

**INDIAN INSTITUTE OF PUBLIC ADMINISTRATION**

**46<sup>th</sup> ADVANCED PROFESSIONAL PROGRAMME  
IN PUBLIC ADMINISTRATION**



**Exploring  
Potential Sustainable Energy Sources Based  
Hybrid Power Supply System at High Altitude**



**A Step towards *Aatma-Nirbhar Bharat***

by

**AIR COMMODORE SUHAS PRABHAKAR BHANDARE VSM**  
Roll No. 4603

**FACULTY GUIDE  
DR. SHYAMLI SINGH**

# Exploring Potential Sustainable Energy Sources Based Hybrid Power Supply System at High Altitude



**A Step towards *Aatma-Nirbhar Bharat***

**A Dissertation submitted to the Panjab University, Chandigarh, for the award of Master of Philosophy in Social Sciences, in Partial Fulfilment of the requirement for the 46<sup>th</sup> Advanced Professional Programme in Public Administration (APPPA)**

by

**AIR COMMODORE SUHAS PRABHAKAR BHANDARE VSM**  
Roll No. 4603

**UNDER THE GUIDANCE OF**  
**DR. SHYAMLI SINGH**



**INDIAN INSTITUTE OF PUBLIC ADMINISTRATION**

**46<sup>th</sup> ADVANCED PROFESSIONAL PROGRAMME  
IN PUBLIC ADMINISTRATION (2020-21)**

# Declaration

This is to certify that the present dissertation on the research project titled "Exploring Potential Sustainable Energy Sources Based Hybrid Power Supply System at High Altitude - A Step towards Aatma-Nirbhar Bharat" is the result of my own and genuine research work and no part of it has earlier comprised any other monograph, dissertation or book. The data, charts and text, wherever required in support of the research, have been taken from reliable sources, and all such references have been appropriately credited.



**(SUHAS PRABHAKAR BHANDARE)**

Dated : 30 March 2021

**Air Commodore**  
Roll No. 4603, 46<sup>th</sup> APPPA

# Certificate

I have the pleasure to certify that Air Commodore Suhas Prabhakar Bhandare VSM has pursued his research work and prepared the present dissertation titled "Exploring Potential Sustainable Energy Sources Based Hybrid Power Supply System at High Altitude - A Step towards Aatma-Nirbhar Bharat" under my guidance and supervision. The dissertation is the result of his own research, and to the best of my knowledge, no part of it has earlier comprised any other monograph, dissertation or book. This is being submitted to the Panjab University, Chandigarh, for the purpose of Master of Philosophy in Social Sciences in Partial fulfilment of the requirement for the 46<sup>th</sup> Advanced Professional Programme in Public Administration (APPPA) of Indian Institute of Public Administration (IIPA), New Delhi.

I recommend that the dissertation of Air Commodore Suhas Prabhakar Bhandare VSM is worthy of consideration for the award of M. Phil. degree of Panjab University, Chandigarh.

*Shyamli Singh*  
(SHYAMLI SINGH)

**Assistant Professor**  
Environment Management & Climate Change

**Indian Institute of Public Administration**

IP Estate, ITO (Ring Road),

New Delhi-110002

Dated : 31<sup>st</sup> March 2021

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**(SUHAS PRABHAKAR BHANDARE)**

**Air Commodore**

Roll No. 4603, 46<sup>th</sup> APPPA

Dated : 30 March 2021

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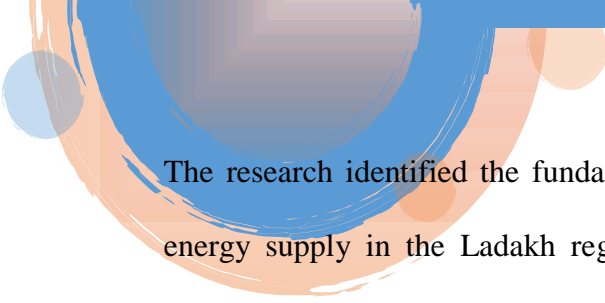
# Executive Summary

The Union Territory (UT) of Ladakh, a high altitude cold desert with most of the region being above 8,000 feet, is located in the trans-Himalayan region and experiences extreme climatic conditions. The developmental models suitable for the other regions cannot get implemented in this region without necessary changes.

Further, UT of Ladakh is still not completely integrated with National Power Supply Grid. Inadequate fossil fuel-based power supply and or renewable energy source-based initiatives do not meet the region's complete energy requirements, making it difficult to tread towards *Aatma-Nirbhar Bharat* and achieve meaningful progress realising Sustainable Development Goals (SDGs). The SDGs, adopted by all United Nations Member States as a universal call to action to end poverty, protect the planet and ensure that everyone enjoys peace and prosperity by 2030. The UT of Ladakh is faring poorly in achieving these goals.

The research has proposed to study reliable and sustainable hybrid power supply solutions, suitably adapted for the high altitude and severe cold environment, as an alternative to supplement the Government initiatives to meet small businesses and households' energy needs.

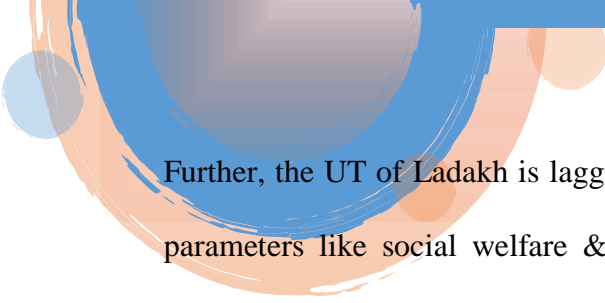
The methodology adopted for data collection and answer the research questions and hypothesis posited was through a literature survey of academic journals, websites, periodicals, policy documents, academic reports, reports from Public Sector Undertaking, private companies engaged in renewable energy-based power supply solutions, and relevant institutional reports. The Government's open data policy & outreach through citizen engagement platform like 'MyGov', the 'Performance Dashboards' & info-graphics on Ministerial websites, annual reports by *Niti Aayog* and other governmental agencies helped in easy access to meaningful data for the research work.



The research identified the fundamental causes of the non-availability of adequate & reliable energy supply in the Ladakh region. Further, the impact of non-availability of adequate & reliable energy supply on *Aatma-Nirbhar Bharat Abhiyan*'s objectives at high altitude regions of Ladakh was studied in conjunction with the United Nations Sustainable Development Goals and recorded. The Government's futuristic and ambitious initiatives were studied and deduced that it would take at least a decade to yield the desired results at grassroots levels. Measures for the early resolution of the issues were studied, and suitable remedial measures identified.

The Ladakh is a cold, high altitude, and inhospitable terrain separated from mainland India by high mountain ranges and lacks all-weather road connectivity with the mainland. Ladakh is geographically the most extensive region amongst the states and UTs of India, and it has the lowest population density. Connecting the entire Ladakh with the national power grid will continue to be a long drawn and expensive proposition to meet the region's energy needs. The region's infrastructure development, including energy distribution, has remained below expectation, thereby affecting the tourism industry, which contributes 50% to the GDP of UT. Similarly, small business, agriculture, communication, healthcare, education, ICT infrastructure, and water supply/management have remained underdeveloped. The region has an overall stunted socio-economic growth and relatively slow in keeping pace with *Aatma-Nirbhar Bharat Abhiyan*'s vision and realising Sustainable Development Goals.

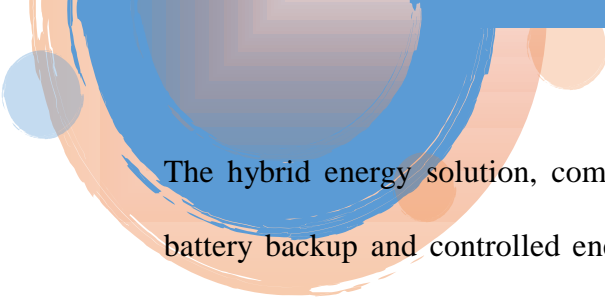
The governments' efforts towards inclusive growth of the region through successive Five Year Plans have not yielded the desired results. The vision document, *Ladakh 2025: a Road Map for Progress and Prosperity*, released in 2005, had brought out the urgent need to provide an adequate and reliable power supply for the Ladakh region's inclusive growth. However, this objective is not yet fully realised. The "Vision 2050" plan released in December 2020 has brought out that the development UT of Ladakh is not in commensuration with the region's growth potential and mainly centred around 50 Km radius of two district towns, Leh and Kargil.



Further, the UT of Ladakh is lagging other hilly areas of the country in all the vital governance parameters like social welfare & development, human resource development, infrastructure, public health, industries & commerce, and agriculture. The region's power supply deficit is of the order of 36%, with no electricity supply available for 30% of the day. The vision document has clearly defined the road map for the region's inclusive growth across all the sectors while preserving the rich culture and heritage. The dream of '*Aatma-Nirbhar Bharat*' envisioned by the Honourable Prime Minister Shri Narendra Modi forms the document's basis. The Government appears to have seized with the issue and has channelled thrust to harness the region's sustainable energy potential and integrate the region with the national grid. However, the envisaged changes are likely to take time to reach the masses because of the inhospitable terrain.

Therefore, for the Ladakh region's accelerated growth and to mitigate people's sufferings, it is essential to adopt a quickly implementable, future-ready energy solution. Hybrid, Scalable, High Altitude Power Supply (HS-HAPS) is one such alternative. HS-HAPS is scalable to meet any energy requirement, even during extreme winter conditions.

The region has an abundance of sustainable energy sources in hydel, solar and wind energy. The solar energy system alone cannot provide a continuous energy source due to low availability during a non-sun period and winter season. Similarly, the wind system cannot satisfy constant load due to varying wind speed magnitudes from one hour to another. The hydel and geothermal energy solutions are area-specific and have a long gestation period. There are challenges in the independent use of these energy sources, and therefore it is beneficial to use solar and wind sources simultaneously for higher energy availability and reduction in required battery storage capacity. Additionally, using a controllable energy source (e.g. petrol/diesel generator) and a battery backup further enhances such a hybrid system's performance.



The hybrid energy solution, comprising solar and wind as a sustainable energy source with battery backup and controlled energy source in the form of a Petrol /Diesel generator set, is considered ideal to meet the region's immediate and future energy requirements. In an off-grid configuration, HS-HAPS can satisfy energy needs directly through efficient distributed energy generation and avoids the long wait for the grid distribution infrastructure to come up. The concept of 'Hybrid, Scalable - High Altitude Power Supply' meets all three core elements of sustainable development: economic growth, social inclusion, and environmental protection.

The research recommends utilising HS-HAPS for speedy and inclusive development of the Ladakh region, an early realisation of SDGs, and thus realises *Aatma-Nirbhar Bharat's* dreams. Research recommends setting up HS-HAPS manufacturing hub in the Ladakh region for enjoying benefits of economy of scale, speedy distribution, and local youth employment. Further, research recommends formulating government policies to incentivise production, prioritise distribution and ensure adequate financial provisioning. Under the Skill-India scheme, local youth training in distribution, assembly, installation, maintenance, upgrade and disposal of HS-HAPS and components will go a long way in ensuring inclusive growth. Incentivising indigenous development of Lithium-ion family of batteries and e-waste management recommended.

# List of Abbreviations and Acronyms Used

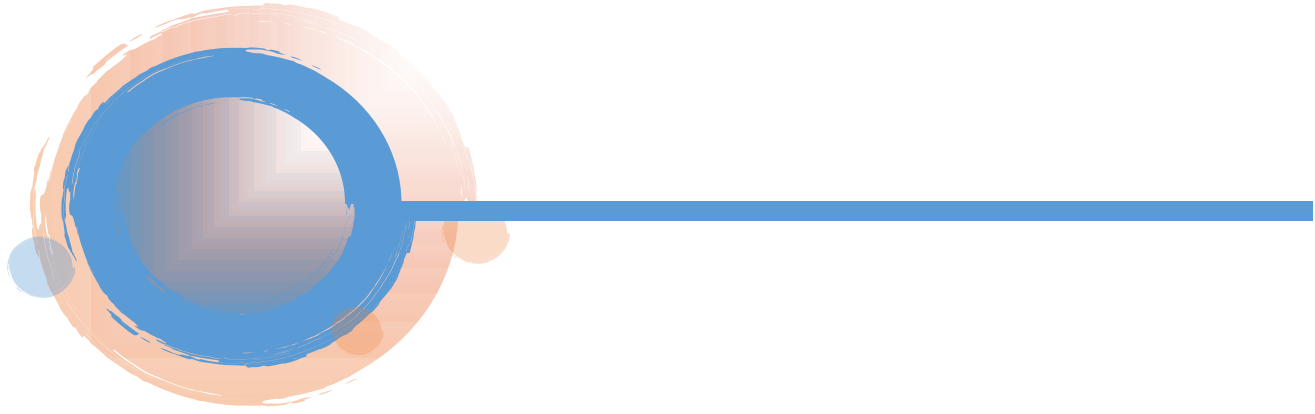
Abbreviation / Acronym	Expanded Form
3-C (approach)	Citizen-Centric, Connectivity & Cluster-Based Centralised Regional Development approach
AHEC	Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee
CCC (approach)	Citizen-Centric, Connectivity & Cluster-Based Centralised Regional Development approach
CD	Community Development (Block)
COTS	Commercial off the Shelf
CPSU (Schemes)	Central Public Sector Undertaking (Schemes)
CSCs	Common Service Centres
CT	Census Town
DG Set	Diesel Generator Set
ft	Feet
FYP	Five Year Plan
GSI	Geological Survey of India
GW	Giga Watt (1,000,000,000 Watts)
HS-HAPS	Hybrid, Scalable, High Altitude Power Supply
ICSCs	Integrated Common Service Centres
ICT	Information and Communication Technology
IEA	International Energy Agency
INDCs	Intended Nationally Determined Contributions
IT	Information Technology
KG Set	Kerosene Generator Set
kmph	kilometre per hour
kVA	kilovolt-ampere

<b>Abbreviation / Acronym</b>	<b>Expanded Form</b>
kW	kilowatt (1,000 Watts Measure of Power)
kWh	kilowatt-hour (Measure of Energy)
LED	Light Emitting Diode
MNRE	Ministry of New and Renewable Energy
MSMEs	Micro, Small and Medium Enterprises
MW	megawatt, (1,000,000 Watts)
NISE	National Institute of Solar Energy
NITI	National Institution for Transforming India
NIWE	National Institute of Wind Energy
NSM	National Solar Mission
ONGC	Oil and Natural Gas Corporation Limited
PG Set	Petrol Generator Set
PV	Photo Voltaic
SDG	Sustainable Development Goals
SHP	Small-Hydro Power
SMEs	Small and Medium Enterprises
SPV	Solar Photo Voltaic
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic And Social Commission For Asia And The Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UT	Union Territory
VALCOE	Value-Adjusted Levelised Cost Of Electricity
VGF (Schemes)	Viability Gap Funding (Schemes)
VNR	Voluntary National Review & report
VRE	Variable Renewable Energy
WEO	World Energy Outlook

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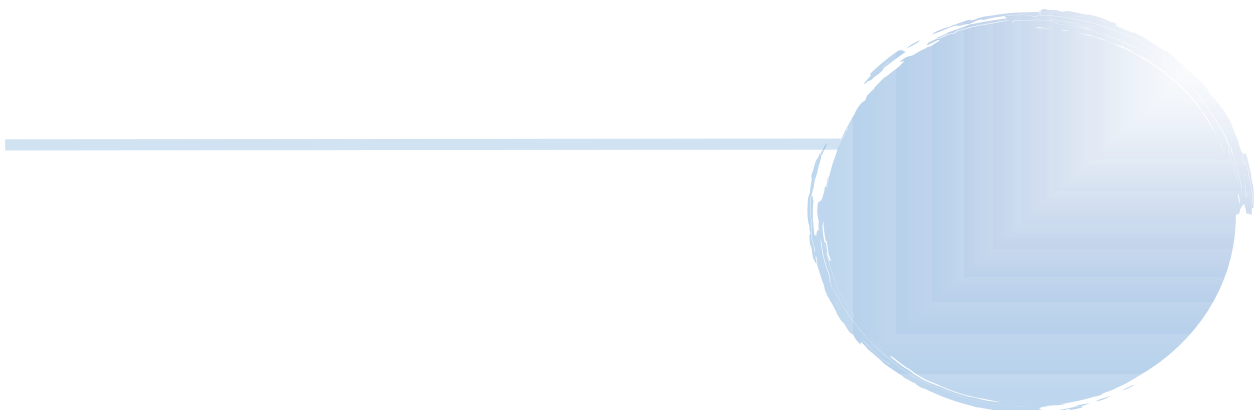


1.  
**Introduction**

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*"Dreams float on an impatient wind,  
a wind that wants to create a new order.  
An order of strength and thundering of fire."*

*-- Dr A.P.J. Abdul Kalam*



# Chapter 1 Introduction

This chapter gives a basic understanding of the Union Territory of Ladakh, the concept of self-reliance introduced in the fourth five-year plan, Key Aspects of Ladakh 2025 vision document, *Aatma-Nirbhar Bharat Abhiyan* launched by the Government and the Vision 2050 document prepared by the Union Territory of Ladakh.

