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Aligning Bio Economy with SDG's 2030: A Special Reference to India

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Abstract:
India's bioeconomy has significantly impacted its economy, promoting resilience and sustainable growth in critical sectors like healthcare and agriculture. The bioeconomy, defined by the production, use, conservation, and regeneration of biological resources, as well as associated knowledge, research, technology, and innovation, are all handled by the Food and Agriculture Organization (FAO). Over the past ten years, India's bioeconomy has expanded dramatically, rising from $10 billion in 2014 to $165.7 billion in 2024. This growth is driven by the integration of biotechnology with digital technologies and the circular economy concepts. By 2030, India's bio economy is predicted to grow to $300 billion, becoming a knowledge-based, bio enabled economy. The bio economy generates new companies, industries, and employment opportunities in agriculture and pharmaceuticals, enhancing food security, creating nutrient-dense crops, and making healthcare more affordable and accessible. By 2030, it is expected to generate 35 million jobs in bio-manufacturing centers and create a thriving startup ecosystem. India is also one of the world's largest providers of inexpensive medications and vaccines, with 25% of the World Health Organization's total vaccine purchases coming from Indian firms. The current study is to explore the projected trend in the Bio Economy of India and to assess the opportunities and challenges. On the other hand, to see at what extent the BioE3 policy would align with SDG Goals. Hopefully the BioE3 Policy would tackle climate change, promote sustainable agriculture, and advance the circular economy in India, focusing on key sectors and innovative research to create a circular bioeconomy.

Keywords: BioE3 Policy, Food and Agriculture organisation (FAO), Sustainable Development Goals (SDG's), Sustainable Bioeconomy

I. Introduction

The bioeconomy for sustainable development refers to the development, revitalization, and establishment of economic systems founded on the balanced and sustainable use of renewable biological resources. Building bridges between research, industry, and society, as well as between biotechnology and the economy, is the goal of the bioeconomy. The challenges and opportunities presented by bio economies are enormous, and the key success factors for various nations working on the bioeconomy vary greatly. India is set to become a hub for innovation and production in the bioeconomy, with new markets emerging in contact lenses,

nerve regenerators, smart tablets, smart proteins, speech restorers, and portable dialysis. The bioeconomy is expected to generate $10 billion in revenue from intelligent tele diagnostics and prosthetic limbs. US startups are focusing on fermentation capabilities in this field, with investment already underway. Within three to five years, India could establish 10-million-liter fermentation facilities, generating over $500 million in investment and $1 billion in annual revenue. The industry requires regulatory and infrastructure assistance to capitalize on this potential. India's bioeconomy is projected to be worth between $270 and $300 billion by 2030, accounting for 3.3% to 3.5% of the country's GDP. This growth is possible due to the biopharmaceutical industry's efforts to reach the $120-125 billion milestone. The three segments - agriculture, bioindustrial, and bioservices - have already exceeded the $60 billion milestone. India has the potential to overtake the vaccines and therapeutics market in the BioPharma sector, which makes up about half of the $60 billion BioPharma and Diagnostics labs, medical equipment, and services industry. Enzymes are expected to generate $20 billion in value, while biofuels contribute close to $50 billion. The BioServices segment is expected to reach $50-60 billion or higher.
India's biofuels capacity is expected to double from 5.2 billion liters in 2021 to 10.1 billion liters in 2025, boosting the BioEconomy's economic output from $6 billion to $20 billion. BioAgri, including Bt cotton, insecticides, marine biotechnology, and animal biotechnology, could quadruple its contribution to the BioEconomy from $10.5 billion to $20 billion by 2025, benefiting from the circular economy. The BioServices sector, including CROs/CDMOS and the BioIT section, is expected to grow from $6.4 billion to $26.6 billion, with biotech accounting for 5-6% of the company's overall revenue.

