

WIND - SOLAR HYBRID ENERGY PRODUCTION ANALYSIS REPORT

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EXECUTIVE SUMMARY

Energy is critical to the economic growth and social development of any country. Indigenous energy resources need to be developed to the optimum level to minimize dependence on imported fuels, subject to resolving economic, environmental and social constraints. This led to a boost in research and development as well as investment in renewable energy industry in search of ways to meet energy demand and to reduce dependency on fossil fuels with ambitious but achievable target of (100GW Solar + 60 GW Wind + 15GW other RE) 175GW by 2022 . Wind and solar energy are becoming popular owing to abundance, availability and ease of harnessing for electrical power generation.

Wind power generation at all the selected 24 sites spread in windy states of India has high potential (having more than 200 WPD (watts per square meters) wind power density with minimal seasonal trend variation. The possible Solar power generation at the windy sites has recorded highest annually at Kalimandayam, Palayam, Chadmal, Devareddypalli, Kompalli, Kuran, Motibaru, Suigam, Haikal, Machenahalli, Mustigeri, Nirana, Taralkatti, Ganesh Goshla, Bassi, Dag, Gara and Pandhro followed by lowest Annual energy of power generation at Akkanayakanpatti, Melamandai, Veralimalai, Kondurpalem, Sunkisala, Gaga and Jamgodrani Hills. Whereever the Wind downtrends Solar tends to compensate with the reduction of wind generation. So integrating these renewable sources together by hybrid power systems is complementary to reduce the power demand and facilitate the continuous power supply to the grid through green energy

In a given wind potential location with bankable met-mast measurement the effective land area (10km circular) will be 314sq.km (77558 acres) . Depending on %area for wind projects the range of possible capacities are 224MW to 1884MW and 1.5 to 7 times that of wind capacity can be added in the same area making the range of Solar capacity addition from 336MW to 15512MW. Hybrid policy of Government of

India needs only the last mile push in tariff determination for hybrid projects with wind and solar along with energy storage and smart grid technologies .

Dr.S.Gomathinayagam
DG/NIWE

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WIND - SOLAR HYBRID ENERGY PRODUCTION ANALYSIS REPORT

1.0. INTRODUCTION

Energy is critical to the economic growth and social development of any country. Indigenous energy resources need to be developed to the optimum level to minimize dependence on imported fuels, subject to resolving economic, environmental and social constraints. This led to a boost in research and development as well as investment in renewable energy industry in search of ways to meet energy demand and to reduce dependency on fossil fuels with ambitious but achievable target of (100GW Solar + 60 GW Wind + 15GW other RE) 175GW by 2022. Wind and solar energy are becoming popular owing to abundance, availability and ease of harnessing for electrical power generation. This report focuses on integrated hybrid renewable energy projects consisting of wind and solar energy. Ministry of New and Renewable Energy directed NATIONAL INSTITUTE OF WIND ENERGY, Chennai to prepare a report on hybrid wind and solar energy production analysis. NIWE, has chosen 24 wind potential sites based on met-masts installed in, Telangana (Kompalli, Sunkisala, Chadmal), Karnataka (Mustigeri, Taralkatti, Machenahalli, Haikal, Nirana), Gujarat (Suigam, Kuran, Pandhro, Moti Baru, Gaga), Madhya Pradesh (Ganesh Goshla, Jamgodrani Hills) and Rajasthan (Dag, Gara, Bassi) and their respective closest available Solar Radiation details to study the possibility of integrating Wind and Solar power generation projects. This report gives the overall view of the wind and solar energy generation possible at the respective sites and would help the developer to understand the feasibility and focus, highlighting the potential advantages of the complementary nature of wind and solar in different seasons of they are to develop hybrid projects in the respective states.

2.0. WIND AND SOLAR HYBRID POWER GENERATION PROJECTS

The availability of renewable energy resources at a site is an important factor to develop the hybrid projects. In many parts of the India, Wind and Solar energy are abundantly available which pay way for their optimal integration.



Fig 2 Wind and Solar hybrid system

Wind speed is low in summer whereas the solar radiation is brightest and longest. The wind is strong in monsoon months whereas less sunlight is available owing to cloud cover. Because the peak operating times of wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce , dependable power to our demands. When neither the wind nor the solar systems are producing, most hybrid systems provide power through the energy stored in batteries. If the batteries run low, the engine generator driven by conventional fuels can also be integrated to recharge the batteries, so that continuous power will be supplied meeting to the load demands from time to time.

3.0 ONSITE DATA COMPARISON OF WIND AND SOLAR POWER GENERATION

Solar data used for this study is from SRRA solar atlas which is prepared based on up to 3 years ground measurement of SRRA network from 115 locations and 16 years (1999-2014) of satellite derived data and maps using method of regional adjustment and validation. The wind speed data acquisition has done with sensors placed at different altitude levels (5m, 10m, 50m, 80m and 100m). The Wind velocity data analysed for this study is from sensor placed at 100m level. Wind velocity data has been adopted with the normalized 2MW power curve given in Fig 3, to arrive at the Annual Energy Production (AEP).

The Hybrid plots explain the annual trends of Wind and Solar; whereas the bar graph shows the total generation of Wind & Solar, and hybrid energy generation .The Wind Generation data and the solar generation data per MW capacities were combined to verify the feasibility of installing hybrid systems at the sites described below.

Normalized 2 MW Power Curve:

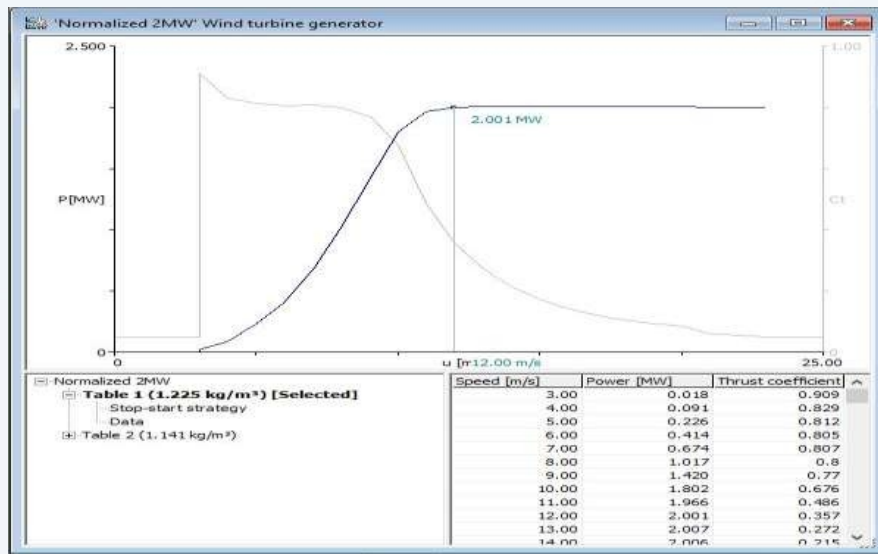


Fig 3 Normalized 2 MW Power Curve

3.1 SITE DESCRIPTIONS OF TAMIL NADU

3.1.1 Site Description of Kalimandayam

Kalimandayam is located in Dindugul district having plain terrain; the ownership of land is Private which is easily accessible and located at 1.7 km from Kalimandayam town towards north. The nearest 33/11 kV substation is at Akkarapalayam Bridge with GPS details of Lat 10°34'33.2"N & Long 77°41'21.3"E with elevation of 302 m.

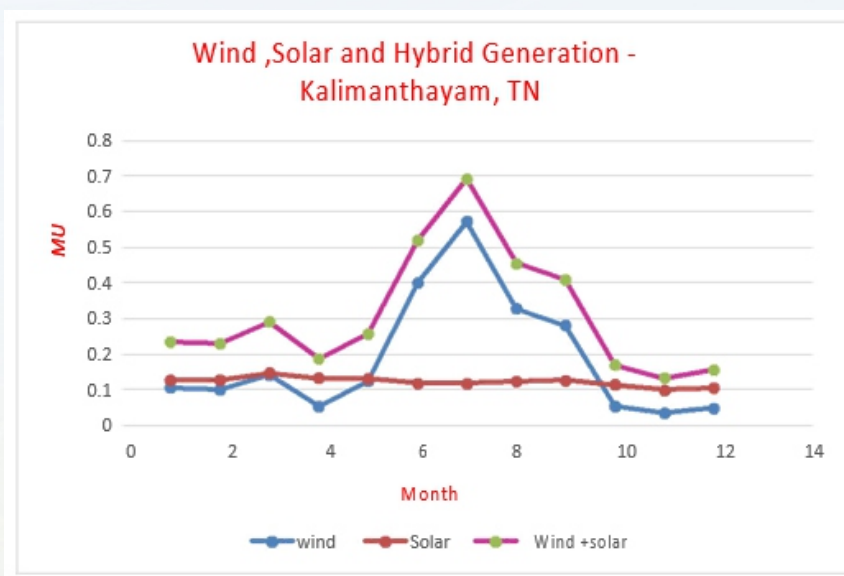


Fig 3.1.1. (a)

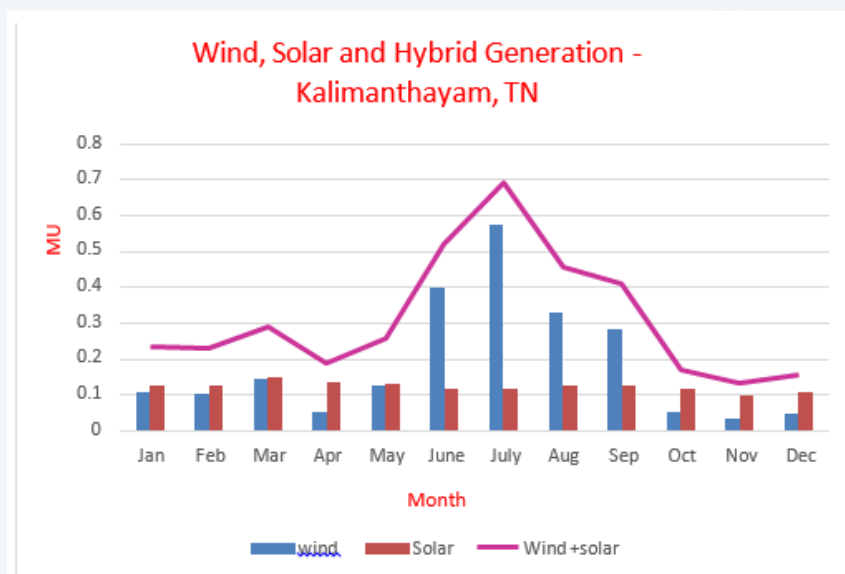


Fig 3.1.1. (b)

Fig 3.1.1. (a) & (b) Hybrid Wind & Solar Energy Generation at Kalimandayam

Fig 3.1.1. (a) and (b) shows trends of solar and wind average monthly power generation from January to December at Kalimandayam. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to mid-February and a drastic increase of Solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after March for a small duration and rises as the southwest monsoon get active. From the end of April and until July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, its end of Monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend. Fig 3.1.1.(b) gives the combination of bar graph and line graph the annual trend and cumulative generation of the typical 1MW each , Solar and wind hybrid System. The Table 1.1 gives details of generation of 1 MW "Solar PV" plant and 1 MW wind turbine generation . Wind Turbine can generate 2.26 MU and Solar PV plant can generate 1.48 MU and cumulatively can generate 3.75 MU of electricity.

Table 1.1 Monthly wind ,solar and Hybrid Power Generation

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
KALIMANDAYAM	2263184.746	1488038	3751222.746

3.1.2 Site Description of Karungal/Palayam

Karungal/Palayam is located in Dindugul district having plain terrain; the ownership of land is Private land which is easily accessible and located at 2kms from Palayam towards south west. The nearest 33/11kV substation is at Pallappatti with grid GPS details of Lat 10°44'36.7"N & Long 78°8'17"E with elevation of 210m.

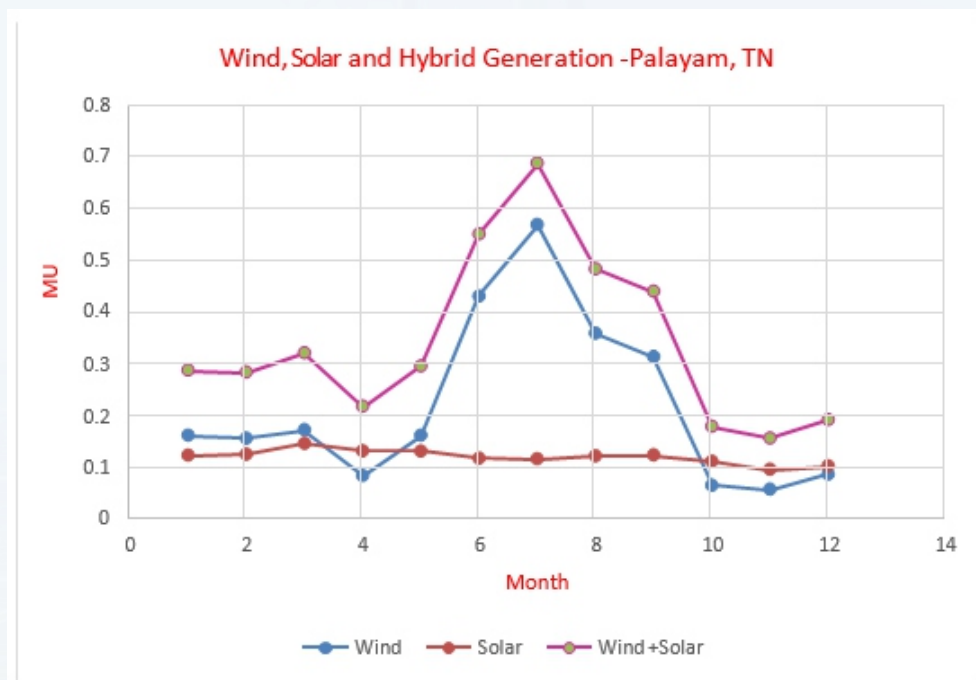


Fig 3.1.2. (a)

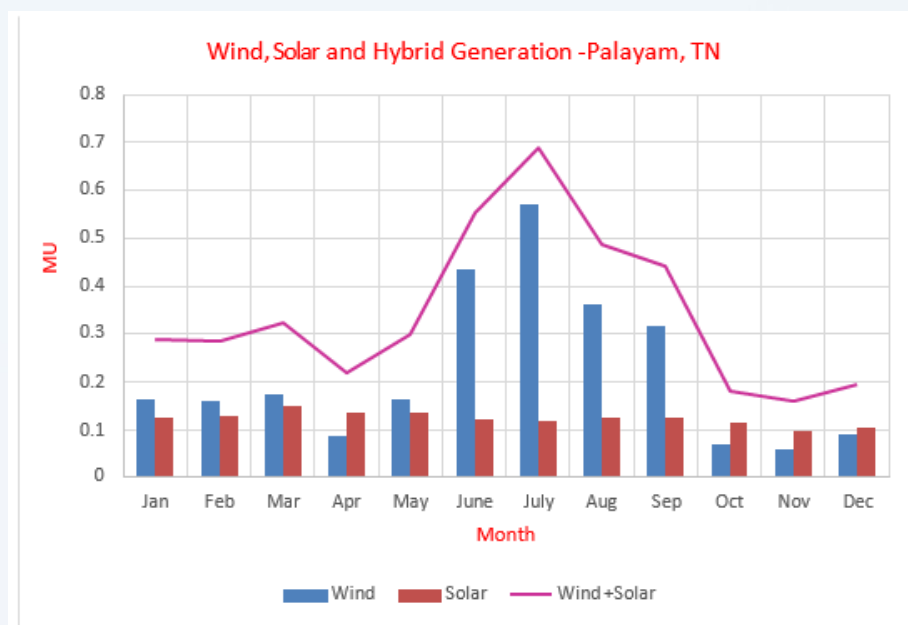


Fig 3.1.2. (b)

Fig 3.1.2. (a) & (b) Hybrid Wind & Solar Energy Generation at Karungal/Palayam

Fig 3.1.2. (a) and (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Palayam. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to March and a drastic increase of solar generation within the same duration. The seasonal variations in this region indicates hybrid average power generation. Though wind trend decreases after March for a small duration and rises with advance of south west monsoon. After April till July, wind trend is depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, its end of Monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of last September from November wind and solar trend to increases simultaneously. After which they slightly rise and contribute to the Annual trend.

The Table 1.2 gives details of generation of 1 MW solar PV plant and 1 MW wind turbine generation . Wind Turbine can generate 2.64 MU and Solar PV plant can generate 1.47 MU and cumulatively can generate 4.12 MU of electricity.

Table 1.2 Monthly wind ,solar and Hybrid Power Generation

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
KARUNGAL/PALAYAM	2649320	1478350	4127669.714

3.1.3 Site Description of Melamandai

Melamandai is located in Thoothukudi having plain terrain land, which is easily accessible land availability, is private ownership of land located at 2kms from Melamandai toward south west. The Nearest substation is 33/11 kV substation at Ettaiyapuram has GPS details of Lat 9°4'47.5"N & Long 8°17'44.3"E with 7m Elevation.

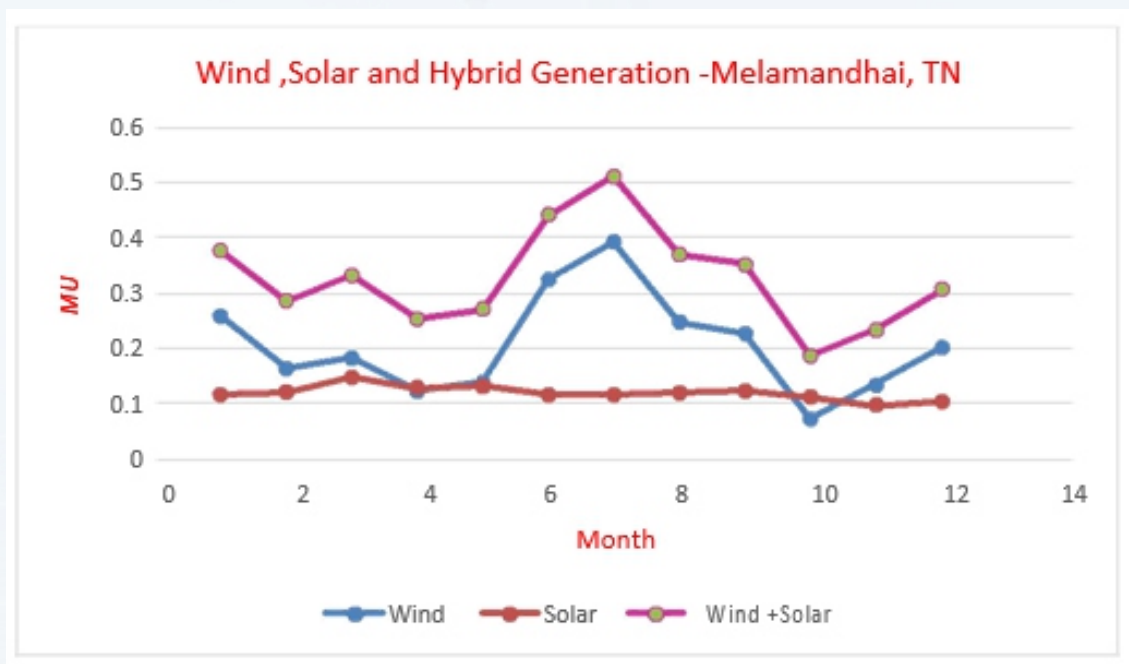


Fig 3.1.3. (a)

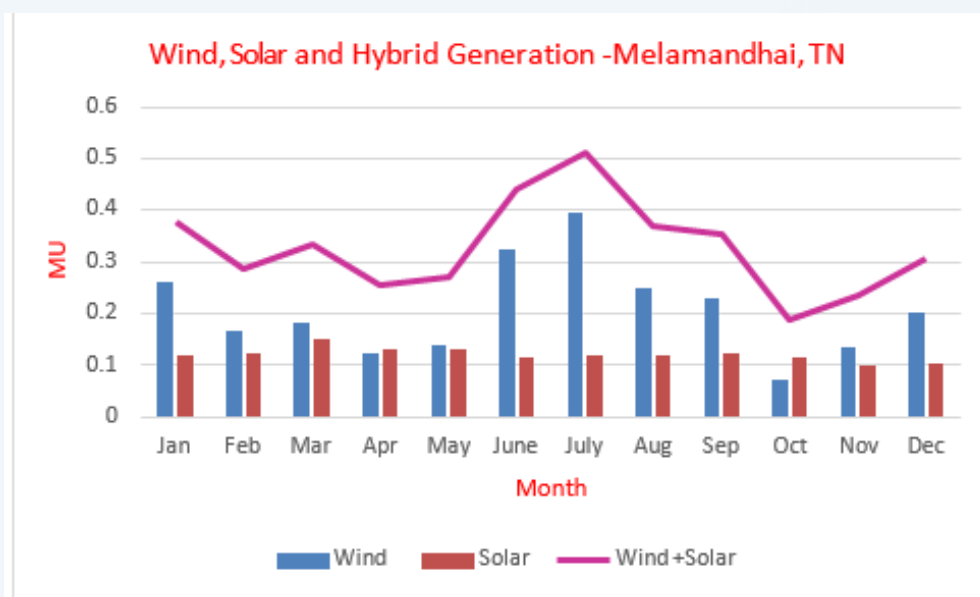


Fig 3.1.3. (b)

Fig 3.1.3. (a) & (b) Hybrid Wind & Solar Energy Generation at Melamandai

Fig 3.1.3.(a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Melamandai. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to March and a slight increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trends decreases after March for a small duration and rises with advancing south west monsoon. During April and July, wind power trends are maximum depicting maximum wind power generation. The solar trends on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of last September from November wind and solar trends to increases simultaneously. After which they slightly rise and contribute to the Annual trends.

