

# **Impact Evaluation of INUP-i2i (Indian Nano electronics Users Program Idea to Innovation )**

## **Executive Summary**

### **1. Introduction and Program Overview**

The Indian Nanoelectronics Users' Program- Idea to Innovation (INUP-i2i) Phase- III was launched in September 2021 supported by the Ministry of Electronics and Information Technology (MeitY) and Government of India (GoI) support prospective users by offering basic and advanced level training in Nano electronics. Under the MeitY support, six centres of excellence IIT's and IISc opens up their nanofabrication and characterization facilities for researchers national wide. This program is considered one of the major capacity building and Research and Development (R&D) initiative synergizing Skill India Program. Its foundation is laid from INUP program in 2008, at IIT Bombay and IISc Bangalore. Later expanded to IIT's include Guwahati, Delhi, Kharagpur and Madras in 2021 through INUP-i2i program. Initially in 2018, the Nano electronics Network for Research and Applications (NNetRA) an umbrella project was implemented by IISc Bangalore IIT Bombay, IIT Delhi, IIT Madras and IIT Kharagpur in collaboration with DST and MeitY. This project was started with a total outlay of ₹299 crore funded equally by MeitY, the Department of Science and Technology (DST), and host institutions in a 1:1:1 ratio. Since the six state of art centre's already collaborating under the NNetRA project. INUP-i2i unifies six Centres of Excellence (CoEs) into a national open-access platform for nanofabrication, characterization, and innovation in Nano-electronics. These CoEs include the Centre for Nano Science and Engineering (CeNSE) at IISc Bengaluru, the IIT Bombay Nano Facility (IITBNF), the Nanoscale Research Facility (NRF) at IIT Delhi, the Centre for NEMS and Nano Photonics (CNNP) at IIT Madras, Nano Fabrication Facility (NNF) at IIT Kharagpur, and the Centre for Nanotechnology (CFN) at IIT Guwahati.

The program's overarching aim is to bolster India's semiconductor ecosystem by providing subsidized access to cleanrooms and advanced lab facilities. It enables low-cost prototyping for external users from academia, industry, and start-ups, addressing vulnerabilities in global supply chains. Operationalized through a three-level training model, Level 1 familiarization

workshops, Level 2 hands-on proficiency sessions, and Level 3 advanced R&D projects, INUP-i2i synergizes with national priorities: the India Semiconductor Mission (ISM) for fabrication manpower, Chips to Start-up (C2S) for entrepreneurial acceleration, National Policy on Electronics (NPE) 2019 for indigenization, Digital India for tech solutions, Start-up India for commercialization, and National Education Policy (NEP) 2020 for interdisciplinary equity.

This impact assessment report prepared by IIPA employs NITI Aayog's Development Monitoring and Evaluation Office (DMEO) RCEIS framework (Relevance, Coherence, Effectiveness, Efficiency, Impact, Sustainability). The methodology relies on secondary data from MeitY annual reports (2021–2025), CoE progress reports (e.g., IISc Bengaluru and IIT Bombay specifics), and the INUP-i2i portal ([inup-i2i.in](http://inup-i2i.in)) for quantitative metrics on trainings, projects, and outcomes. Comparative benchmarking draws from global analogues, such as the U.S. National Nanotechnology Initiative (NNI) evaluations using OECD DAC criteria and EU Horizon Europe's Nano electronics assessments, to inform gap analysis.

As of January 2026, INUP-i2i has delivered 59 Level 1 workshops (7,523 manpower trained), 46 Level 2 trainings (1,059 manpower trained) with Level 3 609 projects completed, it includes 44 industrial trainings and 11 hackathons nationwide. Through the Hub-and-Spoke model, it connects CoEs to 53 institutions (IIITs, NITs, central/state/private universities), mentoring 38 start-ups in domains like aerospace, semiconductor, cavity treatment etc. The recent quintessential event INUP Users' Meet (August 10, 2024, at IIT Bombay, attended by ~350 stakeholders, inaugurated by MeitY Secretary Shri S. Krishnan) and the 2025 Nano Electronics Roadshow (at IISc Bengaluru, partnering with all CoEs) underscore its contributions to ISM workforce goals and regional skilling expansions.

