

Indian focus on creation and utilization of facilities in Science and Technology

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In a nut shell : Indian approach to science & technology

- Roadmap for 2035 and 2047 for Mega-Science by Principal Scientific Advisor's office. A lot of information is available at PSA office website.
- Deliverable mega projects under mission mode
 - Transfer of technologies
 - Involving industry from start, encourage startups
- Better utilization of resources and infrastructure
 - INUP – Indian Nanoelectronics User Program at 6 institutes
 - HPC – High performance computing facilities at 20 institutes
 - I-STEM – Indian Science Technology and Engineering facilities Map

Missions under the PM-Science, Technology, and Innovation Advisory Council

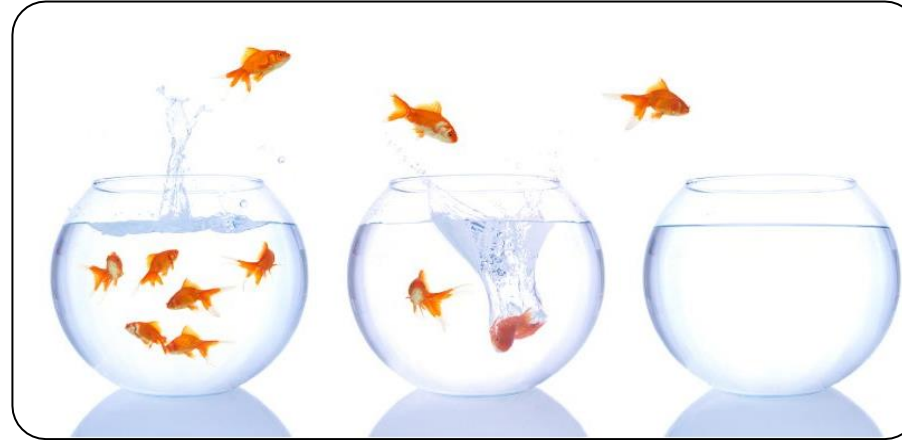
- National Quantum Mission
- Deep Ocean Mission
- National Mission on Interdisciplinary Cyber-Physical Systems
- National Supercomputing Mission : Empower academic and R&D institutions with a vast supercomputing grid
- India Semiconductor Mission
- National Biodiversity Mission
- Electric Vehicles
- Bioscience for Human Health
- Waste to Wealth
- Sustainable Science

Historical Perspective

- Council for Scientific and Industrial Research (CSIR) – 1942
- Department of Atomic Energy (DAE) – 1954
- Defence Research and Development Organization (DRDO) – 1958
- Department of Electronics and Science and Technology – 1971
- Department of Science – 1972
- Department of Environment – 1980

- Anusandhan National Research Foundation Act (ANRF) – 2023
 - To bridge gap in R&D funding and nurture robust research atmosphere in higher education institutes

Research & Innovation (R&I): Challenges, Opportunities



- **Challenge:** Silos (*disciplines, institutions, individuals*)
- **Challenge:** Depth (*Quality*) & Breadth (*Quantity*)

- **Oppty:** Positive Spillovers

- **Oppty:** R&I Human Capital: *Development & Mobility*

Human capital is the most valuable form of national capital (Gary Becker).

Infrastructure, Networks / Ecosystems, Funding, Systems are **catalysts** in service of R&I human capital development with their work driving societal and economic impact in lives of Indians

ANRF slides are courtesy, ANRF CEO, Dr. Shivkumar Kalyanaraman

ANRF: Objectives & Strategies

• Missions & Vertical “+ ANRF” Partnerships

- *Missions: science-based value-chain creation in India for the world.*
- *Catalyze & grow non-government R&D Investments in India*
- *+ANRF: Light-touch joint Initiatives driven by ANRF with many partners (foundations, companies, consortiums)*
- *ANRF Global Flagship Fund: raise a national R&I endowment (similar scale to top global univ endowments)*

• Excellence (“Depth”):

- *Cloud of R&I Infrastructure (for Deep Science, Deep Tech, MSMEs, Industry/GCCs)*
- *Cross-institutional People Mobility (including diaspora/international) to drive excellence*
- *Horizontal inter-disciplinary directorate / programs (Team Science, Interdisciplinary collaboration)*

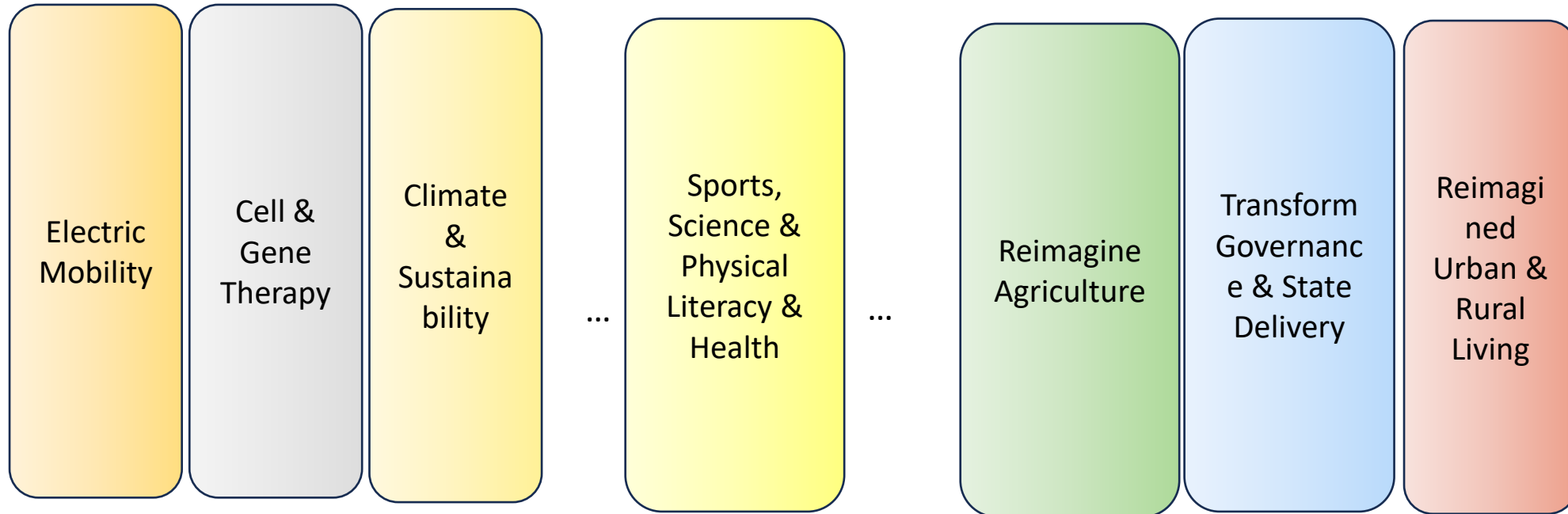
• Capacity Building (“Breadth”)

- *Hub-and-spoke (eg: PAIR) based institution building across the TRL spectrum*
- *Cross-institutional People Mobility programs at scale (eg: 1 lakh+ internships, visiting scholars)*
- *Mentoring + AI-based Networks, PM Professorships as focal points*

• Ease of Doing Research: Technology+People DPI Platform:

- *AI & Social Media to democratize research and transform all of ANRF processes.*
- *Process transformation for quality/outcome accountability, agility, stakeholder experience and scale*

ANRF-led & +ANRF Missions: Create Value-Chains, Transform Government, Reimagine Living



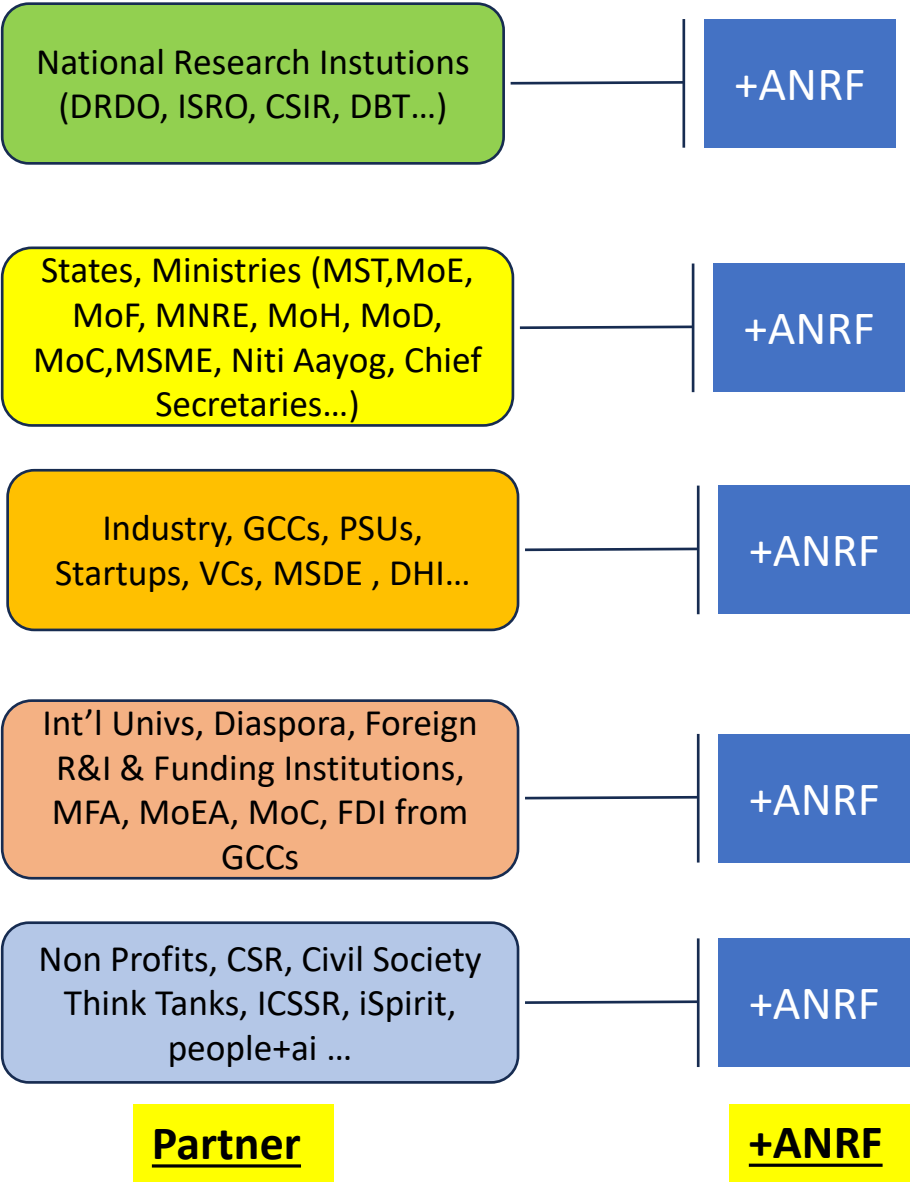
MAHA Value Chain Missions*

MAHA Societal Missions

- In addition, ANRF can partner with ministries on **“+ANRF Missions”**, eg: AI For Science, Reimagined Defense & Security, Advanced Materials, Next Gen Renewable Technologies & Systems (Photovoltaics, Wind, Batteries, Green H2, ...), Leapfrog Health & Medical Technologies, Reimagined Drug/Pharmaceuticals, Reimagined Infrastructure.
- Specific ANRF missions at any time will be prioritized based upon stakeholder consultation, co-investments, national priorities, potential for economic leadership, societal impact & approved by Executive Council (EC) on the authority of Governing Board (GB).
- +ANRF participation by partners in the missions are welcome. +ANRF can be used as incubation for future missions

Slide courtesy, ANRF CEO, Dr. Shivkumar Kalyanaraman

“+ANRF”: Vertical Partnerships



Two types of partnerships: **“Partner+ANRF”**

1. **ANRF-led:**

- ANRF will run the programs / decision process.
- Partners participate in decision & governance process on an equal rights basis (one entity one vote).
- Partners contribute funds to ANRF Innovation Fund, with a relatively simple set of terms that applies across partners (with some variations on scale of co-sponsorship).
- For Rs. 1 from ANRF, partner contributes at least Rs. 1 for the projects of interest to the partner.

