INTEGRATION OF RENEWABLE ENERGY WITH SEWAGE TREATMENT PLANT

A DISSERTATION

Submitted in partial fulfilment of the
Requirements for the award of the degree
Of
MASTER OF TECHNOLOGY
In
ENVIRONMENTAL MANAGEMENT OF RIVER AND LAKES

By
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CANDIDATE DECLARATION

I hereby certify that the work which is being presented in progress report, entitled **“Integration of renewable energy with sewage treatment plant ”** in partial fulfilment of the requirement for the award of the degree of **Masters Of Technology** with specialization in **“Environment Management of River and Lakes”,** submitted in **DEPARTMENT OF HYDRO AND RENEWABLE ENERGY,Indian Institute of Technology Roorkee** is an authentic record of my own work carried out during the period from May 2018 to May 2019 under the supervision of **Dr. S.K. Singal and Dr. M.P. Sharma,Professor, Department Of Hydro And Renewable Energy, Indian Institute of Technology Roorkee India**.

I have not submitted the matter embodied in this dissertation for award of any other degree.

Dated: 14 June 2019

Place: ROORKEE-247667 **(HIMANSHU GUPTA)**

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

Sewage treatment is the process of removing contaminants from wastewater. It includes the physical, chemical and biological process to remove physical chemical and biological contaminants. Collecting, treating, and discharging waste water requires energy, mostly as electricity, but also as natural gas or other fuels. National waste water treatment represent 0.1 to 0.3% of total energy consumption. Due to high electricity consumption and frequent power failure most of the STPs outside India are using renewable energy as the source of electricity.

Under the present work an attempt has been made to integrate the renewable energy with the 27 MLD Sewage treatment plant located at Jagjeetpur, HaridwarUttarakhand.The use of renewable energy is helpful for making STP self sufficient. The energy can be used in production of power, dewatering of sludge, desalination of water and many other purposes most of the plant .. The total load of the plant is 1103.23 kW and total power consumption is 4955 kWh/day and power failure occurs about 7 to 10 % hours per month. In this work part of the electricity is proposed to be provided through renewable energy. Sizing of the SPV system is on the basis of the land availability in the sewage treatment plant and as per the solar radiation, the solar energy potential is calculated as 210 kWp and accordingly the selection of modules, inverter and transformer is done these system are connected together generated electricity is supply to the load of the plant .The current SPV system contributes 4.8 to 5 % of electricity to the plant. Techno economic and life cycle cost analysis has shown that unit cost of electricity is 5.6 Rs/ kWh

ACKNOWLEDGEMENT

I would like to express my deep sense of gratitude and indebtedness to my supervisor **Dr. S.K. Singal and Dr. M.P. Sharma, Professor, Department of Hydro and Renewable Energy, Indian Institute of Technology Roorkee** for guiding me to undertake this progress report work as well as providing me all the necessary guidance and support throughout this work. He has displayed unique tolerance and understanding at every step of progress, without which this work would not have been in the present shape.

I would also thankful to all staff of **Department of Hydro and Renewable Energy** for their constant support at and all my friends, for their help and encouragement at the hour of need.

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Introduction

1.1 GENERAL

Water is the essential basis for all forms of life. Urbanization, industrial development as well as extensive agricultural production have a significant impact on the quality and quantity of the resource water.The municipal wastewater and solid wastes in urban areas can be seen as a direct consequence of the rapidly growing urbanization rate. Today, insufficient water supply for urban inhabitants and the lacking coverage of sewage disposal are based on slower developments of urban infrastructures in the municipal areas. Under the high pressure of population growth, the demographic change and the transformation to a free market economy, India faces a lot of challenges in various sectors, including wastewater and solid waste management.

Waste management and sludge management rely on various technical, ecological, economic and political elements that affect environmental operations. Sewage sludge accumulates in wastewater treatment plants during the treatment phase and must be dealt with appropriately to prevent adverse effects on environmental media and to mitigate the danger of influencing human health. pathogen reduction is relevant when sludge is disposed of or re-used in a way that human contact is possible. In the sanitation sector, a growing attention for issues of sustainability can be observed. In general, these interests are expressed through, an increasing number of initiatives that are focused on the closing of water and nutrient cycles and the recovery and re-use of these resources. Finally, waste in-cineration (waste-to-energy-disposal) may be classified as a method to recover energy if the closing of resource cycles is ineffective. In the 21st century, industrial countries indicate an increasing interest in sustainable sludge management, including the production of value added products from wastewater sludge.

In Western Europe, sewage sludge management and its strategies are implemented but they are authorised according to the respective local conditions. When we want to transfer these Western European technologies and experiences to other countries, a number of factors have to be taken into consideration, including climatic, cultural, social, political and financial conditions. Developing countries do not have much experience with regard to resource recovery from wastewater or sewage sludge management. This is also the case for India.

1.2 STATUS OF WATER SUPPLY IN INDIA

There is an increasing trend in the population of Class-I Cities, due to which the demand of water is also increasing and so the sewage generation.(4)

• There are 498 Class-I cities, having water supply of 44769 Millions Liter Per Day (MLD).

• The population of Class-I Cities is projected 22.76 Crore.

• Among all the states Maharashtra is most populated and has maximum water supply that is 12482MLD (27 % of total water of all 498 class-I cities)

• Next to Maharashtra, Uttar Pradesh has the water supply of 4382 MLD, which is 9.7% of total water supply of all class-I cities.

• Among all the States/UTs per capita water supply of Chandigarh is maximum (540 MLD) followed by Maharashtra with 310 MLD.

• National average for per capita water supply is 179 considering Chandigarh as outlier.

For class-II cities

• There are 410 Class-II Towns (population between 50,000 to 1,00,000) having water supply of 3324 Million Liter Per Day (MLD).

• The population of 410 Class-II Towns is projected to 3.0 Crore.

• Among all the states/UTs Andhra Pradesh is most populated having water supply of 272 MLD and per capita water supply 78 MLD.

• Total water supply of Class-II Towns is reported to 3324 MLD, which is 6.91 percent of total water supply (water supply of class-I cities and class-II towns).

• Uttar Pradesh has the maximum water supply i.e. 432 MLD, which is 13 % of total water supply of class-II towns.

• Next to Uttar Pradesh, Karnataka state has water supply of 291 MLD (8.71%) and then Gujarat with 284 MLD (8.54%).

• Among all the states Punjab has maximum per capita water supply i.e. 177 MLD.

• National average for per capita water supply is 120 MLD.

1.3 WASTE WATER GENERATION AND TREATMENT

It has been projected that domestic wastewater is created by urban centres is 22,900 million litres per day (MLD) of against developed wastewater 13,500 MLD. Only 5,900 MLD treatment capacity is available for domestic wastewater, beside 8,000 MLD of industrial wastewater. Thus, there is a giant gap in treatment of domestic wastewater. Govt. of India in the Ganga Action Plan is supporting the local bodies to create sewage treatment plants and next under the National River Action Plan. Since this job is difficult, it may take long period to grab the treatment of whole wastewater. Formation of effluent treatment arrangements in small-scale industries is a problem, since most of them are placed in residential areas, where space is a main constraint. Furthermore, they have not satisfactory resources to start treatment systems. This type of industries crucial to establish common effluent treatment plants (CETPs). So statistics of such amenities have been established through the nation. It is predictable that founding of CETPs would reduce the pollution load in the marine resources of the country to a huge extent.

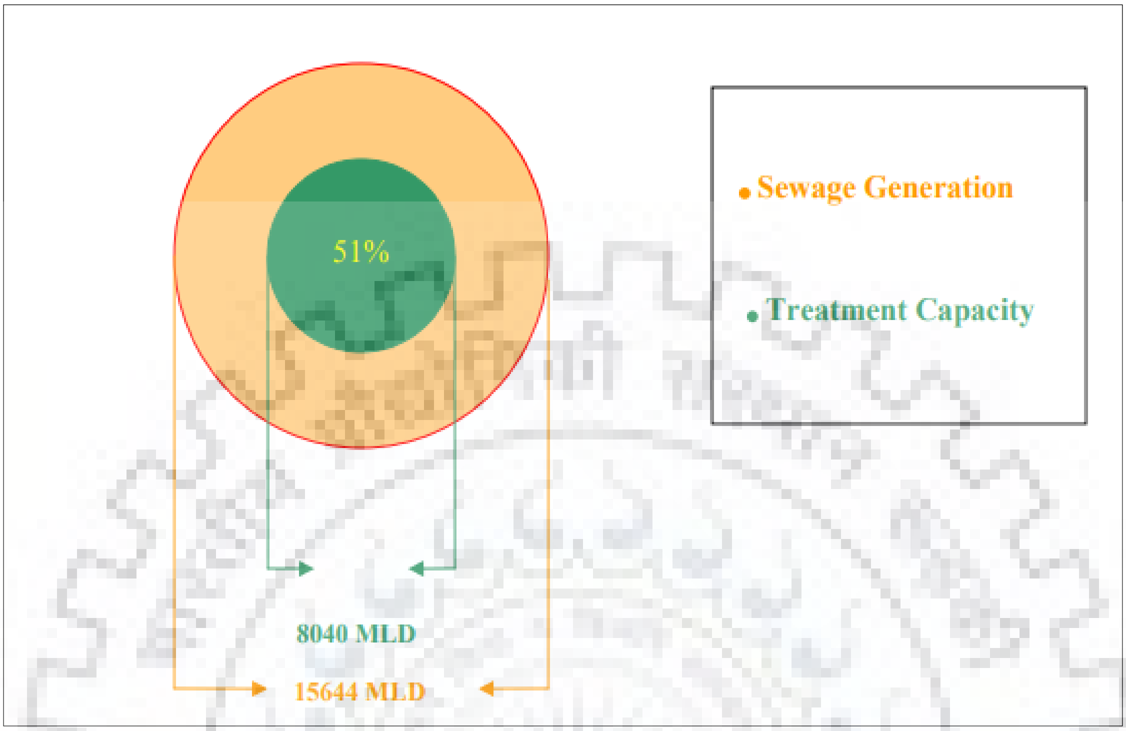

Fig 1.1 Sewage generation and treatment capacity in metroplotian cities (4)

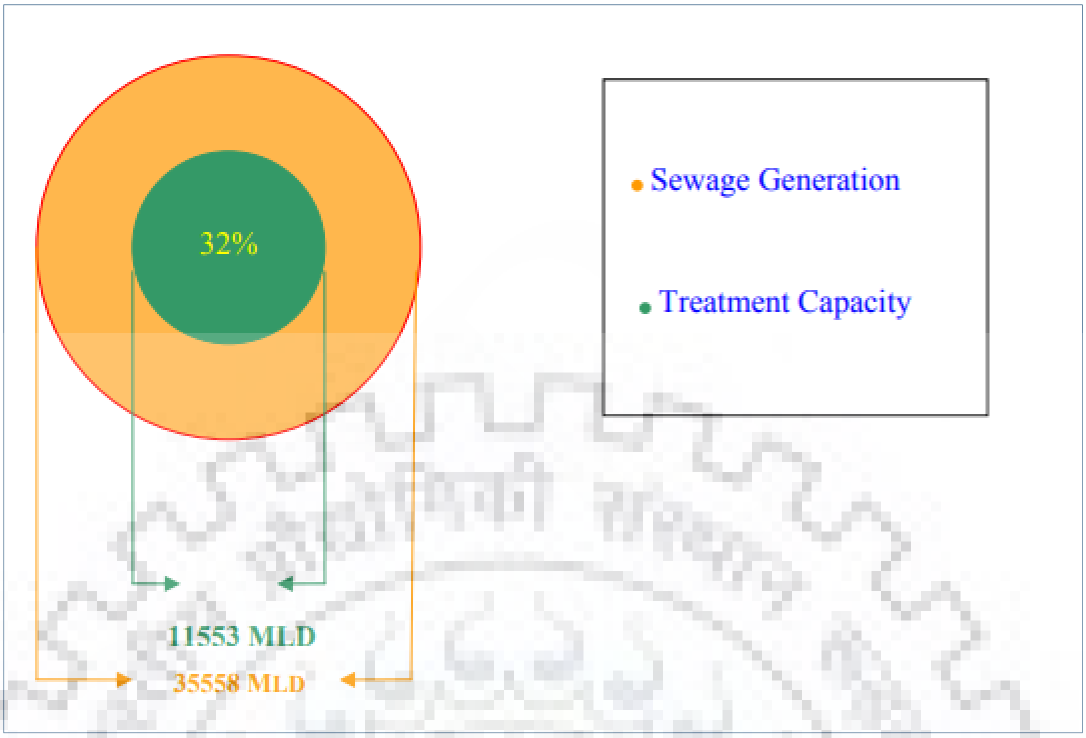

Fig 1.2 Sewage generation and treatment capacity in class I town (4)

