Sustainable Biomass Energy Conversion

- Building an Economically Competitive Biomass Circular Industry Value Chain from Upstream to Downstream
- Demonstrating Diverse Pathways and Carbon Reduction Value for Sustainable Energy Resource Utilization

Background

Expanding bioenergy applications is one of the core pillars of "Innovative Energy" development in Taiwan's "Twelve Key Strategies" for net-zero transition[1]. The 2024 National Project of Hope aims to develop diverse green energy while establishing key net-zero sustainability initiatives. This includes green manufacturing and the circular economy, sustainable consumption and production, and a localized green supply chain[2]. In addition, the Project of Hope will initiate a second energy transition. This will accelerate the development of diversified renewable bioenergy to maximize green energy utilization and enhance domestic energy resilience. Moreover, by aligning with the resource circularity and zero-waste principles of the "Twelve Key Strategies" for net-zero transition, the sustainable conversion of biomass into energy will contribute to the creation of net-zero and green lifestyles.

Since bioenergy can enhance national energy resilience, the full development and utilization of existing and potential domestic biomass resources will strengthen Taiwan's self-sufficiency in energy. By establishing a biomass energy resource system with circular economy value, we can further achieve our 2030 carbon reduction goals of net-zero emissions through bioenergy. Moreover, there is a diverse array of Biomass-to-energy applications such as biogas power generation, biofuels (solid/liquid/gas), biobased chemicals, and the utilization of bio-based materials. Among these, "Sustainable Aviation Fuel" and "Biogas" are identified as key areas for biomass resource utilization. Thus, these two technologies have priority planning status due to their relevance to international agreements, rapidly growing demand in domestic and international markets, resource sustainability and energy production benefits, and the sustainable advantage suitable for supporting base or peak load power needs.

Global Outlook and Domestic Progress

The International Energy Agency (IEA) estimates that by 2050, biomass energy will account for nearly 20% of global energy[3]. However, according to Taiwan's 2022 electricity generation statistics, biomass energy accounted for only 0.05%[4]. Despite this, it is estimated that domestic biomass energy could potentially reach nearly 15% of Taiwan's national energy supply[5-8]. Therefore, Taiwan should actively create diverse pathways for relevant raw materials while taking the lead in developing and integrating advanced technologies in biomass energy.

(1) Sustainable Aviation Fuel

Globally, biofuels have become a widely used replacement for traditional fossil fuels in transportation sectors. In recent years, significant international progress has been made in carbon reduction agreements within the aviation industry. Moreover, the expansion of the Sustainable Aviation Fuel (SAF) supply chain has gradually met international market demand and trends in net-zero carbon reduction. Many countries have integrated diverse policy tools to speed up the promotion of SAF markets. As of May 2024, 41 countries have implemented Sustainable Aviation Fuel initiatives. In addition, 122 airports provide SAF supply and more than 50 airlines have adopted SAF[9].

On average, Taiwan Taoyuan International Airport supplies 3 million kiloliters of fuel annually. Based on the sustainability reports of Taiwan's national airlines, and considering that a refinery needs to produce at least 200,000 to 300,000 kiloliters to achieve economic scale, it has been recommended that Taiwan should have a strategic plan to supply an aviation fuel blend that contains 10% renewable sources. It is estimated that by 2030, domestic demand for SAF will reach 300,000 kiloliters (approximately 240,000 metric tons). In the future, international standards will increasingly require airlines to use SAF. Thus, if Taiwan cannot achieve self-sufficiency in establishing a SAF supply chain, the country may face risks related to fuel prices and supply constraints from abroad. This could impact key domestic export industries and supply chains while even posing a threat to national security.

Therefore, the development of a localized SAF industry and the exploration of diverse raw material sources for SAF have become key issues in Taiwan's net-zero transition for aviation sectors. In addition, developing this industry could also address the overall domestic SAF demand. Drawing on the experiences of the EU, Singapore, and Japan, the Taiwanese government could take on an overarching coordinating role during the initial phases to set up subsequent short-, medium-, and long-term development goals and strategies. This would help create autonomy in the domestic supply of SAF while positioning Taiwan as a critical SAF supply hub for the Asia-Pacific region.

