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ENERGY SECTOR IN INDIA

- Developments in energy sectors such as Hydro power, non conventional sources of energy and nuclear energy including policies, programmes and research base in the country.
- Concepts of non conventional, renewable, clean and environment friendly energy sources. Role of energy in sustainable development.

Energy Sector In India

India's Energy sector is one of the world's most diverse. From conventional sources like coal, lignite, natural gas, oil, hydropower, and nuclear power to viable non-conventional sources like wind, solar, and agricultural and domestic waste, power generation options abound.

Energy Mix:

1. India's energy mix is dominated by fossil fuels, particularly coal, which accounts for around 55% of the country's total primary energy consumption.
2. Oil and gas make up around 33%, while renewable energy sources such as hydro, wind, solar, and biomass account for around 12%.
3. India is the third-largest consumer of oil and coal in the world.

Electricity Generation:

1. India is the world's third-largest producer of electricity, with an installed capacity of over 383 GW as of October 2021.
2. Thermal power plants, which use coal and natural gas, account for around 65% of the total installed capacity, while renewable energy sources such as wind, solar, hydro, and biomass account for around 37%.

Renewable Energy:

1. India has set a target of achieving 175 GW of renewable energy capacity by 2022 and 450 GW by 2030.
2. As of October 2021, India had an installed renewable energy capacity of over 98 GW, accounting for around 27% of the country's total installed capacity.
3. Solar energy is the fastest-growing source of renewable energy in India, with an installed capacity of over 47 GW as of October 2021.

Energy Security:

1. India's growing energy demand has made the country increasingly dependent on imports of oil and gas. In 2020-21, India imported around 82% of its crude oil and 45% of its natural gas requirements.
2. The government has launched several initiatives to enhance energy security, such as the International Solar Alliance, which aims to promote the use of solar energy in member countries.

Energy infrastructure in India:

1. **Power Generation**: India has an installed power generation capacity of over 383 GW as of October 2021. Thermal power plants, which use coal and natural gas, account for around 65% of the total installed capacity, while renewable energy sources such as wind, solar, hydro, and biomass account for around 37%.
2. **Transmission and Distribution**: India's transmission and distribution system is owned and operated by several government-owned entities such as Power Grid Corporation of India Limited, State Electricity Boards, and private companies. The transmission and distribution system suffers from inadequate infrastructure and losses during transmission and distribution.
3. **Oil and Gas Pipelines**: India has an extensive network of oil and gas pipelines for the transportation of crude oil, natural gas, and petroleum products. The pipeline network is owned and operated by several government-owned entities such as Indian Oil Corporation Limited, GAIL (India) Limited, and private companies.
4. **Refineries**: India has 24 refineries with a combined capacity of over 249 million metric tonnes per annum (MMTPA) as of 2021. The refineries are owned and operated by several government-owned entities such as Indian Oil Corporation Limited, Bharat Petroleum Corporation Limited, and private companies.
5. **Renewable Energy Infrastructure**: India has made significant progress in promoting renewable energy infrastructure. As of October 2021, the country had an installed renewable energy capacity of over 98 GW, accounting for around 27% of the country's total installed capacity. The government has launched several initiatives to promote renewable energy infrastructure, such as the National Solar Mission and the Wind Energy Mission.
6. **Smart Grids**: India is also investing in smart grid infrastructure to improve the efficiency and reliability of the electricity grid. The government has launched several initiatives, such as the Smart Grid Mission, to promote the development of smart grid infrastructure in the country.

Challenges faced by the energy sector in India:

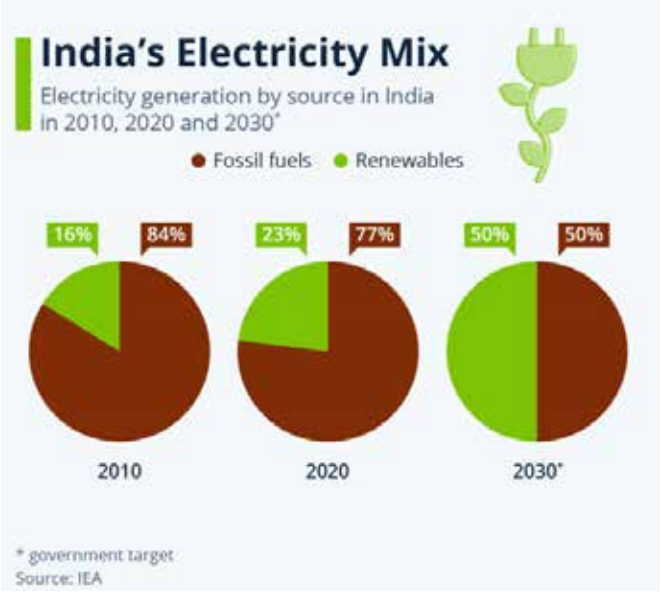
1. **Energy Access:** Despite significant progress in recent years, India still faces challenges in ensuring universal access to energy. According to the International Energy Agency, around 240 million people in India still lack access to electricity. This lack of access to energy impacts the socio-economic development of the country.
2. **Energy Security**: India is heavily dependent on imports for its energy needs. According to the Ministry of Petroleum and Natural Gas, India's crude oil import dependency has increased from 77.3% in 2014-15 to 85.8% in 2019-20. This dependence on imports makes the country vulnerable to global price fluctuations and geopolitical risks.
3. **Environmental Sustainability**: The energy sector is a major contributor to greenhouse gas emissions, which contribute to climate change. According to the Global Carbon Project, India was the third-largest emitter of carbon dioxide in 2019, accounting for 6.6% of global emissions. The challenge for the energy sector is to promote economic growth while ensuring environmental sustainability.
4. **Infrastructure:** The energy sector in India faces infrastructure challenges such as inadequate transmission & distribution infrastructure, inefficient storage systems, and inadequate refining capacity. According to the Ministry of Power, the peak demand deficit in India was 0.5% in 2019-20, indicating a need for additional infrastructure development.
5. Financing: The energy sector requires significant investments to meet the growing demand for energy and to promote sustainable development. However, financing remains a challenge due to the high capital costs associated with energy projects and the limited availability of funding.

