Topic 1: Smart Cities Mission and the Role of Energy Efficiency in Urban Development

1.Introduction

- Cities contribute **50-60% of global greenhouse gas (GHG) emissions,** necessitating a low-**carbon** economy through efficient energy use.
- India is the **third-largest energy consumer**, with **80% of energy sourced from conventional means**, primarily **coal-based generation** (accounting for **70% of emissions**).
- Government initiatives promote **energy-efficient practices** under the **Nationally Determined Contributions (NDC)** and **Long-Term Low Emission Development Strategy (LT-LEDS)**.
- **Smart city frameworks** leverage **ICT (Information and Communication Technology)** for energy efficiency, reducing costs and emissions.
- India's **power demand is expected to double by 2030**, posing challenges for **DISCOMs (Distribution Companies)** in providing **reliable, affordable power**.
- **India's Smart Cities Mission (SCM)** (launched in 2015) integrates **infrastructure and technology** for sustainable urban growth, emphasizing **energy efficiency**.

2.Key Sectors for Energy Efficiency in Smart Cities

(i) Energy-Efficient Buildings

- Buildings account for **over a third of national energy consumption**, with **40% of future building stock yet to be constructed**.
- High-density commercial and residential construction will drive future urban energy demand.
- **Key Energy Efficiency Measures:**
  - ➢ Retrofitting aging buildings with energy-efficient HVAC (Heating, Ventilation, and Air Conditioning), lighting, and water management.
  - ➢ Adoption of Green Building Standards like GRIHA and LEED to promote sustainability.
  - ➢ The National Programme for Climate Change and Human Health (NPCCHH) mandates energy efficiency in hospitals (14% of total energy use).
  - ➢ Future-ready public health infrastructure: 525 smart city projects focus on energy efficiency and renewable energy.
  - ➢ Green public procurement can further lower the energy footprint.

(ii) Energy-Efficient Water Management

- **CSCAF 2.0 (Climate Smart Cities Assessment Framework)** includes energy efficiency in water supply management.
- Technological Interventions:
  - ➢ **SCADA (Supervisory Control and Data Acquisition)** automation for optimized water use.
  - ➢ **Variable Frequency Drives (VFDs)** for pumping system efficiency.
  - ➢ **Real-time monitoring and hydraulic modeling** to reduce **Non-Revenue Water (NRW)**.
  - ➢ Integration of **IoT, AI, and ML** to optimize water demand management.
  - ➢ Use of **bulk metering, water accounting, and pressure management** for better energy utilization.
  - ➢ **Renewable energy (solar, micro-hydro) integration** in water systems.

(iii) Energy-Efficient Waste Management

- Urban waste generation rises **5.5% annually**, projected to reach **436 MMT by 2050**.
- **Key Strategies for Energy Efficiency in Waste Management:**
  - ➢ **IoT-enabled waste collection:** GPS navigation, **RFID (Radio Frequency Identification)** for real-time tracking.
  - ➢ **AI-based waste pyrolysis** and logistics optimization to reduce energy use in waste transportation.
  - ➢ Adoption of **Refuse-Derived Fuel (RDF)** and **Mechanical Biological Treatment (MBT)** systems.
  - ➢ **Energy-from-waste technologies** (bioreactor landfills, sanitary landfills, solar integration).

- **Recycling and reuse:** Lower energy demand in construction through material recovery (**steel, wood, concrete**).

(iv) Energy-Efficient Transportation

- **Transport sector: Third-largest GHG emitter in India**, consuming **94 MTOE (Million Tonnes of Oil Equivalent)** and producing **14% of energy-related CO2 emissions**.
- Strategies for Sustainable Urban Transport:
  - **Multimodal transport networks** integrating **renewable energy**.
  - Expansion of **electric vehicles (EVs)** and charging infrastructure.
  - **Public transport optimization** through AI-based traffic management.
  - **Non-motorized transport** (cycling, walking infrastructure) to reduce dependency on fossil fuels.
  - **Autonomous vehicles, drones, and ride-sharing models** for energy-efficient logistics.

3.Policy and Regulatory Framework

- **Energy Conservation Act (2001)** has evolved towards consumer-centric and industry-oriented energy efficiency programs.
- The **policy trajectory** aligns **energy efficiency with sustainability, climate resilience, and low-carbon urban development**.

4.Future Roadmap: Strategies for Energy Efficiency in Urban Development

(i) Co-Production of Knowledge for Policy and Governance

- Establishing **knowledge-sharing platforms** involving:
  - Think tanks, academic institutions, technology hubs.
  - NGOs, CBOs, regulatory bodies, public utilities.
  - International organizations, funding agencies.
- NAPCC (National Action Plan on Climate Change) and NMEEE (National Mission for Enhanced Energy Efficiency) need integration into city and regional master plans.
- Strengthening urban local bodies (ULBs) for effective decentralized governance.
- **Inter-sectoral coordination** to streamline energy efficiency across urban planning sectors.

(ii) Adoption of Cutting-Edge Technologies

- Strengthening **energy efficiency research** through **DST (Department of Science and Technology), BEE (Bureau of Energy Efficiency), and MNRE (Ministry of New and Renewable Energy)**.
- Encouraging development of **smart grids, advanced energy storage, AI-driven predictive systems, GIS, GPS, and integrated public utilities**.
- Scaling up **sector-specific technologies**, including:
  - Waste-to-energy solutions.
  - Building-Integrated Photovoltaic (BIPV) and smart lighting.
  - EV charging infrastructure and automated traffic systems.

(iii) Strategic Financing for Energy Management

- **Hybrid financing models for urban energy efficiency:**
  - Energy Efficiency Financing Platform (EEFP).
  - Venture Capital Fund for Energy Efficiency (VCFEE).
  - Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE).
  - Green Growth Equity Fund (GGEF).
- **Market-based mechanisms:**
  - Green bonds for sustainable urban energy projects.
  - Perform, Achieve, and Trade (PAT) scheme for high-energy-consuming sectors.
- **Leveraging international partnerships** to fund clean energy adoption in cities.

