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Wind Energy Technology Institute

Research on wind Energy

Wind Farm Project in Gujarat, India

Wind Farm Project Development, WiSe 2024/25

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Date of issue:

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Declaration on Report

We hereby declare that we, **Karan Soni, Mozafary Mostafa, and Patil Rahul**, have independently written the submitted paper. We did not use any outside support except for the quoted literature and other sources mentioned in the paper. We have clearly marked and separately listed all the literature and other sources we employed when producing this academic work, either literally or in content. This report has not been submitted or published before in the same or similar form.

Flensburg, 26.01.2025, Karan Soni

Place, Date, Signature

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1. Abstract

This report presents general information on wind farm development in Poladia, Bhuj, Gujarat, India. The project was developed as part of the “Wind Farm Project Development” module within the Wind Energy Engineering Master’s Program at the University of Applied Sciences in Flensburg.

The report discusses the selection of suitable areas using white map criteria specific to Gujarat's requirements. Subsequently, it considers the installation of six (2.1 MW) wind turbines from Suzlon and details the wind farm layout, total energy yield, and the calculation of CAPEX and OPEX. The analysis uses three main software tools: QGIS, EarthPro and WindPro.

The selection of Suzlon turbines is justified based on their efficiency, reliability, and suitability for the region. The report also addresses regulatory, environmental, and logistical challenges encountered during development and highlights the project's alignment with Gujarat's renewable energy goals and India's wind energy roadmap.

This study evaluates the financial viability of the project, revealing a positive NPV of **58,192 EUR** and an IRR of **7.557%**, indicating profitability and return on investment. With a levelized cost of energy at **0.0184 EUR** and solid debt service coverage ratios, the project promises cost-efficiency and financial stability.

The Poladia wind farm project showcases a successful integration of advanced engineering, strategic planning, and financial prudence, setting a benchmark for future renewable energy projects in India.

2. Introduction: Overview of Wind Farm Development in Gujarat

2.1 The Evolution of Wind energy in India

India has made significant wind energy farm over the past few decades, becoming Globally, India ranks fourth in terms of installed wind power capacity. The journey began in the **1980s** with small-scale wind energy projects. The first wind farm was established in **1986** in coastal Gujarat. India has developed several large wind farms, particularly in states like Tamil Nadu, Gujarat, and Maharashtra. The growth of the wind industry has created a strong support system, improved project management skills, and built a manufacturing capacity of around **15,000 MW** per year. [1] [2]

2.2 Importance of Wind Energy in Gujarat

As of May 2024, Gujarat has an impressive **11,823 MW** of installed wind power capacity. This makes it the leading state in India for wind energy, surpassing Tamil Nadu, which has **10,743 MW**. [3] Its growth has been significantly influenced by a dedicated wind and land policy, which is further explored in a later section of this report.

No	State	Wind Potential at 120 m (GW)	Wind Potential at 150 m (GW)
1	Andhra Pradesh	70.90	123.3
2	Gujarat	142.56	180.8
3	Karnataka	124.15	169.3
4	Madhya Pradesh	15.40	55.4
5	Maharashtra	98.21	173.9
6	Rajasthan	127.75	284.2
7	Tamil Nadu	68.75	95.1
8	Telangana	24.83	54.7
9	Other	18.95	27.1

Table 2. 1: Potential of Energy in Gujarat, India [1]

2.3 Objectives of the Report

- To analyse the growth and current status of wind energy installations in Gujarat, India.
- Design and analyse of Wind Farm using GIS and Wind Pro software
- To examine the policies and regulations that have supported the development of wind energy in Gujarat
- To identify the key drivers and barriers to the expansion of wind energy in Gujarat, India, including infrastructure, financing, and policy support.
- Making schedule and timetable for wind Farm development project in Gujarat, India.

2.4 Scope

- **Geographic Advantage**: Gujarat's long coastline and favourable wind conditions make it an ideal location for both onshore and offshore wind projects. [4]
- **Government Support**: The state government offers various incentives, including subsidies, tax benefits, and streamlined approval processes, to encourage investment in wind energy.
- **Economic Impact**: Wind energy projects create jobs, boost local economies, and contribute to sustainable development goals.

3. Literature Review

3.1 Wind Resource Assessment of Gujarat

The wind resource estimates in this study highlight regions with average annual wind speeds above **8 m/s**, mainly in the Gulf of Kutch and the southern coast. Similar to past research, our **2011** analysis confirms the highest wind potential in the northwestern Gulf of Kutch, with comparable potential found along the southern coastline. While the International Renewable Energy Agency agrees on high wind speeds in these areas, they report higher speeds of **9 m/s** in the Gulf of Khambhat, exceeding our estimates. [4]

Wind speeds in Gujarat peak from May to August, reaching over **10 m/s**, particularly along the coast, and are lowest in October and November, averaging below **7 m/s**. Gujarat has a tropical and subtropical steppe climate, with occasional cyclones, droughts, and floods. The state experiences three main seasons: winter (November-March), summer (March-June), and monsoon (June-September). The northern region is dry, while the southern part is humid, with coastal winds influenced by sea breezes. [4]

