1. Evaluate the scope and significance of non-conventional energy sources in India's energy mix. What are the major barriers to their widespread adoption?

Introduction

India's growing energy demands, coupled with its commitment to **Net Zero emissions by 2070**, have placed **non-conventional energy sources** at the forefront of its energy transition. These include **solar, wind, biomass, small hydropower**, and emerging sources like **geothermal and ocean energy**. The government's ambitious renewable energy targets and policy frameworks underscore their critical role in **decarbonizing the economy**, **reducing import dependence**, and **ensuring energy security**.

I. Scope and Significance of Non-Conventional Energy in India's Energy Mix

1. Solar Energy

- India receives over **300 sunny days** per year, with vast potential across states.
- The **MNRE targets 280 GW of solar power capacity by 2030**.

✓ **Example**: **Rewa Solar Park (MP)** and **Bhadla Solar Park (Rajasthan)** are among the largest solar installations globally.

2. Wind Energy

- Wind potential of over **300 GW**, mainly across **Tamil Nadu, Gujarat, Maharashtra, Karnataka, and Rajasthan**.

✓ India ranks **4th globally in wind installed capacity**.

3. Biomass Energy

- Estimated potential: **18 GW**, utilizing **agricultural residue, animal waste, and urban bio-waste**.

✓ Aligned with **India's Biofuel Policy**, promoting **E10 and E20 blending targets**.

4. Small Hydropower (up to 25 MW)

- Untapped potential of **~20 GW**, particularly suited for **rural, hilly, and remote areas**.

✓ **Example**: **Himachal Pradesh** has harnessed small hydro to power off-grid rural regions.

5. Emerging Sources: Geothermal & Ocean Energy

- Still in pilot phase, but hold potential in **Andaman-Nicobar, Gujarat coast, Ladakh**, etc.
- MoNRE has initiated **feasibility studies and pilot projects** in collaboration with research bodies.

6. Energy Security and Sustainability

- These sources reduce India's **dependence on fossil fuels and imported crude oil**.
- Promote **distributed energy generation**, creating local jobs and ensuring energy access in under-electrified areas.

II. Barriers to Widespread Adoption

1. Financial and Investment Challenges

- **High capital costs** and **long gestation periods** for infrastructure act as disincentives.
- Difficulty in obtaining **long-term financing** for renewable projects, especially in Tier-2 and Tier-3 areas.

2. Technological Limitations

- **Intermittency and storage** remain key issues, particularly for **solar and wind energy**.

✓ **Lack of battery storage** and **smart grid systems** leads to supply instability.

3. Grid Integration Issues

- Inadequate grid infrastructure to handle **variable and decentralized renewable energy**.

✓ **Example**: The need for robust **Green Energy Corridors** to evacuate power from remote solar/wind farms.

4. Policy and Regulatory Gaps

- **Inconsistent policies** across states, **delays in Power Purchase Agreements (PPAs)**, and **land acquisition bottlenecks**.

✓ **Example**: Cancellation of PPAs by some state discoms affected investor confidence.

5. Land and Environmental Concerns

- Large solar and wind parks require **vast tracts of land**, often in ecologically or agriculturally sensitive zones.

✓ **Example**: Resistance in **Rajasthan and Gujarat** over land-use conflicts with pastoral and farming communities.

6. Skill Deficit

- Shortage of **trained technicians and engineers** for installation, O&M (operation and maintenance), and system integration.

III. Way Forward

- **Boost financial incentives and green bonds** to lower capital cost and attract private investment.
- Promote **R&D in energy storage**, hybrid systems, and AI-driven grid management.
- Create **uniform national frameworks** for land acquisition, project approvals, and PPA enforcement.
- Strengthen initiatives like **PM-KUSUM** to promote decentralized solar power for farmers.
- Focus on **building and skill development** through institutions like **NISE** (National Institute of Solar Energy).
- Promote **domestic manufacturing** of solar panels, batteries, and inverters under **PLI (Production Linked Incentive) Scheme**.

Conclusion

Non-conventional energy sources are indispensable to India's aspiration for a clean, secure, and inclusive energy future. Their vast untapped potential, if harnessed through **innovative financing, technological advancement, community participation, and regulatory coherence**, can transform India into a **global leader in green energy**. Overcoming the barriers is essential not just for energy needs but for **climate resilience and sustainable development**.

2. Explain the concept of agro-climatic regions in India. How does this classification aid in effective agricultural planning and development?

Introduction:

Agro-climatic regions refer to geographically contiguous areas that share similar climatic conditions, soil types, and agricultural practices. In India, these regions have been identified by institutions like the Indian Council of Agricultural Research (ICAR) and the Planning Commission based on factors such as rainfall, temperature, humidity, and cropping patterns. Currently, India is divided into 15 distinct agro-climatic regions.

Concept of Agro-Climatic Regions:

The classification into agro-climatic regions enables a scientific understanding of the diverse agricultural environments across India. These regions group together areas with comparable climate-soil-crop relationships, which helps in tailoring farming techniques and crop choices suitable to local conditions.

For example:

- The Lower Gangetic Plain is characterized by high rainfall and fertile alluvial soils, making it ideal for rice cultivation.
- The Western Dry Region has arid conditions, promoting drought-resistant crops like millet and sorghum.
- The Western Himalayan Region, with its hilly terrain and cool climate, favors terrace farming and horticulture.

Utility in Agricultural Planning and Development:

1. **Area-Specific Agricultural Practices:**

- The classification allows adoption of crop varieties, cropping patterns, and farming methods optimized for local agro-climatic conditions. This increases productivity and sustainability.

- *Example:* Rice cultivation in the Lower Gangetic Plain versus millet cultivation in the Western Dry Region.

2. **Resource Optimization:**
- Efficient use of irrigation, water, and soil nutrients is possible by aligning practices to the region's water availability and soil type.
- *Example:* Canal irrigation is widely used in the Upper Gangetic Plain, whereas drip irrigation is promoted in the water-scarce Western Dry Region to conserve water.

3. Climate Resilience and Adaptation:
- Identifying regions prone to specific climatic risks aids in developing resilient farming practices and crop varieties.
- *Example:* Salt-tolerant crops in cyclone-prone Eastern Coastal Plains, drought-resistant crops in arid zones, and short-duration varieties in regions with erratic rainfall.

4. Policy Formulation and Implementation:
- Government schemes and subsidies can be tailored to regional needs, improving effectiveness and resource allocation.
- *Example:* The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) customizes irrigation support according to regional water availability.

5. Focused Research and Extension:
- Agricultural research institutions develop region-specific crop varieties and farming technologies, enhancing productivity and adaptability.
- *Example:* Pusa Agricultural University's development of Basmati rice and wheat varieties suited to the North Indian plains.

6. Balanced Regional Economic Development:
- By promoting crops and farming systems suited to local conditions, agro-climatic classification contributes to increased income and employment opportunities in rural areas.
- *Example:* Gujarat's targeted programs for cotton and groundnut production support regional economic growth.

Conclusion:
The concept of agro-climatic regions provides a scientific foundation for agricultural planning and development in India. By enabling area-specific practices, optimizing resource use, enhancing climate resilience, and guiding policy and research, this classification plays a critical role in ensuring sustainable and inclusive growth in Indian agriculture.