Affordable and Clean Energy in Hubballi-Dharwad Twin Cities

Sustainable Development Goal

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***Abstract*— With 69.5% increase of population in a decade (2010-2019), Hubballi–Dharwad the developing smart cites is consuming a lot of energy day by day be it electricity or Liquid Petroleum Gas. The current energy consumption is 2.13 lakhs (MWh) per year with community & institute 17.6%, Industries 15.3%, Municipal 8.7% and Residential 58.4%. The main sources of energy which fulfill the energy demand are generally fossil fuels but the fossil fuel based energy sources are exhaustible and also causes an environmental pollution. Therefore there is a need for alternative energy sources which can provide energy in a sustainable manner and pollution free. 15.7 (MWh) is generated with the help of solar energy resources. This report presents various methodologies to generate affordable and clean energy at residential area using non – conventional energy resources (i.e., Solar, Wind, Biomass) without polluting the environment. Also, solar water heaters can be installed for water heating purposes. As on December 2018, nearly 98.4% of (as many as 4, 29,121) household have LPG connection. With is estimated to rise up by 2030 with increase in population. In spite of LPG being low carbon emission clean energy source, it is still a fossil fuel originated fuel and hence has the possibilities of being extinct soon. This report also presents an alternative to LPG gas stoves is biogas made up of wet kitchen waste via anaerobic digestion is the safest and eco-friendly fuel for cooking and water heating applications. With rise in individuality and independent trend, there is significant rise need of energy as individualism increases residential buildings.**

Keywords—Sustainable Development Goal; Energy Demand; Renewable Energy; Solar Energy; Biomass Energy

I. INTRODUCTION

The world energy demand is increasing particularly since last few decades and by 2030 it's going to increase by 1.5% p.a., Which has to be more of renewably fulfilled to ensure the safety of environment. By 2030 individual households in Asia will increase by 9% the availability and accessibility of sufficient amount of energy accelerates individual's and nation's growth. In India, power cable from the grid has reached a transformer in each village but 31 million household still lack access to electricity. 3 billion people rely on wood, coal, charcoal or animal waste for cooking and heating which otherwise used productively can generate efficient energy. Indoor air pollution from using combustible fuels for household energy caused 4.3 million deaths in 2012, with women and girls accounting for 6 out of every 10 of these. Energy is the dominant contributor to climate change, accounting for around 60 per cent of total global greenhouse gas emissions. The only way to minimize the damage on the environment and to stop exploiting fossil fuel is to use renewable, affordable, clean and sustainable energy. LPG is a clean burning fuel that is low carbon, emits virtually no black carbon and does not spills. In spite of all the advantage, the major drawback is that it originates from fossil fuel. LPG comes from drilling oil and gas wells. It is a fossil fuel that does not occur in isolation. LPG is found naturally in combination with other hydrocarbons, typically crude oil and natural gas.

Solar energy is abundant and inexhaustible. In a tropical country like India, solar energy is received 300-330 days per year. The power from the sun intercepted by the earth is approximately 1.8x1011 MW, which is many thousands of times greater than present consumption rate on the earth which could meet all the energy requirement of the world, if utilized properly. Hence it is one of the most promising unconventional energy sources. It is environmentally clean source of energy and hence no potential damage to environment. The solar energy utilization includes thermal and photovoltaic conversion. In photovoltaic, solar energy can be used to convert into electrical energy through photovoltaic effect. The amount of solar energy received by earth varies inversely with the square of the distance between sun and the earth. As sun- earth distance is not constant because earth keeps revolving around the sun as well as on its own axis, the amount of radiation received by the earth also varies throughout day and year. The variation is not much and accounts for only 5.9%. So in order to collect the maximum solar radiation, it is important to determine the correct orientation and slope of the solar collectors. Solar tracking is one of the systems being used to maximize the amount of solar radiation falling on solar collectors. But tracking system is expensive and not easily applicable. To improve solar collector performance, optimum tilt angle is one of the alternatives, if solar tracking is not appropriate. Optimum tilt angle is the angle at which maximum solar radiation intercepted by the collector. There is reduction of an incident radiation by around 5% if tilt angle of solar collector is varied by 15° from the optimum tilt angle. So, to receive the maximum solar radiation on collector, optimum tilt is necessary. In northern hemisphere, collector orientation is south facing. In summer months, optimum tilt is less (usually

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latitude minus 15°) and in winter months, it is greater (usually latitude plus 15°). But annually, optimum tilt is given by b = 0. 9. For Indian cities, in practice the collector plate is oriented south facing and at a fixed tilt to receive maximum solar radiation.

