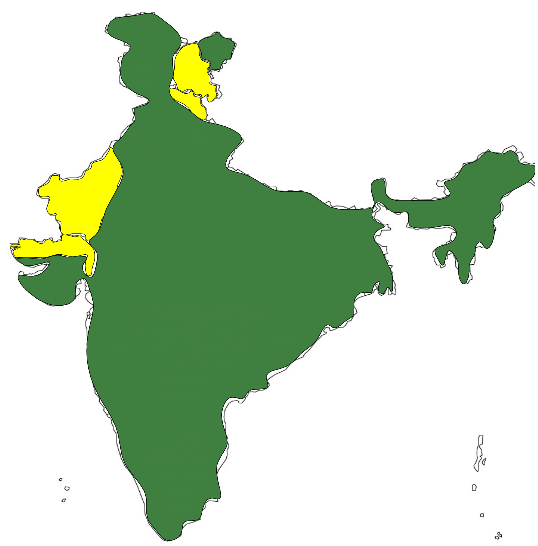
DESERT POWER INDIA -2050

Integrated Plan for Desert Power Development

Thar, Rann of Kutch, Ladakh, Lahul & Spiti



पावरग्रिड

POWER GRID CORPORATION OF INDIA LTD
GURGAON
December'13

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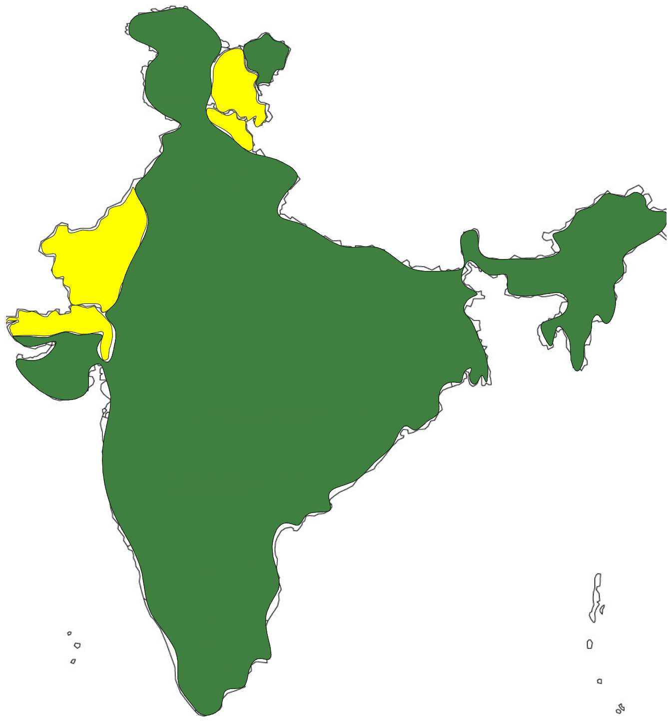

Integrated Plan for Desert Power Development in India

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EXECUTIVE SUMMARY

1.1 BACKGROUND

Energy needs of the country is growing at a very fast pace to meet high GDP growth rate. Present peak electricity demand of the country is 135GW which is expected to grow to about 200 GW & 283 GW by the end of 2016-17 (12^{th} plan) & 2021-22 (13^{th} plan) respectively as envisaged in the 18^{th} EPS report of CEA. To meet growing demand and to reduce supply-demand gap, there is a need of large capacity addition through conventional as well as from renewable sources. However, to achieve sustainable growth, energy security is of paramount importance.

Considering the depleting domestic fossil fuel reserves in the country as well as increasing demand for energy consumption along with environmental concern, there is a need to harness alternate sources of energy. Abundant Renewable Potential in the country, presents excellent solution to meet above challenges i.e. attaining energy security – Access & Delivery at affordable price along with addressing climate change concerns.

Country has immense Solar potential, provided land is available for setting up of such large sized plants. The largest accessible but least tapped form of energy on the earth is solar radiation on desserts. India has large deserts (both Hot & Cold) viz. the Thar (Rajasthan), Rann of Kutch (Gujarat), Ladakh (Jammu & Kashmir) and Lahul & Sipti valley (Himachal Pradesh) having total geographic area (TGA) of over 330,000 Sq km out of which total wasteland area is over 148,000 Sq km. A fraction say about 5-10% of total wasteland (7400-14800 sq km) can produce 220-450 GW from solar and wind generation which can address the future energy challenges in the country to a large extent.

Realising need of large scale development of desert solar power & its grid integration up to 2050, Ministry of New and Renewable Energy (MNRE) have entrusted POWERGRID to make an assessment of renewable generation potential in India's desert regions of the states of Rajasthan (The Thar), Gujarat (Rann of Kutch), Himachal Pradesh (Lahul & Spiti valley) & Jammu & Kashmir (Ladakh) and evolve infrastructure requirements including transmission for up to 2050 time horizon, with phased development plans.

1.2 SCOPE OF STUDY

Considering availability of the desert waste land data at the moment, Terms of reference for the study is divided into different phases. Phase-1, the present study, covers following scope of works:

- Assessment of economic potential of renewable power generation in desert wasteland in Thar (Rajasthan), Rann of Kutch (Gujarat), Laddakh (Jammu & Kashmir) and Lahul & Spiti (Himachal Pradesh)
- Estimated cost of Renewable Capacity
- Demand assessment
- Transmission infrastructure requirement for renewable evacuation & its integration into grid
- Associated grid balancing and spinning reserve infrastructure requirements to address intermittency & variability
- Impact of large scale renewable power on local communities, including positive economic spillovers etc.

1.3 FUTURE POWER SCENARIO

18th Electric Power Survey Report (EPS) by Central Electricity Authority (CEA), projects the electricity demand growth from 12th plan to 15th plan (2031-32). In order to evaluate long term demand for year 2050, two scenarios have been studied. In optimistic scenario, demand growth of 6% CAGR has been assumed which projects the demand to more than 1700 GW by 2050, almost 13 times of present demand. In moderate growth scenario, reduced elasticity of demand growth w.r.t. GDP growth, due to transitioning from developing to developed nation status, large scale implementation of energy efficiency & energy conservation programmes coupled with Smart Grid application, is envisaged to result in moderate CAGR demand growth (16th Plan [2032 onwards]-3.5% and 0.5% reduction in subsequent plan due to increased awareness, technological improvement etc.) up to 2050.Present analysis takes moderate growth scenario in account based on which projections of electricity demand of the country upto 2050 are evaluated as under (Table A1).

As per the Integrated Energy Policy (IEP) of Planning Commission, it is assumed that optimal utilization of resources shall bring down the ratio between installed capacity required to peak demand from 1.39 in 2011-12 to 1.31 in 2031-32. Therefore, generation capacity requirement is estimated to be about 712GW to fulfill the EPS projected demand of 542GW for 2031-32.

However, in view of the envisaged increasing contribution of renewables in overall capacity portfolio and their lower capacity utilisation factors (~20%), it is assumed that ratio between installed capacity to peak demand shall increase progressively by the factor of 0.06 in every plan after 2031-32 (reference factor 1.31). Based on above assumption, installed capacity to peak demand in 2050 shall increase to 1.55. Considering this, projected installed capacity in

2050 scenario would be estimated to about 1388 GW against the demand requirement of about 896 GW. Based on above, in order to meet demand in futuristic scenarios, following generation capacity requirement is estimated as given below in Table A1:

Table-A1 : – Estimated Demand & generation projection by 2050

S. No	Year	Installed Capacity requirement (GW)	Peak Demand (GW)
1	2012	200	130
2	2016-17	271	200
3	2021-22	372	283
4	2026-27	528	401
5	2031-32	712	542
6	2036-37**	882	644
7	2041-42**	1067	746
8	2046-47**	1258	844
9	2050**	1388	896

***** projected***

1.4 SOLAR POTENTIAL IN THE COUNTRY

India is endowed with abundant solar energy due to its convenient location near the equator. However, primary requirement for Solar potential development is based on availability of land and associated infrastructure. Considering above, following three(3) areas have been identified to harness huge renewable potential, provided necessary policy & regulatory measures are taken to develop such potential.

– Utilization of roofs/available open space with individual houses in form of distributed generation (kW level)

– Canal top solar PV which additionally helps in saving of water of the river from evaporating

– Wasteland utilization in different parts of the country in deserts

In addition to above, off shore solar generation is another potential area for renewables.

Rooftop Solar PV is a matured technology and its capacity has been increasing worldwide in last few years due to gamut of benefits offered by this technology. Solar rooftop PV in India is not yet developed but it has a strong growth potential. As per the 2011 Census statistics, India has around 330 million houses out of which with 150 million houses (excluding institutional households) have proper roofs (concrete etc.).Typically such roof can accommodate on an average 1-2kWp of solar PV system. Even accounting for average 1 kWp installation even at 30% of such houses (150 million), potential could be in the range of 45,000 MW. Besides this, there are other commercial buildings, shopping complexes and offices (about 60 million) that can accommodate larger solar PV capacities increasing above potential manifold. Government and regulatory support to the growth and requirement of residential solar rooftop PV is very important at this juncture.

Further, country possess huge network of Canals which includes open main canal and its sub-branches. Utilising this network by covering it through solar PV panels, presents GW scale Solar generation potential in the country. This also virtually eliminates the requirement to acquire vast tracts of land and limits evaporation loss of water from canals, tackling twin challenges simultaneously i.e. providing energy as well as water security.

Besides above, in view of quantum of wastelands availability in the Indian deserts, out of above options, deserts seem to offer maximum renewable potential provided supporting infrastructure is developed backed by suitable policy & regulatory framework along with innovative financing mechanism.

1.5 DESERT POWER POTENTIAL IN WASTELAND

In order to assess economic potential of renewable power generation in deserts and chalk out its phased development plan, MNRE has facilitated wasteland data in the States of Gujarat, Rajasthan, Himachal Pradesh and Jammu & Kashmir to carry out present study..

Based on the provided data of 13 types of wastelands, detailed study has been carried out on suitability of type of wasteland for setting up Renewable Generation Plants. Based on the analysis, four (4) types of wasteland viz ***Upland with or without scrub, Under-utilised/Degraded notified Forest Land, Sand/Inland/costal, Barren Rocky/Stony Waste/Sheet Rock Area*** are found suitable for setting up of Renewable Generation Plants. However, selected wasteland are also found to have associated issues, which have been accounted by establishing probabilistic scenarios in selected four (4) categories.

1.6 RESOURCE ASSESSMENT ON DESERT WASTELAND

The 29th Report of Standing Committee on energy stipulates that as per Ministry of New and Renewable Energy, solar energy potential are estimated at 30-50 MW per Sq.km. Few researchers have also envisaged this potential in the range of 30-50 MW per sq km through Solar PV as well as 40-50 MW/sq km through Concentrated Solar Power (CSP) on account of technological improvements and excellent irradiance (DNI/GHI) levels especially of desert regions.

Similarly for development of wind generation, potential is estimated in the range of 8-10 MW/ Sq km presently, which shall also increase in view of the technological advancements in wind turbine ratings, hub heights and rotor diameter etc. In view of the above, installable Solar & wind generation has been considered as 35 MW/sq km & 9 MW/sq km respectively for capacity assessment.

Further, as deserts have good wind potential also, Hybrid model of Wind & Solar potential is envisaged to be harnessed utilizing identified wasteland in an optimal manner which also reaps out benefit of diversity of resources. In such model, typically 30% of the wasteland area is proposed to be utilized for Wind Turbine installation and balance 70% towards Solar Generation. The 70: 30 ratio (Solar: Wind) is adopted for optimal utilisation of land as solar generation yield per sq km (30-40 MW/ sq km) is 3-4 times more compared to wind generation (8-9 MW/ Sq km).

Details of assessment with above norms for installable potential w.r.t utilization of wasteland area are given as under in Table A2.

Table A2 : – Wasteland utilization scenario

S No	Desert	Total waste land (sq km)	Selected Wasteland (sq km)	Selected Wasteland (sq km)	Generation (GW)		
					Solar	Wind	Total (Wind+Solar) GW
					35 MW/sq km	9 MW/sq Km	
1	Rann of Kutch	19120	12607.4	1260.7 (10%)	30.9	3.4	34.3
2	Thar	67285	57538.5	8630.8 (15%)	211.5	23.3	234.8
3	Laddakh	50362	31211.8	1560.6 (5%)	38.2	4.2	42.4
4	Lahul & Spiti	11177	2393.8	119.7 (5%)	4.2		4.2
	Total	***147944***	***103751.5***	***11571.8***	**284.8**	**30.9**	**315.7**

However, one of the most important aspects of development of such a huge qauntum of desert solar potential is its economic viability. Market analysts have broad consensus that Utility scale Solar PV generation shall achieve grid parity around 2016/17 (in aggressive scenarios) & around 2018/19 (in base case scenarios) on the basis of assumption of pace of cost reduction in PV technology as well as increase in conventional energy prices (Fig-A1).

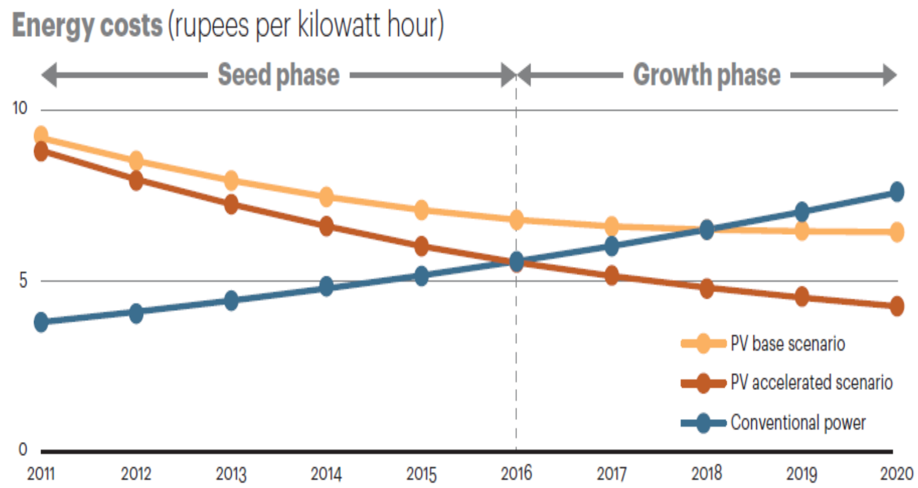

Fig A-1: Levelized Cost Comparison of Solar PV and Conventional Power at Grid (Source: AT Kearney Analysis)

1.7 RENEWABLE SCENARIO BY 2050

Planning commission (draft 12th five year plan) has estimated generation resource mix by 2030 to cater to projected demand. However, to arrive at generation resource mix for 2050, considering various factors like limitation of coal reserves, increasing import dependence as well as environmental concerns, emphasis has been given to increase contribution from renewables due its vast available potential.

In view of the available potential of various generation resources like Coal, Gas, Hydro (Storage + ROR), Renewable (Desert & Non-desert) and Nuclear, generation resource mix by 2050 to cater to projected peak demand, has been estimated, which is given under (Table A3).

Out of total requirement of 485 GW from renewables, it is envisaged that there would be capacity addition requirement of about 455 GW considering present RE capacity as about 30 GW. In view of the estimated renewable desert potential (316 GW) through Wind/Solar & non-desert renewable potential through Wind, Biomass & Waste to Energy, it is envisaged that out of 455 GW, renewable capacity contribution from deserts shall be about 300 GW (@95% of the total desert power).

Table-A3 : – Envisaged Generation mix for 2050

S. No	Resource	Installed Capacity(GW)	Capacity Factor (%)
1	Coal	450	32
2	Gas	128	9
3	Hydro	180	13
4	Renewable	485	35
5	Nuclear	145	11
	Total	***1388***	***100***

On shore wind & solar generation in other parts of the country viz. Tamil Nadu, Karnataka, AP, Maharashtra etc. shall be about 55 GW. In addition, Biomass, Waste to Energy, Small Hydro Capacity, Roof Top Solar, Canal Top PV shall be contributing about 70 GW capacity, given their potential estimate. Off shore Wind generation shall also be exploited in future with envisaged capacity of 30 GW making total renewable capacity to be 485 GW by 2050.

Considering requirement of exploitation of potential in four (4) deserts, following capacity contribution is estimated (Table A4) from each of the desert:

Table-A4 : – Desert Renewable Capacity

S No	Desert	Total available potential (GW)	Envisaged Renewable Capacity contribution @about 95% of Desert Potential (GW)		
			Wind (GW)	Solar (GW)	Total (GW)
1	Thar	234.8	22	201	223
2	Rann of Kutch	34.3	3	30	33
3	Laddakh	42.4	4	36	40
4	Lahul & Spiti	4.2	-	4	4
	Total	**315.7**	**29**	**271**	**300**

1.8 BALANCING/FLEXIBLE CAPACITY REQUIREMENT FOR 2050

Analysis has been carried out for various demand scenarios (peak/off peak/other than peak) in three seasons viz. Summer, Winter and Monsoon. Demand scenario has been segregated into other than peak and off peak hours because of variability of demand pattern at different time of the day in seasons e.g. off peak (minimum demand) as well as other than peak scenario.

Objective of the analysis is to identify challenging operating scenarios where limitations can arise out of variation in seasonal/daily demand patterns. For this, regional & all India load curves have been studied for all the three(3) seasons for a typical day. Analysis reveals that seasonal off peak & other than peak demand scenarios are mostly surplus whereas peak demand scenarios are turning deficit. This situation is expected because of high availability of renewable viz. Solar & Wind during other than peak hours and low demand during off peak hours. However, this gives an opportunity to deploy large scale grid storage solutions like Pumped Storage Hydro, Battery technologies and Concentrated Solar Power (CSP) with Storage facility which can store energy during surplus scenarios to be used later in meeting demand in peak hours.

Considering load generation balance scenarios and total energy storage requirement by 2050, balancing requirement for medium term i.e. 13th plan (2022) and 15th plan (2032) is also estimated as shown is the Table A-5 as under.

Table-A5 : –Balancing Reserve Requirement

S. No.	Type of Storage	Capacity by 2022 (GW)	Capacity by 2032 (GW)	Capacity by 2050 (GW)
1	Concentrated Solar power with storage	-	12	30
2	Pumped Storage (upto @30% of 94GW potential)	5	14	28
3	Other Energy Storage i.e. Grid Scale Battery, Flywheel etc.	2	4	10
		7	***30***	***68***

Strong grid interconnections through transmission corridors, which shall enlarge balancing area by interconnecting various Hydro, Gas, flexible thermal generation complexes, is a mandatory requirement to reap out benefits of flexible resources available at different locations for balancing purpose. In addition, Smart grid tools like demand response and demand side management, Electric Vehicle Integration will facilitate balancing through load management.

1.9 TRANSMISSION SYSTEM REQUIREMENT BY 2050

Transmission is the central link in the entire electricity delivery chain interconnecting sources to the distantly located load centres. A robust and reliable transmission network is needed to ensure supply with safe and secured manner at reasonable cost. In the high renewable penetration scenario, strengthening/expansion of grid interconnection enlarging power balancing area is an essential requirement for dealing with the challenges of renewable grid integration & achieve optimal utilization/sharing of geographically dispersed flexible resources. Broad contours of transmission plan have been prepared with above approach:

(1) Development of Hybrid EHV AC/ HVDC (VSC) Transmission system for flexibility of controls and Power flow regulations
(2) Interconnection of Desert Transmission Corridors with major load centers in the States as touch points including with Green Energy Corridors
(3) Desert Transmission Corridors integrated with other high capacity transmission corridors associated with conventional generation complexes especially gas/thermal as well as new hydro rich complexes to achieve supply balancing

Technology Alternatives

From the technology perspective, latest transmission technology options are to be selected in view of the growing Right-of-Way concerns, establishment of gigawatt scale generation complexes like deserts at concentrated locations, weak short circuit strengths at Renewable complexes etc. In AC technology options, there is further need of increasing power intensity (MW/km) of transmission corridor, which can be addressed through Ultra High Voltage AC technology (1200 kV). Line Commutated Converter (LCC) or conventional HVDC suffers from technical restriction that commutation within the converter is driven by AC voltage of interconnected AC system requiring minimum short circuit level of surrounding AC system. Renewable generation pockets do have weak short circuit strengths posing limitation on the use of conventional HVDC systems. Advent of Voltage Source Converter (VSC)- HVDC transmission technology based on insulated gate bipolar transistors (IGBT) addresses above limitation of Conventional HVDC technology.

High Capacity Transmission Corridors

Installable capacity keeping in view the wasteland availability in four (4) deserts is envisaged to be about 300 GW. Considering the developmental status of Concentrated Solar Plants(CSP) with storage, which also act as flexible reserve, about 10% total capacity (30 GW) is proposed to be established by 2050 in the form of CSP in above four deserts. Further, as gathered from the past experience, maximum availability of Solar generation is about 80% that too in peak season (April-May), therefore transmission capacity has been considered to be developed for peak scenarios. However, CSP with storage technology, is being envisaged as flexible capacity, shall be utilized in storing solar energy in other than peak/off peak hours and for delivery in peak periods. Therefore, transmission capacity available for non-CSP capacity shall only be utilized for transfer of CSP capacity in peak hours when non-CSP capacity will not be at peak. In view of the above, transmission capacity to be developed from each of desert is given as under (Table –A6):

Table-A-6: Transmission Capacity Requirement: 2050

S No	Desert	Envisaged Renewable Capacity contribution @about 95% of Potential (GW)	CSP capacity (GW)	Net capacity (GW) (Total-CSP)	Transmission capacity Requirement @80% of net capacity (GW)
1	Rann of Kutch	33	5	28	23
2	Thar	223	20	203	162
3	Laddakh	40	5	35	28
4	Lahul & Spiti	4	-	4	3
	Total	**300**	***30***	***270***	***216***

Further as discussed earlier, there would be requirement of hybrid AC & HVDC technology for ultra-high capacity corridors emanating from above four deserts connecting to major load centres. Therefore, capacity to be established with HVDC and UHV AC from each of the complex is given as under (Table- A7):

Table-A-7: Transmission Corridors : 2050

S No	Desert	Transmission capacity Requirement @80% of net capacity (GW)	Transmission corridors	
			HVDC Bipole	UHV AC (1200 kV S/c)
1	Rann of Kutch	23	1 no. ±800 kV, 6000 MW (VSC) 1 no. ±500 kV,4x375 MW (under sea cable-VSC) 1 no. ±500 kV,2x375 MW MTDC	3 nos.
2	Thar	162	1 no. ±500 kV,6x375 MW (VSC) 2 no. ±500 kV,8x375 MW (VSC) (MTDC) 5 nos. ±800 kV, 6000 MW (4 nos. MTDC) 1 no. ±500 kV 3000MW	18 nos.
3	Laddakh	28	10 no. ±500 kV,6x375 MW (VSC) 3 no. ±500 kV,8x375 MW (VSC) MTDC	4 nos.
4	Lahul & Spiti	3	1 nos. ±800 kV, 6000 MW (MTDC)	
	Total	***216***	***26 nos. (18 nos. VSC)***	***25 nos***

**1200kV transmission corridors have been envisaged keeping in view the quantum of Power transfer requirement, distance involved as well as addressing ROW issues. As on date it seems difficult to operate the transmission corridors at 1200kV level, however keeping in view the future requirement, it is prudent to address the various issues like variation in power flow over 1200kV corridors, reactive power management etc on immediate basis so that smooth operation in future is feasible.*

Otherwise instead of 1200kV corridors, the same will be developed with 765kV technology for which more no. of corridors shall be required. Alternately, emphasis may be given to develop the High Temperature Superconducting (HTS) line each having 6000-8000 MW capacity at 4000kV level instead of 1200 kV corridor for which developmental project of HTS line need to be taken up urgently.

Details of complex wise transmission corridor are as under:

RANN OF KUTCH COMPLEX

- ±500kV 2x375MW Kutch RE PP1- Thar RE PP3 VSC based HVDC Bipole ***(TRC-1)***
- 1200kV Kutch RE PP2– Vadodara (Gujarat/WR) 3xS/c & 1200kV Vadodara - Pune (Maharashtra/WR) 2xS/c ***(TRC-2)***
- ±500kV, 4x375MW Kutch RE PP3 – Mumbai (Maharashtra/WR) Sub marine HVDC cable ***(TRC-3)***
- ±800kV 6000 MW Kutch RE PP4 – Dabaspet (Near Bangalore) HVDC Bipole ***(TRC-4)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost : Rs 28,000 Cr

THAR COMPLEX

- 1200kV Thar RE PP1– North Punjab (Near Amritsar) 2xS/c ***(TRC-5)***
- 1200kV Thar RE PP2– Thar RE PP1 – Central Punjab (Near Jalandhar) 2xS/c ***(TRC-6)***
- ±500kV 6x375MW Thar RE PP2 – North Punjab (Near Gurudaspur) VSC based HVDC Bipole ***(TRC-7)***
- 1200kV Thar RE PP2– Mid Rajasthan (Near Ratangarh) – Haryana (Near Hissar) 2xS/c ***(TRC-8)***
- 1200kV Thar RE PP3– Thar RE PP5 - Central Rajasthan (Near Ratangarh) – Delhi/Haryana 2xS/c ***(TRC-9)***
- 1200kV Thar RE PP3 - Thar RE PP6–East Rajasthan (Near Jaipur) – Western UP (Near Agra) - Central UP (Near Lucknow) 2xS/c ***(TRC-10)***
- ±800kV 6000 MW Thar RE PP3 – Central MP (Near Bhopal)- North AP (Near Visakhapatnam) HVDC Bipole (Multi terminal) ***(TRC-11)***
- ±500kV 8x375MW Thar RE PP3 – Delhi/Haryana VSC based HVDC Bipole (Multi terminal) ***(TRC-12)***
- 1200kV Thar RE PP4 - Thar RE PP6 – East Rajasthan (Near Jaipur) - Delhi/Haryana 2xS/c ***(TRC-13)***
- ±800kV Thar RE PP4 (6000MW) – Maharashtra (Near Nagpur/3000MW) – Tamil Nadu (near Chennai/3000MW) HVDC Bipole (Multi terminal) ***(TRC-14)***
- 1200kV Thar RE PP5–Central Rajasthan (Near Ratangarh) – Delhi/Haryana 2xS/c ***(TRC-15)***
- ±500kV 8x375MW Thar RE PP5 – Maharashtra (Near Pimpri- Chichwad/1500MW) – South Karnataka (Near Mysore/1500MW) HVDC Bipoles (Multi terminal) ***(TRC-16)***

- ±800kV Thar RE PP5 (6000MW) – Maharashtra (Near Nasik/6000MW) – Tamil Nadu (near Madurai/3000MW) HVDC Bipole (Multi terminal) ***(TRC-17)***
- 1200kV Thar RE PP6–East Rajasthan (Near Jaipur) – Western UP (Near Agra) – Eastern UP (Near Kanpur) 2xS/c ***(TRC-18)***
- ±800kV 6000 MW Thar RE PP6 – Central Bihar (Near Patna) HVDC Bipole ***(TRC-19)***
- ±800kV 6000 MW Thar RE PP7 – Central MP (Near Indore/3000MW) – North AP (Near Hyderabad/3000MW) HVDC Bipole(Multi Terminal) ***(TRC-20)***
- 1200kV Thar RE PP7–East Rajasthan (Near Jaipur) – Western UP (Near Agra) – North UP (Near Bareilly/Moradabad) 2xS/c ***(TRC-21)***
- ±500kV 3000MW Central Rajasthan (near Jaipur) – North UP (Muzaffaernagar/Meerut) HVDC Bipole ***(TRC-22)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 1,57,000 Cr

LEH/KARGIL AND LAHUL & SPITI COMPLEX

- ±500kV 6X375 MW Kargil RE PP1 – North Punjab (Near Gurudaspur) VSC based Two HVDC Bipoles ***(TRC-23)***
- ±500kV 6X375 MW Kargil RE PP2 – North Punjab (Near Gurudaspur) VSC based Two HVDC Bipoles ***(TRC-24)***
- 1200kV North Punjab (Near Gurudaspur) – Punjab/Haryana (Near Mohali/Chandigarh) S/c
- ±500kV 6X375 MW Leh RE PP1 – Pooling point in Himachal (Near Shimla) VSC based Two HVDC Bipoles ***(TRC-25)***
- ±500kV 6X375 MW Leh RE PP2 – Pooling point in Himachal (Near Shimla) VSC based Two HVDC Bipoles ***(TRC-26)***
- ±500kV 6X375 MW Leh RE PP3 - Pooling point in Himachal (Near Shimla) VSC based Two HVDC Bipoles ***(TRC-27)***
- 1200kV Pooling point in Himachal Pradesh (Near Shimla) – Delhi/Haryana 2xS/c
- ±500kV 4X375 MW Kargil RE PP3 – Leh RE PP4 VSC based HVDC three Bipoles ***(TRC-28)***
- ±500kV 8X375 MW Leh RE PP4 - Lahul & Spiti PP (NR) VSC based three HVDC Bipoles ***(TRC-29)***
- 1200kV Lahul & Spiti PP (NR) – Chandigarh(NR) –North UP (Ghaziabad/Noida) S/c

- ±800kV 6000 MW Lahul & Sipti PP(NR) – West MP (Near Bhopal) – Maharashtra (Near Mumbai) HVDC Bipoles ***(TRC-30)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 70,000 Cr

In addition to above corridors, transmission corridors from Hydro Complexes of NER/Bhutan to meet balancing requirement is also proposed.

NER/ER-NR INTERCONNECTION

- Multi terminal ±800kV 6000MW NER/Sikkim/Bhutan/UP location -Delhi/Haryana load centres HVDC Bipole – 3nos ***(TRC-31)***

Estimated Cost: Rs 45,000 Cr

Total Estimated Cost (all complex): Rs 3,00,000 Cr

Additionally, there would be requirement of Intra State Strengthening scheme at different voltage level with about Rs 1,50,000 Cr for absorption of renewable power within states. Further, there would be requirement of balancing cost to compensate conventional generation participating as flexible generation/spinning reserves etc.

Above proposed transmission corridors have also been phased out for medium term scenario i.e. 2031-32 (15th Plan) considering envisaged renewable capacity addition in desert regions. In addition, transmission requirement for envisaged capacity of large scale solar plants i.e. Ultra Mega Solar Power Plant upto 4000 MW capacity in desert lands including surplus lands lying up with Hindustan Salts Limited viz. at Sambhar (Rajasthan) [4000 MW], Kharaghoda (Gujarat) [4700 MW] and Leh/Kargil (J&K) [2400 MW] envisaged for 13th plan period (2021-22) is also evolved. Estimated Cost of transmission infrastructure is about Rs 19,800 Cr including Inter/Intra State transmission, additionally about Rs 2850/Cr per annum should also be attributed towards balancing infrastructure cost towards scale down operation of conventional generation for participating as flexible/spinning reserve (Rs 1/unit fixed charges & Rs 0.5/unit opportunity cost for about 19 Billion units per annum considering 20% CUF).

2.0 CHALLENGES AND IMPACTS OF DESERT POWER DEVELOPMENT

Development of renewable potential of deserts offers many challenges, which are deliberated as under:

Adverse terrain conditions

The desert areas of Thar, Rann of Kutch, Ladakh, Lahul & Spiti valley etc. are very difficult regions for inhabitants offering challenges in terms of very rough climate/weather and terrestrial conditions. Above, severe climatic conditions in certain months in deserts, do not allow round the year working and therefore “No work days” would be a considerable part in total construction period leading to more gestation periods than on main lands.

Deserts also offer very challenging conditions in terms of technical design of mounting structures for Solar panels also.

Infrastructure Constraints

Indian deserts have very thin population density because of very tough terrain condition. Due to above reasons, it lacks availability of basic infrastructure like roads & highways, water supply system, power network, railways, telecom and other public utilities. Absences of these infrastructures provide a major challenge in setting up renewable generation plants as well as transmission infrastructure including substations.

Manpower Availability

Desert areas are very thinly populated. Inhabitants staying in these areas are mainly tribes whose main occupation is agriculture and animal husbandry. Therefore, skilled manpower for construction and O&M would be required from other parts of country. Since dessert areas are far flung and have difficult climatic conditions along with poor infrastructure development, it would be huge challenge to bring skilled manpower at task, which shall be cost intensive.

Transmission Infrastructure Development

Deserts are located very far from electricity demand centers, which would require establishment of long distance transmission lines along with substations to evacuate & transfer renewable power to distant load centers. Considering above discussed infrastructure constraints, development of transmission infrastructure, O&M of Substations/Lines will also face similar challenges as discussed for establishment of renewable generation plants.

Technical Challenges for Generation Plants

In desert environments, Solar PV module inorganic/organic soiling is a major concern. This if not taken care adequately, may affect efficiency as well as module life. Water is scarce in Desert. However, Photovoltaic (PV) panel, needs lot of water (demineralised /osmosis water) to clean the panels. CSP plants also require water predominately for cooling steam in condensers as well as for cleaning. Since Solar PV will occupy large desert area, it is prudent to adopt suitable mechanism of collection of Rain water precipitating on the panels and store suitably for future use. In addition, latest dry cleaning technology which doesn't involve water usage like automated "dry sweep" cleaning solar panel robot (Wallwalker) or "no-water mechanical automated dusting device" (NOMADD) which is a simple, rugged and low-maintenance could be explored to address above challenges.

2.1 SOCIO-ECONOMIC IMPACTS

Desert power not only encourages economic growth by providing electricity, it also has positive socio-economic benefits, such as the creation of new jobs, growth of new industries, infrastructure development etc.

Large scale renewable energy projects in the desert may interfere with wildlife. Though renewable power generation affects minimally to environment, clearances from statutory authority would be required and care should be taken during construction so that there is no adverse impact on wild life.

2.1 IMPLEMENTATION STRATEGY

Government shall have to play key role in development of desert renewable potential. Following broad areas have been identified where government's role shall be required:

- Formulation of National Desert Mission focussing on desert power development
- Provision of Single Window clearance for developers similar to Ultra Mega Power Projects for conventional generation
- Formulation of consistent & stable policies to encourage development of renewable generation in deserts, its integration into grid, balancing infrastructure etc.
- To address Right-of-way for development of transmission system associated with renewable generation, high capacity transmission corridors are to be developed keeping in view long term power transfer requirement. However, as the generation projects materialises in phased manner, during initial period utilisation of corridors will be less.

Therefore, innovative funding mechanism like soft loan over longer terms, access of low cost financing, gap funding etc. may be arranged through national level desert policy.

- Development of associated Infrastructure in terms of approach road/rail/air for equipment transportation, Water transport facilities etc.
- Development of Desert Zones with Solar Plots and prioritisation of areas for development. Facilitating developers for the land acquisition on least cost/lease basis
- Policy for indigenisation of manufacturing as well as technology for Solar PV/CSP including Semiconductors cells & large scale Energy storage technology
- Capacity-building aimed at developing new generation of trained scientists, engineers, skilled manpower etc.
- Allocation of funds specific to desert power development including development of 400kV High Temperature Superconductor(HTS) line
- Considering quantum & stringent nature of work to be carried out, identification of suitable agency (ies) that have sufficient experience in development of generation projects, Transmission corridors, technical expertise as well as strong project management skills
- Setting up of National level Institutes for Renewable energy study
- Establishment of Centre of Excellences for Research, Development & Demonstration (RD&D) for Renewable technologies

2.2 ROLE & RESPONSIBILITIES OF STATUTORY BODIES/AUTHORITIES TOWARDS IMPLEMENTATION

In order to facilitate implementation of various measures with desert power development, it is proposed that following actions may be taken up respectively by the Regulator, Statutory Authorities/Planning commission/MNRE/MOP and CEA/POWERGRID etc.

S no.	Activities	Role/Responsibility
1	National Desert Mission/ Policy to encourage desert power development	MNRE/Planning commission
2	Policy for identification of desert power zones/solar plot, land allotment, associated infrastructure development	MNRE/State Govt
3	Transmission Infrastructure development (ISTS/Intra State) – Planning – Implementation	CEA/POWERGRID/STU
4	Regulation for Flexible Generation, Ancillary Services and Generation Reserves – Market design	CERC/SERC
5	Energy Storage Technologies - selection, design & implémentation	POWERGRID/CEA/POSOCO
6	Capacity Building	MNRE
7	Institutional arrangement (Roles & Responsibilities of Developers /DISCOM/STU/SLDC etc.) – incorporation in EA 2003	MOP/MNRE/CEA
8	➢ Assessment / Reassessment of onshore and offshore wind Energy Potential and update of Wind Atlas ➢ Assessment / Reassessment of Solar Energy Potential and update of Solar Atlas	MNRE/C-WET
9	➢ Establishment of Institutes for renewable energy ➢ Setting up of centers of excellence for RD&D on renewables	MNRE/DST/MOP/CEA/POWERGRID

2.3 RESEARCH, DEVELOPMENT & DEMONSTRATION

Renewable energy sources have huge contribution in achieving our sustainable energy goals. In order to exploit full potential of renewable energy, Research, Development & Demonstration (RD&D) has a key role to play. Investment in RD&D will not be delivered by market signals alone; extensive support at the national and international levels is needed to accelerate the development of renewable technologies. RD&D targeted at different stages of the innovation chain will yield benefits in the short-term (up to five years), medium-term (5–15 years); and in the longer term (15 years plus).

Broad areas of focus for RD&D activity should be:

- Improved performance, including conversion efficiency, reliability, durability and lifetime
- Advanced manufacturing techniques for components
- Reduced material requirements, especially for toxic materials
- Sustainable production processes that minimise life-cycle environmental impacts through manufacturing, use, recycling and final disposal
- Improved methods for integrating renewable energy into buildings, electricity grids and other distribution systems; socio-economic research aimed at developing effective policy measures that will encourage the deployment of renewables and enhance public acceptability of new energy technologies
- Capacity-building aimed at developing new generations of trained scientists, engineers and others
- Establishment of National level Institute for renewables, Center of excellence for research, development & demonstration for renewable technologies

2.4 INDIGENOUS MANUFACTURING

To fulfil Desert Mission ambitious target, manufacturing capacity of solar cell, module, inverter/power conditioner, CSP technology is crucial. Presently, Indian manufacturing capacity on above items is very small as compared to global capacity.

While global demand of solar PV had CAGR of 63% over the period from 2009-12, manufacturing capacity setup has increased even faster. Due to large gap (29 GW in 2012) in demand and manufacturing capacity, many of the manufacturers are feeling the heat of competition and prices are going down. Almost 64% of the global manufacturing capacity of solar cell/module is in China. The huge indigenous capacity build up by Chinese manufacturers resulted in serious demand-supply imbalance in the global PV market. India has annual manufacturing capacity of 900 MW for solar cells and 2000 MW of solar modules per annum.

Presently our annual demand is matching with domestic capacity, but due to dumping of solar panels at lower rates, imports have increased drastically. Further, huge deployment of solar power in deserts shall attract global manufacturers, which may impact foreign exchange demand and current account deficit as well. Therefore, it is prudent to encourage and widen domestic manufacturing base before mass deployment which will further reduce the cost. A lot of policy, regulatory and technical measures shall be required for larger participation of domestic industry. Some of them are as below:

- Consistent and stable policy to increase domestic content in the solar projects
- Suitable policy measures to increase indigenous production and also competitive with global manufacturers
- Stricter regulatory enforcement of the solar renewable purchase obligations on the obligated entities, especially the DISCOMS
- Priority sector lending to solar manufacturers
- Policy support to increase investment and fiscal incentives for indigenous manufacturing like supported through soft loans based on the extent of local value addition, incentivised through investment allowances/interest rate subsidies/tax credit etc.
- Establishment of solar manufacturing parks, ease in land acquisition for establishment of manufacturing facility
- Policy for Technology deployment linked to efficient module development could be subsidized
- Establishment of R & D facilities
- Development of skilled manpower in the field of solar manufacturing

Above measures shall bring domestic industry upfront and shall lower dependence on foreign manufacturers through indigenous manufacturing. Strong manufacturing base shall lead to long term development of solar industry in India and enable envisaged desert power development progressively by 2050.

Development of High Temperature Superconductor line

In order to facilitate transfer of power from remotely located renewable generation plants to the distant load centers, high capacity transmission corridors at 1200kV/765kV AC, 800kV HVDC etc. are required. However, establishment of large transmission network by conventional overhead lines requires consideration of socio-economic and technical challenges that includes Right-of-Way availability, protection of flora and fauna, reduction of transmission losses, control of system fault levels, cost optimization etc.

High Temperature Superconductor power cables, where the combination of high current capacity and low-level losses decipher into high power transmission capacity, has been found as possible alternative to overhead lines for bulk power transmission. The Right of Way requirement of HTS cable is extremely low in comparison to the conventional system. Over the last decade development of HTS power cables has progressed significantly with improvements in superconducting wire performance and technological advancements in the construction of HTS cables. Demonstration projects throughout the world are acting as a catalyst for the commercialization of the technology. A typical HTS line with cryogenic cooling arrangement is shown at Fig A-2 as under:

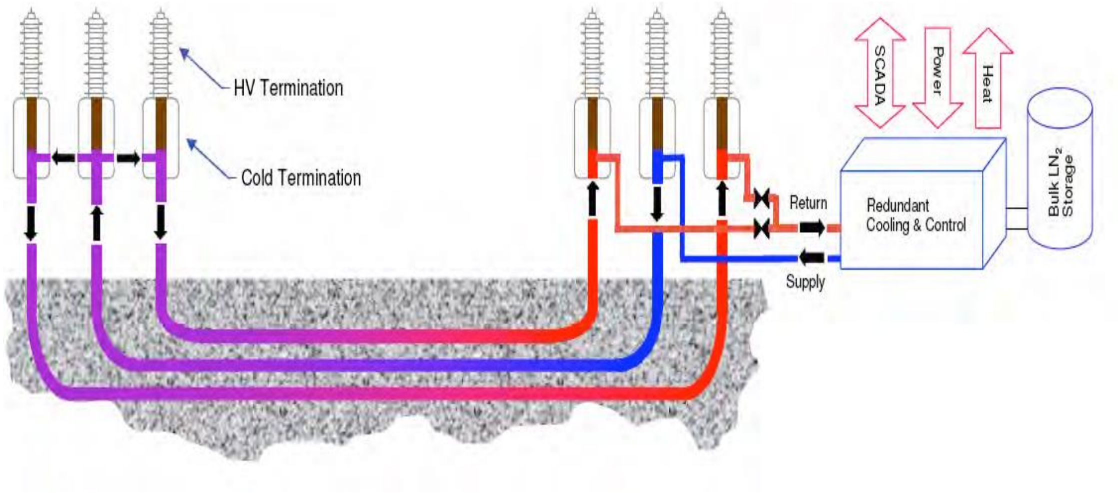

Fig-A-2: Typical HTS facility with cooling arrangement

In order to gain sufficient experience in this technology, POWERGRID is planning to have a demo project at 220kV level for 200 m long underground line to gain sufficient operational experience with Cryogenic Refrigeration System (CRS). Liquid Nitrogen (LN2) shall serve as the refrigerant to keep the HTS core at the Superconducting state.

It is also prudent to undertake indigenous development of a full-fledged transmission line at 400kV level having power transfer capacity in the range of 6000-8000 MW with negligible RoW through HTS technology at commercial level. Experience gained through such project would help in large scale deployment of HTS line in the long run while addressing RoW issue vis-à-vis requirement of high capacity transmission corridors in future to a great extent. Initially cost of such project would be high; however, with increase in volume of HTS lines, economy may be achieved. To undertake first commercial project of HTS line, suitable financing mechanism is to be worked out by the Government.

2.5 INVESTMENT IN RENEWABLE GENERATION INSTALLATION

As per Desertec Industrial Initiative (DII) report on Desert Power 2050, significant cost reductions of around 50% or more are expected for all technologies (Fig-A-3), except for Wind on-shore costs, which are estimated to decline by 20-30%, since this technology is already mature and cost competitive today. However, cost developments in target time frame shall broadly depend on government policies as well as market development in respective countries.

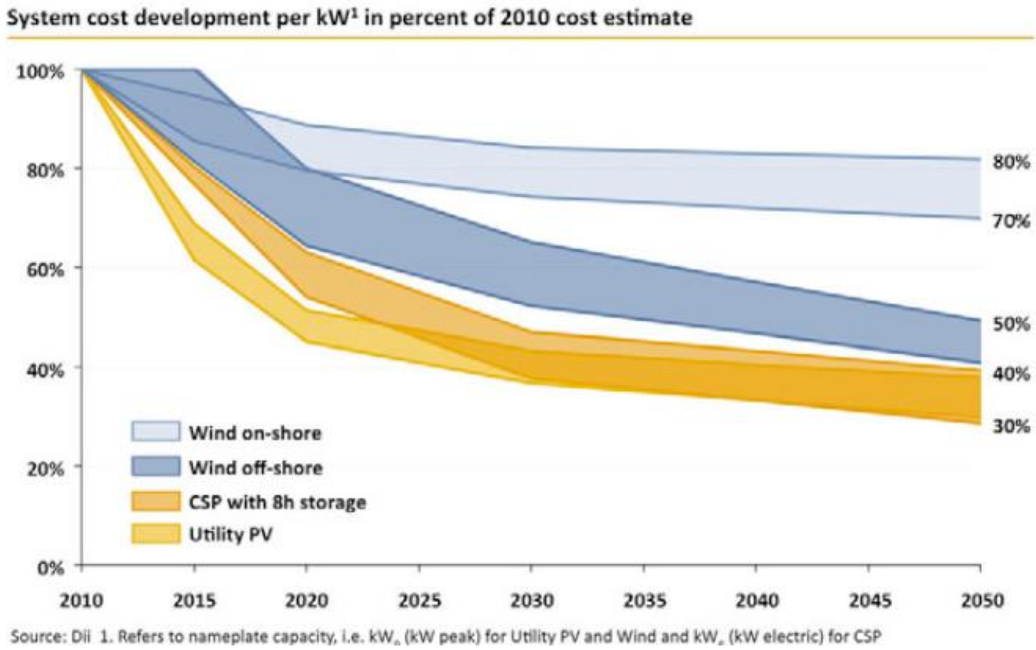

Figure A-3: System cost development per KW (%) of 2010 cost estimate (Source :DII report on desert power)

Considering above (Fig-A-3), price range for different renewable technologies for 2050 time frame is evaluated, however 10% escalation due to harsh ecology conditions of deserts is also considered (Table A-8).

Table-A-8: Cost for different renewable generation technologies in 2030/2050

RE Technology	Anticipated price level (Rs. Cr/MW) (on Lower band)	
	2030	2050
Wind (on-shore) generation	6.7	6.4
CSP (8 hr) generation	20.9	16.5
Solar PV System	9.0	8.0

Cost for different balancing technologies such as Pumped Storage and Battery Storage may also be considered as Rs 8 Cr/MW as well as Rs 5 Cr/MWh on account of cost reduction due to economy of scale as advancement of technologies especially in Battery energy storage.

2.6 INVESTMENT REQUIREMENT

On the basis of present cost trends, total investment requirement has been assessed for the generation, transmission and balancing infrastructure upto 2050 as under.

A) Investment Requirement in 13th Plan (2022)	Estimated Cost
• **Generation**	**: Rs. 1,08,550 Cr**
– Wind (0.7 GW)	: Rs. 4,550 Cr
– Solar PV System (10.4 GW)	: Rs. 1,04,000 Cr
• **Transmission**	**: Rs. 19,800 Cr**
– Intra State	: Rs. 5,000 Cr
– Inter State	: Rs. 14,800 Cr
• **Other Balancing Infrastructure$**	**: Rs. 80,000 Cr**
– Pumped Storage (5 GW)	: Rs. 40,000 Cr
– Battery Storage (2 hr)(2 GW)	: Rs. 40,000 Cr
Estimated Cost (A)	***: Rs. 2,08,350 Cr***
B) Investment Requirement in 14th & 15th Plan (2022-32)	**Estimated Cost**
• **Generation**	**: Rs. 13,88,000 Cr**
– Wind (12 GW)	: Rs. 78,000 Cr
– Concentrated Solar power (12 GW) (Storage: 8 hr)	: Rs. 3,60,000 Cr
– Solar PV System (95 GW)	: Rs. 9,50,000 Cr
• **Transmission**	**: Rs. 1,85,000 Cr**
– Intra State	: Rs. 60,000 Cr
– Inter State	: Rs. 1,25,000 Cr
• **Other Balancing Infrastructure**	**: Rs. 1,12,000 Cr**
– Pumped Storage (9 GW)	: Rs. 72,000 Cr
– Battery Storage (2 hr)(2 GW)	: Rs. 40,000 Cr
Estimated Cost (B)	***: Rs. 16,85,000 Cr***

C) Investment Requirement from 2032 to 2050	Estimated Cost
• **Generation**	**: Rs. 20,04,000 Cr**
– Wind (16 GW)	: Rs. 1,04,000 Cr
– Concentrated Solar power (18 GW) (Storage: 8 hr)	: Rs. 5,40,000Cr
– Solar PV System (136 GW)	: Rs. 13,60,000 Cr
• **Transmission**	**: Rs. 2,45,200 Cr**
– Intra State	: Rs. 85,000 Cr
– Inter State	: Rs. 1,60,200 Cr
• **Other Balancing Infrastructure**	**: Rs. 2,32,000 Cr**
– Pumped Storage (14 GW)	: Rs. 1,12,000 Cr
– Battery Storage (2 hr) (6 GW)	: Rs. 1,20,000 Cr
Estimated Cost (C)	***: Rs. 24,81,200 Cr***
Total investment requirement up to 2050 (A+B+C)	***: Rs. 43,74,550 Cr***

In addition to above, there would be requirement of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions due to volatility of Renewable generation.

$ There would be requirement of Rs 2850 Cr/annum requirement towards balancing infrastructure in 2022

***Present Cost trends; PV- Rs 10 Cr/MW, CSP Storage- Rs 30 Cr/MW, Onshore Wind- Rs 6.5 Cr/MW, PSP- Rs 8 Cr/MW, Battery Storage- Rs 10 Cr/MWh*

CHAPTER-1

CHAPTER 1

INTRODUCTION

Background

Indian economy has been one of the fastest growing economies in the world and continues to hold promising future. However, economy is confronting lots of challenges to keep its pace of growth and attain new heights. Notably, country faces a crucial challenge in terms of meeting its rapid growing energy needs amidst managing environmental impacts arising from the carbon economy as well as addressing energy security. Despite impressive growth registered in generation capacity installations, country still reels under power deficit situation which in turn impacts economic growth. Large chunk of population especially in rural landscapes of India still don't have access to electricity posing threat to inclusive growth. A typical schematic of "***Circle of Energy Challenges***" is shown as under in Fig 1-1.

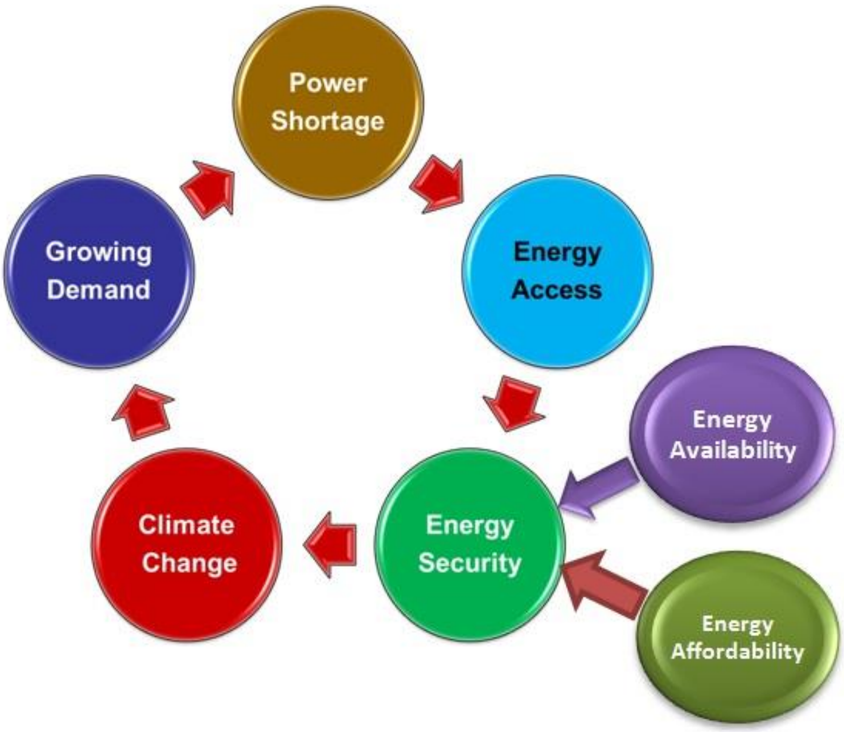

Fig 1-1: Circle of Energy Challenges

Abundant Renewable Potential in the country, if harnessed, presents excellent solution to meet above challenges i.e. meeting long term energy requirements, attaining energy security – Access & Delivery with affordability along with addressing climate change concerns. Considering potential of Indian desert in development of inexhaustible generation resources through Wind & Solar presents a promising solution to country's challenges in power sector. Subsequent sections discuss country's challenges and solutions thereof in details.

1.1. Energy Security

In past, the Gross Domestic Product (GDP) of the country has grown at the rate of about 7-8% for past several years. Although growth is expected to consolidate a bit in 2012-14, medium & long term growth projections are still in the range of 8-9% per annum. GDP Growth and growth in energy needs both have a strong co-relation. Therefore, availability of energy remains a most vital input for sustaining and achieving projected GDP growth.

India is the fourth largest primary energy consumer (711 mtoe) in the world after USA, China and Russia, achieving 5-6% average growth in consumption per annum (Fig 1-2), which is substantial.

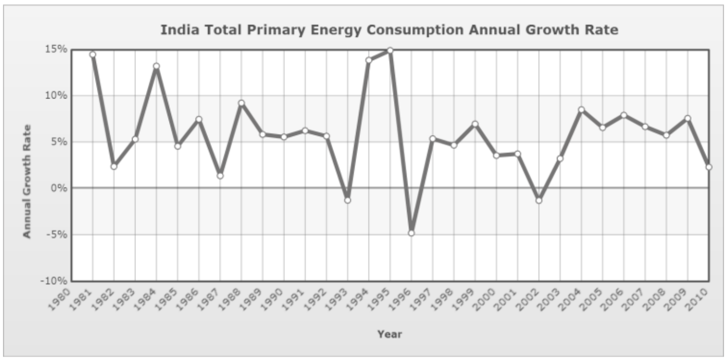

Fig 1-2 : India Total Primary Energy Consumption Annual Growth Rate (Source: US Energy Information Administration)

Out of total primary energy consumption, about 75% is supplied by the commercial energy resources such as Coal, Petroleum products, Large Hydro, Renewables etc. whereas balance 25% is supplied by the non-commercial energy resources i.e. Wood, agriculture residue etc. Coal dominates with 53% contribution in supply of commercial energy resources whereas oil occupies the second place with 34% contribution as shown in Fig 1-3.

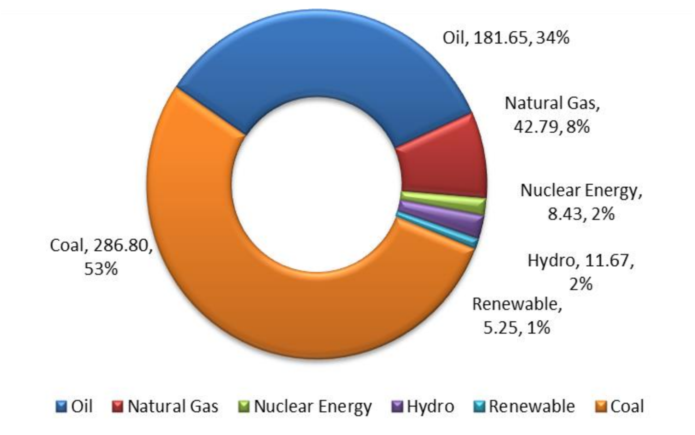

Fig 1-3 : Supply of primary commercial energy portfolio

As per the Planning commission estimates, the annual average growth rate of the total energy requirement is expected to accelerate from 5.3% in the 11th plan to 5.7 % per annum in the 12th plan and moderate to 5.4% per annum in the 13th plan. The faster growth in supply in the 12th plan is a reflection of the need to meet suppressed demand. With above estimates, it is seen that country has voracious appetite for energy but lacks sufficient domestic energy resources particularly of Petroleum, Natural gas and coal.

Planning Commission Statistics (Table 1-1) reveal that though domestic production of energy resources is projected to increase, import dependence will continue to remain at high level. The main area of import will be crude oil, where nearly 78 % of the demand will have to be met from imports by the end of 12th plan and further increase in 13th plan (82%). Similarly, import dependence for coal is also estimated to increase from 18.8 % in 2011–12 to 22.4% by the end of the 12th plan and 25.9% by the end of the 13th plan. Thus, in total, 37% of India's commercial energy needs (i.e. Coal, Petroleum products etc.) are envisaged to be imported, which shall remain of the same order in percentage terms even in 13th Plan, which is a major concern in terms of attaining energy security.

