Bhutan R&D Center of Excellence Strategy

1. Executive Summary

A thriving **National Innovation Ecosystem** requires a strong foundation that integrates science, technology, and innovation to drive sustainable economic growth and national competitiveness. The ***Center of Excellence (CoE)*** for conducting Research and Development in Applied and Fundamental arenas will be an independent entity that builds upon the robust foundation laid by the Department of Innovation and Technology (InnoTech), under Druk Holding and Investments (DHI) Limited. While separate, the CoE will leverage the existing infrastructure, frameworks, and initiatives developed under InnoTech to advance Bhutan's position as a hub for technological innovation and research excellence.

The Innotech Department, established by DHI, has played a pivotal role in creating the necessary groundwork for a transformative research and innovation ecosystem. With its key divisions—the Strategic Technology Planning (STP), DHI Research & Innovation Venture Excellence (DRIVE) , and the Jigme Namgyel Wangchuck Super FabLab (JNWSFL)—InnoTech has strategically positioned Bhutan to address local challenges through innovative solutions and technology adoption. JNWSFL provides essential infrastructure for creating a conducive environment for innovation, knowledge sharing and collaboration. By addressing the foundational aspects, InnoTech has laid the cornerstones upon which the CoE will be built.

As a pillar of the National Innovation Ecosystem, JNWSFL will evolve into a fundamental and applied research center of excellence. A major amount of capital investment has already been injected in establishing a CoE, with the establishment of DRIVE, JNWSFL, STP and the Innovation Fund. The quintessential funding can be accessed from the Innovation Fund and the already existing facilities will be leveraged to conduct fundamental research that underpins sustainable economic growth. Key mechanisms such as robust policies, sustainable financing, and efficient operational frameworks will be critical to ensuring the CoE's adaptability and long-term success. Bhutan is at a pivotal moment of transformation, where science, technology, and innovation present unprecedented opportunities for shaping its future economic landscape. This paper outlines the strategic vision, objectives and ecosystem-building role of the CoE, positioning it as a critical component of Bhutan's broader aspirations in innovation and technology.

2. Objectives

CoE will serve as the nerve center for knowledge creation, fostering fundamental research and innovation, and driving Bhutan's transformation into a high- impact knowledge economy. The CoE is not merely a facility but a strategic enabler for a thriving national innovation ecosystem. CoE will:

i. Act as a knowledge Hub, a channel of exchange between institutes, industries, and government, nurturing next-generation innovators and researchers.

ii. Incubate Talent by providing a nurturing and conducive environment to develop high-caliber researchers, PhDs, and innovators with global competencies.

iii. Strengthen Bhutan's economic resilience by fostering indigenous innovation and deep-tech enterprises. Bridge research and commercialization, transforming ideas into market-ready solutions.

iv. Enablecross-border knowledge exchange, positioning Bhutan as a regional hub for R&D.

3. The CoE as the foundation of Bhutan's innovation EcoSystem

The CoE is envisioned as a key enabler within Bhutan's National Innovation Ecosystem, serving as a facilitator to strengthen and complement the broader research and Innovation framework. Rather than functioning as an isolated entity, the CoE integrates and aligns the core elements of academia, industry, and policy, enabling a synergistic environment where innovation thrives. It acts as the central node, orchestrating connections, collaborations, and capabilities across all stakeholders to drive impactful outcomes.

