Assessing the
Regional Competitiveness
of the Indian Bioeconomy

MOVING TOWARDS A SUSTAINABLE, CIRCULAR MODEL

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Assessing the Regional Competitiveness of the Indian Bioeconomy:

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Assessing the Regional Competitiveness of the Indian Bioeconomy

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Foreword

Dr Renu Swarup

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India's bioeconomy has been growing exponentially over the years, bolstered by the sector's strong performance and growth drivers. This expansion has primarily been driven by the innovative capacities within the existing bio-manufacturing sector with forays made into crucial domains such as biopharmaceuticals, bio-agriculture, bio-services and bio-industry. The current potential and emerging possibilities provide India with great opportunities to develop its existing bio-manufacturing hub to become a $100 billion industry by 2024. With the right enabling environment and creation of robust bio-manufacturing hubs, the Indian Bioeconomy could potentially increase to a valuation of $150 billion by 2024.

The Department of Biotechnology (DBT) and Biotechnology Industry Research Assistance Council (BIRAC) have rightly identified the prospects within this sector and have provided a strong policy base. DBT and BIRAC have facilitated the implementation of bio-tech science clusters, bio-incubators, biotech funding programmes for start-ups and entrepreneurs. India's 2020 Budget has also highlighted the prospects of India's Bioeconomy and has sought to establish Knowledge Translation Clusters, genomics mapping initiative, testbeds, Centres of Excellence dealing with innovation in the field of Intellectual Property and better technology adoption within bioinformatics.

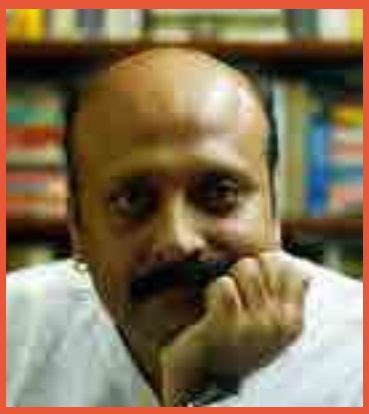
Apart from these initiatives, the Department has also tried to assist state governments in facilitating a culture of cutting-edge research and innovation within their regional bio-economies. DBT has worked with different states in establishing biotechnology parks, building research hubs and regional centres in order to develop an ecosystem to foster innovation and industry-academia linkages within the states' bio-economies. These policy drivers have created a significant impact by aiding in the formation of several new technologies, products, patents, start-ups, small and medium industries.

Within the Indian Bio-Manufacturing sector, DBT and BIRAC have realised the crucial role of bio-clusters in enhancing

the manufacturing capacity of different regions. Through the establishment of knowledge translation clusters, the government is keen to move towards a cluster orientation which would help build shared networks between biotechnology industries, start-ups, allied educational institutions, and research hubs. In accordance with these objectives, BIRAC Foundation Day 2020 is an opportune time to release the report highlighting the future possibilities within Indian bioeconomy. This report has emphasised on the competitiveness of regional bio-clusters and showcased how the clusters could bring about sustainable production processes within the Indian Bioeconomy.

This report has also made several insightful recommendations on bio-cluster development, data management processes, key facilitators as well as provided a roadmap which would aid in the creation of a Sustainable, Circular Bioeconomy within India. The recommendations and findings from the report could potentially play a role in guiding the approach of the government towards developing India's Bioeconomy to become a $150 Billion industry by 2024. I congratulate the entire team at Department of Biotechnology, Biotechnology Industry Research Assistance Council and Institute for Competitiveness in making this effort a successful one.

Message



Amit Kapoor
Chairman, Institute for Competitiveness

The Indian Bioeconomy has been growing at a phenomenal pace over the years, being valued at $51 billion in 2018. Within the next five years, it is expected that India's Bioeconomy will grow to $150 Billion, with the majority share emerging from Bio-Manufacturing. India has developed a strong base in Bio-Manufacturing, especially in the sub-sectors of Biopharmaceuticals, bio-agriculture, bio-services and bio-industry. This growth has been facilitated by targeted government initiatives and actions which have led to the establishment of multiple bio-incubators, bio-clusters and allied start-ups.

As the Indian Bioeconomy grows further, there is a need to sustain this expansion along with enhancing the social benefits derived from it. As global challenges such as ecological destruction and climate change become the norm, developing sustainable, resource-efficient production processes should be prioritized. India' Bioeconomy could lead that way by transitioning to a Circular, Sustainable model which would not only lead to environmental protection but also increased innovation in products and services. However, this transition would require industry units to be of sufficient size and scale. Bio-clusters thus become a crucial component as they would act as a collaborative platform for all key stakeholders and assist in bringing about this to reality. Nonetheless, this vision can only be met through an assessment of Indian bioeconomy's challenges, growth drivers and inherent capabilities of existing bio-clusters which this report aims to provide.

'Assessing the Regional Competitiveness of the Indian Bioeconomy: Moving towards a Sustainable, Circular Model' is a study that analyses the competitiveness of the overall Indian bioeconomy with special emphasis on its regional bio-clusters. The report analyses India's bioeconomy position among its peers, the performance, policy drivers and core growth drivers.
In addition, the study also carries out a holistic regional cluster analysis of the Indian Bioeconomy. The bio-cluster strength mapping has been carried out to understand the regional

distribution as well inherent strengths across the broad categories of size, specialisation, productivity and dynamism. Based on the analysis, a roadmap for the future is envisaged that would enable the central and state governments to collaborate in ushering in $150 Billion Indian Bioeconomy by 2024.

The Institute for Competitiveness is sincerely thankful to the Department of Biotechnology (DBT) and Biotechnology Industry Research Assistance Council (BIRAC) for their constant support and feedback during the course of the story. I would also like to acknowledge the support of my team at the Institute for Competitiveness, including Aniruddh Duttaa, Manisha Kapoor, Jatin Nair and Sampriti Mukherjee in compiling the report. We are hopeful that the recommendations from the study would aid in the achievement of the 2024 vision.

Executive Summary

The world is moving towards more sustainable forms of production spurred by global changes in the form of climate change, and ecological degradation. Additionally, there has been rising pressure on food, health, energy resources and basic amenities propelled by an increasing population, especially in India. Thus, one of the ways to meet such challenges would be to shift away from a fossil-fuel development paradigm to bio-based resources dominated trajectory. This will ensure that India can continue on its high growth trajectory without completely depleting its natural resource base.

The Indian Bioeconomy has been growing steadily over the years, with it reaching $51 billion in 2018, realising a 14.68 percent growth from 2017. Considering the growth potential of this sector, it is expected that during the next five years, the Indian Bioeconomy will grow to $150 Billion by 2025. Within this broader domain, the Indian bio-manufacturing would contribute to 66.7% of the projected growth by 2024. The strong position of this sector has been propelled by its inherent performance, and growth drivers, namely: affordable human capital, cost-competitive manufacturing, a multitude of biodiversity, and rising demand for health services. The Indian government has also initiated several projects to improve its basic infrastructure through the initiation of biotech science clusters, biotechnology parks, and incubators. Additionally, missions and targeted schemes such as National Bio-Pharma Mission, Biotech KISAN Programme, Biotech Start-Up Policy and North Eastern Biotechnology Programmes

have been implemented to nurture nation-wide and region-wide strengthening of biotechnology activities.

Nonetheless, in order to build a strengthened Indian bio-manufacturing hub and bioeconomy, structural reforms are required to be implemented. This would involve that the Indian biomanufacturing needs to move beyond cost-competition and focus on creating high-value, specialized products that would give them an edge over other countries. Additionally, states would also need to orient their bioeconomy strategies with the national vision by driving the growth of their clusters through better incentive models. The formulation of region-wide strengthened clusters also provides India with a perfect opportunity to shift towards a Sustainable, Circular Bioeconomy model. This would not only enable the creation of new market and job opportunities but also aid in the protection of the environment and biodiversity. The necessity of creating sustainable production processes has also been highlighted by NITI Aayog in its strategy to advance India towards a resource-efficient and circular economy.

Against this backdrop, this report analyses the competitiveness of the Indian bioeconomy from the perspective of its regional bio-clusters. It starts by analysing the concept of the circular bioeconomy and why it would be beneficial for the Indian bio-based industry to uptake the same. This is further strengthened with India's position in the global bioeconomy, the key enablers and the future growth opportunities that could allow the transition in a phased manner. Furthermore, the cluster mapping for the Indian bioeconomy has been carried out by drawing conceptual antecedents from "Clusters: The Drivers of Competitiveness" – a report submitted to the Economic Advisory Council to the Prime Minister (EAC-PM). Based on the analysis of the cluster strength of the States and Union Territories, policy recommendations have been provided to enhance the regional competitiveness of India's bioeconomy.

The report suggests that there is an urgent need to move away from the traditional concept of clusters and build a holistic cluster environment that should have strengthened linkages with the labour force, allied industries, research hubs, financial institutions and consumers. In lieu of the findings, policy actions have been suggested on – strengthening region-wide bioeconomy clusters, enabling performance tracking and data management across the sectors of Indian bioeconomy, enhancement of facilitating factors as well as the development of sustainable, circular bioeconomy within India.

Introduction

The world is undergoing a rapid transformation. With a swift rise in global prosperity levels and standard of living, new challenges have emerged. Across the world, drastic effects of climate change and ecological degradation have simultaneously increased with global economic growth. Such growth levels have prompted a simultaneous rise in demand from sectors such as food, health, energy resources, and basic amenities to meet the needs of a growing global population base.

The fulfilment of the above needs of such a large scale has resulted in overexploitation and poor ecological management of the existing natural resources. An urgent transformative change is required to curb the current rate of exploitation of resources while sustaining the growth levels across the world. Hence, the only way countries can continue on the path of sustained growth would be to transition from fossil-fuel development paradigm to a trajectory that takes advantage of bio-based resources. This change would require the use of biotechnology to spur innovations, develop strategies and policies within the domain of biochemistry and life sciences such that it further the development of a strengthened bioeconomy[1].

Within the Indian context, the need for a holistic bioeconomy becomes an essential requirement, with the country's population expected to surpass China's by 2027[2].

This implies that India continues to remain as the most populated country at least until the end of the 21st century. Thus, considering the future requirement of goods

[1]OECD. (2009). The Bioeconomy to 2030: Designing a Policy Agenda – Main Findings and Policy Conclusions.
[2]United Nations. (2019). World Population Prospects 2019: Highlights. Retrieved from https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf

The necessity of creating sustainable production processes has also been highlighted by NITI Aayog in its strategy to advance India towards a resource-efficient and circular economy.

and services, there needs to be additional focus on creating sustainable systems of production and consumption[3]. This will ensure that India can continue on its high growth trajectory without completely depleting its natural resource base.

These strategies, namely "Status Paper and Way Forward on Resource Efficiency and Circular Economy" as well as the "Four Sectoral Strategy Papers on Resource Efficiency on Steel, Aluminium, Construction and Demolition Waste, Secondary Materials Management in Electrical and Electronics Sector" have been developed as a joint initiative between Ministry of Environment, Forest and Climate Change and the European Delegation to India[4]. The potential for Circular Economy has also been highlighted by NITI Aayog CEO, Amitabh Kant who stated that the shift towards resource circularity and sustainable development could lead to the creation of approximately one-and-half crore job opportunities and several lakhs of new entrepreneurs in India by 2027.[5] This policy focus towards sustainable production systems is also in sync with India's commitment to limit its carbon emission goals as per the Paris Agreement, 2016[6].

With respect to the Indian bioeconomy, the Department of Biotechnology has taken initial steps to develop a Circular Bioeconomy vision for India. As part of the vision, there has been a governmental initiative in the form of National Policy on Biofuels 2018, indicating that the Indian bioeconomy is headed towards a transformative phase. The policy aims to promote the production of biofuels from the domestic feedstock, allowing the end-products to be brought into the value chain as green energy. This will be carried out through the Ethanol Blended Programme, Biodiesel Blending Programme and production of advanced biofuels such as bio-CNG, bio-methanol, bio-hydrogen and bio-jet fuel[7].

[3]*World Economic Forum. (2017). What India can teach the world about sustainability*
[4]*Press Information Bureau. (2019, January 22). NITI Aayog pitches for transition to Resource Efficiency and Circular Economy as an Economic Paradigm for New India. Retrieved from https://pib.gov.in/Pressreleaseshare.aspx?PRID=1561008*
[5]*The Economic Times. (2019, June 18). Circular economy can generate 1.4 crore jobs in 5-7 years: NITI Aayog CEO. Retrieved from https://economictimes.indiatimes.com/news/economy/circular-economy-can-generate-1-4-crore-jobs-in-5-7-years-niti-aayog-ceo/articleshow/69836073.cms?from=mdr*
[6]*NRDC. (2017). The Road from Paris: India's progress towards its climate pledge. Retrieved from https://www.nrdc.org/sites/default/files/paris-climate-conference-India-IB.pdf*
[7]*Ministry of New and Renewable Energy. (2018). National Policy on Biofuels. Retrieved from https://mnre.gov.in/file-manager/UserFiles/biofuel_policy.pdf*

In order to realize this vision, there needs to be not only extensive focus on the current strengths and challenges faced by the industry but also a re-orientation as to how bioeconomy is envisioned within government, industry, academia, and civil society. In concordance with of the global changes and government vision, India needs to transition towards a sustainable, circular bioeconomy model in order to compete with advanced and emerging global bio-economies. This change would aid in not only bringing about innovation in products and services related to the bio-based industry but also protect the environment and enhance biodiversity.[8]

Such a model would allow the Indian bio-based industry to play to its core strengths within the domain of bio-agriculture and allow the production of additional economic outputs using food waste and efficient conversion of biomass. Additionally, by creating resource-efficient value chains and organic recycling pathways, the sector would assist in the goals of lowering India's Greenhouse Gas footprint.

Nonetheless, the path towards the creation of a Sustainable, Circular Bioeconomy needs to be carried out in a phased manner. This is because the challenges faced when production processes seek to transition to the Green Economy are mainly of size and scale. Hence, it would be imprudent to impose on individual units to shift towards a Circular Bioeconomy model. Clusters thus become instrumental in such scenarios to facilitate a smooth transition. By acting as intermediaries, clusters become platforms of change and collaboration. A strengthened cluster would quicken the process by helping green and other allied industries to share research, skills, and new innovations. This would allow industries to access new market opportunities, financial resources, and knowledge systems.[9]

[8]Ketels, C. & Prostiv, S. (2017). Priority Sector Report: Circular Economy. European Cluster Observatory.
[9]European Commission. (2019). Clusters in the Circular Economy: Building Partnerships for Sustainable Transition of SMEs. Retrieved from http://circularpp.eu/wp-content/uploads/2019/11/Clusters-in-Circular-Economy.pdf

Thus, the movement towards a circular bioeconomy in India as well needs to emerge from strengthened regional bio-clusters which can incorporate certain transformative practices in a phased manner, such that 2024 could usher in a $150 Billion Sustainable, Circular Indian Bioeconomy. These clusters could also enhance the capacity of India's bio-manufacturing domain as it strives to develop itself into a world-class $100 billion hub by 2024.

The concept of strengthening clusters and forming shared networks across key stakeholders has been reflected in India's 2020 Budget as well. Along with several other initiatives, the government has proposed setting up knowledge translation clusters, especially with respect to new and emerging technologies. Additionally, testbeds and small-scale manufacturing facilities would be established within Technology Clusters to promote designing of new products, validation of proof of concept through industry-academia linkages and commercialisation of research. The Department is also seeking to establish technical platforms known as Technology Propellers (T-Propellers) which are to be anchored around innovation clusters. These platforms would assist start-ups and incubators in converting proof of concept to pilot stage by providing design assistance, process standardization, material selection and knowledge awareness regarding regulatory compliances. Moreover, Manufacture Zones (M-Zones) would also be established to support industries to shift from pilot to manufacturing through the creation of interconnected national innovation network for technology-based start-ups. Furthermore, the clusters would also be enhanced by Centres of Excellence which would promote innovation and application of Intellectual Property Rights[10].

Against this backdrop, the study analyses the competitiveness of the Indian bioeconomy from the perspective of its regional bio-clusters. It starts by analysing the concept of the circular bioeconomy and why it would be beneficial for the Indian bio-based industry to uptake the same. This is further strengthened with the overall analysis of India's bioeconomy and the key enablers that could allow the transition in a phased manner. Furthermore, the regional analysis of the Indian bioeconomy has been carried out to understand the distribution as well as inherent strengths across the factors of size, specialization, productivity, and dynamism. Based on the analysis of the cluster strength of the States and Union Territories, policy recommendations have been provided to enhance the regional competitiveness of India's bioeconomy.

[10]*Ministry of Finance. (2020). Union Budget 2020-2021. Retrieved from https://www.indiabudget.gov.in/budgetspeech.php*

Understanding the Sustainable, Circular Bioeconomy Model

Defining Sustainable, Circular Bioeconomy: Global Practices

The concept of bioeconomy has historically been used in a multitude of activities, with it being recognized within scientific literature as late as the 1960s[11]. Since then, policymakers across the globe have sought to harness the economic potential of this system by following either or merging the two main viewpoints, that is the resource substitution and the biotechnology innovation perspective. While the initial process of developing this concept arose from using bio-based products instead of fossil resources (resource substitution), the perspective soon transitioned towards a knowledge-based driven economy. With further development of this concept, the link between environmental sustainability and bioeconomy was recognized, such that sustainable development could become a primary goal for creating a strengthened bioeconomy[12].

The Circular Bioeconomy (CBE) concept seeks to replace the "take, make and dispose" model by following the 3R's of keeping the waste generated within the system – waste materials are reduced, recycled, and remanufactured.

