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KNOWLEDGE EXCHANGE ON CIRCULAR BIOECONOMY

PRESIDENCY DOCUMENT

JULY 2023

TECHNICAL DOCUMENT DEVELOPED FOR THE G20

Acknowledgement:

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The overall concept, drafting, data compilation, and analysis for the study was conducted by Ms. Mandavi Singh and Ms. Trinayana Kaushik, with support from Mr. R R Rashmi, Mr. Souvik Bhattacharjya and Dr. Shailly Kedia from TERI.

Disclaimer: The report does not necessarily provide exhaustive documentation of all Resource Efficiency and Circular Economy related activities by G20 members and guest countries, rather it is an outcome of work that was conducted between November 2022 and July 2023.

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List of Acronyms

2G	Second Generation
4Rs	Reduce, Reuse, Recycle and Remove
ABS	Acrylonitrile Butadiene Styrene:
BBI-JU	Bio-Based Industries–Joint Undertaking
BIOMET	Bio-Circularity Metrics
BTX	Benzene, Toluene, and Xylene
CAGR	Compound Annual Growth Rate
CBG	Compressed Biogas
CEE	Circular Carbon Economy
CO2	Carbon Dioxide
COP	Conference of the Parties
CSIR	Council of Scientific and Industrial Research
ECSWG	Environment, Climate, and Sustainability Working Group
EJ	Exajoule
EU	European Union
EUR	Euro
FMCG	Fast-Moving Consumer Goods
GBP	Global Bioenergy Partnership
GCBP	Global Circular Bioeconomy Partnership
GDP	Gross Domestic Product
Gha	Giga hectare
GHG	Greenhouse Gases
GJ	Giga Joules
GOBAR-Dhan	Galvanizing Organic Bio-Agro resources
GOTS	Global Organic Textile Standards
ICAR	Indian Council of Agricultural Research
ICCP	Cascading Catalytic Pyrolysis
ICE	Indigenous Circle of Experts
IEA	International Energy Agency
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IOs	International Organisation
kWh	Kilowatt-Hour
LiFE	Lifestyle for the Environment
MEA	Ministry of External Affairs
MECs	Microbial Electrolysis Cells
MFCs	Microbial Fuel Cells
MMT	Million Metric Tonnes
MOEF&CC	Ministry of Environment, Forests, and Climate Change
MSME	Micro, Small and Medium-Sized Enterprises
MSW	Municipal Solid Waste
MT	Million Tonnes
NDCs	Nationally Determined Contributions
NIIST	National Institute for Interdisciplinary Science and Technology
OECD	Organisation for Economic Co-operation and Development
PALF	Pineapple Leaf Fibre
PBAT	Polybutylene Adipate Terephthalate
PET	Polyethylene Terephthalate
PHA	Polyhydroxyalkanoates
PLA	Polylactic Acid

PU	Polyurethane
PUR	Polyurethane
R&D	Research and Development
RED	Resource Efficiency Dialogue
SATAT	Sustainable Alternative Towards Affordable Transportation
SDGS	Sustainable Development Goals
SME	Small and Medium-sized Enterprises
TERI	The Energy and Resources Institute
ton/ha/yr	Tonnes/Hectares/Year
TRL	Technology Readiness Level
UK	United Kingdom
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USD	US Dollars
WBCSD	World Business Council for Sustainable Development
WRAP	Waste and Resources Action Plan

1. Introduction

Bio-based resources have a significant potential to reduce the dependence on fossil fuels and provide sustainable supply of low carbon, or even zero carbon alternatives. These refer to resources that are mainly derived from living matter, i.e., plants, animals, algae, micro-organisms, or organic waste streams). These resources occur naturally or may be found in a synthesized form. Many common materials, such as paper, wood, and leather, can be referred to as bio-based materials. However, in present times, the term usually refers to modern materials that are seen as sustainable substitutes of fossil fuel, derived in terms of their sourcing, or other synthetic materials that have undergone extensive processing to reach its final stage.

Management of bio-based resources from waste streams is a global issue since a vast majority of it is currently burned or buried in the soil, causing pollution, biodiversity loss, and contributing to global warming. Circular bioeconomy is an economic model that is based on the use of these bio-based resources—which can act as renewable natural capital—and integrates principles of waste to wealth. The model has potential to address the current environmental and associated economic crisis by reducing our dependence on consumption of non-renewable resources, such as minerals. Circular bioeconomy can contribute to achievement of more than 50 targets across 12 SDGs.

Apart from reducing dependence on primary resources, transition towards a circular bioeconomy offers holistic and cross sectoral benefits. It creates regenerative benefits for the natural system, combats climate change, enhances economic value creation through use of bio-resources, improves access to nutritious food, and creates livelihoods for the local communities.

In the context of the global south, circular bioeconomy can contribute to generating additional livelihood opportunities, especially in the rural and urban settings, thus contributing to social as well as economic and environmental goals (Tan and Lamers, 2021; Venkatesh, 2022). Circular bioeconomy is said to have a market potential of USD 8 trillion (Salvador et al, 2021). These findings present a strong rationale to the G20 platform for a collaboration on circular bioeconomy to achieve the global goals.

There are several case studies including successful interventions, opportunities, and business model innovations from G20 members, which demonstrate the potential of using bio-based resources across different sectors and applications. Further, given that the momentum of the transition to clean and low-carbon energy pathways is growing in G20 members and beyond, circular bioeconomic transition is an important area for consideration.

This presidency document, *"Knowledge exchange on Circular Bioeconomy"* discusses the sub-theme of circular bioeconomy under the broader theme of *Encouraging Resource Efficiency and Circular Economy for India's G20 Presidency*. The document identifies opportunities, policy options, business models, and institutional architecture for countries to promote the use of bio-resources such as agriculture residues, industrial waste, municipal bio-waste, etc. These bio-resources can be the primary raw material to substitute mineral resources, which will help reduce both the extraction of virgin materials and waste disposal. This technical document developed for G20, "*Knowledge exchange on Circular Bioeconomy"* supports the idea of bringing the industries closer to nature through adoption of circular bio-based solutions, including those related to material innovation.

This document has been prepared by The Energy and Resources Institute (TERI) in collaboration with the Ministry of Environment, Forests, and Climate Change (MOEF&CC), Government of India and is based on the review and analysis of published literature: journal articles, academic papers, policy documents, and country reports.

The Government of India has tried to continuously engage all the G20 members, international organizations (IOs) and the invited countries at the Environment, Climate, and Sustainability Working Group (ECSWG) meetings, and beyond, to gather their inputs on this technical document. The inputs received from this engagement have been immensely valuable and insightful.

2. Imperative of Circular Bioeconomy for Sustainable Development

Domestic material consumption in the world increased from 30 billion tonnes to almost 95 billion tonnes during the period of 1970–2018. However, only 9% of the total materials extracted are brought back after use into the economy, thereby only closing a small share of the resource gap (S Lutter, 2018). Material consumption for G20 members increased from 19 billion tonnes to 73 billion tonnes during the same period. Along with absolute consumption, the share of G20 members in global consumption also saw a rising trend—from 62% to 74%, as depicted in Figure 1.

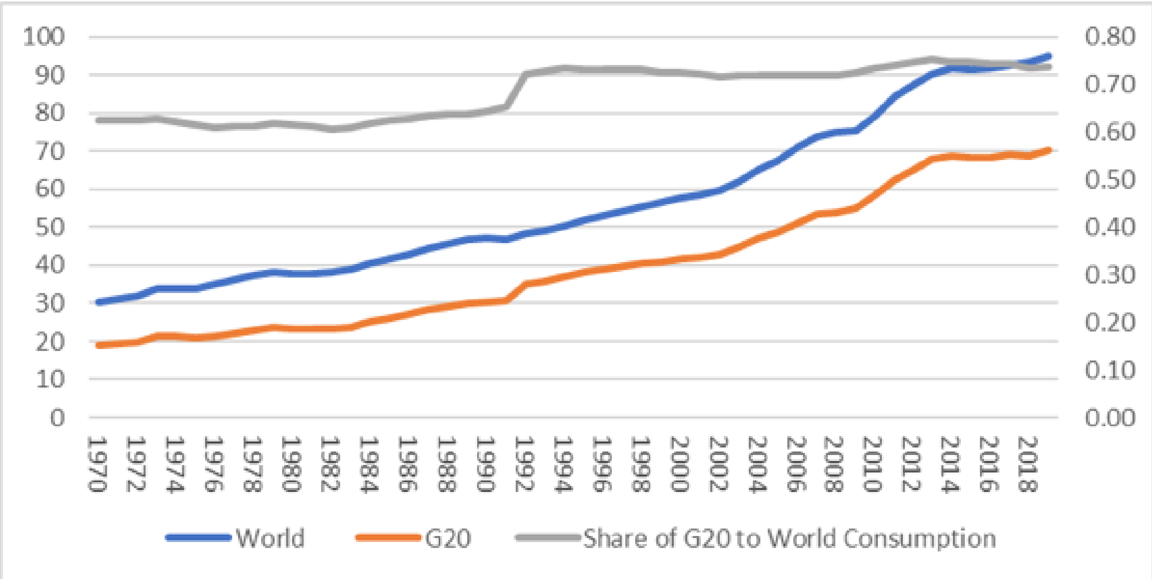


Figure 1: Domestic material consumption (in bn tonnes) of **(i)** world **(ii)** G20 members **(iii)** share of material consumption of G20 members to total share

Source: IRP database (S Lutter, 2018)

Alternatively, Figure 2 presents the domestic material consumption (in bn tonnes) of biomass for G20 members and the share of biomass in total material consumption. With an estimated consumption of 16.6 billion tonnes in 2019, biomass contributed to 23.3% of the total material consumption in G20 members (S Lutter, 2018).

Since 1970, consumption of various biological resources by G20 members has increased two and half times; although its share in total material consumption has decreased from 38% to 23.3%, with an estimated decline of 0.28% per annum(ibid). This decrease in share in total consumption has largely been due to the unprecedented growth in demand for other resources and, in particular, non-metallic resources.

