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Biogas-Solar Hybrid Systems for Solving Issues on Sustainable Energy Supply in Punjab (India), an Agrarian State

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Abstract

Sustainability of human development, along with decreased poverty levels, is attainable with increased usage of new energy services. There are plenty of remotely-located rural regions, where energy for utilization can be extracted from the renewable energy sources that are available within it. This investigation supports the North Indian villages, especially Punjab, in encouraging eco-protection with reduced poverty levels through analyzing the benefits that are associated with the newly emerging hybrid energy supplies. A conceptual and practical framework is presented that incorporates sustainable livelihoods thinking with the provision of sustainable energy services development of cheaper reliable power for agriculture and industrial development. In this case we are taking the case of the state of Punjab which is totally a plain area with lot of available solar energy and 100 % land is agriculturally cultivable with 2 or 3 crops rotation and due to these factors a combined effective energy from an hybrid source of solar and bio-gas(biogas and bio-mass) will help in meeting energy demand and for the development of this agro state in environment friendly or environment healthy system which is the demand of today's polluted world in which energy is needed , produced but without the concern of the environment which is a thing which has to be handed to the next generations in a better form so that they can live a better and healthy life. We have to develop clean, green, power from the locally available resources and the locational positioning and for local consumption. Thus a balanced economical viable system will be developed .

Keywords: Bioenergy, Biomass, UCS (Union of Concerned Scientists), RPR (Residue to produce ratio), Millennium Development Goals (MDGs). Residue.

1. INTRODUCTION

Rendering the rural regions with a better option of renewable energy, along with increased sustainability, need utmost attention. The rural regions lack national grid extension, since factors like, large distribution losses, expensive transmission system and massive distances impede the extension. Further, the rural regions lack access to other newly emerging renewable resources because of the extensive fuel costs as well as the fuel delivery costs. Reasonably-priced renewable energy has a leading role in getting rid of poverty and accomplishing the Millennium Development Goals (MDGs). In the rural regions, energy for the most part relies on compost, crop remains and wood. Power available is used mainly for domestic commercial, micro, small and large industry. Now depending on the available data from the state of Punjab we have the lot of livestock's in Punjab. The Asian countries, which are undergoing continuous development, have biomass energy to be their chief energy source. The reason is that these countries own industries and households, which majorly rely on charcoal, fuel wood and sources of biomass energy like, leaves, compost and agricultural remains. People of these nations have heating as well as cooking as their major domestic application. Processing of minerals like, ceramics, tiles, lime and bricks, along with the processing of textiles, metals and food as well as agro-based products come under the category of industrial applications. The rest of the applications include tarring of roads. Power co-generation is highly feasible with the biomass fuels. For instance, palm oil remains and bagasse of sugar industries.

So many biomass fuels emerge as the co-product of numerous processes in an agricultural and allied industry depending on Residue-to-Product-Ratio (RPR) are moisture content and ash content. Highly expensive fossil fuels and the growing interest towards environmental safety encourage newly emerging alternative raw materials to be created. Agricultural energy sources are rendering considerable attention towards producing excessive raw material with affordable price. Increased sustainability is always a problem with the utilization of natural fuels. For instance, burning of wood for energy is possible within a restricted period of time, since their chemical properties change over time. The quality of biomass necessitates enhancement by considering newly progressing biomass combustion systems, along with a keen knowledge of its producing methodologies. The reason is its emergence as a potentially great bioenergy sector, which gives clean, renewable energy resources for transportation and power generaton. Biomass tackles all the issues, which pertain to security, environment, economy and weather conditions that arise due to fossil fuel usage. In contrast to fossil fuels, the biomass-produced bioenergy own a lower carbon content with increased sustainability towards utilization as a fuel in power generation and transport industries. Since biomass results from manure or plant remains, it serves as a locally existing energy alternative. The Union of Concerned Scientists (UCS) has attempted to spot out the biomass resources with high sustainability. As a consequence, it observed the biomass production quantity in United States, while tackling the tradeoffs that exist between environment and energy. As per UCS 2012, in 2030, United States is known to produce an annual biomass resource quantity of 680 million tons, on an approximate. This quantity is more than sufficient to meet the United States' entire power consumption by 4-5% and encourages the power production of 200 billion kilowatt-hours as well as the ethanol production of 12 billion gallons or more in 2016. Another source of energy, gaining utmost importance, is the agricultural biomass. Specifically, the highly produced agricultural biomass is the crop residue. The resource kind as well as the quantity of a particular site decides the sites' choice of using manure or agricultural biomass in producing the bioenergy. The locally-placed or the regionally-economized areas enjoy numerous benefits from the bioenergy production, which involves the use of manure/ agricultural residue.