Several efforts were introduced to create a 'Green,' sustainable bioeconomy, particularly within the European Commission to link circular economy with the concept of bioeconomy. This concept, as defined by the European Commission's Circular Economy Action Plan seeks to structure the economic space such that "the value of products, materials, and resources is maintained in the economy for as long as possible, and the generation of waste minimized."[13]

The circular model of production goes much beyond the traditional idea of the waste but seeks to eliminate the underutilization of resources and assets in four broad manners –

Wasted resources – Materials that cannot be adequately restored over the due course of time

Wasted capacities – Underuse of generated products and assets

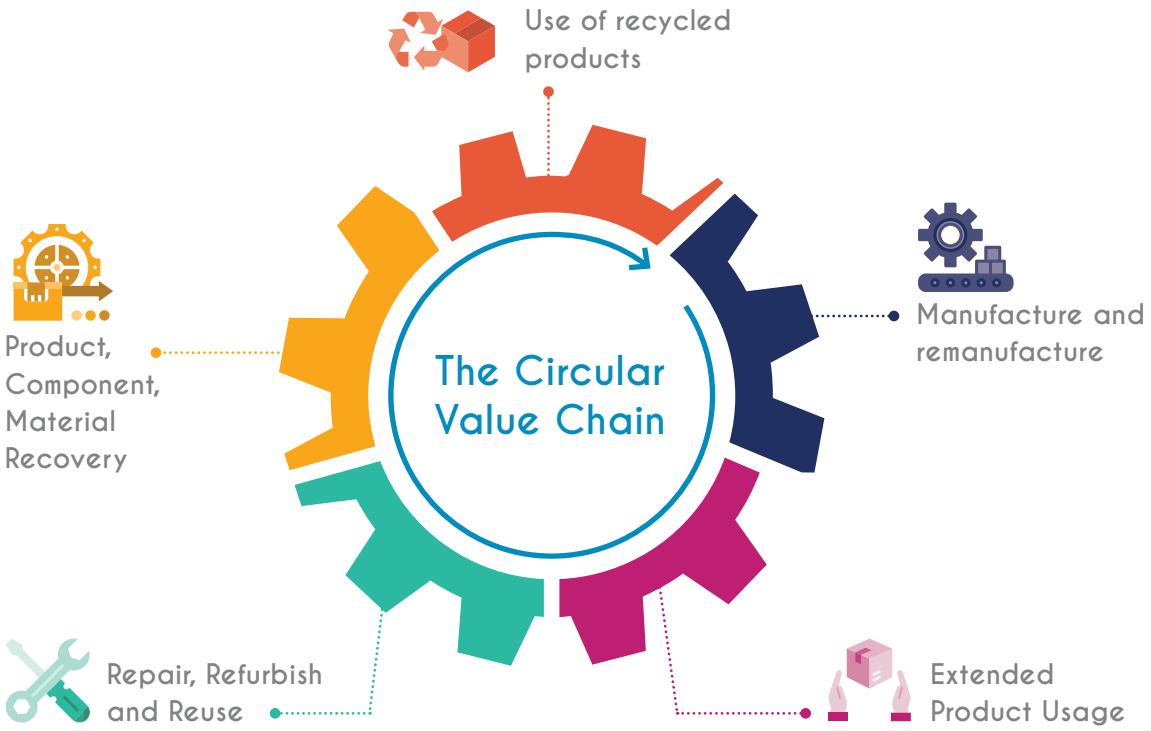
Wasted lifecycles – Poor design of products which lead to the premature end of life without any second life options

Wasted embedded values – Inefficient recovery of components, material, and energy from waste streams.

This form of production seeks to shift away from the traditional methods by developing waste as a monetized product by transforming waste into allied by-products. Additionally, resources are sought to be managed by leveraging on the spare capacities within markets, carrying out business model innovation, product development, and value chain redesign.

[11] *Priefer, C. & Jörissen, J. & Frör, O. (2017). Pathways to Shape the Bioeconomy. Resources.*
[12] *Birner, R. (2018). Bioeconomy Concepts. In I. Lewandowski (Ed.), Bioeconomy.*
[13] *Carus, M. & Dammer, L. (2018). Industry Report: The Circular Bioeconomy – Concepts, Opportunities and Limitations. Industrial Biotechnology, 14(2).*

Figure 1:
The major components of the Circular Economy



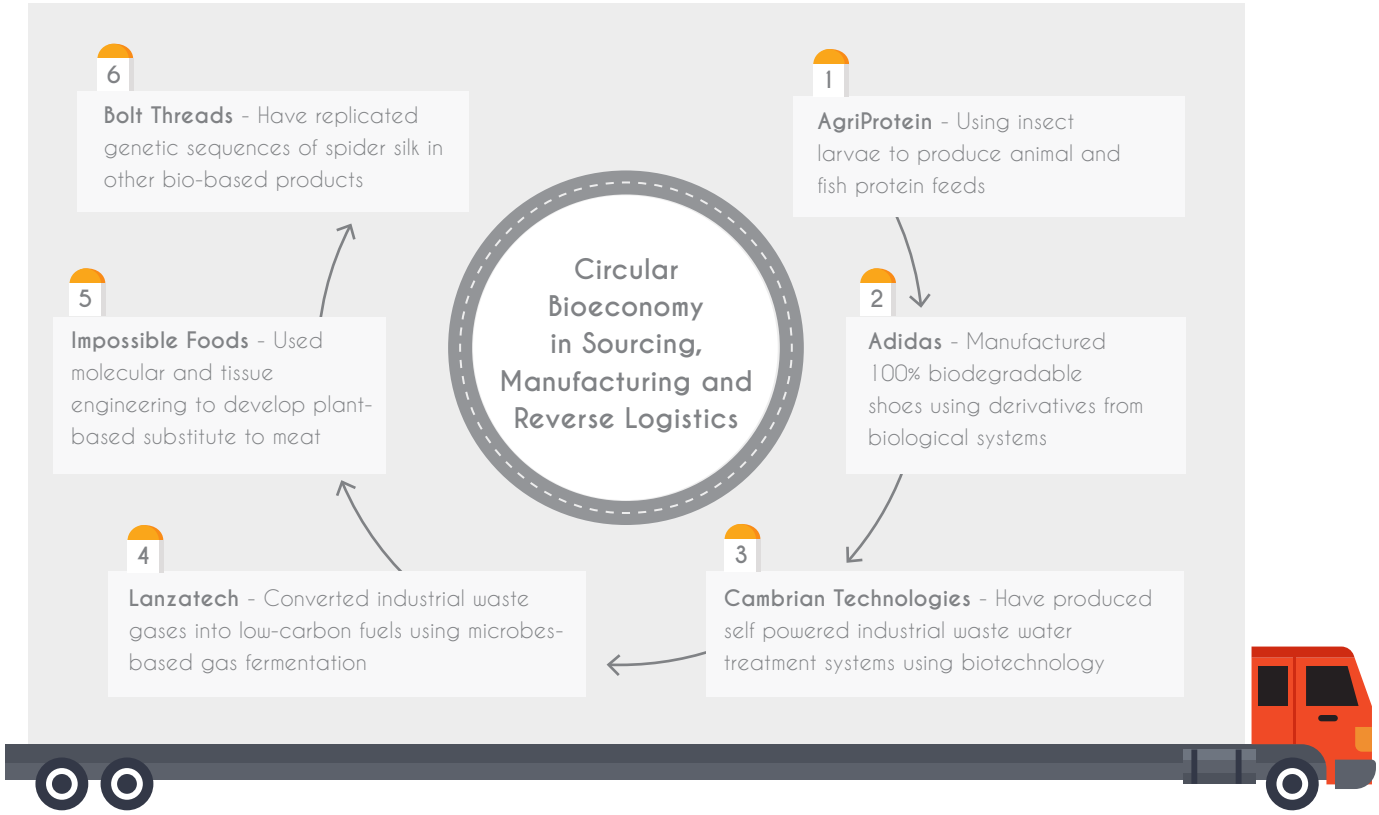
This concept has been globally adopted across various countries to ensure improved resource and eco-efficiency, minimized Green House Gas emissions, lowering the demand for fossil and carbon resources and promoting the use of waste and allied side streams. Nonetheless, the circular economy is just not restricted to achieving environmental sustainability – by improving utilization of resources and creating innovative by-products from the waste generated, the business opportunities from circular economy models are expected to reach $4.5 trillion of GDP globally by 2030. The most substantial contribution from this future projection is expected to come from substituting wasted resources by introducing renewable and bio-based fuel, chemicals, and materials – approximately $1700 billion by 2030 globally.[14]

The use of biological and bio-based technologies is still emerging within the field of the circular economy. For instance, the conversion of bio-waste into energy, the use of bioplastics instead of traditional petroleum-based polymers, usage of

[14]*Accenture Strategy. (2018). Accelerating India's Circular Economy Shift- A Half Trillion USD Opportunity: Future proofing growth in a resource-scarce world. FICCI Circular Economy Symposium 2018.*

hydroponics and aeroponics for providing nutrient-rich water to growing plants have been components of this endeavour. Several renowned firms are also trying to get integrated within the circular economy, across the value chain using such technologies:

Figure 2:
Firms using bio-based products and processes to transition towards a Circular Bioeconomy



Considering these significant potentials, policymakers across the globe have started to bring in elements of circular models within their bioeconomy strategy. In order to do so, policymakers would need to build synergies across various sectors related to the bioeconomy to adjust the education and training of the workforce, research, and development as well as incentives for the creation of new products and processes to be oriented towards sustainability goals. Some of the countries that have sought to uptake this model within their economy are[15]:

[15] *OECD. (2018). Realising the Circular Bioeconomy. OECD Science, Technology and Industry Policy Papers, No. 60.*

Table 1: Brief of the policies under the circular economy and bioeconomy across the globe

Country/ Unions	Bioeconomy Policy	Circular Economy Policy	Brief about the Policies
European Union	Bioeconomy Strategy (European Commission, 2012)	EU Action Plan for the Circular Economy (European Commission, 2015)	The action plan for circular and bioeconomy strategy seeks to promote the cascading use of biomass over energy uses
Denmark	National Bioeconomy Panel (2014)	Waste Prevention Strategy (The Danish Government, 2015).	The circular economy and industrial symbiosis model have been present in Denmark since 1972. At present, it has set an objective of recycling 50% of household waste by 2022.
Finland	National Bioeconomy Strategy (Bioeconomy, 2014)	Strategic Programme (European Commission, 2017)	Finland seeks to create a strong interlink between circular and bioeconomy by focusing on the cascading use of wood for material and energy use in a sustained manner.
Sweden	Swedish Research and Innovation Strategy for a Bio-Based Economy (2012)	Strategy for Sustainable consumption (Government offices of Sweden, 2016)	Sweden has sought to decarbonize the economy by targeting the use of biomass, such that it can be made into allied products such as biofuels. This is in sync with their higher strategy of reducing resource consumption through reuse and recycling.
Italy	Bioeconomy Strategy (BIT, 2016)	Towards a Model of Circular Economy for Italy – Overview and Strategic Framework (Ministry of Environment and Economic Development, 2018).	The bioeconomy strategy aims to shift from fossil fuel to higher renewable resource consumption by bringing in the implementation of biowaste valorization and circularity. The circularity strategy paper seeks to accomplish this goal by making manufacturers responsible for the full life cycle of the product, along with generating environmental awareness among citizens.
Scotland	Biorefinery Roadmap for Scotland (Scottish Enterprise, 2015)	Strategy for the circular economy (Natural Scotland, 2016).	An integrated approach has been followed by the Scottish government by maximizing the use of biological resources through the use of biorefineries. There is a greater focus on prioritizing the materials and chemicals derived from biomass as compared to energy recovery.
China	Plan for Development of Bioindustry (2012), 12th Five Year Development Plan for National Strategic Emerging Industries, Medium and Long-Term Plan for the Development of Science and Technology	Circular Economy Promotion Law of the People's Republic of China (2009)	China follows an ambitious plan of waste management and resource optimization by building upon biomass resources to replace fossil material and energy sources. Along with resource generation, the Chinese administration is also focused on establishing a sound circular economy statistics system, strengthening data-administration of resource consumption, and undertaking data monitoring of utilization and waste generation.
Brazil	National Strategy for Science, Technology, and Innovation (2016-2022), Biotechnology Strategy (2007)	Brazil's National Biodiesel Program (2004), Solid Waste National Policy 2010	While Brazil has a long history of using bio-based products as a way to ensure food security and check the depletion of natural resources. While there does not exist a governmental policy for creating a circular economy, several regional and private organizations have been trying to use techniques of resource optimization and reverse logistics.
Spain	Strategy on Bioeconomy (2016. Spain Government)	Draft Espana Circular 2030	The Circular Bioeconomy Strategy has sought to be established, with particular emphasis on biological wastes and residue use purposes. Bioeconomy annual action plans have also been proposed as a part of ensuring CBE.

Hence, increasingly around the globe, there has been a definitive shift in perspective towards a Circular Bioeconomy. The Indian policy environment has shown signs of moving towards CBE, with the National Policy on Biofuels having been approved in 2018. The policy aims to achieve the target of blending at least 20 percent of biofuels with fossil-fuel-based fuels by 2030, showing conclusive signals of transitioning to a Green Bioeconomy.

The contribution of Sustainable, Circular Bioeconomy to India's priorities

India's economic growth has grown hand in hand with a domestic rose in demand for resources. With an increasing population, especially in the urban areas, several regions within India are facing issues related to resource constraints in domains such as drinking water, electricity, and other basic amenities. Along with these problems, there is intense stress on natural resources, with 11 Indian states registering a sharp decline in natural capital during 2005-2015[16]. Pollution of the existing natural resources has further worsened the situation with 22 Indian cities topping the 50 most globally polluted cities, as of 2018[17].

The absolute resource dependence begs the question if India is well-positioned to grow at the current rates by not changing the existing business models. The present demand-supply gap and degradation of natural resources highlight a need for improved resource efficiency measures within India. This problem has also been emphasized by the Government of India's Indian Resource Panel, which has sought to assess the resource-related issues and formulate a comprehensive strategy for improving resource efficiency within India[18].

Given this background, implementing the Circular Bioeconomy would provide opportunities for the Indian business systems to continue with its growth trajectory without creating undue stress on the present resource supply.

[16]Ministry of Statistics and Programme Implementation. (2018). EnviStats 2018.
[17]IQ Air Visual. (2020). World most polluted cities 2018 (PM 2.5). Retrieved from https://www.airvisual.com/world-most-polluted-cities?continent=&country=&state=&page=1&perPage=50&cities=
[18]NITI Aayog. (2017). Strategy Paper on Resource Efficiency.

The application of Circular Bioeconomy within the Indian business structure would also aid in the fulfilment of targets set to achieve the Sustainable Development Goals –

The goals of 'No Poverty,' 'Zero Hunger,' and 'Decent Work and Economic Growth' (SDGs 1,2, and 8, respectively) are affected by the socio-economic outcomes of the bioeconomy. By directly leading to transformations in agriculture and industries, circular bioeconomy could bring about positive contributions in the broader domains of employment, food security, and poverty.

The SGD 3 goal – 'Good Health and Well-Being' directly correlates with the private and public biotechnology research investments into health applications. With increasing opportunities provided by Circular Bioeconomy, healthy ecosystems can be created, which directly improves the well-being of residents.

'Clean Water and Sanitation,' 'Climate Action,' 'Life Below Water,' and 'Life on Land' (SDGs 6, 13, 14, and 15, respectively) are promoted by the ecological dimensions of the bioeconomy. The industrial and agricultural applications of biotechnology reduce dependency on fossil-based materials and energy and

promote sustainable management of ecosystems. This is further enhanced by the approach of reusing, reducing, and recycling of the waste within the Circular Bioeconomy model.

'Affordable and Clean Energy,' 'Industry, Innovation and Infrastructure' and 'Responsible Consumption and Production,' 'Sustainable Cities and Communities' (SDGs 7, 9, 11 and 12 respectively) can be achieved by promoting bioeconomic production of goods and energy. The production of energy from bioproducts and waste are instances of biotechnology being used for sustainable use of global resources. There has been a definitive focus in this arena within India through the governmental focus on bio-fuels, and waste to energy generation.

Figure 3:
The Circular Bioeconomy and its relation to the Sustainable Development Goals

Along with addressing several socio-economic problems, the Circular Bioeconomy could also lead to the creation of a robust economic foothold and minimization of economic losses.

For instance, the efficient implementation of the Government of India's ethanol program could lead to not only energy self-reliance but also save foreign exchange up to Rs 26000 crore. Other additional economic benefits could emerge through the Circular Bioeconomy in the form of creation of jobs, increased opportunities for entrepreneurship, better innovation, creation of new, green value chains, as well as modernization and strengthening of the industrial base.

Nonetheless, to achieve a sustainable, circular bioeconomy – a top-down approach can no longer be followed. The challenges that are faced in transitioning towards a 'Green Economy' are of grand size and scale. As seen in various analytical reports[19], single production units face severe backlashes in their operation as they fail to meet the requisites needed to transition towards a Green Economy. Hence, clusters, as complex production agglomerations, become useful at this point by acting as an intermediary body to strengthen the capacities of the core stakeholders and create efficient platforms for collaboration and change[20].

[19]*UN Habitat. (2010). Clustering for Competitiveness: Urban Patterns for a Green Economy.*
[20]*Ketels, K. & Protsiv, S. (2017). Priority Sector Report: Circular Economy. Center for Strategy and Competitiveness Stockholm School of Economics*

Thus, in order to evaluate if India is ready to move towards a Sustainable, Circular Bioeconomy, the existing market structure and cluster strength would need to be assessed. This would require a thorough analysis of the Indian bioeconomy's market strength, the growth enablers, and the existing clusters within the system.

The Indian Bioeconomy: Moving towards a $150 bn Valuation

Global Overview: India's position in the Global Bioeconomy

Across the globe, policymakers and key stakeholders have realised the potential of actively promoting bioeconomy with the objective of creating sustainable development. As of 2015, more than 40 countries have created a national-level bioeconomy strategy by focusing on advancing biomedical, energy, nutrition and industrial technologies.

India is one of the earliest adopters of biotechnology and has continued to develop and advance this sector in sync with global priorities.

Nonetheless, due to the lack of a common set of goals and assessment methods, there does not exist a shared roadmap for the creation of an integrated bioeconomy. The bioeconomy strategies of different countries have varied according to their national priorities, core strengths and policy drivers. These differing aspects have allowed some countries/blocs such as the European Union, Japan and the United States to become bioscience leaders. This variation has occurred due to the capability of these nations to convert their policy

actions into the formulation of an environment which is conducive to innovation and development. In lieu of these factors, it becomes vital to assess India's policy landscape and facilitators to develop a strengthened domestic bioeconomy vis a vis its global peers.

Considering the growth potential of India's bioeconomy, India's position has been compared to other countries based on its key enablers, facilitators and performance. The Biotechnology Competitiveness Assessment framework[21] designed by BIRAC and the Institute for Competitiveness throws light on India's competitive advantage over other countries and the steps to be taken to catch up with the top performers.

Overall, India is yet to catch up to the advanced bio-economies, especially in the sections of key enablers and performance.