Some Other issues:

1. India's power sector is plagued by fuel shortages, high **AT&C losses**, a differential tariff structure, and delays in tariff revisions.
2. The capacity to generate electricity has increased over time, but the actual generation of electricity has not kept up. The following are major causes of the low utilization of generation capacity: lack of fuel, particularly coal, renders Power Purchase Agreements unviable.

Achievements of Indian energy sector

1. **Record Low Solar Tariffs**: In July 2020, India achieved a record low solar tariff of INR 2.36 per kilowatt-hour (kWh) in an auction conducted by Solar Energy Corporation of India. This is the lowest solar tariff achieved in India and the world to date.
2. **Solar Energy Capacity**: India has achieved significant progress in promoting solar energy capacity. As of October 2021, the country had an installed solar energy capacity of over 45 GW, which accounts for around 14% of the country's total installed capacity.
3. **Wind Energy Capacity**: India has also made significant progress in promoting wind energy capacity. As of October 2021, the country had an installed wind energy capacity of over 41 GW, which accounts for around 13% of the country's total installed capacity.
4. **UJALA Scheme**: The Unnat Jyoti by Affordable LEDs for All (UJALA) scheme was launched by the government of India in 2015 to promote the use of energy-efficient LED bulbs. The scheme has been successful in promoting the use of energy-efficient LED bulbs, resulting in significant energy savings.
5. **Energy Efficiency Initiatives**: The government of India has launched several energy efficiency initiatives, such as the Perform, Achieve, and Trade (PAT) scheme, which aims to improve energy efficiency in energy-intensive industries. Under the scheme, industries are given energy efficiency targets, and those that exceed the targets can trade the excess energy savings as certificates.
6. **Electric Vehicles**: India has launched several initiatives to promote electric vehicles (EVs). In March 2021, the government announced a PLI (Production-Linked Incentive) scheme for EVs and advanced battery technologies, with a total outlay of INR 18,100 crore. The scheme aims to promote domestic manufacturing of EVs and reduce India's dependence on imports.



Targets and way Forward

1. India isn't energy autonomous. It imports energy for more than Rs 12 lakh crore. By 2047, the government intends to achieve energy independence prior to the 100th anniversary of independence.
2. The Indian government has already begun its green hydrogen journey as green power takes precedence in global affairs.We need to take these initiatives for energy independence to the next level, including adoption, EVs, Mission Hydrogen, solar energy, and solar energy.

Hydro Power

Status:

A. Hydropower accounts for about 12-13% of India's total electricity generation.

B. India has a hydropower potential of around 148,701 MW, but its installed capacity is significantly lower, at around 45,400 MW.

Challenges:

1. Environmental Concerns: The development of hyropower projects often involves the displacement of communities and has environmental impacts, leading to protests and legal challenges.
2. Funding and Investment: Hydropower projects require substantial investment, and securing funding can be a challenge due to their long gestation periods and uncertainties.
3. Regulatory Hurdles: Complex regulatory and clearance processes can delay project implementation, adding to costs and risks.
4. Interstate Water Disputes: Water-sharing disputes between states can complicate the development of interstate hydropower projects.
5. Siltation and Sedimentation: Over time, siltation and sedimentation reduce the efficiency of hydropower plants, necessitating regular maintenance and dredging.
6. Climate Variability: Changing rainfall patterns and reduced snowmelt due to climate change can affect the reliability of hydropower generation.