(iv) Performance Measurement and Monitoring

- **Defined performance targets** for measuring urban energy efficiency:
  - Facility upgrades, awareness campaigns.
  - Quantifiable targets: Energy reduction, renewable energy penetration, GHG emission reduction.
- Robust data management: MIS, city-level sectoral reports for accountability.
- Scaling up Smart Cities Mission (SCM)

- Policy support, advanced technologies, and innovative financing mechanisms.

Topic 2: Biofuels as a Promising Substitute for High Carbon Energy Sources

1.Introduction

The global demand for energy is rising at an unprecedented rate, driven by industrialization, urbanization, and population growth. However, reliance on fossil fuels as the primary energy source has led to environmental degradation, climate change, and energy insecurity. Renewable energy sources such as wind and solar power have gained prominence, but biofuels offer a distinct advantage due to their ability to provide sustainable and cleaner fuel alternatives. India's National Policy on Biofuels (NPB) 2018 underscores the significance of biofuels in reducing dependence on imported fossil fuels and ensuring energy security.

2.The Growing Need for Biofuels

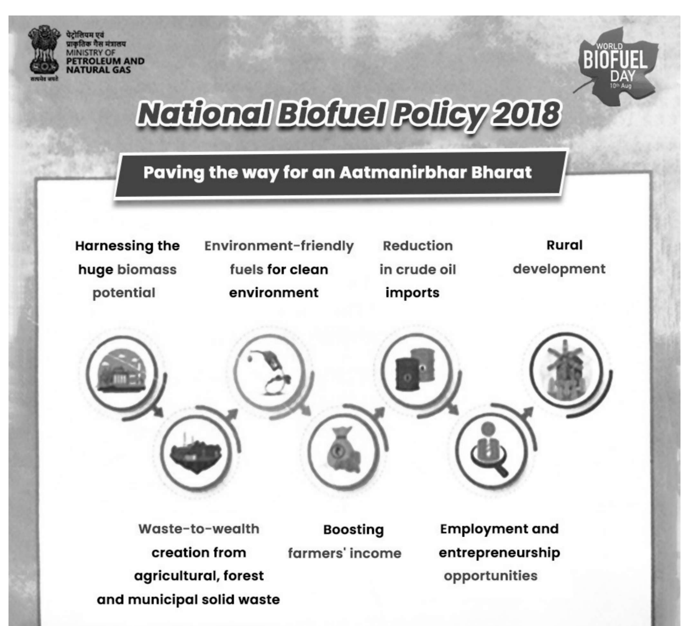
- **Environmental Sustainability:**
  - Biofuels contribute to reducing greenhouse gas (GHG) emissions.
  - They help in mitigating air and water pollution associated with fossil fuels.
- **Energy Security:**
  - India imports approximately 85% of its crude oil, leading to high foreign exchange outflow.
  - Biofuels reduce reliance on imported fossil fuels, promoting self-sufficiency.
- **Rural Development and Economic Growth:**
  - Cultivation of biofuel crops such as Jatropha and sugarcane provides employment opportunities.
  - Farmers receive additional income through biofuel feedstock cultivation.
- **Waste Management:**
  - Agricultural and municipal waste can be converted into biofuels, aiding waste management and reducing landfill

3.Types of Biofuels

- **First-Generation Biofuels:**
  - Derived from food crops (e.g., corn, sugarcane, soybean).
  - Major examples: Ethanol and biodiesel.
  - Concerns: Potential competition with food supply, leading to food price inflation.
- **Second-Generation Biofuels:**
  - Produced from non-food biomass such as agricultural residues, forest waste, and municipal waste.
  - More sustainable and avoids food-versus-fuel conflicts.
- **Third-Generation Biofuels:**
  - Derived from algae and other microorganisms.
  - Higher yield potential per unit area compared to first and second-generation biofuels.
- **Fourth-Generation Biofuels:**
  - Advanced biofuels that use genetically modified organisms (GMOs) to enhance biofuel production.
  - Includes biohydrogen and solar biofuels.

4.India's Biofuel Policy Framework

- **National Policy on Biofuels (NPB) 2018:**
  - Targets 20% ethanol blending in petrol and 5% biodiesel blending by 2030.
  - Encourages the use of advanced biofuels from agricultural waste and non-food sources.



- **Ethanol Blending Programme (EBP):**
  - Focuses on increasing ethanol blending in petrol to reduce crude oil dependency.
  - Sugarcane-based ethanol is widely used for blending.
- **Biodiesel Production Initiatives:**
  - Promotes non-edible oilseeds (e.g., Jatropha, Pongamia) for biodiesel production.
  - Involves the use of used cooking oil (UCO) for biodiesel production.
- **GOBAR-DHAN Scheme:**
  - Converts cattle dung and agricultural waste into biogas and bio-CNG.
  - Promotes rural entrepreneurship and organic manure production.

5. Jatropha Curcas: A Key Biofuel Feedstock

Jatropha Curcas has been identified as a crucial non-edible feedstock for biodiesel production due to its numerous advantages:

- Can be grown on degraded and arid land with minimal water requirements.
- Resistant to pests and adaptable to different soil types.
- Provides high oil content suitable for biodiesel production.
- Contributes to carbon sequestration and soil conservation.
- Supports honeybee population, aiding biodiversity conservation.

6. Challenges in Biofuel Adoption

- **Feedstock Availability and Competition:**
  - Dependence on agricultural feedstock may lead to competition with food production.
  - Uncertainty in yield and market price affects farmer participation.
- **High Production Costs:**
  - Infrastructure for biofuel refining and distribution is expensive.
  - Advanced biofuels require significant research and development investment.
- **Policy and Regulatory Challenges:**
  - Inconsistent policy implementation hinders long-term investment.
  - Need for clear incentives and subsidies for
- **Technological Limitations:**
  - Need for improvements in conversion efficiency for second and third-generation biofuels.
  - Lack of adequate refueling infrastructure for biofuels.