However, India has performed relatively well in the facilitators dimension and has been one of the best performers among emerging bio-economies. Interestingly, among all the indicators in facilitators, India has fared well in cluster development, performing better than China, Israel and South Korea. This becomes an essential element of India's future bioeconomy growth as the transition towards sustainable and innovative practices would be better handled by strong domestic cluster portfolios.

[21] *Institute for Competitiveness. (2019). Assessment of Indian Biotechnology Landscape: An International Perspective.and Competitiveness Stockholm School of Economics*

Nevertheless, a country's policy environment and growth drivers need to be simultaneously assessed with its output. In order to assess India's location relative to other countries, the biopharmaceuticals cluster exports have been taken as a primary indicator for comparison[22]. The rationale for analysing this sector is that biopharmaceuticals comprise the major chunk in production for most countries/ blocs, such as the European Union, USA, India etc. Hence, the understanding of a country's position with respect to its biopharmaceuticals cluster exports would adequately explain the nation's bioeconomy output as a whole.

The analysis of this indicator shows that India is ranked 11th of the top 53 countries used for the comparison. Although India could improve its overall share of biopharmaceutical exports as compared to the advanced bio-economies, it is one of the best performers amongst emerging bio-economies. India has performed much better than Singapore, Japan, Israel and South Korea, showing a high potential of the domestic clusters to advance Indian biopharmaceuticals sector. Moreover, India's CAGR of biopharmaceuticals cluster exports (2005-16) has been remarkably high, with India topping the list. This implies that the economic success of the cluster is not dependent on its starting point but are affected by the factors of cluster development.

[22]*Institute for Strategy and Competitiveness. (2016). International Cluster Competitiveness Profiles. Retrieved from https://www.isc.hbs.edu/competitiveness-economic-development/research-and-applications/Pages/iccp.aspx*

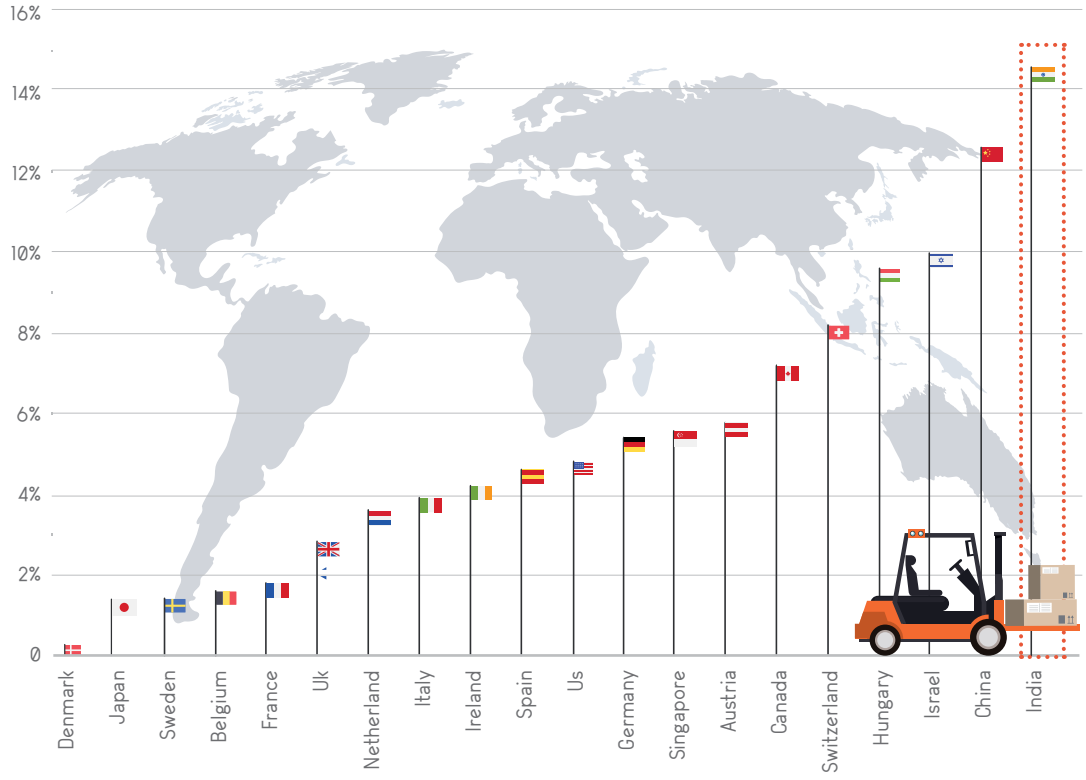


Figure 4: CAGR of biopharmaceuticals cluster exports by country (2005-16)

Similar to the analysis carried out for the biopharmaceutical sector, India needs to also analyse its global position with respect to the other sectors within bioeconomy. However, due to a lack of assessment tools, India has been unable to define the components and industries that constitute its overall bioeconomy. This report seeks to address this gap by defining bioeconomy clusters from the Indian perspective and highlighting the regional bioeconomy cluster strength.

Assessing the Domestic Bioeconomy Landscape

Performance and Growth Drivers

The Indian Bioeconomy has been growing steadily over the years, with it reaching $51 billion in 2018, showing a 14.68 percent growth from 2017. Considering the growth potential of this sector, it is expected that during the next five years, the Indian Bioeconomy is expected to grow to $150 Billion by 2025. Within this broader domain, the biomanufacturing sector dominates, accounting for 22.5 percent of the overall bioeconomy and 40 percent of the exports of the bio-based products[23].

India has emerged as a strong bio-manufacturing hub with major production in sub-sectors of biopharmaceuticals, bio-agriculture, bio-services and bio-industry.

In 2018-19, the Bio-Pharmaceuticals sector contributed to more than half of the value of the overall Indian biotechnology sector with diagnostics and medical devices contributing to 50 percent, vaccines accounting for 30 percent, and biotherapeutics covering the remaining 20 percent. Bio-Agriculture is the second largest contributor accounting for 21.57 percent, majorly being driven by the value generated from Bt Cotton, bio-pesticides, and fertilizers. Bio-Services was the third-largest contributor, valued at 15.73 percent of the entire biotechnology industry, promoted by the increasing number of contract research and development organizations carrying out contract discovery, development, and, in some cases, manufacturing as well. The Bio-industrial segment has also shown promise, reckoning for 7.8 percent share, driven by the production of enzymes and biofuels[24].

[23] BIRAC. (2019). India Bioeconomy Report 2019.
[24] BIRAC. (2019). India Bioeconomy Report 2019.

The strong position of the Indian bioeconomy and its manufacturing sector has been propelled by its inherent growth drivers, namely:

1. The affordable human capital that can be quickly capitalized on through extensive skilling

2. Growing population and rising demand for medical treatments which has increased the potential for biopharmaceuticals and bio-services

3. The multitude of biodiversity and traditional knowledge of the indigenous communities within India provides excellent scope for further research and the manufacture of biologics and allied bio-products.

4. Cost competitive manufacturing and abundance of the skilled workforce have enabled the Indian market to become a potential destination for clinical trial activity.

5. Policy drivers that have promoted the biotechnology industry by improving the ease of doing business, establishing biotechnology parks and incubators, and awarding fellowships to foster the research environment.

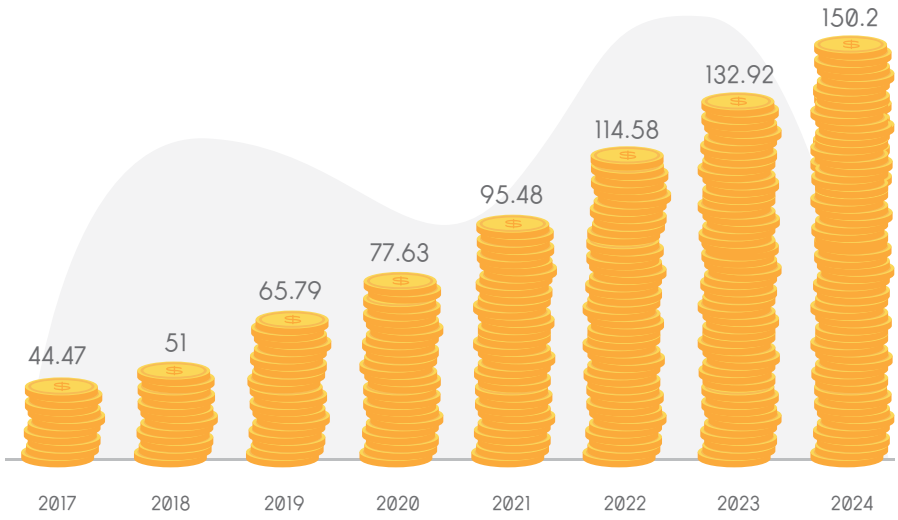
6. The government has also initiated several policies and missions such as the National Policy on Biofuels 2018, DNA Technology (Use and Application) Regulation Bill 2019, Genetic Enhancement on Pulses Mission, Biotech Start-Up Policy, and North Eastern Biotechnology Programme Management Cell to nurture nation-wide and region-wide strengthening of biotechnology activities[25].

The inherent strong position of this sector shows future promise in terms of employment, output, and further innovation. Considering these factors, the Indian bioeconomy has been targeted to reach $150 billion by 2024, with bio-manufacturing contributing to 66.67% of the projected growth[26].

[25] *BIRAC. (2019). India Bioeconomy Report 2019.*
[26] *Sharma, K.E. (2020, January 3). PM Modi aims for $100 billion bio-manufacturing hub; industry says target seems aggressive. Business Today. Retrieved from https://www.businesstoday.in/current/economy-politics/pm-modi-aims-usd-100-billion-bio-manufacturing-hub-industry-says-target-seems-aggressive/story/393106.html*

However, to reach these goals, the sector needs to grow at a CAGR of 17%. This would involve that the Indian bioeconomy needs to move beyond its cost-competitiveness factors and improve on creating high-value, specialized products that would give them an edge above other countries. Additionally, states would also need to orient their bioeconomy strategies with the national vision by driving the growth of their clusters through better incentive models.

Figure 5:
Projected market size of the Indian bioeconomy (2019-2024) in USD Billion



The projected market size of the Indian Bioeconomy has been carried out by analysing how the different sectoral components would be growing in the future. However, there is also a need to understand the various manners in which the Indian bioeconomy could change due to emerging technologies and new production processes. Additionally, global trends could also influence the Indian industry. For instance, currently, there is a lot of ongoing research on how biotechnology laboratory-scale operations could be effectively converted into economically viable, industrial size equivalents. Furthermore, there is additional scope of converging engineering with modern biotechnology such that more productive bioreactors can be designed. Additionally, advances in Big Data and Artificial Intelligence could be especially used with respect to genomics mapping, predictive diagnostic and better healthcare treatment services. This implies the increasingly important role of Bio-IT and Bio-Services for future development. Considering these possibilities and given the potential of the Indian market to capitalise on these new opportunities, there could be an exponential increase in the projected market size of the Indian bioeconomy.

Policy Drivers

India has been one of the pioneers in realizing the potential of bioeconomy, with the government using biotechnological solutions as early as1986[28], to bring change within several production processes. These changes have been reflected in India's Green Revolution, which brought about food security and enhanced farm yields. Such transformations have also been seen in the White Revolution, which made India a milk-surplus nation. Most recently, the Blue Revolution or Neel Kranti Mission is attempting to use biotechnology to improve marine production within India[29].

Indian policymakers understood the varied role of bioeconomy in the promotion of several growth-enabling sectors and hence, realized the need to strengthen the existing bio-based industry. They commenced by institutionalizing the policy process and facilitating enhanced research within this domain. This has been reflected in India's National Biotechnology Development Strategy (NBDS), 2014, which has sought to create a comprehensive bioeconomy strategy by "translating life sciences knowledge into socially relevant eco-friendly and competitive products."[30]

Within this broader framework, NBDS follows a five-pronged approach of:

1. Improving the necessary infrastructure allied with the industry,
2. Enhancing existing research opportunities,
3. Nurturing entrepreneurial support systems,
4. Building positive social acknowledgement for bio-based products &
5. Creating scope for alliances within the domain of biotechnology.

While the Indian bio-based industry has always had strong roots in the pharmaceuticals and personalized medicine sector, it has sought to diversify its portfolio. This was achieved by improving its capacity in sustainable agriculture for strengthening food and nutrition security, efficient management of bioresources and biodiversity, industrial biotechnology, nanobiotechnology, bioinformatics, computational and systems biology over the years.

It can be hence observed that the Indian bioeconomy has historically been structured along the lines of a "development first" strategy such that it could lead to an innovative and resource-efficient economy. Moreover,

by focusing on building capabilities in the use of biosimilars, genetically modified crops, and biofuels, it has sought to expand the positive benefits derived from the bioeconomy across all socio-economic strata.

The expansion of India's bioeconomy has not been just through the efforts of private companies; institutional hand-holding carried out by Department of Biotechnology (DBT) and Biotechnology Industry Research Assistance Council (BIRAC) was crucial to the augmentation of the infrastructural base and commercialization of strategic research into innovative, marketable solutions within the overall bio-based industry.

This strong institutional backing has propelled India's rise to the top 12 biotechnology destinations in the world[31].

Among the several efforts taken up, BIRAC has been single-handedly responsible for supporting 656 start-ups and entrepreneurs, raised funding of approximately Rs 1162 crores, facilitated the development of 133 new products and technologies, created 204 new Intellectual Properties and generated employment for 3300 people[32]. Alongside, the Department of Biotechnology has facilitated the development of 9 Biotechnology Parks and promoted 4 Biotech Science Clusters across various regions in India[33].

These governmental initiatives reflect that India has its targets set towards developing a strengthened bioeconomy. By promoting research, innovation, cluster development and skilling of its labour force, the government is keen on bringing about advancement within this sector.

[27]Lorenzo, V.D. (2018). How biotechnology is evolving in the Fourth Industrial Revolution. World Economic Forum. Retrieved from https://www.weforum.org/agenda/2018/05/biotechnology-evolve-fourth-industrial-revolution/
[28]Department of Biotechnology. Introduction http://dbtindia.gov.in/about-us/introduction
[29]Department of Animal Husbandry and Dairying. (2019). Blue Revolution. Retrieved from http://dadf.gov.in/fisheries-blue-revolution
[30]Department of Biotechnology. (2007). National Biotechnology Development Strategy: Key Elements.
[31]Invest India. Biotechnology Sector; https://www.investindia.gov.in/sector/biotechnology
[32]BIRAC. (2019). Innovation Profiles 2019 – Innovate for Excellence.
[33]Department of Biotechnology. (2019). Biotech Science Clusters. Retrieved from http://dbtindia.gov.in/schemes-programmes/research-facilities-resources-technology-platforms/biotech-science-clusters

Bio-Clusters and their Potential to enhance the Indian Bio-Manufacturing Sector

The Indian government has realised the potential of cluster formation and its impact on the entire bio-manufacturing sector. Taking forward, the Department of Biotechnology has facilitated the implementation of four bio-science tech clusters across Pune, NCR, Bangalore and West Bengal. Additionally, the government has also initiated work on several other knowledge translation and technology clusters which are envisioned to reinforce industry-academia linkages.

The idea of clusters stems from formulating a closely agglomerated, self-reinforcing community of corporations, universities and allied agencies. Across the world, clusters have become essential to advance manufacturing systems within the country, be it the IT agglomeration in Silicon Valley, California or the Biopharmaceutical Cluster in Maharashtra. This is because the proximity and regular interaction between units speed up the level of innovation and formation of new business opportunities. The effect of these factors leads to higher productivity growth by promoting the manufacturing sector to produce more innovative and high value-added goods and services.

Within the Indian bioeconomy and bio-manufacturing sector, clusters range from sectors such as biopharmaceuticals and chemicals to apparel and textiles. Nonetheless, knowledge regarding the variety of Indian bio-cluster categories and their potential impact has not yet been captured to their optimal level.

This report takes a step forward in that aspect by carrying out a bio-cluster strength mapping across the regions of India. It has identified the cluster categories that should be considered within the Indian bio-manufacturing sector by using a compilation of datasets gathered from the European Commission Bioeconomy project, National Industrial Classification codes and Annual Survey of Industries. Furthermore, the strengths of the region-wide bio-clusters and future opportunities for growth have been identified as part of this process. The primary finding from the analysis, (which

has been further elucidated in the upcoming sections), is that – in order to develop a robust bio-manufacturing system within India, it is necessary to move towards creating a healthy bio-cluster environment according to the core strengths of the states. Moreover, the cluster system should have deep linkages with key stakeholders such as suppliers, academic institutions, research hubs, regulatory bodies and other allied companies. This would allow the Indian bio-manufacturing system to develop new market and employment prospects as well as generate higher revenue and output.

The learnings from the cluster mapping exercise could be directly plugged into the existing Indian bio-manufacturing systems. This would allow states to allocate resources depending on their core strengths within the overall bio-manufacturing sector. It would also enable the Indian government to target incentives with respect to research and development, and skill development in order to holistically develop manufacturing hubs throughout the entire country.

Future Opportunities for Growth: Developing the Indian Bio-Manufacturing Hub

The Indian biomanufacturing sector can capitalize on the several opportunities that have emerged over the past decade by developing on its growth and policy drivers. The arenas of future growth are[34]:

Bio- Pharmaceuticals

Globally, the biopharmaceutical market has accounted for approximately $186 billion and is projected to reach $526 billion by 2025, registering a CAGR of around 13.8% from 2018 to 2025[35]. This opens up massive potential for the Indian biotechnology industry to take advantage of in the field of biologics products.