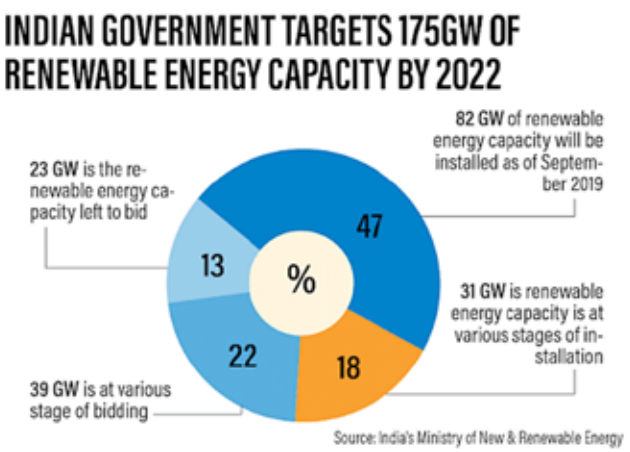
Prospects:

1. Renewed Focus: The Indian government has renewed its focus on hydropower and aims to increase its capacity, recognizing its potential as a clean energy source.
2. Small Hydropower: Small hydropower projects have gained attention as they have a lower environmental impact and can be developed in hilly and remote areas.
3. Pumped Storage: Pumped storage hydropower projects are being explored for grid stability and energy storage.
4. International Cooperation: India is exploring cooperation with neighboring countries like Bhutan and Nepal for cross-border hydropower projects.
5. Technological Advancements: Advancements in hydropower technology, such as improved turbine designs and fish-friendly hydropower, are being developed to address environmental concerns.
6. Associated Development: Hydro power development can also have significant prospect in tourism and aqua farming.

Solar energy in India

India has made significant progress in the solar energy sector over the past decade. The country has set an ambitious target of achieving 100 GW of solar energy capacity by 2022, which was later increased to 450 GW by 2030.

1. **Installed Capacity**: As of January 2022, India's total installed solar power capacity was 50.33 GW, accounting for around 10% of the country's total installed power capacity. The country added 6.54 GW of solar power capacity in 2021 alone.
2. **Auctions:** The Indian government has been promoting solar energy through competitive auctions. The auctions ensure transparency and price discovery in the procurement of solar power. According to the Ministry of New and Renewable Energy, the lowest tariff discovered through solar auctions in India was Rs 1.99 per unit (around $0.027) in December 2020.
3. **Rooftop Solar**: The Indian government has been promoting rooftop solar installations to promote decentralized energy production and reduce transmission losses. As of December 2021, the total installed capacity of rooftop solar was 7.6 GW.
4. **Policies and Initiatives**: The Indian government has launched several policies and initiatives to promote solar energy, including the National Solar Mission, Solar Park Scheme, Solar Rooftop Scheme, and Kisan Urja Suraksha evam Utthan Mahabhiyan (KUSUM) Scheme. The government also provides financial incentives such as subsidies, tax incentives, and concessional financing to promote solar energy.
5. **Manufacturing**: India has been focusing on promoting domestic manufacturing of solar panels and other components to reduce dependence on imports. The government has launched several initiatives such as the Production-Linked Incentive (PLI) scheme to promote domestic manufacturing.



Wind Energy in India

India has one of the largest wind energy markets in the world, with significant potential for further growth. The country has set an ambitious target of achieving 60 GW of wind power capacity by 2022, which was later increased to 140 GW by 2030.

1. **Installed Capacity**: As of January 2022, India's total installed wind power capacity was 40.57 GW, accounting for around 8% of the country's total installed power capacity. The country added 3.18 GW of wind power capacity in 2021 alone.
2. **Auctions**: The Indian government has been promoting wind energy through competitive auctions. The auctions ensure transparency and price discovery in the procurement of wind power. According to the Ministry of New and Renewable Energy, the lowest tariff discovered through wind auctions in India was Rs 2.77 per unit (around $0.038) in February 2020.
3. **Policies and Initiatives**: The Indian government has launched several policies and initiatives to promote wind energy, including the National Wind-Solar Hybrid Policy, Wind-Solar Hybrid Park Scheme, and Kisan Urja Suraksha evam Utthan Mahabhiyan (KUSUM) Scheme. The government also provides financial incentives such as subsidies, tax incentives, and concessional financing to promote wind energy.
4. **Manufacturing**: India has been focusing on promoting domestic manufacturing of wind turbines and other components to reduce dependence on imports. The government has launched several initiatives such as the Production-Linked Incentive (PLI) scheme to promote domestic manufacturing.
5. **Offshore Wind Energy**: India has significant potential for offshore wind energy development along its coastline. The government has set a target of achieving 5 GW of offshore wind power capacity by 2022 and has launched several policies and initiatives to promote offshore wind energy.

