Discovering Innovative Food Processing Technology to Cultivate a Low-Carbon Food Supply Chain

APEC Policy Partnership on Science, Technology and Innovation

September 2026

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Economic Cooperation

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APEC Project: PPSTI 210 2024A

Project Overseer:

Binghuei Barry Yang
Food Industry Research and Development Institute, No. 331, Shipin Rd., Hsinchu 300197, Chinese Taipei
Tel: +886-3-5223191
https://www.firdi.org.tw

Prepared by:

Dr Yu-Yin Wu (Assistant Director); Ms Lien-Ting Lin (Analyst); Mr Yu-Hsien Lin (Research Associate); Mr Kurt Benjamin M. Abalos (Research Associate); Ms Ting-Yu Liang (Program Assistant)
Regional Development Study Center, Chung-Hua Institution for Economic Research

Produced by:

Regional Development Study Center, Chung-Hua Institution for Economic Research
Tel: +886-2-2735-6006
https://www.cier.edu.tw/en/chung-hua-institution-for-economic/

For
Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

APEC#226-PP-04.4

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Acknowledgement

We would like to express our sincere appreciation to all those who provided their support and encouragement throughout the completion of this project. We are deeply grateful to the APEC member economies for their participation and valuable recommendations. We also extend our thanks to all speakers, moderators, and participants for their valuable contributions. Finally, we would like to convey our sincere gratitude to the researchers, research assistants, and staff who have devoted their time and effort to the implementation of this project.

Summary

The APEC Workshop on "Discovering Innovative Food Processing to Cultivate a Low-Carbon Food Supply Chain" emphasized the increasing urgency of transforming food systems in response to climate change, resource limitations, and food security challenges. Since food supply chains contribute approximately one-third of global greenhouse gas emissions, APEC economies acknowledge the need to balance sustainability goals with economic growth and food affordability. Through pre-event surveys, expert presentations, case studies, and panel discussions, participants from government, industry, academia, and research institutions explored practical strategies for developing resilient, low-carbon food supply chains.

Key Findings

Several important findings emerged from the workshop. First, policy support was identified as the most critical factor in advancing low-carbon food supply chains. Survey respondents consistently emphasized the importance of government regulations, technical assistance, capacity building, and financial incentives in driving sustainable transformation. While traditional agricultural production and food processing generally receive substantial policy support, emerging areas such as fermentation-based production technologies, low-carbon distribution systems, and consumer engagement remain relatively under-supported.

Second, technological innovation was identified as a key driver of decarbonization. Throughout the supply chain, technologies such as artificial intelligence (AI), the Internet of Things (IoT), precision agriculture, smart manufacturing, advanced fermentation, digital traceability systems, and carbon accounting platforms have shown significant potential to improve efficiency, reduce waste, and lower emissions. Case studies from Australia; Indonesia; Japan; Malaysia; Peru; Singapore; Chinese Taipei; and Thailand, and demonstrated how emerging technologies can enhance resource utilization while maintaining competitiveness and profitability.

Third, circular economy practices have emerged as a common and effective strategy for reducing carbon footprints. Numerous examples demonstrate how agricultural and food processing by-products can be converted into higher-value products such as bioenergy, animal feed, alternative proteins, sustainable aviation fuel, fertilizers, and consumer goods. These initiatives simultaneously reduce waste, create new revenue streams, and improve overall resource efficiency.

Fourth, the survey revealed that food processing and new technology-based production systems demonstrate the highest levels of technological readiness, innovation potential, and openness to adopting carbon reduction standards. In contrast, downstream segments—particularly food consumption—continue to exhibit lower levels of awareness, engagement, and policy support. Consumer behavior remains a significant challenge due to information asymmetry, limited awareness of low-carbon products, and concerns about higher costs.

Finally, participants identified several barriers hindering the green transition. These include insufficient funding, limited access to information, fragmented supply chains, lack of harmonized standards, difficulties in measuring carbon emissions, limited technical capabilities among SMEs, and uncertainty regarding the economic benefits of low-carbon investments. Despite these challenges, respondents generally agreed that low-carbon food supply chains can enhance sustainability, increase operational efficiency, strengthen food security, and create opportunities for innovation.

Key Recommendations

To accelerate the transition toward low-carbon food systems, participants proposed a series of recommendations at the APEC, government, and industry levels.

At the regional level, APEC should enhance cooperation on sustainability standards, carbon accounting methodologies, and ESG frameworks while promoting technology transfer, knowledge sharing, and capacity-building initiatives. Regional collaboration can help reduce trade barriers, harmonize regulations, and facilitate the dissemination of innovative technologies across member economies.

At the government level, economies should expand financial support mechanisms, including green financing, low-interest loans, public-private partnerships, and sustainability-focused investment programs, particularly targeting SMEs. Governments should also strengthen ESG oversight, support industry-academia collaboration, promote climate-smart agriculture, improve cold-chain infrastructure, and develop transparent carbon labeling systems to enhance consumer confidence and increase market demand for low-carbon products.

At the firm level, businesses should invest in digital technologies, smart manufacturing systems, and circular economy practices while extending sustainability requirements throughout their supply chains. Companies are encouraged to collaborate with research institutions, adopt waste-to-value approaches, improve resource efficiency, and implement practical, low-cost measures

such as localized sourcing, energy management, and optimized logistics. Ultimately, building a low-carbon food supply chain requires coordinated action among governments, industries, researchers, financial institutions, and consumers. Through stronger collaboration, technological innovation, and supportive policy frameworks, APEC economies can develop food systems that are more sustainable, resilient, and capable of meeting future environmental and food security challenges.

1. Introduction

Amid the global push for green transition, economies face the challenge of balancing economic growth with sustainability. World economies continue to grapple with the increasing effects of climate change, which have notable adverse effects on global food security, including reduced harvest yields, extreme droughts and typhoons, and degradation of natural capital. According to a 2024 study from the Food and Agriculture Organization of the United Nations, global food supply chains represent one-third of global greenhouse gas (GHG) emissions. Key segments of the food supply chain, including logistics, production, packaging, storage, and land use—are major sources of GHG emissions. In recent years, governments have been focused on improving their food industries to make them more sustainable, while safeguarding economic prosperity and opportunity.

Asia-Pacific Economic Cooperation (APEC) acknowledges that the region plays a central role in the global economy, particularly in food supply chains. In this context, the region can influence and is influenced by considerable global shocks, such as pandemics, supply chain disruptions, and, most notably, the increasing effects of climate change. Reflecting this role, its member economies have committed to working towards the Putrajaya Vision 2040 for "an open, dynamic, resilient and peaceful Asia-Pacific community by 2040…". Among its three main economic drivers, improving the region's food supply chain falls under the theme of "Strong, Balanced, Secure, Sustainable and Inclusive Growth". Hence, guided by the Aotearoa Plan of Action, APEC is committed to enhancing the sustainability of the region's food supply chain to support food security and addressing climate change.

Against this backdrop, APEC Policy Partnership on Science, Technology and Innovation (PPSTI) held a two-day workshop from 18 to 19 March 2026 in Chinese Taipei organized by the Food Industry Research and Development Institute (FIRDI) and a pre-event survey by Chung-Hua Institute of Economic Research (CIER). Under the theme of "Discovering Innovative Food Processing to Cultivate a Low-Carbon Food Supply Chain", representatives from the APEC region, namely from Australia; Indonesia; Japan; Malaysia; Papua New Guinea; Peru; the Philippines; Singapore; Chinese Taipei; Thailand; and the United States, were invited to share and discuss their experiences in advancing the green transition of food supply chains. Governments have created regulations that mandate sustainable practices and offered financial programs that incentivize the adoption of green technologies. Companies have also been adopting sustainable measures to green their operations. In addition, academic institutions have been active in developing and sharing low-carbon technologies with industry stakeholders. Hence, the PPSTI workshop brings together various actors throughout the food supply chain to share best practices and strengthen regional consensus for a low-carbon food supply chain.

The remainder of this report is structured as follows. Following this introduction, Section 2 presents the results of the pre-event survey. Section 3 outlines the workshop proceedings.

Section 4 reports the APEC regional issues and dialogue on cultivating a low-carbon food supply chain, and Section 5 concludes with the policy recommendations. The results of the project evaluation survey, the workshop's agenda, the pre-event survey questionnaire, comments and issues for the in-person workshop, as well as the project evaluation survey questionnaire are presented in Appendix for reference.

2. Survey Results on Regional Development of Low-Carbon Food Supply Chains

Prior to the event, a pre-workshop survey was conducted to understand the experience of businesses in cultivating a low carbon food supply chain in the APEC region. In addition, the following section showcases the different sentiments of respondents with regards to their respective economies' sustainable initiatives. The findings of the survey noted several observations stemming from the best kind of support for the green transition, as well as various challenges that need to be addressed.

2.1 Sample Characteristics

In total, 34 member economies participated in the survey. Table 1 and Figure 1 show the breakdown of the respondents according to economy. The respondent economies are Australia; Brunei Darussalam; Chile; Hong Kong, China; Indonesia; Japan; Malaysia; Peru; The Republic of the Philippines; Singapore; Chinese Taipei; Thailand; and the United States) as shown in Table 1. In terms of gender distribution, among the 34 respondents, 21 were male and 13 were female, as shown in Figure 1.

Table 1 Respondents by Economy

Member Economy			
Australia	**1**	Peru	**3**
Brunei Darussalam	**2**	The Republic of the Philippines	**3**
Chile	**1**	Singapore	**2**
Hong Kong, China	**1**	Chinese Taipei	**8**
Indonesia	**4**	Thailand	**4**
Japan	**2**	United States	**1**
Malaysia	**2**		

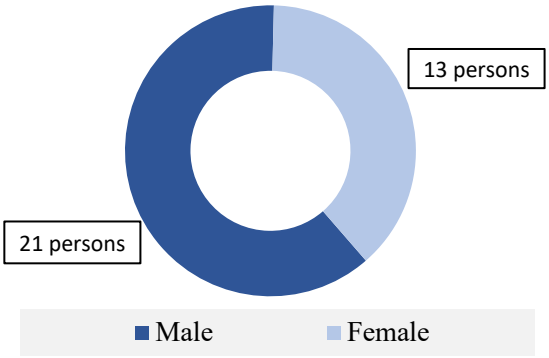

Figure 1 Respondents by Gender

The survey respondents were gathered through different channels. Primarily, the questionnaire was circulated to representatives of Policy Partnership on Science, Technology and Innovation (PPSTI), Small and Medium Enterprise Working Group (SMEWG), Policy Partnership on Food Security (PPFS), and Agricultural Technical Cooperation Working Group (ATCWG) in all 21 APEC economies. Apart from this, individual emails were also sent out to relevant government agencies, not-for-profit organizations and academics in different Member Economies.

Looking at the sectoral breakdown, most of the respondents were from government organizations. Among the 34 respondents, 17 were from government organizations, 11 were from the private sector, 4 were from RTOs, and 2 was from NGO. Figure 2 presents a pie chart illustrating this sectoral distribution.

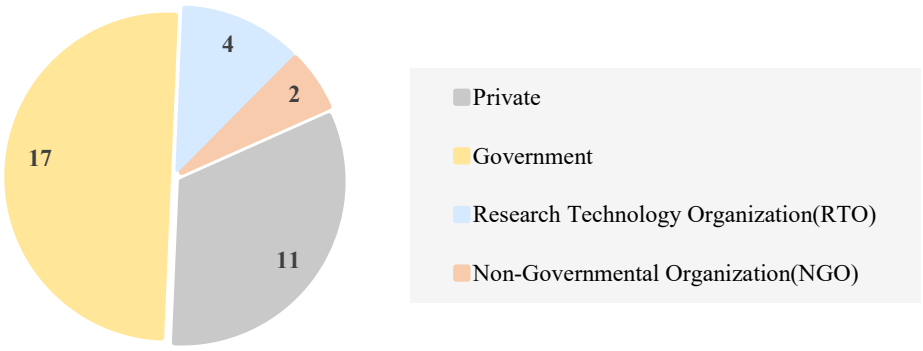

Figure 2 Respondents by Organization Sector

2.2 Results for Overall Recognition of Low-Carbon Food Supply Chain

This section examines respondents' recognition of the development of low-carbon food supply chains in their respective economies through eight survey questions. The results are presented in Figure 3 and Figure 4.

As shown in Figure 3, which includes Questions 1, 2, 7, and 8 in this section, respondents regarded policy-making as the most important factor in developing a low-carbon food supply chain, with an average score of 4.65. This was followed by consumer awareness and its influence

on green food consumption (3.68), funding support progress (3.50), and the integration of food upcycling and circular systems (3.50).

Q1: How important do you believe policy-making is in cultivating a low-carbon food supply chain?

Q2: To what extent do you think the progress of funding support systems for cultivating low-carbon food supply chains in your economy?

Q7: How do you think the development of a food upcycling circular system integrating into your economy?

Q8: How do you think consumer awareness is shaping the trend of green consumerism in food choices in your economy?

