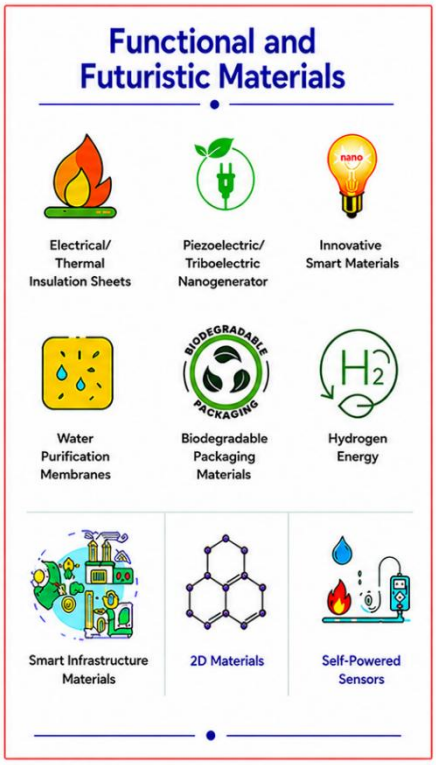
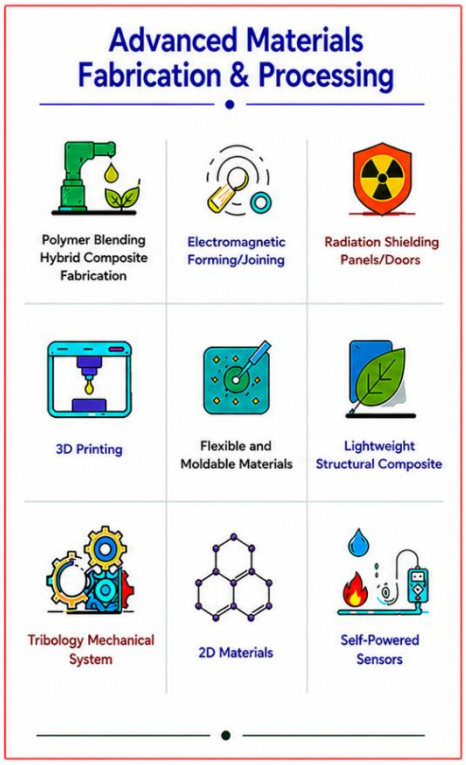
कार्यात्मक पदार्थ एवं सम्मिश्र प्रभाग

Functional Materials and Composites Division (FMCD)

शोध क्षेत्र / Research Areas:





1. Natural Fiber (NF), Composites & Packaging (National Fibre Scheme for Self-Reliance)
2. Hybrid Polymer Composites & Recycling Technologies (Advanced Composite Mission, Waste to Wealth Mission & Circular Economy Mission)
3. Piezo & Triboelectric Nano Generator (NST & Clean Energy Mission)
4. Advanced Functional 2D Materials & Nano Composites (Semiconductor & Quantum Mission)
5. Additive Manufacturing (Atal Innovation Mission)
6. Solid-state Materials for Hydrogen Storage (Green Hydrogen Mission)
7. Electromagnetic Joining & Forming (Make-in-India, AMT)

1. Natural Fiber (NF), Composites & Packaging (National Fibre Scheme for Self-Reliance)

1.1 Sisal Potential for Rural Employment and Making Hybrid Composites:

CSIR-AMPRI Bhopal has expertise and created facilities for sisal fiber based technologies leading to sustainable rural employment, income generation, training of entrepreneurs for creating business opportunities.

Uniqueness of Sisal:

Sisal is natural fiber bearing plants requires minimum water and maintenance for its cultivation.

Sisal fiber exhibits high tensile strength, bright color and highly durable. There is ample scope for application in composite industry and in automobile sector. Alternative for non-renewable petroleum based synthetic fiber, glass fiber etc.

2. Hybrid Polymer Composites & Recycling Technologies (ACM, WW & Circular Economy Mission)

2.1 High-Performance and Hybrid Composite Wood from Industrial Inorganic Wastes:

The principal objective of this program is to explore and recycle marble, granite and stone waste stream for the development of advanced hybrid green composite materials for multifunctional applications as an alternative to timber, synthetic wood, GRP and plastic products.

A comprehensive field work including detailed survey and collection of marble, granite and stone waste samples from seven different districts (Chittorgarh, Makrana, Jaipur, Udaipur, Rajsamand, Kota and Kishangarh) in Rajasthan has been done. About 22 locations with their GPS coordinates in these 7 districts were surveyed from where samples of marble waste (15 nos.), granite waste (6 nos.), marble & granite mix waste (2 nos.), stone waste (6 nos.), soil (2 nos.) and water samples (9 nos.) were collected. In Madhya Pradesh, samples of marble (5 nos.), granite (4 nos.), stone (10 nos.) waste along with water samples (8 nos.) were also collected from four districts of Narsinghpur, Jabalpur, Khajuraho and Katni.

