Perspective: Emerging and Critical Technologies for India

For Prelims: Quantum Technologies, Artificial Intelligence (AI), Semiconductors, Clean Energy, Green Hydrogen, Bioeconomy, Anusandhan National Research Foundation (ANRF), National Education Policy (NEP), 2020, Science and Engineering Research Board (SERB), iDEX model.

For Mains: Significance of emerging and critical technology in development of Indian Economy.

Why in News?

India's target is to expand its economy to **USD 7 trillion** by **2030,** necessitating a strategic emphasis on **smart** and **advanced technology.**

- In the **Budget 2024-2025** the government has announced a **1 lakh crore** for long-term funding of **R&D** including **deep defence technology.**
- The government has laid out a plan to boost R&D in emerging and critical technologies like Quantum Technologies, Artificial intelligence (AI), **Semiconductors**, **Clean Energy**, Green Hydrogen **and** Bioeconomy.

What are the Different Critical and Emerging Technologies in India?

- **Quantum Technology:**
  - **Quantum Technology** is based on the principles of Quantum mechanics that was developed in the early **20th century** to describe nature in the small scale of atoms and elementary particles.
  - Conventional computers process information in **'bits'** or **1s** and **0s**, following classical physics under which our computers can process a '1' or a '0' at a time.
  - Quantum computers compute in 'qubits' **(or quantum bits).** They exploit the properties of quantum mechanics, the science that governs how matter behaves on the atomic scale.
    - In this scheme of things, processors can be a 1 and a 0 simultaneously - a state called quantum superposition.
    - Because of quantum superposition, a quantum computer can mimic several classical computers working in parallel.
- **Artificial Intelligence (AI):**
  - **AI** is the ability of a computer, or a robot controlled by a computer to do tasks that are usually done by humans because they require **human intelligence** and **judgement.**
    - Although no **AI** can perform the wide variety of tasks an ordinary human can do, some AI can match humans in specific tasks.
  - The ideal characteristic of AI is its ability to rationalise and take actions that have the best chance of achieving a specific goal. A subset of AI is **Machine Learning (ML).**
    - **Deep Learning (DL) techniques** enable this automatic learning through the absorption of huge amounts of unstructured data such as **text, images**, or **video.**
- **Semiconductors:**
  - **Semiconductors** are materials which have a conductivity between **conductors** and

insulators. They can be pure elements like silicon and germanium or compounds like **gallium, arsenide and cadmium selenide.**
    - **India's Stand in the Semiconductor Market:**
        - Indian semiconductor industry in **2022** was **USD 27 Billion,** with over 90% being imported, and therefore a significant external dependence for Indian chip consumers.
            - Countries exporting semiconductors to India include **China, Taiwan, the USA, Japan, etc.**
        - The **Indian semiconductor** market is expected to **reach USD 55 Billion** by **2026** with its own consumption of semiconductors expected to cross **USD 80 billion by 2026** and to **USD 110 billion by 2030.**
- **Clean Energy:**
    - Clean energy is energy that comes from renewable**,** zero emission sources that do not pollute the atmosphere when used, as well as energy saved by energy efficiency measures. Some examples of clean energy sources are solar**, wind,** hydro**, and** geothermal energy.
    - Clean energy is important because it can help reduce greenhouse gas emissions, combat climate change, and improve air quality.
- **Green Hydrogen:**
    - **Green hydrogen** is a type of hydrogen that is produced through the **electrolysis of water** using **renewable energy sources** such as solar or wind power.
    - The electrolysis process splits water into **hydrogen** and **oxygen,** and the hydrogen produced can be used as a clean and **renewable fuel.**
    - **Uses:**
        - **Chemical industry:** Manufacturing ammonia and fertilisers.
        - **Petrochemical industry:** Production of petroleum products.
        - Furthermore, it is starting to be used in the steel industry.
- **Bioeconomy:**
    - As per, the **UN Food and Agriculture Organization (FAO)**, Bio-economics could be defined as the production, use, and conservation of biological resources, including related knowledge, science, technology, and innovation to provide information, products, processes, and services to all economic sectors with the aim of moving towards a sustainable economy.

What is the Distribution of Funds for Research & Development?

- Global leaders in emerging and critical technology typically allocate around **2 to 3%** of their **GDP** for **research and** science **development (R&D)**. In countries like Korea, private sector investment in **R&D** can reach as high as **80%** of total investment.
    - In India, this figure stands at only about **0.7%** of the **GDP** and is limited to merely **30 to 40%** of total investments.
- It's crucial to recognise that funding for **R&D** cannot solely rely on government initiatives; the private sector must also play a significant role by enhancing its **R&D capabilities.** One notable initiative taken by the government is the establishment of the **National Research Foundation.**

What are the Various Government Initiatives for Emerging and Critical Technologies?

