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Scope of Solar Energy in Various Districts of Himachal Pradesh, India

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Abstract: Energy demand is increasing exponentially with growth of population , urbanisation , industrialisation and improvement in living standard. This putting high pressure on fossil fuels consumption. These are available in limited amount and will be depleted in next few decades in most of countries as well causes environmental pollution. The renewable energy resources will never exhaust and have capability to meet our future energy demand . In this paper we will study the solar energy resources at various districts , tehsils & sub-tehsils of the Himachal Pradesh , India and further we will discuss the suitability of solar energy. For this, Solar Radiation GHI Data monthly average for 7 years is studied i.e. January 2002 to December 2008. Himachal Pradesh has good non-conventional hydro potential also.

Keywords: Renewable sources, fossil fuels, solar energy, GHI and DNI.

I. INTRODUCTION

The world's primary energy supplied highly depend on fossil fuels. In 2015, 80.1% of global energy demand met by fossil fuels [1]. These fuels are non renewable and will be depleted in next few decades in most of countries as well creates environmental pollution. In 2014 India had ranked 3rd in coal fired thermal generation (868 TWh) after china and USA [2]. India have 4th largest coal reserve and it may last for about 89 years or more at the Reserve to Production (R/P) ratio w.r.t 2015 AD [3] .

At end of 2016, R/P ratio for that year is 137 [4]. In India, total primary energy consumption from crude oil 29.38 %, coal 56.90 %, natural gas 6.23 % , hydro electricity 4.01%, nuclear energy 1.19% and renewable power 2.28% is in 2016-17 [4]. Still our primary majority of energy demand met by fossil fuels. So it's necessary to tap the available renewable energy resource to overcome future energy crisis. Himachal Pradesh has good hydro potential and maximum prime sites has been harnessed or under development. Himachal Pradesh have average global horizontal irradiance of 5.08kWh/m^2/day, which is good for PV generation of electricity. Its solar potential is about 33840 MW [5] .

II. SOLAR ENERGY

This energy is available in the form of light & heat from Sun. It can be harnessed by PV cells, solar heaters etc. It is freely available and renewable source of energy. Himachal Pradesh have average GHI of 5.08kWh/m^2/day which is sufficiently good for generation of electrical energy. This average GHI is average of monthly GHI of various tehsils and sub-tehsils of Himachal Pradesh. Solar radiation above 4.5 kWh/m^2/day is good for PV , concentrator based electricity generation, solar water heater and solar cooking [6].

III. GHI AND DNI

Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground. This value is of particular interest to photovoltaic installations. It includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DIF). DNI is solar radiation that comes in a straight line from the direction of the sun at its current position in the sky.

DIF is solar radiation that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions. For solar collectors which are flat in nature, solar radiation data in the form of Global Horizontal Irradiance (GHI) is useful whereas for solar collectors which are concentrating in nature Solar thermal power plants are essentially. Concentrating Solar Power (CSP) units. For designing solar thermal power plants, DNI data is necessary.

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IV. COMPARATIVE STUDY OFGHI AT VARIOUS DISTRICTS, TEHSIL OF HIMACHAL PRADESH

The solar resource data taken from MNRE for Himachal Pradesh and study data is taken for the year Jan 2002 to Dec 2008 [7,8] and average GHI of all districts is shown in Table 1 and figure 1. Graph plotted for Average GHI in kWh/m^2/day and months for each district also.
Average GHI data for each tehsil is represented in graphical form . For eight months in all the districts the average GHI is $\geq$ 4.5 kWh/m^2/day except Lahaul & Spiti only for seven months, while at districts Shimla, Solan, Sirmaur, Mandi, Hamirpur, Bilaspur and Una monthly average GHI $\geq$ 4 kWh/m^2/day for ten months .At districts Chamba, Lahaul & Spiti, Kangra, Kullu and Kinaur GHI is above 4 kWh/m^2/day for nine months.