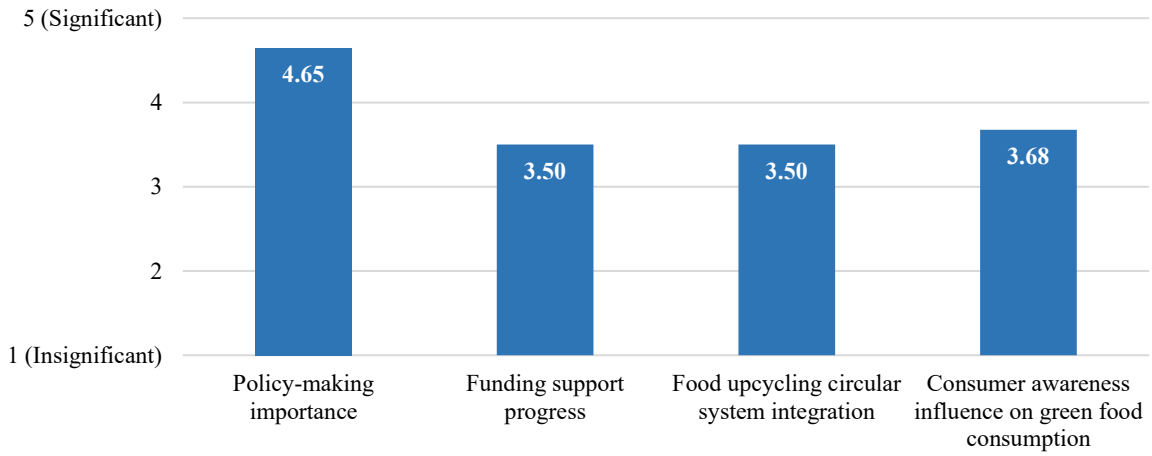

Figure 3 Importance of Developing Low-Carbon Food Supply Chain

Figure 4 presents respondents' views on the significance of investment in different areas of low-carbon food supply chain development. Investment in food loss reduction received the highest score (3.21), followed by processing technologies (3.15). Investment in smart manufacturing systems (3.12) and supply chain management (3.09) received slightly lower scores.

Q3: To what extent does your economy invest in reducing food loss to cultivate a low-carbon food supply chain?

Q4: To what extent does your economy invest in the development of low carbon food processing technology?

Q5: To what extent does your economy invest in the development of low carbon food smart manufacturing system?

Q6: To what extent does your economy invest in the development of low carbon food supplying chain management?

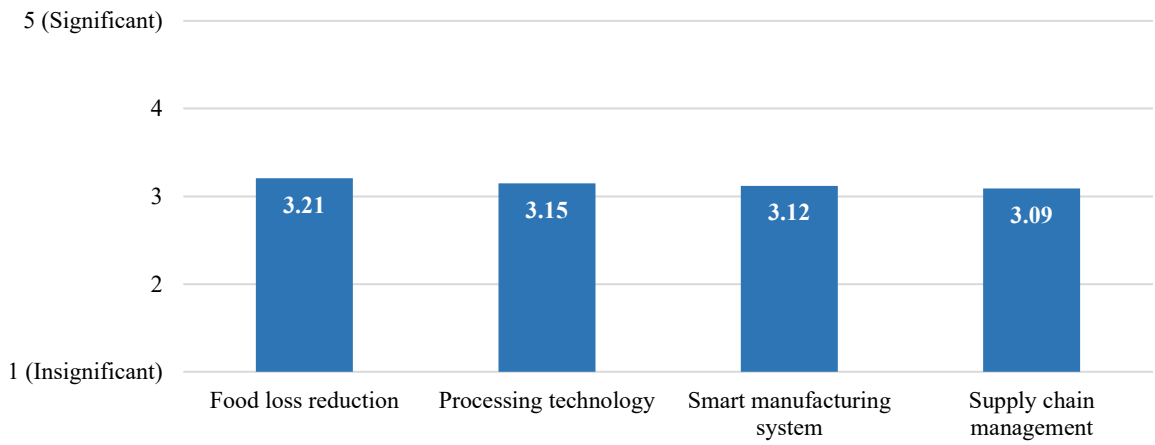

Figure 4 Significance of Investment in Low-Carbon Food Supply Chain Development

2.3 Results for Policy Support for Cultivating a Low-Carbon Food Supply Chain

This section examines policy support for cultivating a low-carbon food supply chain in respondents' economies through seven quantitative questions and one open-ended question that invited suggestions or additional comments. The results are presented in Figure 5 and Figure 6.

Regarding Figure 5, covering Questions 1 and 2 in this section, the survey options include Material production- traditional agriculture, Material production-new technology (e.g., fermentation, cell-culture), Food processing, Food distribution, and Food consumption—allow for a systematic assessment of both the desired government support and the actual policy support received across all key segments in cultivating a low-carbon food supply chain.

Figure 5 presents respondents' assessments of government policy support for different segments of the low-carbon food supply chain, comparing the extent to which support should be provided and the extent of support received.

For material production based on traditional agriculture, the level of policy support received (4.06) exceeded the level considered necessary (3.71). A similar pattern was observed for food processing, where support received (3.24) was slightly higher than the level respondents believed should be provided (3.12). In food consumption, the perceived level of policy support received (2.12) also surpassed the level that respondents considered appropriate (2.09).

In contrast, in material production based on new technologies, the support received (3.03) was lower than the level considered necessary (3.35). A similar pattern was observed in food distribution, where the extent of support received (2.56) was lower than the level respondents believed should be provided (2.74).

Overall, the results suggest that policy support is stronger for the traditional agricultural material production, processing, and consumption stages, while the support received for new agricultural material production and distribution remains more limited and generally falls short of what

respondents considered necessary.

Q1: Based on your understanding, to what extent in each segment should the government support cultivating a low-carbon food supply chain in your economy?
Q2: In your economy, to what extent has each segment of the food supply chain received government policy support for low-carbon initiatives?

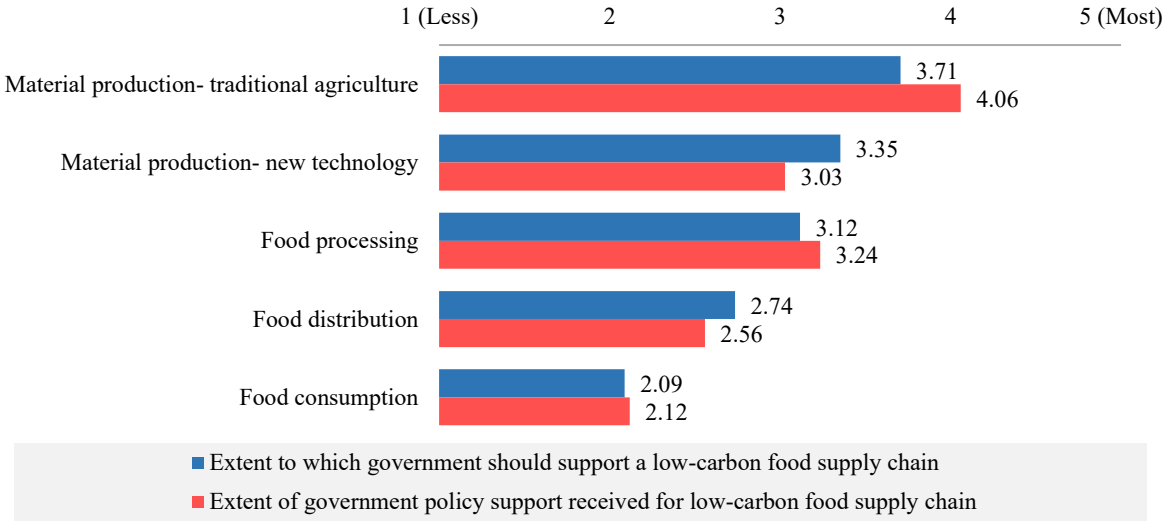

Figure 5 Government Policy Support for Low-Carbon Food Supply Chain Segments

Figure 6 (covering Questions 3–7) presents the types of government support provided to cultivate a low-carbon food supply chain across different segments.

For material production – traditional agriculture, government support includes subsidies (e.g. for land, equipment, renewable energy and clean technology adoption), tax incentives (e.g. for adopting low-carbon agricultural practices, such as cover cropping, regenerative farming), low-interest loans, technical assistance and capacity building, carbon footprint measurement and certification, and carbon credit and allowance (e.g. Emission Trading System (ETS) or voluntary carbon market participation mechanisms). It shows that technical assistance and capacity building (32) and subsidies (27) were the most frequently reported types of support, followed by low-interest loans (16), carbon footprint measurement and certification (13), tax incentives (10), and carbon credits and allowances (9). In addition, one respondent from the United States reported WTO-compliant cost-share funding for conservation practices as a form of government support for traditional agricultural material production.

For material production – new technology, it receives similar types of support to traditional agriculture, with additional emphasis on subsidies for laboratory infrastructure. It shows that technical assistance and capacity building (23) and subsidies (16) were the most frequently reported types of support, followed by carbon footprint measurement and certification (12), tax incentives (12), low-interest loans (7), and carbon credits and allowances (6). In addition, one

respondent from the United States expressed the view that, other than basic research, government involvement in new technology-based material production should be limited. Meanwhile, a respondent from Chile reported the provision of funding for research projects.

For food processing, government supports target energy-efficient and low-carbon production through subsidies (e.g. preferential tax rates for certified low-carbon food processing), tax incentives, low-interest loans, technical assistance (e.g. for circular product design and sustainable packaging and material innovation), carbon footprint measurement and certification, carbon credits and allowance, and food waste reduction initiatives. It shows that technical assistance (27), initiatives to reduce food waste (17) and subsidies (16) were the most frequently reported types of support, followed by carbon footprint measurement and certification (14), tax incentives (11), low-interest loans (9), and carbon credits and allowances (5).

For food distribution, it receives similar types of support to food processing, but more focusing on low-emission logistics, targeting subsidies (e.g. for energy-efficient food storage and retail equipment), tax incentives (e.g. for electrification of distribution fleets, such as electric trucks), low-interest loans (e.g. for investment in low-emission logistics and cold chain infrastructure), technical assistance (e.g. support for digital platforms to optimize logistics and reduce transportation emissions), carbon footprint measurement and certification, carbon credits and allowance, and initiatives to reduce food waste. It shows that technical assistance (21) and initiatives to reduce food waste (20) were considered most common types of support, followed by subsidies (13), low-interest loans (12), carbon footprint measurement and certification (12), tax incentives (8), and carbon credits and allowances (6).

For food consumption, government measures include public awareness campaigns promoting low-carbon diets (e.g. for plant-based, local sourcing), promotion (e.g. for purchasing certified low-carbon food products), financial incentives (e.g. tax deductions or subsidies for purchasing certified environmentally friendly food products), carbon footprint measurement and certification, carbon credits and allowance, and food waste reduction programs. It shows that initiatives to reduce food waste (27) and public awareness campaigns promoting low-carbon diets (22) were the most frequently reported types of support, followed by carbon footprint measurement and certification (8), promotion (7), financial incentives (6), and carbon credits and allowances (3).

Overall, the results indicate that technical assistance and capacity building, subsidies, and initiatives to reduce food waste are the most common forms of government support across the low-carbon food supply chain, with the strongest focus on traditional agriculture-based material production. In contrast, support for food consumption emphasizes initiatives to reduce food waste and public awareness campaigns promoting low-carbon diets, while financial incentives and carbon credit remain limited.

Q3: What types of government support have been provided for material production- traditional agriculture to cultivate a low-carbon food supply chain in your economy?

Q4: What types of government support have been provided for material production- new technology, e.g., fermentation, cell-culture to cultivate a low-carbon food supply chain in your economy?

Q5: What types of government support have been provided for food processing to cultivate a low-carbon food supply chain in your economy?

Q6: What types of government support have been provided for food distribution to cultivate a low-carbon food supply chain in your economy?

Q7: What types of government support have been provided for food consumption to cultivate a low-carbon food supply chain in your economy?