Table-1-1 : Primary Energy Production and Import (Source :Planning Commission:12th FY Plan Vol-II)

(in million tons of oil equivalent (mtoe))

S.No	Source	2011-12		Envisaged			
				2016-17		2021-22	
		Domestic	Import	Domestic	Import	Domestic	Import
1	Coal & Lignite	232.8	54	325.35	90	429	150
2	Petroleum products- Crude Oil, Natural Gas, LNG	82.02	142.42	118.88	177.24	146	225
3	Hydro Power	11.22	0.45	12.90	0.53	17	0.6
4	Nuclear Power	8.43		16.97		30	
5	Renewable Energy	5.25		10.74		20	
	Total (Commercial Energy)	339.72	196.87	484.84	267.76	642	375.6
	Non Commercial Energy like charcoal, firewood and agricultural waste	174.2		187.66		202.16	
	Total Primary Energy	710.79		940.26		1219.76	

High import dependence for energy amounts to compromised energy security of the nation, as GDP growth becomes dependent on external factors like International commodity prices

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(Crude/Gas/Coal), currency fluctuations impacting fiscal deficits & forex reserves and more to competitive prices of the energy for the end consumers.

Therefore, the ability to meet this energy demand shall depend on our capability to expand domestic production base in critical energy sub sectors, notably petroleum, gas and coal, and meeting the remaining balance requirement through imports.

It is worth to mention that, as a percentage of total commercial energy, coal shall continue to remain dominant source (~55%) of primary energy till 2021-22 and possibly beyond. According to Integrated Energy Policy (IEP) estimates of planning commission, India's coal reserves are likely to run out in next 45 years, assuming a 5% per annum growth in demand. Further, as per the statistics, volume of import of coal has more than doubled over last five (5) year plan, which shall continue to be at that level in future. So in the situation, where economy is primarily dependent on Coal as energy resources, its domestic reserves are depleting leading to increase in import dependence. However, coal imports have concerns around limited supporting infrastructure, huge price difference between imported and domestic coal and changing regulations in the source countries. Also, different characteristics of coal typically permit existing power plants to blend imported coal with domestic coal only up to 10% to 15%. So there is a gap in supply to cater to meet the demand without import of coal.

In view of above, Energy Security is to be given utmost priority to provide adequate energy of desired quality in various forms in a sustainable manner at competitive prices. This shall ensure sustainability of GDP growth and achieve even higher targets.

1.2. Environmental Challenges

In the recent times, serious concerns on "Climate Change" & "Global Warming" have been raised globally. India currently emits approximately 4% of global GHG emissions. However, its per capita emissions are only one-quarter of the global average and less than one-tenth of those of most developed nations. India has committed to reduce the emissions intensity of its economy to 20%–25% below 2005 levels by 2020 and has pledged that per capita GHG emissions will not exceed those of industrialized nations.

In light of this, due to dependence on fossil fuel based resources in total primary energy portfolio of our country, India faces formidable challenge in dealing with sustaining its accelerating economy growth and at the same time, addressing global threats of climate change through "decarbonisation". Indian economy is closely tied to its natural resource base and climate sensitive sectors such as agriculture, water and forestry, which may get a threat out of envisaged changes in climate apart from other effects on human life.

National Action Plan on Climate Change (NAPCC) also aims of promoting development goals while addressing GHG mitigation and climate change adaptation. NAPCC suggests that up to 15% of India's energy could come from renewable sources by 2020.

As per estimates, GHG emissions by various sectors in India are as shown in Fig 1-4 as under:

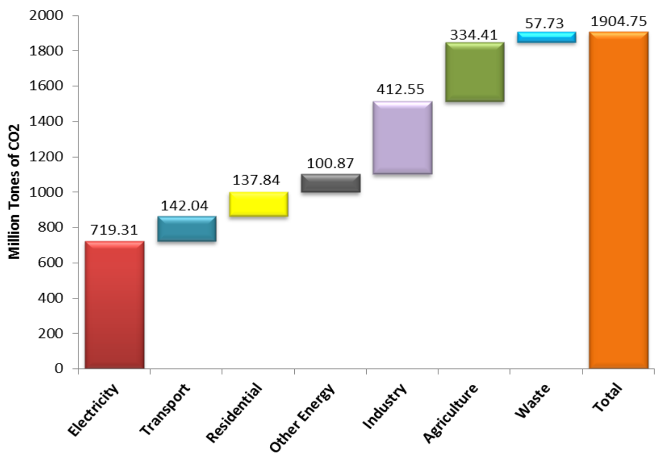

Fig 1-4 : GHG emissions by various sectors in India **(Source: Deloitte-IEC 2013:Sustainable sources of energy)**

This shows that electricity sector accounts for almost 40% of total GHG emissions followed by 20% from Industry and 10% from Transport sector. Primary reason for the contribution of almost half of the total emission by electricity sector is because 70% of the energy is supplied by the Coal based plants in the overall fuel mix. Moreover, domestic coal is characterized by low calorific value and high ash content, posing significant environmental challenges. Despite over dependence of our country on Coal as a resource, which is considered as one of the unclean energy resource in the world contributing significantly towards "Global Warming", country has to adopt Clean Coal Technologies which can led to more efficient combustion & utilization of Coal.

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Similarly, modern transport technologies (Plug in Hybrid Electric vehicle/ Electric vehicle) must also be adopted in transport sector which currently rely solely on petroleum products in order to address GHG emissions & energy security concerns of the country.

1.3. Solution for Energy Security & Environmental Challenges

Considering the increased dependence on imported coal & petroleum products, which are vital primary energy resources as well as growing environmental concerns on account of use of fossil fuels, country has to embark upon large scale development of other alternate energy resources like renewable and take key initiatives like energy efficiency etc. at a much larger scale.

Renewable Potential

Energy the earth receives every year from the sun is 1.6 billion terawatt-hours (TWh), or ten thousand times than world’s entire energy needs and the sun will remain a source of abundant and easily available energy for millions of years to come. One of the challenges in harnessing this abundant source of energy is availability of land to put up Solar Plant. Deserts are known to possess vast area of land i.e. wasteland having excellent solar irradiance which can be utilized to harness Solar energy. Considering the amount of land available with global deserts, the potential solar resource from desert regions is truly astounding. Several studies show that the entire global electricity demand could be provided from just 4% of the area of world's deserts.

Fortunately, India too has been bestowed with abundant Renewable Energy potential. Among various renewable energy resources, India possesses a very large solar and wind energy potential which is seen as the huge energy resource for the future. As per C-WET (Chennai), estimated on shore wind potential is about 103 GW at 80 m hub height whereas off shore potential, considered to be available at much larger scale. Preliminary analysis of off shore wind potential in Gujarat & Tamil Nadu coast is alone of the order of about 37GW. The scientific and research work carried out by various independent agencies have claimed that the potential for wind energy (on shore) of the country is far in excess of Indian official estimates (even 20-30 time higher).

India is also endowed with abundant solar energy due to its convenient location near the equator. Due to its locational advantage, India receives solar energy equivalent to over 5,000 trillion units per year and country has the potential to generate more than 1000 Billion units annually from the Solar energy (matter of fact being present electrical energy consumption-950 BU/annum). This is due to the fact that it has around 250-300 sunny days in a year along with solar insolation of 4.5-6.5 kWh per Sq.m per day in most part of the areas. If this energy is harnessed effectively, it can help in reducing our energy deficit scenario and even meet entire electricity demand of the country, that too with no direct carbon emission.

As per Ministry of New & Renewable Energy (MNRE), Solar Potential in India is in excess of 100 GW. To tap this huge solar potential, GoI has embarked on an ambitious program under the Jawaharlal Nehru National Solar Mission (JNNSM) as a part of NAPCC. The objective of the Jawaharlal Nehru National Solar Mission is to create conditions, through rapid scale-up of solar power capacity and technological innovation to drive down costs towards grid parity. JNNSM targets an addition of 20,000 MW of solar power by 2022 in three phases. First phase of the mission (1100 MW grid Solar & 200 MW off grid applications) has already been achieved in 2013 with huge success, this will be further increased to 10,000 MW by 2017 in the second phase of the programme.

In view of the above, it is a proven fact that country has immense Solar potential, provided land and other infrastructure are facilitated for setting up of such plants. The largest accessible but least tapped form of energy on earth is solar radiation on desserts. India has large deserts (both Hot & Cold) viz. the Thar (Rajasthan), Rann of Kutch (Gujarat), Ladakh (Jammu & Kasmir) and Lahul & Sipti valley (Himachal Pradesh) having total geographic area (TGA) of over 330,000 Sq km out of which total wasteland area is over 148,000 Sq km. A fraction say about 5-10% of total wasteland of mentioned above (7400-14,800 sq km) can offer 220-450 GW generation capacity from solar and wind generation which can address the future energy challenges in the country. Further, based on available data, it can be seen that there is huge untapped potential which can be harnessed through Rooftop Solar PV as well as Canal Top Solar, wherein land is not an issue as available facilities are utilised for such installations with suitable policy and regulatory framework.

1.4. Global Renewable Scenario

Global demand for renewable energy continued to rise during 2011 and 2012, supplying an estimated 19% of global final energy consumption in 2011. Total renewable power capacity worldwide exceeded 480 GW in 2012 (excluding hydropower), up about 21.5% from 2011 (Fig-1-5).

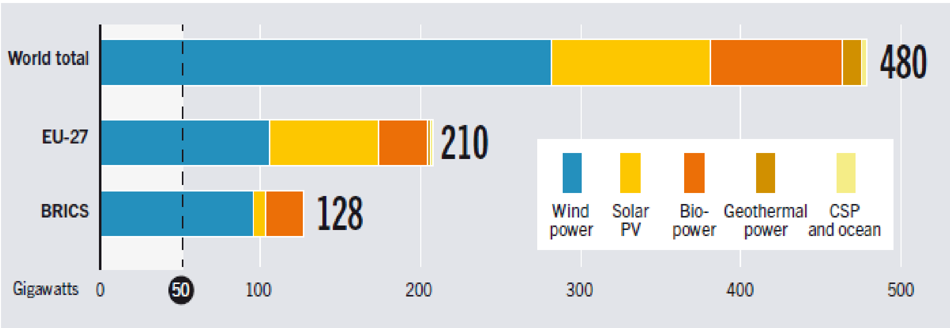


Fig 1-5: Renewable Power Capacity in World, EU-27, BRICS and Top Six countries 2012 (Source: REN21–Global Status report 2013)

With this, Solar PV capacity also reached the 100 GW milestone to pass bio-power and become the third largest renewable technology in terms of capacity, after hydro and wind. Total global CSP capacity also increased more than 60% to about 2,550 MW. However from the Fig-1-6 below, it can be seen that after 2006, the capacity addition in Solar PV segment has been almost exponential lead by Europe. At the beginning of 2012 Germany (32%) and Italy (16%) alone represent about half of the world’s installed PV capacity.

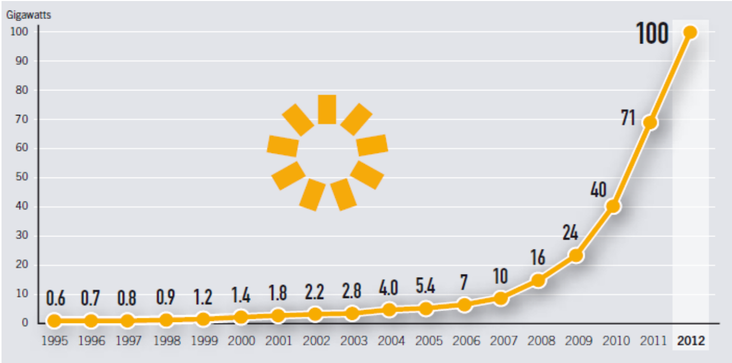


Fig 1-6: Solar Global PV capacity (Source: REN21– Global Status report 2013)

Policy targets for the increased deployment of renewable energy technologies have been identified in at least 138 countries as of early 2013, wherein countries like Sweden etc. have kept 50% renewable energy penetration target by 2020 (Fig-1-7). Above policy targets indicates that global demand for renewable energy shall continue to rise displacing conventional energy sources.

According to the International Energy Agency's (IEA) 2013 edition of the World Energy Outlook also, Renewable energy sources could account for nearly half of the increase in global power generation through 2035. Wind energy and solar energy could make up 45% of that expansion in renewables.

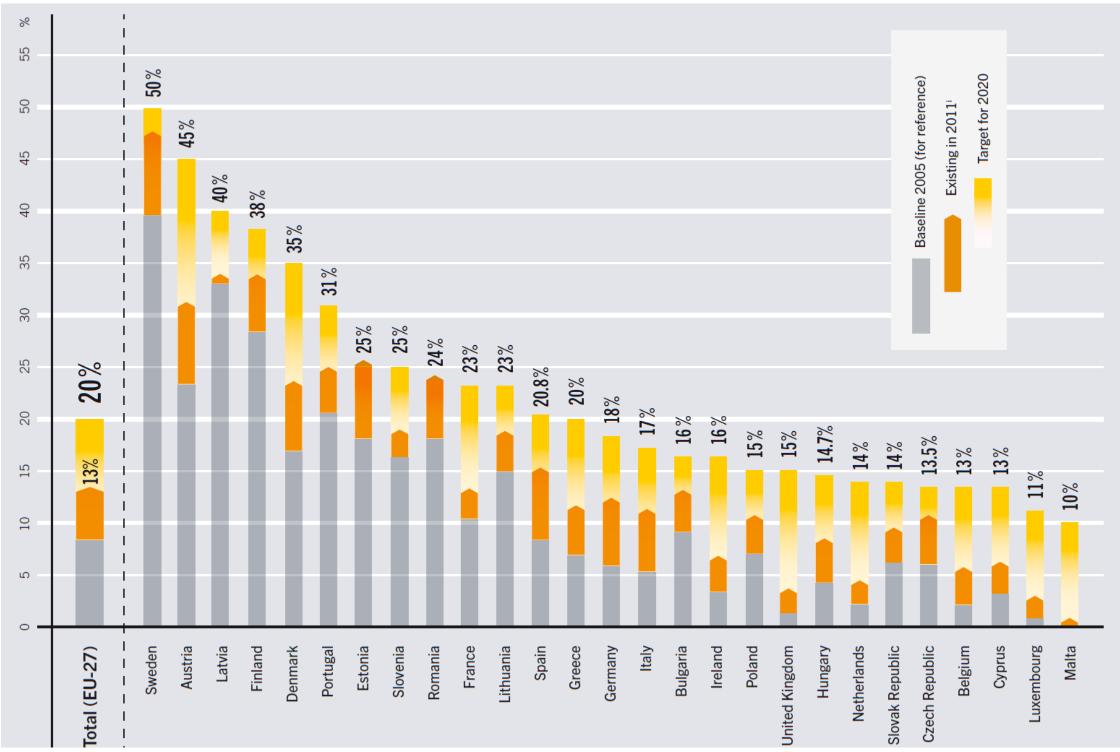


Fig 1-7: Solar Global PV capacity (Source: REN21– Global Status report 2013)

Encouragement of policy makers/regulators for clean energy development programmes & thereby achievement of economies of scale at on-grid as well as off grid level, technological advancements and emergence of low cost manufacturing locations has reduced the renewable generation tariffs. In India, Wind has almost achieved the Grid Parity and Solar PV is expected to achieve it by 2018, as per the analysis carried out by market analysts. Therefore, this shall further increase penetration level of renewables as well as imbibe emerging renewable technologies.

1.5. International efforts on Desert Development

Internationally also, lot of work is being carried out in the domain of Desert Power Potential development. In 2009, the DESERTEC Foundation was founded by public figures, private individuals, politicians and scientists from North Africa, the Middle East and Europe with this aim: to support the systematic use of renewables in deserts and arid regions worldwide as laid down in the DESERTEC Concept.

DESERTEC foundation is exploring towards future energy challenges of Europe, Middle East and North Africa (EUMENA) through development of renewable potential of North African Deserts. Objective of this project is to produce electricity from renewable energy sources in the resource rich desert areas of North Africa and exported to regions through transmission facilities having high demand as the“ DESERTEC Vision” .The vision of generating electricity in the Sahara desert and exporting it to Europe came into lime light after Mediterranean Solar Plan (MSP) was launched in 2008.

The objective of solar plan is to create 20GW of renewable generating capacity in the Mediterranean region by 2020. Another program in this series i.e. Desertec Industrial Initiative (DII) aims to provide 15% of European electricity consumption as well as a significant proportion of domestic demand in North Africa by 2050. Desertec Industrial Initiative (DII) is a private industrial consortium working towards enabling this vision in Europe, the Middle East and North Africa (EUMENA). It is envisaged to develop renewable projects in Sahara desert to generate 100GW by 2050 and export to Europe and African continents under this initiative. The overall objective of DII is to create a market for renewable energy from the deserts. A concept of DESERTEC-EUMENA project is shown in Fig 1-8 depicted as under:

Fig 1-8: DESERTEC EUMENA Project (Source: Desertec Foundation)

The objectives of EUMENA project are to

- Analyze and develop a technical, economic, political and regulatory framework for feasible investments into renewable energy and interconnected grids
- Originate some early reference projects to prove the feasibility of the concept
- Develop a long term roll-out plan for the period up to 2050 providing investment and financing guidance
- Conduct in-depth studies on specific subjects, e.g. siting issues, technology developments or specific conditions in order to provide answers to key questions that will come along on our path

As DII involves inter-country power exchange, therefore, materialization of this initiative requires resolution of various issues, power market conditions in the countries etc. to take up implementation activities.

1.6. Desert Power India

Realising need of large scale development of solar power including identification of infrastructure requirement & its grid integration upto 2050, Ministry of New and Renewable Energy (MNRE) have entrusted POWERGRID to make an assessment of renewable generation potential and evolve infrastructure requirements including transmission arising out the likely large renewable power projects in India's desert regions of the states of Rajasthan (The Thar), Gujarat (Rann of Kutch), Himachal Pradesh (Lahul & Spiti valley) and Jammu & Kashmir (Ladakh), for up to 2050 time horizon, with phased development plans. Copy of the letter from MNRE is this regard is enclosed at ***Annexure-1-1***.

The above mentioned study covers the scope of examining aspects relating to land ownership patterns and examination of associated land availability & acquisition issues; assessment of economic potential of renewable power generation, infrastructure development requirement, including road, water and for renewable power evacuation; estimated cost of generation, area/region specific demand forecast load assessment and associated grid balancing and spinning reserve infrastructure requirements, impact of large scale renewable power on local communities, including positive economic spillovers etc. The study is expected to provide much needed framework for creating future energy systems in the country.

In view of the availability of the desert waste land data at the moment, above Terms of reference is divided into different phases. Phase-1, the present study, covers following scope of works:

- Assessment of economic potential of renewable power generation in desert wasteland in Thar (Rajasthan), Rann of Kutch (Gujarat), Laddakh (Jammu & Kashmir) and Lahul & Spiti (Himachal Pradesh)
- Estimated cost of Renewable Capacity
- Demand assessment
- Transmission infrastructure requirement for renewable evacuation & its integration into grid
- Associated grid balancing and spinning reserve infrastructure requirements to address intermittency & variability
- Impact of large scale renewable power on local communities, including positive economic spillovers etc.

Unlike DII, development of desert power involves activities within India, which is implementable with the support of suitable policy and regulatory framework.

In order to assess generation capacity requirement to meet future electricity demand, present and future power supply scenario by 2050 are analysed which is presented in the next chapter.

CHAPTER-2

POWER SUPPLY SCENERIO PRESENT & FUTURE

CHAPTER 2

POWER SUPPLY SCENARIO

2.1. Present Power Scenario

Indian Power Sector is at a crucial juncture of its evolution from a controlled environment to a competitive, market driven regime which endeavors to provide affordable, reliable and quality power at reasonable prices to all sectors of the economy. The liberalization and globalization of the economy are leading to an increased tempo in industrial and commercial activities and this, coupled with penetration of technology and IT in the day-to-day life of the common people, is expected to result in a high growth in power demand. It is accordingly essential that development of the Power Sector shall be commensurate with the overall economic growth of the nation. Government of India (GoI) has taken several initiatives and announced various policy measures to strengthen the sector.

The Indian power sector is one of the most diversified in the world. The Sector has been continuously progressing in generation capacity addition through conventional viz. coal, lignite, gas, hydro and nuclear power as well as non-conventional/renewable sources viz. wind, solar, small hydro and agriculture & domestic waste.

2

Presently total installed generation capacity in the country is about 232 GW (Nov’13) which constitute capacity from conventional sources (88% share) viz. Coal (137GW), Gas(21GW), Nuclear (4.8GW) and large hydro (40GW). Balance 29 GW (12%) contribution is from renewable generation capacity which has 70% contribution from Wind generation alone. As discussed earlier, coal still dominates as fuel resource (52%) in overall electricity resources portfolio. Present generation capacity along with their resource composition is shown at Fig-2-1.

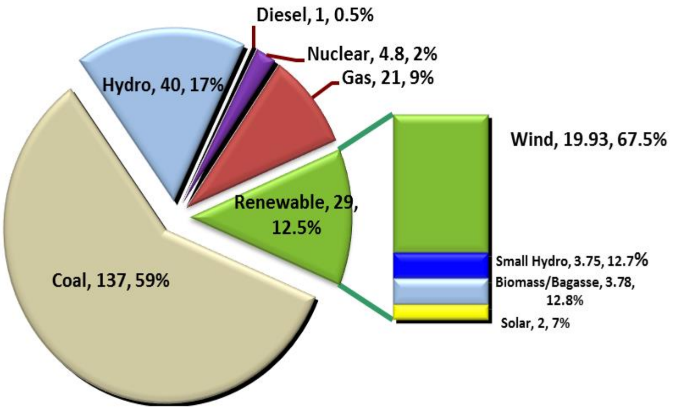


Fig 2-1: Installed Generation Capacity (Conventional & Non conventional)

In view of the growing challenges arising on coal availability, as well as environmental concern, impetus is being given to harness abundant renewable potential in the country. In these conditions harnessing of renewable potential in effective manner is becoming need of the hour, which can provide sustainable power supply as well as mitigate the negative environmental impact due to fossil fuel.

India has been continuously progressing in conventional as well as renewable capacity addition. Since 9th Plan period, share of renewable capacity has increased from 2% to 12% as on today (about 6 fold increase). Electricity generation due to renewable has also increased to about 6% in overall electricity generation mix as on today. With such multifold growth, penetration of renewable power in Indian grid has increased.

As indicated above, presently, about 29,537MW grid interactive (Wind-19,934 MW, Solar-2080 MW, SHP-3,747 MW Biomass/Bagasse-3,776 MW) as well as 927 MW off grid Renewable Energy (RE) generation capacity is available in the country.

2.2. Future Power Scenario

The demand for electricity in the country has been growing at a rapid rate and is expected to grow further in the years to come. In order to meet the increasing requirement of electricity, massive addition to the installed generating capacity in the country is required. While planning the capacity addition programme, the overall objective of sustainable development is to be kept in mind.

Despite tremendous growth in capacity addition past few decades, country continues to face both energy and peak deficit of about 9% (2012-13). Reducing this gap is critical for India to achieve its growth targets. The average per capita consumption of electricity in India is a mere 880 kWh (2011-12), compared to the world average of 2,800 kWh (2010) [Source- The World Bank Data]. The other comparable countries, like Brazil, Russia, China have significantly higher per capita consumption compared to India.

To meet growing demand and to reduce supply- demand gap, there is a need of large capacity addition through conventional as well as from renewable sources. It is estimated that during 12th Plan, about 88,000 MW capacity will be added from conventional sources (Coal- 70 GW, Gas-2.5 GW, Hydro-11 GW & Nuclear-5.3 GW). In addition to this, grid interactive renewable capacity addition of about 33,000 MW (Wind -20.5 GW, Solar -10.5GW, SHP-2GW) has been envisaged during 12th Plan comprising of Wind, Solar and Small hydro in the Eight (8) renewable potential rich states. In 13th plan also, about 86GW capacity is envisaged to be contributed through conventional sources (Coal- 56 GW, Gas-Nil, Hydro-12 GW & Nuclear-18 GW) and about 35 GW through renewable sources (Wind-15 GW, Solar-15 GW & Biomass/WTE-5 GW)[Source-CEA].

Towards implementation of envisaged renewable capacity addition in 12th plan itself, suitable policy initiatives need to be taken on urgent basis. In addition, regulatory enforcement such as compliance of Renewable Purchase Obligation (RPO) target etc. of various states, is required.

2.3. Projected Demand Scenario

According to report on 18th Electric Power Survey Report by Central Electricity Authority (Dec'11), Electricity demand is expected to grow @7.27% CAGR upto 13th plan (2021-22) and would be 200 GW & 283 GW by the end of 2016-17 & 2021-22 respectively considering 8% GDP growth. In 14th (2023-27) and 15th (2027-32) plan, growth in demand would be @ 7.16% and 6.22% CAGR respectively, projecting the demand at 542GW by end of 15th plan (2027-32). In order to evaluate long term demand for year 2050, two scenarios have been studied. In optimistic scenario, demand growth of 6% CAGR has been assumed which projects the demand to more than 1700 GW by 2050, almost 13 times of present demand. In moderate growth scenario, reduced elasticity of demand growth w.r.t. GDP growth, due to transitioning from developing to developed nation status, large scale implementation of energy efficiency & energy conservation programmes coupled with Smart Grid application, is envisaged to result in moderate CAGR demand growth (16th Plan [2032 onwards]-3.5% and 0.5% reduction in subsequent plan due to increased awareness, technological improvement etc.)up to 2050.Present analysis takes moderate growth scenario in account based on which electricity demand projections of the country upto 2050 are evaluated (Table 2-1):

2

Table-2-1 : Electricity demand projection

S. No	Year	Peak Demand (GW)
1	2012	130
2	2016-17	200
3	2021-22	283
4	2026-27	401
5	2031-32	542
6	2036-37*	644
7	2041-42*	746
8	2046-47*	844
9	2050*	896

** projected*

2.4. Generation Capacity requirement

Integrated Energy Policy (IEP) of Planning Commission has evolved generation capacity requirement to meet projected electricity demand by 2031-32. Report assumes that optimal utilization of resources shall bring down the ratio between installed capacity required to peak demand from 1.39 in 2011-12 to 1.31 in 2031-32. Therefore, estimated generation capacity requirement would be about 712GW to fulfill the EPS projected demand of 542GW for 2031-32.

In view of the envisaged increasing contribution of renewables in overall capacity portfolio and their lower capacity utilisation factors (16-23%), it is assumed that ratio between installed capacity required to peak demand shall increase progressively by the factor of 0.06 in every plan after 2031-32 (reference factor 1.31). Considering above assumption, installed capacity required to peak demand in 2050 shall increase to 1.55. Considering this, projected installed capacity in 2050 scenario would be estimated to be about 1388 GW against the demand requirement of 896 GW (Table-2-2).

Table-2-2 : Installed Capacity & Demand projections

S. No	Year	Installed Capacity requirement (GW)	Demand (GW)
1	2012	200	130
2	2016-17	271	200
3	2021-22	372	283
4	2026-27	528	401
5	2031-32	712	542
6	2036-37**	882	644
7	2041-42**	1067	746
8	2046-47**	1258	844
9	2050**	1388	896

***** Projected***

2.5. Resource mix in Capacity requirement

The draft 12th five year plan by planning commission, has projected mix of generation by fuel supply by the end of 2017 & 2030, details are as under in Table-2-3:

Table-2-3 : Long Term Resource Projection –Capacity & Energy

S.No	Source	Capacity (%)			Energy (%)		
		2012	2017	2030	2012	2017	2030
1	Coal	56	57	42	70	69	58
2	Oil	1	1	0	0	0	0
3	Gas	9	6	3	7	5	3
4	Hydro	20	15	13	14	12	11
5	Renewable	12	17	33	6	9	16
6	Nuclear	2	4	9	3	5	12

It specifies that capacity penetration of renewable generation will reach 33% in 2030 from present 12%, whereas renewable penetration of electricity energy shall rise from present 6 % to 16% by 2030, thus making share of Renewable Generation capacity next to coal. It also specifies that due to coal shortage and initiatives towards clean and green energy development, dependency on coal based generation would reduce from present 70% (energy) to 58% by 2030. Further, share of hydro energy is expected to fall from 14 % to 11 % in 2030 due to R&R, environmental clearances and other associated issues for large size hydro development. Share of nuclear power, another clean energy source, is expected to rise to 12% in 2030. Cumulatively, clean energy sources viz. hydro, renewable & nuclear energy shall attain growth from present 26 % to 39% by 2030.

2

Based on the envisaged capacity requirement as per Table-2-4 as well as projections based on planning commission data, fuel mix for generation capacity has been estimated up to 2032 (15^{th} plan).

Table-2-4: Resource Projection –Capacity & Energy

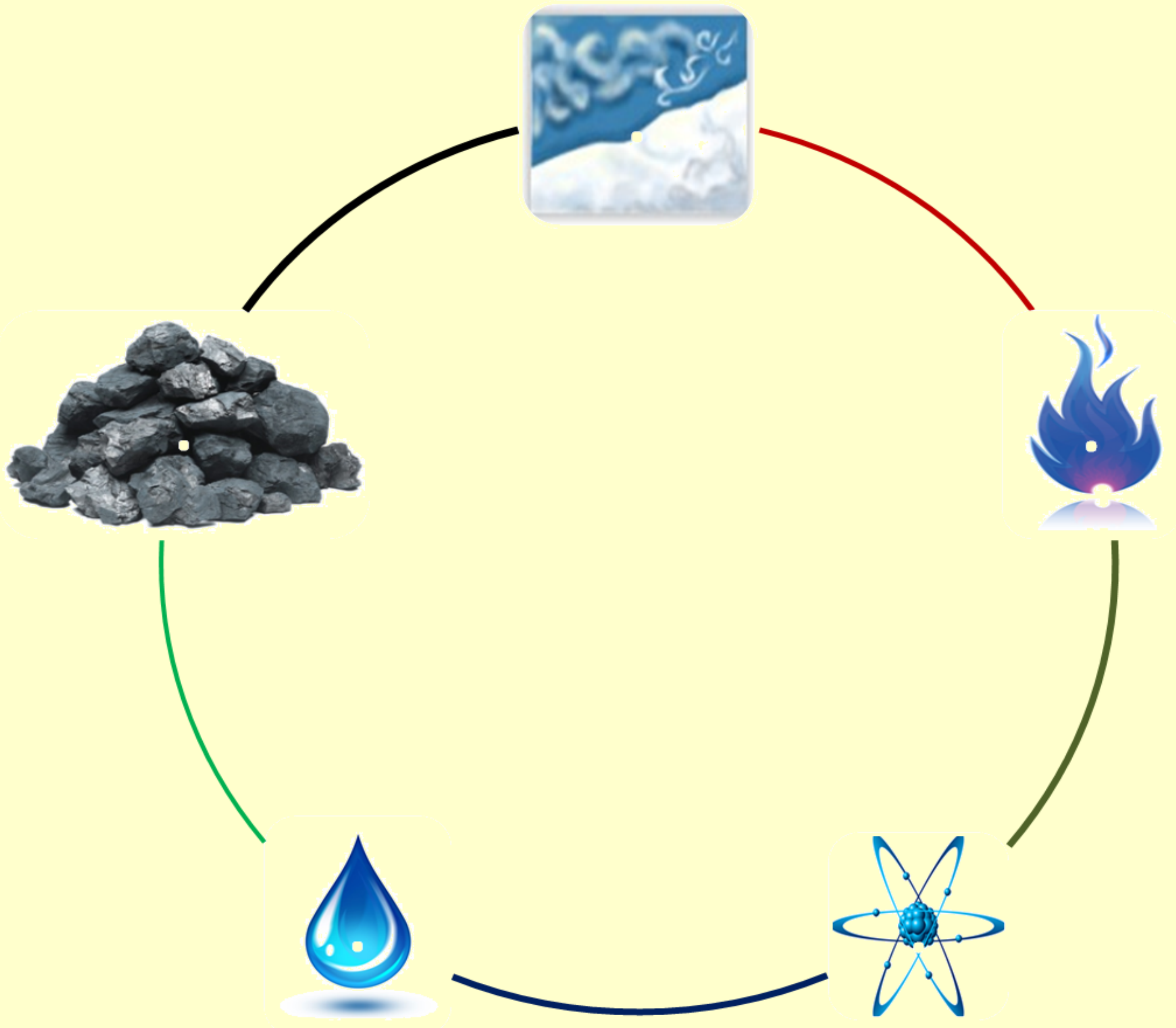
S.No.	Source	Generation (GW)		
		2012	**2017**	**2032**
1	Coal	112	154	299
2	Oil	1.2	3	0
3	Gas	18	16	21
4	Hydro	39	41	93
5	Renewable	25	46	235
6	Nuclear	4.8	11	64
	Total (GW)	**200**	**271**	**712**

In order to derive estimates for fuel mix by 2050, limitation of domestic coal as resources, increasing import dependence as well as environmental concerns needs more weightage to be imparted to the contribution through renewable including Hydro as well as Nuclear resources. However, contribution from renewable and other clean energy resources needs to be allocated based on the availability of the potential for Wind & Solar, land availability and other infrastructure and possibilities of hydro generation imports from neighbouring countries like Bhutan & Nepal.

To estimate fuel mix requirement by 2050 in the overall generation portfolio, assessment of resource potential is required. In the next chapter, potential of various energy resources including renewable generation in four(4) desert regions is described.

CHAPTER-3

RESOURCE POTENTIAL



CHAPTER 3

Resource Potential

In order to arrive fuel mix projection for 2030 & 2050 for power generation capacity, it is proposed to evaluate domestic potential and availability of various energy resources viz. Coal, Gas, Nuclear as well as Renewable.

3.1. Coal Resource

According to Integrated Energy Policy (IEP), with the proven reserves of coal, current level of consumption can last for about 80 years. In case all the inferred reserves also materialize, then coal & lignite can last for over 140 years. But as a known fact, coal and lignite consumption is increasing at a faster rate (average growth-5-6% p.a. as shown in the Fig-3-1 below). In case domestic coal production continues to grow at 5% per year, total extractable coal reserve (including proven, indicated & inferred) will run out in around 45 years.

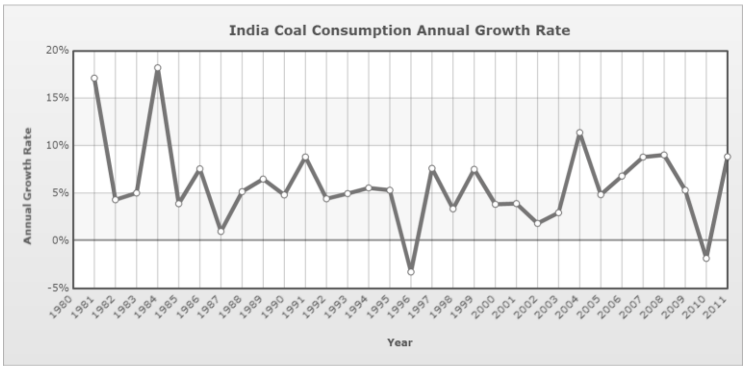


Fig 3-1 : India Coal Consumption Annual Growth Rate (Source: United States Energy Information Administration)

Some of the recent independent study by Greenpeace India viz. “Running on Empty (Sep’13)” indicates that “*At targeted growth rates (8%), Coal India’s extractable coal reserves could be exhausted within 17 years (i.e. by 2030). This is within the lifetime of Indian power plants recently constructed, and those currently under construction/approval. India has 90,000 MW of power plants (predominantly coal) under construction and aims to add another 69,000 MW of coal-fired power by 2017. If Coal India maintains a more realistic 5% growth rate, its extractable reserves would still be exhausted by 2034*”. Thus this would lead to emergence of large gap in capacity & demand.

Presently over 90% of India's coal production currently comes from open cast mines, that too all less than 150 m. depth. It has also been stated by independent analysts that as the most economic shallow coal seams (open cast) are already being exploited, country shall have to exploit deeper seams in existing open cast mines (upto 300 m) and significantly increase investment in underground mining (>300 m) capacity in order to maintain or increase production. Underground mining involves deeper tunnel / shafts, ventilation, pumping & costlier transportation of men and material. Further, it is also associated with complex geological conditions like increased stress concentration zones, weak roof & steep gradients. Therefore due to higher infrastructural cost, mining through underground reserves are estimated to be three (3) times costlier than open cast mining.

However in view of the growing environmental concerns, following processes/technologies are also required to limit the pollution, but this would require additional investments increasing cost of production of coal.

- Adoption of Carbon capture and storage (CCS) technology for capturing waste carbon dioxide (CO_2) from large point sources and transported to storage site normally underground geological formation to protect environment.
- Integrated Coal gasification technology (ICGT) is to be used to remove impurities before combustion for lower emissions.
- Coal washeries for preparing delivered coal from the mine for market use and remove waste material so that transportation cost and ash formation is low
- Ash content in Indian coal is 30-50% which is very high whereas calorific value is low. After combustion handling of this ash involves various precautions to protect environment. Considering the envisaged coal based gigantic capacity, ash handling can be a bigger challenge in view of the emerging land constraints.

An analysis was carried out to evolve installable coal based generation capacity based on the available domestic coal reserves for supply of electrical energy. Study reveals that with 5% growth in consumption of coal in power sector, maximum installable potential can be in the range of 350-400 GW. However, in case new reserves are found and efficient technologies lead to decline in growth, capacity may further increase.

3.2. Hydro Resource

As per CEA's Hydro development plan for 12th plan (Table-3-1), estimated hydro potential in India is about 149 GW (ROR-65GW, Storage-75GW) which also includes Small Hydro Plants (<25 MW). Pumped storage Hydro (PSP) potential is also envisaged to be about 94

GW. A list of potential sites identified for installations of pumped storage scheme is enclosed at ***Annexure 3-1***.

Table-3-1 : CEA's Hydro development plan for 12th plan

River Basin	No. of Schemes	Probable Installed Capacity (MW)
Indus	190	33382
Brahmaputra	226	66065
Ganga	142	20711
Central Indian River System	53	4152
West Flowing Rivers of Southern India	94	94300
East flowing Rivers of Southern India	140	14511
Total	**845**	**148701**
Pumped Storage Schemes	56	94,000

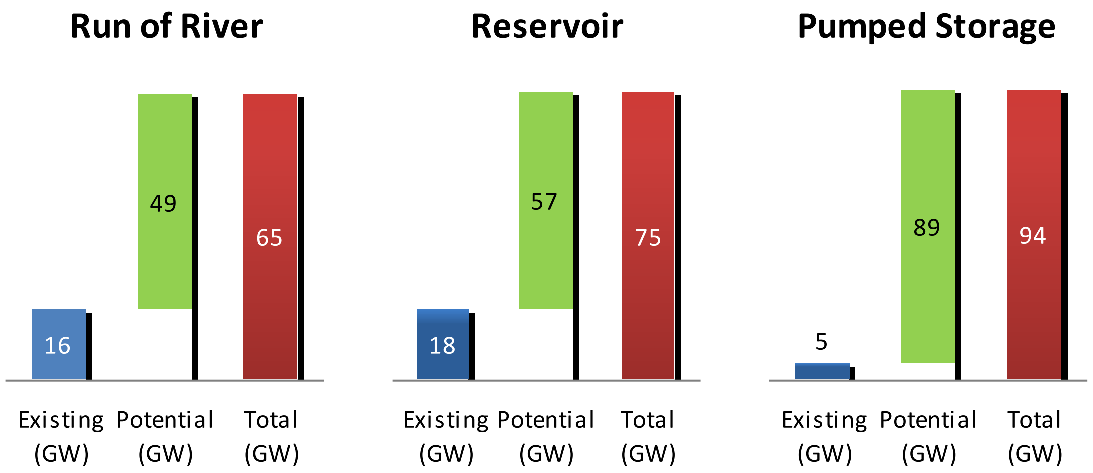


Fig 3-2 : Existing Hydro Generation and Future Potential (Source-CEA)

Pumped Storage Hydro Plants are important elements to provide balancing services to the system. Presently, out of nine (9) plants of 4,785 MW capacity, only five (5) plants of 2600 MW are working in Pumped mode. Considering potential of Pumped storage scheme (96 GW), it is prudent to harness above capacity as well as take up suitable measures to make existing schemes operational.

An analysis has also been carried out in terms of already exploited hydro potential out of the reserves and balance which remain to be exploited as shown in the Fig-3-2 above.

Considering availability of country's hydro potential as well as need of power demand, hydro potential of neighboring countries viz. Bhutan and Nepal is also being estimated which can be utilized to meet our growing demand. As per estimates, Bhutan & Nepal are having 30 GW and 43 GW of hydro potential respectively. Present hydro capacity in Bhutan & Nepal is

3

about 1.5 GW & 0.8 GW respectively. Considering the long term power demand requirement of these countries (Bhutan-4000 MW, Nepal-11000 MW), about 23 GW & 24 GW from Bhutan and Nepal respectively can be harnessed partially by 2030/2050 time frame scenario for exporting to India.

Development of Hydroelectric projects stimulates many issues related to Land acquisition, Environment clearance, Rehabilitation & Resettlement of affected people, long gestation period. In view of complexity in development of Hydroelectric projects, particularly large ones, emanating from dam height, submergence, ramification of submergence, dam safety, drinking water schemes, irrigation, infrastructure etc., development of total hydro potential need to factor in such issues. Considering this, harnessing of hydro potential (196 GW) is considered to be limited to 90% (178 GW) of combined potential of India (149 GW) and neighboring countries (47 GW). In addition, development of PSP (94 GW) is also considered to be about 30% of the potential i.e. upto 28 GW by 2050.

3.3. Gas Resource

According to BP statistical review 2012, natural gas constitutes around 10% of India's total primary energy basket which is likely to increase to 20% by 2025. Domestic natural gas production, in India, was about 180 Million Metric Standard Cubic Meter Per Day (MMSCMD) in FY11 against an estimated demand of approximately 279 MMSCMD in 2011 as per 11th five year plan.

India has total gas reserves (indicated & proven) of 1330 Billion cubic meter (3644 MMSCMD). If Reserve/Production ratio is calculated on existing potential and production level (180 MMSCMD), reserve would be sufficient only for approximately 20 years with no import.

Out of total demand, approximately 45-50% of total gas production is allocated to the power sector. In view of the increasing need of gas based generation, import dependency on gas will increases due to limited gas reserves.

According to working group report on Petroleum and Natural Gas in 12th plan, demand of natural gas is likely to rise to approximately 473 MMSCMD and 606 MMSCMD by 2017 & 2022 respectively. Out of total demand, about 50% i.e. 307 MMSCMD demand would be for power sector at the end of 13th plan that may result in power production of about 74GW (1MMSCMD = 242MW @50% efficiency of combined cycle). However, natural gas production during 12th plan would be only about 187 MMSCMD, balance 286MMSCMD would be supplied from import. So with the growing need, import requirements shall continue to increase unless new reserves are explored.

Country is also gearing up to explore and develop domestic sources in terms of Shale, Coal Bed Methane (CBM) etc. India has about 290 trillion cubic feet of shale gas in place, of which about 63 trillion cubic feet (TCF) is estimated to be technically recoverable. Such new un-conventional sources of energy, if come up, can address country energy requirement though gas supplies significantly.

3.4. Nuclear Resource

As per planning commission statistics (refer table-2-4), nuclear generation is envisaged to contribute about 64 GW by the year 2032. This capacity addition is envisaged through indigenous Pressurized Heavy-Water Reactor (PHWRs) of 4200 MW based on natural uranium, 7000 MW from PHWRs based on reprocessed uranium from Light Water Reactor (LWR) spent fuel, 40,000 MW from LWRs and the balance through 500MW/1000MW Fast Breeder Reactors. Other reactors like the Advanced Heavy Water Reactor (AHWR), a technology demonstrator for thorium utilization and Indian LWR under development are also planned.

Thorium is particularly attractive for India, as country has only around 1–2% of the global uranium reserves, but have one of the largest shares of global thorium reserves at about 30% of the total world thorium reserves. The long-term goal of India's nuclear program has been to develop an advanced heavy-water thorium cycle. The first stage of this program comprise the PHWRs fuelled by natural uranium, and light water reactors, to produce plutonium. Stage 2 program uses fast neutron reactors burning the plutonium to breed U-233 from thorium. The blanket around the core will have uranium as well as thorium, so that further plutonium (ideally high-fissile Pu) is produced as well as the U-233, and it may be recycled there. Later, in stage 3, Advanced Heavy Water Reactors (AHWRs) burn the U-233 from stage 2 and originally some of this plutonium with thorium, getting about two thirds of their power from the thorium.

As per the department of Atomic Energy statistics, India is having domestic reserves of 78,000 tons of Uranium and 518,000 tons of Thorium metal, which can produce 275GW in optimistic scenario and 208GW in pessimistic scenario by 2050 time frame shown below in Table 3-2.

Table-3-2: Nuclear Generation Potential

S.No.	*Year*	***Generation Potential***	
		Optimistic (GWe)	*Pessimistic (GWe)*
1	2020	29	21
2	2030	63	48

3

S.No.	Year	Generation Potential	
		Optimistic (GWe)	Pessimistic (GWe)
3	2050	275	208

** It is assumed that India will be able to import 8000 MW of LWRs with fuel over the next ten years.(Source-DOAE)*

3.5. Renewable

Country is endowed with abundant potential in Wind, Solar etc. C-WET (Chennai) has estimated on shore wind potential of about 103 GW at 80 m hub height whereas off shore potential, considered to be available at much larger scale, even more than of 30GW, is being assessed. The scientific and research work carried out by various independent agencies have claimed that the potential for wind energy of country is far in excess of Indian official estimates (even 20-30 time higher). Wind Potential Map at 80 m level by C-Wet (Wind Power Density) and 3 Tier (Wind Speed) is shown in Figure 3-3 & 3-4 respectively as under

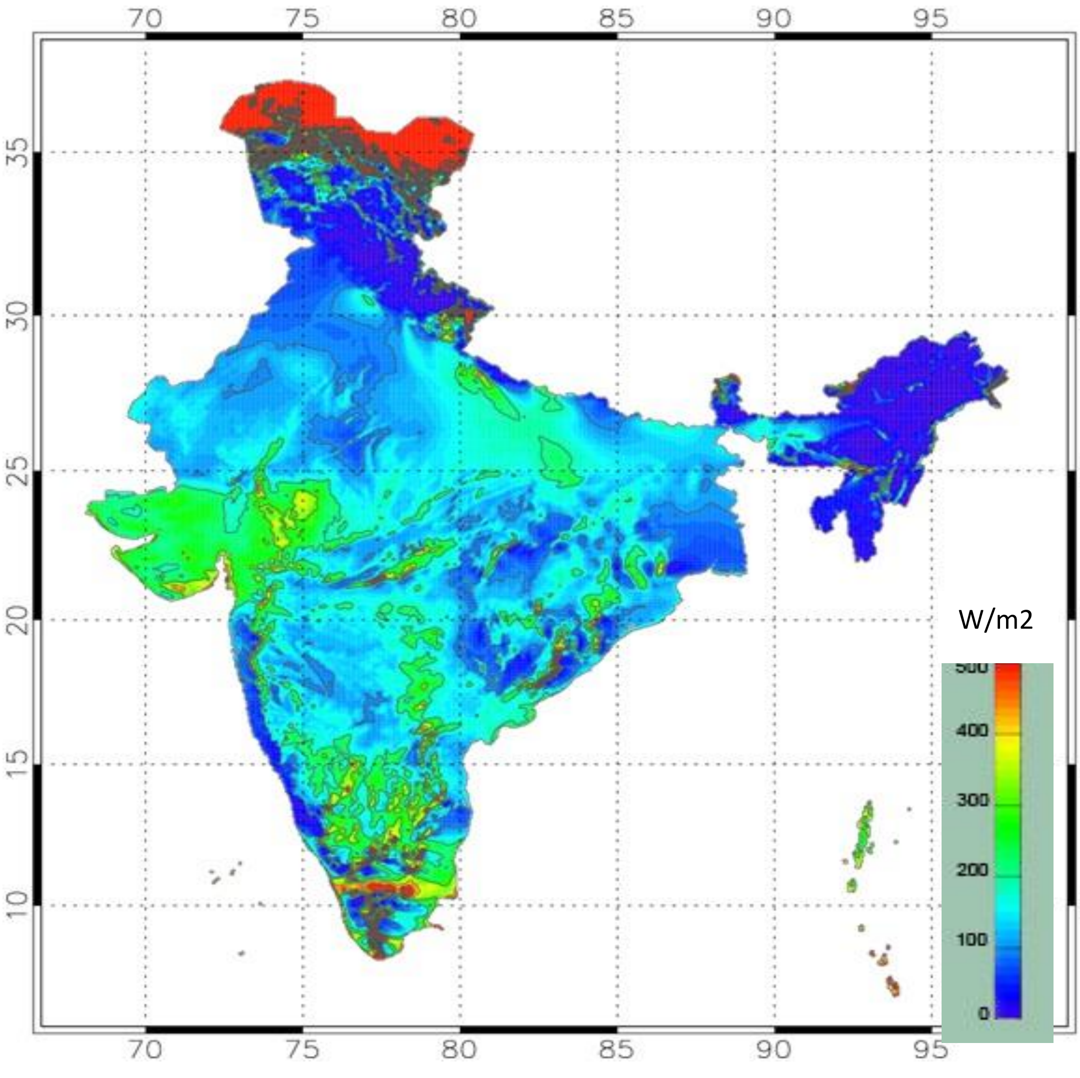


Figure 3-3: Wind power density map at 80 m level (**Source- C-WET**)

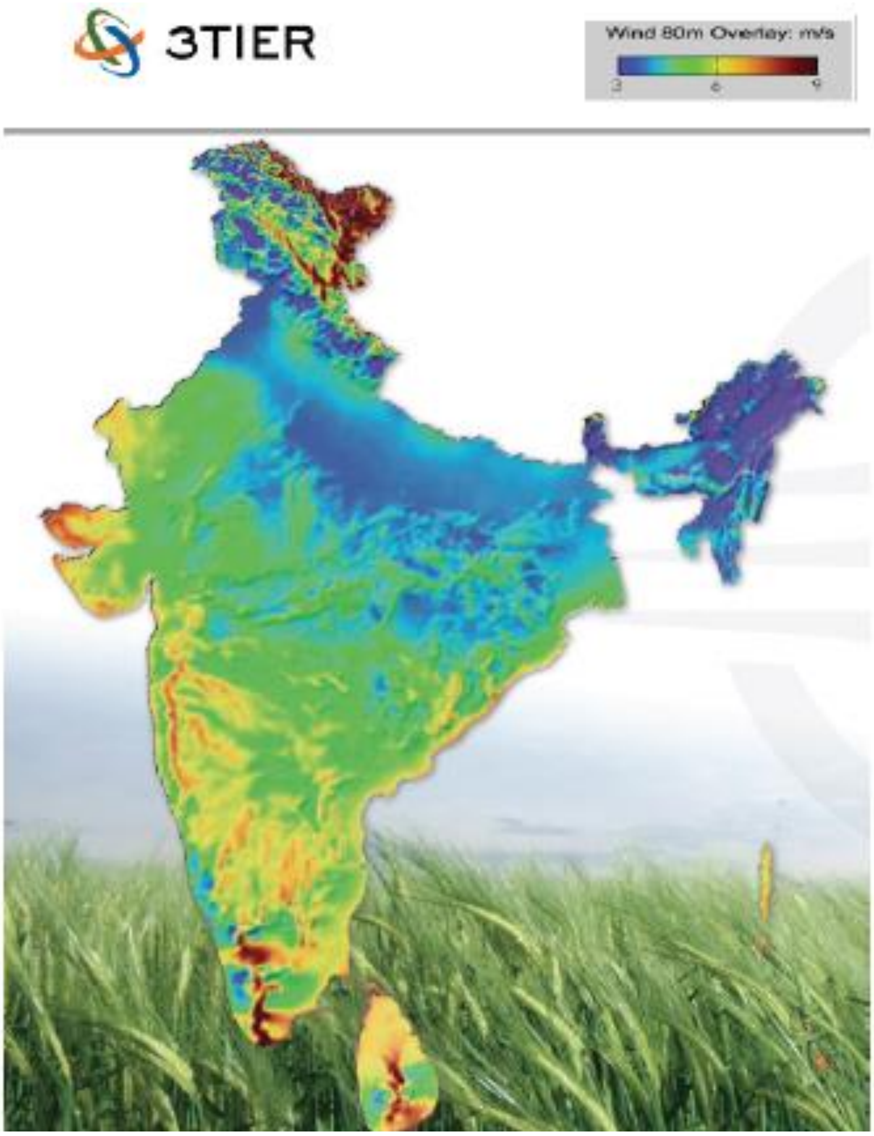


Figure 3-4: Wind Speed map (80 m level) *(Source: 3 Tier)*

Wind power density directly determines cost efficiency in using wind energy. We may categorize the density as poor (< 150 Watt/m^2), fair (150 ~ 250 Watt/m^2), good (250 ~ 350 Watt/m^2), or excellent (> 350 Watt/m^2). Further, in terms of Wind speed, Average annual wind speed is categorised as poor (< 4.5 m/s), fair (4.5 ~ 5.0 m/s), good (5~7 m/s), or excellent (> 7 m/s). It should be noted that above information describes general wind power distribution and can be used as preliminary analysis in selecting regions for wind power projects. From above, it is gathered that deserts of Thar, Rann of Kutch and some pockets of Ladakh has good Wind Potential. Thar (Rajasthan) seems to have relatively lesser wind density than other deserts but offers a steady wind profile yielding good capacity utilisation factor on annualised basis. Results of 3 Tier Wind Prospecting tool for a typical location in above three (3) desert regions is also presented at ***Annexure 3-2***. Results are displayed in terms of Annual & Monthly Mean Wind speed at 80 m hub height and reveals that these deserts have good wind potential also.

The data obtained from Climate Research Unit (UK) (Figure: 3-5) provides preliminary understanding of wind regime in Lahul & Spiti valley. It appears that Lahul & Spiti valley doesn't have much wind potential (<3 m/s) to put up large scale wind generation.

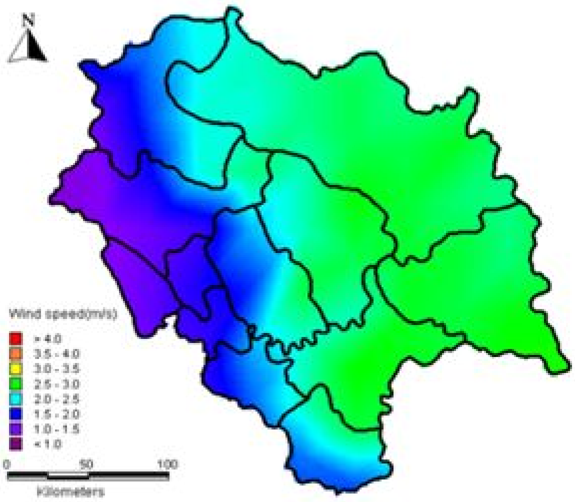


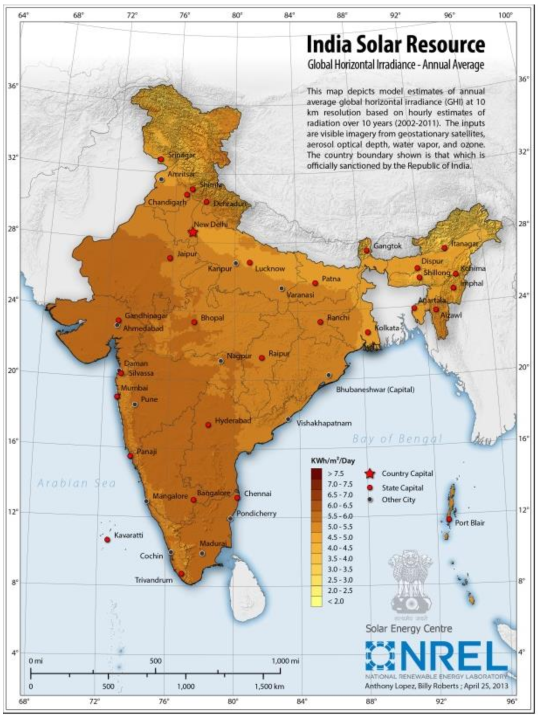
Figure 3-5: HP Wind speed Map (Source- Climate Research Unit-UK)

Results of 3 Tier Wind Prospecting tool for a typical location in Lahul & Spiti is also presented as under (***Annexure 3-3***). Such results also display subdued wind potential in that region.

However, wind resource assessment needs to be carried out in other deserts based on which high quality locations with good wind power density can be identified for putting up wind turbines.

India is also endowed with abundant solar energy due to its convenient location near the equator. As per Ministry of New & Renewable Energy (MNRE), Solar Potential in India is in excess of 100 GW.

U.S. National Renewable Energy Laboratory (NREL) in cooperation with India's Ministry of New and Renewable Energy has developed India Solar Resource Maps. Latest maps (2013) provides 10-km hourly solar resource data using weather satellite (METEOSAT) measurements incorporated into a site-time specific solar modelling approach. India Solar resource map with Annual Average Global Horizontal Irradiance (GHI) & Direct Normal Irradiance (DNI) is presented in Figure 3-6 & 3-7 below.