## **2. Intellectual Origins and Global Trends in Nanotechnology**

Nanotechnology, broadly defined as the study and manipulation of matter at the nanoscale (1–100 nm, or one billionth of a meter), embodies a revolutionary mindset enabling dramatic alterations in materials' chemical, physical, and biological properties compared to bulk forms. Pioneered by the U.S. and Japan, the field has globalized, with the EU, Taiwan, South Korea, China, and India advancing front levels through massive investments exceeding US\$18 billion annually in public-private R&D (Rodríguez, 2017). Recognized as a Key Enabling Technology (KET), it drives low-carbon, knowledge-based economies, offering sustainable solutions for environmental remediation and resource efficiency.

Historically, nanomaterials pervaded nature and early human ingenuity long before formalization. Geological sources include volcanic activity and dust storms; biological examples encompass DNA and bone's nanostructured minerals (European Observatory for Nanomaterials; Chakre & Sharon, 2019). Anthropological evidence reveals 4,000-year utilization: the 4th-century Roman Lycurgus Cup's dichroic effects from gold/silver nanoparticles; medieval church stained glass's vibrant hues via nanomaterials; ancient Egyptian lead sulphide nanocrystals in hair dyes. India's heritage shines in Ayurvedic Bhasma, nano-sized metal/herbal preparations akin to modern synthesis, for nanomedicine, ornaments, paints, and cosmetics (Injal, 2019; Gargade, 2019).

The modern intellectual journey ignited with Richard Feynman's 1959 lecture, "There's Plenty of Room at the Bottom," challenging atom-level manipulation (e.g., tiny motors, Encyclopedia Britannica on a pinhead). Norio Taniguchi coined "nanotechnology" in 1974 for precision nanoscale control. Eric Drexler's 1986 "Engines of Creation" advanced molecular nanotechnology via bottom-up self-assembly, mimicking nature's protein synthesis. Instrumental revolutions followed: Gerd Binnig and Heinrich Rohrer's Scanning Tunneling Microscope (STM, 1986 Nobel in Physics) visualized/manipulated atoms (Binnig & Rohrer, 1986); the 1990 xenon-atom IBM logo demonstrated Nano-writing. The Atomic Force Microscope (AFM, 1986 by Binnig et al.) imaged non-conductive material, enabling silicon/graphene studies.

Some of the innovation breakthroughs transformed the field: John D. Bernal's carbon structural work evolved into fullerenes ( $C_{60}$ , 1985 by Kroto, Heath, O'Brien, Curl, Smalley; 1996 Nobel in Chemistry), buckminsterfullerene's geodesic dome inspiring nanocarbon materials (NCMs) like single-walled/multi-walled carbon nanotubes (SWCNTs/MWCNTs; Iijima, 1991) and graphene (Geim & Novoselov, 2004 isolation; 2010 Nobel in Physics). Graphene's exceptional strength, flexibility, transparency, and conductivity fuel flexible electronics, energy storage, and biomedical engineering (Sharon, 2019). The 2016 Nobel for Chemistry (Stoddart, Sauvage, Feringa) recognized molecular machines for controlled nanoscale motion, enabling miniaturized systems. The 2023 Nobel laureate (Bawendi, Brus, Yekimov) highlighted quantum dots—nanoscale semiconductors with precise optical/electronic properties, for QLED displays, flexible electronics, Nano sensors, thinner solar cells, and quantum networks.