7. Way Forward: Sustainable Biofuel Adoption in India

- **Scaling Up Research and Development:**
  - Investment in genetic modification and biotechnology for high-yield biofuel crops.
  - Development of cost-effective conversion technologies for agricultural and municipal waste.
- **Policy Reforms and Incentives:**
  - Strengthening of the National Biofuel Policy with long-term vision and implementation roadmap.
  - Incentivizing farmers through subsidies for biofuel feedstock cultivation.
- **Public-Private Partnerships (PPPs):**
  - Collaboration between government, private enterprises, and research institutions for infrastructure development.
  - Encouraging foreign investments in biofuel technology.
- **Decentralized Biofuel Production:**
  - Promoting village-level biofuel production units to ensure energy self-sufficiency.
  - Encouraging waste-to-energy projects for localized energy generation.
- **Blending Targets and Expansion:**
  - Achieving and exceeding the ethanol blending target of 20% by 2030.
  - Expanding the use of bio-CNG and biohydrogen as transport fuels.

Topic 3: PRAGATI: Driving India's Development with Purpose

1. Introduction

A recent study by Oxford University's Said Business School and the Gates Foundation, titled ***"From Gridlock to Growth: How Leadership Drives India's Pragati Ecosystem,"*** underscores

Governance and Timely Implementation Initiative). It highlights how decisive leadership and digital governance have revolutionized infrastructure development, making India a global benchmark for fast-track governance models.

2. Background

Launched on **25 March 2015**, PRAGATI is based on the **minimum-government, maximum-governance** approach. It integrates **collaboration, transparency, and technology** to enhance project execution and efficiency. The initiative has **reinforced RBI and NIPFP research findings** that every rupee spent on infrastructure contributes **2.5 to 3.5 times the GDP growth**, demonstrating its high economic impact.

PRAGATI embodies a **digital-first leadership approach**, integrating platforms such as:

- **Parivesh** (for environmental clearances)
- **PM GatiShakti** (for multi-modal infrastructure connectivity)
- **Project Monitoring Group** (for streamlining project execution)

It also draws inspiration from **Swagat (2003),** a real-time grievance redressal initiative, expanding its scope to national development while ensuring **accountability and transparency** in governance.

3. Key Achievements of PRAGATI

Since its launch, PRAGATI has effectively cleared 340 stalled projects worth ₹17.05 lakh crore ($205 billion), significantly reducing delays and enhancing governance efficiency.

- **Impact on Timelines & Approvals:**
- Minimization of Delays:
  - ➢ Structured **monthly reviews and digital tracking** have cut project delays from **3-20 years to months**.
- Faster Environmental and Forest Approvals:
  - ➢ Environmental approvals: **600 days → 70-75 days**
  - ➢ Forest clearances: **300 days → 20-29 days**
- Improved Citizen Services:
  - ➢ CPGRAMS (Centralized Public Grievance Redressal System): Average resolution time cut from 32 days (2014) to 20 days
  - ➢ Passport issuance time: Reduced from 16 days (2014) to 7 days (2023).

4. Major Projects Benefiting from PRAGATI

Several long-stalled infrastructure projects have witnessed rapid execution post-PRAGATI intervention:

- Bhogi-Beel Rail & Road Bridge:
  - ➢ Completed in just 3 years, despite 20+ years of delays.
- Jammu-Srinagar-Baramulla Rail Link:
  - ➢ Overcame prolonged delays and is set for **completion by 2025**.
- Navi Mumbai Airport:
  - ➢ Resolved **15 years of land acquisition hurdles**; launch expected by **December 2024**.
- Bengaluru Metro (Karnataka):
  - ➢ Timely reviews expedited land acquisition for Phase 1, resulting in a 42 km, 40-station metro, significantly improving urban mobility and air quality.
- Haridaspur-Paradeep Rail Connection (Odisha):
  - ➢ Funding and investor issues resolved, leading to **timely inauguration in 2020**.
- Dahisar-Surat Section, NH-8 (Maharashtra & Gujarat):
  - ➢ PRAGATI's intervention **ensured completion**, incorporating **wildlife protection measures and fair compensation for landowners**.
- Varanasi-Aurangabad Section, NH-2 (UP & Bihar):
  - ➢ Initial progress was only 20% in 5 years due to land record issues. After PRAGATI's review, the project is now set for completion in 2024.
- Jal Jeevan Mission:
  - ➢ **Rural tap water access rose from 17% in 2019 to 74% in 2024**, improving public health outcomes.

5. PRAGATI's Role in Leadership & Governance

PRAGATI is directly monitored by the **Prime Minister**, reinforcing **swift decision-making and real-time course correction**. This initiative

- Transformed bureaucratic inefficiencies into a streamlined, transparent system.
- Enhanced cooperative federalism, ensuring seamless coordination between the central and state governments.
- Boosted grassroots governance, evidenced by the push for mobile towers in remote villages within a single financial year.

By embedding **real-time project tracking**, PRAGATI enables **direct engagement with senior officials**, ensuring accountability and accelerating project execution.

6. PRAGATI's Influence on Other Government Schemes

The digital governance model of PRAGATI has directly influenced other flagship programs, enhancing their outcomes and efficiency:

- Swachh Bharat Mission:
  - ➢ 12 crore toilets built, transforming sanitation in rural India.
- Jal Jeevan Mission:
  - ➢ Tap water access increased from 17% in 2019 to 74% in 2024.
- Saubhagya Scheme:
  - ➢ Achieved **universal household electrification**.
- Vibrant Villages Programme (VVP):
  - ➢ Transformed 46 Northeast villages into model 'first villages', boosting rural development.
- MoHUA Lighthouse Projects:
  - ➢ 1,100 houses built in 12 months using advanced digital construction technologies across 6 cities.
- SWAMITVA Initiative:
  - ➢ Drone technology-enabled land ownership records, enhancing property security in rural India.

7. Why is PRAGATI a Global Benchmark for Governance?

PRAGATI has redefined governance models, setting a new standard for efficiency and transparency.