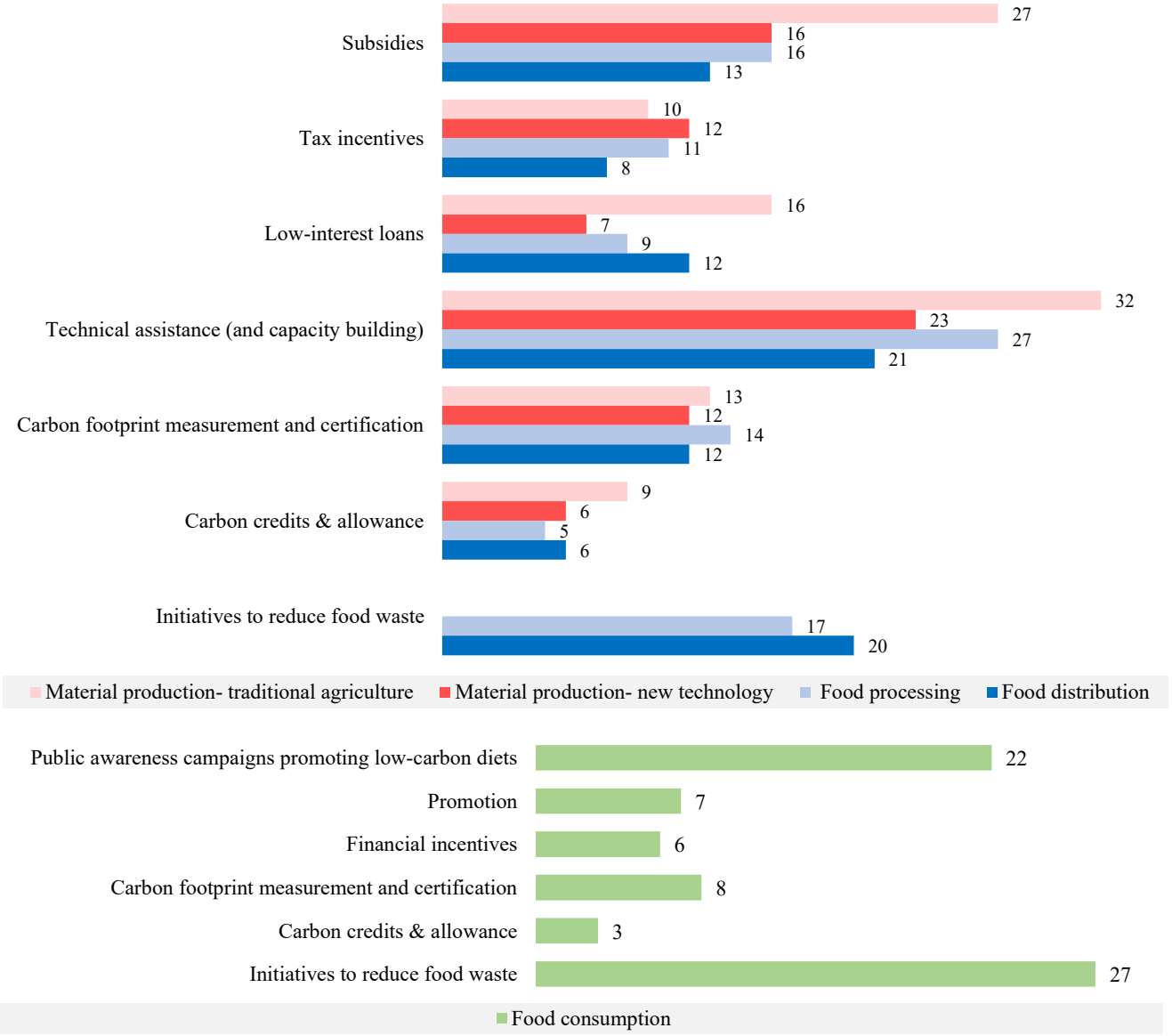

Figure 6 Types of Government Supports to Cultivate a Low-Carbon Food Supply Chain

Finally, Question 8 in this section collected additional **suggestions or comments regarding government policies to cultivate a low-carbon food supply chain** in respondents' economies, including increasing investment in research and development to strengthen recycling incentives, inviting stakeholders from different segments of the supply chain to share their experiences, addressing emission reduction challenges in primary production, creating more awareness programs, adopting phased policy frameworks, and supporting initiatives implemented at the local or provincial level in partnership with the private sector. Respondents also emphasized that governments should prioritize regulating food safety and consumer health, rather than selecting the technologies or production practices that businesses use to meet consumer demand. In addition, one respondent from Indonesia noted that the Indonesian government has begun implementing several policies related to low-carbon food processing technology. However, these initiatives have not yet become the primary policy focus, as the government's main priority remains achieving domestic food self-sufficiency.

Furthermore, one suggestion emphasized the need to strengthen the aggregation of small farmers and fisherfolk, and to develop accessible and integrated agri-fishery processing facilities and hubs, while establishing implementation and monitoring mechanisms for commodity and processing standards to ensure efficiency, product quality, and minimal food loss across the supply chain. Furthermore, strengthening a low-carbon food supply chain requires an integrated policy framework linking production, processing, distribution, and consumption. Priority actions include climate-smart agriculture, improving access to green financing for SMEs, and energy-efficient processing, as well as digital traceability, cold chain expansion, and circular economy practices. Regional cooperation within APEC is also important for technology transfer, knowledge exchange, and capacity building.

2.4 Results for Funding Support for Cultivating a Low-Carbon Food Supply Chain

This section examines funding support for cultivating a low-carbon food supply chain in respondents' economies. Information was collected through five quantitative questions and one open-ended question that invited additional opinions or suggestions. The results are presented in Figures 7, 8, and 9.

Regarding Figure 7, covering Questions 1 and 4 in this section, the survey options include Material production- traditional agriculture, Material production-new technology (e.g., fermentation, cell-culture), Food processing, Food distribution, and Food consumption—allow for a systematic assessment of both the sufficiency of policy-level funding support and where such funding achieves the greatest effect across all key segments in cultivating a low-carbon food supply chain.

Figure 7 presents policy-level funding sufficiency and effects achieved in cultivating a low-

carbon food supply chain. Respondents rated the sufficiency of policy-level funding support for different segments of the low-carbon food supply chain. Material production based on both traditional agricultures received the highest rating (3.53), followed closely by food processing and material production based on new technologies (3.29). Food distribution (2.76) and food consumption (2.12) were considered the least sufficiently supported. Overall, respondents perceive that policy-level funding is concentrated in the production stage, with significantly less support for downstream segments.

In terms of the effect achieved through policy-level funding, material production based on traditional agriculture again received the highest rating (3.91), indicating strong perceived impact. Food processing (3.35) and material production using new technologies (3.12) were perceived as moderately effective. Funding for food distribution (2.65) and food consumption (1.97) was considered to have limited effect. These results suggest that while policy-level funding has a noticeable impact on production activities, its effect on distribution and consumption stages remains minimal.

In addition, a comparison between funding sufficiency and the effect achieved shows that material production based on new technologies and food consumption exhibit lower perceived effects than material production based on traditional agriculture, while food distribution records both low funding sufficiency and limited policy effects.

Q1: Based on your understanding, to what extent for each segment receive sufficient policy-level funding support to cultivate a low-carbon food supply chain in your economy? (Rank the five stages the of the supply chain from 1 to 5 (1=most deficient 5=most sufficient) without duplication)

Q4: Based on your understanding, which segment would achieve the greatest effect on cultivating a low-carbon food supply chain in your economy through funding support? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

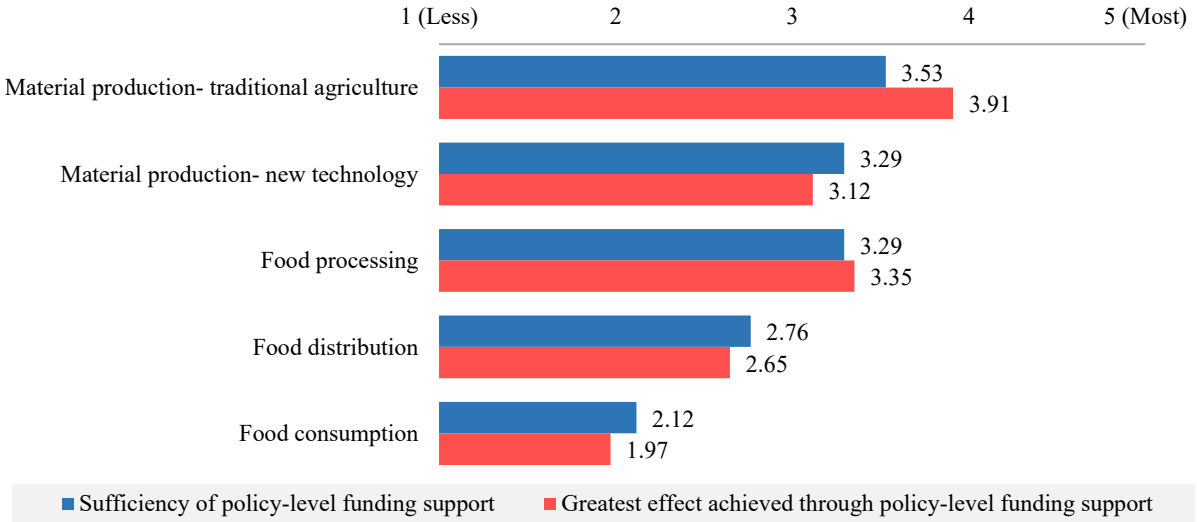

Figure 7 Policy-Level Funding Sufficiency and Effect on Cultivating a Low-Carbon Food

Supply Chain

Regarding Figure 8, covering Question 5 in this section, the survey identifies key barriers or challenges to obtaining policy-level funding for cultivating a low-carbon food supply chain, including lack of accessible information or outreach regarding funding opportunities, lack of diverse funding sources, insufficient incentives in funding terms, difficulties in obtaining loans from financial institutions, and challenges in meeting funding eligibility requirements. It shows that the most frequently cited challenge was insufficient information or outreach regarding available funding opportunities (25) and the lack of strong incentives in funding terms (21). This was followed by the lack of diverse funding sources (20), difficulties in meeting funding eligibility requirements (20), as well as difficulties in obtaining loans from financial institutions (17).

Q5: What are the barriers or challenges in obtaining funding support to cultivate a low-carbon food supply chain? *(Multiple choices)

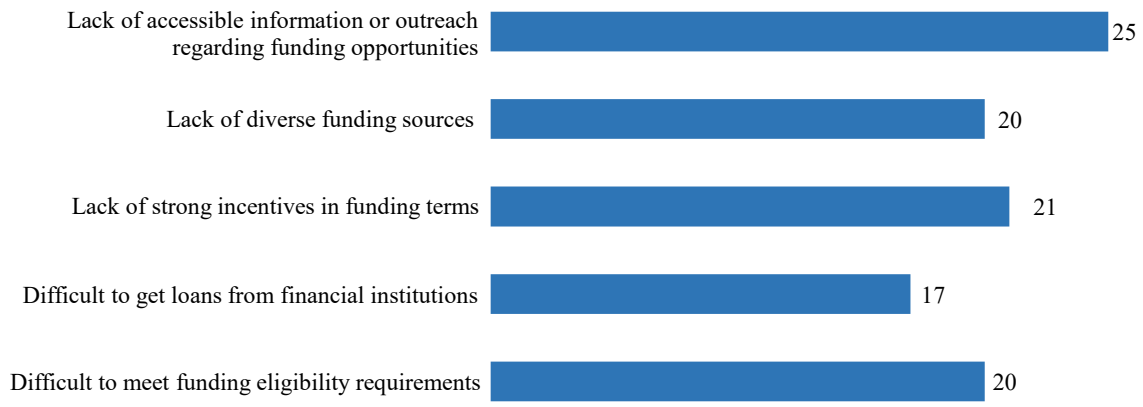

Figure 8 Policy-Level Funding Challenges on Cultivating a Low-Carbon Food Supply Chain

Regarding Figure 9, covering Questions 2 and 3 in this section, respondents who identify the private sector as the primary provider of funding support for cultivating a low-carbon food supply chain in Question 2 proceed to Question 3, which examines the types of funding support available to the private sector. The survey options include government subsidies, policy-based concessional loans, participation in public–private partnerships (PPPs), international cooperation program funding, tax incentives or preferential tax measures, and emerging financial instruments (e.g., green bonds and sustainability bonds).

It shows that participation in public–private partnerships (PPPs) was the most frequently reported funding mechanism (9), followed by government subsidies (5) and policy-based concessional loans (5). In contrast, emerging financial instruments were less commonly reported (3), while tax incentives or preferential tax measures (3) and funding from international cooperation programs (2) were reported less frequently.

The results suggest that private sector funding for low-carbon food supply chains relies primarily on government-linked mechanisms, such as PPPs, concessional loans, and subsidies, while fiscal incentives and international cooperation funding mechanisms remain limited. In addition, one respondent from Australia suggested establishing grant programs to support projects or activities that the private sector can apply for and implement.