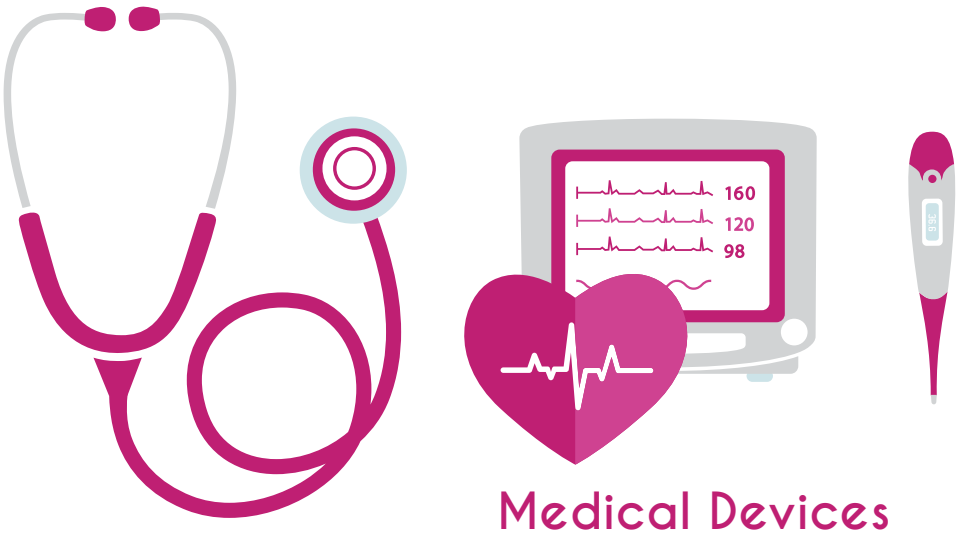
1.1. Bio-similars contribute a large chunk of the global prescription sales and are expected to form approximately 10% of the biologics market by 2020. Additionally, 12 biosimilar products are expected to lose patent exclusivity by 2020, providing more significant opportunities to Indian companies who have a certain level of preparedness in terms of having securing partnerships with big pharma and leading generic drug manufacturing companies. Furthermore, this opens up a higher arena of development and export of the biologics drugs to an approximate amount of $70 billion.

[34]BIRAC. (2016). Make in India for Bio-Tech: The Way Forward
[35]PR Newswire. (2018). Global Biopharmaceuticals Market Expected to Reach $526,008 Million, by 2025, CAGR 13.8% - Allied Market Research. https://www.prnewswire.com/news-releases/global-biopharmaceuticals-market-expected-to-reach-526-008-million-by-2025-cagr-13-8-allied-market-research-895632455.html

1.2. The Indian bio-pharmaceuticals market contributes to approximately 6% ($ 2 billion) of the global vaccine market and has the potential to become an $ 8-12 billion industry by 2025. With India already being the lead global supplier of DPT and measles vaccines, it has the resource base to diversify its vaccine portfolio to meet the rising domestic and global demand.

1.3. The insulin market is growing at a fast pace due to the rising burden of diabetes both at a national and global level. The global insulin market is expected to grow to $57 billion by 2025 from $25-30 billion in 2015, opening more abundant avenues for export. At the national level, India will house more than 100 million diabetics by 2030, with an additional 50% of cases remaining undiagnosed, showing enormous scope for innovation in manufacturing testing equipment, drugs, and medicine delivery systems.

1.4. Emerging fields within regenerative medicine such as tissue engineering, production of biomaterials/biomolecules, and stem cell therapy can be expanded upon in the coming years to provide the early mover advantage to the Indian bio-pharmaceuticals market.



Medical Devices

The medical devices industry, currently valued at 3.5 billion, was accorded the status of an independent industry in 2014 when it was included as one of the focus sectors in Make in India program[36]. The current market size of the medical devices industry is projected to grow to $50 billion by 2025, at a CAGR of 15.8%[37].

[36] *AdvaMed. (2017). Medical Device Industry in India: The Evolving Landscape, Opportunities and Challenges. Retrieved from https://www.advamed.org/sites/default/files/resource/medical_industry_in_india_-_the_evolving_landscape_oppurtunities_and_challenges_white_paper.pdf*

[37] *Invest India. (2020). Medical Devices. Retrieved from https://www.investindia.gov.in/sector/medical-devices*

2.1. The medical devices industry is responsible for the provisioning of crucial medical products that play a role in screening, diagnosing and treating patients. The industry is divided into seven sectors – consumables, patient aids, diagnostic imaging, dental products, ortho and prosthetics, IV diagnostics and others that include artificial dialysis apparatus & hemodialyzer, defibrillator, Lithotripsy equipment, ECHO, EEG, ECG, anaesthesia equipment, Laparoscope, and endoscope. Within the medical devices industry, global future trends highlight that there will be greater interest for Big Data, wearable devices, robotic surgeries and telemedicine.

Within the Indian medical devices industry, orthopaedic prosthetics and patient aids segment are the two fastest-growing segments, showing great potential for the future.

2.2. A characteristic feature of the Indian industry is its heavy reliance on imports, with approximately 90% of the sophisticated devices being imported into India. Figure 6 has illustrated the difference between medical devices imports and domestic production across its various sectors. In every sector except for consumables, more than 40 percent of the industry demand is catered through imports. The high import dependency shows the immense scope that the industry holds for domestic manufacturers. By addressing the challenges that the industry is facing currently, the growth potential of the industry can be realised. The main challenges faced by the industry include:

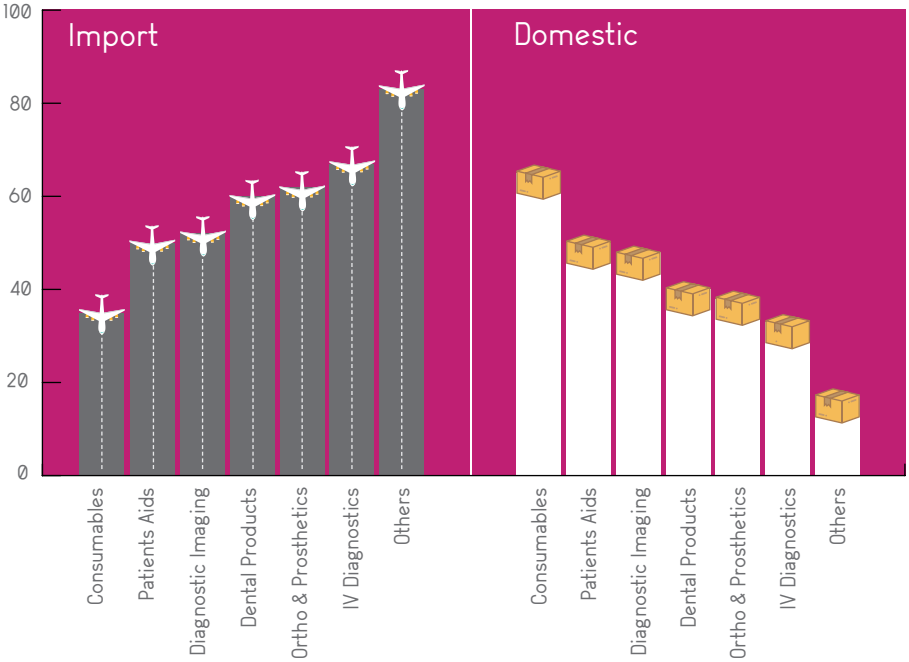


Figure 6: Medical Devices Imports and Domestic Production across sectors in India

2.2.1. Lack of skill base to support domestic manufacturing of medical devices.

2.2.2. Greater need for research and development to provide impetus to innovation within the domestic production of medical devices

2.2.3. Lack of regulatory framework for most of the medical devices - India regulates only 23 medical devices as opposed to the U.S. that regulates over 6000.

2.2.4. Nascent markets for exports - In India, Central Drugs Standard Control Organization (CDSCO) and Directorate General for Foreign Trade (DGFT) issues the Certificate of Free Sale (FSC) for Notified Medical devices for Non-Notified devices respectively. Many importing countries do not accept FSC issued by DGFT and exporters find it challenging to sell the products in those countries.

Bio-Agriculture

With rising issues regarding food security, the global market for bio-agriculture is expected to grow to $59 billion by 2025, with $ 43 billion being contributed by genomic-based products, a sharp increase from just $20 billion in 2015. In India, with the right growth enablers, the bio-agriculture market could reach approximately $37 billion by 2025 from $11.2 billion in 2018.

In the domestic sphere, the use of high-yielding seeds, bio-fortification techniques, pest management, and wastewater utilization could help address issues regarding the widening demand-supply gap in food grain production.

Furthermore, with rising disposable incomes and changing lifestyles, at a national and global scale, the sector could start increased production of nutrition-rich crops. The allied activities tied to the primary agricultural activities, including the manufacturing of biofuels, enzymes, processed foods and beverages, fertilizers, and other forms of secondary agriculture has further potential to increase farm incomes by 30-40% and create additional employment within this sector.

Bio-Services

The Indian Bio-services sector has shown a steady growth trajectory due to definitive improvements in clinical research, contract manufacturing, and contract research. Within this sector, Indian based industries could seek to leverage opportunities in:

3.1. Within the broader domain of Contract manufacturing, the global market is supposed to reach $8.8 billion, while the Indian market is expected to grow to $4 billion by 2025. Having an established pharmaceutical manufacturing base coupled with experience

in meeting quality standards for exportable pharmaceutical products, India can leverage the Eastwards shift in contract manufacturing.

3.2. The contract research market is expected to grow over $95 billion by 2025, with clinical services being the primary driver of growth in this domain. Having a diverse patient pool, skilled researchers, and medical infrastructure allow the Indian companies to utilize emerging opportunities through cost-competition.

Indian Biotech companies could also seek to leverage opportunities in bio-industrials, especially in the areas of biofuels, industrial enzymes, and bio-polymers. Other emerging include bio-informatics (Big Data Analytics, Genomics and Precision Medicine) which has become one of the fastest-growing fields within the Indian biotechnology sector, driven by skilled human resources, increased public and private sector investments as well as rising use of bioinformatics in drug development and clinical diagnostics.

Given these growth drivers and potential opportunities for growth, the Indian bioeconomy is not devoid of its inherent challenges. There is a need to identify the barriers to growth and take practical policy actions to address the same. This would involve driving the existing bioeconomy clusters across India through efficient government facilitation, industry collaboration, and innovative practices.

Regional Analysis of the Indian Bioeconomy: Strengthening Bioeconomy Clusters

Conceptualizing Clusters through the Competitiveness framework

The national strategy for the overall expansion of the Indian bioeconomy needs to be in sync with the regional growth of the biotechnology sector. In order to holistically analyze the strategies followed by the states, greater emphasis needs to be placed on the development of clusters. For better development of the bioeconomy within a region, industry or innovation clusters play a crucial role. Such clusters create a strong network of regionally integrated industries that support each other across the value chain.

This becomes especially important in the case of promoting bioeconomy due to the high capital-intensive and research-oriented nature of the industry.

By formulating clusters, the agglomeration of industries could benefit from the knowledge products derived from the close interaction between research organizations, allied start-up companies, and large, industrial companies. The positive externalities derived from cluster formation could also potentially attract many companies and generate higher employment, revenue, and output.

The concept of clusters has also been widely discussed in academic research, especially by Professor Michael E Porter's cluster theory wherein he defines clusters as "a geographic concentration of related companies, organizations, and institutions in a particular field that can be present in a region, state or nation."[38] Clusters are heavily embedded within the competitiveness framework by actively influencing the quality of the local business environment. By creating backward and forward linkages, clusters allow its members to benefit from the economies of scale without the individual units having to give up on their flexibility[39].

The following sections of the report will use the conceptual framework of Porter's cluster theory to define Indian Bioeconomy's cluster categories and analyze their strength.

[38]*Institute for Strategy and Competitiveness. (n.d.). What are clusters? Retrieved from https://www.isc.hbs.edu/competitiveness-economic-development/frameworks-and-key-concepts/Pages/clusters.aspx*

[39]*Porter, M.E. (1998). Clusters and the New Economics of Competition. Harvard Business Review. Retrieved from https://hbr.org/1998/11/clusters-and-the-new-economics-of-competition*

Clusters: Drivers of Competitiveness

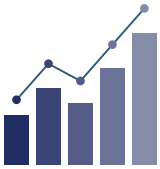
The theorisation of Clusters has been dealt by Prof. Michael. E. Porter who states that clusters have the potential to amplify a region's competitiveness. Clusters drive competition in a three-pronged manner – by increasing the productivity of companies in the location, by driving the innovative capacity of the industries and by incentivising the formation of new businesses.

Clusters and Productivity

- Greater access to employees and suppliers
- Access to specialised information
- Linkages to institutions and public good
- Healthy competition between the industries specialised information

Clusters and Innovation

- Faster access to new processes
- Availability of specialised professionals
- Easier identification of new business opportunities
- Peer-to-peer learning



Clusters and New Business Formation

- Positive externalities from economies of scale
- Greater information symmetry
- Lower cost of specialised inputs
- Established relationships with the market system

Promotion of Productivity

Industries that are a part of a well-functioning cluster have the potential to carry out their operations in a more productive manner by being able to efficiently source their inputs, information, and labour force. In terms of workforce, companies operating within a cluster model could recruit from the existing pool of employees, thereby lowering their transaction costs. The possibility of a variety of employment opportunities also attracts specialised labour force.

Additionally, the proximity between industries provides the potential to source inputs locally, thereby minimising import costs and improving support services. A strong cluster also can develop local supplier networks, thereby developing the allied industries and improving existing job opportunities.

Linkages among the cluster members also lead to extensive flow of market, technical and competitive information within the system. The agglomerated nature of the industries allows for targeted public and private investments providing the scope to all members to take advantage of the derived benefits. Such complementarities flow due to the cooperative and competitive forces among the cluster members, represented in the form of industry associations and/or institutes for collaboration.

Furthering Innovation

Along with enhancing productivity, clusters also promote the members' capacity to innovate by providing new opportunities in technological, operational and delivery domains. Due to its ties with suppliers and customers, companies within a cluster can operate at a much lower cost and have greater propensity to market their new products and services. These ongoing networks also provide cluster members to learn about new technology, services, marketing techniques, components and machinery. Through the learnings generated, cluster members could also collaborate on research and development to produce higher value-added products.

Developing New Businesses

The agglomeration of related industries in a location is also conducive to the creation of new businesses. The development of a core industry is always beneficial to the supplier industries as it lowers their risk and opens new market opportunities. The functioning of the existent clusters could also highlight gaps in products and services, providing new opportunities for business formation. Additionally, the barriers to entry are relatively lower because capital, skills, inputs and workforce are all readily available in the area. Moreover, social relationships with customers and financial institutions are strong, lowering the risk of the operation.

Defining Indian Bioeconomy Clusters: Methodology of Evaluation

The analysis of clusters has often faced impediments in the lack of a systematic methodology to create a cluster definition. Most of the academic literature on cluster formation dealt with case studies in specific sectors and regions but lacked a comprehensive, comparable methodology to compare the findings related to industry performance, job creation, and innovation. This constraint was overcome by the clustering algorithm created by Delgado, Porter, and Stern[40], which generates a group of closely related industries using cluster analysis.

Indian clusters have also been defined by the same methodology to capture the multiple forms of inter-industry linkages and identify various aspects such as innovative capability, employment, and wages[41]. The Indian Bioeconomy has faced similar problems with classification due to the diverse nature of industries present within the sector. As a result, the present academic literature does not have a comprehensive list of industries present within bioeconomy, contextualized to the Indian scenario.

This report has sought to identify regional industries that could be categorized within Indian bioeconomy and highlighted the cluster strengths across the different Indian states.

Scope of the Study

The study analyses the bioeconomy for Indian states during the period 2009-2014 using the data from the Annual Survey of Industries. It is the principal source of industrial statistics in India. It provides data on principal characteristics of factories such as capital, gross value added, employees, and benefits on an annual basis for the five-digit industry.

There are two main reasons for using the above-mentioned

period. First, the industry codes provided by National Industrial Classification, which are used by ASI to categorize industries were changed in 2008. The revision took place to adjust the national classifications in such a way that they can be presented according to the categories of the ISIC. This makes it difficult to draw comparisons with the data available for the period before 2009. Second, the report draws conceptual antecedents from "Clusters: The Drivers of Competitiveness" – a report by EAC-PM.[42] The report is the first attempt to provide state-wise clusters for India. It also develops a framework to analyze the strength of clusters. Since this report also uses the same framework and then compares overall cluster findings for India with the bioeconomy cluster findings, it is useful to keep the time frame similar. The bioeconomy cluster will be updated as soon as an update on EAC-PM is available.

Data and Methodology for Cluster Mapping

The dataset used to calculate the industries categorized within Indian bioeconomy has been derived from the European Commission's list of establishments related to Bioeconomy (according to International Standard Industrial Classification of All Economic Activities, Rev. 3)[43,44]. The ISIC Rev 3 data codes were mapped to NIC 2008 industry codes to contextualize for the Indian system[45]. The dataset used for identifying the cluster strength is the Annual Survey of Industries (ASI), which provides information regarding growth, employment, wages, composition, and structure of the organized manufacturing sector.

[40]Delgado, M., Porter, M.E., & Stern, S. (2016). Defining clusters of related industries. Journal of Economic Geography, 16(1), pp. 1-38. 10.3386/w20375
[41]The Institute for Competitiveness. (2018). Clusters: The Drivers of Competitiveness.
[42]The Institute for Competitiveness. (2018). Clusters: The Drivers of Competitiveness.