Solar water heating (SWH) is the conversion of sunlight into heat for water heating using a solar thermal collector. A variety of configurations is available at varying cost to provide solutions in different climates and latitudes. SWHs are widely used for residential and some industrial applications. A sun-facing collector heats a working fluid that passes into a storage system for later use. SWH are active (pumped) and passive (convection-driven). They use water only, or both water and a working fluid. They are heated directly.

As on December 1, 2018, nearly 98.45% of (as many as 429,121) household have LPG connection. The ecofriendly alternative to LPG is biogas. Biomass energy is available at cheaper cost and it does not harm the environment .In some ways it also controls the pollution of the environment. Biomass energy can be good renewable energy source for both urban and rural areas in India. Biomass results in the production of biofuel which acts like treasures of renewable energy in the world. Biodegradable waste is the waste that can be decomposed and will be broken down into carbon dioxide, water, methane or simple organic molecules by the action of micro-organisms in reasonably less time. These wastes are generated out of human and industrial economic activity and the sources could be the residential areas, commercial areas and industrial areas. The biogas is convenient source of energy. Kitchen waste from Hotels, Houses, Hostels, Canteens, and Temples etc. are to be collected. Where it is a daily large amount of kitchen waste is obtained and Hence for better and effective utilization for better purpose. Biogas is valuable energy source which has high calorific value. It is also used for various purposes. Biogas production is a microbial process in which organic kitchen waste is decomposes into valuable product like Gas and Slurry. Hence bio gas is the most eco-friendly substitute for energy. Biogas is primarily mixture of Methane (CH4), Carbon dioxide (CO2), and other gases like Ammonia (NH3), Hydrogen Sulphide (H2S), Nitrogen (N), Hydrogen (H), and Oxygen (O2).This biogas production also performs the function of waste disposal system and it also prevents the potential source of environment and spreading pathogens and disease causing bacteria. The biogas production is also helpful for the environment cleanliness. It residues is also helpful for fertilizer in farm.

II. LITERATURE REVIEW

Energy Statistics 2013 - “The Indian economy has experienced unprecedented economic growth over the last decade. Today, India is the ninth largest economy in the world, driven by a real GDP growth of 8.7% in the last 5 years (7.5% over the last 10 years). In 2010 itself, the real GDP growth of India was the 5th highest in the world. This high order of sustained economic growth is placing enormous demand on its energy resources. The demand and supply imbalance in energy is pervasive across all sources requiring serious efforts by Government of India to augment energy supplies as India faces possible severe energy supply constraints.”

Karnataka’s Power Sector Roadmap for 2021-22 – “Karnataka has always been on the forefront in power generation. Asia’s 1st major hydroelectric generating station was set up in Karnataka in 1902; Ranks 2nd in installed hydro capacity at 3,599.8 MW Karnataka has a total installed capacity of 11,546 MW i.e. 6.64% of the total power generated in the country (2010-11).The proposed and the on-going projects in Karnataka together contribute 18,183 MW. In terms of total installed capacity of power plants Karnataka stands 5th and in terms of State initiated power plants, Karnataka stands 3rd in the country. Largest Ownership share: State - 57%, Private sector - 32%, Central- 11%. Instead of state taking initiatives increasing the power generation there is a lot of scope for the private investments in the state. The state has a total 95 power generation stations with installed capacity of 6,005 MW. The state is also home for major Independent Power Producers with total installed capacity of 3,609 MW.”

Basic Service, Trade, Business and Commerce – “Over all Energy Consumption of Hubballi-Dharwad is 2.13lakhs MWh per year (with community & institute 17.6%, Industries 15.3%, Municipal 8.7% and Residential 58.4%) out of which 15.7 MWh is solar generated rest of it is been transmitted from power generating stations, 9.67% is the distribution loss. The population as per the survey as on January 2019 is said to be 1.6 Million and is expected to increase by 60% in 2030.”

Hans-Holger Rogner, et al – “For wind mill in Hubballi-Dharwad, wind speed should be the minimum wind velocity for a windmill to function is 15 kmph. As soon as the speed of the wind becomes less than 15 kmph, the generator stops working. 8 km/h (2 m/s) minimum is required to start rotating most small wind turbines. 12.6 kmph (3.5 m/s) is the typical cut-in speed, when a small turbine starts generating power. 36–54 kmph (10–15 m/s) produces maximum generation power. The best places for wind farms are in coastal areas, at the tops of rounded hills, open plains and gaps in mountains - places where the wind is strong and reliable. Some are offshore. To be worthwhile, you need an average wind speed of around 25 kmph. As per the data recorded by the meteorology website, the maximum average wind speed was 9 m/s in the year 2019, which is not at all recommended wind speed for the working of wind mill.”