Q2: Based on your understanding, which sector plays the primary role in providing funding support for cultivating a low-carbon food supply chain in your economy? *(Select one)

Q3: What types of funding support are available for private sectors to cultivate a low-carbon food supply chain in your economy? (Multiple choices)

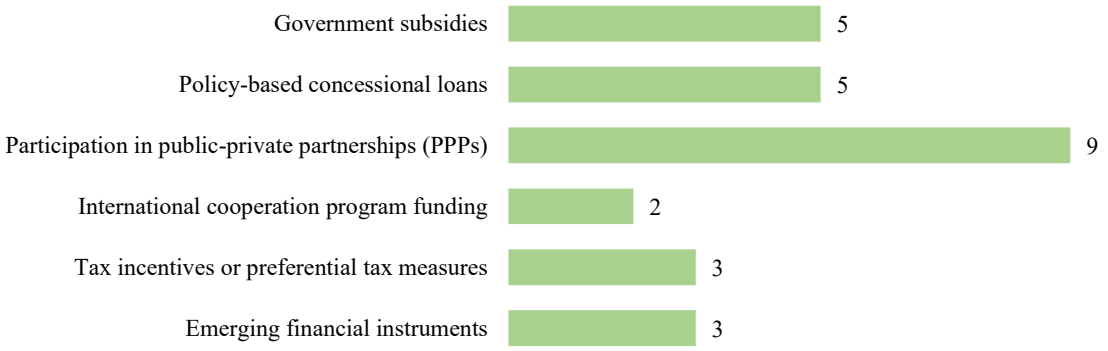

Figure 9 Fundings for the Private Sector in Cultivating a Low-Carbon Food Supply Chains

Finally, Question 6 in this section invited respondents to **share their opinions and suggestions regarding funding support for cultivating a low-carbon food supply chain**, including allocating resources according to the characteristics of different products, avoiding overly decentralized investment approaches, differentiating funding support based on whether measures are commercially viable or exhibit public good characteristics, strengthening incentives for private investment, attracting international investment, recognizing the importance of knowledge and information, ensuring that funding schemes remain flexible and avoid overly restrictive eligibility criteria given the wide range of production systems, supply chain structures, and technological readiness levels, and enhancing the awareness of adopting low-carbon food processing technologies, supported by techno-economic information, to encourage broader stakeholder engagement and implementation. In addition, one respondent highlighted the need to strengthen funding mechanisms by expanding blended finance (public, private, and climate funds) and improving access for SMEs through simplified procedures, technical assistance, and tailored green finance. Furthermore, clear carbon accounting standards, risk-sharing mechanisms, and enhanced regional cooperation within APEC were also considered important for accelerating investment flows toward sustainable food systems.

2.5 Results for Industry Maturity in Cultivating a Low-Carbon Food Supply Chain

This section examines the level of industry maturity in cultivating a low-carbon food supply chain. Information was collected through five quantitative questions. The results are presented in Figures10.

Figure 10 presents respondents' assessments of industry maturity in cultivating a low-carbon food supply chain across different segments, focusing on resistance to carbon reduction, technology readiness, and perceived economic value.

In terms of resistance to carbon reduction, material production based on traditional agriculture was perceived as facing the greatest resistance (3.74), followed by food processing (3.06). Lower levels of resistance were reported for food consumption (2.97) and food distribution (2.71), while material production based on new technologies (e.g., fermentation and cell-culture) was perceived as facing the least resistance (2.53).

Regarding technology readiness for advanced carbon reduction, food processing (3.79) received the highest ratings, indicating relatively mature technological conditions. Food distribution (3.44) and material production based on new technologies (3.24) were also rated moderately high, whereas traditional agriculture (2.41) and food consumption (2.12) were perceived as having lower levels of technological readiness.

In terms of economic value gained from advanced carbon reduction, food processing (3.50), material production based on new (3.38) and traditional technologies (3.21) were rated similarly, while food distribution (2.85) and food consumption (2.06) were perceived as generating more limited economic value.

With respect to the economic value for innovation, material production based on new technologies (3.85) and food processing (3.79) were rated the highest. In contrast, food distribution (2.74), traditional agriculture (2.62), and food consumption (2.00) were perceived as offering lower innovation-related economic value.

Finally, regarding the economic value of importing carbon reduction standards, food processing received the highest rating (3.65), followed by traditional agriculture (3.26) and material production based on new technologies (3.15). Food distribution (2.88) and food consumption (2.06) were again rated lower.

Overall, the results suggest that upstream and midstream segments, particularly food processing and material production based on new technologies, demonstrate higher levels of industry maturity in terms of technology readiness and innovation potential, while food consumption consistently exhibits lower maturity across multiple dimensions.

Q1: Based on your understanding, which segment of the food supply chain face the Maximum resistance for carbon reduction? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

Q2: Based on your understanding, which segment of the food supply chain gain most technology readiness for advance carbon reduction? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

Q3: Based on your understanding, which segment of the food supply chain gain most economic value for advance carbon reduction? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

Q4: Based on your understanding, which segment holds the greatest economic value for innovation (e.g., new products, processes, business models) in cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

Q5: Based on your understanding, which segment holds the greatest economic value for importing carbon reduction standards to cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

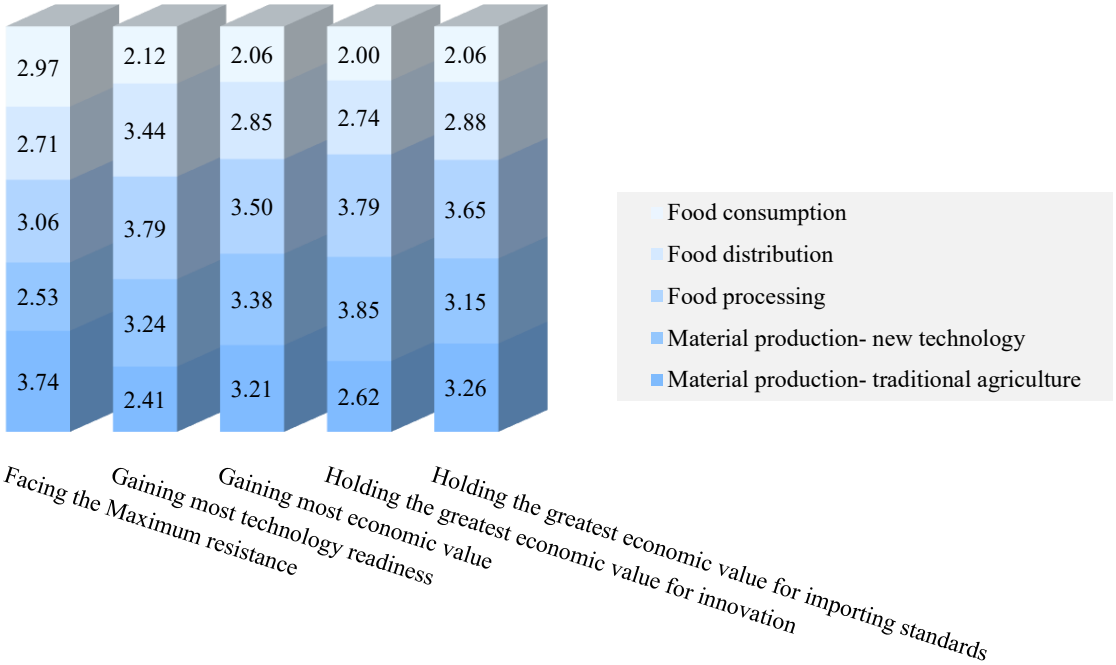

Figure 10 The Industry Maturity in Cultivating a Low-Carbon Food Supply Chain

2.6 Results for Collaborative Approaches to Cultivating a Low-Carbon Food Supply Chain

This section examines collaborative approaches to cultivating a low-carbon food supply chain. Information was collected through four quantitative questions and one open-ended question that

invited additional comments or suggestions. The results are presented in Figures 11, 12, and 13.

Figure 11 presents respondents' views on the perceived advantages of cultivating a low-carbon food supply chain. The most frequently cited advantage was the development of a more sustainable food production ecosystem (32). This was followed by improving the efficiency of the food supply chain (25) and creating opportunities for disruptive innovation (17). Enhancing the supply-demand balance of food distribution was also reported (15), though less frequently than the other benefits.

In addition, one respondent from Chile indicated that it allows the achievement of sectoral and domestic climate targets, while one respondent from the United States noted a lack of interest in claims related to low-carbon food supply chains.

Q1: Based on your understanding, what are the advantages of cultivating a low-carbon food supply chain? *(Multiple choice)

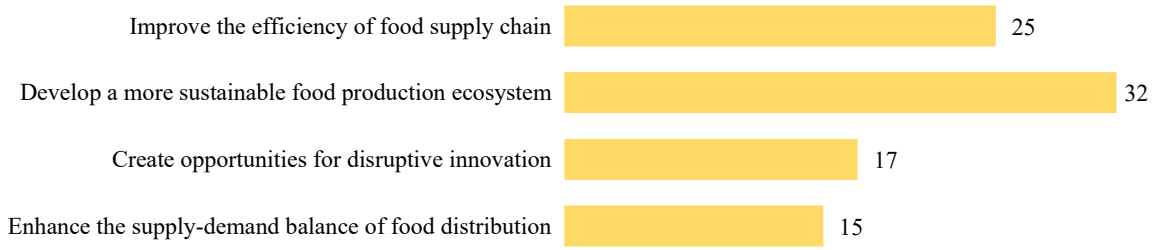

Figure 11 Advantage of Cultivating a Low-Carbon Food Supply Chain

Figure 12 presents respondents' views on the main challenges in cultivating a low-carbon food supply chain. The most frequently reported challenge was the difficulty in seeing the economic benefits of cultivating a low-carbon food supply chain (21). Another significant challenge included the difficulty of changing the food production system (21). In addition, challenges related to the difficulty in importing new technologies into existing food production systems (18), establishing common standards for carbon reduction (18), the lack of attention to low-carbon food initiatives (17), and cross-border trading barriers (11) were also reported.

The results suggest that structural and systemic barriers, as well as limited awareness and perceived economic incentives, are the key obstacles to advancing a low-carbon food supply chain. In addition, one respondent from the United States emphasized that food security should be the priority. A respondent from the Philippines highlighted the importance of the relevance and urgency of the topic to the economy and funding agencies. Meanwhile, a respondent from Peru pointed to the limited technical capacity among small and medium-sized producers to prepare bankable low-carbon projects.

Q2: Based on your understanding, what are the challenges of cultivating a low-carbon food supply chain? *(Multiple choice)

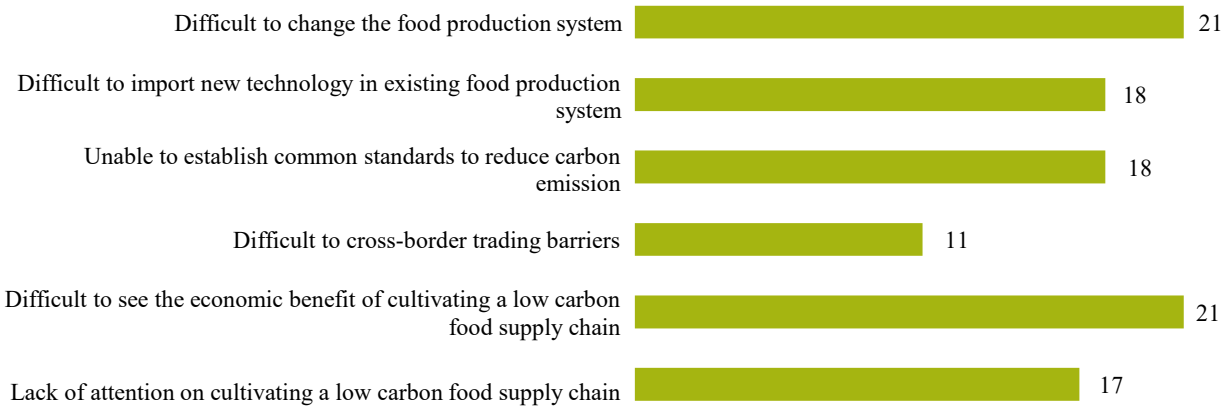

Figure 12 Challenges of Cultivating a Low-Carbon Food Supply Chain

Figure 13 presents respondents' assessments of openness to innovation and to importing carbon reduction standards across different segments of the low-carbon food supply chain. For openness to innovation (e.g., new products, processes, business models), material production based on new technologies was rated the highest (3.91), followed by food processing (3.62). Moderate openness was reported for food distribution (2.85) and traditional agriculture (2.65), while food consumption exhibited the lowest openness (1.97).

For openness to importing carbon reduction standards, food processing received the highest rating (3.76), followed by material production based on new technologies (3.47) and food distribution (3.00). Material production based on traditional agriculture (2.62) and food consumption (2.15) were rated lower.

The results suggest that midstream and upstream segments, particularly material production based on new technologies and food processing, demonstrate higher openness to both innovation and the adoption of external carbon reduction standards, whereas downstream segments, especially food consumption, show comparatively lower openness.