Challenges To Renewable Energy Development In India

1. **Land acquisition**: Land acquisition is a significant challenge in India, particularly for renewable energy projects. Many renewable energy projects require vast tracts of land, which can be challenging to acquire due to complex land ownership structures, land-use policies, and inadequate compensation for landowners.
2. **Grid integration**: Integrating renewable energy into the grid is a significant challenge in India. The country's power grid is outdated and unable to handle the intermittent nature of renewable energy sources. This results in curtailment of renewable energy output and lower capacity utilization.
3. **Financing:** Financing renewable energy projects is a challenge in India, particularly for small-scale projects. Financial institutions are often hesitant to lend money for renewable energy projects due to the perceived risks associated with these projects.
4. **Policy and regulatory framework**: India's policy and regulatory framework for renewable energy is still evolving, and there is a lack of consistency in policy implementation at the state and national levels. This creates uncertainty for investors and slows down project development.
5. **Infrastructure**: Inadequate infrastructure, including roads and transmission lines, is another significant challenge to renewable energy development in India. Infrastructure deficiencies can lead to higher costs and delays in project development.
6. **Public awareness**: There is a lack of public awareness and understanding of renewable energy in India. This can lead to opposition to renewable energy projects and delays in project development.

Way forward

1. In order to meet the ever-increasing demand for energy, India must make use of solar, wind, and especially green hydrogen energy in its electricity system.
2. To accommodate inclusiveness in the development process, aspects such as investment, infrastructure development, private-public partnership, green financing, and the policy framework need to be strengthened at both the national and regional levels.
3. Green energy unquestionably promotes sustainable development and has enormous potential to boost income, employment, and entrepreneurship.
4. It creates jobs and generates income, as well as investment opportunities and new product and service markets. As a result, India ought to concentrate

on developing both green energy and energy independence simultaneously.

Nuclear Energy in India

India has consciously proceeded to explore the possibility of tapping nuclear energy for the purpose of power generation. In this direction three-stage nuclear power programme was formulated by Homi Bhabha in the 1950s. The 3 Stage Nuclear Program in India was designed to exploit the country's huge thorium-232 supplies.

Atomic Energy Act, 1962 was framed and implemented with the set objectives of using two naturally occurring elements Uranium and Thorium having good potential to be utilized as nuclear fuel in Indian Nuclear Power Reactors. The estimated natural deposits of Uranium are about 70,000 tonnes and Thorium are about 3, 60,000 tonnes in the country.

Status

1. Nuclear power constitutes the fifth-largest source of electricity in India, contributing approximately 2% to the nation's overall power generation.
2. India currently has seven power plants with over 22 nuclear reactors that collectively generate 6,780 MW of nuclear energy.
3. Among these reactors, 18 are Pressurised Heavy Water Reactors (PHWRs) while the remaining 4 are Light Water Reactors (LWRs).
4. In January 2021, the Kakrapar Atomic Power Project (KAPP-3), which is India's first 700 MWe unit and the largest indigenously developed PHWR variant, was connected to the grid.
5. The Indian government has authorized joint ventures between the Nuclear Power Corporation of India Limited (NPCIL) and public sector undertakings (PSUs) to promote the country's nuclear program. NPCIL is presently collaborating with the National Thermal Power Corporation Limited (NTPC) and the Indian Oil Corporation Limited (IOCL).

Importance of nuclear energy

1. Although managing radioactive fuel and disposal can be costly, nuclear power plants are less expensive to operate than coal or gas plants.
2. India's significant Thorium resources make nuclear energy a promising solution for the country's energy needs, as Thorium is considered the fuel of the future. India is a leading country in Thorium availability.
3. Nuclear energy has the potential to reduce India's import bills by $100 billion annually, which is currently spent on importing coal and petroleum.
4. Dispatchable power, also known as firm power, is a type of power that can be provided to the electric grid whenever required. It can be turned on or off based on demand.

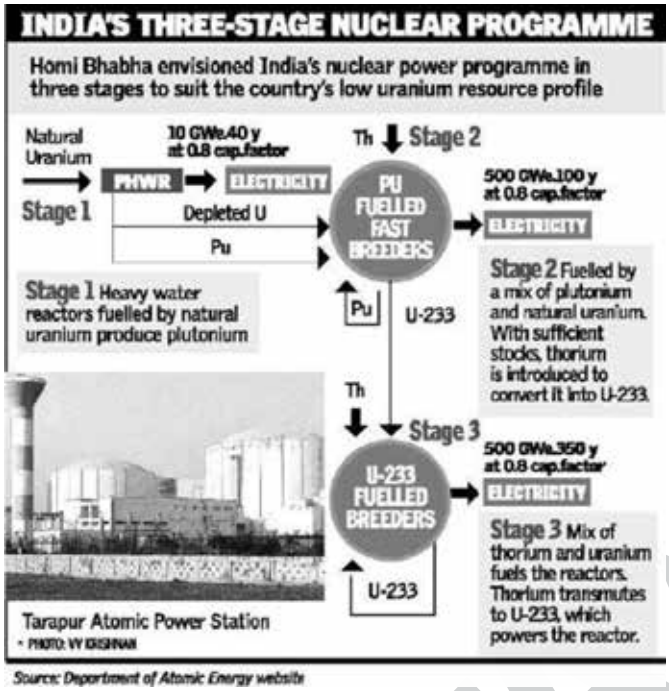
Challenges in nuclear energy

1. India's nuclear plan is focused on overcoming its limited supply of enriched uranium, which is costly and challenging to obtain.
2. The nuclear industry is shifting towards "passive safety" designs for nuclear reactors, which are safer than older designs of nuclear plants.
3. Nuclear power produces nuclear waste, which can have severe negative impacts on life, such as cancerous growths and genetic issues for multiple generations of animals and plants.