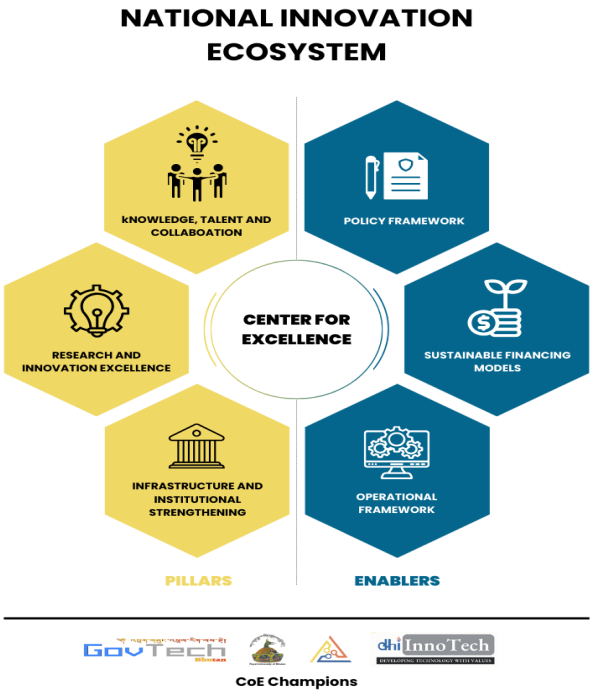
A strong innovation ecosystem relies on robust linkages between its components. The CoE strengthens these linkages by creating platforms for **collaboration and knowledge exchange**, enabling seamless interaction between academic researchers, industry leaders, and policymakers. It operationalizes public-private partnerships (PPPs) to unite efforts and resources, ensuring alignment with national priorities and global trends. By providing an overarching infrastructure and fostering innovation clusters, the CoE ensures that all participants contribute to and benefit from a shared vision of progress.

The CoE also establishes the mechanisms needed for **sustainable research pipelines**, which serve as the backbone of the innovation ecosystem. It prioritizes research areas aligned with Bhutan's long-term vision, focusing on critical sectors such as deep-tech, artificial intelligence, sustainable materials, robotics, and renewable energy. By bridging fundamental research with market applications, the CoE ensures a steady flow of innovations that support economic diversification and global competitiveness.

Furthermore, the CoE champions the development of **enabling policies and funding mechanisms** that sustain the broader ecosystem. By advocating for intellectual property protection, commercialization pathways, and entrepreneur-friendly regulations, it creates a conducive environment for innovation-driven enterprises. The Bhutan Multi-Channel Innovation Fund exemplifies how the CoE mobilizes financial resources to empower researchers and innovators, further solidifying its foundational role.

In essence, the CoE provides the structural integrity, collaborative frameworks, and operational support needed to build and sustain Bhutan's National Innovation Ecosystem. Its role as a unifying force ensures that innovation is not only pursued but also scaled and sustained, driving Bhutan's transformation into a knowledge-driven economy.

4. Center for Excellence



Strategic Pillars for the COE

The **Center of Excellence** will be a dynamic and evolving hub for cutting-edge research and innovation, shaping Bhutan's long-term scientific and technological growth. It will be anchored in Jigme Namgyel Wangchuck Super FabLab, a digital fabrication lab, and one of the few Super FabLabs in the world. The CoE will remain adaptable, expanding into new domains as research needs evolve and infrastructure grows.

i. Knowledge, Talent and Collaboration

The CoE will bridge academia, and industry, fostering collaboration within Bhutan and with international partners to co-develop research programs that address national and global challenges. By attracting and retaining diverse research talent, the CoE will offer fellowships, residencies, and collaborative opportunities with leading institutions worldwide. This will include Master's, PhD, and Postdoc programs aligned with both immediate and long-term national priorities. Additionally, the CoE will actively engage with the local and global research community, forming strategic alliances with universities, research institutes, and innovation ecosystems to facilitate knowledge exchange, joint research, and funding opportunities. These efforts will ensure Bhutanese research contributes to and benefits from the global innovation landscape.

ii. Research and Innovation Excellence

The CoE will build a broad and evolving research portfolio, focusing on deep-tech, digital fabrication, AI, clean energy, and materials science, while remaining open to emerging fields that align with Bhutan's evolving innovation landscape. By encouraging interdisciplinary and high-risk, high-reward research, the CoE will foster an ecosystem where **fundamental research** fuels both scientific discovery and

technological advancement. Research directions will be fluid and responsive, ensuring alignment with Bhutan's Vision, the Sustainable Development Goals (SDGs), and global scientific trends.

iii. Infrastructure and Institutional Strengthening

A strong innovation ecosystem requires world-class research infrastructure. The CoE will support the growth of JNWSFL, while also exploring the development of new specialized labs and facilities to accommodate emerging research needs. To foster a collaborative and networked research environment, the CoE will connect with universities, industries, and innovation hubs across Bhutan and beyond. Digital transformation will also play a critical role, with the CoE integrating AI, blockchain, and big data solutions to enhance research efficiency and collaboration.