Key Success Factors:

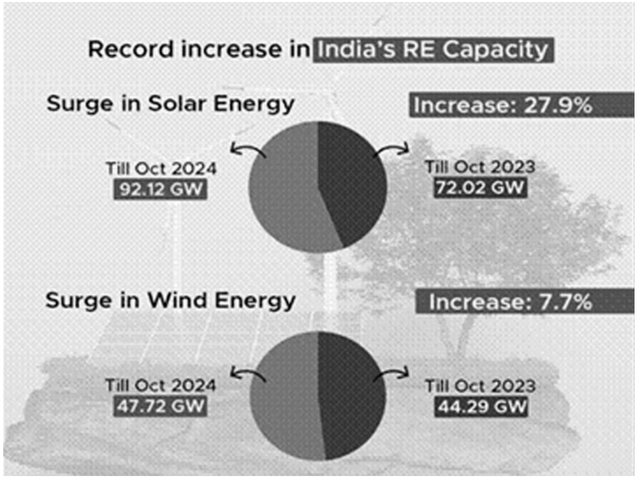
  - ➢ Use of drones, GPS tracking, and digital dashboards for real-time monitoring.
- Cutting Bureaucratic Red Tape:
  - ➢ Faster approvals and reduced corruption, ensuring optimal resource allocation.
- Public Participation & Feedback Mechanisms:
  - ➢ Citizen inputs are integrated into high-level decision-making, ensuring people-centric governance.
- Sector-Wide Integration:
  - ➢ PRAGATI's governance model **spans diverse sectors**, including **roads, railways, aviation, environment, and urban development**.

The Oxford study affirms PRAGATI's role as a model of decisive leadership, proving that technology-driven transparency and efficient governance can transform economies.

Topic 4: Scope and Opportunities for Renewable Energy in Rural India

1. Introduction

- The world today is engaged in a critical battle against pollution and the depletion of natural resources. Renewable energy (RE) stands out as the most viable solution to address these challenges. India has made significant progress in the RE sector, with capacity growing by 165% over the last decade, reaching 203.1 GW in 2024, accounting for 46.3% of the country's total installed energy capacity.
- However, rural India, which constitutes 67% of the population and 37% of GDP, still faces significant infrastructure deficiencies, particularly in electricity access. Nearly 300 million people in rural India lack reliable power, relying instead on harmful traditional fuels. Renewable energy, particularly solar power, offers a transformative opportunity to bridge these infrastructure gaps, improve



2. Why Solar Energy?

The promotion of solar energy in rural India is essential due to several advantages:

- **Decentralized Electrification:** Solar energy provides cost-effective, decentralized electrification, particularly in areas where grid extension is not feasible. Public-private partnerships can play a critical role in implementing these solutions.
- **Improved Rural Productivity and Safety:** Solar lighting enhances productivity and safety by replacing kerosene lamps, reducing health hazards, and enabling extended work hours.
- **Agricultural Applications:** Solar-powered irrigation pumps can improve agricultural productivity by reducing dependence on diesel-powered pumps, which account for nearly 20% of India's installed power capacity.
- **Clean Water Access:** Water treatment in rural areas requires energy, and solar energy presents an effective solution to address this challenge.

3. Government Initiatives for Renewable Energy Expansion

The Government of India has launched various initiatives to promote RE expansion, including:

Policy and Investment Incentives

- **100% Foreign Direct Investment (FDI)** permitted under the automatic route.
- **National Green Hydrogen Mission (2023)** aims for 5 million metric tons of annual green hydrogen production by 2030.
- **Inter-State Transmission System (ISTS) Charge Waiver** for renewable energy projects until specific deadlines (June 2025 for solar and wind; December 2030 for green hydrogen; December 2032 for offshore wind).
- Ultra-Mega Renewable Energy Parks to provide land and transmission facilities for large-scale projects.

4. Key Renewable Energy Schemes

- Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan (PM-KUSUM): Encourages farmers to adopt solar irrigation pumps.
- Solar Rooftop Phase II & 12,000 MW CPSU Scheme Phase II: Expands distributed solar generation.
- PM Surya Ghar: Muft Bijli Yojana: Aims to install rooftop solar plants in 1 crore households with a financial outlay of Rs. 75,021 crore.
- Green Energy Corridor: Focuses on expanding transmission infrastructure for RE projects.

5. Regulatory and Market Reforms

- Standard Bidding Guidelines: Introduced for competitive procurement of solar and wind energy.
- Power Dispatch Regulation: Ensures power is dispatched against a letter of credit (LC) or advance payment to improve financial viability.
- Renewable Energy Tariff (URET): Establishes a uniform pricing framework.
- Offshore Wind Energy Lease Rules (2023): Facilitates leasing of coastal land for offshore wind projects.

6. Renewable Energy Challenges

Despite significant progress, several challenges hinder RE expansion:

- **High Capital Costs:** The cost of generating 1 unit of electricity remains higher for renewables compared to fossil fuels.
- **Land Acquisition Issues:** Securing land with RE potential involves lengthy administrative processes and multiple clearances.
- **Lack of Consumer Trust:** Despite subsidies and incentives, concerns about performance and reliability limit consumer adoption.

- **Manufacturing Quality:** Indian solar panel manufacturers struggle to compete with global counterparts due to limited technical expertise.
- **Intermittency Issues:** RE sources depend on weather conditions, requiring efficient grid management for energy stability.
- **Grid Infrastructure Limitations:** State electricity boards face challenges in approving rooftop solar installations due to existing grid capacity constraints.

7. Future Outlook and Conclusion

India's renewable energy sector is at a crucial turning point, with a strong policy framework, ambitious government targets, and increasing private sector participation. The country aims to achieve 500 GW of non-fossil energy capacity by 2030, positioning itself as a global leader in RE. Initiatives such as the National Green Hydrogen Mission and PM Surya Ghar highlight India's commitment to a greener future. While challenges persist, continued investments in technology, policy support, and infrastructure upgrades can ensure a sustainable and inclusive energy transition for rural India.

By addressing these challenges, India can not only meet its growing energy demands but also drive rural prosperity, environmental sustainability, and long-term energy security.