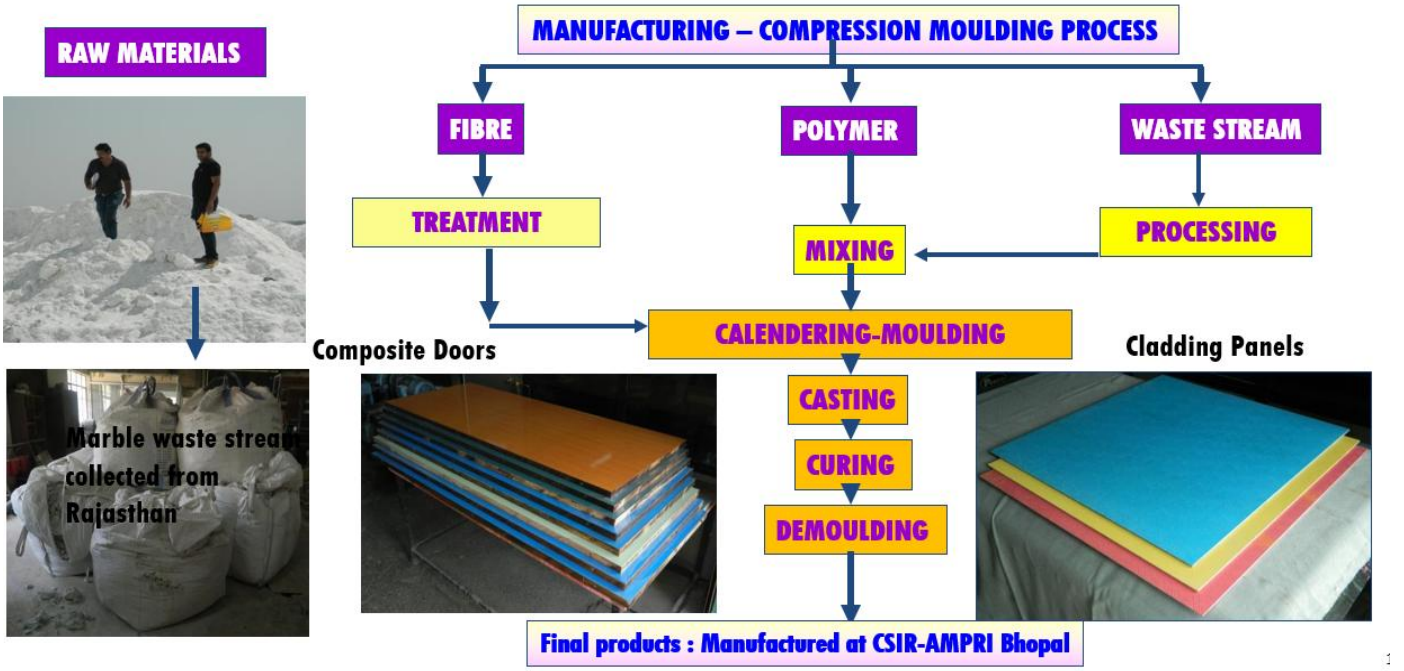
Efforts have been put to create a state-of-the-art facility for the characterization of collected waste samples, preparation and fabrication (lab scale and pilot-scale) of composite samples and their characterization in different polymeric systems . Some of the major equipment include, Injection moulding machine, Compression moulding machine, X-Ray Fluorescence Spectrometer, Weatherometer, Planetary Ball Milling machine, Thermal Analyzer, Ion Analyzer, etc. High speed mixing and calendaring system.

Hybrid green composite materials were developed using more than 65% marble waste as filler material in epoxy resin / polyester resin system and different fibres have been used as reinforcing materials under compression moulding system. The reinforcing materials used were natural (Cotton and Jute) and synthetic fibres (Glass and Nylon) in form of woven fabrics. The density of the composites varied from 1.56 g/cm^3 to 1.70 g/cm^3 while very low water absorption uptake was observed except in the case of jute fibre reinforced composite, although the increase was only 0.7 %. The composites in particular without jute fabrics exhibited zero to very low thickness swelling. The tensile modulus was highest in the case of composite made just from marble waste and epoxy. The tensile strength in general showed higher than 21 MPa while flexural strength ranged from 34–50 MPa. However, the performance of the composite's, especially the mechanical properties and water absorption depends on various factors as several types of composite materials such as lightweight composites, high strength composites, sandwich composites of different colour, texture, surface finish can be made to meet the customer requirement for a particular application.

The composites performance primarily depends on particle size fraction of marble wastes particulates, fibre to binder ratio, types of binder used, physico-chemical characteristics of marble wastes particulates & fibres,

fibre aspect ratio, interfacial bonding between particulates and matrix, processing conditions & casting technique , temperature, pressure, mixing, constituents concentrations.