> ***Q3: Based on your understanding, which segment holds the greatest openness for innovation (e.g., new products, processes, business models) in cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)***
>
> ***Q4: Based on your understanding, which segment holds the greatest openness for importing carbon reduction standards to cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)***

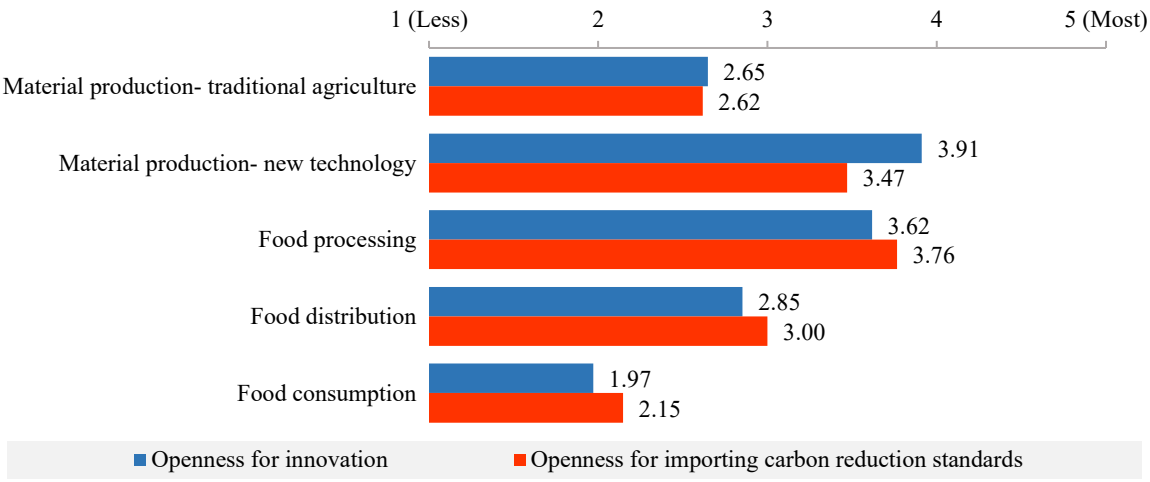

Figure 13 Openness to Innovation and Importing Carbon Reduction Standards in Cultivating a Low-Carbon Food Supply Chain

Finally, Question 5 in this section collected other **comments or suggestions on cultivating a low-carbon food supply chain**, including providing supply chain recommendations for different production scales and organizing exemplary industrial linkages, conducting macro-level and sector-specific GHG emission analyses to identify product-specific emission hotspots, strengthening consumer awareness of low-carbon products, and establishing an enabling policy environment with clear standards, targets, and compliance timelines across supply chain segments. Respondents also highlighted the need to fast-track green energy development to support processing and logistics. In addition, one respondent emphasized the importance of stronger cross-sector collaboration and enhanced support mechanisms, including technology transfer, harmonized carbon standards, APEC regional cooperation, and accessible financing, technical assistance, and simplified certification for small and medium-sized producers to ensure an inclusive and sustainable transition. However, another respondent noted that the high costs of implementing new technologies may create reluctance to change conventional processing methods that are still not low carbon.

3. Discovering Innovative Food Processing Technology to Cultivate a Low-Carbon Food Supply Chain

The two-day workshop consisted of three main sessions and a site visit towards the end of the forum. Discussion themes included Challenges and Strategies on cultivating a Low-Carbon Food Supply Chain; Technological Innovation for Low-Carbon Food Supply Chain by SME; and Technological Solutions for Low-Carbon Food Supply Chains. Each session was concluded with a panel discussion and an open discussion, if time permitted.

3.1 Challenges and Strategies on Cultivating a Low-Carbon Food Supply Chain

As climate change, resource depletion, and environmental degradation continue to threaten global food security, the food industry faces increasing pressure to transform its production and supply chain systems. Across the Asia-Pacific region, governments, industries, and research institutions are actively exploring pathways toward low-carbon food systems that simultaneously enhance sustainability, competitiveness, and resilience. The discussions presented during the APEC workshop demonstrate that technological innovation, supportive public policies, circular economy practices, and international collaboration are all essential components of this transition.

The food industry has undergone significant transformation over the past several decades. As highlighted by Dr. Chii-Cherng Liao of the Food Industry Research and Development Institute (FIRDI), many economies have shifted from labor-intensive food manufacturing to increasingly intelligent and data-driven production systems. However, despite these advancements, food production remains a major contributor to greenhouse gas emissions. High emissions from raw material production, inefficient processing methods, food loss, waste generation, and energy-intensive supply chains continue to pose substantial challenges. To address these issues, industries must first measure their carbon emissions, then implement reduction strategies, and ultimately work toward carbon neutrality. Smart manufacturing technologies, energy-efficient equipment, and the circular utilization of food by-products are becoming increasingly important tools for achieving these goals.

Technology plays a central role in enabling low-carbon transformation. Research conducted jointly by the Chung-Hua Institution for Economic Research (CIER) and FIRDI highlights broad recognition among stakeholders of the importance of reducing food loss, advancing food processing technologies, implementing smart manufacturing systems, and improving supply chain management. Artificial intelligence (AI) has emerged as a particularly promising solution. For example, Chinese Taipei's AI Common Model and Pilot Trial Site Program has demonstrated how digital technologies can optimize production processes in the beverage manufacturing, fermentation, drying, and baking industries, resulting in improved efficiency and reduced energy consumption. These applications illustrate how data-driven decision-making can significantly lower the environmental footprint of food production while maintaining productivity and profitability. The workshop discussions further highlighted the role of clean-label and green-label initiatives in supporting low-carbon product development through ingredient innovation, smart manufacturing, packaging design, and sustainability-oriented standards.

In addition to technological innovation, the circular economy presents valuable opportunities to reduce waste and carbon emissions. Several successful cases demonstrate how waste streams can be transformed into valuable resources. Gugo Kitchen, a carbon-neutral restaurant, integrates

carbon offsetting, green procurement, and smart energy management into its operations. Meanwhile, Young Ray Co. has developed a circular business model that recycles used cooking oil and converts it into feedstock for sustainable aviation fuel through AIoT-enabled collection and traceability systems. Similar approaches are also being adopted in Singapore, where food waste is transformed into animal feed, biogas, agricultural nutrients, and upcycled food products. These examples illustrate how circular economy practices can simultaneously reduce waste, create economic value, and lower carbon emissions.

Government policy plays a crucial role in facilitating low-carbon transitions. Indonesia offers a notable example with its long-term vision of establishing a climate-resilient, inclusive, and circular food system by 2045, while aiming for net-zero emissions by 2060. To achieve these goals, Indonesia has developed sustainable finance frameworks, incentives for low-carbon manufacturing, waste-to-energy projects, and a Sustainable Taxonomy that directs investment toward environmentally responsible activities. Similarly, Singapore's Green Plan 2030 and Resource Sustainability Act mandate that large commercial entities implement food waste segregation and treatment systems. These policy frameworks not only encourage businesses to adopt greener practices but also provide clear market signals that support sustainable investment and innovation.

Financial mechanisms play a crucial role in accelerating the adoption of low-carbon technologies. According to Professor Matthew Tan, venture capital investors often evaluate projects based on their potential to achieve price competitiveness with conventional products, particularly when price gaps can be narrowed within a relatively short timeframe. Public-private partnership models that combine government funding with private-sector expertise can help bridge funding gaps and mitigate risks associated with emerging green technologies. By aligning financial incentives with sustainability objectives, governments and investors can accelerate the commercialization of innovative solutions and encourage broader industry participation in decarbonization efforts.

Despite these advances, significant challenges remain, particularly in influencing consumer behavior. While businesses increasingly recognize the importance of carbon reduction, many consumers lack sufficient motivation or information to choose low-carbon products. Information asymmetry, limited awareness, and concerns about higher prices often hinder adoption. Workshop participants emphasized the importance of developing reliable standards, third-party verification systems, and transparent labeling mechanisms to help consumers identify and trust low-carbon products. Emerging technologies, such as generative AI platforms, may further enhance transparency by facilitating standards harmonization and providing accessible sustainability information across markets.

Furthermore, international cooperation is essential for scaling low-carbon innovations. Many sustainable technologies face commercialization challenges due to limited production scale and

high costs. Collaborative efforts among APEC economies can help overcome these barriers by combining technological expertise, raw material resources, and market opportunities. For example, cooperation between Chinese Taipei's pineapple fiber technology and the Philippines' abundant agricultural by-products could create a larger-scale, more cost-effective circular economy solution. Such partnerships demonstrate how regional collaboration can accelerate innovation while reducing environmental impacts across borders.

In conclusion, building a low-carbon food supply chain requires a comprehensive and coordinated approach that integrates technological innovation, circular economy principles, supportive government policies, sustainable finance, consumer engagement, and international collaboration. As climate challenges intensify, food systems must evolve beyond traditional production models toward smarter, cleaner, and more resilient practices. By leveraging emerging technologies, strengthening public-private partnerships, and fostering regional cooperation, economies across the Asia-Pacific region can create sustainable food systems that contribute not only to carbon reduction goals but also to long-term economic growth and food security.

3.2 Technological Innovation for Low-Carbon Food Supply Chain by SME

The global food system stands at a critical crossroads. Climate change, resource depletion, biodiversity loss, and rising food demand are exerting unprecedented pressure on food production and distribution networks. Simultaneously, governments, industries, and consumers increasingly expect food systems to contribute to carbon reduction and sustainable development goals. Addressing these challenges requires more than isolated technological improvements; it demands a comprehensive transformation of the entire food supply chain. The discussions and case studies presented during the APEC workshop reveal that the future of low-carbon food systems depends on integrating nature-inspired principles, technological innovation, circular economy strategies, smart manufacturing, and strong multi-stakeholder collaboration. Together, these elements can create resilient, efficient, and sustainable food supply chains capable of supporting both environmental and economic sustainability.

A fundamental starting point for this transformation is rethinking the concept of sustainability itself. Professor Y. Martin Lo argued that true sustainability goes beyond operational efficiency and carbon reduction targets. Nature offers valuable lessons through its interconnected ecosystems, where resources are continuously recycled, energy is efficiently distributed, and resilience arises from cooperation among diverse organisms. Natural systems demonstrate that adaptability, interdependence, and circular resource flows are essential for long-term survival. Applying these ecological principles to food systems can help policymakers and industries design

supply chains that are not only environmentally sustainable but also capable of adapting to future uncertainties. Economic resilience, therefore, should be regarded as inseparable from ecological resilience, with factors such as soil health, biodiversity, water conservation, waste reduction, and community engagement playing equally important roles.

Technological innovation is a key driver of low-carbon transformation. In the field of food ingredient production, alternative protein technologies present promising opportunities to reduce the environmental footprint of food systems. Dr. Yu-Wei Lin introduced ULTIMEAT's fungal fermentation platform, which converts regional crops and food industry by-products into protein-rich ingredients through bioconversion processes. Compared to traditional livestock production, fungal protein requires significantly less land, water, and generates fewer carbon emissions. By utilizing locally available crops such as cassava and sweet potatoes as fermentation feedstocks, the platform not only reduces environmental impacts but also enhances regional food security and lowers transportation-related emissions. Furthermore, the upcycling of food processing residues into feed and food ingredients exemplifies how waste streams can be transformed into valuable resources within a circular economy framework.

Similarly, innovative approaches to marine resources offer additional pathways for sustainable food production. Dr. Karla Inés Calderón Mayo highlighted that red seaweed can serve as a climate-smart raw material due to its rapid growth and minimal reliance on freshwater, agricultural land, or synthetic inputs. Through an integrated biorefinery model, nearly the entire biomass can be utilized, with residual materials processed into flour for plant-based food products. This approach minimizes waste while generating additional economic value. These examples demonstrate how circular bioeconomy strategies can simultaneously enhance resource efficiency, reduce carbon emissions, and create new business opportunities.

Beyond ingredient innovation, food manufacturing itself offers significant opportunities for carbon reduction. Although manufacturing accounts for a relatively small proportion of total food supply chain emissions, improving production efficiency can yield substantial environmental benefits. According to Dr. Binghuei Barry Yang, smart manufacturing systems, artificial intelligence, data optimization, and whole-food utilization strategies are becoming essential tools for sustainable food processing. Digital technologies enable companies to increase yields, enhance product quality, optimize energy consumption, and reduce waste generation. Upcycling by-products and incorporating alternative ingredients further contribute to lowering the carbon intensity of production processes. These innovations demonstrate that sustainability and productivity can be mutually reinforcing rather than conflicting objectives.

The experience of Biozyme Biotechnology further demonstrates how smart manufacturing can

support low-carbon objectives. Through factory automation, sensor-based monitoring systems, energy management technologies, and enterprise resource planning integration, food manufacturers can identify inefficiencies and reduce unnecessary resource consumption. Importantly, these technologies are becoming increasingly accessible to small and medium-sized enterprises (SMEs), enabling broader participation in the green transition. Collaboration among academia, industry, and government has been especially important in facilitating technology adoption and innovation within the food sector.

Low-carbon transformation must extend beyond production to encompass food distribution and consumption. Food loss remains one of the largest contributors to unnecessary carbon emissions throughout the supply chain. Dr. Nobutaka Nakamura demonstrated that advanced distribution technologies—such as cold chain management, controlled atmosphere storage, and modified atmosphere packaging—can significantly reduce post-harvest losses in fruits and vegetables. Although these technologies may require additional energy and materials, life cycle assessments show that their ability to prevent food waste often outweighs their direct environmental impacts. Therefore, effective low-carbon strategies require a holistic evaluation of both direct and indirect environmental effects, rather than focusing solely on individual stages of the supply chain.