In electronics, 1947 solid-state transistors (Bardeen, Brattain, Shockley) miniaturized via nanolithography into integrated circuits, birthing spintronics: Single Electron Transistors (SETs), Spin Valves, Magnetic Tunnel Junctions (MTJs), Spin-FETs, Spin-RTDs, and terahertz optical switches/modulators for non-volatile memory and qubits. Global trends feature three actors: U.S. NNI (2000, \$495 million FY2001; >\$40 billion cumulative by 2023 via NSF/DoD/DoE) leads patents (28.3% share; OECD 2024) and grand challenges (e.g., 10x stronger nanostructures, million-fold efficient transistors, tumor-detecting diagnostics, doubled solar efficiency). Japan, via AIST (2001) and JST, dominates nanocarbon commercialization (40.3% patents in 2000; Amoroso et al., 2021), with NBCI (2003) fostering academia-industry networks. The EU's 2004 strategy invests in infrastructure/education, pioneering size-based regulations (REACH/CLP for 1–100 nm particles) amid precautionary governance post-biotech controversies (Rodríguez, 2018).

INUP-i2i emulates these by enabling bottom-up innovations, reducing energy/material consumption, and aligning with India's ₹1,650 crore Nanoscience Mission for self-reliant Nano-devices. India already excels in scientific research publication ranking in 3<sup>rd</sup> position as per National Science Foundation's Science and Engineering Indicator report of 2022 ([Press Release: Press Information Bureau](#)). Further according to the WIPO's Global Innovation Index Database 2025, India ranked 1<sup>st</sup> in lower middle-income countries, and 38<sup>th</sup> in the Global Level. This shows the fast pace growth in innovation and global leader in research publication. The INUP from its inception acted as a catalyst in Nano technology publications fostering deep tech research, training and start-up ecosystem. This program will be a bed rock for Indian self-reliant semiconductor ecosystem.

### **3. Program Background, Structure, Aims, and Implementation Model**

The 9<sup>th</sup> Five Year Plan was the first time mentioned about the national facilities and core group set up to promote research in S&T areas including superconductivity, robotics, neurosciences and carbon and Nano materials. Further, DST in 2000 launched "Program on Nanomaterials: Science and Devices". A formal initiative was taken by DST in 2001 launched "The National Nanoscience and Nanotechnology Initiative (NSTI)", to create R&D infrastructure and basic research in nanoscience and nanotechnology. NST initiative focus on infrastructure and research and application projects like drug delivery, gene targeting, and DNA chips. The 11<sup>th</sup> Five Year Plan (2007-12) focused on Nano material and Nano device in

health and disease. In 2007, Nanoscience and Technology Mission was launched received an allocation of ₹1,000 crores from the 11<sup>th</sup> Five Year Plan. The second phase of Nanoscience and Technology Mission was started by cost of ₹650 crore- allocated in the 12th Plan for application-based R&D (RIS, 2014).

The Ministry of Electronics and Information Technology (MeitY) initiated the 2004 National Nanotechnology Development Program (NDP), creating advanced Nano electronics and metrology infrastructure in India. This led to establishing Research Fabrication Facilities as Centre's of Excellence in Nano electronics (CENs) at IISc Bengaluru and IIT Bombay (identified in 2003 and set up in 2006 with a budget of ₹99.8 crore). The Nano Research Facility launched in 2008, expanded access and training to other IITs including Delhi (2010), Madras (2011), Guwahati (2015), and Kharagpur (2018). These centre's foster cutting-edge nanotech research, skill development, and industry collaboration nationwide. In 2018, The Nano-electronic Network for Research and Applications (NNetRA) integrated all six state of art centre's under MeitY & DST. The INUP-i2i was announced by MeitY as a flagship program in 2021, runs until 2024 and offers extensive training, hands-on workshops, start-up incubation, and collaborative research opportunities across six Centre's of Excellence in Nano electronics to boost India's nano R&D and commercialization ecosystem. The program timeline is extended now till 2025. INUP-i2i extension is now envisioned for leveraging nationwide Nano electronics support, from semiconductor fabrication to start-up/industry training under ISM (PIB, 2024). The August 2024 INUP Users' Meet at IIT Bombay (~350 attendees) discussed achievements like 33 start-ups and 52 institutions via Hub-Spoke, emphasizing industry-academia collaboration. The 2025 Roadshow at IISc Bengaluru fostered ISM innovation, aimed to enhance R&D ecosystems by integrating CoEs for collaborations/prototypes (e.g., MEMS sensors, photovoltaics; access to 52 spokes like NITs/state universities); conduct trainings/workshops (leveled, Foundation/Advanced Programs certified Feb 2023); support exploratory research ( projects in spintronics/2D materials/biosensors); mentor start-ups (theranostics/nanomaterials via TBIs); host hackathons/grand challenges (10 events for SDGs in healthcare/environment/agriculture, e.g., Aug 2024 Meet showcasing scalable solutions).