II. Opportunities and Challenges

Establishing a bio-economy in India is a complex task that faces numerous obstacles in areas such as infrastructure, policy, technology advancement, and socioeconomic considerations. The regulatory system in India is disjointed, leading to delays and misunderstandings. The approval procedure for genetically modified crops has been contentious, and operational challenges are caused by the numerous, intricate, and dynamic regulations in various Indian states. Funding is another challenge, with increased expenses and a protracted payback period for bio-economy initiatives involving bio-plastics and bio-fuels deterring new businesses and even well-established businesses from obtaining consistent funding. The return on investment in biotechnology is also at risk due to many unknowns that discourage private investors. Intellectual property protection (IP) is a concern, as innovation in bio-economy sectors is discouraged by the complicated, difficult, and slow process of applying and obtaining IP rights for biotechnology breakthroughs. Biopiracy is another issue, with indigenous biological resources being exploited by foreign corporations without appropriate benefit-sharing. Restricted scalability is another major obstacle to turning research findings into commercial goods due to the absence of academic-industry connections. India's biotechnology industry heavily relies on international supply chains for vital raw materials, machinery, and cutting-edge technologies. Land-use patterns, climate, and conflicting demands for food or fodder threaten the supply of feedstock, such as agricultural leftovers. Competition in fields like synthetic biology, bioinformatics, and enzyme technology in India's biotechnology industry lacks scientific research and innovation, forcing India to contend with fierce competition from South Korea, China, and the United States using cutting-edge biotechnology. The excessive use of genetic resources, including crops and livestock, in the development of new bio-based products leads to genetic variety loss, species depletion, and the introduction of invasive alien species. The use of agricultural lands for biofuel crops and the construction of bio-refineries in rural areas reduces the area under cultivation. Skill shortages are caused by a lack of people with training in high-tech sectors such as molecular biology and bioengineering. Climate change poses a threat to the Indian bio economy, with hurricanes, floods, and changing precipitation patterns posing a threat. Public perception of genetically modified organisms and other bio-based advancements can hinder the development of bio-economy products. To bolster the bioeconomy of India in the future, regulatory frameworks, international cooperation, public-private partnerships, and IP protection should be reinforced. A sustainable bioeconomy and internationally recognized sustainability standards are needed, along with skill development, rural bio-entrepreneurship, and public trust. The government's BioE3 (Biotechnology for Economy, Environment, and Employment) Policy in 2024 aims to turn India into a global biotech powerhouse by transitioning from chemical-based businesses to sustainable bio-based models and encouraging regenerative bio manufacturing. This action will support the Make in India campaign and assist in attaining environmental sustainability. The BioE3 Policy aims to develop and commercialize bio-based products by providing advanced bio manufacturing facilities, bio-foundry clusters, and bio-AI hubs. These initiatives will foster cooperation among startups, SMEs, and industry while bridging the gap between labs and markets. Bio E3 will use local biomass to create jobs in tier-II and tier-III cities, while emphasizing ethical biosafety and compliance with international regulatory requirements.

The National Biopharma Mission (NBM), led by the Department of Biotechnology (DBT) and BIRAC, seeks to strengthen India's capacities in biopharmaceuticals, vaccines, biosimilars, medical devices, and diagnostics. With a $250 million budget, the mission funds 101 initiatives involving over 150 groups and 30 MSMEs. It offers start-ups and MSMEs 11 shared facilities for manufacturing, testing, and validation, as well as cGMP facilities for manufacturing, GLP labs for biosimilar analysis, and GCLP labs for vaccination testing. India ranks third in pharmaceutical production by volume and fourteenth by value, but has become a global center for affordable, high-quality medications. The country has also made significant strides in agricultural biotechnology, such as the development of SAATVIK (NC 9) and the establishment of the Biotech-KISAN program to empower farmers, particularly women in rural and tribal areas. The Biotechnology Industry Research Assistance Council (BIRAC), founded by the Department of Biotechnology in 2012, greatly supports India's biotech start-up ecosystem by providing funding, facilities, and coaching to start-ups through its 95 bio-incubation sites across the country. Early-stage start-ups can receive up to ₹50 lakh for 18 months under the Biotechnology Ignition Grant (BIG). The SEED Fund offers ₹30 lakh in equity support for start-ups at the proof-of-concept stage, while the LEAP Fund offers ₹100 lakh in equity support for technologies ready for commercialization.