- **iDEX:**
    - iDEX, launched in **2018**, is an ecosystem to foster **innovation & technology** development in **Defence** and Aerospace by engaging innovators & entrepreneurs to deliver technologically advanced solutions for modernising the Indian Military.
    - The **iDEX model** has been very successful in innovative technology development and one of the important objectives of the iDEX model was to provide the much needed support to startups which have been working in the Deep Tech area and critical and emerging Technologies.
    - It provides funding/grants to **MSMEs, start-ups,** individual innovators, R&D (Research and Developments) institutes and academia to carry out research and development.
- **iCET Initiative:**

- The **iCET initiative** was launched by **India** and the US in May 2022, and is being run by the **National Security Councils** of both countries.
    - Under iCET, both countries have identified areas of cooperation including **co-development** and **co-production** that would gradually be expanded to **QUAD**, then to **NATO**, followed by Europe and the rest of the world.
- **Six Areas of Cooperation:**
    - The six areas for cooperation are **scientific research and development; quantum** and **AI, defence innovation, space, advanced telecom** which would include things like **6G** and **semiconductors.**

- **National Quantum Mission:**
    - It'll be implemented by the **Department of Science & Technology (DST)** under the Ministry of Science & Technology.
    - The mission planned for **2023-2031** aims to seed, nurture, and scale up scientific and industrial R&D and create a vibrant & innovative ecosystem in **quantum technology.**
    - **India** is the **7th country** to have a dedicated **quantum mission** after the **US, Austria, Finland, France, Canada** and **China.**
- **Artificial Intelligence Mission:**
    - The primary **objectives** of the **AI Mission** include establishing robust computing powers for AI within India.
    - The mission seeks to enhance services for **startups** and entrepreneurs while fostering AI applications in critical sectors such as **agriculture, healthcare,** and education.
    - **Other Initiatives Related to Artificial Intelligence:**
        - **INDIAai.**
        - **Global Partnership on Artificial Intelligence (GPAI).**
        - **US India Artificial Intelligence Initiative.**
        - **Responsible Artificial Intelligence (AI) for Youth.**
        - **Artificial Intelligence Research, Analytics and Knowledge**
        - **Assimilation Platform**
- **India Semiconductor Mission:**
    - The ISM was launched in 2021 with a total financial outlay of Rs76,000 crore under the aegis of the **Ministry of Electronics and IT (MeitY).**
    - It is part of the **comprehensive program for the development of sustainable semiconductor and display ecosystem** in the country.
    - The programme aims to provide financial support to companies investing in **semiconductors, display manufacturing** and **design ecosystem.**
- **National Green Hydrogen Mission:**
    - It is a program to incentivise the commercial production of **green hydrogen** and make India a net exporter of the fuel. It will facilitate **demand creation, production, utilisation and export of Green Hydrogen.**
    - **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.**
- **National Mission on Bioeconomy:**
    - Amid attempts to boost rural economy by using bio-resources, a 'National Mission on Bioeconomy' was launched by the Institute of Bio-resources and Sustainable Development under the Science and Technology Ministry, in 2016.
- **Anusandhan National Research Foundation (ANRF):**
    - The **Anusandhan National Research Foundation (ANRF)** was established with the **Anusandhan National Research Foundation (ANRF) Act, 2023.**
        - It aims to seed, grow and promote R&D and foster a culture of research and innovation throughout India's universities, colleges, research institutions, and R&D laboratories.
    - ANRF acts as an **apex body** to provide **high-level strategic direction** of scientific research in the country as per recommendations of the **National Education Policy**

(NEP), 2020.

- The **Science and Engineering Research Board (SERB)** established in **2008** has been subsumed into ANRF.
- ANRF will forge collaborations among the **industry, academia**, and **government departments and research institutions,** and create an interface mechanism for participation and contribution of industries and State governments in addition to the scientific and line ministries.

What are the Challenges in Developing Critical and Emerging Technologies?

- **Funding Gap:** Despite the government's initiatives to boost funding for research and development (R&D), India still lags behind global leaders in allocating funds for emerging and critical technologies. The current level of investment, around 0.7% of GDP, is significantly lower than the 2-3% typically allocated by leading nations.
- **Infrastructure and Skill Gap:** Advancing technologies like Quantum Computing, AI, and Semiconductor manufacturing require robust infrastructure and a skilled workforce.
  - Addressing the infrastructure and skill gap is vital for India to compete globally in emerging technologies.
- **Limited Private Sector Involvement**: While government initiatives like iDEX aim to support startups and encourage innovation, there is a need for greater involvement from the private sector in R&D.
  - Encouraging more private sector participation is essential for sustained growth in critical technologies.
- **International Collaboration and Competition:** Emerging technologies are highly competitive, with countries like the USA, China, and European nations investing heavily in R&D.
  - Additionally, managing geopolitical tensions and ensuring access to critical resources and technologies amidst global competition pose significant challenges for India's technological advancement.

Way Forward

- **Boosting Investment in R&D:** Implement policies to incentivize both public and private sector investment in research and development, particularly in emerging technologies like quantum computing and AI. Encourage collaboration between industry, academia, and research institutions to leverage expertise and resources.
- **Enhancing Research Infrastructure:** Allocate funds for upgrading research infrastructure, including laboratories, computing facilities, and specialised equipment, in universities and research institutions. Foster partnerships with private sector firms to access cutting-edge tools and technologies.
- **Adapting Regulatory Framework:** Establish a dynamic regulatory framework that can swiftly adapt to technological advancements while ensuring ethical standards and addressing potential risks.
- **Clarifying Intellectual Property Rights:** Develop clear and transparent policies on intellectual property rights to provide certainty and encourage investment in R&D. Enhance awareness among researchers and innovators about IP protection mechanisms and facilitate easy access to patenting processes.
- **Securing Critical Raw Materials:** Diversify the sources of critical raw materials, such as rare earth elements, to reduce dependence on imports and ensure a steady supply chain for domestic critical and emerging technology development.
- **Promoting Collaboration and Skill Development:** Encourage collaboration between academia, industry, and research institutions to foster knowledge exchange and skill development in emerging technologies.