Agricultural innovation plays a crucial role in reducing emissions during the production stage. Thailand's experience demonstrates how technologies such as laser land leveling, alternate wetting and drying irrigation systems, site-specific nutrient management, and sustainable straw utilization can significantly reduce methane emissions from rice cultivation. Simultaneously, support mechanisms—including sustainability training, carbon footprint certification assistance, and green financing programs—help small and medium-sized enterprises (SMEs) participate in low-carbon transitions. These initiatives underscore the importance of creating enabling ecosystems that integrate technological solutions with knowledge sharing, financial support, and institutional collaboration.

Despite the availability of promising technologies, widespread adoption remains a significant challenge, particularly among small and medium-sized enterprises (SMEs). Throughout the workshop discussions, participants consistently emphasized that profitability is the primary concern for most businesses. Consequently, low-carbon technologies must demonstrate clear economic benefits to achieve large-scale adoption. Innovations become scalable when firms can realize measurable returns on investment, reduce operational costs, or access new market opportunities. Government support, harmonized standards, public-private partnerships, and collaboration between industry and academia are therefore essential to reduce adoption barriers and create favorable business conditions. Equally important is the need for stakeholders to share a common vision and collaborate across the entire value chain to identify inefficiencies and

implement coordinated solutions.

Ultimately, the transition toward a low-carbon food supply chain is not solely a technological challenge but also a systemic one. Nature teaches us that resilience emerges from interconnectedness, adaptability, and cooperation. Similarly, sustainable food systems require collaboration among governments, researchers, industries, financial institutions, and consumers. By combining nature-inspired thinking with technological innovation, circular economy practices, smart manufacturing, sustainable distribution, and supportive policy frameworks, the food sector can build a future that is both environmentally responsible and economically resilient. As climate pressures continue to intensify, such integrated approaches will be essential for ensuring food security, protecting natural resources, and achieving long-term sustainability across the global food system.

3.3Technological Solutions for Low-Carbon Food Supply Chain

The global food system is confronting unprecedented challenges driven by climate change, resource scarcity, population growth, and rising consumer demands for sustainability. Food production, processing, distribution, and consumption collectively contribute significantly to greenhouse gas emissions, land degradation, water depletion, and biodiversity loss. As a result, transitioning to a low-carbon food supply chain has become an urgent priority for governments, industries, and research institutions worldwide. Achieving this transformation requires a comprehensive approach that integrates technological innovation, circular economy principles, smart agriculture, sustainable manufacturing, and cross-sector collaboration. The experiences and case studies shared by experts from APEC economies demonstrate that low-carbon food systems are not only environmentally essential but also economically viable when supported by innovation and coordinated action.

A key foundation of low-carbon food supply chains is the adoption of circular economy models that maximize resource efficiency and minimize waste. The Mitr Phol Group in Thailand provides an outstanding example of how agricultural industries can transform by-products into valuable resources. Rather than treating sugarcane residues such as bagasse, molasses, and filter cake as waste, the company converts them into bioenergy, ethanol, organic fertilizers, and animal feed. This approach simultaneously reduces waste disposal, creates additional revenue streams, and lowers carbon emissions. Such circular strategies demonstrate that sustainability and profitability can complement each other, providing businesses with both environmental and economic benefits. Moreover, these practices highlight the importance of viewing waste not as a liability but as a resource capable of generating new value within the supply chain.

The transition to low-carbon food systems must begin at the agricultural level, where a significant portion of emissions originates. Smart agriculture technologies are increasingly enabling producers to enhance efficiency while minimizing environmental impacts. Mitr Phol's "Modern Farm" model integrates GPS-guided machinery, IoT-enabled irrigation systems, unmanned aerial vehicles, and precision fertilization techniques to optimize the use of water, energy, and agricultural inputs. When combined with sustainable farming practices such as minimum tillage, crop rotation, and controlled traffic farming, these technologies contribute to improved soil health, reduced emissions, and increased productivity. Importantly, the company acknowledges that Scope 3 emissions—those generated throughout the broader supply chain—represent the largest source of environmental impact. Therefore, comprehensive decarbonization efforts must extend beyond individual facilities to encompass agricultural production, transportation, and logistics networks.

Another transformative area is biotechnology and fermentation-based innovation. Grape King Bio exemplifies how advanced fermentation technologies can contribute to sustainable food production while supporting domestic net-zero goals. As a leading biotechnology company, Grape King utilizes probiotic strains and mushroom mycelium to develop health-focused food products with lower environmental footprints. Precision fermentation technologies enable more efficient production processes while reducing resource consumption and emissions. Furthermore, the company integrates sustainability throughout its operations by utilizing saltwater resources, converting food waste into agricultural inputs and biogas, and implementing digital technologies to optimize energy efficiency. The potential of mycoprotein as an alternative protein source further demonstrates how biotechnology can reduce dependence on resource-intensive livestock production while providing nutritious food alternatives for growing populations.

The broader potential of emerging food technologies was further emphasized through life-cycle analyses conducted by Vitalmetrics. Technologies such as fermentation-derived proteins, food by-product upcycling, shelf-life extension solutions, advanced thermal processing, and reduced cold-chain dependence all present significant opportunities to reduce emissions across food systems. However, these benefits are highly contingent on implementation conditions. For instance, the sustainability of fermentation technologies depends heavily on the carbon intensity of the electricity used during production. Similarly, the effectiveness of waste-reduction technologies relies on actual reductions in food loss and the degree to which they replace conventional products. These findings highlight the importance of adopting a systems-thinking approach and employing robust life-cycle assessment methodologies to ensure that technological innovations deliver genuine environmental benefits.

Food processing and preservation technologies play a crucial role in reducing carbon emissions.

Researchers from Indonesia's National Research and Innovation Agency have demonstrated that innovations such as controlled fermentation, food waste upcycling, cold plasma technology, essential oil extraction, and advanced preservation methods can significantly enhance sustainability. Traditional cold storage systems often consume substantial amounts of energy, making food preservation a major source of emissions. Emerging alternatives—including edible coatings, modified atmosphere packaging, plasma sterilization, pulsed electric fields, and Ohmic heating—offer ways to maintain food quality while reducing reliance on energy-intensive refrigeration. By integrating these technologies with efficient processing systems, companies can simultaneously improve product quality, reduce waste, and lower environmental impacts.

Circular economy principles are equally applicable on smaller scales, as demonstrated by Long Sun Brewing Company in Chinese Taipei. The brewery integrates local ingredients, traditional knowledge, and innovative waste utilization practices into its operations. Spent grain generated during beer production is transformed into bread, pet snacks, soap, decorative panels, and other value-added products through partnerships with local businesses. These collaborations illustrate how cross-industry cooperation can reduce food waste while strengthening local economies and preserving cultural heritage. By converting production residues into marketable products, Long Sun Brewing exemplifies how sustainability can drive innovation and provide a competitive advantage.

An essential enabler of low-carbon transformation is the ability to accurately measure and manage emissions. Throughout discussions, experts consistently emphasized that effective management begins with precise measurement. Advanced digital technologies—including enterprise resource planning systems, software-as-a-service platforms, artificial intelligence, and automated carbon accounting tools—are making environmental monitoring more accessible and reliable. By integrating operational data into centralized systems, companies can identify inefficiencies, monitor energy consumption, and uncover opportunities to reduce emissions. AI-powered analytics further enhance decision-making by processing large datasets and generating actionable insights. As carbon transparency becomes increasingly important for international trade and regulatory compliance, digital measurement systems will play a critical role in supporting sustainability initiatives.

Despite the availability of promising technologies, widespread adoption remains challenging, particularly for small and medium-sized enterprises. Financial constraints, fragmented industry structures, compliance costs, and uncertainty regarding returns on investment often limit implementation. Consequently, successful low-carbon transitions require supportive policy frameworks, harmonized standards, research partnerships, and financial incentives. Equally important is ensuring that sustainability initiatives deliver tangible economic value. As several

panelists noted, businesses are more likely to adopt and scale innovations when they clearly contribute to profitability, competitiveness, and long-term resilience. Therefore, government support, industry collaboration, and knowledge-sharing platforms are essential for reducing barriers and accelerating adoption.

Ultimately, building a low-carbon food supply chain requires more than isolated technological breakthroughs; it demands a coordinated transformation of the entire food ecosystem. Smart agriculture, biotechnology, circular economy practices, advanced processing technologies, digital monitoring systems, and collaborative partnerships must work together toward a common goal. Success depends on engaging all stakeholders—from farmers and manufacturers to retailers, policymakers, researchers, and consumers—in a shared vision of sustainability. By integrating innovation with practical implementation and economic incentives, the global food industry can reduce its environmental footprint while maintaining food security, supporting economic growth, and creating a more resilient future. The experiences shared across APEC economies demonstrate that, although challenges remain, the pathway toward a sustainable and low-carbon food system is both achievable and increasingly within reach.

3.4Section Conclusion

The closing remarks were given by Dr. Bing-Huei Yang, deputy director general from Food Industry Research and Development Institute.

Dr. Yang noted that there is increasing pressure on food systems to transition toward low-carbon operations, but firms face several barriers in doing so, including limited incentives, insufficient preparation, and restricted access to technology. These challenges are particularly pronounced for small and medium-sized enterprises (SMEs) that encounter high technology costs, weak implementation of carbon labeling systems, limited incentives, and a lack of transparency across supply chains. As a result, while the urgency for decarbonization is widely recognized, the pace of adoption remains uneven across the industry.

In response, multiple pathways have emerged to support the adoption of low-carbon technologies and practices. Currently, firms can leverage practical strategies such as workforce training, decentralized processing hubs, upcycling initiatives, and greener supply chain promotion to reduce emissions. To further improve SMEs ability to adapt to a low-carbon supply chain scalable financial mechanisms are necessary, such as ESG-based loans, targeted incentives, PPP frameworks, and accessible smart technologies.

Governments, public-private partnerships (PPPs), and collaborations between industry and academia also play a crucial role in enabling the green transition. At the regional level, APEC can further accelerate progress by facilitating policy dialogues, strengthening cross-border collaboration, enhancing supply chain connectivity, and promoting standardized carbon footprint

measurement. Together, these efforts can help create a more supportive ecosystem for building low-carbon food supply chains.

3.5 Case Highlight

Towards the end of the discussion sessions of the workshop, the event concluded with a tour hosted by the King Car Group. There were 41 participants who joined the field trip coming from Australia; Indonesia; Japan; Malaysia; Papua New Guinea; Peru; the Philippines; Chinese Taipei; Thailand; and the United States.

Currently, the King Car Group is a major conglomerate in Chinese Taipei that manufacturers beverages, chemicals, and household items since 1979. In 2022, The company began by conducting a comprehensive greenhouse gas inventory in 2022 to understand the company's footprint. In response, it installed renewable energy infrastructure across its facilities and implemented an Energy Management System, which resulted in annually generating over 1.38 million kWh of clean energy and reducing 700 tons of carbon emissions. Other than managing its energy generation and usage, the company has adopted sustainable packaging for its products, such as lightweight glass bottles and redesigned PET containers. It has also committed to circular economic practices, including sludge drying systems and upcycling spent coffee grounds into eco-friendly products.

The tour group arrived at one of the conglomerate's subsidiaries, Kavalan Whiskey Distillery in Yilan County. Since 2005, the King Car Group established its whiskey brand from imported professionals and capital equipment to build one of Chinese Taipei's most renowned beverage brands. The company has been allocating numerous resources to improve its distillery operations and develop its recipe, which has garnered many international awards from organizations such as the San Francisco World Spirits Competition, the International Wine & Spirit Competition, and the Malt Maniacs Awards. Throughout the tour, delegates from the workshop were given a firsthand look at the distillery facility's operations and various processes from barrel production, brewing, storing, fermenting, and bottling. At the end of the tour, the company prepared some tokens of appreciation showcasing the King Car Group's upcycled byproducts.

4. APEC Regional Issues in Cultivating a Low-Carbon Food Supply Chain

4.1 Climate Change and Food Security Challenges in APEC

As climate change intensifies globally, APEC member economies are facing growing challenges related to food security and sustainable economic development. Rising temperatures, prolonged droughts, stronger typhoons, and other climate-related disruptions continue to threaten food production and supply stability. At the same time, global food supply chains account for

approximately one-third of global greenhouse gas (GHG) emissions, highlighting the urgent need for economies to transition toward more sustainable and low-carbon systems. In this context, APEC plays a critical role in promoting regional cooperation to foster resilient and low-carbon food supply chains for a more sustainable future.

4.2 APEC Initiatives on Sustainable Food Supply Chains

APEC recognizes both the strategic importance and vulnerability of the Asia-Pacific food supply chain, particularly in the face of pandemics, supply disruptions, and climate change, as reflected in the Putrajaya Vision 2040. Guided by the Aotearoa Plan of Action, APEC aims to strengthen sustainable food supply chains to enhance food security and climate resilience. To support these goals, APEC PPSTI organized a workshop in March 2026, accompanied by a pre-event survey, to facilitate knowledge sharing and promote low-carbon food supply chain development across member economies.