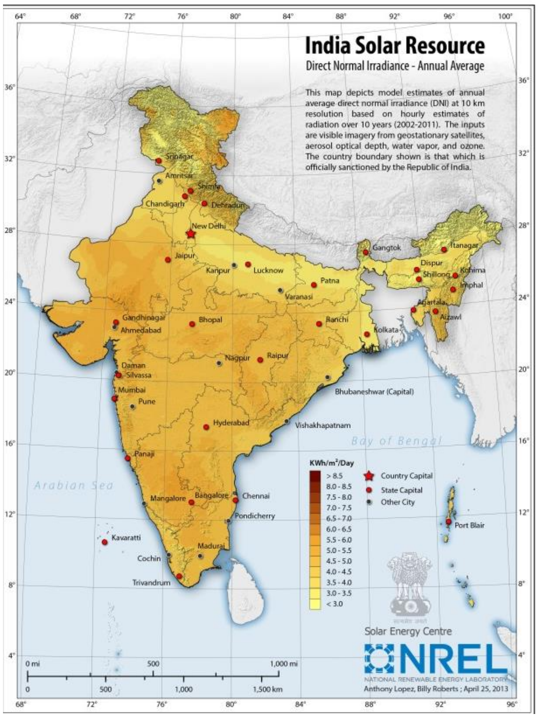


Fig 3-6: **Annual Average GHI (India Resource Map)** ***Fig 3-7:*** **Annual Average DNI (India Resource Map) Source (NREL)**

From above maps, it may be observed that desert of Thar and Rann of Kutch have very high GHI level of about 7-7.5 kwh/m^2/day for solar PV, whereas Lahul & Spiti and Ladakh has high level of GHI i.e. 5-5.5 kwh/m^2/day. Likewise, Direct Normal Irradiance (DNI) at Desert of Thar is at very high level i.e. 5.5-6.5 kwh/m^2/day whereas Rann of Kutch, Lahul & Spiti and Ladakh has moderate level of DNI i.e.4.0-4.5 kwh/m^2/day which is suitable for concentrated solar plant. So it can be concluded that above four (4) Indian deserts possess good Solar Potential for both PV & CSP technologies.

A brief on various technologies available for renewable generation especially Wind & Solar is deliberated at ***Appendix-1.***

However, primary requirement for Solar potential development is based on availability of land and associated infrastructure. Considering the above constraints, we have broadly identified following three areas which can prove to be holding huge renewable potential, provided necessary measures are taken to develop such potential.

- Utilization of roofs/available open space with individual houses in form of distributed generation (kW level).
- Canal top solar PV which additionally helps in saving of water of the river from evaporating.
- Wasteland utilization in different parts of the country including in deserts

In addition to above, off shore solar generation is another potential area for renewables. Globally, it has been gaining the ground with the recent commissioning of Japan's largest offshore Kagoshima Nanatsujima Mega Solar Power Plant (70MW) (Figure-3-8). Considering the India's long coast line (>7000 kms), renewable potential for development of Wind as well as Solar Generation is huge. However, off shore Solar being more challenging than any other technology and yet to be ripe enough for consideration, more efforts including research on renewables are required for such development.

Fig 3-8: Kagoshima Nanatsujima (Japan) Mega Off shore Solar Power Plant (70MW)

Subsequent sections deliberate upon potential of each of the above fields. Out of above three options, the third option i.e. deserts seem to provide maximum renewable potential provided supporting infrastructure is developed. However, in view of the quantum of wastelands availability in the Indian deserts as well as ripeness of Solar generation technology in Indian context, it is prudent to prioritise the development of desert power potential, which is also a low hanging fruit.

3.5.1. Roof Top Solar PV

Rooftop Solar PV is a matured technology and its capacity has been increasing worldwide in last few years. Japan, USA and Germany were the early leaders in adopting rooftop solar PV systems, while Italy, Australia and China have seen strong in recent times. Germany and Italy have the highest cumulative installed PV capacity with 32.3 GW and 16.2 GW respectively (as of 2012), out of which, over 60% of the capacities in both countries are in the form of Roof top PV systems, both in residential and commercial segments. In Europe, over 50% (26 GW) of total Solar PV capacity is in rooftop segment. This has been mainly due to numerous benefits of rooftop solar PV, as it does not require additional precious land and takes unutilized roof/open space of buildings. Rooftop Solar PV capacities can range from few hundred watts to several MW. The other advantages of rooftop Solar PV are as under:

- Clean energy resource, addressing environmental concerns
- Considering declining Solar PV prices and increasing retail tariff, cost economics is near achieved for the high end residential consumers (consumption >200 units/month)
- The power generated is used at the same place locally, therefore less involvement of transmission and distribution, reduces losses, utility investment requirement reduces.
- As the distribution network already exists, generation can be directly interconnected
- Excess electricity generated could be fed into the system of utility, so as to enable consumer transitioning to "Prosumer" category gaining earning capability also
- The consumer becomes conscious about the generation and consumption of electricity
- This being highly "visible" in public eye, generates great deal of public awareness about clean energy and benefits of distributes generation

India accounts for only about 2.4% world's total geographical area and 4% of its water resources, but has to support about 17% of world's human population and 15% of livestock. Increasing human and animal population has reduced availability of land over the decades. Per capita availability of land has declined from 0.89 hectare in 1951 to 0.32 hectare in 2001 and is projected further slide down to 0.20 hectare in 2035. In view of the above, land availability all around the globe including India has become precious and therefore, its optimal utilisation through new age technologies like Solar Roof top system is the need of the hour which can address two of the major issues (energy and land) in current context.

As per 18th EPS of CEA, about 25% of energy demand (2011-12 & 2012-13) was utilised from the domestic consumer category, whereas commercial & Industries accounted for about 10% and 35% respectively. As per Census of India 2011, level of urbanization has increased from 27.81% in 2001 Census to 31.16% in 2011 Census. UN statistics reveals that India shall have about 55% urbanization level by year 2050. With rapid urbanization and improving standards of living for millions of Indian household, the electricity demand is growing significantly. This shall lead to increase in per capita consumption of electricity of urban population at a much higher rate in comparison to rural population. Due to above factors, in near future, energy demand contribution from residential consumer category shall increase at much higher pace than before.

Due to various limitations, the utilities are not able to meet these increasing power demands. Rooftop Solar PV system is the appropriate choice to meet the increasing demands of cities addressing challenges in development of T&D facilities, reduction in losses and reduction in pollution in cities.

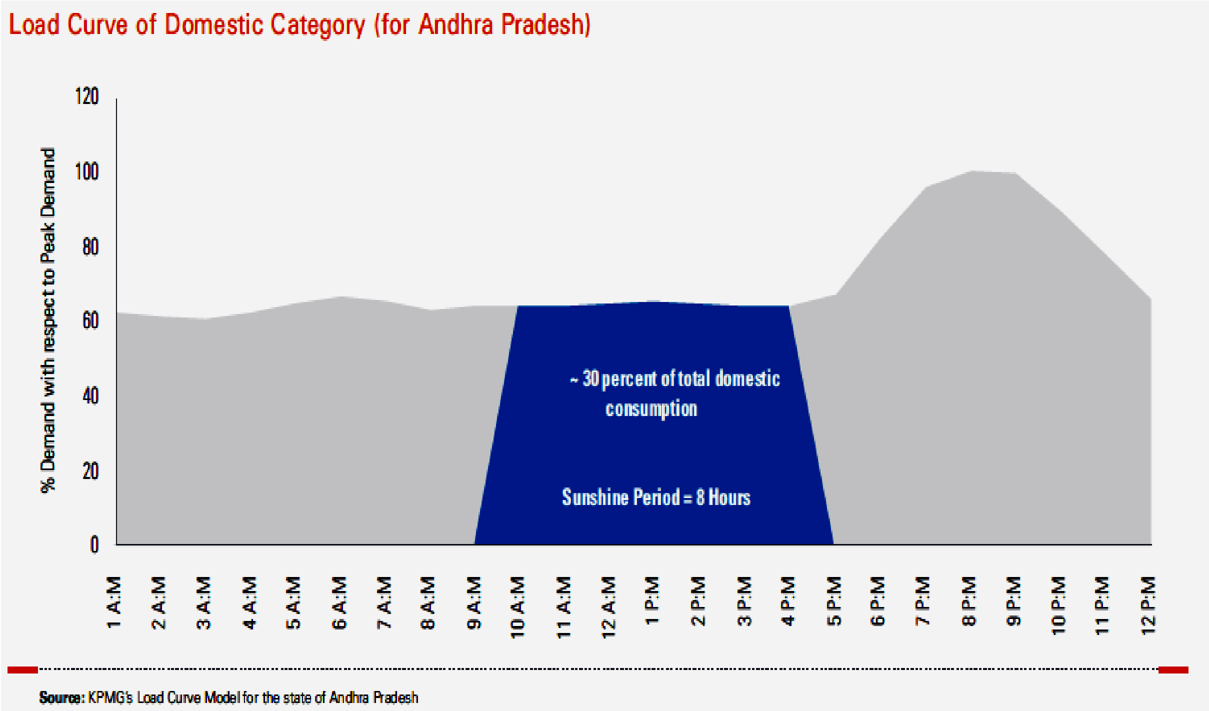


Fig 3-9: Domestic load curve of typical household in AP (Source: KPMG – The Rising Sun)

From above load duration curve (Fig 3.9) for a typical household, it can be estimated that with 8 hours sunshine period and adequate roof top generation capacity (1-1.5 kWP), solar generation can displace about 30% of total domestic consumption during the sunshine hours for a typical household.

Continual decreasing cost of residential solar rooftop PV and increasing cost of fossil fuels provide a way ahead for adoption of rooftop solar PV system at much wider scale. As per the KPMG's "The Rising Sun" report, the grid parity is expected in 2019-20 (Base case scenario) (Fig-3-10), after which residential rooftop shall become economical than the grid supply. However due to slab tariff structures for domestic consumers, economics for high end residential segment will achieve before 2019-20.

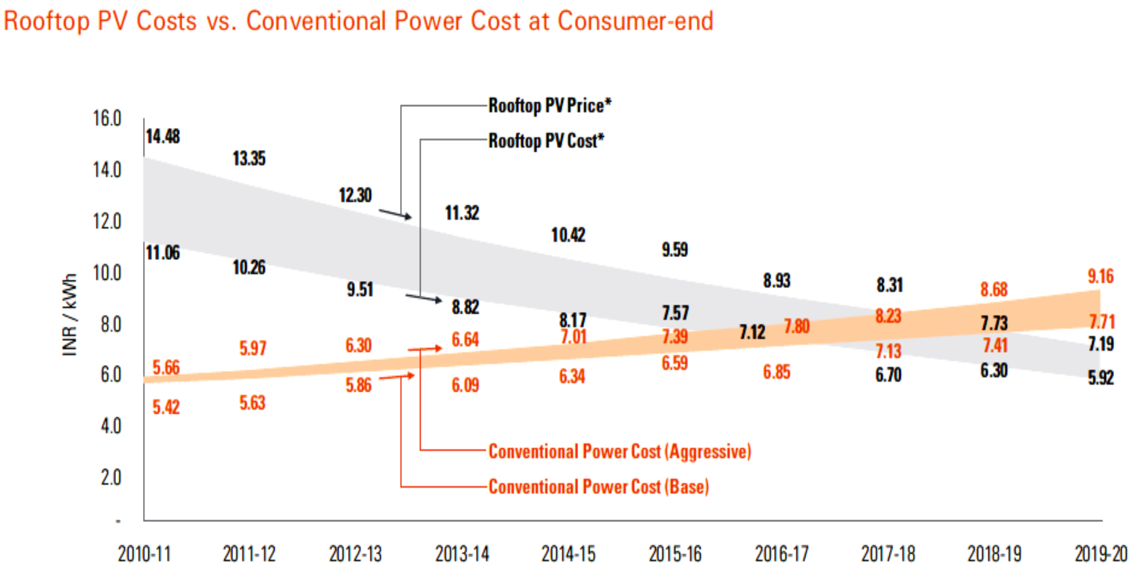


Fig 3-10: Grid Parity projection for Rooftop PV costs vs. conventional power cost (Source: KPMG – The Rising Sun May'11)

The solar rooftop PV segment in India is not yet developed but it has a strong growth potential. As per the 2011 Census statistics, India has around 330 million houses out of which with 150 million houses (excluding institutional households) have proper roofs (concrete etc.). Typically such roof can accommodate on an average 1-2kWp of solar PV system. Even accounting for average 1 kWp installation even at 30% of such houses (150 million), potential could be in the range of 45,000 MW. Besides this, there are other commercial buildings, shopping complexes and offices (about 60 million) that can accommodate larger solar PV capacities increasing above potential manifold.

Government and regulatory support to the growth and requirement of residential solar rooftop PV is very important at this juncture. One of the important aspects of such scheme is metering (Fig-3-11) which can either have net metering (billing is done based on the net of import/export) and gross metering (Feed in tariff for Solar generation and retail tariff for import).

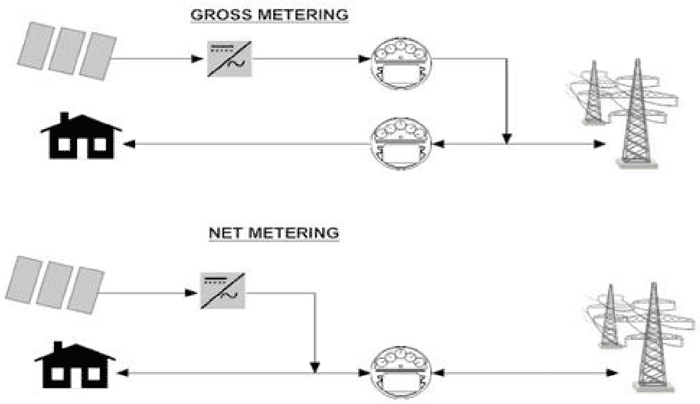


Fig 3-11: Metering Schemes for Roof Top Solar PV

Central and state governments need to encourage consumers by providing subsidies and soft loans, regulatory framework for net metering/Gross metering tariff policy, develop the mechanism/standards for grid integration and make people more aware on the benefits of distributed generation.

A case study on roof top solar PV integrated through Net-Metering under Puducherry Smart Grid Pilot project is enclosed at ***Appendix-2***. Three roof top solar PV installation (3 kW, 3 kW/2.5 kW) at three different houses have been integrated through net metering. Typically per month consumption of such house is around 300-450 kWh which is almost equivalent energy generated through each of the installation. This shows that the net energy exchanged with the grid is almost nil. Typically cost of such installations over a 10-15 years shall be less than the cost of energy procured from the grid. Such type of arrangement through suitable policy & regulatory measures will enable reduction of energy bill to consumer besides other benefits like loss reduction etc.

3.5.2. Canal Top Solar PV

Country possess huge network of Canals which includes open main canal and its sub-branches. Utilising this network by covering it through solar PV panels, presents thousands of MW scale Solar generation potential in the country. This also virtually eliminates the requirement to acquire vast tracts of land and limits evaporation loss of water from canals, tackling twin challenges simultaneously i.e. providing energy as well as water security.

World's first canal top 1 MW solar project on Narmada branch canal network (on 750 meters stretch) in Gujarat is one such example (Fig 3-12). This project was developed by Gujarat State Electricity Corporation Limited (GSECL) with the support from the Sardar Sarovar Narmada Nigam Limited (SSNNL). It generates about 1.6 million units of clean electricity per year and about 9 million litres of water will be prevented from getting evaporated.

Fig 3-12: solar project on Narmada branch canal network (1 MW)

Gujarat has about 458 km of open Main Canal, while the total canal length, including sub-branches, is about 19,000 km at present. When completed, the SSNNL's canal network will be about 85,000 km long. Assuming a utilisation of only 10 per cent of the existing canal network of 19,000 km, it is estimated that 2,200 MW of solar power generating capacity can be installed by covering the canals with solar panels. This also implies that 11,000 acres of land can be potentially conserved along with about 20,000 million litres of water saved per annum.

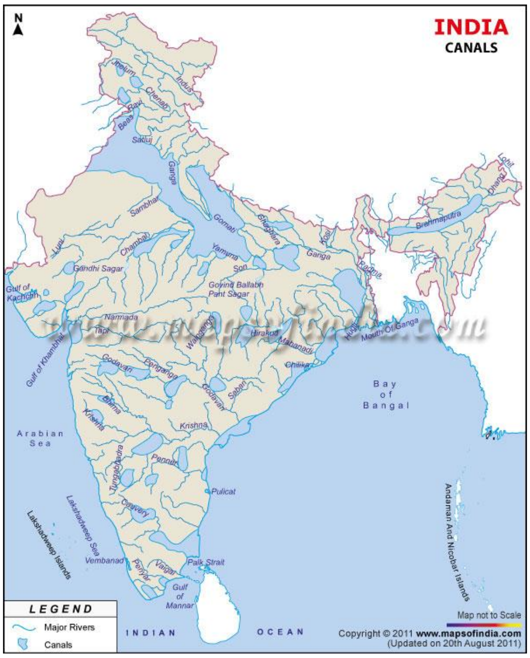


Fig 3-13: Canal Network in India (Source : mapsofIndia.com)

3

Country has thousands of kilometer network of canals across the country (Fig 3-13), which presents an excellent potential of the order of thousands of MW scale Solar generation. However, development of such potential requires suitable policy & regulatory framework.

Considering the potential for Rooftop Solar PV as well as Canal Top solar PV in the country, it is prudent to carry out separate studies to assess the potential of such generation capacity and identify the other infrastructure/facilities required for its grid integration to facilitate meeting growing demand.

3.6. Desert Power Potential

In order to assess economic potential of renewable power generation in deserts and chalk out its phased development plan, MNRE has facilitated waste-land data for the States of Gujarat, Rajasthan, Himachal Pradesh and Jammu & Kashmir to carry out present study. As informed, MNRE gathered this information from the *Department of Land Resources, Ministry of Rural Development*. Land Resources department informed that the information provided is a validated collation of the ground information and satellite data provided by the Indian Space Application Centre (Details of the data is enclosed at ***Appendix-3)***.

Wasteland Utilisation

Data comprises information on district wise wasteland availability in the States of Gujarat, Rajasthan, Himachal Pradesh and Jammu & Kashmir. It comprises thirteen (13) types of waste land, classified in following categories:

- Gullied and/or Ravinous Land
- Upland with or without Scrub
- Waterlogged and Marshy Land
- Land Affected by Salinity/Alkalinity Coastal/Inland
- Shifting Cultivation Area
- Under-utilised/Degraded notified Forest Land
- Degraded Pastures/Grazing Land
- Degraded Land under Plantation crop
- Sands-Inland/Coastal
- Mining/Industrial Wastelands
- Barren Rocky/Stony Waste/Sheet Rock Area
- Steep Sloping Area
- Snow Covered and/or Glacial Area

As this study is primarily confined to harness desert power potential in Hot deserts viz. The Thar in Rajasthan & Rann of Kutch in Gujarat and Cold deserts viz. Ladakh in J&K & Lahul &

Spiti Valley in Himachal Pradesh, Waste land data is segregated for the districts falling under the above deserts only.

Out of above 13 types of wastelands, detailed study has been carried out on suitability of type of wastelands for setting up Renewable generation plants.

As per the information gathered, it was observed that Gullied and/or Ravinous land is prone to erosion into soil due to surface water flow. Waterlogged/Marshy land is usually filled with water for most part of the year while land affected by salinity/alkanity have excess soluble salts, which could cause corrosion of metals used in structures. Shifting cultivation area is a farm field to grow crops. Degraded Pastures/Grazing land is essential for grazing of animals whereas Degraded Land under Plantation crop is used to do farming after locating it outside the notified forest area. Mining/Industrial Wastelands are those lands where waste debris and materials is dumped, however land under this category is miniscule. Steep Sloping Area has a sloppy terrain and may not get quality of resource in term of Sun insolation, obstructions etc. Snow Covered and/or Glacial Area usually face issues during summer seasons because of snow melting. Due to associated issues with above classified wastelands, these were not found suitable for setting up of renewable generation plants.

However, it was also observed that Upland with or without scrub, usually have vegetation cover based on which it is further delineated into two sub classes i.e. land with dense scrub and land with open scrub, this can be utilised well if dense scrub can be removed. Under-utilised/Degraded notified Forest land, being degraded and under utilised can be used for this purpose. In the Sand/Inland/costal type of wasteland, land is with accumulation of sand, in costal, river line or inland areas which can also be utilised to a certain extent. Barren Rocky/Stony Waste/Sheet Rock Area has rock exposure and devoid of soil cover and vegetation and are not suitable for cultivation, but can be used for such purpose and shall take more efforts for development than earlier other two types of wastelands.

Based on the above, following four (4) types of wasteland is selected, which are found suitable for setting up of Renewable Generation Plants.

- ***Upland with or without scrub***
- ***Under-utilised/Degraded notified Forest Land***
- ***Sand/Inland/costal***
- ***Barren Rocky/Stony Waste/Sheet Rock Area***

However, as the GIS or satellite data was not available regarding wasteland as well as resource potential (especially Wind), probabilistic scenarios of using only 5%-15% of the total wasteland in selected four (4) categories depending upon the terrain type, area coming under "World Protected Area" zones etc. Details of analysis are presented in the following sections.

3.6.1. The Thar (Rajasthan)

Great Indian desert-Thar is spread over the states of Rajasthan, Punjab, Gujarat and Haryana. In present case, Thar region spread over Rajasthan (Fig-3-14) has been considered.

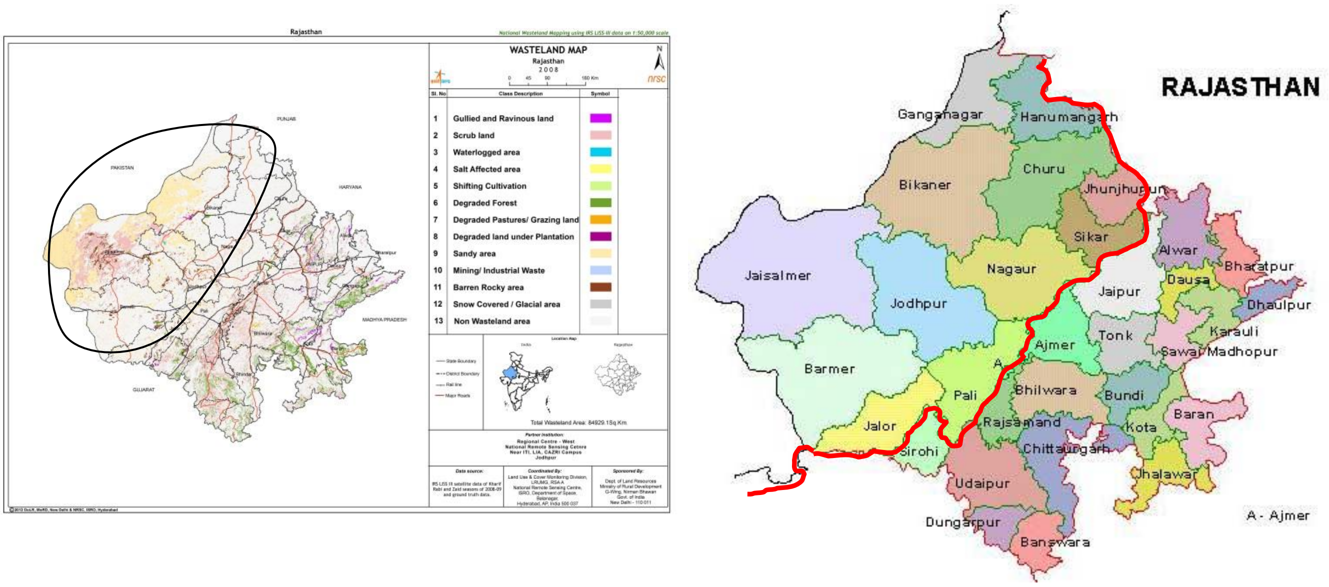


Fig 3-14: **Waste Land Map of Rajasthan (Source : Department of land Resource)**

As per the information, Total Geographic Area (TGA) of Rajasthan is 3,42,239 sq km out of which about 30% (1,05,639 sq. km) is classified under 13 nos. wasteland categories in Rajasthan.

The Great desert of Thar, in Rajasthan is spread over 12 districts of Rajasthan viz. Bikaner, Barmer, Churu, Hanumanghar, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagpur, Pali, Sikar and Shriganganagar encompassing 2,08,751 sq km TGA out of which about 57,539 sq. km (54% of total wasteland) area falls under identified four categories of wastelands.

As some of the area falls under "Protected Area" classification, 15 % of land utilization is being considered out of above identified area of wasteland (57,539 sq. km). In other ways, categorized wasteland area is half of the total wasteland in Rajasthan, therefore proposed wasteland scenario of 15% shall be accounting for only 8% of total wasteland (1,05,639 sq. km) in Rajasthan.

Further, as desert of Thar has good Wind Potential also, Hybrid model of Wind & Solar potential is envisaged to be harnessed utilizing identified wasteland in an optimal manner also reaping out benefit of diversity of resources (Fig 3-15). In such model, typically 30% of the wasteland area is proposed to be utilized for Wind Turbine installation and balance 70% towards Solar Generation. The 70: 30 ratio (Solar: Wind) is adopted for optimal utilisation of land as solar generation yield per sq km (30-40 MW/ sq km) is 3-4 times more compared to wind generation (8-9 MW/ Sq km).

Fig 3-15: Hybrid Wind-Solar Generation project

Choosing a lower land utilisation for Solar like 60: 40 (Solar: Wind) may reduce the total installable renewable potential. Further, an optimistic land utilisation scenario like 80 :20 (Solar: Wind) may devoid the benefit of diversity of natural resources which may behave complementary at times. In view of the above, it is proposed to utilise the land in the ratio of 70: 30 (Solar: Wind) to have a reasonable installable potential as well as to get benefits of diversity.

3.6.2. Rann of Kutch (Gujarat)

Total Geographic Area (TGA) of Gujarat is 1,96,024 sq km out of which about 22% (43,021 sq. km) is classified under 13 nos. wasteland categories (Fig-3-16):

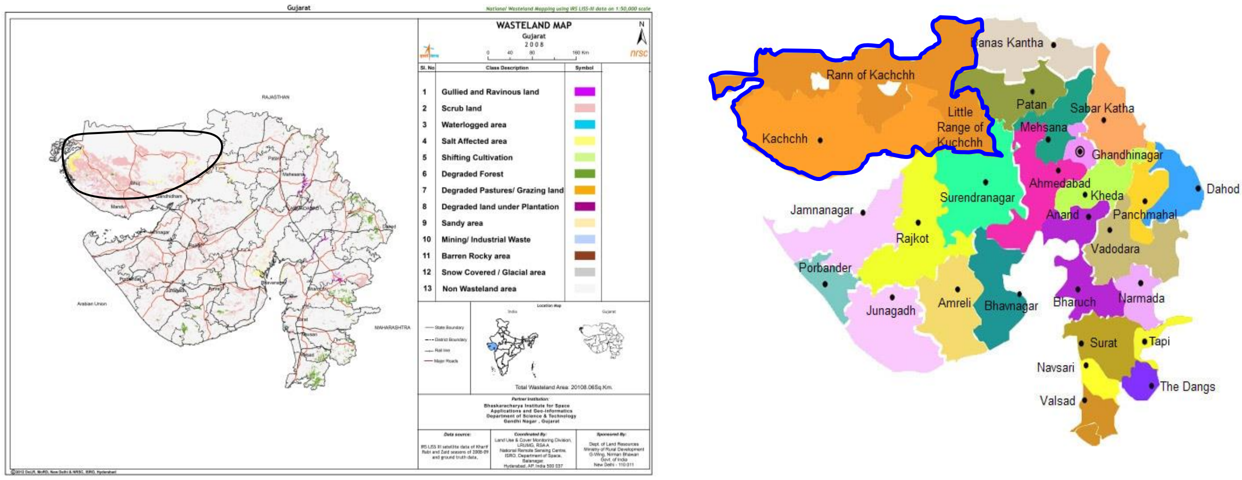


Fig 3-16: **Waste Land Map of Gujarat (Source : Department of land Resource)**

Rann of Kutch, is a salt marsh, or "salty desert" of Kutch (Kutch is the district of which this region belong to). This seasonally marshy land covers a region of more than 12,000 Sq.km and is divided into Little Rann of Kutch and Great Rann of Kutch. Great Rann of Kutch, reputed as the largest salt desert in the world, spans an area of 7505 Sq. km. The Little Rann of Kutch occupies 4,953 sq. kms of land and is spread over majorly in the Kutch district, which has been considered. Some of the area of little Rann of Kutch is also extended in the districts of Surendranagar, Banasakantha, Patan, and Rajkot in Gujarat as it falls on these district boundaries. However as the adequate survey data is not available (also classified as Survey no. zero) for Little Rann of Kutch, extension of the same in above four (4) districts viz. Surendranagar, Banasakantha, Patan, and Rajkot has not been considered in this analysis.

As mentioned above, the Rann of Kutch, is spread mainly in Kutch district of Gujarat. Kutch district has total 45,652 sq km TGA comprising over 12,607 sq. km in four categories of wasteland , which is about 29% of total wasteland area (43,021 sq. km) of Gujarat. In view the limitation of the data exclusively for Rann of Kutch, it is assumed that majority of the above wasteland shall be falling in Rann.

As majority of the above area in Rann falls under “Protected Area” classification as well as the terrain condition, only 10 % of wasteland utilization is being considered out of above identified four (4) categories of wasteland (12,607 sq. km). In other ways, categorized wasteland is 29% of the total wasteland in Gujarat (43,021 sq. km), proposed wasteland scenario of 10% utilisation constitute only 3% of total wasteland (43,021 sq. km) in Gujarat.

Further, as Rann of Kutch also has good Wind Potential, Hybrid model of Wind & Solar potential is envisaged to be harnessed utilizing identified wasteland in the ratio of 70% (Solar) : 30% (Wind).

3.6.3. Lahul and Spiti (Himachal Pradesh)

As per the information, Total Geographic Area (TGA) of Himachal Pradesh is 55,673 sq km, out of which about 57% (31,659 sq. km) is classified under 13 nos. wasteland categories in Himachal Pradesh (Fig 3-17). Lahul & Spiti district comprise over 2,394 sq. km in identified four (4) categories of wasteland, which is about 7.5% of total wasteland area (31,659 sq. km) of Himachal Pradesh.

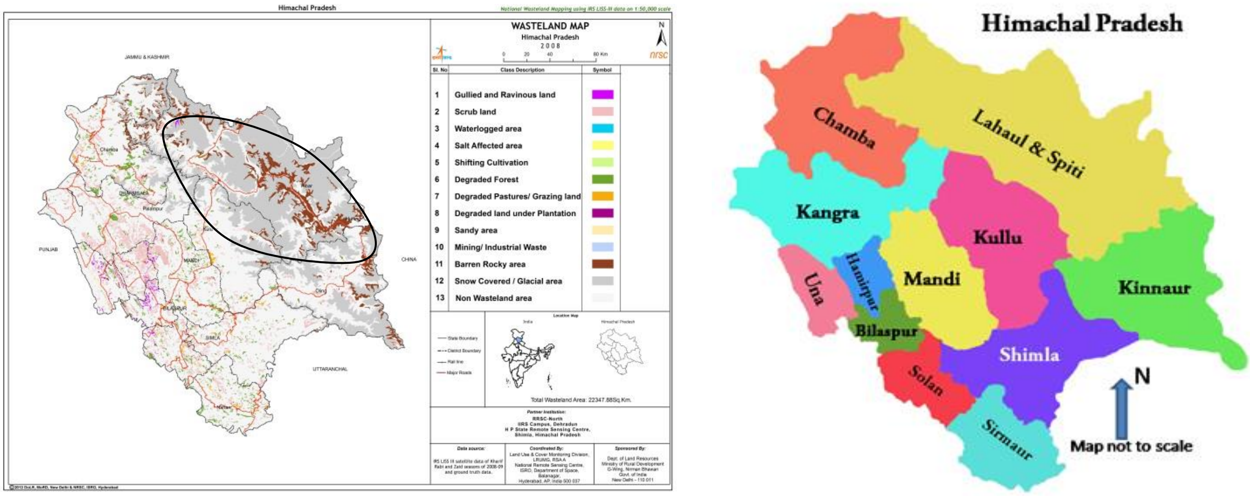


Fig 3-17: **Waste Land Map of Himachal Pradesh (Source : Department of land Resource)**

In view of the very tough terrain conditions of Lahul & Spiti, only 5% land use scenario has been considered out of identified wasteland area (2,394 sq. km). In other ways, proposed wasteland scenario (5%) will constitute only 0.4% of total wasteland (31,659 sq. km) in Himachal Pradesh. Since, Lahul & Spiti doesn't posses good wind Potential, only Solar potential is envisaged to be harnessed utilizing identified wasteland.

3.6.4. Ladakh (Jammu and Kashmir)

Total Geographic Area (TGA) of Jammu and Kashmir is 1,01,387 sq km out of which about 64.5% (65,444 sq. km) is classified under 13 nos. wasteland categories in J&K (Fig-3-18). Ladakh cold desert comprises of Ladakh & Kargil districts which is over 31,212 sq. km in selected in four categories of wasteland, about 48% of total wasteland area (65,444 sq. km) of Jammu and Kashmir.

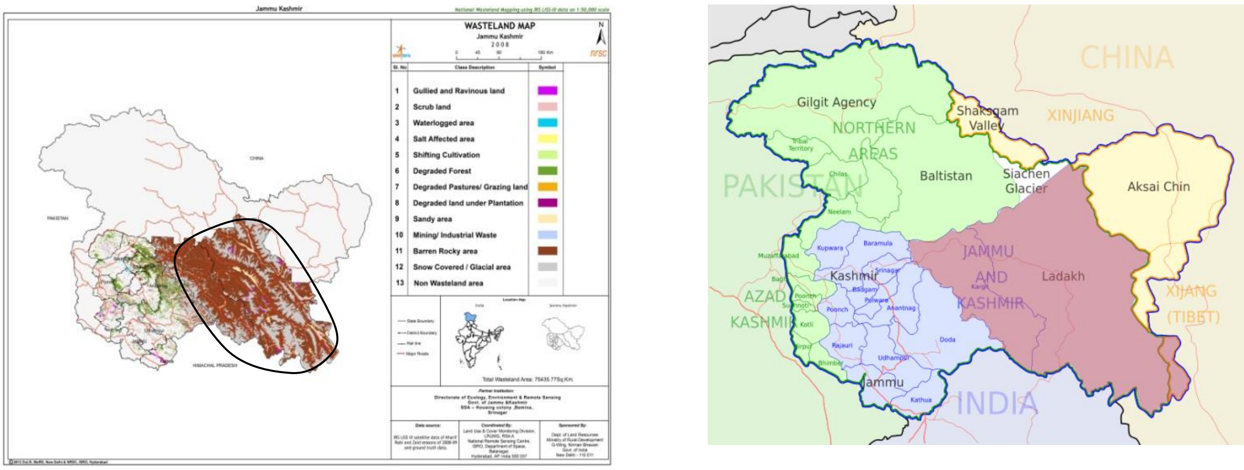


Fig 3-18: **Waste Land Map of Jammu & Kashmir (Source : Department of land Resource)**

In view of the very tough terrain conditions of Ladakh, only 5% land use scenario has been considered out of above area of wasteland (31,212 sq. km). In other ways, proposed wasteland scenario of 5% land use shall constitute only 2.4% of total wasteland (65,444 sq. km) in Jammu and Kashmir.

Further, as Ladakh have good wind potential for large scale generation as well, Hybrid model of Wind & Solar potential is envisaged to be harnessed utilizing identified wasteland in the ratio of 70% (Solar) : 30% (Wind).

3.7. Resource assessment on desert wasteland

From above identified waste land in four (4) deserts, renewable generation potential in each of the desert has been assessed.

The 29th Report of Standing Committee on energy stipulates that as per Ministry of New and Renewable Energy, solar energy potential are estimated at 30-50 MW per Sq.km. Few researchers have also envisaged this potential in the range of 30-50 MW per sq km through Solar PV as well as 40-50 MW/sq km through Concentrated Solar Power (CSP) on account of technological improvements and excellent irradiance (DNI/GHI) levels especially of desert regions.

Similarly for development of wind generation, potential is estimated in the range of 8-10 MW/ Sq km presently, which shall also increase in view of the technological advancements in wind turbine ratings, hub heights and rotor diameter etc.

In view of the above, installable Solar & wind generation has been considered as 35 MW/sq km & 9 MW/sq km respectively for present analysis.

Concept of hybrid system combining wind turbines and Solar PV/CSP systems is also gaining importance as researchers have come out with an analysis that combining wind turbines and photovoltaic systems results in up to twice the amount of electricity being generated across the same surface area, while shading losses caused by wind turbines amount to a mere 1 to 2% – much less than previously thought. Further, this model provides an additional benefit as this may not require additional grid expansion because RE plants generate wind and solar power at different times of day and during complementary seasons (typical yearly pattern of Wind/Solar in Fig-3-19), which may utilise the same transmission system. This also ensures Renewable energy fed into the grid is steadier than that of wind or Solar PV/CSP alone.

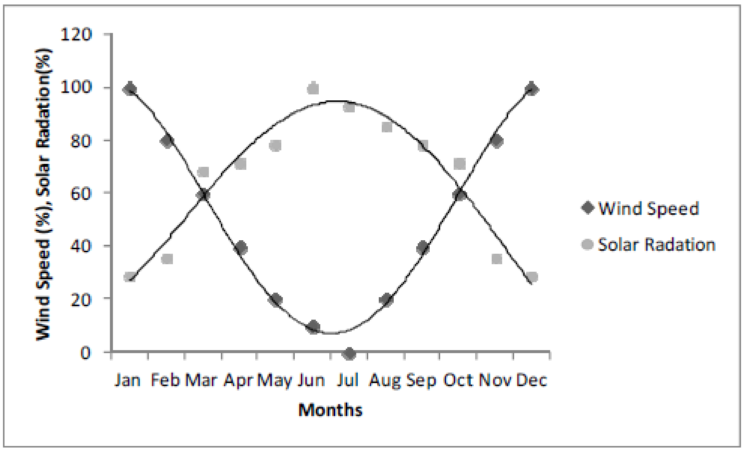


Fig 3-19: **Typical yearly pattern of solar radiation and wind speed**

Assessment has been carried out with above norms for installable potential w.r.t utilization of wasteland area in Table 3-3. Details of the analysis are as under:

Table -3-3 : Wasteland utilization scenario

S No	Desert	Total waste land (sq km)	Selected Wastelan d (sq km)	Selected Wasteland (sq km)	Generation (GW)		
					Solar	Wind	Total (Wind+Solar) GW
					35 MW/sq km	9 MW/sq Km	
1	Thar	67285	57538.5	8630.8 (15%)	211.5	23.3	234.8
2	Rann of Kutch	19120	12607.4	1260.7 (10%)	30.9	3.4	34.3
3	Laddakh	50362	31211.8	1560.6 (5%)	38.2	4.2	42.4
4	Lahul & Spiti	11177	2393.8	119.7 (5%)	4.2		4.2
	Total	***147944***	***103751.5***	***11571.8***	**284.8**	**30.9**	**315.7**

From above, it is assessed that desert may offer renewbale potential development of about 315 GW depnding of the usability of wasteland (5-15% of selected 4 wasteland categories), as indicated above. With the increased usability of wasteland, installable potential would be far higher than above estimates.

Based on above wasteland utilisation scenario, installable renewable generation potential of each district in above deserts has also been estimated, details of which is as under in Table 3-4 to 3-7 respectively.

Table-3-4 : – Thar (15% Wasteland utilization scenario)

S No	Desert	Total waste land (sq km)	Selected Wasteland (sq km)	15% of Selected Wasteland (sq km)	Generation (GW)		
					Solar	Wind	Total (Wind+Solar) GW
					35 MW/sq km	9 MW/sq Km	
1	Bikaner	3389	2593.2	388.98	9.5	1.1	10.6
2	Barmer	9497	7504.5	1125.675	27.6	3.0	30.6
3	Churu	1641	355	53.25	1.3	0.1	1.4
4	Hanumangarh	357	125.8	18.87	0.5	0.1	0.6
5	Jaisalmer	34598	34460	5169	126.6	14.0	140.6
6	Jalore	1246	1133.1	169.965	4.2	0.5	4.7
7	Jhunjhunu	848	548.8	82.32	2.0	0.2	2.2
8	Jodhpur	6981	5426.7	814.005	19.9	2.2	22.1
9	Nagaur	2347	1207	181.05	4.4	0.5	4.9
10	Pali	3295	1729.3	259.395	6.4	0.7	7.1
11	Sikar	1325	819.6	122.94	3.0	0.3	3.3
12	Ganganagar	1761	1635.5	245.325	6.0	0.7	6.7
	Total	***67285***	***57538.5***	***8630.8***	***211.5***	***23.3***	***234.8***

Table 3-5: – Rann of Kutch (10% Wasteland utilization scenario)

S No	Desert	Total waste land (sq km)	Selected Wasteland (sq km)	10% of Selected Wasteland (sq km)	Generation (GW)		
					Solar	Wind	Total (Wind+Solar) GW
					35 MW/sq km	9 MW/sq Km	
1	Kutch	19120	12607.4	1260.7	30.9	3.4	34.3
	Total	***19120***	***12607.4***	***1260.7***	***30.9***	***3.4***	***34.3***

Table -3-6: – Laddakh (5% Wasteland utilization scenario)

S No	Desert	Total waste land (sq km)	Selected Wasteland (sq km)	5% of Selected Wasteland (sq km)	Generation (GW)		
					Solar	Wind	Total (Wind+Solar) GW
					35 MW/sq km	9 MW/sq Km	
1	Laddakh	36575	20026.8	1001.3	24.5	2.7	27.2
2	Kargil	13787	11185.0	559.3	13.7	1.5	15.2
	Total	***50362***	***31211.8***	***1560.6***	***38.2***	***4.2***	***42.4***

3

Table-3-7 : – Lahul & Spiti (5% Wasteland utilization scenario)

S No	Desert	Total waste land (sq km)	Selected Wasteland (sq km)	5% of Selected Wasteland (sq km)	Solar Generation (GW) (35 MW/sq km)
1	Lahul & Spiti	11177	2393.8	119.7	4.2
	Total	***11177***	***2393.8***	***119.7***	***4.2***

MNRE has already envisaged setting up large scale solar plants utilizing surplus lands/wasteland in above deserts. In this direction, Ultra Mega Solar Power Projects (upto 4000 MW) each at Sambhar (Rajasthan), Kharaghoda (Gujarat) and Leh/Kargil (J&K) has already been envisaged for implementation at surplus/desert wasteland in medium term plan (upto 2022). Additionally, Bhadla Ultra Mega Solar Park (4000 MW) is also planned by Govt. of Rajasthan in above medium term plan.

However one of the most important aspects of development of such a huge qauntum of desert solar potentai is its economic viability. Therefore subsequent section discusses the grid parity projections for utility scale solar generation.

3.8. Grid Parity Projections for Utility Scale Solar Generation

Globally, the solar industry has witnessed exponential growth phase in last few years. This growth rate has been accompanied by rapidly dropping Solar PV prices mainly due to encouragement of policymakers/regulators for clean energy development programmes & thereby achievement of economies of scale at on-grid as well as off grid level, technological advancements and emergence of low cost manufacturing locations. In last few years, reduction in prices of solar PV has surprised many market analysts.

Considering continuation of above price trends for Solar PV and continuously rising cost of conventional energy sources especially Coal, it wouldn't be optimistic to state the Grid Parity is bound to happen in near future. KPMG and AT Kearney have carried out grid parity analysis for utility scale solar generation. KPMG analysis considers 4% & 5.5% per annum increase landed cost of conventional energy to consumers in base case and aggressive scenarios respectively which includes cost escalation of raw material import, greenfield generation, network strengthening and improvement in operational efficiency of utility. Solar power cost is considered to decline at the rate of 5-7 percent per annum over next decade on account of economies of scale, technological advancements and emergence of low cost manufacturing locations (Fig-3-20 & 3-21). AT Kearney analysis (Fig-3-22) considers 8% increase in conventional energy cost and decline of about 6-8% per annum in solar energy cost in different scenarios. Results of both analyses are exhibited as under:

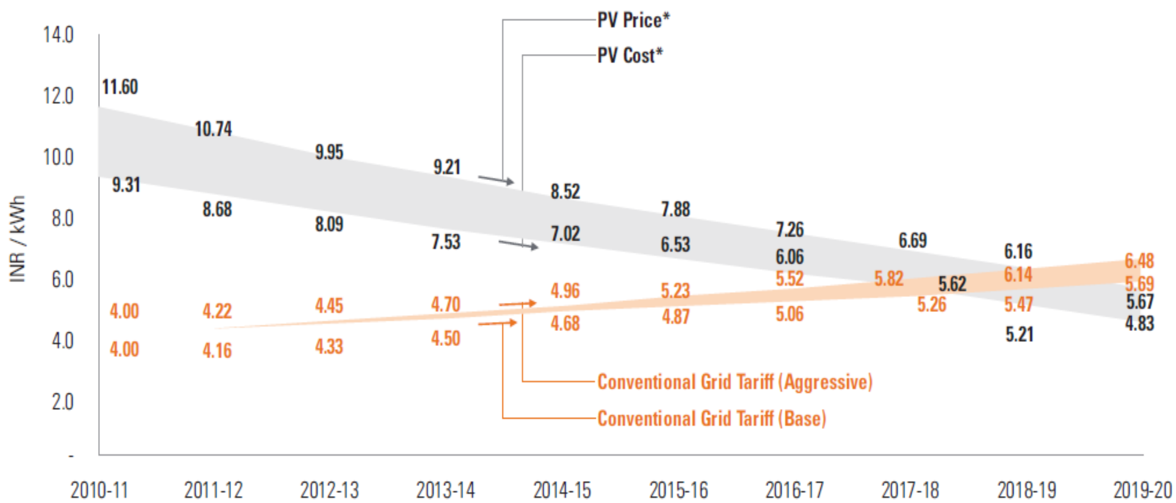


Fig 3-20: Levelized Cost Comparison of Utility-scale PV and Conventional Power at Grid (Source: KPMG – The Rising Sun May'11)

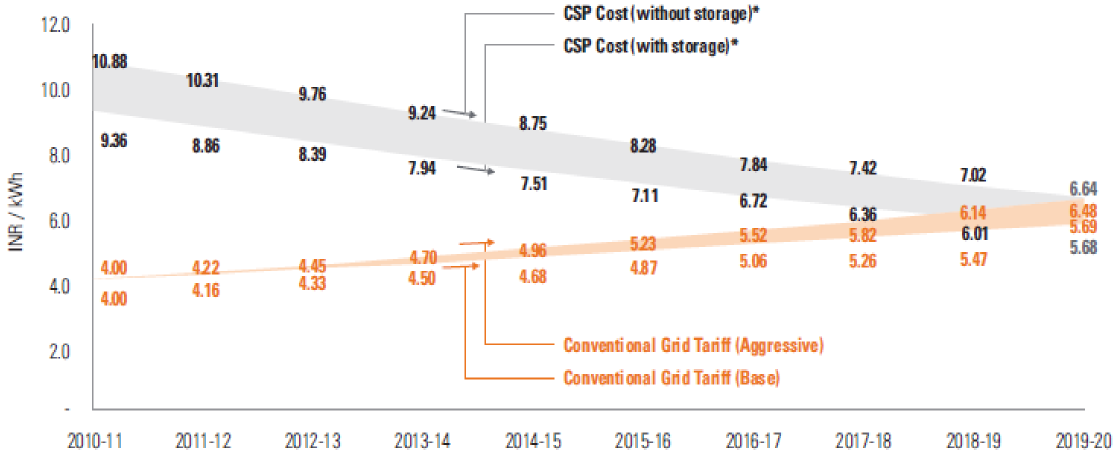


Fig 3-21: Levelized Cost Comparison of Solar CSP and Conventional Power at Grid (Source: KPMG – The Rising Sun May'11)

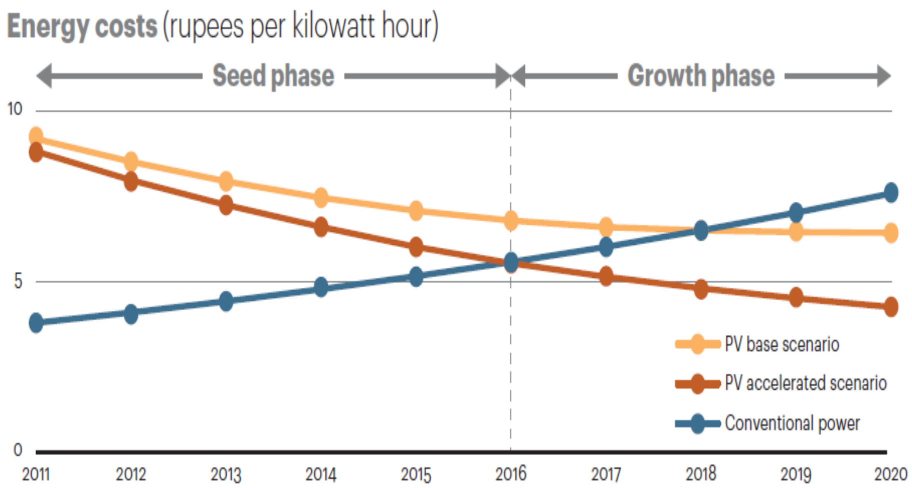


Fig 3-22: Levelized Cost Comparison of Solar PV and Conventional Power at Grid (Source: AT Kearney Analysis)

So the market analysts have broad consensus that Utility scale Solar PV generation delivered cost shall achieve grid parity around 2016/17 (in aggressive scenarios) & around 2018/19 (in base case scenarios) on the basis of assumption of pace of cost reduction in PV technology as well as increase in delivered cost of conventional energy prices eventhough capacity utilisation factor is lower than conventional. Grid parity year shall be an inflection point leading to more interest of offtakers like distribution licensees, Open Access/Captive consumers etc. due to the economic viability. This shall further drive the market to the accelerated growth phase of solar generation as more developers shall enter into the market to offer the capacities to meet the demand. Introduction of Net Metering Policy & suitable regulations for Roof top Solar PV shall further drive the market and may bring the the grid parity at early stage than anticipated.

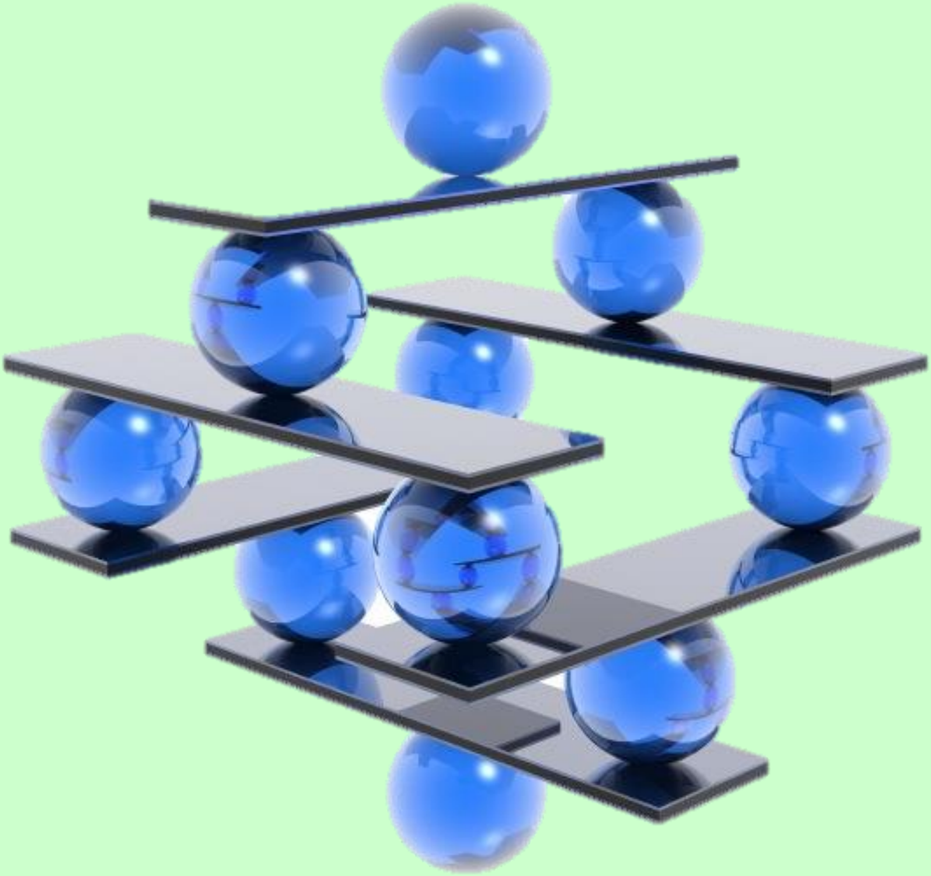
3.9. Environmental Benefits from Desert Power Development

As per National Electricity Plan (Generation) 2012, weighted average specific CO_2 emission from coal based generation is 1.09 ton/MWh. In 2050 scenario, if renewable generation contributed from deserts is to be considered of the order of 300GW, this shall displace 286 metric ton of CO_2 emissions. To arrive at above environmental benefits, it is assumed that desert RE generation shall have about 20-25% CUF which may substitute about 50% of the fossil fuel generation.

To address issues on integration of large scale renewables especially wind and solar which are intermittent and variable in output, maintaining balancing reserves to make up irregular output is crucial. For this, balancing reserve/infrastructure requirement in different forms have been assessed to maintain grid stability, which is presented in the following chapter.

CHAPTER-4

BALANCING RESERVE REQUIREMENT



CHAPTER 4

BALANCING RESERVE REQUIREMENT & RESOURCE DEVELOPMENT

Electricity demand dynamically changes in real time, making variability and uncertainty an inherent characteristic of electric systems. In order to meet varying system load, normally, power system has sufficient flexibility in generation to deal with variable load profile. Therefore low renewable penetration has a minimal impact on the system stability. In this scenario, generation is dispatched to follow the load achieving balance between demand and generation at each instant. However, a significant imbalance in generation and load may result in frequency & voltage excursion and other undesirable performance impacts.

Growing Renewable penetration adds on to dynamic changes in supply as well, due to variability of output depending on weather condition. This added variability result in complexity of power system operation and situation becomes challenging when contribution of renewable penetration increases into the grid, necessitating availability of more flexible resources.

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System operators maintain periodic (15 minutes time block in India) generation schedule & dispatch to supply energy to the loads. In the real-time operation, generation is adjusted to match the difference between actual load and the time block wise (say 15 min) schedule. The real-time adjustment, or within-hour balancing, is segregated into load following (or real-time dispatch) and regulation processes (*Fig-4-1*), according to their time scale.

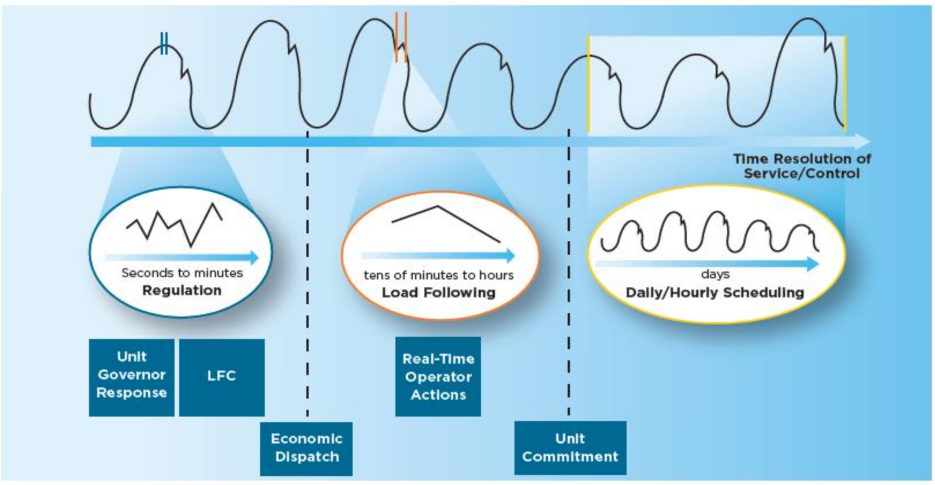

Fig 4-1: Load following (or real-time dispatch) and regulation processes(Source)

Load following (within hour resource dispatching) typically requires adjustments every 5-15 minutes, depending on the system. This is accomplished though a manual re-dispatch by the operators in our country at the moment. Regulation (sub minute adjustment) is effected by making sub minute adjustment. In India, it is achieved through unit governor response which is however limited and a commercial mechanism linked to frequency viz. Unscheduled interchange (UI), imposing penalties on deviating from given schedules. In other countries, this is achieved through Automatic Generation Control (AGC) system wherein generation automatically responds to minute-by-minute load deviations in response to signals from grid operators.

In power system, base load units—typically coal based and large nuclear units —often meet base load demand. These units have slow ramp rates and relatively high minimum generation levels. They also can take a long time (days in some cases) to start back up once they have been in shut down.

Intermediate and peaking units, which are generally gas & hydro generation, have faster ramp rates, relatively lower minimum generation levels, and can be shut down and started up relatively quickly. Such units have relatively higher operating costs, however most often used to provide load following generation service due to their ability to ramp up and down quickly. Gas based generation plants, based on the cycle application, can be further classified into Open/Simple cycle (Brayton) & Combined cycle type (Brayton+Rankine). Latest open cycle gas turbines though have slightly lesser plant efficiency (45-50%) than combined cycle ($\underset{\sim}{}$58-60%), but have relatively higher ramp rate.