## 1.1 Understanding Ladakh

The newly formed Union Territory (UT) of Ladakh, geographically situated between Latitudes 30°45' to 35°50' North and Longitudes 75°45' to 80°31' East<sup>[1]</sup> with Kunlun mountain range in the north and the Himalayas to the south, is popularly known as “The land of Gompas “or “The land of High Passes” (Figure 1).

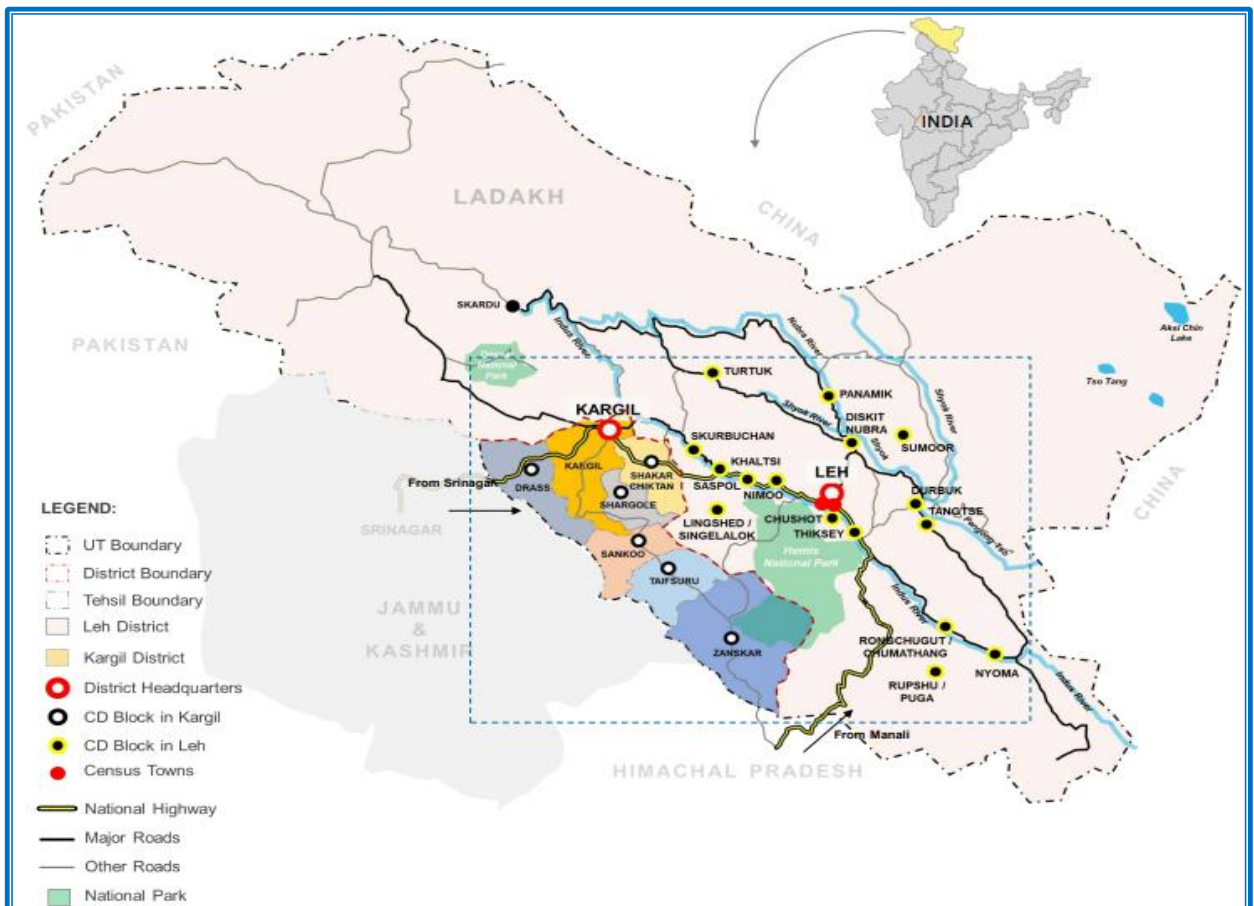


Figure 1 - The Map of the Union Territory of Ladakh

Source: Vision 2050 Document for UT of Ladakh

Ladakh is one of the highest altitude and least populated regions of the world, with the inhabited places varying from 8,000 feet above sea level near Kargil to around 20,000 feet in some places of Chang-Thang sub-division of Leh district. The UT of Ladakh is administratively divided into two districts of Leh and Kargil and has 25 blocks encompassing 238 villages. Leh is the largest town in Ladakh at 11,500 feet, followed by Kargil, the second largest town at 8,780 feet. As per the “Vision 2050 Document”, the Ladakh population, growing at the rate of 1.65% per annum, is likely to cross 3 lakh by 2021. There are 40,247 households in the UT of Ladakh, out of which 21,909 are in Leh district, and the remaining 18,338 are in Kargil district. The average household consist of seven individuals.

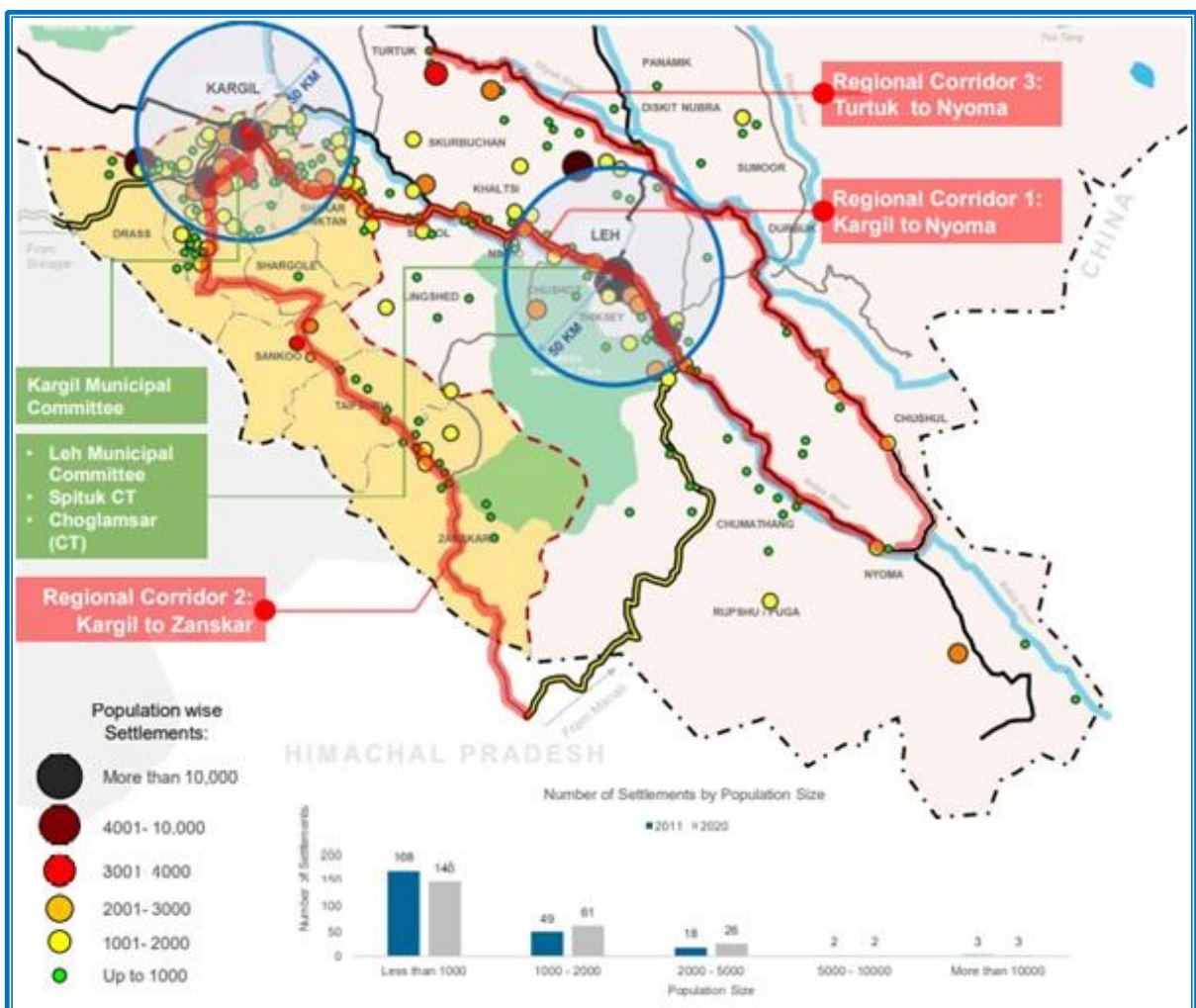
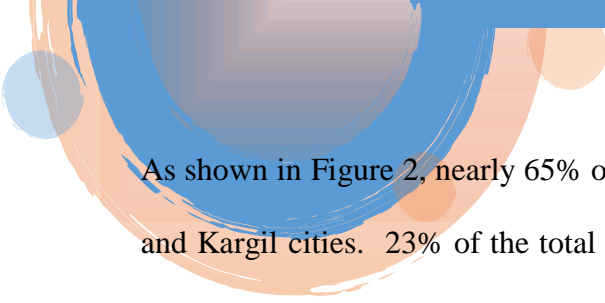


Figure 2 - The Demography of Ladakh & Regional Corridors

Source: Vision 2050 Document for UT of Ladakh



As shown in Figure 2, nearly 65% of the UT population resides within a 50 Km radius of Leh and Kargil cities. 23% of the total population resides in the urban area. From 2001 to 2011, the region has experienced an urbanisation growth rate of 6%. 74% of the urbanisation has happened in and around Leh city itself. An estimated 90% of settlements are along the three regional corridors of Kargil to Nyoma, Kargil to Zaskar and Turtuk to Nyoma.

## **1.2 The Fourth Five Year Plan (1969-74) & the Concept of Self-reliance**

The fourth five-year plan<sup>[3]</sup> was implemented from 1969 to 1974 amidst the pressure of drought, population-explosion, increased unemployment, poverty, devaluation and inflationary recession with two main objectives: “Growth with Stability” and “Self-Reliance”. The plan’s outcome was also no better than the third five-year plan as the funds earmarked for industrial development were diverted to the Indo-Pakistani War of 1971. However, the self-reliance concept introduced initially in the third five-year plan was strengthened during this plan.

## **1.3 Ladakh Vision 2025 Document**

*‘Ladakh 2025: a Road Map for Progress and Prosperity’*, a vision document prepared by the Ladakh Autonomous Hill Development Council, contained a road map for the Ladakh region’s future development. Dr Manmohan Singh, the then Honorable Prime Minister of India, released this document on 09 June 2005, which defines Power and Energy as the most urgently required resources for the Ladakh region’s overall development. As Ladakh is not yet linked to the national power grid and does not have an adequate energy supply, households & small businesses of the region rely mainly on fossil fuel-based energy supply and / or renewable energy source based initiatives. The fossil fuel is transported from the mainland to the Ladakh region, as it has no fuel reserves. During the winters, road links to the

Ladakh region get cut off due to climatic conditions posing difficulties in fuel transportation.

Winter stocking of the fuel done to avoid shortages during winter is called winter stocking.

The vision document released in 2005 had brought out the urgent need to provide an adequate and reliable power supply for the Ladakh region's inclusive growth. Though the Government has taken various steps to meet these requirements, the benefits of such initiatives have not yet reached all the households and small businesses in remote areas. Therefore, exploring the potential of reliable and sustainable hybrid energy sources adopted for the high altitude and severely cold environment is a step towards *Aatma-Nirbhar Bharat* in this High Altitude region.

#### **1.4 Aatma-Nirbhar Bharat Abhiyan**

*Aatma-Nirbhar Bharat Abhiyan* (Self-reliant India campaign) is the vision <sup>[5]</sup> of new India envisaged by the Honourable Prime Minister Shri Narendra Modi. It aims to make the country and its citizens independent and self-reliant in all aspects. To spur growth and build self-reliance, Economy, Infrastructure, System, Vibrant Demography and Demand are considered five essential pillars of *Aatma-Nirbhar Bharat Abhiyan*.

#### **1.5 Vision 2050**

In collaboration with *Niti Aayog*, the Union Territory of Ladakh formulated a Vision Document 2050 with a “3-C” approach.

#### **1.6 Vision 2050: The CCC Approach**

Citizen-Centric Development,

100% Connectivity and

Clusters-based Decentralised Regional Development.

The existing developmental deficit of the Union Territory compared to other hilly areas of the country and the critical challenges that the cold desert faces form the document's basis. It aims to provide good governance and ensures the holistic development of the entire region.



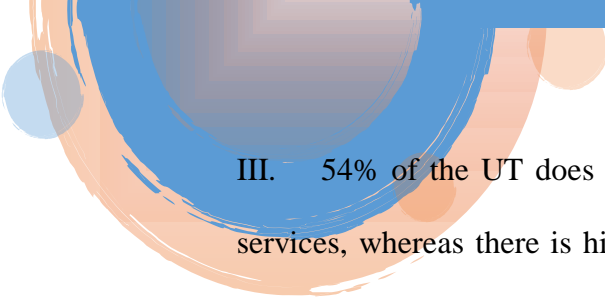
Figure 3 - Development Status of Hill Areas - Based on Good Governance Framework

Source: Vision 2050 Document for UT of Ladakh

### 1.7 Vision 2050: Key Aspects

The Vision 2050 document reveals the following key aspects:-

- I. The Union Territory of Ladakh is lagging behind other hilly areas of the country in all the vital governance parameters like social welfare & development, human resource development, infrastructure, public health, industries & commerce and agriculture. (Figure 3).
- II. Merely 0.2% of the total land area is under agriculture, and 70% of food demand is through imports.



III. 54% of the UT does not have access to telecom and Information Technology services, whereas there is high access to digital services available in Leh and Kargil cities, thereby causing an unfair digital divide.

IV. Only 20% of the population has limited access to specialised healthcare, and the average time taken to reach a District/Sub-District Hospital is approximately three hours.

V. The region's power supply deficit is of the order of 36%, with no electricity supply available for 30% of the day.

VI. There is limited access to the piped water supply with a 38% deficit in the drinking water supply.

VII. 95% of solid waste disposed of is untreated.

VIII. There is limited access to higher educational institutions.

The Vision 2050 Document envisages the region's growth through the following:-

I. Sustainable agriculture development

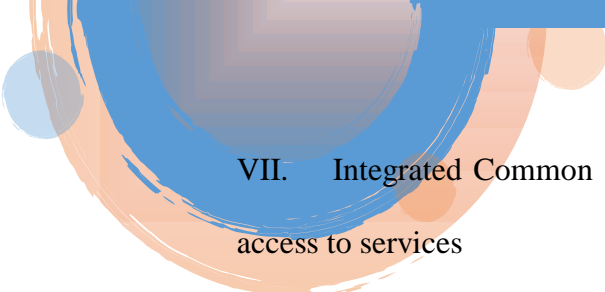
II. Thrust on development of Small and Medium Enterprises (SMEs)

III. Promotion of tourism sector

IV. Connectivity to all the settlements by all-weather roads through the green and sustainable public transport system

V. 30 Giga Watts of power generation through renewable clean energy and connect it to the National Grid System

VI. "Round the clock" water supply to every household



VII. Integrated Common Service Centres (ICSCs) at distributed locations for easy access to services

VIII. Timely access to specialised healthcare and on-demand healthcare through mobile medical units

IX. “Zero Waste Ladakh” and “Waste to Energy” initiatives

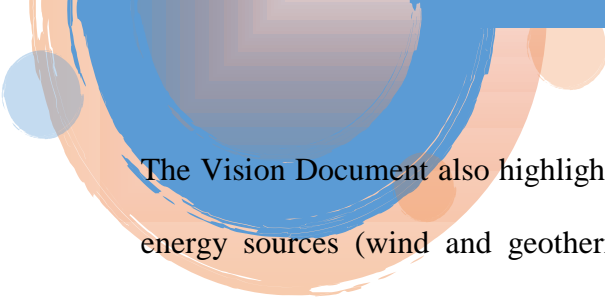
X. A smart education system with a focus on skill development and employability

Currently, Leh and Kargil cities are the nerve centres of all the developmental activities. The UT administration intends to decentralise the developmental activities to other Union Territory regions to control rapid rural to urban migration and ensure balanced regional development.

As far as the agriculture and horticulture sector is concerned, the document envisages a strategy for the development of clusters to produce high-value crops in bulk quantity, the development of model organic villages with model farm marts, integration of organic farming with markets, value chains and trade, branding and marketing of organic products.

About industries & manufacturing sector, the document lays thrust on creation and sustenance of SME clusters with shared infrastructure, dedicated freight network, way-side amenities, warehousing, strengthening of cooperative societies to support village-level growth opportunities, the attraction of investments through marketing and promotion in domestic & international markets and adoption of technology-centric breeding & rearing of animals for milk and wool.