III. BioE3 policy

The Indian government launched the BioE3 strategy (Biotechnology for Economy, Environment, and Employment) as a strategic plan to encourage high-performance biomanufacturing. Through the adoption of cutting-edge technologies and the encouragement of creative research, this policy seeks to transform biomanufacturing processes. The "Circular Bioeconomy," which is expected to grow to $300 billion by 2030, will promote "Green Growth" in India. High-performance bio manufacturing can handle farming and food concerns, generate materials and medicines, and encourage the production of bio-based products. The BioE3 Policy focuses on several sectors, including bio-based compounds, biopolymers, enzymes, functional foods and smart proteins, climate-resilient agriculture, precision biotherapeutics, and the capture and use of carbon. Its goals include economic development, environmental sustainability, and job creation. The policy emphasizes the importance of fostering a Circular Bioeconomy and reaching a Net Zero carbon economy, improving employment development for India's growing skilled workforce, and tackling food security and climate change mitigation by emphasizing sustainable practices. Key features of the BioE3 Policy include the creation of Bio-Artificial Intelligence (AI) Hubs to foster research and innovation, promoting early-stage production through pilot and pre-commercial manufacturing facilities, and promoting biomanufacturing hubs to train and guarantee skilled labor in the rapidly changing biomanufacturing area. The policy also anticipates interministerial coordination to ensure the integration of biosafety and biosecurity considerations. The BioE3 Policy focuses on enzymes, biopolymers, and biobased compounds, which are essential for achieving sustainability goals. Biopolymers, natural polymers created by living things' cells, are essential for various biological processes and functions. Smart proteins and low-carbon functional foods, made from plants, algae, fungi, and insects, provide a more environmentally friendly alternative to conventional animal farming methods.

India's agricultural diversity and current food processing infrastructure can help become a leader in the expanding global market for alternative proteins. The global market for innovative therapeutic modalities, such as gene and cell therapies, may surpass $22 billion by 2027 due to ongoing growth in demand. However, India's share falls short of expectations, and the establishment of specialized research facilities and promotion of discoveries in monoclonal antibodies, mRNA therapeutics, and cell and gene therapies will improve India's ability to compete globally in biotechnology. The BioE3 Policy aims to address the challenges and hazards posed by climate change by encouraging research into climate-smart agriculture methods, focusing on crop resilience, de-carbonization, and marine resources. The policy emphasizes the use of soil microbiomes to improve soil fertility and health, promotes organic farming methods, integrated pest management, and agroecological approaches that improve biodiversity and ecosystem health. India's marine biotechnology research is trailing behind, but the policy aims to improve aquaculture techniques through biotechnology and investigate marine species (bio prospecting). This will improve food security while reducing the strain on terrestrial ecosystems. The Central Salt and Marine Chemicals Research Institute (CSMCRI) and the National Institute of Oceanography (NIO) are pioneering studies in marine organism cultivation and bioprospecting.

The BioE3 Policy also recognizes that microbial biomanufacturing may offer integrated solutions for isolated or harsh environments, such as food quality and safety, shelf life, and packaging waste. This will assist in obtaining wholesome, safe meals for upcoming extended space flights. To achieve the BioE3 Policy, India must implement reuse, repair, and recycling processes, expand start-up investments, and establish a single window clearance system for biomanufacturers. International cooperation is necessary to establish a viable biomanufacturing framework. India ranks third in Asia and is one of the top 12 biotech destinations worldwide, with a 3% sector share in the global biotechnology industry. By 2030, the Indian biotechnology sector is expected to grow to a value of $300 billion. The BioE3 Policy aims to become a world leader in the bio economy through innovation, research, cooperation, and the adoption of sustainable practices. It promotes a regenerative bioeconomy, creating new opportunities for innovation, job creation, and environmental benefits. Economic growth is expected to be driven by R&D, biomanufacturing, and increased investment in biotech companies. The biotech industry in India, which peaked in 2024 at $130 billion, will continue to grow, opening up new markets and innovation opportunities.

Millions of new jobs will be created by research and development centers, providing workers with the skills they need to benefit from it. India's BioE3 Policy promotes a "Circular Bioeconomy" and a Net Zero carbon economy, aiming for faster Green Growth. This innovative, sustainable, and sensitive approach establishes the Bio-vision for Viksit Bharat.

IV. Review of Literature

S. Venkata Mohan et al. (2017) evaluated India's waste-derived bioeconomy, highlighting the challenges of a fossil fuel-based linear economy. These include energy security, depletion of fossil fuels, population growth, urbanization, environmental and climate change issues, and massive waste generation. A sustainable circular bio-economy is replacing the fossil fuel-based economy, and India's massive biogenic waste can be used as a raw material for this new economy. Waste is seen as a valuable resource that can augment petroleum feedstock when used properly. The assessment identifies the bioeconomy's drivers and structures it in a sustainable manner. By combining science and technology with financial aid, the waste-derived bioeconomy offers ample room for industrial-scale innovation and can help address most of the Sustainable Development Goals (SDGs). The government, business community, and scientific community can all take action to fully exploit these opportunities.