Strategic Enablers for the CoE (Backbone)

The Center of Excellence (CoE) requires a comprehensive foundation to ensure its long-term success. The strategic enablers serve as the backbone of this framework, facilitating its adaptability and sustainability. These enablers work in synergy to enhance the CoE's integration into Bhutan's National Innovation ecosystem.

Policy Framework

Establishing a well-defined policy framework will ensure coherence between innovation goals and national strategies. These mechanisms will provide clear guidance on critical areas such as intellectual property management, research ethics, and pathways for commercialization. By aligning national innovation policies with global trends, the CoE will create a supportive environment that fosters collaboration, knowledge-sharing, and technology transfer.

To develop these policy frameworks, the CoE will collaborate with policymakers, government agencies, and relevant institutions. External experts and stakeholders will also play a critical role in refining existing policies and creating new ones that reflect global technological trends and local socio-economic needs. This dynamic engagement will not only ensure that the CoE operates within a supportive policy environment but also position it as a leader in driving policy innovation within Bhutan's National Innovation Ecosystem.

Sustainable Financing Models

Ensuring the financial resilience of the CoE is essential for its long-term viability. The CoE will adopt sustainable funding strategies that draw from multiple sources, including public investment, government, private sector partnerships, and international grants. These financing models will ensure that the CoE has the resources to support high-impact research initiatives, infrastructure development, and talent acquisition while maintaining financial resilience.

Operational Frameworks

A robust operational framework will streamline decision-making processes, foster efficient resource allocation, and ensure accountability in achieving research outcomes. This framework will include governance structures, project management systems, and metrics for evaluating the CoE's performance against its strategic objectives.

Together, these strategic enablers will provide the CoE with the structural and functional foundation required to drive impactful research, foster collaboration, and sustain innovation. By integrating these mechanisms into its operations, the CoE will position itself as a cornerstone of Bhutan's National Innovation Ecosystem.

5. Research Portfolio strategy

A framework will be needed to guide the research portfolio at the CoE. A well-balanced research portfolio is essential for ensuring that R&D initiatives align with Bhutan's long-term economic and innovation goals. The research will initially align with existing capacity and infrastructure and will also depend on new collaborations and linkages that develop along the way. The CoE will develop a diversified research portfolio based on the following principles:

- **Short-Term and Long-Term Research Goals**: Balancing commercially viable projects with foundational research that delivers long-term impact.
- **Project Selection Criteria**: Prioritizing projects based on national priorities, global scientific advancements, and potential market impact.
- **Sectoral Focus Areas**: Research domains will include mechatronics, digital fabrication, sustainable energy, AI, robotics, and biomaterials.
- **Risk and Reward Balance**: Combining high-risk, high-reward research with incremental innovation projects to maintain a dynamic research pipeline.
- **Commercialization Pathways**: Facilitating technology transfer, intellectual property management, and
- startup incubation to bring research to market successfully.

Detailed guidance on research priorities and strategies are outlined in Annexure II. This framework ensures that the research portfolio aligns with Bhutan's socio-economic goals while maintaining a balanced approach to innovation and commercialization.

Way forward

The establishment of the Center of Excellence (CoE) will play a pivotal role in shaping Bhutan's innovation landscape, enhancing economic resilience, and driving high-value industries through advanced research and development. By focusing on collaboration, talent development, and infrastructure, the CoE will become a key component of Bhutan's National Innovation Ecosystem, promoting sustainable growth and global competitiveness. To successfully integrate the CoE and convert JNWSFL into a CoE, thorough studies and preparations will be necessary to ensure alignment with national innovation goals and effective implementation.