3.2 Review of existing wind energy projects.

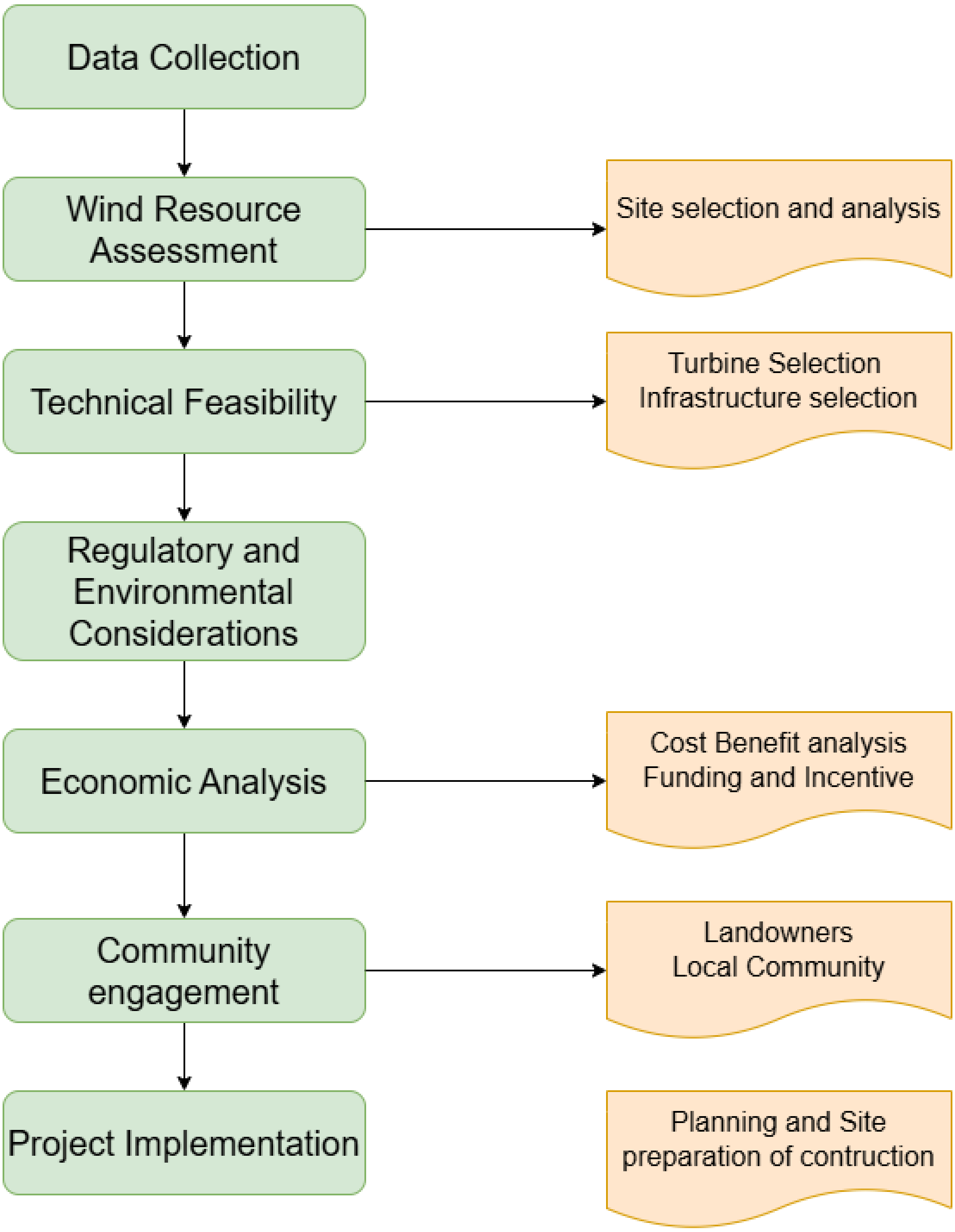
3.2.1 Scaling challenges in Gujarat

Renewable energy development, particularly large-scale wind farms, faces multifaceted challenges (Land Acquisition and local engagement, Logistical Challenges, Grid Integration, Regulatory and Environmental Hurdles, Financial and Contractual Risks, Stakeholder Coordination) that can significantly impact project timelines, costs, and outcomes. The experiences of hypothetical projects like Adani Wind Energy’s **300 MW** wind farm in India’s coastal region highlight key obstacles that often arise during such ventures. Successful wind energy projects, such as those proposed by Adani Wind Energy, provide valuable lessons for future initiatives in the renewable energy sector. [5]

3.2.2 Suzlon secures a repeat order of 193.2 MW in Gujarat

Suzlon Group has secured a repeat order from The KP Group for a wind energy project in Gujarat. This collaboration highlights the private sector's commitment to sustainable growth, supported by Gujarat's favorable policy environment. Suzlon's advanced Doubly Fed Induction Generator (DFIG) technology enhances turbine performance and energy capture. The company's R&D focuses on optimizing energy efficiency and reducing costs. Suzlon’s domestically manufactured turbines contribute to India's self-reliance in the renewable energy sector, aligning with the "Aatmanirbhar Bharat" initiative. This partnership supports India's net-zero goals while promoting economic progress through clean energy. [6]

4. Methodology



5. Requirement & Criterial to develop wind farm in Gujarat

5.1 Regional Planning Requirement

To promote the healthy and structured growth of the wind power sector in India, the Ministry of New & Renewable Energy (MNRE) introduced guidelines for wind power project development in **July 1995**, which have been periodically updated (**Last updated 2024**). Considering advancements in technology, new regulations, and the need for accelerated growth in the sector, the MNRE has recognized the importance of issuing comprehensive guidelines for wind power project development in collaboration with various stakeholders.

The process of wind power project development starts with site selection. Identification of suitable sites depends upon land use permission, availability of wind resource, technically and commercially feasible grid connectivity, transport logistics and environmental acceptability.

- Land use permission
- Availability of wind resource
- Technically and commercially feasible grid connectivity
- Transport logistics
- Environmental acceptability

5.2 Guidelines for Micro siting of wind turbines (MNRE)

Micro siting is the optimization of energy production through the correct placement of wind turbine generators in the wind farm area, considering all physical constraints of the area.

Micro siting criteria are prescribed as under.

Developer(s) shall optimise the wind turbine locations within their land using appropriate wind flow modelling and optimisation tools (linear and Nonlinear)/techniques subject to site assessment as per **IEC 61400-1** standard for turbine safety considering extreme wind, flow inclination, vertical wind shear, and turbulence with added wake effects and corrections for terrain complexity etc.

Developer(s) shall maintain a distance of $\mathbf{2D}$ (D-Rotor Diameter) distance perpendicular to the predominant wind direction and $\mathbf{3D}$ distance in the predominant wind direction from the boundary line of each adjoining land of other developer(s) with appropriate offset.

Developer(s) shall maintain a wake loss (in terms of energy) of **10%** between wind turbines with appropriate offset for wind turbines sited on a footprint basis.

Developer(s) shall maintain a distance of $\boldsymbol{HH + 0.5 \cdot RD + 5m}$ (Hub Height+ Half Rotor Diameter +5 meters) from Public Roads, railway tracks, highways, buildings, public institutions and EHV lines.

Developer(s) shall not site wind turbines within 500 m of any living places for the mitigation of noise. 'dwelling' shall mean at least 15 inhabited buildings. [7]

5.3 Law & Regulation as well as Park Layout

5.3.1 Consent to Establish (CTE) from Gujarat State Pollution Control Board (GPCB)

5.3.1.1 Consent to Establish (CTE)

Required to obtain CTE under section 21(1) of the Air (prevention and control of pollution) Act, 1981. Also, CTE under section 25/26 of the Water Act is required in case of discharge of sewage or trade effluent in a stream or a well or a sewer or a lake. [section 21(1) of the Air (prevention and control of pollution) Act, 1981]

5.3.1.2 Consent to Operate (CTO)

Prior to commercial generation, it is obligatory to apply for CTO under section 21 of the Air (P & CP) Act 1981, with respect to ambient air quality related to noise. [section 21 of the Air (P & CP) Act 1981,]

5.3.1.3 Apply for Hazardous Waste Authorisation

wind power projects use different types of fluids for the smooth operation of the WTG. Primarily, three main types of fluid are used: First, Generator cooling fluid is used as coolant (a mixture of glycol and water, similar to what is used in automobile radiators). Second, Lubricating oil is used in the gearbox (synthetic oil). Third, Hydraulic oil for operating the blade pitch system, yaw mechanism and brakes. To protect transformers from heating, mineral oil (transformer oil) is used as coolant. [8]

5.3.2 Permission from Forest Department

Under Rule 6 of the Forest (Conservation) Rules, 2003, any project that intends to use forest land for non-forest purposes must submit a proposal using the prescribed forms included in the rules.