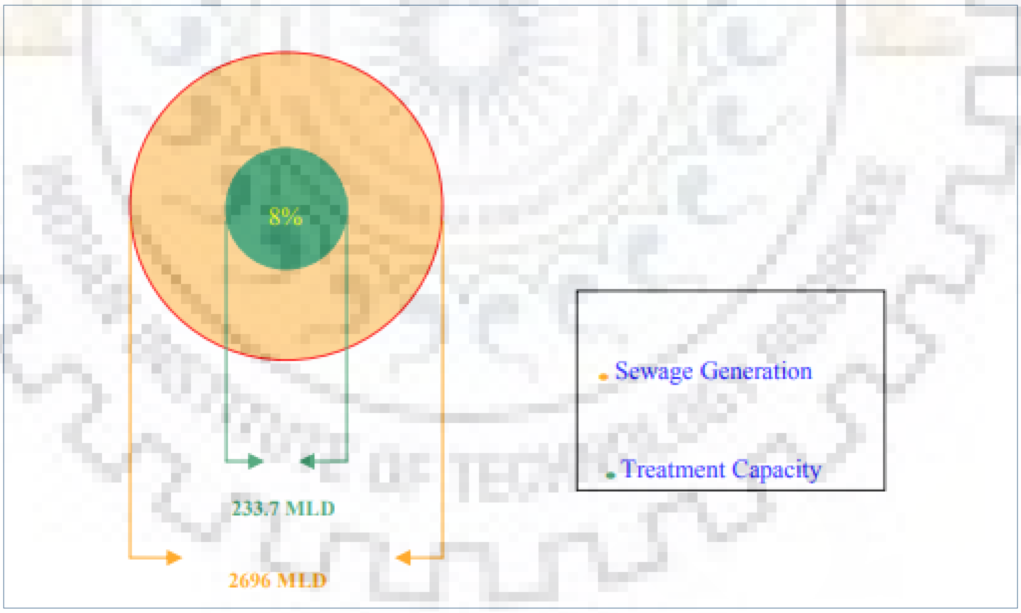

Fig 1.3 Sewage generation and treatment capacity in class II town(4)

1.4 PROCESSES USED IN STP

Sewage treatment is done in three steps which are as follows:

1. Primary treatment.

2. Secondary treatment.
3. Tertiary treatment.

Primary treatment process comprises of temporarily holding the sewage in a still basin where heavy solids goes to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or exposed to secondary treatment.

Secondary treatment removes dissolved and suspended biological matter. Secondary treatment is naturally performed by indigenous, water-borne micro-organisms in a succeeded habitat. Secondary treatment may require a separation process to eliminate the micro-organisms from the treated water previous to release or tertiary treatment.

Tertiary treatment is sometimes defined as anything extra than primary and secondary treatment in order to license refusal into a highly sensitive or fragile ecosystem (estuaries, low-flow Rivers, coral reefs). Treated water is occasionally disinfected chemically or physically (for example, by lagoons and microfiltration) former to discharge into a stream, river, bay, lagoon or wetland, or it can be castoff for the irrigation of a golf sequence, green way or park. If it is adequately clean, it can also be cast-off for groundwater recharge or agricultural purposes.

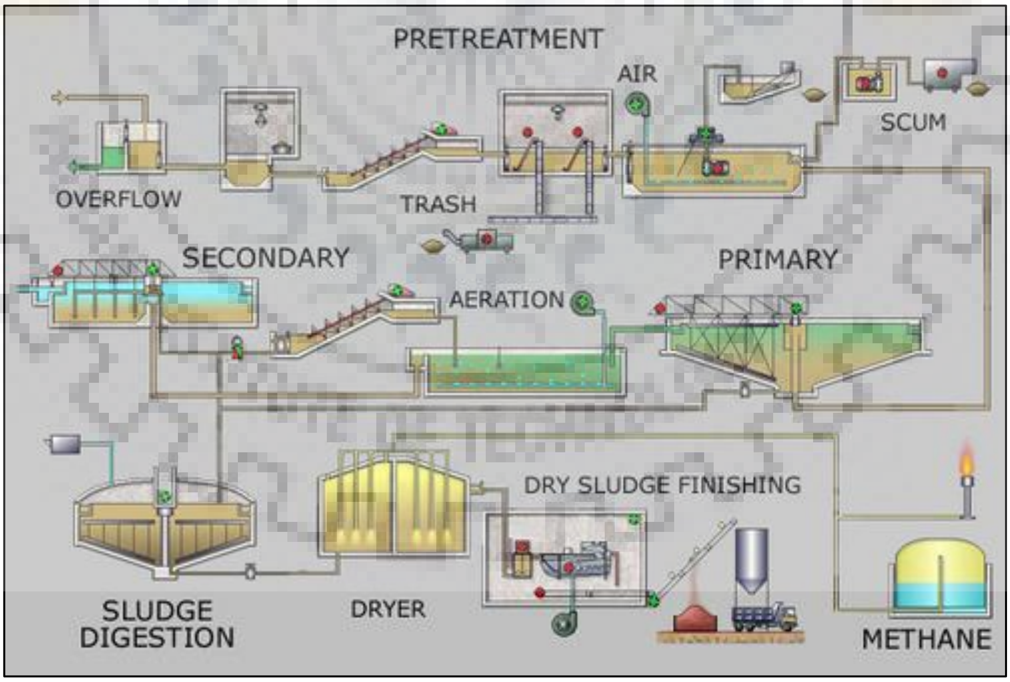

Fig 1.4 Simplified process flow diagram for a typical large-scale treatment plant(8)

1.5 ENERGY CONSUMPTION IN STP

The STPs are used for the treatment of water which needs various processes and various electrical and mechanical equipment's for the management of water certain equipment runs 24 hours while some run's below static time intervals .The energy consumed by both equipment's mark and it's running time .

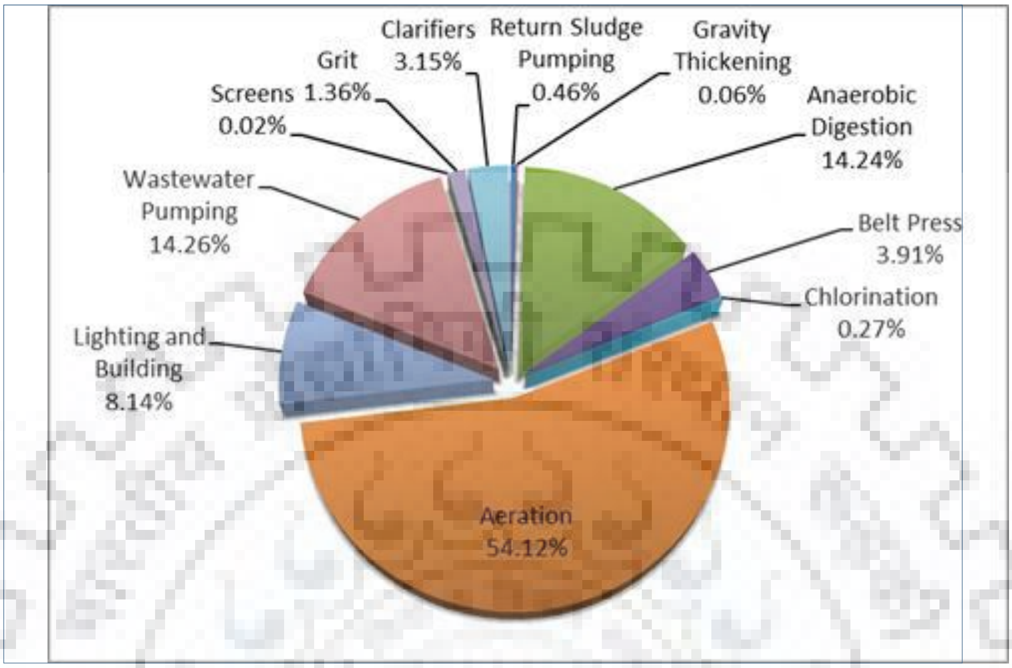

Fig 1.5 Energy used in sewage treatment plant [10].

The above figure shows the electricity consumption in the various part of STP .The major electricity consuming areas is the aeration process followed, clarification, mixing, sludge treatment etc therefore it the integration of renewable energy with sewage treatment plant is solar energy is the source for the generation of electricity therefore SPV system is used for the generation of electricity.

1.6 NEED OF INTERGRATION OF RENEWABLE ENERGY WITH SEWAGE TREATMENT PLANT

Energy sources will performance an important role in the world's future given that the global request for energy is rapidly increasing. Estimates of the world primary energy consumption are that 80% of the source is provided by fossil fuels. Considering several scenarios, the primary energy use is estimated to growing between 32 and 84% by 2050 as compared to 2007. However, the fossil fuel capitals are rapidly depleting and there is an increasing need to substantially reduce greenhouse gases and other contaminants in light of the grim climate crisis that will have to be challenged except developing countries edge carbon emissions from their power sector in the nearby future [11].

The development of low carbon technologies and their global adoption is therefore an immediate significance which has pinched attention to the new and renewable sources of energy which offer a great potential for sufficient mankind‘s energy requirements with insignificant carbon emissions.

Renewable energy is energy found from sources that are basically inexhaustible. Examples of renewable resources comprise wind power, solar power, geothermal energy, tidal power and hydroelectric power. The extreme important feature of renewable energy is that it can be joined without the release of harmful pollutants. Renewable energy also has the benefit of allowing decentralized distribution of energy — predominantly for meeting rural energy needs, and thereby empowering people at the grass roots level.

India had about 36.642 GW of mounted renewable energy capacity as of 31 March 2015. Wind accounts for 68% of the volume, with 23.8 GW of installed capacity, making India the world's fifth biggest wind energy producer. Small hydro power (4.1 GW), bio-energy (4.3 GW) and solar energy (4.1 GW) establish the residual capacity. Although the part of renewable energy in the generation mix has remained growing over the years, India still has large unused renewable energy potential [13].

Renewable energy is existing in many forms. Most of the renewable energies depend straight or indirectly on sunlight. Differential heating of the Earth's surface leads to air moving about (wind) and precipitation forming as the air is lifted are the direct result of Wind and hydroelectric power. Solar energy is the direct change of sunlight using panels or collectors. Biomass energy is stored sunlight contained in plants. Geothermal energy do not depend on sunlight and is the result of radioactive decay in the crust combined with the original heat of accreting the Earth, and tidal energy, is the conversion of gravitational energy.

As the sewage treatment plant run on 24 hour basis the electricity is the major necessity inside the plant for the running of many mechanical and electrical equipment's and due to power failure and power variation the performance of the plant is affected. So the renewable energy can be used as the source of power generation in the STP's for the better running of plant.

It is observed that there are various power consuming areas in the STP .And the use of renewable energy proved to be obliging in STP the energy can be used in production of power, dewatering of sludge, desalination of water and many other purposes most of the plant use solar photovoltaic system, hydro power, wind energy, biomass energy for the generation of power. And the main benefit is that these dynamisms are environmental friendly.

1.7 WORLD ENERGY CONSUMPTION

Although consumption of non fossil fuels is expected to grow faster than fossil fuels, fossil fuels still account for 77% of energy use in 2040. Natural gas is the fastest-growing fossil fuel in the projections. Global natural gas consumption increases by 1.4%/year. Abundant natural gas resources and rising production—including supplies of tight gas, shale gas, and coalbed methane—contribute to the strong competitive position of natural gas. Liquid fuels—mostly petroleum-based—remain the largest source of world energy consumption. However, the liquids share of world marketed energy consumption falls from 33% in 2015 to 31% in 2040, as oil prices rise steadily, leading many energy users to adopt more energy-efficient technologies and to switch away from liquid fuels when feasible.