Topic 5: Perform, Achieve, and Trade (PAT) Scheme

1. Introduction

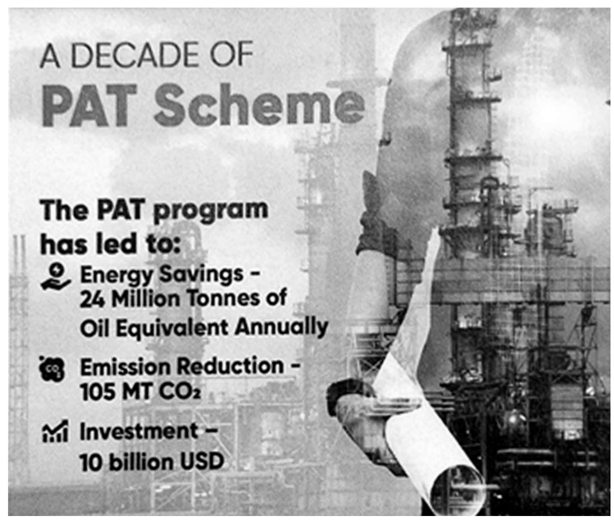
India's economic growth is closely linked to energy consumption, particularly in key sectors like industry, transportation, and electricity generation. The shift towards renewable energy and energy efficiency (EE) is crucial for reducing energy intensity and achieving India's commitments under the UN Framework Convention on Climate Change. The **Energy Conservation Act 2022** provides a legal framework for EE measures, especially in energy-intensive sectors.

2. The Need for Energy Efficiency

waste, and lowering energy demand. A common example is the transition from incandescent bulbs to LEDs, which has significantly reduced energy consumption. Similarly, industries like steel, cement, fertilizers, and textiles require systematic EE interventions. Despite some Indian industries being among the most efficient globally, many lag due to technological and financial constraints.

3. PAT Scheme: Design and Framework

The **PAT Scheme**, under the **National Mission for Enhanced Energy Efficiency (NMEEE)**, aims to enhance industrial EE through a structured approach. Implemented by the **Bureau of Energy Efficiency (BEE)** under the **Ministry of Power**, PAT follows a consultative process involving industrial stakeholders.



4. Key Features of the PAT Mechanism

- Designated Consumers (DCs): Industries identified as high energy consumers must participate.
- Baseline SEC Calculation: Energy consumption per unit of product (SEC) is computed.
- Target Setting: Each DC receives a reduction target based on sector averages and best practices.
- Implementation: DCs adopt EE measures based on technical and economic feasibility.
- **Energy Saving Certificates (ESCerts):**
  - DCs exceeding targets earn **ESCerts**.
  - Shortfall DCs must buy **ESCerts** from surplus DCs.
  - ESCerts can be traded or banked for future

- **Monitoring & Verification:** Accredited energy auditors validate compliance.
- **Trading Mechanism:** Market-driven ESCert trading allows flexibility for industries.

5. Impact and Challenges

The PAT mechanism has led to reduced energy consumption, CO2 emissions, and financial savings. It promotes investment in cleaner technologies and energy-efficient processes. However, some challenges include:

- ESCert Trading: Low demand for certificates has led to low prices. A price floor and ceiling need dynamic adjustment.
- Target Setting: Requires refined sector-wise analysis to ensure balanced ESCert pricing.
- Sector Expansion: PAT must include MSMEs and other energy-intensive industries.
- Building Sector Inclusion: With increasing energy demand, PAT should integrate EE from the design stage of buildings.
- Carbon Credit Trading System (CCTS): PAT should align with India's carbon market for a smoother transition to net zero emissions.

6. Conclusion

The PAT Scheme is a crucial step in India's Viksit Bharat and Atmanirbhar Bharat vision, enabling sustainable industrial growth. Continuous improvements in target setting, sectoral expansion, and market mechanisms will enhance its effectiveness, ensuring energy security, economic competitiveness, and environmental sustainability.

Topic 6: The National Solar Mission: Progress, Challenges, and the Path for Renewable Energy by 2030

1. Introduction

The National Solar Mission (NSM) is a flagship initiative by the Government of India, aimed at promoting ecologically sustainable growth while addressing India's energy security concerns. The mission seeks to position India as a global leader conditions for its rapid expansion. The initiative follows a structured three-phase approach to monitor progress, review capacity, and set evolving targets aligned with technological and cost trends.

2. Progress of the National Solar Mission

Phased Implementation and Achievements

The NSM was implemented in three phases:

- Phase 1 (2010-13) – Initial adoption of solar energy with policy frameworks.
- Phase 2 (2013-17) – Expansion of grid and off-grid solar projects.
- Phase 3 (2017-22) – Large-scale solar deployment with upscaled targets.

Initially, the NSM aimed for 20,000 MW grid-connected and 2,000 MW off-grid solar capacity by 2022. However, in 2015, the government raised the renewable energy target to 175 GW by 2022, comprising:

- 100 GW from solar energy
- 60 GW from wind energy
- 10 GW from bio-energy
- 5 GW from small hydro projects

3. Installed Solar Energy Capacity (As of November 30, 2024)

According to the Ministry of New and Renewable Energy (MNRE), India's installed renewable energy capacity has reached 158.55 GW, including:

- Wind Power: 47.96 GW
- Solar Power: 94.17 GW
- Small Hydro: 5.08 GW
- Biomass (Bagasse and Non-Bagasse): 10.73 GW
- Waste-to-Power: 0.61 GW

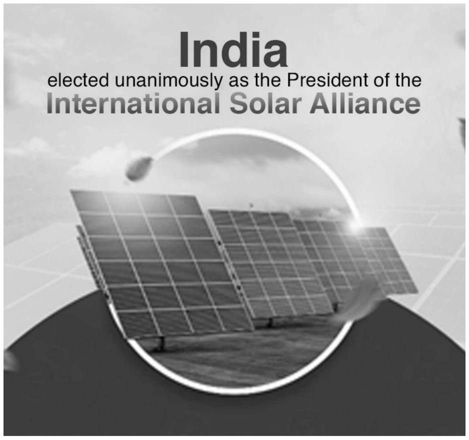
Solar power alone contributed **12,354.21 MW** of new capacity from April to November 2024, demonstrating significant growth.

4. Socioeconomic and Environmental Impact

- Rural Electrification: Millions of rural households have gained access to sustainable energy for cooking and lighting.
- Employment Generation: Expansion in solar

manufacturing, installation, and maintenance sectors.

- Climate Goals: The NSM aligns with India's commitment under the National Action Plan on Climate Change (NAPCC) and contributes to achieving a 45% reduction in emission intensity of GDP by 2030 from 2005 levels.