2. DISCUSSION

The availability of both the biogas and solar for the concept of the development of hybrid system for the region of the agrarian state of Punjab that has both the sources in abundance due to availability of high fertility of soil, good water resource and a typical geographical location. According to a report of Assocham, Punjab exhibits excessive per capita power consumption, as given in following data. Concept is to maintain and generate this power economically and environmental friendly.

Table. 1 Highest Per capita consumption in India.

Name of State	Per Capita Power Consumption kWh.
Haryana	1208.2
Gujarat	1330.5
Punjab	1506.3
Tamil Nadu	1079.9
Bihar	91
Assam	175.1
UP	340.5

***** Source: Assocham study.***

Table. 2 Data of electrification between year 2001-2011

Particulars	**Census 2001**	**Census 2011**	**CAGR**	**As projected from Census figures**	**As per State Data**	**Finally Adopted data**
Total Households	4265156	5409699	2.41%	5959722	6006790	6006790
Rural Households	2775462	3315632	1.79%	3560072	3363099	3363099
Urban Households	1489694	2094067	3.46%	2399650	2643691	2643691
Total Electrified Households	3920301	5225793	2.92%	5862533	6006790	6006790
Rural Electrified H/H	2482925	3166394	2.46%	3489840	3363099	3363099
Urban Electrified H/H	1437376	2059399	3.66%	2377982	2643691	2643691
Total Un-electrified H/H	344855	183906	-6.09%	143420	0	0
Rural Un-electrified H/H	292537	149238	-6.51%	114014	0	0
Urban Un-electrified H/H	52318	34668	-4.03%	29406	0	0

Table 3. Data of households, electrification and energy consumption FY 2014-2015

Sl. No.	**Particulars**	**Unit**	**As per State data (FY 2014-2015)**
1	Total Households in State	Nos.	6006790
2	Total Urban Households	Nos.	2643691
3	Total Rural Households	Nos.	3363099
4	Total Electrified Households	Nos.	6006790
5	Total Electrified Households - Urban	Nos.	2643691
6	Total Electrified Households - Rural	Nos.	3363099
7	Balance Un-electrified Households	Nos.	0
8	Balance Un-electrified Households - Urban	Nos.	0
9	Balance Un-electrified Households - Rural	Nos.	0
10	Electrification of houses under 12th Plan RGGVY	Nos.	0
11	Annual energy sold in the State during FY 2014-15	MU	40403
12	Annual Domestic energy sold in the state during FY 2014-15	%	27.57
13	Annual Domestic energy sold in the State during FY 2014-15	MU	11138
14	Average Annual Energy Consumption per household during FY 2014-15	kWh	1854
15	Average Daily Energy Consumption per household during FY 2014-15	kWh	5.08
16	**Annual Total Rural Consumption**	**MU**	**4942**
17	**Annual per household rural consumption**	**kWh**	**1470**
18	Annual Total Urban Consumption	MU	6195
19	**Annual per Household Urban Consumption**	**kWh**	**2343**
20	**Daily per household rural consumption**	**kWh**	**4.03**
21	Daily per household Urban consumption	kWh	6.42

Table 4. Data of peak demand, energy requirement and energy deficit in different FYs

Period/Items	**Unit**	**FY 2009-2010**	**FY 2010-2011**	**FY 2011-2012**	**FY 2012-2013**	**FY 2013-2014**	**FY 2014-2015**
Peak Demand at state periphery	MW	9786	9399	10471	11520	10141	11534
Peak Met	MW	7407	8007	8834	9074	8903	10155
Peak Deficit (-)/ Surplus (+)	MW	-2379	-1392	-1637	-2446	-1238	-1379
Peak Deficit (-)/ Surplus (+)	**%**	-24.3	-14.8	-15.6	-21.2	-12.2	-11.96
Energy Requirement at state periphery	MU	46426	45249	46264	47996	47347	48864
Energy Availability at state periphery	MU	39977	42513	44824	45389	46610	48380
Energy Deficit (-)/ Surplus (+)	MU	-6449	-2736	-1440	-2607	-737	-484
Energy Deficit (-)/ Surplus (+)	**%**	-13.9	-6.0	-3.1	-5.4	-1.6	-1.0

***** ***Source: State Power Utilities/CEA***

The demand is more during the summer season in the month of May, June, July, August, September and October and this has been explained by the figure 1 below. The generation of biogas is maximum during this period and the solar energy is also maximum during this period.