Compared with the strong growth in coal use in the 2000s, worldwide coal use remains flat in the IEO2017 [2]. Coal is increasingly replaced by natural gas, renewables, and nuclear power (in the case of China) for electric power generation, and demand for coal also weakens for industrial processes. China is the world's largest consumer of coal, but coal use is projected to decline in China by 0.6%/year from 2015 to 2040, and in the combined OECD countries coal also declines by 0.6%/year over that same period. With coal consumption in India and other nations in non-OECD Asia growing over the projection period, worldwide coal consumption is not as low as it would otherwise be in 2040. The coal share of total world energy consumption declines significantly over the projection period, from 27% in 2015 to 22% in 2040.

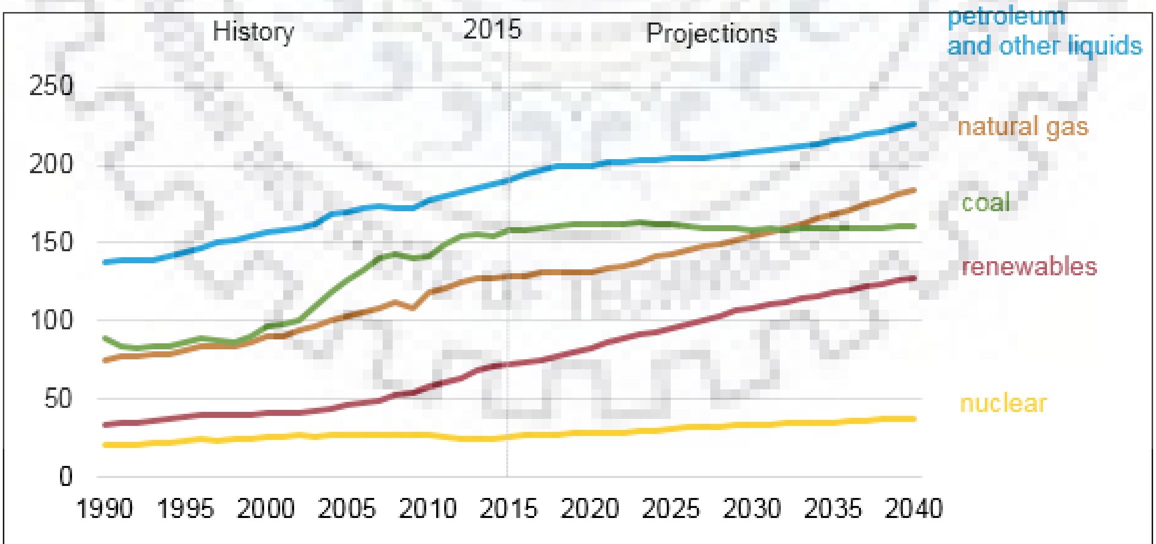

Fig 1.6 Graph showing energy from different resources (11)

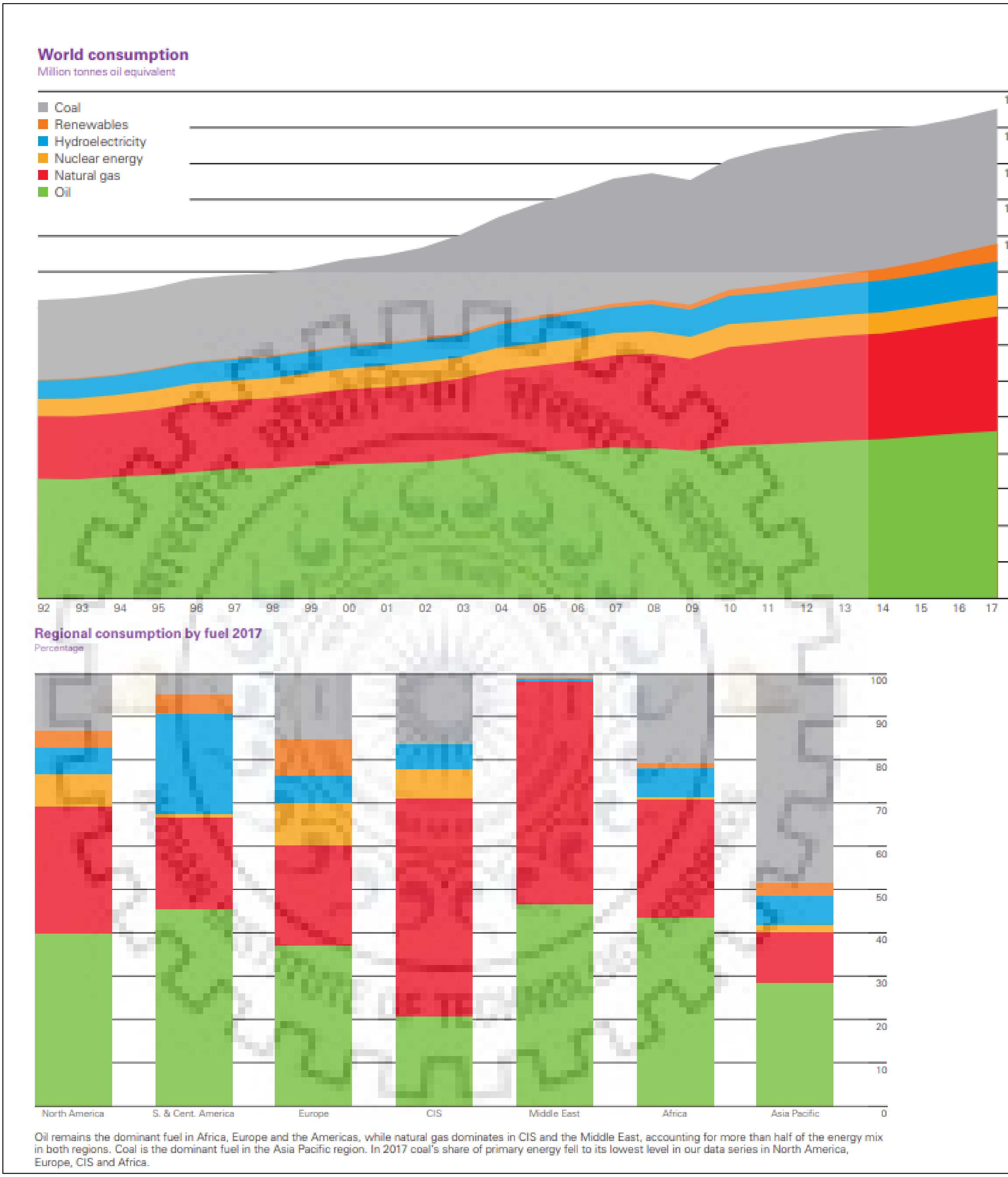

Fig 1.7 World energy consumption by fuel wise (11)

1.8 INDIA ENERGY CONSUMPTION

The 2022 electrical power targets include achieving 227GW (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 and offshore wind power. The development of low carbon technologies and their global adoption is therefore an immediate significance which has pinched attention to the new and renewable sources of energy which offer a great potential for sufficient mankind‘s energy requirements with insignificant carbon emissions.

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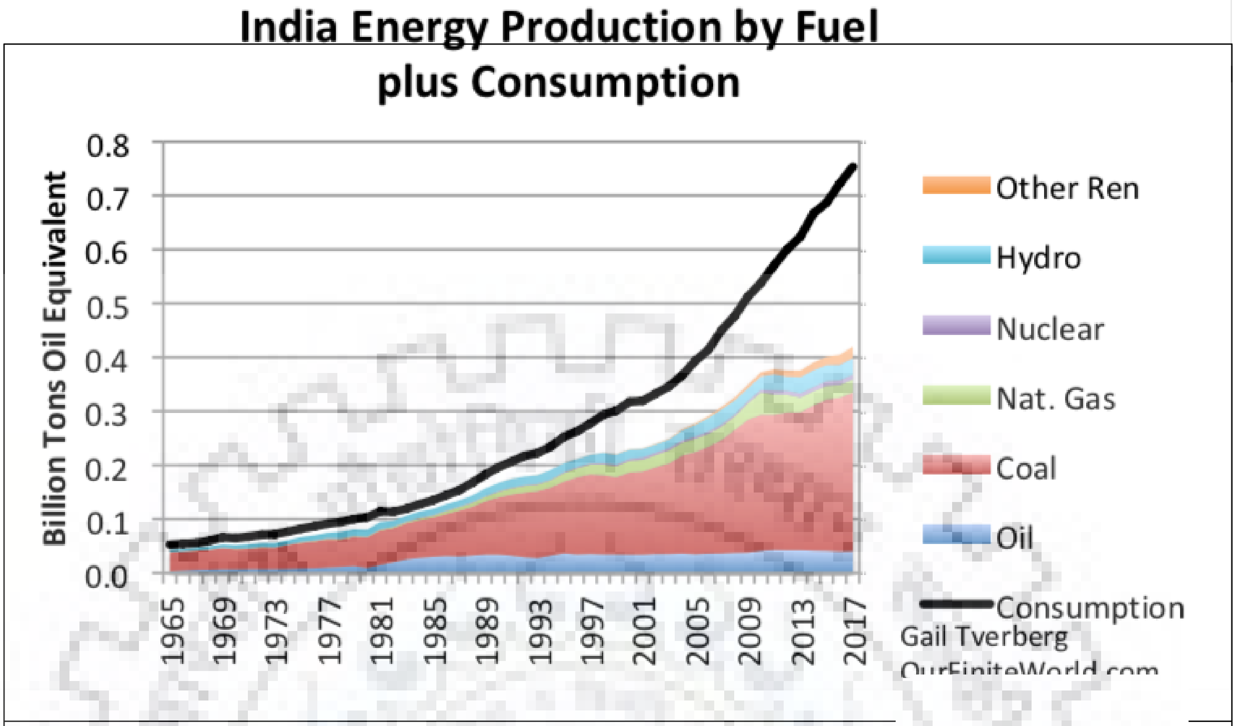

Fig 1.8 India energy production by fuel and consumption (13)

1.9 LITERATURE REVIEW

A number of studies have been carried out by different researchers on the energy conservation, sustainable solid waste management, biomass to sustainable energy. The work is done both on centralized and decentralized practices which are being now days focused by government. Following literature are being studied for understanding the issues, conflicts, loopholes, and upcoming potential for adopting integration of renewable energy with sewage treatment plant.