5. Global Leadership and Collaboration

- International Solar Alliance (ISA): India and France co-launched this initiative to promote solar adoption in tropical countries.
- Competitive Solar Auctions: Transparent bidding has reduced solar power costs, making it a viable alternative to conventional energy sources.

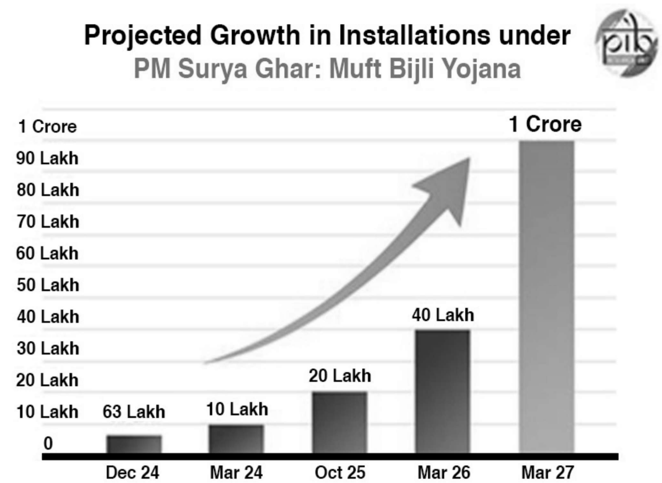
6. Government Schemes Driving Solar Growth

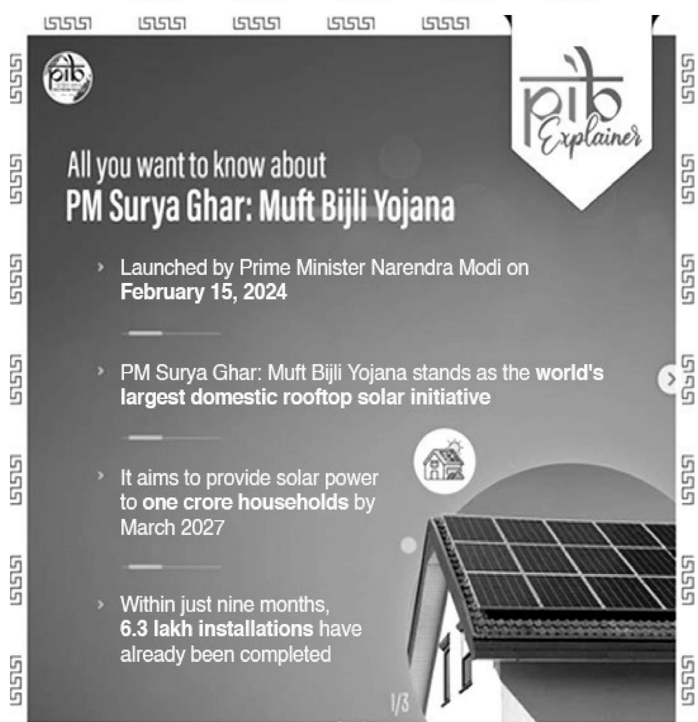
(i) PM-KUSUM Scheme: The Pradhan Mantri Kisan Urja Suraksha Evam Uthaan Maha Abhiyaan (PM-KUSUM) aims to reduce dependence on diesel-based irrigation and increase farmers' income through solar power.

- Provides 50% subsidy for installing solar pumps.
- Farmers can set up solar plants up to 2 MW and sell power to DISCOMs.
- Target: Add 34,800 MW by March 2026, with a financial support of Rs. 34,422 crore.

(ii) PM Surya Ghar: Muft Bijli Yojana (PMSG: MBY)

- India's largest rooftop solar scheme with a Rs. 75,021 crore allocation.
- 1 crore rooftop installations targeted by March 2027.
- 6.3 lakh installations completed in just nine months, with Rs. 3,100 crore in subsidies disbursed.





(iii) Solar Manufacturing and PLI Scheme

- Production-Linked Incentive (PLI) Scheme: Rs. 24,000 crore allocated for high-efficiency solar PV module manufacturing.
- Aims to reduce import dependency and promote self-reliance under Make in India.

7. Development of Solar Parks and Ultra-Mega Projects

- Launched in **December 2014** to facilitate large-scale solar projects.
- **Target:** Establish **25 solar parks** with **40 GW capacity by 2026**.

8.Global Renewable Energy Investment Meets

- Organized since **2015**, attracting global investors.
- **2024 RE-INVEST Meet:** Secured **Rs. 32.45 lakh crore** in investments, generating **82 lakh jobs**.
- State pledges:
  - Gujarat: 128.60 GW
  - Andhra Pradesh: 72.60 GW
  - Maharashtra: 62.73 GW

9. Challenges Facing Solar Expansion

Despite rapid growth, several challenges hinder progress:

- Land Acquisition: Large solar projects require vast land parcels, leading to disputes.
- Grid Infrastructure: Integration of intermittent solar power requires robust grid stability solutions.
- Storage Technology: The need for cost-effective battery storage is critical.
- Regulatory and Policy Barriers: Variation in state-level policies affects uniform solar adoption.
- Financial Constraints: High initial investment deters small-scale solar adoption.

10. Path to 2030: The Road Ahead

Key Focus Areas:

- Strengthening Solar Manufacturing: Expanding PV cell production to reduce
- State-Level Policy Simplification: Encouraging uniform solar policies across states.
- Improving Energy Storage Solutions: Investing in advanced battery technology to address intermittency issues.
- Expanding Rooftop Solar Adoption: Making solar installations more affordable and accessible.
- Enhancing Global Collaboration: Strengthening India's leadership in international solar partnerships.

11. Vision for a Sustainable Future

The National Solar Mission embodies India's commitment to a **greener and more sustainable** energy future. Through strategic policies, financial incentives, and global cooperation, India is poised to achieve its ambitious **500 GW renewable energy target by 2030**. As the country advances, it sets a global benchmark for clean energy transition, demonstrating how ambition, innovation, and collective action can redefine the world's energy landscape.