	Advising/ Recommending body	Route	Final clearance Authority
< 1 hectare	-	-	State Government (Principle Secretary of Forest)
1 – 5 hectares	State forest department	State government to regional office of MoEF	Regional office MoEF
5 – 40 hectares	State Advisory group	State Government to regional office of the MoEF; then to the MoEF with state advisory group recommendations	MoEF
> 40 hectares	Forest Advisory Committee	State government to MoEF	MoEF

Table 5. 1: Forest Clearance Procedure [9]

The forest clearance process begins with the project proponent submitting an application to the nodal officer of the state forest department. The application is forwarded to the district-level field office, where an inspection of the proposed land is conducted. After this evaluation, the application is sent back through the forest department hierarchy to the Principal Secretary of Forests. The final approval authority depends on the extent of forest land to be diverted: the proposal may either be approved by the Regional Office of the Ministry of Environment, Forest, and Climate Change (MoEFCC) or by the Secretary, at the regional or central level, based on the project's scale and requirements. [9]

Further, the forest guidelines also specify certain criteria for the setting-up of a development project, which states that no projects should be in the vicinity of the following:

- National Parks, Wildlife Sanctuaries and Core areas of the Biosphere Reserves.
- Scenic landscapes, areas of geo-morphological significance, unique and representative biomes and eco-systems, heritage sites/structures and areas of cultural heritage and importance.
- Fragile eco-systems such as mountains; areas rich in coral formations as well as marine, coastal, desert, wetland, riverine and island eco-systems. Areas rich in biological diversity, gene pool and other natural resources.

5.4 Eco-sensitive zones

In 2002, the MoEF decreed that an area of **10 km** around national parks and sanctuaries should be assigned as an eco-sensitive zone, with restrictions on development.

Any project including wind power projects that fall inside the zone have to seek approval from the National Board for Wildlife (NBWL). The NBWL may conduct a study if it believes the project may have large-scale impact.

Wildlife Board's guidelines on linear intrusion:

- The guidelines are extensive and focus firstly on how to avoid the need for new roads and powerlines in natural areas. Only after avoidance is ruled out, do the guidelines go into details of how roads and powerlines should be built to minimize and mitigate damage.
- Keep construction phase as short as possible, avoid night-time work as it disturbs animals.
- When one linear intrusion has been made, new projects should align with it so as not to cause further destruction
- According to the guidelines, roads should be no wider than **12.5 m** for primary roads and 8.5 m for secondary roads.
- To avoid electrocution of elephants powerlines should be a minimum of 6.6 m above ground on level terrain and a minimum of **9.1 m** above ground on steeper terrain.

- Maintaining **1.5 m** spacing between energized components, cover and insulate energised hardware, include reflectors and perch deterrants. Install underground cables. Monitor effectiveness of measures.
- Structures, such as retaining walls that can act as barriers to animal movement should not be installed along roads, especially in hilly terrain. [10]

5.5 NOC from Airports Authority of India (AAI) and Ministry of Defence

Aircraft Act, 1934 empowers the Central Government to impose restriction on the construction of buildings and other structures within a radius of **20 Km** from ARP of all aerodromes.

No Wind Turbine Generators (WTGs) shall be installed up to **10 Km** from the Radar Antenna of all Static Air Defense Radars and up to 8 km from ATS Radar antenna/VOR.

Colour Coded Zoning Maps (CCZMs):

- CCZMs have been formulated for all IAF aerodromes and handed over to Local Municipal Authorities (LMAs). Area in the center of CCZM of **4 Km** radius around threshold of an IAF aerodrome is marked in Red. For all proposed constructions falling in Red Grid/Zone, it shall be mandatory for an applicant, to submit application in specified format and obtain NOC from IAF as per existing procedures/guidelines.
- Area beyond 4 Km from threshold has been demarcated in various zones with different Color Coding on the CCZM. Local Municipal Authorities (LMAs) can approve any building/infrastructure plans only up to maximum elevation specified in the respective zones as depicted on CCZM without referring the case to IAF.
- Under GSR 751 (E), the area marked in 'Green' is beyond **20 Km** from Aerodrome Reference Point of an IAF airfield and is outside the purview for issuance of NOC by IAF. Hence, for any construction/proposal in areas marked in 'Green', the applications are not required to be processed for infrastructure up to a max height of **150 m** AGL above aerodrome elevation. [11]
- No Objection Certificate (NOC) from State Electricity Board
- Land Allotment Letter
- NOC from the District Level Industrial and Revenue (DLIR) Department
- NOC from Mining Department
- NOC from Village Panchayat
- Power Purchase Agreement (PPA)

6. Wind Area Selection

To analyse wind farm suitability by integrating wind speed data at **100m** height with geographical and infrastructural constraints.

Steps Involved in the QGIS:

Step 1: Data Preparation

- Wind speed data at **100m** height. [12]
- GIS layers for: Buildings, Forests, Military areas, Railways, Industrial, Roads, Airports, Airfields, Rivers. [13]
- Import all provided data layers.

Step 2: Project Properties Setup

- Set the correct CRS (Coordinate Reference System) as per the dataset.

Step 3: Create Buffers

- Use the Buffer tool to create exclusion zones around:

GIS Layers	Distances [m]
Buildings	250
Forests	10,000
Military Areas	10,000
Railways/ Industrial	250
Roads	250
Airports/ Airfields	20,000
Rivers	250

Table 6. 1: Specify buffer distances for each feature as per the project guidelines

Step 4: Merge Buffers into No-Go Areas

- Combine all individual buffer layers into a single "No-Go Area" layer. [Fig. 6.1 for the merged No-Go Area.]