Both load following and regulation processes requires sufficient capacities and ramp rates from dispatchable generating units to move system generation upward or downward timely. With increased renewable penetration, it is expected that the capacity and ramp rate requirements for the above two balancing processes will be much higher. This requires suitable policy & regulatory framework for its market participation and enable large scale renewable capacity development.

A comparison of ramp rate of different types of units (base load as well as peaking & storage units) is tabulated in Table 4-1 as under:

Table-4-1 : – Ramp rate of different types of generation technology

Generation Technology	Min. Load	Ramp Rate
	(%)	%/min
Coal	55-60	1-2
Nuclear	55-60	1-5
Gas Combustion Technology (Open cycle)	50	22-25
Combined Cycle Gas Turbine	50	2.5-5
Pumped Hydro Storage	33	50
Battery Energy Storage	0	20

In addition to intermediate and peaking units (open cycle gas turbine, hydro generators) which can be considered as flexible resource, there are many additional potential sources of flexibility, ranging from advanced thermal generators viz. Super Critical units, Grid Scale Energy Storage including Pumped Storage Hydro, Battery Storage, Flywheels, Compressed Air Energy Storage (CAES) etc. as well as Smart Grid attribute like demand response/Demand side management for load flexibility. For the hydro generation, turbine design should be of the Pelton wheel type, wherever possible, since the generation from this type of hydro generator can vary easily from zero to full capacity making it one of the most important asset in balancing fleet.

In general, the desired mix of flexibility is determined by the need to maintain reliability in the most economical way possible. New grid-scale storage capacity provides following benefits:

(1) Enhancing the stability and reliability of electric power systems by providing ample regulating capacity and contingency reserves for deployment by system operators

(2) Providing off-peak storage and regulation to accommodate high penetrations of variable renewable energy sources.

The need for and value of these benefits varies according to several factors, including the adequacy of existing generation and transmission capacity in electric power systems, the short-term variability and geographic diversity of wind and solar resources to be accommodated in an electric power system, and the ability of power system schedulers to forecast the availability of variable renewable generation over future hours and days.

4.1. Resource Allocation

As discussed in earlier sections (Table-2-1 & 2-2), in order to meet demand in futuristic scenarios, following generation capacity requirement is estimated:

S. No	Year	Installed Capacity requirement (GW)	Demand (GW)
1	2012	200	130
2	2016-17	271	200
3	2021-22	372	283
4	2026-27	528	401
5	2031-32	712	542
6	2036-37**	882	644
7	2041-42**	1067	746
8	2046-47**	1258	844
9	2050**	1388	896

Planning commission (Table-2-3) has estimated generation resource mix for 2030 to cater to projected demand. However, to arrive at generation resource mix for 2050, considering various factors like limitation of coal reserves, increasing import dependence as well as environmental concerns, emphasis has been given to increase contribution from renewables due its vast available potential. However considering numerous challenges in terms of introduction of variability in supply and consequent regulation as well as load following requirement, emphasis has to be given to flexible generation resources like hydro (Storage) as well as gas (CCGT).

In view of the available potential of various generation resources like Coal, Gas, Hydro (Storage + ROR), Renewable (Desert & Non-desert) and Nuclear, as discussed above, including technological development, past trends of capacity addition programme through conventional sources, encouraging policy, research & development activities, energy security & environmental aspects etc., generation resource mix for 2050 to cater to projected peak demand, has been estimated, which is as under (Table-4-2) :

Table-4-2 : – Envisaged Generation mix for 2050

S. No	Resource	Installed Capacity(GW)	Capacity Factor (%)
1	Coal	450	32
2	Gas	128	9
3	Hydro	180	13
4	Renewable	485	35
5	Nuclear	145	11
	Total	***1388***	***100***

Out of total requirement of 485 GW from renewables, it is envisaged that there would be capacity addition requirement of about 455 GW considering present RE capacity as about 30 GW. In view of the estimated renewable desert potential (316 GW) through Wind/Solar & non-desert renewable potential through Wind, Biomass & Waste to Energy, it is envisaged that out of 455 GW, renewable capacity contribution from deserts shall be about 300 GW (@95% of the total desert power) whereas on shore wind & solar generation in other parts of the country viz. Tamil Nadu, Karnataka, AP, Maharashtra shall be about 55 GW. In addition, Biomass, Waste to Energy, Small Hydro Capacity, Roof Top Solar, Canal Top PV shall be contributing about 70 GW capacity, given their potential estimate. Off shore Wind generation shall also be exploited in future with envisaged capacity of 30 GW making total renewable capacity to be 485 GW by 2050.

Considering requirement of exploitation of potential in four (4) deserts, following capacity contribution is estimated (Table 4-3) from each of the desert:

Table-4-3: – Desert Renewable Capacity

S No	Desert	Total available potential	Envisaged Renewable Capacity contribution @about 95% of Desert Potential (GW)		
			Wind (GW)	Solar (GW)	Total (GW)
1	Thar	234.8	22	201	223
2	Rann of Kutch	34.3	3	30	33

4

S No	Desert	Total available potential	Envisaged Renewable Capacity contribution @about 95% of Desert Potential (GW)		
			Wind (GW)	Solar (GW)	Total (GW)
3	Laddakh	42.4	4	36	40
4	Lahul & Spiti	4.2	-	4	4
	Total	**315.7**	**29**	**271**	**300**

Development of hydro resources, through domestic (135 GW) as well as neighboring countries (47 GW) viz. Bhutan & Nepal is estimated to be about 180 GW. Despite huge potential of Nuclear generation as per DOAE (275 GW), due to socio-techno limitations, about 60% of potential (145 GW) is expected to be harnessed by 2050 which is in line with the trends presented in the planning commission projection (Table-2-3) for capacity mix. In view of the limitation of domestic coal reserves, it is envisaged that about 450 GW capacity shall be contributed from coal including imported coal also. Balance capacity (128 GW) is assumed to be contributed from Gas resource. Gas based capacity is essential in meeting regulation (quick ramp up/down) & load following as well as requirement due to volatility of renewables, therefore despite limitation in domestic reserves, gas based generation has to be developed even if it is to be needed on imported or shale gas based.

4.2. Energy Requirement

Generation fuel mix has been further validated based on whether the envisaged fuel mix is capable of fulfilling annual energy (6200 BU) needs of 2050. This analysis has been carried based on ex-bus energy from each of the generation resources considering auxiliary consumption as well as plant load factor/capacity utilization factor, which is tabulated as under (Table 4-4):

Table-4-4 : – Energy Generation

S. No	Resource	Capacity (GW)	Utilisation factor (%)	Ex Auxiliary Consumption (%)	Energy Produced (GWh)
1	Coal	450	0.8	0.93	2932848
2	Gas	128	0.6	0.97	652585
3	Hydro	180	0.5	0.99	780516
4	Renewable	485	0.23	0.995	972292
5	Nuclear	145	0.8	0.94	955190
	Total	***1388***			***6293431***

From above, it is observed that proposed generation mix shall be able to meet annual energy needs of the country by 2050.

4.3. Demand Generation Scenario

Analysis has also been carried out for various demand scenarios (peak/off peak/other than peak) in three seasons viz. Summer, Winter and Monsoon. Demand scenario has been segregated into other than peak and off peak hours because of variability of demand pattern at different time of the day in seasons e.g. off peak (minimum demand) occurs at early morning during monsoon & winter whereas evening in summer. However, other than peak scenario is considered in day hours (noon) wherein Solar generation is primarily generating at maximum.

Objective of the analysis is to identify challenging operating scenarios where limitations can arise out of variation in seasonal/daily demand patterns. For this, regional & all India load curves (2012) has been examined for all the three seasons for a given day which are as under. However above load curves are presently based on the operation of NR-ER/NER-WR (NEW) & SR grid separately which shall become a single grid by 2014.

A typical daily demand curve of all the three seasons i.e Winter, Summer and Monsoon is shown below in figure 4-2, 4-3 & 4-4 respectively.

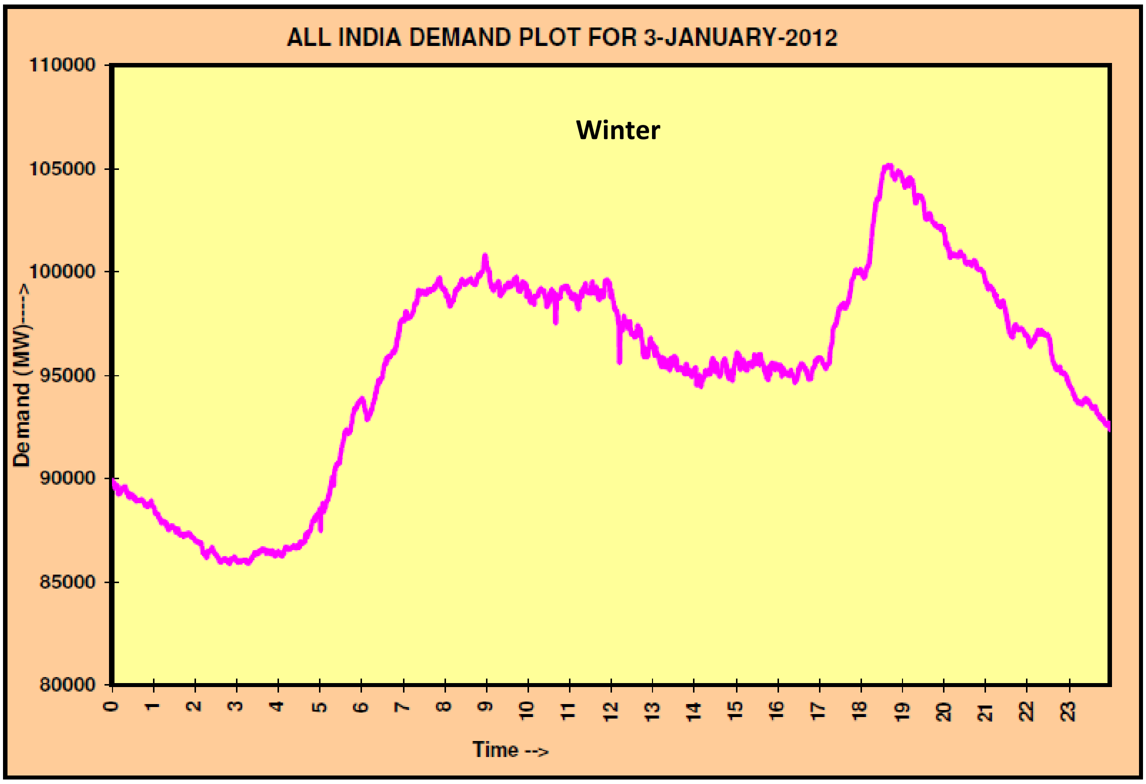

Fig 4-2: Typical Daily demand curve of All India – 03.01.2012 (Source-POSOCO)

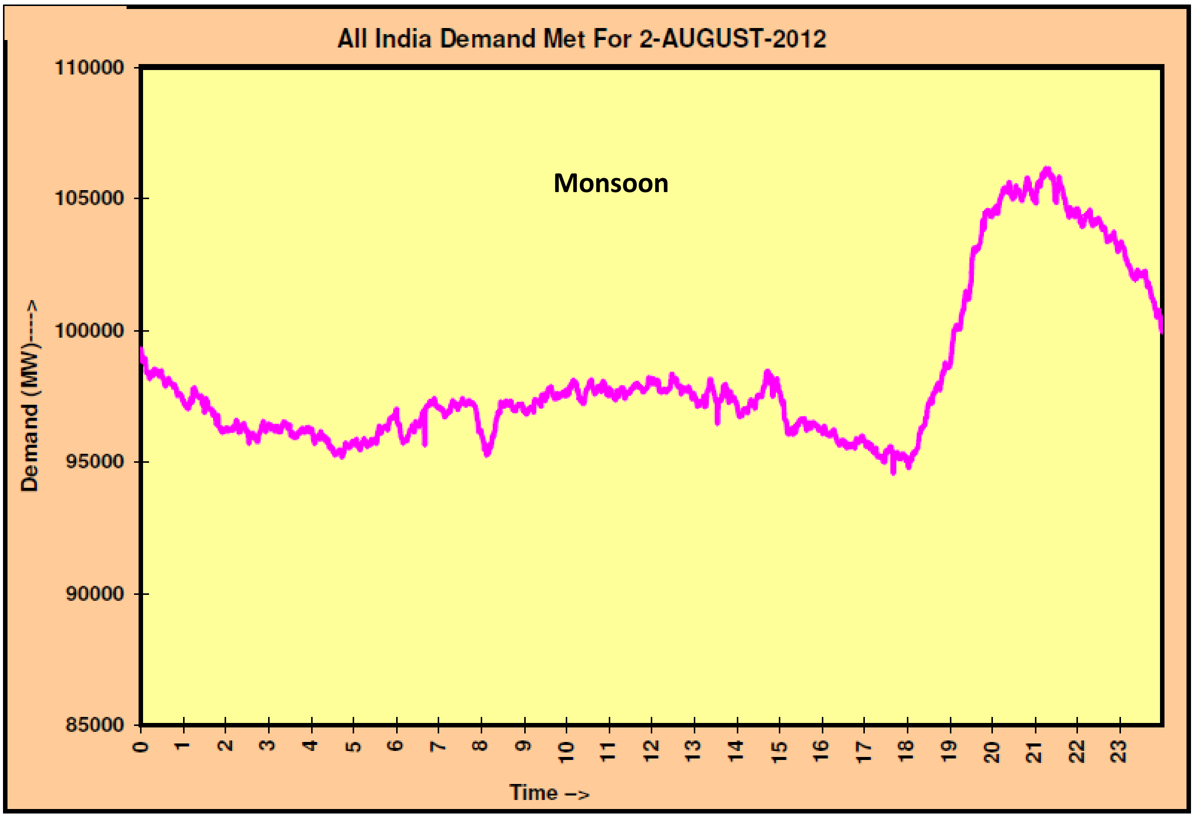

Fig 4-3: Typical Daily demand curve of All India – 02.08.2012 (Source-POSOCO)

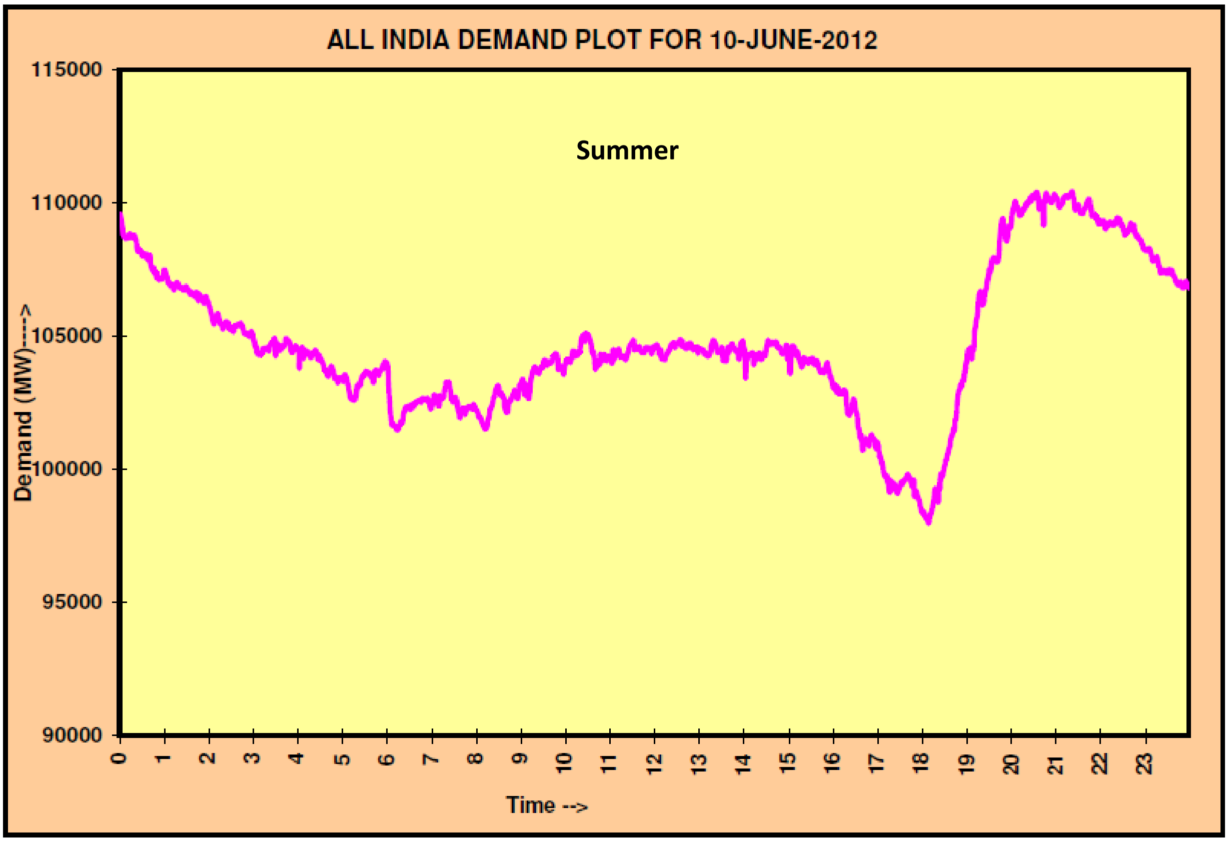

Fig 4-4: Typical Daily demand curve of All India – 10.06.2012 (Source-POSOCO)

From above seasonal demand patterns, it has been observed that peak demand is maximum in Summer season. Therefore, based on the present profile of other seasonal peak demand of Winter/Monsoon, demand for such seasons have been estimated based on present ratios of Winter/Monsoon to Summer peaks in 2050. Similarly seasonal off peak and other than peak demand has also been estimated for 2050 based on the present ratio of their respective peak to off peak & peak to other than peak rations.

Considering above as well as generation availability, surplus/deficit scenarios have been assessed for 2050 (Table-4-5). Generation availability has been derived based on the seasonal availability of resource especially Renewables & Hydro. Further in surplus scenarios, in case of minimum generation requirement, peaking units i.e. gas are reserved or minimally used while operation of base load plants (Coal/Nuclear) is considered at technical minimum (say 80%).

Table-4-5 : –Demand -Generation Scenario by 2050

S. No	Scenario	Resource						Demand (GW)	Surplus /Deficit (GW)
		Coal (GW)	Gas (GW)	Hydro (GW)	RE (GW)	Nuclear (GW)	Total (GW)		
1	Monsoon-Peak	405	76.8	108	86.10	130.5	820.4	850.92	-30.52
2	Monsoon-off Peak	405	25.6	108	50.00	116	726.6	723.28	3.32
3	Monsoon-other than peak	382.5	0	117	180.80	116	824.3	782.85	41.55
4	Summer-Peak	405	115.2	120.6	36.10	130.5	837.7	895.71	-58.01
5	Summer - Off peak	405	57.6	72	110.60	130.5	791.7	788.22	3.48
6	Summer-other than peak	382.5	57.6	81	266.60	130.5	921	850.92	70.08
7	Winter-Peak	405	115.2	108	31.10	130.5	813.1	868.83	-55.73
8	Winter-Off peak	405	83.2	54	26.10	130.5	700.8	695.07	5.73
9	Winter-other than peak	382.5	32	36	237.50	130.5	848.5	781.95	66.55

Above analysis reveals that seasonal other than peak demand & off peak scenarios are mostly surplus whereas peak demand scenarios are turning deficit. This situation is arising because of high availability of renewable viz. Solar & Wind during other than peak hours and low demand during off peak hours. However this gives an opportunity to deploy large scale grid storage solutions like Pumped Hydro, Battery technologies and Solar (CSP) with Storage facility which can store energy during surplus scenarios to be used later in meeting demand in peak hours.

4.4. Balancing/Flexible Capacity Requirement

As discussed in the earlier sections, with the high renewable penetration and consequent upon increased variability, system needs introduction of additional flexibility in terms of flexible resources as well as institutional flexibility. Interestingly, some flexibility in terms of geographical diversity and consequent time diversity shall also be provided by above deserts.

Flexible resources: Balancing infrastructure

In view of the storage requirement towards facilitating balancing in the high renewable penetration scenario as well as to take care of deficit scenarios of peak hours, storage technologies like Pumped Storage Plants (PSP), Large Scale battery, Flywheels, Superconducting Magnetic Energy Storage (SMES) etc. may be deployed. However, storage should only be operated along with renewables in terms of its charging by utilizing surplus renewable energy for it to be considered as clean source supply. Therefore, in various off peak scenarios, it has been ascertained that surplus renewable energy is available for charging various storage solutions so that it can be used later on at the time of requirement

Table-4-6: –Balancing Reserve Requirement by 2050

S. No	Scenario	Total Available Capacity (GW)	Demand (GW)	Surplus/Deficit (GW)- W/o Storage	PSP (GW)	CSP with storage (GW)	Other Storage (GW)	Surplus/ Deficit (GW)- With Storage
1	Monsoon-Peak	820.4	850.92	-30.52	19.74	10	5	4.22
2	Monsoon-off Peak	726.6	723.28	3.32				3.32
3	Monsoon-other than peak	824.3	782.85	41.55	-21.71	-10	-5	4.74
4	Summer-Peak	837.7	895.71	-58.01	19.74	30	10	1.73
5	Summer - Off peak	791.7	788.22	3.48				3.48
6	summer-other than peak	921	850.92	70.08	-21.71	-30	-10	8.37

S. No	Scenario	Total Available Capacity (GW)	Demand (GW)	Surplus/Deficit (GW)- W/o Storage	PSP (GW)	CSP with storage (GW)	Other Storage (GW)	Surplus/ Deficit (GW)- With Storage
7	Winter-Peak	813.1	868.83	-55.73	16.92	30	10	1.19
8	Winter-Off peak	700.8	695.07	5.73				5.73
9	Winter-other than peak	848.5	781.95	66.55	-18.61	-30	-10	7.94

As per the above load generation balance scenarios (Table-4-6), worst case scenarios of deficits occur in winter peak 56 GW) & summer peak (58GW). Considering the available surplus in other than peak periods for above seasons, same may be utilized through suitable storage technologies.

PSP hydro plant is an important element towards balancing infrastructure. However considering various associated issues and present trends of development of such plants, gestation periods etc, it is considered that harnessing of 30% (28 GW) of its total available potential (94 GW) in the country is required in normal scenario.

Towards development of energy storage capacity, desert solar potential should be harnessed in the form of Concentrated Solar Power(CSP) with storage (30 GW) so that surplus solar energy can be scheduled to be harnessed during peak demand & addressing volatility. In addition, balance requirement of 10 GW may be developed through other storage solutions like large scale battery etc. which shall also serve for the purpose of regulation. Therefore it is proposed that about 68 GW storage reserves can be planned to meet requirement of 2050.

Considering load generation balance scenarios and total energy storage requirement by 2050, balancing requirement for medium term i.e. 13th plan (2022) and 15th plan (2032) is also estimated on pro rata basis as shown is the Table 4-7 as under.

Table-4-7 : –Balancing Reserve Requirement

S. No.	Type of Storage	Capacity by 2022 (GW)	Capacity by 2032 (GW)	Capacity by 2050 (GW)
1	Concentrated Solar power with storage	-	12	30
2	Pumped Storage (upto @30% of 94GW potential)	5	14	28
3	Other Energy Storage i.e. Grid Scale Battery, Flywheel etc.	2	4	10
		7	***30***	***68***

In view of gestation period for development of PSP hydro plants, phasing of PSP plant development is considered as 5% (5GW) & 15% (14GW) of available potential (94GW) by 2022 and 2032 respectively. However, considering slow growth rate of CSP plants due to technology and cost constraint in initial phase of desert power development, about 12GW capacity is considered by 2032.

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In order to facilitate balancing reserves in the form of Hydro/thermal generation, to take care of volatility of large scale renewables, it is proposed that blending of certain percentage say 10-15% of Hydro/Thermal generation may be carried out with renewable generation. This provision may be kept for all new hydro/thermal generation projects. Further technology of Hydro/Thermal generation project should be such that it will take care of quick ramp up/down of generation which are essential for taking care of renewables intermittency aspects and grid stability.

Further, strong grid interconnections through transmission corridors, which shall enlarge balancing area by interconnecting various Hydro, Gas, flexible thermal generation complexes, is a mandatory requirement to reap out benefits of flexible resources available at different locations for balancing purpose. Smart grid tools like demand response and demand side management will also facilitate balancing through load management.

4.5. Institutional Flexibility

4.5.1. Smart Grid Deployment

In the Smart Grid regime, Demand Side Management (DSM) and Demand Response (DR) are one of the institutional market mechanisms to introduce demand flexibility. Implementation of Demand management requires suitable policy, regulatory framework as well as deployment of intelligent technology i.e. Advanced Metering Infrastructure (AMI) so as to stimulate participation in the mechanism. In this mechanism, customer gets incentive in the form of lower tariff at the time of day when energy is surplus encouraging consumption and dis-incentivizing with higher tariff at the peak consumption hours to lower the consumption or shift the demand to lean periods. In this manner, it introduces much needed flexibility to the power system and also reduces equivalent peaking capacity requirement at peak hours moderating requirement of flexible resources to some extent. In such market concept, a system operator or aggregator may also play a larger role in participating on behalf of consumer stimulating success of demand management programme.

Demand response, specifically, is a strategy used by electric utility or enables the user, to reduce or shift energy consumption from peak hours of the day, when the demand for electricity is the greatest to leaner demand periods. It involves allowing customers to choose non-essential loads, which can be shed by the customers themselves or by the utility, at peak times. It is a pre-arranged agreement between the Utility or intermediate agencies like aggregators with the consumer with specific conditions of load, price and time intervals. Since power plants and transmission systems are designed to respond to the highest potential demand, lowering peak demand during demand intensive times of the day helps utilities reduce overall installation costs, operating costs and mitigate potential grid failures. Consumer may participate in demand response program through various technologies i.e end-User Interfaces using a variety of channels, including email, mobile application, web portals, in-home display units or business display devices, load control devices and ultimately "smart appliances" seamlessly into the overall smart metering system

4.5.2 Electric Vehicles

Electric and plug-in hybrid vehicles (EVs and PHEVs), if coupled with low greenhouse gas (GHG) electricity generation, can help in reducing energy (particularly petroleum) usage and CO_2 emission significantly. In addition, Plug-in hybrid electric vehicle (PHEVs) also provides a new opportunity towards distributed flexible reserve. Through its Vehicle-to-Grid (V2G) application, such EV/PHEV batteries may be able to provide flexible generation reserve.

Similarly through its Grid-to-Vehicle (G2V) application, EV/PHEV batteries may be able to behave as bulk consumption center participating as flexible demand nodes.

A system operator or an aggregator with access to numerous EV/PHEV batteries could potentially adjust the battery charging rates, thereby providing system ramping services.

Development of power evacuation infrastructure is the key for harnessing large scale renewables. In the following chapter, transmission requirement by 2050 to facilitate integration of desert power is described.

CHAPTER-5

Transmission System Requirement 2050

CHAPTER 5

Transmission System Requirement

Transmission is the central link in the entire electricity delivery chain interconnecting sources to the distantly located load centres. A robust and reliable transmission network is needed to ensure supply with safe and secured manner at reasonable cost. In the high renewable penetration scenario, strengthening/expansion of grid interconnection enlarging power balancing area is an essential requirement for dealing with the challenges of renewable grid integration & achieve optimal utilization/sharing of geographically dispersed flexible resources.

Concentration of envisaged renewable generation potential necessitates development of transmission interconnections for evacuation and dispersal of renewable power to various load centres. Further, due to volatility of renewable and consequent variation in power flows over high capacity corridors, it is suggested to establish hybrid UHV/EHV AC & HVDC transmission system. This shall not only help in transfer of power from renewable rich State to other deficit States but also complement the parallel transmission system of conventional generation projects/grid strengthening scheme for transfer of power as well as to maintain grid parameters. In view of the variation in power flow requirement over high capacity transmission system, adequate reactive compensation in the form of dynamic reactive compensation like STATCOM/SVC as well adequate static reactive compensation like Bus/Line reactors shall need to be provided.

Broad transmission infrastructure plan shall include hybrid ultra-high capacity transmission corridors emanating from potential rich desert locations interconnecting various load centers as well as touch points integrated with large Hydro potential rich zones like Northern-eastern region (NER), Sikkim and Bhutan or other flexible resources. However, along with development of desert transmission corridors, it is equally important to harness hydro potential of Northern-eastern region (NER), Sikkim and Bhutan by development of high capacity transmission corridors between NER/Sikkim/Bhutan and load centers for balancing purpose. Further, to take care of seasonal variation in generation from such hydro complexes, the transmission corridors must be planned with hybrid HVDC and AC system so that regulation of power flow can be carried out & grid parameters can be maintained.

In view of the above, broad contours of transmission plan have been prepared with above approach:

(1) Development of Hybrid EHV AC/ HVDC (VSC) Transmission system for flexibility of controls and Power flow regulations

(2) Interconnection of Desert Transmission Corridors with major load centers in the States as touch points including with Green Energy Corridors

(3) Desert Transmission Corridors integrated with other high capacity transmission corridors associated with conventional generation complexes especially gas/thermal as well as new hydro rich complexes to achieve supply balancing

However, it is to emphasize that apart from above proposed high capacity transmission highways, there would be requirement of intra state transmission system strengthening within STU transmission & distribution network for absorption of renewable energy.

5.1. Technology

(i) AC Technology

In India, in past one decade, 765kV Extra High Voltage (EHV) AC technology has been on forefront towards establishing high capacity transmission corridors. However in view of the growing Right-of-Way concerns, establishment of gigawatt scale generation complexes like deserts at concentrated locations, there is further need of increasing power intensity (MW/km) of transmission corridor (Table 5-1) through Ultra High Voltage AC technology (1200 kV).

Table-5-1: Power intensity (MW/meter) at different voltage level

Voltage	400 kV	765 kV	±500 kV	±800 kV	1200 kV
ROW Meters(M)	46	64	52	70	90
Capacity (MW)	Upto 600-700	Upto 2500-3000	Upto 2000-2500	Upto 6000-6400	Upto 6000-8000
MW/m	15	45	48	90	90

In this direction, POWERGRID has already established world's highest transmission voltage level of 1200kV UHV-AC with the charging of National Test Station at Bina in M.P in 2012. This technology has been fully developed indigenously with the collaborative effort of Indian manufacturers under Public Private Partnership. Despite being world's highest voltage level available only in India so far, the technology is expected on commercial basis by the 13th plan (2017-22) in our country.

To address right-of-way issue, transmission capacity of 1200kV UHV AC line shall be established commensurate to long term power transfer requirement, however in case of low power transfer requirement in initial periods, line may be operated at lower voltage level to maintain the grid parameters.

(ii) HVDC Technology

HVDC Transmission is a well-established method of using controlling power flow within or between networks through power electronics systems. Modern HVDC systems have been based on the use of thyristors as the controlled device (referred to as line commuted converter [LCC], current source converter [CSC], or conventional HVDC) for over 40 long years.

HVDC transmission systems offer many benefits over their AC counterparts, including the following:

- Power flow through the link can be precisely controlled in both magnitude and direction, either through operator action or through automated response
- Voltage and frequency in the two AC networks can be controlled independently of each other, again either through operator action or through automated response
- The HVDC link can be used to assist one (or even both) of the AC networks in responding to disturbances (e.g., power swing damping, by modulation of transmitted power). This is normally fully automated since the operator is unable to respond in this timescale

In general, for transmission distances above 700 km, DC transmission is more economical than AC transmission ($\geq$ 1000 MW). However LCC or conventional HVDC suffers from technical restriction that commutation within the converter is driven by AC voltage of interconnected AC system requiring minimum short circuit level of surrounding AC system. However renewable generation pockets do have weak short circuit strengths posing limitation on the use of conventional HVDC systems.

Advent of Voltage Source Converter (VSC)- HVDC transmission technology based on VSCs and insulated gate bipolar transistors (IGBT) have addressed the above limitation of LCC/conventional HVDC. Voltage Source converter don't require any "driving" system voltage, they can establish a 3 phase voltage via the DC voltage. However, at the same time the technology continues to offer advantages of conventional HVDC. Compared to conventional line commutated HVDC system, the other characteristics of VSC Transmission are:

- Offer similar advantages of conventional HVDC like precise control over power flow etc.
- It can be connected with weak grid/sources
- It can independently control the reactive power flow at each AC network
- Reactive power control is independent of active power control
- It needs no external voltage source for commutation

These features make VSC Transmission attractive for connection of weak AC systems, island networks and renewable sources to a main grid. However, VSC Transmission does have high cost compared to conventional HVDC system. However this may be due to technology being at nascent stage and economies shall be achieved with scalability and improvement in technology. So far, 1000 MW HVDC system has been developed using VSC technology. However, development of Renewable generation pockets generally takes place in modular fashion like 200-300 MW capacity, accordingly VSC based HVDC system is also considered to be developed in modular way of 375 MW capacity each. This will also enable deferment of investment towards terminal capacity. However, due to right-of-way constraints, transmission capacity of HVDC line shall be established commensurate to long term power transfer requirement.

Implementation of multi-terminal DC system is relatively simple in VSC based technology which suits the requirement of transmission corridor development for renewables. Converter can also be used as STATCOMS, when HVDC line is not in service, to provide dynamic reactive power support.

5.2. Ultra High Capacity Transmission Corridors

Installable capacity in four (4) deserts is envisaged to be about 300 GW. Considering the developmental status of Concentrated Solar Plants(CSP) with storage, which also act as flexible reserve, about 10% total capacity (30 GW) is proposed to be established by 2050 in the form of CSP in above four deserts. Further, as gathered from the past experience, maximum availability of Solar generation is about 80% that too in peak season (April-May), therefore transmission capacity has been considered to be developed for peak generation availability. However, CSP with molten salt technology, is being envisaged as flexible capacity, shall be utilized in storing solar energy in other than peak hours and for delivery in peak periods. Therefore, transmission capacity available for non-CSP capacity shall only be utilized for transfer of CSP capacity in peak hours when non-CSP capacity will not be at peak. In view of the above, transmission capacity to be developed from each of desert is detailed (Table -5-2) as under:

Table-5-2: Transmission Capacity Requirement :2050

S No	Desert	Envisaged Renewable Capacity (GW)	CSP capacity (GW)	Net capacity (GW) (Total-CSP)	Transmission capacity Requirement @80% of net capacity (GW)
1	Rann of Kutch	33	5	28	23
2	Thar	223	20	203	162
3	Laddakh	40	5	35	28
4	Lahul & Spiti	4	-	4	3
	Total	**300**	***30***	***270***	***216***

Further as discussed above, there would be requirement of hybrid AC & HVDC technology for ultra high capacity corridors emanating from above four deserts, therefore capacity to be established with HVDC and UHV AC from each of the complex is as under (Table-5-3):

5

Table-5-3: Transmission Corridors : 2050

S No	Desert	Transmission capacity Requirement @80% of net capacity (GW)	Transmission corridors	
			HVDC Bipole	UHV AC (1200 kV S/c)
1	Rann of Kutch	23	1 no. +800 kV, 6000 MW (VSC) 1 no. +500 kV,4x375 MW (under sea cable-VSC) 1 no. +500 kV,2x375 MW MTDC	3 nos.
2	Thar	162	1 no. +500 kV,6x375 MW (VSC) 2 no. +500 kV,8x375 MW (VSC) (MTDC) 5 nos. +800 kV, 6000 MW (4 nos. MTDC) 1 no. +500 kV 3000MW	18 nos.
3	Laddakh	28	10 no. +500 kV,6x375 MW (VSC)	4 nos.

S No	Desert	Transmission capacity Requirement @80% of net capacity (GW)	Transmission corridors	
			HVDC Bipole	UHV AC (1200 kV S/c)
			3 no. +500 kV,8x375 MW (VSC) MTDC	
4	Lahul & Spiti	3	1 nos. +800 kV, 6000 MW (MTDC)	
	Total	***216***	***26 nos. (18 nos. VSC)***	***25 nos***

Above 1200kV transmission corridors have been envisaged keeping in view the quantum of Power transfer requirement distance involved as well as addressing ROW issues.

**1200kV transmission corridors have been envisaged keeping in view the quantum of Power transfer requirement, distance involved as well as addressing ROW issues. As on date it seems difficult to operate the transmission corridors at 1200kV level, however keeping in view the future requirement, it is prudent to address the various issues like variation in power flow over 1200kV corridors, reactive power management etc on immediate basis so that smooth operation in future is feasible.*

Otherwise instead of 1200kV corridors, the same will be developed with 765kV technology for which more no. of corridors shall be required. Alternately, emphasis may be given to develop the High Temperature Superconducting (HTS) line each having 6000-8000 MW capacity at 4000kV level instead of 1200 kV corridor for which developmental project of HTS line need to be taken up urgently.

Details of complex wise transmission corridor is as under:

RANN OF KUTCH COMPLEX

- +500kV 2x375MW Kutch RE PP1- Thar RE PP3 VSC based HVDC Bipole ***(TRC-1)***
- 1200kV Kutch RE PP2– Vadodara (Gujarat/WR) 3xS/c & 1200kV Vadodara - Pune (Maharashtra/WR) 2xS/c ***(TRC-2)***
- +500kV, 4x375MW Kutch RE PP3 – Mumbai (Maharashtra/WR) Sub marine HVDC cable ***(TRC-3)***
- +800kV 6000 MW Kutch RE PP4 – Dabaspet (Near Bangalore) HVDC Bipole ***(TRC-4)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 28,000 Cr

THAR COMPLEX

- 1200kV Thar RE PP1– North Punjab (Near Amritsar) 2xS/c ***(TRC-5)***
- 1200kV Thar RE PP2– Thar RE PP1 – Central Punjab (Near Jalandhar) 2xS/c ***(TRC-6)***
- ±500kV 6x375MW Thar RE PP2 – North Punjab (Near Gurudaspur) VSC based HVDC Bipole ***(TRC-7)***
- 1200kV Thar RE PP2– Central Rajasthan (Near Ratangarh) – Haryana (Near Hissar) 2xS/c ***(TRC-8)***
- 1200kV Thar RE PP3– Thar RE PP5 - Central Rajasthan (Near Ratangarh) – Delhi/Haryana 2xS/c ***(TRC-9)***
- 1200kV Thar RE PP3 - Thar RE PP6–East Rajasthan (Near Jaipur) – Western UP (Near Agra) - Central UP (Near Lucknow) 2xS/c ***(TRC-10)***
- ±800kV 6000 MW Thar RE PP3 – Central MP (Near Bhopal)- North AP (Near Visakhapatnam) HVDC Bipole (Multi terminal) ***(TRC-11)***
- ±500kV 8x375MW Thar RE PP3 – Delhi/Haryana VSC based HVDC Bipole (Multi terminal) ***(TRC-12)***
- 1200kV Thar RE PP4 - Thar RE PP6 – East Rajasthan (Near Jaipur) - Delhi/Haryana 2xS/c ***(TRC-13)***
- ±800kV Thar RE PP4 (6000MW) – Maharashtra (Near Nagpur/3000MW) – Tamil Nadu (near Chennai/3000MW) HVDC Bipole (Multi terminal) ***(TRC-14)***
- 1200kV Thar RE PP5–Central Rajasthan (Near Ratangarh) – Delhi/Haryana 2xS/c ***(TRC-15)***
- ±500kV 8x375MW Thar RE PP5 – Maharashtra (Near Pimpri- Chichwad/1500MW) –South Karnataka (Near Mysore/1500MW) HVDC Bipoles (Multi terminal) ***(TRC-16)***
- ±800kV Thar RE PP5 (6000MW) – Maharashtra (Near Nasik/6000MW) – Tamil Nadu (near Madurai/3000MW) HVDC Bipole (Multi terminal) ***(TRC-17)***
- 1200kV Thar RE PP6–East Rajasthan (Near Jaipur) – Western UP (Near Agra) – Eastern UP (Near Kanpur) 2xS/c ***(TRC-18)***
- ±800kV 6000 MW Thar RE PP6 – Central Bihar (Near Patna) HVDC Bipole ***(TRC-19)***
- ±800kV 6000 MW Thar RE PP7 – Central MP (Near Indore/3000MW) – North AP (Near Hyderabad/3000MW) HVDC Bipole(Multi Terminal) ***(TRC-20)***
- 1200kV Thar RE PP7–East Rajasthan (Near Jaipur) – Western UP (Near Agra) – North UP (Near Bareilly/Moradabad) 2xS/c ***(TRC-21)***

- ±500kV 3000MW Central Rajasthan (near Jaipur) – North UP (Muzaffaernagar/Meerut) HVDC Bipole ***(TRC-22)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 1,57,000 Cr

LEH AND LAHUL & SPITI COMPLEX

- ±500kV 6X375 MW Kargil RE PP1 – North Punjab (Near Gurudaspur) VSC based Two HVDC Bipoles ***(TRC-23)***
- ±500kV 6X375 MW Kargil RE PP2 – North Punjab (Near Gurudaspur) VSC based Two HVDC Bipoles ***(TRC-24)***
- 1200kV North Punjab (Near Gurudaspur) – Punjab/Haryana (Near Mohali/Chandigarh) S/c
- ±500kV 6X375 MW Leh RE PP1 – Pooling point in Himachal (Near Shimla) VSC based Two HVDC Bipoles ***(TRC-25)***
- ±500kV 6X375 MW Leh RE PP2 – Pooling point in Himachal (Near Shimla) VSC based Two HVDC Bipoles ***(TRC-26)***
- ±500kV 6X375 MW Leh RE PP3 - Pooling point in Himachal (Near Shimla) VSC based Two HVDC Bipoles ***(TRC-27)***
- 1200kV Pooling point in Himachal Pradesh (Near Shimla) – Delhi/Haryana 2xS/c
- ±500kV 4X375 MW Kargil RE PP3 – Leh RE PP4 VSC based HVDC three Bipoles ***(TRC-28)***
- ±500kV 8X375 MW Leh RE PP4 - Lahul & Spiti PP (NR) VSC based three HVDC Bipoles ***(TRC-29)***
- 1200kV Lahul & Spiti PP (NR) – Chandigarh(NR) –North UP (Ghaziabad/Noida) S/c
- ±800kV 6000 MW Lahul & Sipti PP(NR) – West MP (Near Bhopal) – Maharashtra (Near Mumbai) HVDC Bipoles ***(TRC-30)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 70,000 Cr

In addition to above corridors, transmission corridors from Hydro Complexes of NER/Bhutan to meet balancing requirement is also proposed.

NER/ER-NR INTERCONNECTION

- Multi terminal ±800kV 6000MW NER/Sikkim/Bhutan/UP location -Delhi/Haryana load centres HVDC Bipole – 3 nos ***(TRC-31)***

Estimated Cost: Rs 45,000 Cr

Total Estimated Cost (All complex): Rs 3,00,000 Cr

Additionally, there would be requirement of Intra State Strengthening scheme of about Rs 1,50,000 Cr for absorption of renewable power within states. Further, there would be requirement of balancing cost to compensate conventional generation participating as flexible generation/spinning reserves etc.

Schematic of perspective high capacity transmission corridors for desert power by 2050 is shown at Fig-5-*1.*

Above proposed transmission corridors have been phased out for medium term scenarios i.e. 2021-22 (13th Plan) as well as 2031-32 (15th Plan) considering envisaged renewable capacity addition in desert regions.

Note : Above scheme is a broad contour of transmission plan to facilitate power transfer from the renewable generation complex in the desert region to major load centers. Exact terminal location shall be finalized based on the progress of capacity addition programme, load growth pattern during the implementation stage.

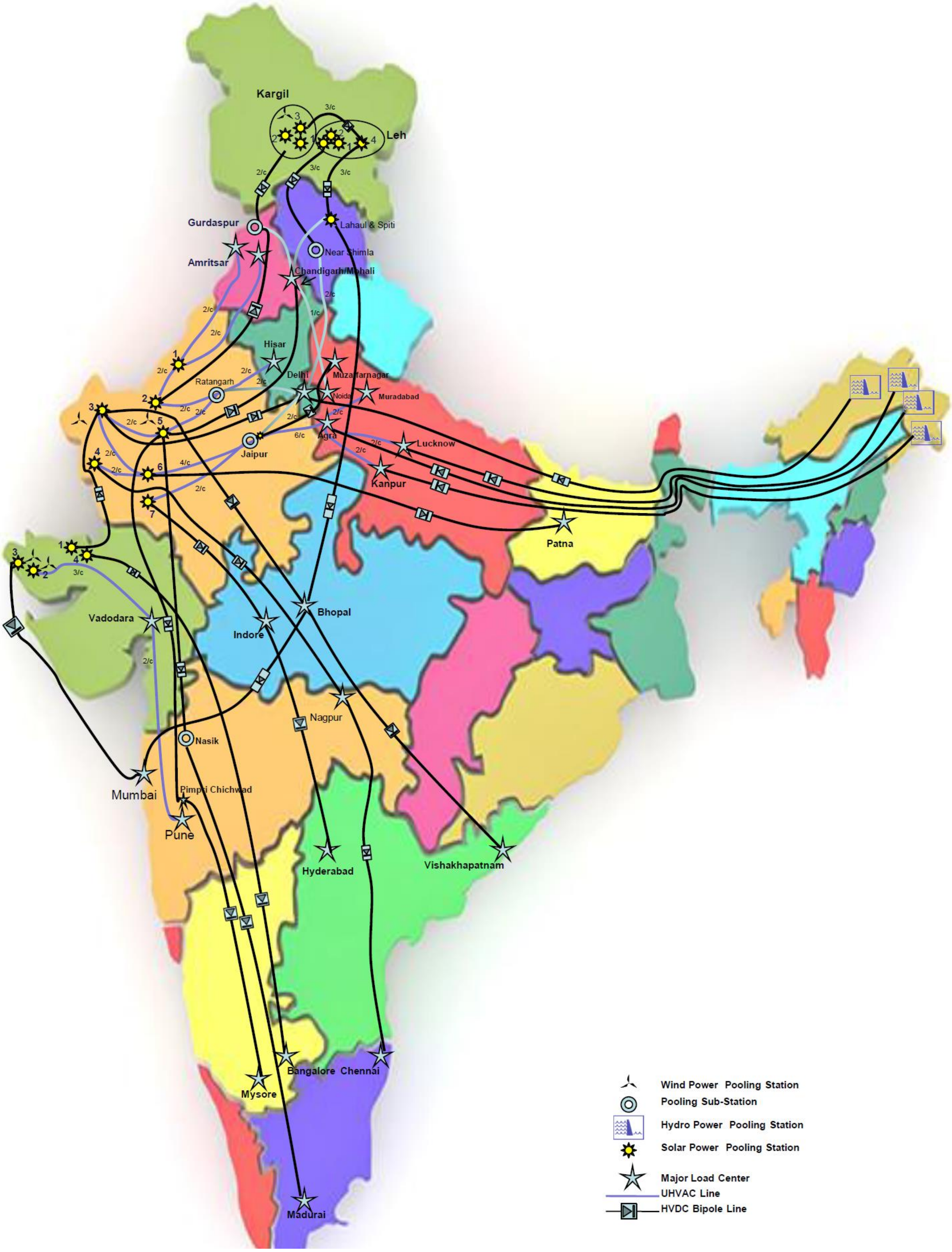

Figure 5-1: High Capacity Transmission Corridors for Desert (2050)

5.3. Medium Term Transmission Plan

MNRE has envisaged setting up of large scale solar plants i.e. Ultra Mega Solar Power Plant upto 4000 MW capacity in desert lands including surplus lands lying up with PSUs viz. at Sambhar (Rajasthan) [4000 MW], Kharaghoda (Gujarat) [4700 MW] and Leh/Kargil (J&K) [2400 MW] in 13th plan period. To facilitate development of matching transmission system for evacuation & onwards transfer of power from above Ultra mega Renewable projects (11000 MW), comprehensive transmission system have been evolved in subsequent sections.

5.3.1. Study Approach for Evolution of Transmission System

Transmission System is evolved considering maximized dispatch scenarios i.e. 80% for Solar & 70% for Wind for other than peak demand scenarios. In view of the huge generation capacity available in the deserts, it has been assumed that major part of this renewable energy shall flow out of the host state of these deserts utilizing the ISTS corridors. However, scenario being of other than peak condition, some of the conventional generation has been backed down as per merit order dispatch.

Considering Variability of Solar generation specially in the event of clouds cover etc. as well as non availability of Solar generation in evening/night, transmission technology is to be selected in such a way that it can support in maintaining grid parameters. Therefore, Hybrid Transmission Technology comprising HVDC and EHV AC is selected to achieve control/flexibility of power transfer. Location of end terminal stations are selected which have grid connectivity to cater to meet the power requirement at the time of non availability of Solar Power. Further due to weak short circuit strength at remote locations like Ladakh/Leh, VSC technology in HVDC system is found to be technically suitable.

5.4. Transmission Requirement for Ultra Mega Renewable Projects in 13th Plan (2021-22)

5.4.1. Sambhar UMPP (4700MW)

In Rajasthan, MNRE has envisaged setting up of Ultra mega Solar Power Project (4000 MW) in vast stretches of salt pan land of Sambhar Lake in Rajasthan (Fig-5-2).

Fig 5-2: Project Location (Latitude: 26^{0}55’ 11’’N **Longitude**: 75^{0}12’ 37’’ E)

Hindustan Salt Ltd. (HSL)/Sambhar Salts Ltd (SSL), a Government of India company, has large tracts (Nearly 18000 acres) of Salt Pan lands bordering Sāmbhar Lake at Sāmbhar, Rajasthan which is proposed to be utilized for setting up of above large scale Solar PV plant. Sambhar Lake is a designated Wetland and important Bird Area Site, which requires wetland clearance required from MOEF.

For the project, a pre feasibility report (PFR) has been prepared. As per the PFR the project is planned to be established in a phased manner with 1000 MW capacity in first phase, utilizing about 4000 acres of above land, and remaining 3000 MW may be considered for development at later phases. The total estimated cost of 1000 MW Solar Plant is about Rs. 7500 Cr. including land cost. Crystalline Silicon Technology has been selected for setting up of phase-1 project with target implementation period of in about 3 year period including 1 year accounted for tendering & clearance and obtaining necessary approval.

To implement above project, a joint venture company (JVC) is being set up amongst JV partners viz. Sambhar Salts Ltd (SSL), BHEL, Solar Energy Corporation of India (SECI), SJVNL, POWERGRID & Rajasthan Electronic & Instruments Ltd (REIL) for implementation of Phase-1 (1000 MW) project.

<u>Transmission System</u>

Considering the time frame for implementation of the above project (in early 13th plan), studies have been carried out taking into account the power scenario in that particular time frame as well as availability of planned transmission & generation capacity addition.

POWERGRID along with CEA, State Transmission Utilities(CEA) has also evolved a comprehensive scheme viz. “***Green Energy Corridors***” comprising Transmission infrastructure at the level of Intra state for absorption of RE power within host state as well as Inter State to facilitate onward transfer of RE power for the envisaged renewable capacity (33 GW) in the 12th Plan. Implementation of above transmission scheme in 3 years' time would be a challenge however assumed to be available in the target study period. As some of the Green Energy corridors traverses near to proposed location of Sambhar Ultra Mega Solar project, interconnection of Sambhar UMPP with one of the nearby 765/400kV Ajmer Substation at 400kV level, to be implemented as part of Green Energy Corridors scheme, is proposed.

In addition, Govt. of Rajasthan has also planned a 3000 MW Ultra Mega Solar project in Bhadla in Thar desert area for development in early 13th plan, which has been considered in the above studies. Considering above, following transmission corridors have been identified for envisaged renewable generation (4 GW) in Sambhar for the identified time frame.

Transmission system associated with Sambhar Solar UMPP (4000MW)

- Sambhar Solar UMPP – Ajmer 400kV D/c line (Triple) – 85 km
- ± 500 kV, 3000 MW Sambhar Solar UMPP - Muzaffarnagar/Meerut HVDC Bi-Pole – 500 km
- Establishment of ± 500 kV, HVDC terminal stations (3000 MW) each at Sambhar & Muzaffarnagar/Meerut
- Muzzafarnagar – Roorkee 400kV D/c -70 km
- Muzzafarnagar – Merrut 400kV D/c -70 km
- Establishment of 400/220kV, 8x500MVA Substation at Sambhar Solar UMPP

Estimated Cost – Rs. 4000 Cr.

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Load flow results for Base case & contingency scenario with the above proposed transmission ssytem is enclosed at ***Annexure-5-1***. From the results, it is observed that line loadings under base case as well as contingency condition is found to be in order.

In addition to above, there would be requirement of Intra State transmission strengthening (estimated cost about Rs 1500 Cr) for absorption of RE power in host state which would also be determined based on the identified traget beneficiaries.

Schematic of above transmission strengthening is shown at Fig 5-3 as under.

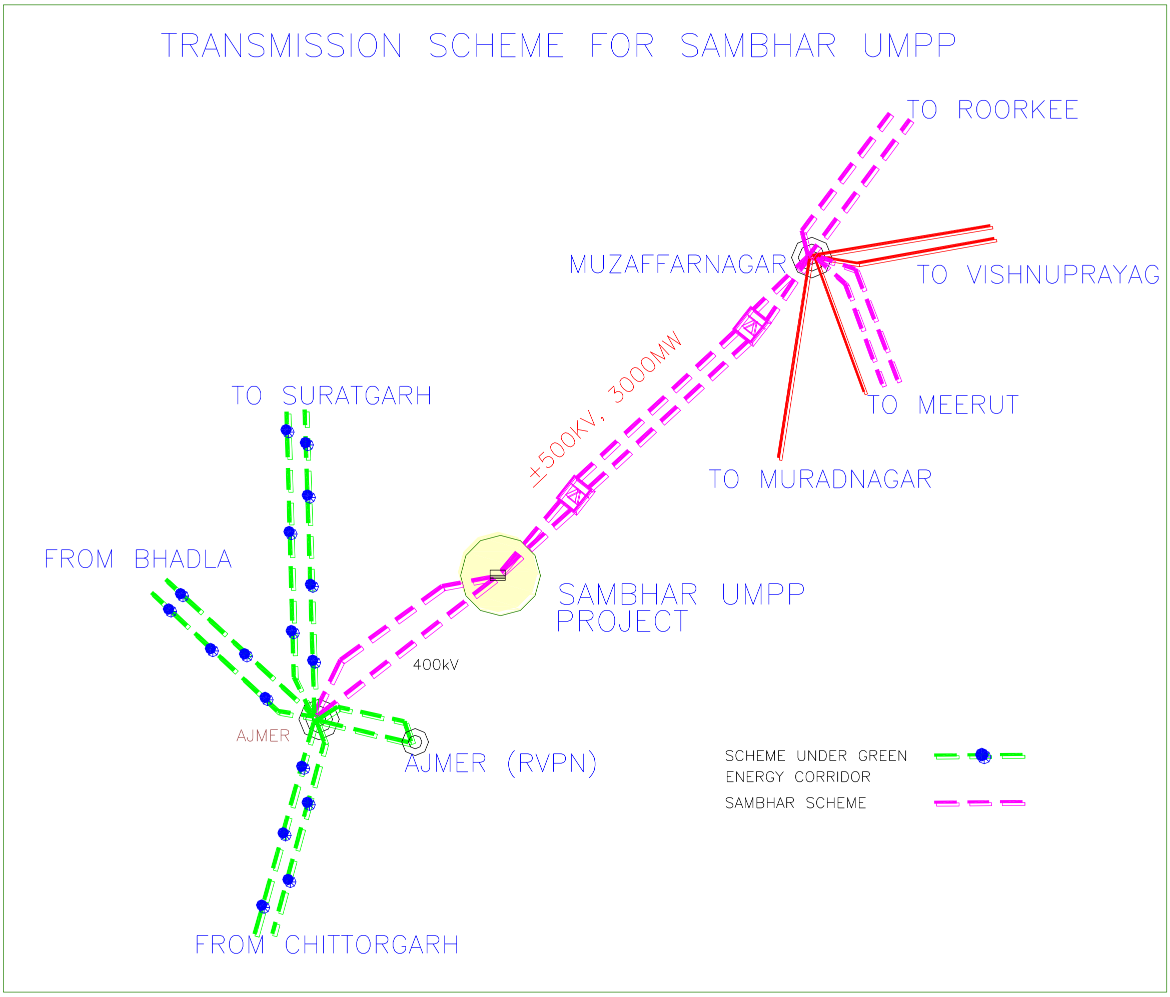

Fig 5-3 : Proposed transmission Scheme for Sambhar Solar UMPP

5.4.2. Kharagoda UMPP (4700MW)

Hindustan Salts Limited/Sambhar Salts Ltd also has surpls salt pan lands (about 18,000 acres) at Kharaghoda which is located at the end of Little Rann of Kutch in Gujarat state. This site (Figure-5-4 & 5-5) has also have large estimated potential of both types of renewable energy i.e.solar & wind.

Figure 5-4: Project Location

Site falls under wetland category as well as within the limits of Wild Ass Sanctuary. In this regard, EIA study is to be carried out and will need clearance from State and Central Wild Life Board. Site submergence during rain season would need to be addressed through proper design/drainage system.

