BIOECONOMY

TREND REPORT

ICDK SHANGHAI

Ministry of Higher Education and Science Denmark

MINISTRY OF FOREIGN AFFAIRS OF DENMARK

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LIST OF ABBREVIATIONS

DTU - Technical University of Denmark

EU - European Union

GDP - Gross domestic product

IP - Intellectual property

NBP - National Bioeconomy Panel

R&D - Research and Development

PPP - Pre-Pilot Plant

SDG - Sustainable Development Goals

SME - Small and medium enterprises

UN - United Nations

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FOREWORD

This report serves as a mapping of the bioeconomy landscape in China and Denmark, with a focus on identifying areas of potential collaboration and shared growth. At Innovation Centre Denmark Shanghai (ICDK Shanghai), we are committed to facilitating partnerships, supporting sustainable development, and driving innovation within bioeconomy sectors. This report specifically focuses on bioeconomy aspects such as circular economy, sustainable agriculture, marine-based resources, and resource efficiency, which align closely with Denmark's strategic priorities. For further insights or to explore collaborative opportunities, please contact ICDK Shanghai.

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EXECUTIVE SUMMARY

The report explores the bioeconomy strategies of both China and Denmark, emphasizing the political landscape, strategic approaches, and collaboration opportunities between the two nations. Bioeconomy involves the sustainable production and utilization of biological resources across multiple sectors, including agriculture, bio-energy, and circular economy. It seeks to drive greener production methods, sustainability, and economic growth, addressing critical global challenges like climate change and resource scarcity.

China's bioeconomy strategy, underpinned by its 14th Five-Year Plan (2021–2025), sets ambitious goals in areas such as bio-agriculture, bio-materials, and bio-energy. The strategy aims to establish China as a global bioeconomy leader by 2035, targeting a total bioeconomy value of approximately €2.8 trillion by 2025. China's approach emphasizes integrated innovation, with a focus on biosecurity, environmental protection, and sustainable resource utilization, leveraging its extensive biological resources and technological advancements.

Denmark, while lacking a formal bioeconomy strategy, excels in sector-specific areas like bio-energy and circular economy. The Danish Circular Economy Strategy, introduced in 2018, highlights maximizing resource efficiency, minimizing waste, and promoting circular design. Denmark's global leadership in biogas production, bio-refining, and sustainable agriculture is supported by robust policies fostering innovation and sustainability. Additionally, Denmark has become a key player in the European bioeconomy, with a particular focus on biogas infrastructure and renewable resource integration.

When comparing the two nations, both emphasize sustainability and innovation. China adopts a broad, ambitious strategy, seeking global leadership across multiple bioeconomy sectors. Denmark, on the other hand, adopts a more targeted approach, prioritizing bio-energy and circular economy principles. Despite their different strategies, both nations highlight the importance of resource efficiency, innovation, and collaboration in advancing their bioeconomy goals.

The report identifies several areas for potential collaboration between China and Denmark, including agricultural residues, forestry biomass, marine-based feedstocks, and organic waste streams. Denmark’s expertise in circular economy and sustainable resource management aligns with China's scale and implementation experience. Potential collaboration areas could include waste management, sustainable agriculture, and marine biomass processing.

The roadmap for stakeholders highlights existing frameworks such as the Sino-Danish Green Joint Work Programme, which provides a basis for policy alignment and cooperative projects. Areas like joint research and development and knowledge exchange platforms offer pathways for enhancing bioeconomy collaboration. ICDK Shanghai plays a pivotal role as a facilitator, connecting stakeholders, offering market insights, and fostering innovation partnerships.

The report highlights the distinct approaches of China and Denmark to bioeconomy development, outlines opportunities for collaboration, and underscores the potential for both nations to contribute to a sustainable and innovative future. ICDK Shanghai remains dedicated to supporting these efforts and fostering impactful partnerships.

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Please contact ICDK Shanghai if you wish to discuss the bioeconomy in greater detail.

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1. INTRODUCTION

Bioeconomy involves producing and utilising biological resources, encompassing various sectors from agriculture to bioenergy, and transforming life science knowledge into sustainable products. In the European Union's Bioeconomy Strategy (2018), the EU explains that "bioeconomy covers all sectors and systems that rely on biological resources – animals, plants, micro-organisms and derived biomass, including organic waste – as well as their functions and principles". Bioeconomy seeks to merge circular economy principles, resource efficiency, and biotechnological advances. This transformative approach enables greener, more sustainable means of production, which simultaneously fosters innovation, enhances economic development, promotes job creation, and addresses food security issues.

The overarching aim is to transition from a reliance on finite and polluting fossil resources to a more sustainable, bio-based economy, thereby aligning economic growth with environmental protection. Moreover, the bioeconomy can play a pivotal role in sustainable development, helping countries meet their commitments to the UN Sustainable Development Goals. By harnessing sustainably sourced biomasses and residual and municipal waste through biorefinery technologies, bioeconomy holds the promise of preserving biodiversity and driving prosperity in a manner consistent with environmental objectives.