2. **ANRF-Amplify:**

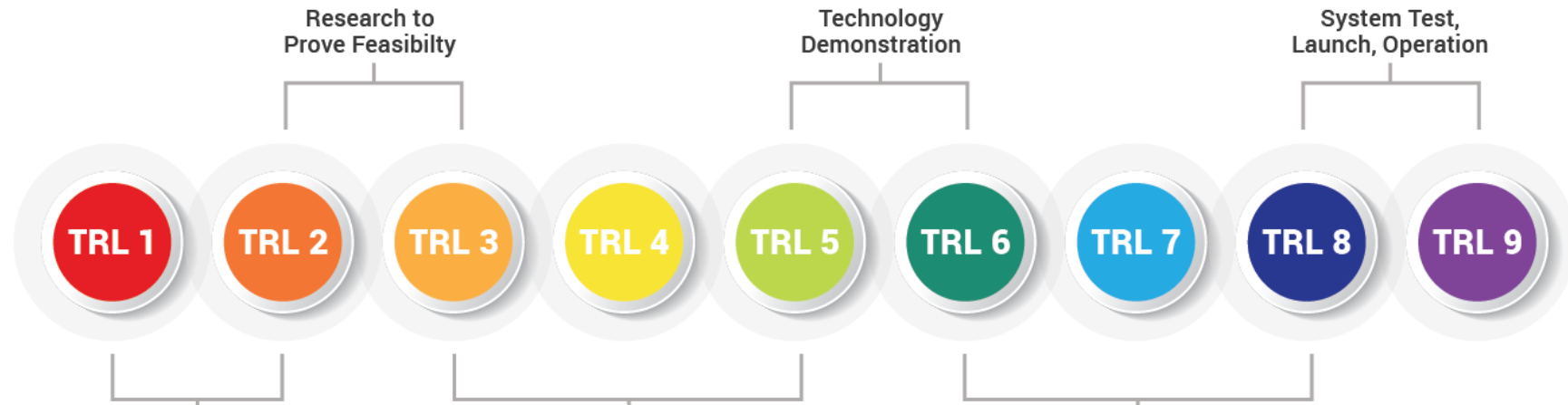
- Should be a program, not a single one-off project. Large endowment to qualifying institutions can also be considered.
- ANRF lays out guidelines for process, evaluation.
- ANRF will nominate a representative to participate (or request detailed information) on decisions.
- For every Rs. 1 invested by a partner, ANRF will invest Rs. 0.2 or less.
- ANRF will enable non-financial value addition via its various ecosystem activities, and customize them as required for the program

Cash-flow limited entities such as MSMEs, startups, NGOs, Think tanks can contribute in kind (details TBD)

ANRF as a “horizontal catalyst” for Research Excellence & Capacity Building



Technology/innovation maturity →



- Universities & Academies
- Industry, PSUs, GCCs
- National Research Institutions
- States, Ministries
- Startups, VCs
- Not for profit sector, CSR
- Think Tanks, Industry bodies
- Diaspora, Foreign Institutions, MFA

“Team science”: aim bolder, collaborative, interdisciplinary, use-inspired research

Cross-Institutional Technology Collaborations, COEs, Consortiums

Startup-academic collaborations, Research parks, Scaleup & Societal Impact

Eg: Nobel, Turing Prizes by 2047.

Eg: Catalyze 10X MSME growth, India-inspired product innovation, R&I GCCs for the world.

Eg: Catalyze emergence of 10 x \$100B companies and a \$1 trillion company in 10 years

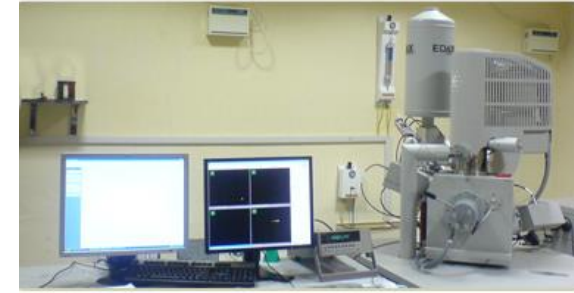
Slide courtesy, ANRF CEO, Dr. Shivkumar Kalyanaraman



“Cloud” of Shared Equipment:

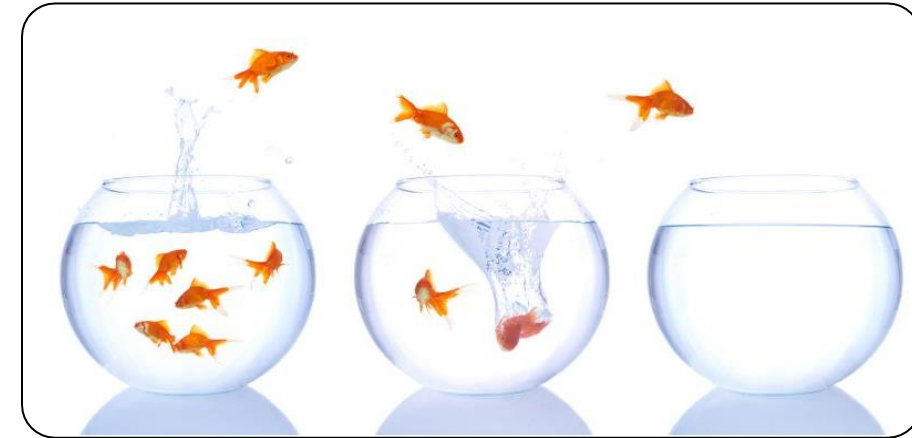
.. for experimental sciences, deeptech & MSMEs

- Enable **breakthrough experimental science**
- Drive **reputation/prominence**
- Drive **global R&D collaboration**
- Shared by:
 - **Deeptech** startups (in exchange for equity),
 - **R&D industry & R&D GCCs** (pay-per-use)
 - **MSMEs**
- Attract **global talent** back to India



Potential Examples of Shared Equipment (a) High Resolution Scanning Electron Microscope (HR- SEM)(b) Single Crystal X-Ray Diffraction (SC-XRD)

People Mobility Programs to Drive Interdisciplinary Research



- **Internships:** Academia \leftrightarrow Industry, Labs, Startups
 - Undergraduates, PhD/MS, Research Staff
- **Visiting Professor/Scholar** (Academia \rightarrow Industry, Startups, Labs)
- **Visiting Professor of Practice** (Industry \rightarrow Academia, Labs, Centers)
- **Diaspora Visitors** (VAIBHAV program – expand)
- **Return to India Fellowship** (1 year, flexible terms with host institutions)
- **Entrepreneur-in-Residence (EiR)**

ANRF will:

- Establish MoUs with host institutions (1:1 pay matching, R&I focus, mentorship requirements, dissemination/social media reqs, simple IPR policy, incremental to existing programs, breadth considerations)
- Operate an online portal & AI tools (incl open reviews) to help match talent to host institutions based upon availability & merit. Host institutions can evaluate on their own criteria. Minimum quality expectations (eg: min GPA or outstanding exceptions).
- ANRF sponsorship to individuals via host universities (or direct transfers TBD)

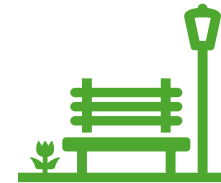
Slide courtesy, ANRF CEO, Dr. Shivkumar Kalyanaraman



Institutional R&I capacity development & Visitorship programs at all levels



**Hub-and-Spoke: Virtual “Engines”
PM Professorship at spokes**

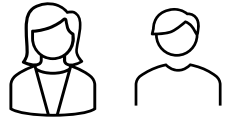


**Scaling & Multiplying best practices / successful models.
Social Media amplification.**



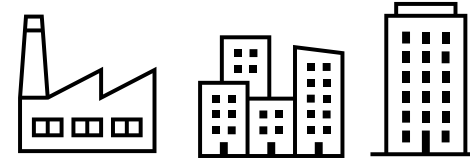
**ANRF Institution Building.
6 Cells for regional outreach & Inward Talent for ANRF**

ANRF Global R&D Flagship Fund



Individuals,
Family Offices,
Foundations

Employer Match,
Corporate Social Responsibility (CSR),
Multi-lateral / Inter-Governmental,
Other Institutional Sources



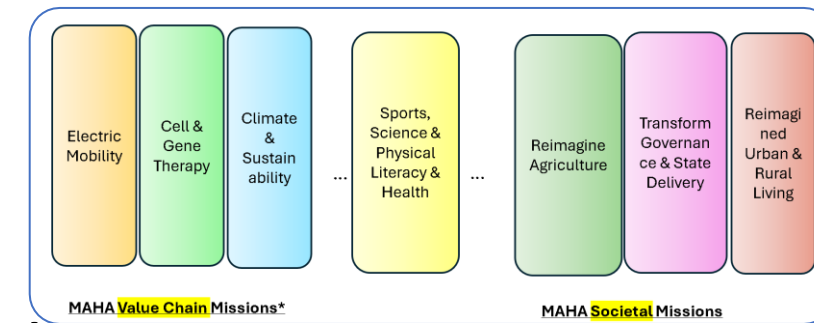
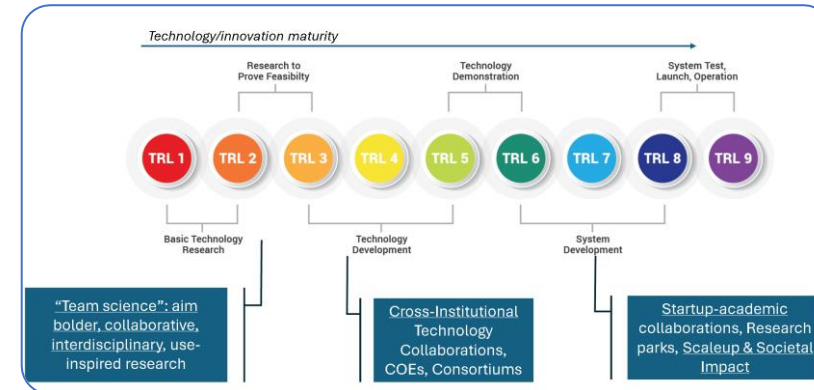
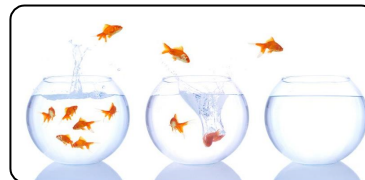
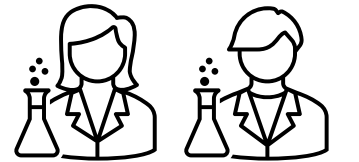
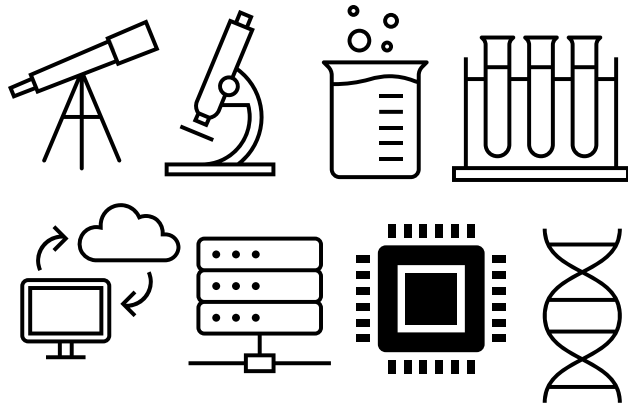
Strong Governance
Transparency
Accountability
Institutional Stability



Horizontal Interdisciplinary Initiatives &
Vertical Missions

Shared "Cloud"
Of Infrastructure

People Mobility Programs,
Fellowships, Scholarships,
Term Professorships,
Undergrad "Maker" / Research Clubs



• Mapped to ANRF Innovation Fund; With Global Entities.