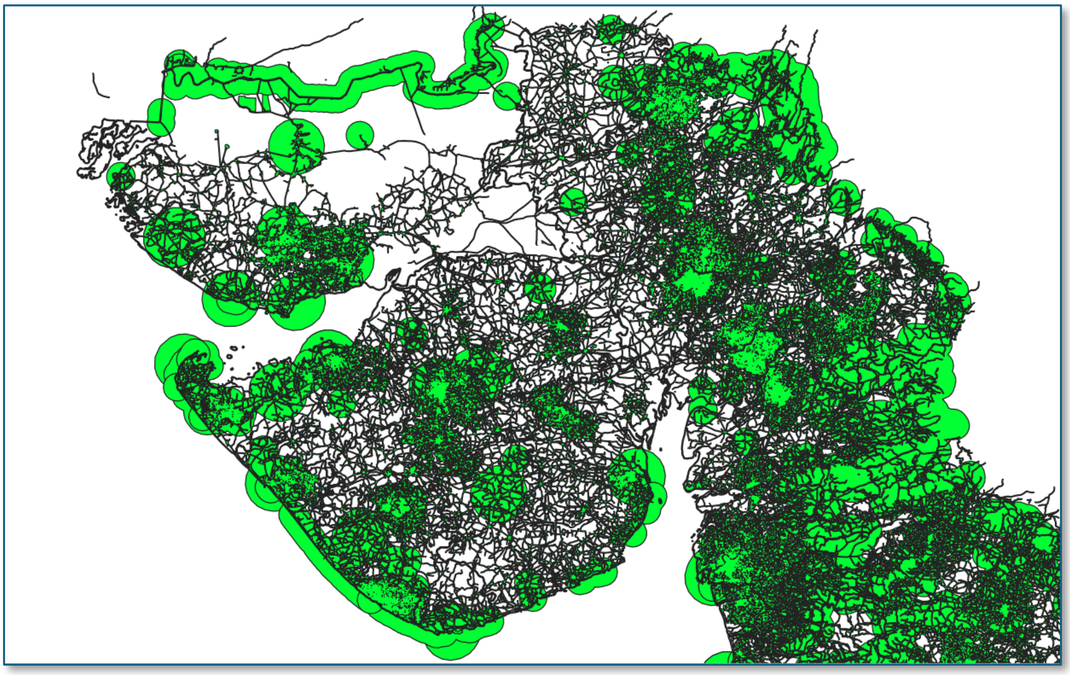


Figure 6. 1 Merged no-go area

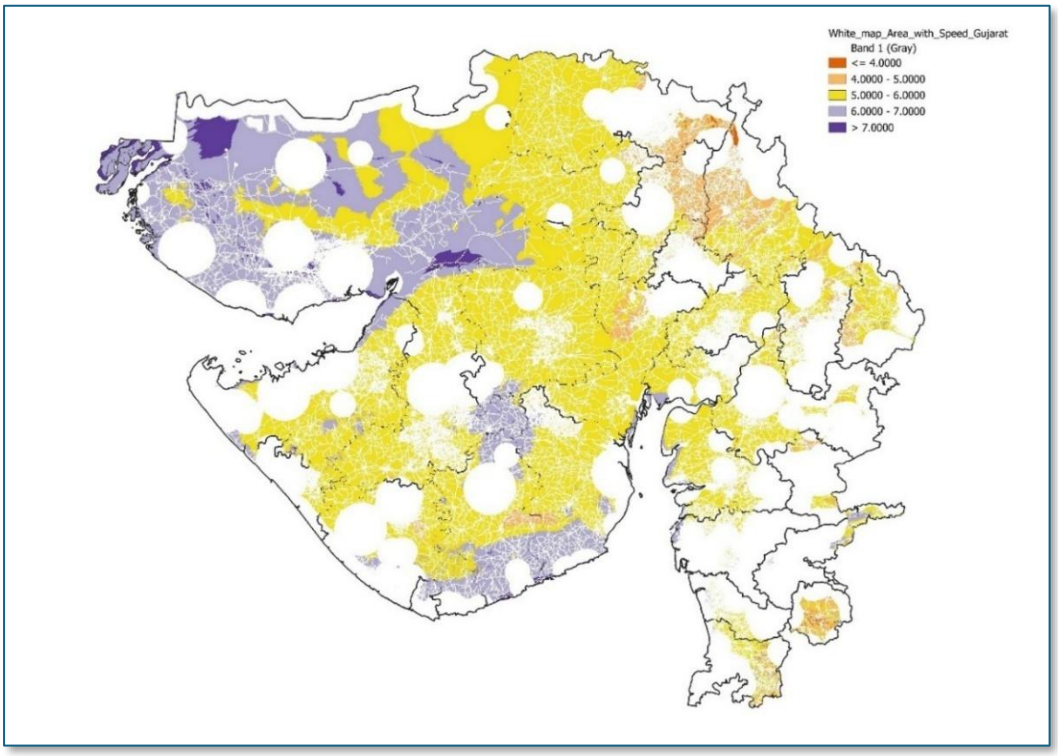


Figure 6. 2 The merged wind speed into white map

Step 5: Identify Suitable Areas Using Difference Tool

- Use the Difference tool to subtract the "No-Go Area" layer from the total study area.
- The output is a "White Map" layer highlighting areas suitable for wind farms.

Step 6: Integrate Wind Speed Data

- Overlay wind speed data onto the White Map layer. [See Fig. 6.2]
- Use the Clip Raster by Mask Layer tool.

Steps Involved in the Earth Pro:

We used Google Earth Pro for a comprehensive site assessment. First, we checked for the presented or not of rivers, existing wind turbines, and other features such as residential areas. Second, we assessed the near of the site to the grid system and evaluated potential cabling routes. Last but not least, we examined transportation facilities and gathered information about land ownership, determining whether it is privately or government owned.

Figure 6. 3: Wind area and available substation [14]

Steps Involved in the Wind Pro:

First, we selected the optimal wind location (Poladia, Bhuj, Gujarat,India) established the wind area boundary. Next, we chose six Suzlon 2.1 MW wind turbines, strategically positioning them to account for wind direction (See Fig 6.3) and wake effects. Finally, we created an energy yield report to assess the project's potential energy production.