Annexure I: Jigme Namgyel Wangchuck as the Center of excellence(rationale)

The Jigme Namgyel Wangchuck Super FabLab (JNWSFL), inaugurated in 2022, represents a pioneering effort in digital fabrication and innovation. Its transformation into a Center of Excellence (CoE) is a strategic step that leverages its world-class infrastructure, expertise, and existing collaborations to broaden Bhutan's research and innovation horizons. By examining successful startups that have emerged from other FabLabs and the MIT Media Lab, we can illustrate the potential impact of this transformation.

Bhutan's growing FabLab ecosystem, comprising more than six FabLabs across the country, represents a valuable asset for advancing research and technological innovation. With most of these FabLabs embedded within academic institutions, they form a dynamic network that fosters collaboration, talent development, and interdisciplinary research. This interconnected ecosystem strengthens the CoE's foundation, providing opportunities for shared resources, joint research initiatives, and expanded access to cutting-edge digital fabrication tools. Establishing the CoE at JNWSFL is a logical and strategic choice, aligning with Bhutan's broader vision for innovation-driven economic transformation.

Leveraging JNWSFL infrastructure

JNWSFL is equipped with cutting-edge digital fabrication tools and high-precision machines, ranging from advanced 3D printers to Wire EDM systems. This robust infrastructure offers a unique advantage for the CoE to:

- **Enable rapid prototyping, precision manufacturing, and exploratory innovation** – accelerating the transition from conceptual research to practical applications.
- **Utilize digital fabrication as a foundation for interdisciplinary research** – integrating fields such as robotics, artificial intelligence, and materials science.
- **Support high-tech projects that align with global research standards** – positioning Bhutan as a competitive player in advanced manufacturing and R&D.
- **Provide industry collaboration opportunities** – offering fabrication and prototyping services to local enterprises, startups, and research institutions.

The advanced capabilities of the lab allow it to serve as a springboard for conducting both applied and fundamental research, transforming JNWSFL into a hub for scientific exploration beyond digital fabrication. The lab also has technical expertise in digital fabrication and machining.

Building a Long-Term Vision for JNWSFL

The transition of JNWSFL to a CoE will provide a structured mandate for continuous innovation, ensuring that the facility remains at the forefront of scientific and technological advancements. By expanding research focus areas and integrating new technologies, JNWSFL will maintain its relevance in an ever-evolving global research landscape.

The CoE's role as a leading research institution will attract additional funding opportunities, including government support, international grants, and industry partnerships. This financial sustainability will enable the CoE to undertake ambitious research projects that address national and global challenges. The transformation will also strengthen Bhutan's position in the global research community by fostering international collaborations and positioning JNWSFL as a preferred destination for R&D initiatives.

Digital fabrication will continue to be a core strength of the CoE, serving as an enabling platform for groundbreaking interdisciplinary research. By leveraging its advanced capabilities, the CoE will drive innovations that contribute to sustainable economic growth and industrial development. Furthermore, aligning the CoE with Bhutan's Vision for the National Innovation Ecosystem ensures that research efforts are directed toward strategic national priorities, reinforcing the country's commitment to fostering a knowledge-driven economy. The establishment of a CoE at JNWSFL is not just an investment in infrastructure but a strategic commitment to long-term innovation and research excellence.

Resources Required for the Transition of JNWSFL into a Center of Excellence

Transforming Jigme Namgyel Wangchuck Super FabLab (JNWSFL) into a Center of Excellence (CoE) requires a structured approach that builds upon its existing strengths while addressing gaps in infrastructure, expertise, and operational mechanisms. While JNWSFL already possesses cutting-edge digital fabrication capabilities, the shift toward a research-driven CoE will require significant upgrades in governance, talent development, funding, infrastructure, and industry engagement.