• Government Investments match Fund inflows

Slide courtesy, ANRF CEO, Dr. Shivkumar Kalyanaraman

Targeted Outcomes Year 1-5, Roadmap & Metrics*



Year 1-2 Foundations: Engagement & Institution Building, Flagship Fund, +ANRF Co-funding Vertical Programs, Social+AI Tools.

Milestone/Metric (Year 1): R&I Community engagement quantity & quality, Programs rollout & governance changes, ANRF institution development & Flagship fund traction. ANRF DPI Tools, Spotlight Portal. Annual outcomes survey. Human capital & mobility in numbers.



Year 1-3 Ecosystems: Virtual Hub-Spoke Engines, Ecosystem Linkage programs, Missions.

Milestone/Metric (Year 3): Measurable numbers in human & intellectual capital output, collaboration outcomes. R&I investment by non-public (60%) vs public sector (40%). Total R&I > 1% GDP.



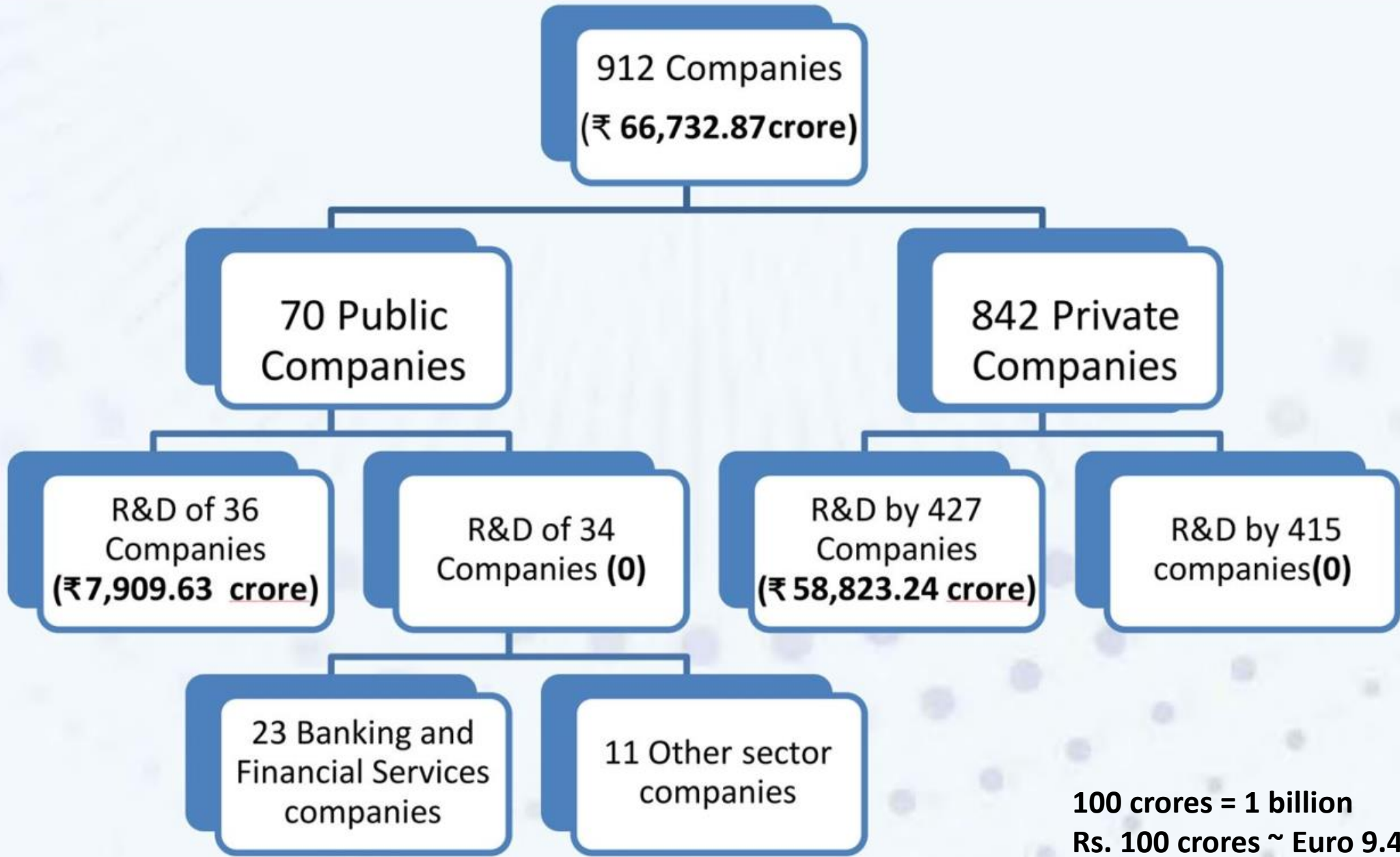
Year 3-5 Scaleup: Scaleup Programs, Directorates, Flagship Fund.

Milestone/Metric (Year 5): Measurable incremental economic impact of 0.5% GDP & growing. Excellence metrics (eg: India's presence in top 100 schools, A* papers, Patents), Collaboration & Human Capital measures. R&I investment by non-public (65%) vs public sector (35%), and total R&I investment > 1.5% of GDP.

* Indicative. Metrics to be determined in consultation with global advisory committee, and approval of governing board.

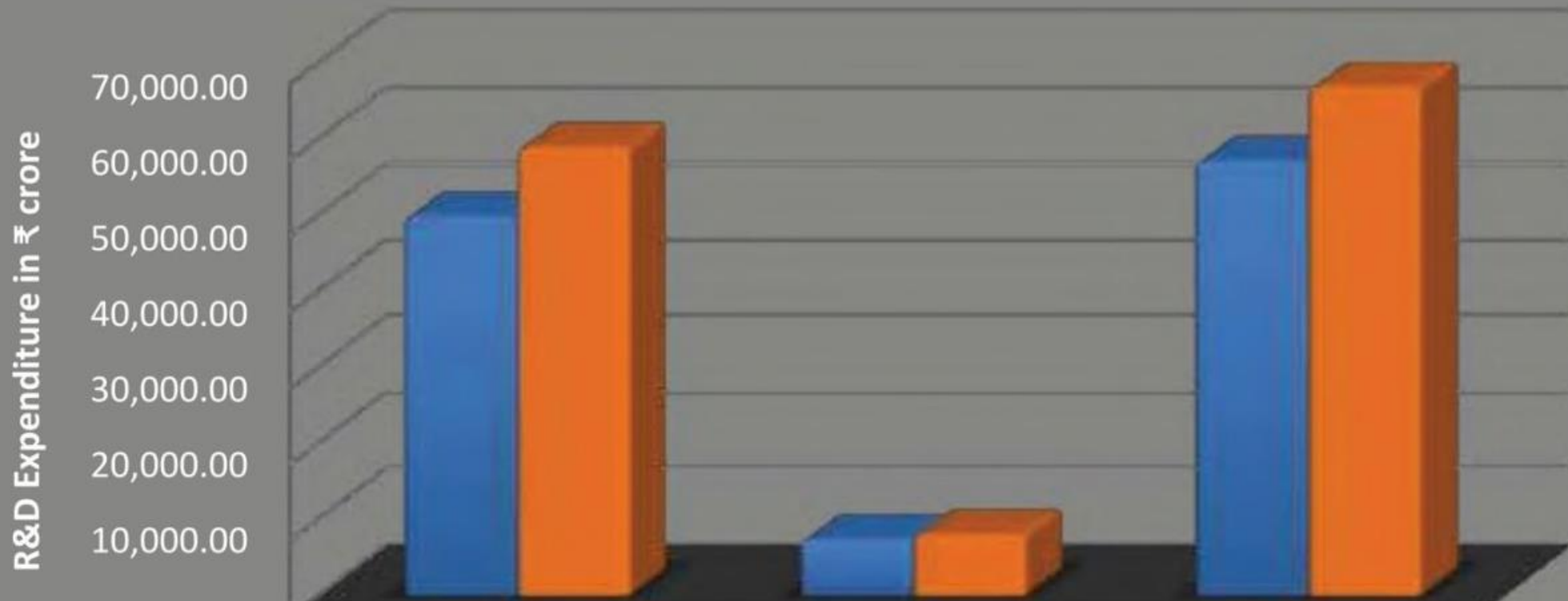
Slide courtesy, ANRF CEO, Dr. Shivkumar Kalyanaraman

- National Deep Tech Startup Policy
- Atal Innovation Mission



100 crores = 1 billion
Rs. 100 crores ~ Euro 9.4 million

Public & Private Sector Spending on R&D



| | Private Companies | PSUs | Total |
|---------|-------------------|----------|-----------|
| 2021-22 | 49,727.74 | 7,254.90 | 56,982.64 |
| 2022-23 | 58,823.24 | 7,909.63 | 66,732.87 |