Both China and Denmark have developed policy frameworks centered around the bioeconomy. China has delineated a comprehensive bioeconomy strategy in the country's 14th Five-Year Plan from 2021. Denmark's approach also includes significant efforts in this area, such as the Strategy for a Circular Economy introduced in 2018, which emphasized integrating circular principles into various sectors, including bio-based industries. This strategy focused on strengthening enterprises, leveraging data and digitalization, promoting circular economy principles in design, changing consumption patterns, establishing functional markets for waste and recycled materials, and maximizing value from buildings and biomass (Regeringen, 2018).

Since then, Denmark has further strengthened its focus on bioeconomy-related areas. For instance, in 2024, the Danish government launched a strategy for biosolutions aimed at advancing sustainable innovation in agriculture and food production, alongside a new life science strategy targeting the doubling of exports to €46.98 billion. Additionally, the National Bioeconomy Panel continues to provide recommendations on how to optimize the utilization of biomass resources in Denmark. These developments highlight Denmark's ongoing commitment to fostering sustainable growth and innovation in the bioeconomy sector.

While both China and Denmark are making significant strides toward bioeconomy, their approach to integrating the principles varies. China's expansive bioeconomy strategy presents opportunities for integrating circular economy principles. However, it does not explicitly centre on them.

In contrast, Denmark's strategy mainly focuses on circular economy principles, contributing to the achievement of all the 17 UN Sustainable Development Goals. China's expansive plan contrasts with Denmark's interdisciplinary research and strategy focus. These nuances, combined with the overarching goals of both nations, will be meticulously explored in the subsequent sections of this report. This in-depth examination aims to provide a comprehensive understanding of the bioeconomy sectors in China and Denmark, shedding light on collaboration opportunities, challenges, market gaps, and the current state of bioeconomy-related policies and stakeholders in these nations.

The first section of the report focuses on a comparative analysis of the strategic approaches of the two countries, shedding light on their unique characteristics and implications. A following feedstock analysis will delve into specific types of feedstock to explore their usage and potential, and how the two countries have used feedstock. Lastly, the report highlights potential areas of collaboration and lays out a roadmap for Danish stakeholders relating to the entirety of the field of bioeconomy.

2. REVIEW OF THE POLITICAL LANDSCAPE OF BIOECONOMY IN DENMARK AND CHINA

2.1 THE CONTEXT AND VISION OF THE CHINESE BIOECONOMY – CHINA'S FIVE-YEAR-PLAN ON BIOECONOMY

China's bioeconomy has experienced significant growth in recent years, driven by strategic efforts to harness bioresources and promote sustainability. This growth can be traced back to the 13th Five-Year Plan, which laid the groundwork for this burgeoning sector. By 2015, China's bioeconomy had already exceeded €465 billion, as reported by Tao and Ouyang (2022). Building on this momentum, China's 14th Five-Year Plan, introduced in 2021, outlined an ambitious vision for the future. It emphasized the importance of integrated innovation and development across key sectors, including bio-breeding, bio-materials, bio-energy, and related industries, thereby expanding and enhancing the bioeconomy's scale (The State Council, 2021).

The National Development and Reform Commission further solidified this commitment by issuing the "14th Five-Year Plan for Bioeconomy Development" in May 2022. This comprehensive plan outlined specific tasks and objectives for bioeconomic development, aiming to achieve a total bioeconomy value of €2.9 trillion by 2025, making it a powerful driver of high-quality development (National Development and Reform Commission, 2022).

China's bioeconomic strategy unfolds in two distinct stages, as detailed by Zhang et al. (2022). The first stage, spanning from 2021 to 2025, focuses on expanding and strengthening the bioeconomy by integrating sectors such as medicine, healthcare, agriculture, forestry, energy, environmental protection, and materials. This stage aims to drive high-quality development and the sustainable utilisation of biological resources. In the second stage, from 2026 to 2035, China aspires to become a global leader in bioeconomy by establishing advanced technology, robust bioindustries, extensive integration and applications, secure resource support, controllable bio-risks, and a comprehensive institutional R&D system.

This bioeconomic plan prioritizes the higher-level needs of society, with a strong emphasis on medicine, food, life, and security. It identifies four key development areas: bio-medicine, bio-agriculture, bio-manufacturing (including the development of biomaterials), and bio-security (improving biosecurity risk control, prevention, and governance systems). Integrated into all four key development areas are environmental protection and bioinformatics, emphasizing the use of biological resources to foster innovation in related technologies. The anticipated market growth of the bioeconomy is expected to surpass that of the information economy, with the bioeconomy driving future economic growth in areas such as human health, green agriculture, and biosecurity (Zhang et al., 2022).

2.2 DENMARK'S (UN)OFFICIAL STRATEGY ON BIOECONOMY

Denmark, as of now, lacks an official bioeconomy strategy. However, it demonstrates commitment through various initiatives like the Growth Plan for Water, Bio and Environmental Solutions (2013), and the Circular Economy Strategy (2018). Renowned for its push towards green energy, Denmark excels in bio-energy, notably biogas, supported by government initiatives and renewable energy targets. Denmark's biogas sector is poised to receive DKK 13.6 billion (1.823.337.040,00 EUR) in subsidies till 2049, in alignment with the objectives of the 2020 Climate Action Plan (Ministry of Foreign Affairs of Denmark). The country aims for 100% biogas consumption, backed by substantial raw material reserves. Strong policy support and technological advancements have fostered a robust bioenergy cluster, offering market opportunities for industrial-scale biogas plants.