The sequential three-level model coordinates via portal for selections/bookings, with CoEs hosting equitably (IISc/IIT Bombay on projects/start-ups; others on training). A Certifications (Level 6 Foundation, Level-6.5 Advanced) via ESSCI partnerships integrate with Academic Bank of Credits. Hybrid formats (lectures + cleanroom) and subsidies (waivers for

remote/leveled for industry) advance from familiarization to prototyping, incorporating translational research for grand challenges. The INUP-i2i program consist of the following levels:

- **Level 1 (Familiarization):** 2–3-day lectures on circuits, MEMS cantilevers, microfluidics, spintronics, transistors, interdigitated electrodes, semiconductor LEDs, photovoltaics, nanophotonics (59 workshops, 7,523 participants/987 institutes).
- **Level 2 (Hands-On):** 10–15 day sessions on fabrication/testing/cleanroom protocols (46 cohorts, 1059/313 institutes; e.g., lithography/thin-film deposition).
- **Level 3 (Projects):** Proposal-based (3 months short/6 months medium; 609 executed, mentored for prototypes/patents/start-ups).

Portal tracks KPIs (e.g., 12,600 trained); Northeast focus (e.g., IIT Guwahati/IISc/IIT Delhi) cohorts for Arunachal Pradesh, Manipur, Mizoram, Nagaland, Sikkim, Jammu and Kashmir ensures equity in participation (1018).

Table E1- Key Activities and Outputs under INUP-i2i Program (2021-2025)

Aim	Key Activities/Outputs (2021–2025)
<b>R&amp;D Ecosystem Enhancement</b>	609 R&D projects comprising 395 short-term and 214 medium-term projects across advanced technology domains; supported through structured mentorship and institutional collaboration involving 53 collaborating institutes.
<b>Trainings/Workshops</b>	59 Level 1 familiarization program; Level-wise trained manpower: 7,523 (Level 1), 1,059 (Level 2), and 578 (Level 3); 44 industry-oriented trainings conducted; 75 digital modules delivered; participation from 987 institutes across multiple centres with diverse laboratory facilities.
<b>Research &amp; Development</b>	Sustained mentorship and R&D support resulting in 291 research publications (Including 251 Journal Publications and 40 Conference publications), 44 patents, and multiple technology outputs contributing to IP generation, prototyping.
<b>Start-up Support</b>	38 start-ups supported, enabling lab-to-market transition through incubation, technical validation.
<b>Hackathons/Challenges</b>	11 Hackathons / Grand Challenges conducted in advanced technology domains, facilitating innovation, hands-on problem solving, mentorship, and linkage

	with fabrication facilities and start-up incubators.
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Primary stakeholders are the six CoEs, housing nanofabrication/characterization for training R&D, collaborations, and ISM contributions (e.g., Tata Assam plant via IIT Guwahati). They facilitate portal bookings, with 2025 events like North-East trainings emphasizing regional equity. Beneficiaries: Researchers (students/faculty from universities/institutes; e.g., undergrads in Level 1 on MEMS/sensors; faculty in Level 3 prototyping); industry/start-ups (prototyping/mentoring); prioritized for remote/North-East (e.g., 1018 Northeast participants). Diversity and inclusion: 48% reserved (Level 1,2 and 3: OBC 36 %, SC 9%, ST 3%) for 27 states/UTs, including level-2/3 and Jammu & Kashmir/Bihar.