(2) Biogas Utilization

Globally, agricultural residues and livestock manure could serve as the primary raw materials in biogas production. The IEA estimates that by 2040, the proportion of biogas used for power generation and heating will increase from 70% to 85%[10]. As of July 2024, only about 17% of Taiwan's total pig population contributes to biogas power generation[11]. This indicates that pig manure and agricultural residues have not yet been fully utilized in power generation and other areas.

Traditional biogas power generation operators use a single organic source, such as pig manure, for anaerobic digestion, which results in limited gas production. However, recent global trends in biogas power generation have significantly increased biogas production rates by focusing on utilizing multiple raw materials (agricultural residues and livestock manure). Moreover, the refining and upgrading processes of biogas could account for 60% to 70% of its total production costs. The bottlenecks of conventional biogas upgrading technologies include high energy consumption and the unstable output of high-purity methane. Therefore, it is crucial to develop technologies for the long-term stable production of biogas while solving challenges related to biogas separation. In Taiwan, some companies have already applied artificial intelligence to cultivate high-quality anaerobic bacteria, implemented intelligent environmental control and energy recycling, and conducted large-scale field tests to upgrade biogas production technologies. In the future, there are plans to further develop a series of co-digestion technologies using a diverse array of organic sources.

Strategic Planning Frameworks

Key application areas in the strategic planning framework for "Sustainable Biomass Energy Conversion" include the development of "Sustainable Aviation Fuel" and the expansion of "Biogas Utilization". Furthermore, six major implementation strategies have been planned (see Figure 1) with the aim of achieving a 5% to 10% SAF in aviation fuel consumption and for 40% to 50% of methane feedstock to be converted into energy by 2030.

Strategy 1: Critical Technology for Circular Biomass Energy Conversion

Prioritize domestic biomass raw materials that are supplemented by international sources, and consolidate and optimize a domestic and international biomass resource database network. Develop emerging biomass materials with the efficient potential for generating fuel, such as algae and black soldier flies. Research cost-effective bioenergy conversion technologies that include prioritizing improvements in the efficiency of converting the Hydrogenated Esters and Fatty Acids (HEFA) of waste cooking oil used for sustainable aviation fuel production while conducting R&D on bioenergy conversion technologies for emerging raw materials. Explore bioenergy applications based on

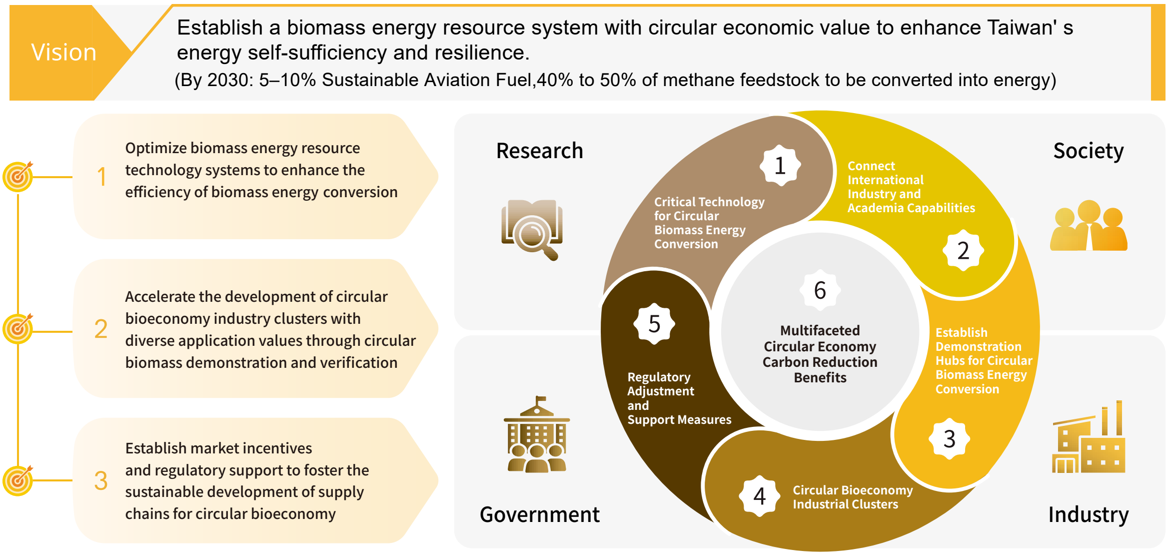

Figure 1 Strategies for the Sustainable Biomass Energy Conversion
Source: Taiwan Science and Technology Office for Net-zero Emission (T-STONE) (2024)