- ***Strengthening Governance & Advisory Framework*** : Establish an Advisory Board of experts to guide strategy, set research priorities, and ensure alignment with national innovation goals. Implement clear governance policies for research funding, IP protection, and industry partnerships.

- ***Expanding Human Capital & Research Talent***: Recruit specialized researchers in biomaterials, AI, robotics, and energy while upskilling existing staff. Launch the Bhutan Innovation Fellowship to attract PhD candidates and establish international collaborations for knowledge exchange.

- ***Enhancing Funding & Financial Sustainability*** : Leverage **Bhutan's Innovation Fund** and seek international grants, industry collaborations, and philanthropic contributions. Develop a research commercialization unit to generate revenue from IP licensing and tech transfer.

- ***Upgrading Infrastructure & Research Facilities*** : Expand lab space and establish new research hubs, including a Microfabrication Lab and AI & Robotics Research Center. Invest in high-performance computing for simulation-based research.

- ***Strengthening Industry & Innovation Ecosystem Engagement*** : Set up a Technology Transfer Office to support IP protection and industry collaboration. Launch Innovation Hubs and Incubation Programs to bridge research and commercialization, attracting startups and investors.

- ***Ensuring Regulatory Compliance & IP Protection*** : Develop research policies for data security, ethics, and IP management, ensuring sustainable and responsible innovation aligned with Bhutan's national priorities.

- ***Expanding Knowledge Dissemination & Public Engagement*** : Increase research publications, public science outreach, and educational initiatives to foster a national culture of innovation. Establish an Open Research & Innovation Hub for knowledge-sharing and collaboration.

Fundamental Research at JNWSFL

In addition to applied research, JNWSFL has the potential to emerge as a leading center for fundamental research. The CoE will focus on advancing scientific knowledge in key domains, bridging the gap between theoretical advancements and real-world applications. The research agenda will prioritize high-impact areas, including robotics, materials science, biomaterials, energy technologies, and mechatronics.

1. Advanced Materials Science

- Research on novel **composite materials** for enhanced durability, flexibility, and performance in fabrication.
- Development of **biodegradable materials** to create sustainable alternatives to plastics.
- Investigation into **smart materials** with responsive properties (e.g., shape memory alloys, self-healing materials).
- Experimentation with **nano-engineered materials** for high-precision manufacturing applications.

2. Biomaterials and Biofabrication

- Exploring **bioprinting techniques** to create artificial tissues and scaffolds for medical applications.
- Research on **bio-inspired materials** that mimic natural properties for use in regenerative medicine and eco-friendly packaging.
- Development of **bio-based filaments** for 3D printing using organic waste or algae-derived polymers.
- Studying the impact of **microfluidics** on biomanufacturing processes for healthcare and pharmaceutical applications.

3. Robotics and Mechatronics

- Developing **soft robotics** that integrate flexible materials for human-friendly automation.
- Research on **human-machine interaction**, focusing on collaborative robotic systems.
- Advancing **precision robotic fabrication**, combining AI-driven motion planning with digital fabrication tools.
- Investigating **self-assembling robotic structures** that can autonomously construct complex designs.

4. Sustainable and Renewable Energy Technologies

- Studying **energy-efficient fabrication methods** to reduce carbon footprints in digital manufacturing.
- Research on **solar-printed electronics**, creating flexible photovoltaic cells through additive manufacturing.
- Investigating **alternative energy storage** systems, such as solid-state batteries and hydrogen-based storage.
- Experimenting with **piezoelectric materials** that generate energy from movement and pressure.

5. Computational Design and Digital Manufacturing

- Developing **algorithmic design models** that optimize structural efficiency and material use.
- Researching **generative design and AI-assisted manufacturing** for automated production workflows.
- Exploring **multi-material 3D printing** to fabricate functionally graded objects with varying properties.
- Studying the potential of **blockchain integration in digital fabrication** to ensure design security and traceability.