Anju K. Chandel et al. (2020) explored the role of biofuels and renewable chemicals in a bioeconomy. The rise of lignocellulosic biorefineries (LBRs) has shown promise in supplying sustainable renewable resources, reducing environmental issues and meeting energy demands. LBRs, which use cellulose, hemicellulose, sugar polymers, and lignin, are a key driver of growth. By 2025, the compound annual growth rate (CAGR) is expected to be 16.43%. Global corporations like Raizen, Du Pont, BASF AG, Cargill, and Braskem are producing bio-based chemicals and biofuels. However, due to lack of viability and innovative genetic engineering or bioprocessing methods, biochemicals and biofuels have not yet achieved their intended economic goals.

Mairon G. Bastos Lima (2022) explored Brazil, India, and Indonesia's transition to a bioeconomy, a shift aiming to replace fossil fuels and plastics with circular economies, zero waste, employment, and biodiversity. However, the social aspects of promoting the bioeconomy are often overlooked. The article examines the social aspects of promoting the bioeconomy through a "just transition" lens, focusing on the social aspects of bio-based production. It analyzes the prevalent bio-based production systems in terms of distributive, procedural, retributive, and restorative justice, using Brazil, India, and Indonesia as case studies. The analysis reveals that while agribusiness has benefited from the bioeconomy, it has contributed to unjust production systems, with little accountability for past and present harms to local populations and traditional communities. Benefits and burdens are distributed unevenly, and procedural governance over landscapes and resource use tends to be exclusionary. The conclusion is that a just bioeconomy transition requires sustainable land use and farming, in addition to replacing fossil fuels.

Deepak Pant et al. (2017) evaluated the development of a biobased economy in Europe and India, highlighting India's potential for a biomass and biobased economy. The European Union and India have partnered to support the growth of these biobased economies. A comprehensive analysis of 80 possible proposals was conducted, dividing biomass production, by-products/waste, biorefineries, and policy, market, and value-added goods into four main categories. Key stakeholders from academia, business, and policymakers in India and the EU were given a questionnaire. A total of 231 responses were gathered and examined. The study concluded that both areas should acknowledge the value-added contributions of biobased products, such as food, feed, valuable materials, and chemicals, while minimizing environmental effects and lowering overall process costs.

Through case studies, Suraj Negi et al. (2021) investigated the circular bioeconomy. The circular bioeconomy is the result of a complete and unified worldwide paradigm shift from the linear to the circular economy. Two concepts that are at the forefront of change are the circular economy and the bioeconomy. By encouraging the development of innovative materials, the circular bioeconomy advances the notion of bringing industries closer to nature. The current study sheds light on the global circular bioeconomy situation both now and in the future. The circular bioeconomy framework and policies that have been implemented globally are described in a wealth of literature. However, only a few countries—India, China, the United States, Brazil, South Africa, and the European Union (EU)—are included in a comprehensive assessment of policy. A specific example of Namibian bush invasion as a circular bioeconomy business model is also presented. It also draws attention to the opportunities and difficulties faced by developing countries, as they transition from a linearized bioeconomy model to a circular loop.

Prakash Kumar Sarangi et al. (2022) opined conventional fossil fuels are the main source of global energy problem. Fossil fuel combustion contributes to greenhouse gas emissions, which pose the greatest threat to the environment and ultimately cause changes in the global climate. In terms of sustainability, materials and fuels made from plant or organic wastes get beyond this drawback and provide a solution to the problem of fossil fuels. In this regard, investigating agricultural residue seems like a good substitute for non-renewable resources to maintain environmental viability and address the severe energy issue. Energy security is increased by using agricultural waste as a feedstock for the biorefinery technique, which turns out to be an environmentally beneficial method of producing biofuel and value-added chemicals. As a result, using this renewable biomass in the future to produce green fuel and other green biochemicals has a positive impact on sustainability and cost-effectiveness.