For most of tehsils in District Kinaur (figure 2) monthly average insolation is above 4.5 kWh/m^2/day for seven months except Pooh and Moorang where it is for eight months .
For Udaipur and Spiti in District Kinaur (figure 3) monthly Average insolation is above 4.5 kWh/m^2/day for seven months except Lahaul where it is for eight months .
In Chamba district (figure 4) , the average monthly GHI is above 4.5 kWh/m^2/day for eight months except Pangi, Bharmour and Bhattiyat which is for seven months only.
In Kangra district (figure 5) , the average monthly GHI is above 4.5 kWh/m^2/day for eight months except Dharamshal & Palampur for six months and Baijnath & Multhan for seven months.
In Kullu district (figure 6) , the average monthly GHI is above 4.5 kWh/m^2/day for eight months except Manali for seven months only.
In Shimla district (figure 7) , the average monthly GHI is above 4.5 kWh/m^2/day for ten months at most of the tehsils except Chirgaon for seven months and Dodhra Kwar & Jubbal for nine months.

Table 1: Average monthly GHI of all district (2002 to 2008) in Himachal Pradesh.

District	Jan kWh/m^2/day	Feb kWh/m^2/day	Mar kWh/m^2/day	Apr kWh/m^2/day	May kWh/m^2/day	Jun kWh/m^2/day	Jul kWh/m^2/day	Aug kWh/m^2/day	Sep kWh/m^2/day	Oct kWh/m^2/day	Nov kWh/m^2/day	Dec kWh/m^2/day	AnnGHI kWh/m^2/day
Chamba	2.91	3.51	4.92	6.04	6.89	6.55	5.70	5.09	5.37	5.15	3.99	3.06	4.94
Lahaul & Spiti	2.56	3.25	4.33	5.49	6.81	6.94	6.42	5.94	5.48	5.27	3.99	2.67	4.94
Kangra	3.20	3.92	5.23	6.33	7.06	6.48	5.31	4.88	5.19	5.07	3.98	3.21	4.99
Kullu	3.30	3.91	5.26	6.18	6.91	6.43	5.47	4.88	5.24	5.21	4.23	3.31	5.03
Kinaur	2.62	3.16	4.59	5.88	7.03	6.71	6.11	5.48	5.36	5.24	4.23	3.00	4.96
Shimla	3.36	4.04	5.39	6.39	7.06	6.43	5.56	4.98	5.25	5.33	4.28	3.44	5.13
Solan	3.36	4.04	5.39	6.39	7.06	6.43	5.56	4.98	5.25	5.33	4.28	3.44	5.13
Sirmaur	3.48	4.24	5.76	6.68	7.21	6.25	5.26	4.81	5.16	5.39	4.27	3.59	5.18
Mandi	3.38	4.14	5.47	6.56	7.16	6.51	5.41	4.85	5.26	5.28	4.23	3.40	5.14
Hamirpur	3.35	4.18	5.46	6.62	7.22	6.56	5.48	5.04	5.38	5.19	4.08	3.32	5.16
Bilaspur	3.35	4.26	5.56	6.72	7.32	6.57	5.59	5.07	5.40	5.23	4.11	3.36	5.21
Una	3.32	4.20	5.52	6.66	7.30	6.63	5.60	5.19	5.39	5.13	4.04	3.31	5.19
Average	3.18	3.90	5.24	6.33	7.08	6.54	5.62	5.10	5.31	5.23	4.14	3.26	5.08

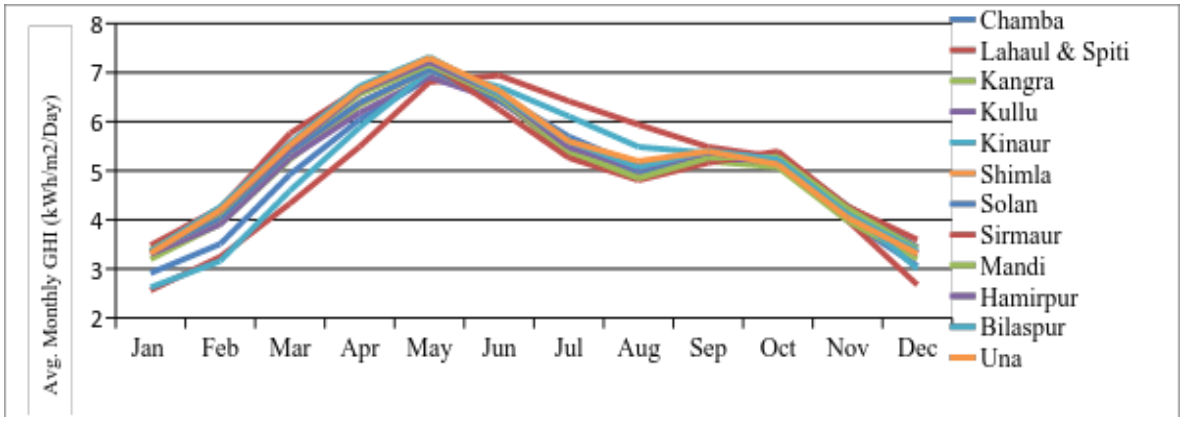

Figure 1: Average monthly GHI of districts of Himachal Pradesh.