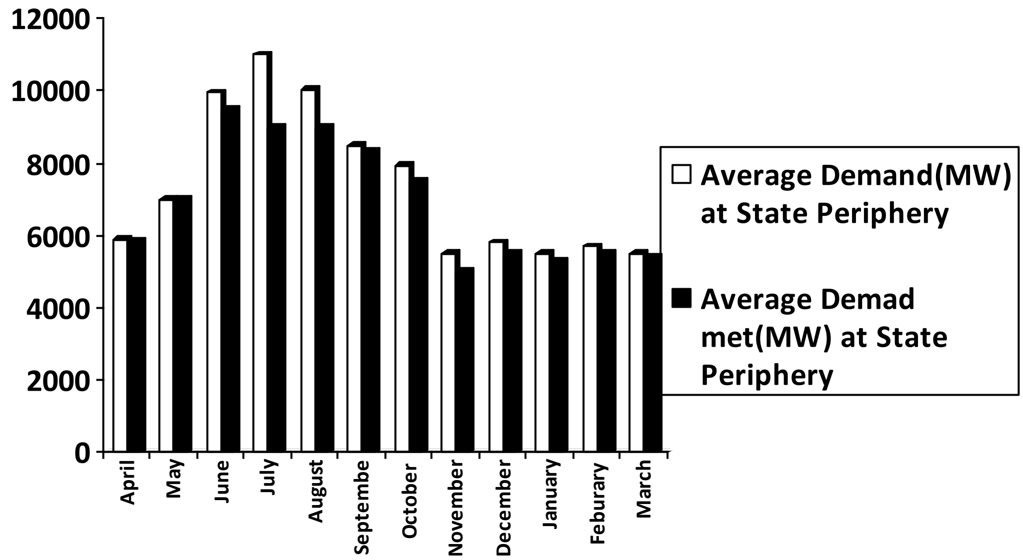

Figure. 1 Month wise Peak Demand Scenario (MW) – Average of FY 2012-13 to 2014-15

The energy consumption is also maximum from the month of May, June, July, August, September and October. This can be seen from the figure 2 below and again our model of solar bio meets the criteria of maximum generation and maximum production at same time. This will help and add a positive point in justification of our model.

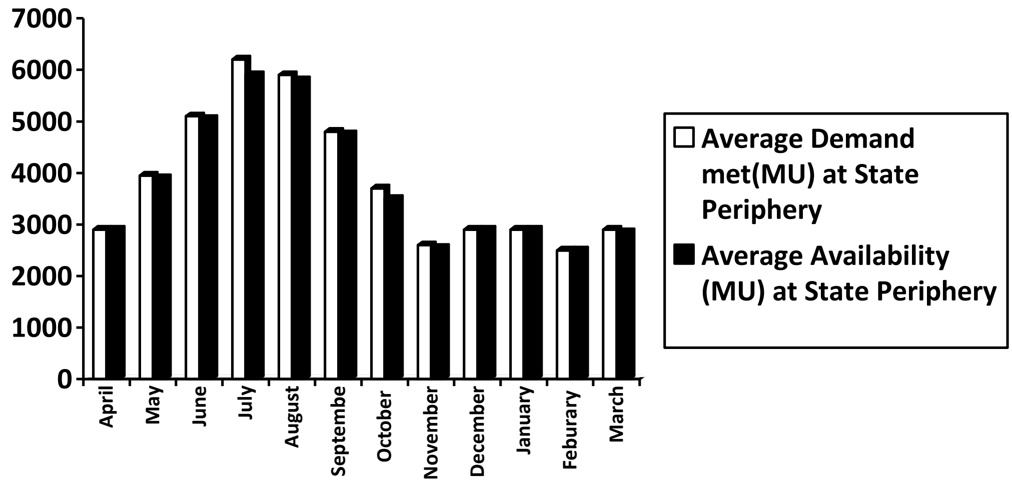

Figure 2. Month wise Energy Scenario (MU) – Average of FY 2012-13 to 2014-15

2.1 Resource Base

Biomass is available in three different forms.

