ASSIGNMENT 2

RENEWABLE ENERGY SYSTEMS

BY

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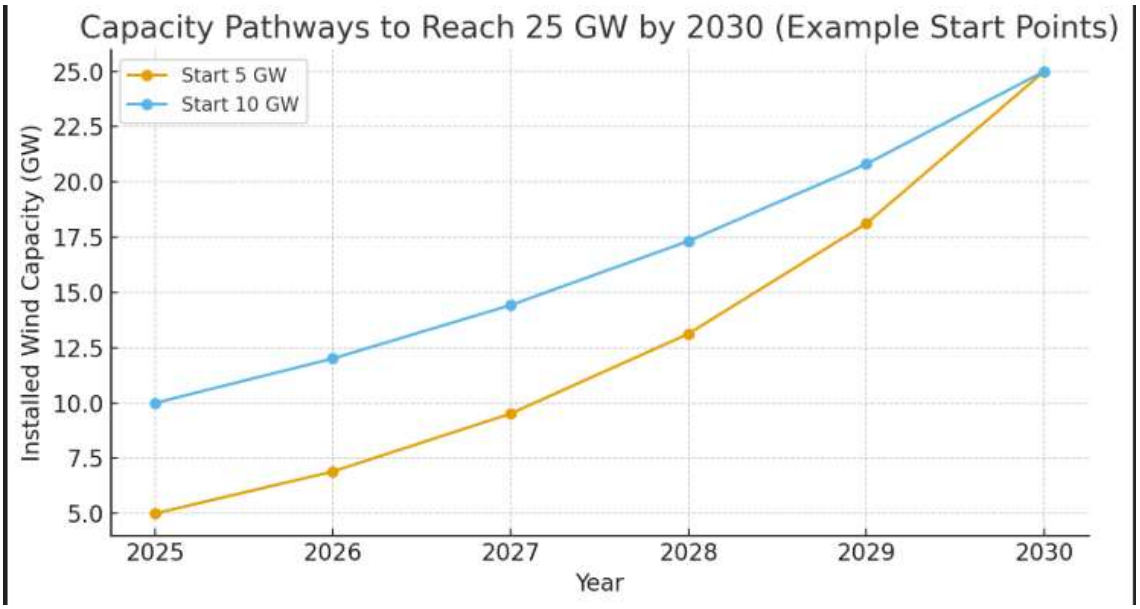
To analyze how wind energy capacity can be increased from 10% to 30% in the next five years and suggest strategies for different stakeholders to meet the state's renewable energy target of 25 GW by 2030.

To increase wind energy capacity from 10% to 30% over the next five years and meet the state's renewable energy target of 25 GW by 2030, stakeholders must collaborate using targeted action plans based on the latest sector trends, growth data, and technology opportunities.



Potential of Wind Energy in India

Wind is an intermittent and site-specific resource of energy and therefore, an extensive Wind Resource Assessment is essential for the selection of potential sites. The Government, through National Institute of Wind Energy (NIWE), has installed over 900 wind-monitoring stations all over country and issued wind potential maps at 50m, 80m, 100m, 120m and 150m above ground level. The recent assessment indicates a gross wind power potential of 695.50 at 120 meter and 1163.9 GW at 150 meter above ground level. Most of this potential exists in eight windy States as given below:-

Sl. No	State	Wind Potential at 120 m (GW)	Wind Potential at 150 m (GW)
1	Andhra Pradesh	74.90	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
	Total 8 windy states	**676.55**	**1136.7**
9	Others	18.95	27.1
	Total	**695.50**	**1163.9**

Roles and Responsibilities in Scaling Wind Energy

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1. Wind Farm Operators

Wind farm operators are the direct developers and managers of wind projects. Their responsibilities cover the full lifecycle of a wind farm — from planning and construction to operations and upgrades.

a) Site Selection and Resource Assessment

- **Wind Potential Studies**: Operators must conduct detailed wind resource assessments using wind masts, LiDAR, and meso-scale modeling to identify high-yield zones.
- **Land Identification**: Securing land with strong wind speeds, low turbulence, and minimal environmental conflicts. Coastal regions, mountain passes, and plateaus are often ideal.
- **Environmental and Social Assessments**: Ensuring minimal impact on local communities, biodiversity, and agricultural land use. Operators must follow Environmental Impact Assessment (EIA) guidelines.
- **Access to Grid Infrastructure**: Site selection must consider proximity to transmission lines to reduce evacuation challenges and costs.

b) Operation and Maintenance (O&M)

- **Routine and Preventive Maintenance**: Ensuring turbines run with minimal downtime by scheduling inspections of gearboxes, blades, and transformers.

- **Predictive Maintenance**: Using AI-based SCADA systems, vibration sensors, and drones to predict failures before they occur. This increases efficiency and turbine life.
- **Minimizing Curtailment**: Adjusting operations to grid conditions and enhancing coordination with grid operators to avoid energy losses.
- **Workforce Training**: Training technicians on safety standards, modern turbine operations, and digital O&M tools.

c) Technology Upgrades and Repowering

- **Repowering Old Turbines**: Many wind farms have smaller turbines (225–600 kW) installed 15–20 years ago. Replacing them with modern 2–3 MW turbines can double or triple energy output without new land.
- **Hybridization**: Adding solar PV and battery storage to existing wind sites to make energy output more consistent.
- **Digitalization**: Using cloud-based monitoring platforms, machine learning algorithms, and real-time analytics to maximize performance.
- **Sustainability Practices**: Ensuring safe recycling or reuse of turbine blades, lubricants, and electronic components.

