IAS COMPASS OF SCIENCE & TECHNOLOGY

CURRENT AFFAIRS COMPILATION
UPSC CIVIL SERVICES
MAINS EXAM

RAU'S IAS STUDY CIRCLE
Since 1953

Preface

Dear Aspirants,

Science and technology is an important part of the syllabus of General Studies Paper III of UPSC syllabus. UPSC has been asking about 40 marks question on this section directly. However, awareness of science and technology has fruits beyond this.

Many times, the points in science and technology can be utilized in both GS Paper 1, GS Paper 2 and even in Essay and Ethics paper. Thus, it is important to be thorough with science and technology.

The Mains Compass for Science & Technology has been developed in accordance with demands of the UPSC exam. We have tried cover all the major technologies revolutionizing the world. Major applications of science and technology, their use cases and concerns with these technologies have been highlighted. The effort has been to comprehensively cover all topics mentioned in the syllabus.

Students are advised to supplement the Mains Compass with previous year's UPSC questions, GS QIP Mains program and Mains Test Series of Rau's IAS. Hopefully, students will excel in the coming mains.

All the best!!!

Rau's IAS Team

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1 CHAPTER SPACE TECHNOLOGY

TOPICS TO BE COVERED

1. *Vision of space technology in India*
2. *Applications of Space Technology*
3. *Satellite technology in Agriculture*
4. *Additional applications of space technology in agriculture*
5. *Communication Satellites and socio-economic development*
6. *Satellite Communication*
7. *Commercialization of space sector and Space Sector Reforms*
8. *Recent advancements in rocket technology in India*
9. *Private sector activities in Launch Vehicles*
10. *Importance of gravitational waves astronomy: LIGO (launch of LIGO India)*
11. *Geospatial Technologies and Geospatial Data Policy*

1. VISION OF SPACE TECHNOLOGY IN INDIA

The long-term vision of space technology is to harness it for national development and at the same time pursue space research and planetary missions.

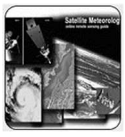
Broadly space activities may be classified into two baskets namely satellite technology for socio-economic development and space exploration for pursuit of science answering deeper laws governing the physical world.

Accordingly, India has over 100 satellites operational in space catering to various requirements.

2. APPLICATIONS OF SPACE TECHNOLOGY

Broadly services from satellites catering to socio-economic development include Meteorology and Earth observation using remote sensing satellites.

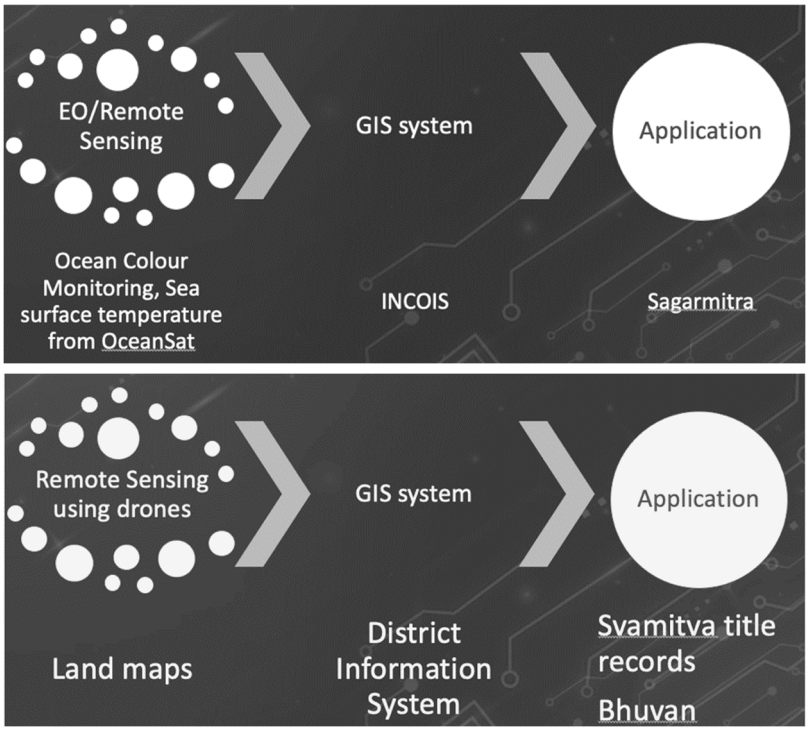
Earth observation satellite images are useful in natural resource management particularly in agriculture, water resource planning, forest resource planning, urban infrastructure planning development, disaster management etc.

					
Tele-medicine Tele-education DTH Satellite-based internet **VSAT:** for secure communication Telecommunication	Agriculture Hydrology Land Use/ Land Cover Forest Cover **Fishery:** Prospective **Fishing Zone:** Sagarmitra Mineral mapping	Weather satellites	Position, Navigation and Timing GAGAN Railways Banks Power grid synchronisation	EWS for Cyclone Land zonation maps Earthquake maps Forest fires Climate change and	Governance Geo-MGNREGA **Svamitva:** Digital land titles District level planning Master Plan for Urban areas using National

	Watershed management Infrastructure management			Environmental studies (NICES)	Urban Information System

Communication services including broadcast services, tele-medicine, tele-education, telecommunication and secure VSAT communication channel to critical services like power stations, banking etc. in the early times to DTH and satellite based-internet today

Position, Navigation and Timing services using navigation satellites used in important domains including railways, air traffic management, road transport, maritime navigation, survey etc.



Coming together the basket of space-based services has led to growth of governance-based geospatial technology products like sagarmitra mobile satellite helping fisherfolks plan fishing activities, bhuvan-soil health card augmenting fertilizer management in agriculture, Geo-MGNREGA etc.

These apps built on the foundation of remote sensing images are example of Mobile Geo-governance augmenting planning of development activities in various domains including land use planning, district development plans, master plans in urban areas, subsidies disbursement in case of crop failures, evacuation plans and relief activities in cyclone and flood affected areas, search and rescue operations etc.

3. SATELLITE TECHNOLOGY IN AGRICULTURE

Remote sensing satellites are the backbone of GIS systems built to augment various activities in agriculture including planning, forecasting and monitoring activities. land use planning, estimation of crop productivity etc. Accordingly, they have been instrumental in pre-harvest planning of agriculture marketing activities in case of 11 major crops, insurance premium and claim calculations under PM FASAL Bima Yojana, fertilizer management using Soil Health Cards, rabi season planning for horticulture crops etc. Further remote sensing images are helping in development of modern geospatial technology products that can be development across the entire agriculture supply chain particularly for perishable items.

1. **FASAL:** Forecasting Agricultural Output using Space Agro-meteorology and Land based Observation.
2. **Crop-yield estimation of 11 major crops:** Pre-harvest forecasting.
3. **Crop Intensification: CHAMAN:** Coord Prog on Horti Assessment & Mgmt using Geo-Informatics
4. Soil health cards for fertilizer management
5. **Input for Crop insurance:** PM Fasal Bhima Yojana
6. **Geo-Farms:** Geospatial data for supply chain management

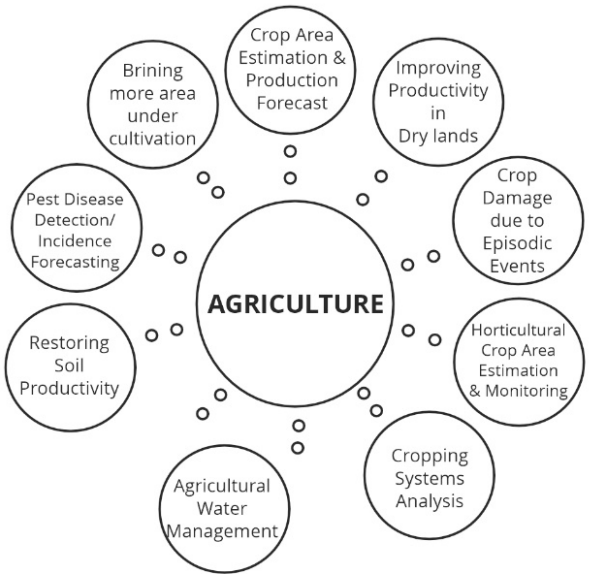
4. ADDITIONAL APPLICATIONS OF SPACE TECHNOLOGY IN AGRICULTURE

Remote sensing images act as the foundation for GIS systems built for planning, forecasting and monitoring of agriculture production.

CROP YIELD ESTIMATION

RS images capable of measuring chlorophyll content have been used as the for estimation of crop-yield, mapping land use/land cover, soil maps, hydrology maps including surface and groundwater maps for watershed management etc.

Remote Sensing Applications in Agriculture



Under FASAL, crop estimation of 11 major crops is done for pre-harvest production forecast enabling farmers to better plan marketing activities. This is done through combination of remote sensing satellites under RISAT series and meteorological satellites under INSAT series.

FASAL: Forecasting Agricultural Output using Space Agro-meteorology and Land based Observation.

In addition, data from Earth Observation systems is the foundation for GIS systems built for planning of agriculture production activities. This is particularly useful in better utilization of fallow land post -kharif season thereby augmenting farmers income.

Recently remote sensing data is used in crop acreage and production estimation is used as for better implementation of PMFBY (PM Fasal Bima Yojana), the primary crop insurance scheme in the country. Remote sensing data acts as the foundation of Crop Insurance Decision Support System (CIDSS) developed for the purpose.

SOIL HEALTH CARDS

EO-satellites act as the foundation of Soil Health Cards that have been the game-changer in fertilizer-management in agriculture in India.

CROP INTENSIFICATION

Coordinated Programme on Horticulture Assessment and Management using Geoinformatics(CHAMAN) is a project that used remote sensing data to monitor fallow

lands in the post-kharif season in order to intensify horticulture production in the rabi season.

NEW INNOVATIONS TODAY: GEO FARMS

With the rise in IoT devices, data collection is accelerated helping emergence of new start ups build geo-spatial products like GEO-Farms. These geo-spatial products help in better supply chain management from farm to plate which becomes critical particularly in case of perishable agri-products.

CHAMAN

India grows 36 Mha of rice crop in kharif season in India. About 30% of this area is left fallow after the harvest of rice crop. Mapping and monitoring of post-kharif rice fallow lands using satellite data will help identification of suitable areas for intensification of rabi crop area.

Sub district level spatial level information is generated and studied for the assessment of crop intensification in major rice-growing states of India namely Assam, Bihar, Odisha, Chhattisgarh, Jharkhand, West Bengal.

The aim of this project is to provide an estimate of spatial extent and distribution of post kharif rice – rabi fallows, and also their suitability for growing short duration pulses.

Mobile applications are deployed for seasonal field data collection for geo-tagging the crop scenario. Information is available on Bhuvan-Crop intensification portal.

WATER RESOURCE MONITORING

GROUND WATER MAPPING

BUVAN BHUJAL is a ISRO's geospatial product that provides groundwater prospects map for the entire country

Ground water quality mapping is another important activity which is carried out by National Remote Sensing Centre having seasonal quality data of geogenic contaminants.

Salt water intrusions in coastal aquifers and its impact on groundwater system is being studied based on GPR & RS techniques.

Groundwater budgeting, draft estimation & Modelling studies under National Aquifer Mapping & Management (NAQUIM) project.

Monitoring Watershed development projects

NATIONAL HYDROLOGY PROJECT

National Hydrology Project is being executed for MoWR RD & GR, GOI.

This project is mainly about flood forecasting, drought estimation through the study of evapotranspiration augmenting irrigation scheduling.

IRRIGATION INFRASTRUCTURE MONITORING

Monitoring of irrigation infrastructure projects including canals, check dams, regulators, cross-drainage structures, syphons etc.

This Cartosat images act as foundation for the geospatial product, Bhuvan-AIBP prepared by Central Water Commission (CWC) helping the implementation of Accelerated Irrigation Benefit Programme (AIBP) of MoWR.

Web based monitoring and evaluation of 108 watershed projects is implemented in Gujarat (28), Rajasthan(31), Madhya Pradesh (13) and Telangana(36). Resourcesat IV and Cartosat series of satellite data is being used for monitoring the watershed related activities on annual basis.

FISHERIES

The remote sensing data like Ocean Colour and Sea surface temperature is used for preparing potential fishing zone forecast.

Note: Ocean colour: tells us about the diatoms and phytoplankton which are food for fish.

Sea surface temperature: temperature conducive for fish to exist.

Earlier INCOIS used to process this data and puts it in the fishing villages telling the fisherman at what distance in which direction you get fish catch.

Now we have Sagarmitra, a geospatial product that is developed which is a combination of Remote sensing, GIS and GPS technologies that sends live-messages in their mother tongue to the fisherfolks when in sea guiding them about potential fishing zones, rough weather and alerts when approaching international boundaries.

URBAN PLANNING AND DEVELOPMENT

Earth Observation satellite images provide the base for preparation of various application specific GIS databases which have augmented governance of urban local bodies.

Examples of thematic maps prepared using RS images include LU/LC maps, topographic maps, geological maps, groundwater potential maps, wasteland maps, infrastructure maps, traffic density maps, GHG emissions map etc.

These maps act as the foundation for National Urban Information System, a GIS database used for planning infrastructure and development activities in urban area like township development, route alignment for road, rail, oil/ gas pipeline, site suitability analysis for hydroelectric projects, facility & utility planning for identification of landfill sites, schools, hospitals, etc.

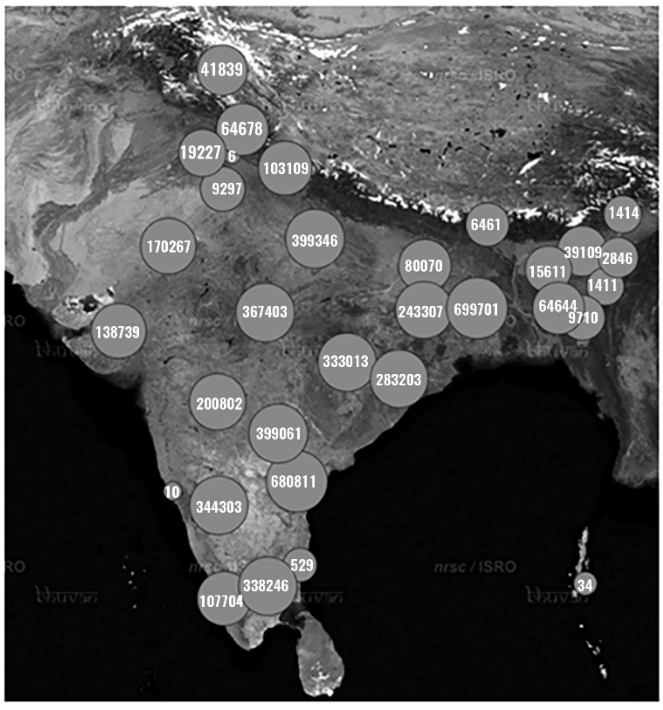
NUIS for 142 towns is prepared currently which acts as input for urban Local Bodies for Master Plan Preparation.

Similarly 242 cities are being mapped for 21 thematic layers using very high resolutions satellite data under national flagship AMRUT Mission ('Atal Mission for Rejuvenation and Urban Transformation') (AMRUT) which aims to provide basic services (e.g. water supply, sewerage, urban transport) to households and build amenities for 500 cities with Ministry of Housing & Urban Affairs (MoHUA).

RURAL DEVELOPMENT

Thematic maps on Land Use/Land Cover, soil, hydrology, wasteland, groundwater potential etc are extensively used by government for rural development.