Rs. 1000 crores ~ Euro 94 million

| S. No. | Industry Group | Sectors | No. of Companies | % of Turnover spent on R&D (2021-22) | % of Turnover spent on R&D (2022-23) |
|---------------|----------------------------|---|-------------------------|---|---|
| 1 | Defense | a) Aerospace & Defense b) Defense Manufacturing | 8 | 6.88 | 7.64 |
| 2 | Pharmaceuticals | a) Pharmaceuticals | 50 | 6.68 | 6.16 |
| 3 | Automobile | a) Passenger cars & Utility Vehicle b) 2/3 Wheelers | 11 | 3.75 | 3.75 |
| 4 | Healthcare | a) Hospitals b) Others - Medical Equipment & Supplies etc. | 25 | 1.59 | 2.54 |
| 5 | Heavy Electrical Equipment | a) Heavy Electrical Equipment | 13 | 1.23 | 1.33 |
| 6 | Auto Components | a) Equipments b) Tyre c) Glass | 53 | 1.05 | 1.07 |

| | | | | | |
|-----------|--|---|----|------|------|
| 7 | Information, Communication, & Technology | a) IT enabled Services b) Software & Consulting c) Diversified Commercial Services d) Trading and distributors e) BPO/KPO f) Software products g) Computer Hardware & Equipments | 44 | 0.91 | 0.89 |
| 8 | Transportation-Railway Wagons | a) Railway Wagons | 2 | 1.22 | 0.76 |
| 9 | Chemicals | a) Paints b) Specialty Chemicals | 75 | 0.73 | 0.71 |
| 10 | Telecom | a) Cellular & Fixed Line b) Equipment & Services c) Infrastructure d) Others | 13 | 0.53 | 0.54 |
| 11 | Paper & Forest products | a) Plywood/Laminates b) Paper & Paper Products c) Rubber | 14 | 0.11 | 0.47 |
| 12 | Industrial Products | a) Compressors, Pumps & Diesel Engines b) Castings & Forgings c) Abrasives & Bearings d) Other Electrical Equipment e) Electrodes & Refractories f) Iron and Casting g) Diversified | 49 | 0.61 | 0.49 |
| 13 | Consumer Durables | a) Gems, Jewellery, & Watches b) Consumer Electronics c) Household Appliances d) Sanitary ware e) Ceramics f) Glass | 31 | 0.37 | 0.42 |
| 14 | Agrochemical | a) Pesticides & Agrochemicals b) Fertilizers | 19 | 0.37 | 0.31 |
| 15 | Metals-extraction & products/ Metals & Mining | a) Iron & Steel Products b) Coal c) Aluminum Products d) Zinc e) Pig Iron, Sponge iron, f) Mineral g) Trading | 48 | 0.24 | 0.21 |
| | | h) Aluminum, Copper, & Zinc Products | | | |
| 16 | Plastic & Packaging | a) Plastic Products b) Packaging | 21 | 0.18 | 0.17 |

| | | | | | |
|-----------|---|---|----|------|------|
| 17 | Oil, Gas, & Petrochemicals | <ul style="list-style-type: none"> a) Oil Exploration & Production b) Refineries & marketing c) LPG/CNG/PNG Supplier d) Industrial gases e) Gas Transmission f) Lubricants g) Petrochemicals h) Oil Storage and Transportation i) Services j) Cylinders | 28 | 0.19 | 0.16 |
| 18 | Textile, Apparel, Leather and Footwear | <ul style="list-style-type: none"> a) Footwear b) Garments & Apparel c) Other Textile Products d) Trading Textile Products e) Leather | 26 | 0.11 | 0.15 |
| 19 | FMCG/CPG | <ul style="list-style-type: none"> a) Animal Feed b) Agriculture Products c) Dairy d) Personal Care e) Sugar | 65 | 0.18 | 0.16 |
| 20 | Other Services | <ul style="list-style-type: none"> a) Logistic Solution provider b) Shipping c) Airport Services d) Workforce Management e) Diversified | 18 | 0.13 | 0.13 |
| 21 | Construction | <ul style="list-style-type: none"> a) Cements and Material b) Water Supply & Management c) Civil Construction d) Residential, Commercial Projects-Real Estate e) Rail & Roads f) Ports & Services g) Ship Building | 95 | 0.1 | 0.1 |
| 22 | Power Generation and Transmission | <ul style="list-style-type: none"> a) Power Transmission b) Power Generation c) Integrated Power Utilities | 19 | 0.11 | 0.1 |
| 23 | Others | <ul style="list-style-type: none"> a) Ratings b) Explosives c) Auto Dealers | 5 | 0.06 | 0.03 |
| 24 | E- Platforms Product and Services | <ul style="list-style-type: none"> a) E-retail/E-Commerce b) Exchange and Data Platforms c) Internet & Catalogue Retail d) Trading & Distributors e) E-Learning | 11 | 0 | 0 |
| 25 | Tourism & Hospitality | <ul style="list-style-type: none"> a) Amusement Parks b) Restaurants c) Hotels d) Services | 21 | 0 | 0 |

| | | | | | |
|-----------|-----------------------|--|-----|---|---|
| 26 | Retail & E-Commerce | a) Diversified Retail b) Specialty Retail | 9 | 0 | 0 |
| 27 | Financial Services | a) Public and Private Sector Banks b) Life Insurance c) Non-Banking Financial Company (NBFC) d) Holding Company e) Investment Company f) Asset Management Company g) Housing Finance Company h) Microfinance Institutions i) Stock-broking & allied j) Financial Products Distributor | 119 | 0 | 0 |
| 28 | Education | a) Education | 2 | 0 | 0 |
| 29 | Media & Entertainment | a) Print Media b) Broadcasting & Software Production c) Film Production, Distribution & Exhibition d) Digital Entertainment e) Printing & Publication | 16 | 0 | 0 |
| 30 | Aviation | a) Airlines | 2 | 0 | 0 |

| Percentage of R&D amount spent on Sustainability | No. of Companies (2021-22) | No. of Companies (2022-23) |
|---|-----------------------------------|-----------------------------------|
| 0% | 129 | 114 |
| 0% up to 25% | 110 | 118 |
| 25% up to 50% | 16 | 22 |
| 50% up to 75% | 14 | 18 |
| 75% up to 100% | 132 | 139 |
| Not Available* | 62 | 52 |
| Total Companies | 463 | 463 |

| Sectors | Sustainability related activities |
|---|---|
| Specialty Chemicals & Agrochemicals | <ol style="list-style-type: none"> 1. Development of indigenous technology has led to cost reduction, use of environment friendly synthesis routes & conservation of foreign exchange 2. Engagement in research activities developing environmental friendly new technologies for pharma, additives and specialty chemicals, which India currently depends on imports. |
| Automobiles | <ol style="list-style-type: none"> 1. Extending EV product range, developing flex fuel power train, fuel cell EV & Hydrogen ICE 2. Investment in improvement of Energy Efficiency |
| Cements – Construction material | <ol style="list-style-type: none"> 1. Conservation of resources through maximisation of the use of low - grade limestone for cement manufacturing 2. Maximisation of industrial wastes utilization and looking into possibilities of environmentally friendly co -processing of wastes in cement manufacture 3. Development of application-oriented cement focusing customer pain points with reduced carbon footprint 4. R&D investment in fuel efficiency |
| Power Generation- (Energy generation and transmission) | <ol style="list-style-type: none"> 1. R&D efforts are centered on carbon capture and utilization technologies, 2. ash utilization technology, 3. waste-to energy solutions, water technology, 4. Efficiency improvement, cost reduction, new and renewable energy, climate change, and environmental protection |
| FMCG | <ol style="list-style-type: none"> 1. Sustainable Packaging 2. Health & Nutrition- Focus on multiple aspects of human health stratified across age, gender, specific health concerns as well as uniqueness of the Indian consumer. 3. R&D investment to manufacture high quality and safe products, improve yields, input substitution and achieve more efficient operations. |
| Software and consulting- | <ol style="list-style-type: none"> 1. R&D investment towards responsible Artificial Intelligence (AI) 2. Works related to carbon capture, digital twins for continuous manufacture of biopharma, and emission reduction in industries. 3. TCS' Clever Energy, HCL's AI Lifecycle Management, etc. are some of the examples from this sector |
| Pharmaceuticals | <ol style="list-style-type: none"> 1. Works toward technologically advanced differentiated products which are convenient and safe for administration to patients |

Nuclear Physics

- Growth of the field in Indian universities and institutes started in 1960s.
 - Electronics Corporation of India (ECIL) established to support the science programs
 - Setup Pelletrons at TIFR-BARC and Nuclear Science Centre (now IUAC), the Cyclotron at the Variable Energy Cyclotron Center (VECC) and the research reactors at the Indira Gandhi Center for Atomic Research (IGCAR) and BARC.
- In 2000s, superconducting linear accelerators were added to boost the beam energies from the Pelletrons. This expanded the region of nuclei that can be investigated.
- UGC-DAE consortium encouraged the use of Department of Atomic Energy facilities by university faculty for nuclear physics studies.
- Synchrotron Radiation Source Facility at RRCAT came up and the era of industrial accelerators began with the electron beam experimental facility at Trombay.
- Nuclear Power Corporation of India Limited, with origins in Nuclear Power Board, was setup to harness nuclear power for societal needs.
- Experiments related to the thermonuclear fusion process as a power source conducted using the tokamak ADITYA and subsequent versions, leading to participation in global efforts in mid-2000s.

| Accelerator | Available Beams | Energy and Current | Major Experimental Programs | Beam Lines and Major Experimental Facilities | Current Users |
|---|---|--|--|---|---|
| <p>BARC-TIFR Pelletron-LINAC Facility, TIFR, Mumbai</p> | <p>^1H, ^4He, $^6,^7\text{Li}$, ^9Be, $^{10,11}\text{B}$, $^{12,13}\text{C}$, ^{14}N, $^{16,18}\text{O}$, ^{19}F, ^{22}Na, ^{24}Mg, ^{27}Al, $^{28,30}\text{Si}$, $^{32,34}\text{S}$, $^{35,37}\text{Cl}$, ^{38}K, ^{40}Ca, ^{48}Ti, ^{58}Ni, ^{107}Ag, ^{127}I, SF_6 molecular beam</p> | <p>5–8 MeV/A up to Ni. 1–5 pA (for some of the beams such as Li and C, one can get up to 10–20 pA)</p> | <ul style="list-style-type: none"> • Nuclear Physics • Atomic Physics • Condensed Matter Physics • Radiochemistry • Agriculture • Terahertz Devices • Medical-isotope R&D • Accelerator Mass Spectroscopy (AMS) • Industrial and Space-science related applications | <p>12 Beam Lines</p> <ol style="list-style-type: none"> 1. 6M high current proton irradiation facility, 2. Two general purpose scattering chambers 3. Large HPGe array (INGA) 4. Neutron array 5. High-energy gamma detector 6. Fission MWPC detector array 7. Charged particle scattering chamber (CPSC) 8. Strip detector array 9. Low background facility 10. g-factor measurement setup with a 7 T magnet 11. Beam scanner 12. Isomer studies with beam chopper | <p>260 Users – National, International Institutes/Centres, Universities, IITs, ISRO, etc.</p> |
| <p>K130 Room Temperature Cyclotron, VECC, Kolkata</p> | <p>H, ^4He, ^{14}N, ^{16}O, ^{20}Ne, ^{32}S</p> | <p>1–10 MeV/A 1 enA–4 eμA</p> | <ul style="list-style-type: none"> • Nuclear Physics • Atomic Physics • Material Science • Radiochemistry • Analytical Chemistry • Biology • RIB production | <p>4 Beam Lines</p> <ol style="list-style-type: none"> 1. Facilities for irradiation 2. General purpose scattering chamber 3. INGA 4. VENUS and VENTURE arrays 5. An array of neutron detectors 6. An array of large-area | <p>National Institutes/Centres, Universities, IITs, ISAC(ISRO), IEST, etc.</p> |

| | | | | | |
|---|---|------------------------|--|--|---|
| | | | | modular BaF ₂ detector (LAMBDA) 7. Fission PPAC and MWPC detector array 8. Charged-particle detector array | |
| IUAC Pelletron-LINAC and LEIBF facility, New Delhi | ¹ H, ^{6,7} Li, ⁹ Be, ^{10,11} B, ¹² C, ^{14,15} N, ^{16,18} O, ¹⁹ F, ²⁴ Mg, ²⁷ Al, ^{28,29,30} Si ³¹ P, ^{32,34} S, ^{35,37} Cl, ⁴⁰ Ca, ⁴⁵ Sc, ^{46,48} Ti, ⁵¹ V, ⁵⁶ Fe, ⁵⁸ Ni, ⁶³ Cu, ⁶⁴ Zn, ⁷⁴ Ge, ⁷⁹ Br, ^{107,109} Ag ¹²⁰ Sn, ¹²⁷ I, ¹⁹⁷ Au | 3–8 MeV/A 1–5 pA | <ul style="list-style-type: none"> • Nuclear Physics • Material Science • Device Fabrication • Radiation Biology • AMS • Radiation Physics | 8 Beam Lines 1. Gamma Detector Array (GDA) 2. INGA 3. Heavy-ion Reaction Analyzer (HIRA) 4. HYbrid Recoil mass Analyzer (HYRA) 5. General purpose scattering chamber (GPSC) 6. National Array of Neutron Detectors (NAND) 7. ASPIRE (Automatic Sample 8. Positioning for Irradiation in Radiation Biology Experiments 9. Beam-foil spectroscopy apparatus | 100 research groups (covering all accelerator-based research) from nearly 160 Universities, 85 Colleges and 60 other National laboratories. |
| FRENA Tandetron facility, SINP, Kolkata | ¹ H, ⁴ He, Heavy ions | 0.2–3 MeV 50–300 μA | <ul style="list-style-type: none"> • Astrophysics | 5 Beam Lines 1. Small target chamber for gamma spectroscopy and neutron detection | |
| Folded Tandem Ion Accelerator (FOTIA), BARC, Mumbai | ¹ H, ^{6,7} Li | 6–12 MeV, 1–5 pA | <ul style="list-style-type: none"> • Nuclear Physics • Atomic Physics • Radiochemistry • Biology | 1. General purpose scattering chamber 2. PIXE 3. Rutherford Backscattering 4. PIGE | |