A. Forest and wood processing residues

i. Log Residues
ii. Saw-milling Industry
iii. Plywood production Industry
iv. Particle board production Industry

B. Perennial Plantation Crop Residue

i. Cocoa
ii. Coconut
iii. Oil Palm
iv. Rubber

C. Agricultural Residues (annual crops)

i. Rice
ii. Maize
iii. Jute
iv. Cotton
v. Sugarcane
vi. Soybeans
vii. Groundnuts
viii. Cassava
ix. Other Cereals

In crops (for instance, wheat, corn and rice), cobs, husks, stalks and similar other inedible parts also exist, along with the edible grains that are fit for livestock/human eating. These inedible remains of the crops form the entire biomass to about half the portion.

The inedible crop remains, which serve as animal beds too, can be burnt and spread over the fields. But, the current developments in the field of science and technology enable the producers of agricultural remains to transform the remains into fuels that are biomass-dependent (for example, ethanol). Additionally, agriculture-dependent biomass supports power generation to a greater extent.

Table. 5 Data of different crops their biomass contents and RPR ratio

SR. No.	Crop	Contents	RPR Ratio
1.	Rice	A. Rice Straw: B. Rice Husk	0.416 – 3.96 (1.757 for calculation) 0.2-0.33
2.	Maize	A. Maize stalk B. Maize Cob C. Maize Husk	1.0-4.328(2 for calculation) 0.273 0.2
3.	Cassava	A. Stalks B. Peelings	0.167-2(4-9 tons per hector per year) One ton per hector
4.	Groundnuts	A. Husk/Shells B. Straw	0.5 2.3
5.	Soybeans	A. Straw B. Pods	2.5(at moisture content 15%) 1(at moisture content 15%)
6.	Sugarcane	A. Bagasse B. Tops/Leafs	0.1-0.33(at moisture content 50%) 0.1-0.3(at moisture content 10%) Calculation value 0.3
7.	Jute	Stalks	2
8.	Cotton	Stalks	3.5-5 (at moisture content 12%)
9.	Cereals	Straw	0.7-1.8(calculation value at 1.75) (at moisture content 15%)

Table 6. Bio mass waste of different agricultural crops in Punjab

Sr. No.	Type of Crops	Area under cultivation (in 1000 hectare)	Percentage of Area	Bio-Mass waste(Per Hectare)
1.	Wheat	3510	45	22 Q
2.	Paddy	2831	36	104Q
3.	Cotton	483	6	80Q
4.	Maize	133	1.69	80Q
5.	Oil Seeds	110	1.4	16Q
6.	Potatoes	83	1.06	14Q
7.	Sugarcane	70	0.89	250Q
8.	Pulses	2.3	0.27	17.5Q
9.	Barley	12	0.25	18Q
10.	Peas	19.6	0.15	15Q

Residues for bioenergy are to be used under conditions, that they do not affect farming, and impart protection against carbon loss as well as erosion of soil. The sustainable removal of crop remain quantity by the farmers relies on the land’s slope, weather in the region, state of the soil and management skills. Hence, the crop remain quantity does not stay constant for all fields or inside a certain field itself. Abundant residue removal produces adverse effects like, frequent erosion of soil. In contrast, less residue removal lowers rapid soil drying during springtime, leading to delayed planting as well as field works.

Hence, the removal of crop remains has to be done in a manner that the environment never gets adversely affected. Planting cover crops or adopting no-till farming can effectively work against water pollution or erosion of soil. The adoption of such agricultural ideas results in massive production with large residue quantity, supporting bioenergy production that exceed our expectations.

Agricultural residues are used to generate power but burning them directly is often unfeasible. Before undertaking the process for energy generation, the agricultural remains has to be formed as pellets or similar other structure.

Availability of agricultural residues and manure is in abundant in large scale in agriculture sector, the nation will develop better biomass resource. Perennial crops play a valuable role in the integrated system, as it prohibits chemical utilization with enhanced quality of water as well as soil. For better energy production, balanced healthy food crops, life stock should be less and low concentrated. Improving soil can be done by planting specific trees and perennial crops of low impact.