The Growth Plan for Water, Bio and Environmental Solutions from 2013 anticipates Denmark's potential to make significant strides in diverse sectors, paving the way for international prominence, business growth, and a shift towards green solutions (Regeringen 2013). The plan emphasises attracting investments, fostering innovation, enhancing quality and diversity, and ramping up export efforts to bolster the food sector. Investments, particularly in start-ups, are particularly critical for the growth of agriculture and food companies. A focus is also placed on educational endeavours and catalysing collaboration between industry, academia, and researchers (Regeringen, 2013). While the food sector gets considerable attention, Denmark's ambitions extend to the spheres of water, bio, and environment.

The plan strengthens the importance of harnessing Denmark's abundant water resources for sustainable purposes, promoting innovative bio-solutions, and adopting eco-friendly practices. Given Denmark's leading position in sustainable water management, the plan envisages establishing Denmark as a global hub for water tech solutions. Furthermore, Denmark's rich biodiversity offers promising avenues for bio-based solutions, which the plan aims to capitalise on. Additionally, the plan aims to enhance efficiency in the water sector by gradually reducing charges for high-volume consumers. It encourages the commercialization of biobased solutions, aligning with EU requirements for biofuel admixture and promoting research and development of biobased products. Denmark's pharmaceutical sector further contributes to the bioeconomy, with plans to bolster R&D capabilities in partnership with the private sector.

The Danish Circular Economy Strategy (2018) prioritizes maximizing resource utilization, minimizing waste, and promoting reuse, repair, and recycling. It advocates utilizing biomass for medicines, bio-based products, and food ingredients while phasing out problematic chemicals to facilitate recycling. Denmark aims to lead in circular technologies, including bioeconomy and sustainable construction, with measures to incentivize businesses and improve access to recyclable waste. The strategy outlines six key areas for action: empowering businesses, leveraging data and digitalization, promoting circular design and consumption, creating a market for waste materials, and maximizing value from buildings and biomass. Digital solutions are crucial for waste reduction and resource efficiency, with plans to promote data-driven circular opportunities through pilot projects and challenge platforms. Initiatives focus on circular product design, waste management, and regulatory improvements, including a national plastic action plan and expanded deposit-refund systems.

Government proposals include introducing sustainability standards for buildings, aimed at evaluating and promoting their environmental performance and resource efficiency. These standards encourage sustainable

construction practices, the use of eco-friendly materials, and improved energy efficiency. Additional proposals focus on promoting selective demolition to facilitate material recycling and expanding bio-refining processes. Collaboration with the private sector aims to establish sustainable biomass value chains and create a food waste think tank for knowledge sharing. Other initiatives include funding for biomass refining pilot plants and investments in green biorefinery facilities, furthering Denmark's commitment to advancing a thriving bioeconomy.

Comparison

The political landscape of the bioeconomy in Denmark and China reveals both similarities and differences in their approaches, particularly in areas relevant to Innovation Centre Denmark (ICDK) Shanghai's priorities.

Both China and Denmark place a strong emphasis on sustainability in their bioeconomic strategies. China focuses on high-quality development and the sustainable utilization of biological resources, while Denmark prioritizes maximizing resource efficiency, minimizing waste, and promoting circularity. Both nations recognize the importance of integrating various sectors into their bioeconomic plans, with overlapping areas such as sustainable agriculture, environmental protection, and resource management. Furthermore, both countries highlight the role of innovation and collaboration. China integrates innovation into its bioeconomy strategies, while Denmark emphasizes collaboration between industry, academia, and researchers.

However, the scope and formalization of their strategies differ significantly. China has developed a comprehensive and ambitious bioeconomy strategy, aiming to become a global leader by 2035. Denmark, while also setting ambitious goals, focuses more narrowly on specific sectors like circular economy and sustainable resource utilization.

Despite these differences, Denmark and China share a commitment to harmonizing economic growth with environmental preservation. This shared dedication is reflected in the Sino-Danish Green Joint Work Programme released on August 18, 2023, which aligns with bioeconomy priorities and areas of collaboration where ICDK Shanghai is actively involved:

Sustainable Agriculture and Food Systems: Denmark's expertise in sustainable agricultural practices and resource-efficient farming complements China's focus on bio-agriculture. This area offers strong opportunities for joint projects and knowledge exchange, particularly in bio-breeding, bio-fertilizers, and food security solutions.

Circular Economy and Resource Efficiency: Both countries are committed to reducing waste and maximizing resource use, with Denmark's leadership in circular economy practices providing a valuable model for collaboration with China.

Environmental Protection and Water Management: Aligning with ICDK Shanghai's focus on green transition, collaboration in sustainable water management and nature-based solutions can build on Denmark's expertise and China's ambitious environmental goals.

Denmark and China emphasize sustainable practices and innovative solutions in areas such as agriculture, environmental protection, and resource efficiency. Their respective strategies aim to address global sustainability challenges and contribute to a resilient bioeconomy.