12. Conclusion

The National Solar Mission has transformed India's energy sector, reducing fossil fuel dependence and positioning the country as a renewable energy leader. With continued investments, policy support, and technological advancements, India is on track to achieve a **sustainable energy future**, inspiring global efforts toward a **cleaner, greener world**.

Topic 7: PM-KUSUM: Empowering Farmers with Solar Energy Solutions

1. Introduction

Agriculture has been the backbone of India's development, playing a crucial role in ensuring food security, nutrition, and employment. Since the Green Revolution in the mid-1960s, food grain production has increased from **72.35 million tons in 1965-66 to 332.30 million tons in 2023-2024**. Alongside food grains, progress in non-food crops like horticulture, sugarcane, and cotton has also been impressive, making India

A key component of agricultural progress has been the expansion of irrigation, which enhances crop yields and mitigates climate risks. The **irrigated area has increased from 19% of net cultivated land in 1960-61 to 56% in 2022-23**, largely relying on groundwater. The share of irrigation using groundwater has risen from **30% to 63%**, leading to a surge in energy consumption. The number of groundwater extraction devices (GEDs) has grown exponentially from **0.6 million in 1982-83 to 21.9 million in 2017-19**, significantly increasing the demand for electricity and diesel in agriculture.

While subsidized electricity has enabled farmers to exploit groundwater resources, it has also led to over-extraction, endangering water security. Additionally, the energy use in agriculture contributes **8-11% of India's total carbon emissions**, amounting to **45-62 million tons of CO2 annually**. To address these challenges, the shift toward **solar-powered irrigation** presents a sustainable and economically viable solution.

2. Overview of PM-KUSUM

The Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan (PM-KUSUM) was launched by the Ministry of New and Renewable Energy (MNRE) in March 2019. As one of the world's largest initiatives integrating solar energy into agriculture, it aims to replace conventional electric and diesel-powered irrigation pumps with solar-powered systems.

3. Objectives of PM-KUSUM

The scheme has three primary goals:

1. Decentralized solar power generation: Establishing decentralized solar power installations.
2. Replacement of diesel pumps: Encouraging farmers to switch from diesel-powered irrigation pumps to solar pumps.
3. Solarization of grid-connected pumps: Converting existing grid-connected agricultural pumps to solar energy.

4. Components of PM-KUSUM

The scheme aims to develop **34.8 GW** of solar capacity by **March 2026** through the following three components:

- **Component A:** Installation of **10 GW** of solar
- **Component B:** Deployment of **1.4 million standalone solar-powered irrigation pumps** in **off-grid areas**.
- **Component C:** Solarization **of 3.5 million grid-connected agricultural pumps and feeders.**

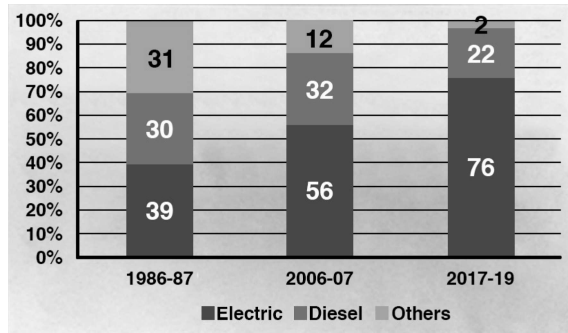


Figure 1 : Changes in composition of energy use for irrigation

As of **September 2024**, the progress includes:

- **298.33 MW** of solar capacity installed.
- **0.5 million** standalone solar pumps deployed.
- **37,271** individual grid-connected pumps installed.
- Development of solar feeder-level power facilities.

5. Benefits of Solar-Powered Irrigation

- **Economic Benefits:**
  - Reduces dependency on subsidized electricity and diesel, lowering production costs.
  - Provides additional income through energy buyback mechanisms.
  - Increases cropping intensity and diversification.
- **Environmental Benefits:**
  - Reduces CO2 emissions; currently, 502,000 solar pumps prevent 1.02 million tons of CO2 emissions annually.

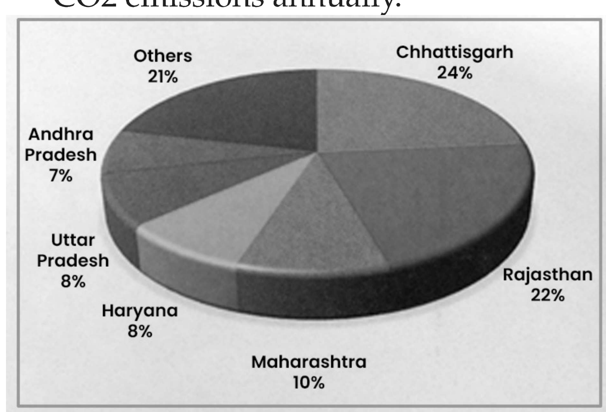
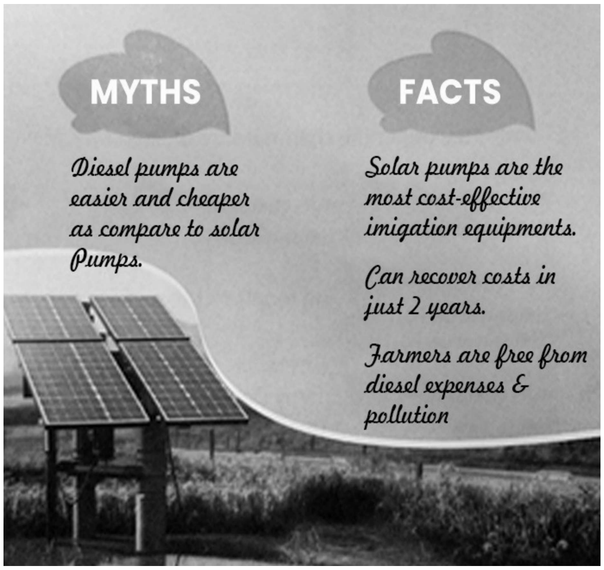


Figure 2 : Distribution of solar pumps across



- ➢ Full solarization of 21.3 million diesel/ electric GEDs can reduce emissions by 45 million tons annually.
- ➢ Mitigates climate change impact by transitioning to renewable energy sources.