#### 4. Detailed CoE Profiles:

**IISc Bengaluru (CeNSE, est. 2006):** The Centre for Nano Science and Engineering (CeNSE) lab at IISc Bengaluru was established in 2006 through the project of Centre of Excellence in Nano electronics alongside IIT Bombay, funded by Ministry of Communication and Information Technology (MCIT), Indian Government. Facilities: CeNSE hosts three national facilities - the National Nanofabrication Centre (NNfC), the Micro and Nano Characterization Facility (MNCF), and the Packaging and Systems Facility (PASF) - along with 16 high-end thematic laboratories equipped with state-of-the-art research infrastructure in nanoscience and engineering. Relevance align with national strategies (Make in India, Skill India, Atmanirbhar Bharat), and synergise with emerging technological demands. Especially, only institution conducted Level 6.5 training. Coherent academia-government-industry linkages (e.g. collaborates with 30 state and private research institutes and industries like ISRO, DRDO, Samsung, Intel and Tata Electronics). Effective hub for others academic universities, institutions and industries/Start-ups for training, research, prototype development at last transcending it to commercial products (including supporting start-ups) for industries. Impact students (Undergrad, Postgrad and Research), faculties and industrial staffs using Nano tech training. Including, start-up support and product commercialization. Sustainable in attaining broader long term objectives of building home grown nanotechnology industries and Semiconductor industries. The centre conducted workshops (3), hands on trainings (8), hackathons (3), start-up support (13), collaborations (9), short-term projects (90), medium-term projects (57), ongoing short-term (12), ongoing medium-term (30), medium-term selected (18), digital modules (19), publications (65), patents (9), theses (182), prototypes (11). Training Level-1 (442), Level-2 (225), Level-3

(312) with certificates (31), institute participation (273), R&D projects (207), collaborative projects (38), PhD access (17), internships (15), Nano-facility setups (7), courses (5), new programs (2), and industrial trainings (16). Achievements; e.g. start-up company Super Q developed a superconducting single photon detector awarded Digital Communication Innovation Scheme 2023 Award from Department of Telecommunication (DoT). Recent INUP SOI-MEMS Hackathon received an overwhelming response with around 140 applications in semiconductor innovation.

**IIT Bombay (IITBNF, est. 2006):**

The IIT Bombay Nano Facility (IITBNF) was established in 2006 through the project of Centre of Excellence in Nano electronics alongside IISc Bangalore, funded by Ministry of Communication and Information Technology (MCIT), Indian Government. Facilities: It comprises state-of-the-art facilities such as the Micro and Nano Characterization Facility (MNCF), Packaging and Systems Facility (PASF), MEMS and IC Packaging, National Nano Fabrication Facility (NNF), and the Systems Engineering Facility (SysEF). Relevance align with national strategies (Skill India, Make in India, Atmanirbhar Bharat), and synergise with emerging technological demands. Coherent activities reinforce systemic inclusion of technological self-reliance. Effective activities institutional collaboration and tangent start-up results. Impact in training students, faculties and staffs all over nation. Sustainable mechanisms like strong institutional integration, human capital skilling, and deliverables of past shows sustainability potential. The centre delivered training (Level 1: 3 workshops/682 trained; Level 2: 7 trainings/195 trained/8 modules; Level 3: 90 short-term projects/48 medium-term/3 hackathons/175 trained), enabled 12 institutional collaborations and 13 start-up supports, and achieved 95 publications, 22 patents, 22 prototypes, and 11 industrial trainings. Achievements; start-ups support for companies (e.g. Multi Nano Sense Technologies, Eywa Neuro Pvt. Ltd., and Tvasht Biotech Pvt. Ltd.) reduces early-stage capital barriers and accelerating commercialization.