The UT plans to provide unique, safe, secure and all-weather tourism by creating an enabling environment for investments and promoting tourism diversification through theme-based development that primarily benefits host communities.



The Vision Document also highlights the strategy to harness the potential of other renewable energy sources (wind and geothermal) and to establish micro-grids for power supply to remote areas not connected to the primary grid.

For the digital infrastructure, the Vision Document lays thrust on establishing 100% IT connectivity throughout the UT, integrated command & control centre at district levels, digitalisation of Government departments like health, education and transport and implementation of all Information and Communication Technology (ICT) Citizen Services through e-Governance.

Inadequate attention to the solid-waste management sector has harmed the cold desert environment; hence, the Vision document focuses on a sustainable integrated solid-waste management system in urban areas for efficient treatment and disposal of waste.

As per the plan, there will be intelligent solid waste management for efficient waste management and monitoring; besides, generating enough awareness through different means for managing plastic waste at tourist locations.



2.

## **Setting up of the Research**

*“Trust in dreams, for in them is the hidden  
gate to eternity.”*

*--Kahlil Gibran*

# Setting up of the Research

This chapter gives insight into the Statement of the problem, research purpose and objectives, the strategy adopted for research, research methods, the justification for research, the hypothesis and research questions. Numerous research papers, journals, web-articles, and various official documents/reports have been studied during the research. The literature reviewed is shared in this chapter.

### **2.1 Statement of the Problem**

**T**he Union Territory of Ladakh is still not completely integrated with Indian National Power Supply Grid. Inadequate fossil fuel-based power supply and existing renewable energy source-based initiatives do not meet the region's complete energy requirements, making it difficult to tread towards *Aatma-Nirbhar Bharat*. The research proposes to study reliable and sustainable hybrid power supply solutions, suitably adapted for the high altitude and severely cold environment, as an alternative to supplement the Government initiatives to meet small businesses and households' energy needs in remote areas.

### **2.2 Research Purpose/ Objectives**

The objectives of the research study are:-

- I. To study fundamental causes for the non-availability of adequate & reliable energy supply in the Ladakh region, even after seven decades of independence.
- II. To understand the impact of non-availability of adequate & reliable energy supply on *Aatma-Nirbhar Bharat Abhiyan's* objectives at high altitude regions of Ladakh.



III. To assess the adequacy of recent Government initiatives to address the related issues.

IV. To recommend measures for the early resolution of the issues.

### **2.3 Proposed Research Strategy and Research Design**

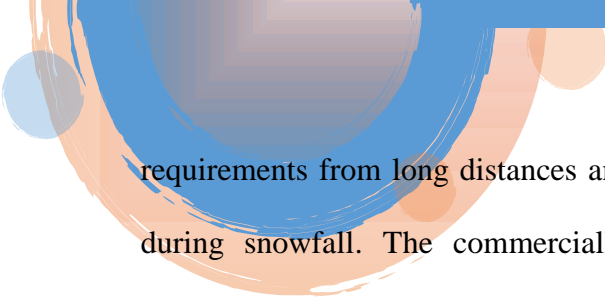
The research approach would be using both Quantitative and Qualitative Methods. The research design would be a combination of Descriptive, Exploratory, and Explanatory research design.

### **2.4 Research Methods and Data Sources**

The methodology of data collection and study proposed to answer the research questions and hypothesis posited is through a literature survey of academic journals, websites, periodicals, policy documents, academic reports, reports from Public Sector Undertaking, private companies engaged in renewable energy-based power supply solutions, and relevant institutional reports.

### **2.5 Rationale / Justification**

The availability of sustainable and reliable energy sources plays a significant role in any region's social and economic growth. The Ladakh region is no exception to this rule. Union Territory of Ladakh is still not completely integrated with National Power Supply Grid due to inhospitable terrain and geographically scattered local habitat. The energy needs of the region, in the non-electrified areas, are met through the use of Diesel or Petrol Generator (DG/PG) sets and renewable energy-based power generation initiatives. DG set-based power supply systems perform sub-optimally at high altitudes<sup>[6]</sup> due to oxygen deficiency and experiences frequent breakdowns. These also have high operating costs due to fuel transportation



requirements from long distances and winter stocking fuel requirements due to road closure during snowfall. The commercially available Diesel or Petrol Generator sets perform optimally at standard pressure and temperature conditions. However, their performance starts deteriorating at high or extreme high altitudes and therefore, they experience frequent breakdowns. Further, these sets' operation at high altitude, extremely-cold climatic conditions leads to higher maintenance cost and lower life span. Such power supply sources also cause environmental damage due to exhaust gas emission, sound pollution, and soil contamination due to improper disposal of used oil waste.

The Government has identified the Ladakh region as having great potential for solar and wind power and has announced various initiatives to tap this potential, as per Rohmetra (2020). However, Ladakh being the land of high altitude passes, these initiatives have not resulted in effectively / adequately mitigating the challenges faced by the households and small businesses, especially in the remote region.

Hybrid, Scalable, High Altitude Power Supply (HS-HAPS) systems utilise renewable energy sources, such as wind and solar power as well as the Petrol Generator of a smaller capacity, which are adapted for high altitude and low temperatures, to charge Lithium-ion-polymer battery pack ruggedised for use at low temperatures. The charged battery pack and inverter combination meet the day/night energy requirements. The system is lightweight, transportable, modular, and scalable. Therefore, it can efficiently meet the power requirements of households and small businesses in remote areas.

## **2.6 Hypothesis**

If the Ladakh region has high solar irradiance & an abundance of wind energy, then effectively harnessing these renewable sources, coupled with the use of traditional fossil energy sources as a backup, could meet the energy requirements of households & small

businesses in the remote areas of the Ladakh region reliably and sustainably. Hybrid, Scalable, High Altitude Power Supply (HS-HAPS) System, designed based on such a concept, can be an effective alternative to the conventional electric supply system.

## **2.7 Research Questions**

The research questions that arise are: -

Q.1 What are the reasons for the non-availability of adequate & reliable energy in the Ladakh region, even after seven decades of independence?

Q.2 How is the non-availability of adequate & reliable, and sustainable energy affecting the objectives of the *Aatma-Nirbhar Bharat* scheme of the Government of India at high altitude regions of Ladakh?

Q.3 What are the recent Government initiatives to address the problem?

Q.4 Are these initiatives adequate to meet the energy needs of all the sections of the society across the Ladakh region?

Q.5 What additional measures should be instituted by the Union and Union Territory Administration so that the individual households or businesses meet their energy needs till the time various Government efforts of providing a reliable electricity supply to every household and small businesses materialise?

## **2.8 Scope and Limitation**

The research scope is limited to studying the households' and small businesses energy needs in high and very high altitude regions of the Ladakh, shortfalls in the energy supply, and suggesting reliable & sustainable alternatives to meet these energy needs. The research is purely based on secondary data analysis as the Covid-19 related nationwide pandemic had

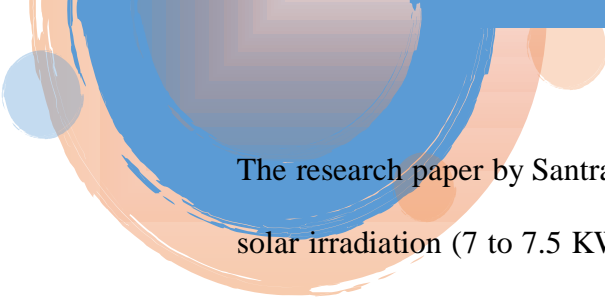
severely restricted public contact and travel. Additionally, due to transparency in the governance, a recent initiative by the Government, all the data envisaged through primary sources was already available in the open-source literature and various Government web-portals.

## **2.9 Literature Review**

The following sub-paragraphs give the details of the literature reviewed:-

According to Statistical Year Book India 2019, India's planned economic development began in 1951 with the First Five Year Plan (FYP). The First FYP focussed on agriculture, price stability, power, and transport; whereas, the Second FYP focussed on the rapid industrialisation in terms of Basic and Heavy Industries. The third FYP aimed to make India a self-reliant and self-generating economy. The Fourth FYP had clearly stated that the National self-reliance and growth with stability could be attained through additional efforts at every level. The country has made much progress since the first FYP. Recently the Government has announced *Aatma-Nirbhar Bharat Abhiyan* intending to make India self-reliant.

Ladakh 2025 vision document <sup>[4]</sup> throws light on the issues, challenges, and potential of the region's traditional economic, physical infrastructure, New Economic, and Social Infrastructure. The vision document highlights the shift of the traditional society from the land-based economy to a predominantly tourism-based economy and identifies IT, Small Scale & Cottage Industry as promising sectors for new employment generation. The document reveals that the scarcity of power and energy is hampering these and all other sectors' growth. The vision document emphasises the need to focus more on renewable energy and decentralised power generation & distribution model to meet the region's energy needs.

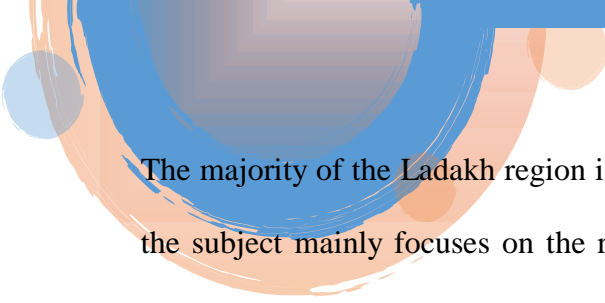


The research paper by Santra (2016)<sup>[9]</sup> reveals that the Ladakh region has the highest solar irradiation (7 to 7.5 KWh per meter square per day) in the country. However, to meet daily energy demands, a substantial amount of diesel is consumed. The author feels that solar energy-based technologies such as solar thermal or solar photovoltaic systems can play a crucial role in the energy security of Leh-Ladakh. The research paper discusses various solar options for meeting energy needs at the domestic level, at the farmers' field, and even at the industrial scale. The research paper also reveals that the Ladakh region's energy requirement will swell to 140.5 MW by 2025, and supplying power to isolated remote areas through a centralised grid and power transmission lines is neither a feasible nor economically viable option.

Notton, G., Diaf, S., & Stoyanov, L. (2011), in their research paper, have brought out that solar energy system alone cannot provide a continuous source of energy due to low availability during a non-sun period and winter season. Similarly, the wind system cannot satisfy constant load due to varying wind speed magnitudes from one hour to another. There are challenges in the independent use of these energy sources, and it recommends using these sources simultaneously for higher energy availability and reduction in battery storage capacity. The Paper also makes a passing reference for using a controllable energy source (diesel generator) to enhance such a hybrid system's performance.

## **2.10 Research Gaps**

Literature survey shows that while plenty of research and data is available about the plains, minimal literature exists in the context of the high altitude region of Ladakh and the challenges faced by its inhabitants. The two main gaps observed are enumerated below:-



The majority of the Ladakh region is above 8,000 feet altitude level, whereas the literature on the subject mainly focuses on the remote areas' energy requirements and or villages below 8,000 feet altitude.

Existing research does not focus on the needs of small businesses or households in remote locations where, due to various constraints, it is difficult to provide energy from the centralised, traditional electricity distribution system.

## **2.11 Methods to be Applied and Data Sources**

The research would be Descriptive, Exploratory and Explanatory. The information collated from the secondary sources will be interpreted and analysed to impart a logical flow of thought & arrive at specific recommendations. The secondary research is proposed through a literature survey of academic journals, websites, periodicals, policy documents, academic reports, reports from Public Sector Undertaking, and private companies engaged in renewable energy-based power supply solutions and relevant reports released by various Institutions.

## **2.12 Chapterisation Scheme**

The broad chapterisation scheme for this research report is as follows: -

### **Chapter 1. Introduction**

This chapter gives a basic understanding of the Union Territory of Ladakh, the concept of self-reliance introduced in the fourth five-year plan, Key Aspects of Ladakh 2025 vision document, *Aatma-Nirbhar Bharat Abhiyan* launched by the Government and the Vision 2050 document prepared by the Union Territory of Ladakh.

## **Chapter 2. Setting up of the Research**

This chapter gives insight into the Statement of the problem, research purpose and objectives, the strategy adopted for research, research methods, the justification for research, the hypothesis and research questions. Numerous research papers, journals, web articles, and various official documents/reports have been studied during the research. The literature reviewed is shared in this chapter.

## **Chapter 3. Energy Options for Ladakh**


This chapter gives a brief overview of the various energy options available for exploitation and their suitability (or otherwise) for the cold, high altitude and inhospitable terrain of the Ladakh region. It also dwells upon the progress of sustainable energy development in India, highlighting the availability of solar and wind energy resources in abundance in UT of Ladakh, various ongoing projects, recent Government initiatives, and the gaps in these initiatives.

## **Chapter 4. HS-HAPS : A Concept**

This chapter gives an insight into the Hybrid and Scalable High Altitude Power Supply System (HS-HAPS) concept, a potential solution to meet the energy requirements of households and small businesses located in the remote areas of the Ladakh region. HS-HAPS can become a game-changer for the energy-starved Ladakh region. To gainfully utilise the concept, efficient deployment needs to be carried out.

## **Chapter 5. HS-HAPS : A Conduit to UN SDGs in Ladakh**

Energy is crucial to realising the Sustainable Development Goals (SDGs); it spurs economic growth, achieves social equity, and ensures environmental sustainability. Government initiative towards achieving SDGs is gathering momentum but will take time to reach all. HS-HAPS deployment will be of enormous help for the Ladakh



region's sustainable development in the interim period. Some of the HS-HAPS applications, which shall align the Ladakh region towards an *Aatma-Nirbhar Bharat*, are listed in this chapter.

## **Chapter 6. Conclusion & Recommendations**

This chapter summarises the research work, analyses the objectives achieved, concludes the findings and makes recommendations for the future roadmap.

3.

## **Energy Options for Ladakh**

*“Intent, inclusion, investment, infrastructure and innovation are fundamental to build self-reliant India”*

*“Economy, infrastructure, system, vibrant democracy and demand are five pillars of self-reliance.”*

*--Narendra Modi, Prime Minister of India*

## Chapter 3

# Energy Options For Ladakh

This chapter gives a brief overview of the various energy options available for exploitation and their suitability (or otherwise) for the cold, high altitude and inhospitable terrain of the Ladakh region. It also dwells upon the progress of sustainable energy development in India, highlighting the availability of solar and wind energy resources in abundance in UT of Ladakh, various ongoing projects, recent Government initiatives, and the gaps in these initiatives.

### **3.1 Sustainable Energy Development in India**

India has seen extraordinary successes in its sustainable energy development initiatives, but many challenges remain to be addressed, including the Covid-19 pandemic, a significant disruptor. In the recent past, the country has provided electricity connections to hundreds of millions of households, promoted the adoption of high-efficiency Light Emitting Diode (LED) lighting, and initiated a massive expansion drive in renewable energy sources, led by solar power and wind power. These efforts have resulted in significant improvement in the quality of life and the march towards self-reliance or *Aatma-Nirbhar Bharat*. However, the pandemic has complicated efforts to resolve other pressing issues. These include lack of reliable electricity supply, an over-reliance on solid biomass like firewood for cooking, financially weak and inefficiently managed state electricity distribution boards, and worsening air quality. Energy use in India has more than doubled since 2000 and now is the third-largest energy consumer globally due to rising incomes and improving living standards. Coal, oil, solid biomass accounts for 80% of energy demand. India's energy use & emissions are less than half of the world's average on a per

capita basis. Other key growth indicators such as steel and cement output, vehicle ownership also indicate a similar trend.

### 3.2 Solar and Wind

In recent years, India’s power sector’s most remarkable progress has been the growth of solar Photo Voltaic (PV) and wind, which have rapidly increased their share of the overall energy mix as coal and hydropower capacity growth has slowed (Figure 4).