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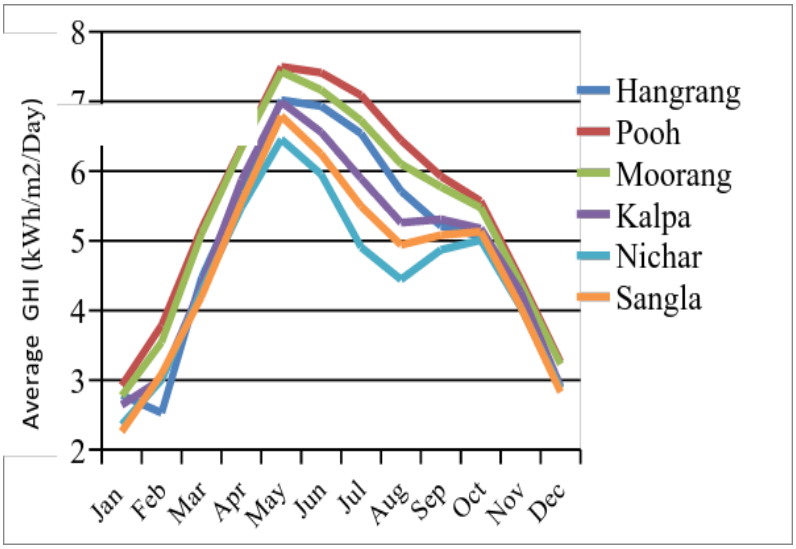

Figure 2: Average monthly GHI of various tehsil places in district Kinaur, HP.

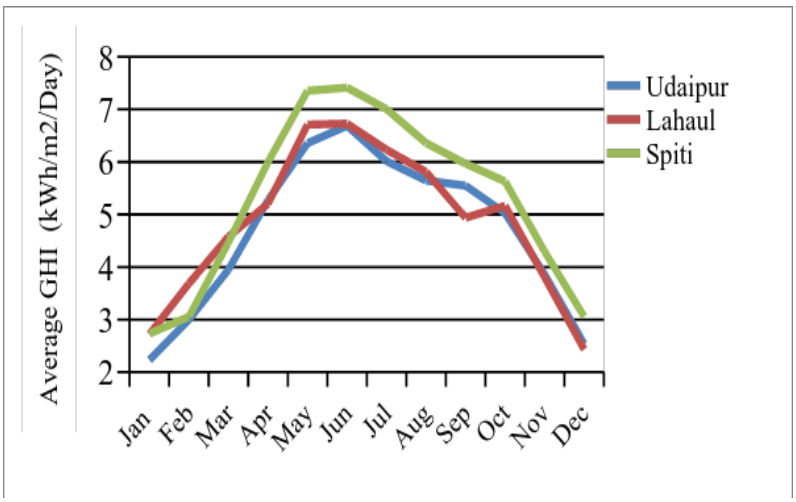

Figure 3: Average monthly GHI of various tehsil places in district Lahaul & Spiti ,HP.