4.3 Complexity of Decarbonizing Food Supply Chains

The workshop discussions highlighted the complex and interconnected nature of food supply chains, which present significant challenges for decarbonization efforts. Greenhouse gas emissions are generated across multiple stages of the supply chain, including agricultural production, food processing, transportation, logistics, and packaging. While many firms have initiated measures to reduce energy consumption and waste, participants emphasized that meaningful decarbonization requires coordinated action and commitment from all stakeholders throughout the supply chain.

4.4 Technological Innovation as a Driver of Decarbonization

Technological innovation emerged as a primary driver in advancing low-carbon food supply chains. During the workshop, delegates shared various technologies and practices aimed at improving sustainability in manufacturing and supply chain operations. Examples included innovative processing technologies developed through partnerships with research institutions, the use of artificial intelligence and data-driven solutions to optimize resource management, and circular economy practices such as reusing and upcycling food waste. These initiatives demonstrate how both advanced and practical innovations can contribute to reducing carbon footprints across the supply chain.

4.5 Key Challenges to Green Transition

Despite encouraging progress, workshop participants also identified several challenges that hinder the supply chain’s green transition. Key constraints include limited financial and technical resources for innovation development and adoption, uneven firm capabilities, and insufficient market awareness of low-carbon practices. These factors reduce incentives for businesses to invest in sustainability measures. Participants emphasized that addressing these barriers and

strengthening cooperation among APEC member economies will be essential to scaling up the adoption of low-carbon technologies and practices.

4.6The Way Forward

Achieving APEC's goal of "Strong, Balanced, Secure, Sustainable and Inclusive Growth" in food supply chains remains a complex but important objective. The workshop underscored both the diversity and complexity of global food supply chains, involving multiple stakeholders with varying interests, capacities, and standards. At the same time, it highlighted encouraging progress by firms that are actively pursuing decarbonization through innovative technologies and sustainable practices. Moving forward, stronger regional cooperation among APEC member economies will be essential, particularly in establishing common standards, reducing trade barriers for low-carbon food products, and addressing existing challenges to support a broader and more sustainable transition.

5. Policy Recommendation

The transition toward sustainable and low-carbon food supply chains has become increasingly important as APEC member economies face growing climate-related risks, resource constraints, and food security challenges. Given the significant contribution of food supply chains to global greenhouse gas emissions, economies across the Asia-Pacific region are under increasing pressure to improve sustainability while maintaining economic growth, operational efficiency, and affordability. At the same time, the complexity of food supply chains, involving multiple stakeholders with varying capacities and interests, requires coordinated and multi-level responses.

In response to these challenges, a range of policy recommendations and operational practices have emerged to support the development of more resilient, resource-efficient, and environmentally sustainable food systems. These recommendations emphasize the importance of regional cooperation, supportive public policies, technological innovation, financial assistance, and practical sustainability measures. The following recommendations are categorized into APEC-level, government-level, and firm-level actions to highlight the complementary roles of regional organizations, governments, and private sector stakeholders in advancing low-carbon food supply chains.

5.1 APEC-Level

(1). Strengthening Regional Cooperation and Harmonized Standards

APEC member economies should strengthen regional cooperation and policy coordination to support the transition toward low-carbon food supply chains. Developing harmonized sustainability standards, regulations, and ESG-related guidelines can help align practices

among firms, suppliers, and consumers across the region. Stronger coordination among member economies would also improve policy consistency, facilitate trade in low-carbon food products, and support the development of transparent and sustainable food supply chain systems.

(2). Promote Regional Knowledge Sharing and Capacity Building

APEC can further strengthen regional dialogue, knowledge exchange, and capacity-building initiatives related to sustainable food supply chains. Sharing best practices, technological experiences, and policy approaches among member economies may help reduce capability gaps and support broader adoption of low-carbon technologies and sustainable operational practices.

(3). Encourage Regional Collaboration on Technology and Innovation

APEC should continue promoting collaboration on emerging technologies such as AI, IoT, GPS, and data-driven management systems that improve operational efficiency and reduce carbon emissions and food waste. Supporting regional innovation platforms, pilot projects, and technology-sharing initiatives may help firms across the region accelerate digital transformation and sustainability efforts.

(4). Support Regional Circular Economy Initiatives

APEC economies may strengthen cooperation on circular economy practices, including food waste reduction, upcycling, and waste-to-value initiatives. Promoting regional cooperation in resource recovery, sustainable packaging, and waste management practices can contribute to improved resource efficiency and more resilient food systems across the Asia-Pacific region.

5.2 Government-Level

(1). Expand Financial Support for Green Transition

Governments of the member economies in APEC should provide accessible and innovative financing mechanisms to support firms, particularly SMEs, in adopting low-carbon technologies and sustainable practices. Potential policy measures include low-interest green financing schemes, tax incentives, Public-Private Partnerships (PPPs), sustainability-focused investment programs, and collaborative funding mechanisms. These measures can help reduce the financial burden associated with sustainability transitions.

(2). Strengthening ESG Oversight and Sustainability Regulations

Governments may strengthen the implementation and oversight of ESG commitments and sustainability-related regulations to encourage greater accountability among firms. Clear

policy frameworks and regulatory guidance can help businesses align their operations with sustainability objectives while improving transparency and consumer confidence.

(3). Support Industry–Academia Collaboration

Governments should encourage stronger collaboration between industry and academic institutions to support research, innovation, and technology transfer. Research institutions can assist firms, especially SMEs, in developing cost-effective technologies related to food processing, packaging, waste reduction, and sustainability management. Public support for collaborative research projects and innovation programs may accelerate the adoption of sustainable technologies.

(4). Promoting Sustainable Agricultural and Operational Practices

Governments may support the adoption of sustainable agricultural and operational practices through technical assistance, training programs, and extension services. Measures such as promoting alternate wetting and drying methods, improving cold-chain efficiency, and encouraging localized sourcing can contribute to lower emissions, improved resource efficiency, and stronger supply chain resilience.

(5). Enhance Consumer Awareness and Market Incentives

Governments should strengthen public awareness campaigns and sustainability labeling systems to improve consumer understanding of low-carbon food products and sustainable practices. Enhancing market awareness may increase consumer demand for sustainable products and strengthen incentives for firms to pursue environmentally responsible operations.

5.3 Firm-Level

(1). Strengthening Sustainability Practices Across Supply Chains

Firms could adopt a more inclusive approach to sustainability by extending carbon reduction measures and sustainability standards to third-party suppliers and business partners. Improving coordination throughout the supply chain can strengthen environmental performance and support broader low-carbon transition efforts.

(2). Invest in Technological Innovation

It is suggested that companies could continue investing in innovative technologies and sustainable production methods to improve operational efficiency and reduce emissions. The measures may include the adoption of AI, automation, and data-driven resource management systems for the firms to optimize production processes, minimize waste, and improve sustainability outcomes.

(3). Collaborating with Academic and Research Institutions

Firms may strengthen partnerships with academic and research institutions to develop affordable and practical sustainability solutions. Collaboration in areas such as food processing technologies, sustainable packaging, and operational efficiency can help businesses improve environmental performance while lowering their own research and development costs.

(4). Adopt Circular Economy and Upcycling Practices

Businesses should integrate circular economy practices into their operations by reducing food waste and exploring upcycling or waste-to-value initiatives. These approaches can improve resource efficiency, reduce carbon footprints, and create new business opportunities through the reuse of by-products and surplus materials.

(5). Implement Practical and Cost-Effective Operational Improvements

Firms could adopt immediate and cost-effective sustainability measures within their daily operations. These may include sourcing inputs from nearby suppliers to reduce transportation emissions, improving packaging and cold-chain systems to enhance energy efficiency, and applying sustainable agricultural practices to reduce carbon emissions and improve soil health. Such operational improvements can provide both environmental and economic benefits while strengthening supply chain resilience.

The transition toward sustainable and low-carbon food supply chains requires coordinated action at the regional, and firm levels. APEC can play an important role in strengthening regional cooperation, harmonizing standards, and facilitating knowledge sharing, while governments are responsible for creating enabling environments through financing support, regulations, and capacity-building initiatives. At the same time, firms play a critical role in adopting innovative technologies and sustainable operational practices. Strengthening cooperation among all stakeholders and leveraging both advanced technologies and practical solutions will be essential for achieving resilient, resource-efficient, and environmentally sustainable food systems across APEC member economies.

Appendix A: Agenda

Day 1: March 18th, 2026, Wednesday	
08:30–09:00	Registration
09:00–09:20	Opening Remarks
SESSION I: Challenges and Strategies on Cultivating a Low-Carbon Food Supply Chain Moderator: Dr. Gow-Chin Yen, Chair Professor, Department of Food Science and Biotechnology, National Chung Hsing University (NCHU), Chinese Taipei	
09:20–09:50	**KEYNOTE SPEECH: Empowering a Low-Carbon Food Industry with Technology** Dr. Chii-Cherng Liao, Director General, Food Industry Research and Development Institute (FIRDI), Chinese Taipei
09:50–10:20	**KEYNOTE SPEECH: Collaborative Approaches to Cultivating - Low-Carbon Food Supply Chain** Dr. Shin-Horng Chen, Vice President, Chung-Hua Institution for Economic Research, Chinese Taipei
10:20 –10:50	Coffee Break
10:50–11:30	**Sharing Cases on APEC Economies: Strategies on Cultivate a Low-Carbon Food Industry** 1. Ms. Dyan Garneta, Director of Food, Marine and Fishery Products Industry, Directorate General of Agro-Based Industry, Ministry of Industry, Indonesia 2. Professor Matthew Tan, Member of Investment Committee, Asia Food Sustainability Fund, Singapore
11:30–12:00	Panel Discussion
12:00–13:30	Lunch
SESSION II: Technological Innovation for Low-Carbon Food Supply Chain by SME Moderator: Dr. Gow-Chin Yen, Chair Professor, Department of Food Science and Biotechnology, National Chung Hsing University (NCHU), Chinese Taipei	
13:30–14:00	**KEYNOTE SPEECH: Nature Holds the Key to the Future of Human Sustainability** Dr. Y. Martin Lo, Professor, College of Sustainability, National Tsing Hua University (NTHU), Chinese Taipei
14:00–14:40	**Sharing Cases on Low-Carbon Food Ingredient Innovation** 1. Dr. Yu-Wei Lin, Chief Technology Officer, Ultimeat Sdn, Bhd, Malaysia 2. Dr. Karla Inés Calderón Mayo, General manager, Pakucha company, Peru
15:10 –15:50	Coffee Break
15:10 –15:50	**Sharing Cases on Low-Carbon Food Manufacturing Innovation** 1. Dr. Binghuei Barry Yang, Deputy Director General, Food Industry Research and Development Institute (FIRDI), Chinese Taipei 2. Dr. Yi-Chung Lai, Plant Director, Biozyme Biotechnology Co., Ltd., Chinese Taipei
15:50 –16:30	**Sharing Cases on Technology in Food Distribution and Low-Carbon Consuming** 1. Dr. Nobutaka Nakamura, Principal Researcher, Institute of Food Research, National Agriculture and Food Research Organization (NARO), Japan 2. Dr. Metinee Srivatanakul, Committee on Quality Agricultural Products, Thai Chamber of Commerce, Board of Trade of Thailand, Thailand
16:30 –17:00	Panel Discussion

Day2: Thursday, 19 March 2026	
SESSION III: Technological Solutions for Low-Carbon Food Supply Chain Moderator: Dr. Jung-Hsien Chiang, Distinguished Professor, Department of Computer Science and Information Engineering, National Cheng Kung University (NCKU), Chinese Taipei	
08:30–09:00	**KEYNOTE SPEECH: Development Trends of Technological Solutions for Low-Carbon Food Supply Chain** Mr. Worrawat Sriyook, Advisor, Mitr Phol Sugar Corp., Ltd, Thailand.
09:00–09:20	**Sharing Cases on Fermentation Technology Solution** Dr. Kevin Lee, Assistant Department Manager, Biotech Research Institute, Grape King Bio, Chinese Taipei
09:20–10:00	**Sharing Cases on Smart Technology Solution** 1. Dr. Sangwon Suh, Founder, Vitalmetrics Inc, USA 2. Dr. Penny Measham, CEO, Cherry Growers Australia, Australia
10:00–10:30	Coffee Break
10:30–11:10	**Sharing Case on Technologies for Circular Economy** 1. Dr. Satriyo Krido Wahono, Head of Research Center for Food Technology and Processing / Senior Researcher, BRIN (National Research and Innovation Agency), Indonesia 2. Ms. Marcie Chan, Brewmaster, Director of Operations, Long Sun Brewing Co. Ltd., Chinese Taipei
11:10–11:40	Panel Discussion
Final Session: Wrap Up Moderator: Mr. Mark Hsieh, Chairman, Food Industry Research and Development Institute (FIRDI), Chinese Taipei	
11:40–12:00	**Wrapping Up the Key Learnings and Discussing Knowledge/ Information Gained from the Workshop** Dr. Binghuei Barry Yang, Deputy Director General, Food Industry Research and Development Institute (FIRDI), Chinese Taipei
12:00–13:30	Lunch
13:30–14:30	Traffic to Yilan county
SESSION IV: Capacity Building Workshop – Case Demonstration to a Low-Carbon Food Supply Chain site Moderator: Dr. Binghuei Barry Yang, Deputy Director General, Food Industry Research and Development Institute (FIRDI), Chinese Taipei	
14:30–16:50	**Showcasing of Upcycling and Circular Economy for a Low-Carbon Food Supply Chain** Representative from KING CAR GROUP
16:50	Close

Appendix B: Pre-event Survey Questionnaire

2026 Survey Questionnaire for APEC Project " Discovering Innovative Food Processing Technology to Cultivate a Low-Carbon Food Supply Chain"

In order to understand the requirements and the current status of cultivating a low -carbon food supply chain in APEC region, we conduct this online survey before the In-person Workshop.
The questionnaire consists of five sections aimed at understanding the recognition of cultivating a low-carbon food supply chain. These sections include overall recognition, policy support, funding support, industry maturity, and collaborative thinking. Additionally, we would like to gather your comments and interest in participating in the In-person Workshop at the end of the questionnaire. Please let us have your reply by **11 Feb. 2026**, your feedback will be helpful for us to ar range the agenda as well as develop the strategy of cultivating a low-carbon food supply chain. Thank you very much.