High Energy Physics : Collaborations

- CMS needs :
 - GPU facilities for Tier 2 and Tier 3 institutes
 - NKN bandwidth of 10 Gbps or more for each institute
 - 25-30 new faculties, 100 phd students and 40 postdocs expected
- Belle :
 - Bharat Electronics Limited (BEL) is making Silicon microstrip sensors for Belle. Other industries and more products/orders needed to sustain Indian involvement at a higher level.
- PICASSO/PICO :
 - SINP group has been contributing to detector fabrication, R&D for the next generation detector. Industry connections need to grow to exploit potential applications.
- MAGIC :
 - The primary objective of the Indian participation is to perform coordinated multi-wavelength observations with the currently running Indian observatories like Himalayan Chandra Telescope (HCT) at Hanle, Giant Metrewave Radio Telescope (GMRT) at Pune and the first Indian multi-wavelength satellite, ASTROSAT.

A few HEP Indian facilities

- GRAPES-3 Collaboration includes 12 Indian institutions and 7 Japanese institutions
- Gamma-ray Astrophysics (HAGAR/MACE)
- The Indian Coherent Neutrino Scattering Experiment (ICNSE) at the Apsara-U research reactor at BARC

- Plastic Scintillators, gas detectors, electronics, trigger and data acquisition, high purity crystals, have promise in future colliders
- Quantum sensors : SNSPDs, Transition edge sensors, magneto- and electrometers, metamaterial based opto-electronic devices,...

LIGO

- Civil and vacuum infrastructure work to initiate in 2026 with the contract about to be awarded

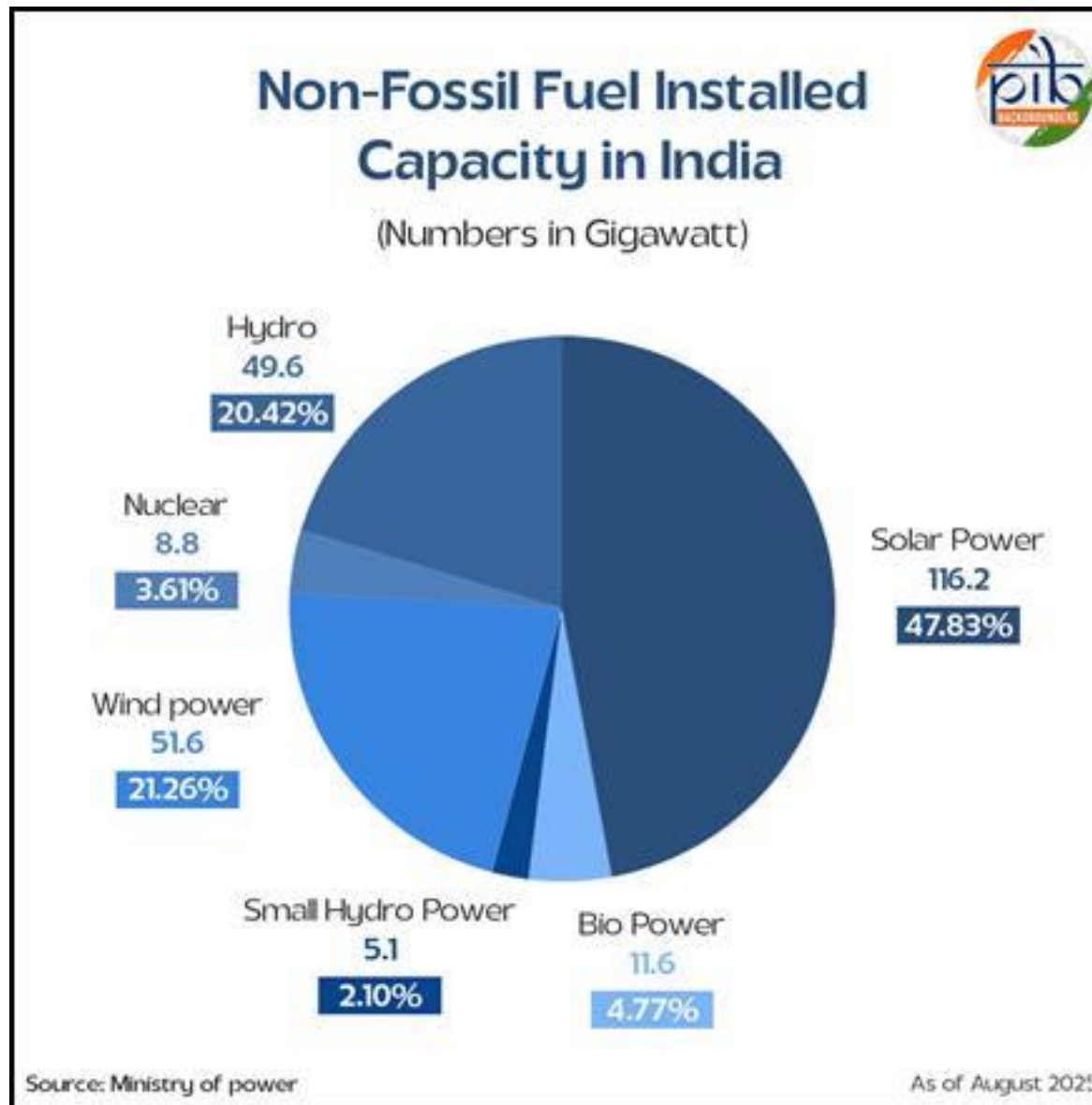
Other facilities approved or proposed

- Detailed Roadmaps are also prepared for other facilities like High brilliance synchrotron radiation source, Accelerators for Rare isotope beams, heavy ion accelerator facility, free electron lasers, among others
- Translation to high power industrial accelerators for biomedical and food safety applications needed

Focus as a national policy

- Develop better utilization of resources
 - I-STEM (Indian Science, Technology, and Engineering facilities Map)
- Address local challenges
 - S&T clusters – 8 across Indian cities (Hyderabad, Jodhpur, Pune, Delhi, Bhubaneswar, Bengaluru, North India)
 - Rural technology activities
 - E-mobility R&D
 - One nation one subscription
 - Biomass cultivation on degraded land for green hydrogen production
- Centres of Excellence

Indian Energy Targets



By **June 2025**, India has installed **242.8 GW** of non-fossil fuel installed capacity, including **233.99 GW** of renewable energy and **8.8 GW** of nuclear power.

This now makes up **50.07%** of the country's total power capacity of **484.82 GW**.

Indian Needs...

- Metrology for Green energy sources :
 - Solar
 - power grid monitoring
 - batteries
 - ethanol blends
 - hydrogen

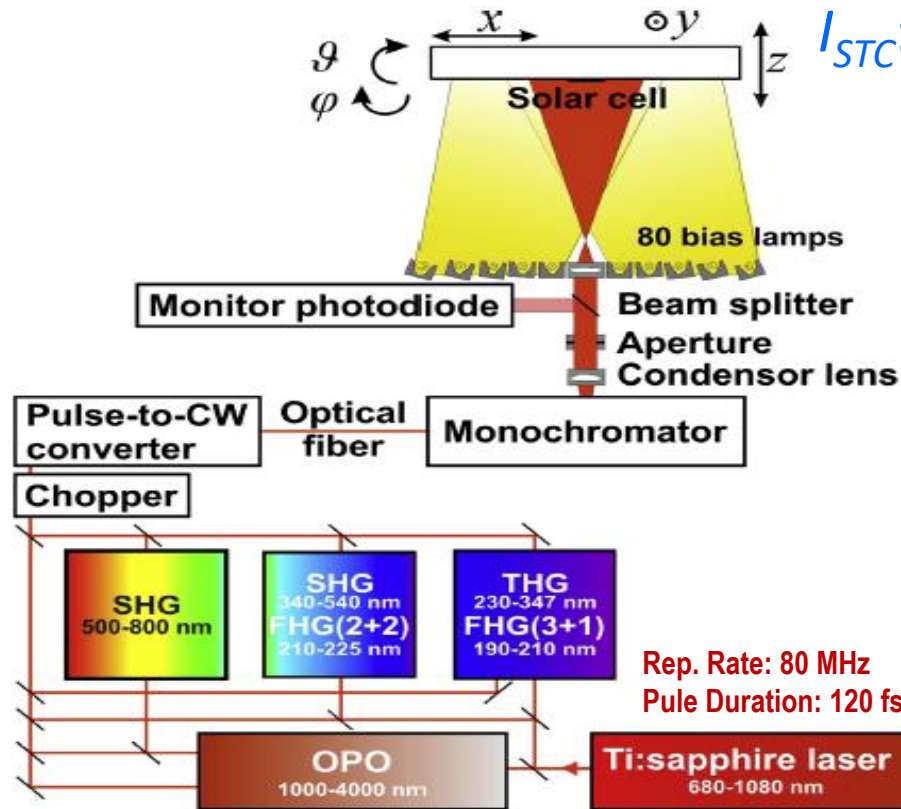
- Circular economy : waste recycling

National Primary Standard Facility for Solar Cell Calibration

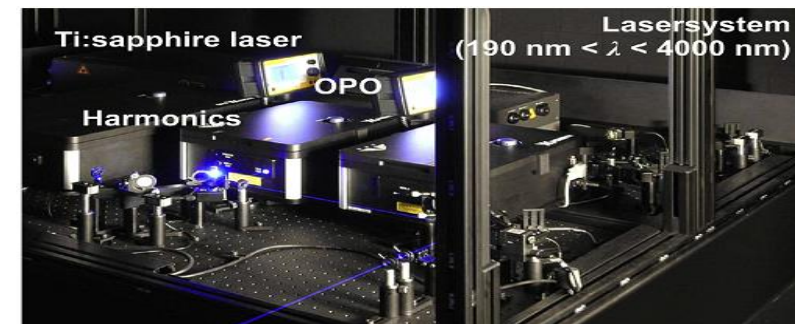
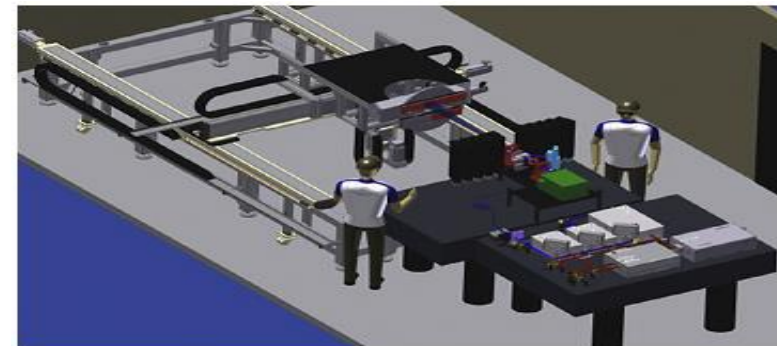
Uncertainty for short circuit current of solar cells