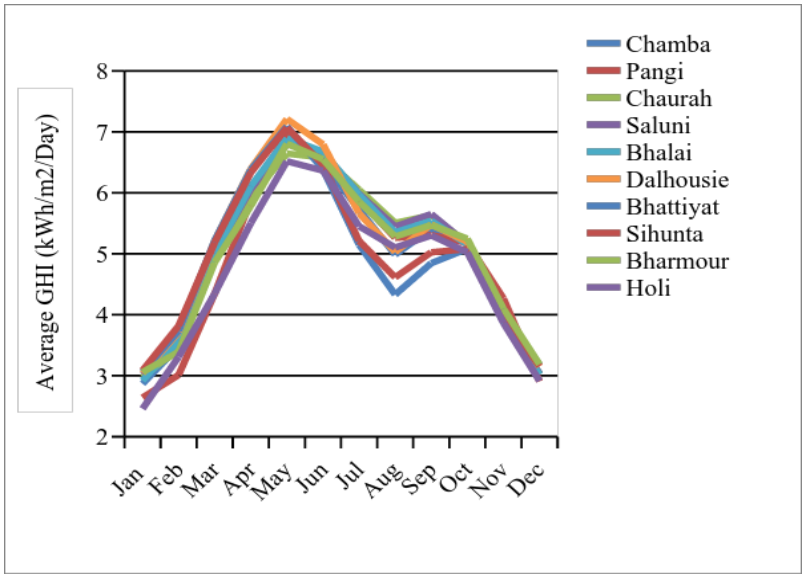

Figure 4: Average monthly GHI of various tehsil places in district Chamba ,HP.

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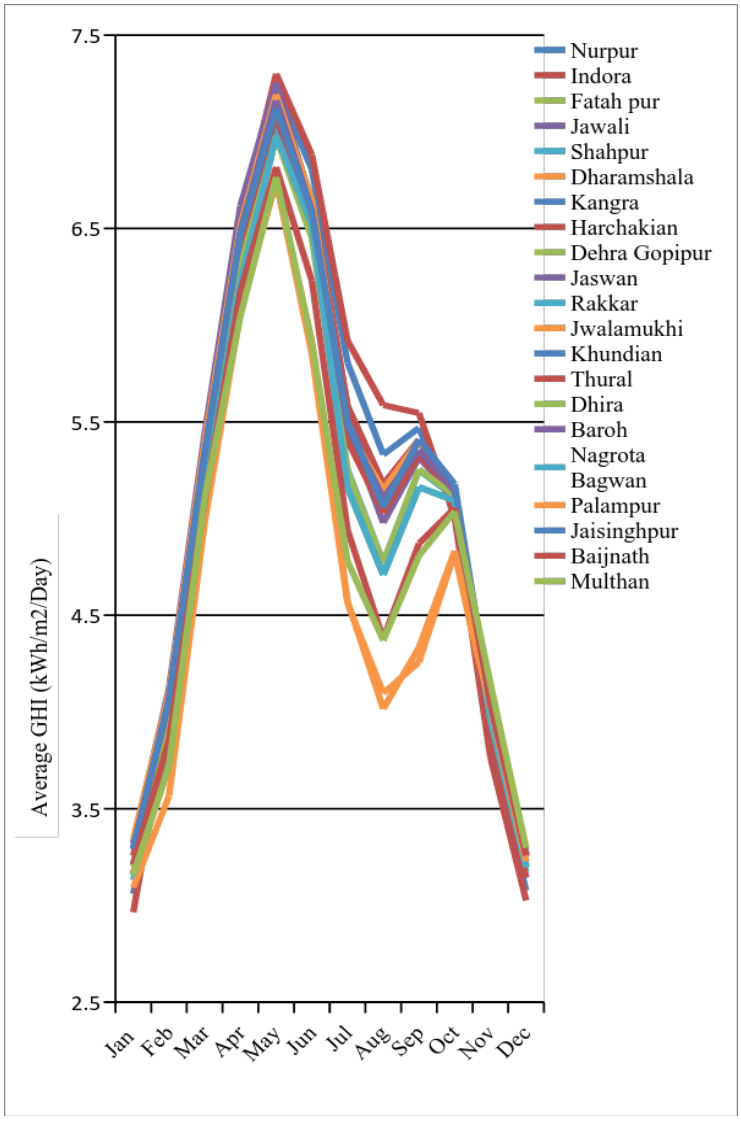

Figure 5: Average monthly GHI of various tehsil places in district Kangra ,HP.