Coverage and Level of data collected

ASI extends to the entire country except for the States of Arunachal Pradesh, Mizoram and Union Territory of Lakshadweep. The data is collected at the factory level and clubbed according to the five levels of industry classification. In order to classify the industries related to Indian bioeconomy, the 2-digit numeric code or 'division' was used to club them into exclusive clusters. For further analysis, the 5-digit code or 'sub-class' was used for a period ranging from 2009-2014. This classification led to these following 22 clusters to be used for further analysis:

Table 2: Cluster classification to define the Indian bioeconomy

NIC Division Number	Clusters
Division 10	Manufacture of food products
Division 11	Manufacture of beverages
Division 12	Manufacture of tobacco products
Division 13	Manufacture of textiles
Division 14	Manufacture of wearing apparel
Division 15	Manufacture of leather and related products
Division 16	Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
Division 17	Manufacture of paper and paper products
Division 18	Printing and reproduction of recorded media
Division 19	Manufacture of Petroleum coke and refined petroleum products
Division 20	Manufacture of chemicals and chemical products
Division 21	Manufacture of pharmaceuticals, medicinal chemical and botanical products
Division 22	Manufacture of rubber and plastics products
Division 23	Manufacture of other non-metallic mineral products
Division 24	Manufacture of basic metals
Division 25	Manufacture of fabricated metal products, except machinery and equipment
Division 27	Manufacture of electrical equipment
Division 28	Manufacture of machinery and equipment n.e.c.
Division 29 & 30	Manufacture of motor vehicles, trailers and semi-trailers+ Manufacture of other transport equipment
Division 31	Manufacture of furniture
Division 32	Other manufacturing
Division 38	Waste collection, treatment and disposal activities; materials recovery

[43]*European Commission. (n.d.). Knowledge for policy – Bioeconomy. Retrieved from https://ec.europa.eu/knowledge4policy/search/site/_en?f%5B0%5D=sm_og_group_ref%3Anode%3A2&f%5B1%5D=bundle%3Adataset&f%5B2%5D=im_field_tags%3A1707*
[44]*UN Data. (2020). Value Added. Retrieved from http://data.un.org/Data.aspx?d=UNIDO&f=tableCode%3A20*
[45]*Ministry of Statistics and Programme Implementation. (2008). National Industrial Classification (All Economic Activities). Retrieved from http://mospi.nic.in/sites/default/files/main_menu/national_industrial_classification/nic_2008_17apr09.pdf*

Aggregation of the ASI data

The required data has been aggregated from the raw ASI data, state-wise and on a national basis to define clusters and their strength:

Table 3:
Definition of the data aggregated for defining clusters and cluster strength

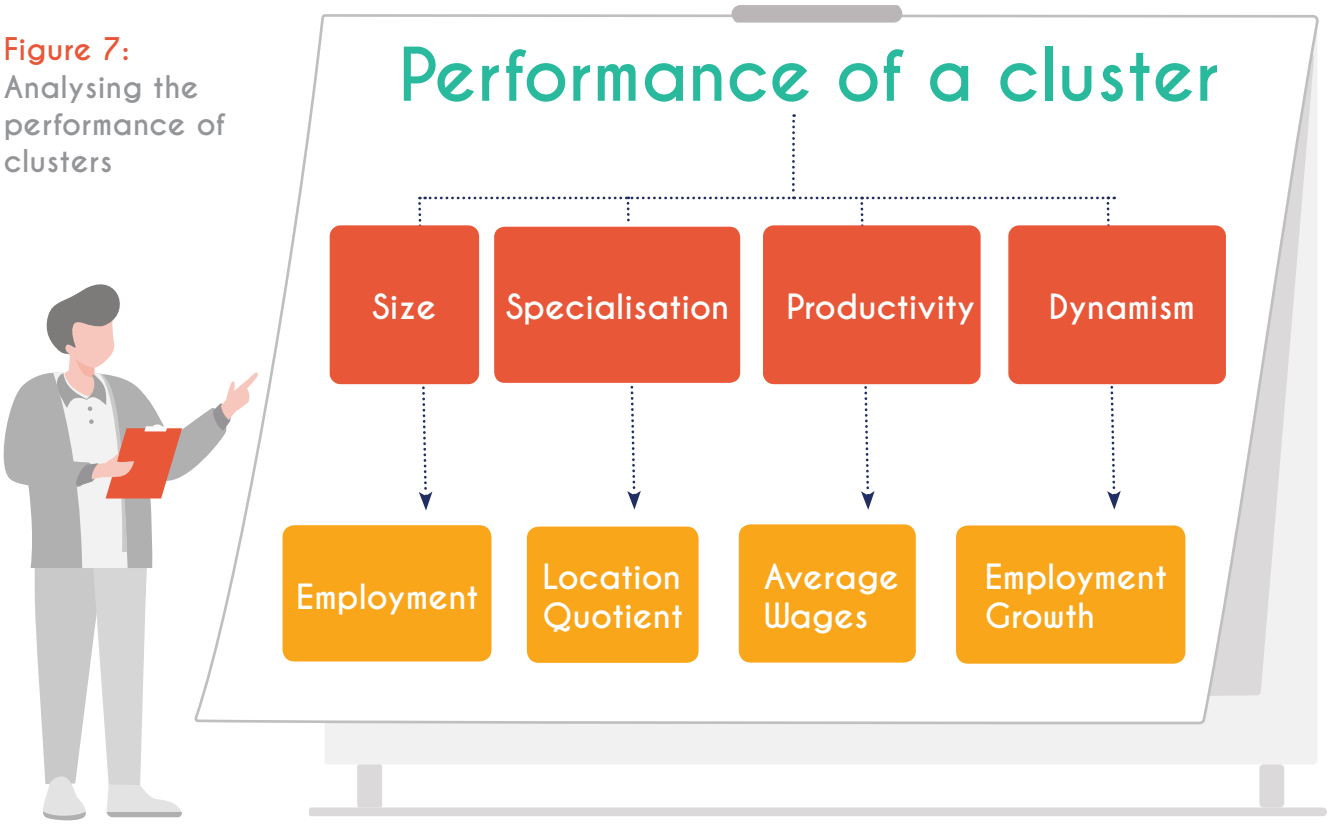
Variable	Definition
Number of units	The number of units that are functioning
Production workers	Male and female workers directly as well as through contractors
Skilled workers	Supervisory, managerial and other related employees
Total employees	The sum of production, skilled workers and unpaid family workers
Total employee wages	Wages of production workers, skilled workers, and unpaid family members

Cluster Mapping: Framework for Assessment

The following framework has been used to measure the overall performance of the cluster[46]:

[46] *The Institute for Competitiveness. (2018). Clusters: The Drivers of Competitiveness.*

Figure 7:
Analysing the performance of clusters



Size is measured by identifying the top 20 percent of the locations based on their total number of employees hired within the cluster category. This emphasizes that with increasing growth and linkages of the cluster category, the number of employees should also increase.

Specialization highlights the strength of the region in a cluster category with respect to other regions. This is calculated by identifying the top 20 percent of the locations based on their Location Quotient (a measure of a region's specialization).

Productivity identifies the top 20 percent of the locations, depending on the average wages of the total employees in the cluster category.

Dynamism captures the top 20 percent of the locations in terms of their employment growth within the given cluster grouping.

The Cluster Strength of a state is a compilation of the above four indicators calculated into a single score through the four-star methodology. The four-star methodology assigns a star for each of the four indicators to the regions that are in the top 27 percent. Since around 31 regions have been taken into consideration for the analysis, a star is assigned to the top 6 regions within each dimension. The strength of the region's cluster portfolio is then measured by summing up the performance across individual clusters.

Cluster Mapping of India's Bioeconomy: Findings and Analysis of the Results

Productivity of the clusters across regions

Analysis of average wages across regions

The analysis of the average wages within the Indian bioeconomy highlights a wide wage disparity amongst regions, with most of the workforce employed in the low-paying sectors. For the formulation of their respective bioeconomy strategies, states would need to make a trade-off between increasing average wages of the existing labour pool or increasing aggregate job opportunities. The decision would depend on the state's alignment with the national vision and its core cluster strengths.

Figure 8: Average wages by states, 2014

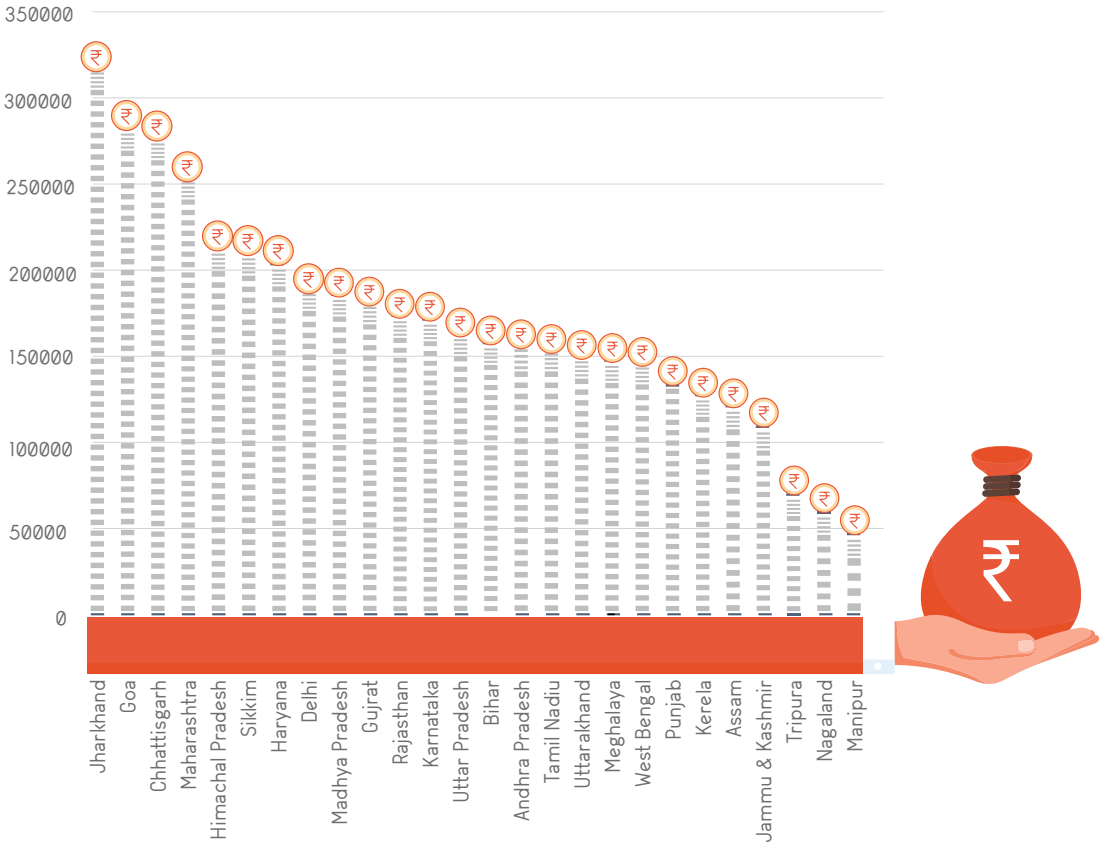


Figure 8 highlights the average wages of employees within the Indian bioeconomy sector across Indian states in 2014. As per the analysis, it is seen that the average wages of the highest-earning state are approximately five times that of the poorest state, showing a wide wage disparity amongst regions. While the national average wage of the Indian bioeconomy clusters in 2014 stood at around Rs.191174, around ten states have higher average wages than the national estimate.

Interestingly, Jharkhand has the highest average wage as compared to the other regions. This has been corroborated by the Labour Bureau, which states that in 2009-10, the highest salaries paid per working day to all the workers was highest in Jharkhand[47].

However, it is surprising to note that certain industrial states such as Andhra Pradesh and Tamil Nadu have average wages below the national estimation. Through an average wage and total employee analysis (Figures 9 and 10), it can be observed that although Andhra Pradesh and Tamil Nadu are known for their high-paying sectors (pharmaceuticals and automobiles, respectively), most of their workforce is employed in the low paying sectors.

[47] *Ministry of Labour and Employment. (2013). Report on Absenteeism, Labour Turnover, Employment and Labour Cost: Annual Survey of Industries (2009-10) – Volume II. Retrieved from http://labourbureaunew.gov.in/UserContent/ASI_2009_10_V2.pdf*

The implications from these findings need to be analyzed in sync with the objectives of promoting bioeconomy within the given states. In case the state prioritizes increased wages and standard of living for the existent work pool, it would need to focus on sectors with higher average wages. For instance, Andhra Pradesh would need to prioritize the sectors of basic metals, Petroleum coke, and refined petroleum products, motor vehicles and allied transport equipment, machinery and equipment, as well as pharmaceuticals. If the state were to increase the number of available job opportunities, it should focus on the high-employment domains, although it would generate lower average wages. For example, if Tamil Nadu targeted to expand the number of employed persons within the state, it should focus on improving the segments of textiles, motor vehicles, and allied transport equipment, apparel, food as well as machinery and equipment.

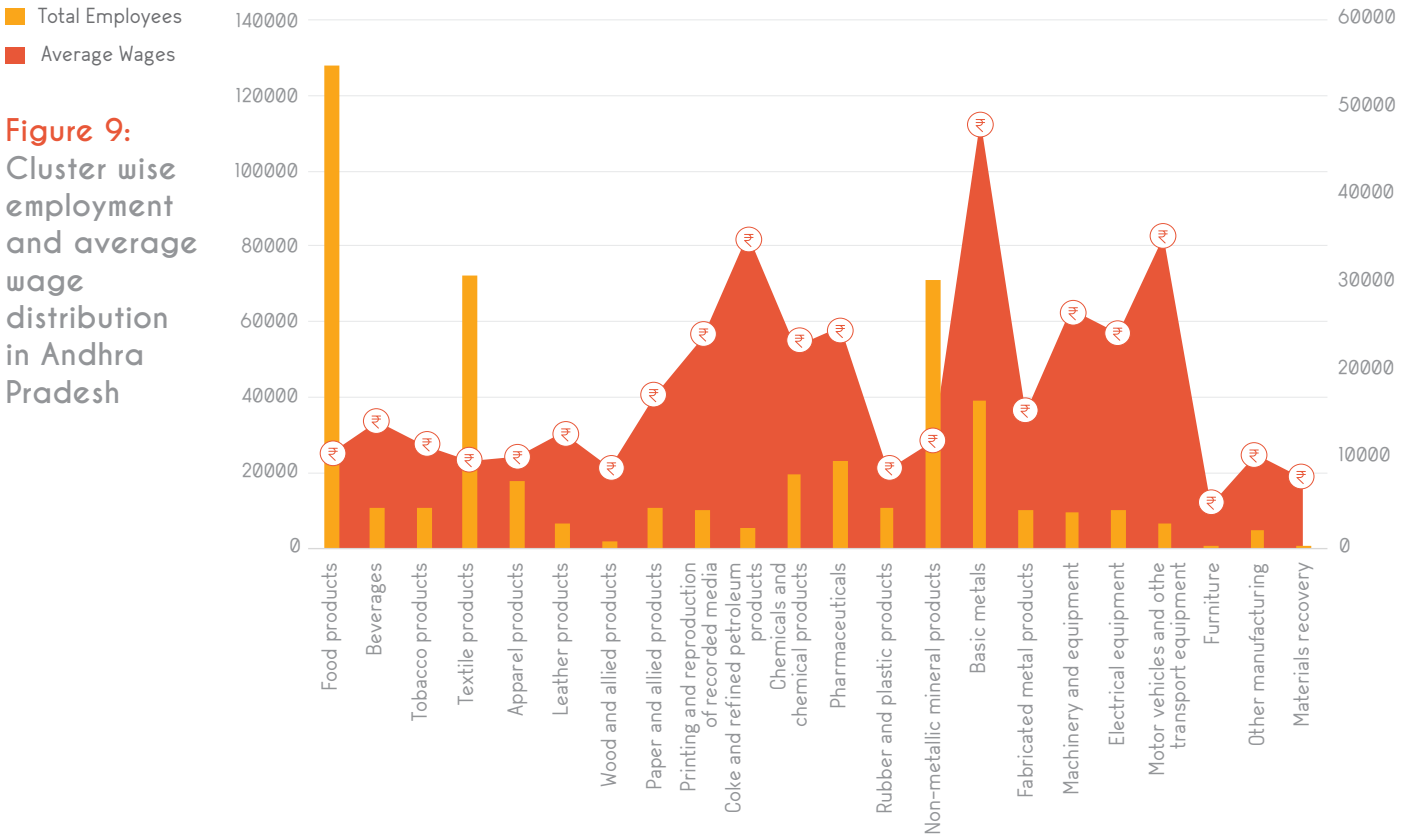


Figure 9: Cluster wise employment and average wage distribution in Andhra Pradesh