MNRE has envisaged a 4700 MW renewable park in Kharaghoda, that would include 700 MW of wind power and balance 4000 MW based on solar power for development in mid of 13^{th} plan.

Fig 5-5: Project Location (Latitude: 23.20°N Longitude: 71.73°E)

Transmission System

Considering the time frame for implementation of the above project i.e. mid 13th plan, studies have been carried out taking into account the power scenario in that particular time frame as well as availability of planned transmission system & generation and following transmission system is identified for evacuation of the proposed generation.

In order to develop a strong National Grid, a high capacity transmission corridor is being conceptualised from Kutch generation complex (Gujarat) to Southern region. To optimally utilize transmission corridors and address ROW issues, it is proposed that Kharaghoda Solar Complex can be integrated with Kutch Complex. Considering above, HVDC system is proposed to be developed initially with 3000 MW terminal capacity which can be upgraded to 6000 MW in case Kharaghoda complex is integrated with other nearby conventional generation complex through multi-terminal HVDC.

Transmission system associated with **Kharaghoda Solar UMPP** (4700MW)

- Kharaghoda Solar UMPP – Banaskanta 400kV D/c (Triple)- 155 km
- ± 800 kV, 3000 MW Kharghoda Solar UMPP - Dabuspet /Near Bangalore HVDC Bi-Pole (provision to upgrade the HVDC terminals to 6000MW at a later date)-1500 km
- Dabaspet – Nilmangala 400 kV D/c (Triple)- 30 km
- Dabaspet- Mysore 400kV D/c -140 km
- Establishment of ± 800 kV, HVDC terminal stations (3000 MW) each at Kharghoda & Dabuspet /Near Bangalore
- Establishment of 400/220kV, 9x500MVA Substation at Kharaghoda Solar UMPP
- Establishment of 400/220kV, 2x315MVA Substation at Dabaspet/Nr. Bangalore

Estimated Cost – Rs. 6000 Cr.

Load flow results for Base case & contingency scenario with the above proposed transmission ssytem is enclosed at ***Annexure-5-2***. From the results, it is observed that line loadings under base case as well as contingency condition is found to be in order.

Schematic of above transmission strengthening is shown at Fig 5-6 as under.

In addition to above, there would be requirement of Intra State transmission strengthening (estimated cost about Rs 2000 Cr) for absorption of RE power in host state which would also be determined based on the identified traget beneficiaries.

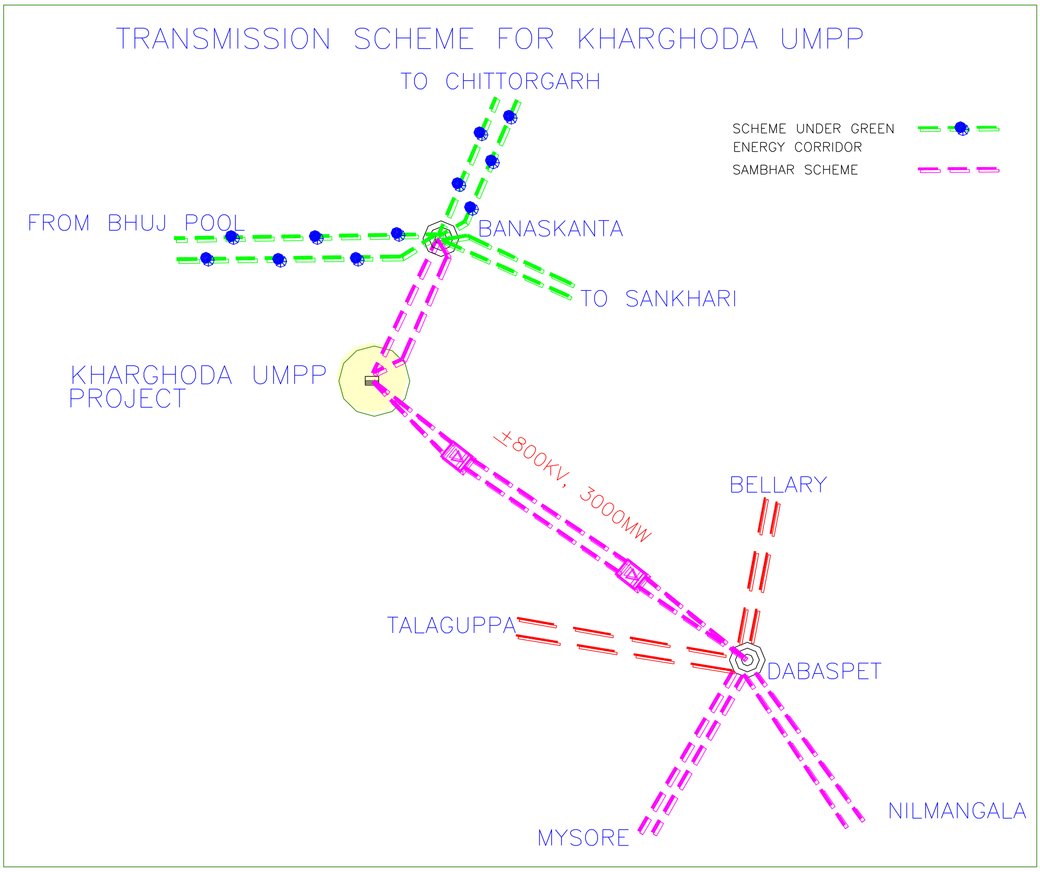

Fig 5-6 : Proposed transmission Scheme for Kharaghoda Solar UMPP

5.4.3. Leh/Kargil UMPP (2400 MW)

MNRE has also envisaged setting up of a Ultra Mega Solar Power Project (2400MW) in desert waste land of Kargil (1800 MW) & Leh (600 MW) (Jammu & Kashmir) (Fig-6) by the end of 13th plan (2021-22). Site identification are being carried out in association with **Ladakh Autonomous Hill Development Council (LAHDC)** for various blocks suitable for such installation.

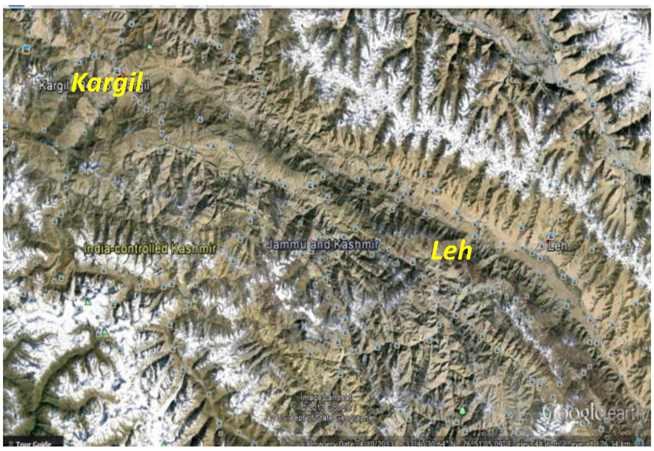

Fig 5-6: Kargil/Leh Ultra Mega Solar Power Project Location

Transmission System

Considering the time frame for implementation of the above project i.e. 2021-22, (end of 13th plan), studies have been carried out taking into account the power scenario in that particular time frame as well as availability of planned transmission system & generation and following transmission system is identified for evacuation of the proposed generation.

Considering hilly terrain and ROW constraints in Leh (600 MW) and issue of weak short circuit strength around Leh/Kargil, VSC based HVDC technology is being used which can be also developed in a modular approach (375 MW terminal) depending on development of Solar generation capacity and commensurate increase in power transfer requirement.

Transmission system associated with **Leh/Kargil Solar UMPP** (2400MW)

- ±500kV, 4x375 MW Kargil Solar UMPP – Leh VSC based HVDC Bipole– 200 km
- ±500kV, 5x375 MW Leh Solar UMPP – Parbati Pooling HVDC Bipole - 450 km
- Parbat Pooling (HP)– Mohali 400kV D/c -250 km
- Mohali –Panchkula 400kV D/c -30 km
- Establishment of ± 500 kV, VSC based HVDC terminal station (4x375 MW) at Kargil
- Establishment of ± 500 kV, VSC based HVDC terminal station (5x375 MW) at Leh
- Establishment of ± 500 kV, VSC based HVDC terminal station (5x375 MW) at Parbati Pooling
- Establishment of 400/220kV, 2x500 MVA transformation level at Mohali
- Establishment of 400/220kV, 3x500 MVA transformation level at Kargil Solar UMPP
- Establishment of 400/220kV, 2x500 MVA transformation level at Leh Solar UMPP

  Estimated Cost – Rs. 4800 Cr.

Load flow results for Base case & contingency scenario with the above proposed transmission ssytem is enclosed at ***Annexure-5-3***. From the results, it is observed that line loadings under base case as well as contingency condition is found to be in order.

Schematic of above transmission strengthening is shown at Fig 5-7 as under.

In addition to above, there would be requirement of Intra State transmission strengthening (estimated cost about Rs 1500 Cr) for absorption of RE power in host state which would also be determined based on the identified traget beneficiaries.

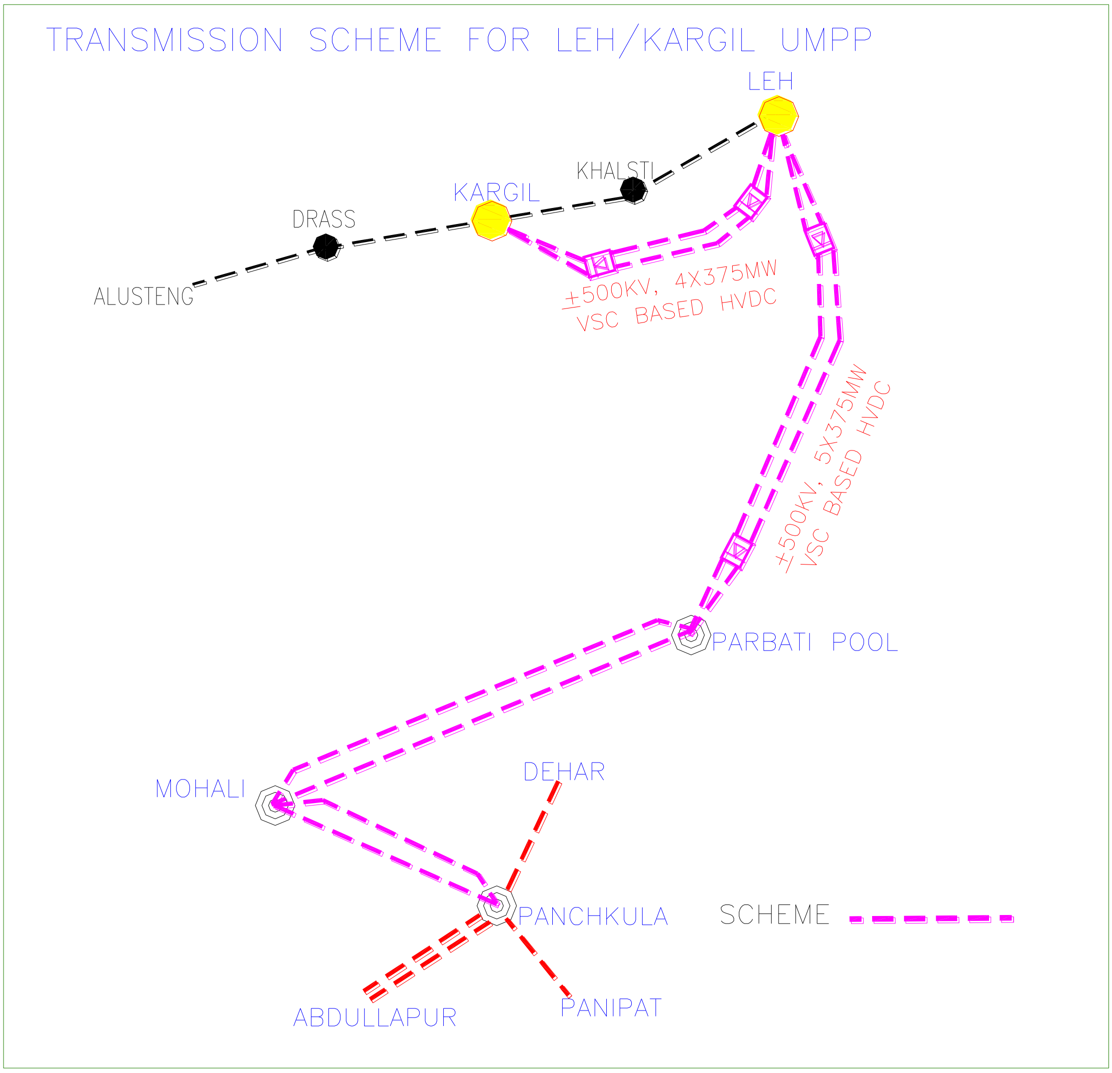

Fig 5-7 : Proposed transmission Scheme for Leh/Kargil Solar UMPP

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5.5. Balancing Requirement

In order to address volatility of renewable generation, balancing reserves are needed which can provide support. For this, to encourage conventional generation to participate as flexible generation, it shall be required to be compensated (Rs 1/unit fixed charges & Rs 0.5/unit opportunity cost).

Therefore, balancing of Renewable generation (11 GW) [19 BU/annum energy generation] would require earmarking of about Rs 2850 Cr/annum to compensate conventional generation participating as flexible generation (Rs 1/unit fixed charges & Rs 0.5/unit opportunity cost for 19 Billion units per annum considering 20% CUF).

5.6. Total Investment requirement

Total Investment requirement for development of Transmission & balancing infrastructure for above 11 GW Solar UMPP at identified locations viz. Sambhar (Rajasthan), Kharaghoda (Gujarat) and Leh/Kargil (J&K) is as under:

(A) Transmission Strengthening : about Rs 19,800 Cr

- Inter State Transmission Strengthening : Rs 14,800 Cr
- Intra State Transmission Strengthening: Rs 5,000 Cr

(B) Balancing Infrastructure : Rs 2850 Cr/annum

5.7. Transmission Requirement for Renewable in Desert in 15th Plan (2031-32)

In continuation to above, transmission requirement in medium term i.e. 15th Plan (2027-32) for envisaged renewable generation capacity (about 235 GW) is also evolved. Out of above capacity, total renewable capacity in deserts is envisaged to be about 130 GW which considers about 119 GW capacity addition [Wind- 12 GW, Solar -95 GW] in the span of a decade (2022 to 2032). However to take care of balancing requirement, about 12 GW CSP capacity is proposed in that time frame.

Table-5-4: Transmission Capacity requirements from Deserts : 2031-32

S No	Desert	Desert Renewable Capacity addition (GW)	CSP capacity (GW)	Already covered in 13th plan (GW)	Net Desert capacity (GW) (Total-CSP-13th plan)	Transmission capacity Requirement @80% of net capacity
1	Rann of Kutch	14	2	5	7	6
2	Thar	97	8	4	85	68
3	Laddakh	17	2	2	13	10
4	Lahul & Spiti	2	-	-	2	2
	Total	***130***	***12***	***11***	***107***	***86***

Considering above, following transmission corridors have been identified for envisaged renewable generation in desert/wasteland generation complexes viz. Rann of Kutch, Thar, Laddakh and Lahul & Spiti for the time frame of 2031-32.

Table-5-5: Transmission Corridors : 2031-32

S No	Desert	Transmission capacity Requirement @80% of net capacity (GW)	Transmission corridors	
			HVDC Bipole	**UHV AC* (1200 kV S/c)**
1	Rann of Kutch	6	1 no. ±500 kV, 2X375 MW MTDC (VSC)	2 nos.
2	Thar	68	2 no. ±500 kV, 8X375 MW MTDC (VSC) 1 no. ±800 kV, 6000 MW MTDC	8 nos.
3	Laddakh	10	4 no. ±500 kV, 6X375 MW (VSC) 1 no. ±500 kV, 8X375 MW (VSC) 1 nos. ±800 kV, 6000 MW (MTDC)	2 nos.
4	Lahul & Spiti	2		
	Total	***86***	***10 nos.***	***12 nos.***

**1200kV transmission corridors have been envisaged keeping in view the quantum of Power transfer requirement, distance involved as well as addressing ROW issues. As on date it seems difficult to operate the transmission corridors at 1200kV level, however keeping in view the future requirement, it is prudent to address the various issues like variation in power flow over 1200kV corridors, reactive power management etc on immediate basis so that smooth operation in future is feasible.*

Otherwise instead of 1200kV corridors, the same will be developed with 765kV technology for which more no. of corridors shall be required. Alternately, emphasis may be given to develop the High Temperature Superconducting (HTS) line each having 6000-8000 MW capacity at 4000kV level instead of 1200 kV corridor for which developmental project of HTS line need to be taken up urgently.

RANN OF KUTCH COMPLEX

- ±500kV 2x375MW Kutch RE PP1- Thar RE PP3 VSC based HVDC Bipole ***(TRC-1)***

- 1200kV Kutch RE PP2– Vadodara (Gujarat/WR) 2xS/c & 1200kV Vadodara - Pune (Maharashtra/WR) S/c ***(TRC-2)***

  Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 10,000 Cr.

THAR COMPLEX

- 1200kV Thar RE PP1– North Punjab (Near Amritsar) S/c ***(TRC-3)***
- 1200kV Thar RE PP2– Thar RE PP1 – Central Punjab (Near Jalandhar) S/c ***(TRC-4)***
- 1200kV Thar RE PP2– Central Rajasthan (Near Ratangarh) – Haryana (Near Hissar) S/c ***(TRC-5)***
- 1200kV Thar RE PP3– Thar RE PP5 - Central Rajasthan (Near Ratangarh) – Delhi/Haryana S/c ***(TRC-6)***
- 1200kV Thar RE PP3 - Thar RE PP6–East Rajasthan (Near Jaipur) – Western UP (Near Agra) - Central UP (Near Lucknow) S/c ***(TRC-7)***
- ±500kV 8x375MW Thar RE PP3 – Delhi/Haryana VSC based HVDC Bipole ***(TRC-8)***
- 1200kV Thar RE PP4 - Thar RE PP6 – East Rajasthan (Near Jaipur) - Delhi/Haryana S/c ***(TRC-9)***
- 1200kV Thar RE PP5–Central Rajasthan (Near Ratangarh) – Delhi/Haryana S/c ***(TRC-10)***
- ±500kV 8x375MW Thar RE PP5 – Maharashtra (Near Pimpri- Chichwad/1500MW) –South Karnataka (Near Mysore/1500MW) HVDC Bipoles (Multi terminal) -***(TRC-11)***
- 1200kV Thar RE PP6–East Rajasthan (Near Jaipur) – Western UP (Near Agra) – Eastern UP (Near Kanpur) S/c ***(TRC-12)***
- ±800kV 6000 MW Thar RE PP7 – Central MP (Near Indore/3000MW) – North AP (Near Hyderabad/3000MW) HVDC Bipole(Multi Terminal) ***(TRC-13)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 60,000 Cr.

LEH AND LAHUL & SPITI COMPLEX

- ±500kV 6X375 MW Kargil RE PP1 – North Punjab (Near Gurudaspur) VSC based HVDC Bipole ***(TRC-14)***

- ±500kV 6X375 MW Kargil RE PP2 – North Punjab (Near Gurudaspur) VSC based HVDC Bipole ***(TRC-15)***
- 1200kV North Punjab (Near Gurudaspur) – Punjab/Haryana (Near Mohali/Chandigarh) S/c
- ±500kV 6X375 MW Leh RE PP1 – Pooling point in Himachal (Near Shimla) VSC based HVDC Bipole ***(TRC-16)***
- ±500kV 6X375 MW Leh RE PP2 – Pooling point in Himachal (Near Shimla) VSC based HVDC Bipole ***(TRC-17)***
- 1200kV Pooling point in Himachal (Near Shimla) – Delhi/Haryana S/c
- ±500kV 4X375 MW Kargil RE PP3 – Leh RE PP3 VSC based HVDC Bipole ***(TRC-18)***
- ±500kV 8X375 MW Leh RE PP3 - Lahul & Spiti PP (NR) VSC based HVDC Bipole ***(TRC-19)***
- ±800kV 6000 MW Lahul & Sipti PP(NR) – West MP (Near Bhopal) – Maharashtra (Near Mumbai) HVDC Bipoles ***(TRC-29)***

Provision of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions is also included.

Estimated Cost: Rs 40,000 Cr.

5

In addition to above corridors, transmission corridors from Hydro Complexes of NER/Bhutan to meet balancing requirement is also proposed.

NER/ER-NR INTERCONNECTION

- Multi terminal ±800kV 6000MW NER/Sikkim/Bhutan/UP location -Delhi/Haryana load centres HVDC Bipole – 1 nos. ***(TRC-20)***

Estimated Cost: Rs 15,000 Cr

Total Estimated Cost (All Complex): Rs 1,25,000 Cr

Additionally, there would be requirement of Intra State Strengthening scheme of about Rs 60,000 Cr for absorption of renewable power within states. Further, there would be requirement of balancing cost to compensate conventional generation participating as flexible generation/spinning reserves etc.

Schematic of perspective high capacity transmission corridors for desert power by 2032 is shown at Fig-5-8.

Note : Above scheme is a tentative transmission plan to facilitate power transfer from the renewable generation complex in the desert region to major load centers. Exact terminal location shall be finalized based on the progress of capacity addition programme, load growth pattern during the implementation stage.

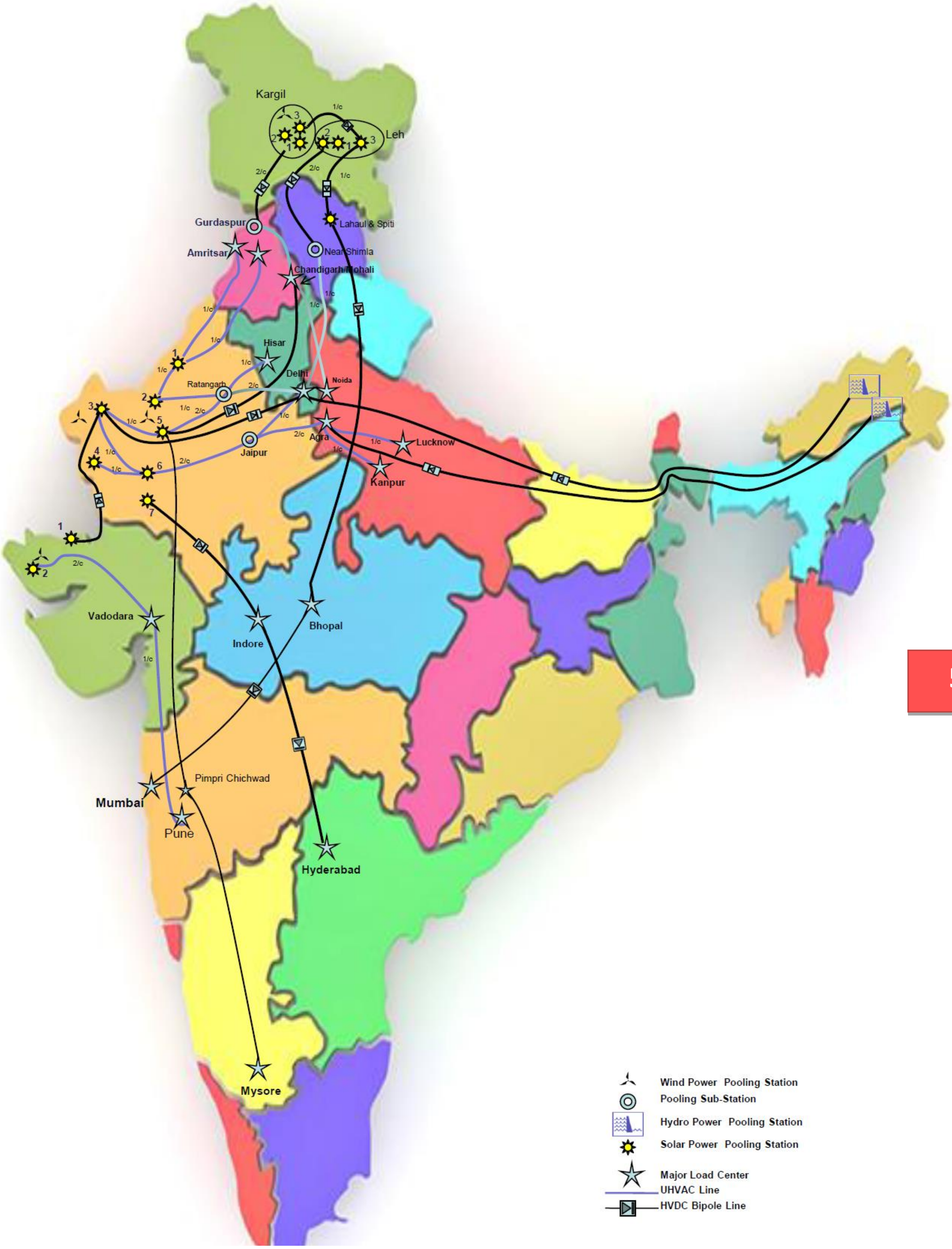


Figure 5-8: High Capacity Transmission Corridors for Desert (2032)

Various challenges and impact of desert power development is analysed in the next chapter

CHAPTER 6

Challenges and Impact of Desert Power Development

CHAPTER 6

Challenges & Impacts of Desert Power Development

Deserts are viewed as vast land areas with inhospitable surfaces, underground wealth, sunny and windy climate conditions and severe living conditions for inhabitants including wildlife. Development of renewable potential of deserts offers many challenges. Following section deliberates on Challenges of desert power development, its impact on human, wildlife, economy etc. Based on the challenges, an Implementation strategy in regard to development of renewable generation and transmission development is also proposed.

6.1. Challenges

(i) Adverse terrain conditions

The desert areas of Thar, Rann of Kutch, Ladakh, Lahul & Spiti valley etc. are very difficult regions for inhabitants offering challenges in terms of very rough climate/weather and terrestrial conditions.

Thar desert is an arid region in the northwestern part of India. The amount of annual rainfall in the desert is generally low, ranging from about 100 mm or less in the west to about 500 mm in the east. May and June are the hottest months of the year, with temperatures rising to 50 °C. Dust storms and dust-raising winds, often blowing with velocities of 140-150 km per hour, are common in May and June, summer days.

Rann of Kutch, is a seasonal marshy saline mudflat having average level of 15m above sea level and filled with standing water. It is inundated during monsoon seasons and receives about 500 mm annual rainfall . It is one of the hottest areas of India - with summer temperatures averaging 44°C and peaking at 50°C. Winter temperatures reduce dramatically and go below 0°C.

Ladakh is a cold desert in northwestern part of country. The amount of annual rainfall in this desert is generally low, ranging from about 80-100 mm or less. In peak winters, the temperature in Ladakh goes down to (-)30°C in Leh and Kargil and (-)50°C in Drass. Temperatures remain in minus for almost 3 months from December to the month of February. On clear sunny days, it also becomes very hot.

Lahaul & Spiti valley has limited rainfall (Lahul: 100-400 mm & Spiti- 12 cm) and high altitude, mostly above 3000m, which results in harsh cold conditions in winter with temperatures even below -30°C. In summers, temperatures rarely rise above 15°C.

Above, severe climatic conditions in certain months in deserts, do not allow round the year working and therefore "No work days" would be a considerable part in total construction period leading to more gestation periods than on main lands. All the above four regions are having very tough climate and geographical boundaries, which requires inhabitants with great will to work, determination etc.

Tough climatic conditions like Monsoon floods & salty atmosphere in Kutch, dust storm in Thar would require frequent maintenance & cleaning of equipment especially Solar PV/CSP plants. Ladakh remains unapproachable for 5-6 months in a year by road. This would require higher inventory & spares to keep the system running.

Technical Design Consideration

All above deserts offer different challenges in terms of technical design of mounting structures for Solar panels. Rann and Ladakh/Lahul found to be very challenging in terms of such designs.

The marshy soil of Rann of Kutch requires detailed testing of expansive nature of soil. Typical marsh land terrain with dynamic water table is shown in Fig-6-1 below:

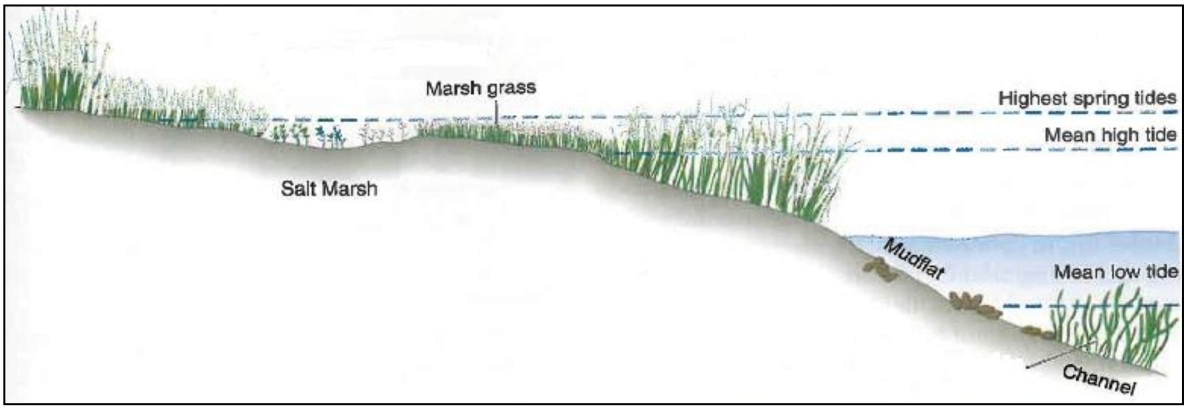


Fig. 6-1 Marsh lands terrain – Soft soil rich with dynamic water table

Expansive soil makes the foundation to settle drastically & topple sometimes due to eccentricity in bearing dead load of solar panels. Load bearing capacity (SBC) of such terrain is 3 to 4 times lesser than the denser soil terrain. Based on above characteristics of the expansive soil, Pile foundation designed (Fig 6-2) is preferred for mounting structures.

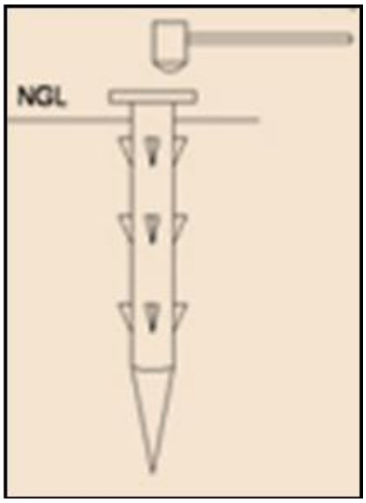


Fig. 6-2 : Special Pile for expansive soil

If soil conditions are certified to be highly expansive in nature for the place of installation, it can be made stable by grouting, artificial drainage & other techniques. However the same shall be very cost intensive.

Leh/Ladakh & Lahul-Spiti presents challenges in terms of sloppy terrain and landslide events (Fig 6-3). Excavation is not a preferred choice in these terrains as it affects virgin soil nature. Disturbed soil also gives poor shear strength leading to lesser resistance to slop stability. This leads to landslide & Cave-in or under-cut issues.

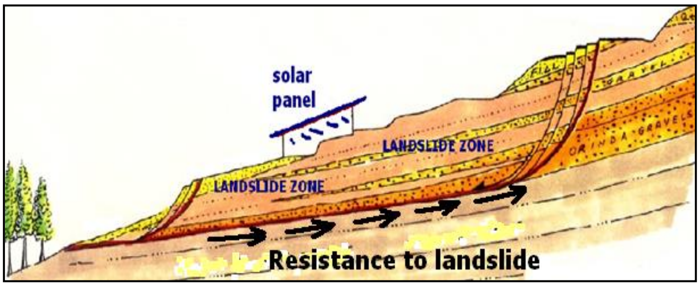


Fig. 6-3 : Landslide- Sloppy terrain & Soil resistance

To meet above requirements, it is proposed to use driven helical foundations. Helical foundation installations are relatively faster but require skilled manpower. To install higher bearing capacity foundations, crawler mounted drivers are also required (Fig-6-4).

Fig. 6-4 Helical Foundation – Crawler mounted driller

(ii) Infrastructure Constraints

Due to very tough terrain condition, Indian deserts have very thin population density. As per Census of India (2011), population density of Lahul & Spiti valley is 2 per sq km and Leh/Ladakh is about 3 per sq km whereas Jaisalmer in Rajasthan has only 17 per sq km against national average of 382 per sq km (Fig-6-5).

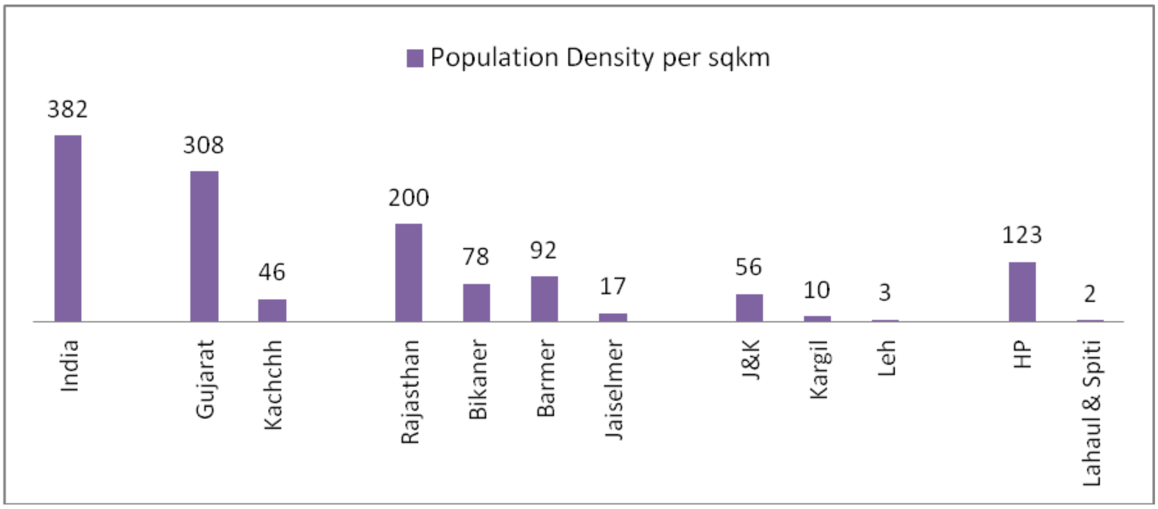


Figure 6-5: Population density of different desert area & their states

Due to above reasons, it lacks availability of basic infrastructure like roads & highways, water supply system, power network, railways, telecom and other public utilities. Absence of these infrastructures provide a major challenge in setting up renewable generation plants as well as transmission infrastructure including substations. Following constraints are foreseen on account of lack of infrastructure availability in desert areas :

- Due to non-connectivity of roads & railways, equipment transportation to the site will be an issue
- Lack of potable water facility will make deployment of working manpower very difficult
- Poor power infrastructure will create an issue in providing construction power to developer as well as working human resources

- Absence of communication infrastructure would affect project management & living standard of working manpower

In view the above addressed infrastructure limitations, lot of transportation cost would incur towards construction material/manpower etc. leading to increase in establishment cost.

(iii) Manpower Availability

As discussed, desert areas are very thinly populated. Inhabitants staying in these areas are mainly tribes whose main occupation is agriculture and animal husbandry. Therefore skilled manpower for construction and O&M would be required from other parts of country. Since dessert areas are far flung and have difficult climatic conditions along with poor infrastructure development, it would be huge challenge to bring skilled manpower at task, which shall be cost intensive.

(iv) Transmission Infrastructure Development

Deserts are located very far from electricity demand centers, which would require establishment of long distance transmission lines along with substations to evacuate & transfer renewable power to distant load centers. Considering above discussed infrastructure constraints, development of transmission infrastructure, O&M of Substations/Lines will also face similar challenges as discussed for establishment of renewable generation plants.

(v) Technical Challenges for Generation Plants

In very dry and desert like environments, most of the module soiling may be inorganic wind borne solids (dust and dirt particles) that are electro statically attracted to the solar module's glass surface both solar PV panels & heliostats for CSP as a result of dry winds. Additionally, some of this dust may consist of abrasive inorganic minerals (e.g. silica) which may scratch and damage the surface of the modules. Therefore, dust is considered to be major problem in operation of solar plants in desert.

In more cooler and wet environments (Cold deserts & Coastal location), most of the module soiling may be organic deposits including wind borne dirt, bird and other animal droppings, pollution (soot from burning coal or diesel), as well as decomposing organic plant matter from leaves, pollen, etc. When these materials become wet, they may be spread over the panel surface and further bond to it, causing potential corrosion and leaching of irons and reduce overall efficiency of plant. In coastal areas, there may be salt deposits on the panel's surfaces resulting from water spray and rain driven dirt.

Allowing dirt to build up, can also lead to local overheating inside the solar modules, so called hot spots. Hot spot heating occurs when a single cell in a series string generates less current than the module, because the cell is shaded (as a result of dirt build up) or otherwise damaged. Hot spots are parts of your solar modules where heat is produced instead of electrical power. These hot spots not only decrease the energy efficiency of solar modules but they can also reduce the life time significantly.

Therefore, Solar PV panels and concentrator mirrors (heliostats) needs to be cleaned almost daily if efficiencies are to stay where they need to be. As per the statistics, even just one (1) gram of dust per square meter of solar panel area can reduce efficiency by around 40 %. In the desert, near Abu Dhabi in the United Arab Emirates, the Middle East's first large CSP plant recently faced down the dust issue. In order to reach the 100 MW capacity goal of the plant, developers had to add substantially more mirrors to the plant than planned originally due to dust in the atmosphere.

Water is scarce in Desert. However, Photovoltaics (PV) panel, needs lot of water (demineralised /osmosis water) to clean the panels. Normal water may leave mineral deposits after evaporation which is another issue. CSP plants require water predominately for cooling steam in condensers as well as for cleaning. A CSP plant's cooling water requirement is similar to a coal-based power plant. Proposed CSP location being in deserts which is arid regions lacks water availability.

Since Solar PV will occupy large desert area, it is prudent to adopt suitable mechanism of collection of Rain water precipitating on the panels and store suitably for future use.

However, latest dry cleaning technology which doesn't involve water usage like automated "dry sweep" cleaning solar panel robot (Wallwalker) or "no-water mechanical automated dusting device" (NOMADD) which is a simple, rugged and low-maintenance could be explored (Fig 6-6).

Figure 6-6: Dry Cleaning Technology for Solar Panels

Technology choices to reduce CSP's water demand are also available, but affect the levelized cost of electricity. An Indian electricity regulator study found that the most water efficient technologies i.e. Dry Cooling technology reduce water consumption by 90%. In dry Cooling technology, air directly cool steam in condenser and needs only 300 litres/MWh, or 10% of wet cooling for parabolic trough CSP (3000 litres/MWh) however results in an 8 -9 % increase of electricity tariff due to production loss (about 7%) compared to wet cooled system.

Certainly wind speed in the desert area is going to play a vital role in deciding the technology for harnessing the solar energy. The remote regions of Leh-Ladakh experience high wind speeds upto and beyond 200 kmph. Designing solar concentrators for these regions require special care regarding the stress analysis from all possible angles. The normal design of reflector stand which is installed in the mainland can be made to withstand upto 180 kmph. For the design of concentrators frame, reflector Stand, supporting channels for tracking are required to be stress analysed. Weather erosion and high ambient temperature fluctuations is also a factor to be taken into consideration here.

For the purpose of using systems in deserts, special care has to be taken such that they are properly insulated against the rapid fluctuations of temperature. In Cold deserts, there is constant problem of freezing of Water and Ice Formation inside the piping. Therefore, higher insulation thickness has to be used for steam lines / riser and down comer which has the propensity to increase costs disproportionately.

Also civil activity for desert / mountainous regions is another factor which has to be taken into consideration. This might increase the cost estimates more than those installed in mainland habitable areas. For instance, as mentioned earlier, Leh/Ladakh offers only a small window of 4-5 months for any construction or field activity.

Above challenges are needed to be conquered for enabling utilization of renewable power in desert areas. There is a need to formulate road map and way forward strategically so that successful implementations of desert power development schemes may be done.

6.2. Socio-economic Impacts

(i) Human kind Impact

Desert power not only encourages economic growth by providing electricity; it also has positive socio-economic benefits, such as the creation of new jobs, the growth of new industries, infrastructure development etc.

A competitive local renewables industry is essential to fully benefit from desert power's socio-economic impacts. For a successful local industry to emerge, however, the desert region's pressing human capital challenges need to be addressed. Without improvement, the region's current deficits in education will limit the availability of skilled manpower and, thus, will impede the expansion of a local renewables industry. What is required is an enabling desert area education policy – an education policy that will allow the groundwork to be laid for a renewables industry, but will also encourage the greater accumulation of skills in desert areas.

Deserts are known for their arid nature and have very little agricultural/habituated lands. Indian desert areas have low population density therefore impact out of land acquisition and rehabilitation is not much of a concern. Widely known "Acoustic Pollution" due to Wind turbine is however also not poses any issues due low population density in theses deserts. However govt/authorities shall need to be approached to obtain requisite clearances as well as facilitate land acquisitions for generation project siting as well as substations establishment in order to have expeditious project implementation.

(ii) Wild Life Impact

Large scale renewable energy projects in the desert may interfere with wildlife and disrupt local habitat. For instance, wind turbines, if not carefully sited, can kill birds or bats. As wind turbines require them to be dig deep into the earth, this could have negative effect on the underground habitats. Studies have also shown that animals see the wind turbine as a threat to their life.

Large solar energy projects can take up hundreds or even thousands of acres and may disturb reptiles, wild animals or other habitat. Such plants typically are fenced which limits movement of animals. Constructions of such large sized plants also require soil scraping to bare ground which may disturb habitats underneath the ground. So broadly, the impact of wildlife is tightly correlated with the biodiversity which requires an eco-system impact analysis so that mitigative measures may be taken to avoid threat to the ecosystem in case of high impacts.

The Rann of Kutch, Thar and Ladakh are three(3) different regions with different ecosystem. They are habitat for many plants / animals which are on the verge of extinction. The Great Rann of Kutch is the only place in India which is a breeding ground for flamingos and pelicans. The Little Rann of Kutch is famous for the Indian Wild Ass Sanctuary, home of the world's last population of Indian wild ass.

The Thar desert has two wildlife sanctuaries, viz. the Desert (Barmer, Jaisalmer) and Tal Chappar (Churu) sanctuaries. These sanctuaries also protect the Great Indian Bustard, whose 70% of the country's population is found here. Ladakh is also having rare ecosystem. The Bactrian magpies, Turkoman rock pigeon, desert wheaters, buntings, larks, kite, kestrel and many kinds of finches, ducks, geese and hundreds of species of rare Himalayan birds inhabits in this region. Black necked Cranes migrate to Ladakh in summer season.

Though renewable power generation affects minimally to environment, **clearances from statutory authority** would be required and care should be taken during construction so that there is no adverse impact on wild life.

6.3. Implementation Strategy

Government shall have to play a key role in development of desert renewable potential. Following broad areas have been identified where government's role shall be required:

- Formulation of National Desert Mission focussing on desert power development
- Provision of Single Window clearance for developers similar to Ultra Mega Power Projects for conventional generation
- Formulation of consistent & stable policies to encourage development of renewable generation in deserts, its integration into grid, balancing infrastructure etc.
- To address Right-of-way for development of transmission system associated with renewable generation, high capacity transmission corridors are to be developed keeping in view long term power transfer requirement. However, as the generation projects materialises in phased manner, during initial period utilisation of corridors will be less. Therefore, innovative funding mechanism like soft loan over longer terms, access of low cost financing, gap funding etc. may be arranged through national level desert policy.
- Development of associated Infrastructure in terms of approach road/rail/air for equipment transportation, Water transport facilities etc.
- Development of Desert Zones with Solar Plots and prioritisation of areas for development. Facilitating developers for the land acquisition on least cost/lease basis
- Policy for indigenisation of manufacturing as well as technology for Solar PV/CSP including Semiconductors cells & large scale Energy storage technology
- Capacity-building aimed at developing new generation of trained scientists, engineers, skilled manpower etc.
- Allocation of funds specific to desert power development including development of 400kV HTS line

- Considering quantum & stringent nature of work to be carried out, identification of suitable agency (ies) that have sufficient experience in development of generation projects, Transmission corridors, technical expertise as well as strong project management skills
- Setting up of National level Institutes for Renewable energy study
- Establishment of Centre of Excellences for Research, Development & Demonstration (RD&D) for Renewable technologies

6.4 Roles & Responsibilities of Statutory Bodies/Authorities towards implementation of measures

In order to facilitate implementation of various measures with desert power development, it is proposed that following actions may be taken up respectively by the Regulator, Statutory Authorities/MNRE, and CTU/STU etc.

S no.	Activities	Role/Responsibility
1	National Desert Mission/Policy to encourage desert power development	MNRE/Planning commission
2	Policy for identification of desert power zones/solar plot, land allotment, associated infrastructure development	MNRE/State Govt
3	Transmission Infrastructure development (ISTS/Intra State) – Planning – Implementation	CEA/POWERGRID/STU
4	Regulation for Flexible Generation, Ancillary Services and Generation Reserves – Market design	CERC/SERC
5	Energy Storage Technologies - selection, design & implementation	POWERGRID/CEA/POSOCO
6	Capacity Building	MNRE
7	Institutional arrangement (Roles & Responsibilities of Developers /DISCOM/STU/SLDC etc.) – incorporation in EA 2003	MOP/MNRE/CEA

S no.	Activities	Role/Responsibility
8	➢ Assessment / Reassessment of onshore and offshore wind Energy Potential and update of Wind Atlas ➢ Assessment / Reassessment of Solar Energy Potential and update of Solar Atlas	MNRE/C-WET
9	➢ Establishment of Institutes for renewable energy ➢ Setting up of centers of excellence for RD&D on renewables	MNRE/DST/MOP/CEA/POWERGRID

Keeping in view large scale deployment of solar/wind generation technology in desert regions over long-term, research, development & deployment (RD&D) exclusively in the filed of renewables need to be undertaken. In the next chapter, various areas of RD&D in renewables and way forward are highlighted.

CHAPTER-7

RESEARCH, DEVELOPMENT & DEMONSTRATION IN RENEWABLES

CHAPTER 7

Research, Development & Demonstration in Renewables

Renewable energy sources have a huge contribution to make in achieving our sustainable energy goals. As per International Energy Agency's ambitious BLUE MAP scenario published in Energy Technology Perspectives 2008, Renewable energy could meet almost half of global energy demand by 2050. Under this scenario, world greenhouse gas (GHG) emissions would be halved. By the end of the century, it is envisaged that global energy needs could be supplied mainly from renewable sources, although their contribution would vary from one region to another.

In order to exploit full potential of renewable energy, Research and Development (R&D) has a key role to play. Investment in R&D will not be delivered by market signals alone; extensive support at the national and international levels is needed to accelerate the development of renewable technologies.

Regardless of whether R&D is conducted with a long or short-term perspective, it must contribute to improved performance and cost reductions or otherwise help to reinforce the role of renewable energy in a sustainable energy system. Broad areas of focus for R&D activity should be:

- Improved performance, including conversion efficiency, reliability, durability and lifetime
- Advanced manufacturing techniques for components
- Reduced material requirements, especially for toxic materials
- Sustainable production processes that minimise life-cycle environmental impacts through manufacturing, use, recycling and final disposal
- Improved methods for integrating renewable energy into buildings, electricity grids and other distribution systems; socio-economic research aimed at developing effective policy measures that will encourage the deployment of renewables and enhance public acceptability of new energy technologies
- Capacity-building aimed at developing new generations of trained scientists, engineers and others

- Establishment of Institute for renewables, Center of excellence for research, development & demonstration for renewable technologies

Fostering competences in the development and deployment of renewable energy technologies across a wide range of countries is a prerequisite if ambitious visions for future sustainable energy systems are to be realised. This will ensure that countries like India at a critical stage of development do not have to suffer the financial burden of importing knowledge and necessary hardware. R&D has a particular role to play in helping to adapt technology to local needs and build capacity through fostering of skills and local enterprise. Thus, all countries can share the economic benefits associated with a transition to a sustainable energy system.

7.1. Research & Development Horizons

R&D targeted at different stages of the innovation chain will yield benefits in the short-term (up to five years), medium-term (5–15 years); and in the longer term (15 years plus). R&D with a short-term focus is needed to improve technologies that are already technically proven. More mature technologies include wind energy and the standard silicon-based conversion of solar energy to electricity in photovoltaic (PV) cells. Strong industries are already associated with these technologies and government deployment measures in several countries are helping to drive rapid market growth.

Much R&D with a short-term perspective will be provided by industry itself. But research activity in publicly-funded institutions (universities, laboratories and institutes) will also be needed. This will provide basic scientific insights and respond to the more fundamental science, engineering and socio-economic challenges that are inevitably thrown up in the process of demonstrating and deploying new technologies.

R&D with a medium and long-term perspective is needed to underpin long-term improvements in renewable technologies and enable breakthroughs that could give such technologies a decisive advantage in energy markets. The medium-term goal must be to ensure that renewables can compete successfully, without subsidy, once external environmental costs and other contributions to social goals (e.g. access, security) are taken into account. Medium- or long-term R&D efforts in this area will largely be developed through public sector support.

7.1.1. Broad Areas of RD&D for Renewables

Following research areas are found to be important in development of renewable generation technologies to facilitate high penetration level:

(i) Photovoltaic (PV)

- High efficiency modules for conventional crystalline silicon as well as thin-film applications based on silicon & other materials to improve yield
- Reduction in the consumption of silicon and other materials in conventional crystalline silicon applications
- Nano-structured devices such as organic, organic/inorganic hybrid devices and dye cells
- Improved power electronics to enhance output quality
- Integrated processing with increased automation across all module types
- Improved sustainability of production, including the use of recycled material, supported by life cycle assessment studies.
- Development of new age technologies like "Off shore" Solar

(ii) Concentrated Solar Power with Storage (CSP)

- Development of new generations of Heat Transfer Fluid (HTF) and Thermal Energy Storage (TES) medium like nanofluids primarily to lower cost of energy generated by CSP
- Technology to increase thermal & optical efficiency of receivers/collectors

(iii) Wind

- Fundamental design issues for very large turbines (up to 10 MW)
- Improved wind forecasting
- Development of support structures for offshore wind
- Analysis of offshore wind regimes and wind characteristics within large arrays
- Condition monitoring and remote maintenance options
- Environmental impacts and management offshore
- Interactions with telecommunications and radar systems

(iv) Other Areas of R&D in renewable integration

- Development of VSC based DC transmission technology for offshore wind as well as remote located utility scale Solar plants
- Development of High Temperature Superconducting lines including cryogenic cooling arrangement system
- Cost effective and larger density energy storage solutions with excellent cycle life

- The design of policy measures, regulatory arrangements and grid management procedures which promote and take account of the particular characteristics of renewable energy
- More reliable and specific information about the sustainable potential for renewable energy globally and regionally
- Contribution of renewables to development goals, particularly in rural areas
- The environmental impacts of renewable energy & social acceptability of renewable energy

7.1.2. Global Trends in R&D for Renewables

Energy-related research and development (R&D) played an important role in the successful outcome of modern era. Funding focused on the development of new knowledge and potential products or ideas related to renewable generation comes from private and (primarily) public R&D funds looking towards a long-term investment horizon with relatively uncertain returns. The share of global new investment in research in renewables technology in 2012 was about 4%. Global research and development (R&D) spending on renewable energy inched 1% higher to USD 9.6 billion in 2012, marking the eighth consecutive year rise as shown in Fig-7-1 below.

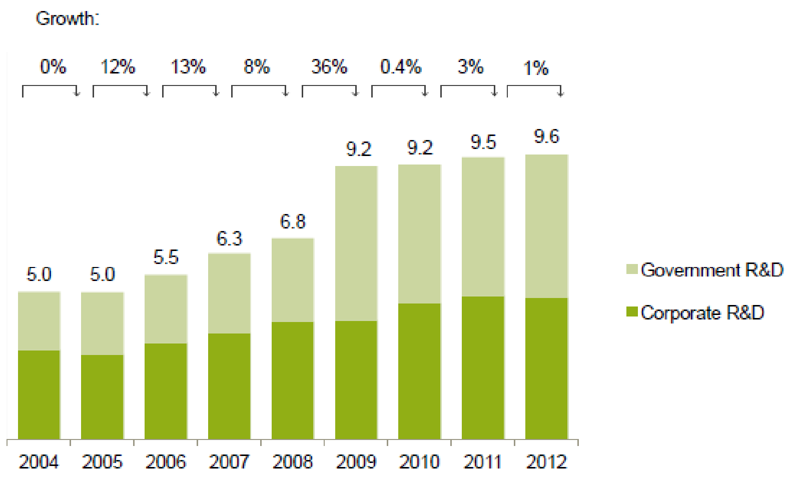


Fig 7-1 :R&D Investment In Renewable Energy, 2004-2012,$Bn (Source: Bloomberg, IEA, IMF, various Govt agencies)

Global R&D investment has almost doubled since 2004 in absolute terms (up 93%). Europe remained the largest centre for R&D in total, but China moved ahead on government spending. The United States was the only region to show positive, although modest, trends in both corporate and government outlays during 2012. In India, R&D expenditure for renewables in 11th Plan was about Rs 525 Cr (USD 87 million) and expected investment isn 12th plan is Rs 1150 Cr (USD 175 million). On the whole, globally, government R&D spending rose 3% to USD 4.8 billion, while corporate R&D fell 1% to just below USD 4.8 billion, making public and private spending broadly equal for the third year in a row. Region wise R&D Investment In Renewable Energy is also shown at Fig 7-2 below.

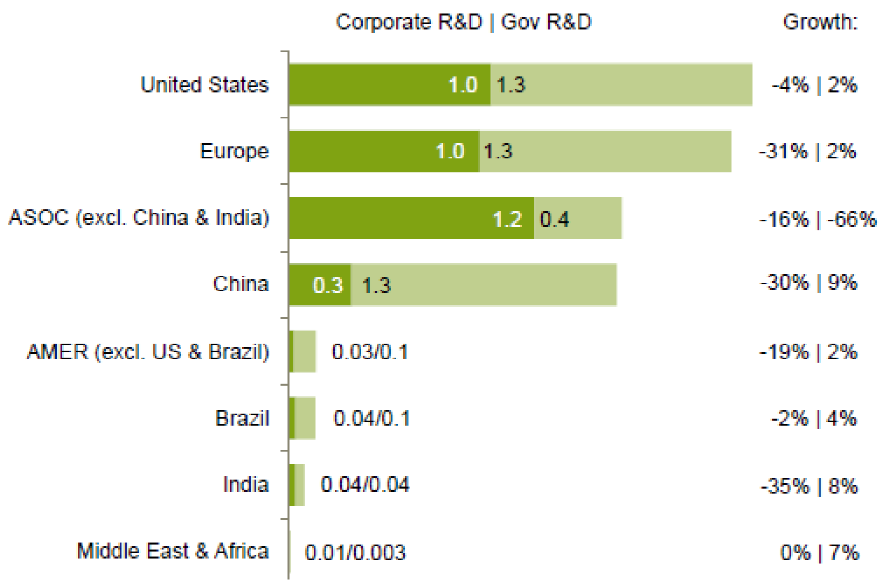


Fig 7-2: Region wise R&D Investment In Renewable Energy 2011 $Bn

(Source:Bloomberg, IEA, IMF, various Govt agencies)

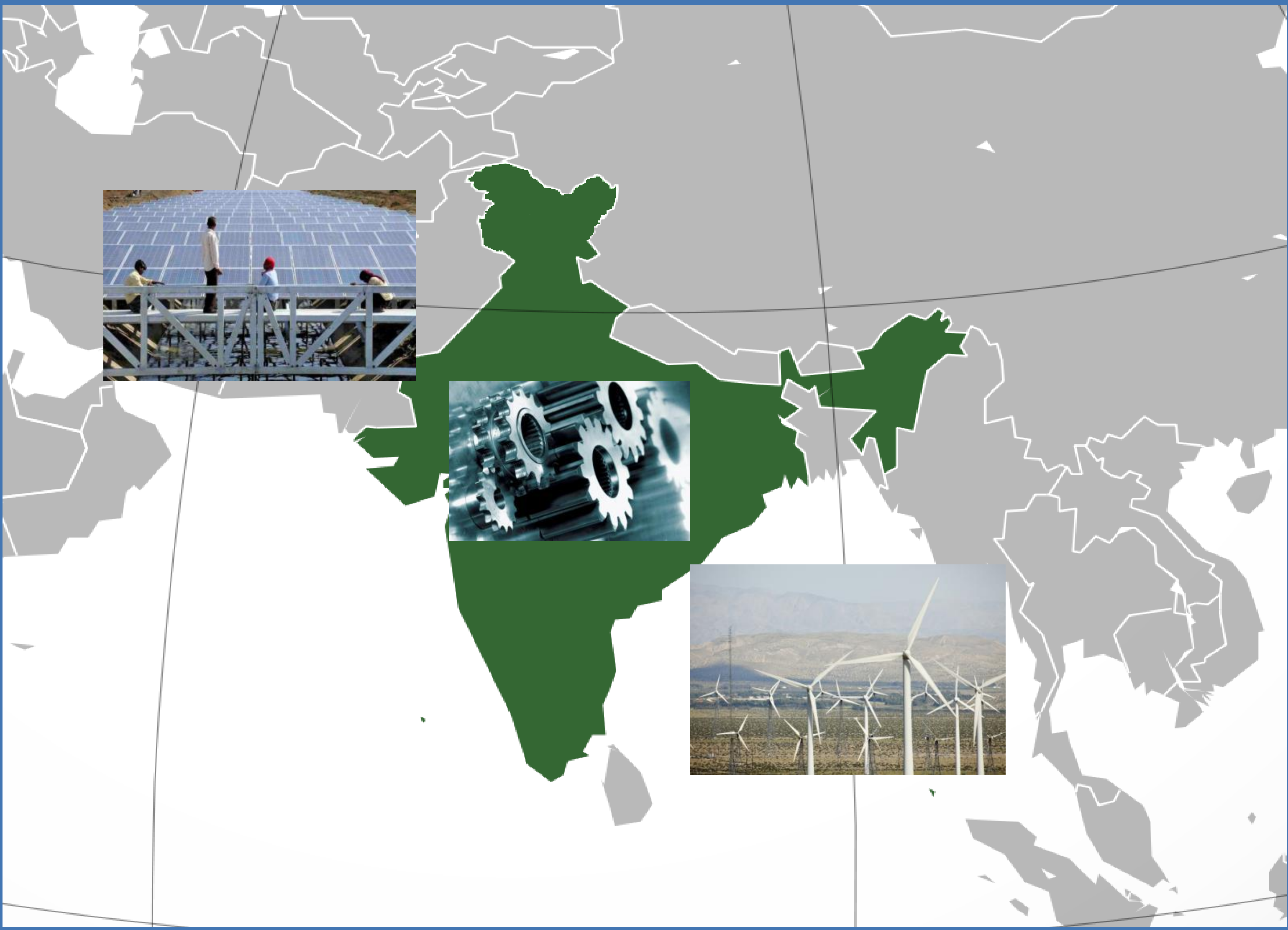
Solar power continued to dominate at USD 4.9 billion, claiming just over half (51%) of all research dollars spent, despite a 1% fall relative to 2011. R&D efforts focused on improving the energy output of PV cells and the efficiency of production processes. It was followed by wind power (up 4% to USD 1.7 billion), and biofuels (up 2% to USD 1.7 billion). One major focus towards wind power is the quest to reduce the cost of offshore development. In the area of biofuels R&D, much of it going on next-generation technologies like cellulosic ethanol, Fischer-Tropsch biodiesel and algal oil.