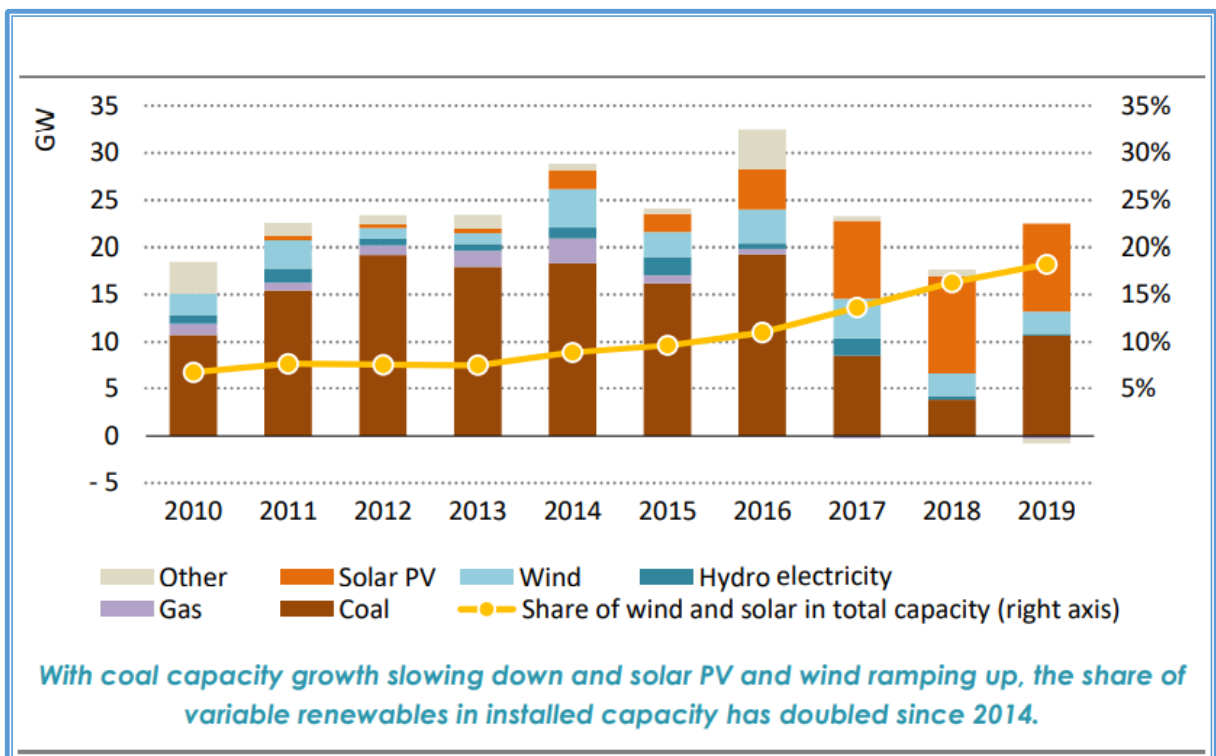
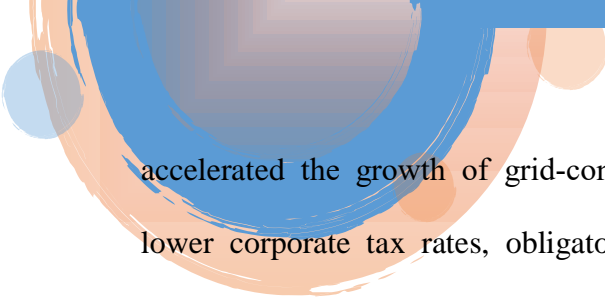


Figure 4 - Annual Power Sector Capacity Additions

Source: Vision 2050 Document for UT of Ladakh

Figure 4 shows the annual power sector capacity addition since 2010. From 2010 to 2016, the power sector witnessed maximum capacity addition in coal-based power generation. However, the share of renewable energy in installed capacity has almost doubled since 2014, with a substantial coal-based generation reduction. The solar PV capacity has grown with an average growth rate of around 60% and wind around 10%, both outpacing the 7% growth in overall installed capacity, owing to falling equipment costs. The policy initiatives that have

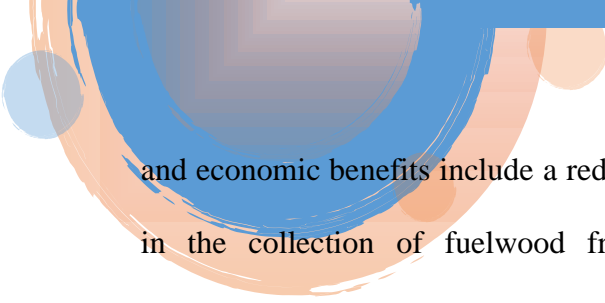


accelerated the growth of grid-connected renewable energy include the reverse auctions, lower corporate tax rates, obligatory procurement of around 17.5% renewable power by utilities, planned investment in transmission line infrastructure, and support for solar parks aimed at reducing the project development cost and land acquisition risks. The phenomenal rise of renewable power percentage in India's power sector has been a significant success story. In 2015, the Government had announced a target of 175 GW of renewables by 2022 (excluding large hydropower projects), which included 100 GW of solar and 60 GW of wind capacity. The 2015 India Energy Outlook identified several challenges to scale up renewables in India, like difficulties in acquiring land and distribution companies' financial status. However, due to the effective management of these risks, solar capacity reached 38 GW by 2019 (mostly utility-scale), with the wind adding a further 38 GW of capacity. Together they now constitute nearly 20% of India's installed capacity. In 2019, India announced a new target of 450 GW of renewable electricity capacity by 2030.

### **3.3 Solar Energy**

India has an abundance of solar energy. Ministry of New and Renewable Energy (MNRE) study indicates that India receives approximately 5,000 trillion kWh of solar energy per year, with most parts of the country receiving 4-7 kWh per m<sup>2</sup> per day. A small fraction of the total solar energy falling on the country, if captured effectively, can theoretically meet India's total power requirements. From India's energy security perspective, solar is the most secure source since it is freely & abundantly available. Assuming only 3% of the country's wasteland area covered by Solar PV modules, the National Institute of Solar Energy (NISE), Gurugram, has estimated India's solar potential to be 748 GW.

Solar photovoltaic energy is easy to generate on a distributed basis and quick to deploy. Off-grid decentralised and low-temperature applications are most suitable for rural electrification and meeting other energy needs in an environment-friendly manner. The social



and economic benefits include a reduction in drudgery among rural women and girls engaged in the collection of fuelwood from long distances and cooking in smoky kitchens, minimisation of the risks of contracting eye and lung ailments, employment generation at the village level, & finally, the improvement in the standard of living as also the creation of opportunity for economic activities at the village level.

Over the years, India's solar energy sector has emerged as a significant player in the grid-connected power generation capacity. The solar sector supports the Government's agenda of sustainable growth and emerges as an integral part of the solution to meet its energy needs. Solar energy has assumed a central place in India's National Action Plan on Climate Change, with the National Solar Mission (NSM) in the forefront. On 11 Jan 2010, NSM launched an initiative to promote ecologically sustainable growth and address India's energy security challenges. The objectives are:-

Establish India as a global leader in solar energy by creating a conducive policy environment for speedy solar technology absorption.

Install 100 GW grid-connected solar power plants by 2022 and achieve India's Intended Nationally Determined Contributions (INDCs) target of setting 40% capacity from non-fossil fuel-based energy resources,

Reduce the emission intensity of its GDP by 33 to 35% from the 2005 level by 2030.

To achieve the above objectives, the Government has launched various schemes to encourage solar power generation in the country like:-

Solar Park Scheme

Viability Gap Funding (VGF) Schemes

Central Public Sector Undertaking (CPSU) Scheme



Defence Scheme

Canal bank & Canal top Scheme

Bundling Scheme

Grid Connected Solar Rooftop Scheme.

Various policy measures undertaken include:-

Declaration of Renewable Purchase Obligation for Solar energy

Waiver of Inter-State Transmission System charges and losses for inter-state trade of solar and wind power

Guidelines for procurement of solar power through a tariff-based competitive bidding process

Standards for the deployment of Solar Photovoltaic systems and devices

Provision of rooftop solar

Guidelines for the development of smart cities

Amendments in building bye-laws for mandatory provision of rooftop solar for new construction or higher Floor Area Ratio

Infrastructure status for solar projects

Raising tax-free solar bonds

Providing long tenor loans from multilateral agencies

Recently, India achieved the fifth global position in solar power deployment by surpassing Italy. Solar power capacity has increased 11 folds in the last five years, from 2.6 GW in Mar 2014 to 30 GW in Jul 2019. Presently, solar tariff in India is very competitive and has achieved grid parity.

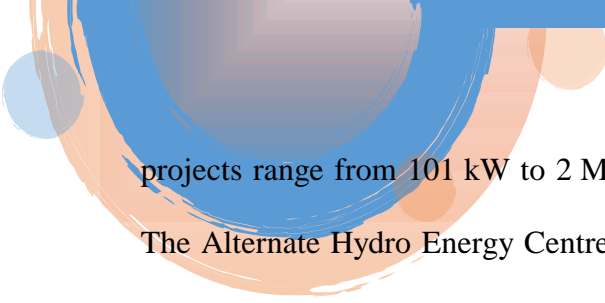
### **3.4 Wind Energy**

India's wind energy sector, led by the indigenous wind power industry with a robust ecosystem, project handling capabilities and manufacturing facility of about 10,000 MW per annum, has shown consistent progress. India has the fourth-highest wind installed capacity globally, with a total installed capacity of 35.6 GW as of 31 Mar 2019. The Government promotes wind power projects through private sector investment by providing fiscal and financial incentives such as Accelerated Depreciation benefit; concessional custom duty exemption on specific components of wind-electric generators.

The wind being a site-specific and intermittent energy resource, an extensive Wind Resource Assessment is essential for selecting potential sites. The National Institute of Wind Energy (NIWE) has installed over 800 wind-monitoring stations across the country<sup>[12]</sup> and has issued potential wind maps at 50m, 80m and 100m above ground level. The assessment by NIWE indicates a gross wind power potential of 302 GW at 100 meters. Most wind potential exists in Gujarat, Rajasthan, Maharashtra, Tamil Nadu, Madhya Pradesh Karnataka, and Andhra Pradesh. As per NIWE, Ladakh, due to its valley terrain and temporal variations, has an estimated wind power potential of 5.3 GW at 50-meter hub height & 100 GW at 120-meter hub height. The region holds tremendous promise for setting up commercial-scale wind energy projects.

### **3.5 Small Hydro Energy**

Hydropower projects, based on their sizes, can be classified as large and small hydro projects. Although the small hydropower project range from 10 MW to 50 MW capacity, in India, hydropower plants of 25 MW or below capacity classify as small hydropower projects. The small hydropower projects are further sub-classified into micro, mini and small hydropower projects. The micro hydropower projects are 100 kW or below capacity; mini-hydropower



projects range from 101 kW to 2 MW, whereas small hydropower projects are 2 to 25 MW. The Alternate Hydro Energy Centre (AHEC), IIT Roorkee, in its Small-Hydro Power (SHP) database of July 2016, has estimated power generation potential from small/mini hydel projects to be 21 GW from 7135 sites. The hilly states, mainly Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir and Uttarakhand, constitute around half of this potential. The MNRE has taken initiatives to promote Small Hydropower projects' development and improve reliability & quality. The commercial SHP projects are made attractive for investments by providing physical and financial incentives. The Ministry also emphasises promoting new and efficient water mills for mechanical and electricity generation and setting up micro hydel projects up to 100 KW for remote village electrification.

### **3.6 Geothermal Energy**

The rocks and fluids beneath the earth contain Geothermal energy. It is also found in the shallow ground to several miles below the earth's surface, reaching up to Magma. About 1.6 kilometres deep holes are drilled into these underground reservoirs for tapping the hot water or steam to drive the turbines linked with electricity generators and generate geothermal electricity. The Geological Survey of India (GSI), through various explorations and studies of geothermal fields since 1970, has identified 350 geothermal energy locations with the estimated potential for geothermal energy of about 10,000 MW. (Figure 5). The most promising location is the Puga valley of Ladakh, which has the highest enthalpy geothermal water.

#### **3.6.1. Puga Geothermal Project**

The Union Territory of Ladakh, Ladakh Autonomous Hill Development Council and Oil and Natural Gas Corporation Energy Centre signed an agreement on 07 Feb 2021 for establishing the first geothermal Power Project in India to tap the natural geysers in

the Puga area, 170 km east of Leh. Oil and Natural Gas Commission (ONGC) would undertake the project in three phases. In the first phase, ONGC would drill up to 500 metres to access the steam and hot sulphur water from the geysers, which would help run the power plant with a megawatt's capacity. In phase two, drilling would be a bit deeper to explore the potential of the thermal reservoir. The third phase will culminate with a 250 MW commercial power plant.

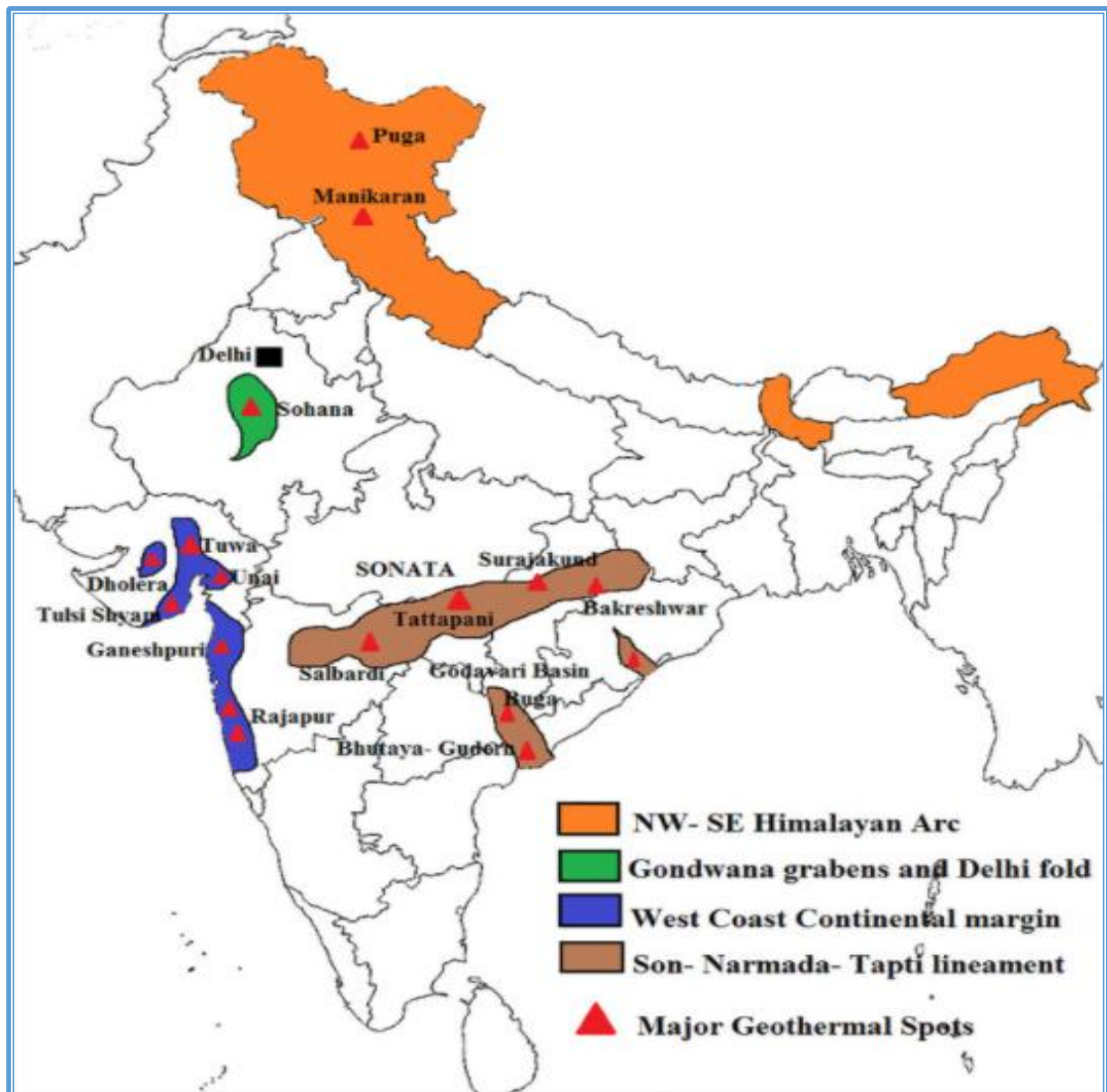


Figure 5 - Geothermal Energy Map of India

Source: <https://doi.org/10.1016/j.ijgeop.2020.12.002>

### **3.6.2. Benefits of the Project**

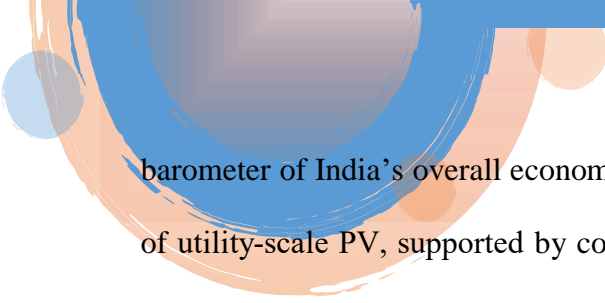
The project would provide a much-needed power supply to the Ladakh region. Establishing the tourism industry near these hot water springs & tapping the hot water from the springs for space heating and the recreational swimming pools will create a self-sustaining economy in the Puga area Ladakh and strengthen the carbon-neutral Ladakh and “Vocal for Local” initiative by the Government.

### **3.7 The Technology and Innovation Aspects**

A crucial factor for India’s growth for renewable electricity production and storage technologies is affordable solar PV, Wind turbine and batteries. A combination of research, economies of scale, and improvements in manufacturing and installation processes will bring down the cost. As per World Energy Outlook 2020 report, with revenue support mechanisms in place that bring down financing costs, new solar PV projects are estimated to cost less than new coal-fired power plants and approach parity with existing operating costs coal-fired plants. The utility-scale solar PV is already very well placed as a preferred technology for a new generation, and there are innovative ways in which solar is being bundled together with other technologies to increase its value.