Biogas:

Biogas implies a gas mixture, which evolves due to the breaking of organic matter without oxygen presence. The raw materials to produce biogas include the wastes from food, green, municipality and agriculture. Other raw materials include sewage, remains of plant and manure. Biogas belongs to the renewable energy kind with traces of carbon content. The process for biogas production is anaerobic digestion, where the anaerobic life forms digest the organic matter within a closed system. The process of fermenting the biologically degradable materials also results in biogas production.

Table7. Biogas Yield, m^3/Kg day solid of different types of vegetable matter.

Sr. No	**Different type of vegetable matter**	**Yield, m^3/Kg day solid**
1.	Straw	0.17
2.	Grass	0.43
3.	Leaves	0.30
4.	Water hyacinth	0.40

Table 8. Biogas requirements of many purposes

Sr. No	***Purpose***	***Specification***	***Gas required, m^3/day***
1.	Cooking	Per person	0.425
2.		Stove, 10cm diameter	0.47
3.	Lighting	200- candle power	0.1
4.		40- Watt bulb	0.13
5.		2- Mantle	0.14
6.	Gasoline engine	Per HP	0.43
7.	Diesel Engine	Per HP	0.45
8.	Refrigerator	Per m^3	1.2
9.	Incubator	Per m^3	0.6
10.	Table Fan	30cm Diameter	0.17
11.	Space Heater	30cm Diameter	0.16

Table 9. List of fuels with their comparisons

Sr. No	Fuel	Calorific Value(kcal)	Burning mode	Thermal Efficiency (%)
1.	Cow dung, KG	2092	Open stove	11
2.	Fire wood, Kg	3821	Open stove	17
3.	Soft coke, Kg	6292	Open stove	28
4.	Charcoal, Kg	6930	Open stove	28
5.	Kerosene, Ltr.	9122	Pressure stove	50
6.	Biogas, m^3	5373	Standard burner	60
7.	Coal gas, Kg	4004	Standard burner	60
8.	Power, Kwh	880	Hot plate	70

In this table 9, after comparison of various fuels we come to the conclusion that biogas has maximum calorific value and high thermal efficiency so we must use biogas to the maximum so that all the positive points of good fuel are utilized to the optimum.

Table 10. Biogas production and the associated optimum conditions

Sr. No	Parameter	Optimum value
1.	Temperature(°C)	30-35
2.	Retention time (Days)	20-40
3.	Solid content (%)	7-9
4.	Carbon nitrogen ratio	20-30
5.	pH	6.8-7.5

In this table 10 we see the various optimum condition of biogas. These conditions are easily available during the month April, May, June, July, August and September. So the maximum gas production takes place during these months and our demand for power is also maximum during this period so we should try to utilize the maximum biogas production during these months.

Table 11. Data of livestock in quantity, biogas produced per unit and total amount of total biogas produced.

Sr. No.	**Livestock**	**Quantity (In Thousands)**	**Bio-Gas Produced per unit**	**Total Bio-Gas Produced 10^3 M^3**
1.	Cows	2427.71	0.25-0.40	728.313
2.	Buffalo	5159.73	0.25-0.40	1547.919
3.	Sheep	128.53	0.02-0.04	3.8559
4.	Goat	327.27	0.02-0.04	9.8181
5.	Pig	32.22	0.06-0.08	2.2554
6.	Poultry	16068.76	0.002-0.004	48.2062
7.	Human Population (Latrine user)	27704.236 (2.77 Crore)	0.02-0.04	831.12
		Total		**3171.488**

The statical data of the table 11 gives us the amount of total biogas directly available from the livestock in the state of Punjab. This amount of biogas, if converted to energy (electrical energy), will help in power production. Additionally, this energy will be environmental friendly and reduce the dependence on exhaustible resources (eg. Coal, Oil , etc.). The massive rise in livestock, followed by Confined Animal

Feeding Operations (CAFOs), has resulted in manure concentrations that are not controllable. Though such surplus manure quantity can aid in bioenergy production, water gets constantly polluted day-to-day in most regions. However, if the livestock is produced in smaller number, the manure to biogas transformation becomes simpler with the utilization of anaerobic digesters itself. In such a case, the farmers are left to enjoy biogas production with improved eco-friendliness and economical advantages. Biogas serves as a good source of power as well as heat in farm operations. Additionally, when purified, biogas acts to be a natural gas with increased renewable power. Biogas extraction using anaerobic digesters facilitate large-scale biogas production, along with enhanced quality of water. Further, it reduces methane that the manure emits and allows land to be fertile enough by returning nutrients. Use of bioenergy with improved efficiency of automobiles and having a technology for advanced automobiles will cut the projected oil use by 50% in 20 years and this will be a step towards self dependence on NCES.