**IIT Delhi (NRF, est. 2010):** Class 100/1000 cleanrooms; 20 characterizations (AGM, AFM, DLS, EQCM, FTIR, Fuel Cell, GCMS, PL/Raman, UV-Vis-NIR, XRD, Tabletop SEM); 12 fabrication (Electron-Beam Lithography, Mask Aligner, RIE, PECVD, E-Beam Evaporation/Sputtering/Thermal/Plasma Cleaning) Developments: DNA Aptamer (prostate cancer); photochip biosensor (NNetRA-funded); Metrics: 78 projects (62 short/16 medium); Manpower trained: Level 1: 2882; (441 Delhi/411 UP/Tamil Nadu 275 and others from 24

additional states) (participants: 42.12% women and 44% from OBC/SC/ST section; Level 2: 159. 28 publications/3 patents/3 prototypes; 10 digital modules; Overall Manpower trained 2916 events (19 familiarizations (Manpower: 2882)/1 hackathon (Manpower: 1)/3 industrial training (Manpower: 33)/ mentoring start-ups/SME/MSME (3); collaborations (6 institutes. Additionally, two onsite workshops were conducted at NIT Srinagar (2023) and NIT Kurukshetra (2024), where around ~120 participants were trained.

**IIT Madras (CNNP, est. 2011):** The Centre for NEMS and Nano Photonics was established in 2011. It was established as a CEN by the support of MeitY. Facilities: The Centre operates a 5,000 sq. ft. cleanroom with advanced fabrication and characterization tools supporting research in silicon photonics, biosensors, RF/optical MEMS, GaN HEMTs, organic electronics, diffractive optics, ultrasonic Nanos copy, and microfluidics. Its major facilities include lithography (optical/e-beam), CVD/PECVD/LPCVD systems, DRIE/ICPRIE etching, metallization tools, bonding/dicing, and comprehensive optical, electrical, structural, and device characterization instruments such as SEM, vibrometers, ellipsometers, probe stations, and solar cell testing setups. Relevance align with national strategies (Skill India, Make in India, Atmanirbhar Bharat), and synergise with inclusive training of women and diverse social sections. Coherence open access to its cleanroom facility for external researchers, offering structured mentorship to start-ups, and promoting institutional inclusivity through targeted engagement with minority and regionally underrepresented academic entities. Effective training capacity, one additional hackathon, and expanded industry engagement, collectively enhancing the program's technical output and national outreach. Impact reserved sections and women in Nano technology activities and training and sustainable advancement in India's Nano electronics and Photonics ecosystem. The centre delivered Level-1 workshops (59; 773 trained), Level-2 trainings (47; 159 trained), Level-3 training (short-term projects (39), medium-term projects (22), manpower trained (75)). The outcomes are publications (48), patents (3), prototypes (3), start-up support (2), institute collaborations (8), hackathons (2), industry trainings (4 involving 9 companies and 45 participants), digital modules (10), and additional capacity-building workshops (for women scholars and diploma students). Achievements: The centre conducted 24 events; it achieves milestone in supporting NGO "Chetna Trust" on Braille Dot studies, and devices are developed by users (MEMS Device, Perovskite Solar Cell, Memory Device, CO<sub>2</sub> gas sensor.etc).

**IIT Guwahati (CFN, est. 2004; Northeast-first Nanofab):** The Indian Nanoelectronics Users Program – Idea to Innovation (INUP-i2i) has been one of the most successful programs

of MeitY. Through this program, thousands of students have gained access to state-of-the-art nanofabrication and characterization facilities which are in line with Indian Semiconductor Mission (ISM). Over the past 4 years, INUP-i2i program hosted at IIT Guwahati helped in the upskilling manpower from several institutes, colleges and universities of North-East (NE) region as well as across India through a series of fundamental and familiarization workshops (virtual and in-person), advanced level hands-on training, implementation of short-/medium-term research projects, supporting start-ups for deep-tech innovation and allowing collaborating institutes to implement, publish and patent the research ideas in the area of nanoelectronics. The facilities at IIT Guwahati, being the first-of-its kind in NE established with the support of MeitY, is envisioned to train the human resources who can become the building-blocks of the ISM. The skilling process is to initiate with scouting bright students from the NITs, IIITs, Universities and Colleges of NE region before providing short- to medium-term (3 to 6 months) access of the cutting-edge facilities in inculcating skill-development in micro/nanoscale electronic research and translation.