S.No	Author	Topic	Workdone	Findings
1	Shizas 2004 (14)	Determination of Energy Content of Unknown Organics in Municipal Wastewater Streams	A bomb calorimetry method has been used to measure the energy content of raw municipal wastewater.	With appropriate energy recovery technology, municipal wastewater treatment plants can become net producers of renewable energy.
2	Shekdar 2008 (15)	Sustainable solid waste management.	Evaluating issues surrounding the sustainability of SWM. Proposing a multi-pronged integrated approach for improvement that achieves sustainable SWM.	Municipal agencies must plan and operate the system in keeping with increasing urbanization and population growth.
3	Marshall 2013 (16)	Systems approaches to integrated solid waste management in developing countries	This review contrasts the history and current paradigms of SWM practices and policies in industrialized countries with the current challenges and complexities faced in	There is a need for new approaches emerging from the interface of SWM, post-normal science, and complex-adaptive systems research as the bleak state of SWM systems in many

			developing country SWM.	developing regions continues to threaten and degrade the health of the most vulnerable human populations and the ecosystems they are a part.
4	Mills 2013(17)	Environmental & economic life cycle assessment of current & future sewage sludge to energy technologies.	This study compared five technology configurations: 1 – conventional AD with CHP, 2 – Thermal Hydrolysis Process (THP) AD with CHP, 3 – THP AD with bio-methane grid injection, 4 – THP AD with CHP followed by drying of digested sludge for solid fuel production, 5 – THP AD followed by drying, pyrolysis of the digested sludge and use of the both the biogas and the pyrolysis gas in a CHP.	An enhanced pyrolysis option is explored that utilises the waste heat from the pyrolysis CHP in the THP plant.
5	Samolada 2013(18)	Comparative assessment of municipal sewage sludge incineration, gasification and	The current status of both European and Greek Legislation on waste management, with a special	Difficulties in securing funding for technologies with limited operating experience and track

		pyrolysis for a sustainable sludge-to-energy management in Greece	insight in municipal sewage sludge, is presented. A SWOT analysis was further developed for comparison of pyrolysis with incineration and gasification and results are presented.	record is one of the serious constrains. Moreover, adopters of pyrolysis systems will still face the challenge of finding markets for the solid and liquid products.
6	Kacprzak 2016 (19)	Sewage sludge disposal strategies for sustainable development	Assessment has been proposed in order to appropriately assess the possible environmental, economic and technical evaluation of different systems.	The main goal should be to maximize energy recovery and small rural facilities where recovery of matter should be dominant. In a medium sized wastewater treatment plant, one can consider increasing the efficiency of energy recovery while still achieving a good quality product possible for further processing (e.g. for composting process).
7	Demirbas 2008 (20)	Potential contribution of biomass to the sustainable energy development.	Study was done to investigate global potential and use of biomass energy and its contribution to the sustainable energy	The main biomass processes utilized in the future are expected to be the direct combustion of residues and wastes for

			development by presenting its historical development.	electricity generation, ethanol and biodiesel as liquid fuels, and combined heat and power production from energy crops. The future of biomass electricity generation lies in biomass integrated gasification/gas turbine technology, which offers highenergy conversion efficiencies.
8	Ayhan (21) 2004	Potential applications of renewable energy sources, biomass combustion problems in boiler power systems and combustion related environmental issues.	Describes the potential applications of renewable energy sources to replace fossil fuel combustion as the prime energy sources in various countries, and discusses problems associated with biomass combustion in boiler power systems.	The issue of combustor fouling and corrosion caused by the alkaline nature of the biomass ash needs attention. Fouling of combustor surfaces is a major issue that has played an important role in the design and operation of combustion equipment. Fouling and corrosion problems are presented by high temperature. practical pulverizer performance needs to be

				examined. Biomass may require separate pulverizers to achieve high blend ratios and good combustion performance.
9	Wang 2017 (22)	Thermochemical processing of sewage sludge to energy and fuel	Study about options of converting sewage sludge to energy and fuel via three main thermochemical conversion processes namely pyrolysis, gasification and combustion.	The traditional methods of sewage sludge disposal are no longer feasible, both economically and environmentally. Thermochemical process, not only incineration, but also pyrolysis and gasification, can be a dominant method of sewage sludge disposal in the near future.
10	Mook 2014 (23)	Prospective applications of renewable energy based electrochemical systems in wastewater treatment	The electrochemical technology used in wastewater treatment covering its advantages such as its high removal efficiency, clean energy conversions, low environment impact, easy operation and compact design.	Combination of electrochemical methods with PV solar cell is a novel technological approach to enhance the sustainability of waste-water treatment processes. Studies on saving the utility cost by using PV electrochemical system

				for treating different wastewater could a new scope for research.
11	Fytili 2006 (24)	Utilization of sewage sludge in EU application of old and new methods	It review past and future trends in sludge handling, focusing mainly at thermal processes (e.g. pyrolysis, wet oxidation, gasification) and the utilization of sewage sludge in cement manufacture as a co-fuel.	There are several factors restricting the options, such as the accumulation of undesirable substances to sludge (e.g., heavy metals, pathogens and organic pollutants) which potentially passes to food-chain. Therefore agricultural use is increasingly regarded as an insecure handling route. The other conventional route, sludge disposal in landfills is eliminating due to EU recent legislation and increased costs.
12	Zamalloa 2010 (25)	The techno-economic potential of renewable energy through the anaerobic digestion of microalgae	The potential of microalgae as feedstock for methane production is evaluated from a process technical and economic point of view. Production of mixed culture algae in	From the technical point of view, the use of high rate anaerobic digesters reaching 10–20 kg COD m_3 d_1, productivities of minimum 90 ton DM ha_1 a_1 and a percentage VS

			raceway ponds on non-agricultural sites, such as landfills, was identified as a preferred approach	fermented of 75% will be crucial to exploit the potential of microalgae biomass for production of commodity kWh-energy. From the economic point of view, a feed-in tariff of €0.133 kWh_1, rewarding thermal and electrical energy on an equal basis, plays a major role in the profitability of the project, in contrast to the carbon credit of €30 ton_1CO2(eq), which only delivers 4% of the revenues.
13	Perry 2008 (26)	Integrating waste and renewable energy to reduce the carbon footprint of locally integrated energy sectors Simon Perry	Total Site targeting, have been applied to locally integrated energy sectors.It can be successfully applied to integrate renewables into the energy source mix and consequently reduce the carbon footprint of these locally integrated energy sectors.	local sources are unable to provide the demands for all of the units in the system, then district renewable sources can be provided. These again would include larger scale wind turbines, solar cell systems. large-scale heat pumps, and combustors using waste provided by

				the units or fossil or bio-fuels. The sources at this level would include power-generating equipment such as steam turbines or gas turbines.

Different treatment technologies are applied for the removal of the undesired substances from waste water (mechanical treatment in screens, sieves and filters, biological treatment in activated sludge and/or biofilm systems, advanced treatment in membranes or the like). All treatment technologies consume certain amounts of electric and thermal energy. The majority of the energy demand is usually provided by external public suppliers, while a smaller part can be produced at the WWTP itself. Anaerobic sludge treatment at WWTPs equipped with digesters produces sewage gas. Today, the electrical and thermal energy gained from sewage gas combustion and solar energy can be used at the STP for making it self dependent.

1.10 GAPS IDENTIFIED

1. The renewable energy is very less used in the sewage treatment plant.
2. Energy from biogas is not properly used for energy conservation in STP.
3.Energy from solid waste in grit chamber and screen bar is never used.
4. The profile for load is taken constant for whole year. Change in load profiles with different weather is not taken into account for calculation of size of renewable energy system.
5. The solar energy is usedmostly for dewatering of waste sludge & desalination purposes but no work has been done on using SPV power for the operation of STPs.
6. In India most of the STPs are going through untimely power failures and creating problems in the continuous operation of the STP this can be reduced using renewable energy which is a new concept for Indian STPs .

1.11 OBJECTIVES

1. To identify and select STP of nearby area.

2. To study the pattern of power failure and energy consumption by observing data’s of electric bills and D.G set.

3. To collect the primary data and estimate the load and resources.

3. To collect the land availability data for the mounting of the SPV system.

4. To collect the solar radiation data, compute the solar energy potential and design the SPV system.

5. To calculate the amount of energy recoverd from biogas.

1.12 METHODOLOGY TO BE ADOPTED

The advantage of grid interconnection of photovoltaic power generation system is more effective utilisation of generated power. However to ensure the safety of the PV installer and the reliability of the utility grid the technical requirements from both the utility power system grade side and the PV system site need to be satisfied. Clarification of the technical requirement for grid interconnection and then solving the problem are there for very important issues for widespread application of PV systems.

Grid interconnection of PV system is done with the help of inverter which convert DC power generated from PV module to AC power used for ordinary power supply for Electrical equipments inverter system is does very important for grid connected PV systems.

In order to have reliable and safety grid interconnection operation of PV system inverter technology is very important in water technologies also required to generate high quality power to AC utility system with reasonable cost. In order to in order to meet the requirements up to date Technologies of power electronics are applied for PV inverters. For example by means of high frequency switching of semiconductor devices with pulse width modulation Technologies high-efficiency conversion with high power factor and low harmonic distortion power can be generated point however the reduction of inverter system cost is to be accomplished.

The greatest influence on system cost depends on the amount of PV module installed. And the other factors include maximum power demand location type and quality of equipment extent of automatic controls and metering provision of suitable accommodation for equipment and the amount of wiring needed the cost of grid connected PV system where is considered only the sizing of SPV system can be done as follows:

1. Selection of modules.
2. Analysis of solar radiation data and total power generated by the incident solar radiation at the given area.
3. Photovoltaic array sizing.
4. Selection of inverter

5. Selection of transformer

6. Selection of fuse and protecting devices

The biogas part of a WWTP comprises a series of steps, in short, starting with sewage sludge pretreatment, followed by the AD process and biogas production, and ending with post-treatment of the digested sludge and the gas, as schematised in Figure 2.1

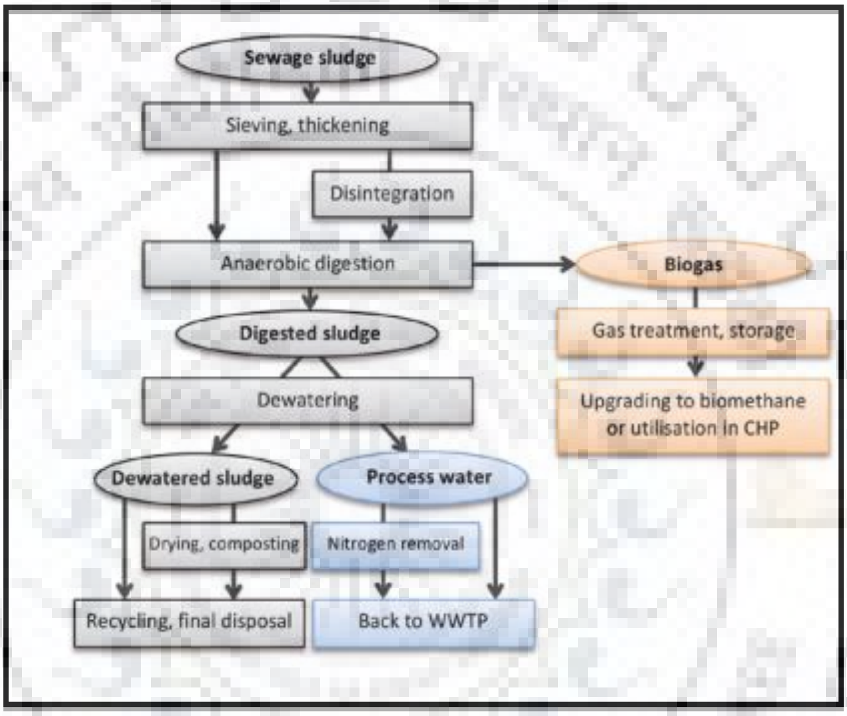

Fig 1.9 Steps for biogas generation in STP (28)

Chapter 2

Selection of STP and data collection

2.1 LOCATION OF STP

The sewage treatment plant which is selected for the integration of renewable energy is 27 MLD sewage treatment plant at Jagjeetpur, HaridwarUttarakhand The plant was located at Latitude of 29.950N and Longitude of 78.1640E and at the Elevation of 314 meters from sea level in district JagjeetpurHaridwar, Uttarakhand [27].Temperature in summer varies from 34 °C to 46 °C and in Winter from 5°C to 15.8°C . The monsoon rains occurs mostly in the summer. The wind speed varies remains between 3m/s to 5m/s. And humidity has an average of 39% to 86%.

The plant works on Sequencing Batch Reactors (S.B.R) technology. SBR reactors treats wastewater sewage or output from anaerobic digesters or mechanical biological treatment facilities in batches. Oxygen is bubbled through the mixture of wastewater and activated sludge to reduce the organic matter (measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD)). The treated effluent may be suitable for discharge to the river Ganga . It was basically constructed with the help of government of Uttarakhand under the department of Uttarakhandpeyjalnigam .This work is done by the government of Uttarakhand by considering pollution abatement of river ganga within Uttarakhand state.