GeoMGNAREGA - View of No. of Assets Created

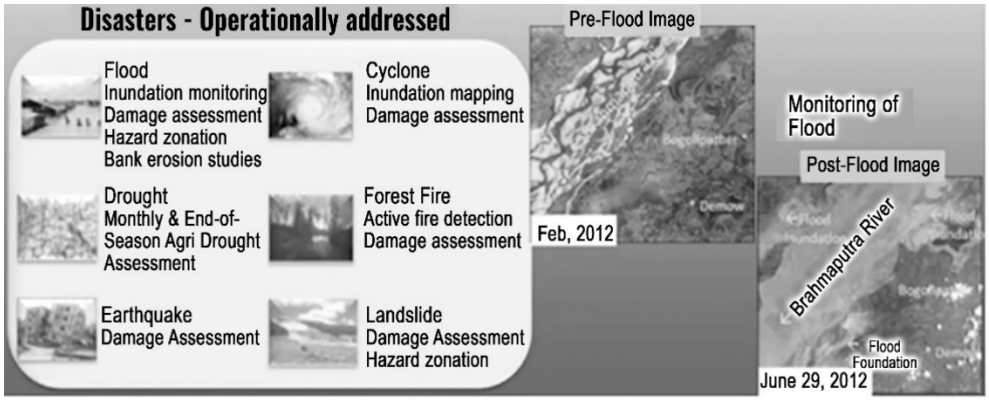


Recently GEO-MGNREGA a geospatial data product on status of assets created under MGNREGA is prepared which shows details of available employment, assets created, assets planned etc Currently information on 3.5 crore assets are already geotagged and distribution maps are in place in Bhuvan portal.

Besides conventionally remote sensing data and corresponding GOS systems are used in Accelerated Irrigation Benefit Programme (AIBP), Integrated Watershed Management, Programme (IWMP), On Farm Water Management (OFWM), National Health Resource Repository (NHRR) Project, Rural connectivity, Rural health sanitation improvement programmes etc.

DISASTER MANAGEMENT

National Remote Sensing Centre, Hyderabad has a Disaster Decision Support Centre established to monitor all natural disasters except volcanoes. These include flood, cyclone, agricultural drought, landslides, earthquakes and forest fires in near real-time using space and aerial remote sensing based inputs.



National Database for Emergency Management (NDEM) a national GIS system has been assisting State / Central Disaster Management Authorities.

Among other things tropical cyclone studies have been the most successful application of meteorological satellites reducing the number of deaths during tropical cycle from 10000 in 1999 to 25 during Cyclone Bulbul in 2019.

CLIMATE CHANGE MONITORING AND ENVIRONMENTAL STUDIES

NICES (National Information System for Climate and Environment Studies) a GIS database is built on input from EO satellites for preparation of glacial maps to study the retreating glaciers in the Himalayan region.

FOREST AND ECOLOGY STUDIES

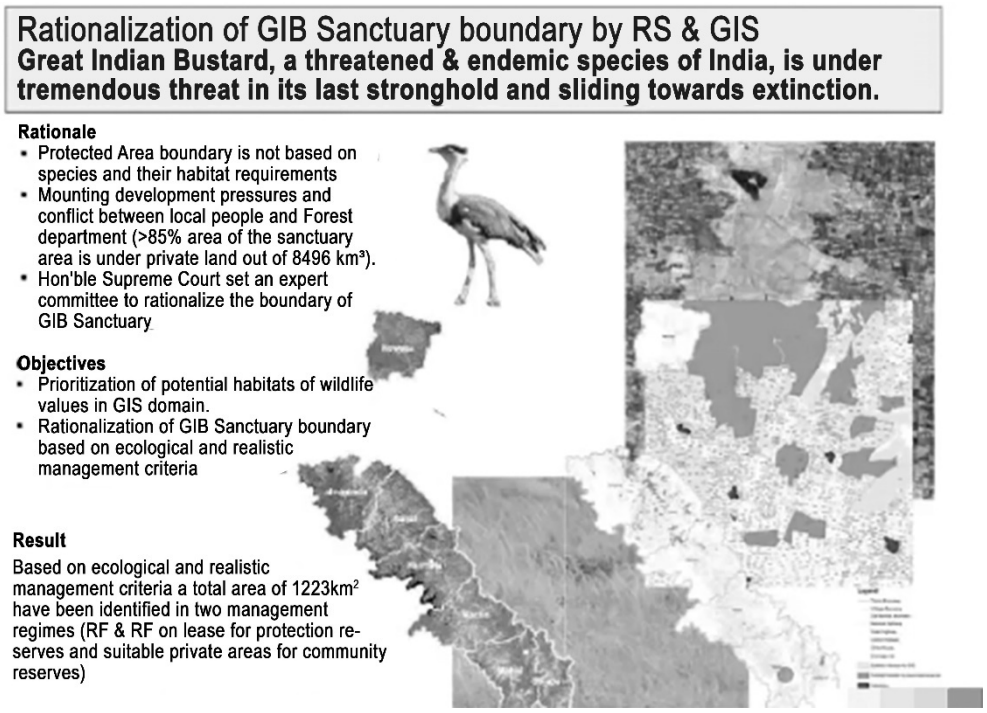
Forestry and Ecology studies at NRSC focuses on the development of GIS database to study forest cover change, spatial biomass estimation, Community Biodiversity characterization, forest fire alert system, inputs to working plan and wildlife plan preparation, Forest carbon sequestration, inputs to UNFCCC etc.

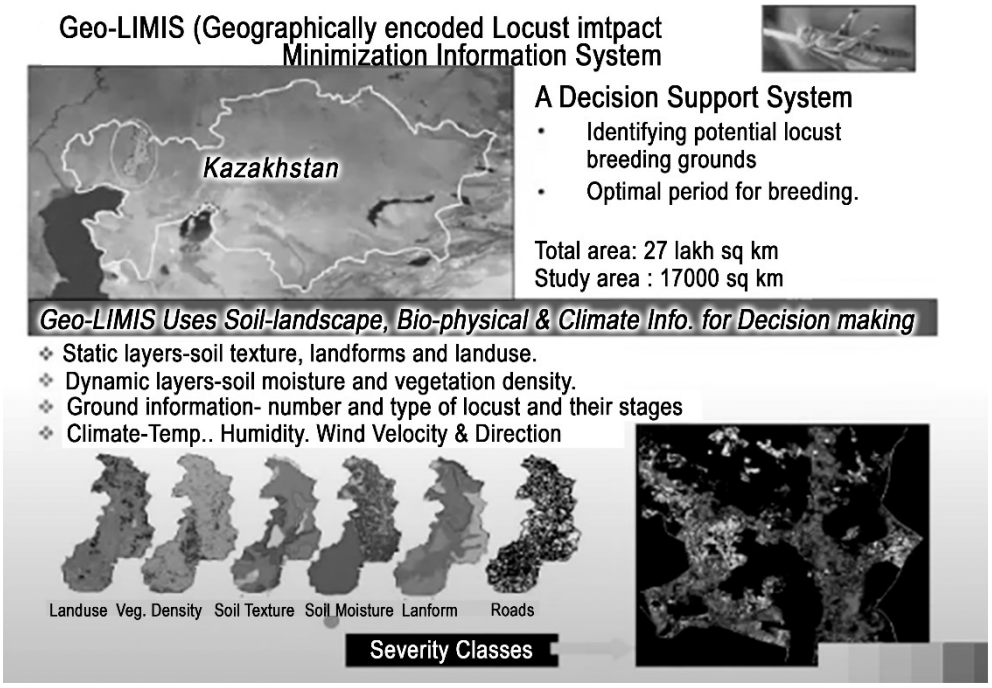
Besides Coral reef mapping and Mangrove mapping are also being carried with the help of EOS.

GEO-LIMIS is a GIS system used to assess the impact of locust attack on crops.

NISAR, a NASA-ISRO collaboration in the domain of remote sensing also aims to provide multispectral images to help in the study of bio-ecosystem of the planet.

BIODIVERSITY MANAGEMENT





5. COMMUNICATION SATELLITES AND SOCIO-ECONOMIC DEVELOPMENT

- SITE 1970s: Largest socio-technological experiment
- STEP: telecommunication late 1970s
- INSAT 2 onwards: All communication satellites are indigenous
- Critical communication services: VSAT
- Mass media revolution: INSAT-3: DTH

- Backbone of Bharatnet in remote locations
- Foundation to Mobile Satellite Services Application like Sagarmitra that enables direct communication from satellites to handheld devices with fisherfolks on the state of weather at the seas, fish catch, international water etc.
- Satellite-based internet: High-throughput satellites

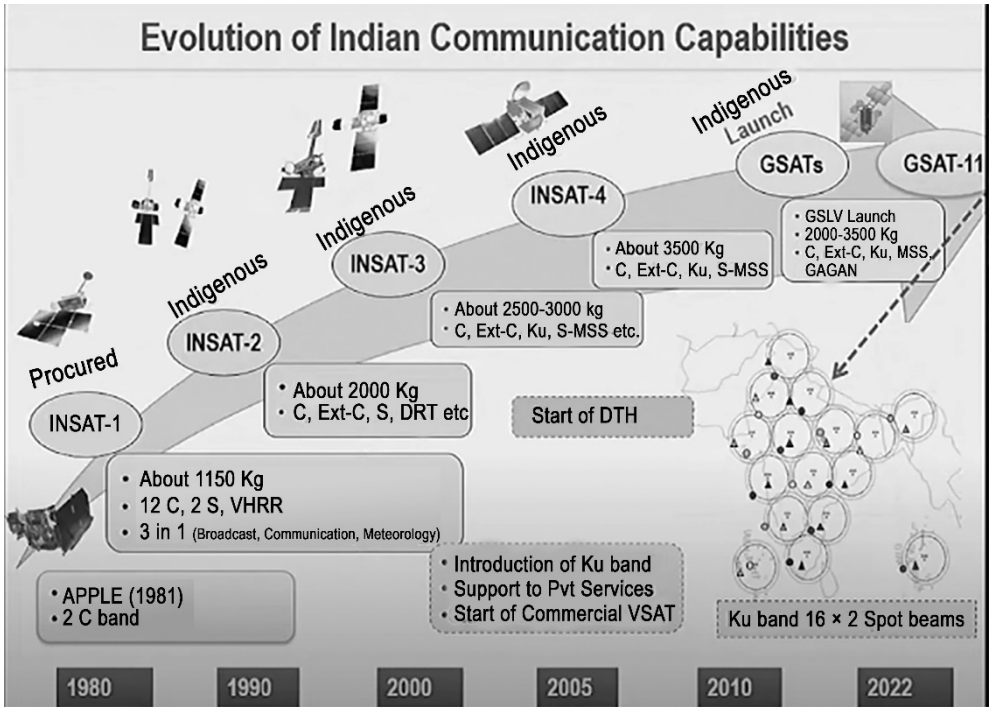
6. SATELLITE COMMUNICATION

The journey of Communication satellites began in 1970s with the SITE program which was the 1st space-based application for societal development. This mass-communication program paved the way for a full-blown communication service including tele-medicine, tele-education, television, telecommunication and meteorological services through the INSAT series which is the backbone of satellite communication in India.

SITE (Satellite Instructional Television Experiment) program was the most successful socio-technological experiment in the world at the time broadcasting instructional programmes to millions in the field of agriculture, primary education, family planning, teacher training etc.

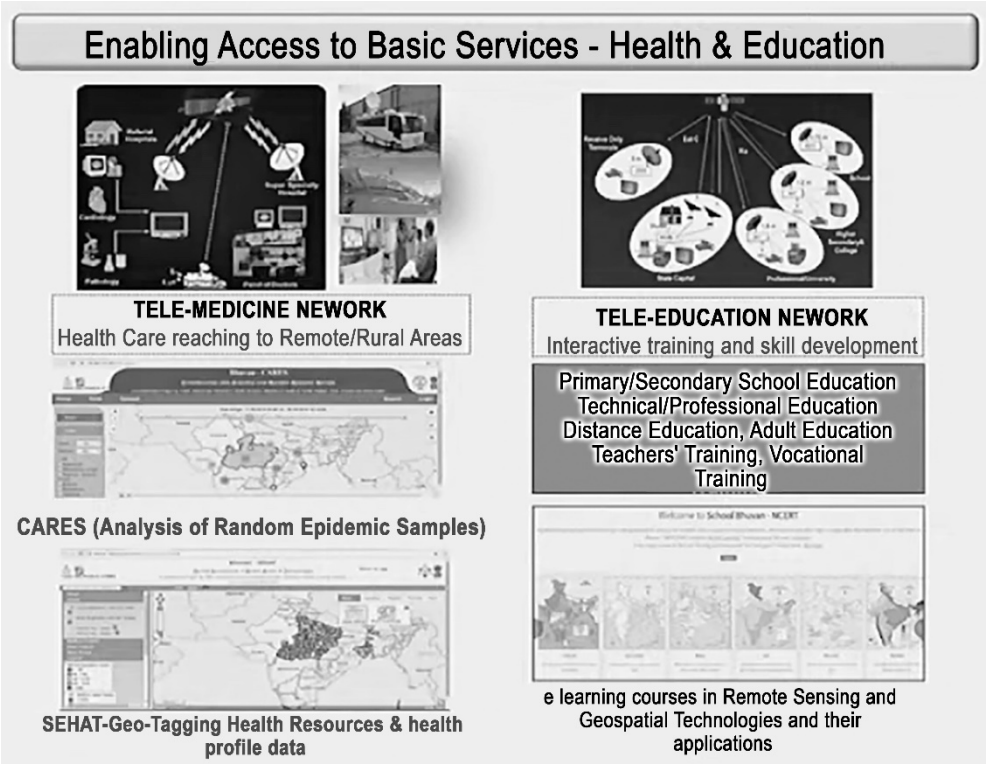
SITE covered more than 2400 remote villages with instructional programs from scientists, educationists, artists, economists and policy makers.

Satellite communication has been instrumental in building country's telecommunication networks, television services, secure communication for critical sectors like banking through VSAT (Very Small Aperture Terminals) etc.



Before the domination of terrestrial broadband network in the recent times it is the INSAT series that has been the backbone of tele-education and tele- medicine services linking people from remote corners of the country to super specialty hospitals.

Besides INSAT 3 onwards Direct-to-Home service has revolutionised mass media in the country.



Satellite communication has been the backbone of implementing Bharat Net project in the remote areas providing upto 20mbps internet to grama sabhas.

Now with the recent class of high-throughput satellites, satellite-based internet services is said to witness wide-spread dissemination including remote areas.

Mobile Satellite Services Application has been very useful in building secure communication networks like MSS Network for Coastal Surveillance, MSS terminal with every train providing real-time tracking services to railways etc.

Position, Navigation and Timing services through navigation satellites

Navigation satellites have wide-ranging applications including vehicle tracking and fleet management, maritime navigation services and port management, railways, aviation, disaster management support, geo-tagging and geo-fencing, survey applications power-grid synchronization, search and rescue etc.

NAVIC is said to move from regional to global coverage in few years helping new-age startups to develop products the global market.

7. COMMERCIALIZATION OF SPACE SECTOR AND SPACE SECTOR REFORMS

STATUS OF SPACE SECTOR: COMMERCIALISATION OF SPACE SECTOR

This is the introduction you can use for questions on both commercialisation of space and space reforms.

Space sector is undergoing a rapid transformation due to rise in demand for geospatial products that require location intelligence, internet-based satellites and massive machine-to-machine communication. (highlights the reason for surge in demand for space-based products in the recent times)

Despite being one of the 6 traditional space powers in the world, India's share in the commercial space sector has been very meagre. It holds less than 2% of the market share in commercial space-based products.

According to estimates, the global space market is currently valued at around $500 Billion and is said to double by 2030. Accordingly, India eyes to increase its market share to 10-20%. Accordingly, India has embarked upon a series of reforms in the space sector starting 2020 throwing open the space sector to private participation.

While India has so far demonstrated capabilities in all domains of space sector including satellite technology and space exploration, commercialisation of space technology products is the next natural leap. (use the flowchart below for Space 1.0 to Space 2.0)

Accordingly, India is taking steps in the recent time for capacity development enabling private participation in space-based activities manufacturing, launching, maintaining and tracking the satellites. With the rise of space-based products in the recent times like geospatial technology products and satellite-based internet, private sector is expected to play a greater role in commercialisation of space sector in India.