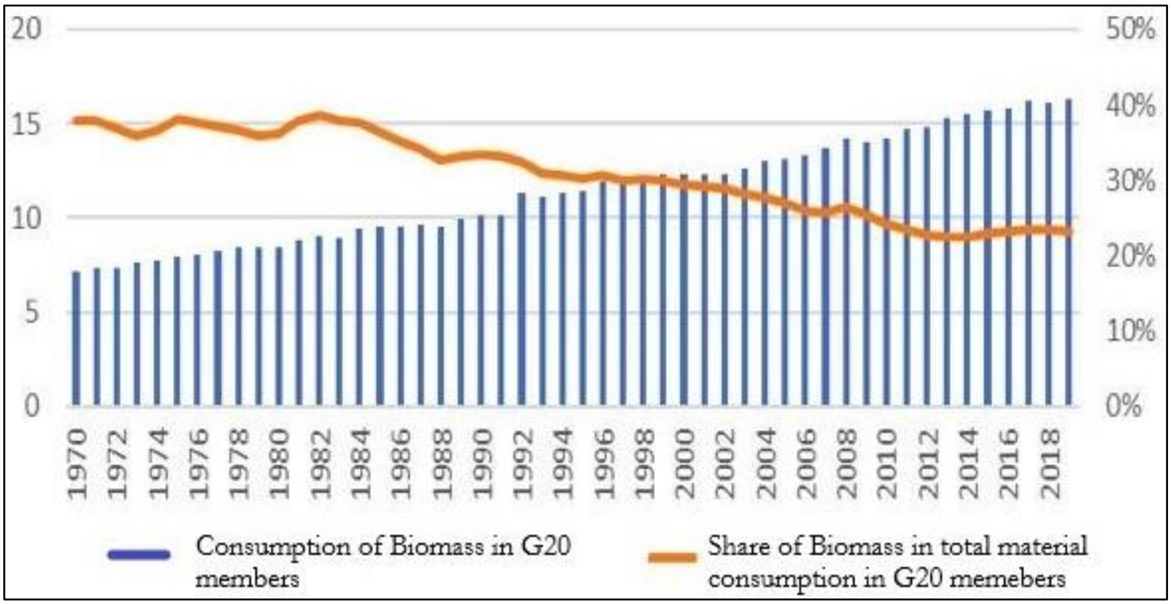


Figure 2: Domestic material consumption (in bn tonnes) of biomass for G20 nations and share of biomass in total material consumption

Source: S Lutter, 2018

The International Resource Panel classifies biomass into 5 major categories: crop residues, food crops, grazed biomass and fodder crops, wild catch, and harvest and wood. From the bioeconomy perspective, the use of these resources holds huge potential for promoting circularity across various sectors in an economy.

Developing circular bioeconomy offers an opportunity for achieving Sustainable Development Goals (SDGs) at the global level. India's G20 presidency comes at the crucial juncture, a midpoint of the 2030 Agenda and the SDGs. With less than 8 years remaining for the target date of SDGs (in 2030), an informed push to circular bioeconomy—that is backed by enabling policy environment, innovations, and implementation support—is urgently required. Circular bioeconomy can contribute to the attainment of 53 targets in 12 of the 17 SDGs (Table 2). Synergies are found with goals 7 (sustainable energy), 11 (cities and waste management), 12 (sustainable consumption and production), and 15 (life on land). Details of the SDG targets that can be met through circular bioeconomy are listed in Annexure 1.

An analysis of synergies and trade-offs between the SDGs and circular bioeconomy finds that circular bioeconomy will lead to more synergies than trade-offs with the SDGs (Ronzon and Sanjuán, 2020).

Table 1: Number of SDG targets that can be met by circular bioeconomy

SDG	Number of targets
SDG 2	4
SDG 4	2
SDG 6	5
SDG 7	4
SDG 8	4
SDG 9	5
SDG 11	3
SDG 12	6

SDG 13	2
SDG 14	7
SDG 15	8
SDG 17	3
Grand Total	**53**

Source: Ronzon and Sanjuán, 2020

3. Bioeconomy and discussions in G20

The G20 discussions have linked circular economy measures to SDGs as well as climate stewardship (see Figure 3).

2013	Saint Petersburg Summit	Bioenergy
2017	G20 Leaders´ Declaration from the Hamburg Summit	G20 Resource Efficiency Dialogue
2019	The G20 Osaka Leaders' Declaration	Circular economy, sustainable materials management, the 3Rs
2020	The Leaders' Declaration of the G20 Riyadh Summit	Circular Carbon Economy (CCE) Platform and 4Rs framework
2021	The G20 Rome Leaders' Declaration	Circular economy approaches for climate mitigation and adaptation
2022	G20 Bali Leaders' Declaration	Lifestyles, resource efficiency and circular economy

Figure 3: G20 discussions with links to circular economy

Source: Analysis by TERI

The G20 Leaders´ Declaration from the Hamburg Summit in 2017 established the G20 Resource Efficiency Dialogue (RED), with an objective to exchange good practices and national experiences, pertaining to lifecycle-based approaches, for improving efficiency and sustainability of natural resource-use in order to foster sustainable consumption and production patterns. However, the first recognition of circular economy (of which circular bioeconomy is a sub-set) was found in the G20 Osaka Leaders' Declaration of 2019. This Declaration recognized that measures such as circular economy, sustainable materials management, and the 3Rs (reduce, reuse, recycle) contribute to SDGs.

The Leaders' Declaration of the G20 Riyadh Summit endorsed the circular carbon economy (CCE) platform with its 4Rs framework (Reduce, Reuse, Recycle and Remove). The Riyadh Declaration of 2020 acknowledged the importance of fostering synergies between adaptation and mitigation, especially through nature-based solutions and ecosystem-based approaches.

The G20 Rome Leaders' Declaration of 2021 underscored the role of local actions and the role of businesses, citizens, academia, and civil society organizations in enhancing G20 efforts towards achieving sustainable consumption and production patterns as well as management and reduction of emissions; including adoption of circular economy approaches for climate mitigation and adaptation. By highlighting the achievement of a balance between anthropogenic emissions and removal by sinks through circular carbon economy, the Rome Declaration laid emphasis on the fourth 'R'. It also emphasized cooperation for deployment and dissemination of zero or low carbon emission and renewable technologies (including sustainable bioenergy) to enable a transition towards low emission power systems.

To increase sustainability and work together on scientific knowledge-sharing, raising awareness, and capacity building, the G20 Bali Leaders' Declaration of 2022 sought to further promote sustainable development and lifestyles, resource efficiency, and circular economy.

In 2013, the G20 Leaders' Declaration at the Saint Petersburg Summit had highlighted the importance of sustainable and responsible production and use of modern bioenergy, along with the role played by the Global Bioenergy Partnership (GBEP) in this regard.

G20 discussions over the last few years have brought focus on circular economy in general, or circular carbon economy. Considering the significance of bioeconomy to realize the SDGs, it is a golden moment for India to take a lead: catalyse discussions on circular bioeconomy, especially in the context of resource-use policies which complement climate policies and are embedded within the large framework of sustainable development.

4. Needs and Status of Circular Bioeconomy in Key Economic Sectors

Essential dimensions of environmental benefits resulting from the use of bio-based resources include: climate change mitigation through fossil-based material replacement; biodiversity protection; prevention of land degradation and land use change; prevention of food loss; and fostering resource security. Figure 4 demonstrates how bio-sourced inputs can create circular loops of production and consumption, thereby helping realize the environmental benefits that are being discussed.

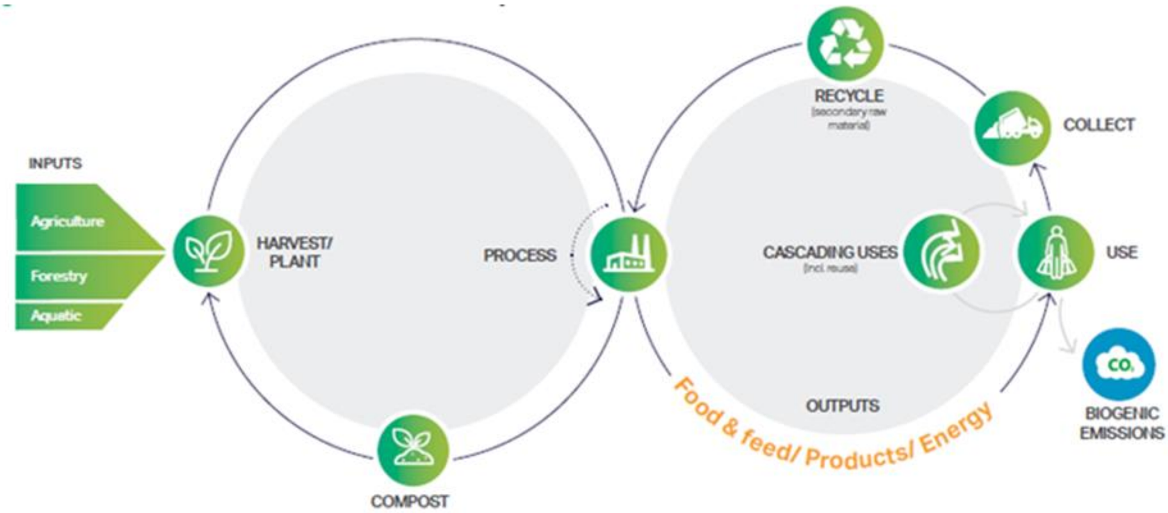


Figure 4: Flows within circular bioeconomy

Source: WBCSD, 2022

Globally, biomass remains the major source of bio-based products. In a recent assessment reported by WBCSD, of the 23 billion tonnes of biomass used in manufacturing various products, agriculture-based biomass had the largest share of 82%, followed by forestry and aquaculture at 17% and 1%, respectively. Table 2 presents the share of biomass in the materials being used in different manufacturing sectors.

Table 2: Biomass consumption and its share of total materials used in key manufacturing sectors

Sectors	Year	Biomass (in M tonnes)	Biomass share of total materials (in %)
Pharmaceuticals	2018	68	21%
	2030	91	38.0%
Textiles	2018	119	46.0%
	2030	185	45.0%
Construction	2018	361	3.5%
	2030	989	7.0%
Packaging	2018	161	43.0%
	2030	352	44.0%
Automotive	2018	255	4.6%
	2030	525	5.0%
Other Forests Products	2018	206	27.0%
	2030	310	29.0%
Electrical and electronics	2018	37	5.3%
	2030	67	7.2%
Machinery	2018	34	4.0%
	2030	58	5.5%
Biofuels	2018	2,011	9.7%
	2030	2,419	10.5%

Source: WBCSD, 2022

It is seen that between 2018 and 2030, this share has risen for all manufacturing sectors assessed in the study, with the increase being as high as 50% in the construction sector. However, there is a need to recognize the challenges linked to sustainability of biomass use. Dependence on first-generation feedstock, like edible food crops and energy crops grown on agricultural land, can create sustainability concerns. Companies that clear forests to provide materials for biomass energy plants harm the natural environment and disrupt the habitats of plants and animals in the process. Clearing plants and organic material from the earth can also impact the health of the surrounding soil, that requires biomass for compost and fertilization. Growing crops for the sole purpose of bioenergy resources also requires a good amount of water: all plants need water to grow,and continuous irrigation of these resources can make an area more vulnerable to drought.