3 Stage Nuclear Program: Process

These three stages are as follows:

- Pressurized Heavy Water Reactors (PHWRs) are fueled by natural uranium.
- The implementation of Fast Breeder Reactors (FBRs) that employ fuel based on plutonium.
- The development of advanced nuclear power systems to harness thorium as a resource.



Source: Department of Atomic Energy website

Here are some of the challenges of using thorium in nuclear power:

- Thorium cannot be used directly. It must be used with added fissile material.
- Thorium absorbs neutrons, producing more plutonium more efficiently in a fast breeder reactor.
- This means that using thorium in the first or early part of the second stage of the nuclear power program would adversely affect the rate of growth of nuclear power generation capacity in the initial periods.

What Are The Benefits of Thorium Technology?

- Thorium reactors produce far less waste than present-day reactors.
- Compared to uranium reactors, Thorium reactors produce significantly less waste. The waste they do generate has a much shorter half-life.
- The minuscule waste that is generated from these reactors is toxic for only three or four hundred years rather than thousands of years.
- Thorium reactors are cheaper because they have higher burnup.
- Thorium reactors are significantly more proliferation-resistant than present reactors. This is because the U-233 produced by transmuting thorium also contains U-232, a strong source of gamma radiation that makes it difficult to work with. Its daughter product, thallium-208, is equally difficult to handle and easy to detect.
- Thorium-based reactors offer enhanced safety features, as the reaction can be swiftly halted and does not require intense pressure.
- Utilizing thorium as a new primary energy source has been intriguing for many years.
- However, effectively harnessing its latent energy value cost-efficiently remains challenging and necessitates substantial research and development investment.

Challenges of 3 Stage Nuclear Program

- The main challenge in India's nuclear power program is not technological. The limited availability of fissile material to convert fertile thorium into fissile U-233.
- India has tested all the technologies related to the program in laboratories, but it needs more fissile material.
- Even after the program is complete, there will still be challenges in maintenance, accident prevention, and nuclear waste disposal. However, these challenges can be greatly reduced with technological innovation.
- The government may need help in land acquisition and finding suitable locations for nuclear power plants.
- Handling and/or recycling spent fuel is more costly due to the difficulty in shielding gamma rays.
- The nuclear industry is highly conservative, and the main challenge with thorium is its lack of operating experience.
- Thorium dioxide melts at temperatures 550 degrees higher than uranium dioxide. Therefore, very high temperatures are necessary to make high-quality solid fuel.

Bio Fuel as energy resource

Unlike other renewable energy sources, biomass can be converted directly into liquid fuels, called "biofuels," to help meet transportation fuel needs. The two most common types of biofuels in use today are ethanol and biodiesel, both of which represent the first generation of biofuel technology.

1. Ethanol (CH3CH2OH) is a renewable fuel that can be made from various plant materials, collectively known as "biomass." Ethanol is an alcohol used as a blending agent with gasoline to increase octane and cut down carbon monoxide and other smog-causing

emissions.

- ❖ The most common blend of ethanol is E10 (10% ethanol, 90% gasoline) and is approved for use in most conventional gasoline-powered vehicles up to E15 (15% ethanol, 85% gasoline). Some vehicles, called **flexible fuel vehicles**, are designed to run on E85 (a gasoline-ethanol blend containing 51%–83% ethanol, depending on geography and season)
- ❖ The common method for converting biomass into ethanol is called fermentation. During fermentation, microorganisms (e.g., bacteria and yeast) metabolize plant sugars and produce ethanol.

2. **Biodiesel** is a liquid fuel produced from renewable sources, such as new and used vegetable oils and animal fats and is a cleaner-burning replacement for petroleum-based diesel fuel. Biodiesel is nontoxic and biodegradable and is produced by combining alcohol with vegetable oil, animal fat, or recycled cooking grease.

- ❖ Like petroleum-derived diesel, biodiesel is used to fuel compression-ignition (diesel) engines. Biodiesel can be blended with petroleum diesel in any percentage, including B100 (pure biodiesel) and, the most common blend, B20 (a blend containing 20% biodiesel and 80% petroleum diesel).

3. **National Policy on Biofuels, 2018**.