The feedstock analysis in the following section explores specific resources that form the foundation of the bioeconomy in both countries. By focusing on areas where ICDK Shanghai is actively engaged, the analysis highlights opportunities for collaboration that align with strategic priorities and foster long-term partnerships.

3. FEEDSTOCK ANALYSIS

To understand the bioeconomy, it is essential to recognize the foundational role of feedstock. Feedstock refers to the biological materials that serve as the raw input for various bioeconomic processes, from energy production to the creation of bio-based materials. These materials are critical because they determine the feasibility, scalability, and sustainability of bioeconomic initiatives. Without a steady and sustainable supply of suitable feedstock, the transition to a bioeconomy would be unattainable.

This section examines the key feedstock types that underpin the bioeconomy in Denmark and China. By providing a comparative analysis of five critical categories, the review aims to illuminate both the challenges and opportunities for collaboration between the two nations. The selection of feedstocks is informed by their availability, economic viability, and environmental impact, emphasizing their importance as the building blocks of a robust bioeconomy.

In both Denmark and China, feedstock utilization highlights the diverse biological resources available, from agricultural residues to organic waste streams. This diversity not only reflects the unique characteristics of each country but also underscores the global potential for innovation and resource efficiency. Furthermore, the sustainability of feedstock is a key consideration, as the bioeconomy is widely regarded as a pathway to greener, more resource-efficient solutions.

This analysis delves into the current usage and innovation potential of feedstock within Denmark's and China's bioeconomy landscapes, offering insights into how these resources can drive sustainable development and foster international collaboration. By addressing the foundational importance of feedstock, this section sets the stage for exploring its broader implications and opportunities within.

3.1 FEEDSTOCKS

Agricultural Residues

Both Denmark and China generate substantial agricultural residues through farming activities. These by-products, which include straw and animal manure, are often treated as waste but offer significant potential for energy generation and material recovery. Utilizing these residues aligns with circular economy principles by turning waste into a valuable resource for bioenergy and bioproducts.

Forestry Biomass

Forestry industries in both Denmark and China provide access to wood and forestry residues, which can be important for bio-based applications. However, it is crucial to emphasize that sustainable forestry practices must be followed. This feedstock primarily involves the use of residual materials, such as branches, leaves, and other by-products from forest management, rather than the harvesting of whole trees solely for fuel. Cutting down trees for bioenergy production would not be considered the most sustainable approach. Ensuring that only forestry residues are used can help avoid undermining environmental goals, maintaining forests' role in carbon sequestration and biodiversity preservation.

Marine-Based Feedstock

Marine biomass, such as seaweed and algae, is a rapidly renewable resource that can be cultivated at scale. It holds significant promise for various bio-products and energy applications. However, large-scale cultivation of marine biomass must be carefully managed to ensure it does not disrupt marine ecosystems or contribute to environmental degradation. While marine feedstock offers a sustainable solution in many respects, it is essential to adopt responsible practices to avoid negative ecological impacts such as eutrophication or loss of marine biodiversity.

Organic Waste Streams

Organic waste streams provide a dual benefit by addressing waste management challenges while also serving as a valuable resource for the bioeconomy. These streams include food waste, green waste, and other biodegradable materials, which can be transformed into bioenergy, compost, or bio-based materials. The utilization of organic waste not only reduces the environmental burden of waste but also contributes to a more circular and resource-efficient economy.

Energy Crops

These crops are grown specifically for bioenergy production. While energy crops such as rapeseed, willow, or sorghum offer a controlled and renewable source of biomass, they do require the allocation of agricultural land. Care must be taken to ensure that the cultivation of energy crops does not compete with food production or lead to unsustainable land-use practices. Developing energy crops with high yields and minimal environmental impact can support sustainable bioenergy systems.

3.2 IDENTIFYING COLLABORATION THROUGH FEEDSTOCK ANALYSIS

Agricultural Residues as Feedstock

Denmark's agricultural sector plays a significant role in the nation's bioeconomy. A key focus area is the use of agricultural residues as feedstock. For example, Nielson’s (2016) report pointed out that the use of straw for energy has increased over time and peaked in 2010 at 1.6 million tonnes. In 2015, the consumption was 1.3 million tonnes, with 1 million tonnes used for CHP and district heating. Straw consumption accounts for 12 % of the renewable energy production in Denmark. As Hansen et al. (2020) detailed, using straw, grain, and manure for bioenergy production contributes significantly to Denmark's renewable energy sources.

In China, agricultural residues constitute a significant proportion of the bioeconomy feedstock as well. As a global agricultural powerhouse, China achieved an agricultural value-added of €1.09 trillion in 2021, accounting for 31.1% of the world's agricultural value-added, according to World Bank data (CPC News). Additionally, According to Zhang et al. (2020), the country's vast agricultural activities generate large amounts of straw and animal manure, which can be used for bioenergy production, offering substantial renewable energy potential. *The National Report on Comprehensive Utilisation of Crop Straw* shows that China's comprehensive utilisation rate of crop straw has been steadily increasing, with 647 million tonnes of crop straw utilised in 2021 and a comprehensive utilisation rate of 88.1%, an increase of 3.4% from 2018 (Ministry of Agriculture and Rural Affairs, 2022).