### **3.8 Options for India’s Power Sector?**

Over the past ten years, India has spent more than Rs 14,700 billion on transmission and distribution networks to establish one of the world’s largest synchronised power grid network with near-universal household access to electricity. India is the fourth-largest electricity market globally, after the United States, China and the European Union. Availability of electricity has enabled an expanding middle class to own the latest appliances and adopt an increasingly digitalised lifestyle. Electricity demand growth is now widely used as a critical



barometer of India's overall economic performance. On the supply side, the explosive growth of utility-scale PV, supported by competitive auctions, has made India a global leader in the solar market. Six Indian states now source 10-30% of their electricity from Variable Renewable Energy (VRE) sources. There are, however, several challenges ahead, such as the fragile financial health of state-owned electricity distribution companies, and cascading effect on the rest of India's power sector affecting the finances of power producers and their investment risks, the level of technical and commercial losses in electricity distribution, and ultimately the quality of electricity supply to millions of Indian households and businesses.

### **3.9 Status of Electricity Supply**

The task of managing the daily variability of demand, and in particular coping with the level at which demand peaks, is a crucial part of electricity system operation and planning. The challenges will increase multi-fold with the scale of growth in variable renewables over the next decade. By 2040 India is expected to add nearly 900 GW of wind and solar capacity. Solar PV leads the charge (Figure 6). The vast majority of capacity additions are from large, utility-scale projects; the share of distributed solar PV remains low because of its relatively high cost compared with large-scale solar projects. The logistical and regulatory challenges have slowed capacity growth to date.

Despite being seen as something of a junior partner to solar, the wind is the second-largest source of capacity growth, with an additional 200 GW underpinned by ambitious targets to exploit India's sizeable potential for both onshore and offshore wind. Although wind power is also a variable resource, it can complement solar effectively in India; the monsoon season from June to September, a relatively lower solar resource availability, brings higher output from offshore wind projects than the rest of the year.

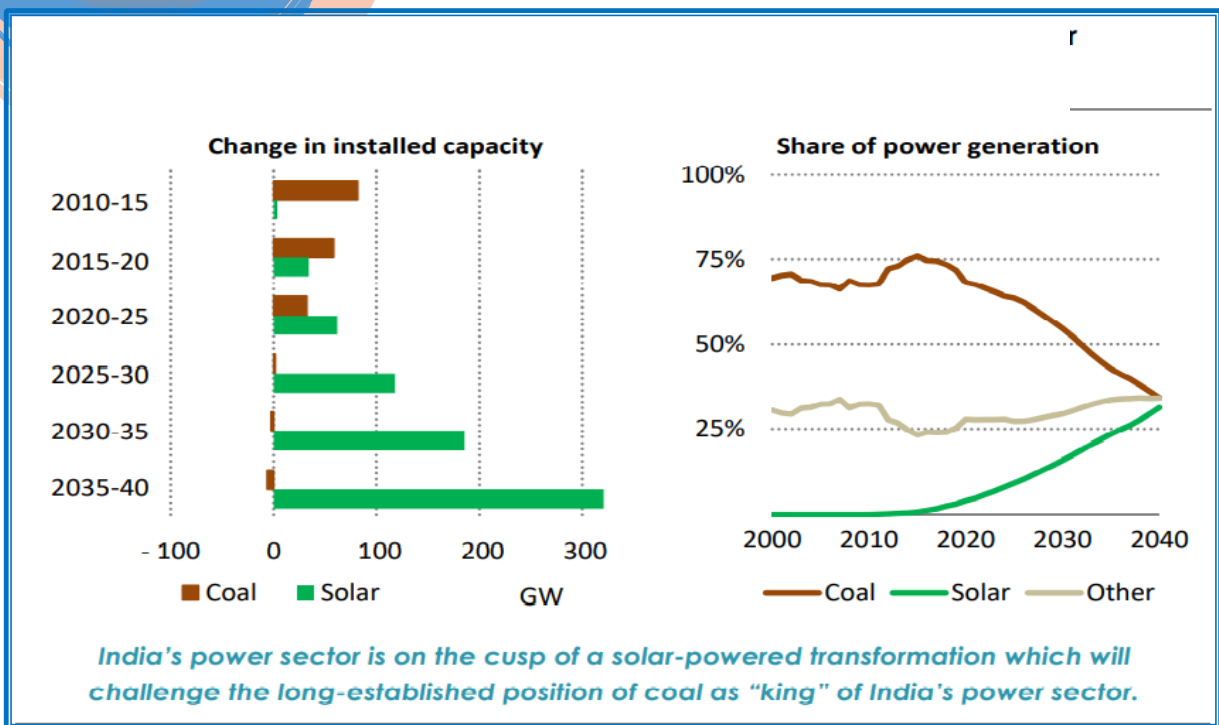


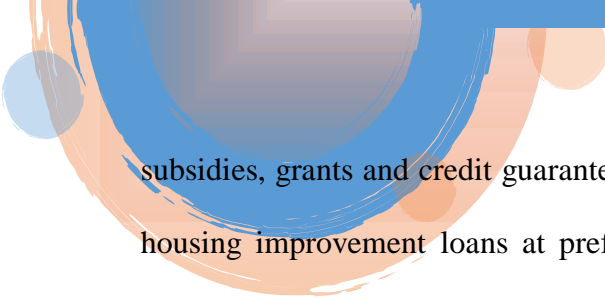
Figure 6 - Changing Share of Coal & Solar Capacity in Power Generation

Source: World Energy Outlook 2020

### 3.10 Prospects for Roof Top Solar

India has ambitious targets to reach 40 GW of rooftop solar by 2022. With around 3 GW of capacity installed since 2015 compared with 30 GW for utility-scale, the rooftop PV deployment has been slow. The reasons are cross-subsidised electricity tariffs for residential consumers, the upfront costs of installation, and difficulty accessing finance, despite options to spread low-interest payments over a longer-term loan period. Those consumers that pay higher tariffs have more incentives to install rooftop solar, especially as net-metering regulations would allow them to benefit from selling surplus solar back to the grid. However, if they were to move to rooftop solar, this would further erode the revenues of financially weak utility companies, which lack commercial incentives to expand into rooftop solar.

Some organisations are well-placed to push ahead with distributed solar – these include those with commercial installations on government buildings and entities taking part in the central public sector undertakings scheme. There are several incentives in place, including tax relief,



subsidies, grants and credit guarantees for MSMEs. Rooftop PV projects are also eligible for housing improvement loans at preferential rates. There are also multiple opportunities for aggregation and economies of scale, reducing the cost of supply for self-consumption and increasing financing availability. Raising consumer awareness and easing the administrative burdens associated with rooftop PV for households and undertakings whilst ensuring that utility companies share rooftop solar benefits could unlock growth. The vast majority of new solar added from 2019-40 is in utility-scale, but a more hospitable regulatory regime would ensure a gradual increase in the rate of solar PV additions in buildings, with total installed capacity reaching 150 GW by 2040.

### **3.11 Cost-Benefit Analysis of Solar PV Plus Batteries**

Solar PV projects are now the cheapest source of new power generation in India and are among the world's lowest cost. However, an evaluation of solar PV competitiveness in India requires looking beyond the technology costs alone. Taking into account both costs and system value for available options is crucial for effective system planning. To differentiate sources of power generation not just according to their technology costs but to their energy, flexibility and capacity value, the World Energy Outlook team has developed a metric called the Value-Adjusted Levelised Cost Of Electricity (VALCOE) (IEA, 2018). This metric enables comparisons between Variable Renewable Energy (VRE) and dispatchable thermal plants by simulating future power systems' behaviour using a detailed hourly power model. However, the VALCOE does not incorporate grid-related integration costs or environmental benefits such as reductions in air pollution; these costs and benefits may well be sizeable.

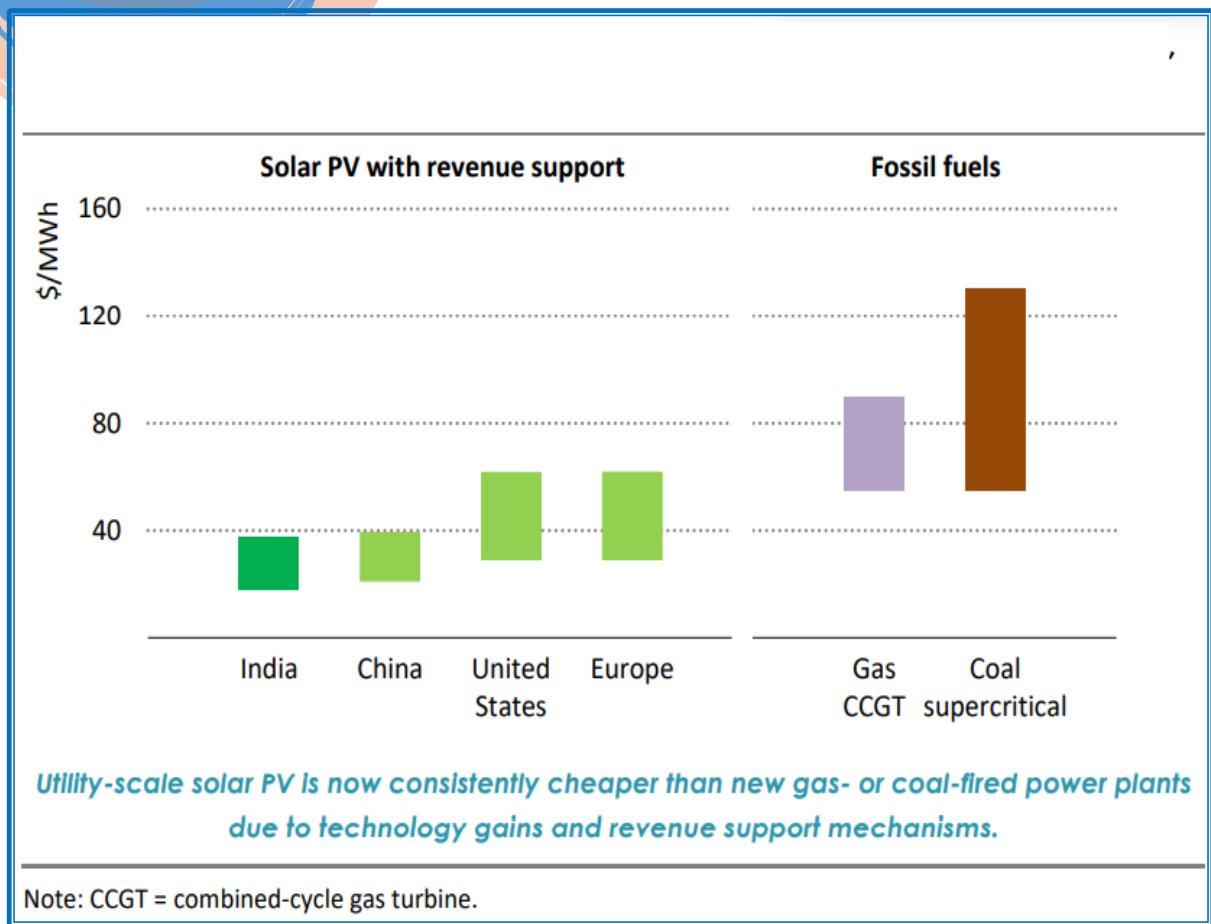


Figure 7 - Cost Comparison of Solar Energy v/s Fossil Fuels

Source: World Energy Outlook 2020

In recent years, new solar PV has become more competitive in India than the new coal-fired power plants, and the VALCOE of solar PV is currently about 25% lower than that of new coal capacity. That gap is slightly narrower than the traditional model would suggest: compared with coal, solar PV has a lower system value, principally because it makes smaller contributions to system adequacy and flexibility. Pairing short-duration battery storage with solar PV increases both the costs and the system value, making this option near competitive with coal-fired power (Figure 7). Although there is a wide variation in coal generation costs, solar PV is already competitive against some existing coal-fired power plants with high variable costs or low thermal efficiencies. However, the fleet-wide average variable cost remains lower than new solar PV, so displacing existing coal-fired power with new solar PV would, in most cases, not yet lower total electricity production costs or electricity prices to consumers. Continuous reductions in the cost of solar PV mean it becomes cost-competitive

against most existing coal capacity in India by 2030, even after taking into account the fact that the energy value of solar PV reduces a little as its share of annual electricity generation rises from 3% in 2019 to 16%.

Moreover, pairing solar with utility-scale battery storage offsets the reduction in value related to solar PV variability: by 2030, the VALCOE of solar PV plus battery storage is 30% below that of new coal-fired power. The VALCOE of solar PV is lower than existing coal-fired power by 2030, alone or paired with battery storage which creates a significant opportunity to deploy solar PV to make electricity more affordable in India.

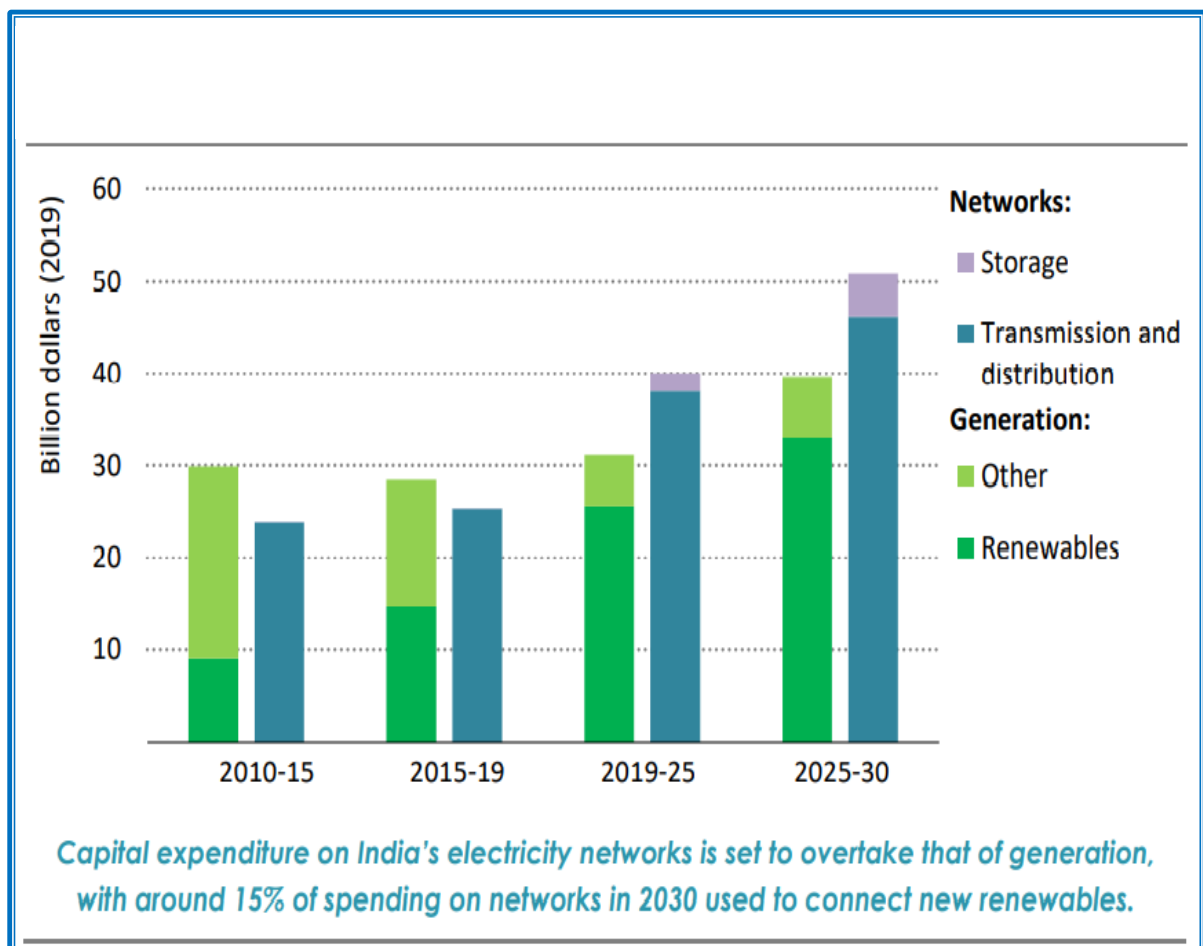



Figure 8 - Average Investment Spending on Electricity Generation & Networks

Source: World Energy Outlook 2020

The transmission system has a crucial part in the efficient use of flexible resources over the next ten years. The system integration of solar PV will require investment in storage and distribution networks to cope with the solar-driven “duck curve” in the morning and evening



hours, while transmission and balancing capacity is required to manage wind power's strong seasonality. Better regional interconnections across India's regions are also critical for optimising power flows between states with differing demand and generation profiles. For example, northern parts of India have significant hydropower flexibility but need to draw on imports during the early evening peak. Thermal plants in the eastern region, by contrast, provide flexibility for demand centres to the south and west, which have high industrial and agricultural loads and may call on imports during periods of low renewables availability.

Therefore, spending on networks quickly overtakes spending on capacity growth, and investments in batteries start to take hold by the end of the decade, reflecting how the current policy focus on achieving ambitious renewable energy targets complemented by a focus on the transformation of the power system (Figure 8).



4.