The Table 1.3 gives details of generation of 1 MW solar PV plant and 1 MW wind turbine generation . Wind Turbine can generate 2.48 MU and Solar PV plant can generate 1.45 MU and cumulatively can generate 3.93 MU of electricity.

Table 3.1.3 wind, solar and cumulative hybrid generation

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
MELAMANDAI	2482315	1452490	3934804.912

3.1.4 Site Description of Akkanayakanpatti

Akkanayakanpatti is present in Thoothukudi district having plain Terrain Land, which is easy to accessible; Land availability is private ownership of land. Direction of land is 1Km from Maniyachi toward north east having GPS details of Lat 8°51'39.3" N and Long 77° 53' 11.4" E with 72m elevation, which is having nearest Sub- Station of 33/11 kV at Milavittan.

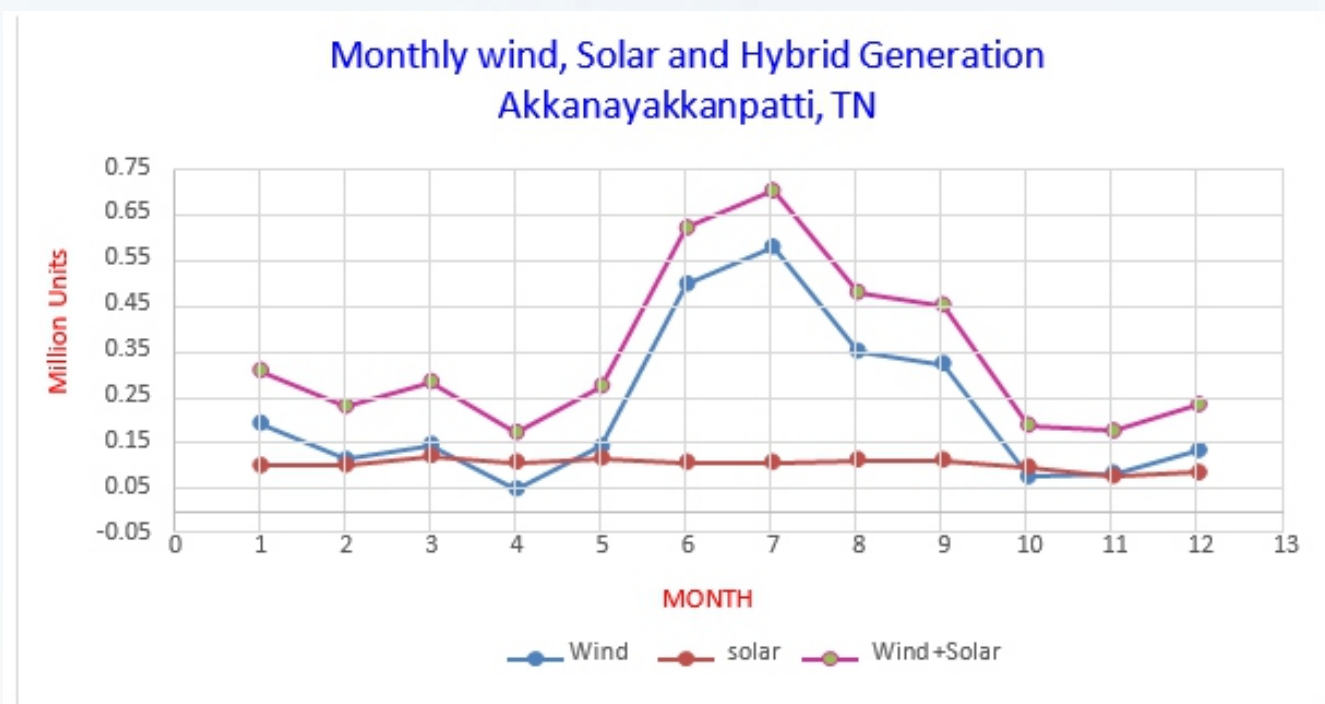


Fig 3.1.4. (a)

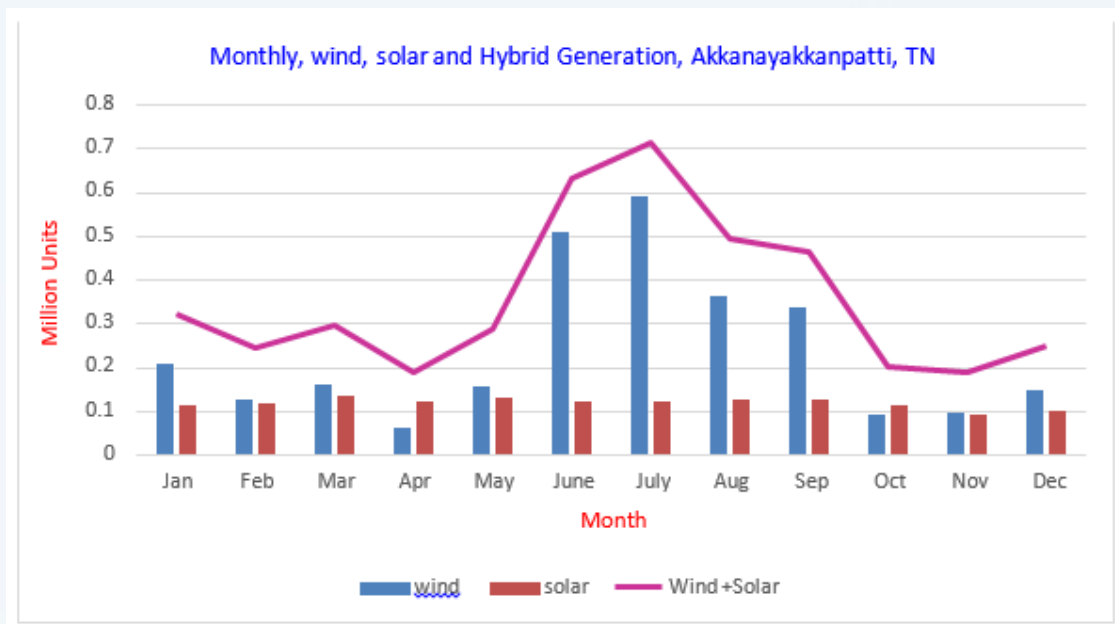


Fig 3.1.4. (b)

Fig 3.1.4. (a) & (b) Hybrid Wind & Solar Power Generation at Akkanayakanpatti

Fig 3.1.4. (a) & b shows trends of solar and wind hybrid average monthly power generation from January to December at Akkanayakanpatti. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to mid-March and a drastic increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trends decrease after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trends are maximum depicting maximum wind power generation. The solar trends on the other hand is not much variation , during the months of April to July and gradually increases from August until September. Post September, its Monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of last September from November wind and solar trends Increases simultaneously. After which they slightly rise and contribute to the Annual trends.

The Table 1.4 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate 2.86 MU and Solar PV plant can generate 1.43MU and cumulatively can generate 4.29 MU of electricity.

Table 1.4 Wind , Solar generation cumulative hybrid generation

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
AKKANAYAKANPATTI	2867774	1430690	4298464

3.1.5 Site Description of Viralimalai

Viralimalai is present in Pudukottai district having dry, open and plain land with red form soil, which is easily accessible from Poruvai village; Enough Land is available for wind monitoring Studies having private ownership of land, Land is located 6 Km east from viralimalai having GPS Details of Lat 10°38'17.74"N & Long 78°31'41.95"E with elevation 150m, The nearest substation is 400 kV substation with grid at Kummathur 12km east.

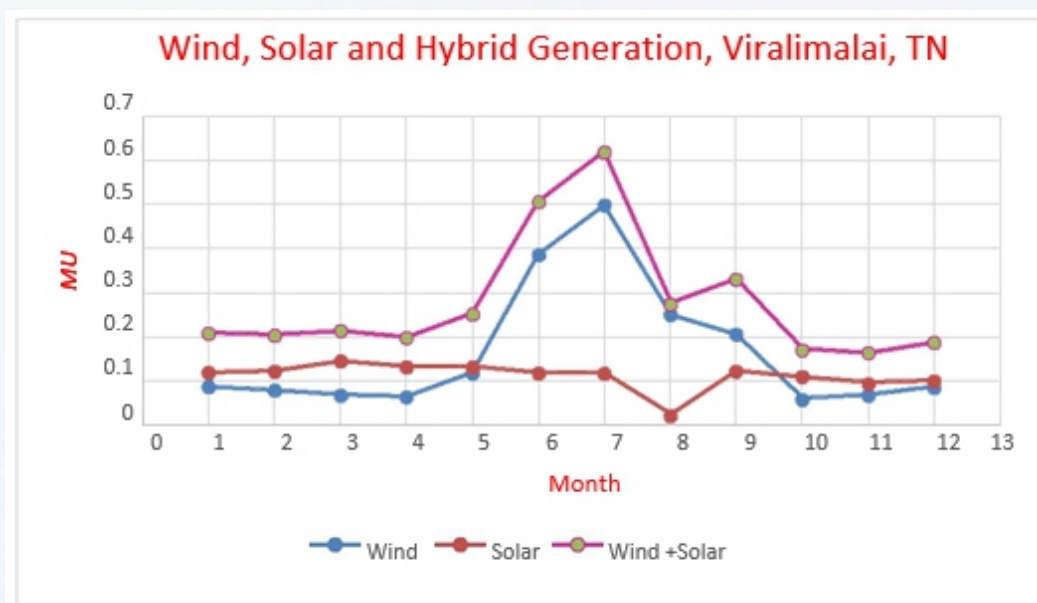


Fig 3.1.5. (a)

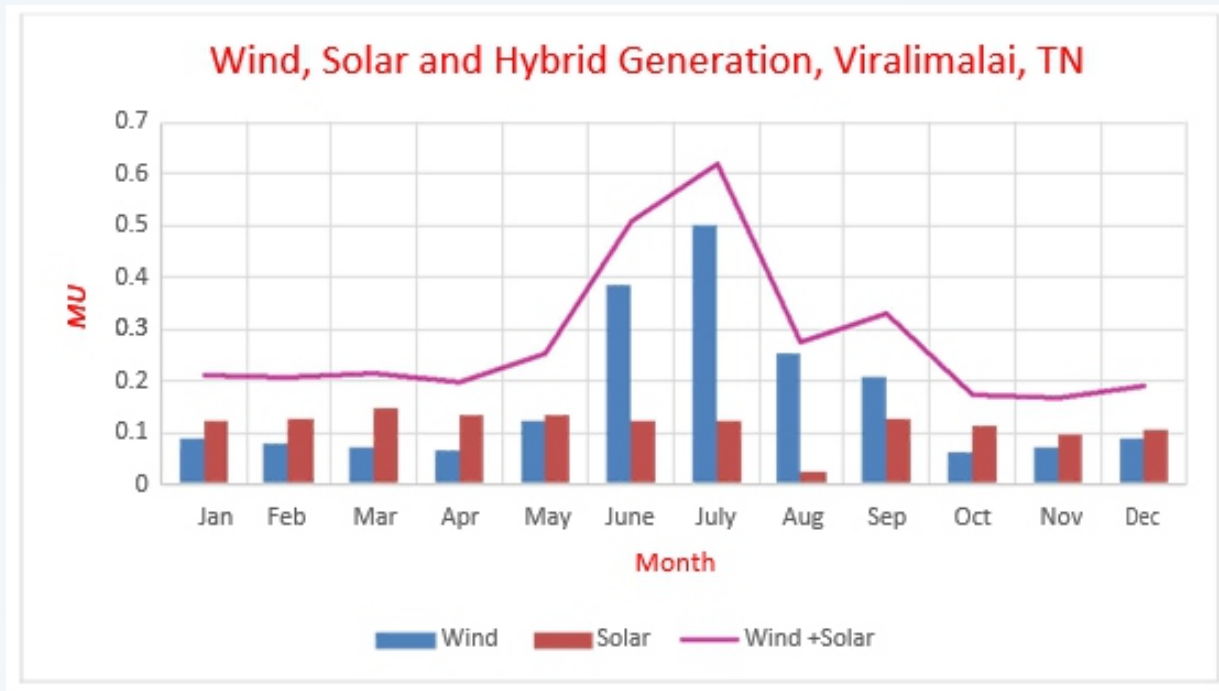


Fig 3.1.5 (b)

Fig 3.1.5. (a) & (b) Hybrid Wind & Solar Power Generation at Veralimalai

Fig 3.1.5. (a) and (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Veralimalai. On an annual span, it is observed that there's slight decrease in Wind power Generation from January up to mid-March and a drastic increase of solar generation within January to April duration. The seasonal variations in this region aids hybrid average power generation. Though wind trends increases after mid-March for a small duration and Rises with advancing south west monsoon.. During April and July, wind trends are maximum depicting maximum wind power generation. The solar trends on the other hand decreases during the months of April to July and gradually increases from August until mid-August and gradually increases from mid August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together show a simultaneous decrease until the month of last September from November wind and solar trends to increase simultaneously. After which they slightly rise and contribute to the Annual trends.

The Table 1.5 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine. Wind Turbine can generate at this particular area about 1.99 MU and Solar PV plant can generate 1.43 MU of electricity and cumulatively can generate 4.2 MU of electricity

Table 1.4 Wind , Solar generation cumulative hybrid generation

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
VERALIMALAI	1993187	1358837	3352024

3.2 SITE DESCRIPTIONS OF ANDHRA PRADESH

3.2.1 Site description of Kondurpalem

Kondurpalem is located in Durgarajapatnam village, Nellore district having Sea sand land. The ownership of land is government land which is easily accessible and locate at 52Km towards south of Nellore. The Nearest EB sub-station with grid is 33/11 KV Substation Durgarajapatnam near 5Km having GPS details of Lat 14° 00'33.6" N & Long 80 ° 08'59.1"E with elevation 4m.

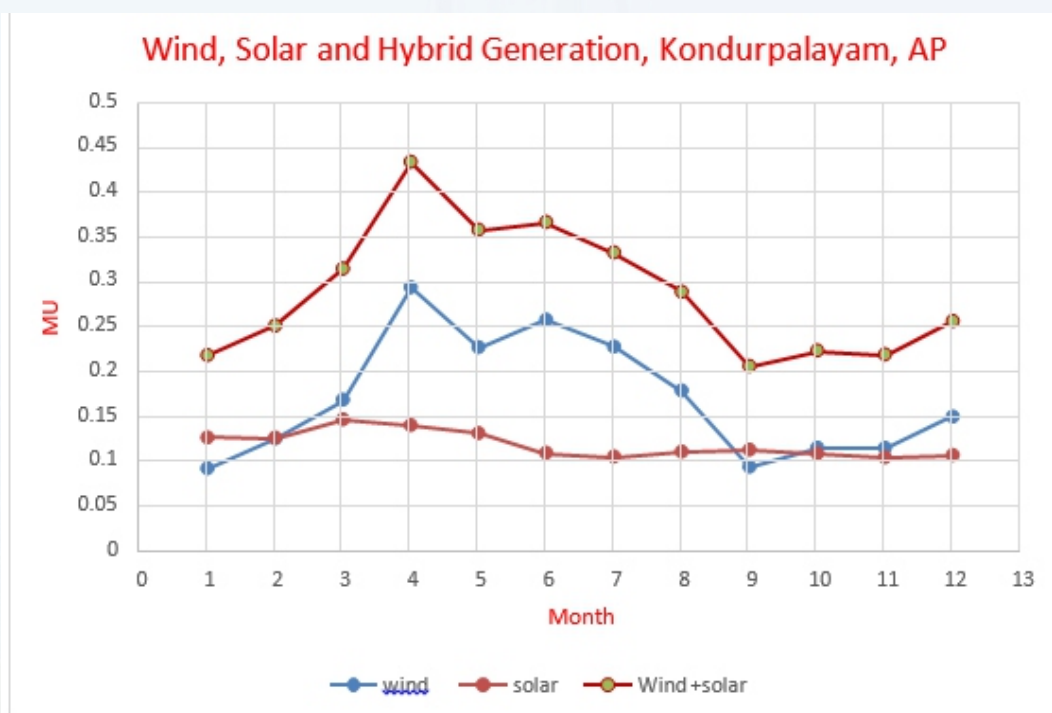


Fig 3.2.1. (a)

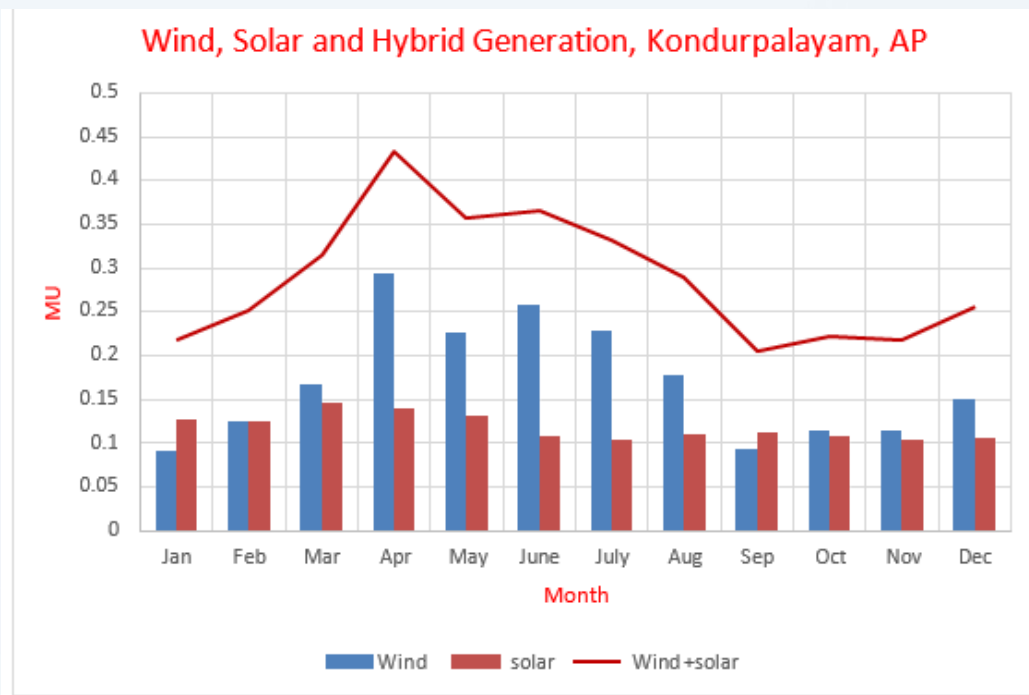


Fig 3.2.1.(b)

Fig 3.2.1. (a) & (b) Hybrid Wind & Solar Power Generation at Kondurpalem

Fig 3.2.1. (a) (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Kondurpalem. On an annual span, it is observed that there's drastic increase in Wind power Generation from January up to March and a gradual increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. During April the drastic increases of wind power and again slight decreasing in May and increasing in June again decreasing trend from July. There is gradual decrease from June to September with advancing south west monsoon.. The solar trends on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of last September from mid of September to start of November wind and solar trends to increases simultaneously.

The Table 1.5 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.04 MU and Solar PV plant can generate 1.42 MU of electricity and cumulatively can generate 3.46 MU of electricity.

Table 1.5 Wind ,Solar energy cumulative energy generation

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
KONDURPALEM	2042049	1425975	3468024

3.2.2 Site Description of Devareddypalli

Devareddypalli is located in Anantapur district having open land with red soil, The ownership of land is private land which is easily available and located at 67 km towards west of Ananthapur. The Nearest substation with grid is 33/11kv at Avaladatla near 4 km having GPS details of Lat 14°40'08.1"N & Long 76°57'45.3"E with elevation 507m.