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A. K. Yadav, et al – "Biogas refers to a gas made from anaerobic digestion of kitchen waste. Methane is a clean gas which generates energy and one of the main constituent of cooking gas. Abundant kitchen waste (biomass) in terms vegetable peelings, kitchen waste, food waste are abundantly available from the each and every house of Indian communities. These kitchen waste biomass mass can be a source for Methane production where combination of waste treatment and energy production would be an advantage. In this Connection many researches carried studies and investigations for the generation of bio gas the Methane from biodegradable waste. The traditional methods of bio degradable wastes results in public health hazards and diseases like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences: It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies , mosquitoes, rats and other disease bearing vectors. Also, it emits unpleasant odour & methane which is a major greenhouse gas contributing to global warming. Hence forth the kitchen waste can be used as a raw material to produce biogas. The produced biogas can be used as a cooking gas in the kitchen. This concept is energy from waste."

III. RELEVENCE

Hubballi Dharwad is cities with abundance of Solar power for 330 days in a year, with makes the city highly capable of generating affordable and clean electricity without effecting the environment. The solid waste generation has increased; a study reveals that the HDMC generates about 400 tons of solid waste every day with per capita waste generation of 0.4 kg/day. Out of the total waste generated, about 360 tons of solid waste is being collected (88.37%). The segregation of waste can help fuel generation from waste which is affordable and clean, most importantly it does not affect the environment. The production of electricity from wind energy is not possible in Hubballi-Dharwad did not pass the site selection criteria, the site for wind energy to be installed should have abundance of wind, but the minimum wind speed needed to generate electricity is 4.1 m/s and Hubballi-Dharwad has a wind speed of 14.0 m/s.

4422 is the population density of Hubballi-Dharwad. Population growth has been slow and low over the years but during the time from 2001-2011, the city experienced rapid growth. Currently, the population growth is of moderate pace but things are expected to change in the coming years with rapid infrastructure and development taking place. With increase in Population, energy demands also increases therefore the energy generation should increase, the energy generated should be affordable and clean and eco-friendly.