- ❖ The "National Policy on Biofuels was notified by the Ministry of Petroleum and Natural Gas in 2018. The policy was notified in supersession of the National Policy on Biofuels, promulgated through the Ministry of New & Renewable Energy, in 2009.
- ❖ Aim: Adopting biofuels as an alternative source of energy can significantly to improve farmers' income, generate employment opportunities, reduce imports and augment waste to wealth creation, etc.
- ❖ The Policy categorises biofuels as "Basic Biofuels" (1G) bioethanol & biodiesel and "Advanced Biofuels" (2G)–ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels, bio-CNG etc. to enable extension of appropriate financial and fiscal incentives under each category.
- ❖ The Policy expands the scope of raw material for ethanol production by allowing use of Sugarcane Juice, Sugar containing materials like Sugar Beet, Sweet Sorghum, Starch containing materials like Corn, Cassava, Damaged food grains like wheat, broken rice, Rotten Potatoes, unfit for human consumption for ethanol production.
- ❖ Policy allows use of surplus food grains for production of ethanol for blending with petrol with the approval of National Biofuel Coordination Committee.
- ❖ Policy indicates a viability gap funding scheme for 2G ethanol Bio refineries of Rs.5000 crore in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels.
- ❖ Instead of 2030, the Centre plans to move ahead with its ethanol blending target of 20% of petrol containing ethanol by 2025-26.
- ❖ It will promote the production of biofuels in the country, under the Make in India program, by units located in Special Economic Zones (SEZ)/ Export Oriented Units (EoUs).

The Bioenergy Technologies Office (BETO) is collaborating with industry to develop next-generation biofuels made from wastes, cellulosic biomass, and algae-based resources. BETO is focused on the production of hydrocarbon biofuels—also known as "drop-in" fuels—which can serve as petroleum substitutes in existing refineries, tanks, pipelines, pumps, vehicles, and smaller engines.

Hydrogen as energy resource

Hydrogen is a **key industrial fuel that has a variety of applications including the production of ammonia (a key fertilizer)**, steel, refineries and electricity. However, all of the hydrogen manufactured now is the **so-called 'black or brown' hydrogen because they are produced from coal.**

Colors attached to hydrogen indicate the source of electricity used to derive the hydrogen molecule. For instance, if coal is used, it is referred to as brown hydrogen.

Hydrogen is the most abundant element in the universe. But pure, or the elemental hydrogen, is very scarce. It almost always exists in compounds like with oxygen to form H2O, or water. But when electric current is passed through water, it splits it into elemental oxygen and hydrogen through electrolysis. And if the electricity used for this process comes from a renewable source like wind or solar then the hydrogen thus produced is referred to as green hydrogen.

Need for Producing Green Hydrogen:

- ➢ Hydrogen is a great source of energy **because of its high energy content per unit of weight**, which is

why it is used **as rocket fuel.**

- ❖ Green hydrogen in particular is one of the cleanest sources of energy with close to zero emission. It can be used in fuel cells for cars or in energy-guzzling industries like fertilizers and steel manufacturing.
- ❖ Countries across the world are working on building green hydrogen capacity as it can ensure energy security and also help in cutting carbon emission.
- ❖ Green hydrogen has become a global buzzword, especially as the world is facing its biggest-ever energy crisis and the threat of climate change is turning into a reality.

1. Potential in India

- ❖ India has a favourable geographic location and abundance of sunlight and wind for the production of green hydrogen.
- ❖ Green hydrogen technologies are being promoted in sectors where direct electrification isn›t feasible.
- ❖ Heavy duty, long-range transport, some industrial sectors and long-term storage in the power sector are some of these sectors.
- ❖ The nascent stage of this industry allows for the creation of regional hubs that export high-value green products and engineering, procurement and construction services.

2. National Green Hydrogen Mission: **National Hydrogen Mission** (NHM) was announced in the Union Budget for 2021-2022. Nodal Ministry: Ministry of New and Renewable Energy

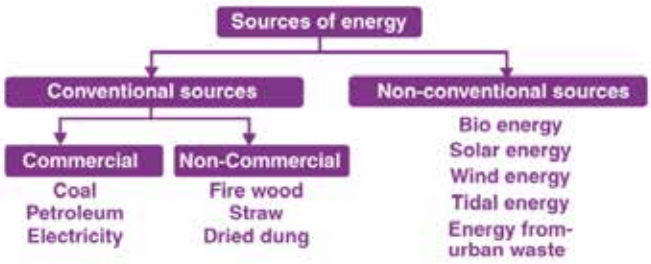
- ❖ It is a program to incentivise the commercial production of green hydrogen and make India a net exporter of the fuel. The Mission will facilitate demand creation, production, utilization and export of Green Hydrogen.
- ❖ **Strategic Interventions for Green Hydrogen Transition Programme (SIGHT) and development os Green Hydrogen Hubs at regional level are sub schemes of mission.**
- ❖ **Objective:**
- ❖ Developing green hydrogen production capacity of at least 5 MMT (Million Metric Tonne) per annum, alongside adding renewable energy capacity of about 125 GW (gigawatt) in India by 2030.
- ❖ It aims to entail over Rs 8 lakh crore of total investments and is expected to generate six lakh jobs.
- ❖ It will also lead to a cumulative reduction in fossil fuel imports by over Rs 1 lakh crore and an abatement of nearly 50 MT of annual greenhouse gas emissions.