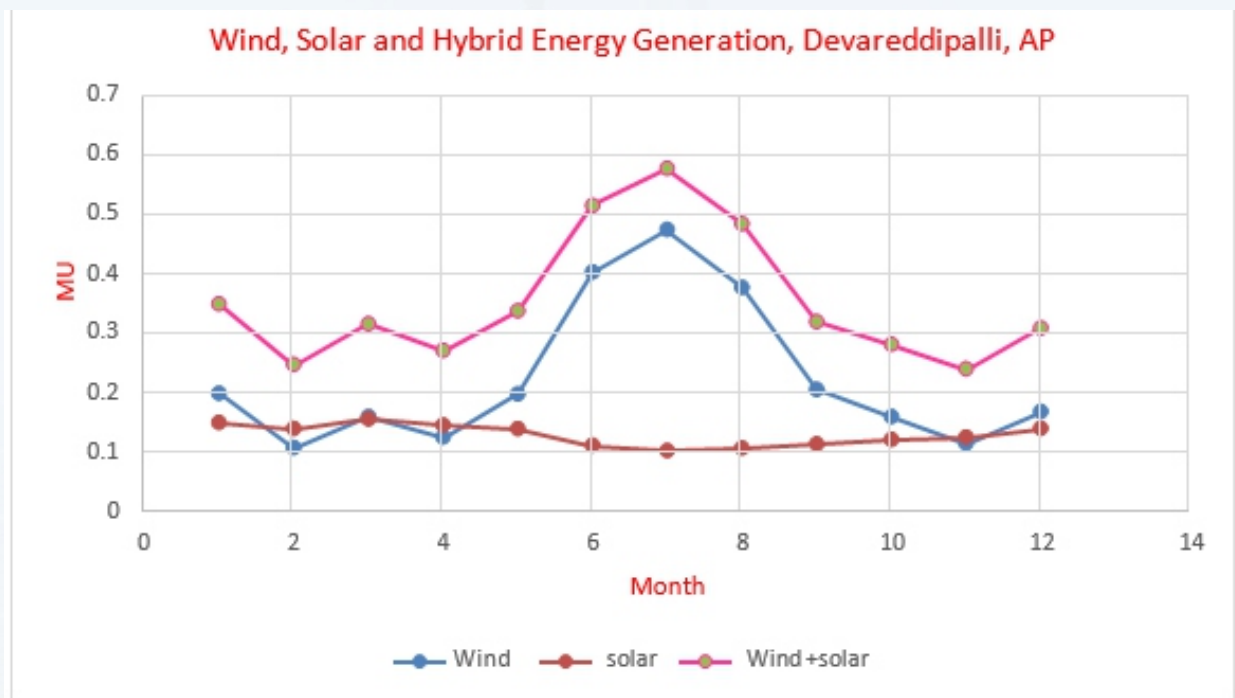


Fig 3.2.2. (a)

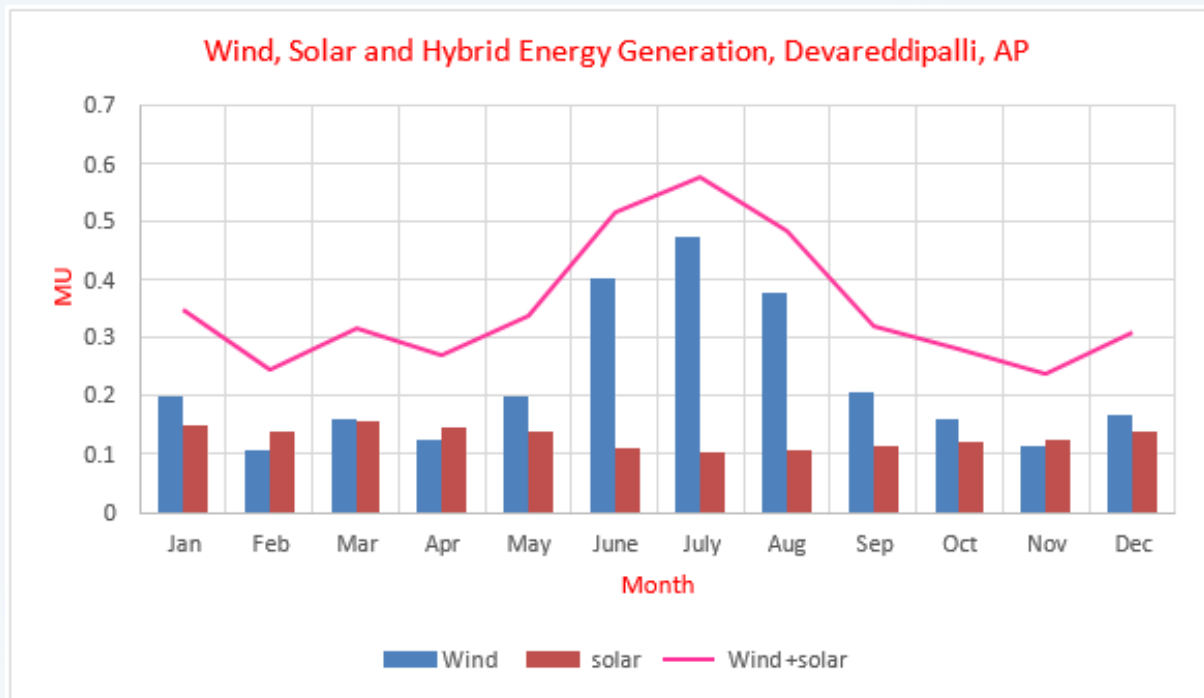


Fig 3.2.2. (b)

Fig 3.2.2. (a) and (b) Hybrid Wind & Solar Power Generation at Devereddyipalli

Fig 3.2.2. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Devereddyipalli. On an annual span, it is observed that there's slight decrease in wind power up to Feb and gradual increase of Wind power Generation from up to mid of June. A gradual decrease of solar generation from May up to August and again gradual increase of solar radiation . The seasonal variations in this region aids hybrid average power generation. Though wind trends increases from mid-March up to July drastically and there is gradual decrease from August end to Starting of November. The Solar trends on the other hand decreases during the months of April to July and gradually increases from August until start of November.

The Table 1.6 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.69 MU and Solar PV plant can generate 1.55MU of electricity and cumulatively can generate 4.24 MU of electricity

Table 1.6 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
DEVEREDDYPALLI	2690845	1551707	4242552

3.3 SITE DESCRIPTIONS OF TELANGANA

3.3.1 Site Description of Kompalli

Kompalli is located in Vikarabab Village, Angareddy district having open land with red soil, the ownership of land is private land which is easily available and enough land available for wind monitoring studies. The Nearest EB substation is 33/11 kV at Vikarabad about 6 km from the site having GPS details of Lat 17°22'27.1"N & Long 77°52'16.7"E with elevation 682m.

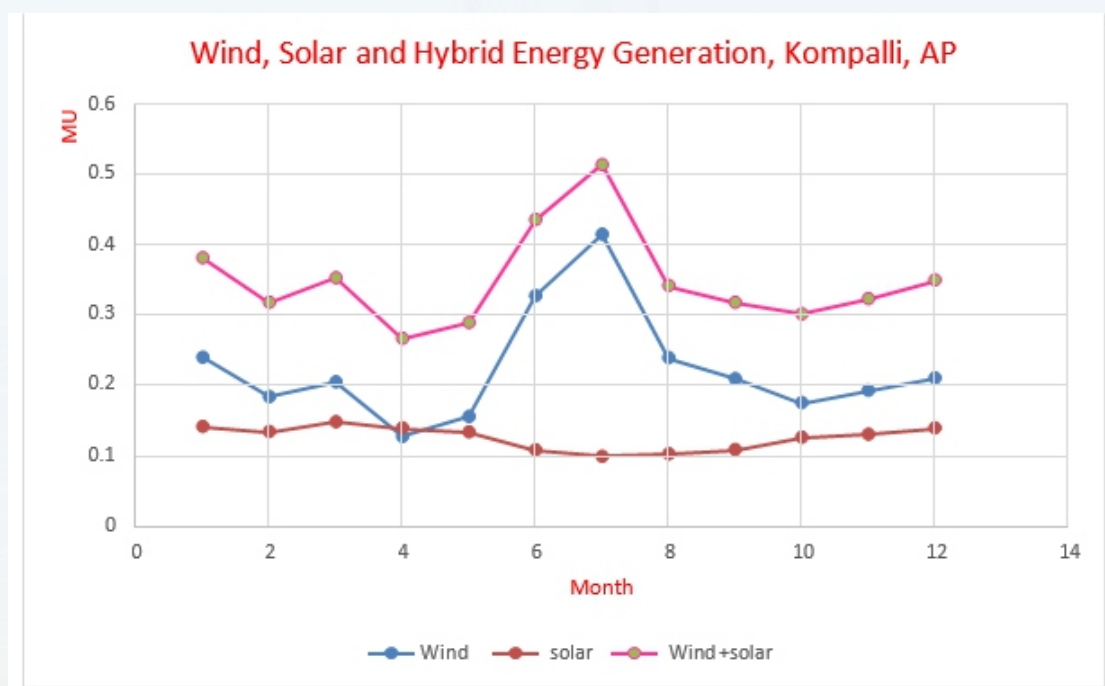


Fig 3.3.1. (a)

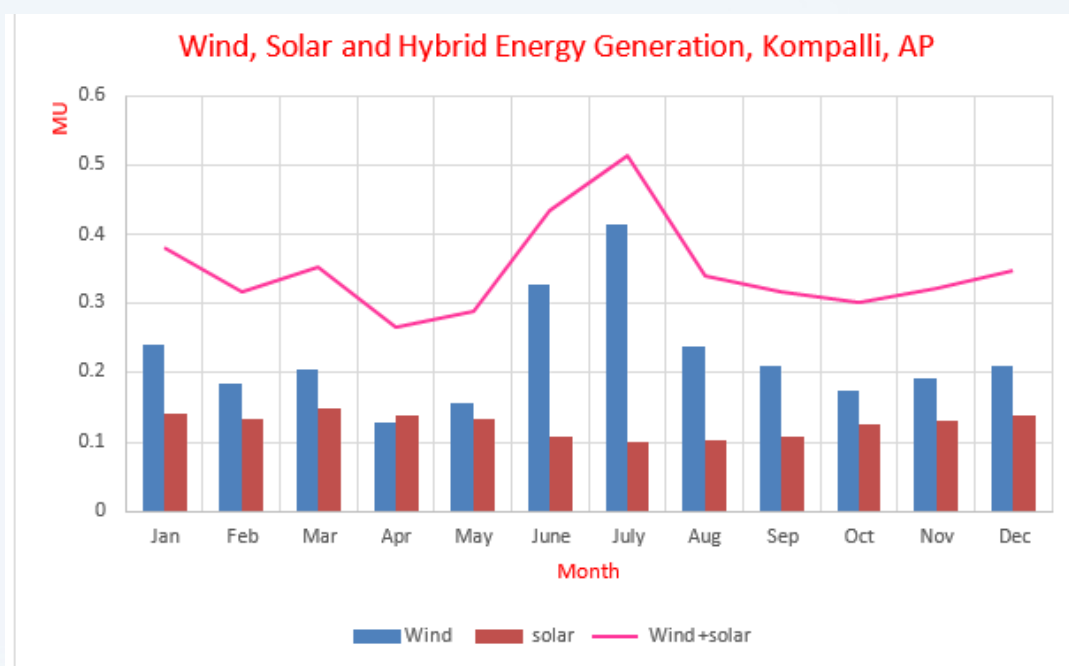


Fig 3.3.1. (b)

Fig 3.3.1. (a) & (b) Hybrid Wind & Solar Power Generation at Kompalli

Fig 3.3.1. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Kompalli. On an annual span, it is observed that there's slight increase in Wind power Generation at starting of January and it gradually until starting of March and a slight increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, solar gradually increase in trend wind get gradual decrease and increase during starting of September to December.

The Table 1.7 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.67 MU and Solar PV plant can generate 1.50 MU of electricity and cumulatively can generate 4.18 MU of electricity

Table 1.7 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
KOMPALLI	2678020	1509371	4187391

3.3.2 Site description of Sunkisala

Sunkisala is located in Nalganda district having open agricultural land , easily accessible with private owner ship and located 50 km from Nalganda toward south-east. The Nearest EB substation is 33/11 kV Substation at Haliya nearly 5 km distance from the site having GPS details of Lat 16°41'10.3"N & Long 79°21'57.6"E with elevation 225m.

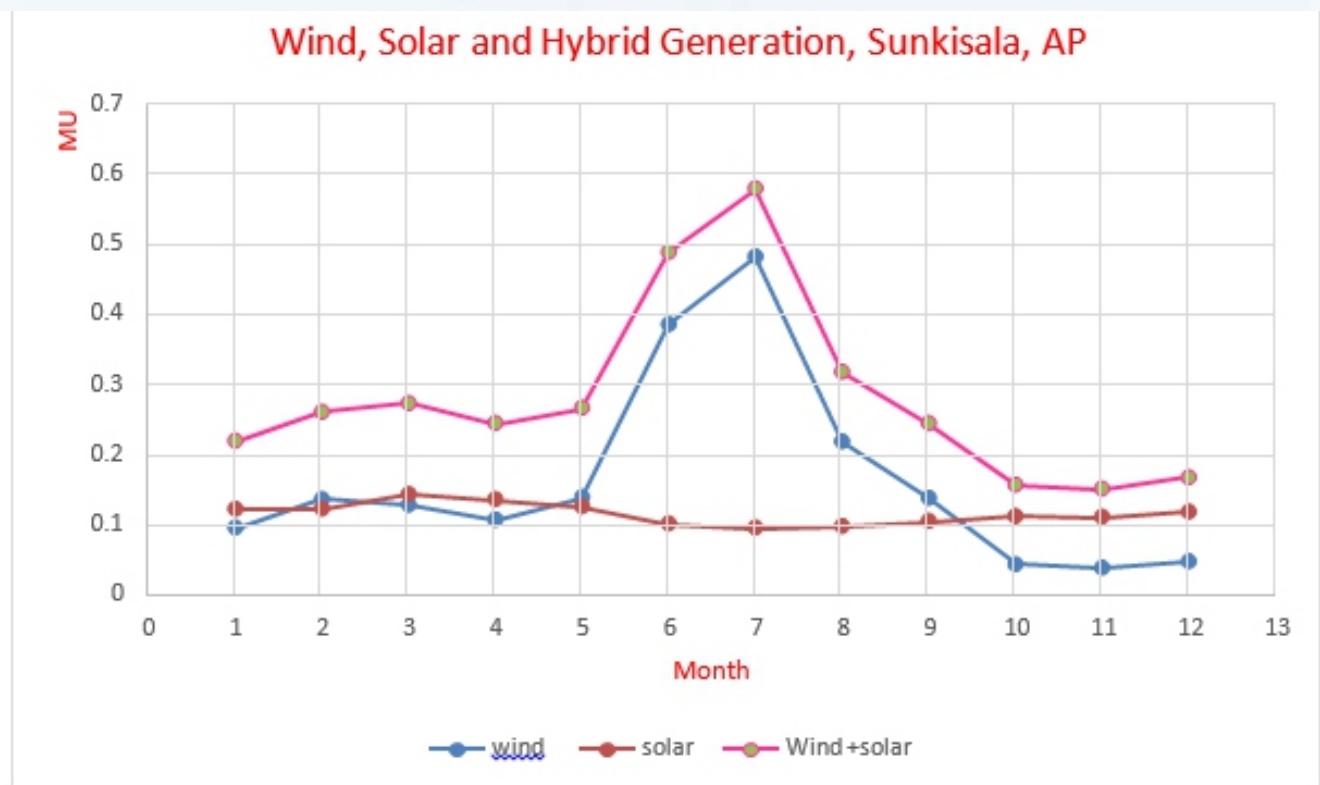


Fig 3.3.2. (a)

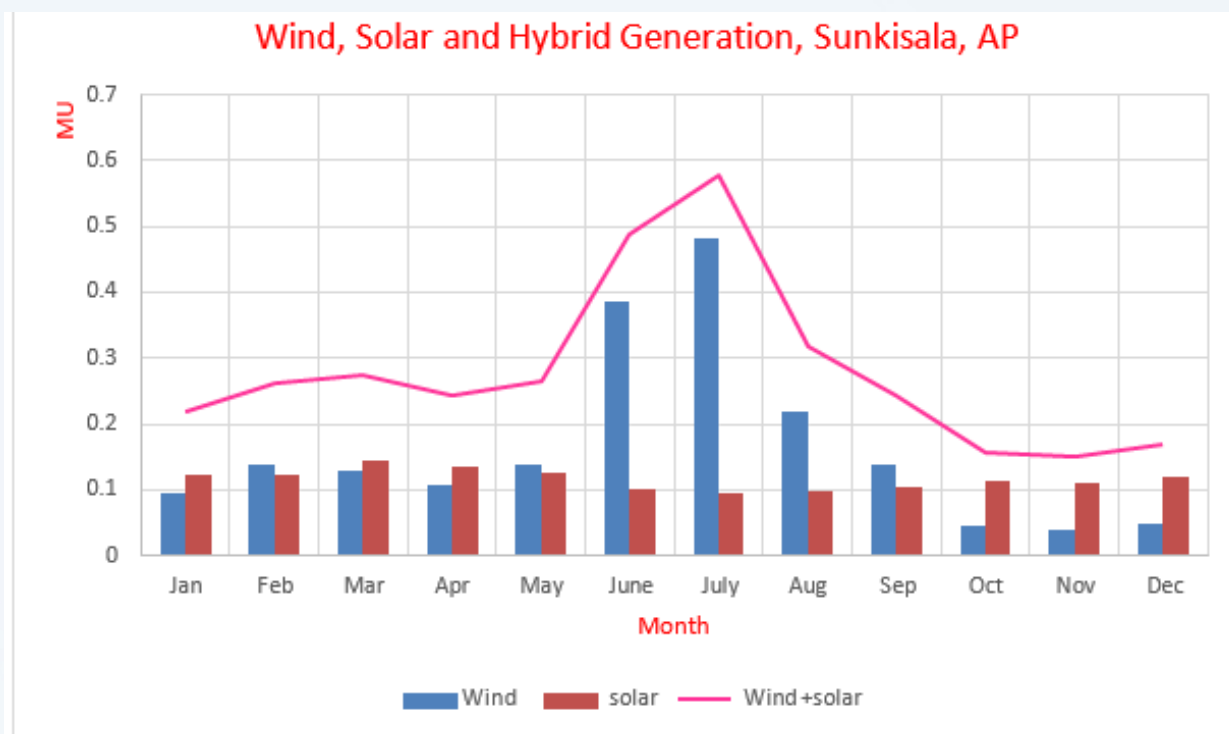


Fig 3.3.2. (b)

Fig 3.3.2. (a) Hybrid Wind & Solar Power Generation at Sunkisala

Fig 3.3.2. (a) shows trends of solar and wind hybrid average monthly power generation from January to December at Sunkisala. On an annual span, it is observed that there's slight decrease in Wind power Generation at starting of January and it gradually until starting of March and a slight increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend increases after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, solar gradually increase in trend wind get gradual decrease and increase during starting of September to December.

The Table 1.8 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine. Wind Turbine can generate at this particular area about 1.97 MU and Solar PV plant can generate 1.40 MU of electricity and cumulatively can generate 3.37 MU of electricity.

Table 1.8 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
SUNKISALA	1970826.413	1404415	3375241.413

3.3.3 Site Description of Chadmal

Chadmal is located in Nizamabad district having open agricultural Land; the ownership of land is Private land which is easily available and located at 40 km from Nizamabad towards south. The nearest substation is 33/11kv substation at Yacharam Nearly 5 km has GPS details of Lat 18°23'14.25 N & Long 78°14'37.92"E with elevation 633m.