Further, electricity produced from biomass—though considered to be an environmentally friendly alternative to coal—does release pollutants into the air, such as carbon dioxide, nitrogen oxides, volatile organic compounds, and the like. This is particularly seen in the case of production of first-generation biofuels that are produced from edible energy crops, such as sugar-based crops (sugarcane, sugar beet, and sorghum), starch-based crops (corn, wheat, and barley), or oil-based crops (rapeseed, sunflower, and canola). Trade-offs are inevitable, but at least some of biofuels' negative impacts can be mitigated through careful planning and subjective solutions (Tomlin, 2021). Conducting sustainability performance assessments of circular bio-based products is vital to understand the underlying trade-offs. For example, the drivers and environmental and socioeconomic impacts of large-scale sugarcane bioethanol production in Brazil are certainly different from those of small-scale jatropha biodiesel production for rural electrification in Sub-Saharan Africa. Furthermore, the drivers, impacts, and potential of the same biofuel practice might vary significantly across different world regions.

Circular bioeconomy may imply environmental burdens, if an integrated assessment encompassing all lifecycle stages of production and consumption is missing. Hence, adopting a lifecycle assessment is crucial to unveil the trade-offs and ensure identification of better options for circular bioeconomy implementation. To guide companies and start-ups along the most critical social, environmental, and economic considerations linked to bioeconomy, it is crucial to consider a checklist across four major aspects, viz. circularity, capture of environmental value, societal value, and corporate and stakeholder value.

The status of circular bioeconomy also depends on the various technological solutions available. Businesses in sectors like bioenergy have upcoming promising technologies, such as bio-electrochemical systems for treatment of wastewater and solid bio-waste that serve as feedstock for bioenergy, or using microbial fuel cells (MFCs) and microbial electrolysis cells (MECs). Many G20 members—including China, USA, India, South Korea, Australia, and Italy—have increasingly invested in R&D for the development of this dual-purpose technology. Additionally, developments in other evolving technologies like Big Data and Artificial Intelligence can help in the development of bioeconomic sectors of various countries. Alongside, social innovations are also emerging that revolve around sufficiency, close affinity to nature, and traditional knowledge. For instance, innovative manufacturing processes seen in UK's fashion industry are elaborated in Box 1.

Box 1: Leather from pineapple lead fibres

Piñatex is a non-biodegradable leather alternative made from cellulose fibres extracted from pineapple leaves, PLA (polylactic acid), and petroleum-based resin. Piñatex is produced by a London-based company, Ananas Anam, pioneers of innovative natural textiles from waste pineapple leaves with operations in the Philippines and Spain.

Piñatex Technology: The leaves are a by-product from existing pineapple harvest, so the raw material requires no additional environmental resources for its production. The long fibres are extracted using semi-automatic machines. The fibres are washed then dried naturally by the sun, or in drying ovens during the rainy season. The dry fibres go through a purification process to remove any impurities, which results in a fluff-like material. This fluff-like pineapple leaf fibre (PALF) is mixed with a corn-based polylactic acid (PLA) and undergoes a mechanical process to create Piñafelt, a non-woven mesh which forms the base of all Piñatex collections. The rolls of Piñafelt are then shipped by boat from the Philippines to Spain, or Italy for specialised finishing. To make the Original, Pluma, and Mineral collections, the Piñafelt is coloured using GOTS (global organic textile standards) certified pigments and a resin top coating is applied to give additional strength, durability, and water resistance. A foil is heat-pressed on it to create the Metallic collection and a high solid PU transfer coating is used to create Piñatex Performance.

Piñatex is fit for multiple uses—fashion, accessories, and upholstery—and has been used by over 1000 brands worldwide including Hugo Boss, H&M, and the Hilton Hotel Bankside.

A Netherland based SME paved the way to circular bioeconomy by producing aromatics from biomass. Read their story in Box 2.

Box 2: Aromatics (Benzene, toluene, and xylene) from Biomass – SME success story

The Integrated Cascading Catalytic Pyrolysis (ICCP) technology has been developed by BioBTX B V, a Netherland based SME, to produce aromatic compounds benzene, toluene, and xylene (BTX) from biomass. The feedstock includes a variety of solid and liquid biomass, for example, crude glycerine, black liquor, wood pulp lignin residues, crude vegetable oils and fats, agricultural waste streams, used cooking oil, as well as end-of-life materials.

The resulting product is a 100% bio-based, 'drop-in' alternative to conventional fossil fuel-based BTX produced as a by-product in oil refineries. BTX's main applications are in high performance and high-volume polymers like PET, PBAT, other polyesters, aramid, PUR, ABS, epoxy resins, polycarbonate, and nylon. They are mostly used as building blocks for downstream products in the petrochemical industry.

BioBTX B V is a technology provider and their business model is based on licensing the technology and providing associated services to companies seeking to produce bio-based BTX. They are among the first-movers to offer a viable technology to produce BTX from biomass. The value proposition of the ICCP technology is the decoupling of these widely used chemicals from fossil sources.

ICCP Technology: The integrated cascading catalytic pyrolysis (ICCP) technology encompasses an integrated two-step pyrolysis which protects the catalyst from minerals often abundant in biomass. This allows the conversion of low-grade biomass and end-of-life materials into BTX in a commercially viable manner. The technology patent was filed in 2014 and published in 2017.

Drivers of Success:

- Patents on core and downstream technologies; an iterative technology development approach, along with catalyst and engineering expertise.
- Capitalizing on diverse funding sources and early phase generation of revenues from research consultancy services.
- Light and flexible company structure allowing for fast decision-making processes and encompassing a small, highly-skilled in-house team, encircled by strong local partners from the University of Groningen and companies along the value chain.
- Ongoing and upcoming regulatory changes and megatrends, such as the electrification of transport that transforms the availability of petrochemicals (especially in the EU), a political focus on circular economy in the EU, and the re-use and valorization of waste streams.

From an environmental perspective, in India, considering the magnanimity of the plastic problem, the prime target of bio-based resources as of today is the replacement of plastics. However, these resources can also prove to be solutions in various other sectors like textiles, packaging, FMCG, agriculture, etc. Even though not explored to its full potential, biomass-based products are widely available. Several R&D institutes in India like CSIR-NIIST, CIPET, IIT-Guwahati and IISc Bangalore, have developed valuable bio-derived products from coir, jute, castor oil, among others, which are widely available.

5. Circular Bioeconomy for Climate Change Mitigation

Circular bioeconomy offers a holistic and cross-sectoral approach. It has major untapped potential to support both climate change mitigation and adaptation in different ways:

- Around one-third of global greenhouse gas (GHG) emissions currently come from agrifood systems. Bioeconomy offers opportunities to reduce GHG emissions from the agrifood system by replacing fossil-based resources and processes with biological interventions; such as that from microbiome innovations, biofertilizers and biopesticides, to new food sources, bio-based plastics and textiles, and biological waste management, to name a few.

- A sustainable and circular bioeconomy also presents opportunities to improve climate change adaptation and resilience through promoting ecosystem restoration and nutrient and water retention in soils, supporting indigenous and local livelihoods based on biological products and services, along with building the conditions for more sustainable management of forests and fisheries.
- More than 60 countries and regions now have bioeconomy, or bioscience-related strategies, which contribute to the efforts to meet their nationally determined contributions (NDCs) for reducing GHG emissions and paves the pathway towards fulfilment of the Paris Agreement targets.
- Bioeconomy considers new food sources (seaweed, microalgae, edible insects, cell culture-based food products, plant-based protein alternatives, and 3-D printed food), which could offer game-changing potential to bolster food and nutrition security while requiring less water, less energy, and fewer chemical inputs, thus reducing the impact of climate change.
- Resource efficient circular bioeconomy alone is projected to reach a value of USD 7.7 trillion in 2030 (WBCSD, 2020). It is important that the right structures are put in place at all levels, so that bioeconomy development supports climate action and the achievement of SDGs. Policymakers at local, national, regional, and global levels should pay urgent attention to how bioeconomy could shape the climate path in the future.

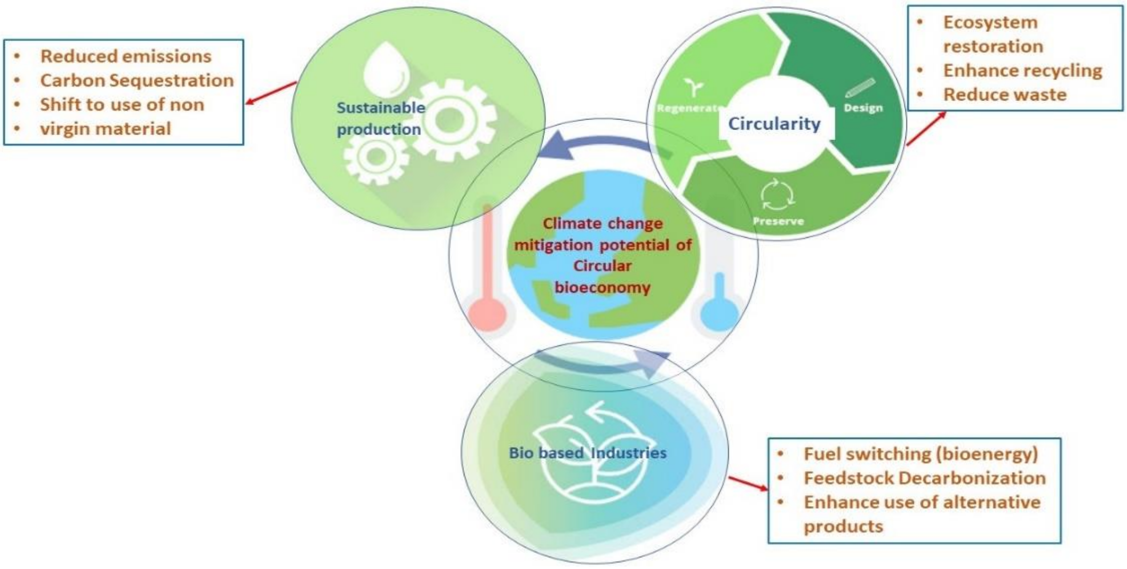


Figure 5: Climate change mitigation potential of circular bioeconomy

Source: Juan et al 2022, FAO

6. Key Opportunities and Challenges for Circular Bioeconomy Transition

6.1 Opportunities

Circular bioeconomy can serve as a new economic model, replacing the current model focused on GDP that has proved to be insufficient for measuring human development. With an emphasis on the use of renewable natural capital, circular bioeconomy focuses on minimizing waste by replacing a wide range of non-renewable, fossil fuel-based products currently in use. It also involves increased sharing and reuse of existing bio-products to extend their lives.