Both Denmark and China recognize the value of agricultural residues in driving their respective bioeconomies. While Denmark has effectively utilized straw, grain, and manure for bioenergy, contributing significantly to its renewable energy portfolio, China's large agricultural output and its utilization of crop straw and animal manure present potential for renewable energy generation. The key area for collaboration lies in sharing best practices and technologies in the conversion of agricultural residues to energy. Denmark’s advanced techniques in efficient bioenergy production, particularly in small-scale, community-level applications, can be invaluable to China, which is looking to expand its renewable energy sources while managing vast agricultural by-products. Conversely, China's experience in large-scale implementation and its innovative approaches to handling diverse agricultural residues can offer new perspectives and scalable solutions to Denmark.

Forestry Feedstock

Although Denmark is relatively flat, with only 16% of its land area covered by forests, the country still effectively uses its forestry resources as part of its bioeconomy. Bentsen et al. (2019) noted that although Denmark is not as forest-rich as some other European countries, it has managed its forests sustainably. This allows for the use of forestry residues, such as wood chips, as biomass for producing bioenergy and bioproducts.

A key example of this is the inauguration of Unit 4 at the Amager power plant in Copenhagen in 2020, which marked a major shift away from coal combustion for electricity and heating. This transition was a significant step toward the city’s goal of climate neutrality. Unit 4 is notable because it uses the world’s largest circulating fluidized bed boiler, which operates exclusively on wood chips. This technology is crucial because it enables the efficient and clean burning of wood as a sustainable energy source, helping reduce reliance on fossil fuels like coal.

China's forestry resources, including waste wood and forest residues, contribute significantly to its bioeconomy feedstock. The total amount of forest resources in China is abundant, effectively providing a raw material base for producing forestry biomass materials. The 2022 Statistical Bulletin of China's Natural Resources shows that China has 283,527,000 hectares of forest land (Ministry of Natural Resources, 2022). Studies by Li et al. (2021) highlight the strategic utilisation of these resources for producing bioenergy and bioproducts, particularly in regions with significant forest coverage.

While Denmark's sustainable management of its limited forest resources showcases efficient use of wood chips and biomass for bioenergy, China's vast forest lands present a significant opportunity for large-scale

bioenergy and bioproducts production. Denmark's experience in maximizing output from relatively smaller forested areas through advanced sustainable forestry practices and efficient biomass utilization can be highly beneficial to China, which is exploring ways to enhance the sustainable management of its abundant forest resources.

In contrast, China's large-scale forestry operations and its experience in managing extensive forest lands can offer insights into handling and processing large volumes of forest residues, potentially aiding Denmark in scaling up its biomass production capabilities.

Marine-based feedstock

The marine environment offers unique bioeconomy feedstock opportunities. A comprehensive study by Petersen et al. (2021) focused on Denmark's use of marine biomass, such as seaweed and microalgae, as a bioeconomic resource. In the seas surrounding Denmark, more than 400 different species of seaweed can be found. Seaweed is a resource that is beneficial both economically and environmentally. On the one hand, seaweed can be refined into several different products in a bio-refinery. On the other hand, there is significant potential for its use in increasing the yield of biogas from manure (AlgaeCenter Denmark, 2013). Moreover, marine biomass can also help address environmental challenges, such as reducing eutrophication, which refers to the excessive accumulation of nutrients in water bodies, leading to oxygen depletion and harm to aquatic ecosystems.

China's aquatic biomass, especially from its extensive freshwater and marine algae cultivation, is essential in its bioeconomy feedstock. China's freshwater resources total 2.8 trillion cubic metres, accounting for 6% of global water resources (State Council, 2005). Also, according to data from the China Fisheries Statistics Yearbook (2022), China's seaweed aquaculture production is increasing, reaching 2,615,100 tonnes by 2020. Cai et al. (2022) discuss how these resources provide raw materials for producing biochemicals, contributing to the diversification of bioeconomy feedstock.

Denmark's exploration of seaweed and microalgae demonstrates significant potential in the marine-based bioeconomy, particularly in biorefining, while also offering environmental benefits such as mitigating eutrophication. China, with its large-scale cultivation of freshwater and marine algae, showcases the versatility of these resources in producing biochemicals.

This presents an opportunity for Denmark and China to collaborate on marine biomass development. Denmark’s expertise in the efficient processing of seaweed and its integration into innovative bio-based systems can complement China’s large-scale algae cultivation techniques. Joint efforts could focus on developing innovative biorefining processes and exploring environmentally sustainable aquaculture practices.

Moreover, both countries can benefit from sharing knowledge on the environmental management of marine ecosystems, particularly in combating issues like eutrophication. This could lead to more sustainable and economically viable uses of marine biomass, significantly contributing to the global advancement of the marine bioeconomy and aiding in environmental preservation.