Different deliverables of this project include Level-1 (familiarization workshops), Level-2 (hands-on training), Level-3 (R&D projects), digital modules, hackathon/grand challenges, industry training, mentoring collaborating institutes, start-up support, publication, patents and prototypes. The program envisaged 11 Level 1 familiarization workshops, against which 7 virtual workshop. The target for trained manpower at Level 1 was 550, while 1,802 personnel were trained. At Level 2, 6 hands-on training program were proposed and 6 were conducted, with 90 personnel targeted and 111 trained. 3 digital training modules were proposed and 22 modules were developed. 1 Hackathon/Grand Challenge was proposed and 1 was conducted. At Level 3, 15 medium-term R&D projects were proposed and 48 were completed, while 30 short-term R&D projects were proposed and 72 were completed. Overall, total trained manpower was targeted at 640, and 1,913 individuals were trained, including 45 tribal students. The publication target was 30, with 36 published. 4 patents were targeted, with 3 filed, 1 in process, and 4+ under preparation. 3 prototypes were proposed and 18 were developed. 2 industry training program were proposed and 4 were conducted. 6 startups/MSME/SMEs were targeted for support and 7 were supported, while 7 institutional mentoring collaborations were proposed and 10 were achieved.

**IIT Kharagpur (Nano Fabrication Facility - SNST):** Integrated Facility Cluster for Advanced Research, Fabrication, and Prototyping at IIT Kharagpur is a multi-disciplinary research ecosystem established in 2013. The lab provides facilities for design, simulation,

fabrication, characterization, prototyping, packaging, and testing of next-generation devices and materials. Facilities includes: Organic Electronics Laboratory (ORELA), Photonics Laboratory, Micro science Laboratory, Functional Nanomaterials & Thin-Film Laboratory, Advanced Material Processing Research Laboratory, BioMEMS & Microfluidics Laboratory, VLSI Engineering Laboratory, Microelectronics & MEMS Laboratory, and the Nano Fabrication Facility (NFF). Relevance in training activities and institutional collaboration. Coherent in INUP-i2i Program implementation including other centre's Effective systematic program level wise training transmission. Impact lives of marginalized section (reserved category and gender), including participants from Level 1, Level 2 and Level 3 city institutions in India. Sustainably build on previous efforts, including projects, workshops, hackathons, and hands-on training, while promoting industry engagement and private-sector collaboration for future growth. At IIT Kharagpur, the centre conducted Level-1 workshops (14; 942 trained) and Level-2 hands-on trainings (8; 211 trained), Level 3 (Trained 47 participants, completed short-term R&D projects (43) and medium-term projects (17), and developed publications (19; 9 under review), patents (4), and prototypes (5). It further enhanced capacity through digital modules (7), a hackathon (1), supported start-ups/MSMEs (3), facilitated institute collaborations (8), and conducted industry training programs (4). Achievements: The star-up supported by the INUP IIT Kharagpur, Senflex Innovations Pvt. Ltd., won the futuristic innovation prize during the Nano Road show, 2025 held at IISc Bangalore.

## **5. Evaluation Findings under RCEIS Framework and Key Achievements**

Overall INUP-i2i outcomes include Familiarization Workshops (59), Manpower Trained (7,523), Hands-on Training (46), Manpower Trained Level-2 (1,059), Digital Training Modules (75), with Level 3 projects short term (395) and medium term (214), Collaborating Institutes (53), Start-up supports/MSME/SME (38), Publications (291), Patents (44), Prototypes (71), and Industrial Training (44).

**Relevance:** The six Centre's of Excellence (CoEs), equipped with nanofabrication and characterization facilities, advance India's strategic priorities - Skill India, Make in India, Atmanirbhar Bharat, and the Indian Semiconductor Mission (ISM) - by training researchers and enabling industrial innovation. Front level technologies, including MEMS, sensors, photovoltaics, and advanced nanomaterials, are leveraged for R&D, prototyping, and start-up

development. Regional equity is emphasized, with 1018 participants from the North-East benefitting from 2025 training initiatives.