The objectives of the STP are:

1. To improve water quality of Ganga.

2. Reducing Biochemical Oxygen Demand (BOD) & Faecal Coliforms.

3. Increasing Dissolved Oxygen (DO) parameter.

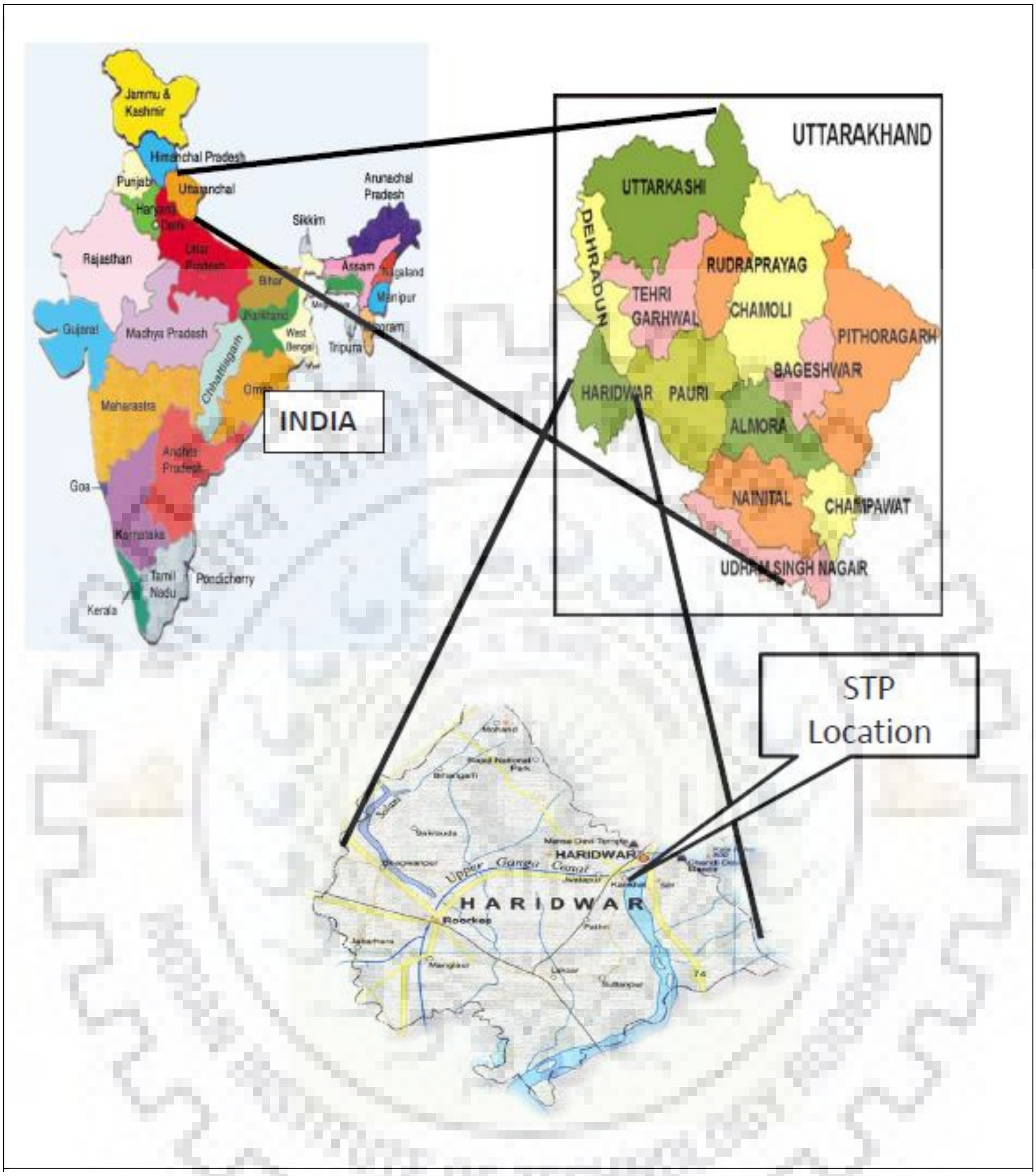

Fig 2.1 LOCATION OF THE STP (27)

Fig 2.2 27 Mld sewage treatment plant JagjeetpurHaridwar(27)

2.2 PLANT LAYOUT

The path of flow of water in the plant is shown in the block diagram and the stages of treatment of waste water. Firstly the Primary treatment process comprises of temporarily holding the sewage in a still basin where heavy solids goes to the bottom while oil, grease and lighter solids float to the surface after that the Secondary treatment removes dissolved and suspended biological matter. And finally in tertiary treatment chlorination is done. There are different unit for handling of the sludge the sludge is collected and then dried and finally disposed off.

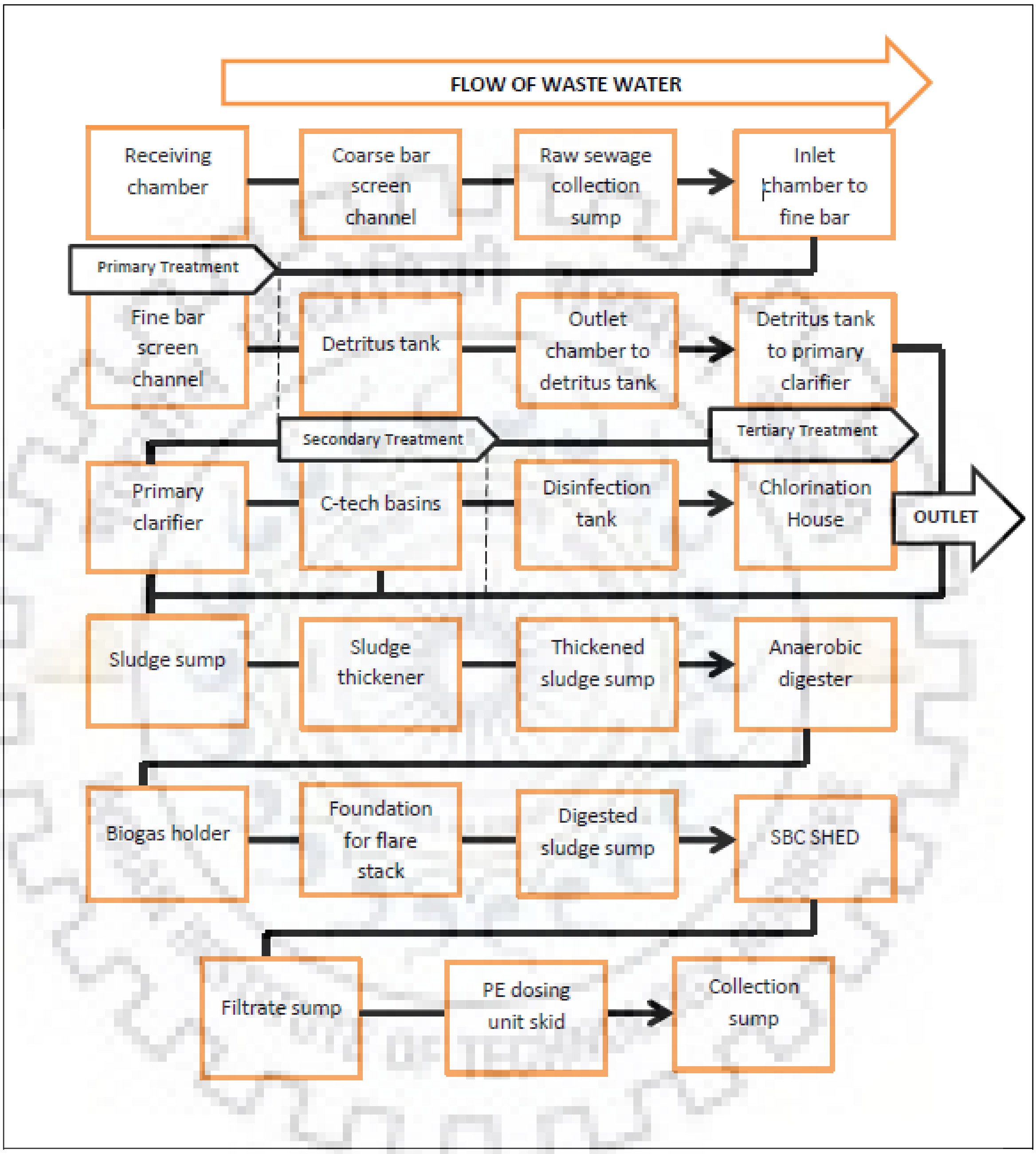

Fig 2.3 Flow chart of 27 mld sewage treatment plant (4)

The above figure shows the block diagram of the flow of water in the plant from the inlet to the outlet of the plant there are 3 stages of the treatment of the water in the plant primary, secondary and tertiary treatment process .and for handling and disposing of sludge there is other system in the plant.

The plant layout design is collected from the site and help in determining the dimensions of the land availability in the plant which is necessary for the mounting of SPV system. To set up SPV system it is most important to consider a shadow free land availability, which is away from nearby tall objects, tree or tall building. It will ensure the optimum solar energy generation from the solar array during the peak sun hours.

2.3 LOAD ESTIMATION OF THE PLANT

The load data contains the detail about the appliance to be powered and their quantity, power rating, nominal operating voltage, and number of operating hours in a day. The load required to electrify the whole plant has been estimated by collecting data by personal visit to the plant. Power demand for the plant is estimated by calculating the number of pumps their rating and correspondingly their operating hours on the daily basis and the calculation for the total demand for the plant is calculated.

Load demand is calculated by using the following expression :

Total load demand= Rating of the appliance x No of appliance x Operating hours Wh/day.

The following table shows the various electric energy consuming equipment's in the plant and the load demand in the plant. And the table is helpful in the load estimation of the plant.

Table 1 Energy consumption of various components of STP

S.No	Name of pump	No	Total demand (KWh/day)
1	Corse screen bar	2	74
2	Conveyor belt	1	35
3	M.P.S pump	2	2650
4	M.P.S pump	3	6830
5	Screen bar	2	52
6	Conveyor belt	1	38
7	Grit separator	2	70
8	Organic return pump	2	34
9	Classifier	2	53
10	Classifier	2	72
11	Inlet gate	4	3
12	Process air valve	4	1
13	Ras pump	4	248
14	SAS pump	4	45
15	Sas pump valve	4	0.35

16	Decanter	4	12.4
17	T T water pumps	2	2155
18	Chlorine booster pumps	2	264
19	Selection air valve	4	0.1584
20	SBC	2	220
21	SBC poly dosing pump	2	36
22	SBC agitator	2	22
23	MST 01	1	18
24	Thickner poly dosing pump	3	26. 64
25	Thickner agitator	3	108
26	air blower for digester	4	17.6
27	digester feed pump	1	3.3
28	digester feed pump	1	6.6
29	centrifugal pump	2	2.25
30	thickener feed pump	1	37
31	thickener feed pump	1	22
32	Air blower for sludge pump	2	14.8
33	air blower for C tech	6	8550
34	cooling fan for air blower	4	52.8
35	LED fitting	42	17.64
36	sodium bulb	30	37.5
37	street light	8	12

The total electricity consumed is 4954.25kWh/daysay 148620kWh/month

2.4 ENERGY CONSUMPTION DATA OF THE PLANT

Electricity consumption if the plant depends upon the following factors:

i. Location and topography of the service area.

ii. Plant size.

iii. Treatment process used.

iv. Age and condition of water transmission system.

The electricity consumption data for the plant is collected through the monthly electricity bills of the plant.

Table 2 Electricity consumption

Month	Electricity consumed (kwh) (monthly)	Deficient (Consumed-Avg value)
Aug 17	186316	37696
Sep 17	182680	34060
Oct 17	187720	38600
Nov 17	189412	40972
Dec 17	169996	21376
Jan 18	162760	14140
Feb 18	149308	10688
March 18	169732	21112
April 18	168712	20092
May 18	173380	24760
June 18	181948	33328

The electricity consumption data of the previous months shows that the electricity consumption increases during the summer compared to winter due to consumption of more water during the summer which leads to generate more sewage compared to the winter.

Cost of the electricity varies according to the consumption of the electricity in the plant. The following table shows the cost of the electricity of the plant of the past months.

Table 3 Electricity cost

Month	Cost (Rs)
Aug 17	905477.24
Sep 17	885620.28
Oct 17	835408.54
Nov 17	816580.34
Dec 17	705867.64
Jan 18	715200.78
Feb 18	725163.04
March 18	791001.68
April 18	856840.36
May 18	876565.24
June 18	915654.76

2.5 ENERGY CONSERVATION THROUGH BIOGAS

In the absence of air, anaerobic bacteria digest the bio-solids, producing "biogas", a mixture of methane and carbon dioxide. Methane is the main component of natural gas, and the biogas produced, can be burnt in an engine or turbine to produce power and generate electricity. In this way, anaerobic treatment can generate electrical energy used in the sewage treatment plant.