## **HS-HAPS : A Concept**

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*“In your heart, keep one still secret spot  
where dreams may go and be sheltered so  
they may thrive and grow.”*

*-- Louise Driscoll*

This chapter gives an insight into the Hybrid and Scalable High Altitude Power Supply System (HS-HAPS) concept, a potential solution to meet the energy requirements of households and small businesses located in the remote areas of the Ladakh region.

HS-HAPS can become a game-changer for the energy-starved Ladakh region.

To gainfully utilise the concept, efficient deployment needs to be carried out.

### **4.1 Need for High Altitude Power Supply System**

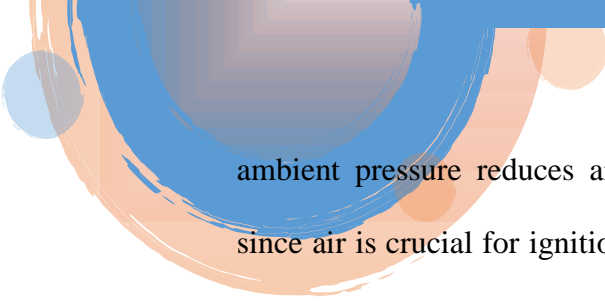
**H**igh altitude and low temperatures is a lethal combination for any man or machine. Ladakh experiences temperatures ranging from minus 50<sup>0</sup>C to plus 30<sup>0</sup>C. The majority of the Ladakh population utilises either Petrol Generator (PG) or Diesel Generator (DG) as the primary & backup power supply source to tide over the unreliable and inadequate conventionally transmitted power supply. These generators perform sub-optimally due to oxygen deficiency and extremely low temperatures at high and very high altitudes. Therefore, a reliable high altitude power supply system, which can work under these extreme weather conditions, is an inescapable requirement to enhance morale, quality of life quality and business in the region.

### **4.2 Environmental Factors Affecting Generators & Batteries**

The environmental factors affect the generators and batteries<sup>[6]</sup> as described in subsequent paragraphs:

#### **4.2.1. Generators**

**Altitude:** - Standard temperature and pressure conditions are crucial for the proper ignition and functioning of a generator. In high altitude areas such as Ladakh, reduced



ambient pressure reduces air density and creates problems with generator start-up since air is crucial for ignition in any generator type. Another factor that gets affected is the availability of ambient air to facilitate heat dissipation from the generator. The heat created during the combustion process needs to be dissipated into the environment to reduce engine temperature. When used for sustained periods at high altitude, generators experience high engine temperatures due to insufficient heat dissipation. Engine overheating is a common problem, leading to decreased efficiency.

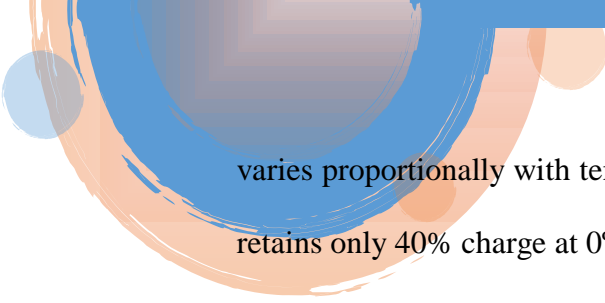
**De-rating:** - The generator's performance decreases by 2–3% for every 1000 ft rise above sea-level. The altitude in Ladakh ranges from 8,000 ft to 21,000 ft. Consequently, the generator gets de-rated by 24% to 63%. Thus, a generator operating under these conditions cannot take a load of even 50% of its rated capacity.

**Fuel and Engine Oil Problems:** - At low temperatures, diesel gelling occurs, leading to clogged fuel filters and pipes. The same is the case with most of the engine oils. As a practice, before the engine's start, the oil has to be drained from the generator and warmed in a pot before pouring it back to the generator, which is a tedious, cumbersome and risky process, particularly at very high altitudes.

**Fouling of Spark Plugs:** - The Kerosene Gensets are started on petrol and run on kerosene, which causes carbon deposition on plug heads, leading to spark plugs' frequent failure.

#### **4.2.2. Batteries**

**Temperature:** - All Lead-Acid batteries supply about 2.14 volts per cell (12.6 to 12.8 for a 12-volt battery) when fully charged. A fully charged battery stored for an extended period eventually loses all its charge. This “leakage” or self-discharge varies considerably with battery type, age, & temperature. The charge retention of the battery



varies proportionally with temperature. A battery, which retains 100% charge at 25°C, retains only 40% charge at 0° C and 0% charge at minus 50°C.

### **4.3 Sustainable & Renewable Energy Sources**

A sustainable energy source is a power source that gets replenished within a human lifetime; therefore, it does no long-term damage to the environment. Renewable resources are replenished continuously and are those derived organically or naturally recycled. Sustainable energy encompasses all renewable energy sources, such as solar, wind, hydel, biomass, geothermal, wave and tidal energy sources. Sustainable energy sources in a standalone mode do not provide a predictable electricity supply due to their inherent nature; therefore, they are used in combination to mitigate the uncertainty. A hybrid energy system comprises a combination of two or more energy sources, combined in a way to provide an uninterrupted and efficient power supply. Biomass-wind-fuel cell, hydel-wind, hydel-solar, wind-solar are some of the hybrid sustainable energy systems. However, due to the abundant solar and wind energy availability in the Ladakh region, a hybrid system with these two energy sources is beneficial.

### **4.4 Hybrid, Scalable, High Altitude Power Supply Architecture**

The solar energy system alone cannot provide a continuous energy source due to low availability during a non-sun period and winter season. Similarly, the wind system cannot satisfy constant load due to varying wind-speed magnitudes from one hour to another. There are challenges in the independent use of these energy sources, and it is beneficial to use these sources simultaneously for higher energy availability and reduction in required battery storage capacity. Further, using a controllable energy source (e.g. diesel generator) and a battery backup further enhances such a hybrid system's performance. The block diagram of the proposed high altitude power supply is given below (Figure 9).

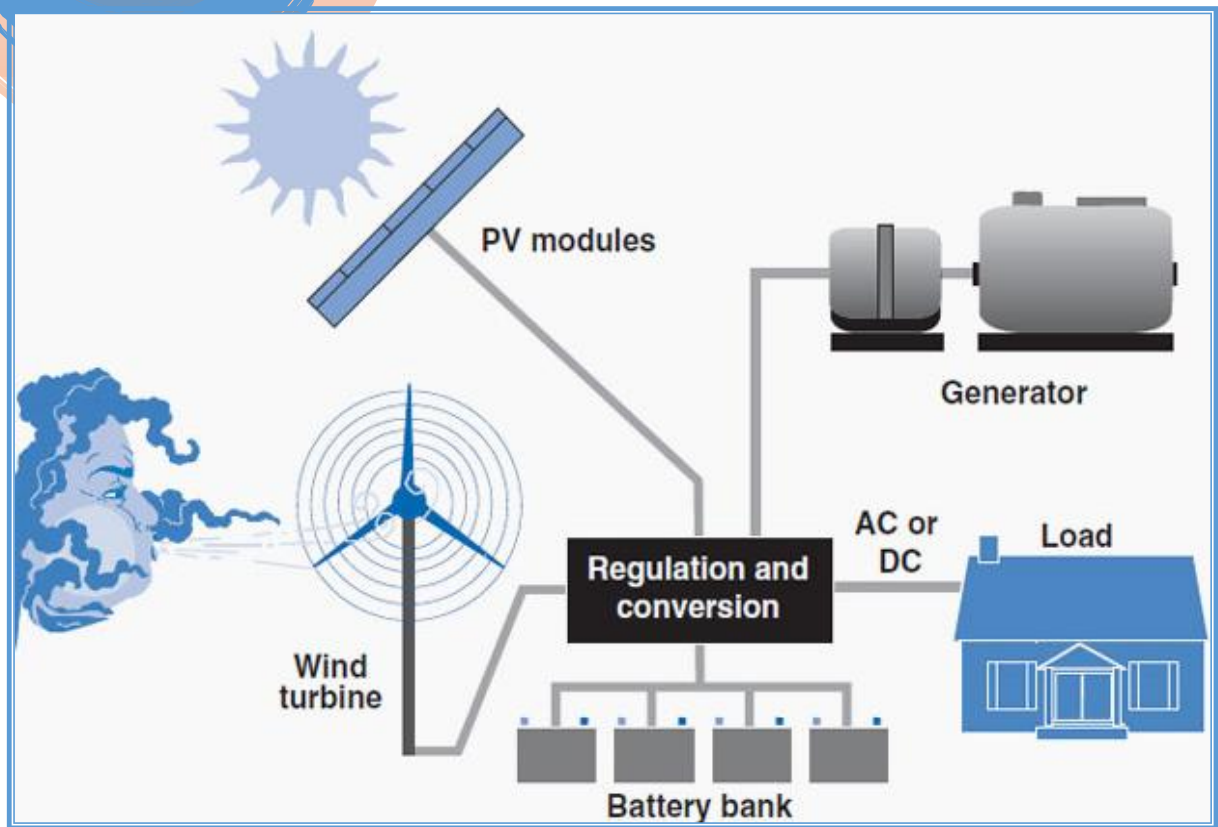
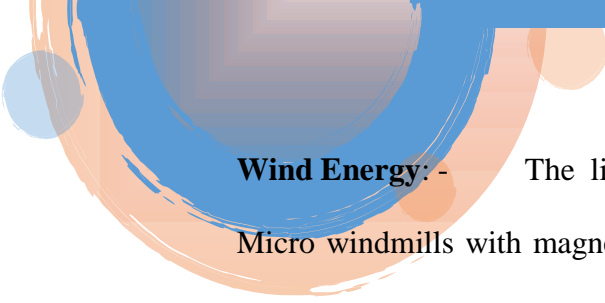


Figure 9 - Block Diagram of Hybrid, Scalable - High Altitude Power Supply

Source: US Department of Energy [energy.gov](http://energy.gov)

The primary energy sources comprise solar and wind power with PG/DG set as a backup. These sources charge a set of Lithium-ion Iron-Phosphate ( $\text{LiFePO}_4$ ), with higher energy density, through a specially designed hybrid charger. The charged batteries drive the DC load directly and the AC load through an inverter. The HS-HAPS harnesses the Wind and Solar energy, abundantly available in the Ladakh region, to charge a 48 V-108 AH battery bank through a 5.2 KVA hybrid charger and universal output controller combination. The entire setup is ruggedised to operate at high altitudes and extreme temperature conditions up to minus 50°C. Renewable sources based power supply system, specially conditioned for the Ladakh region, provides clean and fluctuation free supply during all-weather conditions, leading to reliable equipment performances and reducing breakdowns. The system is scalable. Therefore, it can meet a wide range of load requirements. As compared to a commercial power supply, the HS-HAPS utilises modified or high-performance sub-systems to ensure reliable and improved performance at high and very high altitudes. These systems are:-



**Wind Energy:** - The lightweight, easy to assemble and man-portable vertical Micro windmills with magnetic levitation technology overcome friction and increase efficiency. With magnetic levitation, windmills can start power generation from wind speed as low as 1.5 m/s. The operation of a windmill at lower speeds increases the amount of energy harvested from the windmill.

**Solar Panel:** - Foldable Solar Panels are suitable for high altitude and can operate up to minus 50°C and under high wind conditions up to 160 kmph. These panels have micro thermodynamic heating systems for operations even during snowfall. Micro thermal dynamic filament array is highly transparent, virtually invisible to the human eye, requiring low power for operation, thereby increasing solar photovoltaic panels' efficiency even when exposed to snow and ice contamination.

**PG Set:** - The Commercial off the Shelf (COTS) PG sets designed to operate under standard operating conditions perform sub-optimally at high or very high altitudes. To overcome the problem, the HS-HAPS Genset is housed in a generator enclosure called 'Gencozy', which protects it from exposure to cold temperature. Additionally, incorporating heating pads on the oil sump facilitates the engine's warming up before starting and avoids gelling.

**Battery:** - Batteries are fitted inside a thermally insulated container called 'Batcozy', having heating pads to maintain a healthy temperature of 20°C during winters. The high-performance Lithium-ion Iron Phosphate batteries, which can operate reliably at temperature ranges from minus 50°C to plus 40°C, further enhance the energy availability.

**Hybrid Charger:** - Hybrid Wind/Solar Charge Controller with Maximum Power Point Tracking technology improves overall charging efficiency.

## **4.5 Advantages of HS-HAPS**

Ladakh region urgently needs an assured, sustainable and reliable energy system to achieve long-awaited development and be self-reliant. In an off-grid configuration, as through efficient distributed energy generation, HS-HAPS satisfies these needs directly and avoids the long wait for extended grid-distribution infrastructure to come up. Further, being future-ready, it offers the flexibility to integrate with the national grid. HS-HAPS mainly uses sustainable energy sources, therefore reduce carbon footprint and lower greenhouse gas emissions. HS-HAPS is also an ideal solution where the cost of providing grid extension is prohibitively high, and the price for fuel increases exponentially with the remoteness of the location. HS-HAPS offers the option to integrate with the existing petrol or diesel-based power systems or be a part of a new integrated design within small electricity distribution systems. HS-HAPS, by design, captures each energy source's best features and provides "grid-quality" electricity.

Being scalable can be engineered to provide power from One kilowatt to several megawatts. HS-HAPS gives flexibility for future extension and growth. The system capacity can be increased or decreased based on energy needs. HS-HAPS stores the excess energy generated on bright sunny days or during peak wind conditions in a battery bank, thereby ensuring full exploitation of renewable energy sources. HS-HAPS provides continuous power through these batteries. Optimal or almost nil utilisation of backup generators ensures low operating and maintenance cost. HS-HAPS caters for energy needs during different climatic conditions, thereby ensuring better productivity.

Further, the on-demand energy supply ensures optimal load management. HS-HAPS will accelerate the resultant socio-economic development of the region. HS-HAPS reduces line and transformer losses, transmission and distribution congestion, increased system reliability, power quality, and increased overall efficiency.

## **4.6 Limitations of HS-HAPS**

Like any other real-life system, the HS-HAPS also has some disadvantages like higher installation cost, battery life cycle cost and environmental hazard associated with batteries' improper disposal. Notwithstanding the same, the system, can be carefully designed to mitigate these. For example, production costs shall come down with mass production, use of Lithium-ion Iron-Phosphate ( $\text{LiFePO}_4$ ) batteries reduces the battery lifecycle costs and user education and battery buyback options can prevent the possible environmental damages,

## **4.7 Verdict**

The advantages of the HS-HAPS far outweigh the negatives, and keeping in mind the current and future energy requirements, HS-HAPS implementation works out more cost-effective than providing immediate grid connectivity to these remote, inhospitable areas.

HS-HAPS, being an affordable, sustainable and clean energy source, comes under SDG 7 of the 17 Sustainable Development Goals given by the UN (Figure 10) and in turn supports most of the remaining 16 Global Goals directly or indirectly <sup>[19]</sup> 1. SDG 7 relates to affordable and clean energy and aims to ensure access to affordable, reliable, sustainable and modern energy for all. Chapter 5 deliberates on SDGs and how HS-HAPS can effectively address some of the Ladakh region's concerns.



Figure 10 - SDG-7 at the Core of Other UN SDGs

Source: <https://in.one.un.org/sdg-wheel/>



5.

## **HS-HAPS : A Conduit to UN SDGs in Ladakh**

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*“In the Indian tradition, Sun is the source of all  
forms of energy.*

*The world must turn to the Sun to power our  
Future”*

*--Narendra Modi, Prime Minister of India  
Launch of International Solar Alliance in Paris*

# HS-HAPS : A Conduit to UN SDGs in Ladakh

Energy is crucial to realising the Sustainable Development Goals (SDGs); it spurs economic growth, achieves social equity, and ensure environmental sustainability. Government initiative towards achieving SDGs is gathering momentum but will take time to reach all. HS-HAPS deployment will be of enormous help for the Ladakh region's sustainable development in the interim period. Some of the HS-HAPS applications, which shall align the Ladakh region towards an *Aatma-Nirbhar Bharat*, are discussed in this chapter.

## 5.1 Sustainable Development Goals

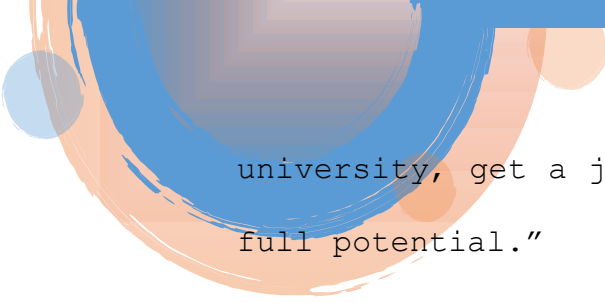
**S**ustainable development is an overarching paradigm of the United Nations. The 1987 Bruntland Commission Report (UNESCO, 2015)<sup>[20]</sup> described the concept of sustainable development as :

"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The seventeen Global Goals or Sustainable Development Goals (SDGs), adopted by all United Nations Member States as a universal call to action to end poverty, protect the planet and ensure that everyone enjoys peace and prosperity by 2030.