In 2020, Andrew Paul Gutierrez et al. evaluated the bioeconomics of farmer suicides and Indian hybrid Bt cotton. The introduction of hybrid Bt cotton, exclusive to India, has been praised as a success, but yields have remained low and production costs have increased by 2.5 to 3. Thousands of farmer suicides result from India's low-yield hybrid cotton system each year. The study used conceptually straightforward, parameter-sparse, theoretically based, mechanistic, weather-driven physiologically based demographic models (PBDMs) to break down the bio-economics of the Indian cotton system. The model successfully identified the proximate bioeconomic factors contributing to low yield and their correlation with farmer suicides. The model also captured the age-stage mass dynamics of rainfed and irrigated cotton growth/development and the interactions with the important pest pink bollworm across five south-central Indian states. The study describes why Indian cotton producers in the five states' rainfed and irrigated cotton regions find short-season, high-density non-GM cotton to be a practical alternative. The existing hybrid long-season Bt technology for irrigated and rainfed cotton results in poor farmer earnings, high input prices, stagnating yields, and increased insecticide use, all of which exacerbate economic suffering and are a direct cause of cotton farmer suicides.

G. and Ramachandra. Saranya (2022) investigated the potential for diatom biorefineries on the west coast of India to contribute to the Sustainable Bioeconomy. The report explores the potential of microalgae biorefineries on India's west coast to contribute to the Sustainable Bioeconomy. Microalgae, naturally producing more biomass and lipids per hectare than other terrestrial bioenergy feedstocks, are becoming a promising renewable energy source for biofuels. The study focuses on the potential for producing microalgal biofuel and other value-added products in a decentralized microalgal biorefinery located in the flood plains (gazani lands) on India's west coast. The study evaluated species prioritization, seasonal availability, tolerance, and biochemical composition to determine the potential for developing biorefineries employing diatoms as renewable bioenergy feedstocks. Amphora and Nitzschia sp. were selected for laboratory-scale productivity investigations based on their macromolecular makeup and tolerance. The study found that Amphora sp. produced 0.56 g L^{-1}, 16 times more productive than traditional shake flask cultures. About 15–24 kg of biodiesel were produced by the design of a diatom biorefinery and its mass budgeting, which took into account 100 kg of dry biomass. The report also discusses India's sustainable bioenergy initiatives, highlighting the need for renewable energy solutions to address energy-related issues such as growing demand for modern energy carriers, a fossil fuel-dominated energy system experiencing a severe resource shortage, providing high-quality energy to the impoverished population, vulnerable energy security, local and global pollution regimes, and maintaining economic development. India has been implementing one of the largest renewable energy initiatives in the world, but early research indicates that the success rate is negligible in comparison to the potential.

Anita Srivastava and Sheetal Bandhu (2022) investigated biotechnological developments and obstacles. Global attention is focused on the textile industry's role in the impending harmful environmental impact. Because textile effluent contains a wide range of contaminants, including colors, acids, bases, metal salts, and microbes, cleanup is frequently difficult. The sustainability of living things is at risk, hence the adoption of biological recycling techniques is being considered to lessen the harmful contaminants from textile effluent. With an emphasis on cost-effective and state-of-the-art methods for the treatment of textile effluents, this review seeks to provide insight into the latest developments and difficulties in biotechnological processes. Economic textile effluent control is made possible by recent trends that use bioprocess engineering and integrated biotechnological techniques. The study came to the conclusion that strict implementation of water management policies and strategies is necessary in order to prevent the release of contaminants into the aquatic environment. Notably, the government, scientific community, and industry should take action to explore the possibilities in this field. Together with the government, business potential in textile effluent treatment can be developed by offering financial assistance through India's "Swachh Bharat" program. In terms of trash management and recycling, start-up businesses have a plethora of options. Proper control of textile wastewater is required by an independent authority, which could spur recycling process innovation. The money collected from polluters should be used to financially support waste management companies.

Biotechnology and the bioeconomy—Towards equitable and sustainable industrial development was the topic of Yvonne Lokko et al.'s (2018) study. Biotechnology could be used throughout the value chain to help develop bio-based industries in a way that ensures the sector's sustainability and lessens potential negative environmental effects, thereby transforming developing and least developed nations into industrialized ones. For example, in agribusiness development, interventions could begin with agricultural mechanization and inputs, modern processing technologies, perishable product packaging, promoting food safety in the processing and regulatory environment, and interventions to increase productivity and competitiveness. With a revenue of over USD 300 billion, biotechnology plays a role that extends beyond industrial growth as it offers chances to advance several UN sustainable development goals (SDGs). From feeding and fueling a burgeoning population to combating a global epidemic of chronic diseases, biotechnology innovation offers answers to many of the development concerns facing our globe today. The potential of industrial biotechnology can be used to promote the equitable and sustainable industrial growth of poor nations through public-private partnerships in the implementation of technological cooperation programs. Additionally, biotechnology for sustainable and inclusive industrial development can help us fulfill our obligations to achieve the Sustainable Development Goals (SDGs), especially Goal 2: to end hunger and achieve food security; Goal 3: to ensure healthy lives and promote well-being for all at all ages; Goal 9: to promote sustainable and inclusive industrialization and foster innovation; and Goal 12: to ensure sustainable patterns of consumption and production.