- Shifting to a circular bioeconomic model will offer the opportunity to transform our land, food, health, and industries to self-sustaining systems, helping reduce the dependency on imports. This is especially important in the global south, where people are still dependent on natural ecosystems like forests for food and livelihoods.
- Creation of sustainable local landscapes and new income opportunities, including employment generation from new and restored ecosystems, primarily in rural and originally unreached regions like forests, agricultural, and coastal regions. This will improve the standard of living for people (especially those relying on natural ecosystems) and eventually decreasing their socio-economic distress and vulnerability.
- Food security of countries will improve once they are able to control their own supply chains linked to bioresources.
- Given the alignment of circular bioeconomy with multiple SDGs, it will help countries to meet their SDG targets along with funds, if approved and acknowledged under carbon crediting systems.
- Industrial innovations around bioeconomy in these regions—in the fields of aquaculture and hydroponics, waste to energy, processing industries, and fisheries—can give the much-needed push for industrial decentralization of big economies.

6.2 Challenges

Despite the expansive business benefits and opportunities that a circular bioeconomy offers, it has not yet developed to its full potential, or reached the scale required for meaningful impact. The key challenges can be classified into five major categories, as given below.

- **Economic:** High capital costs are linked to the technology needed to use bio-resources for conversion into fuels; it especially calls for high initial investments. Scattered availability, miscellaneous supply chain costs, and low scales of production are other economic factors that affect overall delivered costs of production. Often the products produced from bio-based routes are unable to compete with traditional and fossil-based products due to their higher costs that render them expensive and inaccessible.
- **Technical:** The implementation of technology, or availability of viable technology, may not be adequate.
- **Land-use linked challenges:** Land is a scarce resource and is crucial for biomass production. Land allocation for biomass production may face challenges of displacement and unequal distribution of benefits, along with posing a threat to food security. Commercial scale demand of biogenic materials may also adversely impact subsistence of communities dependent on forest and land-based produce for food and fodder. Moreover, land-use related changes due to monoculture

of the energy crops may lead to competition for edible crop production, reflecting increase in prices and thus creating economic strain globally.

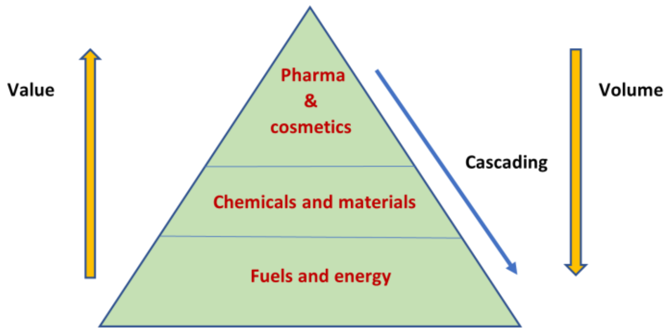
- **Negative socio-economic impacts of biomass/biofuel:** The potential effects vary significantly by feedstock, market structure and conditions, and other local factos such as geography, social structure, etc. There may be difficult trade-offs between economic costs and desired socioeconomic impacts. For example, maximizing employment and income for farmers and workers producing bioenergy biomass may require labour-intensive, smaller-scale production methods with higher wages. In contrast, biofuel producers will generally prefer large-scale production methods to minimize costs and maximize profits, including labour-saving technology. However, this large-scale production—generally more cost-efficient and profitable—may result in large-scale deforestation and significant negative effects on ecosystem services. Impacts (both positive and negative) may be shifted to other countries, if biofuels and/or feedstocks are imported, or if domestic production of biofuels displaces other domestically produced goods and services.
- **Regulatory framework:** Required public support and regulation are not fully in-place and are evolving. There is no methodology to measure environmental safety, durability, and circularity of bio-based products itself. The challenges are especially acute for developing an ecosystem at the global scale, as there is lack of metrics or standards acceptable to all countries.
- **Mindset and values:** Public opinion on bio-based materials is often still ambiguous and customers are rarely willing to pay a premium price.

7. Strengthening Circular Bioeconomy

Globally, there is significant focus on minimizing the negative impacts of the conventional energy and transport sectors, while there is skewed interest towards promoting the use of biomass as an energy carrier. This growing demand of biomass for energy globally, necessitates consideration of how biomass can be used most efficiently. Its primary production is bound on land-use and lies in conflict with a variety of potential problems, such as the competition with food and fodder production and associated land-use changes. This creates the risk that biomass resources will not be allocated to the highest-value use; hence creating a gap between a welfare-maximizing outcome: where environmental externalities are considered, and a market-based outcome: which is distorted by high levels of intervention. To satisfy the needs of the global population and to align bio-economy with the principles of circularity, a more efficient and sustainable use of biomass is essential. Many experts agree that raw materials like biomass should be used several times, in a cascading sequence of material uses, as efficiently as possible.

Cascading maximizes resource effectiveness by using biomass in products that create the most economic value over multiple lifetimes. This approach to production and consumption states that energy recovery should be the last option, i.e., biomass should only be used energetically at the end of the materials' lifecycles: only after all higher-value products and services have been exhausted. This principle is defined as cascading use of biomass. It will help in strengthening the circularity of bioeconomy and will serve to meet increasing demands, without proportionately increasing pressures on natural resources. Cascading biomass-use offers significant efficiency gains, maximizing the value extracted from a given amount of biomass by fulfilling both material and energy needs from the same feedstock. By preferentially directing virgin biomass toward material uses over energy, cascading use maximizes the amount of carbon sequestered in biomaterials.

Circular bio economy's potential environmental benefits, in the form of greater resource efficiency and sustainability, come from the maximization of the value extracted from biomass. The principle of cascading use is central to this.



Source: Adapted from Vis et al (2014).

Figure 6: Principle of cascading use

The opportunities discussed in the previous sections can be tapped and the challenges highlighted in the current circular bioeconomy scenario can be addressed.

7.1 Cleaner energy through circular bioeconomy-based solutions

Energy is the most fundamental resource in the bio-economic system and is key to growth of the global economy. The necessity for a swift transition to a low carbon, sustainable, efficient, and environmentally friendly energy system is of utmost priority. The momentum of the transition to clean and low-carbon energy pathways is growing in G20 members and beyond. This is highlighted by the trends in global energy, the concerns linked to the possibility of irreversible climate change, the desire for energy security, as well as the lookout for alternative sources of energy.

The global energy landscape continues to be dominated by fossil fuels. Over 73% of human-caused greenhouse gas emissions are attributable to energy consumption. International Energy Agency (IEA) estimates oil, coal, and natural gas account for approximately 81.3% of the global energy mix. Energy demand is expected to at least double or perhaps triple during this century.

Biomass is the fourth largest energy source after coal, oil and natural gas and is currently the most important renewable energy option. Biofuels from waste streams account for 9.3% in the global energy landscape and this potential can be increased. The global second-generation (non-food crops such as organic waste, wood, biomass crops, and food crop waste) biofuels market size was valued at $5.5 billion in 2020. It is projected to reach $54.8 billion by 2030, growing at a CAGR of 26.4% from 2021 to 2030. (Faaij et al 2013, IEA). According to the International Energy Agency (IEA), biofuels are likely to substitute enough petroleum products to avoid the gigatons of carbon dioxide emission each year. Sustainable production of feedstock can absorb as much net carbon dioxide as absorbed by the oceans and will ease the transition to cleaner energy. This will be a game changer for decarbonization in hard to abate sectors like transportation. The U.S. Department of Energy estimates that biomass has the potential to produce 40 million tons of hydrogen per year. This would be enough to fuel 150 million vehicles. Modern bioenergy usage, which excludes traditional uses of biomass, nearly will double from about 42 EJ in 2021 to 80 EJ in 2030 (Faaij et al 2013, IEA).

Bioenergy is a major aspect of circular bioeconomy as it involves usage of bio-residues generated by other bioeconomy sectors as a raw material. These bio-residues can be either bio-effluents, or solid residues from forestry, farming or wood and agro-industries. Modern bioenergy is the largest source of renewable energy globally, accounting for 55% of renewable energy and over 6% of global energy supply. Table 3 specifies a classification of different sources of biomass and their potential for energy production.

Table 3: Classification of the different sources of biomass for energy

Biomass category	Main assumptions	Energy potential in biomass up to 2050
Energy farming on current agricultural land	Potential land surplus us: 0-4 Gha (average: 1-2 Gha). A large surplus requires structural adaptation towards more efficient agricultural production systems. When this is not feasible, the bioenergy potential could be reduced to zero. On average higher yields are likely because of better soil quality: 8-12 dry ton/ha/yr.* is assumed.	0- 700 EJ (more average development: 100- 300 EJ)
Biomass production on marginal lands.	On a global scale a maximum land surface of 1.7 Gha could be involved. Low productivity of 2-5 dry ton/ha/yr.* The net supplies could be low due to poor economics or competition with food production.	< 60 - 110 EJ
Residues from agriculture	Potential depends on yield/product ratios and the total agricultural land area as well as type of production system. Extensive production systems require re-use of residues for maintaining soil fertility. Intensive systems allow for higher utilization rates of residues.	15 - 70 EJ
Forest residues	The sustainable energy potential of the world's forests is unclear – some natural forests are protected. Low value: includes limitations with respect to logistics and strict standards for removal of forest material. High value: technical potential. Figures include processing residues	30 - 150 EJ
Dung	Use of dried dung. Low estimate based on global current use. High estimate: technical potential. Utilization (collection) in the longer term is uncertain	5 - 55 EJ
Organic wastes	Estimate on the basis of literature values. Strongly dependent on economic development, consumption and the use of bio-materials. Figures include the organic fraction of MSW and waste wood. Higher values possible by more intensive use of bio-materials.	5 - 50 EJ
Combined potential	Most pessimistic scenario: no land available for energy farming; only utilization of residues. Most optimistic scenario: intensive agriculture concentrated on the better-quality soils. In parentheses: average potential in a world aiming for large-scale deployment of bioenergy.	40 - ll00 EJ (200 - 400 EJ)

**Heating value :19GJ/ton of dry matter*

Source: International Energy Agency (IEA)

The G20 members consume over 70% of global energy. Hence its contribution to usher the world to a cleaner energy transition is essential in creating ripple effect and thus reflecting change globally. The major sources of biomass for energy production are crop residue, organic part of the solid waste, animal waste etc. as mentioned in Table 3. Utilizing waste as feedstock for bioenergy is a two-pronged approach to tackle the waste generation and its associated problems and as well as emerging cleaner energy requirements. Also, assimilation of waste into bioprocesses to produce useful products and metabolites lead towards a sustainable circular bioeconomy and many countries including that of G20 countries itself have started implementing the same. Box 3 and Box 4 present selected case studies highlighting Turkey and India's efforts to generate clean energy in circular bio-economy.