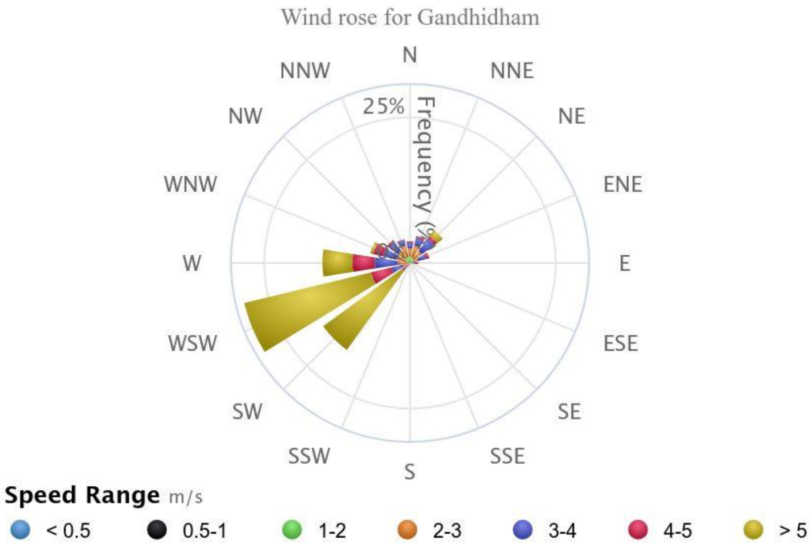


Figure 6. 4 Wind rose

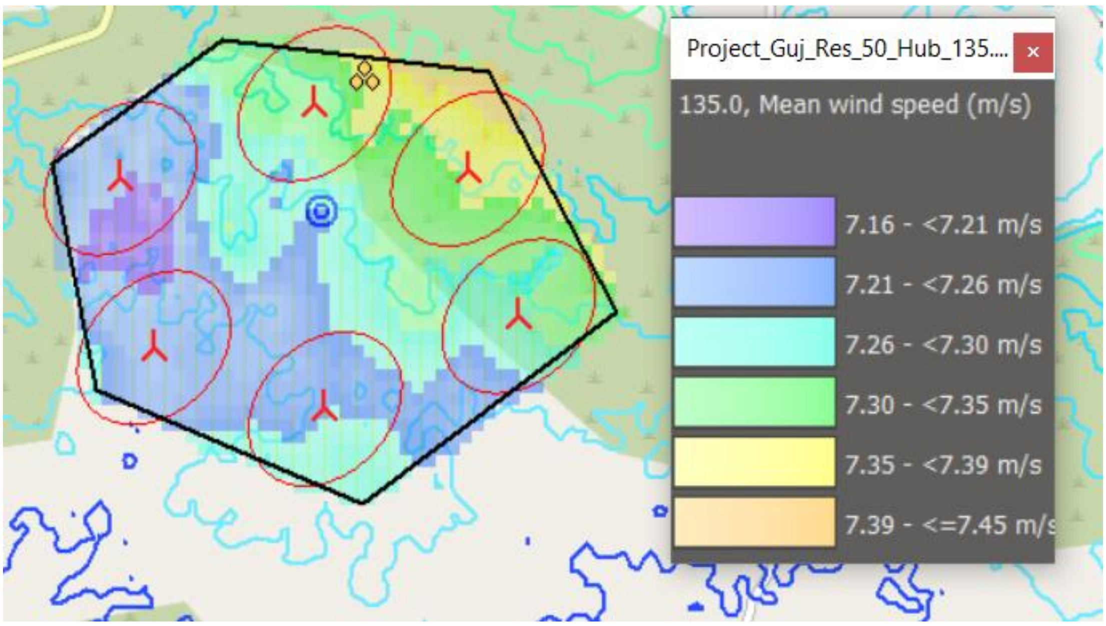


Figure 6. 5 Wind farm area with wind turbine

7. Electrical Grid Infrastructure and Cable Routing: Ensuring Connectivity

Our wind farm has a capacity of **12.6 MW**, which is relatively below 20 MW. Therefore, we utilized an available substation. The substation, named **Renew Wind Energy (AP2) Pvt Ltd**, operates at **33/220 kV**. The length of the 33 kV line from the wind farm area to the pooling substation is **20 km**, as shown in the figure 7.1.

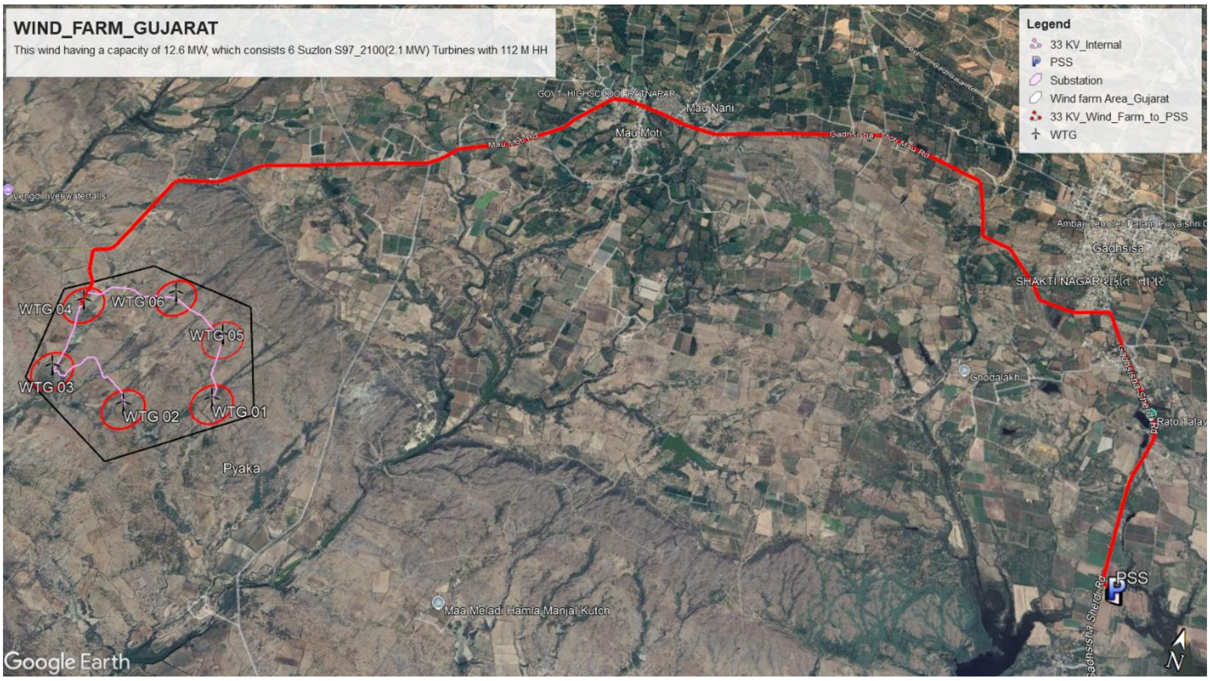


Figure 7. 1: Substation and Cable routing plan

8. Project Development Timeline: From Greenfield to Operation

Phases	Descriptions	Timeline
1	Study Laws and Regulations	
2	Site Assessment	
3	Land Leasing	
4	Planning	
5	Permitting	
6	Financing	
7	Constructions	
8	Commissioning	
9	Operations	

Table 8. 1: Project development timeline

9. Community Engagement: Strategies for Local Acceptance

Community Meetings:

Organize meetings with community members to explain the benefits of the project, such as job creation, infrastructure development, and clean energy. Address any concerns and answer questions.

Engage Local Leaders:

Work with local leaders and influential community members to gain their support. Their endorsement can help in building trust and acceptance within the community.

Transparency:

Maintain transparency throughout the process by sharing project details, timelines, and potential impacts. This can help in building trust and reducing resistance.

Benefit Sharing:

Propose benefit-sharing, such as community development funds, scholarships, or infrastructure improvements, to ensure that the community also gains from the project.

Regular Updates:

Keep the community informed about the progress of the project through regular updates and open communication channels.

10. Land Leasing and Acquisition: Securing the Site

Policy 2023 aims to facilitate the leasing of government fallow land in Gujarat for the establishment of green hydrogen production facilities. These facilities will utilize non-conventional renewable energy sources such as solar, wind, and hybrid wind-solar energy. [15]

10.1 Lease Duration and Terms

- Lease Period: **40 years**
- Annual Rent: **₹15,000 (€ 150 – €170) per** $[\mathbf{10^4}\ \boldsymbol{m^2}]$ area, subject to a **15%** increase every three years.
- Advance Payment: Annual rent and applicable taxes must be paid in advance. Late payments integrate **12%** simple interest after **90 days**.
- Security Deposit: Applicants must provide a deposit equivalent to one year's rent, a **1%** service charge, and necessary stamp duty upon land possession. [15]

10.2 Eligibility and Allocation

- Criteria: Includes financial stability (minimum net worth of **₹1200 crore (€130.44 million))**, experience in renewable energy generation (**minimum 500 MW**).
- Land Allocation Limits: One applicant or their partners can only lease enough land to produce **30 lakh metric tonnes** $(\mathbf{3}\ \boldsymbol{x}\ \mathbf{10^8})$ of green hydrogen each year. This means they can't lease more land than what is necessary for that amount of production. [15]

10.3 Application and Approval Process

- Pre-Feasibility Report: Applicants must submit a preliminary report demonstrating their capability to produce green hydrogen.
- Review Committees: A Committee of Experts evaluates the applications, followed by the High-Power Committee for final recommendations. [15]
- Tripartite Agreement: Upon approval, a tripartite agreement is signed between the Collector, the nodal agency (GPCL), and the applicant. [15]