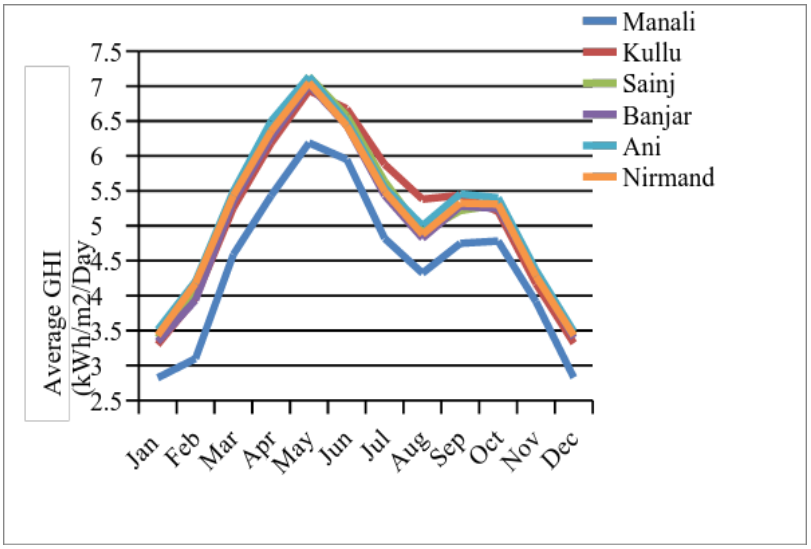

Figure 6: Average monthly GHI of various tehsil places in district Kullu , HP.

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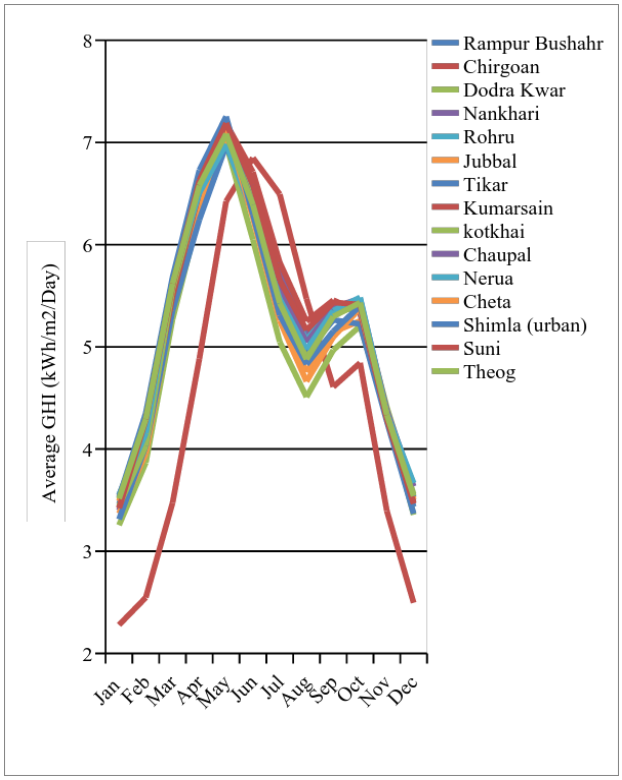

Figure 7: Average monthly GHI of various tehsil places in district Shimla , HP.

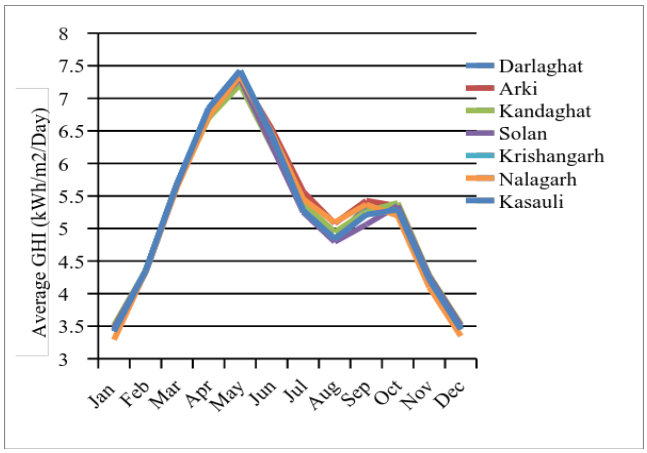

Figure 8: Average monthly GHI of various tehsil places in district Solan ,HP.

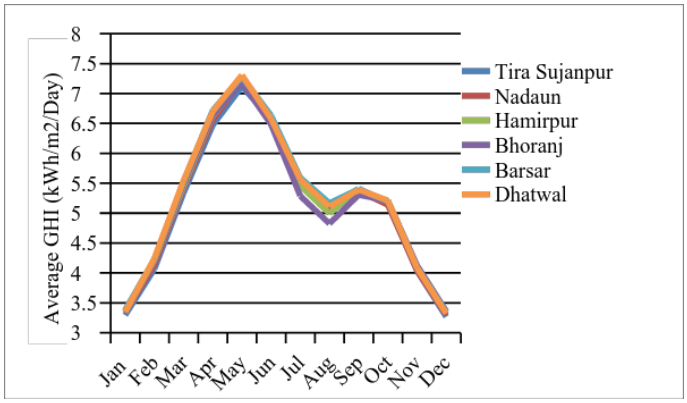

Figure 9: Average monthly GHI of various tehsil places in district Hamirpur ,HP.