I_{STC} : **0.35%** for 20x20 mm² solar cells (k = 2)

0.6% for 156x156 mm² solar cells (k = 2)



Schematic of Laser-DSR facility



Complete laser setup with laser beam routed through the SHG (400 nm)

Intercomparison Status

Present status of measurement uncertainty (short-circuit current of solar cells) at other NMIs/WPVS Laboratories

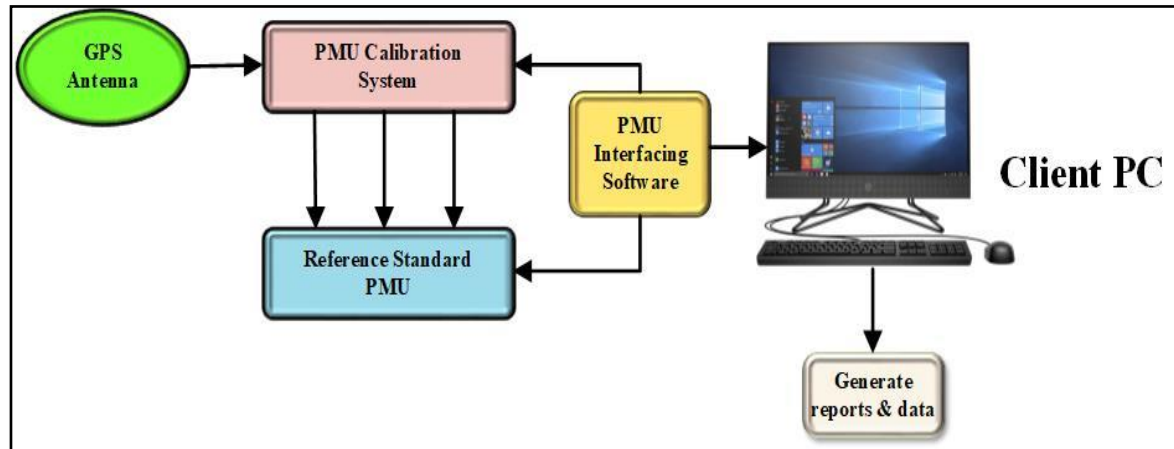
| NMI/WPVS Laboratory | TIPS, China | NREL, USA | AIST, Japan | PTB, Germany | CSIR-NPL, India |
|--|--------------------|------------------|--------------------|---------------------|------------------------|
| Uncertainty (I_{STC} @ $k=2$) | 0.9 % | ± 0.4 % | ± 0.6 % | ± 0.4 % | 0.35 % |
| Calibration Charges | -- | \$3,318 | €5000 | €3200 | \$1400 |

- **CSIR-NPL, India providing the lowest uncertainty among the WPVS (World Photovoltaic Scale) laboratories**
- **Relatively lower calibration charges of reference solar cells**

PMU CALIBRATION SYSTEM

Team: LF, HF Voltage, Current & Microwave Metrology

- The CSIR-NPL PMU calibration system is a fully integrated and automated system traceable to the primary standards at CSIR-NPL.



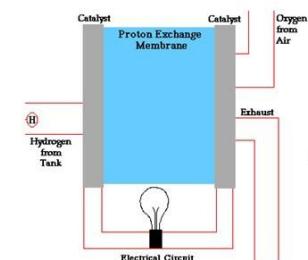
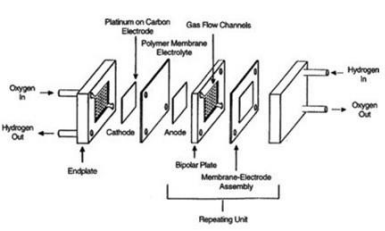
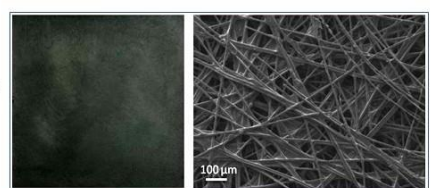
PMU-CAL system calibration setup



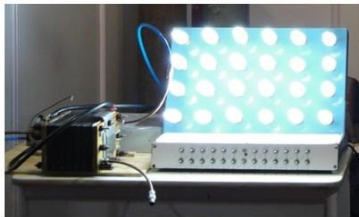
Traceable CSIR-NPL
PMU-CAL system

Carbon components for Polymer Electrolyte Membrane Fuel Cell

Demonstration of PEM Fuel made from indigenous Porous conducting carbon paper and graphite composite bipolar plates






Porous conducting carbon fiber paper as gas diffusion layer

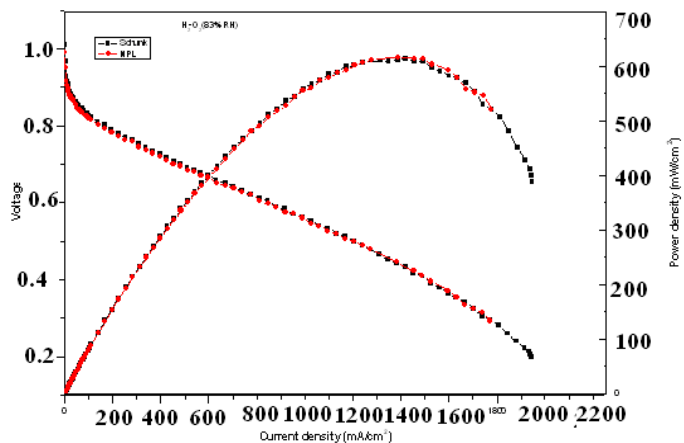


PEM fuel cell demonstration by using NPL bipolar plates and carbon paper

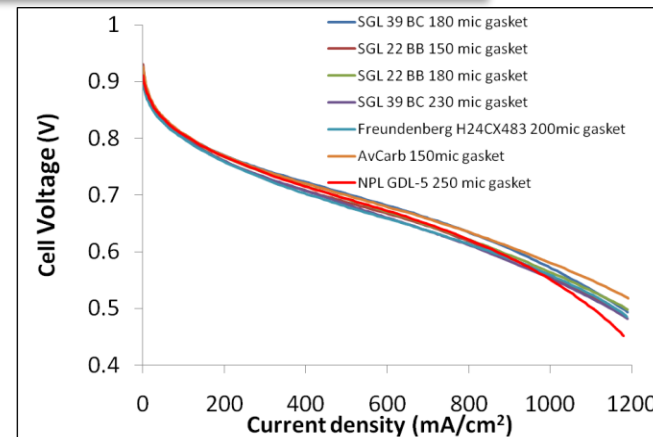
Graphite composite bipolar plates, porous conducting carbon fiber paper, catalyst support active carbon contributes **80 % by weight & 50 % by cost** of fuel cell stack



Multi-component graphite composite bipolar plate

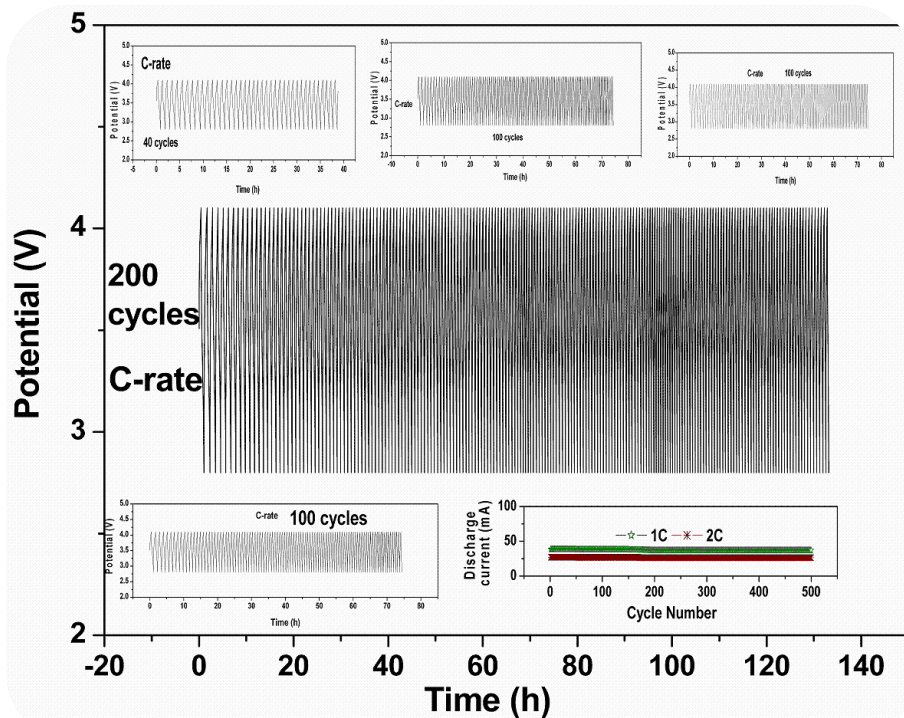
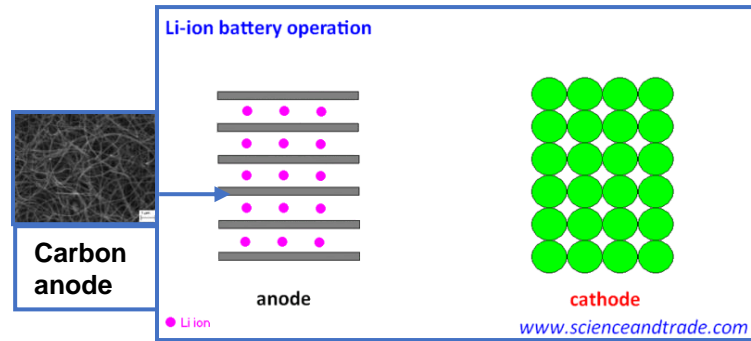


I-V performance of the NPL bipolar plate in comparison with Schunk Germany



I-V performance of the NPL carbon paper vs other commercial papers

Development of carbon based Anode for Li-ion Rechargeable Battery



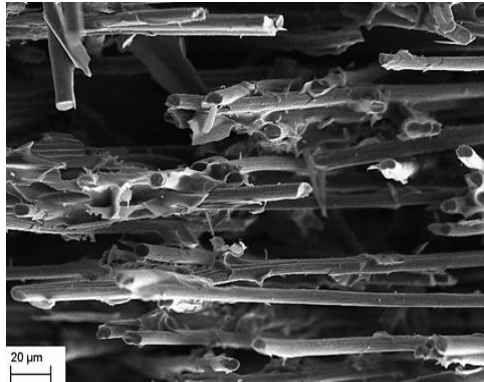
Demonstration of 500 cycles with NPL anode