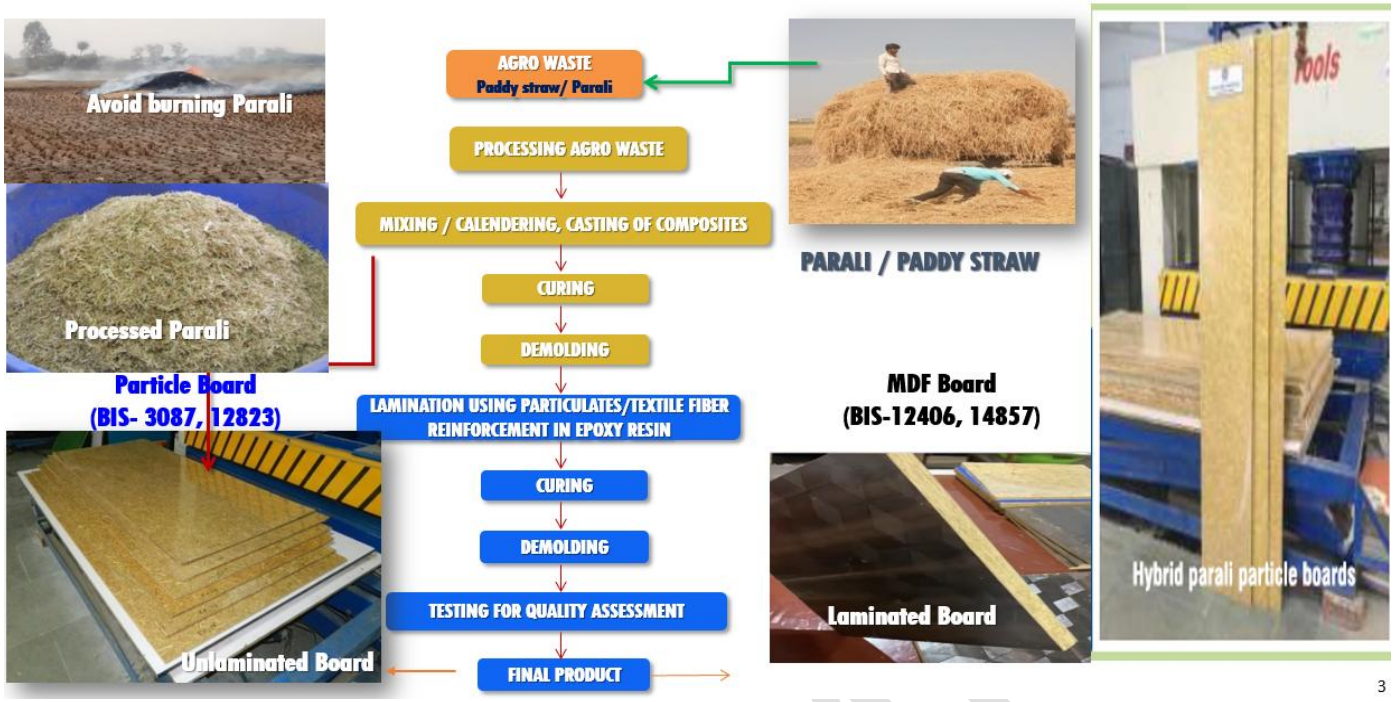
Hybrid green composites were fabricated using compression moulding with epoxy as the matrix, granite powder as filler material (up to 70 wt.%) and woven mats of jute fibres (0, 2 and 4 layers) as the reinforcing material, affording a total of 12 different composites. A very nominal increase in density was observed. The addition of granite significantly reduced the water absorption. The composites containing 60 wt.% granite and 4 layers of jute fibre mat exhibited water absorption of only 0.09 %. In terms of mechanical properties (flexural and tensile), the hybrid composites exhibited significant improvement over pure epoxy. In composites without any granite waste powder filler, flexural strength decreased as the number of layers of jute fibres mat (fibre content) increased. However, as the granite particles were introduced into the system, a steady increase in flexural strength was observed. While addition of granite powder in pure epoxy significantly decreased tensile strength (from 33.63 MPa at 0 to 26.74 MPa at 60 wt.%), the addition of jute fibres compensated for this decrease. The results indicated an overall synergistic effect of jute fibres and granite particles combination on composites' properties. Based on these studies, it is concluded that marble, granite and stone waste streams have high potential to be used with both thermoplastic and thermoset polymer so as to fabricate advanced composite materials that exhibit performance on par with commercially available materials but at lower cost and reduced environmental footprint.



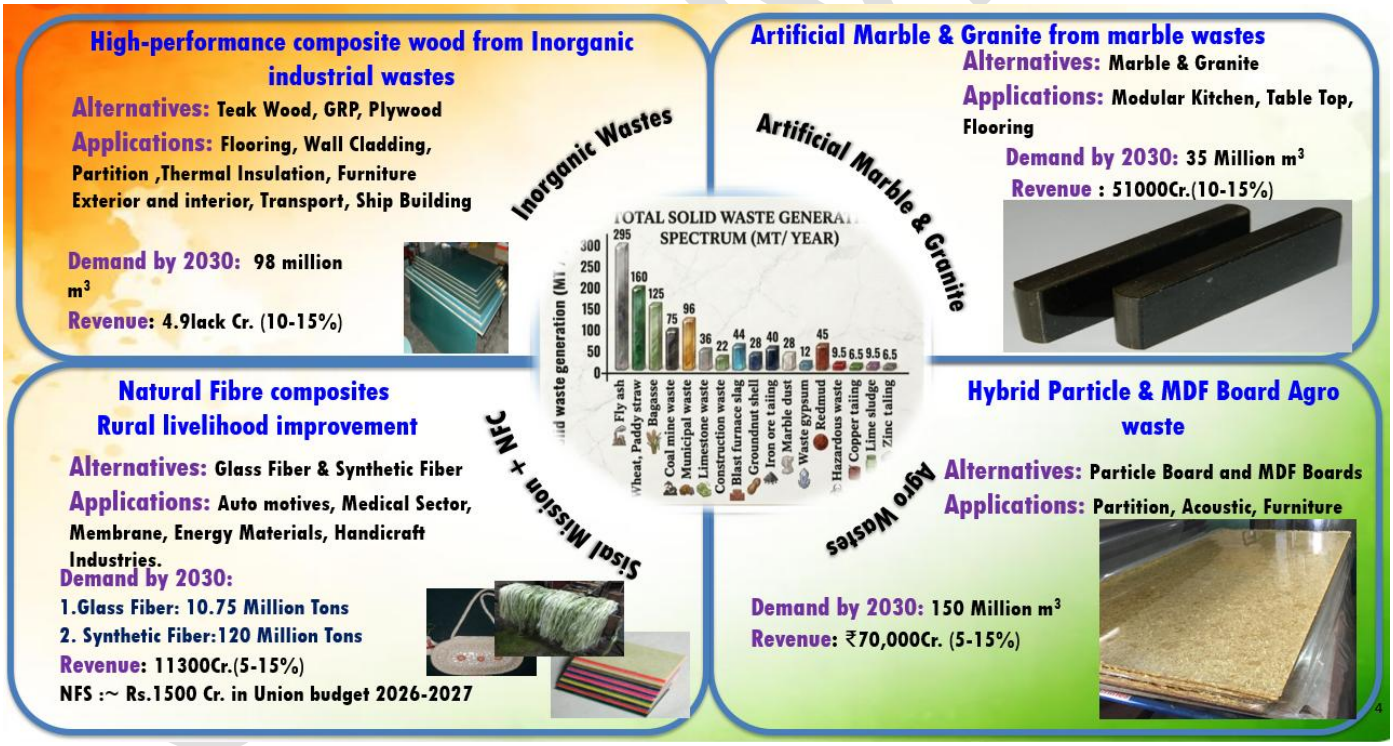
2.2 Hybrid Particle Boards/ Fibre Boards from Parali:

Every year, the burning of agro residues, especially parali burning in open land, created severe air and smog pollution in NCR, where Delhi has been cited as one of the most polluted cities in the world and air pollution level has reached levels many times higher than that of the World Health Organization (WHO) safe limits. Solution to stop parali burning is need of society as well as creating new business on parali use with an aim to safeguard our environment, contributes to the Make in India, Clean India, and UN sustainable development goal. CSIR- Advanced Materials and Processes Research Institute, Bhopal, we have came up with a green technology to manage the paddy straw (parali) agro waste at large and pilot scale level. We have introduced a new class of materials parali-based particle board as a substitute for building applications so that consumption of timber in building and house construction can be minimized and Parali can be consumed in an eco-friendly manner.

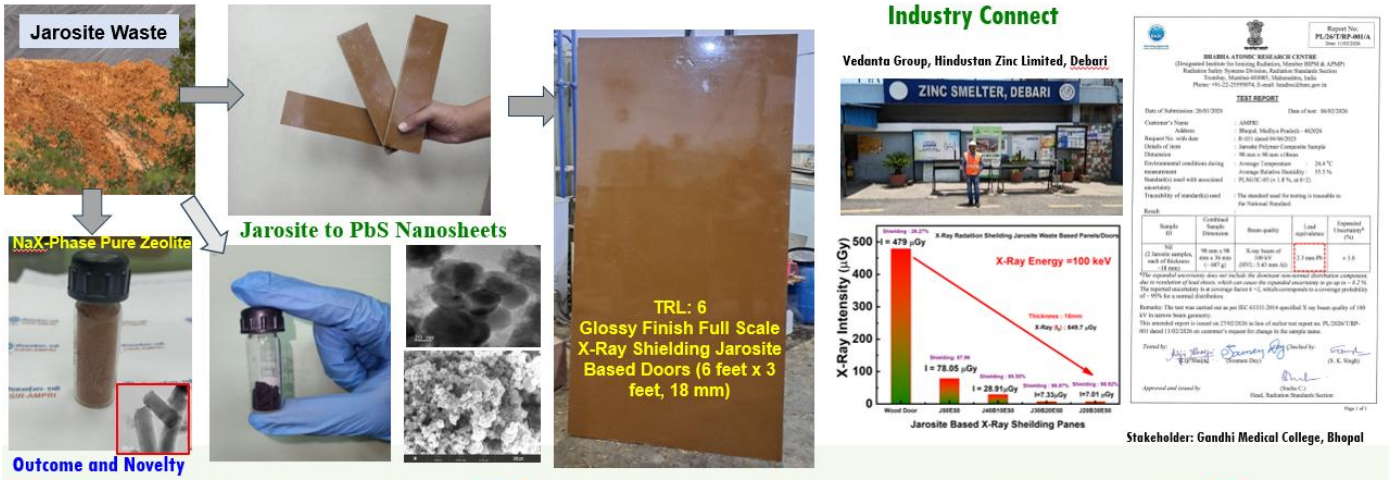
This technology also offers a potential solution for the effective utilization of other several industrial wastes such as paddy straw, wheat straw, marble waste, and fly ash. The developed ecofriendly parali board (evergreen hybrid wood), is cheaper and stronger than the conventional particle Board and Counterpart. The developed technology can solve the long-standing problem of parali burning by farmers in Haryana, Punjab, and NCR. The innovative composite evergreen hybrid parali particle board have a variety of application such as doors, false ceilings, flooring, architectural wall panels, partition, panels for locomotive (train) and other transport systems (buses, ships, etc.) and furniture. The evergreen hybrid ply and composite wood are stronger and environmentally friendly. The developed parali product is an alternate material for wood/timber, plastic, and synthetic wood such as MDF Board. The evergreen hybrid ply and composite wood are stronger and environmental-friendly. The composite materials are fire retardant, self- extinguishing in nature, cost effective and maintenance free materials. We have transferred three technology “Evergreen Hybrid Composite of Parali (agro waste) and Industrial waste” to well-known industry M/s Amit Densified (Doors) Private Limited, Sonipat, Haryana and M/s, Shubh Green Sheet Pvt. Bhilai, Durg (Chhattisgarh). CSIR-AMPRI Bhopal, has also installed our Paddy straw-based particle boards at Conference Hall of the Indira Paryavaran Bhawan, Ministry of Environment, Forest and Climate Change, New Delhi, Govt. of India.



