR ENERGY

solar energy has a lot of innovative and sustainable domestic, industrial and commercial applications like solar street lights, net metering facility for solar bill reduction, railway signalling, microwave repeaters, television transmission, solar water pumps for irrigation and drinking , solar steam cooking, solar water heating, concentrated solar thermal area, grid connected solar PV projects , grid stabilisation, refrigeration and air conditioning application, rain water harvesting , solar lamps, solar heating, hybrid solar plants, solar cookers, solar inverters, solar street lights, solar UPSs, solar fans, solar lanterns, solar cables, solar mobile chargers, solar power conditioning units, solar home systems, solar road safety equipment, solar fencing to solar CCTV cameras , space-based solar power (either photovoltaic or thermal systems), solar updraft tower power plant for generating electricity from low temperature solar heat, solar kits, portable solar panels, solar chargers, planet solar boats, floating solar arrays PV systems (that float on the surface of drinking water reservoirs, quarry lakes, irrigation canals or remediation and tailing ponds.), passivated emitter rear cell (PERC) (for the monocrystalline silicon solar cell variety to increase efficiencies with modest investment **),** Bio-solar cells (for remote areas where replacing batteries difficult), artificial photosynthesis machines, floating solar farms (where there is lack of space), wireless power from space, energy harvesting trees (which by better design, better chemistry and the use of sunlight-absorbing nanoparticles capture the infrared spectrum of light for use in solar panels**),** solar windows for partial power generation, solar transportation like solar powered bus, ship, airplane(that generate no emission), solar powered clothes (that can charge mobile phones and wearable devices like sunglasses ,jewellery, watches etc.), solar desalination plant (uses combination of

ISSN No:-2456-2165

distillation technology) and sunlight harvesting (nanophotonic cells to convert salty water into fresh drinking water) etc. which are available to consumers for use and research for new field application of solar energy for betterment of life of people in India .

XIV. CONCLUSION

In this paper, we have discussed about the current status and future prospects of solar energy in India and all around globally.

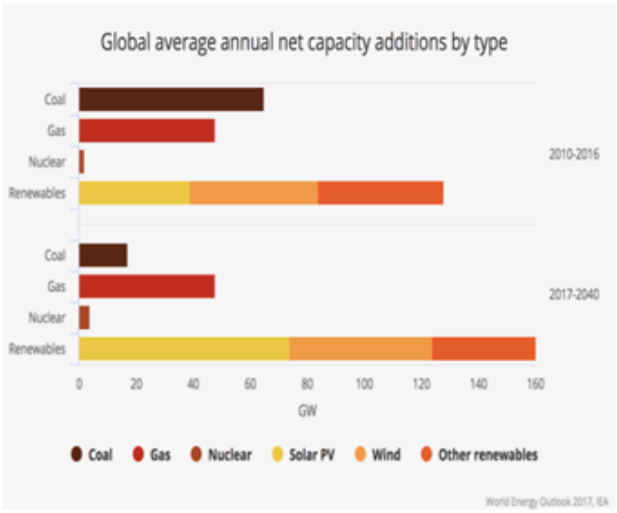


Fig 4

As solar energy generated by nuclear fusion reaction in sun therefore it is available naturally; therefore offering benefits over conventional fossil energy problems (like global warming ,pollution , acid rain ,health issues etc.), diminishing status of sources of coal, domestic gas, increasing energy prices of India, cruciality of project execution and financing, mitigation of peak energy cost, reduction in total energy bills, compensation of power loss due to electricity theft, reduction in transmission and distribution losses, reduction in cost of electricity, increase in energy security for 25 years, saving in property tax, increase in benefit of accelerated depreciation/tax saving ,meeting of renewable energy obligation, reduction in operation and maintenance cost, inexhaustibility (as no fossil fuel required), reduction in requirement of special arrangement for transport, increase in utilisation for both on grid and off grid applications, utilisation for captive power generation, worthiness of the investment (solar panels usually have a lifespan of around 25 years) ,growing employment prospects and opportunities, increase in average retail electricity prices making the average levelised cost of electricity from solar power to lower than electricity tariffs available from the grid etc.