Table 12. Agrometeorological Data for the Year 2014(It gives temperature (0C), SVP(mm), RH*(%),WD(Deg.), EVP(mm), RF(mm) for the state of Punjab station Bathinda.*

Month	Temperature(ºC)			SVP(mm)		RH(%)			WD(Deg.)		WD Mean	EVP (mm)	RF (mm)
	Tmax	Tmin	Tmean	M	E	M	E	Mean (RH)	M	E			
Jan.	18.1	6.3	12.2	7.3	7.4	89.2	46.8	68.0	207.3	233.5	220.4	1.5	0.5
Feb.	19.7	8.1	13.9	8.2	8.4	90.9	48.5	69.7	199.8	220.9	210.4	1.8	1.0
March	26.21	12.55	19.38	10.4	10.4	85.5	40.5	63.0	207.1	232.4	219.8	4.0	0.9
April	34.3	17.6	25.9	12.4	19.1	74.3	23.0	48.7	273.2	230.2	251.7	8.7	0.4
May	38.8	22.5	30.7	14.7	11.3	63.2	22.8	43.0	200.0	195.2	197.6	10.3	1.5
June	41.9	27.5	34.7	18.8	15.5	64.2	26.9	45.6	203.9	255.0	229.5	11.7	0.8
July	37.5	27.9	32.7	23.8	21.9	78.6	45.5	62.0	151.9	180.2	166.0	8.4	0.6
Aug.	36.6	26.7	31.7	23.2	22.2	82.1	47.8	65.0	208.5	224.8	216.7	6.9	1.0
Sep.	34.0	23.9	29.0	20.9	20.9	86.9	52.5	69.7	223.8	248.5	236.2	4.8	5.4
Oct.	32.8	18.6	25.7	14.7	12.3	83.7	32.6	58.1	204.8	242.9	223.9	4.6	0.0
Nov.	27.75	10.71	19.23	9.69	7.96	90.67	27.63	59.15	262.6	268.17	265.42	2.90	0.17
Dec.	17.8	6.0	16.9	7.5	7.9	93.8	56.3	50.8	230.3	248.2	140.6	1.5	0.0

SVP- Saturation Vapour Pressure, RH- Relative Humidity, WD- Wind Direction, EVP- Evaporation, RF- Rainfall, O.F- Over Flow, M-Morning -0730 LMT, E-Evening – 1430 LMT.

(Source – Punjab Agricultural University, Regional station, Bathinda.)

Herbaceous biomass heating is not always advantageous and remains unfit most times, since the biomass combustion system lacks its quality of biomass due to it. At elevated temperatures, vaporization of potassium as well as chlorine takes place. As a consequence, salt is formed along the boiler walls with high corrosive nature. Further, clinkers result due to the agglomeration of silica particles with chlorine as well as potassium. The clinkers formed have adverse effects on the functioning and the performance of the biomass combustion systems. “Staged combustion” has been developed for the combustion systems to tackle the clinker forming issue. In staged combustion, temperatures that are lower than the melting point of ash is used for the combustion of feedstock. With such a lower temperature applied on the fuel, biogas release is effective and the ash is allowed to retain its chemical constituents. Moreover, the fuel bedding is subjected to smaller air quantity in the staged combustion process for decreased alkali release. Hence, the combustion process will be completely achieved with increased cleanliness, when the turbulence as well as the combustion temperature is maintained high. The ash, resulting from the combustion process, is continually removed from the fuel bed for being transferred to an ash pan.
The agricultural fiber sources fall into the following four types.

1. Dedicated energy crops
2. Crop milling residues
3. Feed grains
4. Field crop residues

There is a need for work, which facilitates improved biomass-dependent fuel production. In addition, the agricultural sector has to be improvised to remove the imbalance in healthy food harvesting as well the large-scale biomass production with increased sustainability. Management of the trade-off between food as well as biomass production has large beneficial impact on agriculture and energy generation.