6. Precision Engineering and Microfabrication

- Investigating **microfabrication techniques** using laser sintering and lithography for high-precision manufacturing.
- Developing **microscale sensors** for environmental monitoring, healthcare, and industrial applications.
- Researching **high-speed automated milling and machining** for rapid prototyping of microstructures.

7. Circular Economy and Sustainable Manufacturing

- Researching **waste-to-material innovations**, such as transforming industrial byproducts into new fabrication resources.
- Experimenting with **closed-loop manufacturing systems** that integrate recycling and material recovery.
- Studying the potential of **digital fabrication**

Way Forward/ timeline/ roadmap

Vision 2035

Capacity Building (2024–2026)

- Establish 3 research clusters (Advanced Materials, Biomaterials, Sustainable Energy) with Nu. 200M funding from the Innovation Fund.

- Formalize partnerships with top research institutes in the world for joint projects and researcher exchanges.(MIT….)
- Launch Bhutan Innovation Fellowships (20 PhD candidates annually) in collaboration with RUB and global universities.

Scaling Impact (2027–2029)

- Expand infrastructure: Build a Microfabrication Lab (Nu. 150M) and AI/ Robotics Center (Nu. 100M) through PPPs.
- Achieve 30% commercialization rate for applied research via InnoTech's DRIVE incubator.
- Attract global investors and researchers in BIF 2028

Global Leadership (2030–2034)

- Secure 50% self-funded operations through IP royalties and industry contracts
- Position JNWSFL as South Asia's top CoE via 10+ cross-border projects
- Integrate CoE outputs into national policy

Key Performance Indicators (KPIs)

- Research Output: 50+ peer-reviewed publications annually by 2030.
- Talent Pipeline: 200+ PhDs trained in CoE priority areas by 2034.
- Economic Impact: 25+ startups incubated, contributing Nu. 2B+ to GDP.

Risk Mitigation

- Diversify funding with a CoE Endowment Fund
- Create a Talent Retention Program (e.g., research grants).

Annexure II: Research and Development Ecosystem

The R&D Strategy defines the overarching approach, methodologies, and sustainability mechanisms that guide research activities at the Center of Excellence. It ensures that research is impactful, aligned with national priorities, and contributes to Bhutan's long-term socio-economic growth.The CoE will employ a dynamic and iterative R&D strategy that prioritizes:

A Systems Approach: Recognizing the interconnectedness of research, innovation, and the broader socio-economic context. The CoE will:

- Integrate research efforts: Foster interdisciplinary research that bridges traditional boundaries between disciplines.
- Consider societal and environmental impacts: Ensure that research contributes to sustainable development and addresses Bhutan's unique challenges.
- Engage with stakeholders: Actively involve policymakers, industry representatives, and the public in the research process.

Risk Management and Adaptive Planning

- The CoE will embrace a culture of experimentation and learning, acknowledging that not all research projects will succeed.
- Regularly evaluate and adjust research priorities: Based on emerging trends, new discoveries, and changing societal needs.
- Develop contingency plans: To mitigate risks and adapt to unforeseen challenges.

Knowledge Dissemination and Impact

The CoE will prioritize the effective dissemination of research findings through:

- High-quality publications: Publishing research results in leading scientific journals and conferences.
- Knowledge transfer mechanisms: Facilitating the transfer of research knowledge to industry, government, and the public.
- Public outreach and engagement: Communicating research findings to the broader public to raise awareness and foster public understanding of science and technology.

Building a Sustainable R&D Ecosystem

The CoE will work to create a sustainable and self-sustaining R&D ecosystem by:

- Cultivating a culture of innovation: Fostering an environment that encourages creativity, risk-taking, and entrepreneurial thinking.
- Building research capacity: Investing in the development of human capital and infrastructure to support long-term research excellence.
- Securing sustainable funding: Exploring diverse funding sources, including government grants, industry partnerships, and philanthropic contributions.