10.3.1 Government land Approval Process:

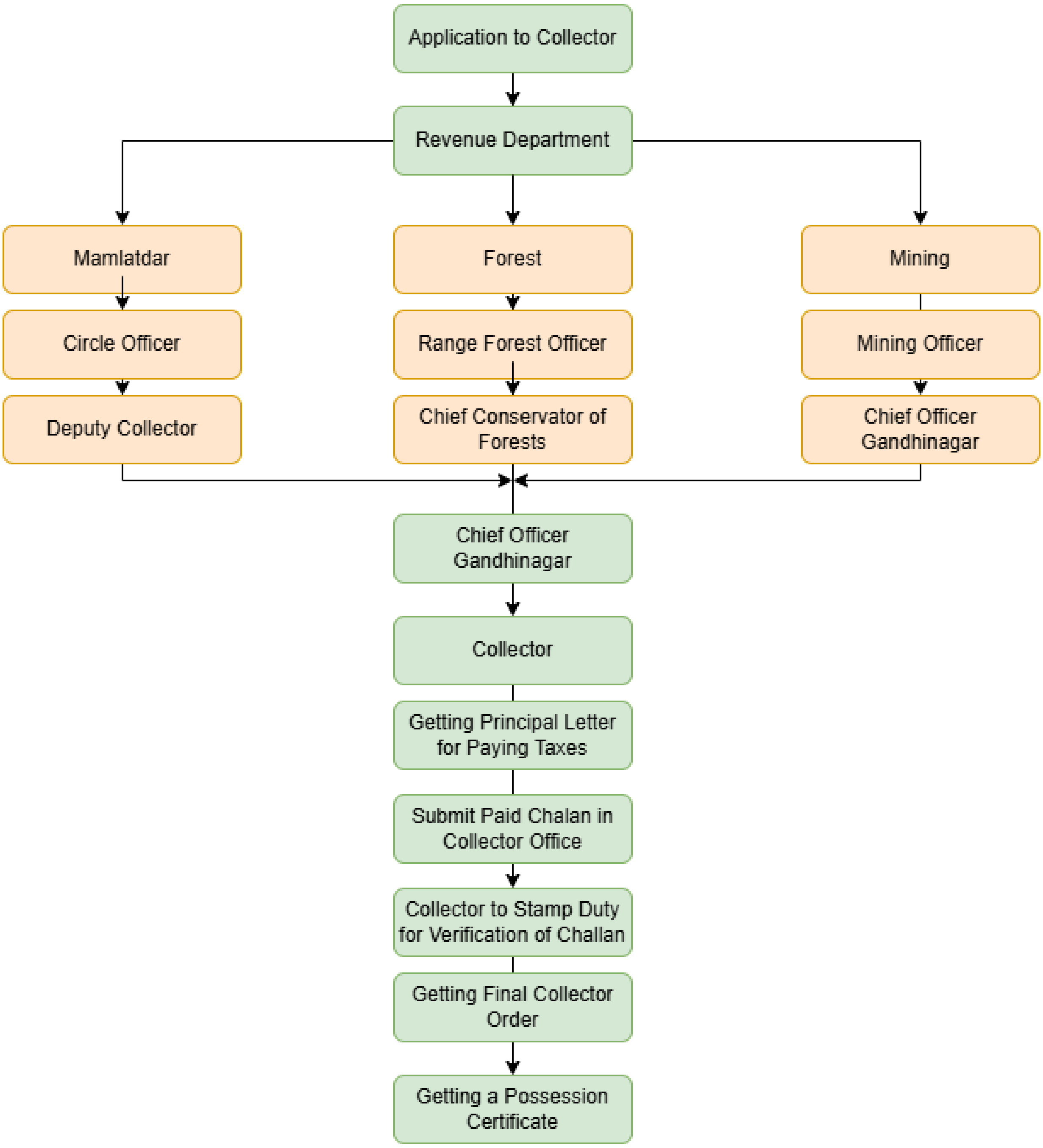


Figure 10. 1: Government land approval process for wind farm [16]

10.3.2 Private land Approval Process:

Step 1: Title Clearance

- The first step involves ensuring that the title of the land is clear. This includes:
- Checking all historical ownership records.
- Ensuring there are no disputes, encumbrances, or legal issues associated with the land.
- Reviewing registered documents with the Sub-Registrar's office.

Step 2: Agreement to Sell (ATS) and Sale Deed

- Agreement to Sell (ATS):
- The developer enters into a formal agreement with the landowner, documenting the agreed price, terms of payment, and timelines for the transaction.
- The ATS may involve an advance payment.
- Sale Deed:
- Once the terms in the ATS are fulfilled, a sale deed is executed.
- The sale deed is then registered with the Sub-Registrar's office, completing the legal transfer of ownership to the developer.

Step 3: Application and Obtaining 89A Permission from revenue department

- Purpose of 89A Permission:
- Under Section 89A of the Gujarat Land Revenue Code, this permission is required to formally register the land transaction.

Step 4: Conversion to Old Tenure Land & Payment of Premium

- Understanding Land Tenure:
- Land in Gujarat is often classified as "new tenure" (with restrictions on sale or use). Developers must convert it to "old tenure" to remove restrictions.

Step 5: Apply and Obtain 65 Kh Permission (Non-Agricultural or NA Use)

Purpose of 65 Kh Permission:

- Land classified as agricultural must be converted to non-agricultural (NA) for setting up infrastructure like wind turbines.

Application Process:

- The developer applies to the District Collector or Revenue Department with relevant documents (title clearance, sale deed, and tenure conversion approval).
- The Collector grants permission, officially converting the land use to NA, allowing construction to proceed. [16]

10.4 Usage and Compliance

Dedicated Use: Leased land must be exclusively used for green hydrogen production.

Development Timeline: Projects must develop infrastructure and achieve 50% capacity within 3 years and full capacity within 8 years.

No Subleasing: The leased land cannot be subleased to third parties. [15]

10.5 Financial and Operational Responsibilities

Infrastructure Development: Applicants are responsible for all infrastructure, including power transmission, roads, water supply, and security.

Energy Usage: Generated renewable energy must primarily be used for green hydrogen production within Gujarat. Excess energy sales are subject to government discretion.

Charges and Taxes: All applicable taxes, licensing fees, and GST must be borne by the lease agreement. [15]

10.6 Governance and Oversight

Nodal Agency (GPCL): Manages land allocation, application processing, and project monitoring.

High Power Committee (HPC): Sets parameters for equipment and production standards, and prioritizes applications based on predefined criteria.

Revenue Department: Ensures land allocation aligns with state requirements and oversees final approvals. [15]

10.7 Provision of Land procurement/ acquisition in Gujarat Wind Power Policy 2016

The Gujarat Energy Development Agency (GEDA) will act as the State Government's Nodal Agency for implementing and facilitating the Gujarat Wind Power Policy-2016. GEDA will support project developers by assisting with the following activities to achieve the policy's objectives:

Project Registration: Ensuring wind power projects are properly registered.

S.No	Department	Designation
1	ACS/PS/Secretary (CCD)	**Chairman**
2	AS/JS/Deputy Secretory (EPD)	**Member**
3	Chief Electrical Inspector & Collector of Elect. Duty	**Member**
4	General Manager (Comm), GUVNL	**Member**
5	Respective District Collector	**Member**
6	**Director, GEDA**	**Member Secretary**

Table 10. 1 Project registration [17]

Developer Assistance: Addressing queries and resolving issues faced by wind power project developers.