By Team for APEC Project PPSTI_210_2024A in November 2025

Section 1 : An overall recognition of low-carbon food supply chain

Questions(*must)	Insignificant (1)→Significant (5)				
1. How important do you believe **policy-making** is in cultivating a low-carbon food supply chain? *	1	2	3	4	5
2. To what extent do you think the progress of **funding support systems** for cultivating low-carbon food supply chains in your economy? *	1	2	3	4	5
3. To what extent does your economy invest in **reducing food loss** to cultivate a low-carbon food supply chain? *	1	2	3	4	5
4. To what extent does your economy invest in the development of low carbon **food processing technology**? *	1	2	3	4	5
5. To what extent does your economy invest in the development of low carbon food **smart manufacturing system**? *	1	2	3	4	5
6. To what extent does your economy invest in the development of low carbon food **supplying chain management**? *	1	2	3	4	5
7. How do you think the development of a **food** upcycling **circular system** integrating into your economy? *	1	2	3	4	5

Questions(*must)	Insignificant (1)→Significant (5)				
8. How do you think **consumer awareness** is shaping the trend of green consumerism in food choices in your economy? *	1	2	3	4	5

Section 2 : The policy supports in cultivating a low-carbon food supply chain

1. Based on your understanding, to what extent in each segment **should the government support** cultivating a low-carbon food supply chain in your economy?* (Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)
   ☐ Material production- traditional agriculture
   ☐ Material production- new technology, e.g., fermentation, cell-culture
   ☐ Food processing
   ☐ Food distribution
   ☐ Food consumption
2. In your economy, to what extent has each segment of the food supply chain **received government policy support** for low-carbon initiatives? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)
   ☐ Material production- traditional agriculture
   ☐ Material production- new technology, e.g., fermentation, cell-culture
   ☐ Food processing
   ☐ Food distribution
   ☐ Food consumption
3. What types of government support have been provided for **material production-traditional agriculture** to cultivate a low-carbon food supply chain in your economy? *(Multiple choices)
   ☐ Subsidies (e.g. for land, equipment, renewable energy and clean technology adoption)
   ☐ Tax incentives (e.g. for adopting low-carbon agricultural practices, such as cover cropping, regenerative farming)
   ☐ Low-interest Loans
   ☐ Technical assistance and capacity building
   ☐ Carbon footprint measurement and certification
   ☐ Carbon credits & allowance (e.g. Emission Trading System (ETS) or voluntary carbon market participation mechanisms)
   ☐ Others (Please specify) _____
4. What types of government support have been provided for **material production-new technology, e.g., fermentation, cell-culture** to cultivate a low-carbon food

supply chain in your economy? *(Multiple choices)

☐ Subsidies (e.g. for labs)

☐ Tax incentives

☐ Low-interest Loans

☐ Technical assistance and capacity building

☐ Carbon footprint measurement and certification

☐ Carbon credits & allowance

☐ Others (Please specify) _____

5. What types of government support have been provided for **food processing** to cultivate a low-carbon food supply chain in your economy? *(Multiple choices)

☐ Subsidies (e.g. for upgrading low-carbon manufacturing equipment and production lines; renewable energy use in food processing plants)

☐ Tax incentives (e.g. preferential tax rates for certified low-carbon food processing companies)

☐ Low-interest Loans

☐ Technical assistance (e.g. for circular product design, sustainable packaging and material innovation)

☐ Carbon footprint measurement and certification

☐ Carbon credits & allowance

☐ Initiatives to reduce food waste

☐ Others (Please specify)_____

6. What types of government support have been provided for **food distribution** to cultivate a low-carbon food supply chain in your economy? *(Multiple choice)

☐ Subsidies (e.g. for energy-efficient food storage and retail equipment)

☐ Tax incentives (e.g. for electrification of distribution fleets, such as electric trucks)

☐ Low-interest Loans (e.g. for investment in low-emission logistics and cold chain infrastructure)

☐ Technical assistance (e.g. support for digital platforms to optimize logistics and reduce transportation emissions)

☐ Carbon footprint measurement and certification

☐ Carbon credits & allowance

☐ Initiatives to reduce food waste

☐ Others (Please specify)_____

7. What types of government support have been provided for **food consumption** to cultivate a low-carbon food supply chain in your economy? *(Multiple choice)

☐ Public awareness campaigns promoting low-carbon diets (e.g. for plant-based, local sourcing)

☐ Promotion (e.g. for purchasing certified low-carbon food products)

☐ Financial incentives (e.g. tax deductions or subsidies for purchasing certified environmentally friendly food products)
☐ Carbon footprint measurement and certification
☐ Carbon credits & allowance
☐ Initiatives to reduce food waste
☐ Others (Please specify)_____

8. Do you have any additional **suggestions or comments** regarding government policies to cultivate a low-carbon food supply chain in your economy? (Open-ended)

_____

Section 3 : Funding supports in cultivating a low-carbon food supply chain

1. Based on your understanding, to what extent for each segment **receive sufficient policy-level funding support** to cultivate a low-carbon food supply chain in your economy? * (Rank the five stages the of the supply chain from 1 to 5 (1=most deficient 5=most sufficient) without duplication)
   ☐ Material production- traditional agriculture
   ☐ Material production- new technology, e.g., fermentation, cell-culture
   ☐ Food processing
   ☐ Food distribution
   ☐ Food consumption
2. Based on your understanding, **which sector plays the primary role in providing funding support** for cultivating a low-carbon food supply chain in your economy? *(Select one)
   ☐ The private sector — If selected, please proceed to Questions 3
   ☐ The public sector — *If selected, you may **skip Questions 3***
3. What **types of funding support are available** for private sectors to cultivate a low-carbon food supply chain in your economy? (Multiple choices)
   ☐ Government subsidies
   ☐ Policy-based concessional loans
   ☐ Participation in public-private partnerships (PPPs)
   ☐ International cooperation program funding
   ☐ Tax incentives or preferential tax measures
   ☐ Emerging financial instruments (e.g., green bonds, sustainability bonds)
   ☐ Others (Please specify)_____
4. Based on your understanding, which segment **would achieve the greatest effect** on cultivating a low-carbon food supply chain in your economy through funding support? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most)

without duplication)

☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

5. What are the **barriers or challenges in obtaining funding support** to cultivate a low-carbon food supply chain? *(Multiple choices)

☐ Lack of accessible information or outreach regarding funding opportunities
☐ Lack of diverse funding sources
☐ Lack of strong incentives in funding terms
☐ Difficult to get loans from financial institutions
☐ Difficult to meet funding eligibility requirements
☐ Others (Please specify)_____

6. Please share your **opinions/suggestions** regarding funding support for cultivating a low-carbon food supply chain. (Opening Question)

_____

Section 4 : The industry maturity in cultivating a low-carbon food supply chain

1. Based on your understanding, which segment of the food supply chain face the **Maximum resistance** for carbon reduction? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

2. Based on your understanding, which segment of the food supply chain **gain most technology readiness** for advance carbon reduction? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

3. Based on your understanding, which segment of the food supply chain **gain most**

economic value for advance carbon reduction? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

4. Based on your understanding, which segment holds the greatest economic value for **innovation (e.g., new products, processes, business models)** in cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

5. Based on your understanding, which segment holds the greatest economic value for **importing carbon reduction standards** to cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)

☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

Section 5 : The cooperative thinking in cultivating a low-carbon food supply chain

1. Based on your understanding, what are the **advantages** of cultivating a low-carbon food supply chain?* (Multiple choice)

☐ Improve the efficiency of food supply chain
☐ Develop a more sustainable food production ecosystem
☐ Create opportunities for disruptive innovation
☐ Enhance the supply-demand balance of food distribution
☐ Others (Please specify)_____

2. Based on your understanding, what are the **challenges** of cultivating a low-carbon food supply chain?*(Multiple choice)

☐ Difficult to change the food production system

☐ Difficult to import new technology in existing food production system
☐ Unable to establish common standards to reduce carbon emission
☐ Difficult to cross-border trading barriers
☐ Difficult to see the economic benefit of cultivating a low carbon food supply chain
☐ Lack of attention on cultivating a low carbon food supply chain
☐ Others (Please specify)_____

3. Based on your understanding, which segment holds the greatest openness for **innovation (e.g., new products, processes, business models)** in cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)
☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

4. Based on your understanding, which segment holds the greatest openness for **importing carbon reduction standards** to cultivating a low-carbon food supply chain? *(Rank the five stages of the supply chain from 1 to 5 (1=less 5=most) without duplication)
☐ Material production- traditional agriculture
☐ Material production- new technology, e.g., fermentation, cell-culture
☐ Food processing
☐ Food distribution
☐ Food consumption

5. Please share your other comments or suggestions on cultivating a low-carbon food supply chain.(Opening Question)

_____

Comments and Issues for the In-Person Workshop

Please let us know your recommendations, interested topics and the intention to be the speakers.

Questions(*must)	Disagree (1)→Agree (5)				
A. In your opinion, do you **contribute** for cultivating a low-carbon food supply chain?*	1	2	3	4	5
B. In your opinion, do you **highly care** the low-carbon food supply chain issue?*	1	2	3	4	5

C.	Is your work **directly related to** cultivating a low-carbon food supply chain?*	1	2	3	4	5
D.	Do you think women face more gender-related challenges in low-carbon food supply chain?*	1	2	3	4	5
E.	Do you think **government** should **consider for gender equality** when supporting cultivating a low-carbon food supply chain?*	1	2	3	4	5
F.	Do you think women have more advantages in cultivating a low-carbon food supply chain?*	1	2	3	4	5

G. What are your interested topics in cultivating a low-carbon food supply chain?*(Multiple Choice)
☐Policy issue ☐Opportunities and challenges ☐Current Status ☐Developing trend ☐Application of technologies ☐Collaboration opportunities ☐Others (Please specify)

H. What do you expect to learn from the forum?(Opening Question)

_____

I. Do you agree to receive the relevant information of the In-person Workshop? *(Single choice)
☐Yes. I agree. ☐No. I don't agree.

J. Are you interested in sharing your experience of cultivating a low-carbon food supply chain, please let us know. *(Single choice)
☐Yes, I'd like to be a speaker.
☐I'm interested in participating the In-person workshop, please send me the information.

Basic Information

Please leave your basic information for questionnaire analysis and we will send you the relevant information such as speaker invitation, forum agenda etc.

1. Salutation*(Single choice)
☐Dr. ☐ Prof. ☐Mr. ☐Ms. ☐Others (Please specify)_____
2. First Name* (Opening Question)

_____

3. Last Name*(Opening Question)

_____

4. Which economy are you from?*
☐Australia ☐Brunei Darussalam ☐Canada ☐Chile ☐People's Republic of China

☐Hong Kong, China ☐Indonesia ☐Japan ☐Republic of Korea ☐Malaysia ☐Mexico ☐New Zealand ☐Papua New Guinea ☐Peru ☐The Republic of Philippines ☐The Russian Federation ☐Singapore ☐Chinese Taipei ☐Thailand ☐The United States ☐Viet Nam

5. Gender*(Single choice)
   ☐Male ☐Female
6. Organization/Company Name*(Opening Question)

   _____
7. What's your organization sector belongs to? *(Single choice)
   ☐Government ☐Research Technology Organization(RTO) ☐ Private ☐Non-Governmental Organization(NGO)
8. Email Address*(Opening Question)

   _____

Asia-Pacific Economic Cooperation

財團法人 食品工業發展研究所 Food Industry Research and Development Institute

CIER 中華經濟研究院 CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

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