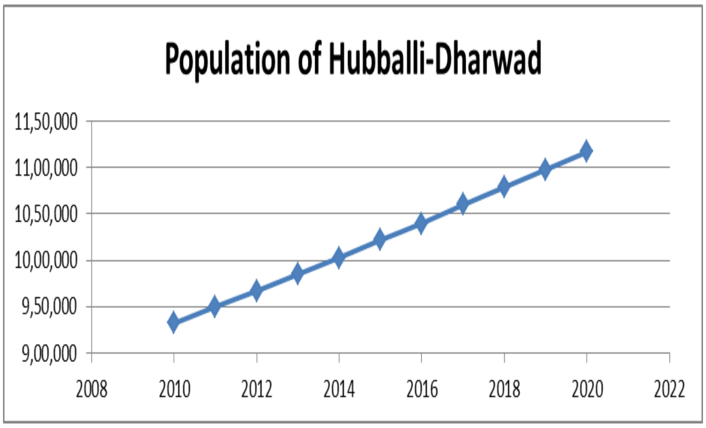

Fig 1. *Population in Hubballi-Dharwad from the year 2010 to 2020*

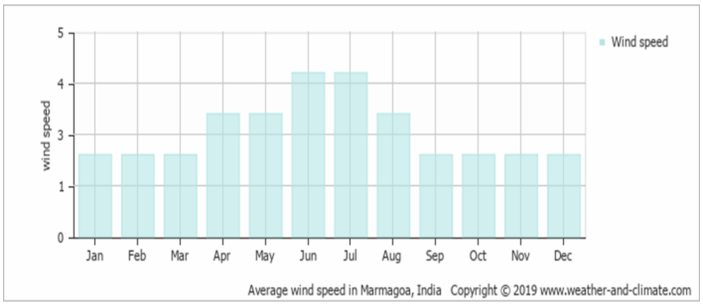

Fig 2. *Average Wind Speed in Hubballi-Dharwad in 2019*

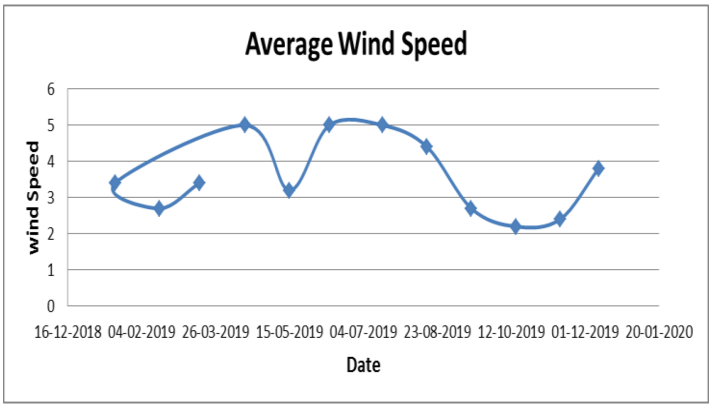

Fig 3. *Wind Data in Hubballi Dharwad in 2019*

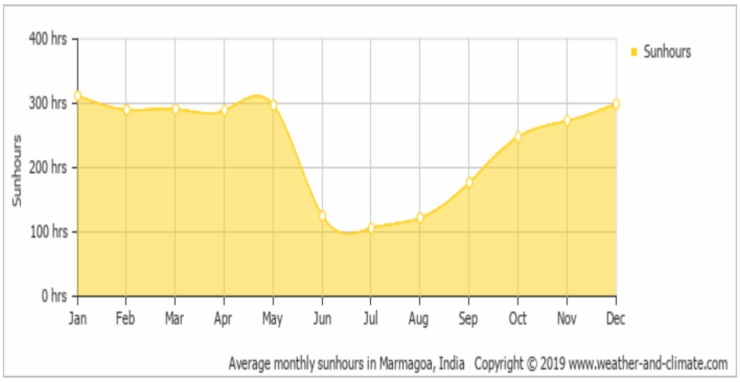

Fig 4. *Daylight and Twilight hours in Hubballi-Dharwad in 2019*

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IV. METHODOLOGY

a. *Solar Energy*

In order to utilize solar energy into useful form of energy, photovoltaic cells are used to capture the solar radiations and to convert the solar energy into electrical energy via pn junction functions. In PV design it is essential to know the amount of sunlight available at a particular location at a given time.

A method to estimate solar insolation is cloud cover data taken from satellite information sent. The common form of radiation data used in system design is the solar insolation. The solar insolation is the amount of solar energy received at a particular location during a specific time period, often in units of kWh per m2 day. Solar Insolation is the instantaneous solar irradiance averaged over a given time period. Solar Insolation data is used for PV system design.

Solar constant is given as 1350 W/m2.

By using the solar insolation method, one can easily know the solar tilt and number of sunshine hours per day to install the solar PV panel and solar water heating system which is clean and green form of energy.

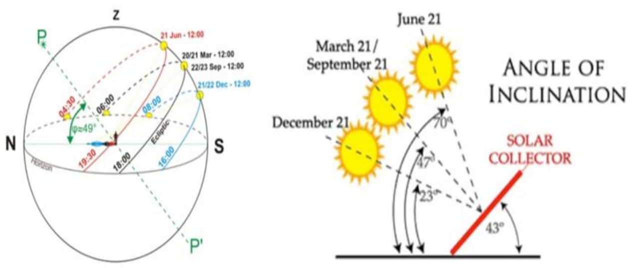

Fig 5. *Solar Solstice*

Parameters to determine solar radiation on Horizontal and tilted surface in Hubballi-Dharwad

- Declination Angle (δ)
- Hour Angle (ω)
- Solar Azimuth Angle (γ)
- Latitude (φ)
- Extra-terrestrial Radiation (IO)
- Day Length (td)
- Monthly average daily Global Solar Radiation on Horizontal Surfaces (IH)
- Tilt Angle (β)

Data Needed:

Solar Constant (Isc) is 1350 W/m2

Latitude and Longitude of Hubballi is 15.3647° N, 75.1240° E

Latitude and Longitude of Dharwad is 15.4589° N, 75.0078° E

Formula's used:

- Solar Extra Terrestrial Radiation:

$I_o = I_{sc}(1+0.033(\cos(360/365)n))$ (1)

$H_o=[(24*3600)/\Pi(I_{sc}(1+0.033(\cos(360/365)n)))*(\cos\phi\cos\delta\sin\omega_s)+(\omega_s\sin\phi\sin\delta)]$ (2)

Where,
I_o = Coefficient
H_o = Solar Extra Terrestrial Radiation
I_{sc} = Solar Constant, 1353 W/m2
n = Day number of year

- Declination Angle:

$\delta = 23.34*(\sin(360/365(284+n)))$ (3)

Where,
δ = Declination Angle
n = Day number of year

- Hour Angle:

$\omega_s = \cos^{-1}(-(\tan\phi)*(\tan\delta))$ (4)

Where,
ω_s = Hour Angle
ϕ = Latitude

- Day Length:

$T_d = 2/15(\omega_s)$ (5)

Where,
T_d = Day Length
ω_s = Hour Angle

- Global Solar Radiation:

$H_{ga}/H_o = a + b\,(((T_d)_{max})/T_d)$ (6)

Where,
H_{ga} = Monthly average of the daily global radiation on a horizontal surface at a location
a, b = coefficients related to latitude, elevation and the sunshine hours
(T_d) max = Monthly average of the maximum possible sunshine hours per day at a location