Challenges

- ➢ Green hydrogen currently accounts for less than 1% of global hydrogen production due to it being expensive to produce.
- ➢ A kilogram of black hydrogen costs USD 0.9-1.5 to produce while grey hydrogen costs USD 1.7-2.3 and blue hydrogen can cost anywhere from USD 1.3-3.6. However, green hydrogen costs USD 3.5-5.5 per kg, according to a 2020 analysis by the Council for Energy, Environment and Water.

Way Forward

- ➢ There is a need to announce **incentives to convince enough users of industrial hydrogen to adopt green hydrogen.**
- ➢ India needs to develop **supply chains in the form of pipelines, tankers, intermediate storage and last leg distribution networks** as well as put in place an effective skill development programme to ensure that lakhs of workers can be suitably trained to adapt to a viable green hydrogen economy



Important Facts and figure

- ➢ The country receives an average of 300 sunny days per year, making it an ideal location for solar energy production. According to the National Institute of Solar Energy, India has the potential to generate up to 750 GW of solar energy, which is more than enough to meet the country's energy needs.
- ➢ India currently has 13.4 GW of prospective projects in wind energy, which are expected to drive installations until 2024 in the market. India is expected to add 3.2 GW in 2022, 4.1 GW in 2023 peaking to 4.6 GW in 2024
- ➢ Estimates from the Indian government place the nation's tidal energy potential at 8,000 MW. This includes around 7,000 MW in the Gulf of Cambay in Gujarat, 1,200 MW in the Gulf of Kutch in Gujarat, and 100 MW in the Gangetic delta of the Sunderbans in West Bengal.

- India has a target of producing 5 million metric tones (MMT) of green hydrogen per annum with an associated renewable energy capacity of about 125 GW by 2030 under the National Green Hydrogen Mission.
- India has reasonably good potential for geothermal; potential geothermal provinces can produce 10,600 MW of power (but experts are confident only to the extent of 100 MW). The most promising of these is in Puga valley of Ladakh.

Concept of Non-conventional sources of energy

They are often referred to as renewable or alternative energy sources, have garnered significant attention as potential solutions to environmental and energy security challenges.

Heads	pros	Cons
Environ-mental Benefits	Non-conventional sources, such as solar, wind, and hydroelectric power, produce minimal greenhouse gas emissions, reducing the impact of climate change. They also have lower environmental pollution and land use compared to fossil fuels	Some renewable technologies, like large-scale hydroelectric dams, can have adverse environmental effects, such as habitat disruption and altered water flow. Solar panels and wind turbines also have environmental costs associated with their production and disposal.
Intermittency	Non-conventional sources are naturally replenished and abundant, making them a long-term energy solution	Their intermittency poses challenges. Solar and wind energy depend on weather conditions, which can lead to variability in energy production. Energy storage solutions are essential to address this issue
Energy Storage	Advances in energy storage technologies, such as batteries, can mitigate the intermittency problem and provide reliable energy supply	Energy storage solutions are still evolving and may involve resource-intensive manufacturing processes and environmental concerns
Economic Viability	As technology advances and economies of scale come into play, the cost of renewable energy has been decreasing, making it increasingly competitive with fossil fuels	The initial investment in renewable infrastructure can be high, and government incentives and subsidies are often necessary to promote adoption.
Resource Availability	Non-conventional sources are widely available in most regions, offering energy security and reducing reliance on imported fossil fuels.	Geographical and seasonal variations can affect the availability and efficiency of certain renewable sources, making it necessary to diversify energy portfolios.
Land Use and Aesthetics	Non-conventional energy sources, like solar and wind, require relatively small land footprints compared to large-scale fossil fuel infrastructure.	Concerns about land use and aesthetics, particularly in densely populated areas, can lead to resistance to renewable energy projects.
Technology Advancem-ents	Ongoing research and innovation in non-conventional energy technologies hold the potential for improved efficiency and reduced costs.	Technological advancements may have unforeseen environmental or social consequences, necessitating careful monitoring and regulation.

Energy Transition	Transitioning to non-conventional sources aligns with global efforts to reduce carbon emissions and mitigate climate change	Phasing out fossil fuels can disrupt existing industries and communities, requiring careful planning and support for a just transition.

In conclusion, non-conventional sources of energy offer substantial environmental benefits and have the potential to address energy and climate challenges. However, they come with their own set of challenges related to intermittency, energy storage, economic viability, and environmental impacts. A holistic and carefully managed approach, considering the specific characteristics of each renewable source and addressing these challenges, is essential to fully realize the potential of non-conventional energy in the global energy mix.