Accreditation: Facilitating the accreditation and recommending wind power projects for registration with the Central Agency under the Renewable Energy Certificate (REC) mechanism.

Wind Turbine Generators (WTGs) can be established on private land, revenue wasteland allotted by the State Government, or land owned by GEDA (if available). The allocation of GEDA-owned land on lease requires the approval of a Coordination Committee, as detailed in the policy's framework. Additionally, this committee is responsible for resolving issues beyond land allotment, such as interpreting specific provisions of the policy.

11. Addressing Conflicting Interests

Impact	PYSICAL ENVIRONMENT								SOCIO-ECONOMIC ENVIRONMENT				
Activity	Visual Aesthetics	Topography	Air Quality	Noice Impact	Ground water Quality	Soil removes	Land use	Ground water Resources	Loss of land	Common Property usage /conflict	Community health	Cultural Heritage	Occupational Health & Safety
Sourcing And transportation of construction material etc.	L		M	L		L				L	L		M
Storage and handling of raw material	L		L		L	L	L				L		M
Establishment of labour camp and hiring of labour	L		L	L		L							
Access road construction	M		L	L					L		L		L
Site clearance	M		L	L		L							L
Foundation excavation	M		L	L									M
Transportation of	M		L	L							L		M

WTG components to site and storage													
Erection of WTG’s	M	M	L	L			M	L					M
Transformer yard construction	M		L	L				L					M
Laying of transmission lines	M		L	L					M		L		M
Periodic maintenance of all WTG’s at every location													M
Maintenance of ancillary facilities such as Store, yard, site office, transmission lines													M
Security of WTG’s in operation											L		M
Operation of Wind Turbine		M									L		

L = Low, M = Medium, H = High [16]

Table 11 1: Addressing Conflicting Interest

12. Turbine Components: Logistics and Transformation

There are four locations: Daman, Vadodara, Gandhidham, and Bhuj (refer to Figure 12.1). Previously, we have selected a wind farm site located in Poladia, Gujarat, India. We had discussed that we chose Suzlon company wind turbines because they are manufactured in Gujarat, India. One of the key advantages is the ease of transportation. The government provides incentives if we select “Made in India” products, it is second key advantages.

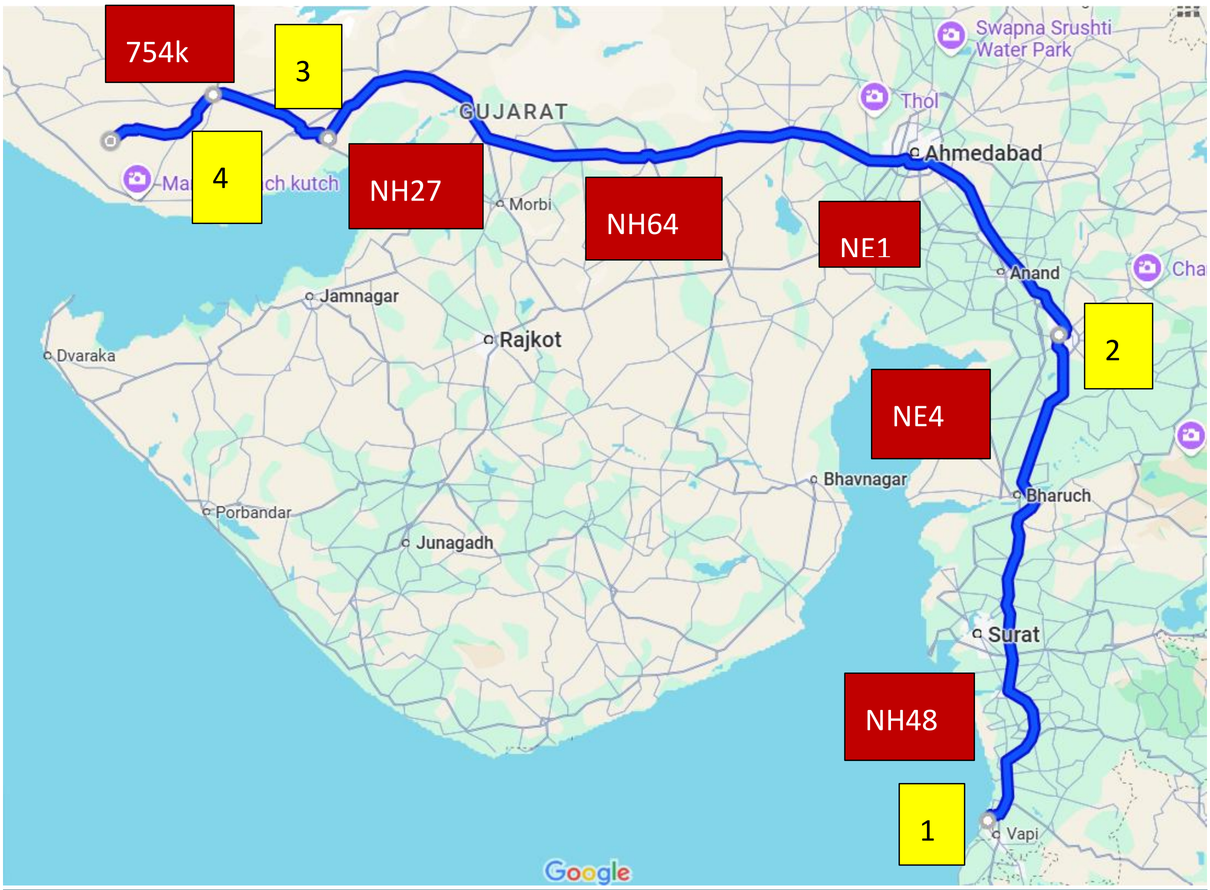


Figure 12. 1: Routes for transporting wind turbine components

You can see Table 12.1, which shows the different turbine component manufacturing locations and the distances to the wind farm. Additionally, in Figure 12.1 and 12.2, the National Highway (NH), National Express Highway (NE), and Sub National Highway (754K) are represented. These are the best routes for transporting wind turbine components

Figure 12. 2: Routes for transporting wind turbine components from Highway to Wind Farm Area

Wind Turbine Manufacturing components	Manufacturing Locations	Distance between Manufacturing location to Wind farm [km]
Nacelle	Daman, Gujarat, India	743
Nacelle Cover	Daman, Gujarat, India	743
Hub	Daman, Gujarat, India	743
Rotor Blades	Bhuj, Gujarat, India	57
Tower	Gandhidham, Gujarat, India	136
Electrical	Vadodara, India	544

Table 12. 1: Suzlon wind turbine manufacturing component's locations and distance from wind farm [18]

13. Profitability Analysis: Calculating the Financial Viability

Income:

$$Income = Net\ energy\ yield\ (kwh)\ \cdot Feed\ in\ tariff\ \left(\frac{Euro}{kWh}\right) \tag{13. 1}$$

$$Income = 38168113\ \cdot 0.033\ = \mathbf{12,59,548}\ € \tag{13. 2}$$

Operating costs:

$$Oprating\ costs = Total\ operating\ costs\ (Euro) \cdot Inflation \tag{13. 3}$$

$$Oprating\ costs = \mathbf{1,05,000}\ (€) \cdot last\ year\ infation\ \cdot (1 + inflation) \tag{13. 4}$$

Inflation: **5.16 %** (for last 10-year average rate)

The total operating cost encompasses a full maintenance contract, lease costs, financial statements, tax advice, insurance, and operational management. It also includes dismantling guarantee reserves, own consumption, miscellaneous expenses, and agricultural impacts like hamster management and yield loss compensation for farmers growing wheat and barley.