Bigger picture of waste-to-wealth to fulfil the demands:



2.3 Extraction of Valuable Metals and Development of Advanced Polymeric Composites from Inorganic Jarosite Waste



Outcome and Novelty

Product 1: Extraction of the metals: PbS nanostructures, **Demand**: Global, USD 180 million in 2024 and expected to reach USD 260 million by 2032: **TRL 4**

Product 2: Direct conversion of the Jarosite to Zeolite Nanostructures TRL 4/5, **Demand:** Global USD 14.74 billion in 2024 to expected to reach USD 27.53 billion by 2033

Product 3: Pilot Scale advanced X-Ray Shielding Polymeric Doors/panels from Jarosite Waste for Hospital Sectors **(Patent Filed),**

Benchmarking: BARC Validated & Tested & by AERB accepted Pb equivalency with thickness of : 0.25, 0.5 and 1.0, 2.0 mm with 80-100 % shielding: **TRL: 6**

Patent Filed: India, USA, Demand: X-RAY Radiation Shielding Doors Market size was valued at USD 120 million in 2024 and expected to grow USD 200 million by 2033

2.4 Biodegradable Sustainable Packaging :

Biodegradable sustainable packaging materials (with paddy straw-PLA-PBAT, PVA) for packaging industries, MSME

2.5 Large Scale Utilization of ZLDR Generated from Grasim Industries Nagda for Development of a New Class of Wall Tiles/Wall Cladding Panels, Grasim Industries Pvt. Ltd, Nagda

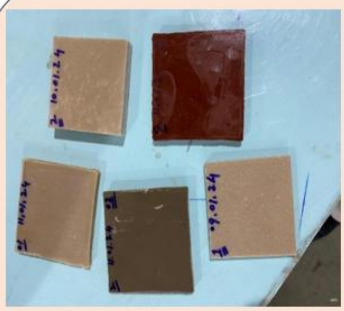
Project Cost :Rs. 21.0Lakhs
TOT Licensee Rs. 10.0 Lakhs

Zero Discharge Residue generated from Grasim

New class of wall panel/tile produced from ZLR

Technical highlights of developed composite

Flexural Strength (Mpa)	:	8.6 - 47.5
Flexural Modulus (Gpa)	:	0.55 - 6.0
Density (gm/cm^3)	:	1.52 - 1.89

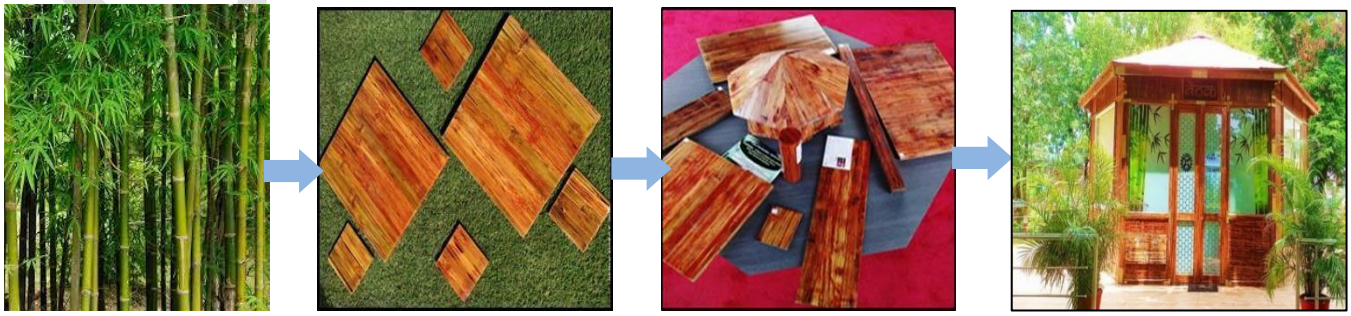


Specimen samples of wall panel developed at AMPRI

Achievement:
Technology licensed and Demonstrated to Grasim Industry, Nagda, MP.

2.6 Bamboo Composite Technology:

The technology focuses on the development of high-strength bamboo composite materials as sustainable alternatives to conventional timber and wood products. Following the 2017 amendment to the Indian Forest Act declaring bamboo as grass and easing its trade, CSIR-AMPRI Bhopal developed advanced bamboo composite structural elements with improved dimensional stability, mechanical strength, fire resistance, and moisture resistance. The technology enables the fabrication of boards, beams, panels, flooring, doors, roofing, furniture, and housing structures. The patented process has been successfully transferred to industries, promoting sustainable construction, faster renewable resource utilization, reduced dependence on timber, and employment generation through bamboo-based industrial applications.



Transformation of Raw Bamboo to Bamboo Composites

2.7 Development of Highly Durable Hybrid Wood Plastic Composites (WPC)

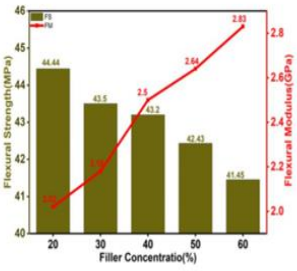
Gap to be addressed :

- In India, no technology available for WPCs So, Indigenous technology as an alternate for existing WPC technology is needed

India Market size of WPC

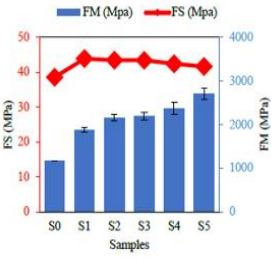
PVC-based share: ~40–50%

- **Import dependency:** 60–70% (India)
- **Domestic production:** 30–40%
- **Exports:** 5–10%



PP+ PSP WPCs

Injection molded WPC mobile stand



PP + PSP+MWP hybrid WPC

SN	Parameters	Traditional WPC	Achieved WPC
1.	Flexural Strength	25-50MPa	40-50 MPa
2.	Density	1.10-1.35g/cm^3	0.9 - 1.20g/cm^3