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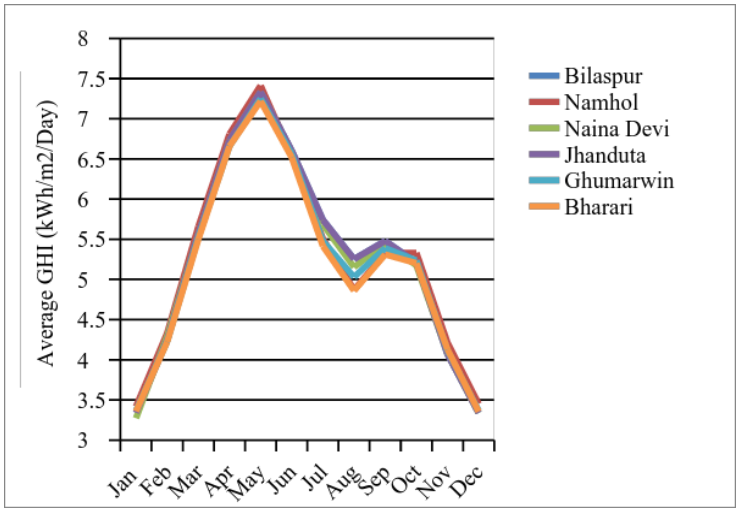

Figure 10: Average monthly GHI of various tehsil places in district Bilaspur ,HP.