Mr Ban Ki-moon, the 8<sup>th</sup> Secretary-General of the United Nations, had said<sup>[21]</sup> :

"Energy is the golden thread that connects economic growth, social equity, and environmental sustainability. With access to energy, people can study, go to

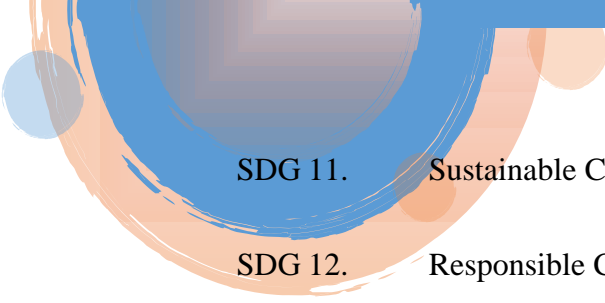


university, get a job, start a business - and reach their full potential.”

“Thus, energy is central to nearly every major challenge and opportunity the world faces today - security, climate change, food production, jobs or increasing incomes. Sustainable energy generates opportunity - it transforms lives, economies and the planet. There are tangible health benefits to having access to electricity and a demonstrable improvement in well-being. Energy access, therefore, constitutes a core component of the sustainable development agenda for energy.”

The list of the 17 SDGs, as defined by the UN, is appended below:

- SDG 1. No Poverty
- SDG 2. Zero Hunger
- SDG 3. Good Health and Well-being
- SDG 4. Quality Education
- SDG 5. Gender Equality
- SDG 6. Clean water and Sanitation
- SDG 7. Affordable and clean energy
- SDG 8. Decent Work and Economic Growth
- SDG 9. Industry, Innovation & Infrastructure
- SDG 10. Reduce Inequalities



SDG 11. Sustainable Cities and Communities

SDG 12. Responsible Consumption and Production

SDG 13. Climate Action

SDG 14. Life Below Water

SDG 15. Life on Land

SDG 16. Peace, Justice and Strong Institutions

SDG 17. Partnership for Goals

## **5.2 Interlinking Between SDG 7 & Other SDGs**

The United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) has analysed the interlinkages between the SDG 7 and other 16 Sustainable Development Goals<sup>[22]</sup> and has brought out that:-

The affordable, reliable and modern energy services are crucial for vulnerable people to meet various essential services, namely access to drinking water and sanitation, access to health care, access to education, access to information and access to adequate and safe housing, and in-turn for reducing poverty in all its dimensions.

Access to energy implies an increase in safety and security, reducing violence against women and inequalities between sexes as women can walk home after work even after dark.

## Visualisation map of the interlinkages between SDG 7 and other SDGs\*

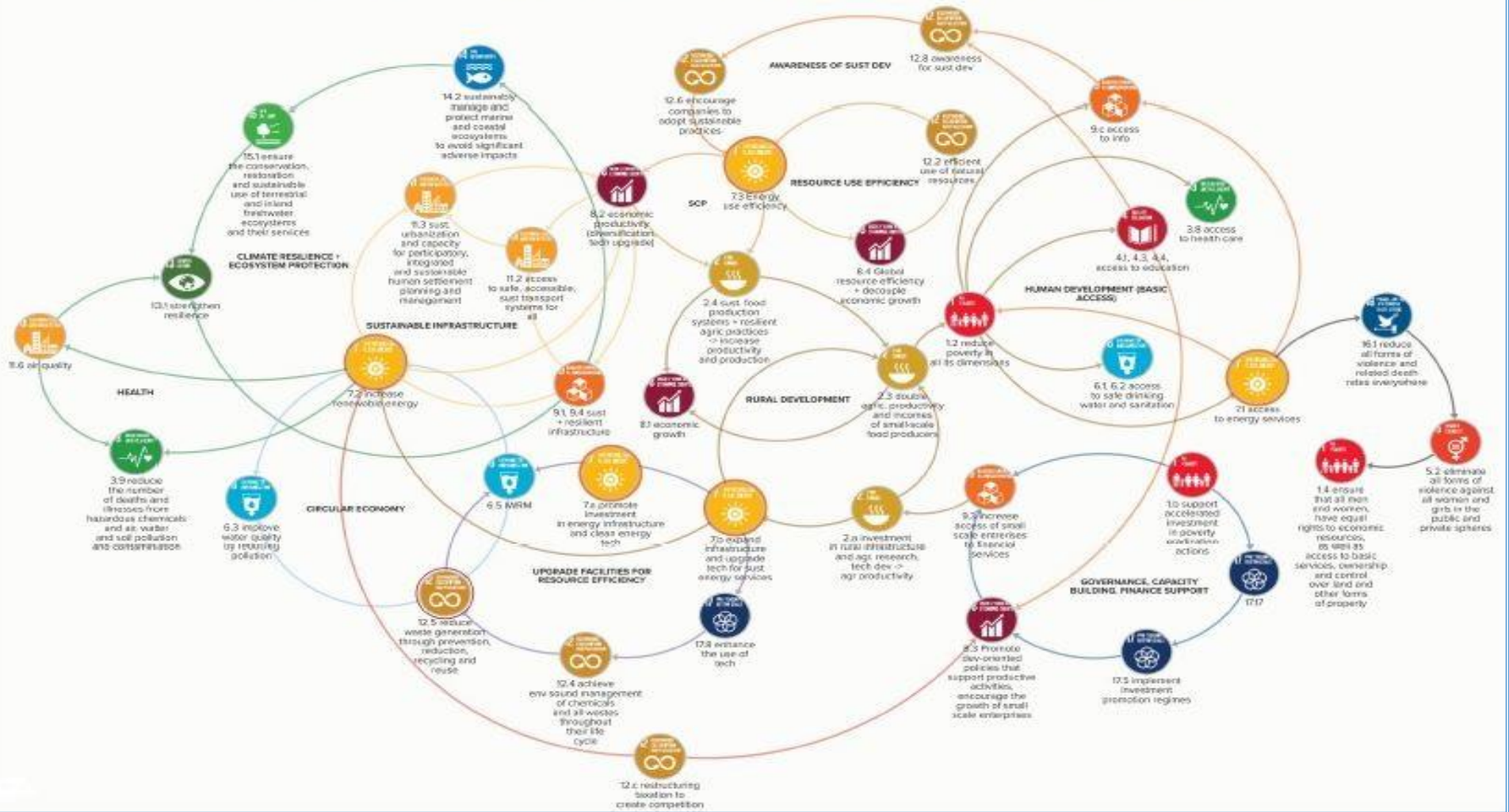
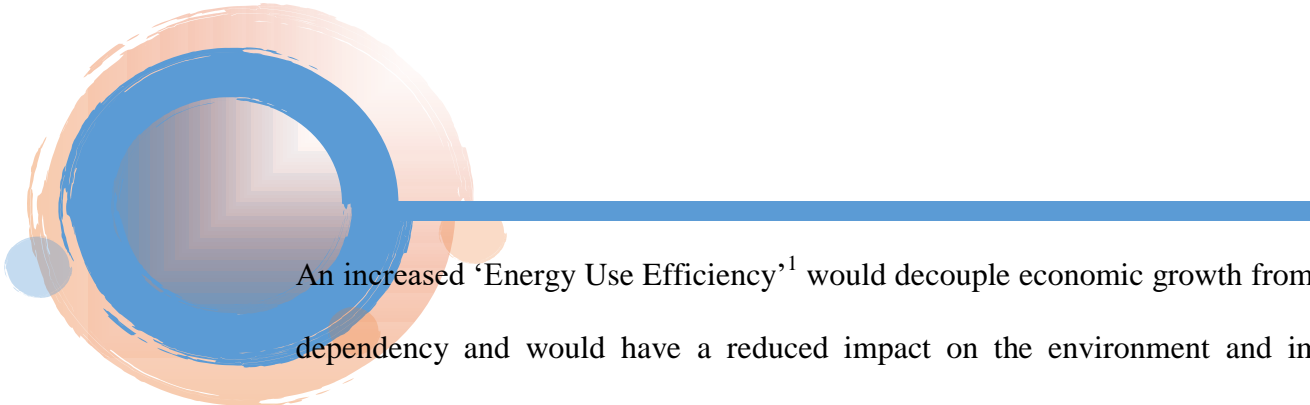


Figure 11 - Impact of SDG-7 (HS-HAPS) on Remaining SDGs

Source: <https://www.unescap.org>



An increased ‘Energy Use Efficiency’<sup>1</sup> would decouple economic growth from energy dependency and would have a reduced impact on the environment and improved economic productivity.

‘Economic diversification’<sup>2</sup> is a crucial component of sustainable development as it assists countries to generate employment and reduce poverty in the long run. Diversification helps to cope with volatility and provide a more stable path for equitable development and sustained growth.

The increase in renewable energy use is critical in strengthening resilience and adaptive capacity to climate-related hazards and reducing contamination of hazardous chemicals in the air, water, and land with a significant impact on reducing pollution linked deaths and illnesses.

Investments in technological innovation towards SDG 7 would stimulate innovations for water efficiency in water-pumping and irrigation systems. It would stimulate new jobs, reduce the transport sector's carbon footprint, allow better air quality in cities, ensure sustainable production and consumption patterns, reduce fuel consumption with environmental benefits, and reduce greenhouse gas emissions.

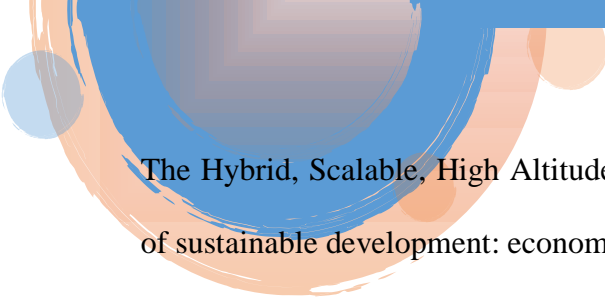
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<sup>1</sup> **Energy Use Efficiency.** Energy efficiency simply means using less energy to perform the same task – that is, eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level. (Source – <https://www.eesi.org/topics/energy-efficiency/description>)

<sup>2</sup> **Economic Diversification.** Economic diversification is the process of shifting an economy away from a single income source toward multiple sources from a growing range of sectors and markets. Traditionally, it has been applied as a strategy to encourage positive economic growth and development. (Source - <https://unfccc.int/topics/resilience/resources/economic-diversification#:~:text=UNFCCC%20Sites%20and%20platforms&text=Economic%20diversification%20is%20the%20process,positive%20economic%20growth%20and%20development.>)

### **5.3 Status Update**

As per the United Nation's Development Agency (UNDP) assessment, globally, one in 10 people still does not have access to electricity. Further, a third of the world's population rely on polluting and unhealthy cooking fuels. As per the Ministry of New and Renewable Energy Year-End Review 2020, the Government has been driving a vibrant renewable energy programme to achieve energy security, energy access and reduce the national economy's carbon footprints. It is in line with India's commitments under the 2015 Paris Agreement to reduce greenhouse gas emissions intensity by 33 to 35 % below 2005 levels and achieve 40 % of installed electric power capacity from non-fossil sources by 2030. India is playing a significant role in green energy transition initiatives worldwide and has achieved a 5<sup>th</sup> Global position for overall renewable energy capacity. As of 31st October 2020, India's total renewable energy installed capacity (excluding hydropower above 25 MW) had reached over 89.63 GW. During the last six years, India has witnessed the fastest growth rate in renewable energy capacity addition among all large economies, with renewable energy capacity growing by 2.5 times and solar energy expanding by over 13 times. Renewable energy now constitutes over 24 % of the country's installed power capacity and around 11.62 % of the electrical energy generation. With the inclusion of large hydro, the share of renewable energy in electric installed capacity would be over 36% and over 26 % of the electric energy generation. Around 49.59 GW renewable energy capacity is under installation, and an additional 27.41 GW capacity tendered. Thus the total capacity that is already commissioned and in the pipeline is about 166.63 GW. Further, large hydropower declared as renewable energy has about 45 GW hydro installed capacity and 13 GW capacity under installation, bringing our total renewable energy portfolio of installed and pipeline projects to 221 GW.



The Hybrid, Scalable, High Altitude Power Supply concept can meet all three core elements of sustainable development: economic growth, social inclusion, and environmental protection.

#### **5.4 A Decade of Action in India -- Taking SDGs From Global To Local**

The Sustainable Development Goals (SDGs) are an ambitious commitment by UN member states to set out a universal and unprecedented agenda that embraces economic, environmental, and social aspects of societies' well-being. India's population is almost 18% of the total world population and ranks number two in the list of countries by population. Therefore, the progress of the world to meet the SDGs targets depends on India's progress. India played a prominent role in the formulation of SDGs, and 17 SDGs, with their 169 targets and 306 national indicators, forms the core part of the country's National Development Agenda.

India recognises that the 2030 Agenda for Sustainable Development constitutes a fitting framework that calls every nation's attention to the challenges of building a sustainable future for the planet and all its life while offering an opportunity to seek consensus and collaborative action. '*Vasudhaiva Kutumbakam*', an ancient Indian phrase, which translates into 'the whole world is my family', concisely captures this Indian approach towards all aspects of life and development.

The United Nation's SDG framework has redefined development policies, government priorities, businesses and citizens' responsibilities, and metrics for measuring development progress across the world. In the second Voluntary National Review & report (India VNR 2020), the Vice-Chairman, National Institution for Transforming India (NITI), has brought out that India has fully adopted the SDG framework and aligned its development priorities with the Global Goals and has also endorsed the fact that the faster socio-economic

development in India, to a great extent, is predicated on universal and equitable access to affordable, reliable and clean energy.

The Performance Index constructed by *Niti Aayog* spanning 16 out of 17 SDGs with a qualitative assessment of SDG 17 tracks the progress of all the States and Union Territories (UTs) on a set of 100 National Indicators derived from the National Indicator Framework, measuring their progress on the outcomes of interventions and schemes of the Government of India. The performance score is computed in the range of 0–100 for every State/UT for all 16 SDGs. If a State/UT achieves 100, it signifies it has achieved the United Nations’ target set for that SDG. The higher the score of a State/UT, the closer it is towards achieving the set targets. Figure 12 depicts the UT wise performance across SDGs. The UT of Ladakh shown at serial no six is faring poorly compared to other UTs in most SDGs and out of the eight UTs, with the least composite score of 59.

		<span style="color: blue;">■</span> Achievers <span style="color: green;">■</span> Front Runner <span style="color: yellow;">■</span> Performer <span style="color: red;">■</span> Aspirant																
#	Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Composite
1	Andaman & Nicobar Islands	48	38	65	61	48	85	73	55	13	94	47	69	72	-	85	65	61
2	Chandigarh	48	73	54	60	47	100	84	64	74	33	83	77	54	-	63	89	70
3	Dadra and Nagar Haveli	33	45	57	53	44	91	60	63	100	57	41	65	41	-	100	80	63
4	Daman and Diu	58	12	50	43	39	96	61	54	100	60	54	41	46	-	89	76	61
5	Delhi	54	56	54	64	27	61	96	60	100	69	63	39	30	-	82	64	61
6	Jammu & Kashmir and Ladakh	58	55	62	54	53	85	76	46	49	47	33	61	59	-	74	59	59

Figure 12 - UT-wise Performance Across SDGs

Source: <https://sdgindiaindex.niti.gov.in>

SDG 7 relates to Affordable and Clean Energy and aims to ensure access to affordable, reliable, sustainable and modern energy for all. Figure 13 gives SDG 7 performance and ranking of all the UTs, and UT of Ladakh ranks sixth amongst eight Union Territories.