- Monthly Average Clearance Index:

$K_T = H_{ga}/H_o$ (7)

- Diffused Solar Radiation:

Garg & Garg proposed an equation to predict the daily diffused solar radiation for India,

$Hd/Hga = 0.8677 – 0.7365\,(((Td)max)/Td)$ (8)

- Tilt Factor

$r_b=(\sin\delta\sin(\phi-\beta)+\cos\delta\cos(\phi-\beta)\cos\omega s)/(\sin\delta\sin\phi+\cos\delta\cos\phi\cos\omega s)$ (9)

$r_d = (1+\cos\beta)/2$ (10)

$r_r = (\rho)*((1-\cos\beta)/2)$ (11)

- Total solar radiation on tilted surface

$H_t/H_{ga}=((1-(H_d/H_{ga}))*r_b)+(H_d/H_{ga})*r_d+r_r$ (12)

Where,
r_b, r_d & r_r = Tilt factors

b. *Biomass Energy*

The techniques used for the conversion of organic materials to biogas have been in existence for many years. Methane

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Vol. 9 Issue 02, February-2020

generation has been applied to meeting the energy needs in rural areas. In the England, India, Taiwan, for example, methane generating units as well as plants using cow manure and municipal waste have been in operation for years. In United States there has been considerable interest in the process of anaerobic digestion as an approach to generating a safe clear fuel as well as source of fertilizer. The use of rural wastes for biogas generation, rather than directly used as fuel or fertilizer, offers several benefits such as, the production of energy resource that can be stored and used more efficiently, the production of stabilized residue (sludge) that retains the fertilizer value of original material and the saving of energy required to produce equivalent amount of nitrogen-containing fertilizer by synthetic process. Indirect benefits of biogas generation include the potential for partial sterilization of waste during formation with consequent reduction of the public health hazard of faecal pathogens and reduction of fungal and other plant pathogens from one year's crop residue to the next. Biogas is a flammable gas produced when organic materials are fermented under anaerobic condition. It contains methane and carbon oxide with traces of hydrogen sulphide and water vapour. It burns with pale blue flame and has a calorific value of between 25.9-30J/m3 depending on the percentage of methane in the gas. The gas is called by several other names, such as: dung gas, marsh gas, gobar gas, sewage gas and swamp gas. The rate of biogas production depends: the nature of the substrate, temperature, pH, loading rate, toxicity, stirring, nutrients, slurry concentration, digester construction and size, carbon to nitrogen ratio, retention time, alkalinity, initial feeding, total volatile acids, chemical oxygen demand (COD), total solid (Ts), volatile liquids etc.

Kitchen waste is the best alternative for biogas production in a community level biogas plant. It is produced when bacteria degrade organic matter in the absence of air. Biogas contains around 55-65% of methane, 30-40% of carbon dioxide. The calorific value of biogas is appreciably high (around 4700 kcal or 20 MJ at around 55% methane content). The gas can effectively be utilized for generation of power through a biogas based power-generation system after dewatering and cleaning of the gas. In addition, the slurry produced in the process provides valuable organic manure for farming and sustaining the soil fertility.

Fig 6. *Biogas Digester*

V. RESULT

Calculation of all parameters for a particular day in June for Hubballi location:

Latitude: 15.3647 N

Assume: a = 0.25, b = 0.47

n = 17, January 17.

δ = 23.34 sin ((360 (284+17))/365)

= -20.91696257°

Solar declination angle is the angle between the perpendicular plane to incoming solar radiation and the earth's rotational axis. The solar declination angle varies from + 23.5 degrees on summer solstice to -23.5 degrees on winter solstice, and 0 degrees on the vernal equinox and autumnal equinox.

ω_s = $\cos^{-1}$(-(tan (15.3647)) * (tan (-20.9169)))

= 83.97152513°

T_d = 2/15(83.9715)

= 11.1934043 hours

The daily insolation is equal in numerically to the number of sun hours in a day. The module is assumed to face the equator so that it is directed South in northern hemisphere, while directed North in southern hemisphere. When the latitude is changed through zero going across the equator, the module is facing the opposite direction.