Solar Energy:

The solar radiation (insolation), which the earth is receiving in its upper atmosphere, is about 174,000 Terawatts (TW). Of this insolation quantity, the land masses, oceans and clouds absorb about 70%, leaving the rest (30%) to be reflected towards the space again. The solar light incident on the Earth has its spectrum to be constituted of visible as well as infrared range and a smaller portion of ultraviolet. The degree of insolation in the living places of people, all around the globe, is about 150 to 300 watts per square meter or 3.5 to 7.0 kWh/m^2 per day.

The oceans, which constitute the world by 71%, and the land surface of Earth absorb the incident solar radiation. Atmospheric circulation is achieved with the rising of warm air, containing vaporized water, from the oceans. The vaporized water in the warm air, on reaching a higher altitude, gets transformed to clouds through the condensation process. The clouds, then, diffuse to create rain on the surface of Earth. In this way, the water cycle gets finished. During the condensing phase of water, latent heat is caused. It is this latent heat, which turns out to be massive for generating thunderstorm, snowfall, cyclones, rain and wind. The landmasses as well as the oceans on Earth absorb ample sunlight, so as to retain 14^{o}C mean surface temperature. In plants, the solar to chemical energy conversion is attained through the process of photosynthesis. As a consequence of photosynthesis, the production of biomass, wood and food takes place. The biomass is mainly responsible for the fossil fuel production

The annual solar energy absorption of the land masses, oceans and atmosphere of the earth is about 3,850,000 exajoules (EJ). This energy is exceedingly higher than the world utilization in 1 hour. Biomass production during photosynthesis involves an annual energy conversion of 3,000 EJ. The annual solar energy that is incident on Earth is twice the amount of energy, which is generated out of the entire number of non-renewable resources in Earth (mined uranium, natural gas, oil and coal inclusive).

The utilization of solar energy by human relies on the solar energy quantity, which is available closer to Earth. The reason is that the land, cloud conditions, change of time and geography has large impact on the solar energy near the earth’s surface.

Basically, the regions that are geographically nearer to the equator, receives abundant solar radiation. The regions that are at a larger distance from the equator can have solar energy with increased use of photovoltaic technology, in relation to the sun’s location. The solar energy potential also varies with the change of time in night. The solar panels are subjected to decreased amount of solar light, if the cloud cover is large. This is because the cloud cover causes the solar cells to receive lesser amount of sunlight by blocking.

Active and passive are the two kinds of existing solar technologies. These technologies have distinct procedure for collecting, converting and distributing the light from sun. With these solar technologies, solar energy can be made available at all places of Earth, including the places that are away from equator. The solar energy is basically obtained from the incident solar radiation of earth. It forms the base for the generation of all the other renewable energy (for instance, tidal as well as geothermal energy), either directly or indirectly.

The sunlight conversion to beneficial outputs in an active solar technology is facilitated by fans, pumps, solar thermal collectors, intensive solar power and photovoltaic cell. In contrast, the passive solar technology involves space designing to achieve air circulation, deciding components of desired thermal attributes and making the reference for the building, in relation to the sun's position. Active solar technology and passive solar technology are deemed to be supply-side technology and demand-side technology, respectively. The reason is that the former technology is dealt with the rise of energy supply, while the latter technology denies the alternate resources from being largely used.

- All around the world, the entire annually-produced solar energy potential ranges between 1,575 EJ (minimum) and 49,837 EJ(maximum)
- The solar energy quantity has increased reliance on the existing land region, annual average sky clearance and annual clear sky irradiance.

. **Table 13.** Data of wind speed solar radiation and clearness index from PAU station Bathinda.

Month	Wind Speed (m/sec) (KM/Hr)	Solar Radiation(kWh/m^2/day) (MJ/m^2/day)	Clearness Index (Bright sunshine (Hrs.))
Jan.	2.8	9.6	2.5
Feb.	3.7	14.5	7.2
Mar.	3.9	18.1	7.3
Apr.	3.4	23.1	7.7
May	6.0	27.6	8.7
June	6.6	23.8	6.5
Jul.	6.8	18.7	5.9
Aug.	2.8	17.1	5.7
Sept.	3.0	18.0	8.2
Oct.	1.8	16.6	7.3
Nov.	1.4	14.1	4.0
Dec.	2.1	12.5	4.9

- ♦ 1 km/hr = 0.277778 m/sec
- ♦ 1 Kwh= 3.6 MJ
- ♦ 1MJ = 0.277778 Kw/hr.