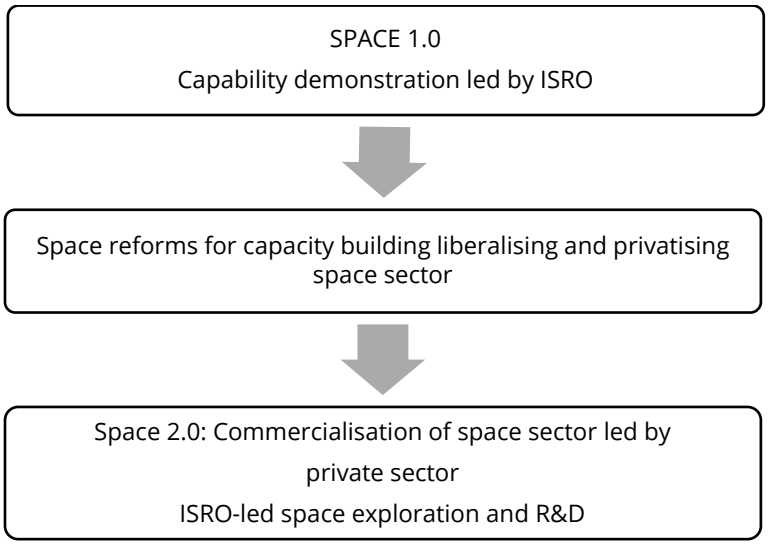
FROM SPACE 1.0 TO SPACE 2.0

The space sector in India is expected to swell in few years to come thanks to the recent space reforms introduced by the government.

A series of steps have been taken in space sector starting 2020 all aimed at liberalizing space sector and throwing open end-to-end space activities to private players.

The vision is to commercialise space sector as space-based products are increasing in demand with the proliferation of geospatial technologies, data-centred products, satellite-based internet and IoT devices.

Any effort towards commercialisation starts with building capability in the sector, then expanding capacity thereby increasing activities in the sector and finally commercializing the products.



SPACE 1.0

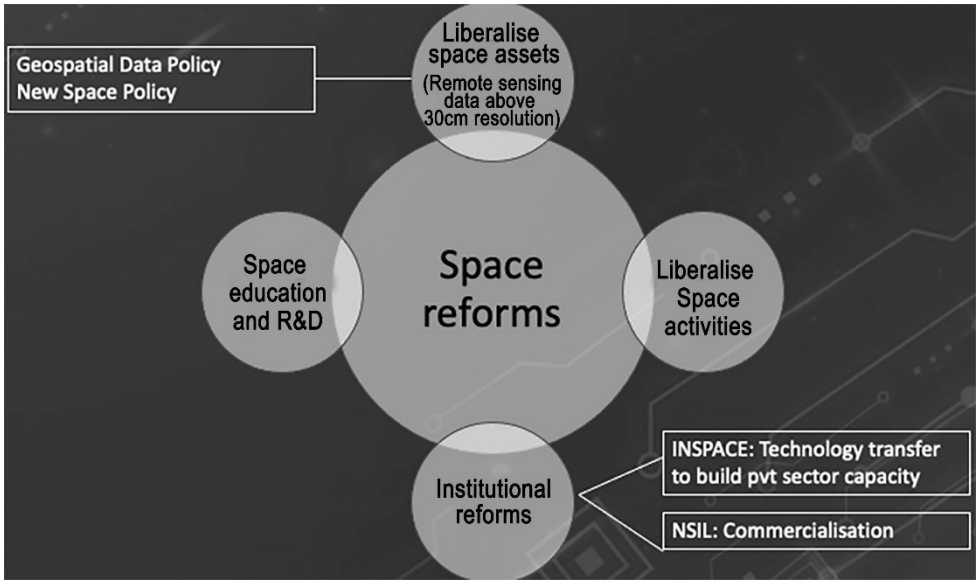
Space 1.0 demonstrates the phase which represents capability demonstration by ISRO which has established India into one of the 6 space powers with capabilities across all space activities including satellite manufacturing to launch vehicle capabilities. This is the phase in which private participation was limited to auxiliary activities in order to augment capability building of ISRO. While ISRO spearheaded space activities including design, development, launching, control, tracking and maintenance of satellites, private sector was involved in auxiliary manufacturing of satellite parts, launch vehicle parts etc.

SPACE REFORMS

Having acquired the capabilities, India is set to develop capacity in space sector to meet the growing demand of space-based products. Accordingly, space reforms is aimed at

enabling the private sector to build products to meet the growing demand be it satellite-based internet or geospatial technology products.

Accordingly space reforms can be put under 4 baskets:



One aimed at liberalisation of data from current space-based assets:

Accordingly data acquired using space-based assets which hitherto has been restricted to government use is being liberalized. Eg: Remote Sensing data upto 30 cm GSD (resolution on one pixel) is freely available to private companies. This can act as the foundation for various innovations in geo spatial technologies.

Two liberalizing space activities: Throwing open all space activities to private sector including satellite launch, launch vehicle, spaceports etc. (write examples from private sector initiatives in the recent times)

Institutional reforms: In the path to commercializing space sector private sector needs hand holding in 2 activities one is technology transfer and related policy framework and another marketing of their products. In order to do the former INSPACE is established and NSIL is helping in marketing of space-based products in India.

Space education and R&D: Programs like UNNATI are aimed at training professionals in satellite building and assembly. Besides to invigorate interest in school children ISRO conducts a training program on space science under the banner YUVIKA (Young Scientist Programme).

8. RECENT ADVANCEMENTS IN ROCKET TECHNOLOGY IN INDIA

LVM 3: 7 successful launches: LV for Gaganyaan

SSLV: Significance

RLV-TD: RLV-LEX: Successful testing of landing module

POEM: PSLV Orbital Experiment Module

Agnikul

PSLV productionisation by L&T and HAL

In line with India's vision of commercializing space sector led by private sector and ISRO-led missions to explore the far reaches of solar system, we are working on developing launch vehicle capabilities in all areas. In addition to ISRO's efforts at developing new-age

launch vehicles, private sector in India is also actively building rockets aiming at an entry into launch services market in space sector.

ISRO'S NOVEL ROCKETS

While SSLV is aimed at augmenting the private sectors capability to send small satellites with specific mission objectives, LVM 3's success in 7 missions is a good news for future inter-planetary missions and sending Indian astronauts to space.

SSLV: Increasingly satellites are becoming smaller as specific use cases have emerged in both remote sensing and communication satellites. With rise in internet satellites in LEO the demand for launch capability particularly for small satellites is increasing. Under current arrangement a small satellite has to wait for a big launch of PSLV or GSLV. Thus a need is felt to develop launch vehicles to provide on-demand services to small launches.

SSLVs can be assembled and launched in a span of 72 hours and capable of launching satellites upto 500kg at which make it suitable.

Besides since building the rocket body includes bulk of the cost of any launch (85%) we have been working on building reusable launch vehicle. RLV is a two-stage-to-orbit rocket that aims to bring back the 2nd stage of the rocket back to earth after placing the satellite in the desirable orbit. The 1st stage is expendable while the 2nd stage of the launch vehicle involves an onboard engine that can come back to earth's atmosphere and make a successful landing which was demonstrated recently.

In addition the last stage of PSLV is now converted to an orbital platform called POEM that can house small experimental satellites that may be used for testing before the actual satellite is launched. This helps in capability demonstration of novel satellites and can be utilised by private sector and research institutions at R&D stage.

In addition to above efforts of ISRO, private sector in India has developed launch vehicle capabilities. Vikram series of rockets are being developed by Skyroot which became the 1st private sector rocket to be launched by a Indian company in November 2022. They are designed to launched small satellites upto 800Kg to SSPO thus suitable for remote sensing satellites.

Agnibaan, an SSLV, is being built by private sector.

In addition HAL and L&T have signed a Service Level Agreement for production of PSLV in ISRO's facility under Government Owned Contractor Operated mode of production.

9. PRIVATE SECTOR ACTIVITIES IN LAUNCH VEHICLES

1st ever private space mission of India by Skyroot Aerospace

Vikram-S was a test-flight for Vikram Series of Rockets to be launched in the coming years.

It was a single-stage solid fueled rocket that did a sub-orbital flight.

VIKRAM SERIES

Series of 3 rockets in development to launch small satellites upto 815 Kg to SSPO

Solid-fuel rockets built on upgradeable architecture with carbon composite and 3D-printed motors

Can be assembled and launched in less than 72 hours.

Support communication services such as broadband internet, GPS, IoT from space and earth imaging.

Raman Engine: 1st private liquid propulsion engine developed by Skyroot **Kalam 5 engine:** Solid-fuel engine **Dhawan engine:** Cryogenic
Agnibaan: SSLV powered by a semi-cryogenic engine, Agnilet. (liquid kerosene as fuel and liquid oxygen) **Agnilet engine:** world 1st single piece 3-d printed rocket engine)
India's First Private Space Vehicle Launchpad

10. IMPORTANCE OF GRAVITATIONAL WAVES ASTRONOMY: LIGO (LAUNCH OF LIGO INDIA)

Gravitational waves are ripples in space-time that are produced whenever matter or energy oscillates. Normally the gravitational waves we detect is from massive objects oscillating thereby producing ripples/waves large enough for us to detect.

The presence of gravitational waves were predicted by Einstein in his general theory of relativity according to which space(normally represented as distance), time are not absolutes but depend on the motion of the observer. Besides space and time are intertwined. Spacetime is not rigid as conceived by Newtonian understanding of space. Rather space-time is affected by matter and energy and inturn affects them. If you think of space-time fabric as rubber sheet a massive object warps space-time making a dent in it. Thus when massive objects oscillate they "shake" the space-time making ripples in it just like how a pebble "shakes" the water molecules up and down creating ripples in the pond.

PRINCIPLE

The observatories that detect gravitational waves work on a principle called Laser Interferometry. This involves measuring the stretching and squeezing of space-time by observing the corresponding change in the path of light. As gravitational waves pass through the fabric of deformed spacetime, they cause light to stretch and squeeze. The observatories precisely measure these light fluctuations, allowing us to detect the presence of gravitational waves.

CONSTRUCTION

The observatory comprises two long vacuum chambers (4 KM each) built perpendicular to each other. At the end of the vacuum chambers are kept mirrors that reflect light.

Light rays are emitted from both ends at the same time detected back as they are reflected by the mirrors. Normally the reflected light has to appear simultaneously. However due to the presence of gravitational wave the spacetime streches and squeezes. As light passes through this deformed spacetime light also stretches and squeezes resulting in the reflected light appearing after a lag. In other words light at two ends are out-of-phase. The phase difference marks the detection of a gravitational wave.

SIGNIFICANCE OF GRAVITATIONAL WAVES

Gravitational waves are a proof to general theory of relativity. Besides we are on the lookout for gravitational waves from cosmic inflation phase of the big bang when universe expanded by 10^50 times in a short span of 10^-43 seconds to 10^-35 seconds.

This gravitational waves are present as background waves everywhere. The only challenge is they are so small our instruments are not sensitive enough currently to detect them.

LIGO-INDIA

LIGO is a network of multiple laser interferometers which are simply validating the readings of each other. As the GW waves are very feeble the instruments need to be very sensitive as they can be very easily affected by external factors like earthquakes, landslides or anything that produces a shaking in the ground.

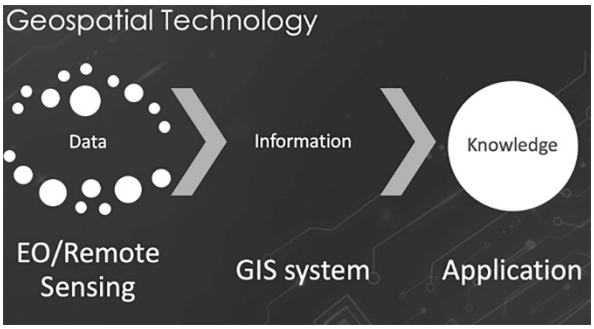
LIGO-India is the 5th of in the network of interferometers.

11. GEOSPATIAL TECHNOLOGIES AND GEOSPATIAL DATA POLICY

WHAT IS GEOSPATIAL TECHNOLOGY?

(Use this for Intro to geospatial technology)

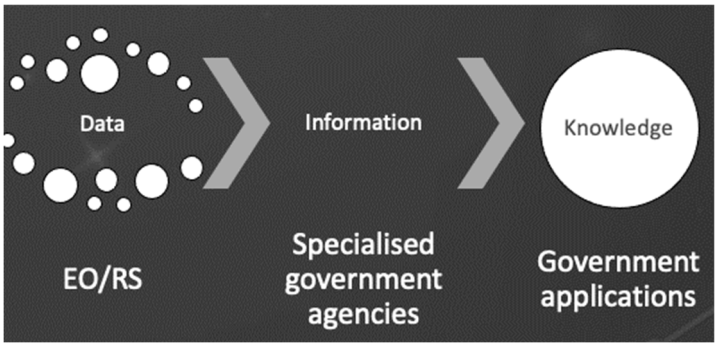
Geo spatial technology product is a location intelligent decision support system that uses a suite of technologies including remote sensing, navigation, communication and GIS systems.

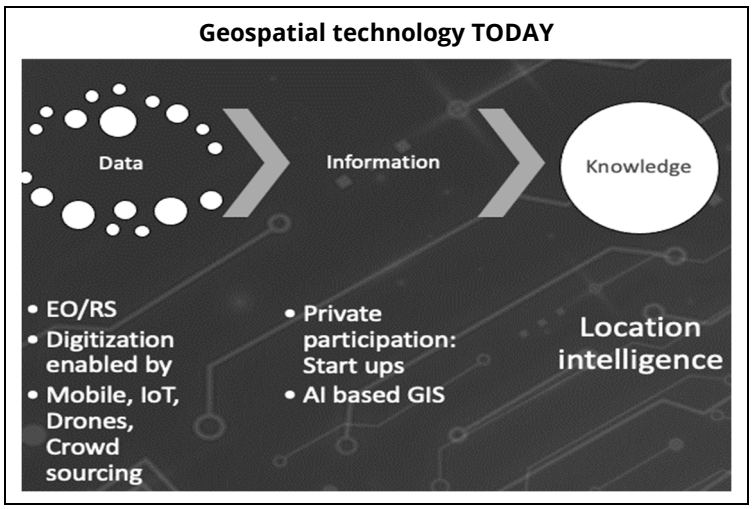


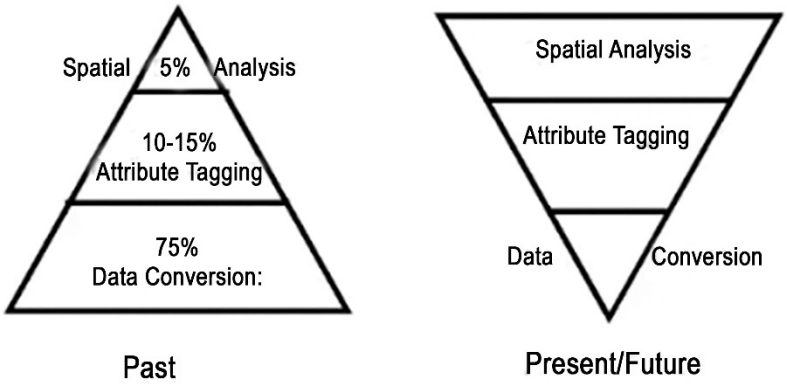
Geotagging, geo-referencing, geo-fencing are used in order to add locational attributes to data thereby enabling preparation of various interactive thematic maps are built as geospatial technology product

Example: ENERGY SWARAJ: NITI Aayog has built a GEOSPATIAL ENERGY MAP OF INDIA to present all energy-related information in one web portal. It is being used in implementation of Saubhagya scheme.

Geospatial technology of the PAST







Geospatial data policy is aimed at bring geospatial data, products and services in the open access movement thereby helping wide-ranging innovation both in private sector and social sector.

Currently the national repositories of geospatial data and information include the Survey of India (under the Ministry of Defence), the National Remote Sensing Agency (under the Department of Space and National Natural Resource Management System under Niti Aayog. If we liberalise geospatial data, products and applications the Indian citizenry can use them for variety of applications.

The current geospatial data and information distribution policies are premised on the principle of presumption of 'access denial' which is an impediment to the optimum use of the country's valuable national data resources for the purpose of the public good.

Almost all advanced nations have geospatial data distribution policies premised on the principle of presumption of open access. This is the crux of geospatial data policy.

2 CHAPTER BIOTECHNOLOGY

TOPICS TO BE COVERED

1. *Status of bioeconomy in India*
2. *Factors responsible for growth of Bioeconomy in India*
3. *Application of biotechnology in India*
4. *Genomics and its impact*
5. *Regulation of gene editing in India (recent amendments)*
6. *DNA Technology Regulation Bill*

1. STATUS OF BIOECONOMY IN INDIA

INTRODUCTION

- Sunrise sector
- Growth potential
- Growing relevance

SIZE

India is among the top 12 destinations for biotechnology in the world, with approximately 3% share in the global biotech industry.

Size of bioeconomy in India: $80 Billion

Target: $150 B in 2025 and $300B in 2030: 20% (India BioEconomy Report 2022 by BIRAC)

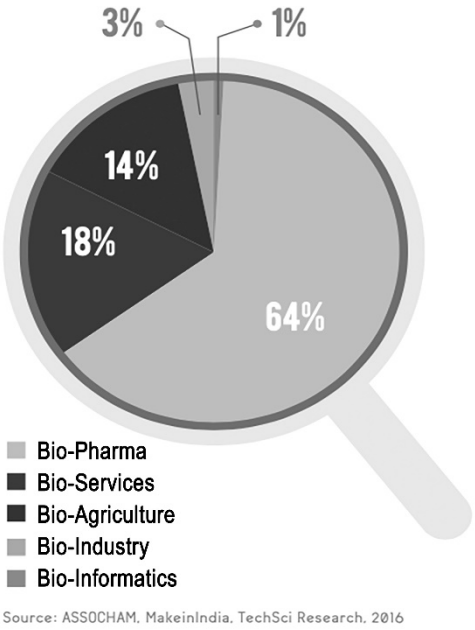
INSTITUTIONAL SUPPORT IN INDIA

- DBT and BIRAC
- No of start-ups: 5300
- No of BT incubators 75

5 COMPONENTS OF BIOECONOMY

Bio-pharma	Biotechnology in Agriculture	Biotechnology in Industry	Bio-Services	Bio-Informatics
• From biosimilars to biologics for therapeutics and cure • Diagnostics, therapeutics, vaccines and nutraceuticals • Preventive, Promotive and regenerative	• Food security Climate smart agriculture • Hunger including hidden hunger • Agri-input management is saturated	• Biofuels for cleaner environment • Alternative material (textile, silk, laundry agents)	• Contract manufacturing • Contract services (clinical trials)	• Omics in agriculture • Omics in health • Data sharing

Bioeconomy includes 5 sub-sectors namely biopharma, bio-agriculture, bio-industries, bio-services and bio-informatics.



Source: ASSOCHAM, MakeinIndia, TechSci Research, 2016

BIOPHARMA

India is often called the pharmacy of the developing world. Accounts for 64% of total bioeconomy of India.

Biopharma includes within its ambit disease diagnostics, therapeutics and preventive vaccines.

DIAGNOSTICS

Development of reagents/kits based on molecular diagnostics decreased the time improved efficacy of tests. India has been a leader in diagnostic kits for malaria, TB, typhoid, filariasis and Hepatitis.

Polyclonal and monoclonal antibodies for HIV-ELISA. Earlier we used to import the antibodies at exorbitant costs.

THERAPEUTICS

Conventionally from biosimilars to biologics (including monoclonal antibodies) Indian pharma products have been the backbone of therapeutic treatments where cure is not available. India has been a leader in generic drug manufacturing as we have low-cost process development. We are not good at building pharmacophores (a molecules that attach to a target biomolecule in cases of diseases) for new drug target. Pharmacogenomics has now helped in development for pharmacophores for new drug targets particularly for new drugs against diabetes, CVD, neurological diseases, cancer which require molecular target based approach.

VACCINES

Through incremental efforts from Vigyan Mission to National Biopharma Mission to Vaccine Maitri India has significantly stepped up its vaccine production. While India is a leader in global supply of DPT, BCG and measles vaccines, India has been supplying vaccines to more than 150 countries. Besides Hep-B vaccine is the 1st R-DNA product made by India.

Besides under Jai Vigyan Mission vaccines for cholera, rabies, TB, malaria, HIV, JE are developed and produced.

India has been home to more than 16 prequalified vaccines by WHO including the recent pneumococcal vaccine, rotavirus vaccines (to control diarrheal diseases) and 2 covid vaccines.

BIO-AGRICULTURE

An area which has contributed products useful in better breeding, nutritious, high-yielding and less resource input- demanding crops.

While conventionally biotechnology has developed improved variety of crops, biological substitutes of fertilizers, pesticides, etc. enhancing the quality of the yield, developments in genetic engineering, genomics and gene editing has resulted in crops resistant to both biotic and abiotic factors, molecular assisted selection for faster breeding, fortification of crops making them nutrition rich.

BIO-INDUSTRY

Enzymes and microbes have been used in production of industry-grade products including chemical and pharmaceutical, pulp and paper, human and animal nutrition, materials and polymers, textiles, energy, using renewable raw materials.

Particularly relevant is engineered microbes for the production of biofuels like ethanol through accelerated fermentation of hard to break sugar polymers.

Another example is enzymes that could remove stains in laundry replacing the conventional chemicals which caused phosphate pollution in water.

BIO-SERVICES

In developed countries due to escalating cost of production and strict regulatory requirements pharma companies look to developing world like India to provide for services like clinical trials, research ecosystem, contract manufacturing etc.

Being the 2nd most populous nation of the world and high disease burden India can be a suitable destination for services like clinical trials. Currently India's participation in clinical trails is less than 2%.

BIO-INFORMATICS

In the era of Industrial Revolution 4.0 there is increasing synergy between physical, digital and biological world. The synergy between biological data, data science and computing has given us new ways to develop new drugs, predict protein structures, find new drug targets etc. Param Biochrome and Parma BioBlaze are CDAC's supercomputing facilities used in cancer research bioinformatics. Besides with the growth in omics including genomics, proteomics, metabolomics, transcriptomics, cell atlas etc. India has stepped its efforts to set up a comprehensive bioinformatic systems through flagship programs like India Genome Project, Indigen, Human Atlas project etc. Further the setting up of Indian Biological Data Centre at Faridabad as an open access national repository for life sciences data has been a shot in the arm bio start-ups in India.

2. FACTORS RESPONSIBLE FOR GROWTH OF BIOECONOMY IN INDIA

Growth of bioeconomy in recent times (India Bioeconomy report)

Factors

- Rapid growth in technology
- Rapid advancement of better and cheaper technologies from R-DNA to genomics to genetic editing. (last decade)
- Eg: Genome sequencing cheaper and faster
- Institutional support (mention few initiatives)
- DBT and BIRAC helping in building research ecosystem and consequent hand holding of private sector.
- Growing relevance of bioeconomy in socio-economic development
- The biotechnology sector due to its holistic nature, holds the potential to provide a solution to the following societal challenges:
- Sustainable agriculture, food and nutritional security through GM crops
- Gene mapping, gene therapy for personalised and precision medicine
- Sustainable fuels for energy security
- Sustainable biodegradable materials for environmental sustainability

- (Replacement for plastics, Cellulo-lignosic biofuels, Xenobots-biodegradable robots used in remote environment like deep sea)

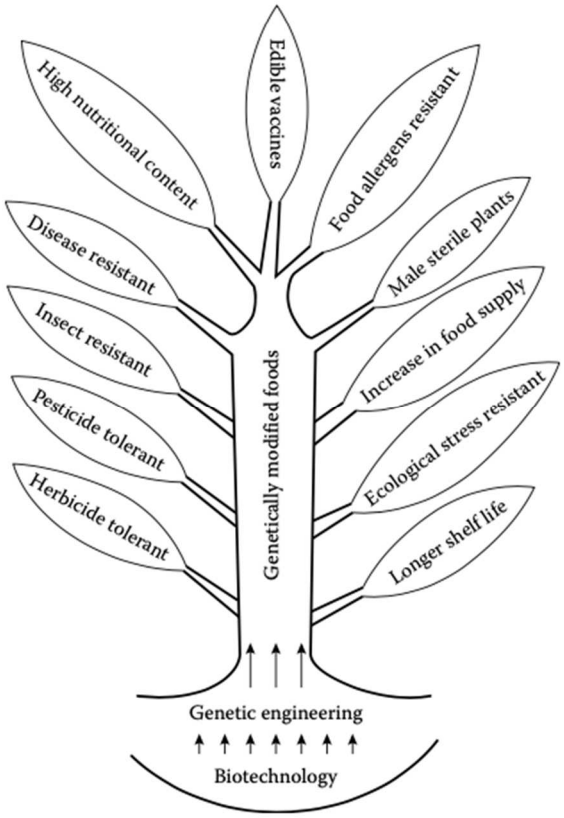
3. APPLICATION OF BIOTECHNOLOGY IN INDIA

***Q*. What are the applications of modern biotechnology? What is the role of modern biotechnology in bringing about socio-economic development in the contemporary times?**

While bioengineering has always been a part of human history since agriculture revolution 10000 years ago, modern biotechnology with the advent of recombinant DNA technology, genome sequencing and gene editing has accelerated this process in understanding and tweaking life processes for the benefit of humanity in various domains including agriculture, health and environment conservation.

Alternate intro:

Modern biotechnology with its ability to be precise, quick and cheap is increasingly seen as a solution to major socio-economic challenges that the world faces today including food and nutritional security (SDG 2: Zero Hunger), environment sustainability (SDG 7: Clean and affordable energy) and good health and wellbeing under SDG 3.



AGRICULTURE - PLANT AND ANIMAL

- Conventional: plant breeding, tissue culture
- Impact of R-DNA: GM Crops Eg: Bt. Cotton, Golden Rice etc.
- Impact of genomics: Marker-assisted selection accelerating breeding disease-free, high-yielding and nutrition rich crops. Rice Genomic Chip, IndiGAU etc.
- Impact of Gene Editing (potential impact for future)

HEALTH- PREVENTIVE, DIAGNOSTICS, THERAPEUTICS

- Conventional: Use of biologics
- Modern
- Impact of R-DNA: Insulin
- Impact of genomics: Omics for disease diagnostics, prevention and cure Eg: Use of Omics in 4 areas Cancer, Maternal and Child Health, CVD, Rare Diseases. (for more examples see answer below on omics)
- Gene Testing
- Impact of Gene Editing : CAR-T cell therapy

ENVIRONMENT – SUSTAINABLE BIO-MATERIALS, SYNTHETIC BIOLOGY

Conventional: Use of enzymes and microbes in various industries using bioremediation of oil spills, fermentation of sugar, laundry agents etc.

Modern

Impact of R-DNA: new material to replace plastics

Impact of genomics: Input for developing synthetic materials.

Impact of Gene Editing: GE-bacteria for nitrogen fixation

Eg: Pharma, Xenobots, Microbial fuel cells, Biofuels, lab-made meat

4. GENOMICS AND ITS IMPACT

What is the role of Genomics in recent advancements in modern biotechnology? What are the initiatives taken by government towards genomic research in India?

Introduction

Genomics is the field of building databases mapping the genotype and phenotype thereby improving our understanding of various traits of a lifeform helping us develop better solutions in agri, health and environment.

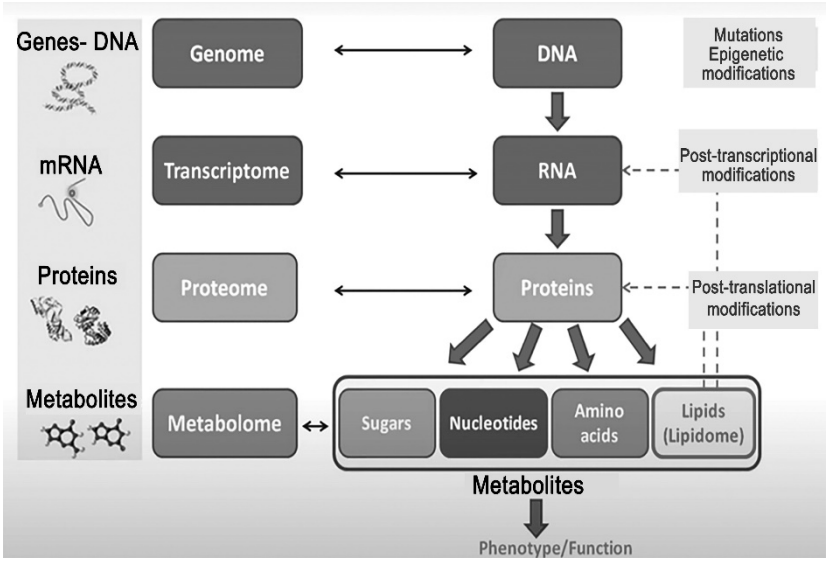
In the field of health genomics has been instrumental in the development of precision and personalised treatments, in disease diagnostics and drug discovery and also developing a reference genome to understand a population at the genomic level.

In agriculture genomics has been instrumental in faster breeding augmented by marker assisted molecular breeding to develop nutrition rich, high-yielding, disease-free and pest and weed-resistant crops.

Genome sequencing of nitrogen fixing bacteria has helped to engineer organisms that can improve their efficiency in the process.

India, in the spirit of One Health, has taken various initiatives including Genome India Project, INDIGEN, Human Microbiome Project, Human Atlas Project, Rice Genome Chips, IndiGAU etc. that will significantly improve our understanding of life forms in India (including humans) their relationship with environment and consequent development of bio solutions to socio-economic challenges we face.

One Health Approach: Omics



IMPORTANCE OF GENOMICS IN AGRICULTURE

APPLICATION

- Faster breeding (Marker-assisted selection)
- Plants reaction to biotic and abiotic stresses: NICRA
- Mechanism of pest attack
- Molecular mechanisms of pest, weed resistance
- Tolerance to herbicide

INDIAN INITIATIVES

- National Initiative on Climate Resilient Agriculture (NICRA):
- Genomics-Assisted Breeding (GAB) in Crops: rice, wheat, and chickpea
- National Bovine Genomic Center for Indigenous Breeds
- Dairying through Genomic Selection
- Genome India Project
- Crop Phenomics Projects

IMPORTANCE OF OMICS IN HEALTH

APPLICATIONS

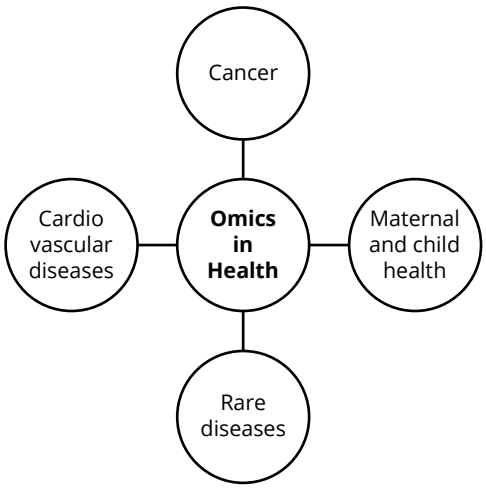
- Disease understanding and diagnosis
- Biomarker discovery and drug development
- Personalised therapeutics
- Preventive care: Nutrigenomics
- Population study and public health: One Health Approach

IMPACT

- Breast cancer: HER2 protein (increase in survival rate from 50% to 80%)
- Leukemia in children (increase in survival rate from 20% to 90%)
- Better understanding of MDR strains in case of infectious diseases
- HPV and its relation to cancer

Some initiatives (majorly in 4 domains shown in the figure)

- INDIGEN: Indian Genome Variation Consortium: Reference genome
- Genome India Initiative (disease factors)
- Genomics for Understanding Rare Diseases - India Alliance (GUaRDIAN)
- India Diabetes Genetics (INDIAGEN) Study
- I-PHARM
- Cancer Genome Atlas - India
- National Initiative on Human Microbiome Research
- Genomics for Understanding Neonatal Disorders (GUaND)



5. REGULATION OF GENE EDITING IN INDIA (RECENT AMENDMENTS)

In light of the recent amendments to rules relating to regulation of GM crops in India, differentiate between R-DNA technology and gene editing techniques. Do you think regulatory discrimination between the two is necessary?

R-DNA technology provides for transgenic organisms by facilitating gene transfer from one organism to another. Under R-DNA technology the desired gene to be inserted in target organism is cut from an organism that shows the desired trait. However this process of cutting lacks precision as the enzyme used for cutting the DNA is non-specific in that does not involve reading of the genome.

On the other hand genetic editing is performed by precisely reading the sequence in the gene thereby adding precision. Under gene editing technologies the enzymes used to cut the DNA can be made more targeted. These techniques are broadly known as Site-directed Nuclease technique. For eg under CRISPR-Cas9 technique an RNA is used to guide the enzyme that is used to cut the genome. This guide RNA can be prepared in the laboratory to have the same sequence as that of the target sequence that is to be modified/deleted/augmented.

Recently the Environment Protection Act (Rules for Genetically Modified Organisms 1989) was amended to bring certain category of gene-edited crops at par with conventionally bred crops. To do this it classifies non-transgenic and transgenic variety of gene edited crops. The rules now exempt those non-transgenic crops from regulatory approval of Genetic Engineering Approval Committee which is the apex body for regulation of GM crops in India.

ADVANTAGES

More precise

Less time-consuming

It could be the key to sustainable environment friendly agriculture.

Gene Editing with its precision can target specific mutation that is not desirable. This makes plant breeding more accurate.

In conventional plant breeding when crossing between 2 plants takes place in addition to desired traits undesired traits are also passed on. In addition it is time taking process. In the wake of climate change stress we need alternatives that act quickly.

CONCERNS

Regulation should be based on effect not on source of gene.

Since biosafety ecosystem is robust in India at the institutional level it is a good step to remove regulatory hurdle thereby augmenting the Indian farmer with much-needed technology.

6. DNA TECHNOLOGY REGULATION BILL

The DNA Technology (Use and Application) Regulation Bill will go a long way in reforming the Criminal Justice System in India. What is DNA profiling? How are DNA profiles established? What are the advantages of DNA profiling in investigation procedures?

Define DNA profiling and its use in criminal investigation.

- Briefly explain how DNA profiles are established.
- Highlight advantages of DNA profiles in crime investigations.

In order to improve the criminal investigation landscape in India DNA Technology (Use and Application) Regulation Bill seeks to allow DNA profiling in specific cases.

DNA profiling is creation of a biometric database comprising DNA information of individuals. It is generally done in order to establish the identity of certain categories of persons including missing persons, offenders, under trials, unknown deceased persons, disaster victims, crime victims etc. Besides DNA profiling also helps in determining biological relationships to establish parentage, viability of organ transplantation etc.

Establishing DNA Profiles

While DNA is unique to an individual's genetic makeup, it is 99.9% similar between all individuals within the human species. The variable regions (0.1%) that are unique to individual's DNA constitute the DNA profile of that individual. The DNA profile of an individual varies in some regions in terms of the number of times a sequence of nucleotide base pairs is repeated. Thus by counting the number of times these base-pair sequences are repeated in these variable regions a DNA profile of an individual is established.

Advantages of DNA profiling in criminal investigation procedures

- DNA profiling helps in precisely establishing the biological identity of a person and thus **more reliable**.
- Further unlike blood samples, DNA material remains **usable for long periods** of time.
- Since DNA profile of an individual reveals no information about age, race, behavior or other features it also helps in **protecting the privacy** of the individuals.

As a result of above advantages, DNA profiling can go a long way in improving the conviction rates in crimes like rape, murder etc which is as low as around 30% in India, currently.

Secondary Patenting

- In order to protect the patent rights of a pharma company over a drug, primary patent is issued.
- Primary patent is issued over the active pharmaceutical ingredient of a drug usually of 20 years.
- During the 20 years the drug is usually expensive as an incentive to the research efforts of the company holding the patent rights.
- At the end of 20 years generic versions of the drug is allowed to be manufactured and thus the prices of the drug come down.


News / Explained / Explained Health / Secondary patent for Johnson & Johnson TB drug rejected: How this will help in India's fight against tuberculosis

Secondary patent for Johnson & Johnson TB drug rejected: How this will help in India's fight against tuberculosis

The move promises to bring down prices and improve access, assisting India in its mission to eliminate tuberculosis by 2025.

Written by Anonna Dutt

New Delhi | Updated: April 2, 2023 23:50 IST

NewsGuard

ADVERTISEMENT

- As a strategy to continue getting profits keeping the price of the drug high, the pharma companies adopt strategies called secondary patents or evergreening.
- Secondary patents are usually sought for derivatives and variants of the API, a new formulation, a dosage regimen, or a new method of administering the medicine.
- This strategy of extending the patent rights beyond the 20 year period by seeking secondary patents even before the expiry of primary patent is called 'Evergreening'.
- Section 3(d) of the Indian Patents Act provides an effective defence against secondary patents misuse and thus evergreening in India.
- According to Section 3(d) in order to be eligible for secondary patent, the drug must demonstrate significant improvement in therapeutic efficacy and not just change in formulation of the drug.

3 CHAPTER NUCLEAR TECHNOLOGY

TOPICS TO BE COVERED

1. *Case for Nuclear in decarbonizing India's energy sector*
2. *Small Modular Reactors*

1. CASE FOR NUCLEAR IN DECARBONIZING INDIA'S ENERGY SECTOR

BOTTOMLINE: NUCLEAR CAN REPLACE COAL IN SUPPLYING BASELOAD.

1. Bulk green power: Lowest emissions per KWh

- Paris Agreement: Limit on the generation unit on CO_2 emission: 50gm/Kwh.
- Coal 888, Gas-499, Nuclear-29

2. High capacity factor:

- 80-90%
- Coal: 55-60, Solar: 20%

3. Higher power per unit

- 1600 MW v/s 500-1000 MW for coal

4. Small land footprint:

- Area/Mwe: Nuclear 13, Wind-71, Solar-44, Hydro-315

5. Low waste volume

6. Competitive

Crores/MWh

- Nuclear - 97-394, Coal - 375-529, LNG: 423-439

7. Nuclear over Renewables

- Intermittency
- Critical mineral dependence

8. Low critical mineral dependence

CRITICAL MINERAL DEPENDENCE

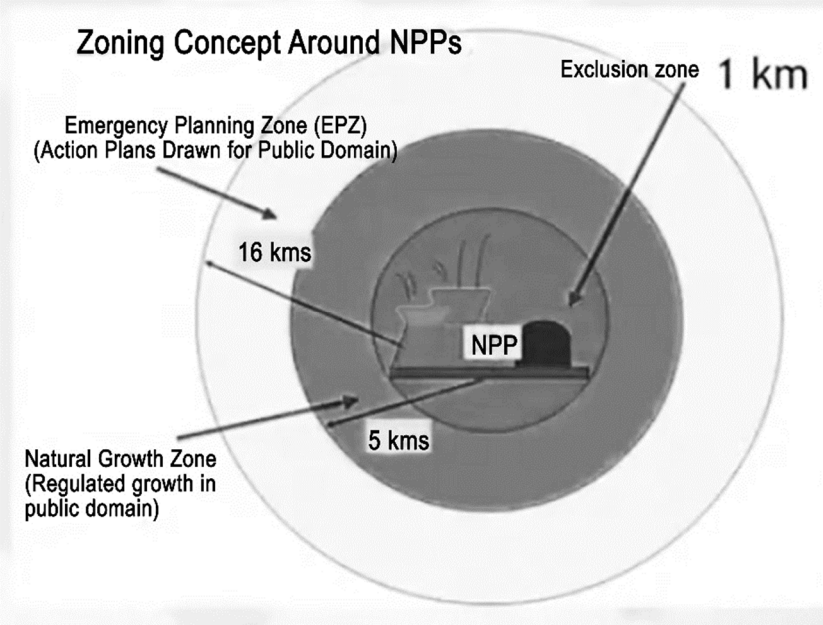
- Solar PV: Cu-1.8 MT, Indium-0.04 MT, Lead – 0.16, Tin – 0.22 MT
- Battery: Li-0.3MT, Cobalt-0.2, Nickle-0.2, Zn-0.7, Al-94(v/s 0.3), Copper-92 (v/s 0.2)
- Nuclear: Nickle-0.004, Hafnium-0.009, Zirconium-0.004

CHALLENGES TO NUCLEAR

Fuel shortage

- Public perception
- High investment
    - For 100 MW plant we need 20000 crores.

- Construction period is about 10 years.



- Time and cost overruns: due to non-modular design
- Zoning requirement
- Dual-use
- Accident history

2. SMALL MODULAR REACTORS

WHAT ARE SMALL MODULAR REACTORS? DO YOU THINK SMALL MODULAR REACTORS WILL DRIVE THE NUCLEAR RENAISSANCE IN INDIA?

Defn: 10-300 MWe as per IAEA definition

NEED FOR SMR

- currently 3% at around 9000 Mwe.
- 42 reactors by 2030
- 400TWh against the total demand of 20000MWh

CASE FOR SMR

Small: makes it scalable

Modular: built as one unit, thus flexible

No time and cost overruns

Walk-away-safe reactor

Passive safety mechanism: Maximum temp reached 1000 degree C

No EPZ requirement

Water-cooled reactor is 6-decades old: No time in R&D

SIGNIFICANCE

- Driver of base load in green-dominated grid: Coal-to-nuclear
- Driver of nuclear renaissance

4 CHAPTER ENERGY TECHNOLOGIES

TOPICS TO BE COVERED

1. *Theme: Components of energy basket for low carbon future for India*
2. *Pathway to low-carbon future*
3. *Coal energy in India*
4. *Methanol economy*
5. *Hydrogen Economy*
6. *Li-ion batteries*

1. THEME: COMPONENTS OF ENERGY BASKET FOR LOW CARBON FUTURE FOR INDIA

India has set on a path towards low carbon future as can be seen in its targets from Paris Agreement to Panchamrit goals declared at COP-26 in November 2021. These targets include

Paris Agreement - 33-35% of 2005 levels

Panchamrit Goals

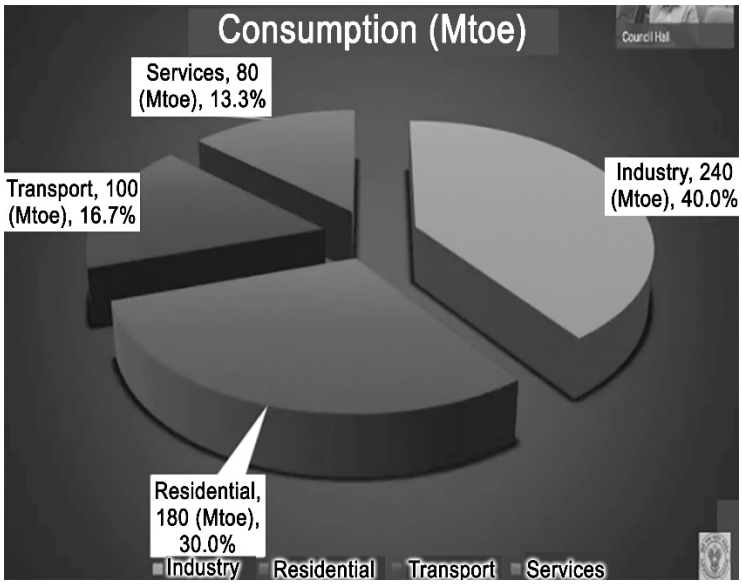
1. Emission intensity reduction by 45% of 2005 level by 2030
2. 50% cumulative electric power installed from non-fossil fuel
3. Mission 500GW (148GW is achieved) RE.
4. Additional carbon sink of 2.5-3 billion tonnes by 2030
5. Mitigate 1 billion tonne
6. Railways to become net zero by 2030

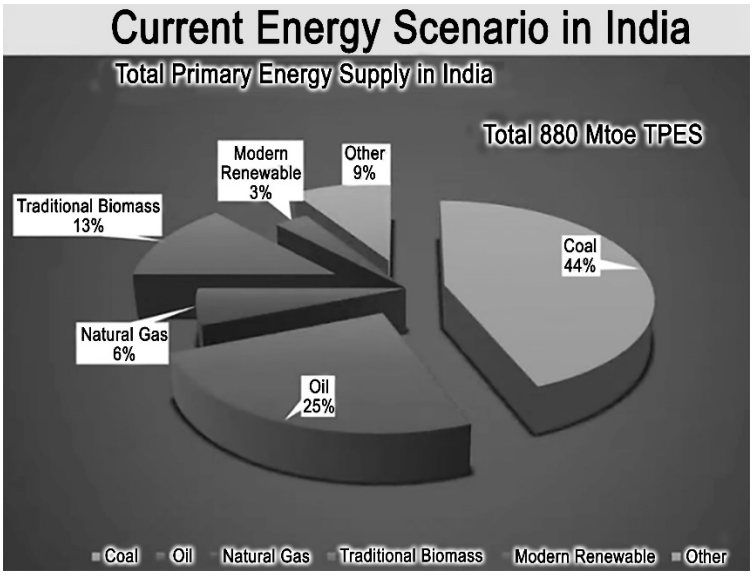
Challenges to low-carbon future

- India's total GHG emissions in 2020: 3.3 billion tonnes: 3-4% CAGR
- Energy sector: 75%
  - Coal based power 45%
  - Industry-24%
  - Transport-12%
  - Agriculture-17%
- We expect to peak only by 2040-45
- Further the efficiency with which we use energy can be determined by the difference between Total Primary Energy Supply and Total Primary energy consumption. Higher the difference lower is the energy efficiency use. While India's TPES is 900 units its TPEC is 600 units which shows low energy efficiency use majorly accounted by T&D losses.
- Besides India has lowest per capita energy consumption which is directly related to standard of living. (see figure)
- Import dependence: More than 50%

- India - 1208 kWh
- Singapore - 9220 kWh
- Malaysia - 4810 kWh
- Thailand - 2870 kWh
- China - 4600kWh
- World Average - 3150 kWh
- OECD countries - 7990 kWh)

- Oil: 2/3
- Coal: 1/3rd
- Natural gas: ½





2. PATHWAY TO LOW-CARBON FUTURE

IN POWER SECTOR

- Short term: Retire coal plants older than 25 years + Coal conversion + CCUS technologies
- Long-term: Mission 500GW & 50%: 500 GW of non-fossil fuel and 50% from renewables
- For green-energy dominated grid use nuclear energy for base load as renewable suffers with intermittency challenge.
- In addition for green-energy dominated energy sector energy storage is quintessential.

IN TRANSPORTATION

- Short-term: Alternate fuel
- Methanol from coal
- Ethanol from bio-origin: cellulosic biofuels

- Long-term: Renewables + Hydrogen (FCEV)

3. COAL ENERGY IN INDIA

- Generation capacity: 54% (due to recent impetus on increasing solar capacity)
- Generation share: 72%

STATUS OF COAL IN INDIA

- How much do we have? 307 Billion Tons
- How much do we take out? 900 MT to reach 1 Billion
- How much do we use? 850 MT
- How much do we use for electricity? 80 %

STATUS OF THERMAL POWER PLANTS IN INDIA

- 611 TPP catering to about 200 GW
- 184 are more than 25-year old.
- Over capacity:
- Peak demand: 200 GW
- Capacity is 390 GW
- Soln: Retire

SOLUTION: COAL CONVERSION

- Coal conversion simply means converting combustible solids (coal) to combustible liquids or combustible gases.

GASIFICATION OF COAL

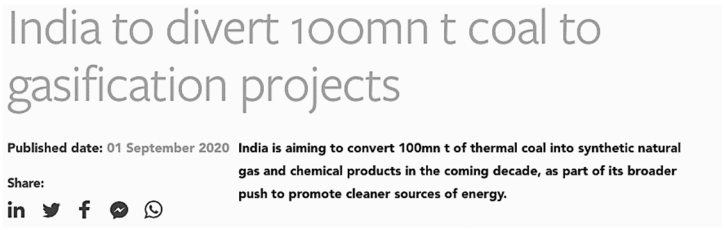
- India has set a target of gasifying 100 MT coal.
- While the goal of combustion is to produce the maximum amount of heat possible by oxidizing all the combustible material, the goal of gasification is to convert most of the combustible solids into combustible gases such as carbon monoxide, hydrogen, and methane.
- Coal gas/Producer gas
- Burn coal with air: complete combustion ----> CO_2
- Burn coal with controlled oxygen: incomplete combustion ----> [CO + N_2]. This is called coal gas or producer gas.
- Advantage
- Fly Ash is absent.
- Less NOx formation due to low temperature of incomplete burning
- Carbon sequestration is easy (easy to remove nitrogen from flue gas as compared to oxides of nitrogen)
- Syn Gas
- Alternately burn Coal with Steam -----> CO + H_2 (Synthesis Gas/Syngas)
- Aptly this is called steam reforming.
- You can make variety of things using Syngas like Methanol, Hydrogen, Methane (methanation).

India's first coal gasification based fertiliser plant on track

Outbreak of Covid-19 pandemic notwithstanding, India's first coal gasification-based fertiliser plant at Talcher is on schedule.

Published: 10th January 2021 04:35 AM | Last Updated: 10th January 2021 08:51 AM

- Syngas can be used to make ammonia-based fertilizer.
- N2(g) + 3 H2(g) -----> 2 NH3(g)
- Advantage
- Reduced CO2 emissions.
- Syngas is combustible.
- NOx is not formed.
- Fly Ash is absent.
- Syngas can be used to make methane in a process called Methanation/ Hydrogasification
- CO+3H2----->CH4 + H2O


India to divert 100mn t coal to gasification projects

Published date: 01 September 2020

Share:

India is aiming to convert 100mn t of thermal coal into synthetic natural gas and chemical products in the coming decade, as part of its broader push to promote cleaner sources of energy.

Advantage:

- CH_4 is combustible.
- CO_2 is not produced.

4. METHANOL ECONOMY

METHANOL

- Methanol is obtained by tweaking the temperature and pressure of syn gas obtained from gasification process.
- CO(g) + 2 H_2(g) ----> CH_3OH(l)
- Methanol is also called wood alcohol.


Coal ministry to focus on coal gasification to produce methanol, fertilisers over 3 years

During the gasification process, oxygen and water molecules oxidize the coal and produce syngas - a gaseous mixture of carbon dioxide (CO2), carbon monoxide (CO), water vapour (H2O), and molecular hydrogen (H2)

Anshul Joshi • ETEnergyWorld • Updated: March 11, 2020, 11:22 IST

ADVANTAGE

- Methanol can directly be used in IC engines or even converted to petrol using a zeolite catalyst.
- Note that methanol can be produced from any hydrocarbon not just coal including natural gas, biomass, and even captured carbon dioxide. Only thing you need to adjust the amount of hydrogen.

SIGNIFICANCE OF METHANOL

- Methanol cars are becoming common especially in China where coal is in abundance.
- Methanol can also be used in fuel-cells and thus could drive the EV revolution.
- India by adopting Methanol can reduce its import dependence on oil and at the same time have a cheaper fuel (at least 30% cheaper than any available fuel)
- Niti-Aayog is set to come out with a roadmap for transition to Methanol Economy.

ROADMAP FOR METHANOL ECONOMY

TARGET

- Replace 10% of crude oil with methanol

HOW DO WE GET THERE?

- Produce 30 MT methanol
- 2 MT coal = 1 MT methanol

- M-15 for 2 and 4 wheeler
- M-100 for buses and trucks
- Replace 15% of vehicular fuel

SIGNIFICANCE

- Import bill to reduce by $100 Billion by 2030
- Cost of producing 1 litre: Rs.20
- Consumer spends 30% of what she is paying.

5. HYDROGEN ECONOMY

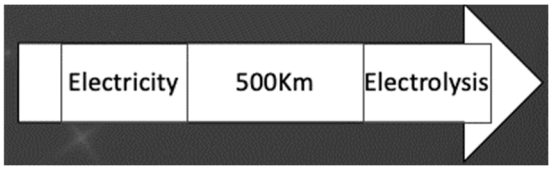
ROADMAP TO HYDROGEN ECONOMY

TARGET BY 2030

- 5 MT : 10 times increase

CHALLENGE

- No universal definition of green hydrogen
- Import barriers: Germany case: (hydrogen produced out of electrolysis using electricity transmitted for more than 500 km is not considered green hydrogen by Ge)



- Cost of manufacturing: 65%
- Rs. 300-500 per kg
- Source energy for 5 MT
- Capacity: 8GW today
  - from renewables: 110 GW: Rs. 6 Trillion
  - Water: 50 billion litre (1 Kg H2= 9 litres of water)
- Electrolyser challenge
- Global capacity: 8GW/year
- India needs: 60-100 GW
- Critical mineral dependence: Nickle, Platinum, Lanthanum, Yttrium, Zirconium
- No resource: Concentrated in China, Democratic Republic of Congo, Australia, Indonesia, South Africa, Chile and Peru
- No processing facility.

WHY HYDROGEN?

- A general trend towards development of better fuels is hydrogen-rich fuels.
- This means more of hydrogen in the fuel and less of carbon or more hydrogen to every carbon atom. Eg: Natural gas 4 hydrogen to every carbon as opposed to very little hydrogen in coal.
- This is because just like carbon, hydrogen is also combustible, i.e. it mixes with oxygen in the air and gives heat.
- In addition, moving from a solid to a liquid and then finally to a gaseous state energy carrier.

NATURE OF HYDROGEN

HYDROGEN AS AN ENERGY CARRIER

- It is important to understand that all fuels we have seen so far are energy carriers.

- Hydrogen is the best energy carrier as there are no harmful impact (read carbon emissions)
- This is because hydrogen is not freely available on earth, but it is in abundance in the form of in water and hydrocarbons.
- However, to extract hydrogen from water or hydrocarbons you need to expend energy and the energy spent in extracting hydrogen is much more than the amount of energy the so-extracted hydrogen gives out. This is why hydrogen is energy carrier and not an energy source. (in fact all fuels we have seen are energy carriers)

COMBUSTIBLE NATURE

- Hydrogen is highly combustible i.e. it mixes readily with oxygen to produce heat.

HIGH ENERGY DENSITY PER GRAM

- Further the amount of energy out of this process is about 3 times higher than that you get when you burn petrol. (26 Kcal/gm for hydrogen compared to 10 Kcal/gm for gasoline).

EXTREMELY LOW DENSITY PER VOLUME

- However, the problem with hydrogen is that it has low density, meaning the amount of hydrogen mass you can hold in 1 liter is about 71 grams.
- That means the tank size at normal temperature and pressure to hold hydrogen is very big.
- In other words, though the fuel itself is lightweight the tank size and therefore the weight of the tank goes higher.
- This puts a limitation on hydrogen being used as a fuel in private transport.
- Thus, hydrogen is suitable for large vehicles like buses which requires a limited range but can hold a large tank.
- This requires hydrogen to compressed at high pressure. Alternately you can liquify hydrogen by compressing and taking away heat.

HOW TO MAKE?

- You can't mine hydrogen. There is virtually no hydrogen gas (or liquid) in the environment.
- But there's lots of hydrogen in water and in fossil fuels (hydrocarbons)-but not "free" hydrogen, the molecule H2.
- That's what we want for the hydrogen economy.
- Two major sources of hydrogen on earth are water and hydrocarbons
- From hydrocarbons
- Take any hydrocarbon and treat it with steam we get syn gas which is a source of hydrogen.
- Any hydrocarbon+H2O→ CO+H2
- Hydrocarbon could be either fossil or biofuel or even organic waste.
- However, hydrocarbon source of hydrogen is again a problem because the left over carbon has to go to atmosphere.
- This makes it dirty. That's why hydrogen from these sources is colour coded with 'dirty' colours like grey, blue, black etc.

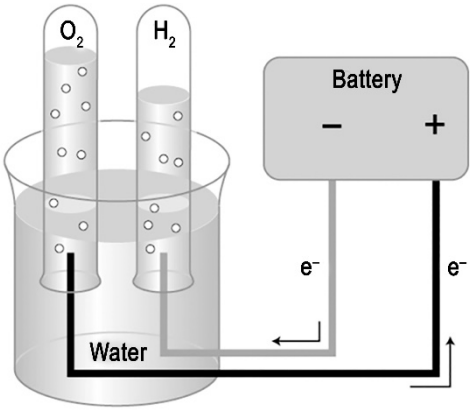
NATIONAL GREEN HYDROGEN MISSION

- Budget 2021-22 proposed the National Hydrogen Mission to make India the hub of green hydrogen production.

- In Feb 2022 the National Green Hydrogen Policy was formulated.
- In 2023, the cabinet approved Rs.19,744 crore towards other Mission components.

ELECTROLYSIS OF WATER

- Pass electricity through water, it will split it into its constituent Hydrogen and oxygen.
- Process where electricity is used to make a chemical change that wouldn't happen otherwise.
- In a normal situation oxygen pulls electrons and hydrogen pushes its electron.
- In case of electrolysis, water is split into hydrogen and oxygen and for this to happen hydrogen has to gain electron and oxygen has to lose electron which is the opposite to what happen normally.
- This requires energy which is what electricity gives.



- So, take a battery use the energy to pull the electrons out of oxygen and push it towards hydrogen.
- If the electricity you use to split water comes from renewable source, it gives you green hydrogen, the cleanest source of hydrogen.

HOW TO USE HYDROGEN?

- Burn it in directly IC engine, blend it with another gaseous fuel or use it in fuel cell.
- Hydrogen being combustible can be used directly in IC engine. However, the efficiency is very low, hardly 25-30%.
- Alternately we blend hydrogen with natural gas. This is what is called H-CNG.
- Advantages of HCNG
- The energy density increases.
- Carbon emissions are reduced.
- Low NOx emissions
- No sulphur emissions

6. LI-ION BATTERIES

The success of Electric Vehicle revolution is said to be dependent on the success of Lithium ion batteries manufacturing in India. What are the advantages of Lithium ion batteries? List down some of the challenges to the development of Li-ion battery manufacturing in India.

APPROACH

- **Introduce by highlighting the importance of Li-ion batteries in EV revolution.**
- **Highlight the advantages**
- **List down challenges**

Lithium ion, batteries are rechargeable, lightweight batteries that have revolutionised safe energy-storage. Thus, light weight and high energy density of Li-ion batteries make it an ideal choice for Electric Vehicles that have high efficiency compared to internal combustion engines. However, given that batteries constitute the major constituent of

electric vehicles, developing manufacturing capabilities of Li-ion batteries is a must for electric vehicle revolution in India.

THE ADVANTAGES OF Li-ion BATTERIES INCLUDE

Light weight: Lithium ion batteries are the lightest batteries because lithium is the lightest metal available.

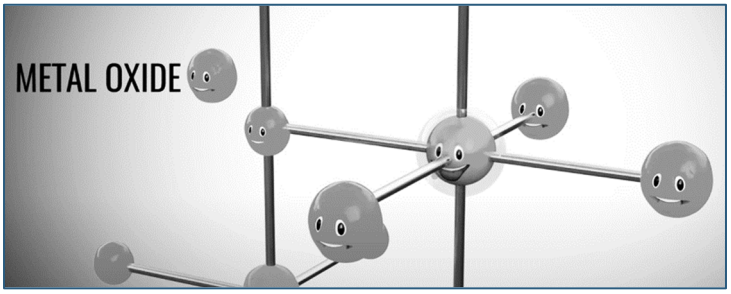
High Energy Density: Lithium being a highly reactive element, it has high energy density. Compared to a lead-acid battery, Li-ion battery weighs 6 times less to store the same amount of energy. A typical lithium-ion battery can store 150 watt-hours of electricity in 1 kilogram of battery.

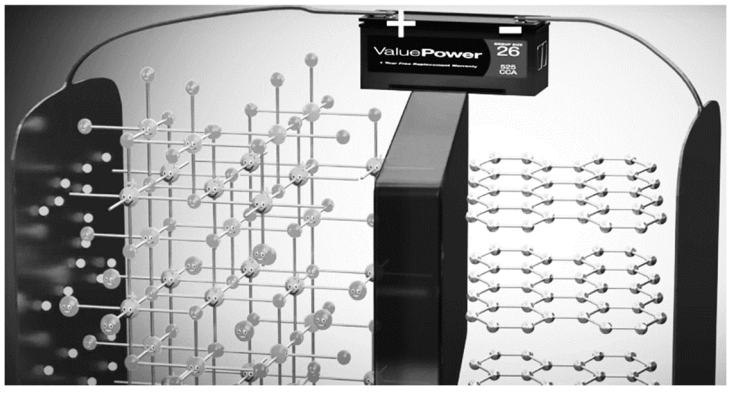
Low Maintenance: The low self-discharge capability of Li-ion batteries enables it to be recharged before it completely discharges making it easily rechargeable just like any other fuel.

CHALLENGES TO Li-ion BATTERY MANUFACTURING

- **Nascent industry:** Li-ion battery manufacturing is a nascent industry in India. Currently Li-ion batteries are imported mostly from China, South Korea and Taiwan. In order to give a push to Li-ion battery manufacturing in India ISRO recently announced a technology transfer package to competent Indian industries for setting up local production units.
- **High manufacturing cost:** Lithium-ion batteries are around 40% more costly to manufacture than Lead-acid batteries.
- **Resource crunch:** LiBs use lithium, cobalt, nickel and manganese which are in short supply in the world restricted to Bolivia, Chile.
- **Difficult switch:** Given that internal combustion engine has more than 2000-odd moving parts, the survival of MSME landscape in India currently depends on manufacturing of these auto part. This has hindered the switch to EVs which have significantly less number of auto components (20-odd) in turn hindering the growth of LiB manufacturing in India.

LITHIUM-ion BATTERY

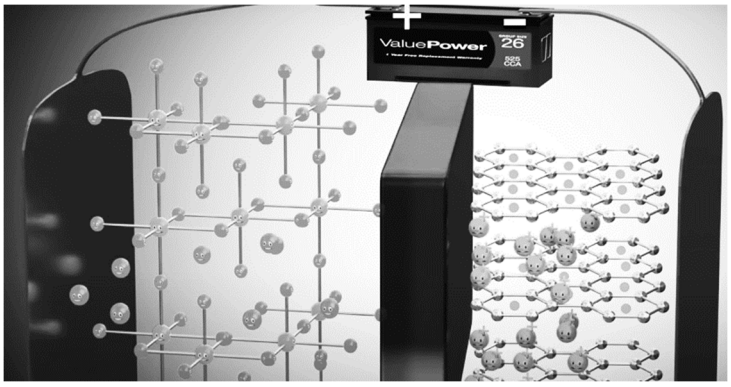




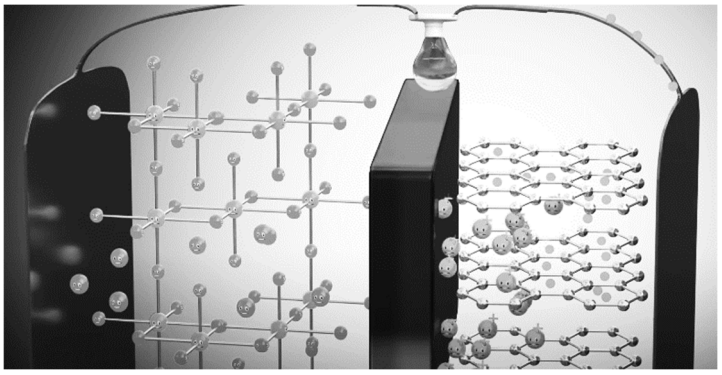
- Lithium has the highest electrochemical potential.
- It wants to lose electrons readily which makes it very reactive. That's why you don't get lithium in free form.
- However, when mixed with metal oxide lithium sits very stably.
- Thus, if we use this ability of

lithium to be very unstable by itself to becoming very stable in metal oxide, we can derive electricity. This is what happens in a Li-ion battery.

- Working of a Li-ion battery
- Lithium is mixed in metal oxide (typically cobalt, nickel, or manganese)) is used as cathode.
- Graphite is use as a place to hold Li-ions which becomes an anode.
- As we have seen Lithium in metal oxide is very stable.
- In Li-ion battery we separate Lithium from metal oxide by pulling out its constituent electrons and ion forcefully by applying energy.



- The electrons and ions of Lithium are then given separate paths namely a metallic wire and an electrolyte.
- This is called charging as it required external energy to separate electrons and Li-ions from Lithium metal oxide.
- The li-ions moving through electrolyte and electrons moving through the wire then recombine at anode which is graphite.



- Once all the electrons and ions are pulled out the battery is completely charged.
- The lithium ions and electrons that is sitting between graphite sheets are unstable and wants to go back to metal oxide. If we again give separate paths to electrons and ions we can derive electricity.
- Thus Li-ion battery is used to store energy by shuttling lithium ions back and forth between the anode(Li-ion in graphite) and cathode(Lithium in metal oxide).

ADVANTAGE OF Li-ion BATTERIES

- Light weight
- Lithium being lightest metal.
- High Energy Density
- Lithium having highest electrochemical potential has very high energy density.
- A typical automobile lead-acid battery weighs 6 kilograms more to store the same amount of energy than a lithium-ion battery.
- In consumer electronics like mobile, laptops, camera etc I kilogram of Nickle cadmium batteries stores typically 60 to 70 watt-hours.

- A typical lithium-ion battery can store 150 watt-hours of electricity in 1 kilogram of battery.
- Minimum losses
- A lithium-ion battery pack loses only about 5 percent of its charge per month, compared to a 20 percent loss per month for Ni-Cd batteries.
- Low Maintenance
- Lithium-ion batteries can handle hundreds of charge/discharge cycles.

DISADVANTAGES

- Faster discharge
- While quick discharge is an advantage in electric vehicle and consumer electronics applications, it is not suitable to store energy for longer than 4 hours.
- Thus, it is not suitable for grid-level storage which is necessary for renewable energy like solar which suffer from intermittency problem.
- Ageing
- Li-ion batteries suffer from ageing at room temperature. Therefore, in a consumer electronic, batteries need to be partially charged for longer life.
- Transportation
- Another disadvantage of li-ion batteries is that there can be certain restrictions placed on their transportation, especially by air to protect against short circuits.
- Cost
- Lithium-ion batteries are around 40% more costly to manufacture than Nickel cadmium cells owing to high cost of lithium refining, cobalt and nickel.

LITHIUM RESERVES

- Lithium reserves
- Lithium is currently produced from hard rock or brine mines.
- Australia is the world's biggest supplier, with production from hard rock mines.
- Argentina, Chile and China are mainly producing it from salt lakes.
- Chile, Argentina and Bolivia (Lithium triangle) in South America is believed to account for more than 50% of the world's proven Lithium reserves.

LITHIUM RESERVES IN INDIA

- The ancient igneous rock deposits in the Karnataka's Mandya district holds the first traces of Lithium ever to be discovered in India. But it is merely 1,600 tonnes.
- But in a big development, recently 5.9 million tonnes of lithium reserves found for the 1st time in Jammu and Kashmir.
- India currently imports all of its lithium batteries.

INDIA'S STEPS

- In March 2019, India signed a MoU with Bolivia to explore and extract Lithium.
- India has also signed bilateral agreement with Argentina for securing strategic minerals, which will be operationalized via KABIL's contract with three state-owned organizations in Argentina.
- India and the US are also looking at setting up an alternative supply chain for lithium. o KABIL is also exploring the direct purchase of cobalt and lithium.
- Lithium plant: India's first Lithium plant has been set up at Gujarat in 2021, where a private company has planned investment of Rs 1000 crore to set up a refinery. The refinery will use Lithium ore to produce base battery material.

- KABIL
- A PSU to ensure a consistent supply of critical and strategic minerals to Indian domestic market.
- It would carry out identification, acquisition, exploration, development, mining and processing of strategic minerals overseas.
- India has also signed Critical Mineral Investment Partnership with Australia primarily for supply of lithium and cobalt.

CHINA'S DOMINANCE

- China contributes to 60% of global production of rare earth elements.
- China's share of refining is around 35% for nickel, 50-70% for lithium and cobalt, and nearly 90% for rare earth elements.
- China has a huge head start on India in terms of securing lithium deposits.
- Around 3/4th of battery cell manufacturing capacity is in China,
- China has heavily invested in mines of both Australia and Latin America to ensure an overall command of lithium supply chain.
- It also controls cobalt mines in the Democratic Republic of Congo, from where 70% of this mineral is sourced.

5 CHAPTER QUANTUM TECHNOLOGIES

TOPICS TO BE COVERED

1. *Quantum Technologies*
2. *Superposition and Quantum computing*
3. *Scope and Applications of Quantum Computing*
4. *Quantum computers in News*
5. *Quantum entanglement and Communication network*
6. *Squeezed states and Quantum sensing*

1. QUANTUM TECHNOLOGIES

- An understanding of the quantum world and ability to utilize principles of the quantum world to develop useful things is what is quantum technology all about.
- The development of quantum technologies can be seen in 2 phases
- Phase1 or Quantum 1.0 represented technologies like semiconductors, transistors, lasers, superconductors, SQUIDs, Bose Einstein condensates, quantum dots etc.
- Under this phase we merely used the principles of quantum mechanics to build useful products.
- Phase 2 or Quantum 2.0 is where we are able to build manipulate physical systems to manifest some quantum mechanical principles like superposition, entanglement, squeezed states to build technologies.
- This phase is more recent (1980s) and includes development of quantum computers, quantum cryptography, quantum communication networks and quantum sensing and metrology.
- Now let us understand what these principles are and corresponding technologies.

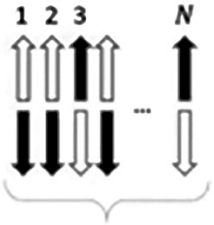
2. SUPERPOSITION AND QUANTUM COMPUTING

- Today's quantum computers work on the basis of the quantum mechanical principle called superposition. Now there are quantum computers being built that use in addition to superposition, the property of entanglement, but most quantum computers you have heard of use the principle of superposition.
- Superposition as we have seen is the unique ability of objects in the quantum world like photons, electrons etc to exist in multiple or composite states at the same time. This ability changes computing in fundamental ways.

CLASSICAL COMPUTING V/S QUANTUM COMPUTING: A COMPARISON

- Today's computers work which work with bits is a 2-state system that can represent either 0 or 1 at a time.

- All information in today's computers is fed in, processed, stored and transmitted using bits represented by a transistor or a capacitor. (they just act like a light bulb to represent ON/OFF).
- While each transistor or capacitor can switch states (to process information) in billionths of a second, there is still a physical limit as to how quickly these devices switch states.



N Classical bits 2^N Configurations

- Quantum computer on the other hand is not a 2-state system.
- If we can make bits using photons (or electrons etc) it can store all states simultaneously owing to the principle of superposition. These are what are called qubits.
- For instance, while a 2-bit computer can store only one of four binary configurations (00, 01, 10, or 11) at any given time, a 2-qubit quantum computer can store all four numbers simultaneously.
- In general, if more qubits are added, the increased capacity is expanded exponentially.
- In addition, a comparison of number of possible states between a classical and quantum computer may be appreciated using the table below.

Number of bits	**No of states in a bit-based system 2^N**	**No of states in a qubit-based system N^N**
1	2^1	1^1
2	2^2	2^2
3	2^3	3^3
4	2^4	4^4
5	2^5	5^5
32-bit	2^32	32^32
64-bit	2^64	64^64

3. SCOPE AND APPLICATIONS OF QUANTUM COMPUTING

In general quantum computers are useful wherever there is need for large-scale calculations.

Large factoring Quantum Cryptography	Most digital transactions (including blockchains) today use an encryption system for safety called RSA encryption. (An RSA encryption simply depends on factoring of a 2048-bit integer) Similarly, there are other algorithms (rules of encryption) like elliptic curve digital signature algorithm (ECDSA) used in digital signatures and SHA-25 used in blockchains etc. Though today's quantum computers cannot break such codes if we can build a 10000-qubit computer it can break such codes very easily. So, quantum computers could be a threat to current cryptography landscape including blockchain technology which is built using the principles of cryptography (RSA encryption). Therefore, we need to move towards quantum-resistant encryption systems in the future.
Simulations	Materials science simulating complex molecules to find new materials to develop safe and sustainable batteries and fuel cells. New materials are also being modelled for novel airplane, automotive designs for better fuel efficiency, and aerodynamic properties. Climate modelling enabling meteorologists to better predict trajectories of hurricanes, winter storms, and other weather events.
Traffic optimization	Volkswagen carried out the world's first pilot project for traffic optimization in Lisbon More intelligent navigation systems could prevent traffic jams by assigning allocated routes to millions of users. The ability of QCs to reduce computational time from half a month to a few moments implies that vehicle-to-vehicle communication is safeguarded in real time, time and again.
Network optimization	Configuration of data networks for better energy efficiency
Drug discovery	Computer-aided drug discovery (CADD) is being transformed by quantum chemistry techniques specifically to model the interactions between proteins.

4. QUANTUM COMPUTERS IN NEWS

QUANTUM COMPUTER	NO OF QUBITS
Eagle (IBM)	127-qubit
Sycamore of Google	53
Jiuzhang (first photonic quantum computer	

Wuyuan 1st commercial quantum computer sold in China	24-qubit system
Osprey (IBM) The number of classical bits that would be necessary to represent a state on the IBM Osprey processor far exceeds the total number of atoms in the known universe,	433-qubit
IBM's wants to scale up towards the goal of 4,000+ qubits by 2025	
nanoscopic technology that could present a massive leap for "photonic quantum computing" — they have successfully managed to get two entangled quantum light sources.	

RELATED TERMS IN NEWS

Quantum supremacy	• Ability of quantum computers to perform a mathematical calculation that is beyond the reach of even the most powerful conventional computer like supercomputers. • Google announced quantum supremacy for the 1st time in 2019 when it's 53-bit quantum computer Sycamore performed a calculation in 200 seconds what would have taken 10000 years for the world's fastest supercomputer today.

5. QUANTUM ENTANGLEMENT AND COMMUNICATION NETWORK

WHAT IS ENTANGLEMENT?

- Quantum entanglement is the quantum mechanical principle behind next-gen communication systems.
- As we have seen entanglement is the ability of elemental particles to be correlated with each other.
- If we have 2 entangled photons, knowing the property of one (say spin, polarization state etc) at any point of time, allows us to know the property of its counterpart at the same instance.
- Quantum entanglement allows photons (or any elemental particle) that are separated by incredible distances to interact with each other instantaneously (not limited to the speed of light).

QUANTUM COMMUNICATION AND CONVENTIONAL COMMUNICATION SYSTEM

- Modern day communication systems work using some medium used to transmit data.
- Wireless transmission includes the use of electromagnetic waves propagated in air. Wired transmission includes use of photons or electric pulses sent through optical cables, copper cables respectively.
- This 'transmitting' happens by sending 'signals' represented as electricity (wires) or electromagnetic waves (optical cables, air). This is susceptible to interception.

- Quantum communication, on the other hand, owing to quantum entanglement sends information instantaneously if information or signal could be represented by entangled photons or electrons separated by a distance.
- Thus, quantum entanglement enables interception-free communication because there is nothing to interrupt.

Basics: Normally modern communication systems send information that is scrambled. The scrambling is done applying some rules(key). This is called encryption. If you have the key, you can unscramble the scrambled information. (decryption)

Quantum communication networks can of two types

1. Hybrid: based on Quantum key distribution
2. Pure: based on Quantum teleportation

QUANTUM KEY DISTRIBUTION-BASED COMMUNICATION

- This type of communication system transmits scrambled information through conventional means (wired or wireless) and 'distributes encryption key (to unscramble) between sender and receiver through quantum systems liked entangled photons. (this is why is it is called quantum key distribution)

HOW DOES IT WORK?

- Properties of photons (like spin, polarization etc) can be used to represent information (qubit) and can be used as encryption key.
- 2 photons entangled in the lab are distributed between two ends of the communication link.
- If I measure the property of one photon, I know the property of the other.
- In short, photons used to represent encryption key communicating instantaneously owing to entanglement is what is called quantum key distribution.

QUANTUM KEY DISTRIBUTION AND POST-QUANTUM CRYPTOGRAPHY

- Post-quantum cryptography uses QkD to distribute interception-free encryption keys made of entangled photons.
- This next-gen encryption system which is quantum-resistant is called post-quantum encryption system.
- It is called post-quantum cryptography because these keys cannot be broken by quantum computers.

QUANTUM KEY DISTRIBUTION IN NEWS

1st QkD by India	ISRO demonstrated QkD in 2021 for the 1st time between a 300-meter communication link.
QkD over 100 km	IIT Delhi and DRDO demonstrated QkD between Prayagraj and Vindhyachal.
Space-based quantum communication	ISRO plans to build satellite-based communication link using QkD
China and QkD	In 2017 China has established a 2000 km communication link based on quantum key distribution between Beijing and Shanghai.

Quantum satellite Micius	In 2021 a ground-to-satellite communication link was established based on QkD. The name of this quantum satellite is **micius**.
Nanoscopic technology	Note: Recently scientists have entangled 2 light sources. If you separate them through a distance (keeping one at the sender and other at the receiver) you can have continuous communication network using quantum key distribution. The technology used to develop entangled quantum light sources was nanoscopic technology.

Quantum teleportation-based communication (Pure)

- Alternately communication system can work by representing entire information using qubits of entangled photons instead of only the encryption key. The qubits may be instantaneously transferred owing to their entanglement.
- This instant transfer of "qubits" to send information is called "quantum teleportation".
- The entangled photons may also be used to send information through optical cables and received through single-photon detector at the receiver end.

Quantum teleportation in news

NASA's quantum teleportation demonstration	NASA's jet propulsion laboratory has demonstrated 44 km teleportation of qubits of photons over a fiber-optic network and single-photon detectors

Related terms in news

Quantum internet	• Future quantum internet is going to be built using communication links based on quantum teleportation. • A quantum internet would be able to transmit large volumes of data across immense distances at a rate that exceeds the speed of light. • It is said to energy efficient because it does not involve transmission through electricity or light. • Quantum internet will be safe due to interception-free nature of qubits. • Future tamper proof Conventional internet v/s Quantum internet Traditional computer data is coded in either zeros or ones. Quantum information is superimposed in both zeros and ones simultaneously. We need to create infrastructure of quantum internet including: quantum routers, repeaters, gateways, hubs, and other quantum tools.

6. SQUEEZED STATES AND QUANTUM SENSING

- Quantum sensing and measurement use quantum mechanical principle called squeezed states explained by Heisenberg's uncertainty principle.
- According to uncertainty principle, there is a limit to the precision with which you can measure two related properties of a quantum particle like photon, electron etc. For eg position and velocity or time and frequency.

- The uncertainty with which one can measure is split between the 2 variables that we are measuring.
- If we manipulate the quantum system to reduce uncertainty in one at the cost of the other, we can measure one variable with extremely high precision.
- This can be used in ultra-sensitive sensing.
- A quantum sensor, built on the basis on this property of squeezed state, essentially senses how a particle interacts with its environment including gravity, magnetic fields, temperature, pressure, rotation etc.

Scope and Application

Medical Imaging and diagnostics	
Gravity sensors	Used in seismology, mineral exploration
Navigation	Extremely sensitive clocks to be used in navigation systems are being built using squeezed states in quantum systems. Such quantum-system based navigation will redefine navigation in vehicles particularly autonomous vehicles.
Gravitational waves	The present-day gravitational wave observatories are built on laser-based interferometers which essentially detects stretch in space-time fabric due to gravitational waves. However the fluctuation of light limits the sensitivity of these instruments. This is why future gravitational-wave observatories use extremely sensitive quantum sensors. Ligo and Virgo, two of the gravitational wave observatories, are being updated with quantum sensors.

6 CHAPTER IT AND DIGITAL TECHNOLOGIES

TOPICS TO BE COVERED

1. *Data centered living*
2. *Regulation of digital technologies*
3. *Public digital Infrastructure/ Digital Public Goods (DPGs): IndiaStack*
4. *DPGs in financial sector*
5. *Data Empowerment and Protection Framework*
6. *Digital Personal Data Protection Act*

1. DATA CENTERED LIVING

DIGITAL FOOTPRINT TODAY

The amount of data in the world today is close to 100 Zettabyte. (1000GB→1TB, 1000TB→1Petabyte, 1000PB→1Exabyte, 1000EB→1 Zettabyte)

This number is expected to grow to 175 ZB by 2025.

Everyday 500exabyte will be produced by 2025

No of devices connected to the internet today is around 65 billion.

In 2025 IoT devices alone will constitute more than 75 billion devices.

BIG DATA

The colossal growth in digital footprint is due to rise in digital devices but also due to our ability to process unstructured data. This is what we call Big Data. It is the advent of big data that has enabled technologies like Artificial Intelligence, IoT revolution, drone technology, geospatial technology to flourish.

Big Data is simply new capabilities to process unstructured data. It is often said Big data is characterised by 3 Vs Volume, Variety and Velocity.

2. REGULATION OF DIGITAL TECHNOLOGIES

Basic conundrum while regulating digital technologies is between the protection of privacy rights right and creating an enabling environment for innovation. While Digital Personal Data Protection Act is intended to do the former, data sharing of non-personal data for public policy making and building public digital goods are intended to do the latter.

The broad goals one has to keep in mind in regulation of any technology includes

1. Encourage innovation
2. Ensure protection of rights of end users (citizens, consumers)
3. Prevent money-laundering
4. Prevent fraud
5. Taxation regime for cross-border flow (data flow knows no boundary)

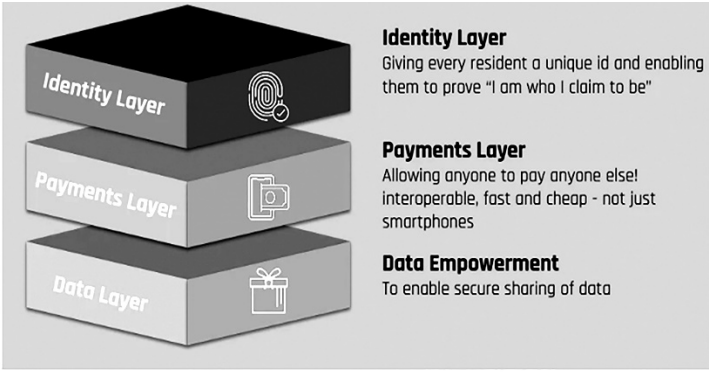
3. PUBLIC DIGITAL INFRASTRUCTURE/ DIGITAL PUBLIC GOODS (DPGS): INDIASTACK

Starting Aadhar, India embarked upon the journey of digitizing experiences in the physical world necessitating the building of public digital infrastructure. A suite of digital public goods are developed under the umbrella IndiaStack to enable smooth transition to digital economy.

At the heart of any digitizing effort are the following basic requirements. One a digital identity, once we identify we need a way for authenticating the identity and finally we need to be able to authorize a person to conduct activities for instance digital transactions. This is what Aadhar is established to do.

Once the identification, authentication and authorization is established the next layer is to enable activities layer. This depends on what activity we are trying to digitize. For instance in financial sector we need to enable payments, credit, trading etc. This is what UPI is doing.

Finally, data sharing is the link that enables seamless exchange of related organisations participating in the said sector. This is what Data Empowerment and Protection Framework is said to do.



The three layers of India Stack. iSPIRT

The above 3 layers are called economic primitives. So called because they are at the heart of digitizing activities. This what the public digital infrastructures are designed to do. Further DPGs can be open-source software, open APIs, open datasets, open AI models, open standards, open content etc. India is building these DPGs under the overarching umbrella IndiaStack.

India Stock	**Consent Layer**	Provides a modern data sharing framework	Data Empowerment and Protection Architecture (DEPA)
	Cashless Layer	Game changing electronic payment systems; transition to cashless economy	AEPS, APB and UPI
	Paperless Layer	Rapidly growing base of paperless systems with billions of artifacts	Aadhar e-KYC, E-sign, Digital Locker
	Presence-less layer	Unique digital biometric identity with open access of nearly a billion users	Aadhaar Authentication
	JAM	Jan Dhan, Aadhaar, Mobile	

Examples of DPGs built under IndiaStack constitutes

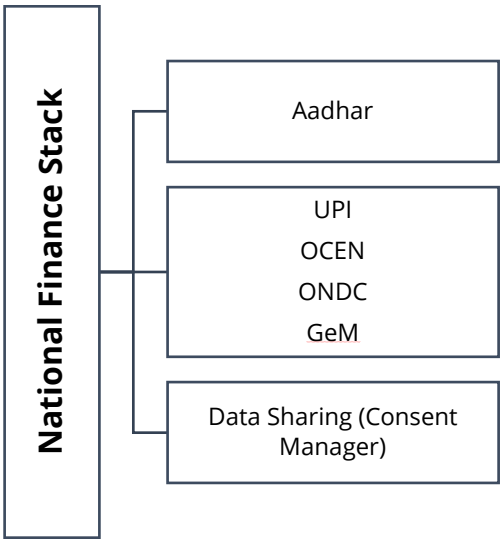
1. Aadhaar - API to ID the consumer. Identity, Authentication (e-Auth), Authorization (e-sign)
2. eKYC - Tools to digitise the whole KYC process. (based on Aadhar)

3. UPI - Platform for micropayments directly between banks.
4. Digilocker - Storage and retrieval of digital documents.
5. eSign - Sign documents electronically. (aadhaar holder can generate an e-sign)

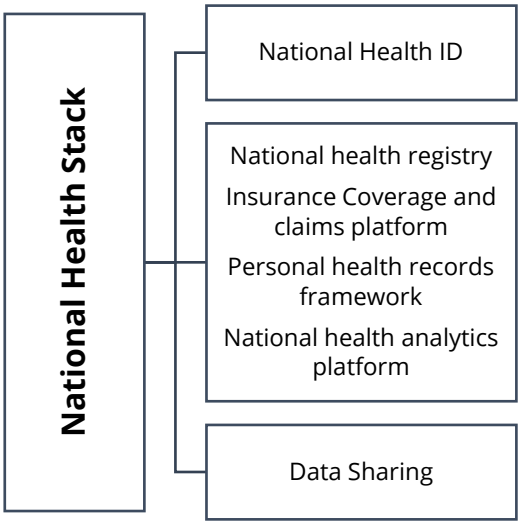
Indiastack: *Set of APIs that allows governments, businesses, startups and developers to utilise a unique digital Infrastructure to solve India's hard problems towards presence-less, paperless, and cashless service delivery.*

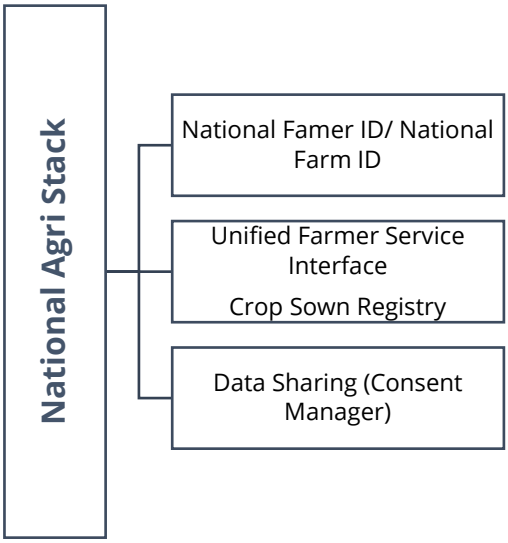
4. DPGS IN FINANCIAL SECTOR

Currently DPGs are built in financial sector to make financial activities cashless, paperless, presence-less. While payment was the 1st activity to be digitized now we are building DPGs to digitize other activities in the financial sector including OCEN, ONDC, GeM etc.



Similar DPGs may be built in order to digitize other sectors including agriculture, health etc.





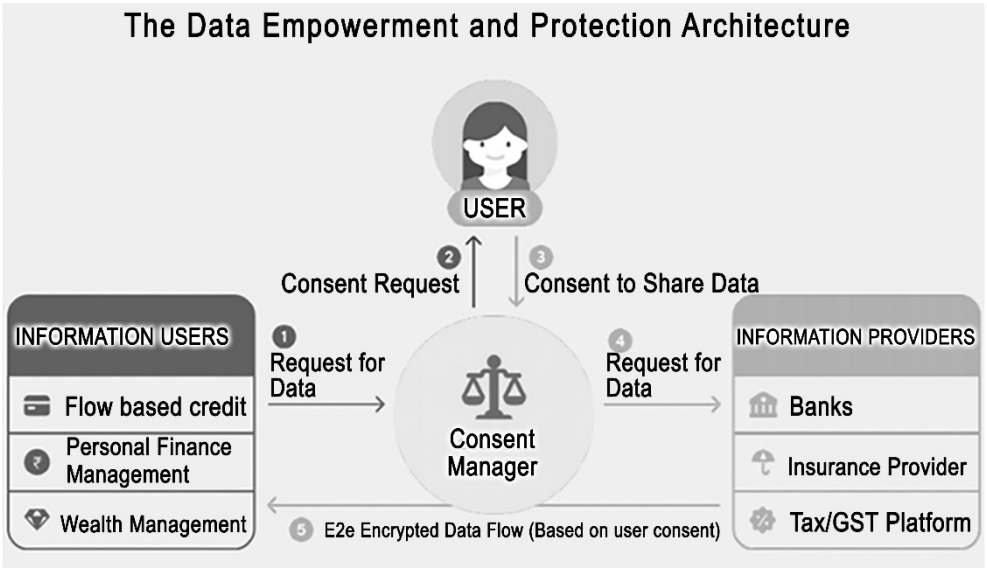
5. DATA EMPOWERMENT AND PROTECTION FRAMEWORK

DEPA allows seamless sharing of data between producers of data and end-users of data based on consent of the data principals. (One-liner on DEPA could be used in answer)

User can determine the terms of data flow such as the scope and duration of data sharing and can revoke the same along the entire duration of data flow. This is in line with the principle of Sri Krishna Committee. One of the pillars of Data Protection Bill is consent requirement. Thus, DEPA is said to be a technology solution to data protection.

DEPA provides for the missing link in the Indian digital ecosystem which is the data sharing layer.

WHAT IS DEPA?



- Consent-based data sharing
- Standardized API for data sharing (UPI-like platform)
- Data dashboard
- Separates consent requirement at data collection stage from consent requiring at data processing, data storing and data sharing stage

- It reinstates the asymmetry in control of data from custodian-controlled to individual-controlled.

Scope

- Financial sector
- Health sector
- Agriculture
- Personnel management
- Telecom sector

Impact

- Promote innovation and commercialisation
- Reduction in transaction cost
- Increased competition
- Technological solution to privacy and data protection
- Data interoperability
- Link between data providers and data users

6. DIGITAL PERSONAL DATA PROTECTION ACT

Seeks to establish the relationship of Data Principal and Data Fiduciary at every stage of data journey with the primary goal of protecting the right of individuals to privacy at the same time upholding the security of India.

Rights of Data Principals at various stages of data journey

Collection stage	Informed consent
Processing stage	Right to be informed, Right to revoke consent
Storage of Data	Data Localisation How long can you store the data
Dissemination	
	Right to be forgotten/erasure
	Right to modify, delete
Sharing of data	Who can you share the data with and for what?

PILLARS OF DATA PROTECTION LAW

1. Principles for d7ata protection:

- Only essential data must be collected
- Data so collected should be used only for the said purpose
- Once the purpose of data so collected is fulfilled the data must be deleted

2. Grounds for collection, processing and use of personal data

- Collection of and use data must be on the basis of free and informed consent

3. Rights of individual

- Right to review
- Right to access
- Right to modify
- Right to erase

4. Data Protection Authority

- Central regulator that ties together the above 3 pillars and ensure compliance for the same.

Issues related to Digital Personal Data Protection Act 2023

- Data Protection Board: Autonomy, Powers?
- Lopsided
- Exemptions in case of government as fiduciary:
- *The Bill does not mandate government agencies to erase personal data once the processing purpose has been fulfilled:* Right to erasure?
- Fair and reasonable reasons: Consent
- Grounds for violation of privacy is too vague
- Eg: For preventing, detecting, investigation and prosecution: Processing
- "necessity of processing personal data for legitimate objectives"
- Outright exemption for research, sovereignty and integrity, security, public order, friendly relations, avoiding incitement of violence.
- Right of minor
- Dent on Right to Information?: Modifies Section 8(1)(j) under which public authority can seek immunity from disclosing information provided it is personal data. Currently the test was 'if a public authority can deny information to parliament, he/she can deny it to public". With the amendment under the garb of "personal data" any data that identifies itself with a person can be denied leaving a large scope for denial of information. Thus it can act as dent on privacy.

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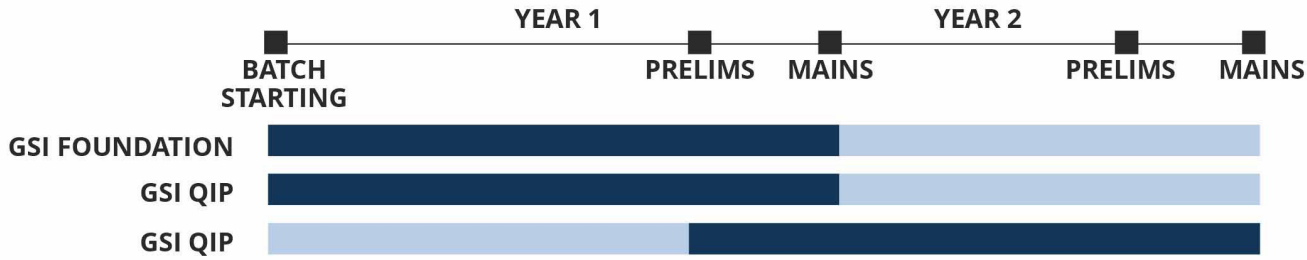

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