H_o=(24*3600)/Π*(1353*(1+0.033*(cos(360/365)*17)))*[{cos(15.3647)*cos(-20.91)*sin(83.97)}+{(83.97)*sin(15.3647)*sin(-20.9169)}]

= 9.653690211 (KWh/m^2)

H_{ga}/(9.653690211)=0.25+0.47(11.9051/11.1934)

H_{ga}=7.700616201 (KWh/m^2)

K_T=(7.700616201)/9.653690211

= 0.797686277 (KWh/m^2)

r_b=(sin(-20.916)sin(15.3647-0)+cos(-20.9169)cos(15.3647-0)cos(83.9715))/(sin(15.3647)sin(20.9169)+cos(-20.91) cos(15.3647)cos(83.9715))

r_d=((1+cos(0))/2)

r_r=0.2*((1-cos(0))/2)

H_d/H_{ga}=(0.8677–0.7365)(11.9051/11.1934)

= 0.649716978

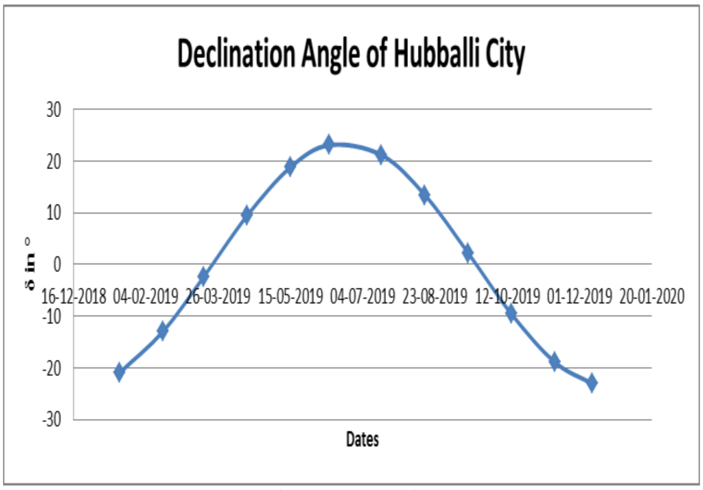

Fig 7. *Declination Angle of Hubballi City for some particular dates*

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ISSN: 2278-0181
Vol. 9 Issue 02, February-2020

TABLE I. ESTIMATED TOTAL GLOBAL SOLAR RADIATION FOR SOME PARTICULAR DATES

Date	t_d (hour)	H_o (KWh/m^2)	H_{ga} (KWh/m^2)	K_T (KWh/m^2)	H_d (KWh/m^2)
17th Jan	11.1934043	9.653690211	7.700616201	0.797686277	0.649716978
16th Feb	11.51391415	10.02457444	7.773869918	0.77548129	0.825409085
16th March	11.90838718	10.15420866	7.613554272	0.749792971	1.000446178
15th April	12.34511257	9.840036559	7.116983658	0.72326801	1.120574874
15th May	12.71215775	9.279769965	6.517968367	0.702384692	1.159926131
11th June	12.89360413	8.928683649	6.183116293	0.692500321	1.16035257
17th July	12.81187617	9.031732625	6.294375547	0.696917835	1.15392701
16th Aug	12.49946248	9.512840449	6.795371222	0.714336718	1.129535732
15th Sep	12.07824353	9.961906738	7.364325925	0.739248632	1.043950963
15th Oct	11.64193239	10.03392456	7.695557181	0.766953861	0.881536143
14th Nov	11.27691112	9.749359185	7.719340968	0.791779318	0.696073891
12th Dec	11.10197678	9.513206922	7.651048233	0.80425542	0.596178685