Table 4 : Estimation of power generation from the digester(28)

Item	Value
Average amount of Gas Generated From 27 MLD Plant	2400m3/DAY, 100m3/ hr
Gas consumption for 1000 Kwh	In the range of 1300-1400 Nm3 (depending on the methane in produced gases)
Calorific Value of Gas	5000 TO 5600 KCAL/M3 (Av value 5300 KCAL/ M3)
1000 KCAL	= 1.163 Kwh
Total Heat Energy of 100 m3	530000Kcal/hr
Total energy in kw hour	616.9Kwh
Efficiency of biogas engine and generator	28 % and 95% respectively
Electrical Energy can be produced	164 Kwh say 150 (3600unit/day)

2.6 LAND AVAILABILITY FOR DESIGN OF SPV SYSTEM

To set up SPV array it is most important to consider a shadow free land, which is away from nearby tall objects, tree or tall building. It will ensure the optimum solar energy generation from the solar array during the peak sun hours. The area calculated for sitting various components of SPV System is shown in table 5.

Table 5 Available area for SPV installation

S.NO	Structures	Dimensions (m)
1	Pump & blower room	5.0 x 10.0 x 4.0
2	MCC Room-3	3.5x5.5x4.0
3	Anaerobic digesters (existing)	18.00 x 7.9 LD
4	Pump & blower room	5.0 x 15.0 x 4.0

5	Chlorine house	10.0 x 8.0 x 5.5
6	Blower room for c-tech	23.0 x 6.5 x 5.5
7	Control room for digester & gas holder	4.0 x 4.0x5.5
8	Laboratory	4.0 x 5.0x4.0
9	Toilet block	4.0 x 4.5x4.0
10	Biogas engine / dg set room	15 x 8.0 x 4.5
11	Substation / control room	8.0 x 15.0 x 4.0
12	HT room	4.5 x 8.0 x 4.0
13	Transformer yard	19.50 x 6.5 x 4.5
14	Workshop	5.0 x 4.0 x 4.0
15	Tool room	5.0 x 4.0 x 4.0
16	Security cabin	4.0 x 3.0 x 4.0
17	Toilet block	4.0 x 3.0 x 4.0
18	PE dosing unit skid	9.5 x 5.5 x 5.0
19	Administrative building	20 X 15 x 5.0

From the above table the total area is calculated as 1531 m2where the solar photovoltaic system can be installed.This area is used for the calculation of the solar potential at that location that can be used to calculate the energy availability from incoming solar radiation.

- **Load**: Stands for the network associated with appliances that are nourished from theinverter, or alternatively, from the grid.
- **Meters**: They measure the energy being taken from or fed to the local supplynetwork.
- **Protective devices:** Some protective devices is also installed, like under voltagerelay, circuit breakers etc. for resisting power flow from utility to SPV system**.**
- **Other devices:** Additional devices like ac filter, dc-dc boost converter, also used forimprove the performance of system.

3.3 SELECTION OF MODULE

Selection of solar photovoltaic module depends upon the solar cell technology and module parameter such as efficiency of solar cell ,short circuit current (I_{SC}), open circuit voltage (V_{OC}) ,fill factor, nominal operating cell temperature (NOCT) and peak power (W_p) for each solar panel.

3.3.1 Selection of SPV modules

Selection of particular solar cell depends upon the characteristic of cell, availability and cost .SANYO HIT-215NHE5 (Hetero-junction with Intrinsic Thin layer) PV modules are chosen for the sewage treatment plant. The solar cell of the module is made of a thin mono crystalline silicon wafer surrounded by ultra-thin amorphous silicon layers. The solar cell gives high performance at high temperatures. HIT can generate more annual power output per unit area than other conventional crystalline silicon solar cells. Special Features SANYO HIT solar modules are 100% emission free, have no moving parts and produce no noise. The dimensions of the HIT modules allow space-saving installation and achievement of maximum output power possible on given roof area [39].

3.3.2 Solar PV module parameter

For this project 215 W_p indigenous mono crystalline solar module has been selected table 6 gives the information about the module parameters. Solar module parameters are given at standard test conditions (STC); solar radiation 1000 w/m^2., cell temperature 25^{0}C and air mass 1.5 AM.

Table 6: Module parameters [39]

Module Parameters	Units	Values
Maximum power (P_{max})	W	215.0
Max. power voltage (V_{pm})	V	42.0
Max. power current (I_{pm})	A	5.12
Open circuit voltage (V_{OC})	V	51.3

Short circuit current (I_{SC})	A	5.60
Warranted minimum power (P_{min})	W	204.4
Output power tolerance	%	-2.0
Maximum system voltage	V_{dc}	1000
Temperature coefficient ofP_{max}	%/°C	−0.3
Temperature coefficient ofV_{oc}	V/°C	−0.13
Temperature coefficient of I_{SC}	mA/°C	1.69
Dimensions L x W x H	mm	1570 x 798 x 35
Weight	kg	15.0

To calculate the number of modules and theirseries and parallel connections, the solar energy potential at the STP plant is first calculated according to the availability of the land. Thereafter the module calculation can be done.

3.4 SOLAR RADIATION

Incoming solar radiation (insolation) originates from the sun, is modified as it travels through the atmosphere, is further modified by topography and surface features, and is intercepted at the earth's surface as direct, diffuse, and reflected components. Direct radiation is intercepted unimpeded, in a direct line from the sun. Diffuse radiation is scattered by atmospheric constituents, such as clouds and dust. Reflected radiation is reflected from surface features. The sum of the direct, diffuse, and reflected radiation is called total or global solar radiation.

To find out the solar potential available at Jagjeetpur district of HARIDWAR, the solar radiation over different months measured. Then the diurnal variations, average monthly output, yearly output are find out and related graphs are plot for showing the variation in different season and time.

3.4.1 Measured solar radiation data

The Global Horizontal Irradiation Data which is Available at National Renewable Energy Laboratory (NREL) to the geographical coordinate latitude 29.9457° north and longitude 78.1642° East at the tilt angle 29.1^0 has been used for the study purpose. The solar radiation data is taken for the months (January to December) of year 2018. The solar radiation data are collected and calculated the SPV potential for all the months. The diurnal variation for twelve months & are plotted. From that the monthly output and yearly output are calculated. Also observing the peak value in different days, the monthly average peak is calculated and variation of the monthly peak is plotted for a year and the average annual peak is calculated. Input solar radiation means how much amount of solar radiation is coming from sun and Output solar radiation means how much amount of solar radiation we can utilize to generate electricity which is depends upon the efficiency of the PV module. For calculating the output the efficiency of the PV module is taken as 17.20 %. Chosen area for the estimated plant capacity is considered as 1480 m².

3.4.2 Average solar radiation at different time interval for month

The calculation for the average solar radiation for the various month of the year is calculated by multiplying input solar radiation at of a particular time at different days with the module efficiency which will give the output solar radiation then the total solar radiation is calculated by adding the output solar radiation and then the average solar radiation is according to the number of days in that particular month.

Here below the tables shows the average solar radiation W/m^2 for various months.

Table 7 Average solar radiation output (W/m^2) at different time interval for months of year 2018

Time / Month	9.00 AM	10.00 AM	11:00 AM	12.00 PM	1.00 PM	2.00 PM	3.00 PM	4.00 PM
January	65.77	91.77	108.38	113.6	106.94	89.12	62.05	29.6
February	77.58	105.58	123.17	130.09	124.11	106.28	78.57	44.89
March	100.68	128.82	146.43	151.92	144.77	125.63	96.33	60.06
April	121.82	148.16	163.8	167.41	158.69	138.4	108.36	71.58
May	126.27	150.3	162.57	167.11	158.43	139.03	110.61	75.99
June	119.99	143.18	157.09	160.51	153.06	135.41	109.1	76.8
July	112.46	135.81	150.26	154.43	147.93	131.37	106.24	75.08
August	109.91	134.35	149.3	152.36	146.15	128.31	101.49	68.54
September	106.49	130.85	144.96	147.43	138.08	117.72	88.33	53.29
October	92.11	115.11	127.6	128.3	117.13	95.24	64.96	30.61
November	92.11	115.11	127.6	128.3	117.13	95.24	64.96	30.61
December	82.13	105.23	117.68	118.15	106.64	84.25	52.65	19.75

Average solar radiation output (W/m^2) at the different time interval of the month shows that the month of April gives the maximum monthly energy output and the month of December gives minimum solar radiation during the period January 2018-december 2018. Now these data are used to calculate monthly and yearly outputs of solar radiation. The monthly peak, the average peak output is used to estimate of the possible plant rating is done.

3.5 DIURNAL VARIATIONS FOR MONTHS OF YEAR 2018

The table below displays us the diurnal variation for the various months of year 2018. The average solar radiation obtainable for whole month at different time interval of day is shown in second column. From this data we calculated the daily energy output and then monthly energy output is calculated in Watts-hour per mtr^2. This means number of watts acting on one mtr^2 area over a period of 1 hour. The daily energy output is calculated by adding average output solar radiation for different time interval of day. Monthly energy output is calculated by multiplying the number of days of month with the daily energy output.

3.5.1 Diurnal variations tables (January 2018 to December 2018)

Table 8 Diurnal variation for January month

Time	Average output solar radiation	Average output solar radiation in Hour	Daily energy Output	Monthly energy Output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	65.77	65.77		

10.00 AM	91.77	91.77	667.23	20684.13
11:00 AM	108.38	108.38		
12.00 PM	113.6	113.6		
1.00 PM	106.94	106.94		
2.00 PM	89.12	89.12		
3.00 PM	62.05	62.05		
4.00 PM	29.6	29.6		

Daily and monthly energy output is calculate and comes out to be 667.23 watts-h /m^2 and 20684.13 watts-h /m^2 respectively for the month of January. The monthly energy is used to calculate the average yearly output of solar radiation.

Table 9 Diurnal variation for February month

Time	**Average output solar radiation**	**Average output solar radiation in Hour**	**Daily energy output**	**Monthly energy output**
	watts /m^2	**watts-h /m^2**	**watts-h /m^2**	**watts-h /m^2**
9.00 AM	77.58	77.58	709.27	19859.56
10.00 AM	105.58	105.58		
11:00 AM	123.17	123.17		
12.00 PM	130.09	130.09		
1.00 PM	124.11	124.11		
2.00 PM	106.28	106.28		
3.00 PM	78.57	78.57		
4.00 PM	44.89	44.89		

Daily and monthly energy output is calculate and comes out to be 709.27 watts-h /m^2 and 19859.56 watts-h /m^2 respectively for the month of February.

Table 10 Diurnal variation for March month

Time	Average output solar radiation	Average output solar radiation in Hour	Daily energy Output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	100.68	100.68	954.64	29593.84
10.00 AM	128.82	128.82		
11:00 AM	146.43	146.43		
12.00 PM	151.92	151.92		
1.00 PM	144.77	144.77		
2.00 PM	125.63	125.63		
3.00 PM	96.33	96.33		
4.00 PM	60.06	60.06		

Daily and monthly energy output is calculate and comes out to be 954.64 watts-h /m^2 and 29593.84watts-h /m^2 respectively for the month of March.

Table 11 Diurnal variation for April month.

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	121.82	121.82		
10.00 AM	148.16	148.16		
11:00 AM	163.8	163.8		

12.00 PM	167.41	167.41	1078.22	32346.6
1.00 PM	158.69	158.69		
2.00 PM	138.4	138.4		
3.00 PM	108.36	108.36		
4.00 PM	71.58	71.58		

Daily and monthly energy output is calculate and comes out to be 1078.22watts-h /m^2 and 32346.6 watts-h /m^2 respectively for the month of April.

Table 12 Diurnal variation for May month.

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	126.27	126.27	1090.31	33799.61
10.00 AM	150.3	150.3		
11:00 AM	162.57	162.57		
12.00 PM	167.11	167.11		
1.00 PM	158.43	158.43		
2.00 PM	139.03	139.03		
3.00 PM	110.61	110.61		
4.00 PM	75.99	75.99		

Daily and monthly energy output is calculate and comes out to be 1090.31 watts-h /m^2 and 33799.61 watts-h /m^2 respectively for the month of May.