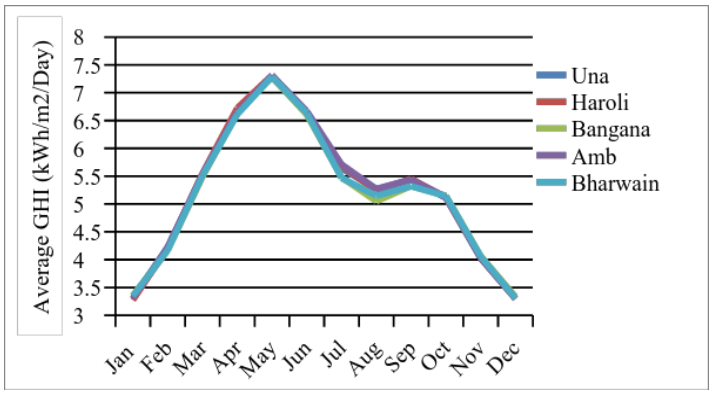

Figure 11: Average monthly GHI of various tehsil places in district Una , HP

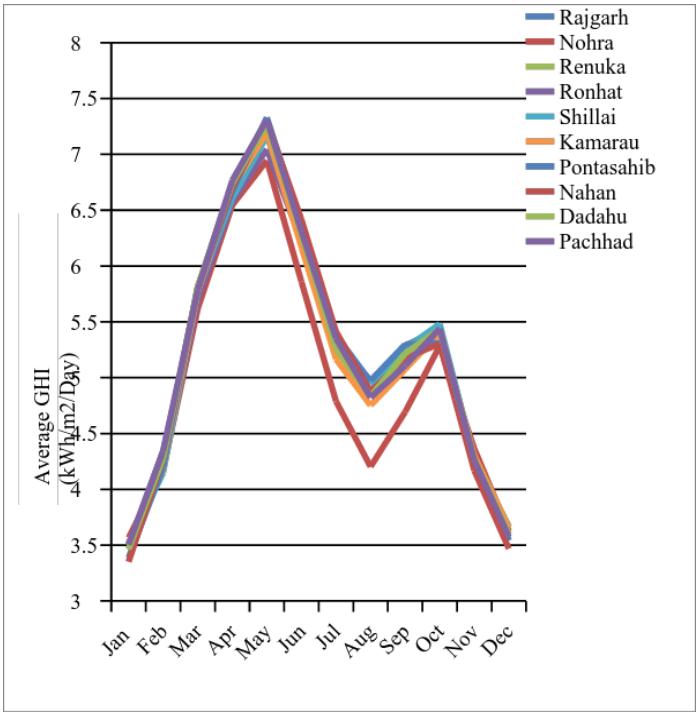

Figure 12: Average monthly GHI of various tehsil places in district Sirmaur , HP

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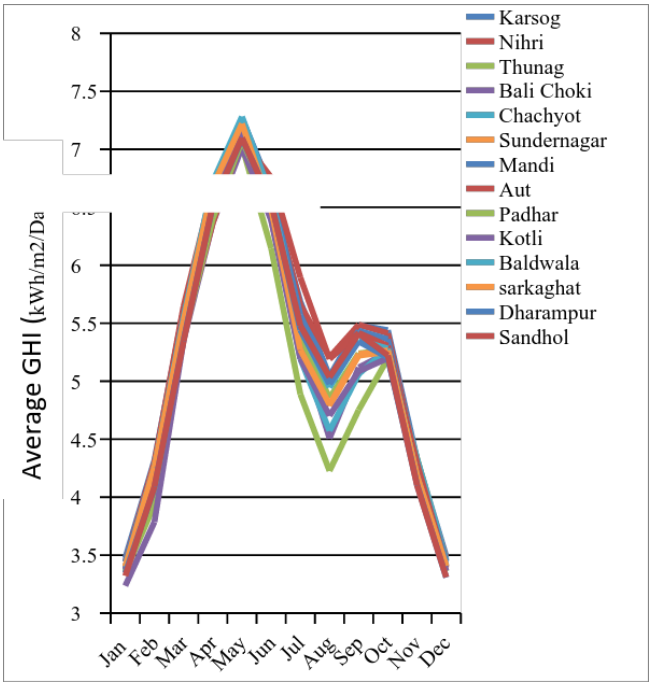

Figure 13: Average monthly GHI of various tehsil places in district Mandi, HP.

In Solan district (figure 8) , the average monthly GHI is above 4.5 kWh/m2/day for eight months at all the tehsils from March to October. While in November and February it is above 4 kWh/m^2/day.
In Hamirpur district (figure 9) , the average monthly GHI is above 4.5 kWh/m^2/day for eight months at all the tehsils March to October. While in November and February it is above 4 kWh/m^2/day.
In Bilaspur district (figure 10) , the average monthly GHI is above 4.5 kWh/m^2/day for eight months at all the tehsils March to October. While in November and February it is above 4 kWh/m^2/day .
In Una district (figure 11) , the average monthly GHI is above 4.5 kWh/m^2/day for eight months at all the tehsils March to October. While in November and February it is above 4 kWh/m^2/day .
In Sirmaur district (figure 12) , the average monthly GHI is above 4.5 kWh/m^2/day for eight months at all the tehsils March to October except Thunag . While in November and February it is above 4 kWh/m^2/day at all places.
In Mandi district (figure 13) , the average monthly GHI is above kWh/m^2/day for eight months at all the tehsils March to October and for mid November and February GHI is above 4 kWh/m^2/day .

V. SCOPE

In Himachal Pradesh domestic electrification is 99.5% in 2016-17. Most of the villages and places are now connected with state grid. By using roof top PV array consumer can use and sell the electricity under bilateral transactions through Inter-state trading Licensees and directly by distribution licensees, power exchanges (Indian Energy Exchange ltd. (IEX) & Power Exchange India ltd. (PXIL)) and Deviation Settlement Mechanism (DSM) at most of the places in Himachal Pradesh. In some tribal isolated areas in Himachal Pradesh there is problem of unreliability which can sorted out by using solar systems with appropriate energy storage system. The particular zone can be run in islanding mode even if grid is not able to supply.

VI. CONCLUSION

This paper deals with comparison study of solar GHI at various tehsil & sub-tehsil level and discuss about most suitable zone for Integrated Renewable Energy System (IRES) with Demand Side Management (DSM)
In Himachal Pradesh at district Shimla ,Solan, Sirmaur, Mandi , Hamirpur , Bilaspur and Una has good insolation above 4 kWh/m^2/day for ten months February to November.

Here an attempt is made to study the renewable energy forecasting considering the seasonal and topographical variations. The solar energy could be a vital source for various electrical applications and bilateral transactions mainly in the period of March to October.

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