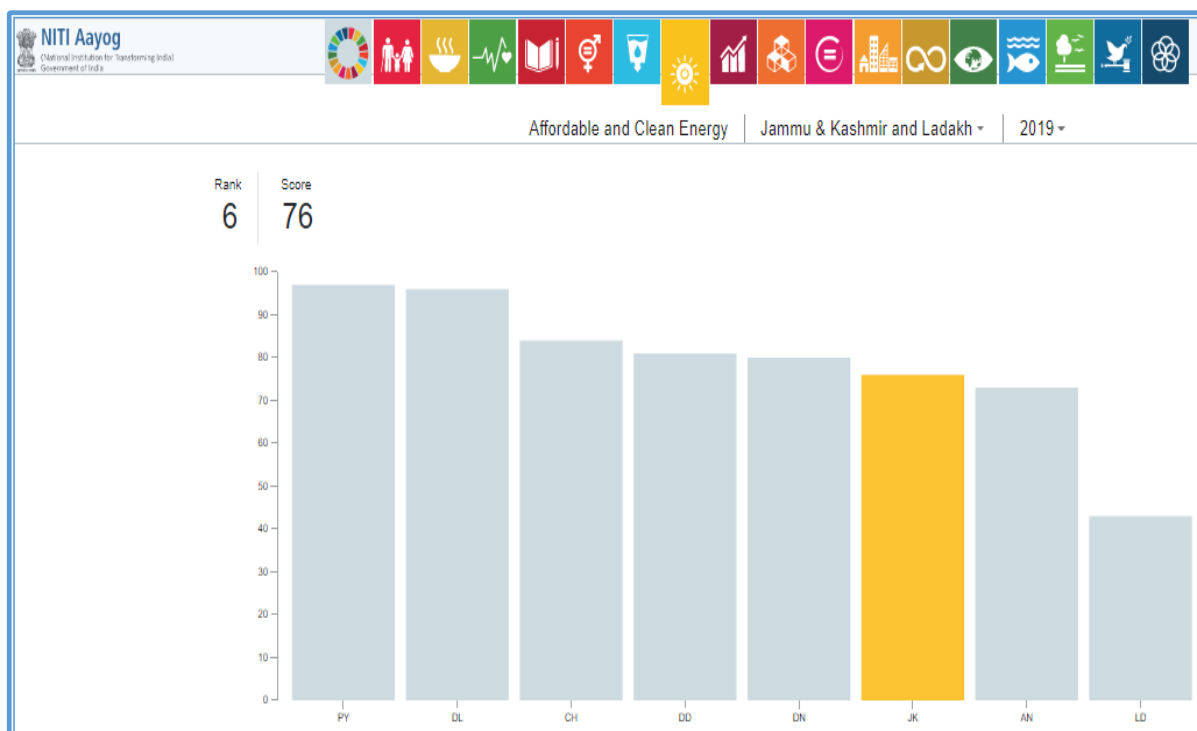


Figure 13 - Performance of Ladakh in SDG 7

Source: <https://sdgindiaindex.niti.gov.in>

## 5.5 Realising SDGs through HS-HAPS Implementation

Subsequent sub-paragraphs discuss the core areas for HS-HAPS deployment:

### 5.5.1. Providing Electricity to Remote Areas

HS-HAPS in an off-grid configuration can satisfy the needs of providing energy directly and avoid the long wait for extended distribution infrastructure to come up. Being scalable, it can cater to the various capacity and types of load requirements.

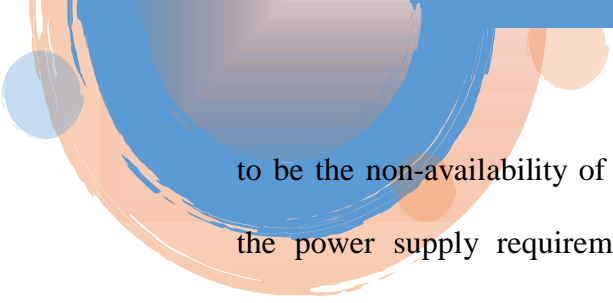
### **5.5.2. Helping Small Businesses Flourish**

Small businesses facilitate employment generation, ensure optimal utilisation of local resources, promote rural development, ensure equitable distribution of income, and generate tax revenues for the Gram-Panchayat. These businesses require less amount of capital and run by a single person or a family. They operate on low-profit margins & have a low annual turnover. The businesses like catering services, courier services, mobile repair shop, hairdresser services, laundry & cleaning Services, online tutoring and many more such ventures fall under this category.

In a real sense, the small businesses operating in rural areas are the localities' nerve centre as they reduce peoples' migration from rural areas to urban areas. Rural to urban area migration occurs due to low employment opportunities & abysmal standard of living in villages. The non-availability of reliable energy source to start the business is one of the main reason for low employment opportunities in villages. HS-HAPS can bridge this gap effectively.

### **5.5.3. Boosting Tourism**

A total of 527 tourists (500 foreign & 27 domestic tourists) visited Ladakh in 1974 when it opened to tourism for the first time. Since then, tourism has grown exponentially, to an annual inflow of 2.4 lakh, due to better air and road connectivity, good publicity through Bollywood films like "3 Idiots", and increased purchasing power. The vision 2050 document envisage 50% GDP of Ladakh through tourism. However, tourism is restricted to the summer seasons and is concentrated mainly around Leh and Kargil. The tourists wanting to explore new offbeat places beyond Leh and Kargil, to satiate their desire for adventures and pleasure, are looking for better facilities in the remote regions of Ladakh. However, the measure hurdle remains



to be the non-availability of a reliable power supply. HS-HAPS is ideal for meeting the power supply requirement for a secure and all-weather tourism dream and elevating the local population out of poverty.

#### **5.5.4. Augmenting Agriculture**

With only 33% area under cultivation, the Ladakh region produces just 10 lakh and 1.6 lakh quintals of food grain and fruits per annum. Consequently, 73% of the food and 85% of the Ladakh region's fruits demand must meet through imports due to the demand and supply gap. Therefore, to bridge this gap, the region requires a multipronged approach to increase land yield already under cultivation and bring additional land under cultivation.

The possible measures to make farming sustainable and profitable may include producing high yield & high-value crops, developing organic farm clusters through modern technologies such as greenhouse farming and drip irrigation, reclamation of land. However, this potential growth sector's progress is plodding due to the lack of reliable energy source required for agriculture. HS-HAPS can be effectively used to meet the requirement of this sector.

#### **5.5.5. Other Fields for HS-HAPS Applications**

Improving the quality of life, boosting the economy by facilitating/promoting small businesses, tourism and agriculture being the major potential sectors have been discussed in detail in the preceding paragraphs. However, there are numerous other sectors, which may benefit from the HS-HAPS implementation.



6.

## **Conclusion & Recommendations**

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*“When one door closes another door opens;  
but we so often look so long and so  
regretfully upon the closed door, that we do  
not see the ones which open for us.”*

*-- Alexander Graham Bell*

# Conclusion & Recommendations

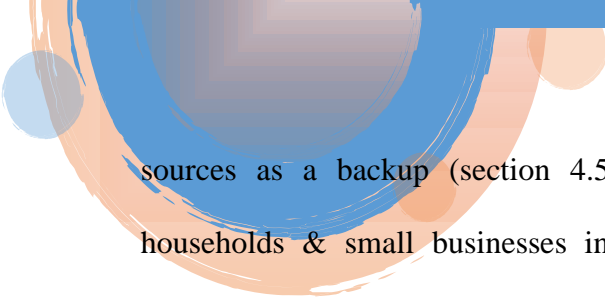
This chapter summarises the research work, analyses the objectives achieved, concludes the findings, and makes future roadmap recommendations.

Access to sustainable, reliable and affordable energy resources is an inescapable prerequisite for any geographical region to flourish. Even after several decades since independence, the Ladakh region remains deprived of vital resources, and hence the region's development has remained non-inclusive which needs to change. Energy is one such essential resource. The Central Government's impetus to development, ambitious planning by the UT in collaboration with *Niti Aayog*, and preparation of comprehensive Ladakh Vision Document 2050 are testimonies of the envisioned changes. However, it may not be out of context to mention that there is at least a decade of inevitable delay for the ground reality to change.

To prevent the Ladakh region's suffering in its socio-economic development during this period, the proposed HS-HAPS offers a viable and affordable solution while we see the envisaged development happening. The HS-HAPS will be a tool to improve the people's quality of life in remotely located regions of Ladakh and boost the local economy by facilitating small businesses, agriculture, and tourism.

### **6.1 The Extent of Proof of the Hypothesis**

Since the Ladakh region has high solar irradiance (as brought out in section 3.3) & an abundance of wind energy (as brought out in section 3.4), effectively harnessing these renewable sources (section 4.1 & 4.4), coupled with the use of traditional fossil energy



sources as a backup (section 4.5), would definitely meet the energy requirements of households & small businesses in the remote areas of the Ladakh region reliably and sustainably (refer chapter 5), Hybrid, Scalable, High Altitude Power Supply (HS-HAPS) System, designed based on such a concept, can be an effective alternative to the conventional electric supply system.

## **6.2 Research Objectives Achieved**

The fundamental causes for the non-availability of adequate & reliable energy supply in the Ladakh region, even after seven decades of independence, have been studied and are brought out.


The impact of non-availability of adequate & reliable energy supply on *Aatma-Nirbhar Bharat Abhiyan's* objectives at high altitude regions of Ladakh has been studied in conjunction with the United Nations Sustainable Development Goals and recorded.

The Government's futuristic and ambitious initiatives studied and deduced that it would take at least a decade to yield desirable results at grassroots levels.

Measures for the early resolution of the issues and recommendations were studied and documented in the subsequent section.

## **6.3 Answers to the Research Questions**


Ladakh is a cold, high altitude and inhospitable terrain separated from mainland India by high mountain ranges. Ladakh is geographically the most extensive region amongst the states and UTs of India, and it has the lowest population density. Difficulties in transportation, lack of any fuel reserves and winter problems. Therefore, the region's infrastructure development, including the energy distribution, has remained neglected



mainly since independence till about 1974. The developments have now started with the increased focus on the region's development post-Fourth FYP and worldwide advancements in the technology in sustainable and renewable energy options, batteries and electronics/communications. However, the developments are not likely to reach all the Ladakh region's remote areas for another decade or so. These shortcomings seem to be the reason behind the non-availability of adequate & reliable energy in the Ladakh region, even after seven decades of independence.

Tourism is the mainstay of the Ladakh region's economy, envisaged 50% by the Vision 2050 document. However, the tourism industry suffers in remote areas due to the non-availability of reliable energy supply. Similarly, small business, agriculture, communication, healthcare, education, ICT infrastructure, and water supply/management have remained mainly underdeveloped in the region's remote areas, once again due to the non-availability of reliable energy. The region has an overall stunted socio-economic growth. Ladakh depends on its food, fuel, textile, and energy requirements in mainland India. Therefore, the Ladakh region is relatively slow in keeping pace with *Aatma-Nirbhar Bharat Abhiyan's* vision and spirit.

The Government has identified India's hilly regions' problem and has started making special provisions for these regions' progress. The focus is on inclusive growth through Self Reliance. Therefore, aligning with the *Niti Aayog*, the UT of Ladakh has made elaborate plans for developing Ladakh regions as listed in Vision 2025 and Vision 2050 documents. Integration of the region with the national grid is one such ambitious initiative. Ladakh slowly but surely is moving in the direction of the objectives of the *Aatma-Nirbhar Bharat Abhiyan*.

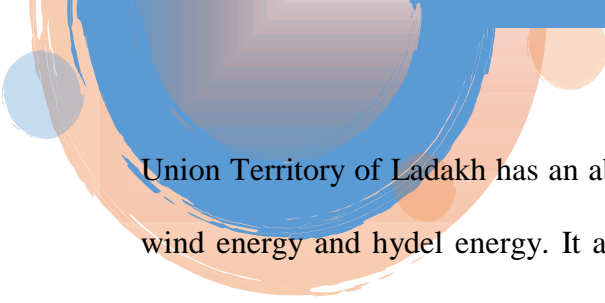


The Vision 2050 document envisages comprehensive and elaborate plans for the region's growth and self-reliance. With adequate funds available to Ladakh progressively and a clear political mandate for the region's development, adequate and steady progress is being made. However, as brought out earlier, because of the inhospitable terrain and very low population density, the envisaged changes shall take over a decade to reach the households and small businesses located in remote areas of the region. Therefore, to obviate the consequent retardation of the socio-economic growth, there is a need to fill the gap with an off-the-grid reliable and sustainable energy supply source.

Implementation of HS-HAPS in Ladakh would act as a catalyst for the socio-economic growth and well being of the region across all the sectors. Recommended Government's adoption of the HS-HAPS by facilitating its mass production through a Ladakh region's manufacturing industry. Further, providing scaled subsidies based on the economic strata of beneficiaries would ensure equity. Creating an efficient local ecosystem for production, distribution, deployment, maintenance, upgrade and disposal of the HS-HAPS and its components as an offline energy option will create jobs and accelerate inclusive growth. With adequate planning, HS-HAPS is easy to integrate with the national grid. Obtaining funding from appropriate agencies like IMF & World Bank, if deemed necessary

#### **6.4 Conclusion**

Since independence, the development UT of Ladakh is not in commensuration with the region's growth potential and mainly centred around 50 Km radius of district towns, namely Leh and Kargil.



Union Territory of Ladakh has an abundance of sustainable energy resources in solar energy, wind energy and hydel energy. It also has a reasonably good amount of geothermal energy resources. However, these resources continue to remain underutilised.

The United Nation's SDG framework has redefined development policies, government priorities, businesses and citizens' responsibilities, and metrics for measuring development progress across the world. In the second Voluntary National Review & report (India VNR 2020), the Vice-Chairman, National Institution for Transforming India (NITI), has brought out that India has fully adopted the SDG framework and aligned its development priorities with the Global Goals and has also endorsed the fact that the faster socio-economic development in India, to a great extent, is predicated on universal and equitable access to affordable, reliable and clean energy. Vision 2025 and Vision 2050 documents have clearly defined the road map for the region's inclusive growth across all the sectors while preserving the rich culture and heritage. The ambitious development plan envisioned for the region, in the vision 2050 document prepared by UT of Ladakh in collaboration with *Niti Aayog*, is expected to unfold over the next three decades as per the plan.

Due to extreme climatic conditions, inhospitable terrain, and poor connectivity with the mainland, the household and small businesses face daily hardship and need immediate relief. The main issue remains to be the non-availability of reliable and adequate power supply. For accelerated growth of the Ladakh region and to mitigate people's sufferings, it is essential to adopt a quickly implementable, future-ready energy solution. Hybrid, Scalable, High Altitude Power Supply is one such alternative. HS-HAPS is scalable to meet any energy requirement, even during extreme winter conditions.

## **6.5 Recommendations**

The research work recommends the following for speedy and inclusive development of the Ladakh region and to realise the dreams of *Aatma-Nirbhar Bharat*.:

- I. Mass production of HS-HAPS for cost reduction
- II. Setting up of HS-HAPS manufacturing hub in Ladakh region
- III. Formulating Government policies to incentivise production and deployment of HS-HAPS
- IV. Formulating policies for prioritisation of HS-HAPS deployment across social and geographical strata of the region
- V. Ensuring speedy deployment of HS-HAPS in the region
- VI. Incentivisation for indigenous development of Lithium-ion family of batteries
- VII. Ensuring adequate financial provisioning
- VIII. Educating end-users for the usage of HS-HAPS
- IX. Under the Skill-India scheme, local youth training in distribution, assembly, installation, maintenance, upgrade and disposal of HS-HAPS and components
- X. Formulating environment-friendly battery disposal procedure
- XI. Installation of e-waste management plant in the region

## **6.6 Scope for Further Study & Research**

As brought out in Chapter 2, the present research objectives were limited to studying the households' and small businesses energy needs in high and very high altitude regions of the Ladakh, shortfalls in the energy supply, and suggesting reliable & sustainable alternatives to

meet these energy needs. There is ample scope for further studies and research. Some of the suggested areas for extended research are to work out the modalities for distribution and deployment of HS-HAPS, implementation of HS-HAPS solution to meet the need of the troops deployed in the high altitude region and research towards the development of efficient, reliable and affordable wind, solar and battery technologies for high altitude regions.



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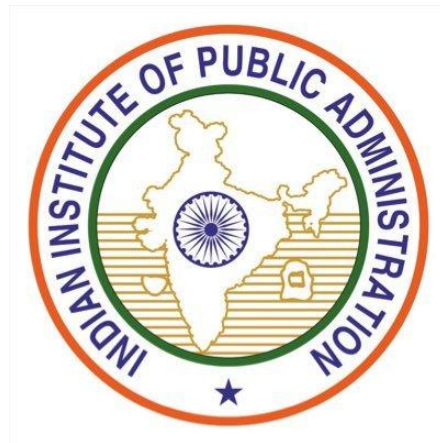
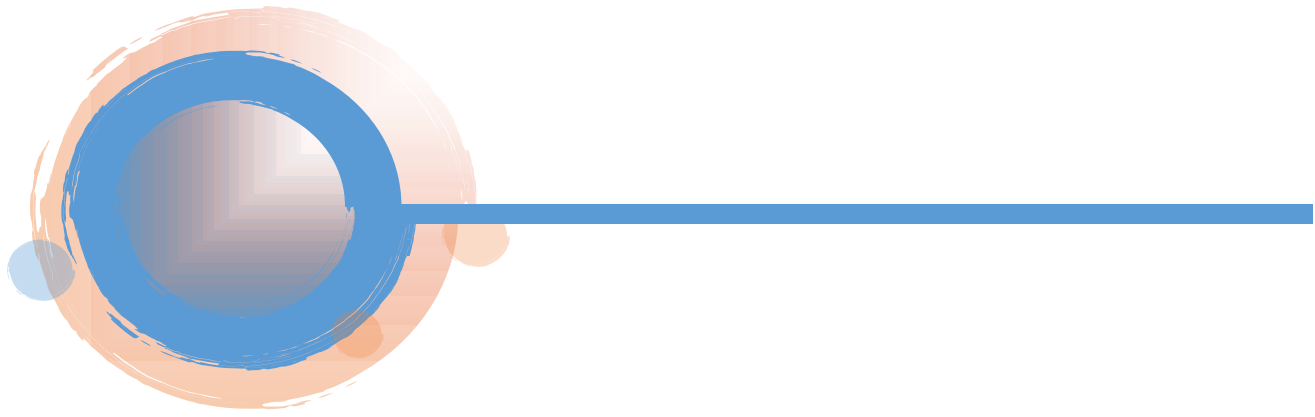
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