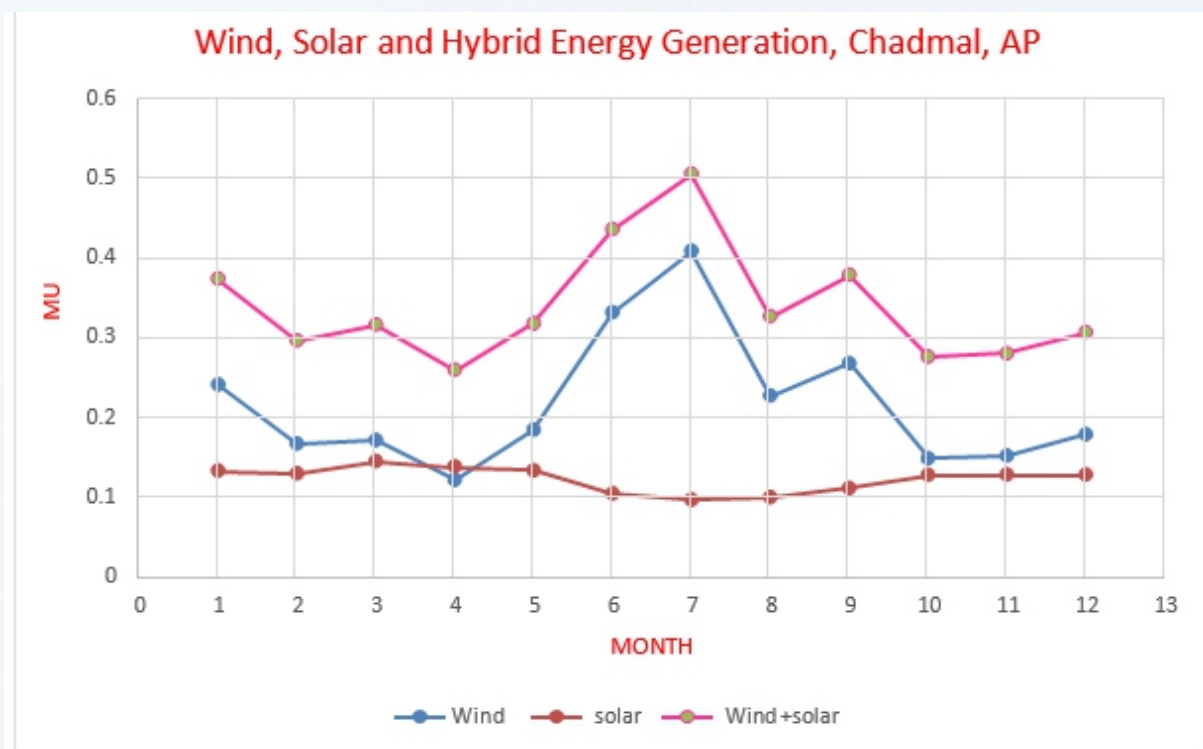


Fig 3.3.3. (a)

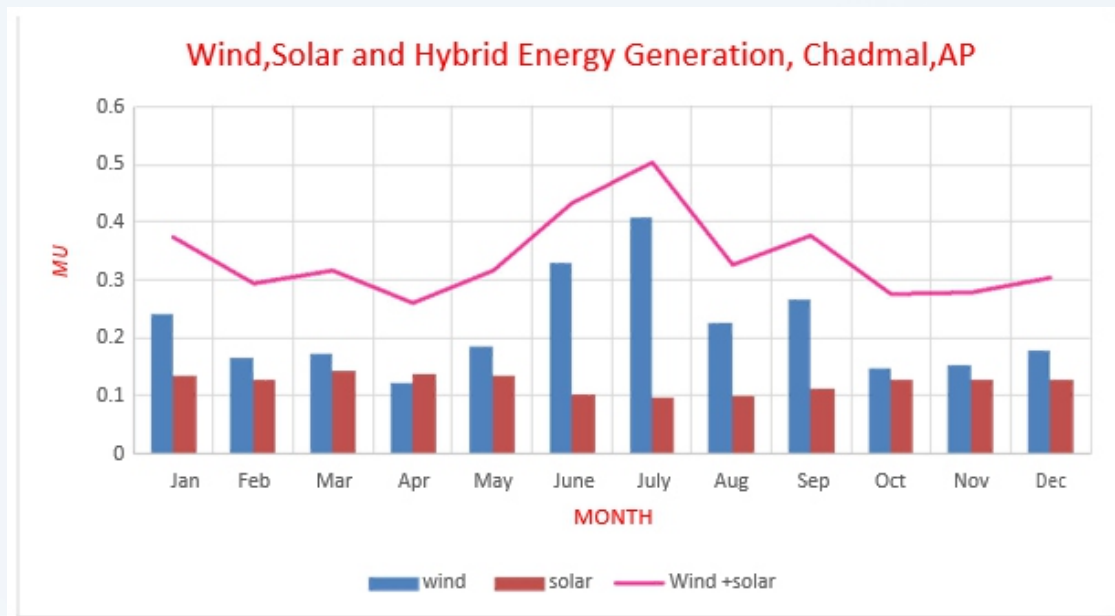


Fig 3.3.3. (b)

Fig 3.3.3. (a) & (b) Hybrid Wind & Solar Power Generation at Chadmal

Fig 3.3.3. (a)& (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Chadmal. On an annual span, it is observed that there's slight decrease in Wind power Generation from January up to March and a drastic increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trends increases after March up to June drastically for duration and rises with advancing south west monsoon.. During April and July, wind trends are maximum depicting maximum wind power generation. The solar trends on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoonat most of the places, due to which solar and wind trends together shows a simultaneous increase until the month of September. From November wind decrease and solar trends to increases simultaneously. After which they slightly rise and contribute to the Annual trends.

The Table 1.9 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.59 MU and Solar PV plant can generate 1.47 MU of electricity and cumulatively can generate 4.06 MU of electricity.

Table 1.9 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
CHADMAL	2595608	1472125	4067733

3.4 SITE DESCRIPTIONS OF KARNATAKA

3.4.1 Site Description of Mustigeri

Mustigeri is located in Bagalkati district having plain terrain; the ownership of land is private land which is easily accessible and located Near Mustigeri village. The nearest substation is Badamai substation near 12kms has GPS details of Lat 15°58'39.3"N & Long 75°33'39.0"E with elevation 616m.

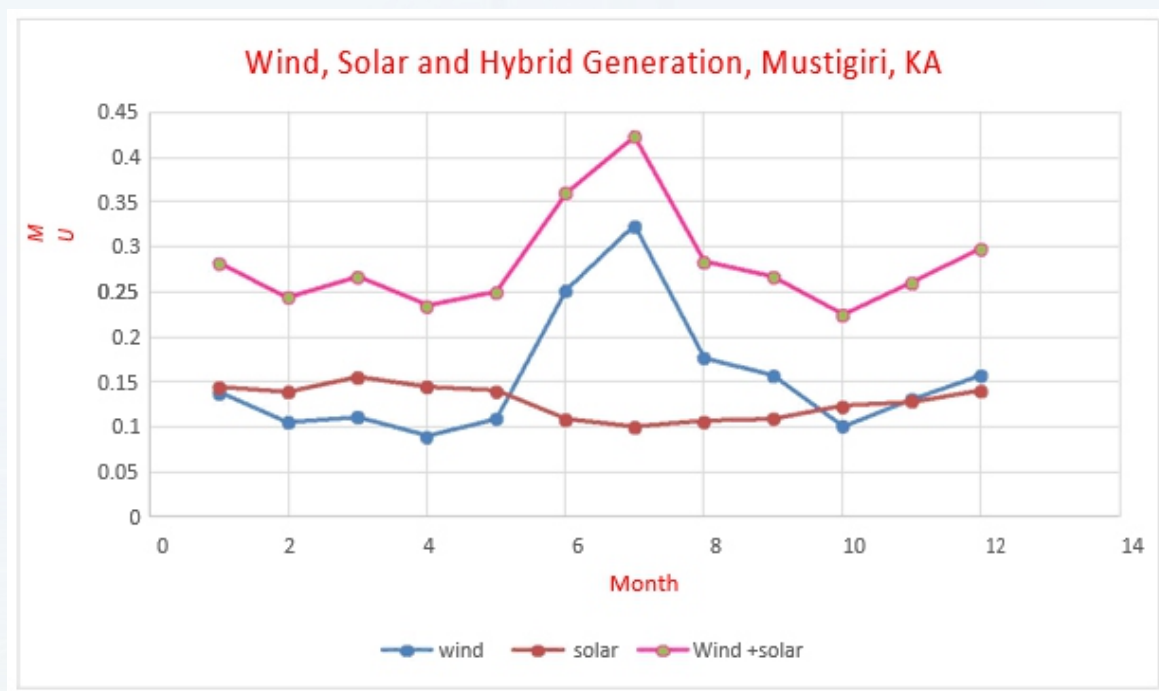


Fig 3.4.1. (a)

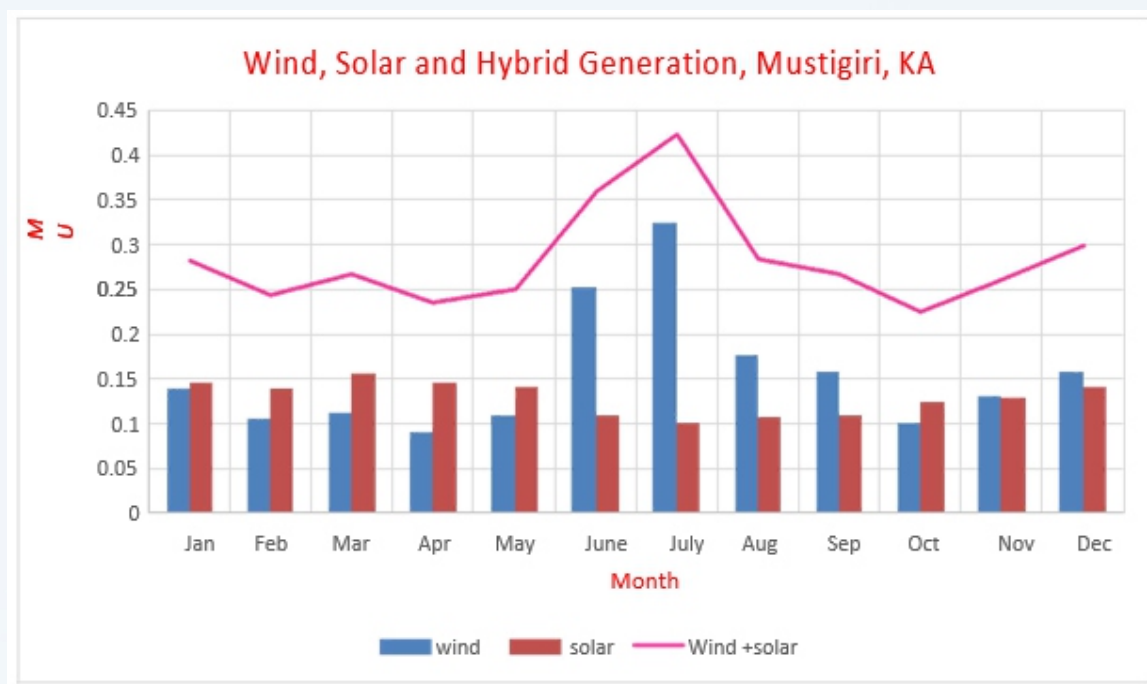


Fig 3.4.1 (b)

Fig 3.4.1. (a) & (b) Hybrid Wind & Solar Power Generation at Mustigeri

Fig 3.4.1. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Mustigeri. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to March and a drastic increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of March to July and gradually increases from end of August until November. Post September, it's end of monsoon at most of the places, due to which wind trends together shows a simultaneous decrease and increase until the month of December and solar trend to increases simultaneously. After which they slightly rise and contribute to the Annual trend.

The Table 1.10 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 1.85 MU and Solar PV plant can generate 1.54 MU of electricity and cumulatively can generate 3.40 MU of electricity.

Table 1.10 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
MUSTIGERI	1857387	1543907	3401294

3.4.2 Site Description of Taralkatti

Taralkatti is located in Koppal district having Plain terrain; the ownership of land is Private Land which is easily accessible and located near 5 km from Taralkatti village. The nearest substation is Yalburga Substation near 10 km has GPS details of Lat 15°39'15.4"N & Long 76°10'56.3"E with elevation of 679m.

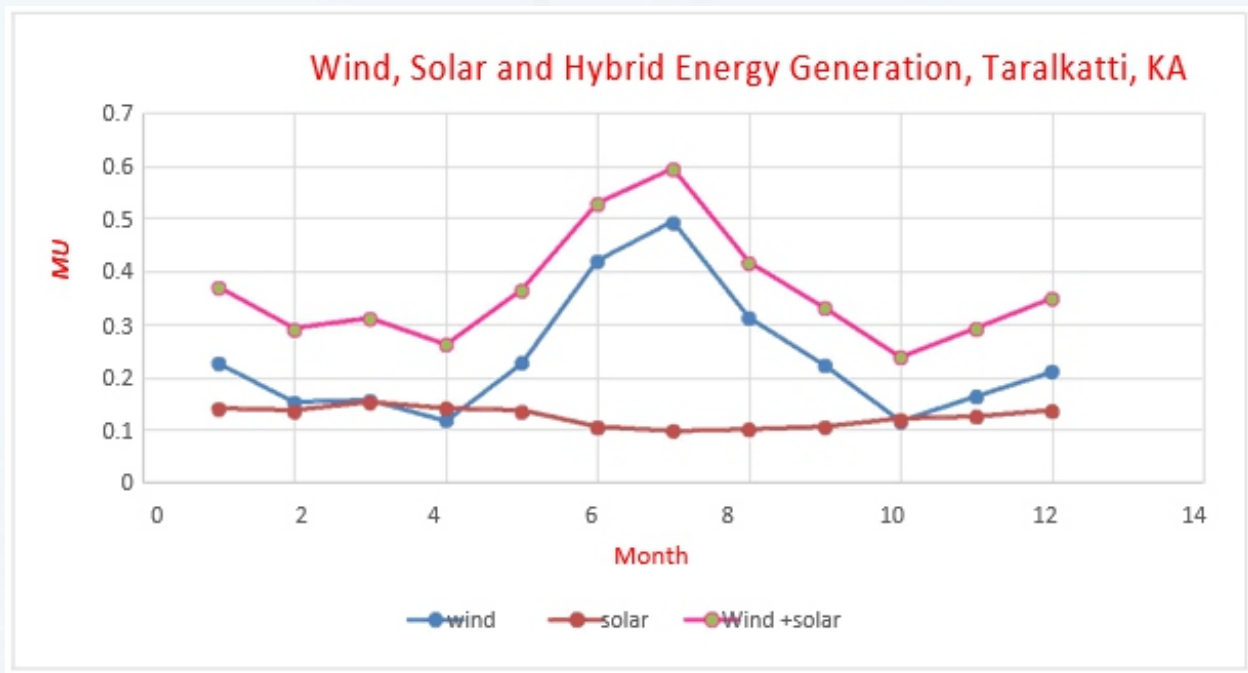


Fig 3.4.2 (a)

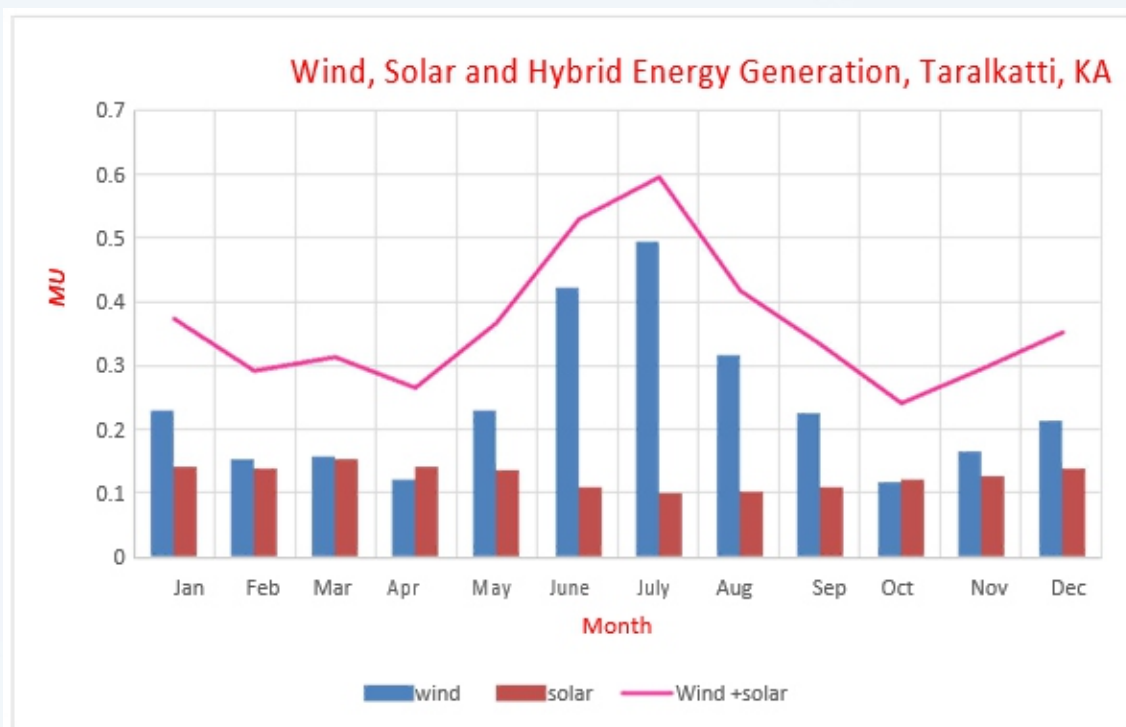


Fig 3.4.2 (b)

Fig 3.4.2. (a) & (b) Hybrid Wind & Solar Power Generation at Taralkatti

Fig 3.4.2. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Taralkatti. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to March and a drastic increase of solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trends decreases after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trends are maximum depicting maximum wind power generation. The solar trends on the other hand decreases during the months of April to July and gradually increases from August until November. Post September, it's end of monsoon at most of the places, due to which solar trend to increase and wind trends to decrease simultaneous until the month of December. After which they slightly rise and contribute to the Annual trends.

The Table 1.11 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.84 MU and Solar PV plant can generate 1.52 MU of electricity and cumulatively can generate 4.37MU of electricity.

Table 1.11 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
TARALKATTI	2849633	1525679	4375312

3.4.3 Site Description of Machenahalli

Machenahalli is located in Godag district having plain terrain; the ownership of land is private land which is easily accessible and located near 4km from Belhatti, between Belhatti and Machenahalli. The nearest substation is Shriahatti substation near 12kms has GPS details of Lat 15°06'37.3"N & Long 75°39'45.3"E with elevation of 612m.

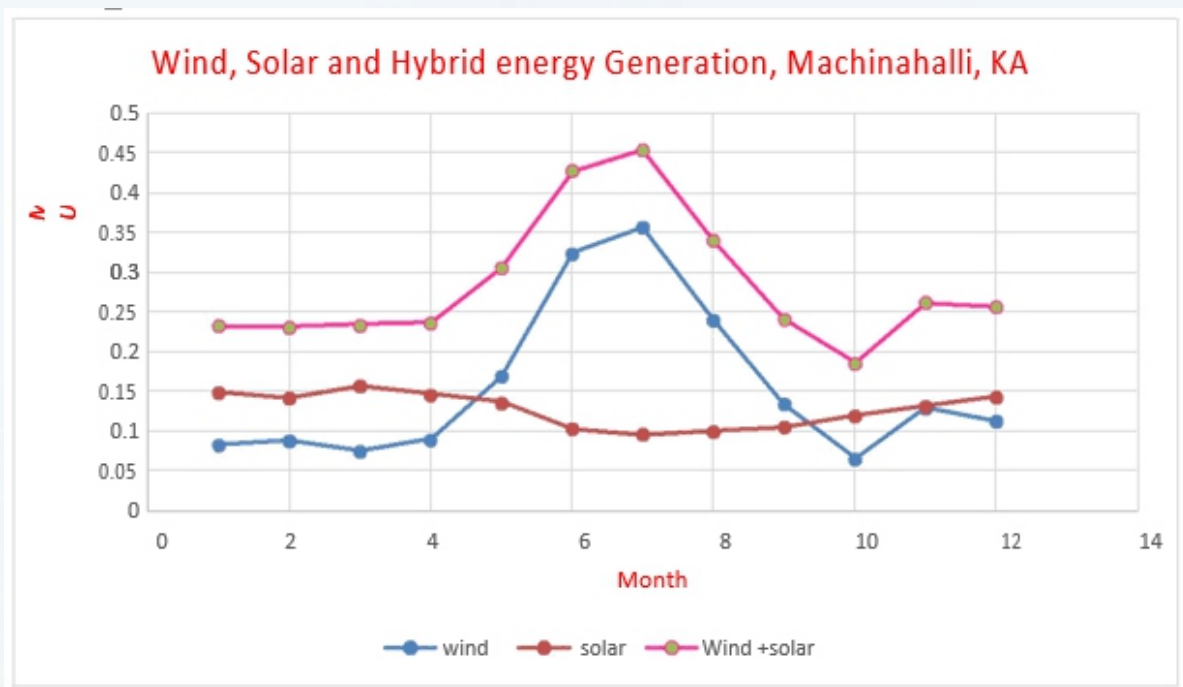


Fig 3.4.3 (a)

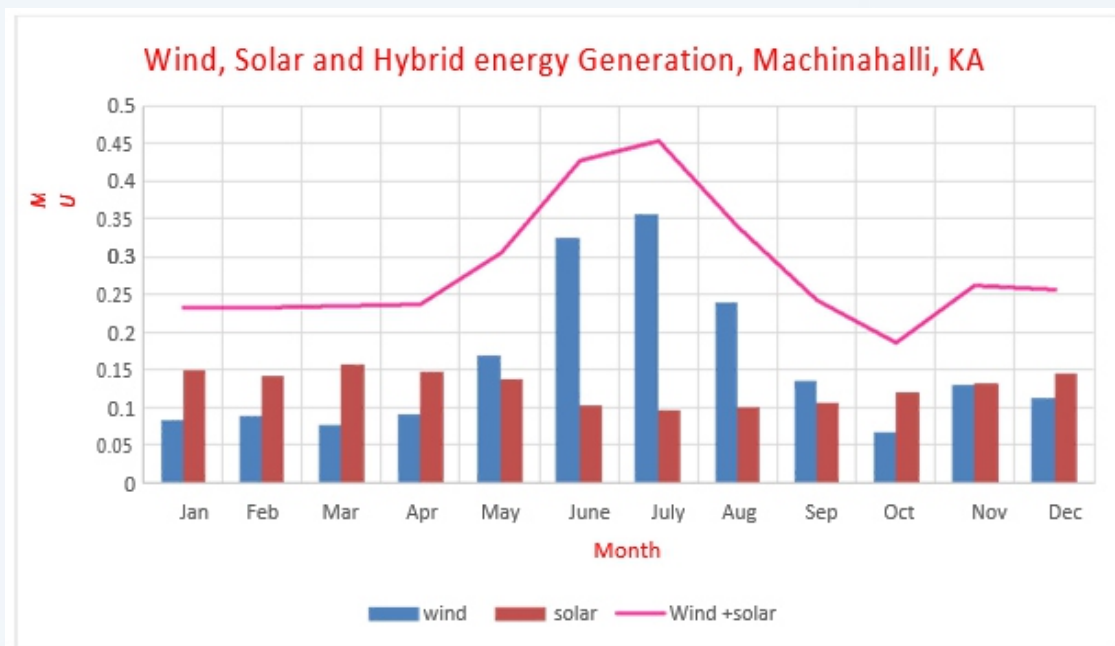


Fig 3.4.3 (b)

Fig 3.4.3. (a) & (b) Hybrid Wind & Solar Power Generation at Machenahalli

Fig 3.4.3. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Machenahalli. On an annual span, it is observed that there's slight decrease and increase in Wind power Generation from January up to March and a drastic increase of Solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trends decreases after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until November. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.12 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 1.87 MU and Solar PV plant can generate 1.57 MU of electricity and cumulatively can generate 3.41 MU of electricity.