Delivering on the Promise of Bioeconomy in the Developing World: Connecting It with Social Innovation and Education was evaluated by Sandipan Ray et al. (2016). Research and development (R&D) is frequently overlooked in emerging nations because a number of issues, including fast population expansion and ingrained social issues, impede fair economic progress and education. However, R&D is important for reasons other than science. All nations should have the ability to produce and promote their scientific scholarship since such autonomous scientific thinking abilities may also strengthen the ability and desire of their inhabitants to think democratically in an interconnected, globalized globe. Here, social innovation is defined as a type of responsible innovation that unites knowledge user communities, funders, and scientists to tackle enduring and/or deeply ingrained societal issues. Furthermore, with social innovation, user groups like citizens can do more than just embrace ideas created by scientists; they can also actively participate in the scientific design and funding process. Therefore, creating effective connections between the education environment, social innovation, and bioeconomy is essential to the overall prosperity of developing countries. In light of this, innovative projects like virtual biotechnology laboratories and e-learning programs are quickly changing society in emerging nations. In developing nations with limited resources, where there are more prospective students than experienced teachers and educational institutions that can offer the necessary infrastructure for basic and advanced scientific education, distance education, e-learning, and open learning initiatives are unquestionably beneficial. Particularly in India, biotechnology dispersed learning techniques have seen remarkably creative and progressive investments that can provide light on the global community of scientists and citizens.

A study by Bhoomika Yadav et al. (2021) looked at the bioeconomy's role in the circular economy. Globally, biomass is a rich energy source, but its supply chain is complicated. In the process of recovering resources from waste systems, biomass is produced, destroyed, and distributed in a complex pattern. Bioenergy systems tend to follow a circular loop in their processes and mirror nature. One of the most important aspects of sustainability is thought to be the utilization of renewable energy. All bioeconomic systems are cyclical and regenerative. The bioeconomy is naturally circular since plants absorb carbon from the atmosphere, which is then recycled into soil or atmospheric carbon after use and reuse. The idea of a product's end-of-life is eliminated when the circular economy incorporates a circular loop into a product's life cycle. The circular economy emphasizes the effective use of limited resources while ensuring their maximum reuse or recycling. The majority of the circular economy models in use today cannot do away with the infusion of new resources. Modern bioeconomic systems have advanced to the point where they aim to do away with the need for additional resources. Landfills or disposal sites are currently visible in any stage of the product's life cycle. The bioeconomy, problems, and solutions for sustainable bioeconomic pathways are discussed in this chapter. Additionally, it describes the changes in biomass and how they affect climate change. The Smart and Sustainable Bioeconomy Platform offers a fresh perspective on sustainable development by (Gaspare D'Amico et al., 2021), focusing on improving the quality and efficiency of industrial and urban processes and operations. Countries like Austria, Costa Rica, Finland, Germany, Ireland, Latvia, Malaysia, South Africa, and Thailand have adopted various methods and practices to enhance the circularity of dimensions such as waste, water and wastewater, energy, land, biodiversity, economy, health, safety, education, and agriculture. The platform integrates various bio-initiatives globally, providing a clear understanding of the concept of a smart and sustainable bioeconomy. It outlines stakeholder management and planning stages, identifies economic, social, environmental, and technological aspects, and establishes objectives for decision-making. This platform advances knowledge about how the intelligent and sustainable bioeconomy operates. However, more quantitative research is needed to fully explore the smart and sustainable bioeconomy. The study's findings highlight that the smart and sustainable bioeconomy can improve the participation, accountability, and understanding of citizens, local authorities, and companies. However, it also generates numerous social, economic, and environmental challenges that are still being observed by the scientific and managerial community today. To provide a comprehensive and exhaustive point of view for future analyses, the paper suggests enriching it with a quantitative approach.