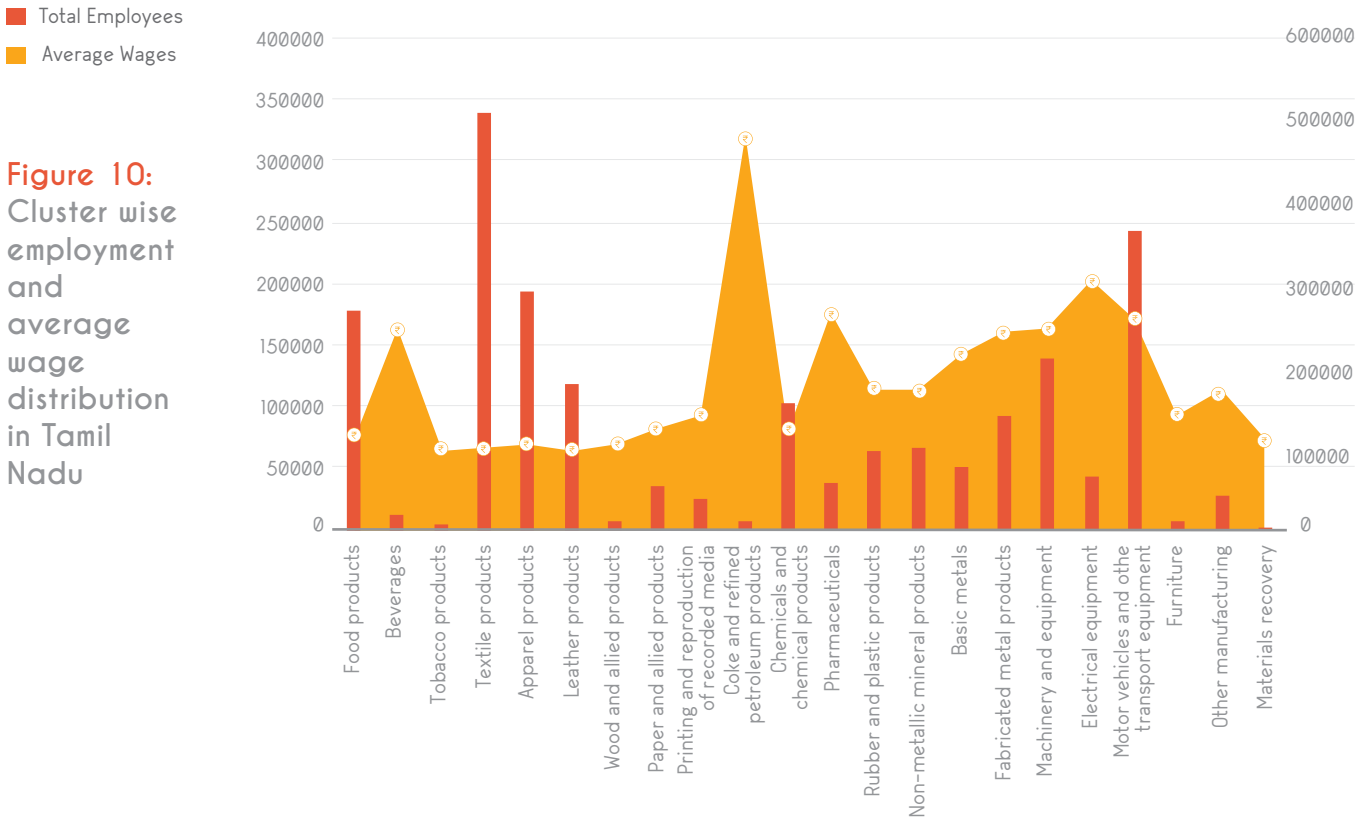
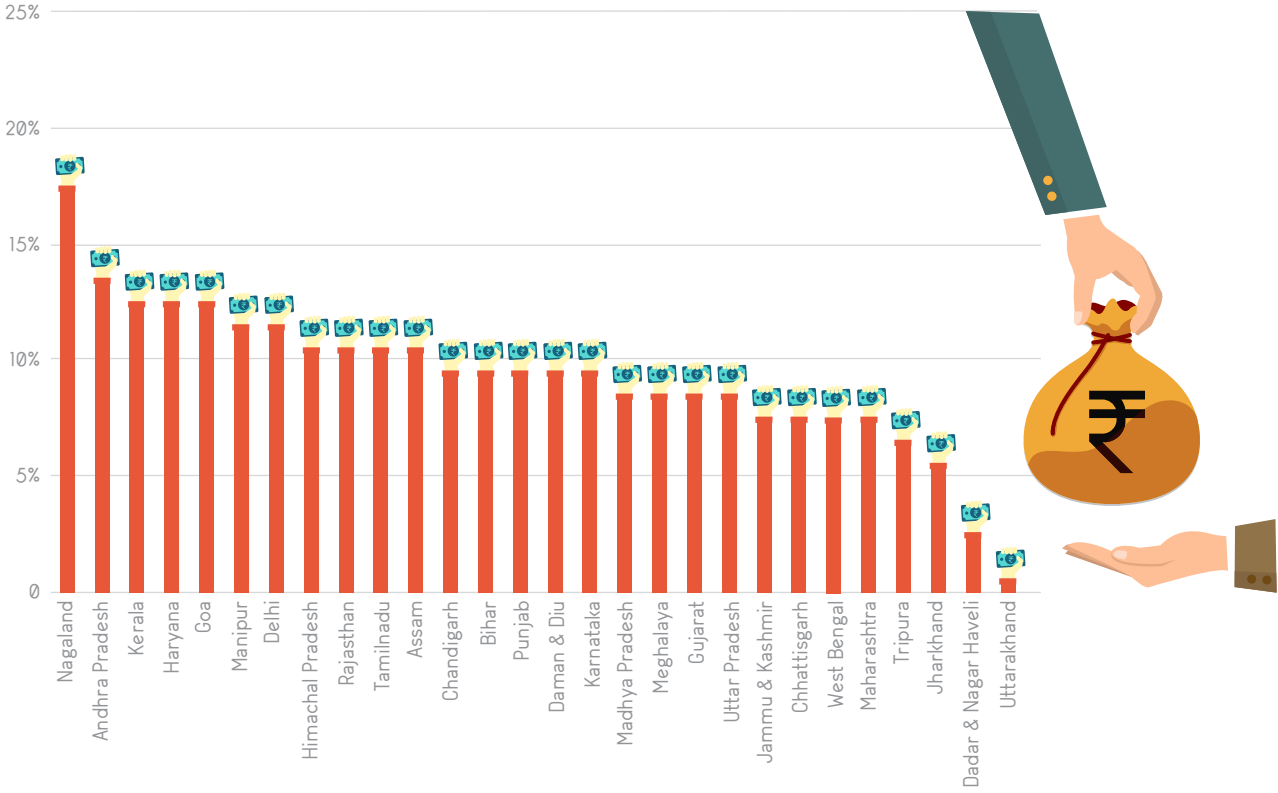


Figure 10: Cluster wise employment and average wage distribution in Tamil Nadu

Change in average wages across regions

Within Indian Bioeconomy, the productivity of the states is not entirely dependent on the existing wage structures for the concerned cluster categories. This is because, despite average wages being higher in legacy industrial states, smaller states have shown higher growth in average wages over the years. There has been a marked interest within smaller states to improve the productivity of their regional bioeconomy. This needs to be furthered with focused attention on their core cluster strengths and skilling of existing labour force.

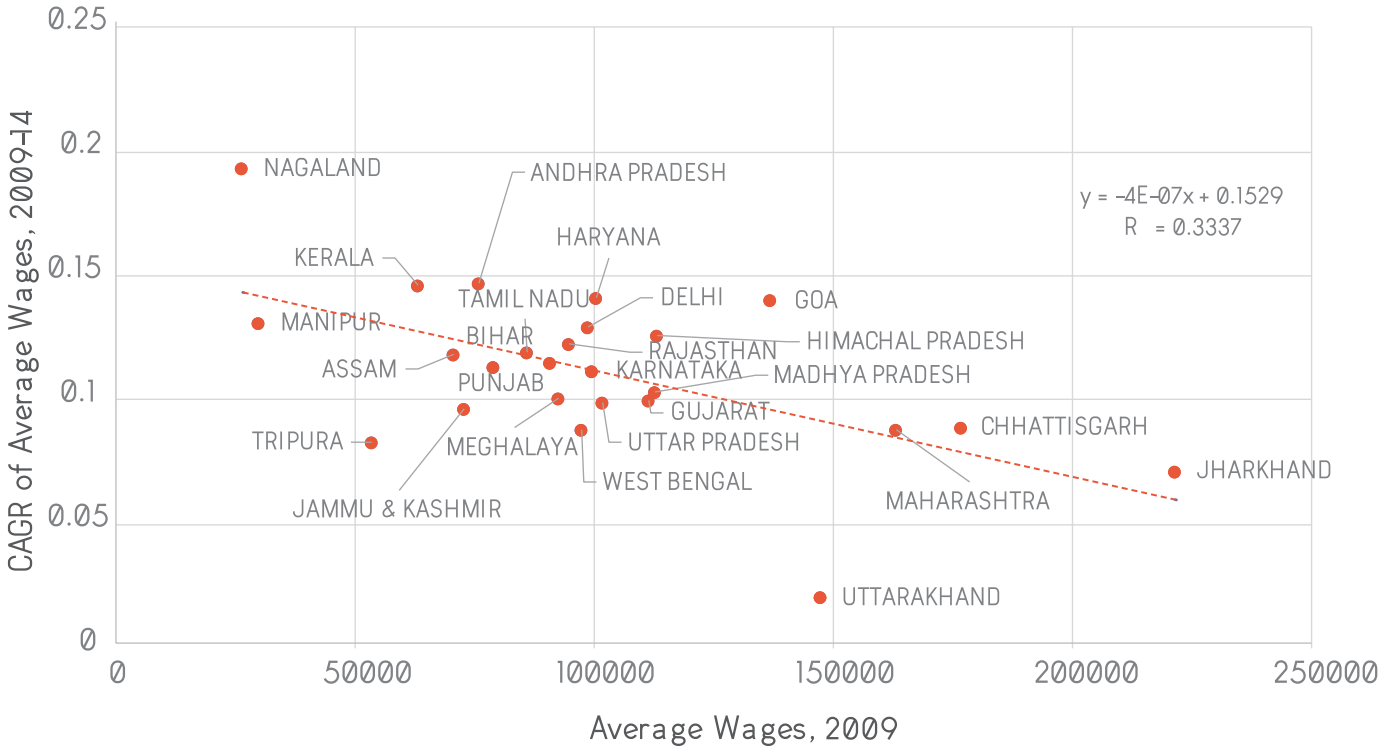
Figure 11: CAGR of average wages across regions, 2009-2014



The analysis of the CAGR of average wages from 2009 to 2014 (in Figure 11) across regions highlights an interesting trend of states with higher total average wages than the national average, showing relatively less growth in average wages over the years. With the national CAGR of average wages is approximately 10 percent for the same time period, the legacy industrial states such as Maharashtra, Madhya Pradesh, and Gujarat have shown less growth in average wages over the years. Notably, even Jharkhand has a CAGR of only 7 percent, revealing that its position as the highest wage payer has not occurred due to a recent spurt in growth. Remarkably, states with lower average wages have shown a higher growth in average wages over the years. This implies that though the states might have lower total wages, there are definitive signs of economic convergence between the different regions. This is especially important for smaller states, particularly those in North-East regions since they are showing a marked interest in developing the productivity of industries categorized within bioeconomy.

The relationship between average wages and their CAGR is further enhanced from the findings of Figure 12. The negative correlation reveals that states with lower average wages grew at a much faster rate than the states with higher average wages. This implies that within Indian bioeconomy, smaller states can still catch-up to the legacy industrial states by building on their core clusters and skilling the existing labour force to transition into higher value-added sectors.

Figure 12:
Relationship between average wages, 2009 and CAGR of average wages, 2009-14

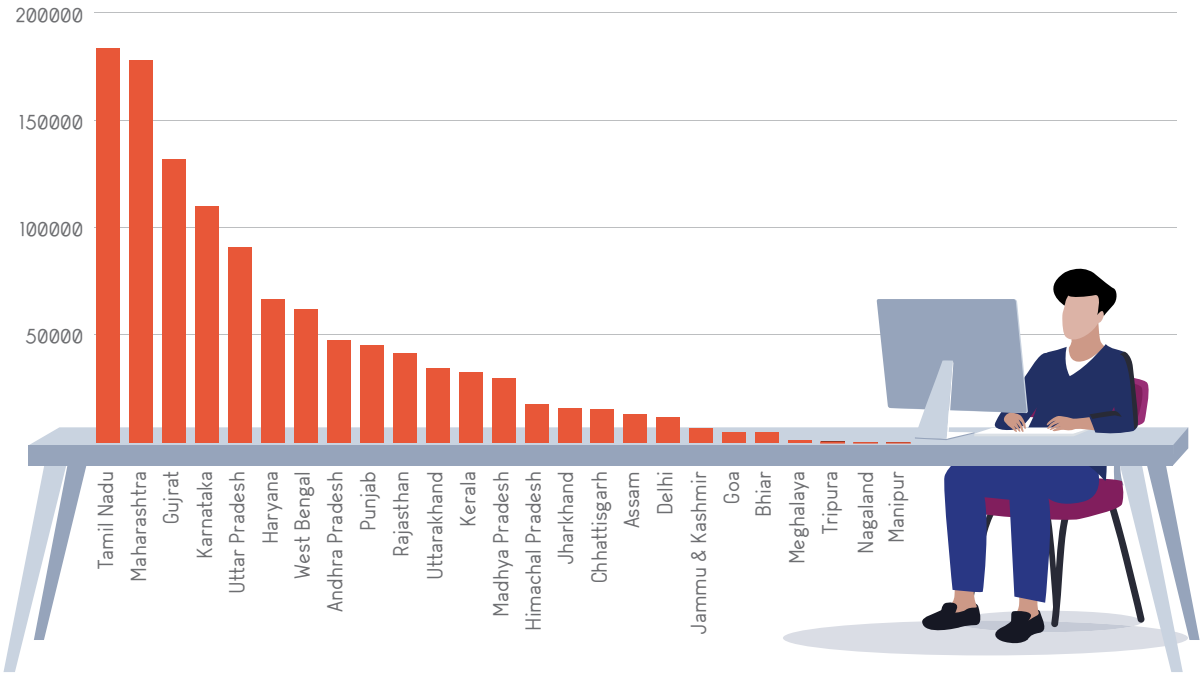


Size and Dynamism of the clusters across regions

The Indian Bioeconomy shows a higher trend of employment in legacy industrial states. However, states with lower number of aggregate employees than the national estimate

have performed better in the dynamism indicator. The increasing growth of employment in the smaller states is a positive indication of improving job opportunities within the states' bio-based industries. The state administration needs to facilitate the development of the cluster categories within the smaller states by enabling supplier industries to develop in tandem with the core clusters and reducing the entry costs for new businesses to develop in the region.

Figure 13: Total employees by states, 2014

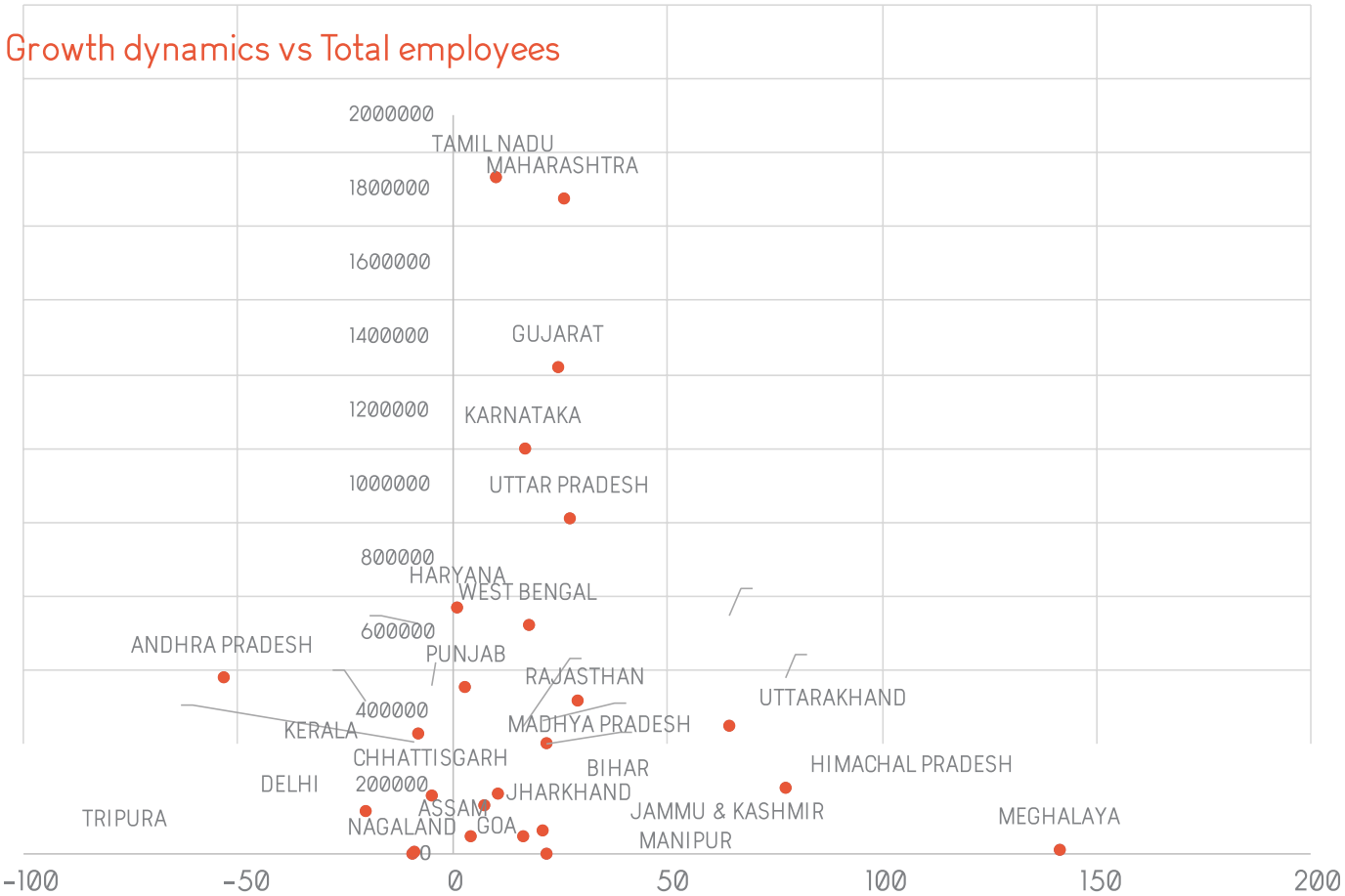


The distribution of total employees within Indian bioeconomy clusters across regions shows the maximum employment in legacy industrial states such as Tamil Nadu, Maharashtra, and Gujarat. This observation is in congruence with the well-developed clusters in these regions, for instance, the automobile and textile hub in Tamil Nadu. Thus, the Indian bioeconomy follows the market logic of conglomerating the highest employment in states where the clusters have historically been functioning well.

However, similar to the trends seen in the CAGR of average wages, the states with lesser aggregate employees than the national average (approximately 458966 employees) have performed way better in dynamism or growth of total employees over the years. As seen in Figure 14, Meghalaya, Uttarakhand, and Himachal Pradesh have performed the best in the

growth of total employees from 2009 to 2014. This implies that total employment cannot be viewed as a sole factor of the state's performance. The growth in employment of the smaller states is an encouraging sign of increasing opportunities within the states' bio-based industries. Special attention to these states, especially in the hilly regions, can prove beneficial to the expansion of the clusters. The initiatives carried out by the Department of Biotechnology through its North Eastern Region Biotechnology programs is an example of a successful initiative to train and attract high-skilled labour into these regions.

Figure 14:
Interlink between total employment, 2014 and growth dynamism, 2009-2014 across states



Location Quotient and Cluster Strength of the regions

The analysis of cluster strength highlights that Southern regions of India have fared much better in creating a stronger bioeconomy cluster profile than other regions. However, certain states like Uttarakhand, Haryana, Himachal Pradesh and Goa have shown potential for future expansion.
In order to develop a strong Indian bioeconomy, there is a need to transform the identified 3-star clusters into 4-star cluster categories. This would enable the states to enhance their cluster portfolio and improve the innovative capacity of their existing clusters.

1. Cluster Portfolio of the regions

The location quotient of each state presents the region's specialization by analyzing the concentration of the cluster category in the region as compared to the rest of the states. The presentation of the top 3 bioeconomy cluster categories of each State and Union Territory (in Table 4) shows the inherent strengths of the region and the industries by cluster categories.

Table 4 also provides information on the overall cluster strength of the various regions. It can be observed that the Southern regions have a much stronger bioeconomy cluster profile than other regions. However, apart from the traditionally well-performing states, Uttarakhand, Haryana, Himachal Pradesh, and Goa have more than 20 stars each, highlighting the great potential for future growth. Interestingly, Gujarat, Himachal Pradesh, and Tamil Nadu are the only states with four-star clusters in materials recovery, pharmaceuticals, and electrical equipment cluster categories, respectively. Moreover, with 35 3-star clusters across India, there has a huge potential to not only develop Indian bioeconomy's cluster portfolio but ensure the benefits arising from the same are distributed across all regions.