Box 3: A case study of Turkey's bioenergy

In 2018, the Turkish Government began working with UNIDO on a five-year programme to increase the use of biomass in the agro-industrial sectors to accelerate the growth of the bioenergy market. The biomass plant in Aydin, generates electricity using corn and cotton stalks, tree roots, bark, and forest residue. The steam generation biomass boiler supplies steam to five enterprises in the Cine industrial zone. Once fully operational, the boiler will run on around 6,000 tons of biomass a year, to generate 26,476,000 kWh of thermal energy. This thermal energy will produce 2 tons of steam an hour, saving 20,240 tons in annual carbon emissions, equivalent to removing 4,432 cars from the roads every year. It will also stop hazardous gases like nitrous oxides from polluting the air. This project has showcased the economic and environmental potential of bioenergy in mitigating climate action.

Box 4: Case Study—India's biopower initiatives

1) GOBAR-Dhan Scheme: Under the banner of India's successful programme, the Swachh Bharat Mission Grameen (SBM-G), the Galvanizing Organic Bio-Agro resources (GOBAR-Dhan) scheme was launched in 2018. The following are a few characteristics of the scheme:
   - 584 Biogas/CBG plants have been installed and are functional
   - 311086 installed capacity of commercial CBG plant (in kg)
   - 152 Districts have been covered under GOBAR-Dhan
   - Improves indoor air quality, health, and saves time
   - Improves savings and empowers women
   - Help to sustain ODF and solid and liquid waste management of rural India
   - Aid to other schemes: Govt. Of Madhya Pradesh has implemented the 'Midday meal programme' under this scheme

2) SATAT Scheme: The Sustainable Alternative Towards Affordable Transportation (SATAT) scheme is an initiative by the Government of India with PSU oil marketing companies (OMCs). It provides opportunities to potential entrepreneurs for setting up compressed biogas (CBG) production plants and supply/provide/produce CBG in the market for use as automotive fuels. The initiative was launched in October 2018, given the abundance of biomass in the country and with the objective of utilizing more than 62 million metric tonnes of waste generated every year in India. Along with these, the scheme also addresses other objectives of reducing the import dependence, supplementing job creation, reducing pollution from burning of agricultural waste, and (most importantly) reducing vehicular emissions.

- The aim is to set up 5000 CBG plants for production of 15MMT per annum of CBG by 2023–24. For this purpose, the government is giving production offtake guarantee for such plants. There will be no restriction on the technology chosen and the government will incur the capital expenditure for setting up infrastructure for a city gas distribution network.
- The CBG plants will provide 75,000 direct job opportunities and lakhs of indirect jobs, with an additional revenue source to farmers' income, rural employment, and entrepreneurship.
- Approximately, 9019 tonnes CBG production has taken place till October 2022.

3) PM JIVAN (Pradhan Mantri Jaiv Indhan-Vatavaran Anukool Fasal Awashesh Nivaran): The scheme has proposed 12 commercial scale and 10 pilot projects for 2G biofuel production in regions with adequate biomass supply. India also unveiled Asia's first 2G biorefinery in August 2022, under the same program. The aim of such a multi-pronged approach is to eventually help the country to achieve success: both in terms of its economic and environmental priorities. Replacing conventional fuel with biopower has major positive implications for the Indian exchequer, while also helping the country meet its national targets and international commitments.

Source: Press Information Bureau, Government of India.

7.2 Bioeconomy and bio-based materials

Bio-based materials are perceived as potentially greener alternatives than their synthetic counterparts; but this claim is being scrutinized closely. New bio-based materials that may compete with conventional materials are emerging and the opportunities to use them in existing and novel products are being explored. However, bio-based products arising from waste streams, produced at each level of the different sectoral value chains, will truly be classified as products of circular bioeconomy.

Application of these materials can be classified into three broad categories: (i) Food and feed (ii) Products (iii) Energy. Today these novel materials are introduced in almost all sectors of the economy including packaging, cosmetics, construction, and energy.

For many G20 members, their construction sector is the largest single user of metals and uses more minerals than all other industrial sectors combined. Modern buildings use a host of minerals—from concrete to bricks and stones, to glass, plaster, and ceramics—which are non-renewable and often require invasive and polluting processes for their extraction. Traditional and vernacular architecture across the world has always used bio-based materials majorly. As humans adopted a more settled and sedentary way of life, bricks and mortar came to be associated with stability, safety, and prestige. Given the resource scarcity and pollution linked challenges that are being faced, it is important to take inspiration from traditional buildings. For example: lime, industrial hemp, cotton fibres, and timber can be assembled into cladding panels that have comparable performance as their conventional counterparts. Another innovative product in this sector is mycelium bricks that are formed from the vegetative part of fungi. There are several case studies from G20 members demonstrating the potential of bio-based materials for construction purposes (see boxes 5 and 6). Increased penetration of bio-based construction materials significantly improves performance of hard to abate sectors like construction.

Box 5: Paddy stalk bricks of Ladakh

Straw bricks have been designed that are made from paddy straw. These are easy to work with due to their low weight and reduce construction time owing to their large size. This is especially helpful in geographies with a short construction season due to the harsh weather conditions.

The brick is highly insulative, so cavity wall systems are not needed. Moreover, especially trained construction workers are also not required. The binding material used for making the bricks is locally procured clay, which further adds to the sustainability factor. The material, on top of all these benefits, is highly cost effective as well.

Box 6: ICAR technologies

The Indian Council of Agricultural Research (ICAR) has demonstrated thousands of pilot technologies for converting crop waste and by-products into high value commodities. These include recycled paper from jute waste, organic mud production and bio char production, *kulhad* cups using corn cobs, fortified food production, fodder for livestock, porous bricks production, green crematoriums, and several others. These technologies and other required know how are periodically published and are readily available for start-ups to upscale them to a commercial level.

On the packaging front, bio-plastics, primarily PHA (polyhydroxyalkanoates), is another crucial bio-based material that has the potential to utilize and minimize global solid waste. PHA is a polyester produced by fermentation of vegetable materials, like cellulose and/or potato, or corn starch, using microbes. It is biodegradable and equally resistant and durable like plastic. It finds application in medical products (protheses and sutures) and in packaging materials for catering products, disposable containers, and the like. PHA can also be used in injection moulding to manufacture automobile parts and in the textile industry. To give an example, an enterprise by the name of *Orange Fibre* is a leading Italian luxury brand which makes clothing out of orange peel thereby avoiding significant landfill dump. Italy also leads in production of grape leather.

UK is a leading example for sustainable textile production. UK's Waste and Resources Action Plan (WRAP) has launched a new initiative called 'Textiles 2030', which is an ambitious voluntary national plan that seeks to encompass all clothing and textile companies of the country. It aims to change UK's make-use-dispose clothing culture into a circular one.

Lignin is also an excellent biomaterial whose application so far, is mostly restricted to manufacture of fuels, resins, and lubricants. Being the second most abundant organic substance in plants, expanding the horizon of its application is instrumental. An upcoming and crucial use of lignin is in the pharmaceutical sector. It serves as a renewable macromolecular building block for preparation of polymeric drug encapsulation and scaffold material for targeted drug release, guided soft tissue repair, etc.

Canadian agricultural sector has made rapid strides and gone beyond food production in their limited agricultural land. The focus has expanded to feed, fibre, and bio-products along with securing rural livelihoods and providing environmental goods and services to global consumers. There is also an emphasis on minimizing external inputs in agriculture, closing nutrient loops, reducing negative environmental impacts by eliminating discharges. This all-round approach to production in any sector contributes to improved resource utilization and circularity in the sector.

In most of the above-mentioned sectors, R&D followed by technological innovations to identify and/or develop bio-based materials is extremely important. Some of these are in the pilot phase, while others have been rolled out commercially. Usually, demand creation for such products needs push from the government in the form of policies around procurement, economic incentives, awareness generation, etc.

The case is slightly unique for bio-based products in the cosmetic and personal care industry. Over the past decade, cosmetic companies have invested significantly in bio-based ingredients due to the growing consumer demand for advanced cosmetic formulations and efficacious ingredients. Bio-active ingredients derived from natural sources have a well-known positive effect on cosmetic usage, which serve as an incentive for consumers, despite the higher prices. Tapping the niche market to begin with, where people are willing to pay for products which they believe will give them immediate and observable benefits, could be the point of action.

7.3 Business model innovation around Circular Bioeconomy

In the field of circular bioeconomy, although more and more consumers are interested in recognizing a high value for sustainability, many SMEs and start-ups adopt non-innovative and solid business models, risking the Valley of Death, followed by the inability to reach the market. Researchers have examined the barriers and challenges for SMEs, in case of introduction of circular bioeconomy, and concluded that there are internal and external factors hindering development of greener SMEs. These barriers and challenges include lack of appropriate value, culture, and knowledge of consumer preferences, leading to market failure in spite of enough support and funding programmes (Rizos et al, 2016).