Table 13 Diurnal variation for June month.

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	119.99	119.99	1055.14	31654.2
10.00 AM	143.18	143.18		
11:00 AM	157.09	157.09		
12.00 PM	160.51	160.51		
1.00 PM	153.06	153.06		
2.00 PM	135.41	135.41		
3.00 PM	109.1	109.1		
4.00 PM	76.8	76.8		

Daily and monthly energy output is calculate and comes out to be 1055.14watts-h /m^2 and 31654.2watts-h /m^2 respectively for the month of June.

Table 14 shows us the diurnal variation for July month.

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	112.46	112.46	1013.58	31420.98
10.00 AM	135.81	135.81		
11:00 AM	150.26	150.26		
12.00 PM	154.43	154.43		
1.00 PM	147.93	147.93		

2.00 PM	131.37	131.37		
3.00 PM	106.24	106.24		
4.00 PM	75.08	75.08		

Daily and monthly energy output is calculate and comes out to be 1013.58 watts-h /m^2 and 31420.98watts-h /m^2 respectively for the month of July.

Table 15 Diurnal variation for August month

Time	**Average output solar radiation**	**Average output solar radiation in hour**	**Daily energy output**	**Monthly energy output**
	watts /m^2	**watts-h /m^2**	**watts-h /m^2**	**watts-h /m^2**
9.00 AM	109.91	109.91	990.41	30702.71
10.00 AM	134.35	134.35		
11:00 AM	149.3	149.3		
12.00 PM	152.36	152.36		
1.00 PM	146.15	146.15		
2.00 PM	128.31	128.31		
3.00 PM	101.49	101.49		
4.00 PM	68.54	68.54		

Daily and monthly energy output is calculate and comes out to be 990.41watts-h /m^2 and 30702.71 watts-h /m^2 respectively for the month of August.

Table 16 Diurnal variation for September month

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	106.49	106.49	927.15	27814.5
10.00 AM	130.85	130.85		
11:00 AM	144.96	144.96		
12.00 PM	147.43	147.43		
1.00 PM	138.08	138.08		
2.00 PM	117.72	117.72		
3.00 PM	88.33	88.33		
4.00 PM	53.29	53.29		

Daily and monthly energy output is calculate and comes out to be 927.15 watts-h /m^2 and 27814.5 watts-h /m^2 respectively for the month of September.

Table 17 Diurnal variation for October month.

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy Output	Monthly energy output
	watts /mtr^2	watts-h /mtr^2	watts-h /mtr^2	watts-h /mtr^2
9.00 AM	92.11	92.11	771.06	23902.86
10.00 AM	115.11	115.11		
11:00 AM	127.6	127.6		
12.00 PM	128.3	128.3		
1.00 PM	117.13	117.13		
2.00 PM	95.24	95.24		
3.00 PM	64.96	64.96		
4.00 PM	30.61	30.61		

Daily and monthly energy output is calculate and comes out to be 771.06watts-h /m^2 and 23902.86watts-h /m^2 respectively for the month of October.

Table 18 Diurnal variation for November month.

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	82.13	82.13	686.48	20594.4
10.00 AM	105.23	105.23		
11:00 AM	117.68	117.68		
12.00 PM	118.15	118.15		
1.00 PM	106.64	106.64		
2.00 PM	84.25	84.25		
3.00 PM	52.65	52.65		
4.00 PM	19.75	19.75		

Daily and monthly energy output is calculate and comes out to be 686.48 watts-h /m^2 and 20594.4 watts-h /m^2 respectively for the month of November.

Table 19 Diurnal variation for December month.

Time	Average output solar radiation	Average output solar radiation in hour	Daily energy output	Monthly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
9.00 AM	67.27	67.27	617.82	19152.42
10.00 AM	91.29	91.29		
11:00 AM	105.37	105.37		
12.00 PM	107.92	107.92		
1.00 PM	98.73	98.73		
2.00 PM	78.73	78.73		
3.00 PM	50.29	50.29		
4.00 PM	18.22	18.22		

Daily and monthly energy output is calculate and comes out to be 617.82 watts-h /m^2 and 19152.42watts-h /m2 respectively for the month of December. The daily and monthly solar radiation increases from January till April and reaches maximum in April and then gradually starts decreasing from may till December and minimum value is in the month of December.

3.6 TOTAL OUTPUT FROM THE SOLAR RADIATION

The average yearly energy output is calculated by multiplying average monthly energy output with total number of month 12. The daily energy output also found for various months shown in 2nd column. And then monthly energy output is calculated by multiplying the no of days of month with the daily energy output as shown in 3rd coulomb for the various months. Kilowatt-Hour (kWh) means 1000 thousand watts acting over a period of 1 hour.The kWh is a unit of energy. 1 kWh=3600 kJ.

Table 20 Average yearly energy output from solar radiation

Months	Daily energy Output	Monthly energy output	Average monthly energy output	Average yearly energy output
	watts /m^2	watts-h /m^2	watts-h /m^2	watts-h /m^2
JANUARY	667.23	20684.13		
FEBRUARY	709.27	19859.56		
MARCH	954.64	29593.84		

APRIL	1078.22	32346.6	26793.8	321525.8
MAY	1090.31	33799.61		
JUNE	1055.14	31654.2		
JULY	1013.58	31420.98		
AUGUST	990.41	30702.71		
SEPTEMBER	927.51	27814.5		
OCTOBER	771.06	23902.86		
NOVEMBER	686.48	20594.4		
DECEMBER	617.82	19152.41		

The average value of the monthly energy output comes out to be 26793.8 Watt-h/m^2 and the average yearly energy output comes out to be 321525 watts-h/m^2.

3.7 PEAK VARIATION AND POSSIBLE PLANT RATING

Table 21 Peak value of solar potential for the different months

Months	Peak output	Average peak output	Average peak per 1480 m^2 area	Possible plant capacity
	watts/m^2	watts/m^2	watts	Kilowatts
JANUARY	113.6	141.6	209571.7	210
FEBRUARY	130.09			
MARCH	151.92			
APRIL	167.41			
MAY	167.11			
JUNE	160.51			
JULY	154.43			
AUGUST	152.36			
SEPTEMBER	147.43			
OCTOBER	128.3			
NOVEMBER	118.15			
DECEMBER	107.92			

For the overall months is 141.6 Watts/m^2 is Average peak solar radiation output. and we have 1531 m^2 area which is available out of which approximate 1480 m^2 areas are obtainable for installation of array for solar power plant. So the possible plant rating can be calculated by multiplying average peak solar radiation value 141.6 Watts/m² with available area 1480 m², we get 209571.7 Watts. So predicted plant rating in Kilowatt is 210 Kilowatt.

3.8 SOLAR PV ARRAY SIZING

Individual solar PV modules are connected in series and parallel combination to form solar PV array to achieve the required power output. For the calculation firstly we have to determine the total power can be generated by the incoming solar radiation at the STP for the given area in the plant.

$$\text{Number of PV Modules} = \frac{\textit{Total peak watt}}{\textit{Individual module peak watt}}$$

$$\text{Total number of modules} = \frac{210000}{215}$$

$$=976 \text{ modules}$$

Here the total no of modules that can be placed in the given area comes to be 976 modules. But we can take it 980 modules for the sizing purpose which make can be helpful in making the series and parallel combination of the modules and fulfill the requirement of invertor input.

3.8.1 Solar panel connection: modules in series (Ns)

Number of modules connected in series is known as one string. Opposite polarity of individual modules are connected together in series to enhance the voltage output .In series connection voltage get added up in the string but the current of the string will be the same as individual module. In series combination identical current rating is preferred, voltage can be different for each module. Number of modules in parallel combination can be estimated by using following expression.

$$\text{Number of modules in strings} = \frac{\textit{PV System Voltage}}{\textit{Unit module voltage}}$$

3.8.2 Solar panel connection: modules in parallel (N_p)

PV modules are connected in parallel to increase the current output to get the required power output to supply for the connected load .voltage of parallel connection module will be same as the individual module or the voltage of the string .In parallel connection same polarity of module connected together to form parallel connection; positive end to positive end ,negative terminal to negative terminal . It is most important that all modules have identical voltage in parallel connection .Individual modules or strings can be connected parallel to get the required current output. Number of modules in series combination can be estimated by using following expression.

$$\text{Number of strings} = \frac{\text{Total number of modules}}{\text{number of modules in a string}}$$

Now to form a solar photovoltaic power plant 980 modules are connected in series-parallel combination.

20 modules are connected in series and there are 7 parallel paths of 20 modules each connected with each other. And such a set of 7 combinations are made in which 20 modules are connected in series with 7 parallel path connected with each other. It also supports the fact that these 980 modules can be accommodates within 1480 m^2 available area. And the arrangement is such that the inverter input is maintained. As 20 modules are connected in series and each module is of 42 volts so the total output voltage of one string is 20 x 42 = 840 V. And here we have 7 string connected in parallel and each module have current output of 5.13 A. So the total current output comes to be 7 x 5.13= 35.91 A. And we have total such 7 set of connections so now according to PV output the inverter selection has to be done. This 840 Volts dc output from solar photovoltaic structure is the input of 3 phase inverter and it will convert the dc voltage into ac voltage.

VII. Efficiency.

VIII. No load power consumption.

IX. Surge power.

X. Output wave form

Inverter DC input voltage has to be matched with the PV array Output voltage and the output voltage of the inverter must be matched with the nominal load voltage. For the supply of the voltage to the system before that transformer is fitted so that the fluctuation in current and voltage can be minimised in the grid tied system.

Solar edge extended power three phase 25 kVA inverter is use for the SPV system the inverter has in built maximum power point tracking system. Specifically designed to workwith power optimizers Having Superior efficiency of (98%) , Small, lightest in its class, and easy to install Built-in module-level monitoring Internet connection through Ethernet or Wireless Fixed voltage inverter, DC/AC conversion only. The input specifications and the output specifications of the inverter are given in the table below.[40]

Table 22 Input specifications of inverter

Input Inverter Parameter	Value	Unit
Maximum DC Power (Module STC)	33750	W
Transformer-less, Ungrounded	Yes	
Maximum Input Voltage	900	Vdc
Nominal DC Input Voltage	750	Vdc
Maximum Input Current	37	Adc
Reverse-Polarity Protection	Yes	
Ground-Fault Isolation Detection	700 kΩ Sensitivity	
Maximum Inverter Efficiency	98.3	%
European Weighted Efficiency	98	%
Night time power consumption	<4	W

Table 23 Output specifications of inverter

Output Inverter Parameter	Value	Unit
Rated AC Power Output	25000	VA
Maximum AC Power Output	25000	VA
AC Output Voltage - Line to Line / Line to neutral (nominal)	380/220; 400/230	Vac
AC Output Voltage - Line To Neutral Range	184-264.5	Vac
AC Frequency	50/60 +/-5	HZ
Maximum Continuous Output current per phase	38	A
Residual Current Detector /Residual Current Step Detector	300/30	mA
Grids Supported - Three Phase	3/N/PE(WYE with neutral)	V

As there are 7 set of connection therefore are 7 such inverter put in the system whose input voltage is 840 volt and input current is 35.91 Ampere. These inverter will convert the dc supply into 3 phase Ac supply which is further given to the transformer for boosting the AC voltage and maintain the output voltage according to requirement.

3.10 TRANSFORMER

Transformer is electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Electromagnetic induction produces an electromotive force inside a conductor which is exposed to time fluctuating magnetic fields. Transformers are used to increase or decrease the alternating voltages in electric power applications. Here transformer is used according to the output of the inverter and the rating of the inverter the output of the inverter is Line to Line / Line to neutral (nominal):380/220; 400/230 and the rating of one inverter is 25 kVA.

As there are 7 inverter of 25 kVA each so one transformer is fitted of 175kVA with the input of Line to Line / Line to neutral (nominal):380/220; 400/230. And the output can be made according to grid connection 11 kVA/440v load requirement by providing the taps in secondary winding of the transformer [41].

Others: Junction boxes, meters, distribution boxes, wiring materials, mountingmaterials, relays etc.