Organic Waste Stream

Denmark's bioeconomy is innovatively transforming organic waste streams, including food waste, green waste, and manure, from end-of-life materials into valuable bioeconomic feedstocks. This strategy aligns with the circular economy's principles, turning waste into wealth and contributing significantly to sustainability goals. A prime example is the biogas sector. As highlighted by Bentsen et al. (2019) and Pedersen et al. (2021), biogas from organic waste is a growing contributor to Denmark's renewable energy portfolio, accounting for over 15% of total gas consumption in 2019. This approach not only underscores Denmark's commitment to renewable energy and waste reduction but also sets a standard for sustainable resource management in the bioeconomy.

Organic waste streams, particularly from urban areas, offer significant bioeconomy feedstock potential in China. China is the world's largest producer of organic waste. China's annual urban and rural organic waste generation exceeded 6 billion tonnes in 2015, of which about 3.8 billion tonnes were generated from livestock and poultry manure. Also, about 200 million tonnes of urban domestic waste were generated in 2016 (Zhiyan Consult, 2019). A comprehensive study by Liu et al. (2023) presents a detailed overview of using urban organic waste, including food waste and sewage sludge, for biogas and biofertilizer production.

Both Denmark and China are leveraging the potential of organic waste streams to bolster their bioeconomies, albeit with different focal points. Denmark's effective use of biodegradable waste, particularly in biogas production, exemplifies its commitment to circular economy principles and renewable energy. This approach not only addresses waste management but also contributes significantly to Denmark’s sustainability goals. China, facing the challenge of managing vast amounts of urban organic waste, focusses on transforming food waste and sewage sludge into biogas and biofertilizers. This addresses both energy and waste management needs in its rapidly urbanizing society.

The potential for collaboration lies in exchanging expertise and technologies in organic waste processing. Denmark’s advanced technologies and experience in small-scale, community-focused biogas plants can provide valuable insights for China, which is dealing with urban organic waste on a much larger scale. Meanwhile, China's experience in handling massive volumes of organic waste and converting it into valuable resources could offer scalable solutions and innovative technologies that might be adapted for use in Denmark.

Joint initiatives could include developing new technologies for efficient organic waste conversion, sharing best practices in urban waste management, and exploring innovative uses of by-products like biofertilizers. Such collaborations can lead to more efficient waste management practices, enhanced renewable energy production, and contribute to the overall sustainability of both countries’ bioeconomies.

Energy Crops

Energy crops are plants that are grown specifically to produce energy. Energy crops are a cornerstone of Denmark's renewable energy strategy, with rapeseed, willow, and miscanthus leading due to their robust biomass yields and suitability for local climates. These primary crops are complemented by emerging contenders like corn and beets, identified by the Danish Energy Agency's research for their potential to boost biogas outputs. Chosen for their sustainability and energy content, these crops are integral to Denmark's

bioeconomy, diversifying feedstocks and reinforcing the country's commitment to environmental sustainability. Their strategic cultivation, supported by studies such as Thalbitzer (2010), marks a significant step toward a resilient, diverse bioeconomic landscape.

Energy crops, such as sweet sorghum and cassava, have also been considered in China's bioeconomy. For example, benefiting from the rapid development of China's feed and baijiu (Chinese liquor) industries in recent years, the growing demand has fuelled growth in China's sorghum acreage, from 424,900 hectares in 2015 to 675,000 hectares in 2021 (Huajing Industry Research, 2022). Sun et al. (2022) state that these crops offer substantial bioenergy potential due to their high biomass yields and resilience to marginal growing conditions.

Denmark and China both recognize the importance of energy crops in their respective bioeconomy strategies, though their focus on different crops reflects their unique agricultural contexts and objectives. Denmark's emphasis on crops like rapeseed, willow, and miscanthus, chosen for their adaptability to local climates and high biomass yields, aligns with its commitment to environmental sustainability and renewable energy diversification. In China, crops such as sweet sorghum and cassava are gaining prominence, driven by their resilience to marginal growing conditions and high biomass output, which aligns with the needs of the country's expanding bioenergy sector.

The potential for collaboration lies in the exchange of research and development efforts in crop optimization, cultivation practices, and bioenergy conversion technologies. Denmark's advanced agricultural research and experience in cultivating energy crops for high-efficiency bioenergy production could provide valuable insights for China, particularly in areas of crop sustainability and environmental impact. Conversely, China's extensive experience in large-scale cultivation of crops like sorghum and cassava, and its innovative approaches to maximizing yield in diverse climatic conditions, could offer practical lessons for Denmark, particularly in terms of scalability and adaptability.

4. SECTORS OF POTENTIAL COLLABORATION BETWEEN CHINA AND DENMARK

China and Denmark have significant potential for collaboration in several key areas within the bioeconomy. Each country brings unique strengths that can complement the other, enabling the advancement of sustainable solutions and innovations.

Feedstock Utilization

One of the most promising areas for collaboration lies in the utilization of feedstock. Both countries generate substantial agricultural residues and forestry biomass, which are essential components of their bioeconomy. Denmark has developed advanced methods for converting agricultural residues, such as straw and manure, into valuable products, significantly contributing to its sustainability goals. China's large-scale agricultural activities also produce vast quantities of residues, which are increasingly being utilized for various bioeconomic applications. By sharing expertise, Denmark can help China optimize its processing capabilities,

while China's experience with large-scale implementation can offer Denmark insights into scaling its bioeconomic systems.