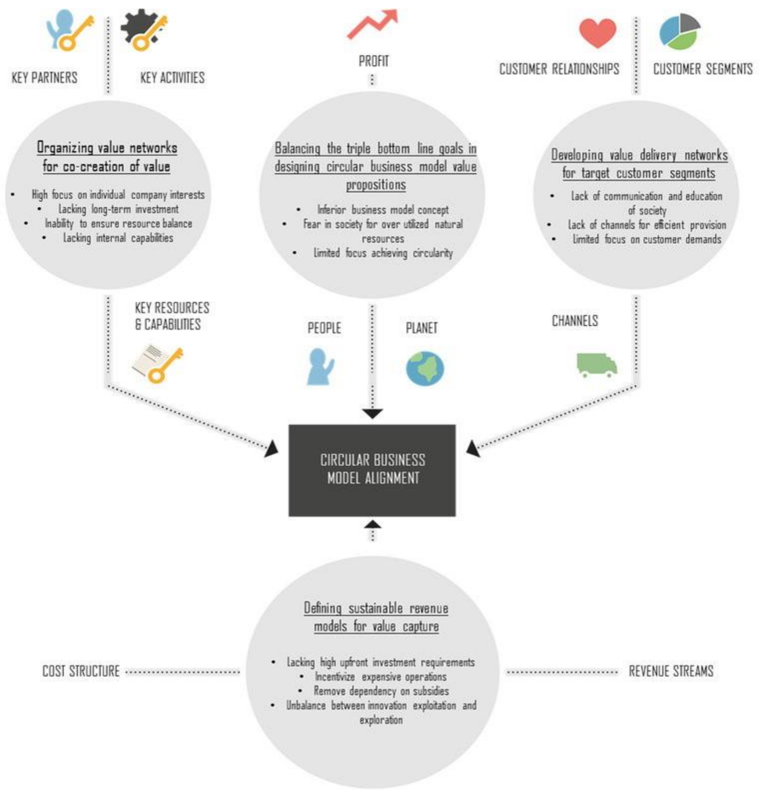


Figure 7: Barriers to developing a circular business model in a bioeconomy

Source: Riem et al 2019

Although designing a business model for a novel bio-based technology is pertinent for the commercialization and eventually for circular bioeconomy, research on business models in the context of the circular bioeconomy is still limited. However, particularities of the circular bioeconomy such as limited understanding of the complex knowledge base, fragmented policy schemes, and diverse innovation types, create challenges for the design of business models. Figure 7 highlights the barriers to developing a circular business model in a bioeconomy. Box 7 presents the case of EU's bioeconomy strategy.

Box 7: Case study EU's policy pathway

In 2012, the European Union launched the first bioeconomy strategy, which was updated in 2018, providing the opportunity to create a coherent political framework to accelerate the deployment of a sustainable bioeconomy and maximize its industrial contribution for fulfilment of the SDGs. Its prime focus was unlocking investments and markets, deployment of local bio-economies, and understanding ecological boundaries of bioeconomy. It subsequently led to formation of bio-based industries–Joint undertaking (BBI-JU) with an EUR 3.7 billion investment. Today, it represents the most remarkable example of industrial cooperation in Europe, in the industrial biotechnology sector, based on a public-private partnership model and is destined to become the reference point for bioeconomy. Industrial biotechnology is rightly considered a "key enabling technology" for the development of bioeconomy. It can generate value from what is deemed to be worthless, or even a cost to businesses (i.e., CO_2, biomass, or waste); transform waste into a resource according to the principles of the circular economy.

Even though a lot of industrial researches have devoted enormous investments to demonstrate sustainable circular bio-based business models—capable of overcoming the "Valley of Death" through alternative strategic orientations of "technological-push" and "market-pull"—there are numerous challenges to these business models. Their success is hampered by several factors, including high production costs, lack of consumer awareness of related benefits, and low investor confidence in high-risk models.

There exists a gap between innovative research studies and profitable commercial exploitation. The hurdles in overcoming this gap, reaching the market, and successfully attracting private investors are due to limited financial resource availability to young start-ups, lack of organizational skills, coupled with associated risks of early-stage (unproven and proven technologies) and middle-stage (pre-commercial) technologies. Raising the inventor's awareness and encouraging a trust relationship with a potential financial investor, or business angel, represent crucial tools that need equal emphasis. Critical market acceptability affects the last phases of the process, in which the scalability of the process and technology readiness level (TRL) have to be effectively demonstrated. Finally, an inherent problem linked to the local availability of biomass supply suitable for continuous processes, transformation cost, and transformation conditions is a big concern.

The two main guides for a technological innovation heading in the right economic and institutional direction are represented by science and technology (push) and market (pull). Market-pull is a situation in which the market demands a product (or service) type, or defines a problem, so designers and producers make a product to meet that need. While technology-push is the state in which the producer creates a product type and the demand for that type. Technology-push related product development is mainly based on the belief that the supplier recognizes a market need even before the market does. In the case of bioeconomy sector, and even more in circular bioeconomy, the trade-off between the "market-pull" and "technology-push" approach plays a crucial role in the success of new bio-based business models for start-ups or SMEs. For instance, PHA is a biopolymer which meets the former criteria, as it is a technological marvel, but its use is limited in terms of its commercialization; with several disadvantages compared to conventional plastics. Conversely, bio-based aromatic compounds meet the market pull strategic orientation even more.

7.4 Circular bioeconomy catalysing MSME competitiveness

Micro, small and medium-sized enterprises (MSMEs) play a major role in the global economy, particularly in emerging economies. MSMEs contribute around 50% to the global GDP and form 60–70% of all employment. (United nations 2022, MSME data). These jobs are especially significant because they contribute to local economies and help in sustaining livelihoods among working poor, women, youth, and other vulnerable sections. Despite their crucial role, a vast majority of MSMEs tend to be less productive and lucrative than large firms. Productivity gap between SMEs and large companies in Germany and Turkey is 41% and 60%, respectively (United Nations 2022, MSME data). This gap can be attributed to MSME-specific barriers, related to scaling up and accessing strategic assets, as well as the challenges they face at times in accessing the global value chains—where the larger companies may have an advantage with a well-established capital base and access to finance mechanisms.

The rapid development of circular bioeconomy has emphasized the high business potential of the enhancement of renewable biological resources. There is no dearth of entrepreneurs who have brilliant ideas of making the best use of waste resources. For instance, there are several start-ups globally that are now focusing exclusively on developing sustainable food packaging solutions. Many of them also have been successful at a regional or national level. A noteworthy mention from India is a Rajasthan-based company making bioplastics from agricultural waste, which is then mixed with other biodegradable polymers. Their products are compostable, biodegradable, and water soluble, thus preventing further contribution to marine pollution. This is a case in point of a successful SME through the circular bioeconomy business model. In fact, MSMEs needs to be introduced into each stage of the bio-economic value chain; especially the feedstock segment. An upcoming waste management entrepreneur also needs to push into the bio-economic value chain to expand their horizon.

Nevertheless, for MSMEs to continue playing a sustained role in global economies, it is still essential to participate in global trade. Along with their economic relevance, participation in global value chains is also important as they are a well-established vehicle for productivity spillover to the local level. Development of local or intra-national supply chains within economies may help connect MSMEs to global value chains. In this aspect as well, circular bioeconomy has immense potential to serve as the catalyst for improving existing competencies of MSMEs, increasing their competitiveness for more productive and lucrative outcomes out of the global value chains. In the presence of well-established incentives, waste can be quickly turned into wealth provided markets, for such products also exist. For example, establishment of biorefineries, increasing blending targets, and creating awareness among people for better acceptance of blended fuel.

8. Bioeconomy and Society

A circular bio-economy is not just about mending environmental wrongs, given the fact that evidence shows it can bring big opportunities and positive impacts across various industries, sectors, lives, and society.

Circular bioeconomy aims to provide sustainable wellbeing through the provision of ecosystem services and the sustainable management of biological resources (plants, animals, micro-organisms, and derived biomass, including organic waste). These are transformed in a circular manner into food, feed, energy, and biomaterials—within the ecological boundaries of ecosystems that it relies on and thus, intertwined with society. This is depicted in Figure 8.

It is important to involve society in this transformation to shape the change towards sustainability.

The fundamental benefits that bioeconomy brings for the society are:

- **Sustainability**: Circular bioeconomy promotes the sustainable use of natural resources, which helps to preserve the environment for future generations.
- **Economic growth**: It can provide new economic opportunities and contribute to local and national economic growth.
- **Job creation**: Circular bioeconomy can create new jobs in sectors such as agriculture, forestry, and renewable energy.
- **Food security**: By promoting sustainable agriculture and forestry practices that can increase crop yields and reduce the need for chemical fertilizers and pesticides, circular bioeconomy can help increase food security.

- **Climate change mitigation**: Circular bioeconomy can contribute to reduce greenhouse gas emissions by promoting the use of renewable energy and sustainable land-use practices.
- **Social benefits**: It also contributes to social benefits, such as improving rural development, supporting local communities, and promoting equity.

On the overall, circular bioeconomy has the potential to create a more sustainable, prosperous, and equitable society.