Major part of Punjab falls between 29^o **N** to 32^o **N** latitude and 74^o **E** to 77^o **E** longitude. From the table 13 we have the data of wind, solar radiation and clearness index and these all data's show that the maximum solar radiation is available from the month of March to September and this is again the peak load period and if we convert this solar energy to electric energy it will be at high efficiency.

Benefits of purposed solar-biogas hybrid system as a solution to sustain energy supply in Punjab an agro state

1) Economic benefits
2) Environmental benefits
3) Social benefits

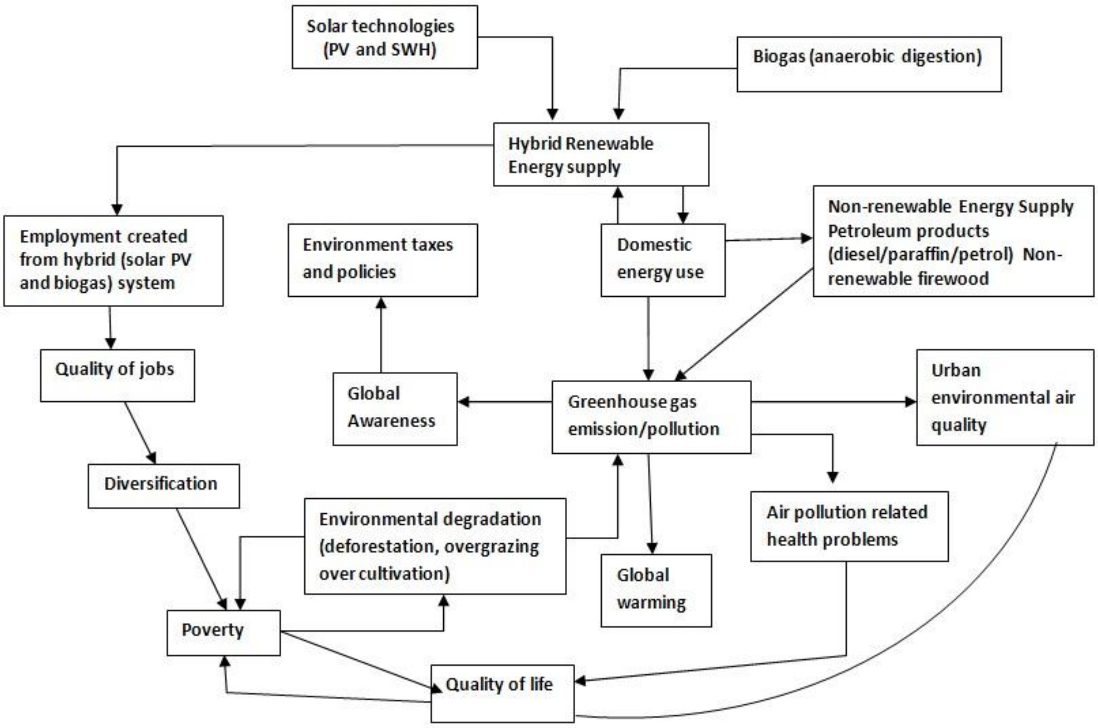

Figure 3. The solar biogas energy system and its associated economical, environmental and social advantages

3. CONCLUSION:

From the table 1. per capita power consumption of Punjab is highest in India. Table 2,3,4 gives the data of 100% electrification power consumption in urban and rural areas specifying peak demand, energy requirement and energy deficient in different FYs. So power demand is maximum in months of April to October and the production of biogas and solar energy is maximum during these months. So this model of development will help us meet the demand in which we will have a balanced development that will help the economical, environmental and social benefits to the society and our society which is an agro based will be neat and clean and it will help in the job generations in the rural areas and help us from the transmission losses which are from 16% to 20% . This will also add up for uninterrupted power supply 24/7. We will not dependent on high capital oriented mega projects and it will save us from the dependence on exhaustible fuels (coal, oil, gas etc.)

In the above research paper we have arrived at a balanced development projects that could help the economical, environmental and social benefits and a complete development of all sectors for the agro based state of Punjab which will help in development of an individual, remotest person who could not have been effected by the conventional mega power generating units because it depended only on the large investor and large consumer so we can say in other worlds they are the capitalist form of energy generation and distribution but in underdeveloped and developing country we need the generating distribution system that is more of a socialist pattern.