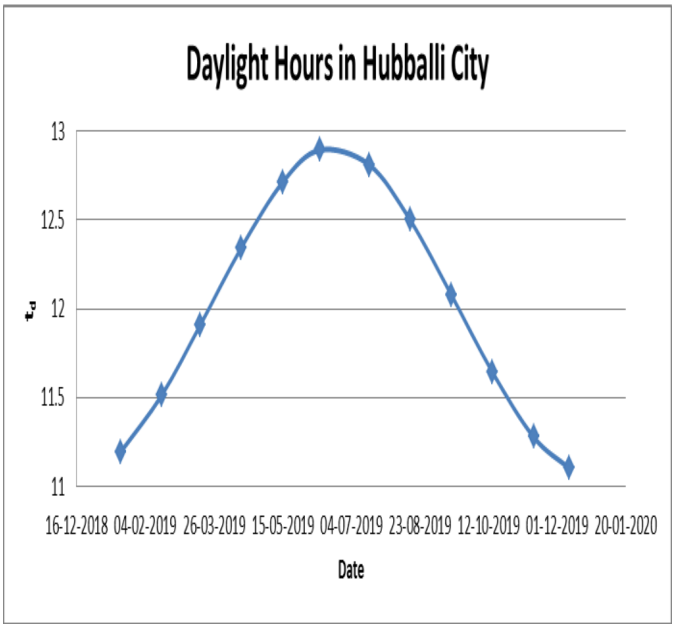

Fig 8. *Daylight hours in Hubballi City for some particular dates*

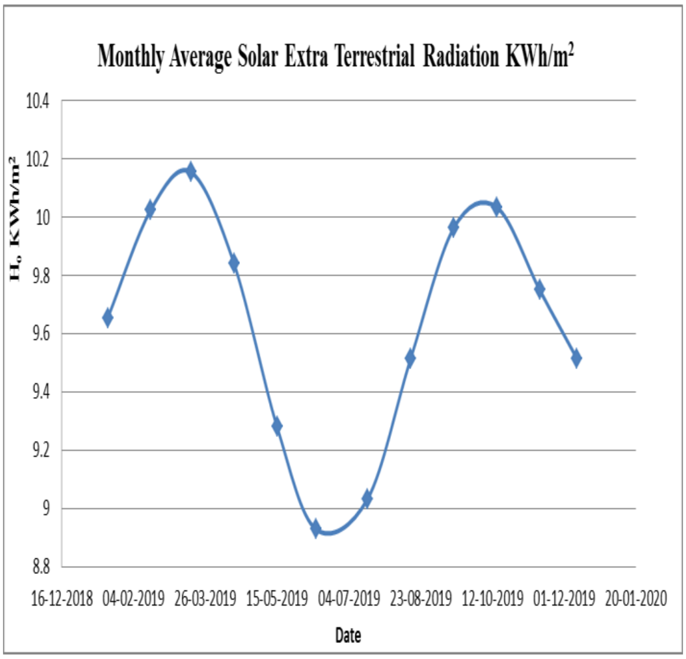

Fig 9. *Daily Solar Extra Terrestrial Radiation for some particular dates (KWh/m^2)*

The monthly average daily extra – terrestrial, beam, global radiation are calculated using the equations mentioned above. Global Horizontal Irradiance; total solar radiation; the sum of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), and ground-reflected radiation; however, because ground-reflected radiation is usually insignificant compared to direct and diffuse, for all practical purposes global radiation is said to be the sum of direct and diffuse radiation only.

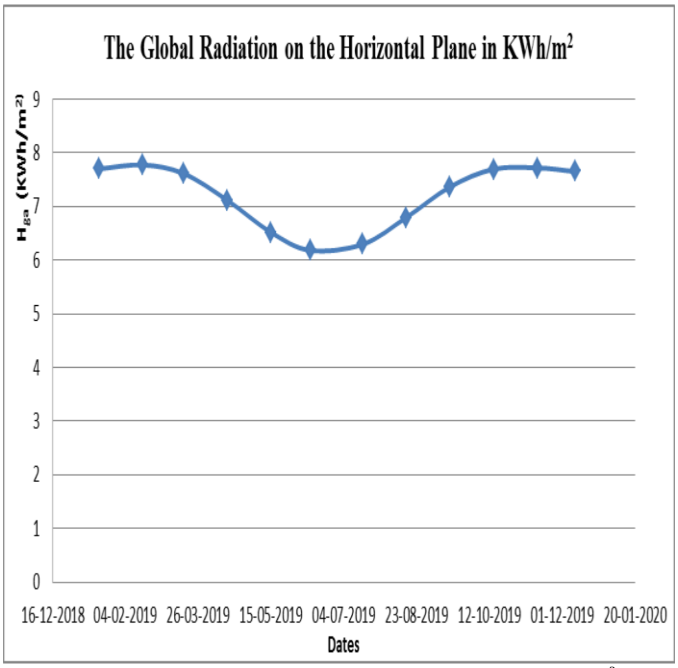

Fig 10. *The Global Radiation on the Horizontal Plane in (KWh/m^2)*

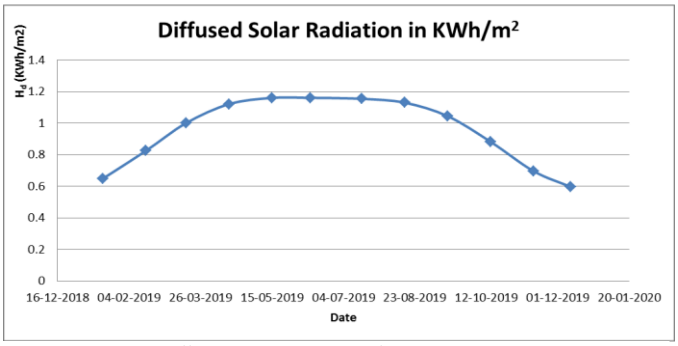

Fig: 11. *Diffused Solar Radiation for some particular days*

To optimize overall production year-round, tilt your panels at your latitude. To lean toward more production in the summer, tilt your panels at your latitude minus 10-15°. To lean toward more production in the winter, tilt your panels at your latitude plus 10-15°. Optimum solar tilt for this location is calculated using the values given by Electrical Handbook solar tilt calculator [10]. For implementation of seasonal optimum tilt angle, the collector tilt has to be changed three times in a year. The value of total solar radiation with different collector tilt angle is calculated for Hubballi which is given in the table below.