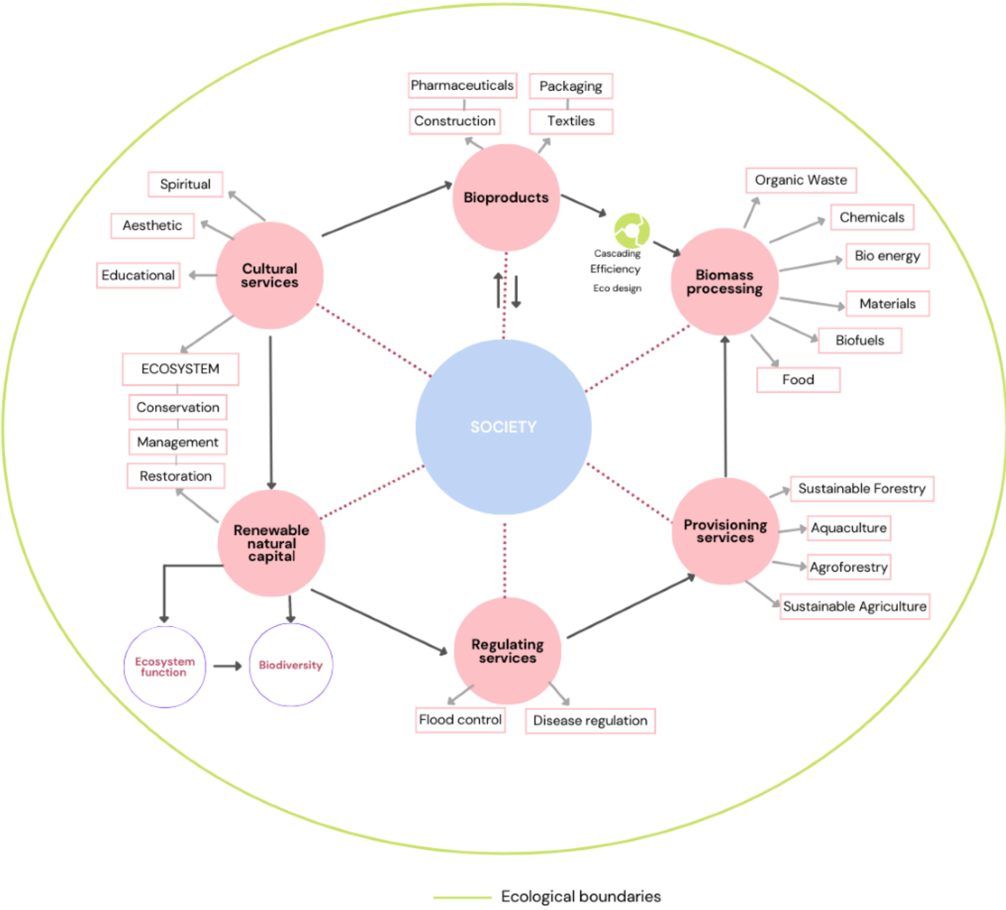


Figure 8: Circular bioeconomy and society

Source: Circular bioeconomy alliance

Circular bioeconomy and indigenous communities

Circular bioeconomy as a nature-based economy is restorative and regenerative by design. For indigenous peoples worldwide, it has been the essence and a way of life for millennia. From cashew harvest by-product fueling a new beverage industry in Benin (helping farmers supplement their off-season incomes) to repurposing marine plastic waste in the manufacturing of high-value products (such as architectural and decorative pieces) and creating green jobs as well as sustaining Costa Rican fishing villagers' livelihoods—all these practices are synonymous to circular bioeconomy. There is a need to recognize and learn from grassroots communities, as well as to document and scale-up indigenous communities and their traditional technologies and practices in economy. A few case studies are presented in boxes 8 and 9, respectively.

Box 8: Indigenous-owned producer collective in India

Aadhimalai Pazhangudiyinar Producer Company Limited, an indigenous-owned producer collective located in the Nilgiri Biosphere Reserve in the Western Ghats of southern India, where traditional collection and production practices of non-timber forest products (honey, amla, soap nuts and berries) are helping ensure the management of precious resources of the reserve, along with sustaining the livelihoods of indigenous communities. For example, the rituals and traditional ways of indigenous 'honey hunters' and the marking of wild bee hives means that hives are not overharvested and bee colonies remain stable. Such practices are critical for a thriving biodiversity and sustianing the community.

Box 9: Indigenous women of the Talamanca region in Costa Rica

In Costa Rica's Talamanca region, indigenous Bribri women are championing sustainable agroforestry practices through a tradition. Known as *fincas integrales*, it's a system that mimics the diversity and productivity of the forest: timber trees provide shade for fruit trees, which in turn shelter medicinal plants, amid all of which livestock and even wildlife thrive. Talamanca is also home to vast monoculture plantations of crops like bananas—a completely different farming system that relies on the heavy use of pesticides and practices that destroys the land. Drawing on their traditional agricultural practices and knowledge, waste becomes an input for the next cycle, animals play their part in fertilizing the soil, and weeds provide useful functions for growing crops. Traditional medicinal plants and local native seed varieties are grown and exchanged, creating local exchange fairs between families and communities, which help strengthen food sovereignty and security as well as community resilience in the face of external shocks. This is a system rooted in reciprocity and self-sufficiency.

While indigenous peoples have accumulated valuable traditional knowledge about nature and sustainable practices, this knowledge often is not appropriately recognized as an important tool. Box 10 provides a brief about an initiative by Canada to acknowledge traditional knowledge.

Box 10: The establishment of the Indigenous Circle of Experts (ICE) in Canada in 2016

ICE comprises indigenous and non-indigenous citizens of Canada, who together make progress for conservation of biodiversity using traditional knowledge in accordance with the Pathway to Canada Target 121. The Pathway underscores the protection and conservation of areas identified and managed in partnership with indigenous governments, consistent with the principle of free, prior, and informed consent. This demonstrates that traditional knowledge of indigenous peoples can be preserved and protected to better their environment in collaboration with states; thereby creating a symbiotic relationship.

Circular bioeconomy policies and strategies provide a key entry point for the integration of rich indigenous knowledge with local, subnational, and national climate action.

9. Circular Bioeconomy and Linkages with LiFE

In 2021, Mission LiFE (i.e., 'Lifestyle for the Environment') was introduced by India's Prime Minister, Shri Narendra Modi, during the 26th United Nations Climate Change Conference of the Parties (COP26) in Glasgow, to put forward green and environment friendly solutions in every aspect of life to effectively achieve climate and energy goals. The idea promotes an environment-conscious lifestyle that focuses on 'mindful and deliberate utilization' through advocating sustainable choices and behavioral changes by 'Pro-Planet People'. In global discussions, India has advocated for sustainable lifestyles and climate justice; lifestyle is a major area of focus for India's G20 Presidency as well (MEA, 2022).

Lifestyle for the Environment (LiFE) and bioeconomy are joined by the common ideal to reconcile economic, environmental, and social goals. Key concepts around LiFE include reduce, reuse, and recycle, along with utilization of traditional knowledge, sustainable bio-based material, and adaptation of circular economy. The major features of LiFE are in coherence with the objectives of circular bioeconomy, includes knowledge-based production and utilization of biological resources in a circular way in order to support resource value chains; thus helping crucial economic sectors. Bioeconomy supports various social and technological innovations that can contribute towards sustainable lifestyles.

The link between LiFE and circular bioeconomy is an emerging area of interest. Strengthening the connection of LiFE with circular bioeconomy would involve advocating for policies that carve a role for governments, businesses, and citizens especially in terms of awareness, as well as involving them as co-creators of solutions linked to both products and services involving circular bioeconomy across issue sectors and areas. Technological innovations involve upcycling and recycling of bio-based products in sectors like bioenergy, textile, cultivation, and bio-based cosmetics. Social innovations would revolve around sufficiency, close affinity to nature and traditional knowledge. Figure 9 presents a framework for circular bioeconomy and its linkages with lifestyles.

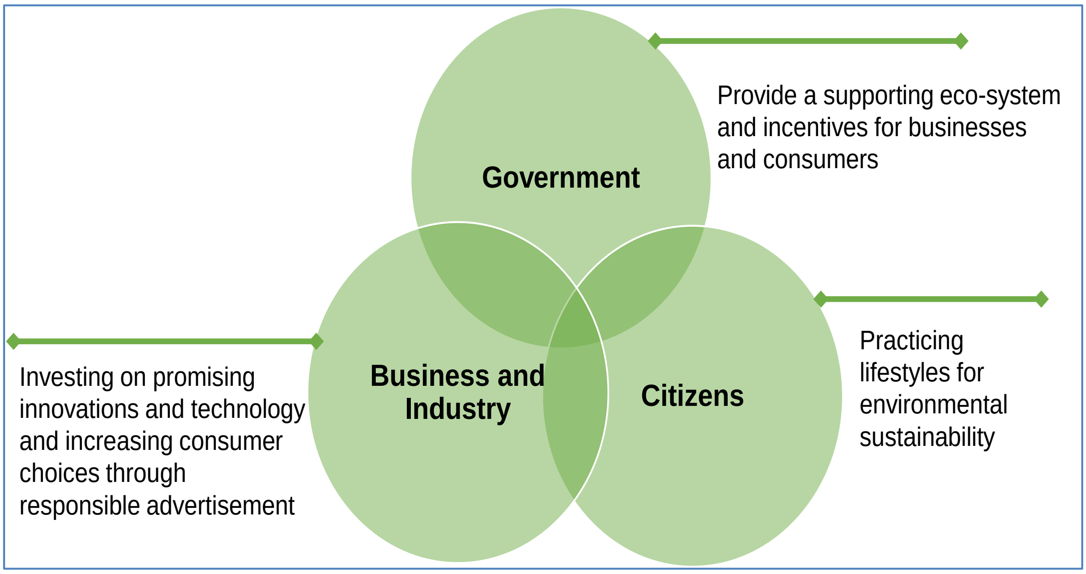


Figure 9: Framework for circular bioeconomy and its linkages with lifestyles

Source: European Bioeconomy Scene 2019

10. Policy Recommendations

10.1 Promoting innovative circular bioeconomy technologies, business models, and institutional structure

While businesses are exploring and developing innovative business models to promote sustainable technologies and products around circular bioeconomy models, there is a need to incentivize and support to translate these emerging technologies and processes so that they are scalable and commercially viable. Identifying key pain points and developing a consensus for a concerted action through favourable market regulations and policies—including incentives, product standards, public procurements, conducive trade policies through Free Trade Agreements—would help in a faster resolution of the supply chain, technology, and market access challenges. Existence of a dedicated institutional structure can bring marked change in the ecosystem. Brazil's Vice Minister on Circular Bioeconomy, under the Environment Ministry, has accorded special attention to circular bioeconomy in the Amazon region for adding values to Brazilian socio-biodiversity products, from family farming by traditional communities. Post implementation policies that go beyond public procurement and involve active scanning, creating database, rewards, and incentivization are need of the hour.

10.2 Consensus building areas for G20

Considering that circular bioeconomy is an emerging area of work, there is ample scope for consensus building in the G20 Forum. First and foremost, there needs to be a common understanding of options for circular bioeconomy. It is also important to critically examine the implications of circular bioeconomy for various contexts in a collaborative manner.

Area 1: Launch the Global Circular Bioeconomy Partnership (GCBP)—This should serve as a platform for sharing best practices across domains of policy, science-technology-innovation, industry (including MSMEs), institutions, and citizen engagement. The platform should be able to engage with G20 members and non-G20 members to forge multistakeholder partnerships involving governments, world-class research institutions and the private sector. The platform should also be able to facilitate a dialogue on innovative financing and business models. This platform would involve and encourage MSMEs, farming communities, municipalities, communities, and citizens to adopt practices for utilizing waste streams and byproducts to manufacture bio-based products and generate bioenergy.