3.11 LIST OF COMPONENTS POWER WITH PV SYSTEM

The electricity generated through SPV system is used by the various components of the plant .The following are the component getting powered from SPV system

Table 24 Components powered by SPV system

S.NO	Name of pump	Numbers	Rating (kW)
1	COARSE SCREEN BAR	2	1.5
2	CONVEYOR BELT	1	1.5
3	M.P.S PUMPS	1	55
4	FINE SCREEN BAR	2	1.1
5	CONVEYOR BELT	1	1.5
6	AIR BLOWER FOR c-TECH BASIN	1	75
7	ORGANIC RETURN PUMP	2	0.75
8	CLASSIFIER 1	2	1.1
9	CLASSIFIER 2	2	1.5
10	T.T WATER PUMPS	1	45
11	CHLORINE BOOSTER PUMPS	2	5.5
12	THICKNER MST 01	1	0.75
13	THICKNER AGITATOR	3	1.5

As the SPV cannot satisfy the load demand of whole plant. The table shows the list of the equipment's and their quantity with rating that are powered by the Using the SPV system.

The total solar potential of the plant is 210kWp and the number of modules calculated is 980 modules which are connected in series and parallel to get the desired output there are 20 modules connected in series and 7 parallel strings are connected together and there are 7 such connection these connection are the input to the inverterwhich convert the DC suplly through the modules to the AC power supply which is supply to the transformer which removes the fluctuation of the voltage and maintain the output voltage supply the power is supplied to the load all the demand of the load is not satisfied by the SPV system so the remaing load get supply from the grid .Around 4.8 to 5 % of the electricity is provide by SPV system in the plant.

To estimate the life cycle cost of the grid connected solar photo voltaic system, cost of acquisition of all the equipment which are used to designing and operation of the power plant has to be considered.

4.2.1 Cost of the system

The cost of the SPV system consists the cost of the various items which together will enhance the generation of power output ,starting from generation (collection and conversion of sun rays) to the final power utilisation.in this work the main part of the system such as modules, inverter, mounting structure, electrical support ,transformer are considered.

- **Module cost**

  The cost of one SANYO HIT-215NHE5 (Hetero-junction with Intrinsic Thin layer) PV modules module is Rs 21,500 and total number of module used is 980 therefore total cost of modules = 30,265 x 980= Rs 2,96,59,700 [43].

- **Inverter cost**

  The cost of one 3 phase Solar edge extended power three phase 25 KVA inverter inverters 2,80,000 and the total number of inverter used is 7 therefore the total cost of the inverter

  =6 80,000 x 7 = Rs 47,60,000 [44].

- **Electrical work with material and commissioning**

  Cost of electronic items such as junction box, wires, DB, connectors, etc. is generally taken as 3 % of module cost = 0.03 x 2,10,70,000 = Rs 6,32,100.

- **Cost of structure supporters**

  The cost include Civil Work with Material Module Mounting, Shifting, Loading and unloading cost is 3100 Rs/kW therefore total cost is Rs 7,77,945 (including taxes) and the cost of Hardware Electro Plated & Foundation Bolt cost is 4500 Rs/ kW therefore total cost is Rs 11,29,275 (including tax) [45].

- **Cost of transformer**

  One transformer of 175 kVA is selected. And the cost of the transformer purchased from macroplastpvt. Ltd. is Rs 1,75,000.

- **Labour cost**

  Labour cost is calculated as 20 % of material cost therefore labour cost is Rs 74,26,804.

Table 25 Costs of materials

S.NO	Item	Total cost in INR
1	Modules	2,96,59,700
2	Inverter	47,60,000
3	Electrical work with material and commissioning	6,32,100
4	Cost of structure supporters	19,07,220
5	Transformer	1,75,000
6	Labour cost and miscellaneous items	74,26,804
	Total	4,45,60,824

Therefore the total cost of the designing of the SPV system is come out to be Rs 4,45,60,824.

4.2.2 Simple payback period

The SPP is the period which the invested money can be recovered or served .SPP can be explained as the mathematical product obtained after dividing the initial investment of the project with initial cost of energy saving of the system .It is simple in the calculation.

$$\text{Simple payback period} = \frac{\text{Initial investment cost}}{\text{Annual cost of energy savings}}$$

Data and the assumption taken as;

Load demand =210 kW_p.

The estimated working hours are 8 hrs/day

- price of the unit is 4 Rs/kWh.
- The efficiency of the power output 0.87
- Labour cost and other contingencies is 20% of material cost.

Therefor simple payback period can be calculated as;

$$\text{Simple payback period} = \frac{44560824}{210x365x8x4} = 18 \text{ years}$$

4.2.3 Estimation of life cycle cost

4.2.3.1 Estimation of the capital cost

Capital cost is the cost which is spent initially to purchase all the necessary equipment such as the solar photo voltaic panels, inverters, power conditioning units, junction boxes, distribution board, building cost, cost incurred in the transportation of material, erection of the system, design and engineering cost, and cost of spares. the capital cost of solar power plant is identified as 4,45,60,824INR. The current inflation rate in India is 9% and the general escalation 5% have been considered to estimate the life cycle cost analysis for this purpose of grid connected SPV syatem .life cycle cost analysis of the proposed grid connected system is considered as 20 years. But it may serve for 25 year also as per pannel and inverted life time. But here it has been taken lesser period for safer side .Present worth of capital cost has been estimated by using the following expression.

Present worth of capital cost = Capital cost x $\{\frac{1+GE}{1+DR}\}$

Present worth of capital cost = 44560824 x $\{\frac{1.05}{1.09}\}$

PWCC=Rs 4,29,25,565

Therefore the present worth of capital cost is estimated as Rs 4,29,25,565 or its life time of 20 years period.

4.2.3.2 LCC Fuel cost

There is no diesel generator used in this system, so there is no annual fuel cost in this proposed grid connected SPV system. Therefore LCC fuel cost =0

4.2.3.3 LCC Maintenance cost

The annual recurring cost, and the multiplies buy the factor which accounts for the discount rate, general escalation factor and life cycle terms. The LCC maintenance cost is computed by using following expression (5.4)

$$LCC = AMC * \left\{ \left(\frac{1+GE}{DR - GE} \right) \right\} \times \left\{ 1 - \left(\frac{1+GE}{1+DR} \right)^{Term} \right\}$$

Where,

AMC =Annual maintenance cost

Table 26 gives details breakout values of operation and maintenance cost to operate the proposed grid ties SPV system . It has been considered that two technical person at 2500 rupees as monthly salary per person are needed to work daily and one watchman is required for ward and watch. SPV array must be cleaned at least once in a week time , for these 500 has been considered as panel cleaning charge one labour is sufficient to clean them weekly at accost of 500 Rs per month . Rupees 1500 has been considered as monthly insurance charge for SPV plant.

Table 26 Operation & Maintenance Cost

S.no	Particulars of expenditure	Cost / month	Annual cost in INR
1	salary of 2 employees	5000	60000
2	Wages for night watchman	1000	12000
3	Array cleaning charge	500	6000
4	Miscellaneous	500	6000
5	Insurance coverage	1200	14400
6	Inspection for other authorities	300	3600
	Total O & M cost	8500	102000

Available data

I. Annual O & M cost=

1,02,000 II. Discount Rate DR= 9 %

III.General escalation factor GE= 5%

IV. Life cycle of the project = 20 year.

LCC maintenance cost is calculated by substituting the available values as follows .

$$LCC \; O \,\&\, M \; Cost = 102000 \; x \left\{ \left(\frac{1+0.05}{0.09 - 0.05} \right) \right\} \times \left\{ 1 - \left(\frac{1+0.05}{1+0.09} \right)^{20} \right\}$$

where

Item Cost = is the non-recurring expenditure in present day costs

GE = represents General Escalation

DR = represents Discount Rate, and

RY = is the "Replacement Year"

$$\text{LCC RC} = 47{,}60{,}000 \text{ X } \left\{\frac{1+0.05}{1+0.09}\right\}^{15} + 6{,}32{,}100\text{x } \left\{\frac{1+0.05}{1+0.09}\right\}^{15}$$

LCC RC = Rs 30,73,968

Available data

I. Cost of inverter=47,60,000

II. Cost of wire and connector = 6,32,100

III. Year of replacement = 15 year

IV. Discount rate =9%

V .General escalation = 5%

LCC replacement cost is calculated by substituting the available values in the above expression .And it is estimated 30,73,968 rupees will be required to replace the inverter and wires & connectors for the expected 15 year life time of grid connected SPV system.

4.2.3.5 Life cycle cost of project

The sum of capita Cost of grid connected SPV system, Life cycle fuel cost life cycle maintenance cost and life cycle replacement cost is known as the life cycle cost of the project .it is estimated by adding all the above costs.

Life cycle cost = Capital cost + LCC Fuel cost + LCC Maintenance cost + LCC Non recurring cost …....(5.6)

LCC = 4,45,60,824+ 0 +14,18,820+30,73,968

Life Cycle Cost = Rs. 4,90,53,612 .

4.2.3.6 Energy generation

The proposed grid connected SPV system is expected to generate 210 units of electricity in one day by considering 5 hours of peak sun hours (PSH) in a day. Daily average peak sun hours are estimate between 5.5. to 6 hours in haridwar. The annual expected energy generation is estimated by using following expression

Annual Energy Generation = Period in days x Installed capacity in kW x PSH …..(5.7)

Annual energy generation = 365 x 210 x 5

= 3,83,250 kWh/Year

Life time energy generation = 20 x 388250

= 76,65,000 kWh

=7.665 Million units

4.2.3.7 Unit electricity cost

Unit electricity cost is estimated to know the generation cost of one unit of power generated by this proposed grid tied SPV system .Life cycle cost is divided by the estimated total units of electricity generated by the project in its life cycle. Cost per unit is estimated by using the following expression.

$$\text{Life cycle unit electricity cost} = \frac{\text{life cycle cost}}{\text{termx365xkw/day}}$$

Unit electricity cost = 4,90,53,612 /(20x 365x210 x5)

=5.6 Rs/kWh

From the above estimation it has been clear that the unit electricity cost is Rs 5.6.Therefore the proposed grid connected SPV plant which is proposed at sewage treatment plant seems to be economically viable. The above unit price without considering central finance assistance from ministry of new and renewable energy.

After analysing data collected from the site the total load connected in the site is 1103.23 and the electricity consumed is 21872.65 kWh/day. After the calculation of land avilable in the plant for the mounting of SPV system and the incident solar radiation to plant the solar power of the plant is 210 $kW_{p.}$Acoordingly the total number of modules is estimated which is 980 modules .The tilt angle of the site after analysis of the data is found to be 29.1^{0} while the type of mounting used in this work are roof top fixed mounting . There are seven inverter used of 25kVA to convert the DC supply by the modules to AC.One transformer of 175 kVA is used for maintaining the voltage requirement at the output

The total cost of the system is Rs4,45,60,824 and the unit cost of generation of electricity is Rs 5.60 / Unit respectively.

Based on the result analysed above,it is found that the project is viable and can be implemented. Attention should be taken in the case of selections of the devices and installation due to the situation of the roof top site as well as the solar resources avilable. Iin order to obtain the maximum power output electronic devices are to be installed in the near by area to avoid losses as well as the cost of other supporting devices .

Solar intensity varies depending hour to hour and day to day so it is much better to install a system at an optimum tilt angle so that to allow the solar panel to receive maximum radiation hour per day.the optimum tilt angle seleted for the site is 29.1^0 as the solar radiation is maximum at this tilt angle. Further the cost analysis is done without without considering central finance assistance from ministry of new and renewable energy.if any possibility of CFA it can be included so that the overall cost of the system reduces.

- System optimization is required, especially to replace the equipment which consumes large amount of energy should be replaced by energy saving units.
- Energy conservation measures should be adopted so that wastage of energy should be minimised.
- Engineering work required to economise the system, also to increase the efficiency of the system as well as to receive power outputs .It is also recommended that a critical analysis of the system sizing and cost estimation is required in order to optimize the SPV system.
- Center finance assistance by MNRE regarding the sizing of SPV system for STPs should be considered so that the overall cost of the system gets reduced.

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