TABLE II. OPTIMUM SOLAR TILT ANGLES WITH RESPECT TO MONTHS

Months	**Optimum Solar Tilt in °**
January	36.4
February	28.1
March	17.5
April	5.6
May	-3.7
June	-7.9
July	-5.7
August	2.2
September	13.5
October	25.3
November	34.5
December	38.5

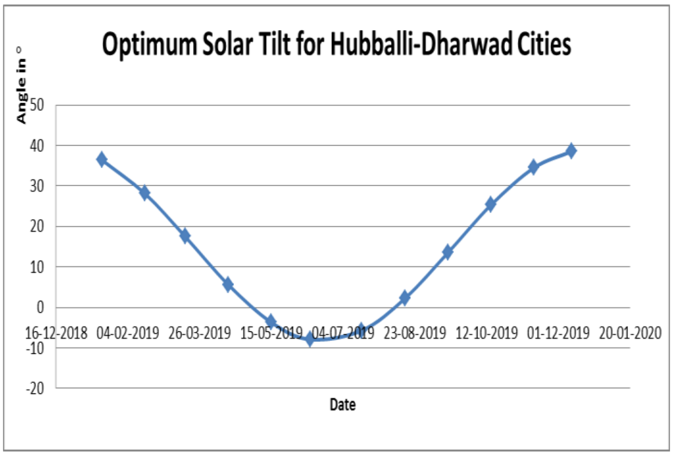

Fig 12. *Optimum Solar Angle tilts for Hubballi City for some particular dates*

TABLE III. TOTAL RADIATION ON SURFACE WITH VARIOUS INCLINATION VALUES

	Ht (KWh/m²)	H_t (KWh/m²)	H_t (KWh/m²)	H_t (KWh/m²)
Date	β = (ϕ)°	β = 0°	β = (ϕ-15)°	β = (ϕ+15)°
17th Jan	1.609096	5.183237	6.1814	7.774062
16th Feb	5.018261	0.275117	6.586372	3.26758
16th March	7.654104	4.53219	4.191294	0.534149
15th April	5.138192	0.976046	6.576623	2.6888
15th May	4.224877	6.01565	2.22241	5.809148
11th June	7.153491	5.373955	2.96551	1.857448
17th July	9.28327	4.12168	5.48745	3.408509
16th Aug	3.429531	0.63917	6.779172	3.58428
15th Sept	1.32943	4.85555	5.00551	7.160626
15th Oct	8.730317	7.427255	0.919497	4.052435
14th Nov	13.5833	8.821427	5.111873	1.57737
10th Dec	4.541827	4.541827	7.635147	4.90342

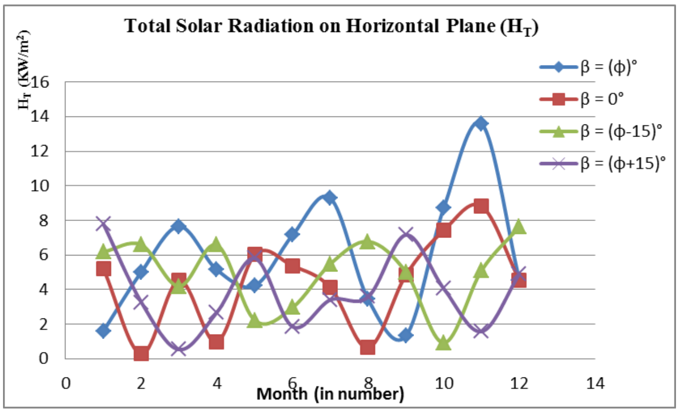

Fig 13. *Total Solar Radiation on a horizontal surface for different inclination on some particular dates*

CONCLUSION

Hubballi Dharwad can be made a city using affordable and clean energy by installation of solar PV Cells on residential, commercial and industrial buildings roof top, for water heating purposes, solar water heater can be utilized. In tropical countries like India, when solar energy is abundantly gifted, Indians should make it a prime duty to utilize the energy forms which is in free of cost as their primary mode of energy generators. The best months to generate solar electricity are January – April & September to December. The radiations like, beamed & diffused are calculated with respect to months. Optimum tilt angle is calculated with the help of solar electricity handbook. Therefore this report presents a detailed information and calculation and estimation of average solar radiation on horizontal and tilted surfaces for Hubballi city. The report also proposes how kitchen waste can be utilised to generate biogas which can be and alternative for LPG which is a fuel from fossil fuels. .

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