Solar energy also offers benefits over other renewable energy sources options for sustainable development i.e. unlike other renewable energy sources ; solar power use at anywhere, solar equipment's long life, predictable output most of the time, Solar equipment's simplicity and easy installation, long periods management without monitoring, zero greenhouse gas emissions etc. Solar energy beneficial than wind energy as it has no moving parts, less risk to damage, no maintenance requirement, better reliability (almost up to 25 year warranty with almost more than 44 percent efficiency), more predictable energy outputs, relatively silent in operation, fast installation with less transmission cable required, less susceptible to lightning and high wind damage, can be deployed close to load centres, versatility etc. similarly solar energy offers benefits over hydro energy as it do not alter environment and ecosystem, wildlife's habitat alteration, it can be built in a matter of months, it can be set up almost anywhere, less investment and less area required, no human relocation required etc. as well as solar energy beneficial than biomass energy on the basis of no carbon emissions ,no volatile organic compounds, do not require fertile land that could be used for crops, more efficiency, accessibility to most homeowners, increasing affordability, lease-to-buy options , **e**nergy prices below the prices offered by conventional utilities, possibility of individuals to invest in their own power generation etc. Lastly it offers advantages over Nuclear power as solar power costs less, no risk of environmental catastrophe in the event of an accident or terrorist attack, no production of radioactive waste that lasts for 10,000 years as in nuclear energy, no critical safety measures required for storage and transportation, no effect on surrounding habitat and ecology etc.

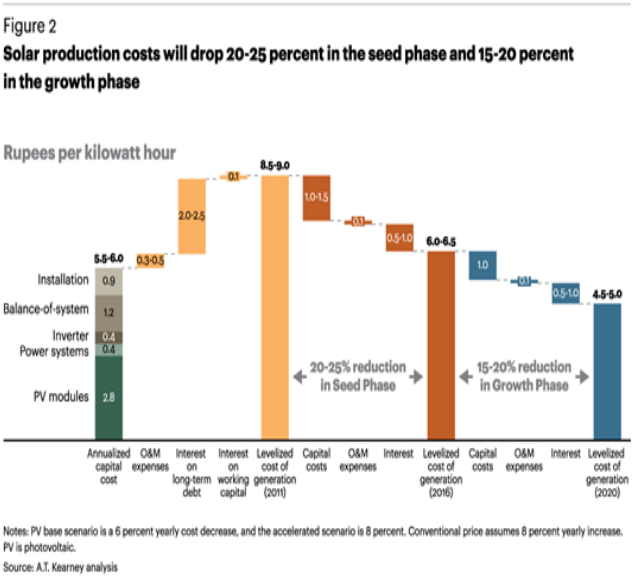


Fig 5

There are lot of ongoing activities in the field of Solar energy for utilisation as an energy source for India considering it's abundant availability due to tropical region, Indian government's research and development activities, Indian government initiatives for solar energy development, formation of various research laboratories and supporting organisations, information and public awareness of solar energy**,** National solar mission, Start up and Make in India opportunities in solar field, renewable energy obligations**,** global solar alliance, formation of various solar corporations, private and local business

dominance ,hybrid power generation ,peak energy satisfaction, remedial solutions for solar energy development for commercial application by government, global dropping prices for photovoltaic (PV) module , subsidies, incentives, tax and tariff benefits by government, rising demand and favourable economics lead to rapid industry growth attracting larger utilities, various efficiency increasing measures etc. causing solar capacity increase by 8 times from 2630MW to more than 22000 MW in last some years.

Therefore on above mentioned benefits of solar energy over both conventional fossil fuels, renewable energy sources in India and potential, various innovative and sustainable domestic, industrial and commercial applications, opportunities and various measures taken by government and private sector for solar energy exploitation in India; it can be concluded that solar energy will be future renewable energy option for India.

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