**Coherence:** The three-level training structure integrates foundational (Level 1), hands-on (Level 2), and advanced prototyping/research/start-up support (Level 3) with courses and digital access via portals. CoEs coordinate research projects, industrial collaborations, and ISM contributions, such as e.g. Tata Assam plant engagement through IIT Guwahati, ensuring synergy between academic research, industrial application, and national technology missions.

**Effectiveness:** The R&D Ecosystem enhanced with 609 projects, including prototypes in MEMS and photovoltaics, subsidized access for researchers, IP generation, and technology transfer. Through Trainings/Workshops (59 Level 1, 46 Level 2, and 44 industrial sessions), reaching students, faculty, and industry practitioners reached. Provided Start-up Support: 38 ventures linked with Technology Business Incubators, bridging lab-to-market gaps. Conducted Hackathons/Challenge for addressing SDG-linked solutions in diverse (e.g. health and agriculture), promoting applied innovation.

**Impact:** The initiatives generate inclusive and measurable outcomes, particularly by engaging North-East participants (1018). Gender and social diversity are integral, with 48% reserved category representation (OBC 36%, SC 9%, ST 3%), ensuring equitable access. They enable research translation, entrepreneurship, and human capital development, supporting India's self-reliance in nanotechnology and semiconductor sectors.

**Sustainability:** The signs of robust movement towards PPP-driven model - linking CoEs, industry, start-ups, and government- ensures long-term sustainability. Certification, portal-based training, subsidized R&D access, and TBI-linked start-ups create a self-reinforcing ecosystem that scales skill development, innovation, and technology commercialization nationwide.

## **6. Recommendations, and Forward-Looking Roadmap**

The INUP-i2i scheme has been instrumental in advancing nanotechnology R&D, skill development, and start-up support in India. To ensure its long-term sustainability and enhance its national impact, the following focused recommendations are proposed:

### **1. Transcendence and Continuity:**

The INUP-i2i program beyond March 2026 should transcend to next phase integrating additional Centres of Excellence (CENs) to scale training, publications, patents, and start-up incubation.

## **2. Public–Private Partnership (PPP):**

Institutionalize a PPP model to attract private R&D investments and ensure financial sustainability, leveraging collaborations with NASSCOM, industries, and start-ups.

## **3. Strengthening Training Activities Transition to Enhanced Research Output:**

The program strengthened training activities, especially IIT Guwahati and IIT Delhi have excelled in no. of trainings provided and manpower getting trained. Despite of achievements in training, the program need more emphasis and focus on output translation along with activities scaling up.

## **4. Enhancing Systemic Progression in publications**

The IIT Bombay and IISc Bangalore part of INUP program from its inception. The others institutions are catching up in all aspects. But there is minimal gap and potential opportunities to scale publications by learning from IIT Bombay and IISc Bangalore, and increasing phase 3 timeline.

## **5. Accelerated Certification:**

Expedite the rollout of certification programs at all CENs to standardize nanotechnology skill credentials and enhance career mobility.

## **6. Focus on Emerging Technologies:**

Broaden research to include quantum dots, quantum computing, MEMS/NEMS, biosensors, optoelectronics, AI-driven chip design, and semiconductor innovation.

## **7. Inclusivity and Regional Outreach:**

Strengthen participation of trainees from the North Eastern states through targeted outreach, scholarships, and institutional collaborations. A key achievement is IIT Guwahati's role in enhancing inclusiveness in the North-Eastern region, by training 620 participants from 60+ institutes and providing access to the region's first advanced cleanroom facility.

**8. Infrastructure and Equipment Reliability:**

Ensure timely maintenance and availability of critical lab instruments, expand characterization facilities, and streamline access to equipment for external users.

**9. Research Timelines and Project Support:**

Simplify project approval processes and allow longer research durations to facilitate meaningful experimentation and output.

**10. Accessibility, Accommodation, and Awareness:**

Improve travel and accommodation support for researchers, enhance awareness about the program, and foster a more inclusive and gender-balanced research environment.