various raw materials that include advanced co-digestion technologies and biogas production sources from various co-digestion types (livestock manure, agricultural residues, municipal sludge, and food waste) suitable to unique regional characteristics. In addition, expand the use of anaerobic treatment and biogas measures for high-concentration organic wastewater.

Strategy 2: Connect International Industry and Academia Capabilities

Develop key technologies through international cooperation. Exploring new raw materials and developing technologies for next-generation low-carbon sustainable aviation fuels, establish an international industry-academia alliance focused on biomass-based carbon-negative technologies. Draw on the experiences of foreign demonstration and verification sites so Taiwan can accelerate the development of an integrated verification system for biomass resource utilization. Support the development of key technologies by aligning with international testing and certification frameworks for diverse raw materials.

Strategy 3: Establish Demonstration Hubs for Circular Biomass Energy Conversion

Establish a dedicated demonstration zone for SAF (including raw materials, technology, blending, and certification). Integrate artificial intelligence, blockchain, and the Internet of Things (IoT) to optimize the management of raw materials for domestic sustainable aviation fuel, improve collection and transportation efficiency, and enhance production technologies. Enhance Taiwan's capacity for international export and supply by turning the country into a SAF center for aircraft in the Asia-Pacific region. Create a circular biogas demonstration zone tailored to local needs (diverse raw materials/high-value applications) and promotes closed-loop and zero-waste sandbox pilot projects (for foresight production technologies).

Strategy 4: Circular Bioeconomy Industrial Clusters

Facilitate an international supply chain system for SAF by developing a sustainable aviation fuel industry ecosystem that incorporates benefit assessments of the whole life-cycle carbon footprints, business models, and economic scale. Furthermore, develop localized circular biomass industrial clusters and establish raw material collection and transportation business models for biomass collections. Promote the innovative use of biogas residues and liquids while expanding their circular reuse and carbon sequestration value. Explore international market opportunities by facilitating the export of turnkey biogas energy industry technologies.

Strategy 5: Regulatory Adjustment and Support Measures

Implement regulatory adjustments and relaxation to enhance the flexibility of biomass equipment installations, applications of raw material sites, and disposal channels. Accelerate certification mechanisms and methodologies for carbon credit offsets and carbon sequestration. Additionally, dynamically improve relevant support measures and incentive mechanisms (e.g., new environmental subsidies for biomass materials and sustainable aviation fuel taxes). Review Taiwan's carbon offset trading and carbon pricing mechanisms to assess the economic benefits driving biomass technology development. Establish a sustainable development of a green finance system for the biomass resource industry.

Strategy 6: Multifaceted Circular Economy Carbon Reduction Benefits

Introduce the whole life-cycle assessments to promote carbon offsets for circular biomass resources. Achieve carbon neutrality goals by expanding the market scale for renewable energy certificates related to sustainable biomass energy. Align with the Task-Force on Nature-related Financial Disclosures (TNFD) framework to guide investments toward carbon negative endeavors.

Potential Benefits

Biomass recycling is a key pillar in building a sustainable net-zero society. If potential domestic biomass resources can be efficiently developed and utilized, they could greatly replace traditional fossil fuels while enhancing energy resilience and self-sufficiency in Taiwan. Maximizing biomass energy resource recycling could reduce annual carbon emissions by 65 million tons. In addition, SAF is set to reduce 1.44 million tons of carbon emissions per year by 2030 with biomethane energy reducing 950,000 tons of carbon emissions annually. This will accelerate the decarbonization of domestic energy in Taiwan.

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