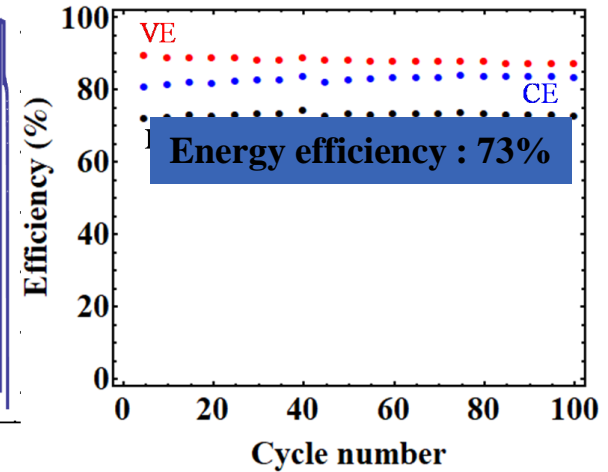
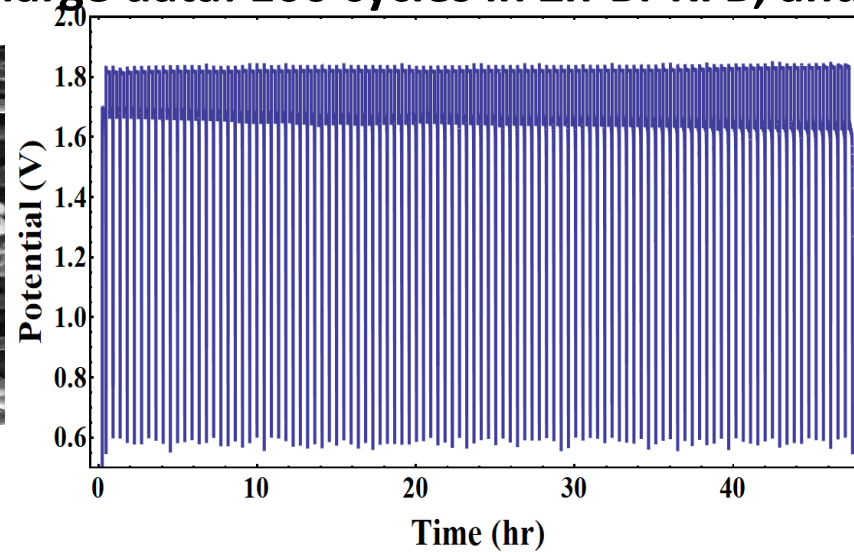
Demonstration of solar lamp with NPL anode & CECRI cathode

Development of Electrode bipolar plate for Redox Flow Battery

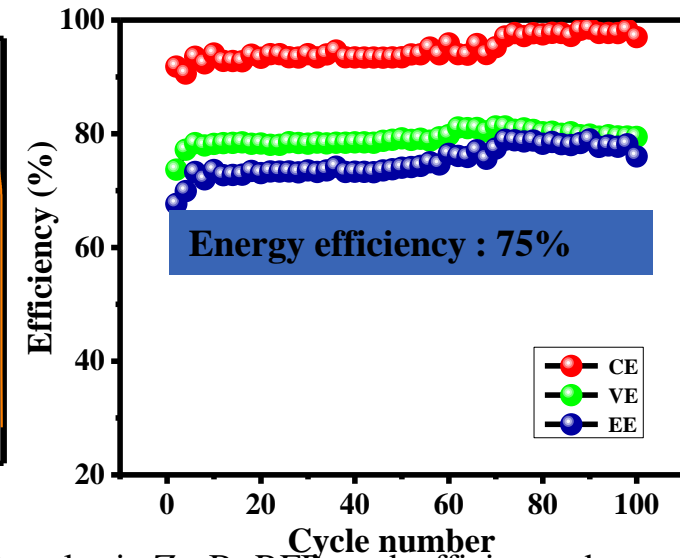
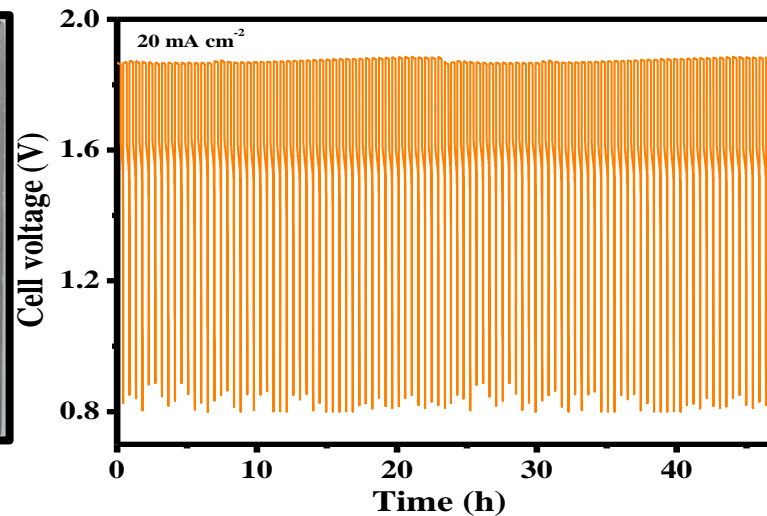
Charge-discharge data: 100 cycles in Zn-Br RFB, and efficiency data



NPL carbon paper electrode



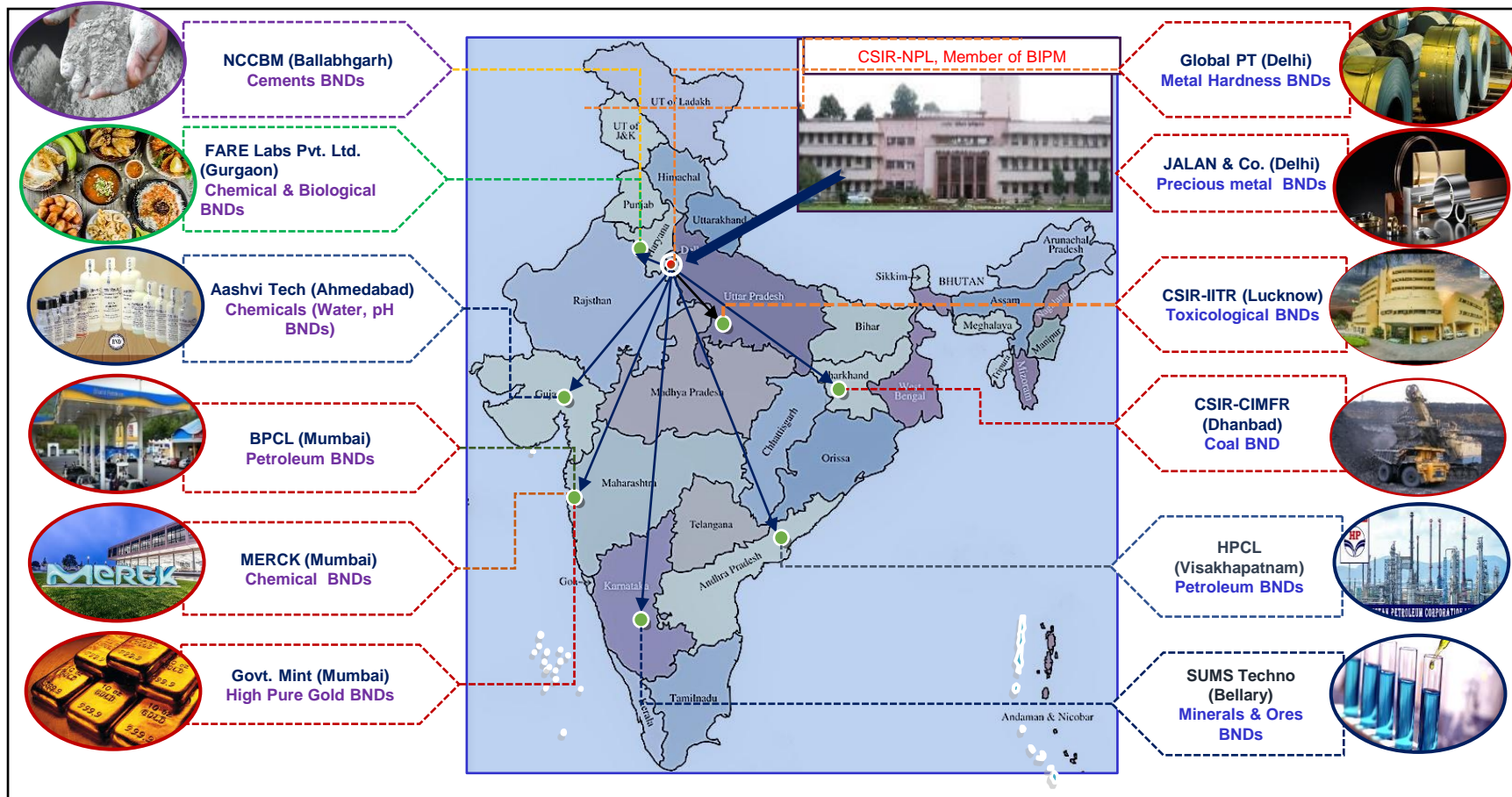
NPL Bipolar plate



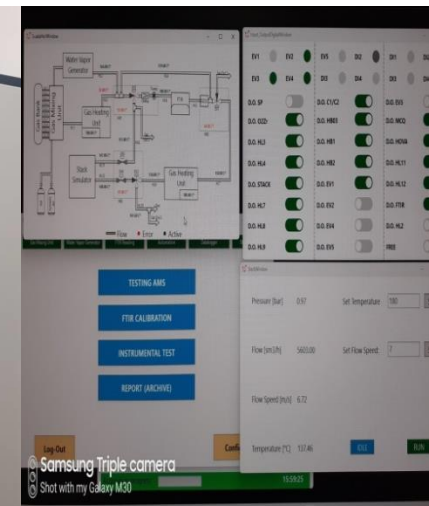
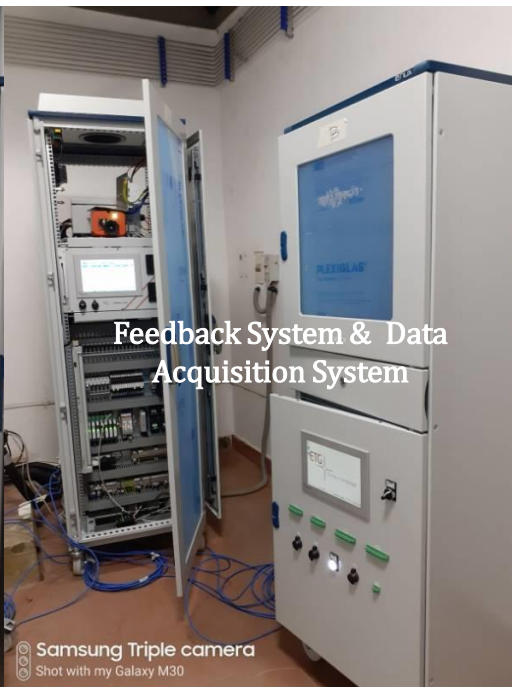
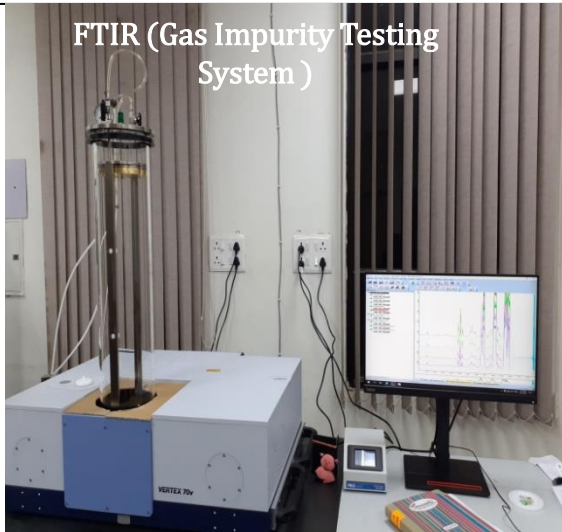
GCD data with NPL bipolar plate for 100 cycles in Zn-Br RFB, and efficiency data

Bharatiya Nirdeshak Dravya (BND®): Production & Certification of Reference Materials (Registered trademark: TM no. 3669341)

Vision: Flagship program of CSIR-NPL for development of Indian Reference Material (Bharatiya Nirdeshak Dravyas, BND) based on ISO 17025, 17034, in-house and collaboration of RMPs. BND partners: HPCL, BPCL, NCCB, Mint Mumbai, sister labs of CSIR: IITR Lucknow; IHBT Palampur; CIMFR Dhanbad; IIP Dehradun...