Bench Marking

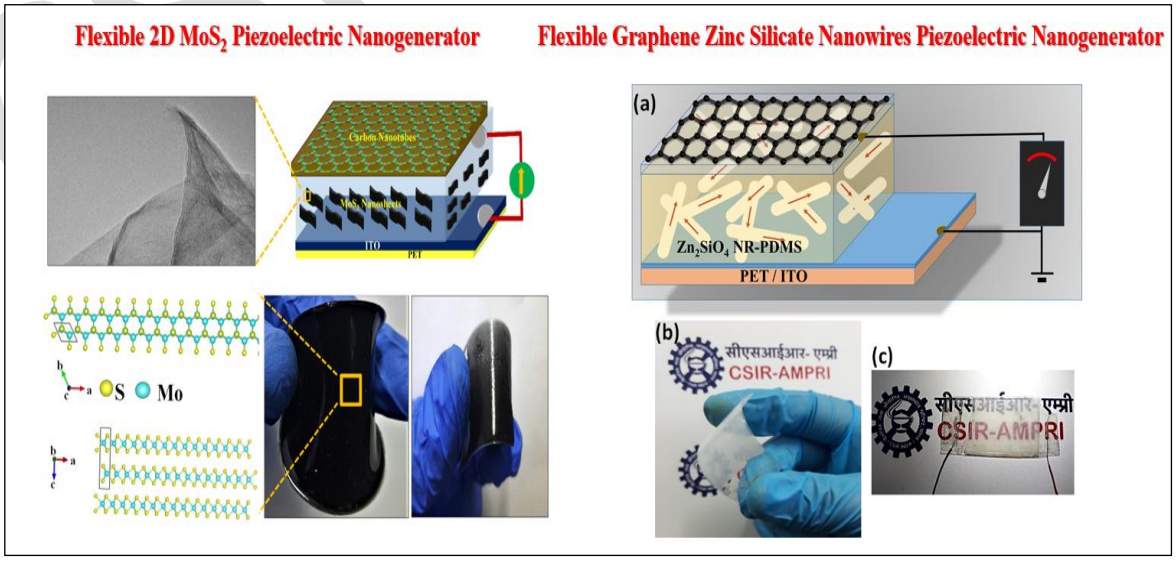
2.8 Development of Advanced Materials Utilizing EOL Solar Panels as well as Air Conditioner (AC) e-wastes

Working on the development of polymeric composites utilizing EOL solar panel wastes as well as developing advanced flexible materials as thermal insulators utilizing air-conditioner wastes.

3.Piezo & Triboelectric Nanogenerator (NST & Clean Energy Mission)

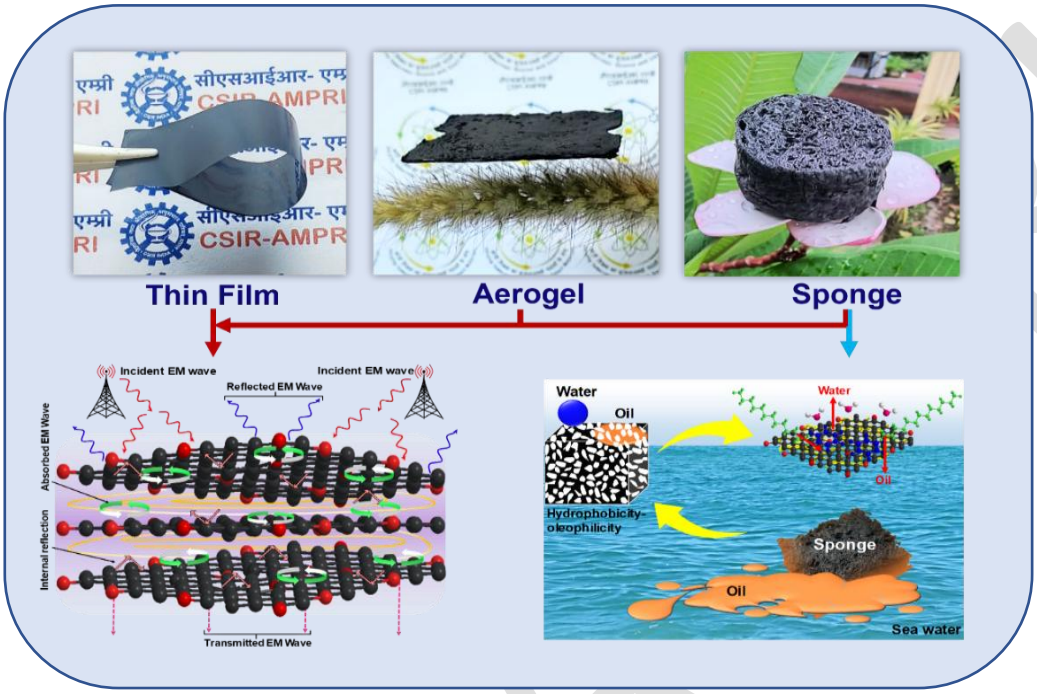
3.1 Piezoelectric & Triboelectric Nanogenerator:

Flexible Device with targeted stable output voltage of 200 V and Current of 20 µA, renewable energy and sensors sectors