Considering the requirement of renewable capacity addition for meeting renewable energy goals of India, it is the need of the hour to increase RD&D efforts in the sector. In this direction, it is proposed to set up several “Center of Excellence for Renewables in India (CERI)” which can perform dedicated RD&D activities under the aegis of MNRE. Government should allocate more funds to such institutions for carrying out RD&D works.

To facilitate production of competitive energy through technical improvement in solar/wind technology, mass production of modules for desert power, addressing right of way for development of high capacity transmission corridors through High Temperature Superconductor(HTS) lines, indigenization of above technology plays a crucial role. In view of the above, efforts required for indigenization of above technologies are discussed.

CHAPTER-8

Indigenous Manufacturing



CHAPTER 8

Indigenous Manufacturing

8.1 Indigenisation of Solar cell/module manufacturing

To fulfil Desert Mission ambitious target, manufacturing capacity of solar cell, module, inverter/power conditioner, CSP technology is crucial. Presently, Indian manufacturing capacity on above items is very small as compared to global capacity. Global PV cell and module production was 32,223 MW and 35,945 MW respectively in year 2012. Year wise growth of global production of solar PV cell & module is shown in following Fig 8-1:

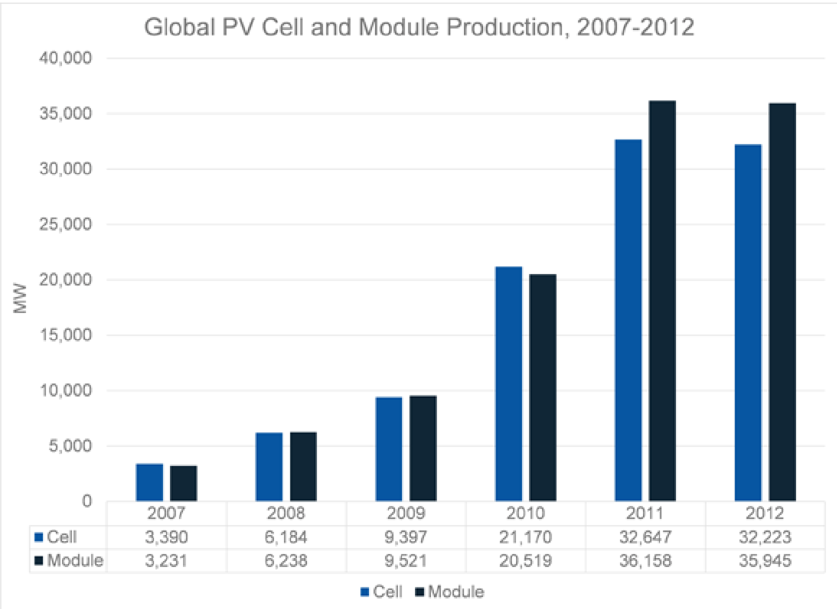


Fig 8-1: Global PV Cell and Module Production 2007-12 (Source: GTM Research)

While global demand of solar PV had CAGR of 63% over the period from 2009-12, manufacturing capacity setup has increased even faster. Figure 8-2 shows that global installations were very less than the manufacturing capacity by year 2011 and in future also trend is expected to continue.

8

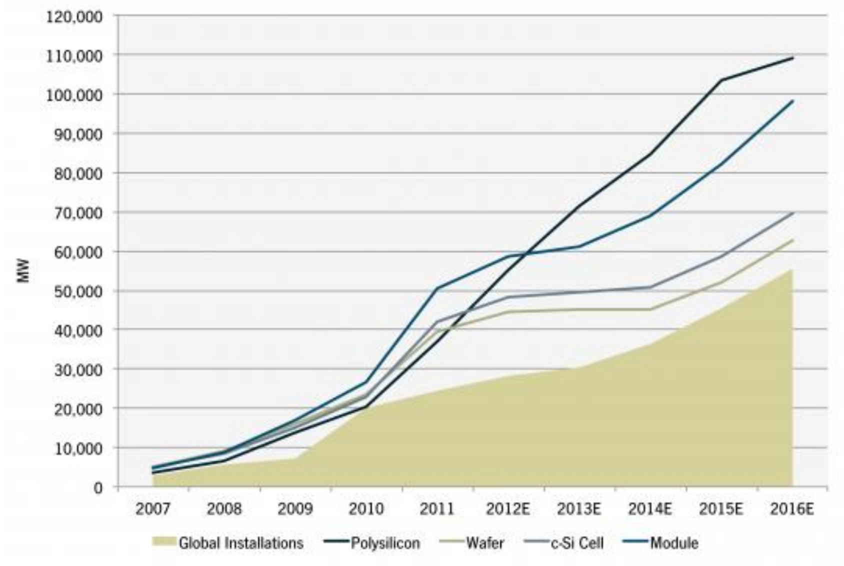


Figure 8-2: Ramped PV Manufacturing Capacity vs. Global Installations, 2007-16 (Source: Greentechmedia.com)

Due to large gap (29 GW in 2012) in demand and manufacturing capacity, many of the manufacturers are feeling the heat of competition and prices are going down. China has made their grip tighter on overall solar cell/module manufacturing. Almost 64% of the global manufacturing capacity of solar cell/module is in China. Further in next two(2) years Chinese manufacturing capacity is expected to reach 50 GW per annum from present level of 30 GW. The huge indigenous capacity build up by Chinese manufacturers resulted in serious demand-supply imbalance in the global PV market. Over 50 solar PV companies announced bankruptcy/exit globally (key players -Bosch, Siemens, Q Cells, Solyandra, Abound Solar, Conergy etc.).

India has annual manufacturing capacity of 900 MW for solar cells and 2000 MW of solar modules per annum. Nineteen(19) PV cell makers are registered with the Ministry of New and Renewable Energy (MNRE) and the country has more than fifty (50) module manufacturers. Presently our annual demand is matching with domestic capacity, but due to dumping of solar panels at lower rates, imports have increased drastically. Globally solar module prices have dropped by 80% from 2010 to 2013 and imports into India have increased at CAGR of 188% over the period from 2010-12. Global scenario of solar cell/module manufacturing has impacted our Indian manufacturers as well and utilisation factor of domestic manufacturers has reduced to 15% in 2012 from 65 % in 2010.

In such a situation, huge deployment of solar power in deserts shall attract global manufacturers, which may impact foreign exchange demand and current account deficit as well. Therefore, it is prudent to encourage and widen domestic manufacturing base before mass deployment which will further reduce the cost. A lot of policy, regulatory and technical measures shall be required for larger participation of domestic industry. Some of them are as below:

- Consistent and stable policy to increase domestic content in the solar projects
- Suitable policy measures to increase indigenous production and also competitive with global manufacturers
- Stricter regulatory enforcement of the solar renewable purchase obligations on the obligated entities, especially the DISCOMS
- Priority sector lending to solar manufacturers
- Policy support to increase investment and fiscal incentives for indigenous manufacturing like supported through soft loans based on the extent of local value addition, incentivised through investment allowances/interest rate subsidies/tax credit etc.
- Establishment of solar manufacturing parks, ease in land acquisition for establishment of manufacturing facility
- Policy for Technology deployment linked to efficient module development could be subsidized
- Establishment of R & D facilities
- Development of skilled manpower in the field of solar manufacturing

Above measures shall bring domestic industry upfront and shall lower dependence on foreign manufacturers through indigenous manufacturing. Strong manufacturing base shall lead to long term development of solar industry in India and enable envisaged desert power development progressively by 2050. Indigisation of technology as well as mass production of solar module for large scale deployment would facilitate competitive energy prices of Solar generation in few years

8.2 Development of High Temperature Superconductor line

In order to facilitate transfer of power from remotely located renewable generation plants to the distant load centers, high capacity transmission corridors at 1200kV/765kV AC, 800kV HVDC etc. are required. As mentioned earlier, task of establishment of large transmission network by conventional overhead lines requires consideration of socio-economic and technical challenges that includes Right-of-Way availability, protection of flora and fauna, reduction of transmission losses, control of system fault levels, cost optimization etc.

An alternative to the overhead lines has been in the mind of researchers for a long time. In course of time, after the discovery of High Temperature Superconductors (HTS) that can be cooled to their operating temperature using liquid nitrogen, researchers and engineers thought of using superconductivity technology in electric power applications. A typical HTS line with cryogenic cooling arrangement is shown at Fig 8-3

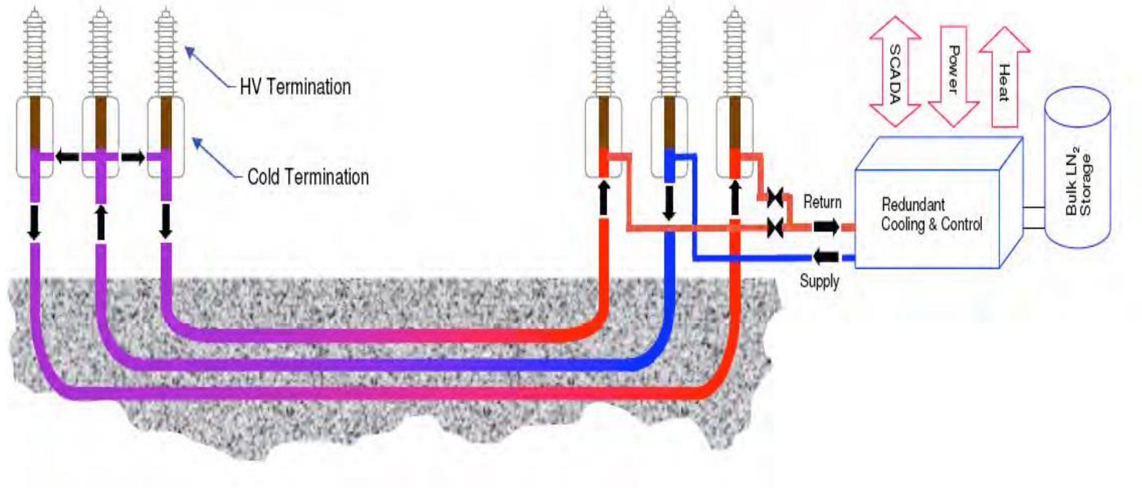


Fig:8-3 Typical HTS facility with cooling arrangement

High Temperature Superconductor power cables, where the combination of high current capacity and low-level losses decipher into high power transmission capacity, has been found as possible alternative to overhead lines for bulk power transmission. The Right of Way requirement of HTS cable is extremely low in comparison to the conventional system. Over the last decade development of HTS power cables has progressed significantly with improvements in superconducting wire performance and technological advancements in the construction of HTS cables. Demonstration projects throughout the world are acting as a catalyst for the commercialization of the technology.

In order to gain sufficient experience in this technology, POWERGRID is planning to have a demo project at 220kV level for 200 m long underground line to gain sufficient operational experience with Cryogenic Refrigeration System (CRS). Liquid Nitrogen (LN2) shall serve as the refrigerant to keep the HTS core at the Superconducting state.

Keeping in view the quantum and long term power transfer requirement, number of high capacity transmission corridors are to be constructed which will pose challenges considering present state of right of way(RoW), forest clearances etc. It is prudent to undertake indigenous development of a full-fledged transmission line at 400kV level having power transfer capacity in the range of 6000-8000 MW with negligible RoW through HTS technology at commercial level. Experience gained through such project would help in large scale deployment of HTS line in the long run while addressing RoW issue vis-à-vis requirement of high capacity transmission corridors in future to a great extent. Initially cost of such project would be high; however, with increase in volume of HTS lines, economy may be achieved. To undertake first commercial project of HTS line, suitable financing mechanism is to be worked out by the Government.

In the next chapter, tentative investment requirement for development of desert power by 2050 is presented.

CHAPTER-9

Investment in Setting up Renewable Generation Projects

CHAPTER 9

Investments in Setting up Renewable Generation projects

9

World over encouragement of renewables due to supportive govt. policies, has led to large capacity set up around the globe. Significant and rapid reduction in cost of many renewable technologies is attributed to Government initiatives, Market forces, Technological advancements (Fig-9-1), Scaled up production etc. As per the statistics, for Solar PV, approx. 20% drop in prices has been seen per year in last few years. Due to very sharp decrease in the prices of Solar PV technology, MW scale Solar generation projects are reaching towards grid parity. As solar PV technologies continue to evolve, significant cost reductions are expected to continue as a result of improving power conversion efficiencies, development of low-cost cell fabrication processes and increasing cell production volume with attendant economies of scale.

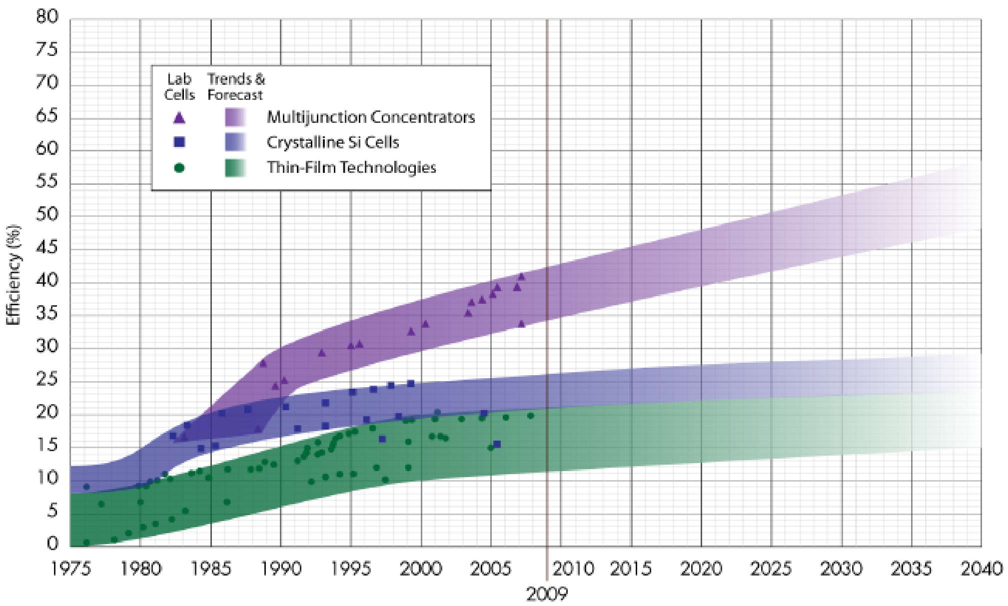


Fig 9-1: PV technology Trend 1975-2040 (Source :Lab cell Efficiencies from NREL)

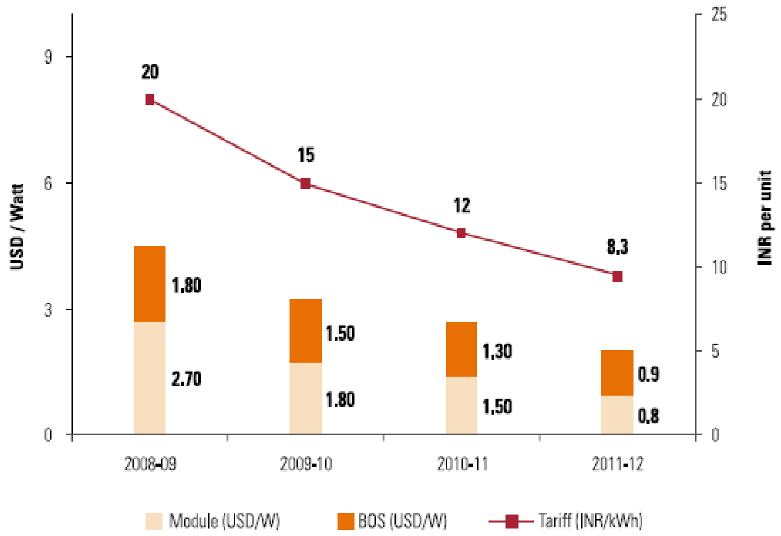


Fig 9-2: Global Solar PV Prices

Solar PV has relatively higher capital cost, but after capital expenditure; the cost goes to be the lowest among any source of energy.

In past three (3) decades, the cost of wind energy has significantly decreased (around 50%), due to both capital cost reductions and performance improvements (Fig-9-3).

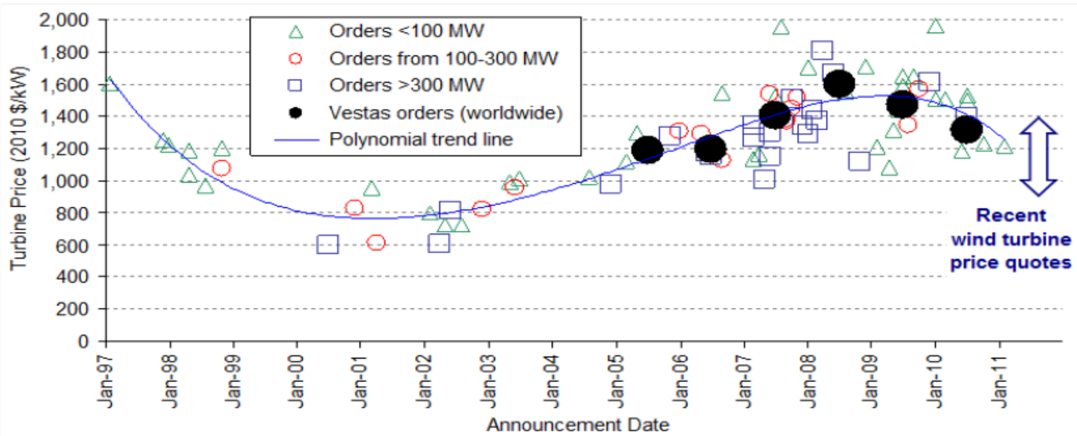


Fig 9-3: Wind turbine prices in United States (Source :Wiser and Bolinger 2011, Vestas (2011a,2011b,2011c) and BNEF (2011a), NREL)

Between 1980 and early 2000s, commercial turbines size grew from less than 100 kW to more than 1-1.5 MW in capacity, rotor diameter grew from roughly 15 meters to more than 70 meters, and tower heights grew from 20 m to more than 65 m. Hence turbine prices have seen a decline before the early 2000. Then prices have increased from early 2000 to 2008, as raw material commodity prices and energy prices have been main factors for influencing capital cost increase during this time period. Both material and energy prices increased substantially up to late 2008 due to financial crisis. Nevertheless, as capital costs have moderated from their 2009–2010 levels, the cost of wind energy has fallen and is now at an all-time low within fixed wind resource classes.

In Figure 9-4 below, the growth of turbine nameplate capacity, hub height, and rotor diameter, over the past 3 decades is illustrated. Performance of turbines is also improving because of use of more advanced turbine component and larger turbines. This has resulted in greater efficiency, improved availability and reduced generation losses.

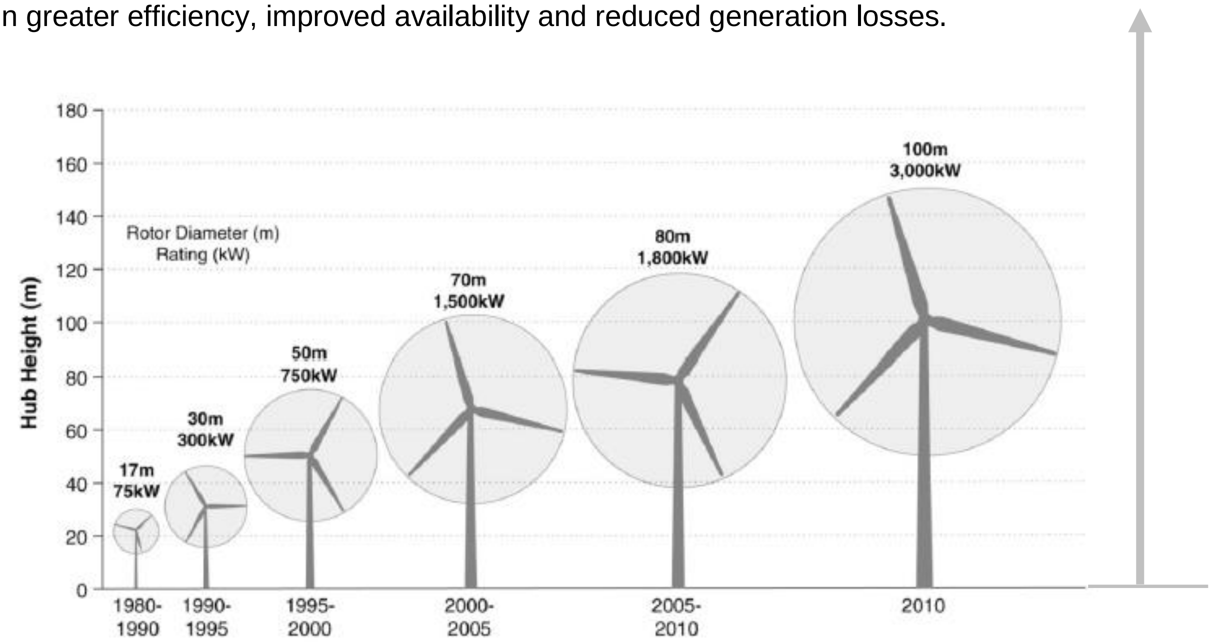


Fig 9-4: Representative turbine architecture from 1980 to 2010 (Source :NREL)

9.1. Future Price Patterns

As per DII report on Desert Power 2050, significant cost reductions of around 50% or more are expected for all technologies, except for Wind on-shore costs, which are estimated to decline by 20-30%, since this technology is already mature and cost competitive today. However, cost developments in target time frame shall broadly depend on government policies as well as market development in respective countries.

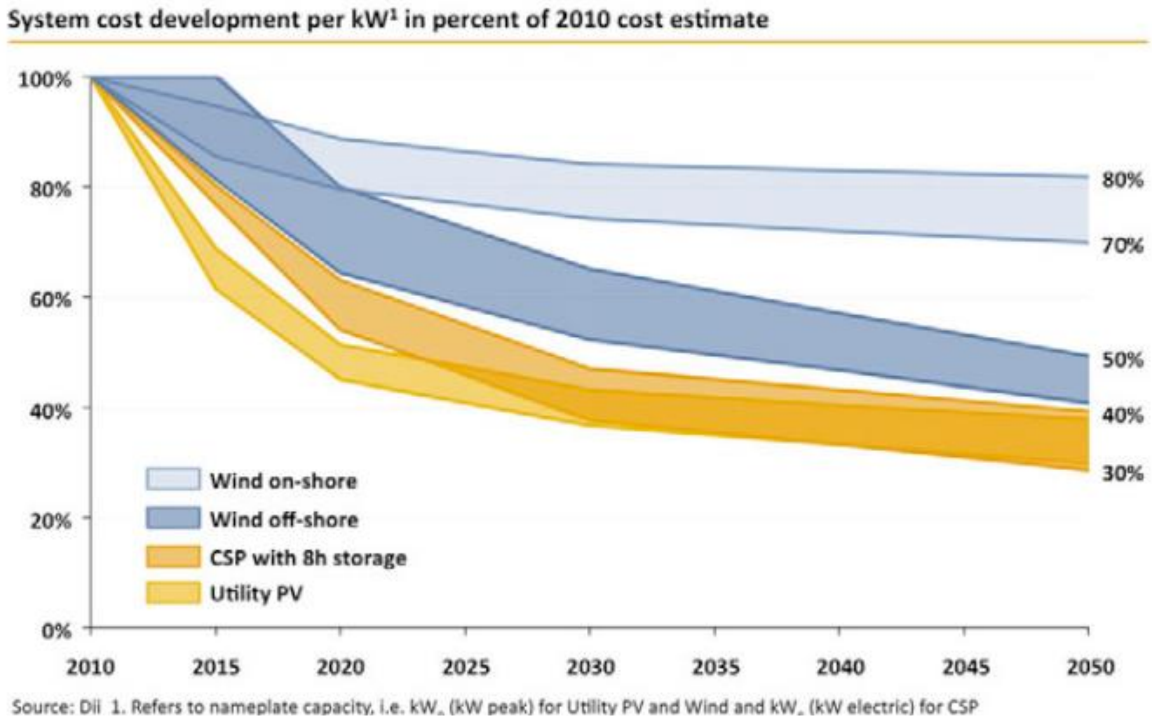


Fig 9-5: System cost development per KW (%) of 2010 cost estimate (Source :DII report on desert power)

Considering above, price range for different renewable technologies for 2050 time frame is evaluated. As it can be seen from above chart (Fig-9-5) , prices of the Wind, CSP and Solar PV shall decline in following trajectory for 2050 with reference to 2010 base prices (Table-9-1).

Table-9-1: Price range for different renewable technologies: 2050

RE Technology	Price Level (2010) Rs. Cr/MW	% Reduction on base of 2010 price level for		Anticipated price Level (on Lower band) Rs. Cr/MW	
		2030	2050	2030	2050
Wind (on-shore) generation	7.2	15-25%	20-30%	6.1	5.8
CSP (8 hr) generation*	38	50-60%	60-70%	19	15.2
Solar PV System	15	45-55%	55-65%	8.2	6.8

Cost for different renewable generation technologies in 2030/2050 is arrived with conservative reduction estimates (lower side of band). Further in view of the harsh ecology conditions of deserts, an additional 10% cost escalation is considered for different renewable generation technologies in 2030/2050 on base prices are given at Table 9-2:

Table-9-2: Cost for different renewable generation technologies in 2030/2050

RE Technology	Escalation @10% in technology deployment at deserts (Rs Cr/MW)	
	2030	2050
Wind (on-shore) generation	6.7	6.4
CSP (8 hr) generation*	20.9	16.5
Solar PV System	9.0	8.0

Cost for different balancing technologies such as Pumped Storage and Battery Storage may also be considered as Rs 8 Cr/MW as well as 5 Cr/MWh on account of cost reduction due to economy of scale as advancement of technologies especially in Battery energy storage.

9

9.2 Investment Requirement

On the basis of present cost trends, total investment requirement has been assessed for the generation, transmission and balancing infrastructure upto 2050 which is as under.

A) Investment Requirement in 13th Plan (2022)	**Estimated Cost**
• **Generation**	**: Rs. 1,08,550 Cr**
– Wind (0.7 GW)	: Rs. 4,550 Cr
– Solar PV System (10.4 GW)	: Rs. 1,04,000 Cr
• **Transmission**	**: Rs. 19,800 Cr**
– Intra State	: Rs. 5,000 Cr
– Inter State	: Rs. 14,800 Cr
• **Other Balancing Infrastructure$**	**: Rs. 80,000 Cr**
– Pumped Storage (5 GW)	: Rs. 40,000 Cr
– Battery Storage (2 hr)(2 GW)	: Rs. 40,000 Cr
Estimated Cost (A)	***: Rs. 2,08,350 Cr***
B) Investment Requirement in 14th & 15th Plan (2022-32)	**Estimated Cost**
• **Generation**	**: Rs. 13,88,000 Cr**

– Wind (12 GW)	: Rs. 78,000 Cr
– Concentrated Solar power (12 GW) (Storage: 8 hr)	: Rs. 3,60,000 Cr
– Solar PV System (95 GW)	: Rs. 9,50,000 Cr
• **Transmission**	**: Rs. 1,85,000 Cr**
– Intra State	: Rs. 60,000 Cr
– Inter State	: Rs. 1,25,000 Cr
• **Other Balancing Infrastructure**	**: Rs. 1,12,000 Cr**
– Pumped Storage (9 GW)	: Rs. 72,000 Cr
– Battery Storage (2 hr)(2 GW)	: Rs. 40,000 Cr
Estimated Cost (B)	***: Rs. 16,85,000 Cr***
C) Investment Requirement from 2032 to 2050	**Estimated Cost**
• **Generation**	**: Rs. 20,04,000 Cr**
– Wind (16 GW)	: Rs. 1,04,000 Cr
– Concentrated Solar power (18 GW) (Storage: 8 hr)	: Rs. 5,40,000Cr
– Solar PV System (136 GW)	: Rs. 13,60,000 Cr
• **Transmission**	**: Rs. 2,45,200 Cr**
– Intra State	: Rs. 85,000 Cr
– Inter State	: Rs. 1,60,200 Cr
• **Other Balancing Infrastructure**	**: Rs. 2,32,000 Cr**
– Pumped Storage (14 GW)	: Rs. 1,12,000 Cr
– Battery Storage (2 hr) (6 GW)	: Rs. 1,20,000 Cr
Estimated Cost (C)	***: Rs. 24,81,200 Cr***
Total investment requirement up to 2050 (A+B+C)	***: Rs. 43,74,550 Cr***

In addition to above, there would be requirement of dynamic compensation in the form of STATCOM/SVC at various strategic locations of suitable capacities to take care of grid stability under different operating conditions due to volatility of Renewable generation.

** There would be requirement of Rs 2850 Cr/annum requirement towards balancing infrastructure in 2022*

***Present Cost trends; PV- Rs 10 Cr/MW, CSP Storage- Rs 30 Cr/MW, Onshore Wind- Rs 6.5 Cr/MW, PSP- Rs 8 Cr/MW, Battery Storage- Rs 10 Cr/MWh*

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ANNEXURE

ANNEXURE I-1

भारत सरकार
नवीन और नवीकरणीय ऊर्जा मंत्रालय
Government of India
MINISTRY OF NEW AND RENEWABLE ENERGY
ब्लाक नं. 14, केन्द्रीय कार्यालय परिसर, लोदी रोड, नई दिल्ली-110003
BLOCK NO. 14, C.G.O. COMPLEX, LODI ROAD, NEW DELHI - 110 003

Telegram: RENEWABLE

सं.
No. [illegible]

दिनांक
Dated [illegible] April [illegible]

To,

1. The Director, Gujarat Energy Development Agency, 4th Floor, Block No. 11 & 12, Udyog Bhawan, Sector 11, Gandhinagar-382017, Email : director@geda.org.in

2. The Chief Executive, Himachal Pradesh Energy Development Agency (HIMURJA), SDA Complex, Kasumpti, Shimla-171009, E-Mail: [illegible]

3. The Chief Executive Officer, Jammu & Kashmir Energy Development Agency, 181, Jawahar Nagar, Srinagar. Email: ceojakeda2@gmail.com

4. The Chairman & Managing Director, Rajasthan Renewable Energy Corp Limited, E-166, Yudhister Marg, "C" Scheme, Jaipur - 302 001, Email: rrec_jai@yahoo.co.in

Subject: Renewable power in desert regions of India by 2050- Study by PGCIL

Sir,

On behalf of the Ministry of New and Renewable Energy, the Power Grid Corporation of India Ltd. (PGCIL) is carrying out a study to identify transmission infrastructure requirements arising out the likely large renewable power projects in India's desert regions of the states of Gujarat, Rajasthan, Himachal Pradesh and Jammu & Kashmir, for upto 2050 time horizon, with phased development plans.

2. The abovementioned study will examine aspects relating to land ownership patterns and examination of associated land availability /acquisition issues; assessment of economic potential of renewable power generation; infrastructure development requirement, including road, water and for renewable power evacuation; estimated cost of generated power; area /region specific demand forecast / load assessment and associated grid balancing and spinning reserve infrastructure requirements; impact of large scale renewable power on local communities (including positive economic spillovers) etc.

3. The study is expected to provide much needed framework for creating future energy systems in the country. PGCIL representatives will be visiting the respective states for obtaining data and other inputs as deemed necessary for the study purposes. It is requested that all necessary support may please be provided to PGCIL in terms of availability of relevant data, facilitating field survey, interaction with related departments/agencies and also with local communities etc.

Yours faithfully,

(P.C. Maithani)
Director
Ph/Fax: 011-24361830
pcmaithani@nic.in

Annexure 3-1

PUMPED STORAGE PLANTS IN INDIA

S. No.	Name of Project / State	Installed Capacity		Pumping Mode Operation	Reasons for not working in Pumping mode
		No. of units x MW	Total (MW)		
1	Kadana St. I&II Gujarat	2x60+2x60	240	Not working	Due to vibration problem
2	Nagarjuna Sagar Andhra Pradesh	7x100.80	705.60	Not working	Tail pool dam under construction
3	Kadamparai Tamil Nadu	4x100	400	Working	-
4	Panchet Hill - DVC	1x40	40	Not working	Tail pool dam not constructed
5	Bhira Maharashtra	1x150	150	Working	-
6	Srisailam LBPH Andhra Pradsesh	6x150	900	Working	-
7	Sardar Sarovar Gujarat	6x200	1200	Not working	Tail pool dam not constructed
8	Purlia PSS West Bengal	4x225	900	Working	-
9	Ghatgar Maharashtra	2x125	250	Working	-
		Total	4785.60		

ANNEXURE 3-2

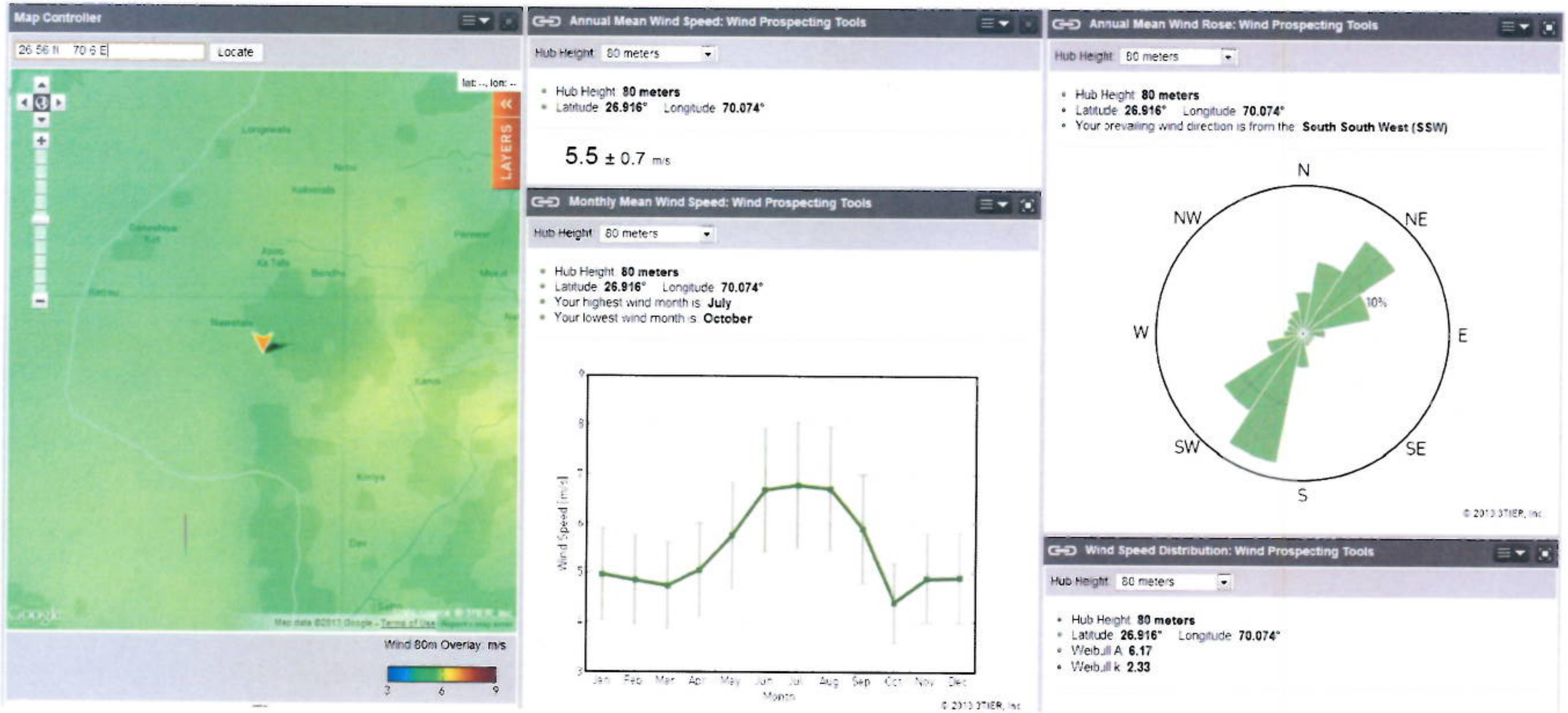


Figure 1: 3 Tier Wind Prospecting Tool Result for Thar Desert

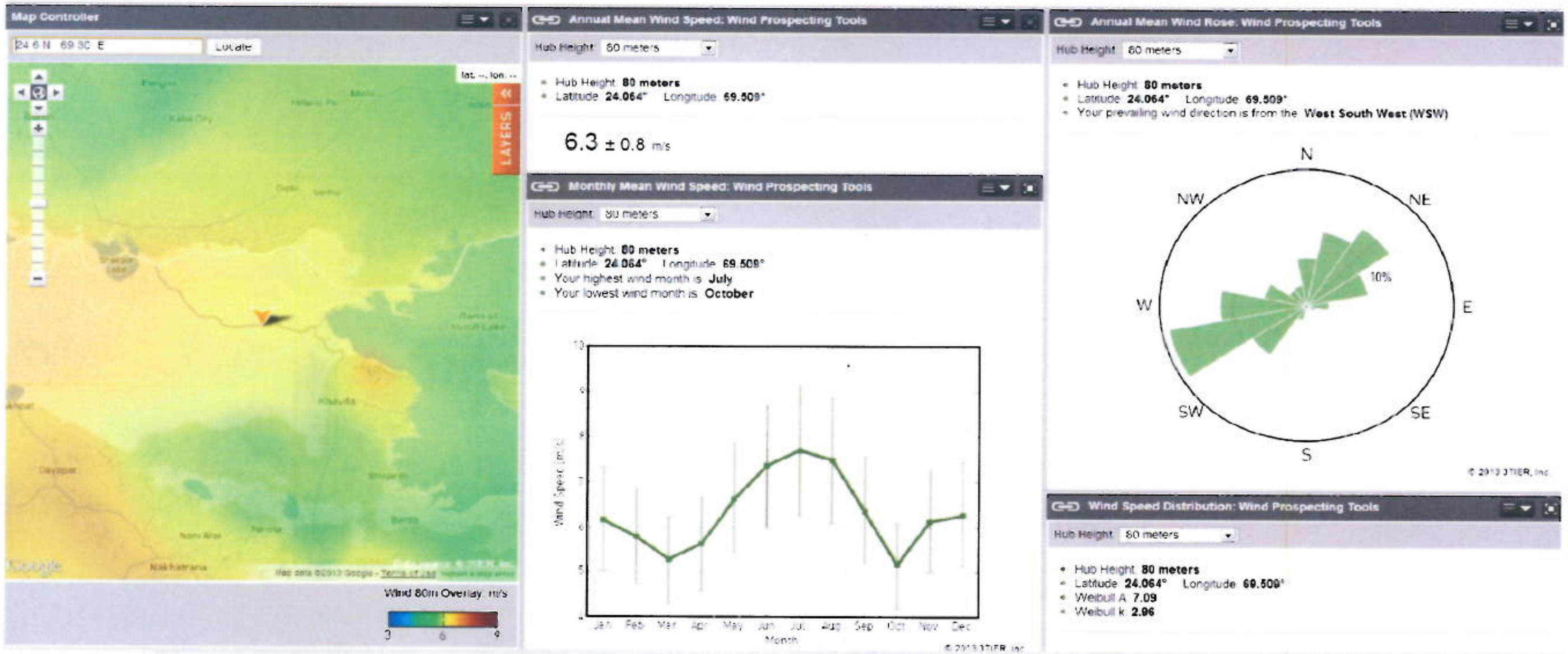


Figure 2: 3 Tier Wind Prospecting Tool Result for Rann of Kutch Desert

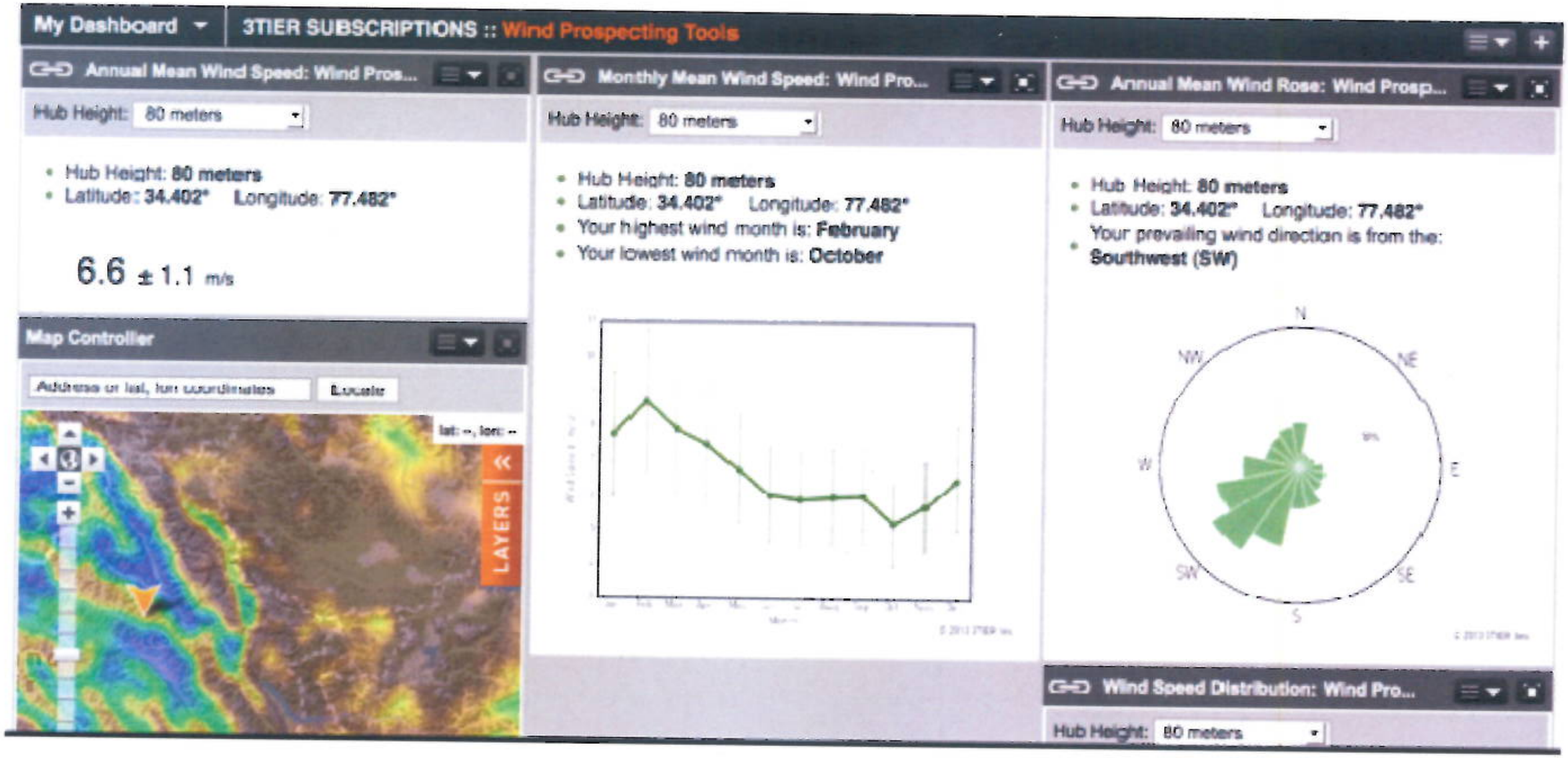


Figure 3: 3 Tier Wind Prospecting Tool Result for Ladakh

ANNEXURE 3-3

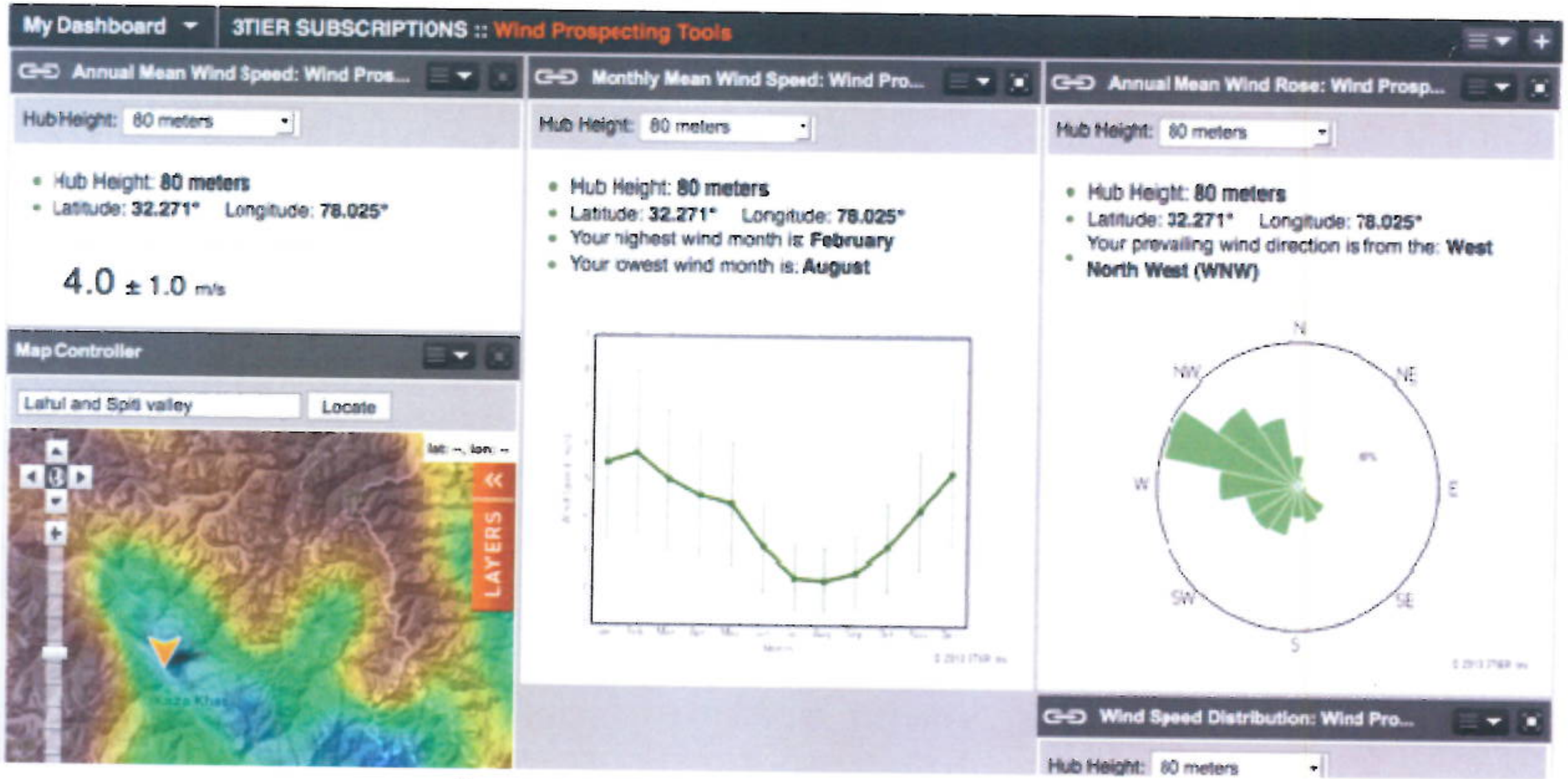
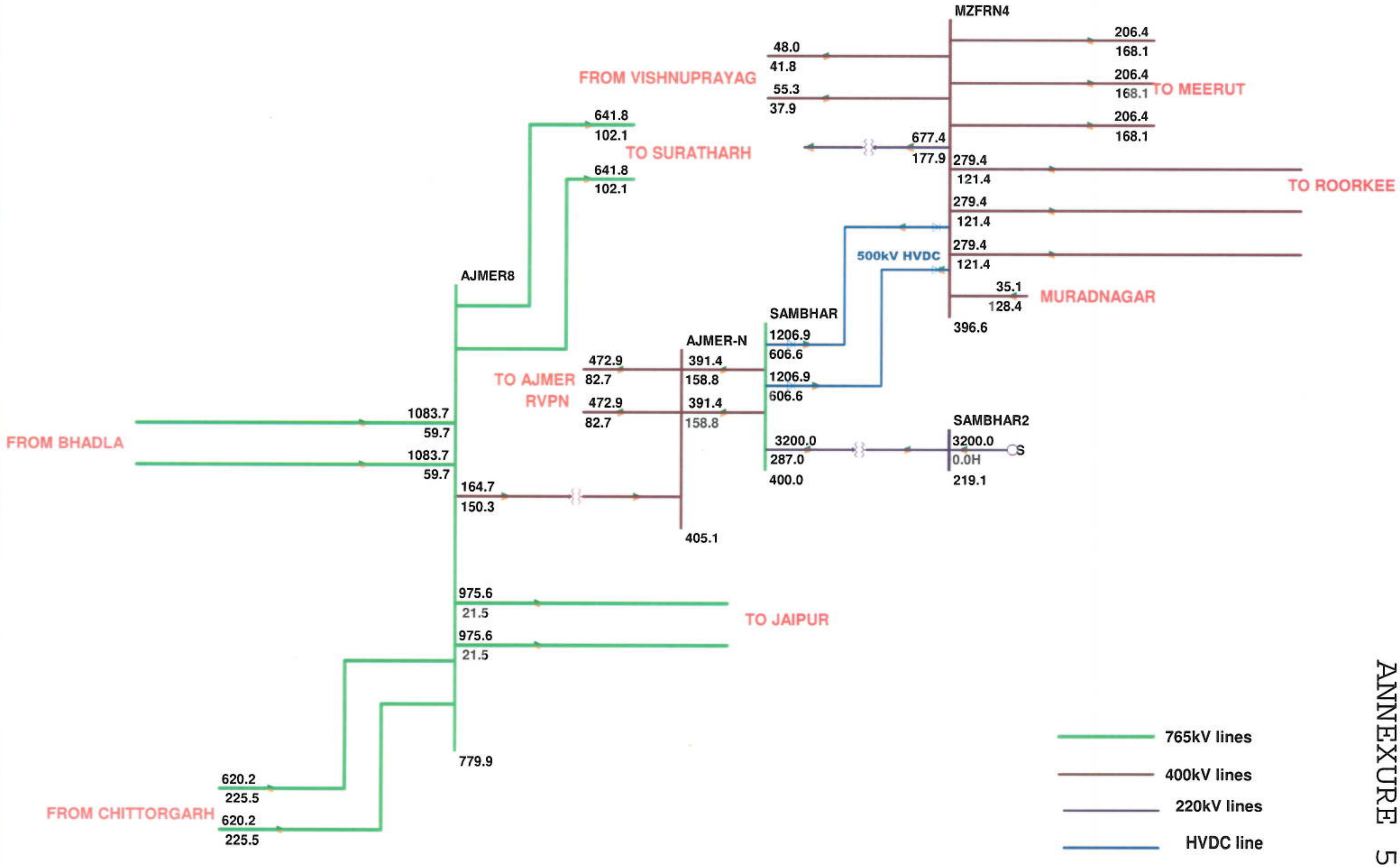


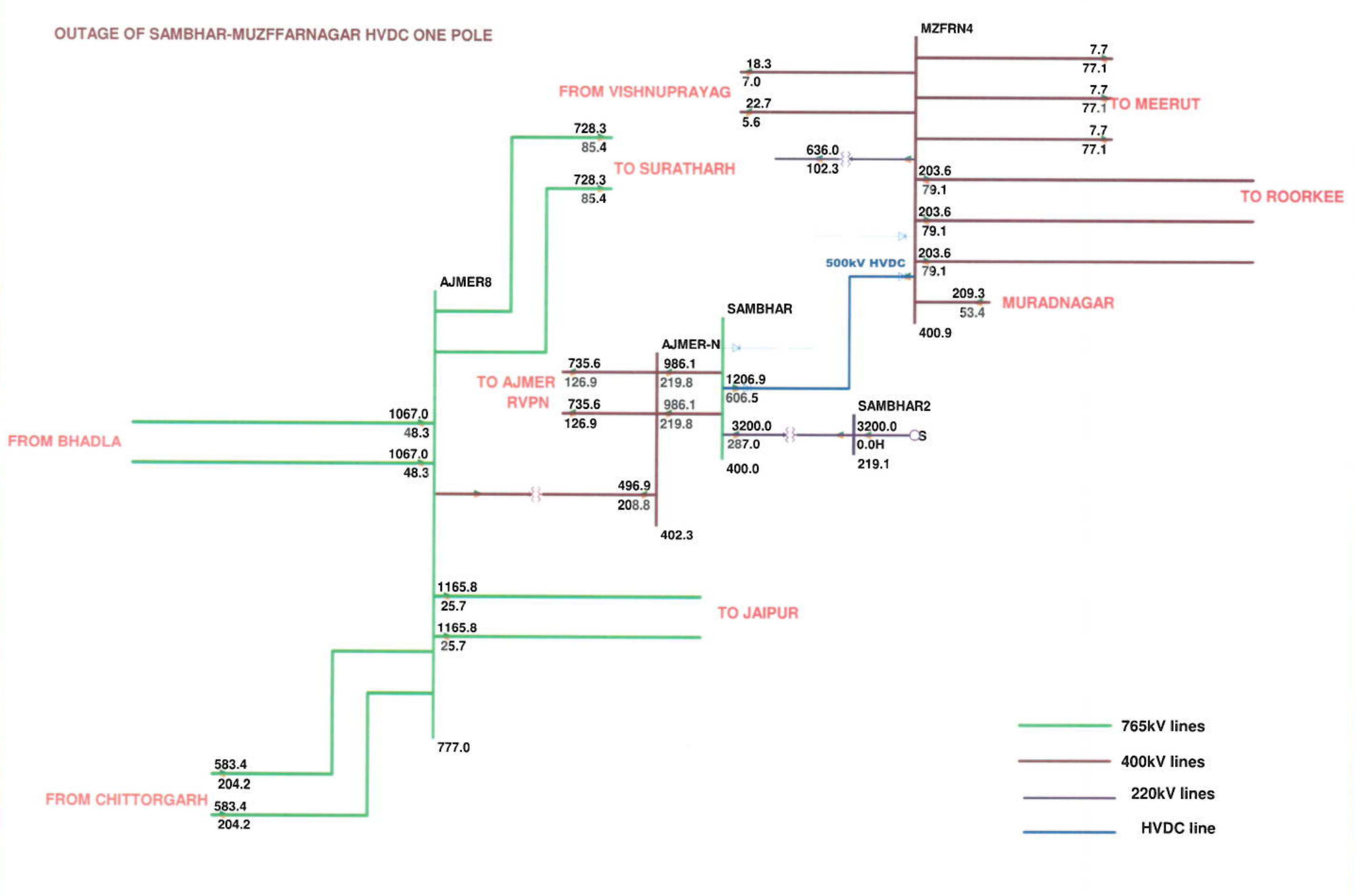
Figure 1: 3 Tier Wind Prospecting Tool Result for Lahul & Spiti