Table 1.12 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
MACHENAHALLI	1878793.982	1540516	3419309.982

3.4.4 Site Description of Haikal

Haikal is located in Chitradurga district having plain terrain, the ownership of land is private land which is easily accessible and located near 16kms from Haikal Village. The Nearest substation with grid is Chitradurga substation near 16kms has GPS details of Lat 14°19'23.7"N & Long 76°29'02.1"E with elevation of 666m.

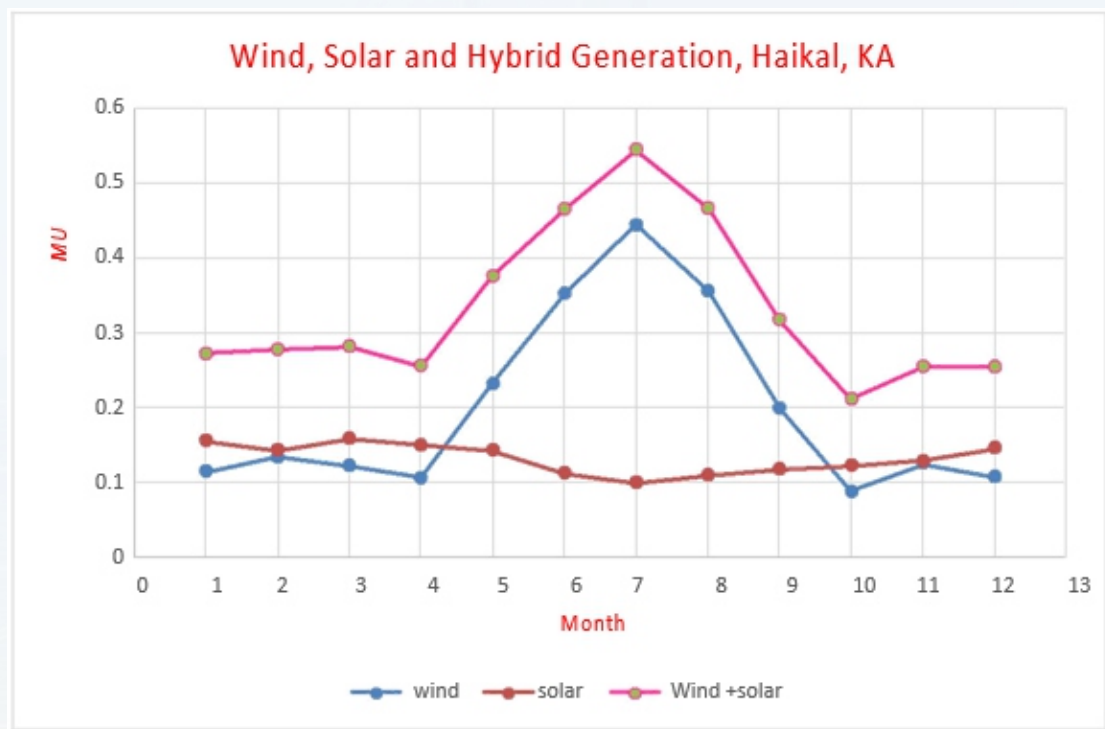


Fig 3.4.4 (a)

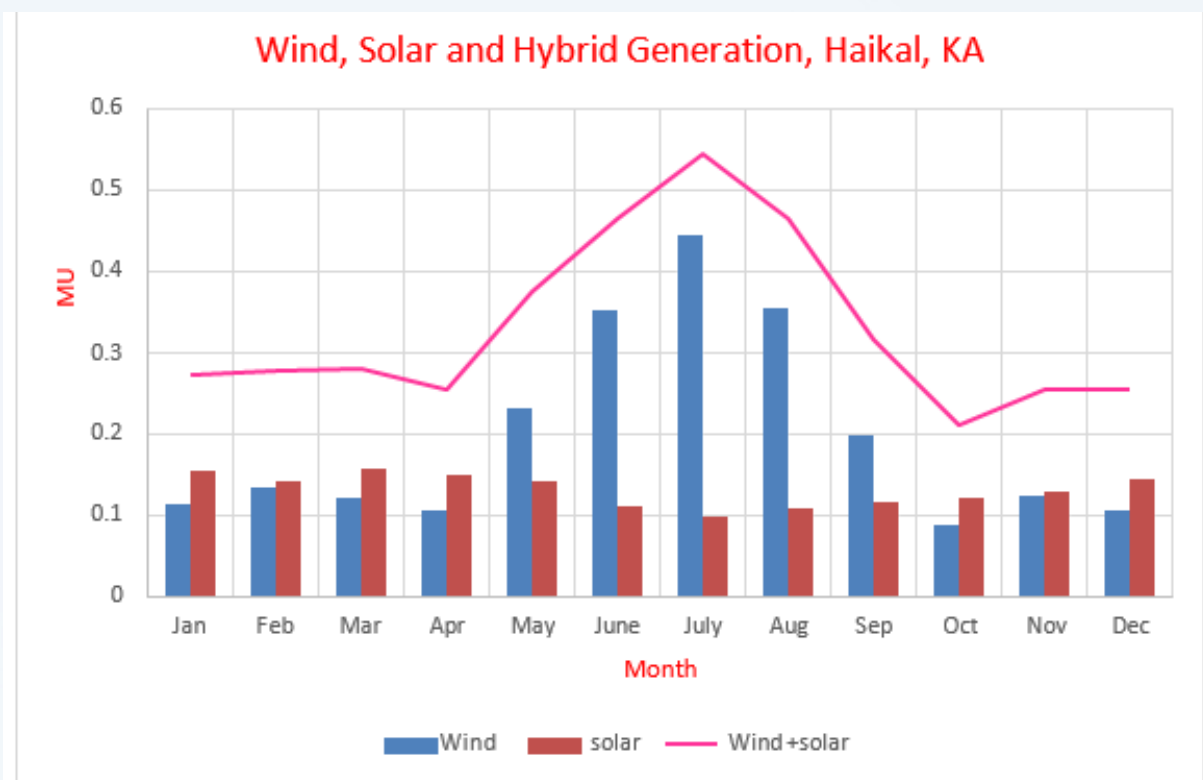


Fig 3.4.4 (b)

Fig 3.4.4. (a) & (b) Hybrid Wind & Solar Energy Generation at Haikal

Fig 3.4.4. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Haikal. On an annual span, it is observed that there's slight decrease in Wind power Generation from January up to March and a drastic increase of solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until December. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease and increase until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.13 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.38 MU and Solar PV plant can generate 1.59 MU of electricity and cumulatively can generate 3.98 MU of electricity

Table 1.13 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
HAIKAL	2386807	1597156	3983963

3.5 SITE DESCRIPTIONS OF GUJARAT

3.5.1 Site Description of Suigam

Suigam is located in Banasktha district having agricultural land; the ownership of land is private land which is easily available and located near 6km from Zelloriya. The nearest substation with grid is 33/11kV substation Zelloriya near 6 km has GPS details of Lat 24°10'05.5"N & Long 71°20'48.5"E with elevation of 30m.

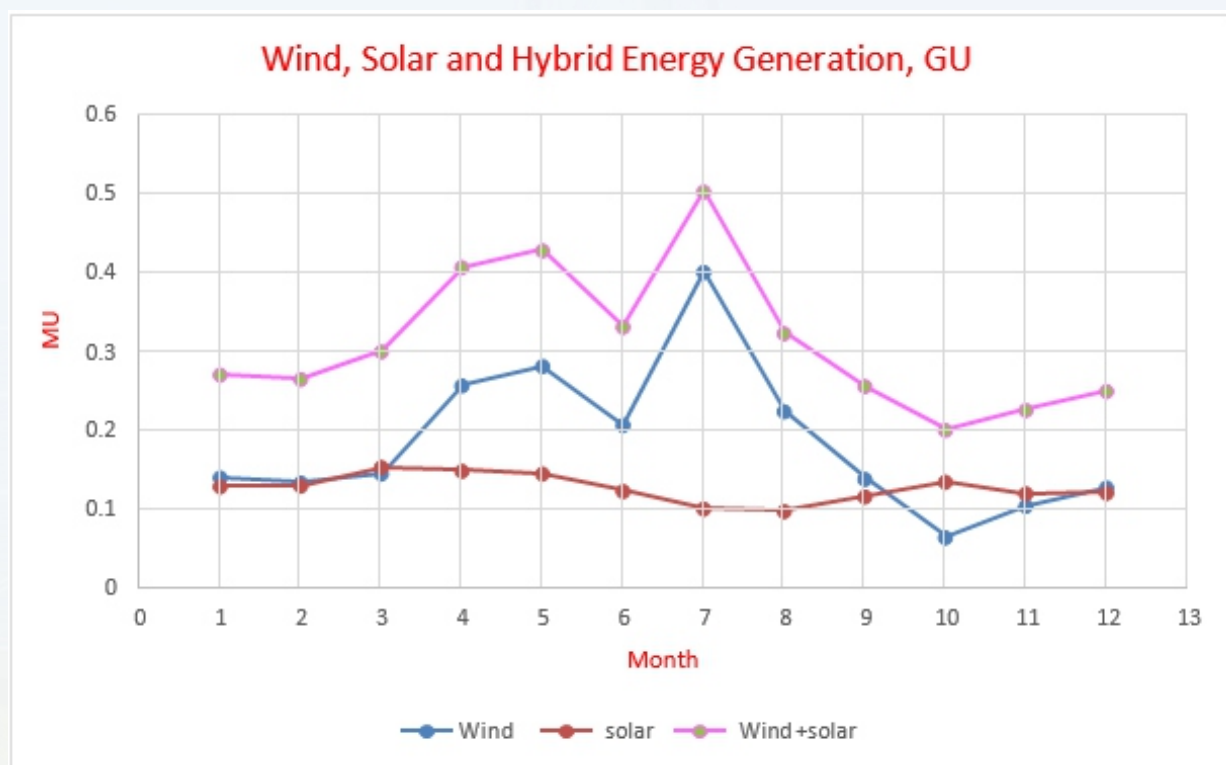


Fig 3.5.1 (a)

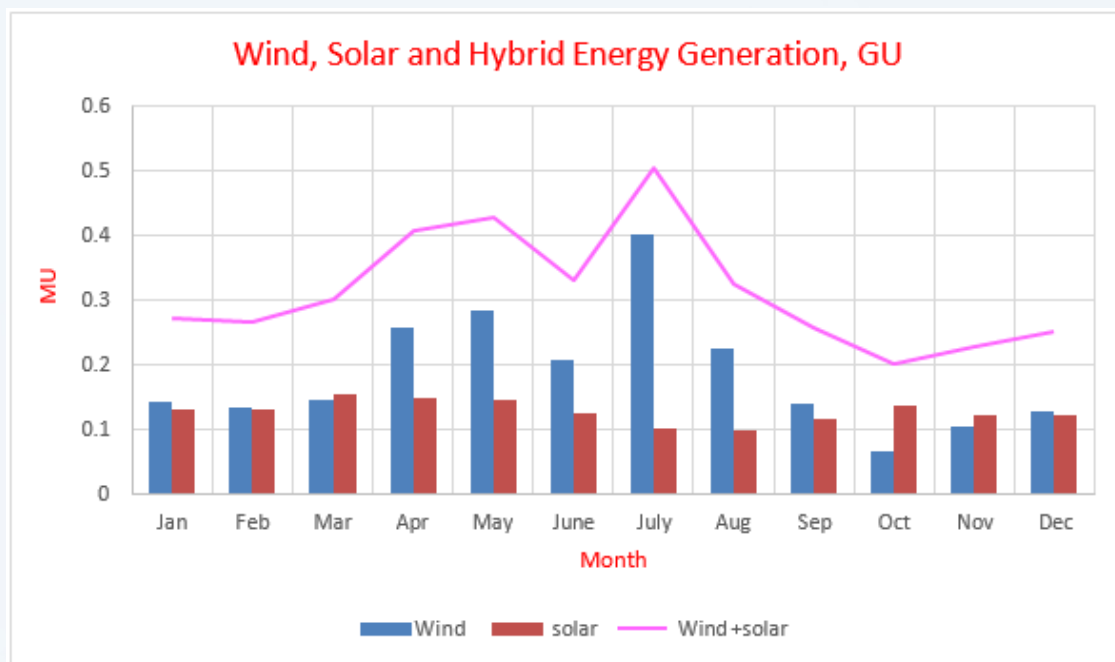


Fig 3.5.1 (b)

Fig 3.5.1. (a) & (b) Hybrid Wind & Solar Power Generation at Suigam

Fig 3.5.1. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Suigam. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to mid-March and a drastic increase of Solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend increases after April for a small duration and rises with advancing south west monsoon. until July. During April and July, wind trend is maximum depicting maximum wind power generation. Again from August to October wind trends to gradually decrease. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.14 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.23 MU and Solar PV plant can generate 1.53 MU of electricity and cumulatively can generate 3.76MU of electricity.

Table 1.14 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
SUIGAM	2235199	1531701	3766900

3.5.2 Site Description of Kuran

Kuran is located in Kutch district having agricultural land; the ownership of land is Private land which is easily available and located 70km from Bhuj. The nearest substation with grid is 33/11 kV Substation Khawda near 100 km has GPS details of Lat 23°57'06.6" N and Long 69°45'10.2"E with elevation of 35m.

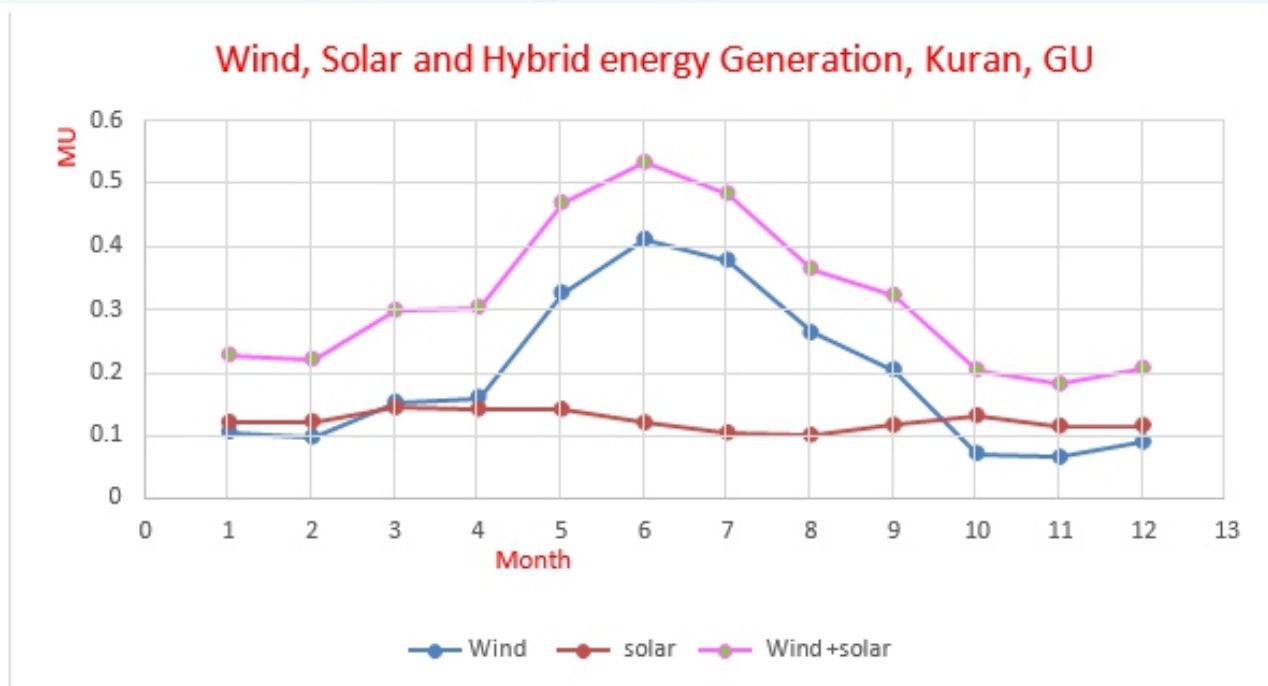


Fig 3.5.2 (a)

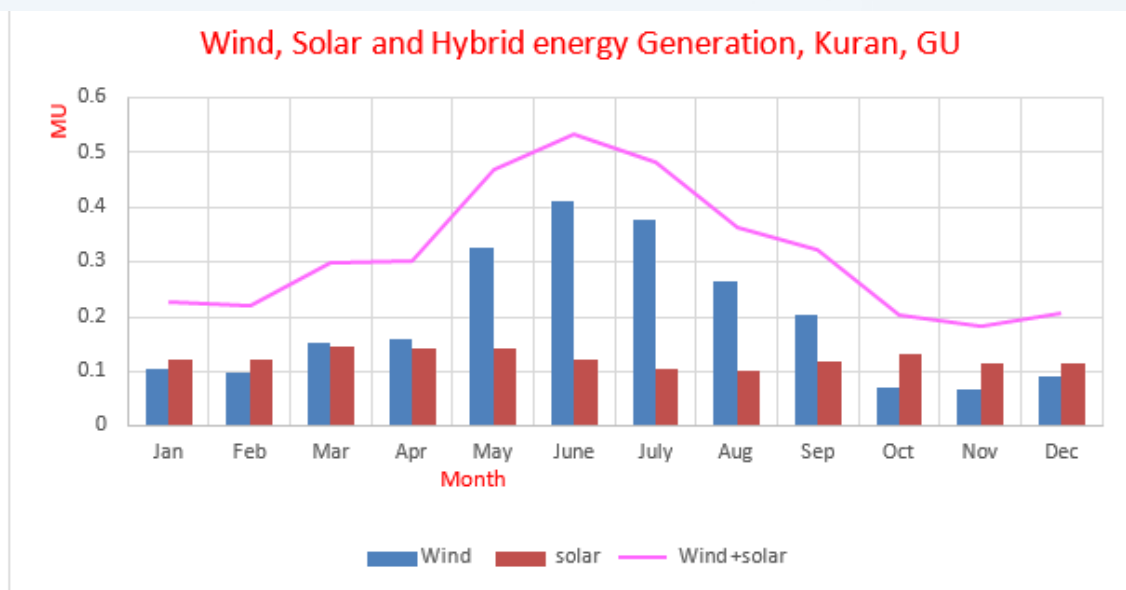


Fig 3.5.2 (b)

Fig 3.5.2. (a) & (b) Hybrid Wind & Solar Power Generation at Kuran

Fig 3.5.2. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Kuran. On an annual span, it is observed that there's Gradual increase in Wind power Generation from January up to end of April and a drastic increase of solar power generation within the same duration up to April. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after June for duration of June to September end. Within March and end of June, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.14 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.33 MU and Solar PV plant can generate 1.48 MU of electricity and cumulatively can generate 3.82 MU of electricity.

Table 1.15 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
KURAN	2335965	1485120	3821085

3.5.3 Site Description of Pandhro

Pandhro is located in Kutch district having agricultural land, The owner ship of land is Private land which is easily available and located in 70 km From Bhuj. The nearest substation with grid is 33/11 kV Substation Dhaiper near 20 km has GPS details of Lat 23°41'36.8"N & Long 68°43'46.8" E with elevation of 47m.