V. Trend analysis of Bio Economy of India

The following table shows the trend of Bio Economy of India

Table No.5.1

Bio Economy and its Components in India Value in US Billion Dollars

year	Bio Pharma	Bio Agri	Bio Industrial	CRO/BIO IT/ RESEARCH	COVID Economy & Others
2020	38	11.11	5.11	10.52	5.50
2021	39.43	10.52	10.32	5.42	14.51
2022	45.44	12.51	13.51	10.64	10.1
2023	50.57	14.31	15.51	13.57	10.1
2024	55.99	16.42	18.12	16.51	10.2
2025	61.34	18.92	21.13	19.51	10.1
2026	66.71	21.81	24.11	23.13	10.2
2027	72.22	25.11	26.92	26.64	10.2
2028	77.6	28.62	29.63	30.21	10.1
2029	83.23	32.82	32.61	33.71	10.1
2030	89.85	36.31	36.13	37.81	10.2

Sources: IBEF-India Brand Equity Foundation

As per the above table Bio pharma is expected to grow totally worth of 680 billons dollars by 2030, followed by Bio Agri around 228 billion and Bio Industrial about 232 billion. Similarly, CRO/BIO IT/Research expected to be 227 billion and covid economy and other around 110 billion.

Table No:5.2

Descriptive Statistics

	Bio Pharma	Bio Agri	Bio Industrial	CRO/BIO IT/ RESEARCH	COVID Economy

					& Others
Mean	61.81818	10	20.67273	21.17273	20.75455
Median	61.3	10	19.5	21.1	18.9
Maximum	89.8	14.5	37.8	36.1	36.3
Minimum	38	5.5	5.4	5.1	10.5
Std. Dev.	17.67393	2.012461	10.50372	9.710004	8.937826
Skewness	0.113771	0	0.202901	-0.05395	0.465946
Kurtosis	1.759812	5.5	1.831992	1.957544	1.897706
Jarque-Bera	0.728677	2.864583	0.700754	0.503413	0.954926
Probability	0.694656	0.238761	0.704422	0.777473	0.620355
Sum	680	110	227.4	232.9	228.3
Sum Sq. Dev.	3123.676	40.5	1103.282	942.8418	798.8473
Observations	11	11	11	11	11

Source: Computed

As per the descriptive analysis of Bio Economy the Mean output of Bio-Pharma is expected to be $61.81 billion and Standard deviation is 17.67, whereas Bio-Agri Mean output is $10 billion and the deviation is 2.01 and Bio-Industrial average output is $20.67 Billion and standard deviation is 10.50, CRO/BIO IT and Research is averaged around $21.17 Billion and standard deviation is 9.71. Finally, covid Economy & others average output is $20.75 billion and standard deviation is 8.93.

VI. Findings Suggestions and Conclusion

Bio pharma is expected to grow totally worth of 680 billons dollars by 2030 , followed by Bio Agri around 228 billion and Bio Industrial about 232 billion. Similarly, CRO/BIO IT/Research expected to be 227 billion and covid economy and other around 110 billion. In India's Bio Economy the Mean output of Bio-Pharma is expected to be $61.81 billion and Standard deviation is 17.67, whereas Bio-Agri Mean output is $10 billion and the deviation is 2.01 and Bio-Industrial average output is $20.67 Billion and standard deviation is 10.50, CRO/BIO IT and Research is averaged around $21.17 Billion and standard deviation is 9.71. Finally, covid Economy & others average output is $20.75 billion and standard deviation is 8.93. The BioE3 Policy would address the challenges posed by climate change, promote sustainable agriculture, and advance the circular economy. It aims to promote sustainable bio manufacturing, environmental sustainability, and job creation in India. By focusing on key sectors and promoting innovative research and development, the policy could create a circular bioeconomy and contribute to India's sustainable development and economic expansion. Hence, India aims to become a global centre for bio-manufacturing, focusing on inclusive economic advancement, sustainable development, and innovation-led growth. The convergence of bio-manufacturing, bio-agriculture, and bio-energy aligns with India@2047's overarching objectives, which emphasize sustainability, economic independence, and green growth.

Through the study and literary survey, it is observed that, the potential of bioenergy can be used to address rural energy needs in three ways: gasification and combustion of biomass for electricity; bio methanation for electricity and cooking energy (gas); and efficient wood-burning cooking appliances. It evaluated the demand for bioenergy and its potential, technologies, the state of commercialization and technology transfer and dissemination in

India, the performance and effects on the economy and environment, bioenergy policies, regulatory measures, and barrier analysis. In conclusion, the report highlights the importance of considering microalgae biorefineries and sustainable bioenergy initiatives in India to address energy-related challenges and promote sustainable development.

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