Marine-Based Feedstock

Marine biomass, including seaweed and microalgae, presents another compelling area for collaboration. Denmark has pioneered research into the use of marine resources for biorefining and sustainable applications, such as reducing eutrophication through the use of seaweed. China, with its extensive aquaculture capabilities, is a global leader in algae cultivation. Collaborative efforts could focus on optimizing the production and processing of marine biomass, ensuring sustainable practices, and jointly developing innovative applications that benefit both economies.

Organic Waste Streams

Denmark's innovative circular economy model has successfully transformed organic waste, including food waste and manure, into valuable bio-based products, reducing waste and enhancing sustainability. In contrast, China, facing the challenge of managing vast urban organic waste volumes, has developed large-scale systems for converting food waste and sewage sludge into bio-based fertilizers. Collaborative opportunities lie in exchanging technologies and best practices for organic waste conversion. Denmark's expertise in small-scale, community-based solutions can complement China's large-scale urban waste management systems, fostering efficient and sustainable waste utilization.

Energy Crops

Energy crops also provide a basis for collaboration. Denmark cultivates crops such as rapeseed and willow for sustainable applications, while China has focused on crops like sweet sorghum and cassava. Joint research into crop optimization and sustainable agricultural practices could enhance productivity and environmental performance, supporting the bioeconomy goals of both nations

By focusing on these shared interests and complementary strengths, Denmark and China can deepen their bioeconomy collaboration. Leveraging expertise in feedstock utilization, marine resources, organic waste streams, and energy crops provides a pathway for innovative and sustainable partnerships. These efforts can not only drive economic growth in each country but also contribute meaningfully to global sustainability goals. ICDK Shanghai stands ready to facilitate these collaborations, aligning initiatives with mutual priorities and fostering impactful partnerships.

Overall, by building on these shared interests and complementary strengths, China and Denmark can deepen their bioeconomy collaboration. Joint initiatives could not only enhance their individual bioeconomy sectors but also contribute to sustainable development and global bioeconomic leadership.

4.1 FEEDSTOCKS

Denmark and China have both made significant advances in utilizing diverse feedstocks as part of their bioeconomy strategies. Denmark excels in the efficient use of agricultural residues, forestry resources, marine-based biomass, organic waste streams, and energy crops. However, the country faces challenges

related to land availability and maximizing resource efficiency. Similarly, China leverages its vast agricultural and forest resources, as well as aquatic biomass, but must address the complexities of managing large-scale waste and ensuring sustainable practices in its expansive bioeconomy.

The potential for collaboration between Denmark and China lies in areas where their respective strengths can complement each other. Denmark's expertise in agricultural residue utilization and marine biomass processing could offer valuable insights for China as it continues to expand its bioeconomy. Conversely, China's experience in managing large-scale operations and its innovations in resource utilization can provide Denmark with scalable solutions and new approaches to optimizing biomass use.

Specific opportunities for collaboration include:

Agricultural Residues: Joint efforts to improve the conversion of agricultural by-products into sustainable materials and applications.

Marine Biomass: Collaborative research and development into sustainable marine-based feedstock applications, with a focus on reducing environmental impacts.

Organic Waste Streams: Sharing best practices in organic waste processing and resource recovery, tailored to both large-scale urban systems and smaller, community-based solutions.

By focusing on these areas, Denmark and China can leverage their expertise to address mutual challenges and unlock the potential for sustainable innovation in feedstock utilization. This cooperation can strengthen their bioeconomy sectors while contributing to broader global sustainability goals.

4.2 OTHER AREAS

Despite their differences in size, culture, and economic development, Denmark and China share a strong commitment to sustainable development and the bioeconomy. Both countries recognize the urgency of addressing environmental challenges and promoting sustainable practices. Denmark, renowned for its leadership in green initiatives and sustainable agriculture, exemplifies eco-friendly policies. Meanwhile, China, as it continues its rapid economic growth, has increasingly prioritized environmental sustainability. Both nations emphasize the importance of transitioning towards a bioeconomy that harnesses renewable resources, minimizes waste, and advances sustainable agricultural practices.

The rich biological resources and biodiversity found in both nations offer fertile ground for collaboration and innovation. Denmark's strengths in sustainable agriculture and bio-agriculture innovation align with China's focus on developing bio-agriculture as one of the four pillars of its bioeconomy. Both countries have significant opportunities to collaborate on advancing bio-breeding, bio-fertilizers, and bio-pesticides, strengthening industrial systems that conserve and utilize genetic resources.

Biological Resources and Biodiversity

China's vast and varied geography encompasses diverse ecosystems and abundant natural resources. These include germplasm (the genetic material of plants and animals), agricultural and forestry products, and a long tradition of utilizing herbal medicine. This wealth of biological resources supports China's ability to innovate

and expand its bioeconomy. As consumer demand grows for higher-quality, eco-friendly solutions in areas like food, healthcare, and environmental management, China's expansive market presents opportunities for scaling bioeconomy solutions.