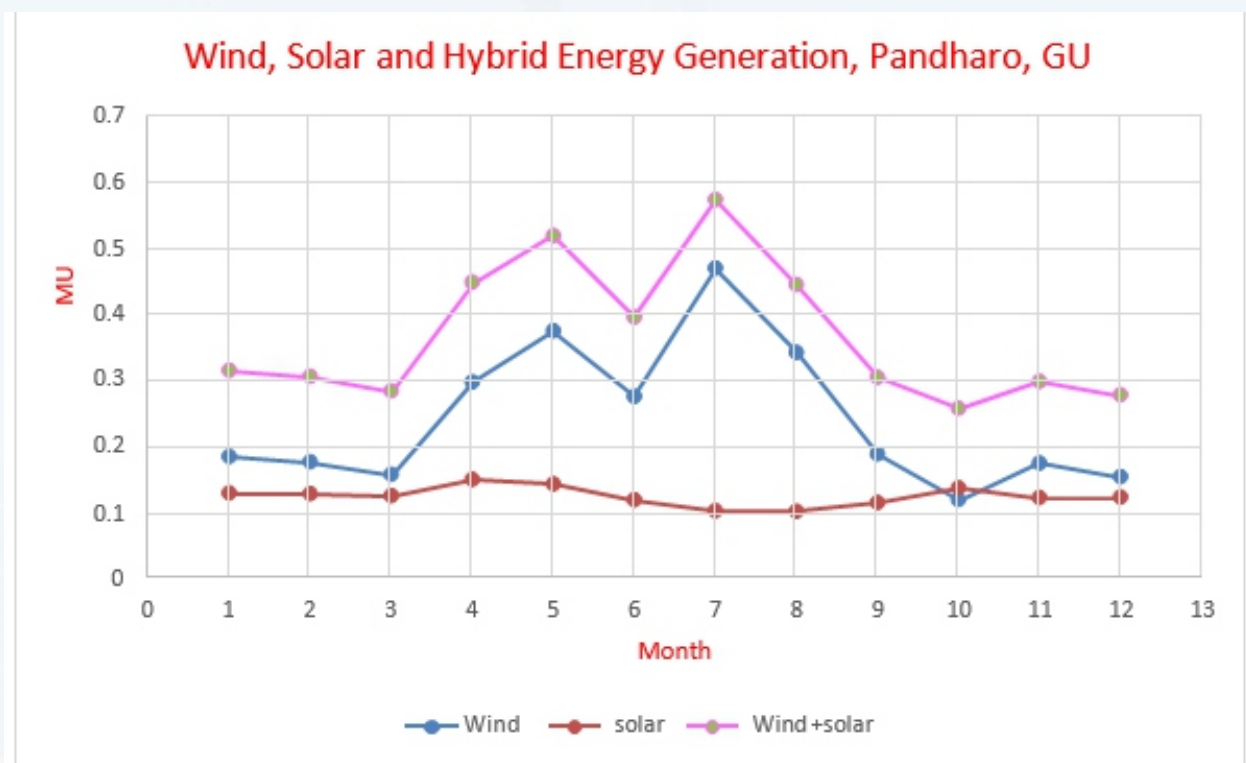


Fig 3.5.3 (a)

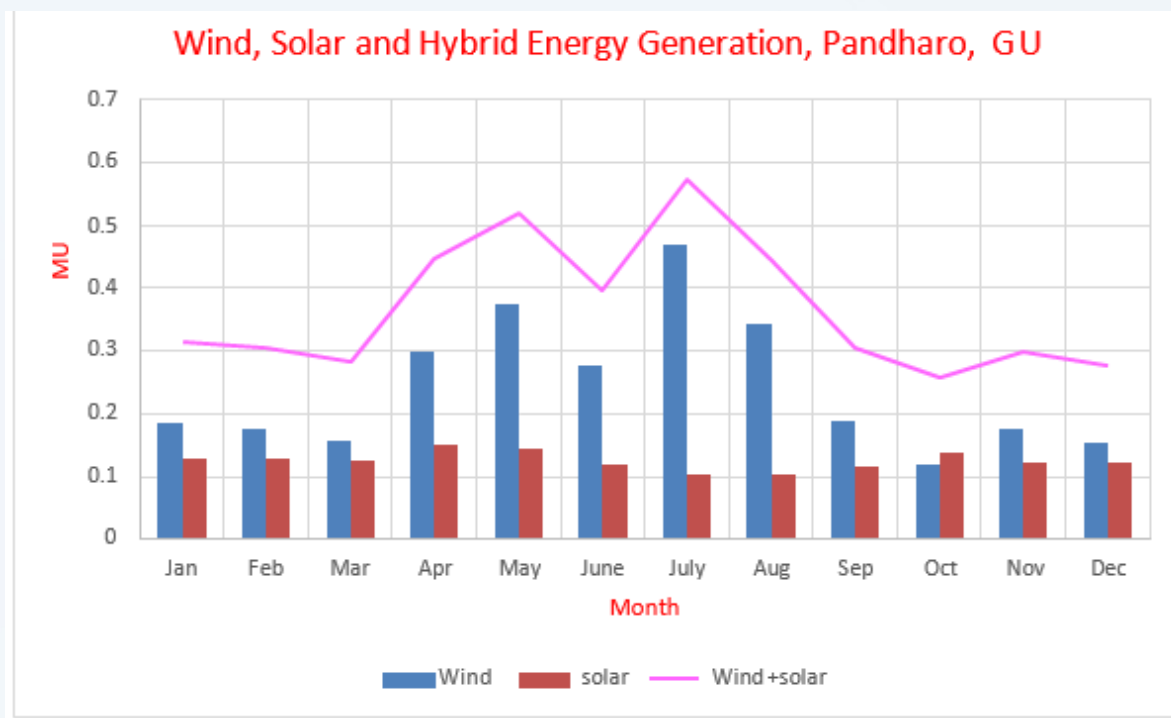


Fig 3.5.3 (b)

Fig 3.5.3. (a) & (b) Hybrid Wind & Solar Power Generation at Pandhro

Fig 3.5.3. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Pandhro. On an annual span, it is observed that there's Gradual increase in Wind power Generation from January up to end of April and a drastic increase of solar power generation within the same duration up to April. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after June for duration of June to September end. Within March and end of June, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.16 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.91 MU and Solar PV plant can generate 1.50 MU of electricity and cumulatively can generate 4.41MU of electricity.

Table 1.16 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
PANDHARO	2916398	1503197	4419595

3.5.4 Site Description of Motibaru

Motibaru is located in Ahmadabad district having agricultural land with black clay soil; the ownership of land is Private land where tar road is available between Ahmadabad & Rampur and located 70 km west from Ahmadabad. The nearest substation with grid is 33/11 kV substation in Rampur, 10km from site has GPS details of Latitude 22° 28' 15.6"N and Longitude 72° 21' 4.21"E with elevation of 16m.

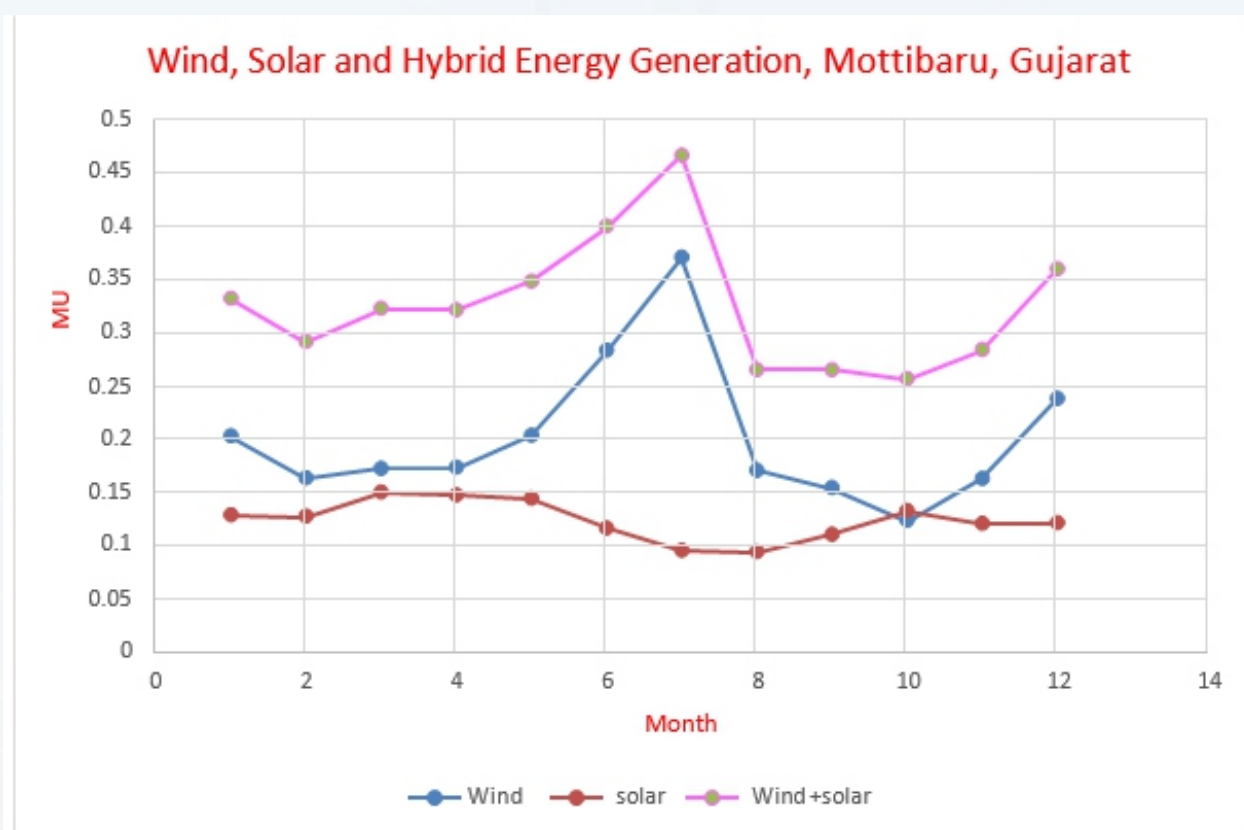


Fig 3.5.4 (a)

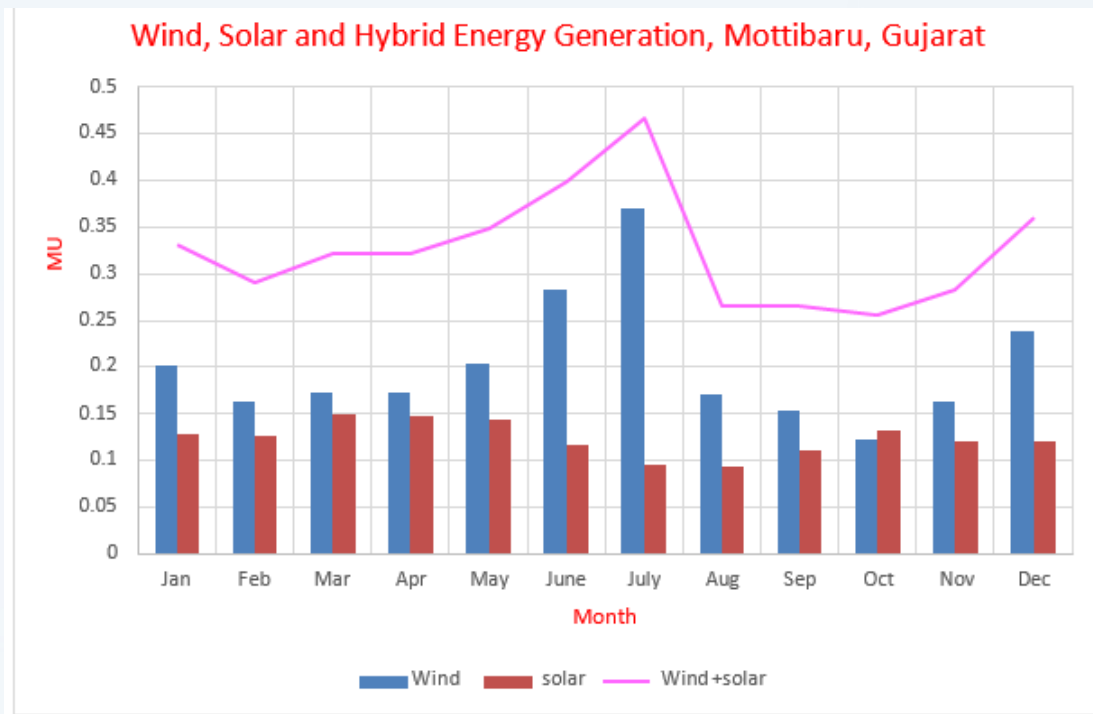


Fig 3.5.4 (b)

Fig 3.5.4. (a) & (b) Hybrid Wind & Solar Power Generation at Motibaru

Fig 3.5.4. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Moti Baru. On an annual span, it is observed that there's slight decrease in Wind power Generation from January up to March and a drastic increase of solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trends increases after March for a small duration and rises with advancing south west monsoon.. During April and June, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to June and gradually increases and decreases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.17 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.41 MU and Solar PV plant can generate 1.48 MU of electricity and cumulatively can generate 3.90 MU of electricity

Table 1.17 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
MOTIBARU	2416565	1489402	3905967

3.5.5 Site Description of Gaga

Gaga is located in Jamnagar district having dry waste land, Surrounded by agricultural land, the owner ship of land is Private land which is good type of Tar road is available from Kalyanpur and Dwarka and located in 10 km from Kalyanpur. The nearest substation with grid is 33/11kV substation in Kalyanpur 7 km from site has GPS details of Latitude 22° 07'53.1"N and Longitude 69°12'51.80" E with elevation of 2 m.

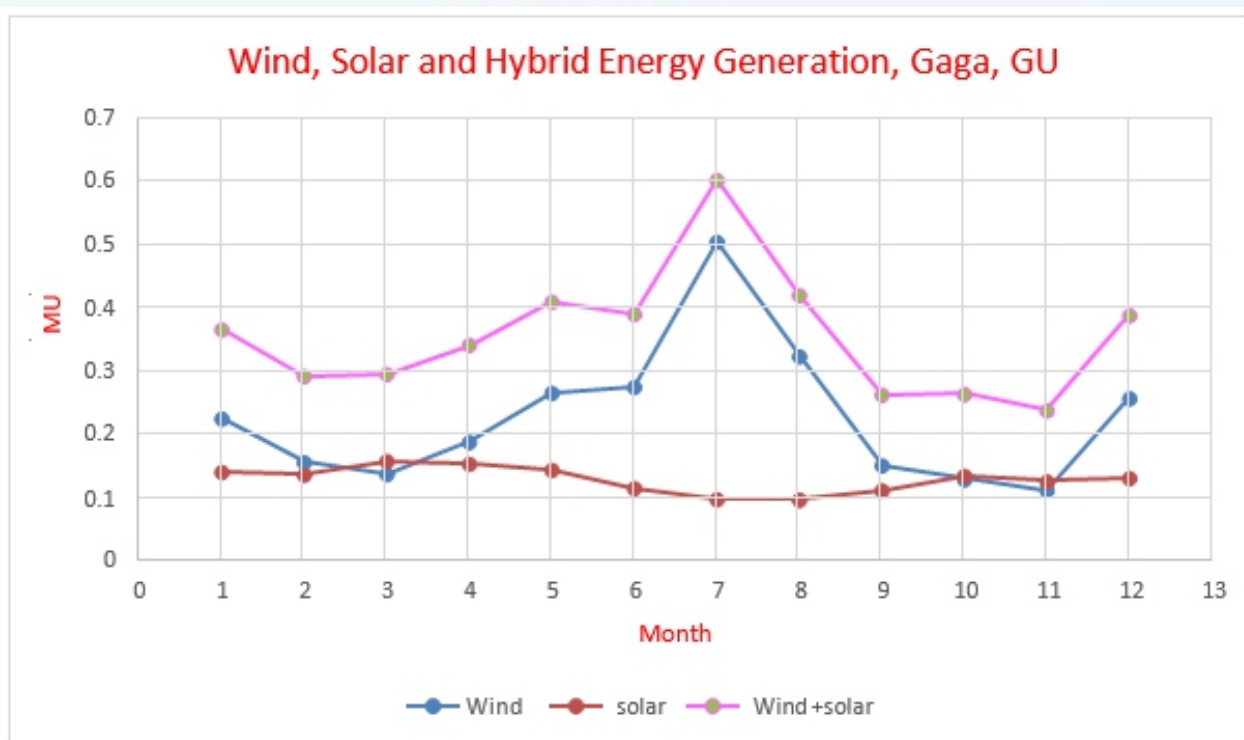


Fig 3.5.5 (a)

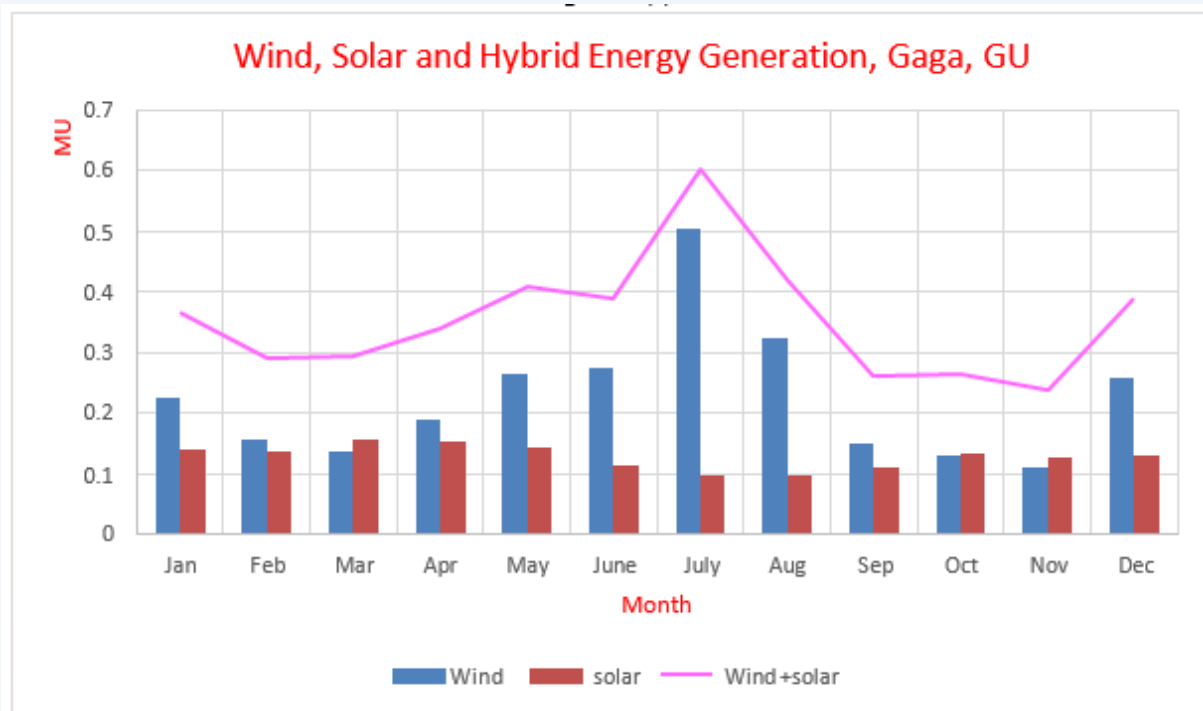


Fig 5.3.5 (b)

Fig 3.5.5. (a) & (b) Hybrid Wind & Solar Power Generation at Gaga

Fig 3.5.5. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Gaga. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to July and a gradual increase of solar power generation up to March and gradual decrease in solar generation within the same duration. The seasonal variations in this region aids hybrid average power generation. The solar trend on the other hand decreases during the month of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.18 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.72 MU and Solar PV plant can generate 1.54 MU of electricity and cumulatively can generate 4.27 MU of electricity

Table 1.18 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
GAGA	2727095	1546925	4274020

3.6 SITE DESCRIPTIONS OF MADHYA PRADESH

3.6.1 Site Description of Ganesh Goshla

Ganesh Goshla is located in Shajapur district having flat plain agricultural land; the ownership of land is private which is easily accessible located at 15 km from Satna towards north-west. The nearest substation is 33/11 kV substation near Agar has GPS details of Latitude 23°43'42.9"N and Longitude 75°56'46.8"E with elevation of 527m.

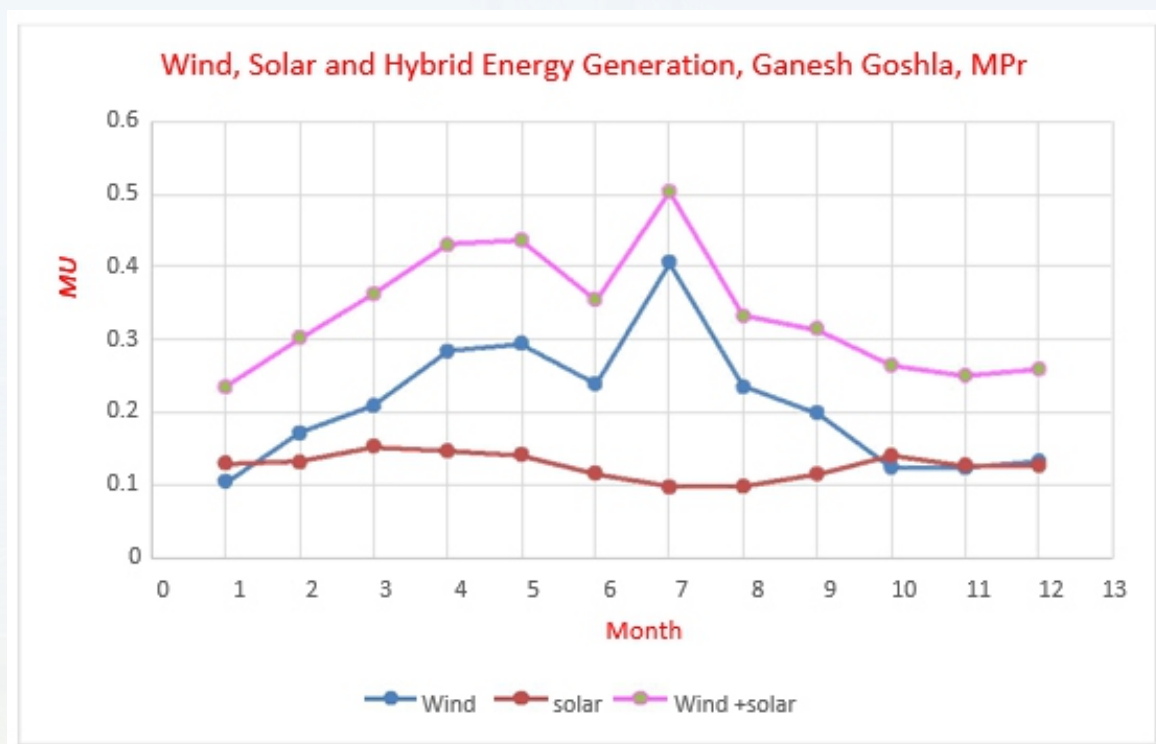


Fig 3.6.1 (a)

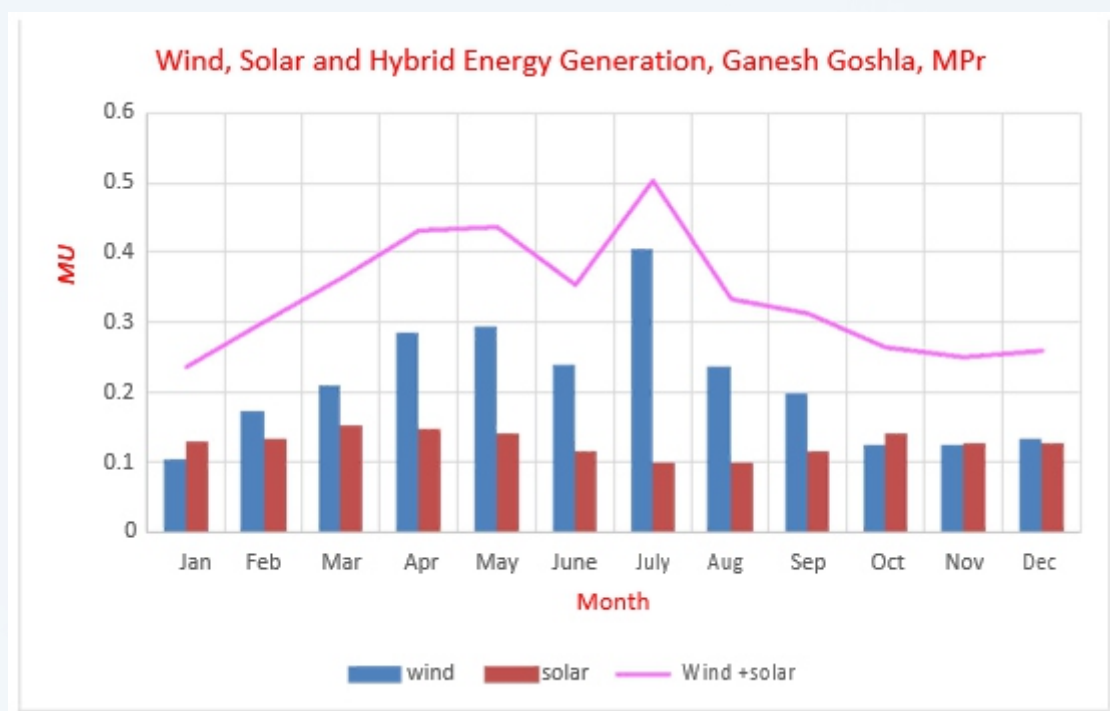


Fig 3.6.1. (b)

Fig 3.6.1. (a) & (b) Hybrid Wind & Solar Energy Generation at Ganesh Goshla

Fig 3.6.1. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Ganesh Goshla. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to March and a drastic increase of solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after March for a small duration and rises with advancing south west monsoon.. During April and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which the y slightly rise and contribute to the Annual trend.

The Table 1.1 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.52MU and Solar PV plant can generate 1.52 MU of electricity and cumulatively can generate 4.04 MU of electricity.

Table 1.19 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
GANESH GOSHLA	2522452	1523679	4046131

3.6.2 Site Description of Jamgodrani Hills

Jamgodrani is located in Dewas district having semi complex terrain land; the ownership of land is private which is easily accessible located at 12 km from Dewas towards east. The nearest substation with grid is 220kV substation nearly 3.5 Km towards west has GPS details of Latitude 22°58'25.2"N and Longitude 76°9'2.5"E with elevation of 573m.

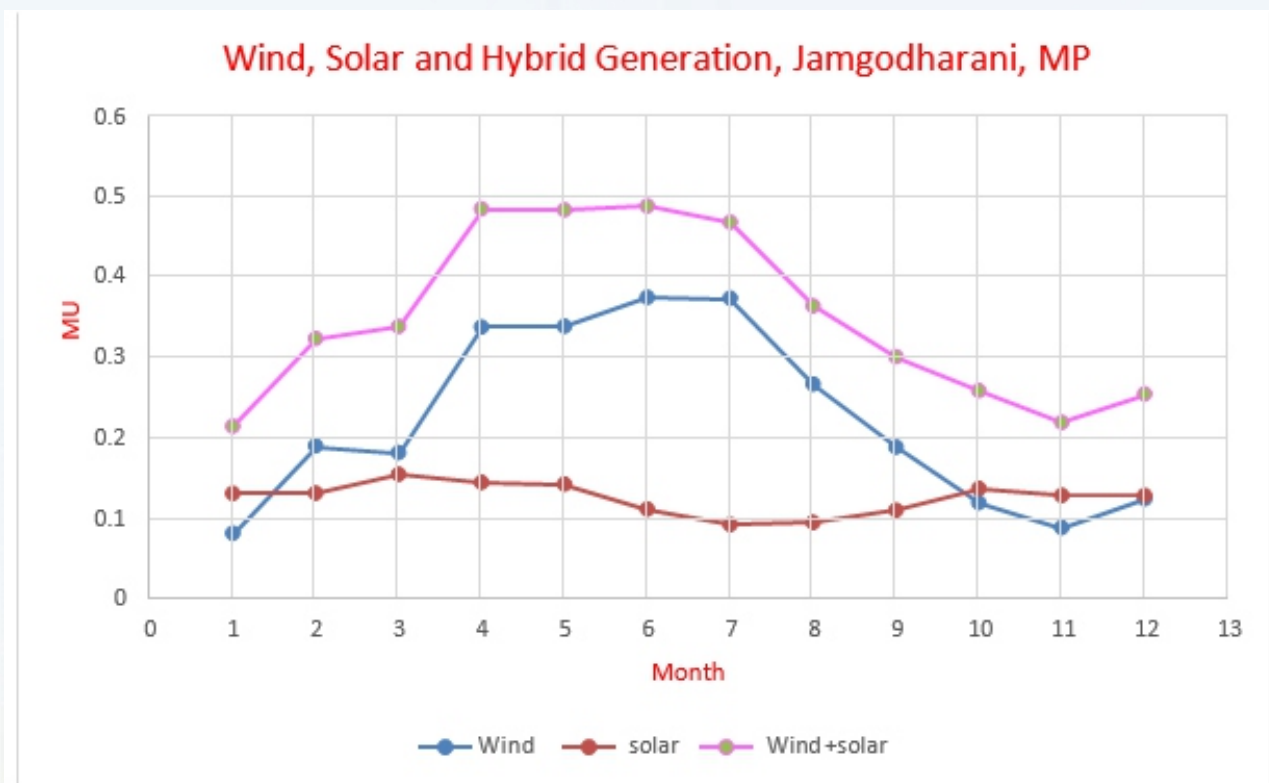


Fig 3.6.2 (a)

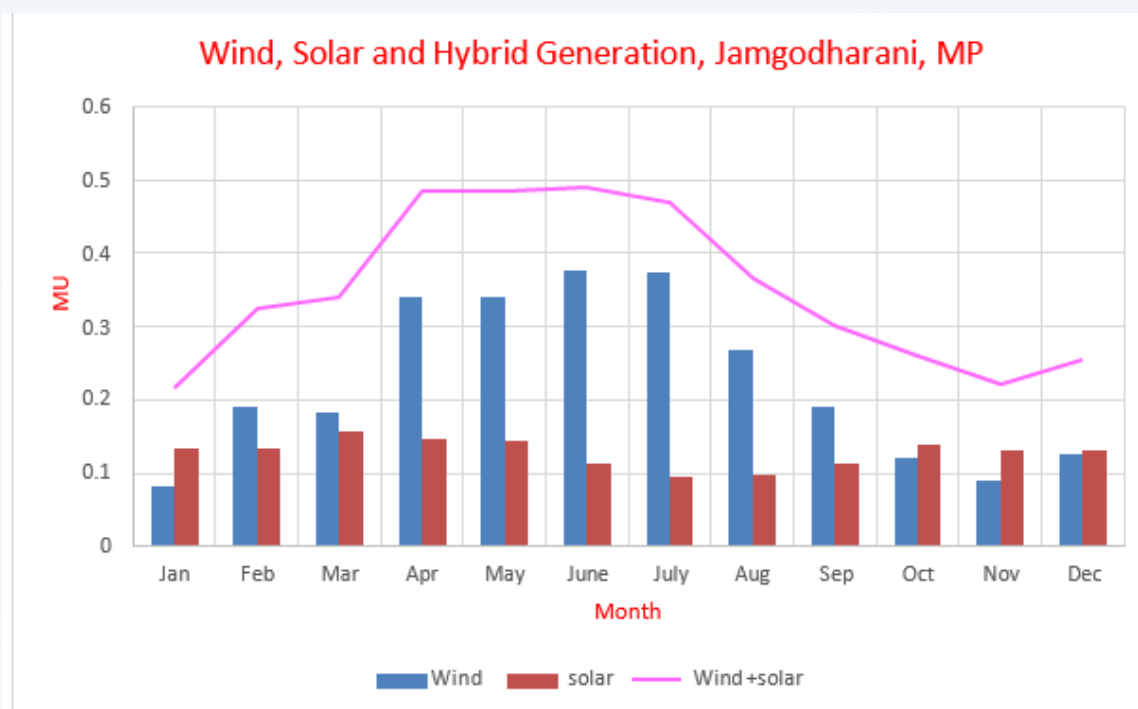


Fig 3.6.2 (b)

Fig 3.6.2. (a) & (b) Hybrid Wind & Solar Power Generation at Jamgodrani Hills

Fig 3.6.2. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Jamgodrani Hills. On an annual span, it is observed that there's gradual increase in Wind power Generation from January up to April and constant up to July and a drastic increase of solar power generation within the same duration p to March. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after July up to November for a duration and rises with advancing south west monsoon.. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.20 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.68 MU and Solar PV plant can generate 1.52 MU of electricity and cumulatively can generate 4.21 MU of electricity

Table 1.20 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
JAMGODRANI HILLS	2685247	1528843	4214090

3.7 SITE DESCRIPTIONS OF RAJASTHAN

3.7.1 Site Description of Dag

Dag is located in Jhalawar district having flat terrain of agricultural land, The owner ship of land private which is easily accessible located at 15 Km from Dag towards east. The nearest substation is 33/11 kV substation at Agar with GPS details of Latitude 23°55'14.6"N and Longitude 75°55'5.1"E with elevation of 484m.

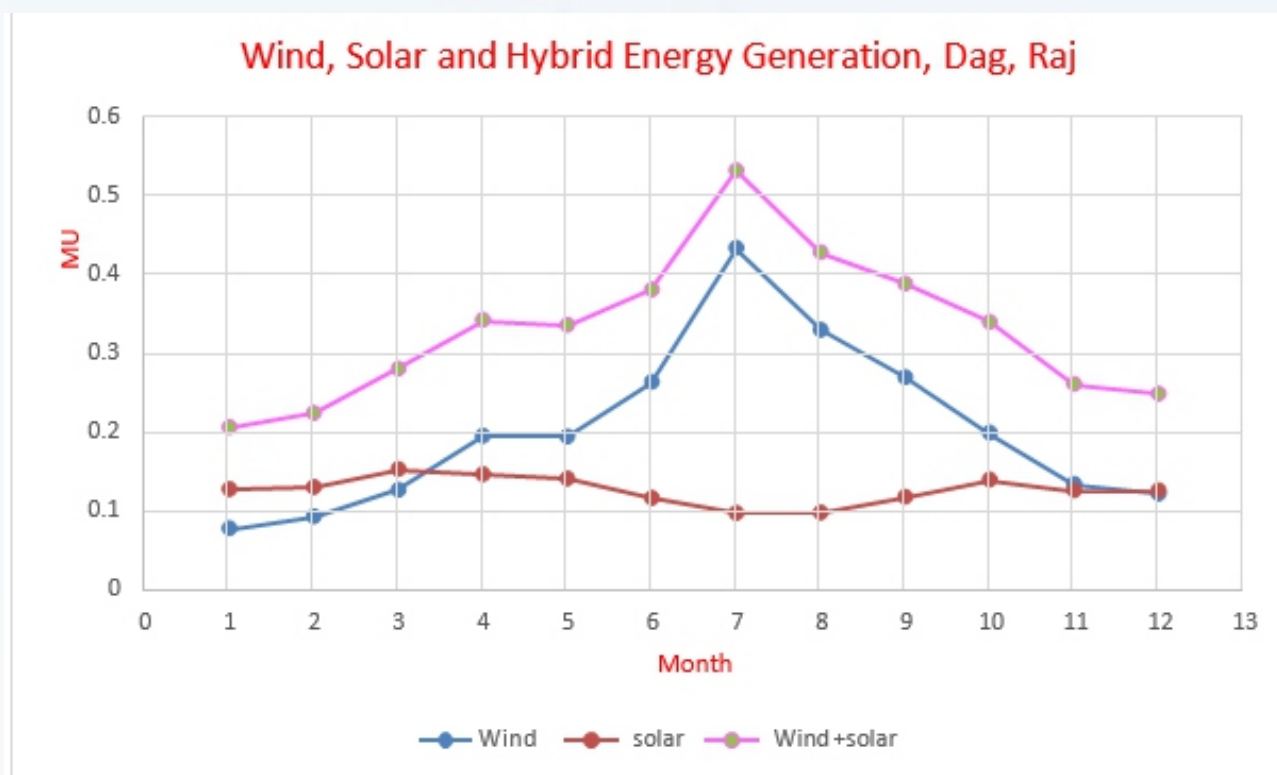


Fig 3.7.1 (a)

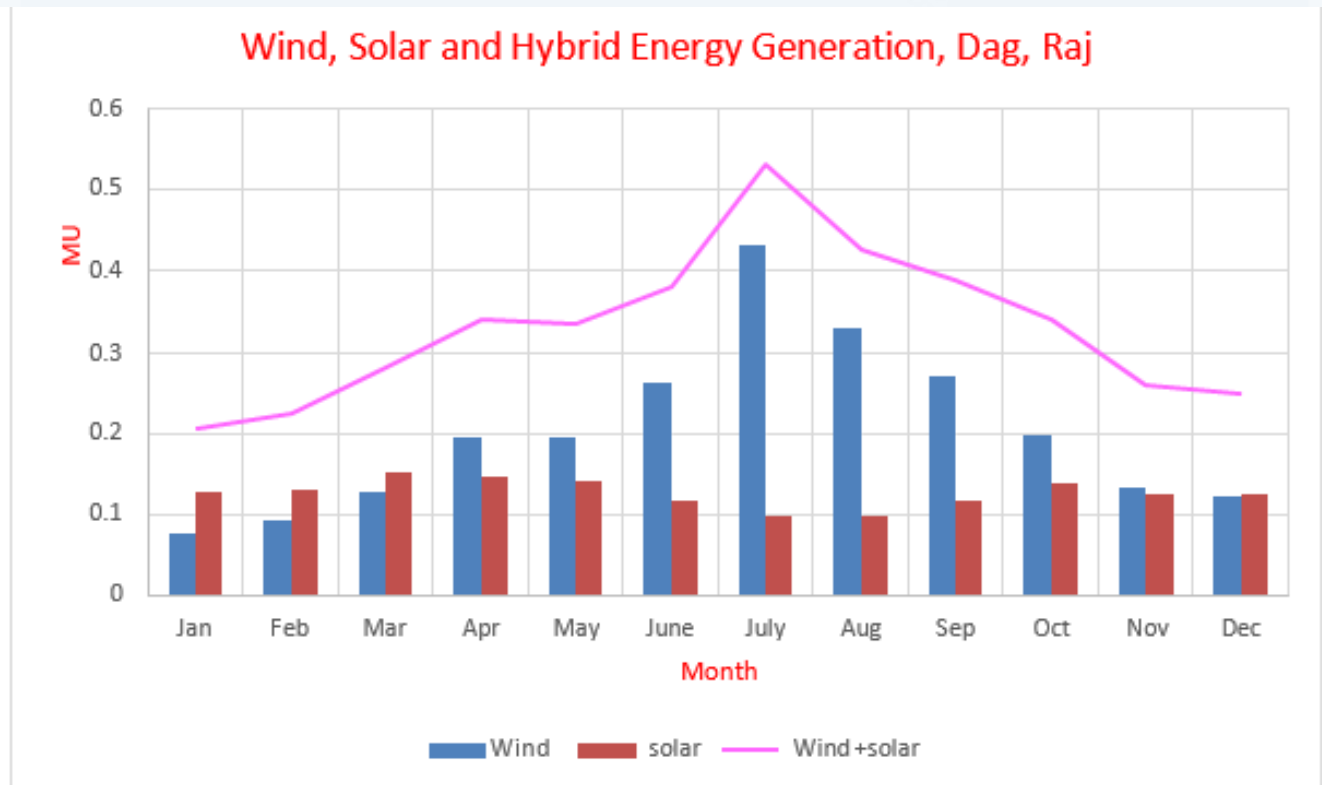


Fig 3.7.1 (b)

Fig 3.7.1. (a) & (b) Hybrid Wind & Solar Power Generation at Dag

Fig 3.7.1. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Dag. On an annual span, it is observed that there's gradual increase in Wind power Generation from January up to July and a drastic increase of solar power generation up to April. The seasonal variations in this region aids hybrid average power generation. During April and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to August and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.21 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 2.43 MU and Solar PV plant can generate 1.52 MU of electricity and cumulatively can generate 3.96 MU of electricity.

Table 1.21 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
DAG	2438858	1522642	3961500

3.7.2 Site Description of Gara

Gara is located in Banswara district having dry, open and waste land; the ownership of land is private which is easily accessible from Banswara. The nearest 33/11 KV substation is at Talwara with GPS details of Latitude 23°20'13.09"N and Longitude 74°25'45.41"E with elevation of 422m.

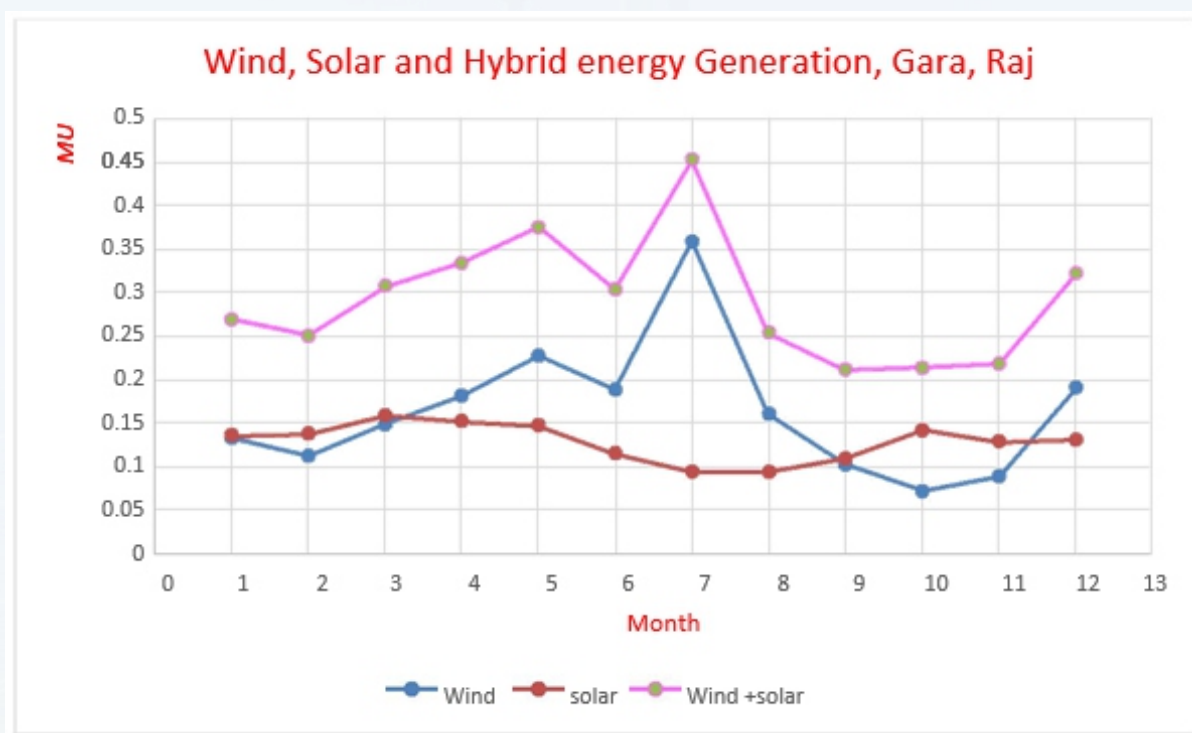


Fig 3.7.2 (a)

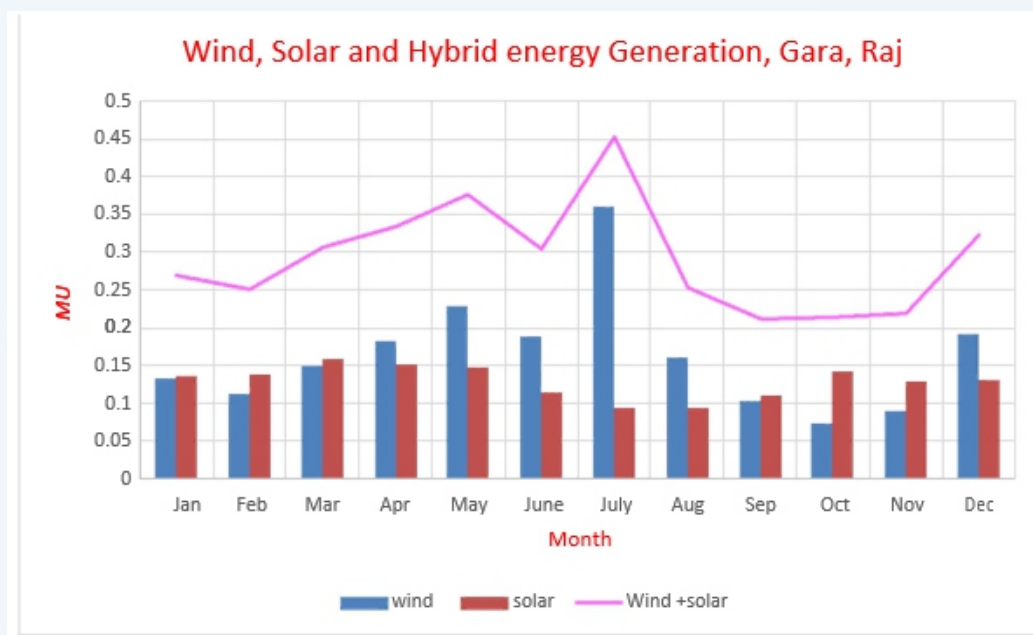


Fig 3.7.2 (b)

Fig 3.7.2. (a) (b) Hybrid Wind & Solar Power Generation at Gara

Fig 3.7.2. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to May and a drastic increase of solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after May for a small duration and rises with advancing south west monsoon. up to July. The solar trend on the other hand decreases during the months of April to Aug and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November. After which they slightly rise and contribute to the Annual trend.

The Table 1.22 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 1.96 MU and Solar P V plant can generate 1.54 MU of electricity and cumulatively can generate 3.51 MU of electricity

Table 1.22 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
GARA	1964369.881	1547663	3512032.881

3.7.3 Site Description of Bassi

Bassi is located in Chittorgarh district having Mountain, plain terrain, the ownership of land is private land which is easily accessible. The nearest substation is 33 kV substation with grid at Bassi having GPS details of Latitude 25°0'16.9"N and Longitude 74°46'15.8"E with elevation of 566m.

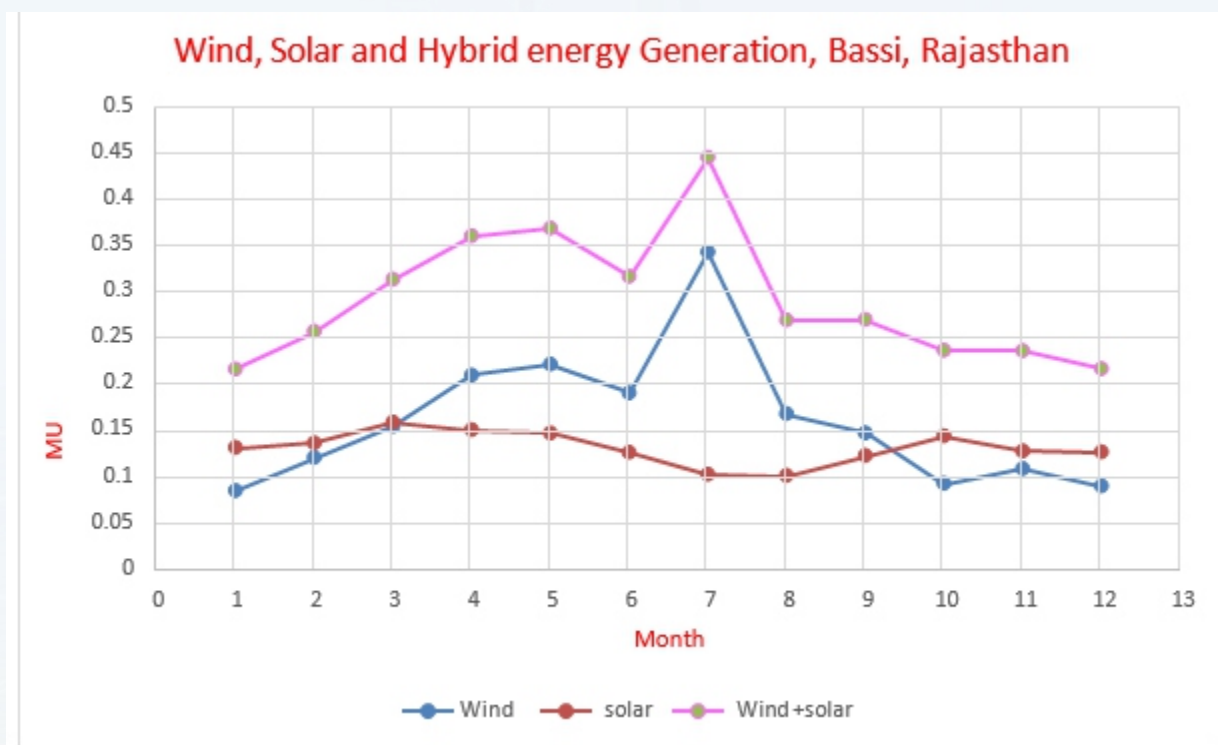


Fig 3.7.3 (a)

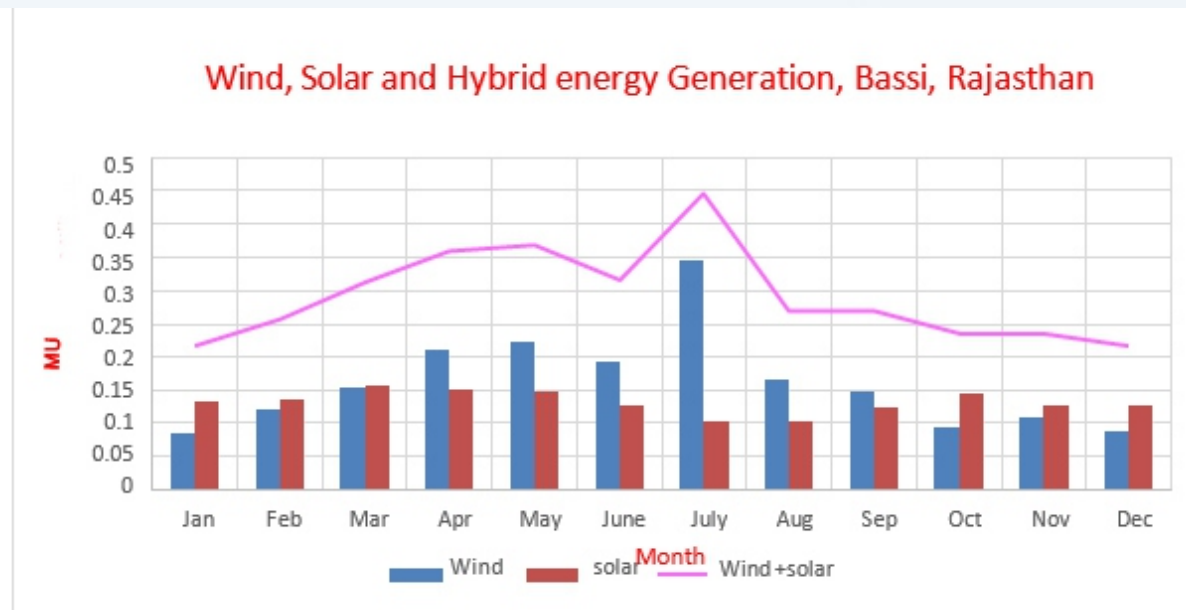


Fig 3.7.3 (b)

Fig 3.7.3 (a) & (b) Hybrid Wind & Solar Energy Generation at Bassi

Fig 3.7.3. (a) & (b) shows trends of solar and wind hybrid average monthly power generation from January to December at Bassi. On an annual span, it is observed that there's slight increase in Wind power Generation from January up to mid- March and a drastic increase of Solar power generation within the same duration. The seasonal variations in this region aids hybrid average power generation. Though wind trend decreases after May for a small duration and rises with advancing south west monsoon.. Within June and July, wind trend is maximum depicting maximum wind power generation. The solar trend on the other hand decreases during the months of April to July and gradually increases from August until September. Post September, it's end of monsoon at most of the places, due to which solar and wind trends together shows a simultaneous decrease until the month of November.

The Table 1.24 gives details of expected annual energy production from 1 MW solar PV plant and 1 MW wind turbine . Wind Turbine can generate at this particular area about 1.93 MU and Solar PV plant can generate 1.57 MU of electricity and cumulatively can generate 3.50 MU of electricity

Table 1.23 wind, solar and hybrid annual production

STATION NAME	Annual Wind Energy Production per MW (kWh)	Annual Solar Energy Production per MW (kWh)	Annual Hybrid Energy Production (kWh)
BASSI	1930770	1575382	3506152

4.0 CONCLUSION

Wind power generation at all the selected 24 sites spread in windy states of India have high potential (having more than 200WPD (watts per square meters) Wind Power Density) with minimal seasonal trend variation. The possible Solar power generation at the windy sites has recorded highest annual at Kalimandayam, Palayam, Chadmal, Devareddypalli, Kompalli, Kuran, Motibaru, Suigam, Haikal, Machenahalli, Mustigeri, Nirana, Taralkatti, Ganesh Goshla, Bassi, Dag, Gara and Pandhro followed by lowest Annual energy of power generation at Akkanayakanpatti, Melamandai, Veralimalai, Kondurpalem, Sunkisala, Gaga and Jamgodrani Hills. Whereever the Wind downtrends Solar tends to compensate with the reduction of wind generation. So integrating these renewable sources together by hybrid power systems is complementary to reduce the power demand and facilitate the continuous power supply to the grid through green energy.

In a given wind potential location with bankable met-mast measurement the effective land area will be 314sq.Km (77558 acres) . Depending on %area for wind projects the range of possible capacities are 224MW to 1884MW and 1.5 to 7 times that of wind capacity can be added in the same area making the range of Solar capacity addition from 336MW to 15512MW.

The generated wind energy production can be increased by, 49% to 84% of wind generation by hybridization with equal MWe of solar capacity depending on the site specific conditions of wind and solar seasonal resource. An average of 64% increase in hybrid energy production can be realized with 1MW Solar capacity addition to 1MW Wind in windy site.

If equal amount of wind and solar are deployed on an average of 61% MU, million units of electricity (kWh) would be realized from wind per MW and 39% MU would come from per MW of Solar per year, based on the limited production analysis.

It is more than obvious the complementary nature of wind+ solar would be the right road map for renewable development in the country. More so, with steady solar at a base level day power and the seasonal wind in any given year can be optimally used to easily meet the RE target of 100GW solar and 60GW wind just by tapping the low hanging fruits at the already identified locations, where 6GW of wind and 18GW solar with less than 10% of land use can easily be deployed.

AUTHOR PROFILE

Dr. S. GOMATHINAYAGAM, a graduate (Civil Engineering) of Regional Engineering College, Trichirapalli of the Madras University, obtained his post-graduate and doctoral degrees from the IIT-M. After serving as a Project Associate at IIT-M for about one and a half years, and with a brief stint at Best & Crompton design office, he joined Structural Engineering Research Centre (SERC) as Scientist and has risen to the position of Deputy Director and Project Leader of Field Experiments in Wind Engineering. After serving 25 years in solving various multi-disciplinary industrial, consultancy and software development problems at SERC, he has joined as Executive Director in NIWE. He has got UNDP, AUSAID fellowships and has visited several countries.

He shares as a scientist involved for CSIR- Technology Prize for Engineering Software development in 1999, and is one of the members of the team which has won the CSIR Technology Shield for centre of excellence in wind engineering in 2000 and the "A.S. Arya – UOR Disaster Prevention Award" in the year 2001, for their contribution towards cyclone disaster mitigation. He has published over eighty (80) interdisciplinary technical papers in referred national / international journals / conferences / seminars. He has over hundred technical reports to his credit based on the research and consultancy in the areas of power, wind energy, space, railways and Indian Navy involving instrumentation experimental analysis, design and testing and software development.

He is a Life Member and Chartered Engineer of Institution of Engineers (India) and life member of Computer Society of India, Instrument Society of India and Indian Society for Wind Engineering and India Meteorological Society. He has guided several ME, M-Tech, MSc and MCA projects. He served/serves in various awards/ selection /promotion/ Academic/ Professional committees including Wind Energy committee of Bureau of Indian Standards. Now, at NIWE as Director General, doing technology management and coordination of research, analysis, design, certification and performance testing, consultancy and human resource development related to Wind Power development in India.

Mr. K. Boopathi is basically a Mechanical Engineer, received Master Degrees (M. Tech) in Energy Engineering at Regional Engineering college, Trichy and Footwear Science & Engineering in Anna University, Chennai. He entered as faculty at Vellore Institute of Technology, Vellore, where he has effectively educated various Mechanical Engineering and Renewable energy subjects for about one year and also he worked in various Renewable Energy Projects such as 10 kW Solar Dish Stirling Engine and 100 kW Biomass Gasification plant.

He has been appointed in January 2003 as Scientist in National Institute of Wind Energy, (NIWE) (formerly Centre for Wind Energy Technology) in which he dedicated to assess the wind resource potential of India at 50 m height and successfully published for public. He also involved in wind monitoring station site selection and installation & commissioning of 50 m mast in various states and various research projects such as wind turbine's noise emission, Blade profile development and Small Wind Turbine Testing, etc.

In 2009, he has been moved to Wind Resource Assessment Unit, NIWE and been actively involved in wind data monitoring, measurement campaign management, data Validation, Site Pre-feasibility studies and Gained an experience in wind resource assessment with various industrial standard software's to estimate the Annual Energy Production, Turbine array layout design, optimization, field Micro siting and prepare bankable report, installation and monitoring of remote-sensing instruments such as LIDAR and SODAR stations and wind atlas preparation of 50 & 80 m height .

In March 2012, he has been championed as Wind Resource Assessment Head and has been leading the unit prosperously. He has been giving consultancy for leading Government organization, Public sectors and Private organizations such as Wind Farm design and development, Analysis of existing wind farm operations, Technical due diligence in virtuosity with international standards, DPRs (Detailed Project Report) preparation, etc. He has also been involving in various research projects such as offshore wind profile measurement, study on Wake behind the wind turbine and wind power forecasting, etc. In May 2015 successfully launched wind power forecasting project for the state of Tamilnadu and the project has been successfully progressing in the state. In September 2015 successfully prepared and released 100 m height wind potential map with 500 m resolution and in 2016 August prepared & released 20 m height wind speed map for small wind energy sectors.

His current responsibilities include preparation of wind atlas at 120 m height, offshore wind profile measurement activities in various locations and coordination with FOWIND offshore project, extending wind power forecasting services to other states, prefeasibility study, DPR preparation, wind resource and energy assessments, training, analyzing wind data and performing correlation between wind measurements systems and long term Data, Provide energy resource assessments and production calculations, Optimize turbine layouts according to resources and constraints and carrying out research works in wind resource assessment.

Dr. G. Giridhar, is Director in the Ministry of New and Renewable Energy (MNRE), Government of India, New Delhi and presently posted as Deputy Director General, Solar Radiation Resource Assessment (SRRA), National Institute of Wind Energy, Chennai, since, 2011. Completed Master's Degree in Organic Chemistry with specialization on Forest Products Chemistry from Sri Venkateswara University, Tirupathi 1981. Joined for Ph. D., IIT, Delhi in the year 1982 and completed in 1987 on, "Integrated Utilization of Biomass Studies on Calotropis procura and Bougainvillea" and worked as Senior Scientific officer in IIT, Delhi till 1989. Later in 1989 joined Region Office, Chennai, Ministry of New and Renewable Energy Source as Senior Scientific Officer and monitored various Renewable Energy technologies established in field with the support of the Ministry. In 2006, transferred to Solar Energy Center, Gurgaon, a specialized R&D institution established under the Ministry as in charge of Solar Thermal Division. In 2009, shifted to Bio Gas division, Ministry Head Quarters in New Delhi, for Power Generation Programs, Solar Cities and Solar Steam Generation divisions.

Presently is posted from the Ministry to National Institute of Wind Energy (NIWE), Chennai as Deputy Director General in the Solar Radiation Resource Assessment (SRRA) Project and established world's largest network of 118 Solar Radiation Resource Assessment (SRRA) stations and 4 Advanced Measurement Stations (AMS) in solar potential areas of the country. Involved in solar data collection, data processing, quality control and in the preparation of Solar Atlas of India.

Areas of interest are Energy Independence for Educational Institutions, Biogas for power generation, Solar Radiation Resource Assessment and Off-Grid Solar Energy Technologies. As part of official duties visited UK, China, Spain,

France and USA to study the international developments taking place in the fields of High Rate Biomethanation, Solar Energy Technologies and Radiation Resource Assessment Technologies. Made several publications in National and International Journal and authored important chapters in books published by reputed publications.

M.C. Lavanya, is basically an Electronics and communication Engineer, Completed her Masters in VLSI Design and has 5 years' experience in various organizations. She started her career in ISRO and later joined in SAMEER. Center for electromagnetics, Chennai as Research Scientist from 2010 to 2012. Before joining in NIWE as Assistant Director, WRA unit in December 2013 she gained experience in National Institute of Ocean Technology as Project Scientist. She excelled in the field of signal processing. Data Acquisition, Design and Development of RF Circuits and acquainted knowledge in MATLAB, Verilog, LabView, Xilinx-ISIS, Model-sim and Altera-Quartz-II, ADS and Sonnet software's.

Prasun Kumar Das, Assistant Director, Technical, National Institute of Wind Energy, an R&D institute under Ministry of new and renewable energy, Govt of India, is an alumnus of Tezpur University, Assam. He has completed his M.Sc in Physics and M.Tech degree in Energy Technology with gold medal. He has been actively associated solar energy research for the last eight years. He has developed one prototype of solar power based air conditioning system during his tenure in Solar Energy Centre, Gurgaon.

Presently he is working in the Solar Radiation Resource Assessment (SRRA) Project. It is a project national importance to establish a network of 115 Solar Radiation Resource Assessment (SRRA) stations and 4 Advanced Measurement Stations (AMS) in potential areas of the country. He is actively involved in solar data processing, quality control and in the preparation of Solar Atlas of India.

He is actively involved in setting up calibration laboratory for solar sensors in NIWE, Chennai. He has successfully completed for designing and feasibility study of many solar Photovoltaic power plants. He has published many research papers in national and international journals and guided many B.Tech/M.Tech students.



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