- **Operational Benefits:**
  - ➢ Requires low maintenance and minimal supervision.
  - ➢ Provides a reliable and cost-effective irrigation solution.
  - ➢ Reduces dependence on grid electricity, ensuring uninterrupted supply.

6. Challenges in Implementation

Despite its potential, the adoption rate of solar pumps is only 2.64% due to the following barriers:

- **High Initial Investment:**
  - ➢ A **7.5 HP solar pump system costs ₹3,49,000**.
  - ➢ Farmers receive a **60% subsidy**, but the remaining **₹1,40,000 is a burden**, particularly for **marginal farmers (70% of farm households)**.
  - ➢ Limited access to bank loans and financial institutions' reluctance due to high transaction costs.

- **Electricity Subsidy Structure:**
  - ➢ Heavily subsidized grid electricity discourages farmers from switching to solar.
  - ➢ Gradual reduction of electricity subsidies and redirecting funds towards solar power

- **Risk of Groundwater Over-Exploitation:**
  - ➢ Solar energy's **zero marginal cost** can lead to **excessive groundwater extraction**.
  - ➢ Promoting solar irrigation alongside micro-irrigation technologies (drip and sprinkler systems) can mitigate this risk.

- **Institutional and Policy Challenges:**
  - ➢ Lack of convergence between solar irrigation and water-saving technologies.
  - ➢ Separate schemes managed by different agencies hinder effective integration.

- **Regional Disparities in Adoption:**
  - ➢ Two-thirds of solar pumps are concentrated in Chhattisgarh, Rajasthan, Maharashtra, Haryana, Uttar Pradesh, and Andhra Pradesh.
  - ➢ State-specific policies, financial incentives, and awareness programs impact adoption rates.

7. Way Forward

- **Innovative Financing Models:**
  - ➢ Low-interest loans, extended repayment periods, and pay-as-you-save models.
  - ➢ Public-Private Partnerships (PPP) or community-based ownership models to distribute costs and risks.

- **Policy Reforms and Incentives:**
  - ➢ Gradual phasing out of electricity subsidies and incentivizing solar adoption.
  - ➢ Bundling solar irrigation with micro-irrigation subsidies.

- **Awareness and Capacity Building:**
  - ➢ Large-scale awareness campaigns about solar energy benefits.
  - ➢ Training programs for farmers on solar pump maintenance and water conservation.

- **Improved Institutional Coordination:**
  - ➢ Unified implementation framework to integrate solar irrigation with other water-efficient technologies.
  - ➢ State-level strategies to ensure uniform adoption across regions.

Topic 8: Green Hydrogen: India's Path to a Sustainable Energy Future

1. Introduction

Green hydrogen is emerging as a pivotal element in India's transition towards a sustainable energy future. With its potential to decarbonize industries, power generation, and transportation, green hydrogen aligns with India's commitment to achieving net-zero emissions by 2070. The country has set ambitious targets under the **National Green Hydrogen Mission**, aiming to position itself as a global leader in hydrogen production and export.

2. What is Green Hydrogen?

Green hydrogen is produced by electrolyzing water using renewable energy sources such as solar and wind. Unlike grey and blue hydrogen, which rely on fossil fuels, green hydrogen ensures zero carbon emissions, making it a crucial component in achieving climate goals.

3.Types of Hydrogen Based on Production Methods

- **Grey Hydrogen**: Produced from natural gas or coal, emitting CO_2.
- **Blue Hydrogen**: Derived from fossil fuels with carbon capture and storage (CCS).
- **Green Hydrogen**: Generated using renewable energy, with zero emissions.

4. India's Green Hydrogen Potential and National Green Hydrogen Mission

India has immense potential in green hydrogen production due to its vast renewable energy resources. The National Green Hydrogen Mission (2023) focuses on:

- Developing an indigenous green hydrogen ecosystem
- Producing 5 million metric tonnes (MMT) annually by 2030
- Reducing dependency on fossil fuel imports
- Creating export opportunities and green jobs
- Providing incentives for domestic production and research

5. Applications of Green Hydrogen in India

(i) Decarbonization of Industries

- **Steel Industry**: Hydrogen can replace coal in direct reduced iron (DRI) production, reducing CO_2 emissions.
- **Chemical Industry**: Green hydrogen is used in ammonia and methanol production, crucial for fertilizers and petrochemicals.

(ii) Transport Sector

- Hydrogen Fuel Cell Vehicles (FCVs): Adoption in heavy-duty vehicles and railways.
- Aviation and Shipping: Hydrogen-based fuels can reduce emissions in long-haul transport.

(iii) Power Generation and Energy Storage

- Hydrogen-based Power Plants: Helps in grid stabilization and energy storage.
- Renewable Energy Integration: Converts excess solar and wind power into hydrogen for later use.

6. Challenges in Green Hydrogen Adoption

Despite its potential, India faces several challenges:

- **High Production Costs:** Electrolysis and renewable energy costs need further reduction.
- **Infrastructure Gaps:** Storage, transport, and distribution networks require significant investment.
- **Technological Barriers:** Efficient electrolyzer technology is still evolving.
- **Policy and Regulatory Framework:** Need for robust government policies and incentives.

7. Government Initiatives and Roadmap

- Incentives under Production-Linked Incentive (PLI) Scheme
- Hydrogen Purchase Obligations (HPOs) for industries
- **Faster adoption of electrolyzer technology** through research & development
- **Public-Private Partnerships (PPP)** to accelerate investments
- **Strategic collaborations with global players** for technology transfer.

8. Global Perspective and India's Competitive Edge

- EU Hydrogen Strategy: Aims to produce 10 MMT of green hydrogen by 2030.
- Japan & South Korea: Investing heavily in hydrogen-based transport.
- **India's Strengths**: Lower renewable energy costs, vast solar potential, and government support provide a competitive edge.

9. Conclusion

Green hydrogen presents a transformative opportunity for India's energy security, industrial growth, and climate commitments. While challenges exist, strategic investments, innovation, and policy support can propel India to the forefront of the global hydrogen economy. By leveraging its renewable energy advantage, India can lead the world in sustainable hydrogen production and usage, driving a cleaner and greener future.