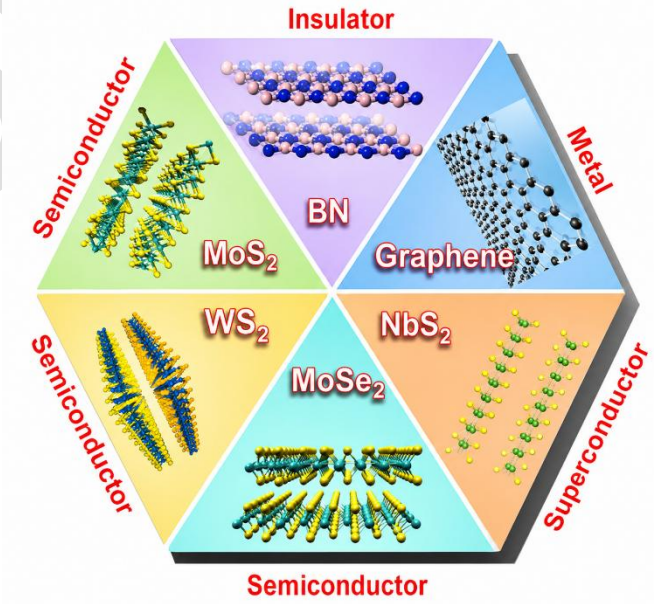
4.Advanced Functional 2D Materials & Nano Composites (Semiconductor & Quantum Mission)

4.1. 2D Materials-based Lightweight Composites for EMI Shielding and Environmental Remediation:

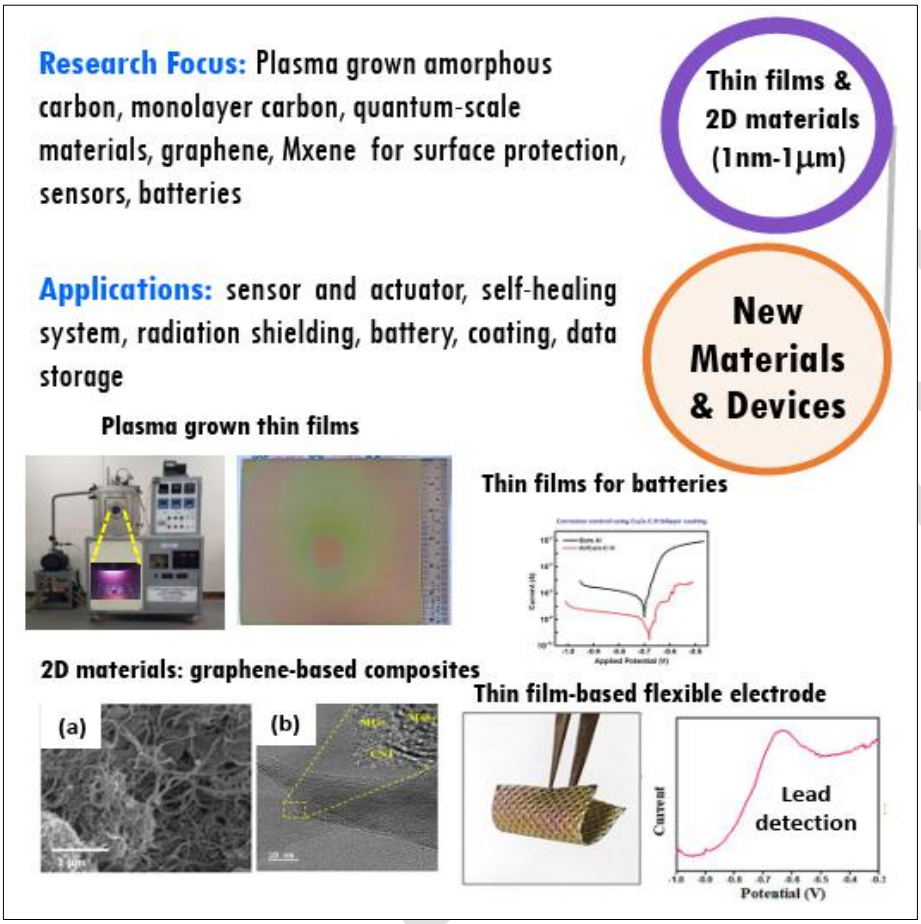


4.2 Advanced Functional Materials:

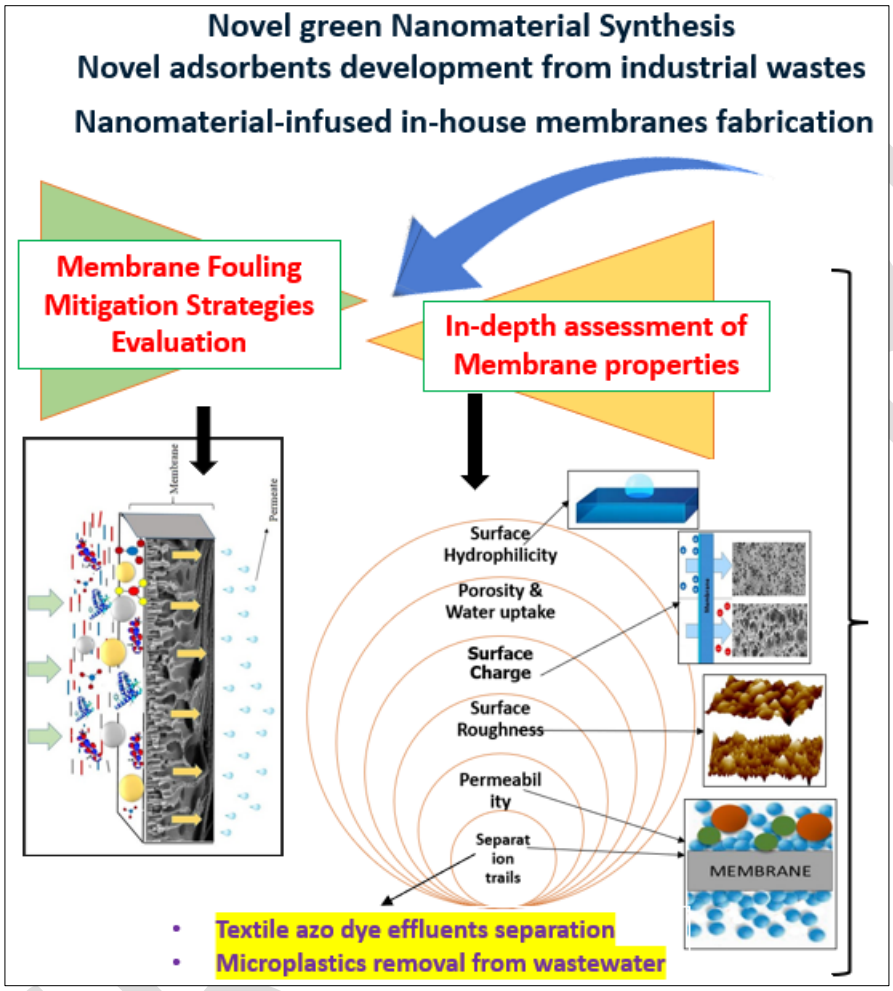
Crystalline and tailored properties, nanomaterials manufacturing industries (1D, 2D, QDs Graphene, ZnO, CNT, MXene, PVDF, PDMS, nanocomposites with tunable properties for Optoelectronic, Semiconductor, Dielectric and Graphene Industries