Area 2: Establish the BIOMET (bio-circularity metrics) Initiative—While many G20 members are drawing up action plans on circular economy, it is also important to focus on circular bioeconomy. A first step towards the same would be establishing an initiative that defines the metrics and an indicator framework for bio-circularity metrics. This initiative should convene empirical studies to help estimate circular bioeconomy's potential, as well as impacts of circular bioeconomy measures. There is a need to come up with a comprehensive experiential database.

Area 3: Development of standards of international trade, primarily for developing countries that have the highest potential to benefit from bio-based material production is required. The parameters considered should be acceptable to the developing countries and fixed in consultation with them, to allow mitigation of non-tariff barriers to trade.

10.3 Explore blended finance opportunities for promoting innovation

According to OECD, blended finance is the strategic use of development finance for the mobilization of finances addition to the existing private capital towards sustainable development in developing countries.

Blended finance is crucial to both innovation and scalability of circular bioeconomic projects due to multiple barriers that plague smooth business development.

Blended finance has successfully worked in the implementation of SDGs. Over past decades, blended financing facilities have shown an upward trend for greener causes. A lot of this transition is due to the government policy and general awareness about the significance of these greener causes. However, blended finance has additional benefits, as it potentially creates a positive feedback loop in financing. Previously uninterested stakeholders may also be willingly to pitch in on seeing the wide scope of projects and wide scale involvement of several parties. Blended funds can also mobilize investors itself at multiple levels. It also enables more strategically targeted finance into requisite sectors and can draw funds from institutional investors as well.

10.4 Forge international cooperation across public and private sectors.

There is a general agreement that circular bioeconomy holds the potential to provide global environmental benefits and seems promising to promote the much-needed transformation at the national level, through new cycles of innovation and investments. To foster these innovations and investments at the grassroot level, collaborations among the G20 members on advances in science and technology and sharing existing experiences would be valuable. However, effective progress will only be possible if national strategies evolve within a coherent and harmonized global framework. G20 members have a strategic role in promoting this transition not only among its members, but within the broader development community. International cooperation is crucial for effective contribution for the practical actions to reach till the local level, with cooperation among interdisciplinary actors and financial support. Global reflections are required in order to measure the potential benefits of small-scale projects, evaluating the time needed to move towards a sustainable future in low-income countries.

An international collaboration between public and private entities will enable knowledge exchange, sharing of experiences, know-how, and expertise. International cooperation—both on the economic and political front—should focus on promoting a common understanding of circular bioeconomy objectives and strategies to deliver several concrete public goods on a global basis, facilitating the exchange of technology. This global cooperation can coordinate funding from both public and private sectors, along with formulating common methods for the development of credible and effective economic indicators to support public and private decision-making, as well as general principles of good practice to support these processes. At the same time, it is important to periodically assess the activities and development happening under existing platforms, like International Advisory Council on Global Bioeconomy, International Bioeconomy Forum, World Bioeconomy Forum. Representative membership, funding, equitable sharing of information and benefits are the key responsibilities of such platforms.

There is a requirement for generating greater consensus among different stakeholders (both public and private) on the potential of circular economy, for promoting R&D support for bioeconomy-related technological challenges and for market development of bioeconomy products to enhance circularity.

10.5 Harnessing collaboration on building a comprehensive experiential database

Developing economic opportunities for circular bioeconomy requires significant R&D. Business, academic institutions (including government funded and private), think tanks, etc., are actively pursuing various R&D activities. There is no doubt about the development of new technologies in recent years that has been a game changer for circular business models while opening new opportunities faster than ever before.

However, sharing of non-critical data (including leads and findings) can provide insights to further improve the efficient use of resources, for current and future community of stakeholders.

The utilization of new knowledge will help in creating values for businesses in manufacturing new products, while reducing costs and risks and increasing revenues. Currently, related data and information sharing is largely confined to a specific business entity, or often between trusted players in the value chain.

In the presence of unprecedented benefits of data and knowledge sharing in accelerated transition of circular bioeconomy, there is a need for enhanced formal collaboration among key stakeholder in sharing experiential data emerging from related research and development activities. However, policies related to regulation on data governance, regulation on the free flow of nonpersonal data, and open data will deepen confidence and support collaboration and partnerships.

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Annexure

Annexure 1: SDG Targets Linked to Circular Bioeconomy

SDG 2 (End hunger)
Target 2.3 – "double the agricultural productivity and incomes of small-scale food producers (...), including through access to (…) financial services"
Target 2.4 – "ensure sustainable food production systems, (…) that help maintain ecosystems"
Target 2.5 – "maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species"
Target 2.a – "Increase investment (…) in rural infrastructure, agricultural research and extension services, technology development"
SDG 4 (Quality education)
Target 4.4 – "increase the number of youth and adults who have relevant skills"
Target 4.7 – "ensure that all learners acquire the knowledge and skills needed to promote sustainable development"
SDG 6 (Clean water)
Target 6.3 – "improve water quality by reducing pollution"
Target 6.4 – "increase water-use efficiency across all sectors"
Target 6.5 – "implement integrated water resources management"
Target 6.6 – "protect and restore water-related ecosystems"
Target 6.a – "including (…) water efficiency, wastewater treatment, recycling and reuse technologies"
SDG 7 (Clean energy)
Target 7.2 – "increase substantially the share of renewable energy in the global energy mix"
Target 7.3 – "improvement in energy efficiency"
Target 7.a – "access to clean energy research and technology" and "promote investment in (…) clean energy technology"
Target 7.b – "upgrade technology for supplying modern and sustainable energy services"
SDG 8 (Decent work and economic growth) and SDG 9 (Industry, innovation, and infrastructure)
Target 8.2 – "higher levels of economic productivity through diversification, technological upgrading and innovation (…)"
Target 8.3 – "support productive activities (…), creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises"
Target 8.4 – "Improve (…) resource efficiency in consumption and production"
Target 8.5 – "achieve full and productive employment"
Target 9.2 – "Promote inclusive and sustainable industrialization (…), significantly raise industry's share of employment and gross domestic product"
Target 9.3 – "Increase the access of small-scale industrial (…) to financial services (…) and their integration into value chains and markets"
Target 9.4 – "retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes"
Target 9.5 – "Enhance scientific research, upgrade the technological capabilities of industrial sectors"
Target 9.b – "Support domestic technology development, research and innovation (…) for, inter alia, industrial diversification"

SDG 11 (Sustainable cities and communities)
Target 11.6 – " by paying special attention to (…) municipal and other waste management"
Target 11.a – "by strengthening national and regional development planning"
Target 11.b – "implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change"
SDG 12 (Responsible consumption and production)
Target 12.2 – "sustainable management and efficient use of natural resources"
Target 12.3 – "reduce food losses along production and supply chains"
Target 12.5 – "reduce waste generation through prevention, reduction, recycling and reuse"
Target 12.6 – "Encourage companies (…) to adopt sustainable practices"
Target 12.7 – "Promote public procurement practices that are sustainable"
Target 12.8 – "ensure that people everywhere have the relevant information and awareness for sustainable development"
SDG 13 (Climate action)
Target 13.2 – "Integrate climate change measures"
Target 13.3 – "institutional capacity on climate change mitigation, adaptation, impact reduction"
SDG 14 (Life below water)
Target 14.1 – "reduce marine pollution"
Target 14.2 – "sustainably manage and protect marine and coastal ecosystems" and "take action for their restoration"
Target 14.3 – "Minimize and address the impacts of ocean acidification"
Target 14.4 – "science-based management plans, in order to restore fish stocks"
Target 14.7 – "sustainable management of fisheries, aquaculture'
Target 14.a – "Increase scientific knowledge, develop research capacity and transfer marine technology"
Target 14.b – "access for small-scale artisanal fishers to marine resources and markets"
SDG 15 (Life on land)
Target 15.1 – "ensure the (…) sustainable use of terrestrial and inland freshwater ecosystems and their services"
Target 15.2 – "sustainable management of all types of forests, (…) restore degraded forests and substantially increase afforestation and reforestation"
Target 15.3 – "restore degraded land and soil"
Target 15.4 – "conservation of mountain ecosystems, including their biodiversity"
Target 15.5 – "protect and prevent the extinction of threatened species"
Target 15.9 – "integrate ecosystem and biodiversity values into national and local planning"
Target 15.a – "increase financial resources (…) to conserve and sustainably use biodiversity and ecosystems"
Target 15.b – "finance sustainable forest management (…), including for conservation and reforestation"
SDG 17 (Partnerships for the goals – Policy and institutional coherence)
Target 17.14 – "policy coherence for sustainable development"
Target 17.17 – "effective public, public-private, and civil society partnerships"
Target 17.19 – "develop measurements of progress on sustainable development", "support statistical capacity-building"

Source: *Based on Ronzon and Sanjuán (2020)*

Presidency Outcome Document on Circular Bioeconomy

Background & Context

Bio-based resources when sustainably sourced and managed may contribute to reduce the dependence on fossil fuels and provide sustainable alternatives. Many bio-based resources from non-sustainable waste streams are a global issue since its vast majority is currently burned or landfilled, contributing to pollution, biodiversity loss and climate change. Therefore, use of biowaste streams such as municipal waste, agricultural residue, industrial waste as well as crops suited for use on degraded lands can enhance circularity in bioeconomy.

Need for Circular Bio-economy Transition

Apart from reducing dependence on primary resources, transition towards a circular and sustainable bioeconomy offers holistic and cross sectoral benefits.

There are several case studies including successful interventions, opportunities and business model innovations from G20 members that demonstrate the potential of use of bio-based resources across different sectors and applications. Further, given the momentum towards the transition to clean and low-carbon economy pathways that is growing in the G20 and beyond, circular and sustainable bioeconomy transition is an important area for consideration.

Knowledge Exchange Opportunities

The G20 Presidency of India prepared the Technical Document for Knowledge Exchange on Circular Bioeconomy, which aims to identify opportunities, policy options, business models and institutional architecture for countries to promote the use of sustainably sourced bio resources such as agriculture residues, industrial residues, municipal bio-waste etc. These bio-resources can be the primary raw material to substitute mineral resources, which will help reduce primary material extraction and lead to enhanced use of organic waste and the recycling of biological resources. It supports the idea of bringing the industries closer to nature by adopting circular bio-based solutions including those related to material innovation.

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