Table 4: Localisation Quotient and Cluster Profile of the States and Union Territories

States and Union Territories	Cluster strength	1-star cluster	2-star cluster	3-star cluster	4-star cluster	Top 3 clusters by Location Quotient
Andaman and Nicobar Islands	4	4	0	0	0	Manufacture of wood and products of wood Manufacture of beverages Manufacture of food products
Andhra Pradesh	12	5	2	1	0	Manufacture of non-metallic mineral products Manufacture of textile products Manufacture of food products
Assam	11	7	2	0	0	Manufacture of food products Manufacture of wood and products of wood Manufacture of beverages
Bihar	18	10	4	0	0	Manufacture of wood and products of wood Manufacture of beverages Manufacture of petroleum coke and refined petroleum products
Chandigarh	10	4	3	0	0	Printing and reproduction of recorded media Manufacture of electrical equipment Manufacture of beverages
Chhattisgarh	8	3	1	1	0	Manufacture of basic metals Manufacture of fabricated metal products Manufacture of non-metallic mineral products
Dadra and Nagar Haveli	13	5	1	2	0	Manufacture of chemicals and chemical products Manufacture of textile products Manufacture of rubber and plastic products
Daman and Diu	12	8	2	0	0	Other manufacturing products Manufacture of rubber and plastic products Manufacture of furniture
Delhi	18	5	5	1	0	Printing and reproduction of recorded media Manufacture of apparel products Manufacture of leather related products
Goa	21	8	5	1	0	Manufacture of pharmaceuticals Other manufacturing products Manufacturing of beverages
Gujarat	32	13	3	3	1	Materials recovery Manufacturing of textile products Other manufacturing products
Haryana	23	10	2	3	0	Manufacture of motor vehicles and other transport equipment Manufacture of apparel products Manufacture of electrical equipment
Himachal Pradesh	22	8	5	0	1	Manufacture of pharmaceuticals Manufacture of machinery and equipment Manufacture of paper and paper products

Jammu and Kashmir	8	6	1	0	0	Manufacture of chemicals and chemical products Other manufacturing products Manufacture of furniture
Jharkhand	15	5	2	2	0	Manufacture of petroleum coke and refined petroleum products Manufacture of motor vehicles and other transport equipment Manufacture of non-metallic mineral products
Karnataka	35	7	8	4	0	Manufacture of apparel products Manufacture of electrical equipment Manufacture of beverages
Kerala	18	10	4	0	0	Manufacture of wood and products of wood Manufacture of food products Manufacture of petroleum coke and refined petroleum products
Madhya Pradesh	14	9	1	1	0	Manufacture of textile products Manufacture of rubber and plastic products Manufacture of non-metallic mineral products
Maharashtra	47	5	9	8	0	Manufacture of electrical equipment Manufacture of furniture Other manufacturing products
Manipur	10	6	2	0	0	Manufacture of non-metallic mineral products Manufacture of furniture Manufacture of beverages
Meghalaya	10	4	3	0	0	Manufacture of non-metallic mineral products Manufacture of wood and products of wood Manufacture of beverages
Nagaland	5	5	0	0	0	Manufacture of wood and products of wood Printing and reproduction of recorded media Manufacture of furniture
Odisha	6	2	2	0	0	Manufacture of basic metals Manufacture of paper and paper products Manufacture of beverages
Puducherry	6	6	0	0	0	Manufacture of furniture Manufacture of rubber and plastic products Manufacture of chemicals and chemical products
Punjab	14	8	3	0	0	Manufacture of textile products Manufacture of electrical equipment Manufacture of beverages
Rajasthan	21	11	2	2	0	Manufacture of textile products Manufacture of non-metallic mineral products Manufacture of furniture

Sikkim	2	2	0	0	0	Manufacture of pharmaceuticals Manufacture of beverages Manufacture of chemicals and chemical products
Tamil Nadu	33	12	7	1	0	Manufacture of textile products Manufacture of leather related products Manufacture of electrical equipment
Tripura	11	7	2	0	0	Manufacture of furniture Manufacture of textile products Manufacture of food products
Uttar Pradesh	25	8	7	1	0	Manufacture of leather related products Manufacture of beverages Manufacture of apparel products
Uttarakhand	27	9	3	4	0	Manufacture of motor vehicles and other transport equipment Manufacture of pharmaceuticals Manufacture of paper and paper products
West Bengal	17	2	6	1	0	Manufacture of textile products Manufacture of leather related products Manufacture of wood and products of wood

2. Mapping regional cluster strength to the existing government initiatives

Figure 15 presents the visualisation of cluster strength across the various regions. Along with presenting the inherent strength of the regions, the governmental initiatives by the Department of Biotechnology have also been highlighted.

The National Biotechnology Development Strategy is focused on establishing a world-class bio-manufacturing hub by developing technology development and linkages through the formation of bio-clusters, incubators and technology transfer centres. In tandem with these objectives, the Department of Biotechnology has helped establish four Bio-clusters at Faridabad, Bangalore, Kalyani and Pune to advance research, innovation and entrepreneurial activities. The location of these four bio-science tech clusters is significant as it covers the four main regions of India. This would enable the distribution of benefits derived from bioeconomy across various regions.

The bio-science clusters are[48]:

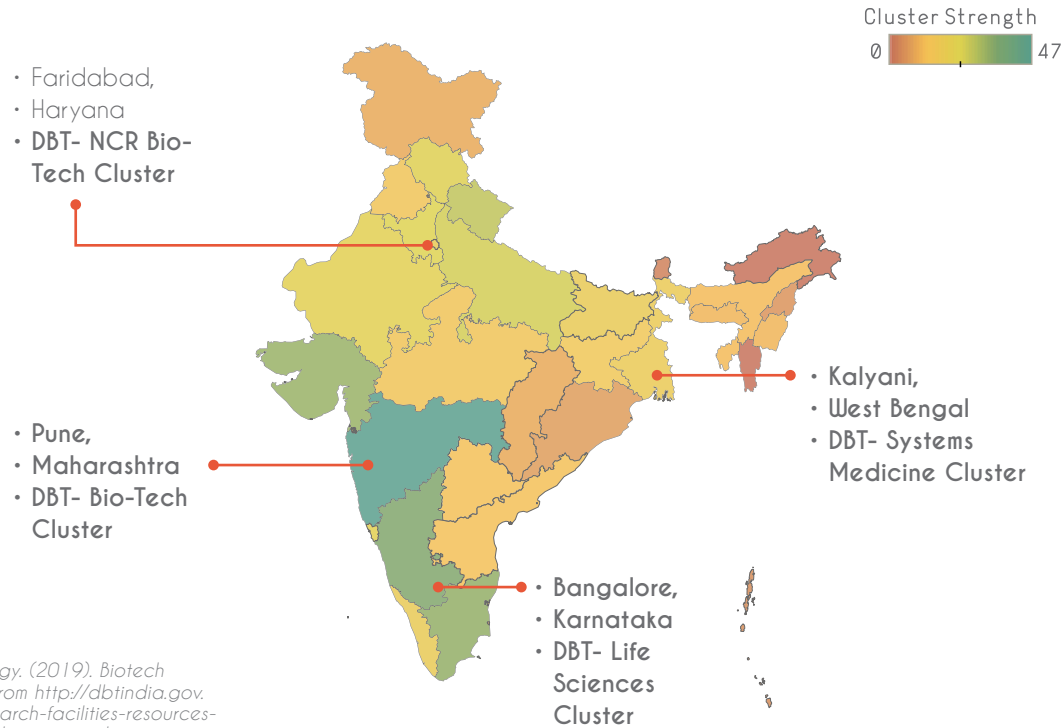
1. The Systems Medicine Cluster, Kalyani, West Bengal – This hub includes six major research institutions and seeks to act as a platform for doctors, basic scientists and biotechnologists to come together to develop clinical management in India.

2. NCR Biotech Science Cluster – This cluster has sought to foster biotech innovation by sharing knowledge products across its member institutions. Furthermore, the NCR-BSC provides support to national and regional research organisations to help develop technical, scientific and business-related frameworks.

3. Bangalore Life Sciences Cluster – This hub aims to create the required infrastructure and skill labour force to promote research and innovation across the domains of biotechnology and life sciences.

4. Pune Biotech Cluster – This project acts as a platform to develop new technologies for developing solutions to human disease. By connecting key stakeholders within public, academia and biotechnology companies, commercialisation of research to market solutions is prioritized.

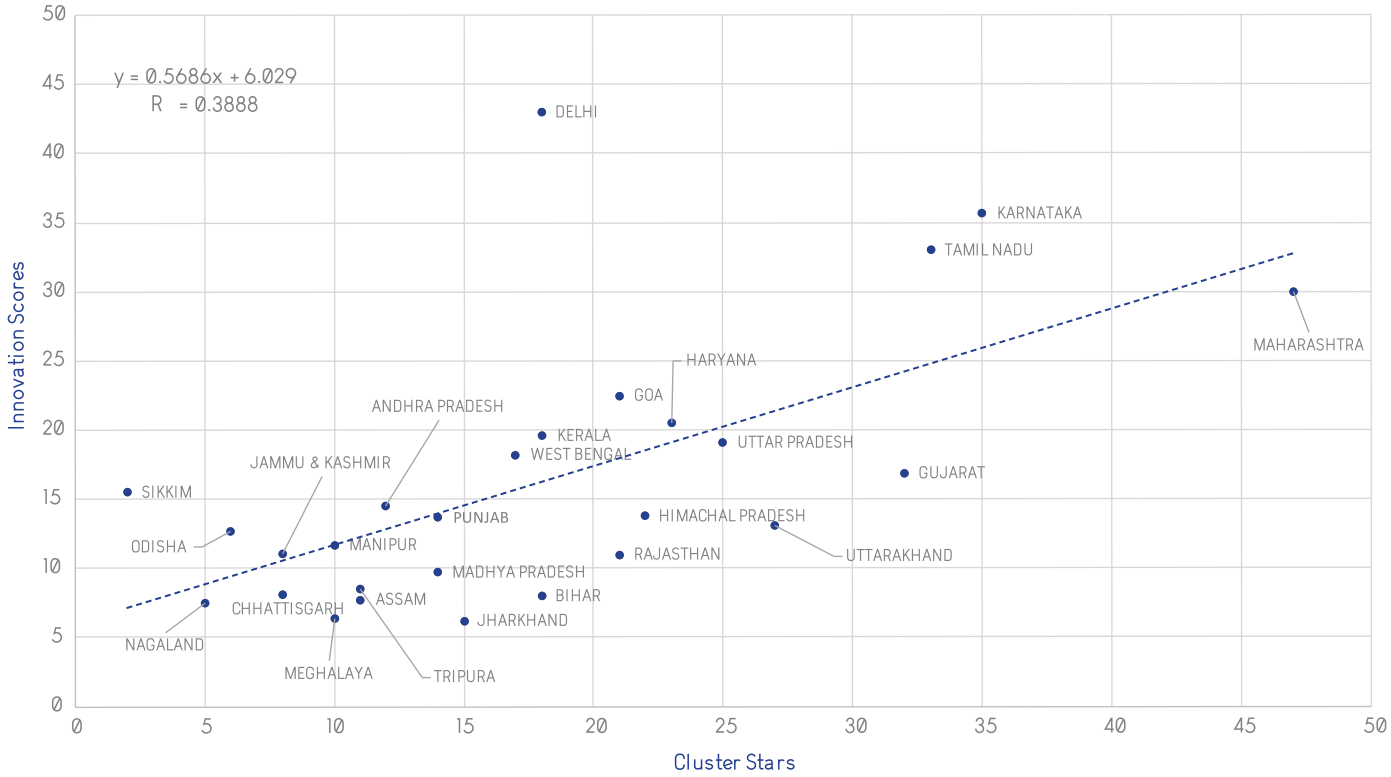
Figure 15: Cluster Strength of the regions



[48]*Department of Biotechnology. (2019). Biotech Science Clusters. Retrieved from http://dbtindia.gov.in/schemes-programmes/research-facilities-resources-technology-platforms/biotech-science-clusters*

3. Linkages between innovation and cluster strength: Identifying potential areas of cluster development

Figure 16:
Innovation and Cluster Strength across regions



The importance of having a strong cluster portfolio is directly linked with the conducive environment that it creates for innovation and knowledge creation.

This can be observed in Figure 16 as well, with states having more robust bioeconomy cluster profiles performing better in their innovation scores. Although no causal relationship can be drawn from the existing data on innovation and cluster strength, theories have shown that well-functioning clusters facilitate the process of learning and innovation. The proximity of industries and easy transfer of knowledge also aids in better research and development, creation of new products, and generation of market opportunities.

One of the ways to build a strong bioeconomy cluster

profile across India would be to enhance the innovative capacity, productivity, and size of the 3-star cluster categories identified across regions. The conversion of the identified clusters into 4-star clusters would not only enhance the states' bioeconomy cluster strength but also advance the innovative capacity of the specified industries.

Furthermore, the region-wide dispersal of 4-star clusters would ensure that the benefits arising from India's bioeconomy would not be concentrated in legacy industrial states. By advancing upon the core strengths of the regions, India's bioeconomy could be designed in such a fashion that states could start collaborating amongst themselves and sharing knowledge regarding cluster development.

Table 5 highlights the states and cluster categories that show high potential for future growth.

Table 5: 3-star cluster categories across regions

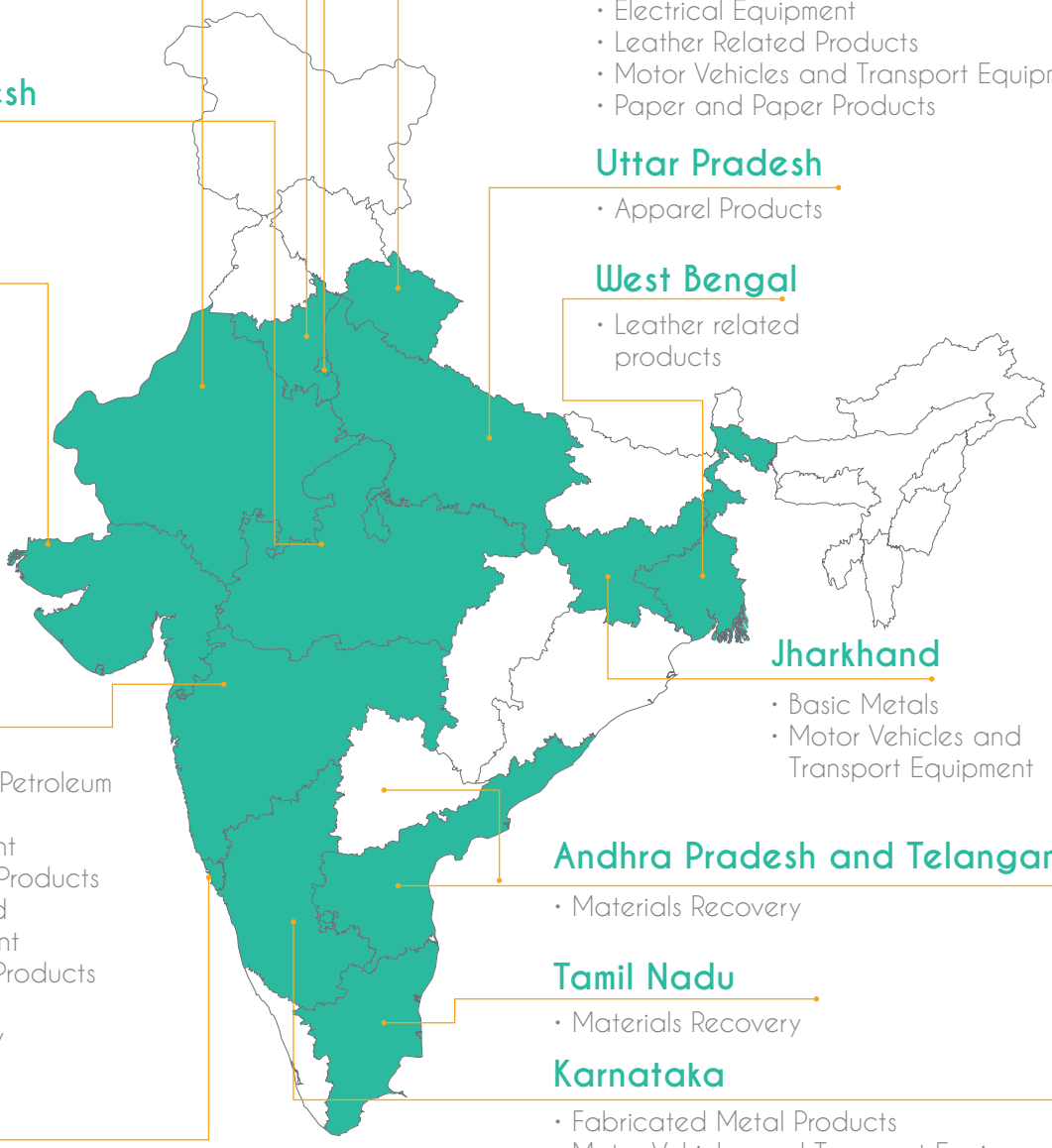
Future Areas of Growth across Regions	
State	**3-star cluster categories**
Andhra Pradesh	Materials Recovery
Dadra and Nagar Haveli	Manufacture of chemicals and chemical products Manufacturing of textile products
Delhi	Manufacture of apparel products
Goa	Other manufacturing products, such as medical and dental instruments, sports goods, sports goods, jewellery, etc.
Gujarat	Manufacture of chemicals and chemical products Manufacturing of textile products Other manufacturing products, such as medical and dental instruments, sports goods, sports goods, jewellery, etc.
Haryana	Manufacture of apparel products Manufacture of leather related products Manufacture of motor vehicles and other transport equipment
Jharkhand	Manufacture of basic metals
	Manufacture of motor vehicles and other transport equipment
Karnataka	Manufacture of fabricated metal products Manufacture of motor vehicles and other transport equipment Manufacture of rubber and plastic products Manufacture of tobacco
Madhya Pradesh	Materials Recovery

Maharashtra	Manufacture of apparel products Manufacture of petroleum coke and refined petroleum products Manufacture of electrical equipment Manufacture of fabricated metal products Manufacture of motor vehicles and other transport equipment Manufacture of paper and paper products Manufacture of pharmaceuticals Materials recovery
Rajasthan	Manufacture of non-metallic mineral products Manufacturing of textile products
Tamil Nadu	Materials recovery
Uttar Pradesh	Manufacture of apparel products
Uttarakhand	Manufacture of electrical equipment Manufacture of leather related products Manufacture of motor vehicles and other transport equipment Manufacture of paper and paper products
West Bengal	Manufacture of leather related products

Policy Recommendations

Future Areas of Growth to develop the Indian Bio-Manufacturing system

The creation of a holistic bioeconomy in India would need targeted action to promote bio-clusters across all the regions. Based on the above analysis, Figure 17 provides a visualisation of the possible industries which needs dedicated government support to transform them into well-strengthened clusters. While these industries have been highlighted on their current strengths, there is always potential for new technologies to emerge and help in the creation of new cluster portfolios. Other regions could effectively use new production processes, technologies and form shared networks between industry, academia and government to take advantage of the positive externalities of cluster development.