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2. Grid Operators

Grid operators are responsible for ensuring that increasing amounts of wind energy can be reliably integrated into the power system. Their role is critical because wind is variable and requires flexibility in grid management.

a) Grid Integration and Infrastructure Development

- **Transmission Planning**: Building new high-voltage transmission lines in wind-rich states like Tamil Nadu, Gujarat, and Karnataka to connect generation with demand centers.
- **Green Energy Corridors**: Strengthening grid infrastructure to handle the variability of renewable power.
- **Dynamic Grid Management**: Implementing smart grids with automated switching, real-time monitoring, and demand-supply balancing.

b) Energy Storage and Flexibility

- **Battery Energy Storage Systems (BESS)**: Installing utility-scale batteries near wind farms to store excess energy during high generation and release it during peak demand.

- **Pumped Hydro Storage**: Integrating large-scale hydro projects to act as natural storage for variable wind power.
- **Demand Response Programs**: Encouraging industries to shift energy-intensive processes to times of high wind availability, thereby balancing the grid.
- **Flexible Thermal Backup**: Using fast-ramping gas plants or retrofitted coal plants to provide backup during wind lulls.

c) Forecasting and Scheduling

- **Short-Term Forecasting**: Using AI/ML models and weather satellites to forecast wind speeds and power output on hourly and daily scales.
- **Medium- and Long-Term Forecasting**: Developing seasonal wind patterns for better planning of maintenance and scheduling of energy reserves.
- **Data Transparency**: Sharing forecast data with wind farm operators to help them plan generation and minimize penalties in the scheduling system.
- **Grid Code Compliance**: Ensuring wind projects adhere to voltage, frequency, and reactive power standards for stable operations.

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3. Government

The government plays the most crucial role in creating an enabling environment for wind energy expansion. Policies, regulations, and incentives directly determine the pace and scale of wind development.

a) Policy Support and Regulation

- **Clear Targets and Roadmaps**: Setting ambitious but achievable targets (e.g., 25 GW by 2030 in the state) with interim milestones.
- **Simplified Approvals**: Creating single-window clearance systems for land acquisition, environmental permits, and power purchase agreements (PPAs).
- **Grid Access Policies**: Mandating priority grid access for renewable energy and introducing fair compensation for curtailment.

b) Financial Incentives

- **Capital Subsidies and Tax Benefits**: Providing accelerated depreciation, GST exemptions, and reduced import duties for turbines.
- **Viability Gap Funding (VGF)**: Offering financial support for projects in less commercially attractive but high-potential regions.

- **Competitive Auctions**: Conducting transparent reverse-bidding auctions to bring down tariffs and encourage private participation.
- **Green Bonds and International Finance**: Facilitating cheaper financing through multilateral banks and climate funds.

c) Land Clearance and Infrastructure Development

- **Wind Land Banks**: Identifying and earmarking government land suitable for wind farms to reduce project delays.
- **Transmission Investments**: Co-investing with grid operators in national green corridors to ensure timely evacuation.
- **Port and Logistics Infrastructure**: Supporting offshore wind projects by upgrading ports for turbine transport and assembly.

d) Public-Private Partnerships (PPP)

- **Hybrid Parks**: Developing large-scale renewable energy parks where wind, solar, and storage coexist.
- **Community Engagement**: Ensuring local communities benefit through job creation, revenue sharing, and CSR initiatives.
- **R&D and Skill Development**: Funding wind turbine research centers and vocational programs to build a skilled renewable workforce.
- **Domestic Manufacturing Support**: Incentivizing local production of turbine blades, gearboxes, and nacelles to reduce import dependence.

Conclusion

The successful scaling of wind energy from 10% to 30% in the next five years requires a **collaborative ecosystem**:

- **Wind farm operators** must deploy modern technology, repower old sites, and ensure efficient operations.
- **Grid operators** must strengthen infrastructure, adopt storage solutions, and improve forecasting.
- **Governments** must create supportive policies, financial incentives, and partnerships to mobilize large-scale investment.

By aligning the responsibilities of all three stakeholders, the state can achieve its renewable energy target of **25 GW by 2030** while ensuring sustainability, reliability, and inclusive growth.

Action Plans for Scaling Wind Energy

1. Wind Farm Operators

- **Accelerate Repowering**: Replace older, low-capacity turbines with modern high-MW turbines to double/triple output on existing sites.
- **Adopt Digital O&M**: Use predictive maintenance, AI-based SCADA systems, and drones to reduce downtime and extend asset life.
- **Hybridization & Storage**: Co-locate wind with solar and battery storage to smooth variability and maximize capacity utilization.
- **Sustainable Practices**: Develop blade recycling methods, ensure eco-friendly land use, and engage with local communities for social acceptance.

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2. Grid Operators

- **Strengthen Transmission**: Invest in green energy corridors and high-capacity lines from wind-rich zones to load centers.
- **Deploy Storage Solutions**: Integrate large-scale battery systems and pumped hydro storage to manage intermittency.
- **Improve Forecasting**: Implement advanced weather forecasting tools to reduce scheduling errors and curtailment.
- **Enhance Flexibility**: Introduce demand response programs and ensure market mechanisms for ancillary services where wind+storage can participate.

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3. Government / Regulators

- **Policy & Targets**: Publish a clear 5-year wind roadmap with annual milestones aligned to the 25 GW by 2030 goal.
- **Financial Incentives**: Continue competitive auctions, offer tax benefits, concessional finance, and viability gap funding for challenging sites.
- **Land & Approvals**: Create wind land banks, streamline single-window approvals, and fast-track environmental clearances.
- **Public-Private Partnerships**: Promote large hybrid renewable parks, support local manufacturing of turbines, and fund R&D in offshore wind and storage.
- **Community Integration**: Mandate local job creation, CSR projects, and transparent revenue-sharing to build public trust.