To strengthen the National Environmental Governance System, CSIR-NPL established a Type Testing, Calibration & Certification facility for Emission and Ambient Air Monitoring Systems



All airlines and aircraft operators will have to offset any growth in CO₂ emissions above 2020 levels

Coal → Syn Gas → MeOH → SAF
1.5 TPD pressurized fluidized bed gasifier (PFBG) configuration – CSIR-CIMFR



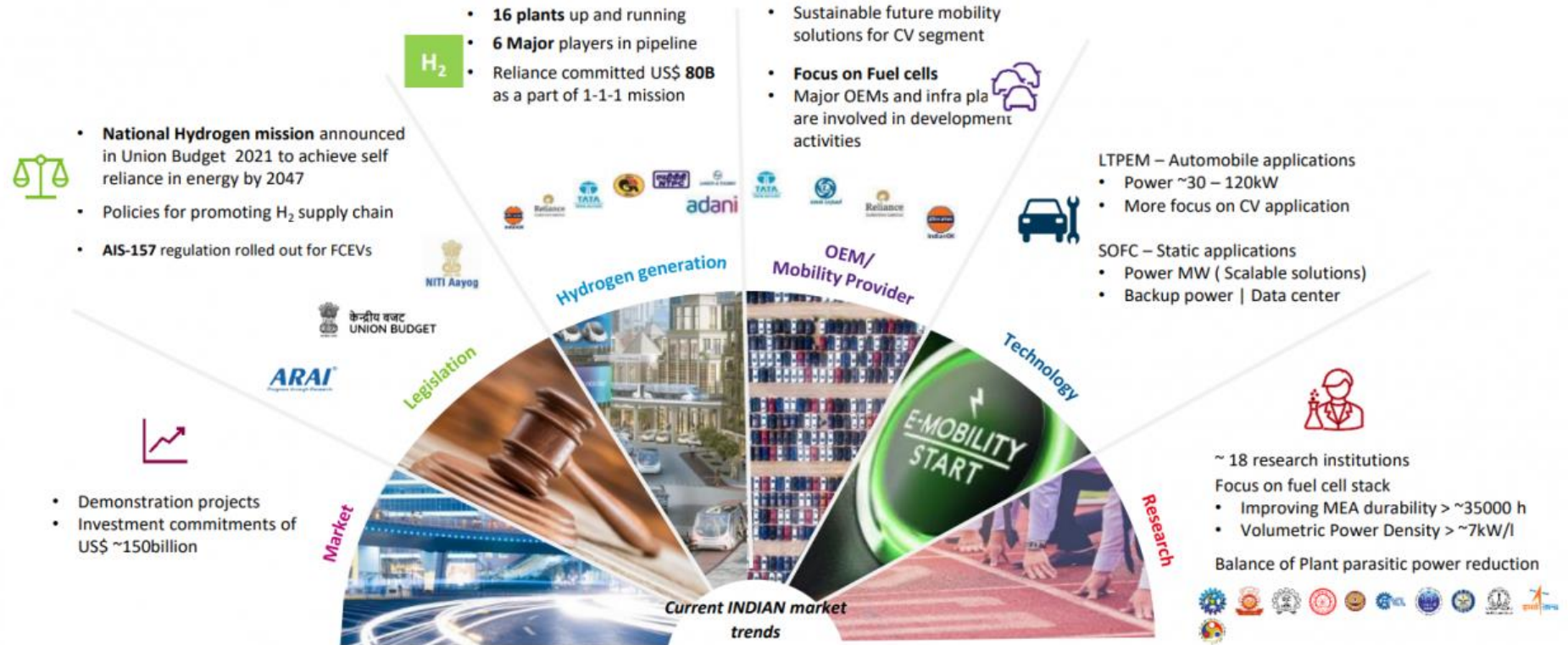
CSIR-IIP pilot plant produces 30 liters/day of sustainable air fuel

World Economic Forum’s “Clean Skies for Tomorrow Coalition Report 2021” : 20 of the 80 private and public-sector organizations that make up the Clean Skies for Tomorrow Coalition are from India.



Green Hydrogen projects and opportunities

Favorable Hydrogen trends – INDIA



Indigenous technologies for electrolyzers, hydrogen storage, and fuel cells.

CSIR's Hydrogen Technology (H2T) Program focuses on various electrolyzer types – Proton/anion exchange electrolysis membrane (PEM/AEM) Solid oxide electrolysis (SOEC)

Advancing hydrogen storage (Type IV cylinders, liquid organic hydrogen carriers), and creating high-performance fuel cells

Indian Oil R&D Centre, Faridabad



Indian Oil Green Hydrogen Project- Integrated Refueling Station for Buses in Leh (Ladakh)

NTPC- Integrated Hydrogen Refuelling Station at Greater Noida





First indigenously manufactured electrolyser, commissioned by L&T electrolysers Ltd, Hazira-Gujarat

**Green Hydrogen Project for Steel :
Jindal Stainless, Hisar, Haryana**





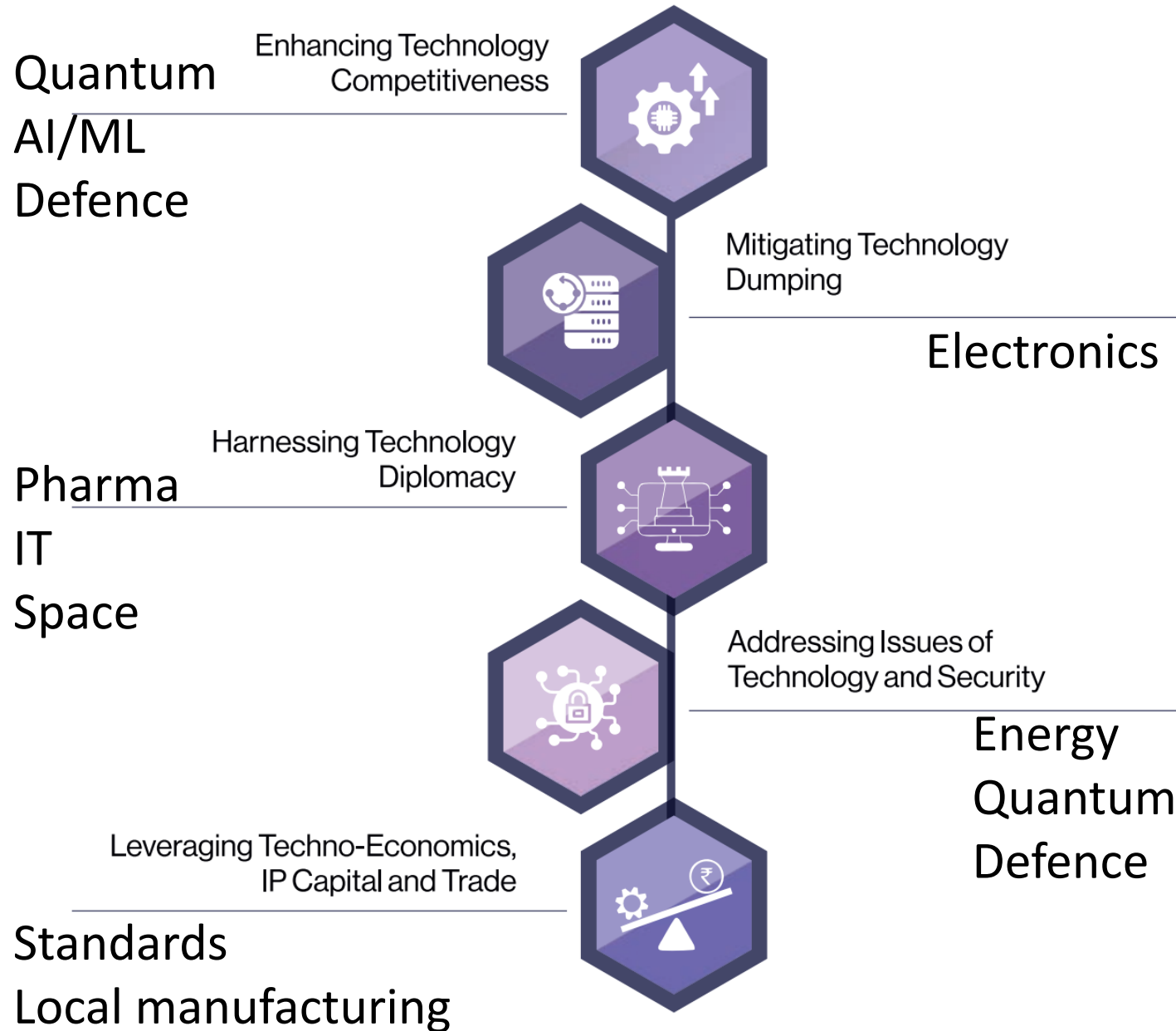
**India's First Hydrogen Fuel Cell Ferry by
Cochin Shipyard Limited
Kashi-Prayagraj route for 50 passengers**

Indian Railways- Pilot Project for Conversion of Old Diesel Locomotives with Hydrogen Fuel Cells



**1200 HP Hydrogen train to carry 2638
passengers
Max. speed 140 kmph
Sonipat-Gohana-Jind route**

International Engagement



Summary

- India has focused S&T approach to best utilize the resources
 - By carrying out big national mission mode projects
 - By encouraging to share the resources and infrastructure
 - By engaging in international cooperation with focused bilateral and multilateral agreements
 - By promoting startup ecosystem and industry involvement in projects from the proposal stage
- With the roadmaps for 2035 and 2047 in place for mega-science areas, we need to focus on facilities for big questions

Acknowledgments

Data taken from

- Principal Scientific Advisor (PSA) Office
- Anusandhan National Research Foundation (ANRF)
- Various ministries of government of India
- International Energy Agency