ANNEXURE 5-1

TRANSMISSION SYSTEM FOR SAMBHAR UMPP

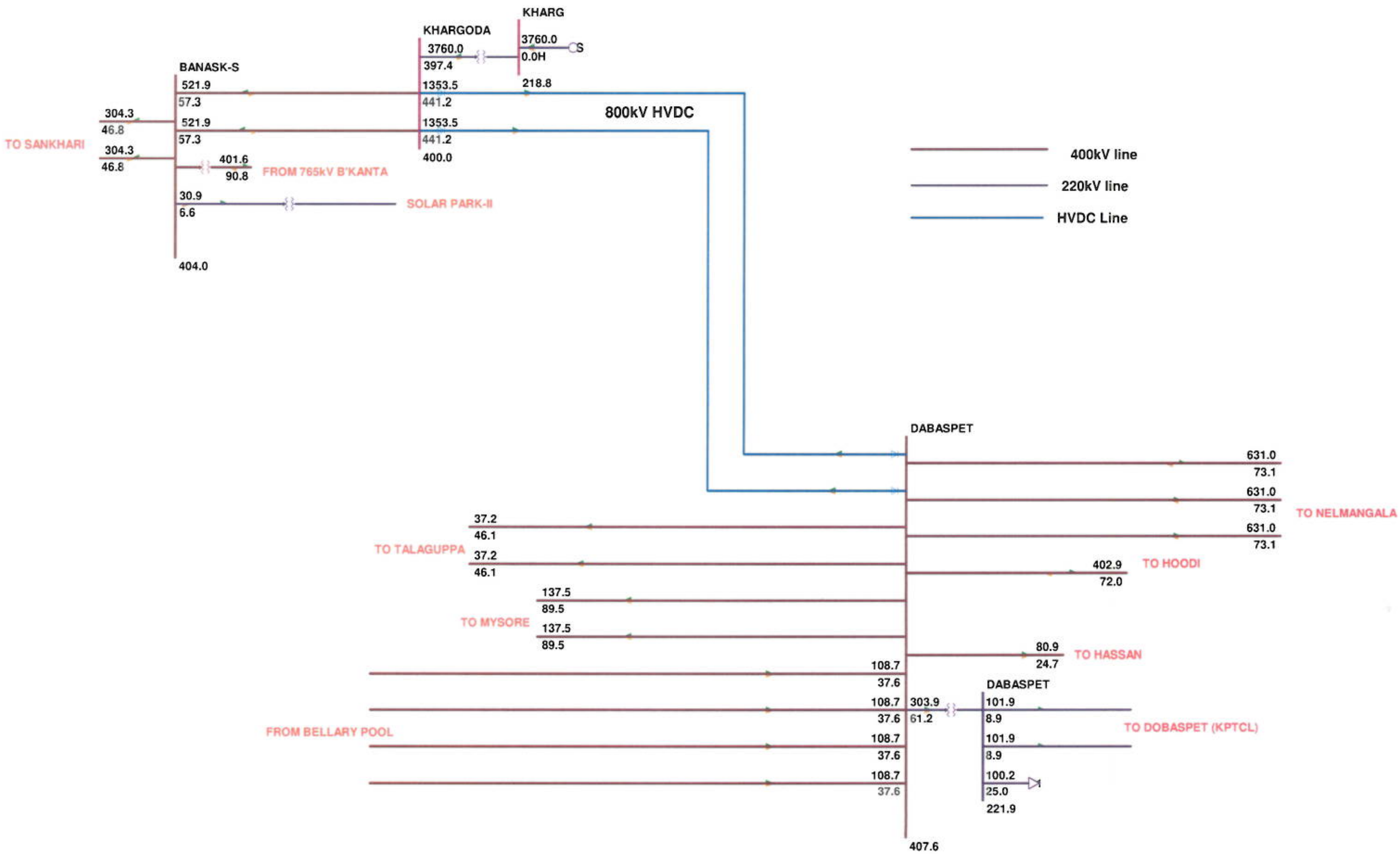


TRANSMISSION SYSTEM FOR SAMBHAR UMPP

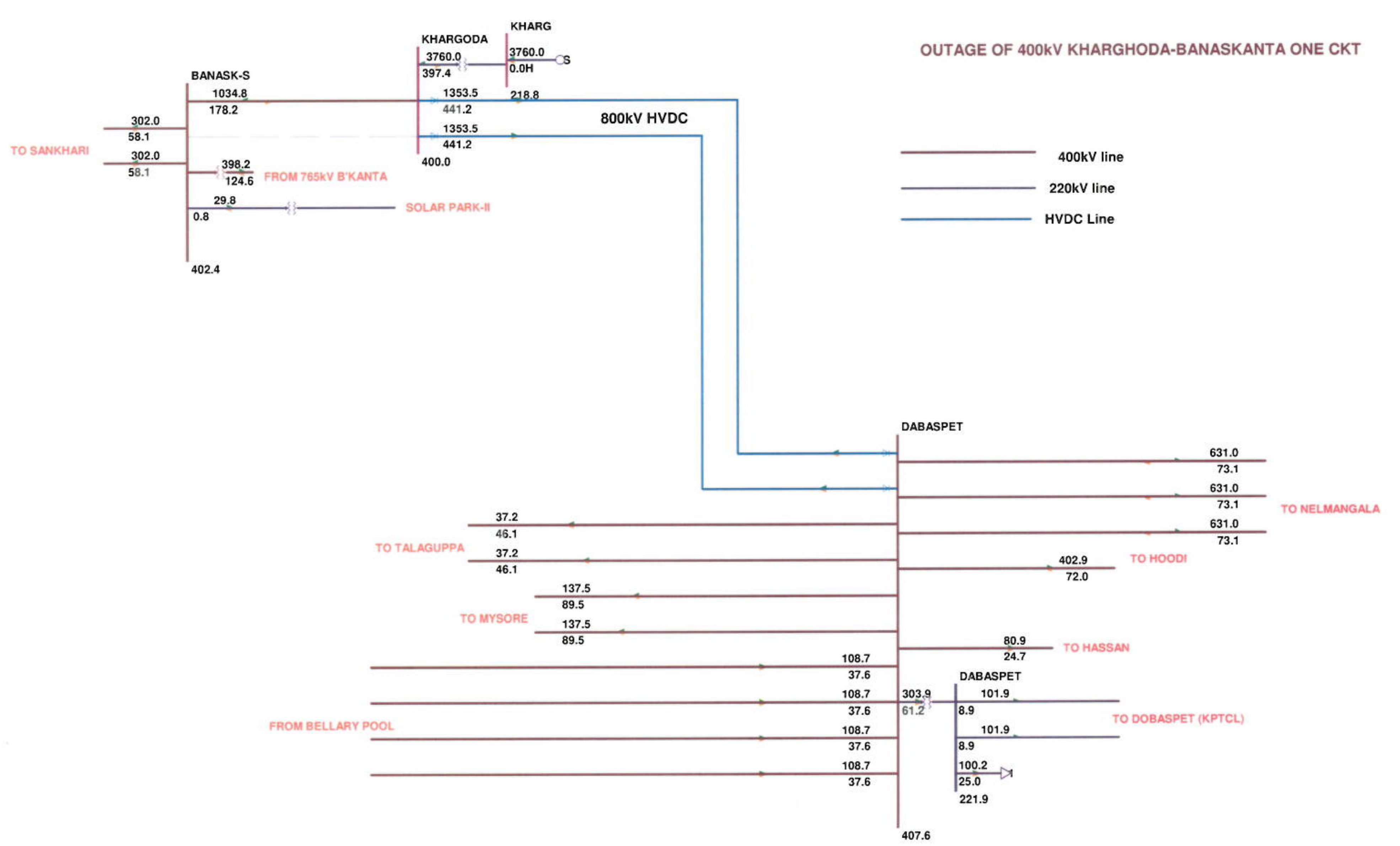


ANNEXURE 5-2

TRANSMISSION SYSTEM FOR KHARGHODA UMPP

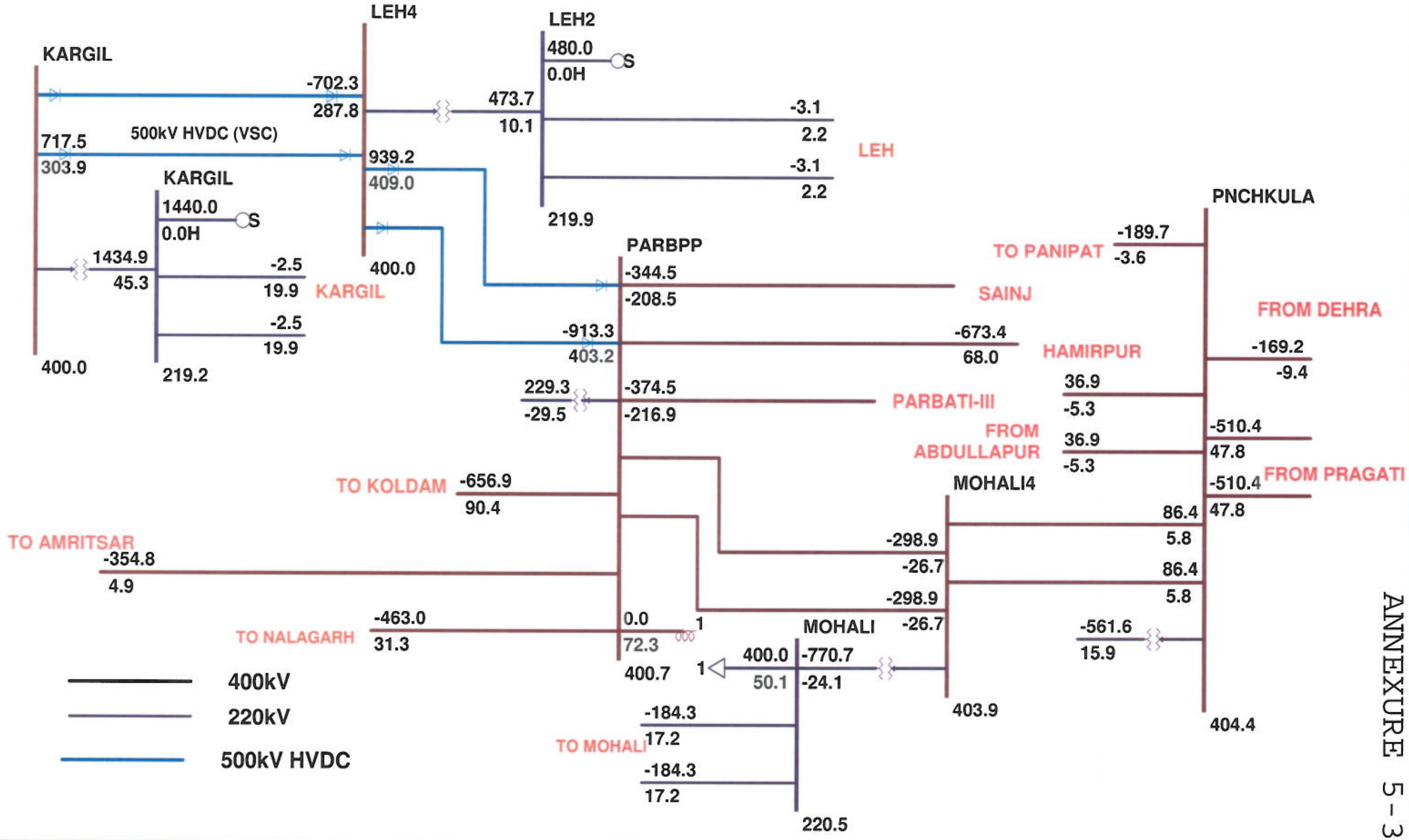


TRANSMISSION SYSTEM FOR KHARGHODA UMPP

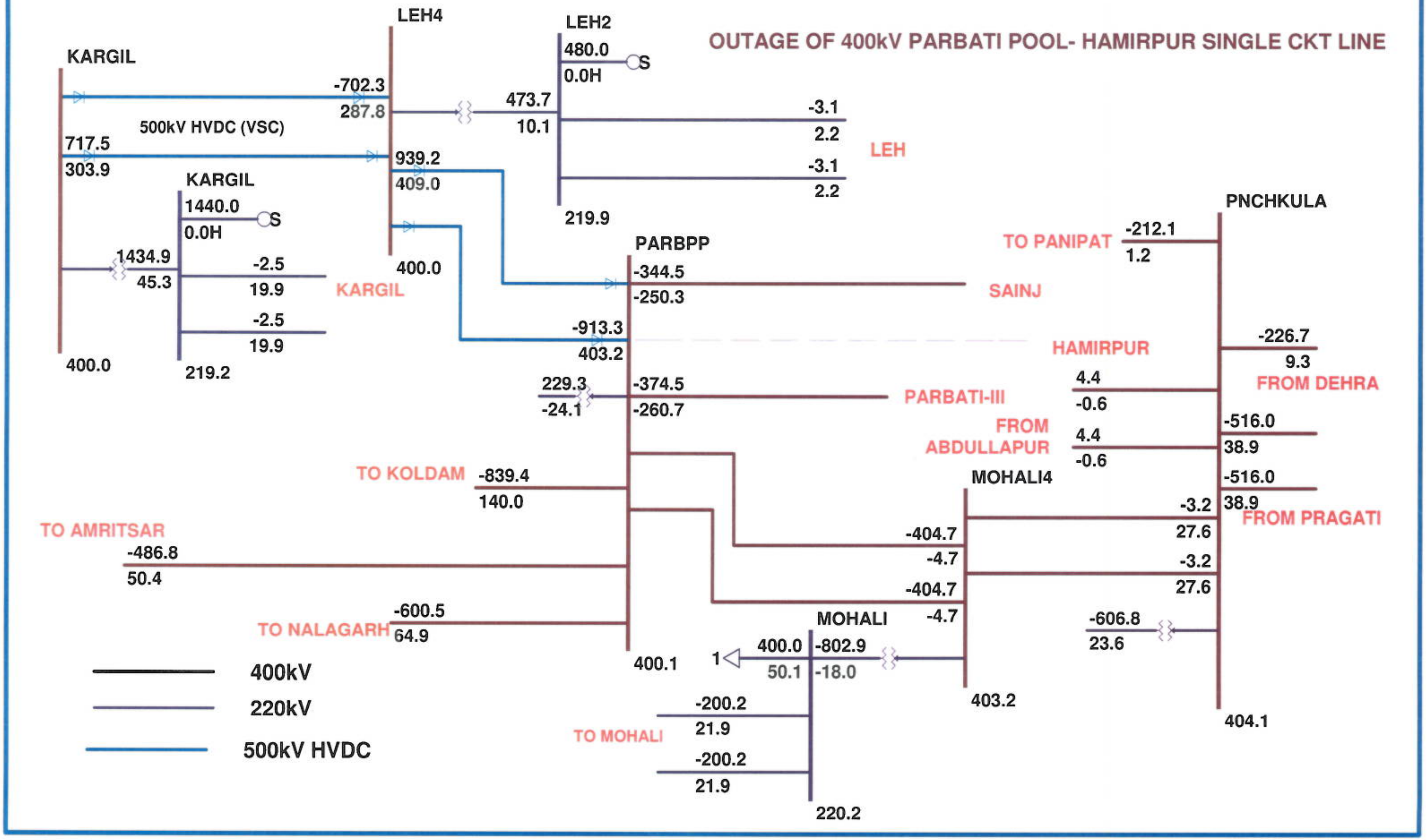


ANNEXURE 5-3

TRANSMISSION SYSTEM FOR LEH/KARGIL UMPP



TRANSMISSION SYSTEM FOR LEH/KARGIL UMPP



APPENDIX

APPENDIX 1

Solar Power Technology

Solar Power Technology

The largest accessible but least tapped form of energy on earth is solar radiation on deserts. There are mainly two types of solar generation technologies available world wide as under

a) Solar photovoltaic (PV)
b) Concentrating solar power

Solar photovoltaic (PV) uses GHI, directly converts solar energy into electricity using a PV cell made of a semiconductor material. However, Concentrating solar power (CSP) uses DNI, devices concentrate energy from the sun's rays to heat a receiver to high temperatures. This heat is transformed first into mechanical energy (by turbines or other engines) and then into electricity – solar thermal electricity (STE)

Very Large Scale Photo Voltaic (VLSPV)

PV (photovoltaic) technology is based on the principle of direct conversion of solar irradiation into electrical power by using the photovoltaic effect. It uses the P-N junction to convert light to electricity. The resulting DC current can then be converted with an inverter into an AC -current. Crystalline silicon wafer-based cells and modules are best proven in mass production and will soon be produced at a GW scale by several companies.

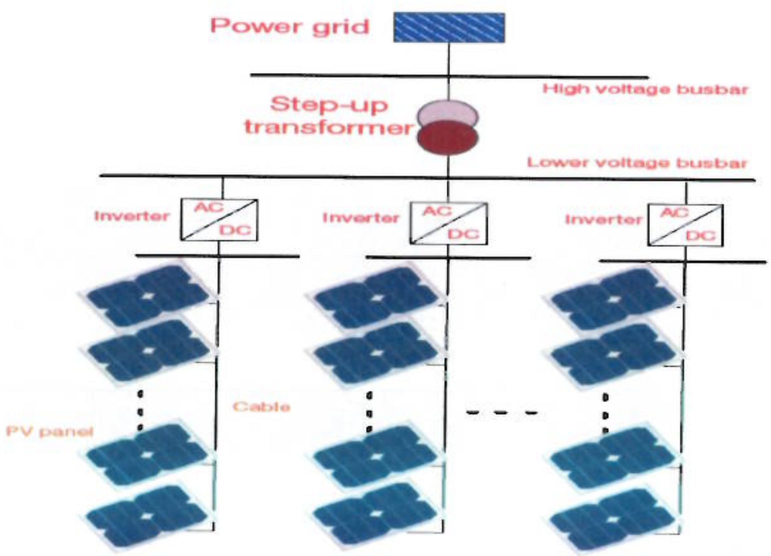


Fig A1: solar power station connected to grid

A major advantage of PV is its scalability, from a few watts to MW class. PV also offers a high degree of modularity in the construction phase. The installation, maintenance and cleaning are simple and fast compared to other technologies. These can also work with diffuse light and easy to maintain. The biggest disadvantage is these PV panels are highly dependent in temperature due to which reliability comes to a stake

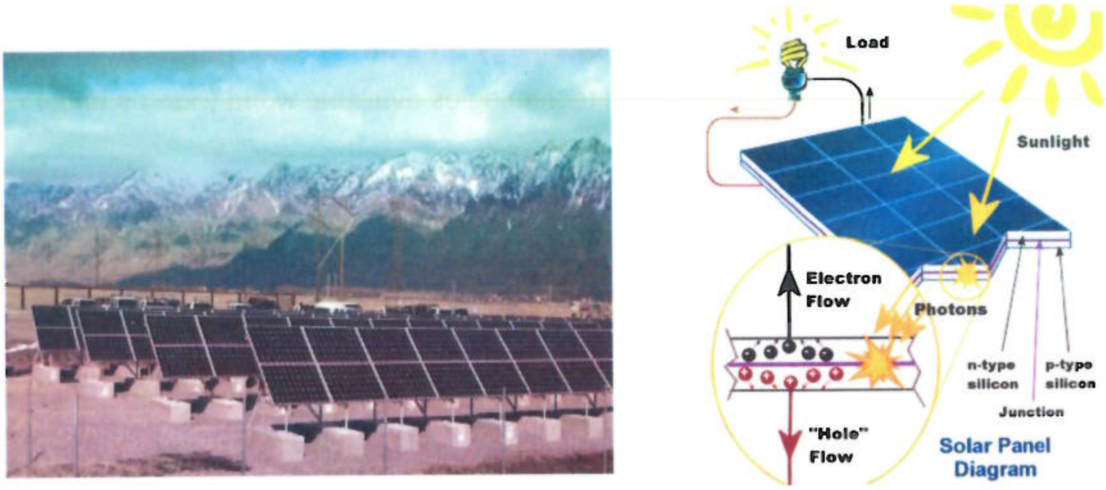


Fig A2: A Typical Solar PV plant

Solar Photovoltaic (SPV) cells convert solar radiation (sunlight) into electricity. A solar cell is a semi- conducting device made of silicon materials, which, when exposed to sunlight, generates electricity. Solar cells are connected in series and parallel combinations to form modules that provide the required power. PV modules are manufactured by assembling the solar cells after stringing, tabbing and providing other interconnections.

Fig A3: Solar power station in desert

Manufacturers of thin film panels in each technology are rapidly expanding their production capacities in order to utilize their potential economies of manufacturing scale. The dominant material and technology today is crystalline silicon, which accounts for approximately 90% of the globally installed PV capacity. Significant cost reduction can be achieved by applying thin film solar cell technology

Fig A4: Typical Waste Land for Solar PV Systems

Comparison of SPV technologies:

A comparison of different cell type used in Solar Photo Voltaic Technologies is described as below:

Cell Type	Efficiency of Cell	Cost of technology	Approximate Temperature Coefficient of P_{max}	Land requirement per MW
Mono Crystalline Silicon	Around 18%-24%	High cost	$-0.48\%/^0C$	3 to 4 Acres
Poly/ Multi crystalline Silicon	Around 14%-18%	Medium	$-0.44\%/^0C$	4 to 5 Acres
Thin Film (Different Types)	Amorphous silicon 6%-10%	Low cost	$-0.2\%/^0C$	7.5 to 9 Acres
	Cadmium Telluride 10%-11%	Lower cost	$-0.2\%/^0C$	
	Copper Indium Gallium Diselenide 12%-14%	Lowest cost	$-0.2\%/^0C$	

Collector Orientation

To get the most of the radiation from position-fixed (or seasonally adjusted) photovoltaic or thermal solar panels, you need to point them in the direction that captures the most sun. As per the collector's orientation, the solar PV systems can be classified as three types as below:

a) Fixed Tilt Sytems
b) Single Axis Tracker
c) Dual axis Tilts

(a) Fixed Tilt Sytems:

Fixed Tilt system have following characsterics as given below

- Fixed Tilt Solar Racking System is applicable to install the usual framed module to tilt a certain angle with the roof.
- The solar system can be a fixed angle or adjustable such as 10~15 deg, 15~30 deg and 30~60 deg as per the requirement. It's a mainly having the Latitude Tilt.
- This type of structure is cheapest among other kind of tilt systems.
- The approximate age limit of such type of solar panels are 20 years.
- These systems can scale easily from small to large, multi-megawatt installations with a 18% plant load factor.

Fig A5: Solar panel with fixed tilt system

(b) Single Axis Tracker:

Single axis tracker system have following characsterics as given below

- It consists of a PV panel rotating around a tilted shaft under the action of a Bidirectional-DC Motor controlled according to the real sun position estimated by means of two light intensity sensors.
- The single-axis panel produces more power than that of the fixed mount solar panels. It has the 20% Plant Load Factor.
- The light sensor's consists of two LDR's placed on either side of the panel separated by an opaque plate. Depending on the intensity of the sun rays one of the two LDR's will be shadowed and the other will be illuminated.

- When axis tilt approaches from zero to latitude, more solar energy can be harvested but at costs of more material and land use, and less stability under gusty wind.
- The power efficiency calculated for the singe-axis solar tracker is said to be 13% more than that of the fixed mount type.
- When it is cloudy, light sensing mode will be put on idle, while timing control takes in charge, allowing the tracker to continue moving from East to West.
- It is the most expensive structures among other types.

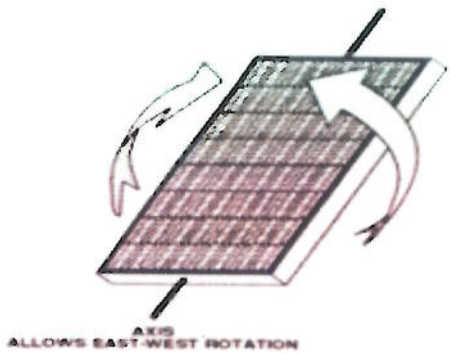


Fig. 1 Single-Axis Tracker

Fig A6: Solar panel with Single axis tracker

(c) <u>Dual axis Tilts</u>

Dual axis tilt system have following characsterics as given below

- The dual-axis tracking system is a readily available solution for the PV systems that yield a 40% increase in producing power compared to single axis tracker.
- An optimally aligned dual-axis tracking system produces about 40% more power than an optimally aligned fixed-frame system as it can tilt on azimuth and zenith axes. A dual-axis tracking system follows the sun daily and seasonally, always positioning the solar array so that it optimally faces both the sun.
- It increases efficiency by 35% as compared to fixed tilt solar plant of same PV capacity.
- It is also called Seasonal Tilt type of solar tracking system as the change of mounting angle of the panels to follow the seasons in your area your system will produce energy at the maximum potential for each season.

- Promotes excellent Land usage for Maximum energy generation

Fig A7: Solar panel with double axis tracker

CONCENTRATING SOLAR POWER (CSP):

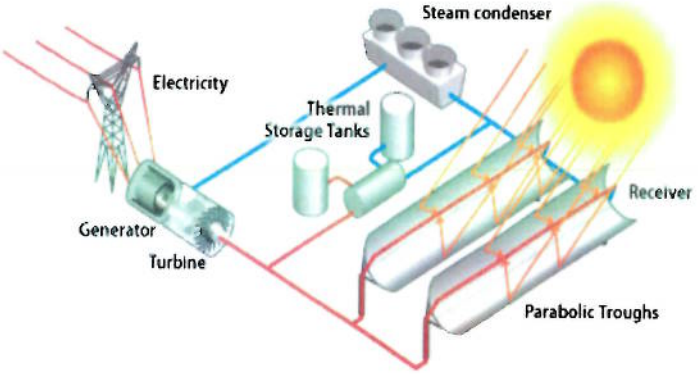
CSP (concentrating solar power) plants belong to the group of thermal power plants in which heat, in this case generated by solar irradiation, is transformed into electricity. In order to reach the high temperatures necessary for power cycles, the unscattered part of solar irradiation (direct normal irradiation, DNI) is concentrated. It is reflected and thereby concentrated by the use of large reflectors or reflector fields onto receivers which are perfused by a heat transfer medium. This medium is either directly used in a gas turbine or exchanges its heat into a water/steam cycle to power a standard steam turbine. It is another way of obtaining lower system costs and, consequently, lower electricity costs, is the use of concentration.

The sunlight is concentrated by lenses or mirrors and concentration factors of 500 to 1000. By concentration, expensive semiconductor material can be partly replaced by comprehensively cheap glass or plastic material for lenses and metal for cooling. Concentration systems need to be placed in direct sunlight and need to follow the sun. Therefore, they are only effective in locations with a lot of direct sunshine and they need to be placed on sun-tracking systems. One of the attractive options for using concentrating solar panels in desert regions is that a major part of the panels can be produced locally.

A major advantage of CSP technology is that it is possible to integrate comparatively cheap thermal storage, which allows for more constant electricity production and a certain degree of dispatch ability. This positions it somewhere between fluctuating PV/Wind and fully controllable gas power plants. For the concentration of sunlight, line focusing collector systems (Parabolic Trough systems, Linear Fresnel systems) and point focusing systems (Power Tower, Parabolic

Dish) with different characteristics exist. CSP installations require 7.5 acres to 10 acres/MW. High temperature solar energy collectors are basically of four types:

a) Parabolic Trough Systems:



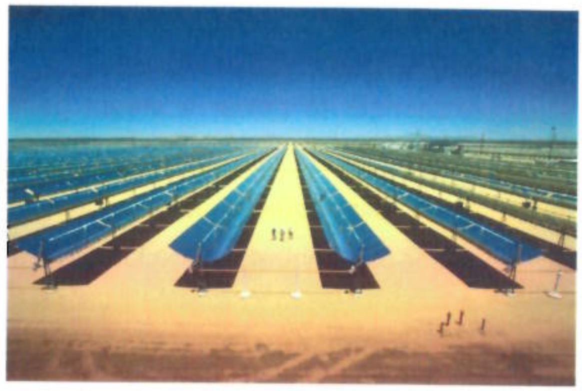


Fig A8: Parabolic Trough System

Parabolic Trough collector systems are a proven utility scale technology, in commercial operation since 1984, and currently the most common type of CSP worldwide. Trough solar systems use parabolic curved/ trough shaped reflectors that focus the sun's energy onto a receiver pipe running at the focus of the reflector. The concentrated energy heats a heat transfer fluid (HTF), usually oil, flowing through pipe. This fluid is then used to generate steam which powers a turbine. In a parabolic trough system, the receiver can reach 4000 C and produce steam for generating electricity. Depending on the arrangement of collector units, parabolic trough power stations can generate 10- 300MW of electricity. This technology is used in the Andasol complex in the Spanish province of Granada and also in the Californian Mojave Desert. Commercial plants have been operating since 1984.

As per the report on CSP by IRENA, at the end of 2010, around 1 220 MW of installed CSP capacity used the parabolic trough technology and accounted for virtually all of today's installed CSP capacity. As a result, parabolic troughs are the CSP technology with the most commercial operating experience.

b) Linear Fresnel Reflector Systems (LFC)

The linear Fresnel reflector technology receives its name from the Fresnel lens, which was developed by the French physicist Augustin-Jean Fresnel for lighthouses in the 18th century. The principle of this lens is the chopping of the continuous surface of a standard lens into a set of surfaces with discontinuities between them. This allows a substantial reduction in thickness (and thus weight and volume) of the lens, at the expense of reducing the imaging quality of the lens.

It is the most cost-effective and land-efficient Concentrated Solar Power (CSP) technology. Linear Fresnel reflectors use long, thin segments of mirrors to focus sunlight onto a fixed absorber located at a common focal point of the reflectors. These mirrors are capable of concentrating the sun's energy to approximately 30 times its normal intensity This concentrated energy is transferred through the absorber into some thermal fluid (this is typically oil capable of maintaining liquid state at very high temperatures). The fluid then goes through a heat exchanger to power a steam generator. As opposed to traditional LFR's, the CLFR utilizes multiple absorbers within the vicinity of the mirrors. It has the advantage of lower production costs and requires least amount of land per MW capacity among all solar technologies. The major components of the Linear Fresnel Solar power plant is as follows:

- **Collector:** The mirrors in the realized linear Fresnel collectors are made of flat mirror stripes, which receive a small curvature by mechanical bending. Like in parabolic troughs, the reflecting material is silver.
- **Receiver:** The receivers of the realized Fresnel systems have another structure than the receivers of parabolic trough power plants. The most eye-catching feature is the existence of a secondary concentrator and the absorber. In the systems that were realized until now they are much simpler than the absorber tubes in parabolic troughs. The receiver is placed on rollers to compensate the thermal expansion due to the high temperatures during operation. In the case of steel receivers the longitudinal thermal expansion at high operation temperatures amounts to approximately 0.6 %, i.e. 6 m for a 1000 m receiver.
- **Tracking system:** Like parabolic troughs, Fresnel collectors have a single axis tracking.
- **Steam drum:** These power plants are operated in direct steam generation mode. They need, hence, a water/steam separator within the solar field or between the solar field and the power block. In superheated steam systems it is integrated into the solar field between the evaporation section and the superheating section as a steam/water separator. In saturated steam systems it is located between the solar field and the power block.

The main advantages of linear Fresnel CSP systems compared to parabolic trough systems are

- LFCs can use cheaper flat glass mirrors, which are a standard mass-produced commodity;
- LFCs require less steel and concrete, as the metal support structure is lighter. This also makes the assembly process easier;
- Considerably lower investment costs for the solar field (at the same aperture area) and, hence, of the whole power plant (at the same nominal power), the lower operation and maintenance cost and the higher land use efficiency.

- The wind loads on LFCs are smaller, resulting in better structural stability, reduced optical losses and less mirror-glass breakage; and.
- The mirror surface per receiver is higher in LFCs than in PTCs, which is important, given that the receiver is the most expensive component in both PTC and in LFCs.

The disadvantage is that the solar-to-electric efficiency is still lower. The first large plant, Novatec Solar's PE-2 with 30MW, is still under construction. An estimation made in 2002 after the construction of the Solarmundo collector in Liège/Belgium claimed a total cost reduction for the solar field of nearly 50% in relation to the solar field of a parabolic trough power plant (measured in €/m2of aperture area). It is also claimed that the total cost reduction for the whole power plant to be up to 30%.

In 2008, Ausra built the first Fresnel power plant (solar only) in Bakersfield/California. Its electric power reaches 5 MW. Ausra was acquired in 2010 by the French Areva group. The first commercial Fresnel power plant in Europe, PE 1, was built by Novatec Solar AG (at that time Novatec Biosol). PE 1 is situated in Murcia/Spain and has an electric power of 1.4 MW. It started commercial operation in March 2009. A second Fresnel power plant, PE 2, is under construction. With 30 MW electric power it will be the largest Fresnel power plant worldwide at the moment when it starts its operation.

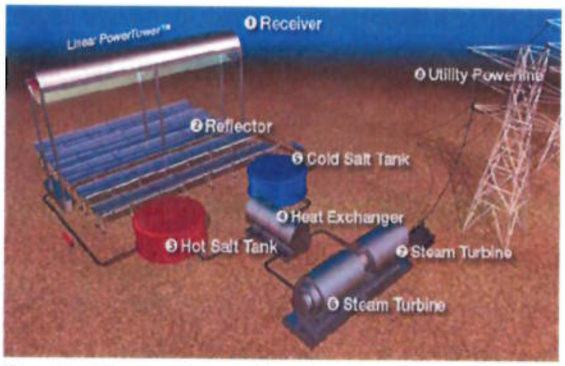


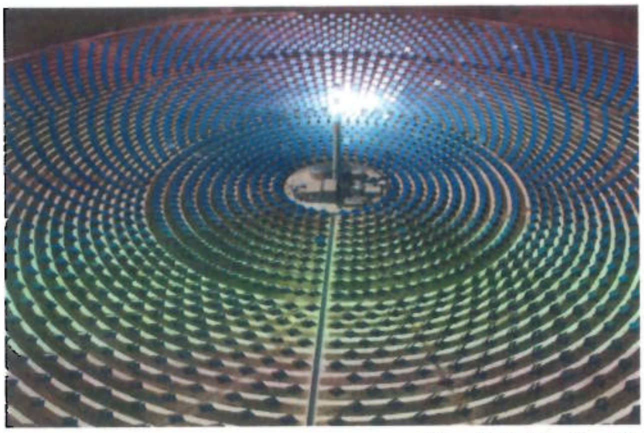
Fig A9: Linear Fresnel Technology (Overview)

Fig A10: which will be the largest Fresnel power plant with 30 MW electric power (source: Novatec Solar)

Fig A11: Ausra's Fresnel power plant in Bakersfield/California (source: www.ausra.com) Almería (source: DLR)

Fig A12: Fresnel reflector at the Plataforma Solar de

c) Power Tower Systems:



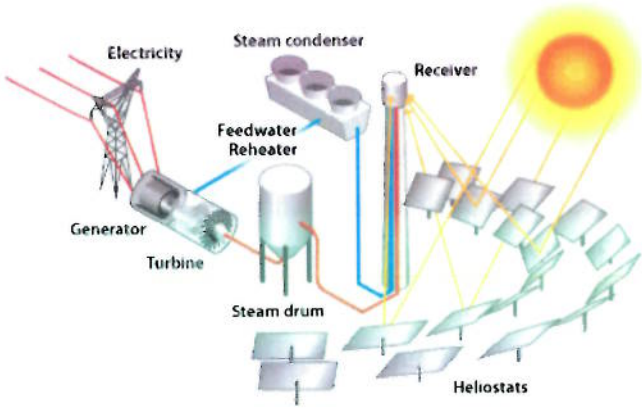


Fig A13: Typical Power Tower System

The solar tower plant is a type of solar furnace using a tower to receive the focused sunlight. It comprises an array of heliostats (mirrors) which concentrates the sun's rays on the top of the high tower where the solar receiver is located. The receiver collects the concentrated sun radiation and transfers the energy to generate steam. The reflected rays of the sun are always aimed at the receiver, where temperatures well above 1000^0C can be reached. The steam drives the turbo generator thereby producing electricity. Large plants comprising hundreds of square meter of heliostat and tower heights between 100-200 meters can generate many hundred MW of electricity. The high operating temperature enhances efficiency, because more heat can be stored. The receiver can be either a photovoltaic receiver for high concentrated solar radiation for direct electricity production (Concentrating Photovoltaic – CPV) or a thermal receiver (CSP).

A heliostat is a device that includes a mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky. The support structure of a heliostat typically consists of a foundation, a stand and a reflector frame holding the mirror and giving it the required shape.

Compared to linear concentrating solar power plants such as parabolic trough systems and linear fresnel reflectors, solar towers plants can reach higher concentration of solar radiation and therefore reach significantly higher temperatures from 500 to 1000°C. Therefore, the turbines can convert the heat into electricity more efficiently since the efficiency of turbines increases with the temperature.

The waste heat from a solar power plant can be used to run a solar desalination process. Thereby, solar power plants are also used to desalinate water if installed near the sea. This is a very useful application in sunny and dry regions or islands.

Solar towers have a number of potential advantages, which mean that they could soon become the preferred CSP technology. The main advantages of this technology are as below

- Higher temperatures can potentially allow greater efficiency of the steam cycle and reduce water consumption for cooling the condenser
- Higher temperature also makes the use of thermal energy storage more attractive in order to achieve schedulable power generation
- Higher temperatures will also allow greater temperature differentials in the storage system, reducing costs or allowing greater storage for the same cost

The key advantage is the opportunity to use thermal energy storage to raise capacity factors and allow a flexible generation strategy to maximize the value of the electricity generated, as well as to achieve higher efficiency levels. Given this advantage and others, if costs can be reduced and operating experience gained, solar towers could potentially achieve significant market share in the future, despite PTC systems having dominated the market to date.

The PS10 Solar Power Plant (Spanish: Planta Solar 10), is the world's first commercial concentrating solar power tower operating near Seville, in Andalusia, Spain. The 11 megawatt (MW) solar power tower produces electricity with 624 large movable mirrors called heliostats. It took four years to build and so far cost €35 million (US$46 million). PS10 produces about 23,400 megawatt-hours (MW·h) per year, for which it receives €271 (US$360) per MW·h under its power purchase agreement, equating to a revenue of €6.3 million per year.

d) Parabolic Dish Systems

Fig A14: Stirling Energy System Inc.'s 300 MW

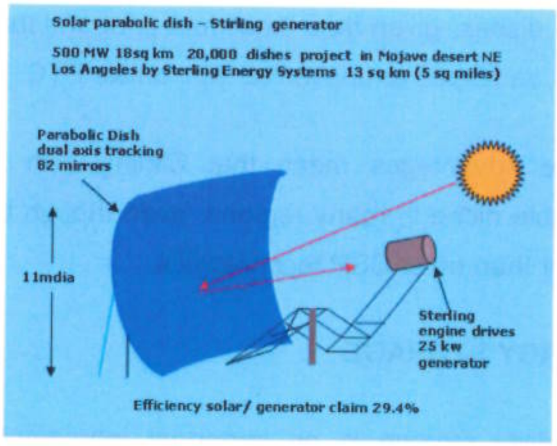


Fig A15: The parabolic dish technology (commercial solar thermal power plant in California)

Parabolic Dish systems use satellite-like mirror dish(es) to focus the light onto a single central receiver in front of the mirror. They so far have the highest heat-electricity conversion efficiencies among all CSP designs (up to 30 %). The size of the concentrator is determined by its engine. A dish/Stirling system's concentrator with a nominal maximum direct normal solar insolation of 1000 W/m2 and a 25-kW capacity has a diameter of approximately 10 meters. It could also run on a single Brayton cycle, where air, helium or other gas is compressed, heated and expanded into a turbine. Parabolic dish could be applied individually in remote locations, or grouped together for small-grid (village power, 10 KW) or end-of-line utility (100 MW) applications. The electricity has to be used immediately or transmitted to the gird as the system has no storage device. Intermittent cloud cover can cause weakening of highly concentrated receiver source flux. Sensible energy storage in single-phase materials was proposed to allow a cylindrical absorber element not only absorb the energy but also store it in its mass, thus reducing the amplitude of cloud cover transients. Although this design only allows short period energy storage, potential longer time storage technology would make parabolic dish more appealing. The system produces relatively small amounts of electricity (3 to 25 kilowatts of power) compared to other concentrating solar power technologies.

The main advantages of Stirling dish CSP technologies are as below:

- The location of the generator - typically, in the receiver of each dish - helps reduce heat losses and means that the individual dish-generating capacity is small, extremely modular (typical sizes range from 5 to50 kW) and are suitable for distributed generation;
- Stirling dish technologies are capable of achieving the highest efficiency of all types of CSP systems;
- Stirling dishes use dry cooling and do not need large cooling systems or cooling towers, allowing CSP to provide electricity in water-constrained regions; and » Stirling dishes, given their small foot print and the fact they are self-contained, can be placed on slopes or uneven terrain, unlike PTC, LFC and solar towers.

These advantages mean that Stirling dish technologies could meet an economically valuable niche in many regions, even though the levelised cost of electricity is likely to be higher than other CSP technologies.

ENERGY STORAGE

Electricity storage is an important ingredient in the operation of large-scale solar power generation systems especially in CSP. There should be a finite size of storage media, and balances the need to provide backup energy with the need to dump surplus solar power production. Thermal energy storage provides a workable solution to this challenge. A storage system enables:

- To negate the variability in system output due to sudden shifts in the weather
- Extend the range of operation beyond daylight hours

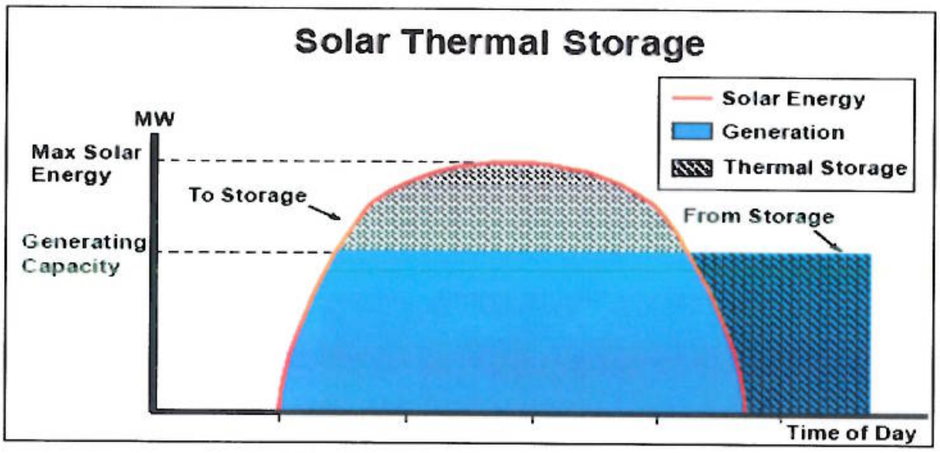


Fig A16: Solar Thermal Storage

In a concentrating solar power (CSP) system, the sun's rays are reflected onto a receiver, which creates heat that is used to generate electricity. If the receiver contains oil or molten salt as the heat-transfer medium, then the thermal energy can be stored for later use. This enables CSP systems to be cost-competitive options for providing clean, renewable energy. Several thermal energy storage technologies have been tested and implemented since 1985. These include the two-tank direct system, two-tank indirect system, and single-tank thermocline system.

a) Two-Tank Direct System:

Solar thermal energy in this system is stored in the same fluid used to collect it. The fluid is stored in two tanks—one at high temperature and the other at low temperature. Fluid from the low-temperature tank flows through the solar collector or receiver, where solar energy heats it to a high temperature, and it then flows to the high-temperature tank for storage. Fluid from the high-temperature tank flows through a heat exchanger, where it generates steam for electricity production. The fluid exits the heat exchanger at a low temperature and returns to the low-temperature tank.

Fig A17: Two Tank Moltan Salt thermal (Source : NREL)

Two-tank direct storage was used in early parabolic trough power plants (such as Solar Electric Generating Station I) and at the Solar Two power tower in California. The trough plants used mineral oil as the heat-transfer and storage fluid; Solar Two used molten salt.

b) Two-Tank Indirect System

Two-tank indirect systems function in the same way as two-tank direct systems, except different fluids are used as the heat-transfer and storage fluids.

Fig A18: Two Tank Indirect thermal energy storage (Source : FLAGSOL)

This system is used in plants in which the heat-transfer fluid is too expensive or not suited for use as the storage fluid.

The storage fluid from the low-temperature tank flows through an extra heat exchanger, where it is heated by the high-temperature heat-transfer fluid. The high-temperature storage fluid then flows back to the high-temperature storage tank. The fluid exits this heat exchanger at a low temperature and returns to the solar collector or receiver, where it is heated back to a high temperature. Storage fluid from the high-temperature tank is used to generate steam in the same manner as the two-tank direct system. The indirect system requires an extra heat exchanger, which adds cost to the system.

This system will be used in many of the parabolic power plants in Spain and has also been proposed for several U.S. parabolic plants. The plants will use organic oil as the heat-transfer fluid and molten salt as the storage fluid.

c) Single-Tank Thermocline System

Single-tank thermocline systems store thermal energy in a solid medium—most commonly, silica sand—located in a single tank. At any time during operation, a portion of the medium is at high temperature, and a portion is at low temperature. The hot- and cold-temperature regions are separated by a temperature gradient or thermocline. High-temperature heat-transfer fluid flows into the top of the thermocline and exits the bottom at low temperature. This process moves the thermocline downward and adds thermal energy to the system for storage. Reversing the flow moves the thermocline upward and removes thermal energy from the system to generate steam and electricity. Buoyancy effects create thermal stratification of the fluid within the tank, which helps to stabilize and maintain the thermocline.

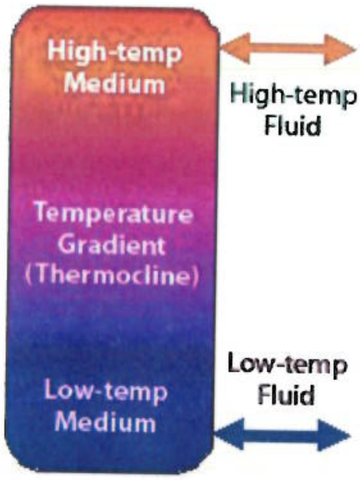


Fig A19: Single Tank Thermo cline thermal energy storage

Using a solid storage medium and only needing one tank reduces the cost of this system relative to two-tank systems. This system was demonstrated at the Solar One power tower, where steam was used as the heat-transfer fluid and mineral oil was used as the storage fluid.

COMPARION BETWEEN SPV & CSP

- Over the period 2000 - 11, solar PV was the fastest - growing renewable power technology worldwide. Cumulative installed capacity of solar PV reached roughly 65 gigawatts at the end of 2011, up from only 1.5 GW in 2000. In 2011, Germany and Italy accounted for over half the global cumulative capacity, followed by Japan, Spain, the United States and China.
- The problem with the big CSP projects is that they require a large upfront investment unlike Solar PV.
- In CSP, the sunlight is concentrated to produce heat/steam and the steam turbine is used to generate electricity. However, in Solar PV systems, direct conversion of sunlight to electricity is done with a proper tracking systems.
- The CSP is capable of generating when combined with storage systems. However, the solar PV can work in diffuse light also.
- CSP is more combinable with conventional power plant than solar PV.
- Solar PV is easier to maintain than CSP.

- Global Energy Generation: As per the World Energy Outlook 2012, by 2010, the solar PV energy generation is about 32TWh and the solar energy generation by CSP is about 2TWh.
- Initial Investments :The initial investment for a PV plant and for a CSP plant, respectively. Comparing the total cost/unit (about Rs. 1.5L/kWp for PV plant and about Rs. 2.7L/kWe for CSP), it can be noted that, nowadays, CSP plant requires a higher initial investment than that necessary for a PV plant with the same rated power.
- Maintenance Costs for 20 Years : Both the plants show degradation in the energy performance during the whole life-cycle; for both of them the degradation can be estimated in 0,5% to 1% for year. As CSP plant produces more energy than PV plant, this degradation has worse absolute economic effects for CSP plant than for PV plant. For PV plant the ordinary maintenance costs are equal to 1% of the initial investment for each year, then around Rs. 585L per year, while, for CSP plant, the annual maintenance costs are equal to 2%, due to the major complexity of the plant, then the yearly maintenance costs are around 2.3Cr.
- CSP technology lends itself to grid integration more readily than does VLS-PV (there being no need for a direct current/alternating current (DC/AC) inverter).
- Indeed despite higher costs CSP is very desirable when it comes to domestic consumption as it has the ability to store energy, unlike PV. This makes it inherently attractive; the storage capacity means the energy created can be stored and then used by the domestic population outside of daylight hours.

Wind Power Technology

The wind turbine generator converts mechanical energy into electrical energy and airflows is used to run wind turbines. Wind turbine generators differ from conventional generators, as it has to generate electricity using highly fluctuating mechanical power i.e, wind. A schematic of wind based generation system is shown at Fig A20

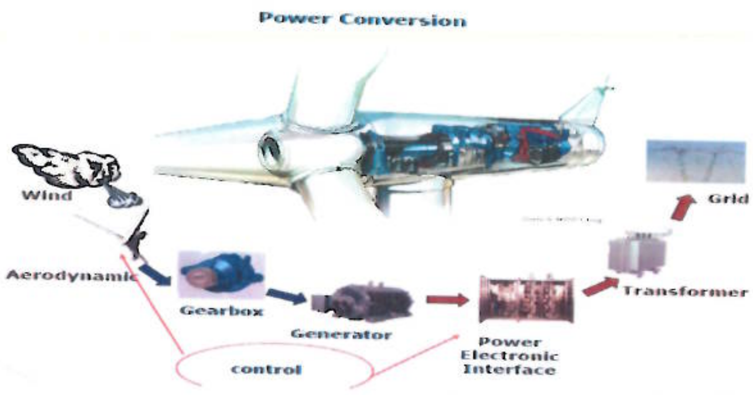


Fig-A20: Wind Turbine Blocks

Today the wind turbines on the market mix and match a variety of innovative concepts with proven technologies both for generators and for power electronics. The wind turbines can operate either with a fixed speed or a variable speed. The current power control topologies of wind turbines are described below:

Based on the design

a) Horizontal Axis Wind Turbine (HAWT)

Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind. Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor. Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator. Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Wind turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount. Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds, the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since turbulence leads to fatigue failures, and reliability is so important, most HAWTs are upwind machines.

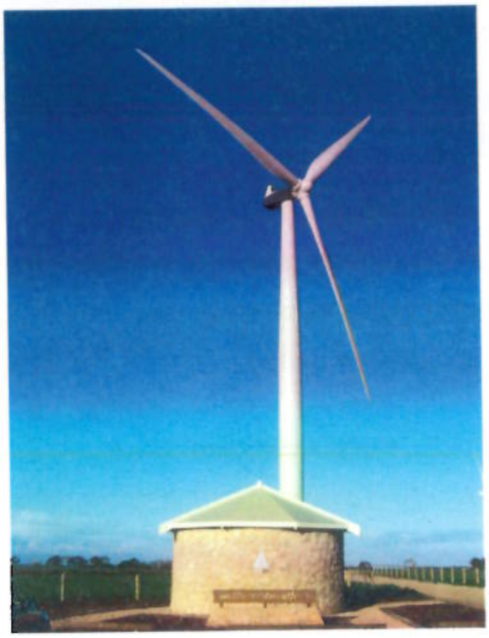


Fig-A21: Horizontal Wind Axis Turbine

HAWT advantages

- The tall tower base allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up the wind speed can increase by 20% and the power output by 34%.
- High efficiency, since the blades always move perpendicularly to the wind, receiving power through the whole rotation. In contrast, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring airfoil surfaces to backtrack against the wind for part of the cycle. Backtracking against the wind leads to inherently lower efficiency.

HAWT disadvantages

- Massive tower construction is required to support the heavy blades, gearbox, generator and an additional yaw control mechanism to turn the blades toward the wind.
- Downwind variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow (for this reason, the majority of HAWTs use an upwind design, with the rotor facing the wind in front of the tower).
- HAWTs generally require a braking or yawing device in high winds to stop the turbine from spinning and destroying or damaging itself.

b) Vertical Axis Wind Turbine (VAWT)

VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds. With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT is that it generally creates drag when rotating into the wind. It is difficult to mount vertical-axis turbines on towers, meaning they are often installed nearer to the base on which they rest, such as the ground or a building rooftop. Hence these models are not frequently used for off-shore installations which if used might require water proof casings that adds to extra costs. Also, offshore installations require very high height towers. The wind speed is slower at a lower altitude, so less wind energy is available for a given size turbine. Air flow near the ground and other objects can create turbulent flow, which can introduce issues of vibration, including noise and bearing wear which may increase the maintenance or shorten its service life. However, when a turbine is mounted on a rooftop, the building generally redirects wind over the roof and these can double the wind speed at the turbine. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence.

Fig-A22: Vertical Wind Axis Turbine

VAWT Advantages

- No yaw mechanism is needed because they have lower wind startup speeds than the typical the HAWTs.
- A VAWT can be located nearer the ground, making it easier to maintain the moving parts.
- VAWTs situated close to the ground can take advantage of locations where rooftops, mesas, hilltops, ridgelines, and passes funnel the wind and increase wind velocity.

VAWT Disadvantages

- Most VAWTs have an average decreased efficiency from a common HAWT, mainly because of the additional drag that they have as their blades rotate into the wind.
- Having rotors located close to the ground where wind speeds are lower due and do not take advantage of higher wind speeds above.

<u>Based on the principle of operation</u>

a) Asynchronous type wind generators

The most common generator used in wind turbines is the induction generator. It has several advantages, such as robustness and mechanical simplicity and economical.

When the rotor of the induction machine is rotated faster than the synchronous speed by a prime mover, it acts as a generator and feed power to the grid. An asynchronous generator allows slip, i.e deviations from the frequency of the connected grid. In other words, the rotational speed is allowed to vary somewhat with the applied torque.

Induction generators are self exciting type and the stator needs a reactive magnetizing current hence consumes reactive power.

b) Synchronous type generators

Synchronous type generators always operate at constant speed, dictated by the frequency of the connected grid, regardless of the applied torque and there is no relative movement (slip) between rotor speed and synchronous speed of the rotating stator field. The synchronous generator is much more expensive and mechanically more complicated than an induction generator of a similar size.The magnetic field in the synchronous generator can be created by using permanent magnets or with a conventional field winding.

<u>Based on Wind Turbine Technology</u>

Wind turbines can operate either with a fixed speed or a variable speed. Based on the operating speed categorisation, details of different types of generators are as under:

a) Fixed speed Generators

The fixed speed generators are directly connected to the grid using a Squirrel Cage Induction Generator (SCIG). The fixed speed SCIG consumes reactive power and can't contribute to voltage control. Schematic of fixed speed SCIG is shown at Fig A23.

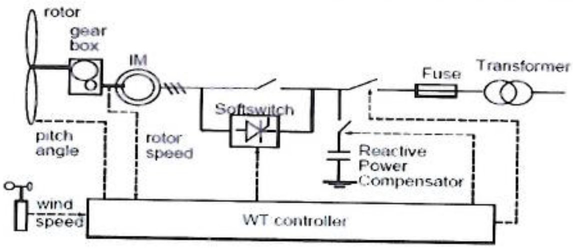


Fig-.A23: Squirrel Cage Induction Generator

Wind turbine and the rotor of the generator is coupled with a gear box which is used to match the rotational speed of blades with that of generator. Typically, the speed range is 0–2% above synchronous speed, which is almost a fixed speed. The reactive power compensation is achieved by connecting capacitor bank on stator side. SCIG are typically equipped with a soft-starter mechanism for smoother grid connection.

The fixed speed wind turbine has the advantage of being simple, robust and reliable and well proven. Moreover, the cost of its electrical parts is low. Its disadvantage are an uncontrollable reactive power consumption, mechanical stress and limited power quality control. Owing to its fixed-speed operation, all fluctuations in the wind speed are further transmitted as fluctuations in the mechanical torque and then as fluctuations in the electrical power on the grid. In case of weak grids, the power fluctuations can also lead to large voltage fluctuations, which in turn, will result in significant line losses.

b) Variable speed wind generator

During the past few years the variable-speed wind turbine has become the dominant in market. The control flexibility offered by static converters in the variable-speed wind turbines make possible independent active and reactive power control exchanged between the machine and the grid. In addition, it also facilitates better use of the available wind energy and higher power production as the wind turbine can rotate at the optimal rotational speed for range of wind speed and the grid voltage control as the reactive power generation can be varied. It also keeps the harmonic contents injected into the grid by the power converter at low level improving the quality of the energy injected into the public grid. As disadvantages, variable speed wind turbines need a power electronic converter (PEC) that increases the component count, cost and make the control more complex. The various configurations of the variable speed generator systems are as under :

(i) Wound Rotor Induction Generator with dynamic slip control

It is direct grid connected induction generator with variable generator rotor resistance. The variable speed conditions are achieved by dissipating energy within the resistors. This type of

WRIGs also termed as Semi variable speed wind turbine with speed range of upto 10% above synchronous speed

(ii) Double-Fed Induction Generator (DFIG)

As compared to above WTG technologies, doubly fed induction generator, offers advantage of reduced capacity converter (PEC), decoupled control of active and reactive power and wider range of dynamic speed control (- 40% to + 30%). In DFIG a power electronic converter is connected between the rotor circuit and the grid, this means that only the slip power is handled by the inverter and the rating of the inverter is often only 20%–30% of the generator rating. In this type of technology, the rotor is supplied with power from the grid such that over synchronous operation and sub synchronous operation of the generator is possible. Schematic of DFIG is shown at Fig A24

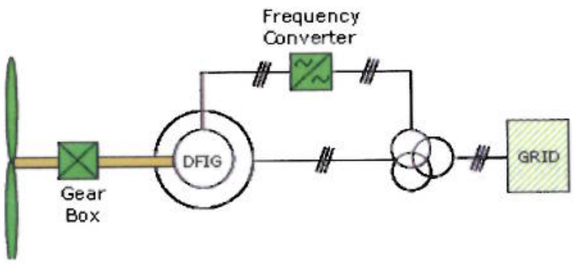


Fig-A24: Double fed Induction Generator

A DFIG wind turbine can transmit power to the network through both the generator stator and rotor, depending upon the operating mode. Now-a-days manufacturers are offering this type of wind turbines with fault ride-through capabilities also.

(iii) Direct driven (gearless) multi-pole Synchronous Generator

This type of technology offers advantage of full control of active/reactive power, operation at wide range of wind speed, better fault ride through as well as gearless connections. In this type of technology, generators are connected to the grid through full size PECs which performs the reactive power control and ensures smoother grid connection. Schematic of synchronous WTG is shown at Fig A25.

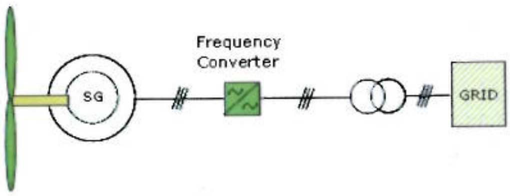


Fig-A25: Synchronous Generator

Variable speed operation is usually effected via an AC-DC-AC link. The variable frequency AC from the generator is rectified into DC and fed into the grid via an AC inverter. This concept permits wide range of speed variation as DC link circuit effects a complete decoupling of the rotor speed from the grid frequency.

Appendix-2

1. Introduction

POWERGRID jointly with Puducherry Electricity Department (PED), Renewable Energy Agency of Puducherry (REAP) and collaborators in the field of Smart Grid established a pilot smart grid project at Puducherry and already implemented following attributes.

- Advanced Metering Infrastructure (AMI)
- Outage Management System(OMS)
- Power Quality Management (PQM)
- Virtual Demand Response (DR)
- Renewable integration
- Solar charging based Electric Vehicle (EV)
- Automatic street light control

2. Renewable Integration

As part Smart Grid Pilot Project renewable integration (rooftop solar PV) at three (3) locations through net metering arrangement have been installed at Puducherry.

Net metering is an electricity policy which allows utility customers to offset some or all of their energy use with self-produced renewable energy. Roof top SPV system generates power during the day time which is utilized by powering the captive loads and feeding excess power to the grid as long as grid is available. In case, where solar power is not sufficient due to cloud cover etc. the captive loads are served by drawing power from the grid. The grid- interactive rooftop SPV systems thus work on net-metering basis wherein the beneficiary pays to the utility on net meter reading basis only. Net metering works by utilizing a smart meter that is able to record energy flow in both directions. The meter records both import/export energy separately when a customer is drawing (Import) power from the utility grid (i.e., using more energy than they are producing) and when energy is being sent back to the grid (Export) surplus situation. At the end of a given month, the customer is billed only for the net energy used (Export-Import). Figure 1 depicts the net metering arrangement. Month wise performance of 3 kW solar plant in year 2012 is depicted in Figure 2.

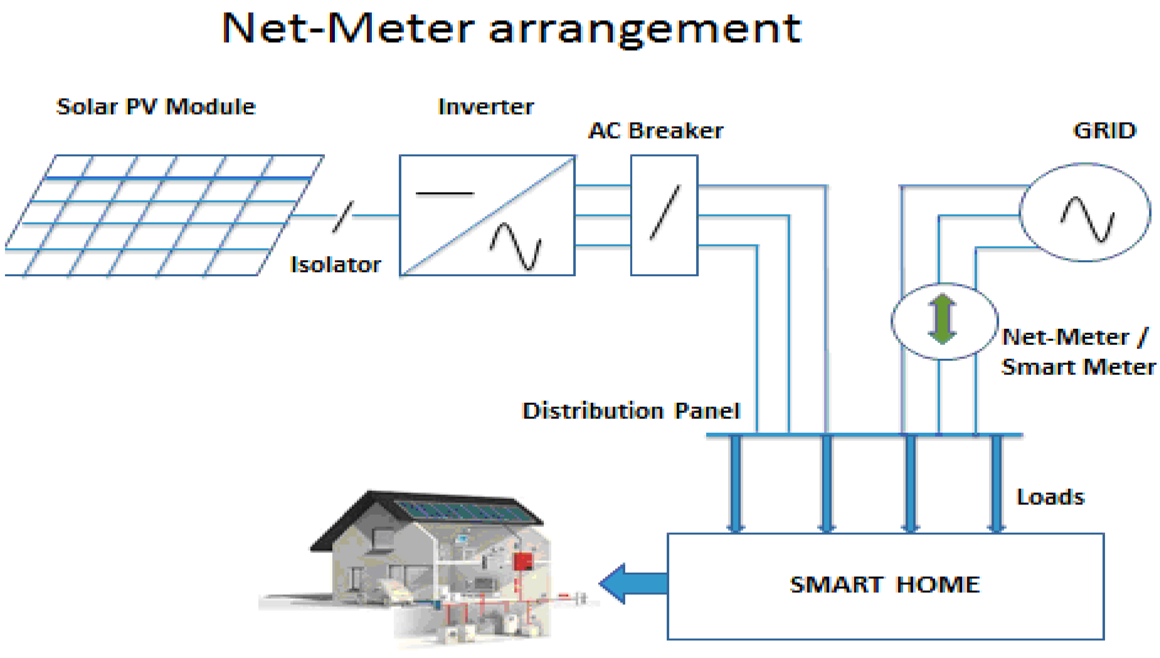


Figure 1: Net Metering Arrangement

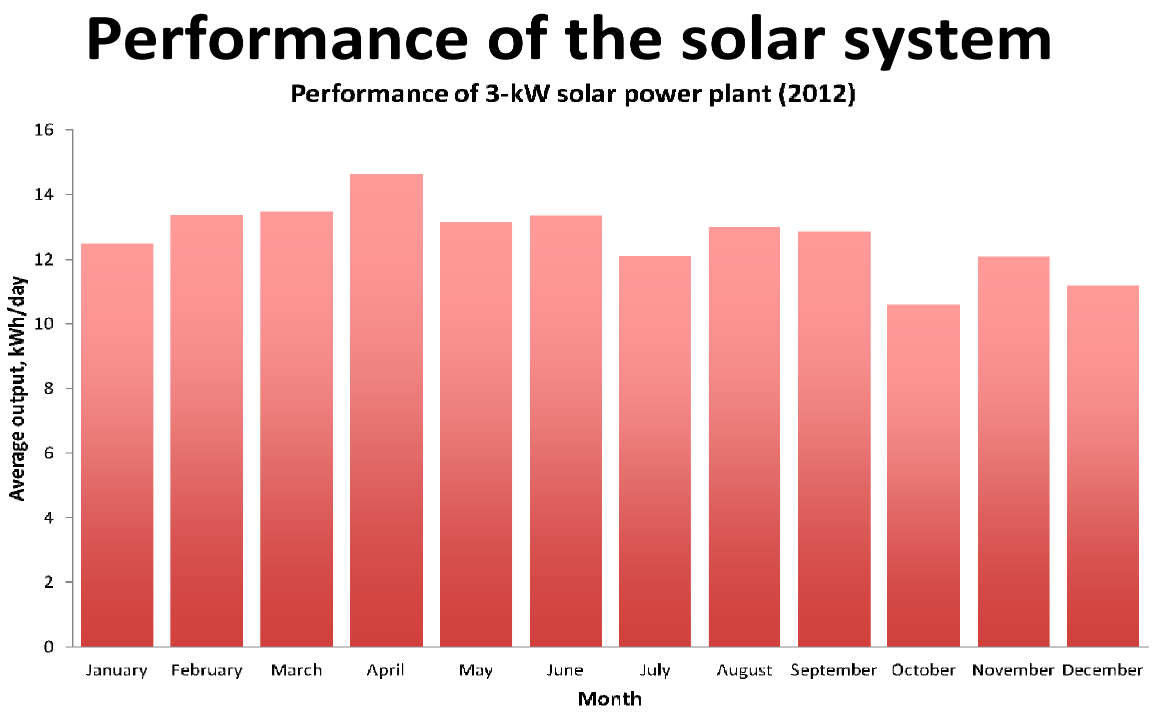


Figure 2: Month wise performance of 3 kW solar plant in year 2012

3. Location where Net metering implemented

S.no	Consumer details	PV system capacity
1	Consumer – 1, Residential consumer	3 kW
2	Consumer – 2, Educational Institute	3 kW

3.1. CASE – 1

Residence of Consumer – 1 (installed capacity 3 kW)

- The house in Puducherry has a long history of using solar energy
- The house installed efficient equipment like LEDs lamp, 5-star rated Fans, 5-star rated and inverter-based air conditioners, 5-star inverter based refrigerator, inverter-based Washing machine etc. Figure 3 depicts hourly & daily solar electricity generation pattern for the 4 seasons. Figure 4 shows the solar PV and smart meter installation.

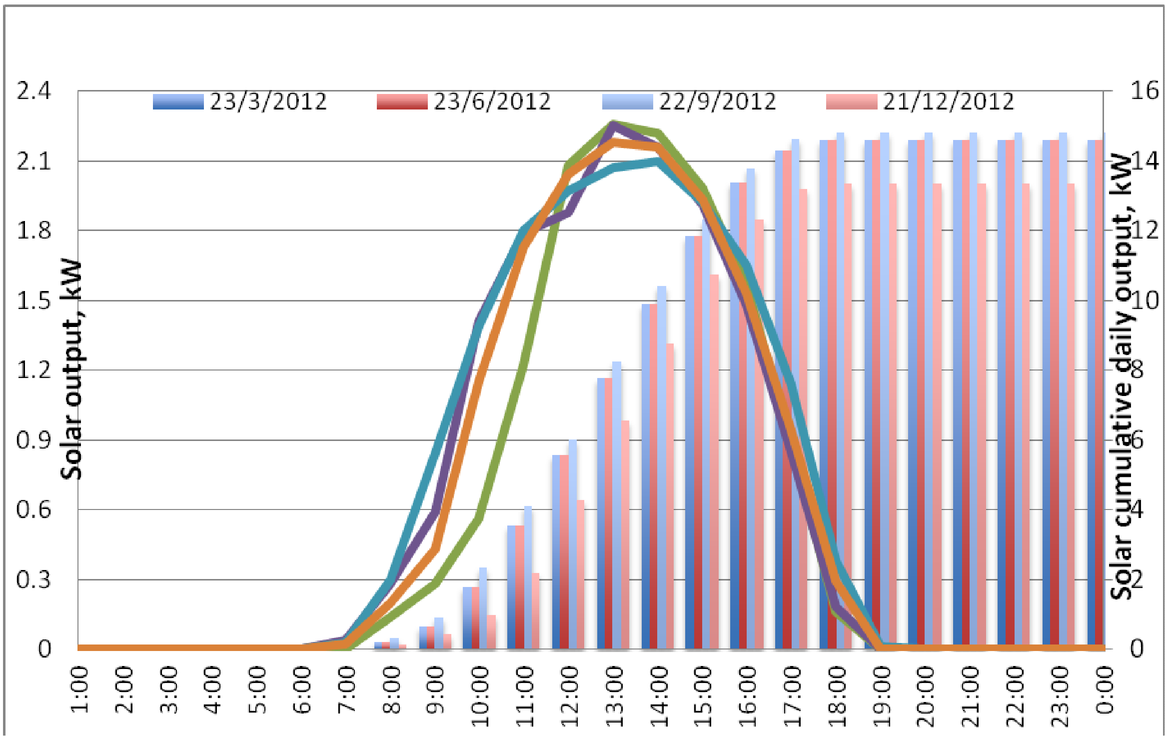
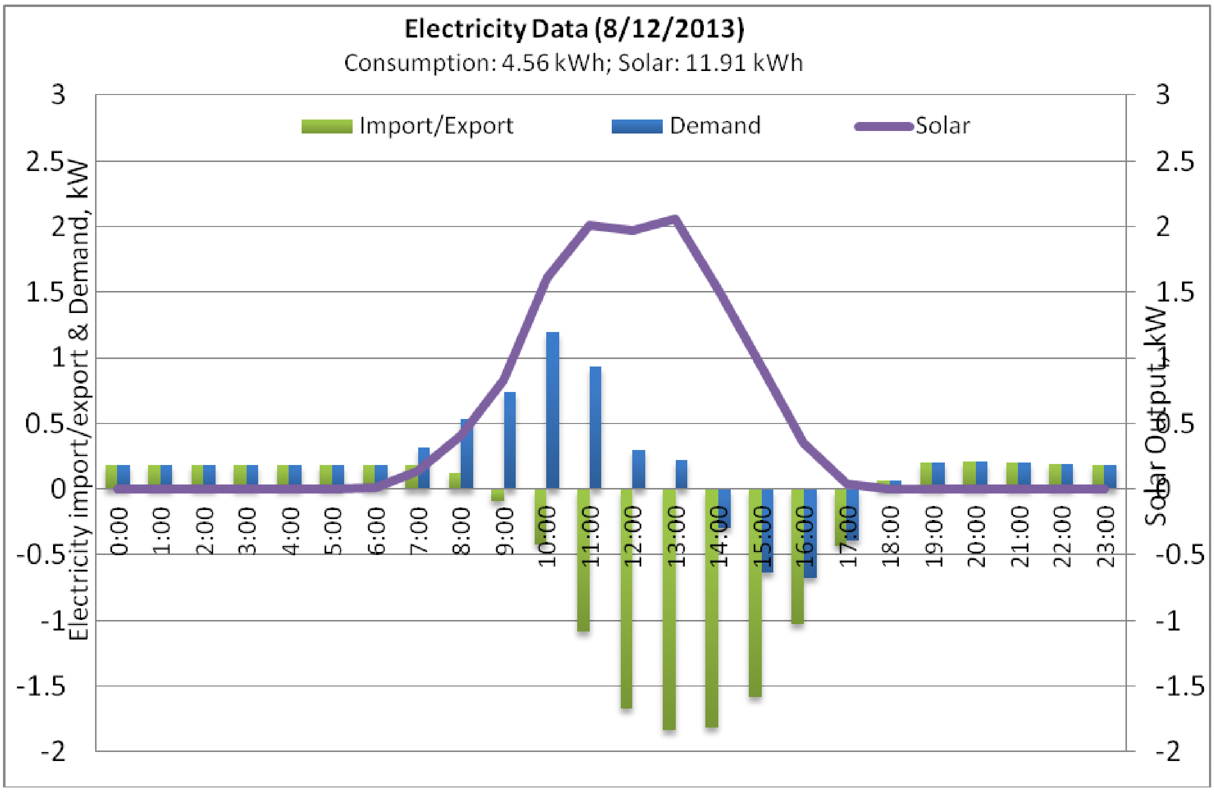


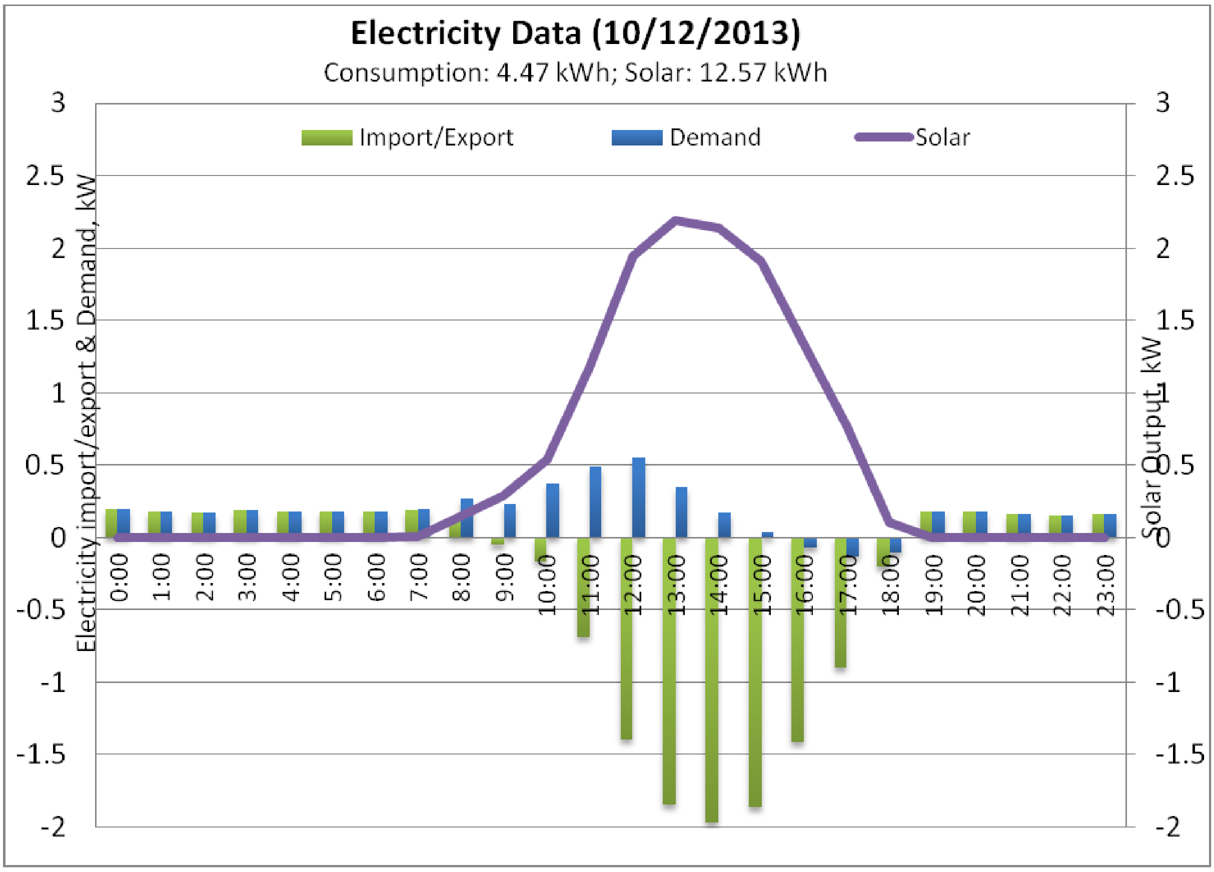
Figure 3: Performance of the solar system for 4 seasons

Figure 4: Solar PV modules and Smart meter at consumer – 1 Residence

Performance analysis

Consumer – 1's transaction of electricity (Import / Export) with electricity grid on hourly basis for couple of days has been scrutinized and depicted in Figure 5. The results show that consumer - 1 is exporting more power to the grid than importing. Performance of solar plant at consumer -1's premises with net metering facility throughout a month (November, 2013) and monthly electricity consumption & solar plant output is depicted in Figure 6.





Electricity Data (10/12/2013)
Consumption: 4.47 kWh; Solar: 12.57 kWh
Import/Export
Demand
Solar
Electricity import/export & Demand, kW
Solar Output, kW
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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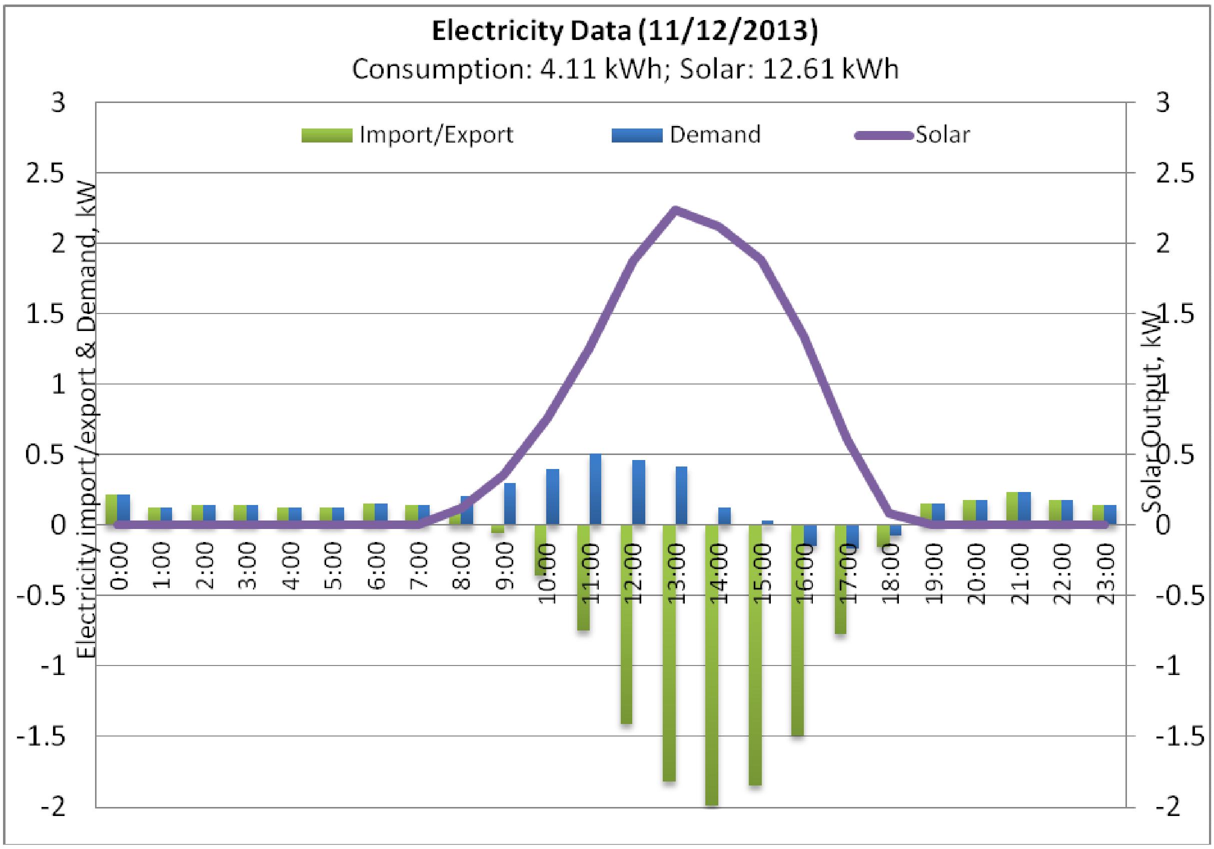
23:00



Electricity Data (11/12/2013)
Consumption: 4.11 kWh; Solar: 12.61 kWh
Import/Export
Demand
Solar
Electricity import/export & Demand, kW
Solar Output, kW
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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22:00
23:00

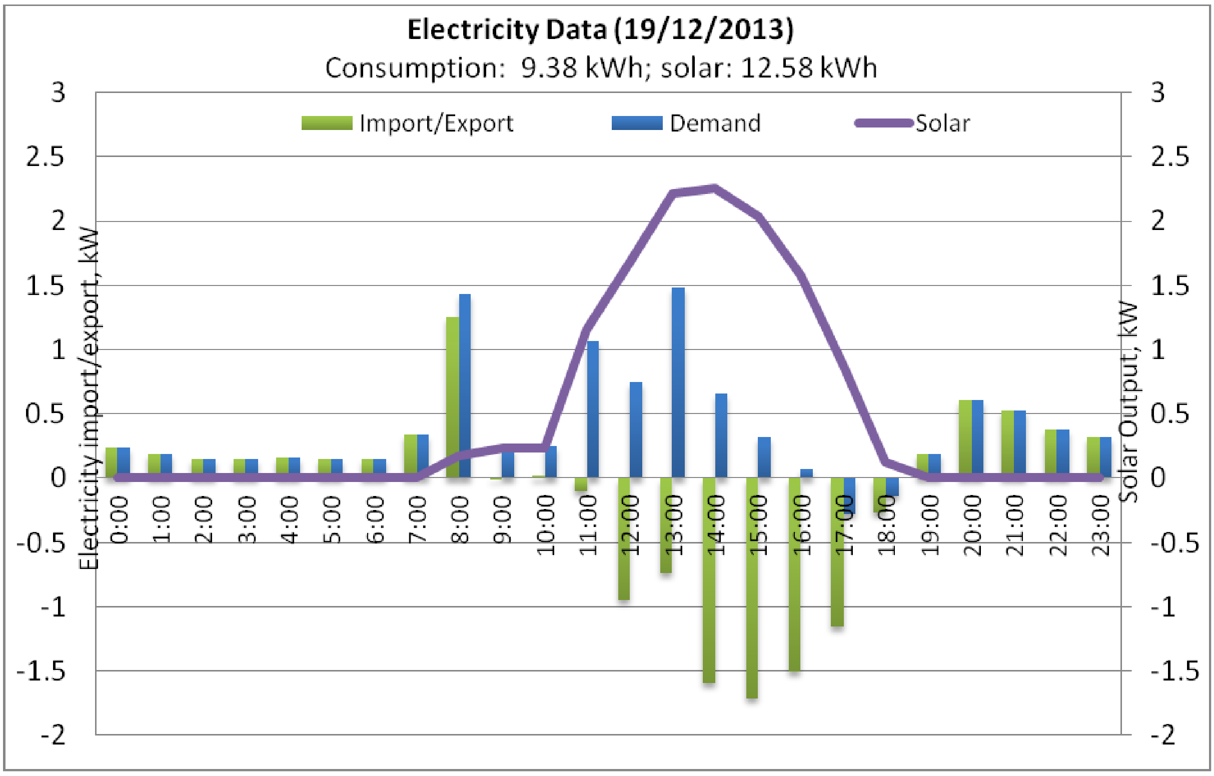

Figure 5: Solar plant performance for couple of days

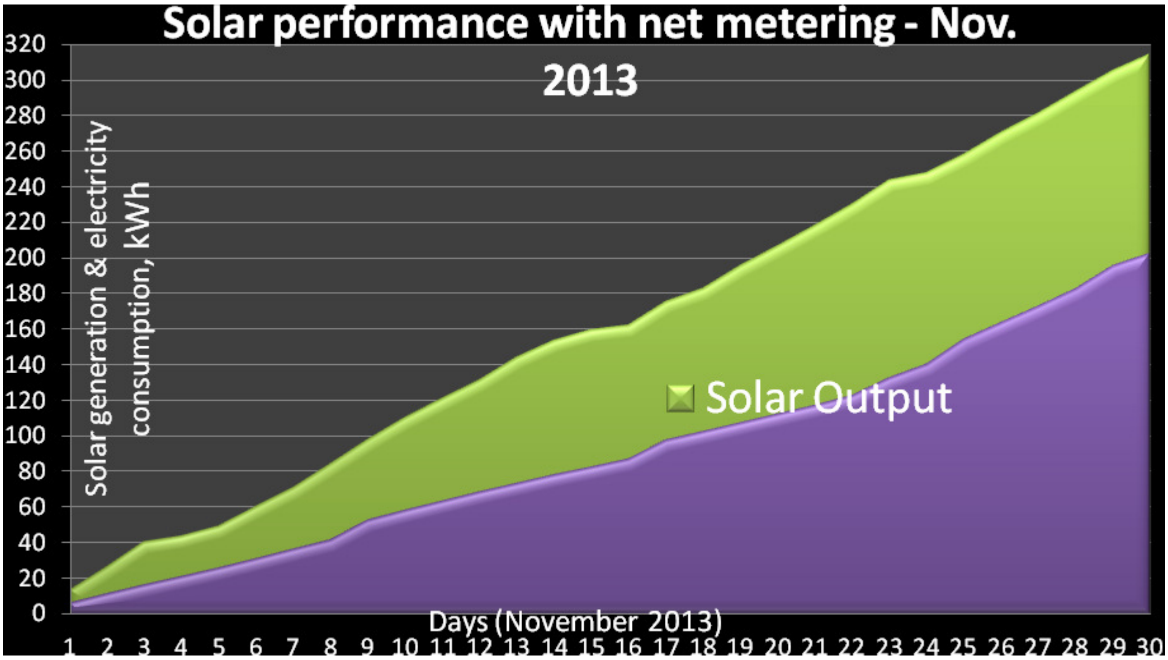

Figure 6: Solar plant performance for November month

Energy for three months: From 21.09.2013 to 20.12.2013

S No	Description	Units
1	Total Import energy (kwh)	557.03
2	Total export energy (kwh)	633.65

3	**Net energy (kwh)**	**-76.62**

- The consumer exporting more energy than Importing from Grid

3.2. CASE - 2

Educational Institute Consumer – 2

Sri Aurobindo International Centre of Education (SAICE) was established on 24 April 1951.

At present, the Centre of Education has about 150 full or part time teachers and 500 students, ranging from nursery to advanced levels. The curriculum includes the humanities, languages, fine arts, sciences, engineering, technology and vocational training; Facilities include libraries, laboratories, workshops, a theatre and studios for dance, music, painting, etc.

SAICE has a Solar PV of 3 kW installed at the roof top of its Building.

Figure 7: Solar PV module at SAICE

Typical generation for solar PV is depicted in Figure 8 & 9.

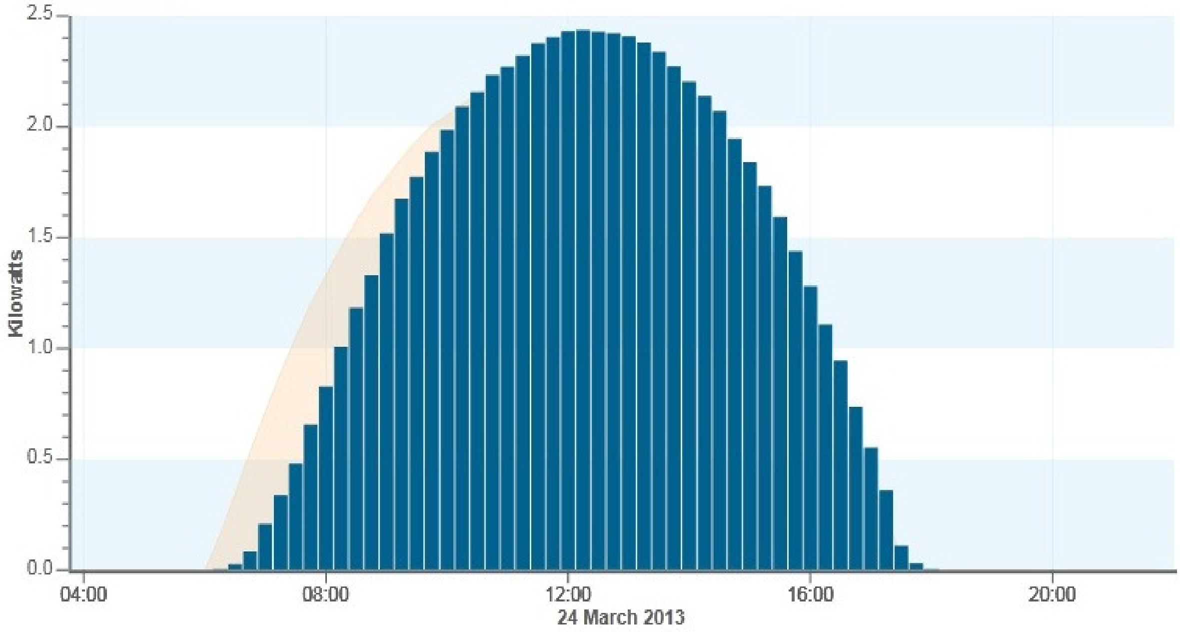

Figure 8: Typical Generation of clear Sunny Day

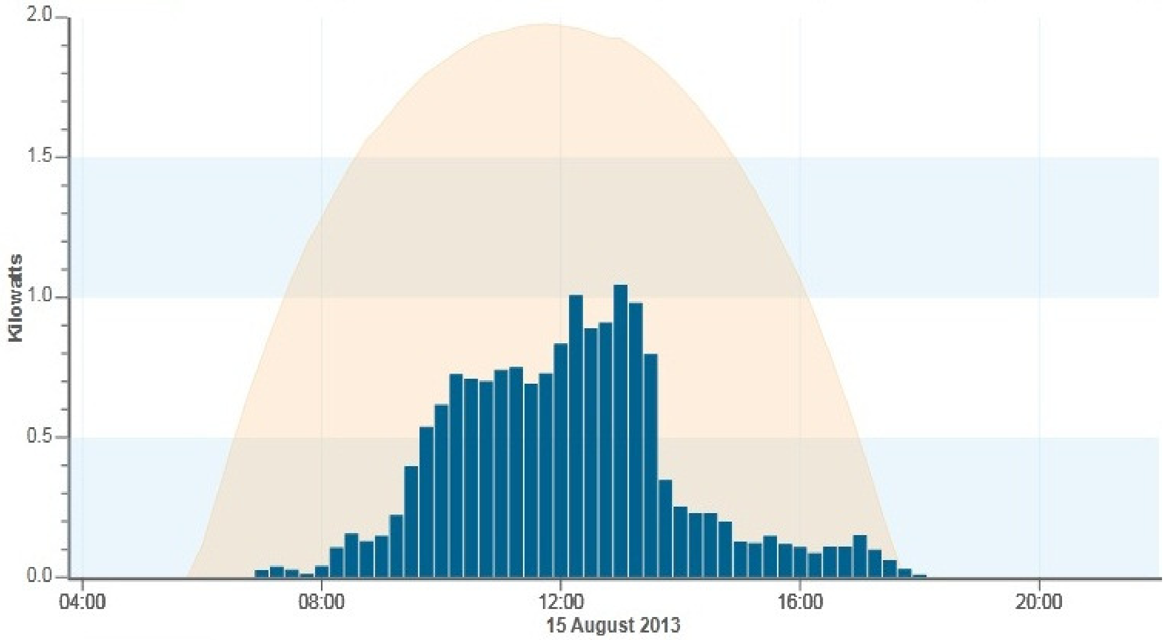

Figure 9: Typical Generation on Cloudy/Rainy Day

Performance analysis

Solar plant performance of a typical day at SAICE is depicted in Figure 10.

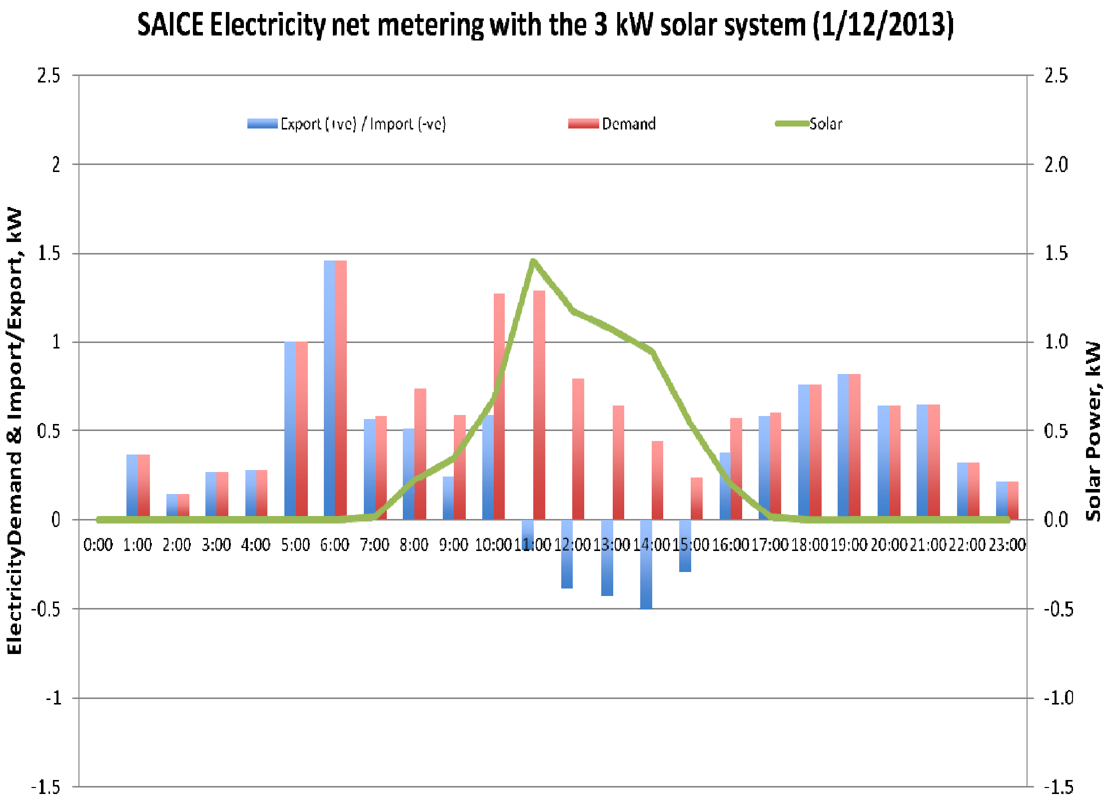

Figure 10: Solar plant performance of a typical day at SAICE

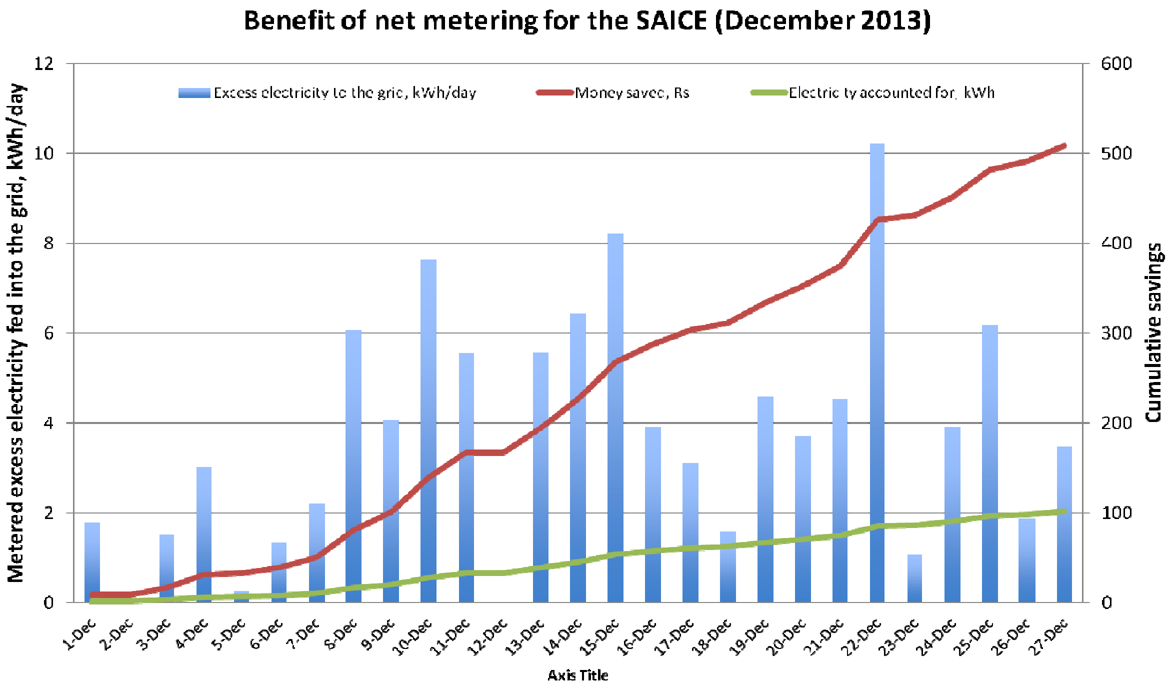

Figure 11: Benefit of Solar plant through net metering at SAICE

Energy for three months: From 21.09.2013 to 20.12.2013

S No	Description	Units
1	Total Import energy (kwh)	1720.89

2	**Total export energy (kwh)**	**358.88**
3	**Net energy (kwh)**	**1362.02**

4. Conclusion

The net metering allows consumer to get full credit for every kWh of electricity that is generated by the solar plant and they are able to achieve benefits after installation of net metering. Given below are the benefit achieved through of Net Metering

- The average electricity consumption of the house is around 300-450 kWh/month. The solar output also varies from 300 to 450 kWh/month depending on the season, therefore net energy exchange is zero leading to "net zero" billing.
- Consumer – 1 meeting whole requirement through the solar generation and he is exporting energy to grid also (Total energy import 557 KWH, Total energy export 633 KWH).
- The solar electricity production of consumer -2 (Educational Institute) from solar is 64.4% of the electricity consumption
- Additional saving of consumer - 2 for a period of one month due to net metering is Rs 508.
- Enable sustainability and low carbon emission

5. Way Forward

The above Pilot project of installation of rooftop solar PV through net metering at at Puducherry gives following way forward:

- This pilot experience should be used by the policy and decision makers to create awareness and formulate suitable policy/regulation that encourages every consumer to become a "prosumer", thereby reducing the dependence on fossil fuels.
- Every school/ institution/office/factory/house may be encouraged to install such facility to achieve a low-energy or net-zero energy installation.

APPENDIX-3

District And Category-Wise Wastelands- Rajasthan

In Sq Kms	DISTRICT	Gullied and/or Ravinous Land	Upland with or without Scrub	Waterlogged and Marshy Land	Land Affected by Salinity/Alkalinity Coastal/Inland	Shifting Cultivation Area	Under utilised/Degraded notified Forest Land	Degraded Pastures/ Grazing Land	Degraded Land under Plantation crop	Sands-Inland/Coastal	Mining/Industrial Wastelands	Barren Rocky/Stony Waste/Sheet Rock Area	Steep Sloping Area	Snow Covered and /or Glacial Area	Total Wastelands	Total Geographical Area	Percentage of total Geographical Area
1	AJMER	124.12	1553.63	0	386.79	0	480.65	600.94	0	68.81	0.9	121.52	0	0	3337.36	8481	39.35
2	ALWAR	206.07	616.3	0	13.45	0	956.92	1.37	0	20.8	5.99	252.47	0	0	2073.37	8380	24.74
3	BAIKANER	73.19	415.86	35.88	4.05	0	78.84	669.23	0	2098.47	13.77	0	0	0	3389.29	27244	12.44
4	BANSWARA	1.83	948.71	0	0.12	0	153.95	5.05	0	0.37	0	0.31	33.04	0	1143.38	5037	22.7
5	BARMER	0	1193.15	0	254.19	0	126.97	1734.71	0	5893.09	3.7	291.3	0	0	9497.11	28387	33.46
6	BHARATPUR	122.7	369.61	0.67	21.24	0	20.97	40.97	0	2.47	0	6.35	19.82	0	604.8	5092	11.88
7	BILWARA	32.25	1371.94	0	66.74	0	423.5	1293.52	0	3.63	0	597.1	0.7	0	3789.38	10455	36.24
8	BUNDI	417.52	446.32	0	41.19	0	1045.54	156.42	0	0	0	253.44	8.76	0	2369.19	5550	42.69
9	CHITTAURGARH	110.31	1468.76	0	224.47	0	373.69	344.96	0	0	0	166.23	0	0	2688.42	10856	24.76
10	CHURU	0	3.35	0	15.17	0	32.03	1264.75	0	318.39	5.7	1.2	0	0	1640.59	16830	9.75
11	DHOLPUR	468.46	743.57	0	0	0	139.31	0	0	0	0.57	5.89	0	0	1357.8	3008	45.14
12	DUNGARPUR	0	807.12	0	0	0	214.11	0	21.14	0	0	0.62	0	0	1042.99	3770	27.67
13	HANUMANGARH	0	0	108.51	9.43	0	5.55	110.66	0	120.3	2.19	0	0	0	356.64	9656	3.69
14	JAIPUR	859.45	250.24	0	211.23	0	942.67	145.99	0	375.76	4.1	67.84	0	0	2857.28	14068	20.31
15	DAUSA	This district is newly formed out of Jaipur district and the statistics included in combined Jaipur district															
16	JAISALMER	0	6958	19	119	0	165	0	0	26432	0	905	0	0	34598	38401	90.1
17	JALORE	56.05	422.28	0	56.98	0	141.86	0	0	438.21	0	130.75	0	0	1246.13	10640	11.71
18	JHALAWAR	242.98	350.3	0	0	0	911.31	350.09	0	0	0	75.08	1.42	0	1931.18	6219	31.05
19	JHUNJHUNU	299.11	134.65	0	0	0	288.67	0	0	114.27	0.37	11.2	0	0	848.27	5928	14.31
20	JODHPUR	91.46	2197.2	0	169.62	0	34.93	1267.55	0	3103.77	25.63	90.82	0	0	6980.98	22850	30.55
21	KOTA	582.64	99.44	0.62	1.09	0	2438.86	679.02	0	0	41.25	222.04	27.27	0	4092.23	12436	32.91
22	BARAN	This district is newly formed out of Kota district and the statistics included in combined Kota district															
23	NAGAUR	44.82	507.37	0	216.54	0	127.25	862.35	0	504.72	16.52	67.7	0	0	2347.27	17718	13.25
24	PALI	15.57	928.77	0	668.73	0	616.18	864.67	0	53.96	0	130.35	16.5	0	3294.73	12387	26.6
25	SAWAI MADHOPUR	830.7	139.57	0	3.28	0	1105.61	327.72	0	13.6	0	1040.56	72.77	0	3533.81	10527	33.57
26	KARAULI	This district is newly formed out of Sawai Madhopur dist. and the statistics included in combined Sawai Madhopur dist.															

In Sq Kms	DISTRICT	Gullied and/or Ravinous Land	Upland with or without Scrub	Waterlogged and Marshy Land	Land Affected by Salinity/Alkalinity Coastal/Inland	Shifting Cultivation Area	Under utilised/Degraded notified Forest Land	Degraded Pastures/Grazing Land	Degraded Land under Plantation crop	Sands-Inland/Coastal	Mining/Industrial Wastelands	Barren Rocky/Stony Waste/Sheet Rock Area	Steep Sloping Area	Snow Covered and /or Glacial Area	Total Wastelands	Total Geographical Area	Percentage of total Geographical Area
27	SIKAR	123.42	83.79	0	28.74	0	560.14	353.26	0	151.8	0	23.83	0	0	1324.98	7732	17.14
28	SIROHI	50.83	424.83	0	0	0	820.54	370.77	0	125.77	3.37	311.79	0	0	2107.9	5136	41.04
29	SRIGANGANAGAR	0	912.57	124.98	0.23	0	0	0	0	722.95	0	0	0	0	1760.73	10978	16.04
30	TONK	197.81	80.97	0	210.71	0	241.01	685.07	0	76.37	0	22.52	0	0	1514.46	7194	21.05
31	UDAIPUR	1.48	3724.46	0	0	0	95.83	79.37	0	0	4.59	3.11	2	0	3910.84	17279	22.63
32	RAJSAMAD	This district is newly formed out of Udaipur district and the statistics included in combined Udaipur district															
	TOTAL	**4952.77**	**27152.8**	**289.66**	**2722.99**	**0**	**12541.9**	**12208.4**	**21.14**	**40639.5**	**128.65**	**4799.02**	**182.28**	**0**	**105639**	**342239**	**30.87**

District And Category-Wise Wastelands- Gujarat

In Sq Kms	DISTRICT	Gullied and/or Ravinous Land	Upland with or without Scrub	Waterlogged and Marshy Land	Land Affected by Salinity/ Alkalinity Coastal/ Inland	Shifting Cultivation Area	Under utilised/Degraded notified Forest Land	Degraded Pastures/Grazing Land	Degraded Land under Plantation crop	Sands-Inland /Coastal	Mining/ Industrial Wastelands	Barren Rocky/ Stony Waste/ Sheet Rock Area	Steep Sloping Area	Snow Covered and/or Glacial Area	Total Wastelands	Total Geographical Area	Percentage of total Geographical Area
1	AHMEDABAD	65.44	107.09	0	864.93	0	0.83	53.01	0	5.44	0	2.81	0	0	1099.55	8707	12.63
2	AMRELI	2.9	372.19	6.44	12.09	0	72.94	0	0	0	0	33.06	0	0	499.62	6760	7.39
3	BANASKANTHA	80.4	1236.66	53.62	551.86	0	546.97	8.84	1.08	47.05	3.77	52.78	159.93	0	2742.96	12703	21.59
4	BHARUCH	76.1	143.6	291.9	108.6	0	110.2	0	2	0	6.7	2.8	0.3	0	742.2	9038	8.21
5	NARMADA	This district is newly formed out of Bharuch dist. and the statistics included in combined Bharuch dist.															
6	BHAVNAGAR	25.8	1265.07	0	574.37	0	33.56	8.41	0	7.14	0	47.42	0	0	1961.77	11155	17.59
7	DANGS	0	0	0	0	0	113.4	0	0	0	0	0	0	0	113.4	1764	6.43
8	GANDHINAGAR	24.01	1.24	0 .	0	0	0	1.64	0	0	0	0	0	0	26.89	649	4.14
9	JAMNAGAR	0	2535.96	0	1.3	0	35	0	0	0	0	311.32	0	0	2883.58	14125	20.41
10	JUNAGADH	0	2328.6	0	0	0	487.38	0	0	0	0	325.16	0	0	3141.14	10607	29.61
11	PORBANDAR	This district is newly formed out of Junagadh dist. and the statistics included in combined Junagadh dist.															
12	KHEDA	152.57	73.19	0	147.02	0	26.94	19.39	3.96	9.17	1.86	92.88	0	0	526.98	7194	7.33
13	ANAND	This district is newly formed out of Kheda dist. and the statistics included in combined Kheda dist.															
14	KUTCH	108.2	8859.8	1618.7	4461.6	0	1764.6	160.6	0.9	106.6	14.2	1876.4	148.3	0	19119.9	45652	41.88
15	MEHSANA	79.5	329.87	0	115.56	0	0	90.06	0	3.69	0.19	0	0	0	618.87	9027	6.86
16	PATAN	This district is newly formed out of Mehsana & Banaskantha dist. and the statistics included in combined Mehsana & Banaskantha dist.															
17	PANCHAMAHAL	33.28	272.17	0	0	0	984.98	0	0	0	2.55	63.03	0	0	1356.01	8866	15.29
18	DAHOD	This district is newly formed out of Panchamahal dist. and the statistics included in combined Panchamahal dist.															
19	RAJKOT	56.69	1592.16	22.6	49.15	0	100.3	23.75	24.32	0	0.98	125.11	1.4	0	1996.46	11203	17.82
20	SABARKANTHA	180.99	599.81	0	2.61	0	431.54	2.16	2.48	3.6	0.44	135.33	162.59	0	1521.55	7390	20.59
21	SURAT	19.6	132.7	249.5	30.3	0	250.9	16.7	15.7	0	8.4	0.6	0	0	724.4	7657	9.46
22	SURENDRA NAGAR	35.39	1514.19	82.28	710.1	0	55.72	2.49	0	0	0	213.58	0	0	2613.75	10489	24.92
23	VADODARA	60.9	217.5	7.6	0	0	304.4	0	1.8	0	0.4	9.5	2.5	0	604.6	7794	7.76
24	VALSAD	11.62	204.92	323.62	7.85	0	123.36	0.4	26.08	5.73	10.17	1.61	12.29	0	727.65	5244	13.88
25	NAVSARI	This district is newly formed out of Valsad dist. and the statistics included in combined Valsad dist.															
	TOTAL	**1013.39**	**21787**	**2656.3**	**7637.34**	**0**	**5443.02**	**387.45**	**78.32**	**188.42**	**49.66**	**3293.4**	**487.31**	**0**	**43021**	**196024**	**21.95**

District And Category-Wise Wastelands- Jammu and Kashmir

In Sq Kms	DISTRICT	Gullied and/or Ravinous Land	Upland with or without Scrub	Waterlogged and Marshy Land	Land Affected by Salinity/ Alkalinity Coastal/ Inland	Shifting Cultivation Area	Under utilised/Degraded notified Forest Land	Degraded Pastures /Grazing Land	Degraded Land under Plantation crop	Sands- Inland/ Coastal	Mining/ Industrial Wastelands	Barren Rocky/ Stony Waste/ Sheet Rock Area	Steep Sloping Area	Snow Covered and/or Glacial Area	Total Wastelands	Total Geographical Area	Percentage of total Geographical Area
1	ANANTNAG	0.5	82.71	0	0	0	340.09	0	0	0	0.1	0	0	1429.9 9	1853.39	3984	46.52
2	BARAMULLA	0	1088.12	61.19	0	0	24.05	5.77	30	3.5	0.21	419.85	209.33	11.09	1853.11	4588	40.39
3	BUDGAM	0	183.36	47.91	0	0	0	0	2.84	0	0	178.71	0	1.76	414.58	1371	30.24
4	DODA	0	1210.6	0	0	0	912	0	0	0	0	1454.9 7	925.62	913.77	5416.96	11691	46.33
5	JAMMU	0	6.64	0	0	0	94.34	54.39	318.71	0	0	167.8	30.56	0	672.44	3097	21.71
6	KARGIL	0	4.35	0	0	0	1.5	169.07	0	61.97	0	11117. 2	100.59	2332.6 7	13787.3	14036	98.23
7	KATHUA (RAISE)	17.05	446.54	0	0	0	348.75	4.67	0	0	0	0	0	225.55	1042.56	2651	39.33
8	KUPWARA	0	337.37	0.09	0	0	63.38	0	8.75	0	0	7.74	2.96	0	420.29	2379	17.67
9	LADKH	0	27.12	0	0	0	0	0	0	803.79	0	19195. 9	0	16547. 6	36574.4	45110	81.08
10	POONCH	0	226.39	0.08	0	0	22.45	0	17.93	0	0	71.14	149.79	1.59	489.37	1674	29.23
11	PULWAMA	3.7	5.36	1.3	0	0	36.43	0	18.73	0	0	27.97	66.93	0	160.42	1398	11.47
12	RAJOURI	0	8.5	0	0	0	143.82	8.51	241.43	0	0	25.91	170.02	0	598.19	2630	22.74
13	SRINAGAR	0	547.17	135.93	0	0	3.75	0	2.17	0	0	3.18	29.62	22.65	744.47	2228	33.41
14	UDHAMPUR	0	321.07	0	0	0	501.1	25.1	0	0	0	151.14	0	418.28	1416.69	4550	31.14
	TOTAL	**21.25**	**4495.3**	**246.5**	**0**	**0**	**2491.7**	**267.51**	**640.56**	**869.26**	**0.31**	**32822**	**1685.4**	**21905**	**65444**	**101387**	**64.55**

District And Category-Wise Wastelands- Himachal Pradesh

In Sq Kms	DISTRICT	Gullied and/or Ravinous Land	Upland with or without Scrub	Waterlogged and Marshy Land	Land Affected by Salinity/ Alkalinity Coastal/ Inland	Shifting Cultivation Area	Under utilised/Degraded notified Forest Land	Degraded Pastures /Grazing Land	Degraded Land under Plantation crop	Sands-Inland/ Coastal	Mining/ Industrial Wastelands	Barren Rocky/ Stony Waste/ Sheet Rock Area	Steep Sloping Area	Snow Covered and/or Glacial Area	Total Wastelands	Total Geographical Area	Percentage of total Geographical Area
1	BILASPUR	33.41	58.03	0	0	0	134.74	278.13	0	0	0	0.64	59.46	0	564.41	1167	48.36
2	CHAMBA	0	0	0	0	0	254.97	0	2456.94	0	0	68.44	231.6	388	3399.95	6528	52.08
3	HAMIRPUR	0	17.35	0	0	0	4.87	83.85	0	0.25	0	1.26	56.49	0	164.07	1118	14.68
4	KANGRA	5	72.04	4.03	0	0	7.04	93.06	0	6.28	0	11.92	284.1	1003.07	1486.54	5739	25.9
5	KINNAUR	0	552.85	0	0	0	45.18	1410.45	0	1.31	0	1699.63	117.6	1438.76	5265.78	6401	82.26
6	KULLU	0.55	173.83	0.42	1.31	0	275.36	427.49	0	0	0	66.46	45.13	1744.63	2735.18	5503	49.7
7	LAHUL & SPITI	1.64	443.5	0.99	0.05	0	68.98	703.81	0.01	9.56	0	1871.79	344.92	7731.99	11177.2	13835	80.79
8	MANDI	8.3	229.57	0.92	0	0	1407.35	446.73	0	7.93	0	49.2	219.67	0	2369.67	3950	59.99
9	SHIMLA	1.6	172.02	0.09	0	0	330	231.91	0	0.08	0	60.9	19.76	252.97	1069.32	5131	20.84
10	SIRMOUR	0.52	87.42	0.65	0	0	1528.25	302.53	0.64	19.71	85.66	19.79	131.36	0	2176.53	2825	77.05
11	SOLAN	34.04	123.45	0.09	0	0	312.36	266.29	0	0	0	0.76	19.58	0	756.57	1936	39.08
12	UNA	36.83	126.44	8.5	0	0	220.88	33.92	0	59.92	0	7.25	0	0	493.74	1540	32.06
	TOTAL	**121.89**	**2056.5**	**15.69**	**1.36**	**0**	**4590**	**4278.2**	**2457.6**	**105.04**	**85.66**	**3858**	**1529.7**	**12559**	**31659**	**55673**	**56.87**

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