EBITDA: Earnings before Interest, Taxes, Depreciation and Amortization:

$$EBITDA = Income\ - Operating\ Costs \tag{13. 5}$$

Depreciation and Amortization:

$$Depreciation\ and\ Amortization = \frac{Total\ Investment\ costs}{Depreciation\ period} \tag{13. 6}$$

$$= \frac{98{,}07{,}253\ Euro}{14\ Years}$$

It refers to the reduction in the value of an asset over time, typically due to wear and tear, usage, or obsolescence. We have considered value of **7,00,518 euro** until 14 years.

EBIT: Earnings before Interest and Taxes:

$$EBIT = EBITDA - Depreciation\ and\ Amortization \tag{13. 7}$$

Net Financial Income:

$$Net\ financial\ income = \frac{Opening\ Balance - Repayment}{2} \cdot Interest\ rate \tag{13. 8}$$

$$Opening\ Balance = Total\ inverstment\ cost - Equity \tag{13. 9}$$

$$Equity = Total\ inverstment\ cost\ \cdot (1 - Debt\ ratio) \tag{13.10}$$

Here,

Debt ratio = **72.73%**, Total investment cost = Total purchase price = **98,07,253** €, Repayment = **4,19,584** €, Interest rate = **9 %**

EBT: Earnings before Taxes:

$$EBT = EBIT + Net\ financial\ income \tag{13. 11}$$

[19] [20] [21] [22] [23]

Parameter	Economics	Unit
Number of WT	6	-
Installation output	2100	KW
Total output	12600	kW
Gross Energy Yield	39026700	KWh/a
Total losses	2.20	%
Net Energy Yield	3,81,68,113	kWh
Site Quality	71.04	%
Feed in Tariff	0.033	Euro/kWh
Total Investment Costs	98,07,253	Euro
Total Operating Costs	1,05,000	Euro
Constant Payment Loan Type (Debt ratio)	72.73	%
Equity	26,74,327	Euro

Term	17	Years
Interest rate of Bank	9.0	%
Debt Capital	71,32,926	Euro
Inflation rate	5.16	%

Table 13. 1 Economics of A Typical Wind Farm

Years	Profit after tax (Euro)
2025	-3,43,353
2026	-3,49,051
2027	-3,55,044
2028	-1,92,465
2029	-1,61,330
2030	-1,30,537
2031	-1,00,103
2032	-70,048
2033	-40,391
2034	-11,152
2035	17,647
2036	45,834
2037	73,834
2038	1,01,173
2039	8,28,491
2040	8,04,212
2041	6,16,212
2042	6,33,766
2043	6,50,816
2044	6,67,381

Table 13. 2 Income Statement

14. Results

The financial analysis of the project shows a strong performance with a positive NPV of **58,192 Euro**, indicating profitability. The IRR of **7.557%** demonstrates a return on investment, while the LEC of **0.0184 Euro** confirms cost-efficient energy production. The project shows solid financial stability with a minimum DSCR of **1.08** and an average DSCR of **1.38**, ensuring the capability to meet debt obligations. Although the NPV costs are **25,42,246 Euro**, the substantial NPV kWh value of **39,56,79,974 Euro** highlights significant revenue generation from energy production. Overall, the metrics suggest a viable and profitable project.

	Value	Unit
NPV	58,192	EUR
NPV costs	25,42,246	EUR
NPV kWh	39,56,79,974	EUR
IRR	7.557	%
LEC	0.0184	EUR
Min. DSCR	1.08	
ADSCR	1.38	

Table 14. 1 Results

NPV = Net Present Value

IRR = Internal Rate of Return

LEC = Levelized Cost of Energy

Min. DSCR = Minimum Debt Service Coverage Ratio

ADSCR = Average Debt Service Coverage Ratio

15. Long-term Strategy: Wind Energy Development Roadmap to 2030/2050

The state of Gujarat has good potential for wind energy development, which can significantly contribute to India's renewable energy goals.

Vision and Goals:

By 2030:

- Achieve an installed wind energy capacity of **15 GW**.
- Increase the share of wind energy to **20%** of the state's total energy mix.
- Launch the first phase of offshore wind projects. [7]

By 2050:

- Establish Gujarat as a global leader in wind energy.
- Fully integrate smart grid solutions for efficient energy distribution.
- Achieve a **50%** reduction in carbon emissions from energy production. [7]

To achieve long-term wind energy goals, Gujarat will improve policy support, adopt advanced turbine technologies, and upgrade infrastructure. By integrating smart grids and encouraging community engagement, the state aims to significantly reduce carbon emissions. Government and company will spend more money in research and development of wind turbine and energy storage system. This comprehensive approach ensures sustainable and efficient wind energy development, positioning Gujarat as a leader in renewable energy.

16. Barriers and Obstacles to Wind Farm Development

High Initial Costs:

The setup and installation of wind turbines and related infrastructure require significant upfront investment.

Land Use Conflicts:

Large-scale wind farms can lead to land acquisition issues and conflicts with local communities.

Environmental Concerns:

Wind turbines can impact local wildlife, particularly birds and bats, and may cause noise pollution.

Maintenance Issues:

Challenges in maintaining and servicing of Wind Turbine, leading to operational inefficiencies.

Grid Integration:

Integrating wind energy into the existing power grid can be challenging due to the need for stable and reliable energy supply.

Standardization and Quality Control: Lack of standardized practices and quality control measure for wind turbine.

Limited Awareness: Low awareness among potential users and stakeholders about the benefits and applications of wind turbine.

Preference for Solar Energy: Higher preference for solar energy over wind energy due to various factors. [24] [25]

17. Conclusion: A Strategic Plan for Wind Energy Development in Gujarat

The Poladia wind farm project represents a significant step in renewable energy development, Taking advantage of Gujarat’s favourable policy environment and advanced Suzlon technology. By focusing on efficient and reliable turbines, the project achieves a positive NPV and an impressive IRR, indicating strong financial viability. However, the project faces significant challenges due to high bank tax rates and low energy prices, which reduce its overall profitability. Increasing capital investment could enhance project benefits, while alternatives such as raising energy prices or seeking government support for loans could also improve financial outcomes.

The project contributes to India's net-zero goals by reducing carbon emissions and promoting sustainable development. It also drives economic progress through job creation and local manufacturing, aligning with the "Aatmanirbhar Bharat" initiative.

Despite legal barriers and logistical challenges, the project shows strength and effective planning. It serves as a model for future renewable energy projects and highlights the potential for expanding renewable infrastructure in Gujarat.

In the long-term, the Poladia wind farm sets a benchmark for sustainable energy development, supporting India's transition to a greener economy and contributing to global sustainability efforts.

18. References

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19. Appendices