Denmark's extensive expertise in sustainable practices, particularly in bio-agriculture and resource optimization, complements China's ambitions in this field. This partnership has the potential to support the development of innovative solutions that enhance food security, improve resource efficiency, and strengthen global sustainability efforts.

By focusing on these shared priorities, Denmark and China can build a robust foundation for collaboration that advances their individual bioeconomy agendas while contributing to global sustainability goals. This partnership underscores the importance of aligning strengths and fostering innovation to address pressing environmental challenges and support the transition to more sustainable bioeconomic practices.

4.3 ROADMAP FOR STAKEHOLDERS IN DENMARK AND CHINA

The transition to a sustainable bioeconomy is not only an environmental necessity but also a key economic opportunity for both Denmark and China. Recognizing this, the roadmap for stakeholders in both countries outlines strategic areas for collaboration, aiming to leverage the unique strengths of each nation. In this context, Innovation Centre Denmark Shanghai (ICDK Shanghai) plays a critical role as a facilitator and catalyst for bioeconomy partnerships, bridging the gap between Danish and Chinese stakeholders. ICDK Shanghai focuses on areas such as sustainable agriculture, circular economy practices, resource efficiency, organic waste management, and marine-based resources within the bioeconomy. Its in-depth understanding of local markets, combined with its ability to foster international cooperation, positions it as a key resource in driving forward collaborative initiatives in these areas.

Joint Research and Development

Collaborative R&D projects focusing on sustainable feedstock production, resource-efficient technologies, organic waste utilization, and innovative applications of bio-based materials can unlock new opportunities for both nations. Denmark's strength in precision agriculture and circular economy practices, alongside China's advancements in large-scale implementation and sustainable resource utilization, can lead to pioneering solutions that address global sustainability challenges. ICDK Shanghai can facilitate these R&D initiatives within its focus areas, ensuring that joint efforts align with the strategic interests of both nations.

Knowledge-Exchange

Creating robust knowledge-exchange platforms between Danish and Chinese research institutions and enterprises is essential to accelerating innovation. This exchange allows stakeholders to share best practices,

technological know-how, and market insights. ICDK Shanghai can spearhead these efforts by organizing knowledge-sharing forums, workshops, and collaborative platforms. These activities not only expedite the development of bioeconomy solutions tailored to the needs of both markets but also create a vibrant ecosystem that fosters long-term collaboration.

Policy Understanding and Regulatory Guidance

One of the key challenges in cross-border collaboration is navigating different policy landscapes and regulatory frameworks. ICDK Shanghai can help stakeholders understand regulatory requirements, reduce market entry barriers, and promote bilateral trade in the bioeconomy sector. ICDK's involvement ensures that Danish and Chinese stakeholders can collaborate within a framework that supports innovation, sustainability, and long-term success.

Innovation Centre Denmark Shanghai's Relevance

As a central player in fostering these collaborative efforts, ICDK Shanghai is crucial to the success of Danish-Chinese partnerships in the bioeconomy. By offering strategic guidance, connecting stakeholders, and providing insights into market dynamics, ICDK helps Danish and Chinese entities navigate the complexities of international collaboration. Whether by identifying potential areas for cooperation or aligning initiatives with national strategies, ICDK Shanghai ensures that stakeholders can tap into new opportunities in the rapidly evolving bioeconomy landscape.

REFERENCES

AlgeaCenter Denmark (2013) – Cited in the marine-based feedstock section, discussing the use of seaweed and microalgae in Denmark for biogas production and environmental benefits such as eutrophication reduction.

Bentsen, N. S., Larsen, S., & Stupak, I. (2019) – Cited when discussing Denmark's sustainable management of forestry resources and the use of wood chips as biomass for bioenergy production.

Cai, G. Q. (2022) – Referenced when discussing China's aquatic biomass, particularly algae cultivation and its contribution to the bioeconomy.

CPC News (2023) – Used in the analysis of China's agricultural residues, providing data on China's agricultural output and comprehensive utilization rate of crop straw.

Hansen, J. H., Hamelin, L., Taghizadeh-Toosi, A., Olesen, J. E., & Wenzel, H. (2020) – Referenced in relation to Denmark's use of agricultural residues, particularly straw and manure, for bioenergy production.

Huajing Industry Research (2022) – Used to discuss China's energy crops, specifically the increase in sorghum acreage in response to industrial demand.

Li, H. Y., & Jia, L. M. (2021) – Cited in relation to China's forestry feedstock and the use of waste wood and forest residues for bioenergy and bioproducts.

Ministry of Agriculture and Rural Affairs (2022) – Mentioned regarding China's comprehensive utilization of crop straw, which supports the discussion of agricultural residues as feedstock.

Petersen et al. (2021) – Referenced in relation to Denmark's exploration of marine biomass, particularly seaweed and microalgae.

Sun, Z. J., & Sun, Y. M. (2020) – Referenced in the context of agricultural residues in China's bioeconomy, discussing the potential for biofuel production from these residues.

The State Council (2005) – Referenced for data on China's freshwater resources, contributing to the discussion of aquatic biomass and marine-based feedstock.

Zhiyan Consult (2019) – Used in the section on organic waste streams, describing China's urban and rural organic waste generation.