Role Of Energy In Sustainable Development

Energy plays a crucial role in sustainable development for several reasons:

1. Economic Growth: Adequate and reliable energy sources are essential for India's economic growth. Energy fuels industries, agriculture, and services, contributing to GDP and job creation.
2. Access to Energy: Ensuring access to energy for all is a key aspect of sustainable development. India has made strides in electrifying rural areas and improving energy access, which enhances living standards and reduces poverty.
3. Environmental Sustainability: India's commitment to sustainable development includes reducing carbon emissions. The transition to cleaner energy sources like renewables and increased energy efficiency can help mitigate environmental impacts.
4. Energy Security: Reducing dependence on imported fossil fuels enhances India's energy security. Diversifying energy sources and investing in domestic energy production contribute to stability and reduced vulnerability to global energy price fluctuations.
5. Social Inclusion: Sustainable energy development involves inclusive policies to benefit marginalized communities. Initiatives like decentralized renewable energy projects can empower rural areas and improve social equity.
6. Rural Development: Sustainable energy projects, such as solar mini-grids, can stimulate rural development by providing electricity for lighting, education, healthcare, and small-scale businesses.
7. Technological Advancement: Innovation in clean energy technologies can drive economic growth and position India as a leader in the global transition to sustainable energy.
8. Climate Change Mitigation: India's commitment to mitigating climate change requires transitioning away from fossil fuels and adopting renewable energy sources, reducing greenhouse gas emissions.
9. Energy Efficiency: Improving energy efficiency in industries, transportation, and buildings can reduce energy consumption and costs while promoting sustainable development.
10. Energy Policy and Governance: Effective energy policies and governance are crucial to balance economic, environmental, and social objectives. Regulatory frameworks, incentives, and capacity building are vital components.

In the Indian scenario, energy plays a multifaceted role in achieving sustainable development, addressing issues related to poverty, environment, equity, and climate change while supporting economic growth and energy security. It requires a holistic approach that combines economic, social, and environmental factors to ensure a sustainable and prosperous future for the country.

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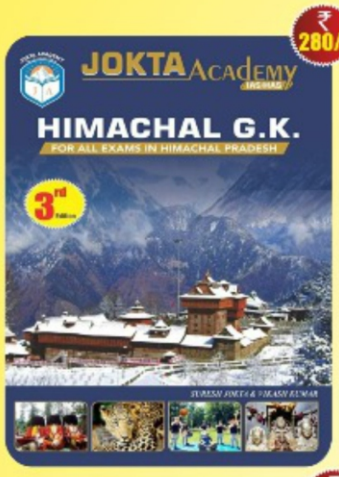

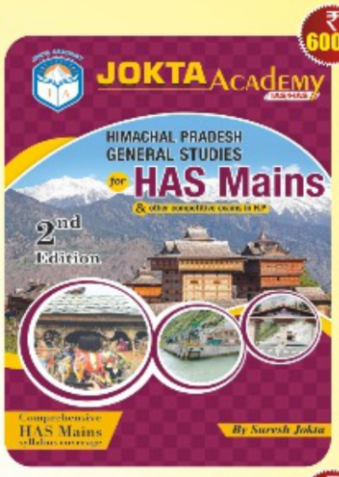

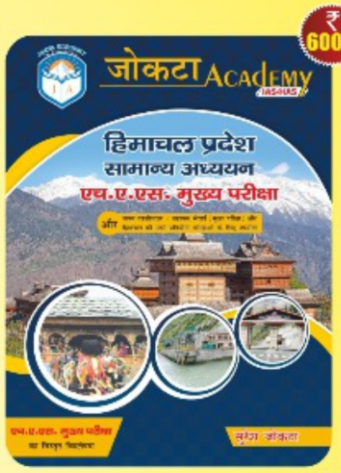

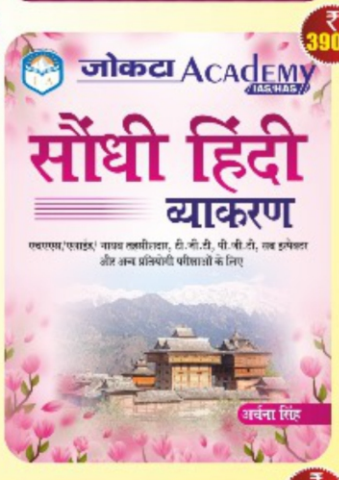

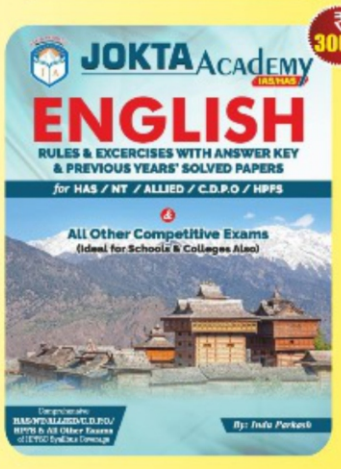

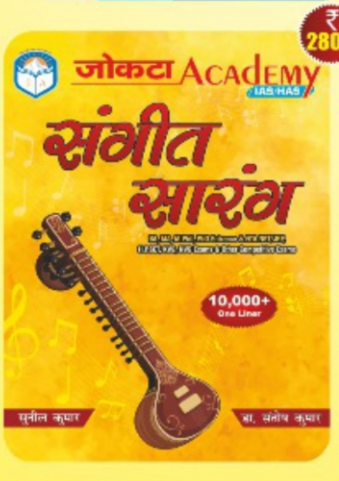

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