4.3 New Materials & Devices

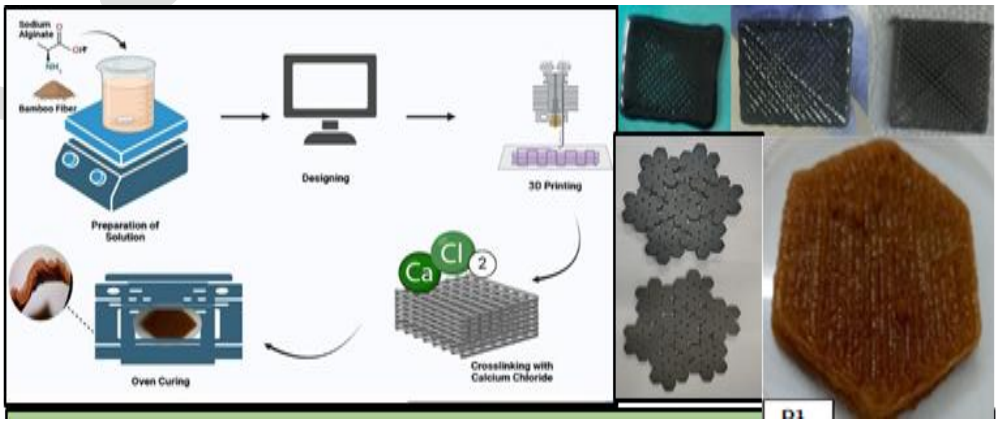


4.4 Novel Green Nanomaterial Synthesis and Novel Adsorbents Development from Industrial Waste



5. Additive Manufacturing (Atal Innovation Mission)

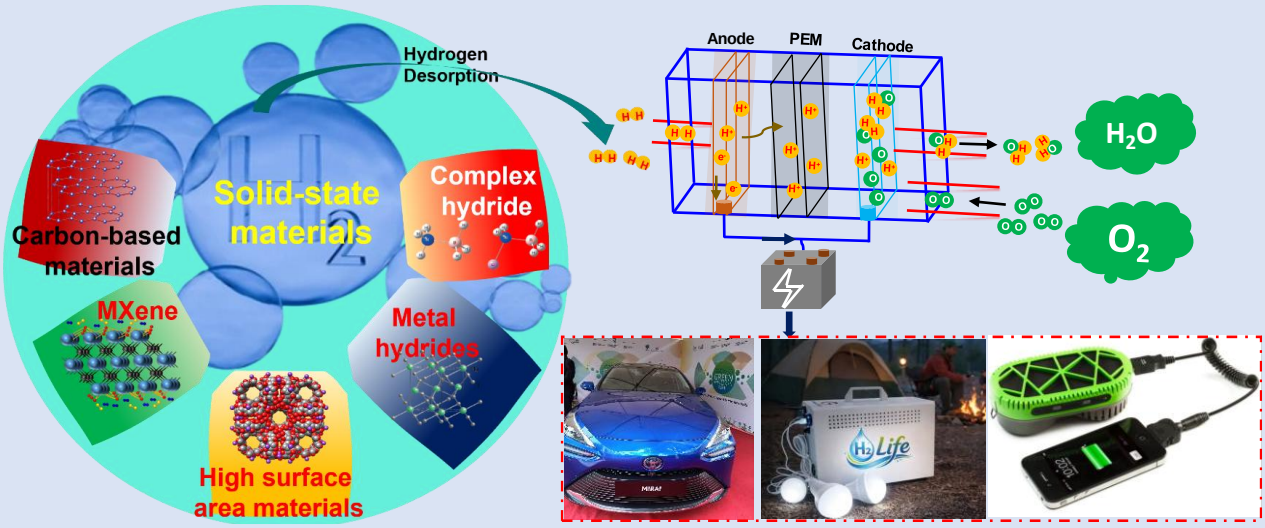
5.1 New Generation Advanced 2D Printed Composite Materials Using Mxene, Graphene Oxide – 3D Printing Technology



6. Solid-state Materials for Hydrogen Storage (Green Hydrogen Mission)

6.1 Hydrogen Storage in 2D Materials-Metal Hydrides Composite for Fuel Cell Device Applications:

- Target TRL: 3/4



Solid-state materials are central to making hydrogen fuel cells safer, lighter, and more efficient. The biggest opportunities lie in hydrogen storage for stationary and vehicular applications.

7. Electromagnetic Joining & Forming (Make-in-India, AMT)

7.1 Electromagnetic joining: