सत्यमेव जयते

SCIENCE & TECHNOLOGY CLUSTER

Flagship programme of the Office of the Principal Scientific Adviser to the Government of India

M3M FOUNDATION
Empowering to Evolve

INNOVATION CHALLENGE

on

Clean Energy Transition & Environmental Sustainability

under the aegis of

MASHAAL Fellowship

Use cases-Green Energy Transition and Environmental Sustainability

1. Renewable Energy Transition

- Energy Storage Systems
- Battery Recycling
- Electric Vehicles
- Building Energy Efficiency

2. Environmental Sustainability

- Carbon Capture, Utilization, and Storage
- Green Hydrogen Production
- Cleaner Fuels (Biodiesel, Ethanol Blends, and CNG)
- Circular Economy and Waste Management
- GHG Emission Reduction

3. Ensuring Water Security

- Potable Water
- Augmenting Capacities of Existing STPs

1. **Renewable Energy Integration**

Transforming the Indian power sector in to a secure, adaptive, sustainable and digitally enabled ecosystem that provides reliable and quality energy for all with active participation of stakeholders.

- **Energy Storage Systems**

  - **Advanced Battery Chemistry**: Advanced battery technologies, such as lithium-ion, lithium-S, grapheme-based, sodium-ion, flow batteries (vanadium redox flow batteries) etc, enable better storage of renewable energy for use during periods of low production.
  - **Sustainable Battery Materials:** Innovative battery materials to reduce reliance on rare, environmentally harmful materials like cobalt and lithium, while improving recyclability and the life cycle of battery packs also reducing mining impact to promote a circular economy in battery production.
  - **Advanced Battery Management Systems (BMS):** Developing smarter BMSs that use AI and ML to optimize battery performance, extend battery life, reduce the need for frequent replacements, waste and emissions and ensure safe operation under various conditions.
  - **Solution for Remote Communities and Disaster Relief**: Energy storage systems paired with renewable energy sources, such as solar panels to provide reliable power to remote or off-grid communities that lack access to conventional electricity infrastructure.

- **Battery recycling**

  - **Advanced and Enhanced Recycling Technologies:** New recycling methods, such as hydrometallurgical and biotechnological processes to improve efficiency and recovery rates for different types of batteries. Innovations like direct recycling techniques are being explored to simplify the process and improve the quality of recovered materials.
  - **Critical Metals Recovery and Reuse**: Recycling batteries to recover valuable metals such as lithium, cobalt, nickel, and rare earth elements, which are crucial for the production of new batteries and other electronic devices and reduce the need for mining for virgin resources and the associated environmental impact.

- **Electric Vehicles**

Innovations in EV technology, including improvements in battery efficiency, charging infrastructure, and vehicle-to-grid (V2G) systems, contribute to reducing reliance on fossil fuels.

Smart Charging Infrastructure, Wireless Charging and Range Improvement: Innovations in ultra-fast charging technology to reduce charging times significantly,

- making EVs more convenient for long-distance travel. EV charging infra powered by renewable energy sources like solar or wind to reduce the carbon footprint associated with charging and grid dependency in peak hours. Developing wireless or inductive charging systems for EVs, allowing for convenient charging without the need for physical connectors.
- **Range Improvement and Optimization:** Advanced materials and chemistries increasing the energy density of batteries, thereby extending the range of EVs. Innovations in vehicle design (using lightweight materials like aluminum, carbon fiber, or advanced composites) and energy management systems to maximize the efficiency and range of EVs.
- **Vehicle-to-Grid (V2G) Integration:** Development of bidirectional charging systems that allow EVs to supply power back to the grid or home, enhancing grid stability and providing additional value to EV owners.
- **Vehicle-to-Everything (V2X) Communication**: Developing V2X communication technologies that enable EVs to interact with infrastructure, other vehicles, and pedestrians for improved safety and traffic management.
- **EV as power bank**: Using an EV as a backup power source can be integrated with home energy management systems to automatically switch to EV power when the grid is down.
- **Last-Mile Connectivity**: EVs tailored for last-mile transportation, integrating them with public transit systems to improve overall mobility.

- **Building Energy Efficiency**

- **Smart Grids**: Innovations in smart grid technology can optimize the distribution of renewable energy sources like wind and solar to use real-time data to balance supply and demand, integrating various energy sources efficiently contributing to reduction of T&D losses, peak load management, improved quality of service, increased reliability.

- **Pumped Hydro Storage**: large-scale storage solution which stores energy by pumping water to a higher elevation during times of low demand and releasing it to generate electricity during peak periods.

- **Smart Building Systems**: Integrated systems that use AI to optimize energy use in buildings, such as smart thermostats, lighting controls, and HVAC systems, can greatly reduce energy consumption. Innovations in building materials, such as advanced insulation and energy-efficient infrastructure, contribute to reducing the energy needed.

- **Environmental Sustainability**

- **Carbon Capture, Utilization and Storage**: Technologies that capture CO_2 directly from the atmosphere and either store it underground or convert it into useful products, such as fuels industrial products or building materials. Combination of biomass energy production with carbon capture and storage to achieve negative emissions (Bioenergy with Carbon Capture and Storage).

- **Green Hydrogen Production:** Innovations with techno-commercial feasibility in electrolyzer technology can produce hydrogen from renewable resources. Fuel cells that use hydrogen to generate electricity, emitting only water as a by-product to use in vehicles and as backup power sources.
- **Cleaner Fuels (Biodiesel, Ethanol Blends, and CNG):** Cleaner alternative fuels such as biodiesel, ethanol-blended fuel, and compressed natural gas (CNG) to replace traditional petrol and diesel in the transportation sector.

- **Circular Economy and Waste Management**

  - **Conversion of Plastics to High-Value Products:** Advanced chemical recycling technologies are being used to convert plastic waste into high-value products such as graphene and biofuels.
  - **Plastic Waste in 3D Printing:** Plastic waste can be shredded and processed into filament for use in 3D printers.
  - **Biodegradable Plastics and Alternatives:** Biodegradable plastics and alternatives are emerging as critical solutions to the global plastic waste problem. These materials break down more easily than conventional plastics and are made from renewable resources.

- **Plastic Recycling Innovations:** Advanced recycling (depolymerization) processes that break down plastic waste into its basic monomers, allowing them to be reused in creating new plastic products without quality degradation.
- **Microplastic Filtering Technologies:** Innovative filtration systems that prevent microplastics from entering water systems through domestic wastewater, industrial effluents, and runoff.

- **E-Waste Sorting System:** AI-driven system to automatically sort e-waste into different categories (plastics, metals, circuits) for efficient recycling.
- **E-Waste to Energy Conversion**: Implement technologies that convert non-recyclable e-waste into energy through advanced waste-to-energy solutions like gasification or pyrolysis.
- **Urban Mining for Resource Recovery**: Extracting valuable metals like gold, silver, and copper from discarded electronics through advanced recycling techniques.

- **GHG emission reduction**

Vehicular emission control: Innovations in this area need to focus on how to control or manage the vehicular emission.

- **Retrofit Technology for Older/ICE Vehicles**: Retrofitting older diesel and petrol vehicles with emission control devices or converting them to electric vehicles to reduce emissions from legacy fleets.

- **Tailpipe Emission Reduction:** Hybrid air treatment technology that can be used to treat vehicular emissions and improve air quality. The treatment system might combine a particulate filter with a catalytic converter to remove both particulate matter and harmful gases from vehicular emissions. This System can be fitted to tailpipe or exhaust pipe to reduce the gaseous as well as particulate matter from the emissions before throwing them to atmosphere.

2. Ensuring Water Security

- **Potable water**

- **Wastewater Reclamation for Drinking:** Advanced treatment systems that reclaim and purify wastewater to produce potable water, promoting sustainable water use in water-scarce urban areas.
-

- **Smart Water Filtration Systems:** Automated filtration systems that monitor water quality in real-time and automatically adjust filtration processes ensuring safe drinking water, especially in remote areas.
- **Solar-Powered Water Purification:** Portable solar-powered water purification units that can provide clean drinking water in disaster-stricken or off-grid regions without relying on electricity.
- **Low-Cost Arsenic and Fluoride Removal:** Innovative, affordable and effective filtration technologies to remove harmful substances like arsenic and fluoride from groundwater, providing safe drinking water.

- **Augmenting capacities of existing STPs**

  - **Advanced Biological Treatment Technologies:** Advanced biological treatment methods to enhance the capacity and efficiency of STPs without the need for large infrastructure expansions.
  - **Modular STP Expansion Units:** Modular, containerized STP units that can be added to existing facilities, allowing for quick and scalable capacity expansion to meet growing urban wastewater demands.
  - **Retrofitting for Energy Efficiency:** Retrofitting existing STPs with energy-efficient equipment and low-energy aeration systems to increase operational capacity while reducing energy consumption.
  - **AI-Driven Process Optimization:** AI/ML based algorithms to monitor and optimize STP operations in real-time, adjusting parameters such as aeration, chemical dosing, and sludge management to maximize throughput and improve effluent quality.