Delhi
- Apparel Products

Rajasthan
- Non-metallic Mineral Products
- Textile Products

Madhya Pradesh
- Materials Recovery

Gujarat
- Chemical and Chemical Products
- Textile Products
- Other manufacturing products like medical and dental products, sports goods, jewellery etc

Maharashtra
- Apparel Products
- Coke and Refined Petroleum Products
- Electrical Equipment
- Fabricated Metal Products
- Motor Vehicles and Transport Equipment
- Paper and Paper Products
- Pharmaceuticals
- Materials Recovery

Goa
- Other manufacturing products like medical and dental products, sports goods, jewellery etc

Haryana
- Apparel Products
- Leather Related Products
- Motor Vehicles and Transport Equipment

Uttarakhand
- Electrical Equipment
- Leather Related Products
- Motor Vehicles and Transport Equipment
- Paper and Paper Products

Uttar Pradesh
- Apparel Products

West Bengal
- Leather related products

Jharkhand
- Basic Metals
- Motor Vehicles and Transport Equipment

Andhra Pradesh and Telangana
- Materials Recovery

Tamil Nadu
- Materials Recovery

Karnataka
- Fabricated Metal Products
- Motor Vehicles and Transport Equipment
- Rubber and Plastic Products
- Tobacco

Figure 17:
Future Areas of Growth across regions

Along with this broad overview, the following sections have provided specific policy actions across the major themes of – Cluster Development, Data Management, Enhancement of Facilitators and Promotion of Sustainable, Circular Bioeconomy:

Specific Policy Actions to strengthen the Indian Bioeconomy

Strengthening Region-Wide Bioeconomy Clusters		
Broad Recommendations	**Challenges**	**Steps**
Development of state-level policies focused on advancing regional bio-economy clusters	Within India, only a few states such as Maharashtra, Assam, Sikkim, Odisha and Karnataka have formulated dedicated biotechnology policies. However, none of these states has defined bioeconomy within their state policies. The absence of a decentralised approach within the creation of bioeconomy visions would be problematic as it does not account for the specific cluster strengths and variations amongst states.	• State policymakers need to collaborate with industry bodies and allied key stakeholders to define which sectors should be focused upon within the state-level bioeconomy. Moreover, future targets and goals for the development of the states' biomanufacturing sector can also be identified through the same process. • The state administration should focus on identifying and further developing on its core growth drivers and clusters within the bioeconomy policy.
Development of state-level policies focused on advancing regional bio-economy clusters	With respect to cluster development, there exists a tendency amongst states and national governments to keep on creating new clusters. Moreover, it has been observed that clusters which do not add much value to the national productivity are often abandoned by the state administration.	• The government should focus on upgrading the established and emerging bio-clusters rather than creating further new clusters. • Policymakers would need to identify the core bio-clusters and remove the inefficiencies impeding their growth. • Based on the identification of the bio-clusters and its possible growth drivers, linkages need to be developed with other allied supplier industries, educational institutions and research hubs. • Bio- Clusters with low-value productivity could be developed further, in sync with the core clusters. Rather than abandoning them, these clusters could be converted into support/supplier industries. This would not only enhance cluster linkages but also increase job opportunities.
Development of state-level policies focused on advancing regional bio-economy clusters	Governments tend to focus on providing incentives to benefit individual firms and industries. This distorts the market and leads to inefficient allocation of resources. Moreover, providing subsidies and grants to individual units could also limit competition.	• The state government would need to identify the core bioeconomy strengths of every region through cluster mapping based on size, specialisation, growth dynamism and location quotient. • Government incentives need to focus on improving the overall environment of the bio-clusters, such that the total productivity of the clusters can be enhanced.

Enhancement of existing clusters to develop their innovative capacity, connectedness and competitive advantages.	I Across states, most of the employment is concentrated within clusters that use relatively lesser high-technological inputs. This hinders the innovative capacity of clusters.	• States would need to finalise an optimum level of trade-off between creating new job opportunities and increasing the wages of the existing labour force within the bio-manufacturing sector. This balance needs to be based on the state's core strengths and priorities for future development. • Based on the decision, the administration would need to identify the state bioeconomy's top-performing high-tech clusters for further development. • These bio-clusters would need to tie up with the allied research and development hubs, high-skilled workforce and requisite technology systems. For instance, the Telangana government has followed the same model of growth in its establishment of India's first Bio-Pharma Hub. This agglomeration has over 200 biopharma hubs with strong links to biopharma research and development activities, manufacturing facilities and incubator modules.
Developing inter-cluster linkages	Within Indian Bioeconomy clusters, there is a lack of information symmetry and inter-relationship between existing clusters and hubs within India.	• Indian bioeconomy clusters can move beyond the development of knowledge products from within the cluster ecosystem to amongst clusters distributed across various regions. • The inter-cluster linkages can be created by forming regional networks of similar industries such that knowledge and skill can be easily distributed. For instance, Europe's Bioeconomy Intercluster, "3BI" has been developed with the joint action of leading bioeconomy clusters in France, Germany, Netherlands and UK. This partnership builds on the complementary strengths of these clusters to create new opportunities and strengthen innovation.
Formulating Cluster Mapping visualisations for the Indian Bioeconomy clusters.	The Indian Bioeconomy faces a dearth of publicly accessible data with respect to its existing clusters. Moreover, there does not exist any updated information regarding the cluster strength due to a lack of commonly accepted assessment tools.	• States should seek to develop region-specific Bioeconomy cluster mapping tool that would provide data regarding the cluster presence, economic performance, business environment quality and linkages with allied industries/ clusters. • The cluster mapping should be updated on an annual basis for all the regions. This would help highlight the changes in the states' bioeconomy clusters and help track their performance. • A national-level portal can be established to provide real-time data regarding the bioeconomy clusters, outputs generated and progress over the years. This would instil a competitive spirit among states and help identify the "Champions of Change within Indian Bioeconomy".

Enabling Data Management across the Indian Bioeconomy		
Broad Recommendations	**Challenges**	**Steps**
Market Database and Availability of Data	The rapid progress of the Indian bioeconomy does not seem to be halting any time soon and therefore must be registered for the convenience of policymakers and industry analysts. New firms are entering this expanding industry and it is crucial to identify them and document their contributions to the industry.	• Data management of the Indian bioeconomy would be enhanced by developing a user-friendly, public domain portal. This portal should provide at least a quarterly update of the overall Indian bioeconomy's market size and incremental growth. • For instance, Indian agriculture has taken the lead in such regards with the real-time recording of data which includes all agricultural inputs, benefit transfers and e-market platforms. Thus, based on similar lines, bioeconomy could also introduce a public-friendly domain where all the relevant data is available, which is also a highlight of data-driven policymaking.
Combining Subnational Data with Exports	Lack of bioeconomy-based export data affects in identifying the strategic trading partners and the change in the rate of exports from various bio-segments.	• India has fared well in biopharma exports and with its growing influence in global bio-agriculture and bio-services; it is pertinent that better documentation and presentation of data must capture the true reach of exports. Similar data has been made available for biopharma for the year 2016 by the Institute for Strategy and Competitiveness. • India, with its export tracking, could identify potential trading partners, quantify logistical costs and can also conduct comparative analysis amongst bioeconomy segments in terms of final exported values. Gaps could also be identified with respect to the untapped markets, required standards and emerging products. • With the further enhancement of the biotechnology allied data tools, Artificial Intelligence, Machine Learning (AI & ML) could be used to develop the predictive modelling such that market prospects could also take into consideration external shocks, risks and other emerging opportunities.

Enhancement of Facilitating Factors within Indian Bioeconomy		
Broad Recommendations	**Challenges**	**Steps**
Investment in R&D	In India, the public-funding is the major investing source and thus, more private participation is required to improve the quality and quantity of research in the field of life sciences.	• Joint efforts by all the three sectors government, industry and academia – would ensure overall growth of the bioeconomy industry. • The capacity of existing biotechnology research institutes needs to be evaluated, such that they can be upgraded to meet optimal levels. • Through inter-ministerial collaboration, the universities could also be brought in and given the agency to conduct relevant research in the field of bioeconomy. This could be done by ensuring flexibility of transition between academia and industry bodies. Furthermore, specific research incentives should be tied to the commercialisation of the knowledge outputs. • Long term biotechnology research consortiums between the industry and academic bodies could also be developed to enhance partnerships and showcase the knowledge outputs and their applicability.
Technology Transfers	Available literature suggests that Industry-Academia ties are weak and strong policy measures are required to introduce smooth lines to transfer both knowledge and technology.	• Technology transfers within biotechnology need be strengthened through strong industry-academia partnerships. One of the ways to do that would be to formulate legislation that would allow smooth transfer of knowledge from universities to industries without compromising the ownership of the intellectual property. • For instance, the case of the Bayh-Dole Act in the US is an example of the same. This allowed knowledge creation to be boosted by increasing the pace of the transfer of technology from universities to industries.
Conducive Business Environment and Regulatory Compliances	India has made significant progress in improving its business environment. This is evident from its constantly improving performance in the Ease of doing business rankings. However, some domains still deter foreign investment from entering the domestic market, which in turn hurts the production process and rate of knowledge creation.	• According to the International Property Rights Index 2019, India fares poorly in indicators such as 'Registering Property', which could hurt potential investment ideas. Also, India imposes some of the highest tariffs which deter trading partnerships. In such cases, it is crucial that inter-ministerial coordination can help in eliminating these existing trade barriers. • With the introduction of NBDS-2015 and National IPR policy, India is heading in the right direction, but more trade-friendly strategic policies are needed to ensure that the Indian Bioeconomy becomes an ultimate investment destination. • Additionally, due to the large number of ministries involved in sanctioning regulatory approvals, especially with relation to biotechnology companies, the transaction costs are much higher in India. This could be cut down by streamlining the regulatory approval through the creation of a single-window clearance system. • Furthermore, the government needs to promote the Rule of Contract and credibility within the biotechnology industry bodies. This would provide industry and research organisations security to innovate on new products.

Clinical trials and Endemic Diseases	India has been able to increase its rate of clinical trials, thanks to outsourcing. However, the issue with outsourcing and clinical trials is that it neglects the diseases that affect the life of the local population and instead benefits the population of the country that outsources the service.	• Dedicated investment in building state-of-the-art infrastructural facilities must be the primary objective to improve the clinical trial rates in India. • India has previously neglected trials for tropical diseases in favour of outsourced clinical trials. Thus, more clinical trials must be promoted that could target endemic diseases such as malaria, dengue, leishmaniasis etc.
Monitoring and Evaluation of Research Output	India's scientific research output delivers polarizing figures. While engineering-based research papers are some of the most widely published and cited ones in the world; Indian biotech and life-sciences based papers do not enjoy the same popularity. This is also evident from the quality of biotech papers published by India, which remains one of the least cited academic papers.	• Strong and stringent monitoring and evaluation framework is required to assess the quality of the bioeconomy-based research output. Life-sciences tend to the biggest contributing discipline to publish research work in predatory journals which are a serious concern. • DBT has already introduced IR@DBT, which is a repository of Government approved scientific papers. But, additional steps must be taken to review the research output. Encouraging a ministry-backed peer-review system along with the elimination of predatory journals could be one of the few first steps to maintain the integrity of the research quality.

Developing Sustainable, Circular Bioeconomy within India

Broad Recommendations	Challenges	Steps
Incorporating circular economy elements within the existing bioeconomy clusters	The Indian Bioeconomy is yet to develop a holistic definition for incorporating circular economy elements within itself. Furthermore, there is a lack of knowledge as to how Indian bioeconomy clusters could transition towards a circular, sustainable model	• Policymakers should extend the circular economic strategies to Indian bioeconomy. This would include components of following the 3R's (reuse, remanufacture and recycling) within production processes, cascading use of biomass, utilisation of organic waste streams, organic and nutrient recycling as well as the development of resource-efficient value chains. • State authorities would also need to identify the region-specific 4-star clusters within their regions and/or industry categories that have direct links with the circular economy. These clusters could then be provided public and private incentives to transform them into Circular, Sustainable Bio-clusters.
Creation of better awareness regarding Circular Bioeconomy models across key stakeholders	The concept of the circular economy has yet to gain prominence within the Indian policy scenario. Due to the lack of assessment tools and knowledge systems, there exists a lack of awareness amongst key participants.	• To drive adoption at scale, the benefits of the bioeconomy circular economy need to be conveyed to consumers. This would ensure that the overall consumer behaviour shifts towards more sustainable products. For instance, the use of biofuels, plant-based meat substitute food needs to be highlighted to the existing consumer base. • Knowledge sharing sessions and workshops also need to be carried out to generate awareness regarding Circular Bioeconomy amongst entrepreneurs, owners of medium and large industries as well as government officials.

Developing an enabling policy landscape for the promotion of circular bioeconomy within India.	The Government of India has shown definitive interest in developing a Circular Economy model for India. However, the Indian government is yet to formulate a targeted Circular Bioeconomy Vision. There is also a lack of standards to identify circular bio-based products such that there is the effective implementation of circular business models in India.	• A thorough analysis of the risks and opportunities of the Indian Circular Bioeconomy model needs to be carried out by carrying out baseline assessments of allied sectors. • Short, medium and long-term plans need to be developed based on prioritizing certain materials and sectors, as per the core competitive advantages of the various regions. • Further analysis needs to be developed to identify standards or criteria to identify circular bioeconomy goods and services. For instance, the UK government has created the world's first circular economy standards – "BS 8001:2017 – Framework for implementing the principles of the circular economy in organisations."
Establishing Collaboration and Partnerships	The concepts pertaining to bioeconomy and green circular economy are still loosely connected.	• More synergy is required to formulate precise circular bioeconomy policies that could benefit all the stakeholders. • At the industrial level, biotechnology companies could combine with upstream suppliers and downstream consumers to introduce new products into the market that plug leakages in the material flow.
Monitoring and Evaluation Framework	Monitoring a circular economy is an arduous task as it involves a chain of sectors and systems.	• A list of carefully planned and designed indicators must be released to monitor the progress of output creation from the circular bioeconomy. • Research output specializing in the evaluation of circular bioeconomy must be rolled out to guide the policymakers.
Capacity Building	Limited capacity building is a hindrance which prevents the circular bioeconomy from reaching its full potential.	• DBT and BIRAC could assist the relevant stakeholders by providing training and advisory support. • Specially tailored capacity building programmes could be initiated for the entrepreneurs and businessmen to enhance their knowledge regarding the use and potential of circular bioeconomy. This would develop the growth of small and medium scale enterprises within the circular bioeconomy.
Innovation Platform	Green circular economies have the potential to drive the rate of innovation and thus generate new products into the market to achieve sustainable production. However, there is a need to introduce a platform where innovation could be showcased.	• Since circular bioeconomy is an emerging field within India, there is a need to highlight the outputs generated to the public and interested investors. • Following the similar route of the Aspirational Districts programme by NITI Aayog, a platform must be established to record best practices arising from the circular economy • This innovation platform could also become a site for venture capitalists and angel investors to come together to fund the sustainable solutions emerging out of the circular bioeconomy model of operation.
Green Capital Funding	Special financing modelling is required to correctly quantify the benefits of circular bioeconomy.	• The government could allocate the budget to finance the Circular Economy initiatives. This would also help in analysing the economic impacts of the regional circular bioeconomy. • An investment corpus could be created where public and private partners could pool funds. This could financially support entrepreneurs.

Conclusion

The Indian Bioeconomy has been growing exponentially over the years, accelerated with support from the government and flourishing private initiatives. Nonetheless, as it strives to enhance its market size to $150 Billion by 2024, the gaps within the Indian bio-manufacturing sector must be minimised. This is because the Indian bio-manufacturing sector is the most significant contributor to the growth of the Indian bioeconomy. This report has taken a step forward in that regard by analysing the regional bio-clusters and their link to develop state-specific biomanufacturing strategies.

The findings generated through this report reveals that in comparison to its global peers, India has fared well in cluster development, performing better than China, Israel and South Korea. However, in order to compete with the advanced bio-economies, the Indian bioeconomy needs to move beyond cost-competition and focus on creating high-value, specialised products. Additionally, states would also need to orient their bioeconomy strategies with the national vision by driving the growth of their clusters through better incentive models.

The evaluation of regional bio-clusters also highlights the better performance of India's Southern regions in the creation of a stronger bioeconomy cluster profile than other regions. However, states like Uttarakhand, Haryana, Himachal Pradesh and Goa have also shown potential for future expansion across the various cluster categories identified for the Indian bioeconomy.

The way forward from here would be to provide targeted incentives to aid in the transition of the assessed 3-star bio-clusters into 4-star bio-clusters across the various regions of India. This would involve strong policy actions across the broader domains of cluster development, promotion of sectoral data management and enhancement of Indian biomanufacturing's facilitators and key enablers. These well-developed clusters could then be further promoted to move towards a Sustainable,

Circular Bioeconomy model. The rationale for doing so is that these strengthened clusters would have the substantial capacity, specialisation and labour force to handle the challenges allied with transitioning to a Green Bioeconomy system.

The creation of an India-specific Circular, Sustainable Bioeconomy by 2024 would not only boost the Indian biomanufacturing sector by providing new market and employment opportunities but also aid in minimising several environmental issues. Moreover, it would highlight India's position in the global arena with several countries adopting circular bioeconomy strategies to improve their resource and eco-efficiency.

Going ahead, there is a necessity to identify the specific components and clusters that would be engaged within the Indian Circular Bioeconomy vision. This would require extensive research with respect to the applicability of the concept within the Indian scenario, and incentive formulation for industry clusters to take up this idea. As we move forward, regional networks of clusters and research consortiums could be developed to allow not only a smooth shift across the industry but also knowledge awareness across various platforms. Moreover, an enabling policy landscape and circular bioeconomy specific standards could be developed through extensive consultation between industry, academia and government agencies.

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